EFFECTIVENESS OF GUINEA FOWL AS BIOLOGICAL CONTROL METHOD FOR TICKS IN PROTECTED AREAS: A CASE OF SAANANE ISLAND NATIONAL PARK, MWANZA REGION TANZANIA

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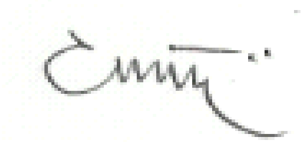
A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT FOR THE REQUIREMENTS OF THE DEGREE OF MASTER OF ARTS IN NATURAL RESOURSES ASSESSMENT AND MANAGEMENT OF THE OPEN UNIVERSITY OF TANZANIA

2019

CERTIFICATION

I, the undersigned do certify that I have read and hereby recommend for acceptance by the Open University of Tanzania a dissertation entitled: ***"Effectiveness of Guinea Fowl as Biological Control Method for Ticks in Protected Areas: A Case of Saanane Island National Park, Mwanza Region Tanzania"***, in partial fulfillment of the requirements for the award of the Degree of Master of Arts in Natural Resources Assessment and Management of the Open University of Tanzania.



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(Supervisor)

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DECLARATION

I, **Upendo Elifinya Massawe**, do hereby declare that this dissertation is is entirely my own original work and has not been submitted and will not be presented to any other college, institution or university other than the Open University of Tanzania for academic credit. In addition, all the sources that I have used or quoted have been indicated and acknowledged my means of complete references.

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Date

DEDICATION

This work is dedicated to my father Elifinya Shiletano Massawe and my mother Salome Isai Ndossy who sacrificed their time and the little resources they had on building the foundation of my education. My husband Mr. Ramson Swai, my daughters Ronny, Elnora and sons Ebenezer and Elisha for their tolerance in so many ways including my limited attention throughout the coursework and research period.

ACKNOWLEDGEMENT

I would like to thank Almighty God for keeping me alive, strengthen me and His guidance that enabled me to accomplish my goal. I extend my thanks to the Chief Conservation Commissioner for TANAPA for granting me permission to pursue my studies at Open University of Tanzania.

I would like to express my heartfelt gratitude and appreciation to my supervisor Dr. Haule (PhD) from the Faculty of Arts and Social Science, Open University of Tanzania for his generous guidance, constructive criticism and indeed his tireless supervision, encouragement, valuable suggestions and remarkable interest which paved a way to the fulfillment of my research work. I thank all staff members of the Faculty of Arts and Social Science particularly Department of Geography for their encouragement and constructive criticisms during all stages of proposal development. Special thanks should go to Dr. Kilewo for immobilizing animals and Mr. Kime from Tanzania Veterinary Laboratory Agency- Lake Zone, Mwanza for his support during tick samples analysis in the Laboratory.

I am very grateful to Dr. Fyumagwa and Dr. Mdetele for sharing their experience on the subject matter. My sincere thanks are also due to the George Ikwabe, Juma Said, Sylvester and Twaha Mohamed for their valuable assistance during field data collection.

A number of people made important contributions to the completion of this dissertation and they surely deserve my thanks but I cannot mention all.

ABSTRACT

Saanane Island National Park (SINP) is the smallest Park in Tanzania and highly infested with ticks. Burning of pasture is the common method used in other PAs to control ticks but in the case of Saanane it is not feasible because of the limited areas suitable for animal pasture and dispersal area. The study focused on determining the current population of ticks and assessing effectiveness of guinea fowl as a biological control of ticks. The experimental study was carried out in eight paired plots in homogenous habitat and data were collected once per week for eight weeks between end of September to early November 2018. Ticks were collected from 16 randomly selected sites in grassland and rocky woodland vegetation by dragging, visual search and handpicking from immobilized and non immobilized animals. A total of 1,108 ticks were collected in the field and preserved in 70% ethanol for laboratory analysis. Three tick species were identified *Rhipicephalus appendiculatus, Rhipicephalus evertsi* and *Amblyomma marmerium.* Data were analyzed using Wilcoxon matched pair test where the results suggested that there is significant reduction of ticks using guinea fowl as biological control (Wilcoxon z –value =1 and p value 2). Further statistical analysis revealed no significant difference in rate of tick removal between nymph (Wilcoxon z-value =1; p value 2.365) and adult Wilcoxon z-value=1; p value = 2.306). To determine the feeding habits of guinea fowl Spearman's Rank Correlation was used to obtain the value for rho(r) which was 0.3304 positive correlations in tick reduction. Based on this finding it is concluded that guinea fowls are effective biological control of ticks in the ecosystem.

