EFFECTS OF PRESCRIBED BURNING ON RODENT COMMUNITY ECOLOGY IN SERENGETI NATIONAL PARK, TANZANIA

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ABSTRACT

A study on the effects of prescribed burning on rodent community ecology was conducted in Serengeti National Park, Tanzania. The study aimed at generating ecological knowledge on the changes in rodent communities when areas of the park are intentionally burned to regulate grasslands or reduce undergrowth that can lead to uncontrolled forest fires. A Complete Randomized Design (CRD) factorial layout with two treatments (burned and unburned) and two replications was applied. A total of 148 animals comprising six species of rodents and one insectivore were captured over 2,940 trap nights. Among the trapped individuals, 41.9% were adults, 16.1% juveniles and 41.9% sub-adults. Males and females were at parity between treatments. Species abundance was estimated using the Minimum Number Alive method for different rodent species and was found to vary with treatment, where *Mastomys natalensis* declined in burned plots whilst *Arvicanthis niloticus* increased. However, species diversity did not differ across treatments ($F_{1, 10} = 0.15$, p = 0.70). Differences in the reproductive condition of female *M. natalensis* (z = 4.408, df = 15, p = 0.000) and *A. niloticus* (z = 2.381, df = 15, p = 0.017) were observed between treatments showing that higher numbers of reproductively active females were observed in burned plots in March, whilst in unburned plots it was from November to February. Conservation strategies involving periodic habitat burning should, therefore, consider small mammal reproductive periods to ensure that potentially at risk species are not adversely affected and able to rapidly recover from the effects of burning on temporarily lowering food resources and longer term impacts of increased predation caused by reduced cover.

DECLARATION

I, **ABEID MUNUBI MANYONYI**, 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 has neither been submitted nor is being concurrently submitted in any other institution

………………………….. ……………………….

ABEID MUNUBI MANYONYI **Date**

(MSc. WMC Candidate)

The above declaration is confirmed by

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DEDICATION

This dissertation is dedicated to:

My beloved parents, Lameck M. Munubi, Anastazia Manyonyi and Ester Munubi and my aunt, Lucia Manyonyi, who laid the foundation of my education and for their affectionate love.

My young brothers Frank Munubi, Juma Munubi and Elia Munubi and sisters, Neema Munubi, Zera Munubi, Sofia Munubi and Revina Munubi for their patience and encouragement during the course of this study.

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ACRONYMS

ACE - African Centre of Excellence

ANOVA - Analysis of Variance

BTD - Biosensor Technology Development

CRD - Complete Randomized Design

FAO - Food and Agricultural Organization

FGM - Fire Management Plan

GLM - Generalized Linear Model

IRPM - Innovative Rodent Pest Management

LSD - Least Significant Different

MNRT - Ministry of Natural Resources and Tourism

NRCS - Natural Resources Conservation Services

PAs - Protected Areas

PAST - Paleontological Statistics

SENAPA - Serengeti National Park

SUA - Sokoine University of Agriculture

TAWIRI - Tanzania Wildlife Research Institute

URT - United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Fires have been the most common disturbances to small mammals in many woodlands, grassland, savannah ecosystems and forested areas for millennia (Maishanu *et al.*, 2017). It has occurring naturally for millions of years and become an important ecological factor since the early development of terrestrial ecosystems (Bond and Keane, 2017). Currently, fire are normally done annually due to human demand (Sinclair, 2004) for cultivation, grazing livestock, remove parasites, control of insects such as tsetse flies, vegetation manipulation and defense against predation (FAO, 2013; Maishanu *et al.*, 2017). In a rare incidence burning occur through natural agents such as volcano, earthquake, thunder, lightning and sparks from rock fall (Maishanu *et al.*, 2017). This burning has resulted in change of different vegetation types in protected areas (FAO, 2013) leading to major habitat loss in forests, swamps, kopjes, grasslands and woodlands (Msindai, 2014).

In controlling habitat loss from fire in protected areas, prescribed burning was adopted as the appropriate method of fire control intended to accomplish a particular management objective (Johnson and Hale, 2002; Block *et al*., 2016). The method aimed to ensure the maximum sustained yield of silt-free water, maintain species diversity, control alien invasive plants and control wildfires (SENAPA, 2010; Bobel *et al*., 2012; Griffiths and Brook, 2014). The method was accepted in Africa as a way to improve foraging conditions for herbivores, and to make it easier for tourists to observe and make wildlife photograph (Owen, 1971). It spreads to Tanzania with a pilot practice applied as early burning to Serengeti National Park (Owen, 1971). The method led to the adoption of Fire Management Plan (FGM) for the park in 1976, which included early and late burning (Sinclair, 2004).

However, not all prescribed burning are advantageous to the environment in protected areas (Strauch and Eby, 2012), sometimes burnings may occur under conditions (i.e. environmental and weather condition control) that threaten human life, properties and small mammals like rodents (SENAPA, 2010). Most rodent species can be affected due to slow locomotion to escape from fire because they are quite limited in the distance they can travel for foraging or mating (SENAPA, 2010; Adam *et al*., 2015).

Rodents are key successful small mammals in the ecosystem, accounting for 40% of mammalian species in the world (Chekol *et al*., 2012; Bantihun and Bekele, 2015) due to being environmental generalist and rapidly developing changes, and serve as predators, prey, seed dispersers, pests, pollinators, grazers and bio-indicators of habitat condition(Magige and Senzota, 2006; Mueller, 2019). However, their species abundance and diversity have been ecologically affected by burning either directly through effects of heat and gases (Engstrom, 2010), and/or indirectly through changes in vegetation (Bowman *et al*., 2017), resulting to loss of food and cover (Bantihun and Bekele, 2015).

1.2 Problem Statement

Prescribed burning is an important tool in wildlife management and conservation as it helps in reducing fuel load, stimulating the growth of new plant species and reducing competition to fire adapted species (Adams *et al*., 2013) and some parasites such as ticks and tsetse flies (Hassan *et al.,* 2007). On the other hand, it can be lethal to some of the wild animal species, mostly small mammals especially rodents through limiting resources availability and alteration of habitat structure (Strauch and Eby, 2012). For example, Lyme *et al*. (2004); Griffiths and Brook (2014) and Bowman *et al*. (2017) reported that burning alter habitat suitability and food availability, consequently affect the composition, abundance, diversity and behavior of rodent communities in the area. Such lethal create a cascade of ecological changes, from the level of rodent species to ecosystem.

Rodents are among the species that form the important diets for some of the birds of prey (such as black shouldered kite, owls) and mesopredators (such as Jackals, Serval cat, and Snakes) (Senzota, 1990; Hassan *et al*., 2007). Apart from being food for birds of prey and mesopredators, they are also important consumers often focus foraging efforts on grasses and under and near shrubs (Byrom *et al.,* 2014). Rodents are likely to be adversely affected by prescribed burning due to the nature of their food and cover requirements.

Of recent, much research in Serengeti has been done on the effects of prescribed burning to vegetation (Hassan, 2011) and large mammals (Hassan *et al*., 2007). Though there is little information that can be traced on the long term and short term responses of vegetation and large mammals from burning in Serengeti, none of the study has tried to explore the effect of prescribed burning on rodent community ecology in the Serengeti National Park.

1.3   Justification of the Study

This research shed some light on the composition, abundance, diversity, breeding and population fluctuation of rodents between burned and unburned areas in the park. This is essential in understanding the changes caused by prescribed burning on the ecology of rodents and biological feedbacks on ecological characteristics and ecosystem in general.

Furthermore, variation of rodents species in the Park make our understanding better on the effect of post prescribed burning, how burning change the abundance and diversity and how it might recover after burning to equalize the ecosystem.

1.4   Objectives of the Study

1.4.1   General objective

To assess the effects of prescribed burning on the ecology of rodents in Serengeti National Park.

1.4.2   Specific objectives

  i.   To investigate the rodent's community structure and composition in burned and unburned areas in Serengeti National Park

 ii.   To determine rodents abundance and diversity in burned and unburned areas in Serengeti National Park

iii.   To investigate the population fluctuation and breeding patterns in the study area

1.5   Hypothesis

H_0;   Prescribed burning does not affect the structure, abundance, diversity and fluctuation of the rodents.

H_1;   Prescribed burning affects the structure, abundance, diversity and fluctuation of the rodents.

CHAPTER TWO

2.0   LITERATURE REVIEW

2.1   Abundance, Diversity and Role of Rodents on Ecosystem

Rodent's history extends back to the late Paleocene epoch about 60 million years ago (Legendre, 2003; Churakov *et al.*, 2010). Rodents are small mammals of the order Rodentia which are characterized with gnawing teeth as the unifying characteristic which is a single pair of open rooted, chisel-shaped incisors in each jaw (lower and upper) (Leirs and Verheyen, 1995; Kay and Hoekstra, 2008). The incisors grow continuously and kept short by gnawing to provide rodents with a powerful tool in defense, excavate burrows to force entrance into closed places and gnaw different food sources (Leirs and Verheyen, 1995; Kay and Hoekstra, 2008; Happold *et al*., 2013). They are also relatively small animals with robust body size, short limbs and long tails (Leirs and Verheyen, 1995; Happold *et al*., 2013; Kingdon, 2015).

The currently known rodents in the world are mice, rats, squirrels, prairie dogs, porcupines, beavers, hamsters, guinea pigs, gerbils and capybaras (Happold *et al*., 2013). They are distributed all over the world, being diurnal, nocturnal, or sometimes active part of the day and night (crepuscular) (Senzota, 1982; Bergstrom, 2013). Some species are herbivorous, omnivores, insectivorous and others are opportunistic generalists, and some are specialized predators, not only of arthropods but sometimes of vertebrates (Leirs and Verheyen, 1995; Bergstrom, 2013).

Therefore, their diets most include plants (grains, seeds, fruits), animal matters (meat, insects) and household materials (rubbish, paste, glue, soap and building materials) where food is either eaten where gathered or carried to burrows and stored (Senzota, 1982; Leirs and Verheyen, 1995). They have wide variety of shelters ranging from tree holes, rock

crevices and kopjes, or simple burrows to hidden nests on the forest floor, leaf and stick structures in tree crowns, mounds of cut vegetation built in aquatic environments, or complex networks of tunnels and galleries (Timbuka and Kabigumila, 2006; Mueller, 2019).

Rodents may be active all year or enter periods of dormancy or deep hibernation (i.e. dormice), thus breeding time and frequency, length of gestation, and litter size vary widely (Leirs and Verheyen, 1995; Mulungu *et al*., 2016). They have cryptic life style and prolific breeders with a litter size ranging from 1 to 28 offspring in a single litter (Leirs and Verheyen, 1995; Kay and Hoekstra, 2008; Happold *et al*., 2013; Kingdon, 2015). This makes population size to remain stable or fluctuate, and some species, may migrate when populations is disturbed or become excessively large (Massawe *et al*., 2006).

