MOVEMENTS OF RODENTS AND HOME RANGE OF *RATTUS RATTUS* IN DOMESTIC AND PERI-DOMESTIC AREAS IN BEREGA VILLAGE, MOROGORO, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

The aim of this study was to estimate the home range size of *Rattus rattus* by using radio telemetry and range of movements of different rodent species by using Rhodamine B biomarker in domestic and peri domestic areas in post harvest, pre planting and pre harvesting seasons in Berega village, Kilosa district, Morogoro region, Tanzania; for developing ecologically based rodent management. The rodent species composition in the study area was found to be dominated by nine species namely: *Rattus rattus, Aethomys chrysophilus, Acomys spinosissimus, Mus minutoides, Lemniscomys zebra, Gerbilliscus vicinus, Grammomys dolichurus, Mastomys natalensis* and *Arvicanthis neumanni. Rattus rattus* were found spending most of their time in houses especially in roofs. *Rattus rattus* had a small mean home range size of 5.09 (± SD = 5.87) m^2 calculated from Minimum Convex Polygon (MCP). They were active during night hours (nocturnal). *Rattus rattus* movements were restricted in houses only and did not move far away from domestic areas whereas *M. natalensis* were found to be entering houses presumably depending on the availability of food in the field. Maximum daily movement registered for *M. natalensis* was 100 m. The findings indicate that *R. rattus* and *M. natalensis* overlap in their resource use because *M. natalensis* enter houses in which *R. rattus* inhabit during food shortage in the field. It is recommended that management practices such as use of rodenticides, environmental manipulation and biological control measures should take into account the home range size and distance moved by rodent pest species in order to get best control results which are economically viable and environmentally friendly.

DECLARATION

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

Signature .... Date 19/07/2013

(ELIUD FRANCIS KONGOLA – MSc. CROP SCIENCE CANDIDATE)

The above declaration is confirmed

Signature .... Date 22/7/13

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This work is dedicated to my parents Mr. Francis Moses Kongola and Mrs. Mary Massi - Kongola for taking initiatives to send me to school.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

AAFRD	Alberta Agriculture Food and Rural Development
AMAE	Animal Movements Arc View Extension
ANOVA	Analysis of Variance
APOPO	Anti Persoonsmijnen Ontmijnende Product Ontwikkeling
CMR	Capture Mark Re-capture
DADPs	District Agricultural Development Programs
DED	District Executive Director
df	Degrees of Freedom
EBRM	Ecologically Based Rodent Management
ECORAT	Ecologically Based Rodent Management Project
FAO	Food and Agriculture Organization
GLM	General Linear Model
GPS	Global Positioning System
HRE	Home Range Extension
IPM	Integrated Pest Management
LSD	Least Significant Difference
MCP	Minimum Convex Polygon
MOAFS	Ministry of Agriculture and Food Security
N	Population
Ns	Not Significant
P	Probability
RB	Rhodamine B
SAS	Statistical Analysis System
SD	Standard Deviation

SPMC	SUA Pest Management Centre
SUA	Sokoine University of Agriculture
UD	Utilization Distribution
USA	United States of America
UV	Ultraviolet

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Rodents are the biggest problem among the vertebrate pests in Africa (Buckle, 1994). They consume and damage large quantities of stored grains (Mdangi, 2009). other types of food and crops in the field (Mulungu, 2003). They carry diseases (e.g. Leptospirosis and Toxoplasmosis) which can be transmitted to humans and which are responsible for considerable economic loss in terms of decreased worker productivity and health care-costs (Machang'u *et al.*, 2004). Despite being destructive to crops, farms and fruit trees rodents tend to destroy what they are unable to consume, by urinating and defecating on remains of their meals, ruining grain, cereals, and other food sources (Nowak, 1999). It is estimated that every year rodents eat or contaminate enough food to feed 200 million people worldwide during post harvest period (Gregory, 2002). Rodents, therefore, are one of the major causes of post- harvest crop losses (Buckle, 1994). Mdangi (2009) reported a crop loss in the store to be 35% while the contamination continues to increase as the time of storage increases. It has been reported that within six months, one pair of mice can eat more than a kilogram of food and deposit about 18,000 droppings therefore, food contamination by mice is about ten times more than what is eaten (AAFRD, 1996).

According to Kilonzo (2006) the commonest storage rodent pests in Tanzania are the roof rats (*Rattus rattus*) and house mice (*Mus musculus*). However, where the grains are stored outdoors in dry weather, multimammate rats, *Mastomys natalensis* (Smith 1834) may also cause damage and sometimes may enter houses and cause losses (Fiedler, 1994). Singleton *et al.* (1999) report that rodent pest management has gone through a period of stagnation over the last 20 years due to the fact that too little research efforts have been geared towards understanding the biology, behaviour and habitat use of rodent pests. Therefore, it is necessary to have basic knowledge of the behaviour of the rodent species in question (Myllymaki, 1987) and information on movements, home range and colonization ability (Gosling and Baker, 1989).

The efficiency of rodent control approach depends largely on understanding why and when the targeted species prefers a particular habitat (Fitzwater, 1988). Failures encountered in rodent control may be attributed to bait placed out of the home ranges (Pratt and Brow, 1976). Data on habitat preferences and on distances traveled by rodents are scarce and have been obtained through various methods including Capture Mark Recapture (CMR). However, this method allows neither the exact determination of the movements and home range of animals nor the exact location of their nests nor burrows (Happold, 1977). Telemetry often is the only way to differentiate individuals and acquire data on their physiology and habitat use (Genest–Villard, 1978). In population studies, live trapping alone provides only broad demographics at a population level, whereas telemetry provides additional individual-level data on survival and activity budgets of individuals. The most widely used methods of gathering information about animals' movements and home range size are the use of Rhodamine B and Radio telemetry methods, respectively (Genest–Villard, 1978). These methods provide more accurate data on the movements, home range size, habitat use and the exact location of nests and burrows of animals (Genest–Villard, 1978). In this study, Rhodamine B biomarker was used to study movements of different rodent pest species and Radio telemetry was used to study home range size of *R. rattus* which is the major storage rodent pest in Berega village (Mdangi, 2009).

1.2 Objectives:

This study had the following overall and specific objectives:-

1.2.1 Overall objective

To assess movements and home range of rodents in domestic and peri- domestic areas for development of ecologically based rodent management.

1.2.2 Specific objectives

i. To establish rodent pest species composition in the study area.
ii. To estimate distance moved by different rodent pest species in domestic and peri domestic areas.
iii. To determine home range size of *R. rattus*.

1.2.3 Hypotheses

i Home range and distance moved by rodent pest species are affected by cropping seasons.
ii. Home range and distance moved by rodent pest species are affected by house arrangements in the village.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Rodent Pest Species

During the last 55 million years of mammalian evolution, the order Rodentia has had a radiation in mammalian communities and has emerged as the largest order of mammals, encompassing 2277 species which have been described (Wilson and Reader, 2005). This represents over a quarter of the families, 35 per cent of the genera and 42 per cent of the world's extant mammals although this is by no means a complete list (Wilson and Reader, 2005). About 150 species have been defined as pests at some localities to some crops at some time or another. Fiedler (1994) identified 15 species of rodents as important crop pests in Eastern Africa.

Reports by Hubbard (1972) and Fiedler (1994) cited by Makundi *et al.* (1999) reveals that over 25 rodent species are implicated in crop depredation in this region. Of these, three species are found throughout the world: the house mice (*Mus musculus*), *R. rattus* and the brown rats (*R. norvegicus*) (Greaves, 1982). The spiny mice (*Acomys cahirinus*) and *M. natalensis* are found in Africa (Posamentier, 1989). The major rodent pest species in Tanzania are multimammate rats (*M. natalensis*), Nile rats (*Arvicanthis spp.*), *R. rattus* and *M. musculus* (Kilonzo, 1993). In some localities, the African giant rats (*Cricetomys gambianus*), Cane rats (*Thryonomys spp.*), Gerbils (*Tatera spp.*) and mole rats such as *Tachyoryctes spp.* are found (Makundi *et al.*, 1991).

These species are serious pests in field crops and they can cause serious damage before or after harvest (Leirs, 1999). Rodents cause numerous problems as agricultural pests but also act as reservoirs and transmitters of pathogens, which are particularly problematic in developing countries (Stenseth *et al.*, 2001).

The following is the description of few important rodent pest species:-

2.1.1 The ship rat, Roof rat (*R. rattus*) (Linnaeus1758)

This is a cosmopolitan rodent which originated in South East Asia and spread to other parts of the world (e.g. Africa) through international trade (Meehan, 1984). There are many subspecies and forms of *R. rattus* and, because of this; it is difficult to give a definitive description of it. In the same country the coloration may range from almost black to red brown dorsally and dark grey to white ventrally (Buckle, 1994). The head + body length of the rodent can be between 150-220 mm and the fully grown adult can weigh between 150-250 grams (Niethammer, 1981). The tail is longer than the head + body length. The ears are thin, translucent, relatively large and hairless, while the snout is comparatively pointed (Lund, 1996).

Although it has become fairly rare in Central and Northern Europe and Asia, *R. rattus* has become a field pest in many countries, and because of its good climbing ability, this rat infests fruit orchards besides entering buildings. This species was responsible for carrying the fleas which spread the plague in the middle ages (Sumangil, 1990).

2.1.2 The house mouse (*Mus musculus*) (Linnaeus1758)

This species is also cosmopolitan, and has originated in the steppes of Central Asia on the Iranian-Russian border (Schwartz and Schwartz, 1943). It is now the most widespread mammal in the world (Meehan, 1984). There are many subspecies and with diverse colour variations: the fur dorsally is usually brown to brownish grey (although black and other colours occur), and grey ventrally. The head + body length can be between 70-110 mm, and a fully grown adult weighs between 15-30 g (Marshall and Sage, 1991). The tail is about as long as the head + body length. The ears are quite large in relation to the rest of the body, while the feet are comparatively small and the snout pointed (Lund, 1990 cited in Buckle, 1994). The house mouse is a good climber and lives in social groups. It can be a serious pest in agricultural fields and buildings, but has also been recorded in native or natural vegetation (Lund, 1990).

2.1.3 The multimammate rat (*Mastomys natalensis)* (Smith 1834)

This species is economically the most important rodent pest in Africa South of Sahara, and a true indigenous commensal (Fiedler, 1988). In many areas, it may be replaced by the much larger *R. rattus* (Monadjem *et al.*, 2011). The fur is soft, brownish on the back and greyish underneath. The head + body length can reach 150 mm, and the fully grown adult weight can weigh between 50-100 g. The tail, which is uniformly dark, is about the same length as the head + body (Lund, 1990). Most distinctively, the female can have up to 24 nipples on her belly (other rat species rarely have more than 10) and the reproductive potential is high, particularly since this species lives in large social groups (Lund, 1990 cited in Buckle, 1994). Consequently, very large population explosions occur from time to time, causing huge losses (Mulungu, 2003). Its number reaches a peak in the dry season after harvest where upon they invade the villages and storage huts. This semi commensal biology makes it important transmitter of plague from field rodents' populations to the roof rat inside the structure (Buckle, 1994).