Due to that, they are successful small mammals in the world accounting 40% (Chekol *et al*., 2012; Bantihun and Bekele, 2015) of mammalian species with 29 living families, 468 genera and more than 2065 species (Kassa and Bekele, 2008). In Africa, more than 1150 species are currently listed, while East Africa rodents account for 28% of the total mammalian fauna with 62 genera and 161 species (Venance, 2010).

Tanzania is composed with more than 101 species of rodents from 43 genera and 11 families (IUCN, 2019). In Serengeti, 36 species of rodents have been recorded from 4 families including Gerbillidae (Gerbils) which includes *Tatera robusta* and *Tatera boehmi*; Muridae (Mice and Rats) which includes *Arvicanthis lacernatus*, *Arvicanthis niloticus*, *Acomys dimidiatus*, *Acomys wilsoni*, *Aethomys hindei; Aethomys kaiseri*, *Grammomys dolichurus*, *Lemniscomys barbarous*, *Mastomys natalensis*, *Mus triton, Mus minutoides* and *Rattus rattus*; Nesomyidae (Mice) includes *Dendromus melanotis, Steatomys*

pratensis and *Steatomys parvus*; and Myoxidae or Gliridae (Dormice) includes *Graphiurus kelleni* and *Graphiurus murinus* (Senzota, 1982; Senzota, 1990; Magige and Senzota, 2006; Timbuka and Kabigumila, 2006).

Their success is driven by climate, topography, altitude, human disturbances, interaction with other animals, habitats adaptation and vegetation type which are home to a large number of small mammals especially Rodentia order (Hagenah, 2006; Mulungu *et al*., 2008; Churakov *et al*., 2010; Chekol *et al*., 2012; Bergstrom, 2013; Bantihun and Bekele, 2015). They are also influenced by variation in food habits (are insectivores, herbivores/folivores of savanna grasses and sometimes coexist within granivores/omnivores guild when resources are limiting) (Hagenah, 2006; Mulungu *et al*., 2008; Churakov *et al*., 2010; Chekol *et al*., 2012; Bergstrom, 2013; Bantihun and Bekele, 2015).

2.2   Ecological Importance of Rodents

Rodents provide ecological services like diets for a list of vertebrate predators that feed principally or entirely on them, mostly some of the birds of prey such as black shouldered kite, owls and mesopredators such as jackals, serval cat, and snakes (Senzota, 1990; Hassan *et al*., 2007; Byrom *et al*., 2014). When in burrows they are comparatively free from capture by predators, but a predator such as a snake may sometimes force its way into a burrow and some predation seems unavoidable, owing to accidents, forced entry by predators, attacks by ants, chilling, overheating, or even drowning during heavy rainfall and fire (Reidy and Thompson, 2012; Mendonça *et al*., 2015).

Despite of being successful in various habitats, burning have been an ecological factor affecting small mammals abundance and diversity (Bowman *et al*., 2017). Prescribed fire

management and subsequent changes to the vegetation (Bowman *et al.*, 2017) which makes loss of cover and food (Bantihun and Bekele, 2015) can impact rodent's abundance, richness and diversity.

2.3   History of Prescribed Burning

Burning has been occurring naturally for millions of years resulting in Paleozoic, Mesozoic and Cenozoic sediments and be an important ecological factor since the early development of terrestrial ecosystems (Brown and Rollins, 2005). Burning is the result of the reaction between the fuel, heat and oxygen in the air which form the fire triangle (Yakubu *et al.*, 2015; Bond and Keane, 2017; Williams and Armstead, 2018; Jones *et al.*, 2019). It is believed to have three eras with a widespread process in ecosystem composition and distribution (Pausas and Keeley, 2009). The process begins on the era of pre-human which shows the evidence of fire since the origin of land plants, the era of human which shows the interaction of fire and humans in the preindustrial time, believed to appear during the middle Pleistocene time as part of the tool maker technology made by man in the 1.6 million years ago (Gowlett, 2015), and the era of modern world with rapid alterations in fire regimes (Pausas and Keeley, 2009).

Some centuries ago fire has been widely used by most of the people to look for fruits and herbs for their diet (Block *et al.*, 2016). Major adaptations changes of environment which appeared to have different diets forced people to adapt from one environment of diet to different environmental diets (Gowlett, 2015). This resulted to origin of hunting and gathering whereby people used fire as a mechanism tool to gather food resources in the bush. The use of fire in the bush leads to the disturbances on the environment which in turn play role in forming ecosystem dynamics (Brown and Rollins, 2005).

In many instances, indigenous have been using fire for centuries, as an instrument to modify their surroundings (Pyne, 2015; Pyne, 2017), but currently burning is subjected to a host of different pressures that stem from the increasing demands of a growing human population (Sinclair, 2004). In most areas, these demanding pressures include collection of firewood and other forest produce, grazing of cattle and promoting agricultural green pick and weed management (Sankaran, 2005).

Furthermore, presently burning are subjected to annual burning, mostly caused by man through expansion of farmland for cultivation, flushing new grasses for grazing livestock, remove parasites, hunt game animals and defense against predation (Pausas and Keeley, 2009; Maishanu *et al*., 2017). There has been also seasonal burning caused by natural agents such as volcano, earthquake, thunder and lightning (Maishanu *et al*., 2017). All the two burning can occur under two scenarios: wildfire (are either naturally caused through lightning or man-made through foolish actions including improperly attended or extinguished campfires, lit cigarettes and arson activity-the crime of starting a fire in order to damage or destroy something) or prescribed burning differed on how and when they are ignited (Willis and Christensen, 2004; FAO, 2013; Chinamatira *et al*., 2016).

In Tanzania burning have been common visitor to the wooded savannahs, savanna grassland and forested areas (FAO, 2013; Green *et al*., 2015). In the 1970s high andvery widespread burning frequency increased and experienced in Tanzania, occurring during the dry season due to increased demand of fire for human activities and protected areas (PAs) management (Sinclair, 2004), consequently, resulted in change of different vegetation typesnamely riverine, forests, swamps, kopjes, grasslands and woodlands in protected areas (Byrom *et al*., 2014; Msindai, 2014). The destruction started for a variety of reasons including the control of insects (tsetse flies) and vegetation manipulation which were the main concerns (Maishanu *et al*., 2017).

There have been combined efforts of protected area authorities and scientists in controlling wildfires in Tanzania since 1960's to date (FAO, 2013). The most appropriate method adopted for fire control in protected areas is prescribed burning (Owen, 1971). In 1976 fire management plan for Serengeti National Park was adopted and being in operation up to this time (Sinclair, 2004). Is applied as early burning from January to February and late burning from June to September which is prior to the burning season used in the majority of burning experiments (SENAPA, 2010; Laris *et al*., 2017; Namukonde *et al*., 2017).

Early burning is the lighting of fires while the grass is still rather green (SENAPA, 2010). Is often called a cool burn playing a role on assuring minor damage to the ecosystem and is a primarily means to protect ecosystem (Owen, 1971; Laris *et al*., 2015). Late hot burning is the commonest form of fire at present with a frequency, extent, and severities of fires strongly influence development patterns of vegetation (SENAPA, 2010; Laris *et al*., 2017). Late burning (occurring at the start of the long dry season up to the end of the long hot weather in October) are more harmful to vegetation and animals and can better control wildlife populations than are early burning (N'Dri *et al*., 2018).

2.4   Roles of Prescribed Burning on Ecosystem

Prescribed burning is a human-ignited burning intended to accomplish a particular management objective (Block *et al*., 2016). Prescribed burning can also be defined as fire applied to describe the planned and deliberate use of fire as a land management tool (NRCS, 2009). In other words prescribed or controlled burning is applied to a predetermined area within a prescribed set of conditions, dates and with appropriate safety precautions to achieve specific purposes (NRCS, 2009). It can be applied to forest land, grass land, pasture land, wildlife land, hay land and other land uses as appropriate (FAO, 2013; Maishanu *et al*., 2017). It has been the practice to burn off old vegetation to promote

new grass growth, to improve grazing and clearing vegetation for photographic tourism to fostering pastures for wildlife (SENAPA, 2010; Green *et al*., 2015).

In Tanzania, prescribed burning started for a variety of reasons including vegetation manipulation and wildlife management tool which were the main concerns (Maishanu *et al*., 2017). In different protected areas, burning is a common occurrence in savannas and grasslands, and has long been used as a tool in ecosystem management (Sankaran, 2005). Sinclair (2004) describes prescribed burning as the deliberate use of fire under specified conditions for the purposes of ecological management. Burning is applied widely to meet various objectives such as reducing fuel loads, enhancing wildlife habitats, improving forage by increasing palatability (grasses and forbs), digestibility, enhancing nutrient cycling, controlling exotic weeds, control of insects (tsetse flies) and enhancing resilience from climate change (Marsden-Smedley, 2009; Pedó *et al*., 2010; Maishanu *et al*., 2017). Burning plays a key role by modifying and shaping the ecosystem composition and structure (Strauch and Eby, 2012). Burning control has social and ecological importance (Gowlett, 2015), but influencing major dynamics of the ecosystems (Pereira *et al.*, 2012).

Most protected areas in Tanzania are characterized by dry climates which can slow biological decomposition which is the rate at which plant material is incorporated into organic matter in the soil (FAO, 2013). Prescribe burning is one of the nature tools for consuming the dead plant and decadent biomass that can accumulate in vegetation (Pyne, 2017). It rapidly converts that dead plant material into inorganic ash that frees nutrients and minerals for new plant growth (SENAPA, 2010). However, if burning is too frequent or intense in the area, plant cover and organic matter at the soil surface can be reduced consequently affecting small mammals (Pyne, 2017).

In Serengeti, prescribed burning has been the most appropriate method adopted for fire control in the Park, which is done as late burning and early burning (the lighting of fires while the grass is still rather green) (SENAPA, 2010), is applied in different vegetation types requiring periodic fire to maintain ecological values, tourism activities and reduce adverse impact to human life and property (SENAPA, 2010). Such early burning are not as severe as later burning because the higher moisture content of the grass prevents all the fuel from being burned (Owen, 1971). Thus the fires do not reach such a high temperature. Some plants and wild animals are reported to depend on early burning for good health (Owen, 1971).

It has been performed in conjunction with a wide range of risk management strategies, including public education, effective training of personnel and resourcing of wildfire suppression, along with appropriate management of ecological values (SENAPA, 2006). It is well known from field studies that late-season fires (occurring at the end of the long rain season) are more harmful to vegetation and can better control plants and animal populations than are early burning (SENAPA, 2010).

Many studies show that lack of bush burning in protected areas may cause dangerous fuel accumulations, which may result in catastrophic fires, diseases and insect problem like tsetse flies (Maishanu *et al.,* 2017). This indicates that burning is an essential tool for improvement of ecosystem in protected areas (FAO, 2013).

Regardless of the particular importance, prescribed burning in protected areas affects ecosystem structure, composition, and function that render it unsuitable for some species (Hagenah, 2006). Given the variations in fire and in species responses, the only real generalization one can make is that, fire does not occur uniformly across a landscape,

instead manifesting as a heterogeneous mosaic that provides ecosystem nutrient cycle, energy flow and habitats fluctuation for different species, thereby influencing animal's abundance and diversity (Pedó *et al.*, 2010).

2.5 Effects of Prescribed Burning on Rodents

The use of fire in the bush leads to the disturbances on the environment which in turn play role in forming ecosystem dynamics (Brown and Rollins, 2005), consequently, resulted in changes to the vegetation, loss of nutrients through volatilization, oxidation, ash transport, and erosion (Bowman *et al.*, 2017). This makes loss of cover and food (Bantihun and Bekele, 2015) to impact animal's abundance, richness and diversity in protected areas (Sinclair, 2004; FAO, 2013).

Prescribed burning affects wildlife in various spatial scales. It can create or maintains habitats for some species at the same time render unsuitable habitats for other species (Block *et al.*, 2016; Bowman *et al.*, 2017). Furthermore, a species may benefit from fire in one situation but not another. Thus rodent's abundance and diversity may be affected directly through mortality due to the fire and high temperatures produced kill all rodents which are unable to escape (Layme *et al.*, 2004), or indirectly through changes in the structure of the vegetation initiated by the fire leading to habitat change (Layme *et al.*, 2004; Bowman *et al.*, 2017).

Moreover, changes in rodent population in different vegetation have been documented by relating the rodent's changes to changes in the vegetation due to fire (Litt and Steidl, 2011). Structural changes in the vegetation may results to invasion of non-native plants which can drive into negative functional changes to numerous ecosystem processes (Brooks *et al.*, 2004).

In many ecosystems, fire is the principal process governing vegetation structure and composition in turn, altering many other important physical and chemical processes, such as soil erosion, water infiltration, and nutrient cycling resulting to invasion of non-native plants (Dukes and Mooney, 2004; Priesmeyer *et al.,* 2014). Consequently, invasions by nonnative plants can alter ecological processes relative to ecosystems dominated by native plants (Brooks *et al.*, 2004). Animals that inhabit the ecosystems often have adaptations to cope with the resulting habitat changes initiated by fire (Fox *et al.*, 2003, Letnic *et al.*, 2004). After fires, some species respond positively and others negatively especially rodents due to changes and food resources (Tietje *et al.*, 2008; Litt and Steidl, 2011).

Few studies have examined effects of prescribed burning on rodent population structure in terms of age structure, sex ratios, recruitment and breeding. Age groups of adults, sub-adults and juveniles categories have been studied in different habitats (Leirs and Verheyen, 1995; Yihune and Bekele, 2012). Studies on effects between age class on burned and unburned field have been explained by different scholars (e.g. Fisher and Wilkinson, 2005; Monroe and Converse, 2006) showing juveniles and sub-adults individuals moving from burned to unburned habitats than adults.

Similarly, rodents breeding can be affected negatively by burning during the near breeding season where early burning is mostly applied before long rain season (Monroe and Converse, 2006). At this time females spend time in nursing their litters, as the litters begin making nearby burrows excursion at three weeks (Yihune and Bekele, 2012). This might affect female's movement from the nest area to another, as a result limiting the chance of escaping from fire quickly than males that make broader field excursion (Yihune and Bekele, 2012). It is also this time males have been trapped more than females and their proportion variation between burned and unburned presumably being a result of differences in the mobility of males (Bowman *et al.,* 2017).

In Serengeti National Park, the responses of different mammal species to burning vary in different vegetation. Typically, large mammals forage in different vegetation cover to maintain or increase their abundance and richness (Owen, 1971; Hagenah, 2006). In contrast, small mammal species (e.g. rodents) often focus foraging efforts on grasses as well as under and near shrubs in Serengeti (Magige and Senzota. 2006), which might decrease their abundance and richness after burning (Bowman *et al*., 2017).

A direct impact of prescribed burning on rodents is rare but habitat changes as indirect impacts due to burning can alter their abundance, richness and diversity in the ecosystem (Bowman *et al*., 2017). There have been different mixed evidences on rodent's abundance, richness and diversity in different areas, where some times rodents are detected to be greater on unburned than burned areas and sometimes no difference in both areas (Bowman *et al*., 2017).

CHAPTER THREE

3.0   MATERIALS AND METHODS

3.1   Description of the Study Area

The field study was conducted from 25th October, 2018 to 20th March, 2019 at Alokole plains in the central part of the Serengeti National Park. The area is characterized by grassland (SENAPA, 2010) and woodlands (Byrom *et al*., 2014). The Park covers an area of 14763 km^2 (SENAPA, 2010) and lies between 1°28' - 3°17'S, 33°50' - 35°20'E (Timbuka and Kabigumila, 2006), and an altitude ranging from 920m to 1850m above sea level (SENAPA, 2010), while mean temperature varying from 13 - 28°C (SENAPA, 2010).

The Park is surrounded by several protected areas including Ngorongoro Conservation Area, Maswa Game Reserve, Kijereshi Game Reserve, Speke Gulf Game Controlled Area, Ikorongo-Grumeti Game Reserves and Loliondo Game Controlled Area in Tanzania, and Maasai-Mara National Reserve in Kenya (Kideghesho, 2010; Msindai, 2014). The location of this park makes it the heart and cornerstone of the Serengeti-Mara Ecosystem (Msindai, 2014), by supporting the largest animal species including largest populations of birds, herbivores, carnivores and small mammals (Byrom *et al*., 2013; Msindai, 2014). The Park is also characterized by grassland, woodlands, kopjes (SENAPA, 2010), gallery forest with a closed canopy and hilltop thicket (Sharam *et al*., 2006). Permission to carry out the research was granted by Tanzania National Parks, permit number TNP/HQ/E.20/07 C. Ethic permission and clearance was granted by Sokoine University's ethics board (ref SUA/ADM/R.1/8/229).
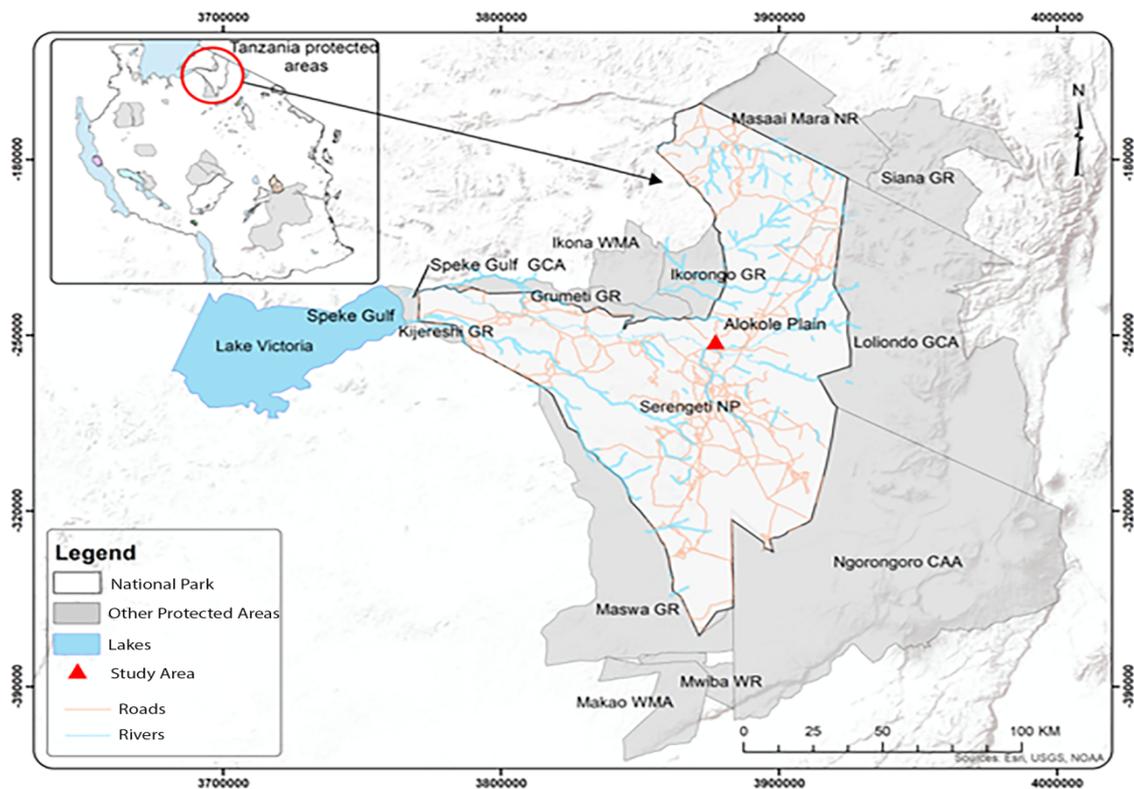
Figure 1: A map showing the study area within Serengeti National Park, Tanzania

3.2   Experimental Design

Complete Randomized Design (CRD) was used in factorial layout with two treatments (viz: burned where the fire established in the mid November 2018 and unburned area which was the opposite side of the fire containment), each with two replications. Each replication were having a trapping grid of 60×60 m^2 (approximately 1 acre), with a distance of more than 300 m from each other (Fig. 2). A large distance setting was done to avoid interaction of rodents from one grid to another as most of them occupy a home range of 200 to 2000 m^2 in free land areas (Mulungu *et al*., 2015). Setting of the grids was conducted in October and in the following month (November) burning was conducted. Burning involved making fire break through cool burning surrounding the two grids set to be burned to control sudden increase of fire to untargeted areas. After segregation and provide control line for spread of fire, the entire area inside the fire break was burned (Fig. 2).
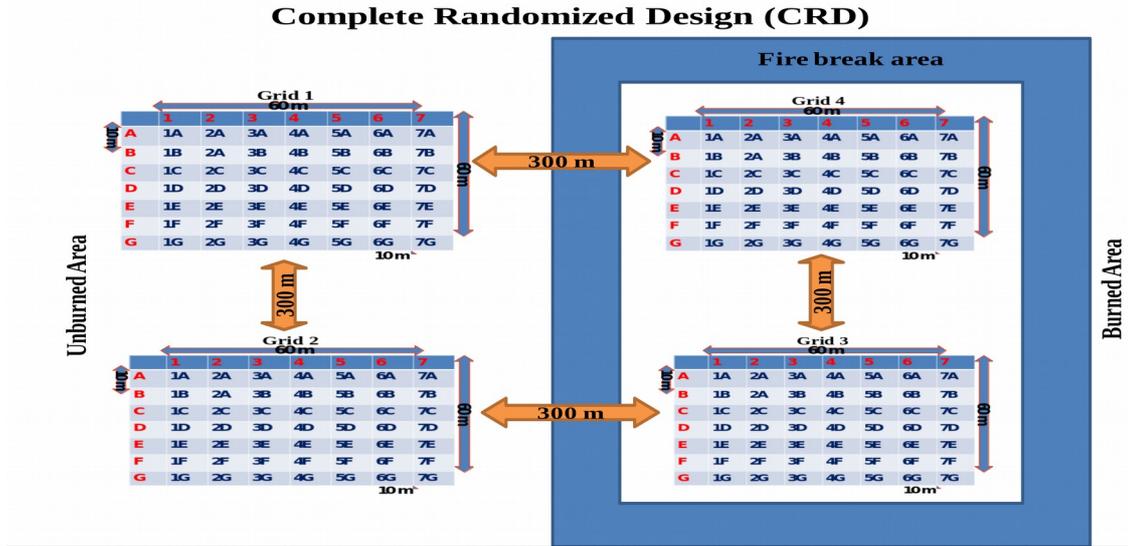
Figure 2: Sketch of grids in factorial layout