2.2 Economic Importance of Different Rodent Species

The problem of rodent damage in agriculture is complex because almost any crop can be the target of rodent attack (Fiedler, 1988). Rodent pest outbreaks have been recorded in Africa since early 19th century (Fiedler, 1988). However, of the almost 400 existing rodent species on the African continent, only about 5% are known to cause damage to agricultural crops (Makundi *et al.*, 1999). *Mastomys spp* and *Arvicanthis spp* are most frequently involved in population explosions and they are considered as the dominant vertebrate pest species in sub Saharan Africa.

Broad scale management of these rodents tends to rely on rodenticides. Ecologically based rodent management (EBRM) techniques (Singleton *et al.*, 1999) are still rare in Sub Saharan Africa, although there has been a considerable increase in the knowledge of the involved species ecology during the last two decades. Rodents cause crop loss both in the fields and stores. The types of damage most often caused by rodents to crops such as maize include: (i) destruction of seeds after sowing and during the first week of growth (ii) damage to the mature crop on the stem and damage to stored crops and (iii) contamination to stored grains through droppings, hairs and urine which results into low market value (MOAFS, 1984).

Crop loss caused by rodents in Tanzania is estimated to be an average of 15% (Makundi *et al.*, 1991). It has been reported that maize damage by rodents in stores to be 35% (Mdangi, 2009) and sometimes losses in the fields were reported to be over 80% in some seasons and locations (Mulungu, 2003). According to Mdangi (2009) contamination due to droppings is high and can affect the value of produce.

2.3 Current Rodent Management Strategies

2.3.1 Chemical control

The use of rodenticides has proven to be relatively an inexpensive way to reduce rodent damage by increasing mortality which is one of the key demographic processes in population dynamics (Leirs, 2003). There are a variety of compounds and ways of delivery, with second- generation anticoagulants giving the best results (Buckle, 1994). It is important, however, that the rodenticides are evaluated relative to the degree of protection they give to the crops, and not from the viewpoint of rodent mortality (Buckle, 1994). An important reason why the latter does not hold is that density-dependent effects on recruitment and natural mortality may compensate for the mortality caused by the rodent control so that the population size as such is hardly affected (Leirs *et al.*, 1997). Another and less often recognized reason is that the relationship between rodent numbers and damage is not necessarily linear. Mulungu *et al.* (2003) reported that the relationship between rodent density and maize damage is sigmoidal function indicating that rodent damage increases more rapidly above a certain threshold in rodent abundance (this occurs if rodents switch to eating and damaging the crops only above a certain population density). In this situation, any decrease in rodent abundance will result in a proportionally higher decrease in damage, especially if rodent abundance moves from above to below the threshold value. It is also important to recognize that physiological and behavioural differences among rodent species can affect the effectiveness of particular toxicants or formulations. In order to be effective, rodenticides must be applied at the correct point, both in space and time (Tobin *et al.*, 1997).

Generally, management of rodent pests in Tanzania relies on the use of chemical rodenticides (Makundi *et al.*, 1999). However, rodenticides are rarely economically and ecologically sustainable and are often applied only when the damage has already occurred

(Skonhoft *et al.*, 2006). In general, the success of rodent control using rodenticides depends on:- (i) availability of required rodenticides, (ii) acceptability of bait formulation to rodents and (iii) the timing of bait application: this is critical for alleviating rodent damage (Mulungu, 2003). However, correct application rate can be a problem under farmer's situation.

2.3.2 Biological control

Biological control of rodent pests in Africa in general is almost an unexplored area and less attention has been directed to the role of predation in tropical rodent population dynamics (Vibe-Petersen, 2003). Van Gulck *et al.* (1998) reported an increase of raptor activity in areas with perch poles and an increase of survival of *M. natalensis* in areas without avian predators. Vibe-Petersen (2003) investigated the effects of different levels of predation pressure on the population dynamics of *M. natalensis* in maize fields and its consequences on crop damage and maize yield production.

The author showed that (1) population growth during the annual increase phase was faster and peak population size increased in the absence of predators, (2) predation may be the strong driving force for rodent emigration and (3) manipulating predation pressure by perch poles and nest boxes did not affect rodent population dynamics directly, but may have an indirect beneficial effect on maize yield by changing the rodents foraging behaviour.

2.3.3 Mechanical control

Mechanical rodent control is not very practical; it is cumbersome, labour intensive, and often not very efficient (Prakash, 1990). Mechanical techniques are more appropriate in households, and can be used if the owner has no access to poisons or is averse to their application. The method most commonly used in buildings is trapping (Meehan, 1984). Often local traps are available and in some cultures people are very good at using them. Such traps should be placed where rats move regularly. Sticky or glue traps are another way of catching rats and mice (Prakash, 1990). These are boards made of wood, hard- or cardboard covered with very sticky material. The boards are placed in the same way as traps, and there is normally no need for the bait to attract the rats. These traps should be checked daily. The traps are not however regarded as very 'humane'.

Flushing rodents out of their burrows, with smoke or by flooding them with water, can be very effective and suitable in some situations. Ultrasonic devices are another method which is mentioned regularly, particularly by manufacturers of these devices, as a good repellent of rats and mice in buildings. However, there is no scientific evidence of their effectiveness. It appears that rats become habituated to the sound or stay in 'sound shadows' (Meehan, 1984).

2.3.4 Integrated rodent pest management (IPM)

Very few studies have been done in Tanzania on IPM. An IPM Programme for rodents is not applicable during outbreaks because the mortality may not be high enough to reduce damage while the remaining population often compensates due to better survival of breeding performance (Leirs, 1992).

2.4 Ecological Considerations in the Management of Rodent Damage

Ecological considerations are of paramount importance in formulating strategies for managing vertebrate pest populations (Swihart, 1992). Effective strategies for reducing damage rely upon an understanding of the biological factors that lead to damage. Population size is often the principal determinant of the extent of damage (Leirs and

Verheyen, 1995; Mulungu *et al.*, 2003). In fact, rodent management in its simplest form may be defined as the application of ecological knowledge to rodent populations. In addition, numerous behavioural and ecological attributes of individuals may influence the extent of damage, including foraging habits and food preferences, mobility and habitat requirements. Interfering at population level requires a good knowledge of the ecology of the species and which can be an important basis for pest control (Leirs and Verheyen, 1995). Rodenticides have commonly been used for symptomatic treatment to reduce damage when rodent populations are already high. This necessitates the application of large amounts of rodenticides. Knowledge of rodent population dynamics is required to suggest appropriate timing of prophylactic treatment to alleviate the damage caused by rodents (Mulungu, 2003).

Ecologically based rodent management was developed to provide a sound ecological basis required for developing management strategies for rodent pests (Singleton *et al.*, 1999). Ecologically based rodent management has been an important paradigm for research on rodent management over the past several years in many regions of the globe (Singleton *et al.*, 1999). Recent economic analyses of EBRM in Indonesia indicated positive outcomes (Davis *et al.*, 2004).

2.5 Home Range

The home range refers to the area used by an animal during its normal activities of food gathering, mating and caring for the young (Jewell, 1966). This definition is associated with social activity but is influenced by several factors. In ungulates, for instance, spatial behaviour may depend on density (Vincent *et al.*, 1995), forage availability (Larter and Gates, 1994), habitat dispersion (San José *et al.*, 1996), human activity (Creel and Creel, 2002) and climatic conditions (Krasin´ ska et *al.*, 2000). The home range area is not only dependent on external variables but also on individual conditions such as sex (Cederlund and Sand, 1994), age (Cederlund and Sand, 1994), body mass (Mysterud *et al.*, 2001) and pregnancy and weaning (Bertrand *et al.*, 1996).

Generally, home range size is regarded as an indicator of habitat quality (Tufto *et al.*, 1996). The lengths of movements are a good index of home range size in small mammals (Slade and Rusell, 1998). Length of foraging trips affects both the energetic cost of food acquisition and the risk to be predated (Yletyinen and Norrdhal, 2008). Reintroduced animals had exploratory requirements to know the new environment and probably their larger home ranges included unsuitable areas (Pedrotti *et al.*, 1995). The female ibex population of the Gran Paradiso National Park in Graian Alps in Italy showed a high fidelity to site: explorative movements were reduced as suggested by the high overlaps of the annual home range and the small distances between the activity centres.

As reported in other ungulate species such as red deer (Clutton-Brock *et al.*, 1982), Chamois (*Rupicapra rupicapra*) (Hamr, 1985); Spanish ibex (*Capra pyrenaica*) (Escos and Alados, 1992); moose (*Alces alces*) (Cederlud and Sand, 1994), home range sizes of female Alpine ibex were remarkably smaller than those of males (Perrin *et al.*, 1999). The extreme sexual dimorphism of ibex (Bassano *et al.*, 2003), that seems correlated with the spatial segregation of the sexes (Villaret *et al.*, 1997) and the different aggregation between sexes (Bon *et al.*, 2001), could influence female spatial behaviour. The presence of physiological necessities correlated to pregnancy and weaning, combined with an anti-predatory strategy directed to defending kids, could induce females to reduce movements and generate high site fidelity as suggested in other ungulate species (Boschi and Nievergelt, 2003).

In studying home range size of rodents, several techniques such as CMR, Spooling and Radio telemetry methods have been used. However, Radio telemetry is the most advantageous than other methods because it gives the exact location of burrows and nests of the individual.

2.6 Factors Influencing Movements and Home Range of Rodent.

There are a number of factors that influence movements and home range of rodents. Such factors include food availability, predation, vegetation cover, population density and sex and reproduction condition. Each of these factors is explained below.

2.6.1 Food availability

It has been suggested that food resources are clearly a limiting factor for rodents (Monadjem and Perrin, 1998) and may therefore, strongly affect the habitat utilization of these selective feeders. For instance, the availability of suitable food resources influenced the distribution, numbers, reproduction, and mass of rodents (Monadjem and Perrin, 1996). The analysis of mobility and reproduction in *Mastomys erythroleucus* showed that, during periods of food availability *M. erythroleucus* were sexually active and population was in a grouped sedentary with home range size of 530 m^2, whereas during the period of restricted foods. *M. erythroleucus* were sexually inactive, mobility and displacement increased with home range size of 1200 m^2 (Sicard and Papilion, 1996) Therefore, food availability is the key factor which determines the home range size and movements of rodents. In Australia rodents were known to move in response to changes in availability of food resources (Jacob *et al.*, 2003).