3.3   Trapping Procedure and Data Collection

Permanent trapping was conducted at Alokole plains after survey of the site. A total of 196 Sherman live traps (23 x 9.5 x 8 cm, H. B. Sherman Traps Inc.) were set in the four trapping grids (two grids in burned and two grids in unburned). A grid consisted of seven parallel lines located 10 m apart. The traps were arranged in seven trapping stations per line each 10 m apart (making a total of 49 trapping stations per grid) (Fig. 3).
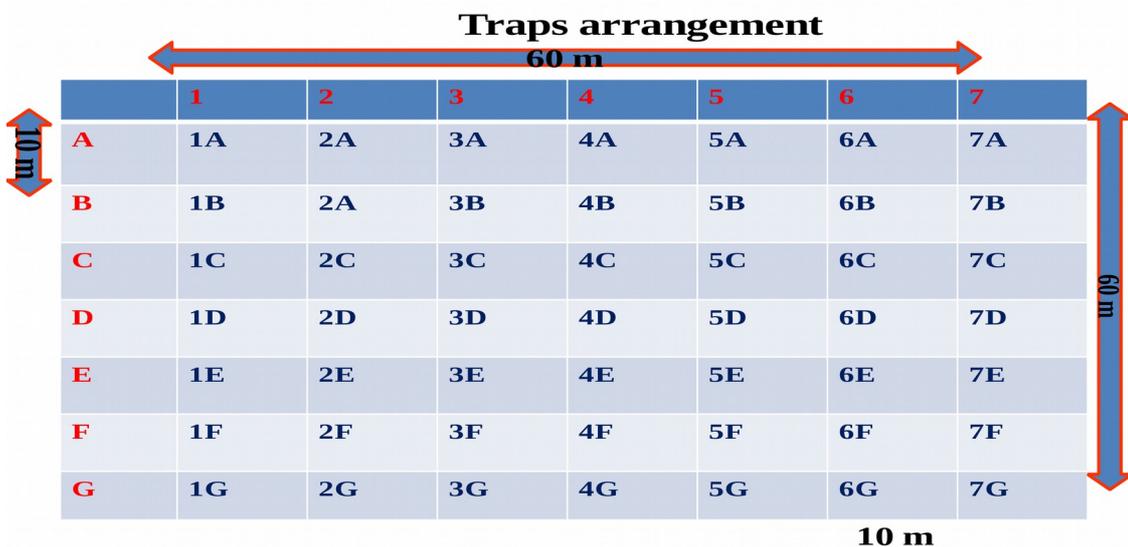
Figure 3: Sketch of Sherman live traps layout in a grid

Animals Traps were set on the evening of the first day and were baited with a mixture of peanut butter and maize flour replaced with new ones after every trap check which was conducted each early morning and late evening for three consecutive nights per month. This is because most rodents are active at night and few at day time (Senzota, 1982; Mulungu *et al*., 2008; Magige, 2016). Animals were trapped before burning (October 2018) and repeated monthly from November (one week after burning) to March 2019, with the exception of January where no trapping was possible due to operational issues.

A Capture-Mark-Recapture trapping technique was applied. Rodent species captured in Sherman live traps were identified to species level (Happold *et al*., 2013; Kingdon, 2015) and age classes (*M. natalensis*) based on mass (Leirs and Verheyen, 1995). Their taxonomic groups were properly categorized based on field guide books (Happold *et al*., 2013; Kingdon, 2015) and animal identification experts from Pest Management Center at Sokoine University of Agriculture. All the new captured animals were marked through toe clipping using specific number coding. This helped to identify them as recaptures during subsequent trap check and released at the site of capture where the cover and burrows as the escape route of the animal was noted.

The data was recorded separately by treatment type (burned and unburned) and different location and population parameters especially, trap location, weight (in grams), sex and reproductive conditions (either a perforated or closed vagina in females and scrotal or non-scrotal testes in males) were recorded.

3.5   Data Analysis

Species composition is the proportions (%) of various rodent species in relation to the total on a given area to reflect the relative contribution of a species to a community and

dominance of a specific species on a site. Species composition was calculated in terms of

percentages (%) where by each species in relative to others were calculated. The number

of captured individuals of each species were divided by the total number of captured

animals in each habitat (burned and unburned), and multiplied by 100. The percentage (%)

of each species was computed using the formula;

$$Percent\,species\,composition\;A = \left(\frac{Number\,of\,species\,A}{Total\,number\,of\,individuals}\right) \times 100$$

Age structure individuals were determined for one species *Mastomys natalensis* as the

only species in Sub-Saharan countries studied in terms of age by categorizing juveniles,

sub adults or adults following the relationship between age and body weight (gm) (Leirs

and Verheyen, 1995). Individuals weighing > 24 g were grouped as adults, 21 - 24 g were

grouped as sub adults, while those weighing $\leq$ 20 g were grouped as juveniles.

The presence of active adults rodents (including sub-adult individuals) was used as an

indicator of reproduction and the presence of juveniles in a population was used as proof

of recent reproduction and was determined in each habitat and each month. Because data

was not uniform, GLM (Generalized Linear Model) for estimation of effect was used to

determine the influence of habitat types, and months on the abundance of juvenile, sub-

adult and adults rodents. The Least Significant Different ($LSD_{0.05}$) was used for mean

separation of the unburned and burned with months.

Sex ratio was determined as the ratio of the number of individuals of one sex (females) to

that of the other sex (males) in the population (normalized to 100 or 1). Typically

fluctuated around in a ratio of 1:1 (expected ratio) as the most common evolutionary stable

strategy (ESS), led by frequency-dependent natural selection due to competition for mates

among individuals of the same sex (Jennions and Fromhage, 2017). Sex ratio variation

was determined in both habitats and in different months. In this study, the sex ratio was the proportion of females in the whole population and is in favor of females, as males can be active throughout the time and one male can impregnate many females in one breeding season. The minimum expected number is at least 1, and less likely than the one observed (Campbell, 2007; Mulungu *et al*., 2013).

Where by Female Population is given

$$r = \frac{f}{f + m}$$

Where, r = Gender (sex) ratio m = Number of Males f = Number of Females

Pearson's Chi-squared test was used in this study to compare 5 two-sided tests of two-by-two tables to test if there is a significance association of sex ratio between burned and unburned habitat.

In this study recruitment defined as only new individuals (first-capture) captured in each habitats and month. Calculations included only first-captures in each habitats and month in order to avoid bias that could result if the same individual being captured multiple times and potentially at the same locations. In analysis and tests we assumed that potential differences in detectability between old capture and new capture were consistent among the treatments and time, and therefore, the comparison of proportion of captures among treatments would be unbiased. Data was analysed using GLM with a poisson distribution to determine the influence of habitat types, and month on the abundance of rodents in the SENAPA. Species were included in the model in order to determine their associations (i.e. does one species increase or decrease in relation to the other).

The number of individuals captured in each species, habitat and month were recorded and estimation of abundance in the area was done. The minimum number alive (MNA) index (also called the minimum number known alive, MNKA) was used to estimate the true abundance in the area. MNA in Capture-Mark-Recapture is defined as the number of

individuals caught in that time in a capture session on each habitat and those that were caught both previously and subsequently (Krebs, 1966). The method is used in a small number of trapping occasions and individuals to reduce bias on detection of the true abundance of live capture and recaptures for rodents (Pocock *et al*., 2004). It is a widely used index of abundance in mark-recapture programmes and unbiased due to the use of information from prior and subsequent capturing sessions of rodent's number. To determine if there were effects of burning on rodents' abundance, GLM tests for estimation of effects was used to determine the influence of habitat types, and months on the abundance of species.

Diversity was calculated using the Simpson index and the Shannon index (Shannon and Weaver, 1949). Both of these indices are a function of the proportion of individuals found in each species. The Simpson Diversity Index ($\lambda = 1 - D$) (Jiang *et al*., 2017) is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species giving weight to dominant species (Magige, 2013). Simpson's Dominance (D) is defined as:

$$D = \frac{N(N - 1)}{\sum (n - 1)}$$

Where by

n = the total number of organisms of a particular (each individual) species

N = the total number of organisms of all species

D = the Simpson's Dominance (D)

The index of dominance was measured in order to find the probability of taking randomly two individuals belonging to different species. Dominance measures the extent of common species in the habitat ranging from 0(low species dominance) to 1 (high species dominance). In order to get species diversity, D was subtracted from 1 to give Simpson's Index of Diversity 1 – D.

Simpson's Diversity Index (1 - D)

$$\lambda = 1 - \left(\frac{N(N-1)}{\Sigma n(n-1)}\right)$$

The value of the index ranges from 0 (low species diversity) to 1.0 (high species diversity).

Microsoft excel was used to compute Shannon diversity index and defined as:

$$H^i = -\sum_{i=1}^{R} p_i \ln p_i$$

Where p_i is the proportion of the observations found in category i.

The two diversity tests were used to determine if there were differences between unburned and burned treatments using a one way ANOVA and t-test.

The rodent's population fluctuations were proportioned through species accumulation in the graph to show the trend of rodent species obtained for the two habitats. Breeding patterns were determined by sexual conditions through establishing the percentages (%) of physiological condition (active and non-active) individuals of female rodents in both habitats and months and not as a typical behavior (Mlyashimbi *et al.*, 2018). Thus, females were considered to be non-sexually active when the vulva was closed and sexually active when the vulva was perforated, pregnant and nipples swollen on account of lactation.

In order to investigate the burning effect to reproductive activity of females, we developed GLM with percentage abundances of reproductive status as response variable and time (month) and fields (burning, unburned) as explanatory variables tested as glm (formula = Number ~ Burning.status + Breeding, family = poisson). The approach was used because the percentage of reproductive condition animals did not follow a linear

pattern over the entire period. Reproductive condition in individuals was analysed assuming a logit-link function with poisson.

All analysis was performed with program Paleontological Statistics (PAST) 9.1.3 Service Park 4 XP_PRO platform (Hammer *et al*., 2001) and R Version 3.5.1 (Zuur and Ieno, 2016) which has minimal bias and is robust to variation in test probability.

CHAPTER FOUR

4.0   RESULTS

4.1   Rodent's Community Structure and Composition on Burned and Unburned Habitats

4.1.1   Species composition

A total of six (6) species and six (6) genera belonging to three (3) families of Rodentia in over 2,940 trap nights were identified (Table 1). The study trapped another non rodent species (*Crocidura* spp.) making a total of seven (7) species and seven (7) genera belonging to four (4) families from two (2) orders. Five species (*Mastomys natalensis, Arvicanthis niloticus, Mus* spp., *Aethomys* spp. and *Crocidura* spp.) were present in burned and unburned plots while *Graphiurus* spp. was observed in burned plot and *Steatomys parvus* in unburned plot (Table 1).

Table 1: Rodents species trapped in the area

S/N	Genus	Species	Family	Order
1.	*Mastomys*	*M. natalensis* (Smith, 1834)	Muridae	Rodentia
2.	*Arvicanthis*	*A. niloticus* (Geoffrey, 1803)	Muridae	Rodentia
3.	*Mus*	*Mus* spp. (Clerck, 1757)	Muridae	Rodentia
4.	*Aethomys*	*Aethomys* spp. (Thomas, 1915)	Muridae	Rodentia
5.	*Steatomys*	*S. parvus* (Rhoads, 1896)	Nesomyidae	Rodentia
6.	*Graphiurus*	*Graphiurus* spp. (Smuts, 1832)	Gliridae	Rodentia
		Non-rodents species trapped in the area		
1.	*Crocidura*	*Crocidura* spp. (Wagler, 1832)	Soricidae	Eulipotyphla

Species composition and individual species capture rates varied considerably. In burned area the *M. natalensis* was the most dominant species with 52 individuals, comprising 55.91%; in unburned the *A. niloticus* was the most dominant species with 32 individuals contributing 58.18% (Table 2). A comparative species composition of rodents was mostly

contributed from burned area (62.84%) as weigh against to the persistence contribution of

unburned (37.16%).

S/N	Species	Plot 1	Plot 2	Plot 3	Plot 4	Unburned	%contribution	Burned	%contribution	Total	%contribution
	Rodents										
1	*Mastomys natalensis*	4	8	24	28	12	21.82	52	55.91	64	43.24
2	*Arvicanthis niloticus*	7	25	1	6	32	58.18	7	7.53	39	26.35
3	*Aethomys* spp.	1	2	3	20	3	5.45	23	24.73	26	17.57
4	*Mus* spp.	3	1	7	2	4	7.27	9	9.68	13	8.78
5	*Steatomys parvus*	1	0	0	0	1	1.82	0	0.00	1	0.68
6	*Graphiurus* spp.	0	0	0	1	0	0.00	1	1.08	1	0.68
	Non rodent										
7	*Crocidura* spp.	1	2	0	1	3	5.45	1	1.08	4	2.70
	Total	**17**	**38**	**35**	**58**	**55**	**100**	**93**	**100**	**148**	**100**

Table 2: Species composition of small mammals in unburned (Plot 1 & 2) and burned (plot 3 & 4) fields in a study area

4.1.2 Age structure

Mastomys natalensis is the only rodent species, which is well-known and dominant in sub-Saharan countries (Martynov *et al*., 2020), with age category also well known (Leirs and Verheyen, 1995). In the current study, the information on *M. natalensis* allowed an analysis of age class pattern in the two habitats and shows the proportion of the population of *M. natalensis* in juvenile age, sub adult age and adult age. Among the trapped individuals, 13 (41.94 %) were adults, 13 (41.94 %) sub-adults and 5 (16.12 %) juveniles. Adult communities in burned area were increasing (based on occurrence and abundance) as on different to the unburned control which were absent in October, December and February and few occurred in November and March (Fig. 4).

In all trapping period, more adults and sub adults were captured in the two habitats. Statistical inference showed no significance differences observed in the number of sub adult (October, $z = -0.859$, df = 15, $p = 0.390$; November, $z = -1.147$, df = 15, $p = 0.251$; February, $z = 0.345$, df = 15, $p = 0.730$ and March, $z = -0.079$, df = 15, $p = 0.937$) between the two habitats. However, only November significant differences ($z = 2.490$, df = 15, $p = 0.0128$) was observed in the number of sub adult capture at the two habitats. Other months showed no significant differences (October, $z = 1.390$, df = 15, $p = 0.1645$; February, $z = -0.785$, df = 15, $p = 0.4325$; March, $z = -0.003$, df = 15, $p = 0.9975$).

The number of juveniles was less than the sub adults and adults for both trapping periods with the only occurrence in October. There were no significance differences ($z = 0.533$, df = 5, $p = 0.594$) in the number of juveniles capture at the two habitats.
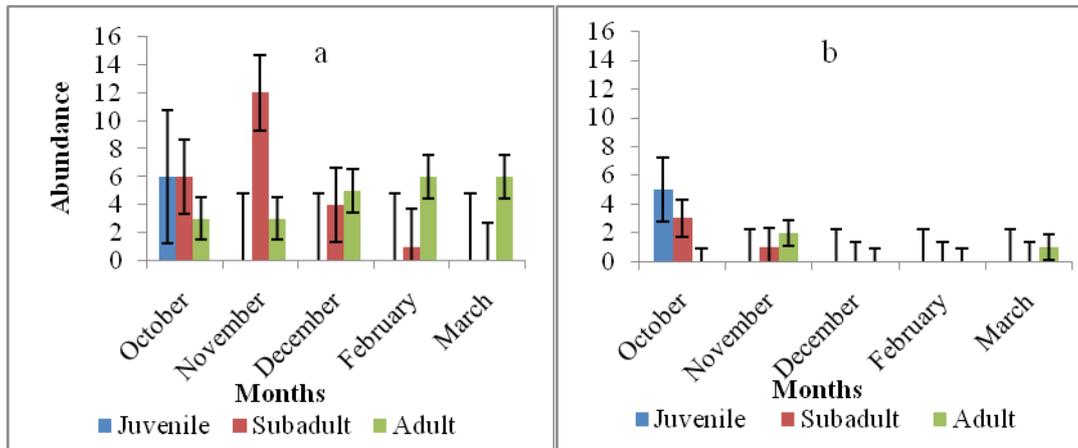
Figure 4: Relative differences in the average (±SD) number juvenile, sub-adult and adult *Mastomys natalensis* in (a) burned and (b) unburned habitats

4.1.3 Sex ratio

Sex ratio varied in both habitats and in different months. This observation justified analysis of *M. natalensis* and *A. niloticus* as two species common and captured in large numbers in burned and unburned sites. The persistence point of females was particularly high in November and December for both *A. niloticus* and *M. natalensis* in unburned field and particularly low in March (Fig. 5). The comparison between sex ratio in habitats showed no significant differences between the numbers of females and males of *M. natalensis* captured between the two habitats (χ^2 = 0.43761, df = 1, p = 0.5083). However, significant differences among the months were observed (χ^2 = 7.5208, df = 1, p = 0.00609). Differences were observed during November, after burning when the capture comprised more females than males (Fig. 5).

The sex ratio of *A. niloticus* did not differ between habitats (χ^2 = 0.42718, df = 1, p = 0.5134) from the expected 1:1. However, the proportion of female to male between months was significantly observed (χ^2 = 7.2057, df = 1, p = 0.00316).
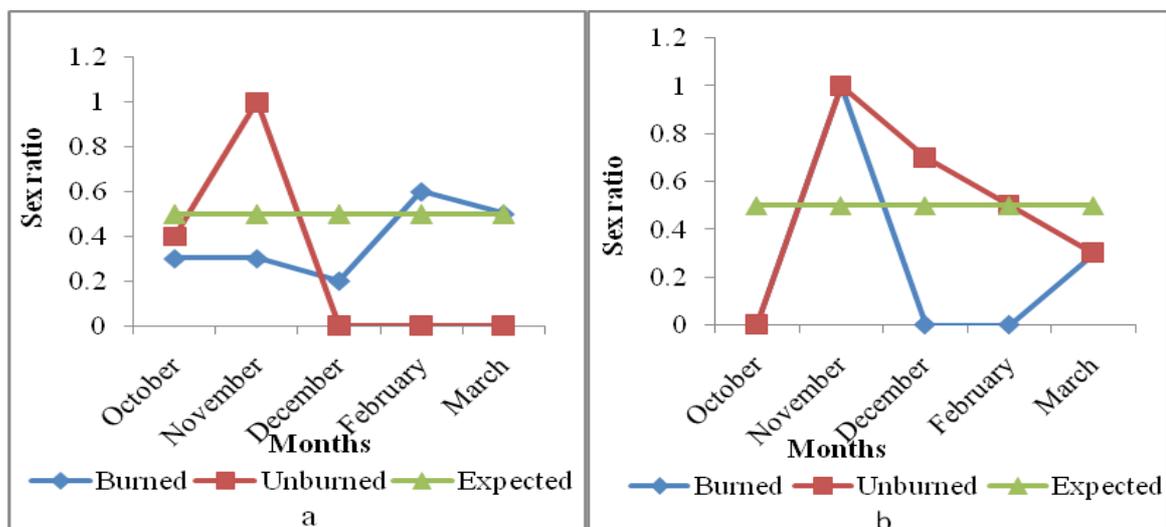
Figure 5: **Females sex ratio of (a)** *Mastomys natalensis* **and (b)** *Arvicanthis niloticus* **between burned and unburned field**

4.1.4 Recruitment

A total of 76 new individual captured were observed with a relative number of individuals in the two habitats (burned N = 39 and unburned N = 37) for whole trap period (Table 3). In unburned area, the new capture was highly observed in March with 11 individuals, contributing 73.3%. In burned area, October contributed high number of new rodents with 15new capture individuals contributing 63.6% and decreasing for the following months (Table 3). A comparative new rodent individuals captured was mostly contributed from unburned area (71.15%) than burned area (42.39%). Statistical inference showed a highly significant difference on interaction between new capture with habitat (burned and unburned) and time (month) in March (z = 2.127, df = 69, p = 0.0334) and October (z = 1.989, df = 69, p = 0.0467), and November, December and February didn't show any significance differences (all, p > 0.05).