2.6.2 Predation

Predators can affect their prey in a variety of ways including numerical effects (Meserve *et al.*, 1993) and changes in a prey's behaviour (De Witt *et al.*, 1999). Predators can also affect the movements and spatial behaviour of prey irrespective of microhabitat (Desy *et al.*, 1990). Predation risk may limit the distance prey move, reducing individual home range size and overlap between individuals. Alternatively, individuals preferentially exploiting microhabitats with reduced predation risk could increase movements by travelling between specific locations, increasing individual home range size and overlap between individuals (Lagos *et al.*, 1995).

2.6.3 Vegetation cover

Many studies on habitat selection have found that vegetation cover is an important determinant of rodent distribution not only in Africa (Monadjem, 1997) but also in temperate and boreal zones (Dickman, 1992). The preference for high cover has been suggested to be the most likely adaptation for reducing predation risk especially the one imposed by birds of prey (Thorson *et al.*, 1998). Anderson (1986) and Desy *et al.* (1990) also found home ranges of some species of rodents to be smaller in the sites where the risk of predation was greater (i.e. habitat with sparse cover), suggesting that predation risk may also influence home range size and movements.

2.6.4 Population density

Population density affects home range size through competition for space and resources. Thus, population density should have a negative influence on home range size (Ostfeld and Canham, 1995).

2.6.5 Sex and reproductive condition

Females of promiscuous species are presumed to display territorial behaviour directed at the protection of nestling from infanticidal females, whereas home ranges of males are based on food availability or dispersion of potential female mates (Bond and Wolf, 1999). It follows, therefore, that reproductive females, because of the need to protect the nest, would have smaller territories than would non reproductive females. Home ranges of males and females overlap in behaviourally monogamous and communal nesting species Therefore; home range size would be expected to vary between sexes and within sexes during breeding and non breeding periods of promiscuous species, but not for monogamous or communal nesting species (Getz *et al.*, 2001). Leirs (1992) reported that reproductive females of *M. natalensis* require more carbohydrate therefore; they would have larger home range size because they are more mobile in search of food than would non reproductive females.

2.7 Radio Telemetry

Radio tracking, one type of biotelemetry, is defined as "The use of radio-transmitters and receivers to record location information" (Honess and MacDonald, 2003). Radio telemetry is an important technique for gathering information on the movement patterns and survival rates of wildlife species (Millspaugh and Marzluff, 2001). The use of biotelemetry in vertebrate field studies is ubiquitous (Moorhouse and MacDonald, 2005). In the early 1960s, radio tracking techniques were developed to remotely monitor movement and activities of free ranging animals (Cochran and Lord, 1963). Through the years, several designs have been devised to mount antenna(s) on, to increase mobility and accuracy of the data collection (Mechlin and Sapp, 1997). However, there is no single devised radio tracking system that will work in every situation. Therefore, radio tracking systems must be designed individually to meet requirements of each study (White and Garrot, 1990).

An extensive study of nocturnal rodents by mammalian ecologists who wish to quantify patterns of movement such as habitat preference or size and shape of the home range is difficult (Schroder, 1979). Unlike the easily observed animals such as birds or diurnal mammals, much of what we know about movements of nocturnal rodents must come indirectly from trapping. By its nature, however, trapping can only yield fairly good information on movement patterns, however, little is known as to how baited traps may affect the behaviour of animals (Schroder, 1979).

More recently, some ecologists have been using radio transmitters which have many advantages over trapping because it gives the exact location of the animal's nests and burrows (White and Garrott, 1990). However, in forest, radio tracking of small mammals is time consuming and the range of the transmitters does not usually exceed 20 – 30 m. Moreover, this technique is difficult to apply to species of very small size such as shrews (weight less than 3 g) (Genest – Villard, 1978). Harris *et al.* (1990) revealed that even after radio tracking was first used in ecological research, many studies still failed to achieve their full potential because of problems with the collection and analysis of data. This reason reinforces the need for using appropriate and sophisticated analytical techniques.

2.8 Home Range Analysis

One of the basic requirements in the study of animals is an understanding of the relationship between the animal and its environment. At a grossly simplified level, this requirement is complemented with home range analyses. Home range is a concept that attempts to describe the spatial context of an animal's behavior (Mitchell and Powell, 2003). Home Range was formally defined by Burt (1943) as "that area traversed by the individual in its normal activities of food gathering, mating, and caring for young". Home ranges have been analyzed since the time earliest hunting cultures to track their quarry. Today, the techniques and uses of home range analysis have become more sophisticated (Mitchell and Powell, 2003). With the improvement in the conceptual grasp of home range, and its analysis, the concept has been used for habitat evaluation and recently the concept has been used to even predict fitness (Mitchell and Powell, 2003).

2.9 Home Range Estimation Software Discrepancies

Larkin and Halkin (1994) reviewed several software packages used in estimating animal home ranges. At that point of time, few options were available for kernel estimation, and no comparison was possible. Lawson and Rodgers (1997) made a similar comparison using a single real dataset. They found significant differences between the results from the programs reviewed (CALHOME, RANGES IV, RANGES V, and TRACKER). The differences in kernel estimation were attributed to algorithms used in the programs. For this reason, it is recommended that algorithms be clearly stated in program documentation (Lawson and Rodgers, 1997). They also noted differences in the options the users were given in terms of the type of smoothing (fixed and adaptive) and the actual kernel used in the analysis. Two extensions for Arc View3x have come into popular use. These are the Animal Movements Extension to Arc View v2.0 (AMAE) (Hooge and Eichenlaub, 2000) and the Home Range Extension (HRE) (Rodgers and Carr, 1998).

Unfortunately no detailed review has been done for these kernel estimators. Several Minimum Convex Polygon (MCP) estimators are available, but it is hoped that different packages would provide identical results for a deterministic measure such as MCP. All techniques used to estimate size or use patterns of an animal's home range require subjective decisions on the part of the investigator, and all of these techniques have statistical limitations (White and Garrott, 1990). Most home range estimators were developed to analyse data points collected once or a few times a day, often from live-trapping or radio telemetry studies. However, many studies investigate habituated individuals or groups of animals. The data collected in these studies are often multiple sequential location points collected over a long period of time, and are usually highly auto correlated. Probabilistic estimators that assume independence of points cannot readily be applied to these data (Worton, 1989).

Increasing the time interval between data points to achieve statistical independence can result into underestimation of an animal's range and loss of information, such as distance moved in a 24-hr period (day-range length). Harris *et al.* (1990) found that even after 25 years after radio tracking was first used in ecological research; many studies still fail to achieve their full potential because of problems with the collection and analysis of data. This reason reinforces the need for using appropriate and sophisticated analytical techniques. The usual definition of the home range (the area used by the animal for its normal activities) suffers from drawbacks, since "use" and "normal" are not explained (White and Garrot, 1990). The estimation of the home range size thus depends on the objective of the study, thus field biologists need to clearly identify what is to be learned before undertaking data collection (Kenward, 1992).

2.10 Rodent Movements

Movements of animals are an important element in their ecology (Slade and Russell, 1998) also provides essential information about the spatial distribution of species (Stapp and Van Horne, 1997). Movement patterns and distances are related to several aspects of the ecology of a species, like genetic structure, feeding habits, food availability, mating systems, and reduction of exposure to predators (Roche *et al.*, 1999). Moreover, movements are associated with the social organization and population dynamics of a species (Bergallo and Magnusson, 2004).

The knowledge of distances moved by different species is necessary to calculate basic parameters of the ecology of a population, such as density estimates, as well as to understand its genetic structure (Mendel and Vieira, 2003). The use of distances moved between successive captures instead of area calculations like minimum convex polygons has several advantages. Movement distances are comparatively easy to assess, easy to calculate, and can be used even for individuals with capture histories are too brief for models (Slade and Swihart, 1983). Studies have indicated that distance measurements are correlated with home range size (Slade and Russell, 1998). They provide an average index of the home range for the species and can be used for comparison between groups within a species (e.g., age- or sex-specific analyses) (Slade and Russell, 1998) or between different species (Gentile and Cerqueira, 1995).

Nevertheless, using trapping distances as an index for spatial use also has some disadvantages. Some individuals might preferentially be caught in one trap or make a trap unattractive for others. The capture probabilities between individuals or species might differ because of different behavioral responses or heterogeneity due to age or sex, or to time effects (White *et al.*, 1982). Therefore, the use of distances between successive captures to reflect movements of species is not directly comparable to home range size data obtained by direct measurements (e.g., radio-tracking). Pratt and Brow (1976) reported that when dealing with rodents in an area, it is of great significance to be aware of their movements. Thus, when planning a rodent control program it is important to know their home range in order to achieve maximum results.

Pratt and Brow (1976) reported that nearness of food, water and hiding-places are important factors in the extent of the home range, if food and water are close by, such that the rats need only to move a short distance to find them, then the rats may be able to live their entire lives in one building. Many rodent pests are characteristically mobile and able to disperse rapidly, this allows them to move quickly into and take advantage of new areas with favourable conditions (Meehan, 1984). However, once individuals have established a territory or home range, they will not move very far, as long as conditions remain favourable (Fiedler, 1988).

The number of rodents may suddenly increase if the environmental conditions become favourable. The indigenous populations are able to increase at several places in the area at about the same time (Leirs, 1994). This then gives the impression that the animals are on the move. It should be realised that for such a small ground living animal like a rat it is far too risky to move long distances because of predation and exhaustion (Leirs, 1994). However, it is known that bandicoot and other rats, in East Asia move from surrounding fields into villages at harvest time, which is when fields suddenly no longer provide enough food (Posamentier, 1989).

In built up areas containing food stores, *B. bengalensis* moves within an area of 30 to 146 meters in diameter (Frantz, 1984), depending on the location of the warehouses (when they are emptied), structural conditions and the availability of water. Under experimental conditions and in certain environments *R. norvegicus* will move about three kilometres in one night (Meehan, 1984). It is therefore not surprising that disinfested areas can easily be invaded by new animals from neighbouring areas or buildings. Increasing the area in which a rodent control programme is to be carried out will therefore help to reduce the rate of reinvasion (Meehan, 1984).

2.11 Rhodamine B Dye for Studying Movements of Animals

Clover (1954) and Taber (1956) suggest various mechanical means of externally marking large mammals. New (1958) and Brown (1961) used various organic dyes either in food or injected under the skin to stain droppings of rodents, rabbits and ruminants. Miller (1957) traced vole movements by detecting radioactive excretory products. An industrial dye, Rhodamine B (RB) was used by Carpenter (1987) and others to trace water circulation and dispersion in estuaries. Rhodamine B is a non toxic dye that has been used as a bait marker around the world, it is detectable by fluorescence techniques in concentrations as low as 1 part in 10 billion (Mohr *et al.*, 2007). The dye is seemingly unaffected by metabolic processes. Stability is excellent and natural sunlight has little effect on its fluorescent characteristics. Hence, this material has an advantage in for tagging the droppings of wild animals (Gast, 1963). The use of RB as bait marker is a practical alternative for the study of movements of rodents (Mohr *et al.*, 2007). Rhodamine B is a non-toxic dye that has been used for the coloration of cosmetic, pharmaceutical and agricultural spray products. Its application to staining biological tissue has been extended for use as a systemic marker in a variety of animals, because it often shows a high degree of persistence (Fisher, 1998).