Table 3: Rodents new individuals captured per month between unburned (plot 1 & 2) and burned (plot 3 & 4) fields

Months		October				November				December				February				March				Total	
Treatment		Unburned		Burned		Unburned		Burned		Unburned		Burned		Unburned		Burned		Unburned		Burned		Burned	Unburned
Species / Replication	Recruitment	Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4		
Mastomys natalensis	New capture	0	4	2	6	1	0	4	0	0	0	0	0	0	0	0	2	1	0	0	0	14	6
	Recapture	0	4	3	4	2	0	6	5	0	0	5	4	0	0	1	4	0	0	3	3	38	6
Arvicanthis niloticus	New capture	0	1	1	2	1	1	0	0	2	3	0	0	2	5	0	1	0	9	0	2	6	24
	Recapture	0	0	0	0	0	0	0	0	0	1	0	0	2	1	0	0	0	4	0	1	1	8
Aethomys spp.	New capture	0	1	0	2	0	0	1	2	1	0	0	1	0	0	0	1	0	1	0	2	9	3
	Recapture	0	0	0	0	0	0	0	3	0	0	1	5	0	0	0	2	0	0	1	2	14	0
Mus spp.	New capture	0	1	2	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	3	2	9	3
	Recapture	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Steatomys parvus	New capture	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	Recapture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graphiurus spp.	New capture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
	Recapture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New capture	0	7	5	10	2	1	5	2	3	3	2	1	5	5	0	4	1	10	3	7	39	37
Total	Recapture	0	4	3	4	2	0	6	8	0	1	6	9	3	1	1	6	0	4	4	6	53	15

4.2 Abundance and Diversity of Rodents in Serengeti National Park

4.2.1 Abundance

A total of 148 individuals were trapped in burned and unburned areas, whereas burned areas have higher abundance (N = 93) than unburned areas (N = 55) (Table 4). Variation in species abundance was observed across all habitats. *M. natalensis, A. niloticus, Mus* spp. and *Aethomys* spp. were widely abundant in all habitats. In burned area *M. Natalensis* (n = 52) and *Aethomys* spp. (n = 23) were the largest recorded rodent species, while *A. niloticus* (n = 32) and *M. natalensis* (n = 12) were the largest recorded rodent species from unburned habitat. On the other hand, *Steatomys parvus* (n = 1) and *Graphiurus* spp. (n = 1) were the least recorded species in the study area. *Steatomys parvus* was recorded from unburned habitat whereas *Graphiurus* spp. was recorded from burned habitat (Table 2).

Table 4: Rodent's species abundance and diversity assemblages in burned and unburned fields

Habitats	Burned	Unburned
Richness (absolute number of species)	6	6
Number of individuals (absolute number of individuals)	93	55
Simpson diversity index	0.8	0.79
Shannon diversity index	1.39	1.195

No statistical significance differences were observed on species abundance (*Mus* spp. z = 0.737, df = 23, p = 0.46085; *Graphiurus* spp. z = -1.172, df = 23, p = 0.24114; *Steatomys parvus* z = -0.011, df = 23, p = 0.99149) except for *Mastomys natalensis* (z = 3.560, df = 23, p = 0.00037) and *Arvicanthis niloticus* (z = 4.633, df = 23, p = 3.6e-05). Their variation in monthly individual abundance was observed across all habitats but there were no significant difference (all p > 0.05).

4.2.2 Diversity

Species richness was similar in both treatments with a resemble species diversities in burned area (λ = 0.8) and unburned area (λ = 0.79) (Table 4). Simpson's diversity index for

all trapping periods did not differ between burned and unburned plots ($F_{1, 10} = 0.15$, p = 0.70), similar to the variations in Shannon's diversity indices between the two treatments were insignificant (t = 1.104883, df = 79, p = 0.27). Before burning, high species diversity was seen in field to be burned than unburned site (λ = 0. 0.52; λ = 0.49 respectively), but one week after establishment of fire in November, the diversity was high in unburned than burned site (λ = 0. 0.73; λ = 0.43). For all five trapping periods, in burned area, the highest diversity was recorded in March (λ = 0.82), while in unburned area the highest diversity was recorded in November (λ = 0. 73).

4.3 Population Fluctuations and Breeding Patterns in the StudyArea

4.3.1 Population fluctuation

Population trend of all species for each treatment are presented in Table 5. A total of 104 minimal number animal alive were estimated in burned and unburned areas, whereas burned areas have higher abundance (N = 58) than unburned areas (N = 46). Variations in the population trend were seen on both habitats although they were not significant, meaning that population change was not so obvious (except for *Mastomys natalensis* and *Arvicanthis niloticus*). A decrease in the population abundance in the two habitats occurred after burning (November and December). Population peak in burned area was high during October and November and declined in subsequent months after burning December, February and March with the colonization of *M. natalensis*. *Aethomys* spp. increased for two months after fire in November and decreased the following last months, while *Mus* spp. disappeared after burning (Table 5). Population peak in unburned area reached high during February and March with the colonization of *Arvicanthis niloticus*. Also very few rodents were present at the beginning of the data collection in unburned area but during February and March, there were more individuals captured (Table 5).

Table 5: Rodent population abundance changes in burned and unburned fields during the study period.

Months	October				November				December				February				March			
Treatment	Unburned		Burned		Unburned		Burned		Unburned		Burned		Unburned		Burned		Unburned		Burned	
	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot	Plot
Replication	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Mastomys natalensis	0	2	3	4	1	2	4	3	0	0	2	2	0	0	1	3	1	1	1	1
Arvicanthis niloticus	0	3	1	1	1	3	0	1	2	4	0	0	1	6	0	1	2	7	0	3
Aethomys spp.	0	1	0	1	0	0	1	4	1	0	0	6	0	0	1	1	0	1	0	3
Mus spp.	0	1	2	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	2	2
Steatomys parvus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Graphiurus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Mastomys natalensis was the species common in burned site and *A. niloticus* in unburned site and were captured in large numbers. This observation justified analysis of population fluctuations and breeding patterns for these species. Temporal variations in population changes were observed between habitats and months. Their fluctuations in the population trend occurred in all the two habitats whereas *M. natalensis* decreased for every month in burned area while *A. niloticus* individuals increased for every month in unburned area (Fig. 6).

In both burned fields and unburned fields, *M. natalensis* population change was observed but there was no significant difference (all $p > 0.05$), and for *A. niloticus* the population change was observed during February ($z = 0.989$, df = 4, $p = 0.023256$) to March ($z = 1.736$, df = 4, $p = 0.042485$).
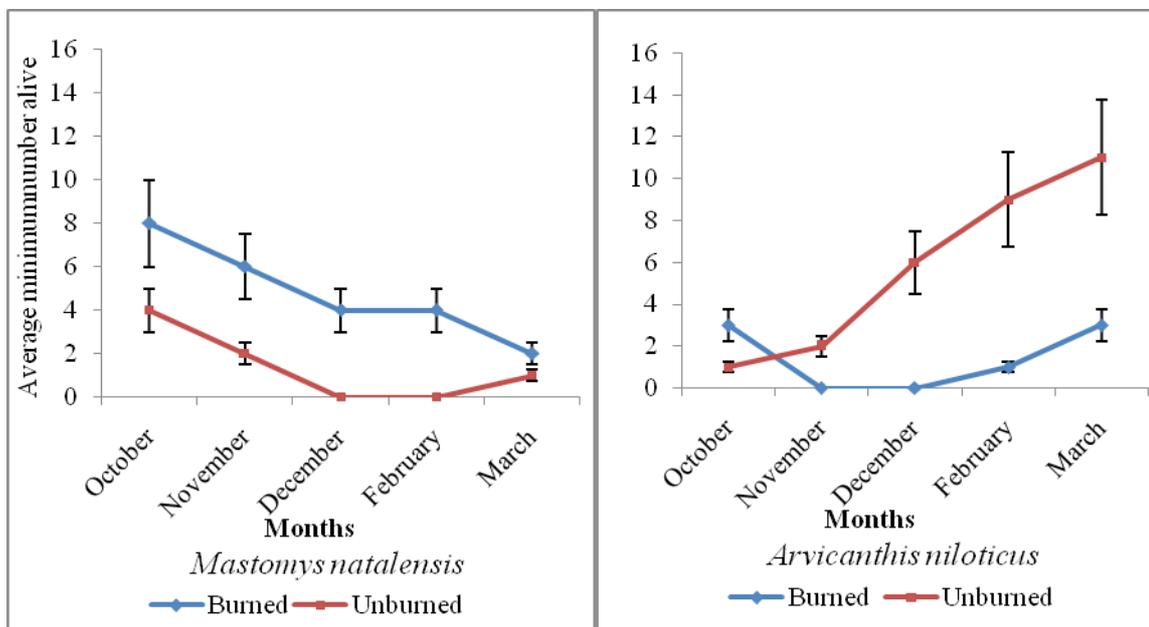

Figure 6: Average (±SD) population fluctuation of *M. natalensis* and *A. niloticus* between burned and unburned fields

4.3.2 Breeding patterns

The individual number of active and non-active rodents in burned and unburned areas was observed. Generally, sexually active females (perforated, pregnant and lactating) were

observed in habitats but in different months during the entire study period (Fig. 7 and 8). The breeding activity of females *M. natalensis* in unburned fields was extended (February, March and few in November), but in burned area a small proportion of the animals were observed to be sexually active during March (Fig. 7). Sex condition was observed to be statistically significant (z = 4.408, df = 15, p = 0.0000104) in numbers of sexual active rodents between burned and unburned areas.
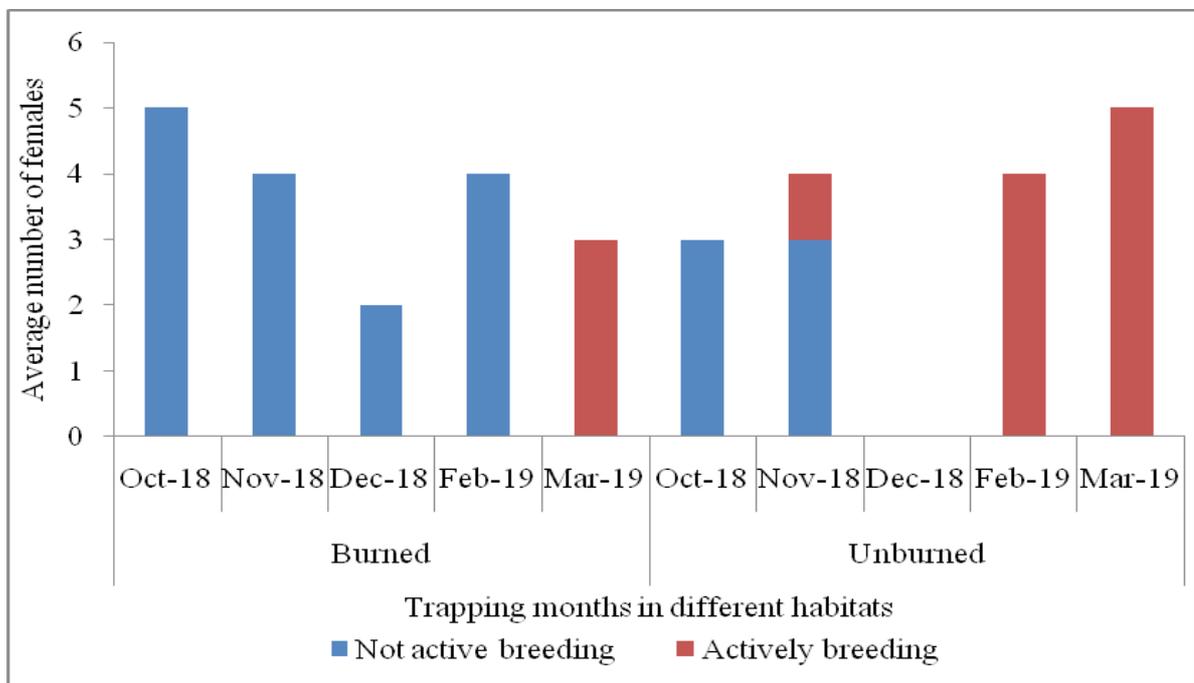
Figure 7: Breeding patterns of female *Mastomys natalensis* in burned and unburned fields

Similarly, high peaks of reproductively active females *Arvicanthis niloticus* in burned fields were observed in the months of March while in unburned area, the contribution of active females based on occurrence and abundance were found mostly in November, December and February (Fig. 8). Sexual activity differed (z = 2.381, df = 15, p = 0.0167) in numbers of female sexual active rodents between burned and unburned areas.
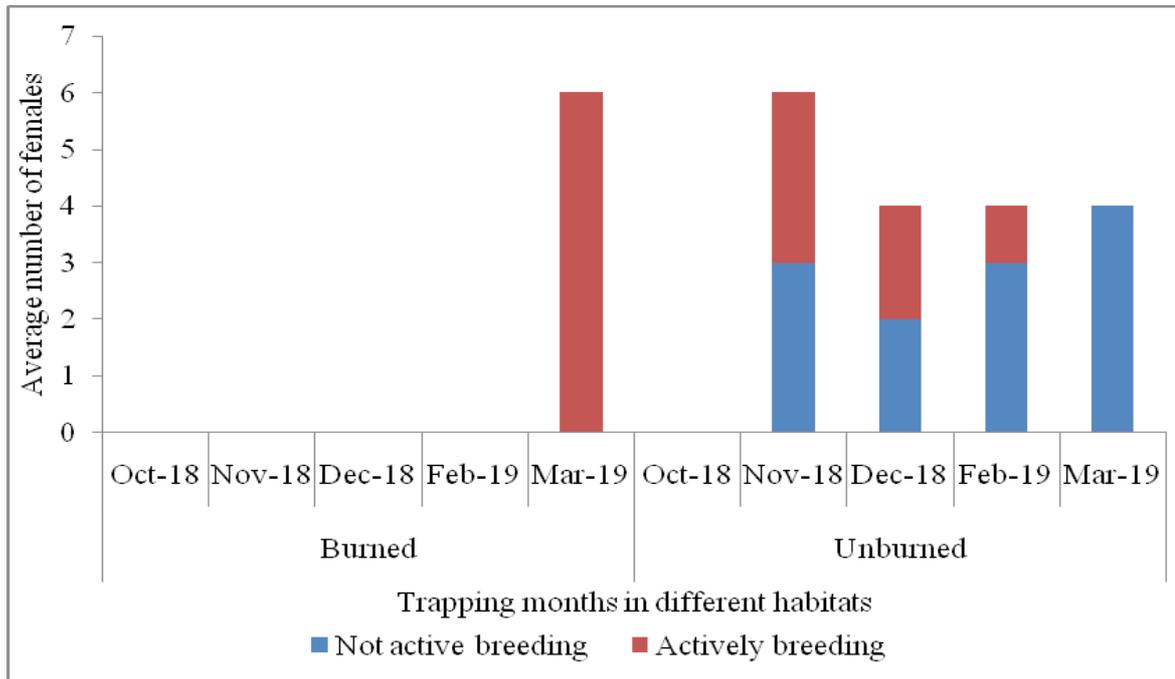
Figure 8: Breeding patterns of female *Arvicanthis niloticus* in burned and unburned fields

CHAPTER FIVE

5.0   DISCUSSION

The current study shows variation in rodent composition in different habitats. The contribution of total individual of *M. natalensis* remained constant one week after burning and decreased on the following month though the abundance remained higher than the unburned contribution. This constant contribution was probably due to the transient individuals in the surrounding habitat by uti1izing their preferred food types in relation to its abundance or availability. The decrease in number of rodent individuals in every following month was probably due to food use patterns in the area, which was not similar to those before burning. This shows that rodents may shift their food habits slightly in response to availability of food on the burned area. Leahy *et al*. (2016) reported the same result by experiencing a decrease in number of individuals. Contrary, Fitzgerald *et al*. (2001) reported an increase of rodents after burning due to resources availability. Studies on food use patterns (Mulungu *et al*., 2011) and population dynamics (Massawe *et al*., 2006; Mayamba *et al*., 2019) revealed some of the species to be opportunistic by uti1izing their preferred food types in relation to its abundance or availability.

The total individual contribution of *Arvicanthis niloticus* in unburned area was probably influenced by sufficient resources form rich medium height grasses and dense vegetation cover of the ground layer to provide shelter. Such vegetation is believed to offer favorable conditions for settlement of the species. Senzota (1982) observed ground cover to be important for survival strategy and shielding the rat from predators in a certain area. The species is also a grass rat, which feed on grass seeds and grass leaves (Senzota, 1982).

The results of this work show some changes in the age class of *M. natalensis* population. Though factors like unfavorable weather, disease, and parasites may affect age structure

but in a special case, burning with predation is probably the most important cause of the change of age structure in the area. Monadjem and Perrin (2003) and Byron (2014) related vegetation change into bare land may attract predators in the area. The rodents may generally live in constant fear of capture by predators when escaping from worse and unfavorable weather like fire.

In addition, this study observed an increase of adults in burned area. This may be due to their large home range, active movement, and higher social ranking as identified by Assefa and Srinivasulu (2019). This observation suggests that high capture of adults, predicts the established adult territories and burrows, and high movement over the course of their lives, except for minor boundary changes to protect the juvenile (Mora *et al*., 2010).

A decrease of sub adults in burned field after burning, probably owing to decreased vegetation and occasional predation at a time when their movements are away from their burrows. Sub adults decrease in burned field after burning has demonstrated by Leahy *et al*. (2016) and MacFadyen (2012) that they are not mature enough to sense on predation at a time when their movements are away from their burrows and occupy small home range. Sub adults are also apparently believed that they burnout physiologically because of attainment of sexual maturity at an uncommonly early age and little cessation of activity in its search for food (Mora *et al*., 2010).

This study also shows that all juvenile individuals were only captured in October, implying that they were produced before burning in the previous breeding months. It is suggested that juvenile animals may quickly decrease due to harsh environment, as they first venture from the nest (Monadjem and Perrin, 2003). They are apparently range over

smaller areas than do the adults and occasionally travel with adults far from their nesting searching for food (Monadjem and Perrin, 2003; Mulungu *et al*., 2013).

Sex ratio assorted among habitats was not affected indicating that males and females were at parity, though not necessarily a reflection of stable sex ratio in habitats. *M. natalensis* and *A. niloticus* tolerate to equal ratio as a result of habitat intersexual by showing movement in search of food and mating. This has demonstrated in other studies talking about the differences in behaviour, immune and predation pressure as common characteristics in regulating balance between sexes in different species of animals (Greenberg *et al*., 2006; Zwolak and Foresman, 2008; Mulungu *et al*., 2013; Borremans *et al*., 2014).

Similarly, Kennis *et al*. (2008) observed both males and females using different mating behavior strategies. For example male *M. natalensis* may roam around to mate with as many females as possible, while females also mate with several males as a promiscuous mating system and high frequency of sexual contacts to produce litters of multiple paternities by several males (Kennis *et al*., 2008; Borremans *et al*., 2014). The current study agree with the above explanation but contrary to what was reported by Duque *et al*. (2005) that males were more mobile in searching for food and mates, while females did not walk far from their burrows due to taking care of their offspring.

New rodent captures into this study were relatively higher in both habitats. This could have been due to the high mobility of animals in search for favourable areas for their needs. Kennis *et al*. (2008) and Borremans *et al*. (2014) suggested that good cover and green vegetative materials are residences of rodents. For example in this study, increase in new vegetative regrowth in burned area, might attract new capture rodents. Within four

months after the fire new individual catches were more abundant in the unburned area than the burnt area. This was possibly owing to differences in vegetative cover as noted by Zwolak and Foresman (2008) and Korner and Spehn (2019). In unburned there was good vegetative regrowth and the cover was good with high quality supply of food.

Furthermore, the presence of new capture was the indicator of recolonization, and proof of population reproduction which was determined in each habitat and month (Gebresilassie *et al*., 2006). The actual extent of recolonization after burning was confounded by the presence of *Aethomys* spp. and *M. natalensis* as early new individuals capture. The early new regrowth plants during this event probably attracted these species to appear in the area. The relationship between the amount of cover and rodent returning to burned areas has been reported in the literature.

MacFadyen (2012) and Bowman *et al*. (2017) reported that the rapid return and recovery of rodents to a burned area appeared to be correlated with the fast regrowth and redevelopment of the ground cover in slash or longleaf habitat. Similarly, Silva-Lugo (2014) explained the relative colonization recovery of rodents were due to regrowth of the vegetation and returned to its levels in burned area after grasses and forbs cover regrew. Therefore, this study trapped relatively new individuals in burned sites following prescribed burning, probably, new individuals were attracted by the early new plants supporting for cover and food.

Although the phenology of rodents in Serengeti is understood (Timbuka and Kabigumila, 2006), and some study of rodents has been done in Serengeti-Mara ecosystem (Senzota, 1980; Senzota, 1982; Senzota, 1990; Magige and Senzota, 2006; Magige, 2013; Byrom *et al*., 2014), this study also assessed the abundance and diversity of rodents between

unburned and burned habitats. Earlier studies show a maximum of 36 rodent species in Serengeti (Timbuka and Kabigumila, 2006; Byrom *et al*., 2014), which is much higher species abundance compared to this study. This is probably because they targeted all small mammals, long duration of their studies and their study locations were into different altitudes and habitats with in the Park and outside the Park. For example, Magige and Senzota (2006) and Magige (2013) concentrated on human–wildlife interface and altitudinal gradient, where migratory rodent species and permanently dwell such as the *Acomys* spp. and roof rat (*Rattus rattus*) could be trapped while searching for food and escape from adverse weather conditions (Timbuka and Kabigumila, 2006; Magige, 2013).