Persistence appears to vary in different species, although the tissues examined and modes of administration are not always consistent among studies. Fichet-Calvet (1999), working with coypu (*Myocaster coypus*), found under-fur hairs to retain visible traces of RB for up to 225 days after feeding them for 3 days with carrots containing RB at 0.5 g/kg of carrots. Lindsey (1983) found the hair of mountain beavers (*Aplodontia rufa*) to remain visibly marked for up to 196 days after 15–35 mg/kg was delivered by oral gavages, whereas the blood plasma, analysed with a fluorometer (Turner Model 111), remained marked for only 7 days. In the same study, beavers fed on apple bait coated with 0.1–0.34% Rhodamine B remained stained around the urogenital area for only 14 days.

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Spurr (2002) found whisker marking in stoats to last for at least 19 weeks with a dose of 83 mg/kg, though the whisker that remained marked for longest was believed to have ceased growing after administration. The dye is incorporated into the hairs of animals as they grow during the few days following ingestion of RB, and can be detected in the hair shafts under ultraviolet (UV) light. Whiskers are useful because, unlike body hair, they grow all year round, so RB can be used and detected in any season. RB is typically expressed as a bright band at some point along the shaft length (Fisher, 1998) or as a series of bands depending on the number and frequency of doses taken (Spurr, 2002).

The standard method of detection is relatively unobtrusive. Only the whiskers of live-trapped animals need be collected, rather than blood or other tissue samples that may require traumatic surgical procedure or destruction of the animal. However, not all hairs are growing at any given time, and if too many non-growing hairs and whiskers are included in the sample, the result may be a false negative. One way to overcome this problem is to take a large sample from each animal, which is easy to do from carcasses, but there may be a strict limit on the number of whiskers that can be safely or ethically taken from live animals. A further problem is natural fluorescence, which is sometimes evident on whiskers and can be difficult to distinguish from Rhodamine B induced staining (Fisher, 1998). Classical methods like CMR studies and telemetry both require the release of captured rodents, communities wishing to rid themselves of rats will not accept (Krebs, 1989). Fluorescent bait marker (i.e. RB) method does not provide detailed information at the individual level, but does allow estimating minimum distances that are covered by animals from the baiting point (Papillion *et al.*, 2002).

In this research I tested the hypotheses that, home range and distance moved by rodent pest species were affected by cropping seasons and house arrangements in the village and recommended on the use of home range size and distance moved by different rodent pest species in the development of EBRM.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Site

The study was conducted at Berega village located at 06^{O}10'S; 37^{O}5' E and lies at 830 to 840.1 m above sea level in Kilosa district, Morogoro region, Tanzania. The houses in Berega village are near the crop fields (Plate1) however, there is less vegetation cover around the houses. Most houses are built of burnt bricks or mud blocks with grass thatched roofs. Kitchen and toilets are constructed with wooden poles with roofs thatched with grass. There are ten hamlets (Fig. 1) in Berega village out of which three namely Msalama, Sokoni and Mlingoti 'A' were selected for Radio telemetry study and two namely Sokoni and Mlingoti 'A' were selected for Rhodamine B. study.

The distance from Msalama hamlet to Sokoni is 300 m and from Sokoni to Mlingoti 'A' is 1.5 km. The selection of these hamlets was based on house arrangements and distances to the crop fields. Most of the houses in Msalama were grass thatched and close to each other. Sokoni houses were scattered and separated by crop fields in between. In Mlingoti 'A' most of the houses were roofed with Iron or Asbestos sheets, the houses are built close to each other with few crop fields surrounding them. Selection of the study area was based on the information obtained from the ECORAT Project, which was implemented in Berega village. Previous studies in the area showed 19% and 34.6% crop losses were due to rodents in the field and storage respectively.

R. rattus has been implicated as the major storage rodent pest while *M. natalensis*, *Arvicanthis neumanni* and *Gerbilliscus vicinus* are the major field rodent pests in the study area.

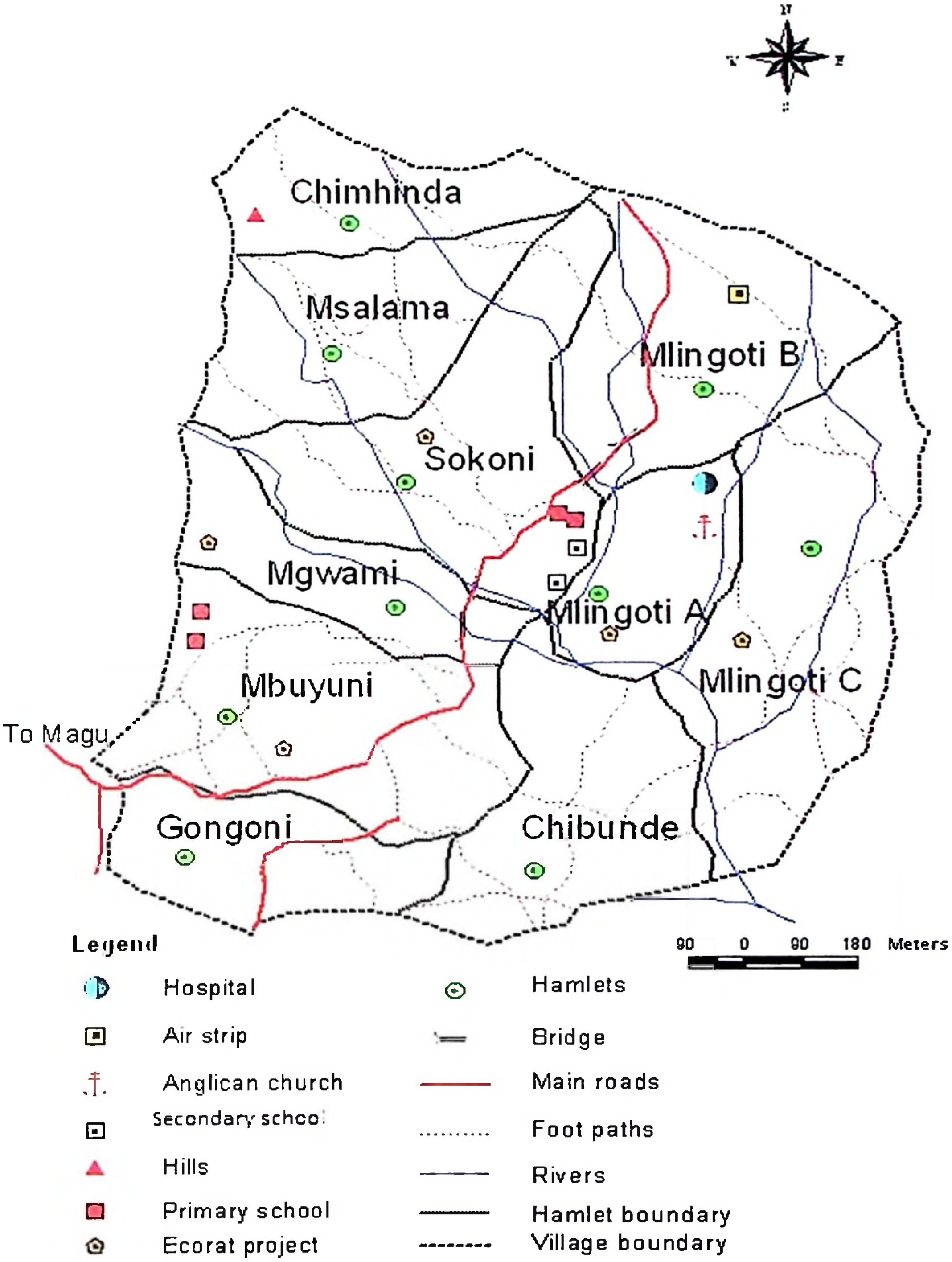


Figure 1: Map of Berega village showing Hamlet boundaries in the study area.

Plate 1: A grass thatched house at Berega village surrounded by maize field.

3.2 Experiments

Two experiments were conducted i.e. Rhodamine B. (RB) experiment for movements studies for different rodent species whereby Factorial experiment with two factors (i.e. distances and seasons) replicated in three hamlets was used and Radio telemetry experiment was used for *Rattus rattus* to establish the home range size in houses (domestic areas) and outside houses (peri domestic areas).

3.2.1 Rhodamine B. experiment for studying rodent movements

3.2.1.1 Preparation of bait

Bait was prepared from RB (Sigma– Aldrich product No. R6626) with 0.2% w/w mixed with peanut butter (i.e. 2 g of RB in 1 kg of peanut butter) then heated to 50 °C and gently stirred until the RB was uniformly mixed into the peanut butter and then allowed to cool down. Thereafter, it was mixed with 0.5 kg of maize bran and was ready for use as bait.

3.2.1.2 Experimental layout and data collection

Two experiments were conducted one in laboratory for control and another one in the field for test animals. In control experiment, rodents were captured live using box traps and Sherman traps (H.B. Sherman Traps Inc., Tallahassee, FL, USA) and standard bait (peanut butter mixed with maize bran). The experiment was conducted for three consecutive nights in houses and peri domestic areas. The captured individuals were used as controls. All captured individuals were put into two groups; one group of 127 animals had whiskers removed in the laboratory immediately after they were captured to get negative control. The second group of 156 animals was fed by bait mixed with RB in the laboratory for four days and six whiskers from both snouts were removed and labeled separately to get positive control.

The whiskers removed from animals fed with RB and those without RB were observed under Fluorescent Microscope (Olympus Education Microscope, CX21FS1, Olympus Corporation Tokyo, Japan). The six whiskers from an individual rat were placed on a single glass slide in a drop of water and then covered with a cover slide. The whiskers were then examined under UV light for any signs of fluorescence.

In field experiment, Bait mixed with RB was placed in a total of 10 houses in two hamlets. In each house 50 g of bait was introduced in coconut shells then placed within the building where rats were most likely to come into contact with it. Rebaiting of the consumed bait continued for four consecutive nights. Trapping of rodents began on the fifth night after the last night of rebaiting. Rodents were trapped at varying distances from the houses where the RB bait was placed. The trapping points were at distances of 0, 20, 50, 100 and 200 m from odamine B bait was placed: or three consecutive nights in houses and peri domestic areas.. Ten box traps were placed at 0 m (inside the house) then ten Sherman traps were placed at each trapping point outside the house (i.e. 20, 50, 100 and 200 m) making a total of 50 traps per house. The trapping continued for three consecutive nights and the trapped animals were identified to species level using Kingdons' description (Kingdon, 1994). Trap success was calculated from the number of trapped rodents, trap nights and the number of traps used as described by Telford (1989).

$$Trap\ success = \frac{Total\ number\ of\ trapped\ animals}{Trap\ nights\ x\ \ Number\ of\ traps}\ x\,100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ [1]$$

The trapped individuals had six whiskers removed with tweezers from both sides of the snout. These whiskers were placed in an eppendorf tube and labeled (Plate 2). The six whiskers from an individual rat were placed on a single glass slide in a drop of water and then covered with a cover slide. The whiskers were examined under UV light for any signs of fluorescence. The slide was investigated under a fluorescent microscope (Plate 3) under low magnification of 40x. The whiskers were compared for fluorescence with those of the control animals. Results showed RB positive whiskers were golden yellow and RB negative whiskers were greenish in colour. The whiskers were thereafter dried and stored in the eppendorf tubes for other studies and future reference.

3.2.1.3 Data analysis for movements

Rodent Movements data were subjected to analysis of variance (ANOVA) using the SAS computer program (SAS, 1990): Means Separation for all factors (i.e. distances moved, species, sex, seasons and hamlets) was tested by $LSD_{0.05}$ method for significant differences among and between the factors.

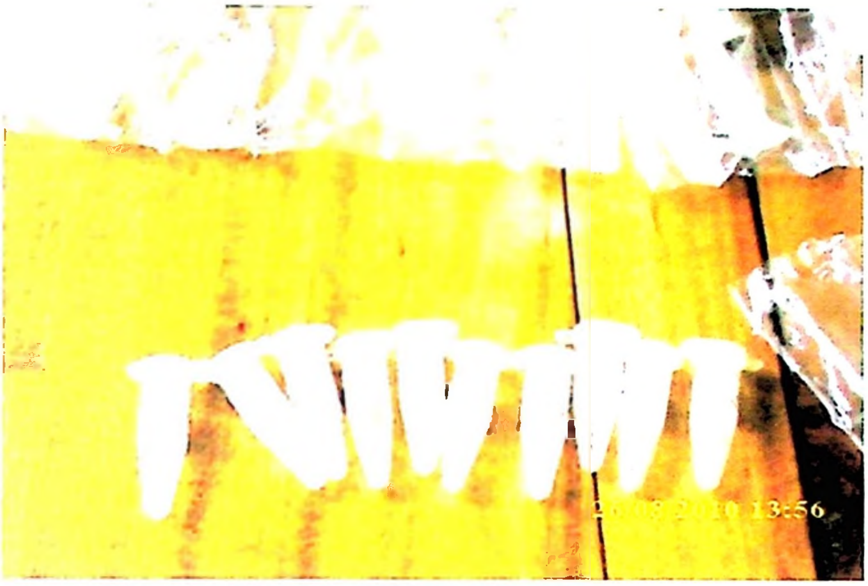


Plate 2: Whisker samples in the eppendorf tubes

Plate 3: Examination of whisker samples under Fluorescent Microscope

3.2.2 Radio telemetry experiment for home range size estimation

3.2.2.1 Rodent trapping

Trapping of rodents was conducted in the domestic areas using box traps for three consecutive nights. The captured animals were checked early morning and identified to species level using Kingdons' description (Kingdon, 1994). Weight and sex of each animal were recorded. In this experiment only *Rattus rattus* was collected for further experiment because they were the most important rodent pests in stores and houses in the study area (Mdangi, 2009).

3.2.2.2 Rodent collaring

The captured animals were anaesthetized with ether and fitted with VHF radio transmitter (Plate 4) around the neck. Twenty one (12 males and 9 females) rodents were fitted with radio transmitters. The receiver (Plate 5) was tuned to the frequency of the animal's collar in order to be able to detect the signals. The receiver was equipped with an aerial antenna (plate 6) which was designed to be directional in order to pick up the best signal.

3.2.2.3 Tracking of the collared *Rattus rattus*

The radio antenna was rotated in both vertical and horizontal positions to identify the location of the animal. The exact position of the animal was pinpointed through triangulation whereby the signal was strongest. The animals with collars were monitored at intervals of four hours for three nights when they were active (i.e. norctunals) between 1900 and 0700 hours during routine tracking operations using a radio – receiver (Biotrack Sika, Dorset, UK) and Yagi antenna (Biotrack, Wareham, Dorset, UK). This experiment was conducted for three consecutive nights in the post harvest season (August to October).

3.2.2.4 Data collection

Three fixes (i.e. Easting , Northing and elevation) were recorded from GPS (etrex, Legend C, Garmin Company, Taiwan) as location of every radio-tracked individual each time it was tracked and remarks on where it was found during monitoring. Each fix was localized in the centre of the corresponding square using the altitude of the square centre as the altitude of the fix.

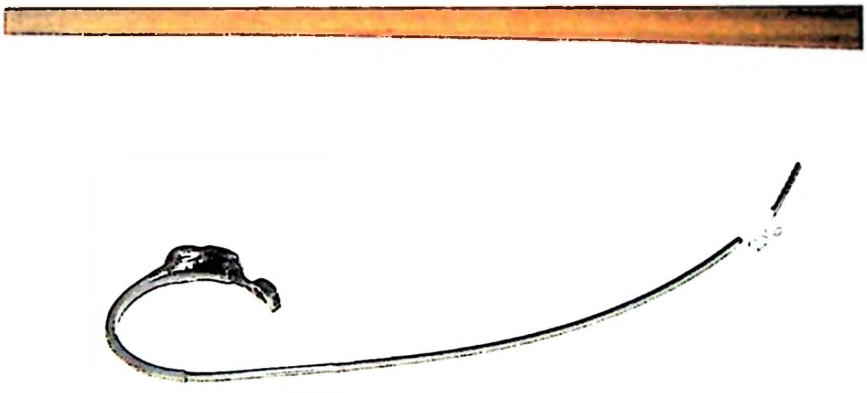


Plate 4: Radio transmitter.

Plate 5: Radio receiver.

Plate 6: *Rattus rattus* tracking in peri domestic areas in Berega village.

3.2.2.5 Data analysis

Home range sizes were calculated using Arc GIS 3.2 computer Software whereby the Eastings and Northings of a particular tracked *R. rattus* were entered in the program to get the points on the map. The points were joined to get polygons (Fig. 7a-d) which were used to calculate the home range size using Minimum Convex Polygon (MCP) (Hayne, 1949).

The variations between hamlets on home range size were analysed using one way ANOVA (SAS, 1990). Mean effect between hamlets were separated using Least Significant Different ($LSD_{0.05}$) to test if there were significantly different from each other.

CHAPTER FOUR

4.0 RESULTS

4.1 Rhodamine B Experiment

4.1.1 Rodents species composition, richness and abundance in the study area

During the study period, a total of 437 individuals were captured in three different maize cropping seasons of the year. These individuals were captured as follows, during post harvest there were 120 rodents, during pre planting there were 99 rodents and during pre harvest there were 218 rodents. The population composition in the study area was dominated by nine rodent species namely: *R. rattus* (Linnaeus 1758), *Aethomys chrysophilus* (de Winton 1897), *A. spinosissimus* (Peters 1852), *Mus minutoides* (Smith 1834), *Lemniscomys zebra* (Heuglin 1864), *G. vicinus* (Peters 1852), *Grammomys dolichurus* (Smuts 1832), *M. natalensis* (Smith 1834) and *A. Neumanni* (Matschie 1894). The results show that rodent species composition varied in different cropping seasons. *Rattus rattus* was highest in post harvest and pre planting seasons, accounting for 36% and 41%, of the rodent population respectively while *M. natalensis* dominated at pre harvest accounting for 50% of the total. In general, the overall composition of other rodent pest species shows no clear pattern of abundance at different cropping seasons (Fig 2a – c).

Species richness in post harvest season was relatively higher with eight species namely: *R. rattus*, *G. dolichurus*, *M. natalensis*, *A. chrysophylus*, *A. spinosissimus*, *M. minutoides*, *L. zebra* and *G. vicinus* followed by pre planting season with seven species namely: *R. rattus*, *M. natalensis*, *A. chrysophylus*, *A. spinosissimus*, *M. minutoides*, *A. neumanni* and *G. vicinus* the lowest was pre harvest season which had only five species namely: *R. rattus*, *M. natalensis*, *A. spinosissimus*, *A. neumanni* and *G. vicinus*.

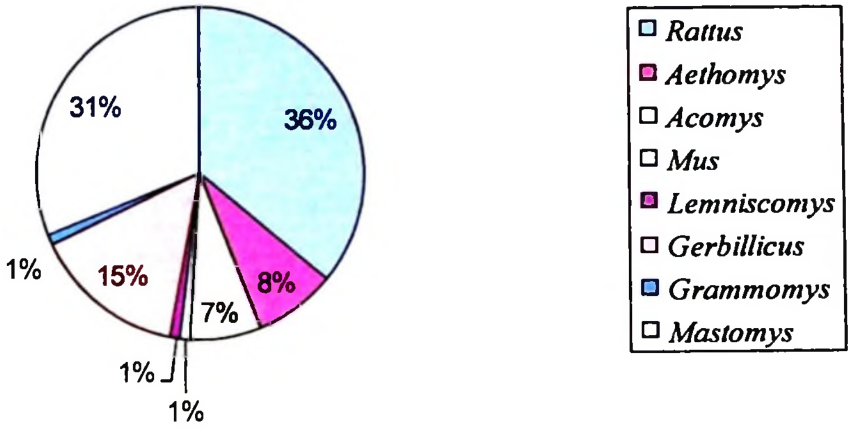


Figure 2a: Rodent species composition during post harvest season

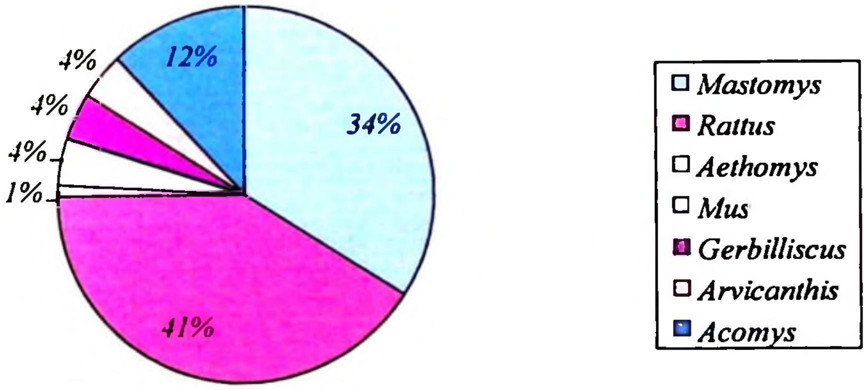


Figure 2b: Rodent species composition during pre planting season

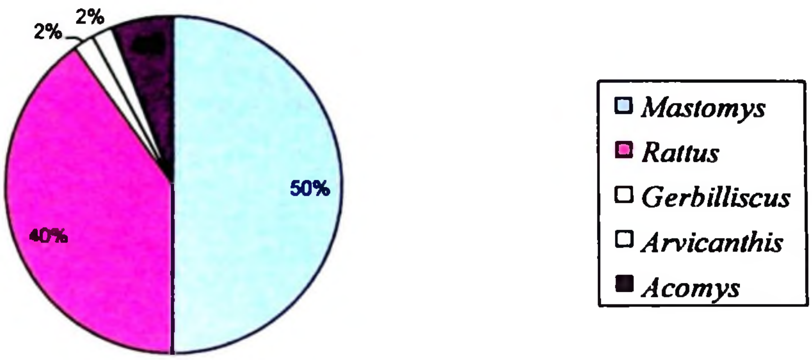


Figure 2c: Rodent species composition during pre harvest season

4.1.2 Trap success

The trap success was not significantly different (F= 4.56; df = 2, 2; p= 0.18) between seasons. However, the results show that during the pre harvest season trap success was relatively greater (Mean = 7.24) followed by post harvest (Mean =3.47) and the lowest was during pre planting season (Mean =3.30). Similarly, hamlets were not significantly different (F= 0.14; df = 1, 2; p= 0.75) in terms of trap success but Sokoni had relatively greater trap success (Mean = 4.89), compared to that of Mlingoti "A" (Mean = 4.44).