Some rodent species have been reported to be opportunistic in habitat specific, for example, *Rattus rattus* flourishes in areas inhabited by humans and *Acomys* spp. in the rocky outcrops (Timbuka and Kabigumila, 2006) and thus could not be trapped in this study. In other region where similar studies have been conducted with similar study designs involving burned and unburned habitats, a range of 4 and 10 species of rodents has been reported (Fitzgerald *et al*., 2001; Bowman *et al*., 2017). While this study reports seven species, one shrew and six rodent species, two of them which include *Graphiurus* spp. and *Steatomys parvus* were rarely encountered with one individual each in the whole study period.

The low numbers of rare encountered species could suggest possibly unsuitable habitats for these species' settlement, breeding, and survival, as *Steatomys parvus* inhabit riverine forest, with dense grasses savanna habitats interspersed with forest relicts (Schlitter and Monadjem, 2004; Kingdon *et al*., 2013). *Graphiurus* spp. inhabits habitats from montane forest or riverine forest, little in woodland, savanna, grassland and rocky areas, because they are browsers (Cassola and Child, 2016).

The results also show more rodent abundance in the burned area than the unburned area within the whole trapping period. This is quite different with other studies, which shows numbers in the burnt area were much lower than in neighboring unburned areas (Bowman *et al.,* 2017). The large number of rodent individuals collected in burned area might be an indication of species change to food and vegetation. Some rodents have reported to prefer the early grasses and others be influenced by the site and other factors (Byrom *et al.,* 2014; Shilereyo, 2017).

Low number of rodents in unburned habitats probably was due to disturbance of large mammals grazing on vegetation especially impalas, hartebeest, zebras and buffaloes were always grazing near the study site. This limits the number of rodent's movements, food and cover (Senzota, 1982). Moreover, differences in abundance between species and within habitats could be due to their difference in adaptation, food preferences and habitats selection (Yihune, and Bekele, 2012; Assefa and Srinivasulu, 2019).

Decline in abundance of some rodent species specially *M. natalensis* appears to be driven primarily by the change in individual numbers probably caused by limitation in rodents movements and searching food by fearing predation as the area remained uncovered by reduction of vegetation patches for the specie shelter after burning. Rodent movements and food utilisation have observed from other studies to be not similar to those before burning (Hoffmann and Zeller, 2005; Namukonde, *et al.,* 2017). The abundance of *A. Niloticus* decreases and disappears at burned than unburned sites have been demonstrated in savannah grassland habitats. The species is a diurnal, thus have specific niche requirements for food (Senzota, 1982; Dejene and Reddy, 2016). Differences in food supply, litter cover and interspecific competitors may be dependable for their response to

fire. They often exhibit a negative response to burning in wooded grassland, thus why they were unable to sustain populations after burning (Senzota, 1982).

The abundance of *Aethomys* spp. increased after fire but after two months later the abundance decreased. *Aethomys* spp. may respond to a decline in grass cover and seeds, but an increase in early greenness food quality and quantity might initiate their presence (Cassola, 2016). *Mus* spp. species disappeared on burned field after establishment of fire and appeared after the early grasses grow up because their requirements for food depreciated. Three months after burning, these species (i.e. *Mus* spp. and *A. niloticus*) were captured, although only few were trapped.

The equality in species diversity between the burned and unburned plots indicates that both habitats had equally adequate resources (i.e. vegetation) to support diversity of species in the area. Vegetation is known to supports the existence of different animals in several habitats as it provides macro and microhabitats in addition to the main source of food for rodents (Cramer and Willig, 2002; Byrom *et al*., 2014). This is quite different with other studies which indicated a very low biological diversity of rodents in burned area as compared to unburned area (Bowman *et al*., 2017), similarly in the park (undisturbed area) as compared to outside the park (disturbed) (Magige and Senzota, 2006; Timbuka and Kabigumila, 2006; Magige, 2016). Low diversity on their studies may be due to frequent disturbances such as ecological disturbances and human activities including agriculture, grazing, grass cutting and may be burning which interfere with ecological niches of rodents (Senzota, 1982; Magige, 2016).

The diversity in burned area was probably contributed by green early food (early plants species) availability inhabit after burning. Burned area always reduce vegetation patches,

habitats and cover, creating opportunities for specialization and niche partitioning to create center of other species of rodents (Mowat *et al*., 2015; Read *et al*., 2018). Nevertheless, the diversity of rodents at unburned area is primarily due to the rich vegetation and ground materials. This may contribute and stabilize species interactions with an ultimate resulting of relatively species diversity (Fitzgerald *et al*., 2001).

Previous studies have found that diversity has been greater in unburned than burned (Bowman *et al*., 2017). For burned area to be similar to unburned, it takes two or more years after fire (Bowman *et al*., 2017). This indicates that burned areas might have a temporal loss of native plant species like vegetation cover and ground materials which might affect species diversity of rodents (Newmark and Newmark, 2002; Schabel, 2006). Therefore, changes in diversity following prescribed burning in the ecosystem are flexible with time and resources.

Furthermore, results of this study have yielded useful information for wildlife managers to synchronize control strategies in line with population fluctuation. Prescribed burning affects the population of some of the rodents (e.g. *A. niloticus*) through the way it affects their habitat. Their habitats might be affected depending on time and kind of burning. With apparently contradictory results, direct effects such as injury, mortality, and movement (immigration and emigration) might be the short-term population responses (Silva-Lugo, 2014). Indirect effects of prescribed burning through habitat alteration could influence long-term responses such as feeding, movement, reproduction, and availability of refugia like the bare land due to burning (Silva-Lugo, 2014; Bowman *et al*., 2017).

In the area, none of the direct effects of burning observed but the indirect effects of burning mediated by changes in the plant community expected to have impact on rodent

population. Higher population change in *M. natalensis* after burning suggests that this species is slowly decreased due to fire. Some species remained undetected for a relatively early time, like *A. niloticus* affected after three months. Bowman *et al*. (2017) detected the effects on rodent population after four months of the burn; no differences were detected soon after fire.

The affected species were observed to exhibit dominance associated with burning conditions, as it affects key factors such as availability of quality food and habitat cover for rodents (Hoffmann and Zeller, 2005). These shows that prescribed burning led to loss of vegetation cover which impacts on the plant species composition (Hassan, 2007; Hassan and Rija, 2011) and consequently affect the abundance of rodents.

In terms of interaction on ecosystem, the population change in rodents after burning suggest that, they might play role on the slowly disappearance of their dependent animals (predators) in the life cycle of Serengeti-Mara ecosystem. Increase in *A. niloticus* may serve as a substitute potential food but not to the satisfied adequate level of their predators in periods of low population of *M. natalensis.*

A substitute species is a diurnal species seem to be more affected in burned by the removal of vegetation cover. The species is more prone to predation when get out searching for food than nocturnal species *M. natalensis*, whose predators rely on hearing or smell to detect prey during night (Namukonde, *et al*., 2017). Furthermore, an increase fluctuation of *A. niloticus* in unburned area was due to the degree of ground cover such as long grasses, short bushes and trees, under which they provide protection for their colonial burrows and nest (Senzota, 1982).

Burning is essential for understanding breeding activities of rodents. It has been reported that the onset of the breeding season is accelerated by food availability (Duque *et al*., 2005). The present observations show that almost all females were active in March for both habitats, indicating that either there is no relationship between burning and reproductive activity of females because the breeding fall in the normal rain time trend of their breeding or their reproductive activity might ceases when burning interfere in habitats and that the effect is visible after for certain time. Therefore, the effect observed in March was probably caused by the strong relationship between rainfall, green plant growth after burning(Senzota, 1982; Magige and Senzota, 2006; Magige, 2013) and reproductive activity of female rodents (Makundi *et al*., 2007; Mulungu *et al*., 2016).

Existing literature already show that rodents show seasonal reproductive patterns synchronized with the most favourable periods of the year as a strategy to maximize reproductive success (Mulungu *et al*., 2016). Effects have been reported between burning and breeding in populations of rodents (Makundi *et al*., 2007; Leahy *et al*., 2016). It has been reported that in mixture habitats (wooded grassland), rodents breeds continuously especially during the long rains, and normally starts one month after the usual peak rainfall (March and April), lasting until the dry season (Makundi *et al*., 2007; Mulungu *et al*., 2016). They are known to have tuned their reproduction by anticipating rainy periods of abundant food supply.

For this study, the results agreed with the above statements in unburned area due to the presence of active females in both months except October, but differ in burned area, where sexually active animals fall only in the month of March. This was probably due to the removal or destruction of suitable nesting and 1itter (Mlyashimbi *et al*., 2018), as the rodents breeding depend on good vegetation cover and foraging conditions (Layme *et al*.,

2004). Therefore breeding patterns of rodents in Serengeti depend on the nature of the circumstances they face and be affected by it in regulating breeding activity in the area.

Some studies indicated that rodents have a reproduction cycle which is related to circumstances they face (Mlyashimbi *et al*., 2018). In areas where prescribed burning is applied per year, the breeding duration of rodents is limited (Mulungu, 2017). According to Mulungu (2017) and Byrom *et al*. (2014) reported that, breeding of rodents in woodland and grassland is limited due to unpredictable changes related to circumstances appeared in different periods, leading to lower litter sizes and subsequent population decreases.

In Serengeti wooded grassland, the link between breeding and prescribed burning is weak, although breeding has been observed to decrease in burned area. Probably burning is likely to play indirect role by influencing reproductive physiology on food availability and cover (Layme *et al*., 2004). This could be the reason why in this study reproductive activity in burned area is at its lower point after burning and timing of breeding is related to the timing of germination in grasses.

CHAPTER SIX

6.0   CONCLUSION AND RECOMMENDATIONS

6.1   Conclusion

Species composition of rodents was maintained in burned study sites. However, species dominance was influenced, with a dominance of *M. natalensis* in burned habitats and *A. niloticus* dominance in unburned habitats. In terms of community structure, the number of sub-adults decreased in burned habitats compared to unburned areas. Sex ratio was at parity in burned and unburned habitats. New individuals trapped in burned areas were probably attracted by the new vegetation. The effect of burning did not influence the breeding patterns of rodents during the peak of female reproductive activity at the start of long rains in March.

6.2   Recommendations

Conservation strategies involving periodic habitat burning should consider small mammal reproductive periods and baseline species diversity to ensure that potentially at-risk species are not adversely affected and able to rapidly recover from the effects of burning on temporarily lowering food resources and longer term impacts of increased predation caused by reduced cover.

This information serves as a guide for future research in Tanzania. Therefore, several studies should be carried out such as testing the effect of timing of burning (e.g. early and late burning), and on relationship between rodents abundance, diversity and their required habitat types.

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