4.1. 3 Rodent movement

Ratus rattus were only captured within houses, whereas *Mastomys natalensis* and other rodent species were captured at various distances from the houses. The percentage of Rhodamine B. positive individuals varied with season whereby during post harvest, pre planting and pre harvest there were 57.14, 19.05 and 23.81% of the total capture in that particular season, respectively (Figure 3).

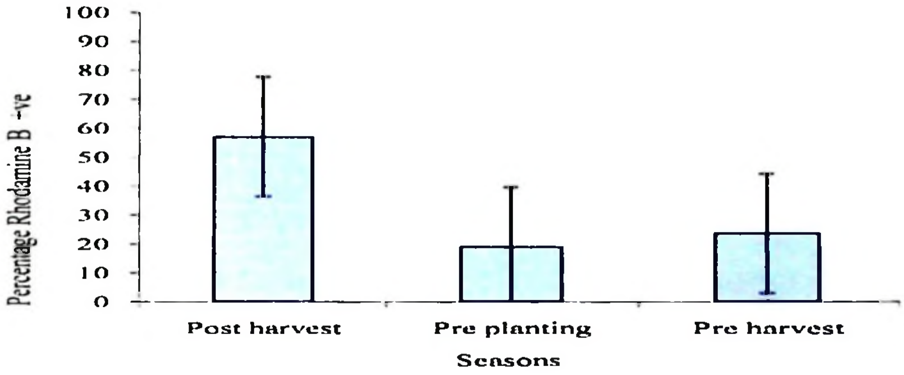


Figure 3: Percentage (± SD) composition of RB positive individuals in different seasons

The percentage of Rhodamine B positive individuals also varied with distance from the houses (i.e. at 0 m within the house to 200 m away from the house). The percentage of rodents which had Rhodamine B. positive whiskers at different distances from the houses were 56.82% (0 m), 22.73% (20 m), 4.55% (50 m), 13.64% (100 m) and 2.27% (200 m), respectively (Figure 4 and appendices 2a – c).

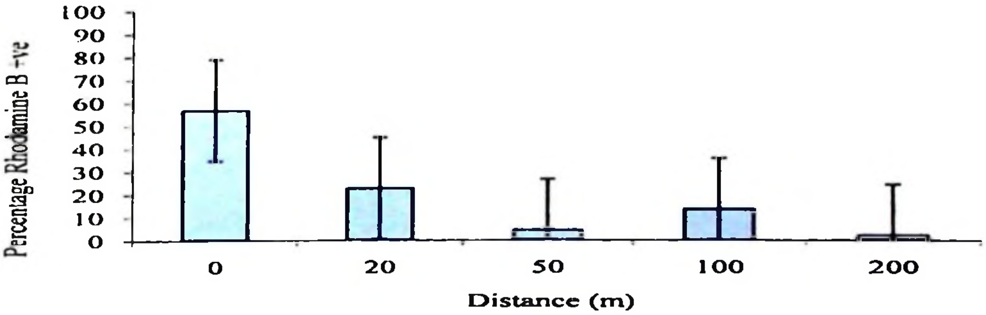


Figure 4: Percentage (± SD) composition of RB positive individuals at different distances

The results show further that, the distance moved by different rodent pest species did not differ significantly between hamlets, and was not dependent on house arrangement (F= 0.13; df= 1, 38; p= 0.72). The distance moved by the rodents did not differ significantly between males and females (F= 0.01; df= 1, 38; p= 0.93) (Table 1). However, there were significant differences (F= 6.56; df= 2, 38; p= 0.00) between seasons in terms of distances moved by different rodent pest species whereby during pre harvest season there were higher number of RB positive individuals as compared to other seasons (Table 2). Similarly, distances moved by different rodent pest species were significantly different (F= 13.22; df= 1, 38; p= 0.00), whereby more rodents with RB positive whiskers were found at 0 m (inside houses) as compared to other individuals captured at different distances and the lowest number of rodents with RB positive whiskers were found at 200 m (Table 3).

Table 1: ANOVA table for effect of hamlets, seasons and sex on movements of different rodent pest species with RB positive

Source of variation	Degrees of freedom	Mean squares
Hamlet	1	4.27
Season	2	222.35**
Hamlet*Season	2	22.12
Distance	4	448.04***
Sex	1	0.27
Hamlet*Distance	4	32.73
Distance*Sex	4	13.81
Hamlet*Sex	1	21.60
Season*Sex	2	18.32
Experimental error	38	33.89
Total	59	

* = $p \leq 0.05$ **= $p \leq 0.01$ ***$p \leq 0.001$

Table 2: Mean separation for effect of seasons on movements of different rodent pest species with RB positive

Seasons	Mean squares
Pre planting	5.05
Pre harvest	10.85
Post harvest	5.10
LSD0.05	3.73

Table 3: Mean separation of movement to feeding stations placed at different distances from the house

Distances (m)	Mean squares
0	17.17
20	6.67
50	4.42
100	5.92
200	0.83
LSD0.05	4.81

4.2 Telemetry Experiment

4.2.1 Habitat use by *Rattus rattus*

The results from this study show that 74% of the tracked *Rattus rattus* were found inside houses in all hamlets; 23% of *R. rattus* were not tracked after collaring because they were either eaten by cat or not found and only 3% were found outside houses during tracking (Fig. 5). Each fix corresponds to one animal found in a particular location. Tracked *R. rattus* rarely left the houses, in which they were initially captured and released. The results show that the proportional distribution of *R. rattus* was as follows; in the roof (37% of fixes) and bedroom (35%), kitchen (14%), along the walls (7%) and windows (7%) (Fig. 6). *Rattus rattus* rarely ventured outside of buildings and they were located either in the firewood pile (50%) or neighbour houses (50%).

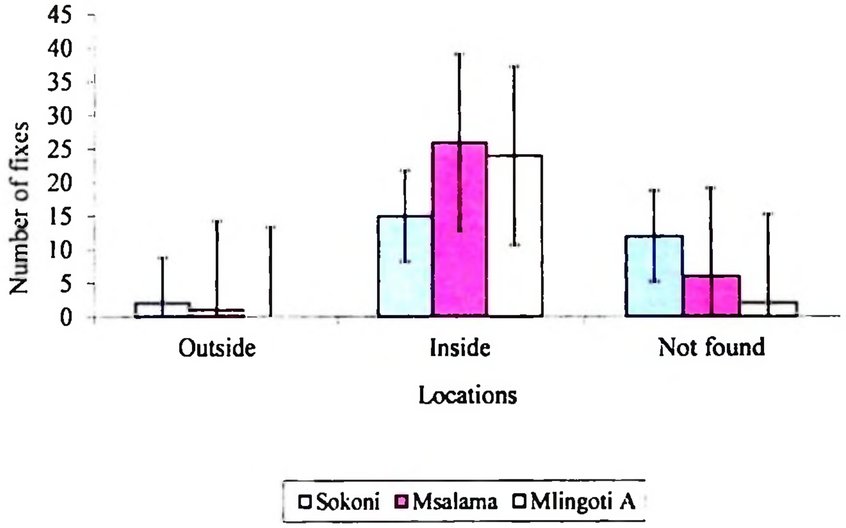


Figure 5: Habitat use fixes (± SD) by *R. rattus* in domestic and peri domestic areas in different hamlets

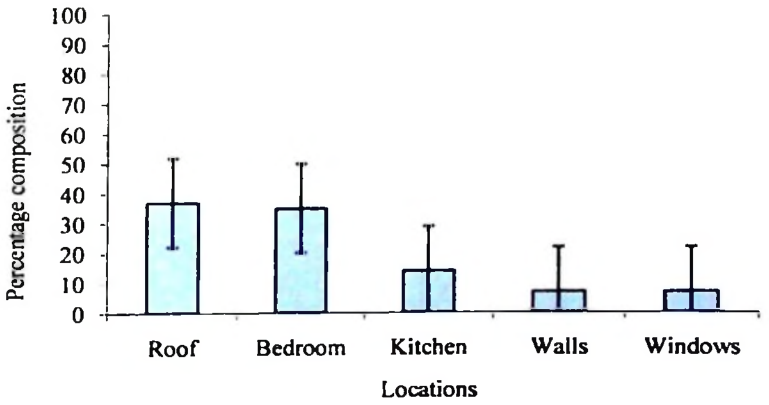
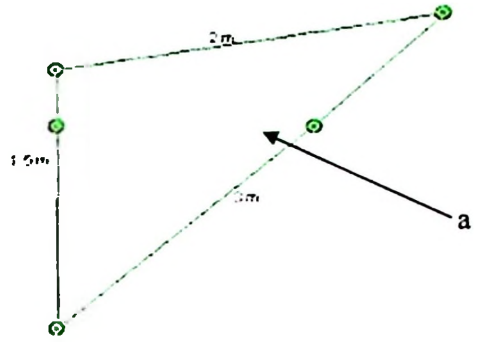


Figure 6: Distribution (± SD) of locations in which *R. rattus* were found

4.2.2 Home range

The mean home range size of *Rattus rattus* was found to be 5.09 (± SD = 5.87) m^2, (N = 13) after calculations of the areas of different polygons (Fig. 7) drawn from tracking data of each *R. rattus* monitored during the telemetry experiment in the study area. The results show that females had higher home range sizes (mean = 6.34 m^2) than males (mean = 4.54 m^2). The result further shows, there was no significant difference (F= 1.27; df = 2, 6; p = 0.35) between hamlets. However, the home range was relatively higher at Sokoni hamlet (mean = 8.09) as compared to Mlingoti 'A' (mean = 2.86) and was least at Msalama (mean = 2.19).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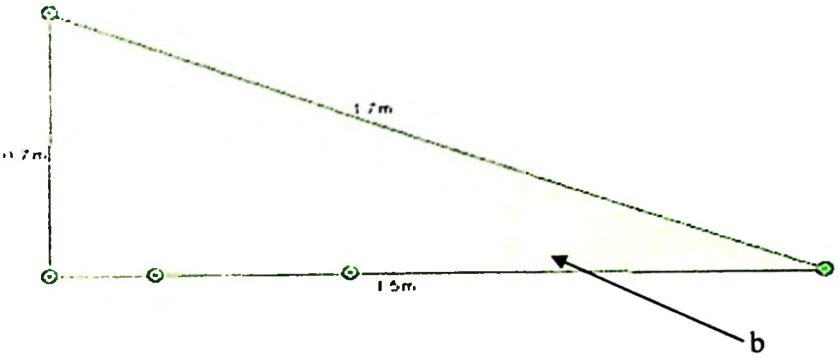
a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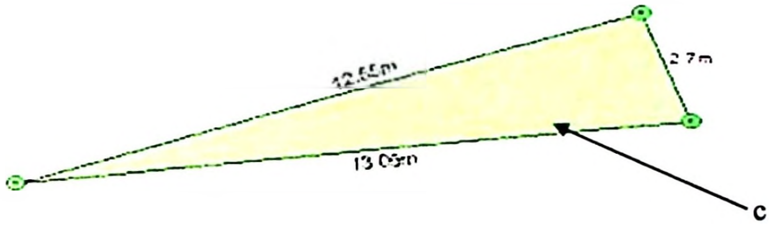
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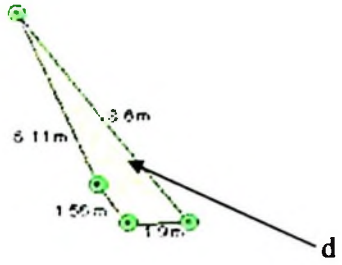
c


3.6m
6.11m
1.56m
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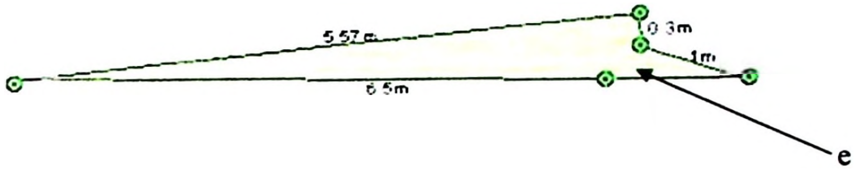
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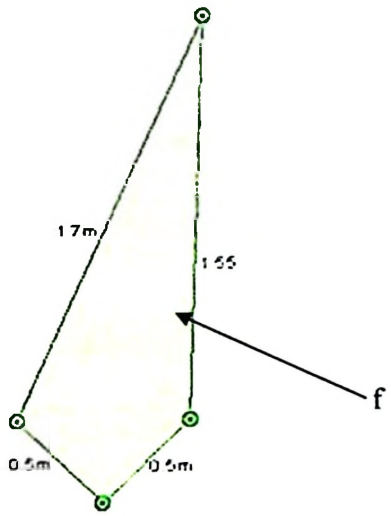
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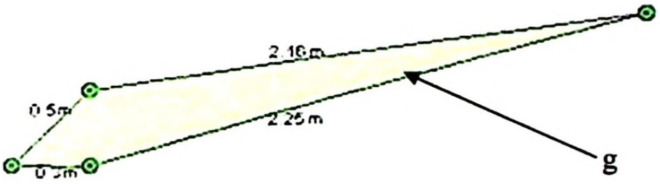
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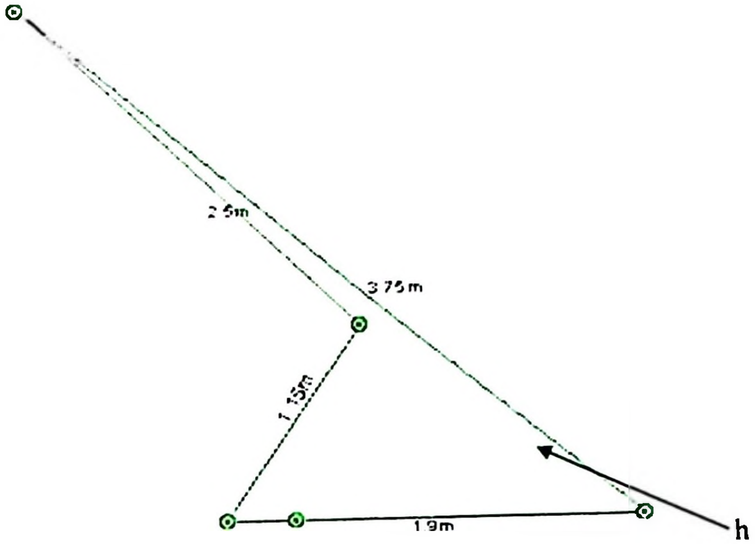
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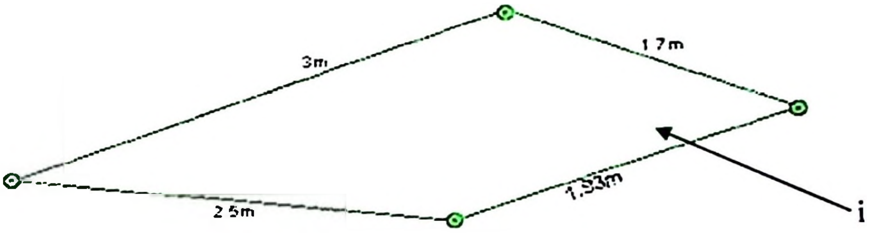
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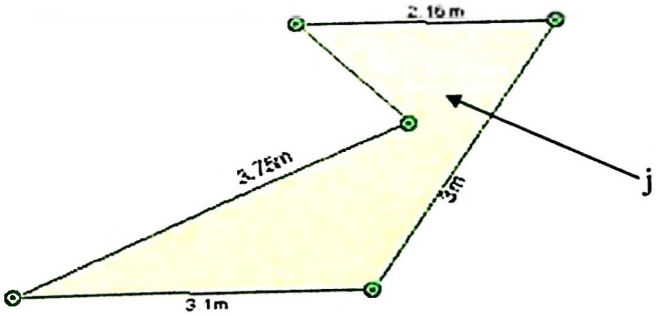
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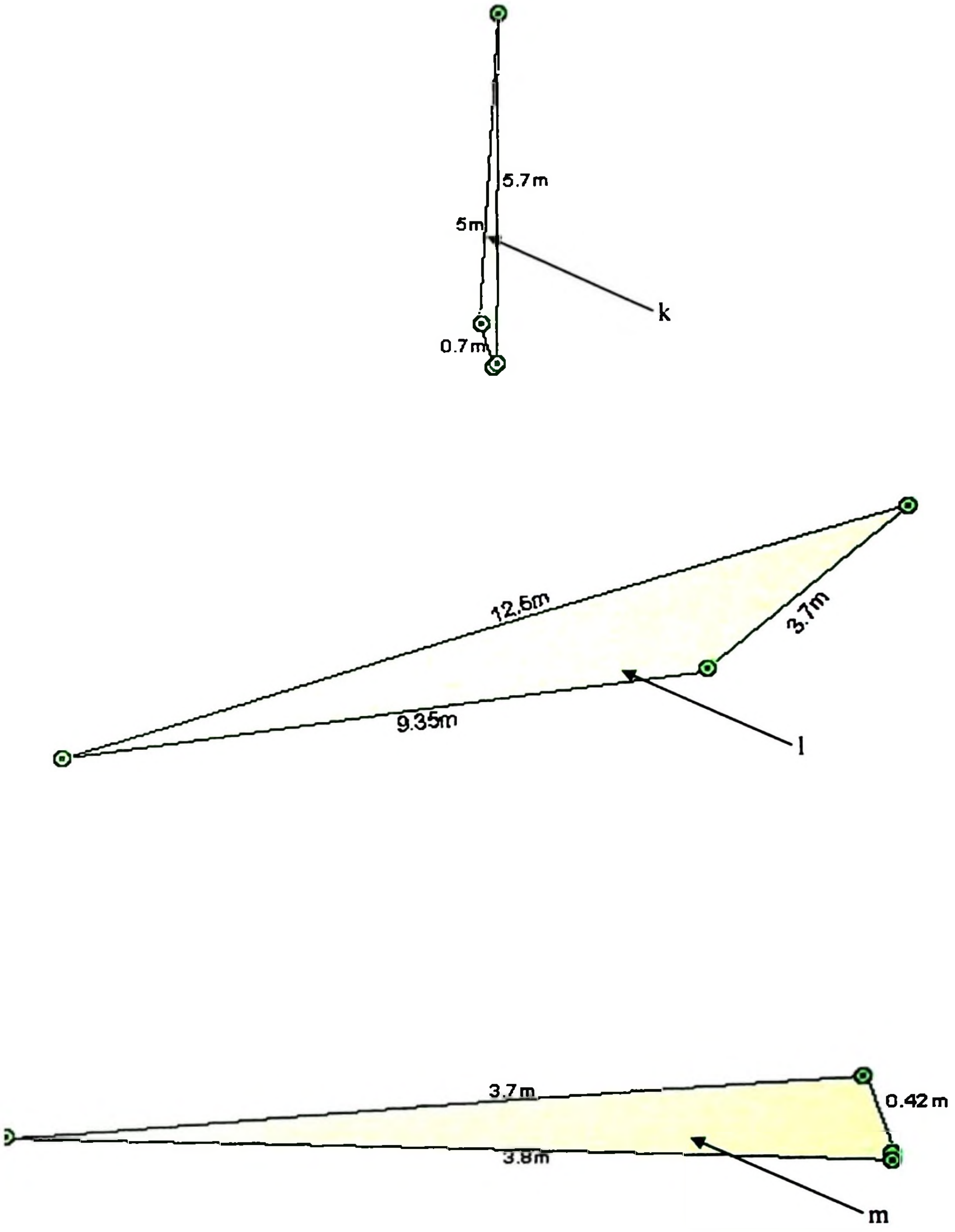

Figure 7: Polygons showing home range size of *R. rattus* (a-m)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Species Composition in the Study Area

The results show that in the study area, *R. rattus* dominated the population during post harvest and pre planting seasons. Similar results were reported by Mdangi (2009) who showed that *R. rattus* is the most abundant rodent pest species in stores during post harvest season in the study area. *Mastomys natalensis* were found to be more abundant during pre harvest season. This is probably the species reproduces during the wet season, at the end of pre planting and at the beginning of pre harvest seasons as such their population is highest towards the beginning of dry season and is lowest during pre planting season. Similar results were reported by (Monadjem and Perrin, 2003; Makundi *et al.*, 2005).

Leirs (1992) revealed that, seasonal density fluctuations are often resulting from variations in weather conditions. Hubert (1977) reported that for *Mastomys natalensis* and presumably the other species, the annual trends are dictated by timing, duration and the amount of rainfall. *Mastomys natalensis* has been reported by Leirs (1992) to take advantage of the favourable environment during the rains by producing a large number of offspring. Hansson (1991) reported that the temporal variations in density are also influenced by demographic characteristics of the species as well as dispersal within and between the species. Makundi *et al.* (2009) reported that quantity and quality of vegetation are important factors determining population size.

Other extrinsic factors (e.g. cover, predation) and intrinsic factors (e.g. competition) could also determine the temporal dynamics of the species as reported by Makundi *et al.* (2009). It is suggested by Monadjem and Perrin (1998) that food resources are clearly a limiting factor for rodents and may therefore strongly affect the habitat utilization of these selective feeders. For instance, (Leirs and Verheyen, 1995; Monadjem and Perrin, 1996) reported that the availability of suitable food resources influences the distribution, numbers, reproduction, and mass of rodents.

The rodent pest species were most abundant in pre harvest season with trap success of 10% followed by 4.8% during post harvest and 4.6% during pre planting seasons. The rodent pest species population densities were presumably affected by food availability and vegetation cover in different cropping seasons. During post harvest and pre planting seasons there was no shelter for the sylvatic species because the fields were cleared, therefore, their population were probably affected by food shortage and lack of vegetation cover to protect them from predators while during pre harvest season the sylvatic species were protected from predators by the bushes and there was enough food for them in the fields. For comensal rodents such as *R. rattus*, *M. musculus* and *M. domesticus* which live in domestic areas throughout the year, vegetation cover did not affect them directly but food availability and competition probably affected their population density. Getz *et al.* (2005) reported a correlation between food availability, movement distances, and cover appeared to be a more important determinant of home range size (estimated by movement distances). Similar results were reported by Lima *et al.* (2001) who revealed the variations in rodent community composition and /or structure between neighbouring sites and across seasons due to food availability, vegetation cover and predation.

5.2 Rodent Movements in Different Seasons of the Maize Crop Cycle

The movement of different rodent species clearly showed that *R. rattus* was found in domestic areas only. They did not move far away from their habitat regardless of the seasons because they are commensals, they feed on various domestic materials, drink water, find their mating partners in the same area and there is low competition for space to hide themselves. Similar results were reported by Pratt and Brow (1976) which show that, nearness of food, water and hiding places are important factors in the extent of the home range of species in question. According to the same authors, rodents need only to move a short distance to find food, water and hiding places. If all the requirements are nearby, rodents may be able to live their entire lives in one place.

The results show further that sylvatic rodent species especially *M. natalensis* and *A. chrysophilus* were entering houses and retreating far into the neighbour fields up to 100 m and 20 m during post harvest and pre planting seasons, respectively. This could be in search of food, water and shelter. The fields were cleared and farmers were preparing the land for planting which could have exposed them to predation after destruction of burrows and nests. Sylvatic species were not moving into the houses at pre harvest season probably because it was the period of increased food availability in the field and there was enough vegetation cover to protect them from predators. Similarly, Monadjem *et al.* (2011) reported that six out of seven tracked *M. natalensis* entered the houses during post harvest season. The same authors reported further that no rat entered the houses in the pre planting and pre harvest seasons in Namibia. This was caused by the farming system, distance to natural habitats, climate and the degree of human land conversion (Weibull *et al.*, 2003).

5.3 *Rattus rattus* Home Range Size and Habitat Use

The radio tracking results show the mean home range size of *R. rattus* to be 5.09 (± SD = 5.87) m^2. Few radio- tracked *R. rattus* left houses in which they were originally captured. The home range size of *R. rattus* was found to be smaller than that of *M. natalensis* which was 4152 (± SE = 892) m^2 and 4407(± SE= 839) m^2 in Swaziland and Namibia, respectively (Monadjem *et al.*, 2011). The small home range size of *R. rattus* is attributed to the fact that these rodents normally live in domestic areas and feed on domestic materials therefore, they do not move far away from their habitat in search of food, shelter and mating partners. However, female *R. rattus* had higher mean home range size (6.34 m^2) as compared to males (4.54 m^2).

The results further show no significant difference between the three hamlets. However, the mean home range size was relatively higher at Sokoni (8.09 m^2) where houses were scattered as compared to Mlingoti 'A' (2.86 m^2) and Msalama (2.19 m^2) where houses are nearby. Most of the tracked females were reproductively active, therefore were more mobile than were the non reproductive females whereas most of males tracked were reproductively inactive therefore, less mobile. Similar results were reported by Getz *et al.*, (2005) who found that movement distances of non reproductive voles (both sex) were smaller than those of reproductive voles. Leirs *et al.* (1992) reported that female require more carbohydrates for reproduction than males therefore the former becomes more mobile than the latter when are sexually active.

The information about *R. rattus* home range is scarce around the world, more so in Tanzania, therefore, this work is a contribution to the increased knowledge of the movements of *R. rattus*. Radio telemetry was an adequate technique to monitor the movements of the rats during the study and therefore establish its home range size.

5.4 Ecologically Based Rodent Management

The results obtained from the study shows that, *R. rattus* and *M. natalensis* are the most abundant and major rodent pest species in the study area. Furthermore the home range size of *R. rattus* is small ranging from 4.54 to 6.34 m^2 for males and females, respectively and distance moved by different rodent pest species ranges from 0 to 100 m from the nearest house. According to Swihart (1992) ecological considerations are important in formulating strategies for managing rodent pest species. Also numerous behavioural and ecological attributes of individuals may influence the extent of damage including foraging habits, mobility and habitat requirements (Leirs, 1995). Therefore, species composition, distance moved and home range sizes obtained in this study are useful information on developing EBRM. Singleton *et al.* (1999) reveals EBRM was developed to provide a sound ecological basis required for developing management strategies for rodent pests. According to Davis (2004) recent economic analyses of EBRM in Indonesia indicated positive outcomes; therefore, these findings are useful for developing EBRM for the study area.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the present study, it was found out that, the study area has high species richness (i.e. 9 species namely *R. rattus, A. chrysophilus, A. spinosissimus, M. minutoides, L. zebra, G. vicinus, G. dolichurus, M. natalensis and A. neumanni*) due to heterogeneity of the habitat. *Rattus rattus* and *M. natalensis* are the major rodent pest species in the study area.

The study also shows that, *R. rattus* were not moving away from human settlements but sylvatic species (i.e. *M. natalensis* and *A. chrysophilus*) were entering houses and retreating to the surrounding (peri domestic areas) up to 100 m away from the nearest house seasonally depending on availability of food in the fields, water and shelter. *Rattus rattus* have got a small home range sizes ranging from 4.54 to 6.34 m^2 for males and females, respectively because they inhabit and feed in domestic areas, they need to move only a small distance searching for food, shelter and mating partner, also *R. rattus* spends most of their time in houses especially in the roof. There were also an overlap in the resource use by *R. rattus* and sylvatic species (i.e. *M. natalensis* and *A. chrysophilus*).

6.2 Recommendations

In view of the above conclusion it is recommended that, *R. rattus* should be controlled early before transporting harvest to the house/store while *M. natalensis* should be controlled shortly before pre planting and pre harvest seasons by habitat manipulation so as to reduce the extent of crop damage and loss caused by the rodent pest species.

Placement of rodenticides should be from 0 m to 100 m because distance moved by the rodents was not more than that. Bushes which are nearby houses should be cleared so as to prevent rodents from entering houses and cause loss to stored crops. Cracks on the house walls and burrows should be repaired to prevent rodents from outside to enter the houses by denying entry and breeding points also burrows on the houses floor should be repaired to reduce hiding places for rodent pest species.

Grass thatched houses should be properly built to avoid allowing rodents to enter and leave houses easily also care should be taken in placement of the rodenticides in human settlements because rodenticides can harm other livestock, human, food poisoning and are not environmentally friendly because of its toxicity.

From the limitations and challenges encountered during this study, it is hereby suggested that:-

i. Radio collars with a longer battery life are available and may be used in the future studies in order to have better estimates of rodent's home range size covering different seasons of the year. The telemetry experiment however, was conducted only in one season because the transmitters were out of function after one season, therefore; these results need to be supplemented with more data covering different cropping seasons of the year, since many animals show differences in dispersal rates according to the seasons and state/age.

ii. More study is required to establish ecological and behavioural interactions between *R. rattus* and *M. natalensis* because they overlap in their resource use. Also the ecological relationship between *R. rattus* with other Sylvatic species because they do not interact in their resource use.

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APPENDICES

Appendix 1a: Rodent Species composition in Post harvest season

Rodent species	**Negative control in Laboratory.**	**Positive control in Laboratory**	**Test animals in the field**	**Total**
Rattus rattus	15	15	22	52
Mastomys natalensis	5	7	22	34
Others	9	9	16	34
Total	**29**	**31**	**60**	**120**

Appendix 1b: Rodent species composition in Pre planting period.

Rodent species	**Negative control in Laboratory.**	**Positive control in Laboratory.**	**Test animals in the field**	**Total**
Rattus rattus	17	12	12	41
Mastomys natalensis	4	13	16	33
Others	9	11	5	25
Total	**30**	**36**	**33**	**99**

Appendix 1c: Rodent Species composition in Pre harvest season.

Rodent species	**Negative control in Laboratory.**	**Positive control in Laboratory.**	**Test animals in the field**	**Total**
Rattus rattus	23	36	24	83
Mastomys natalensis	34	43	32	109
Others	11	10	5	26
Total	**68**	**89**	**61**	**218**

Appendix 2a: Rodent Species Response to Rhodamine B. in Post harvest season.

Species	**Negative control in Laboratory**	**Positive control in Laboratory**	**RB. Negative in the field**	**RB. Positive in the field**	**Total**
Rattus rattus	15	15	9	14	53
Mastomys natalensis	5	7	16	6	34
Others	9	9	11	4	33
Total	**29**	**31**	**36**	**24**	**120**

Appendix 2b: Rodent Species Response to Rhodamine B. in Pre planting season.

Species	**Negative control in Laboratory**	**Positive control in Laboratory**	**RB Negative in the field**	**RB Positive in the field**	**Total**
Rattus rattus	17	12	10	2	41
Mastomys natalensis	5	13	12	4	34
Others	9	11	3	2	25
Total	**31**	**36**	**25**	**8**	**100**

Appendix 2c: Rodent Species Response to Rhodamine B. in Pre harvest season.

Species	**Negative control in Laboratory**	**Positive control in Laboratory**	**RB Negative in the field**	**RB Positive in the field**	**Total**
Rattus rattus	23	36	19	5	83
Mastomys natalensis	34	43	24	5	106
Others	11	12	3	0	26
Total	**68**	**91**	**46**	**10**	**215**