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LIST OF ABBREVIATIONS

A.marmerium	*Ambryomma marmerium*
E	East
IUCN-	International Union for Conservation of Nature
NBCB	National Biological Control Programme
NCAA	Ngorongoro Conservation Area Authority
Pas	Protected Areas
PE	Park Ecologist
Rh.appendiculatus	*Rhipicephalus appendiculatus*
Rh.avertsi	*Rhipicephalus avertsi*
S	South
SENAPA	Serengeti National Park
SINP	Saanane Island National Park
TANAPA	Tanzania National Parks
TAWA	Tanzania Wildlife Authority
TFS	Tanzania Forest Service Agency
TVLA	Tanzania Vet nary Laboratory Agency
USA	United States of America
WDPA	World Database on Protected Area

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

This chapter gives an eye opener of research problem, what has been done by other scholars, what researcher will have added to what is known, specific objectives of the study, limitation and significance of the study.

1.2 Research Problem

Current epidemiologic research focuses on potential biological controls as alternative method of suppressing vector – borne diseases (Sharma, 1995 as cited by Prince, 2004)). However, the failure of many conventional vector-borne disease control methods has led modern research to consider biological control methods (Prince *et al*, 2004). The use of guinea fowl (*Numida* species) to eat ticks is widely accepted biological control method used in backyards; however no sound scientific research has examined the role of guinea fowl in reducing tick loads in small protected areas like Saanane Island National Park (SINP) in Lake Victoria, Tanzania.

Using guinea fowl, which eat insects, to reduce tick numbers in backyards and, subsequently, tick- borne diseases risk, is an increasingly popular tactic. Duffy *et al.* (1992) described to have read unpublished report that revealed detection of ticks in the stomachs of three guinea fowl. These findings spurred Duffy *et al.* (1992) to conduct a study at Suffolk country and New York which assessed the effect of guinea fowl on blacklegged tick densities in lawns. His findings revealed that the presence of guinea fowl decreased adult blacklegged tick numbers but not nymph. It is obvious that if the numbers of adult ticks are reduced in the ecosystem the subsequent nymph load will decline with time because few adult ticks will be available to lay eggs in the habitat (Fyumagwa *et al*. 2007).

The Helmeted Guinea fowl (*Numida meleagris*) has been used as a fork defense against ticks acting as vectors for Lyme disease in America (Wilson *et al.* 1992 as cited in Duffy *et al*. 1992). In Africa, this species eats a wide variety of arthropods (Skead, 1962; Angus and Wilson, 1964; Grafton, 1971; Mentis *et al*. 1975 as cited in Duffy *et al.* 1992) and glean ticks from warthog (*Phacochomruase thiopicus),* (Maclean, 1984). Guinea fowl may be most appropriate as one means of controlling ticks in low-density housing areas and in public parks and school yards where their noise is unlikely to be a problem and where custodial care is available for the flock (Prince *et al.* 2004).

In proving whether guinea fowl are useful in reducing tick populations series of experiments in exclosure and enclosure has been conducted in USA. The results of exclosure indicated a significant higher probability of finding deer ticks within exclosure than enclosure (Sokal and Rohlf, 1981, as cited in Duffy *et al.* 1992). Another experiment revealed that predation by guinea fowl reduced numbers of adult ticks on lawns adjacent to dense foliage (Lane *et al,* 1991).

Saanane is smallest park which covers an area of 2.18 square kilometer including aquatic environment and terrestrial part (0.76sq.km). However, the terrestrial part is mostly covered by rocks with very limited pastures for herbivores to graze. On top of that, the limited grazing area is heavily infested by ticks of various species and those ticks are observed on animals and grasses (Personal field observation; Mdetele, unpub.data, 2011). Those ticks could be vector of diseases to wild animals and tourists as well. Moreover, the ticks can be the limiting factor for the tourists visiting the island because of its habit of attaching to any type of host walking on grasses where they inhabit. Therefore presences of free- ranging guinea fowl may probably help to reduce tick loads at SINP because it is very small habitat which is suitable for ticks.

A variety of measures for controlling ticks have been suggested such as pesticides, burning, host eradication or removal (Mather *et al*. 1987, Wilson *et al*. 1988) but, no single method has demonstrated to be effective over a wide variety of habitats. Chemical pesticides applied to habitat occupied by ticks can be effective but appear to have significant negative impact on non-targeted organisms (Ostfeld, 2006). Burning of pasture is commonly used in protected areas as tick control and as a way to stimulate new pasture for animals, but in case of Saanane is very challenging due to small size of the park with limited area, which has pasture for feeding animals. Therefore introducing guinea fowl in the park is ideal to control ticks.

1.3 Statement of the Research Problem

Saanane is one of the ecosystem which harbor a good number of ticks as two third of its size is covered by water and rocks and only small size contains palatable grasses where animals spend more time grazing. During dry season animals suffer more due to shortage of palatable grass and ticks at that period are many on grasses and on wild animals. Last year one young zebra died and the finding showed it was infested with numerous ticks which caused anemic condition. The park practices non chemical methods like dragging, use of acaroids as recommended in the previous study (Mdetele unpub. 2011; Bayona 2016 personal comm.). But, the problem of ticks has persisted and no single method has demonstrated to be effective. Since the park has intention of introducing other species to enrich visitor's satisfaction, then control of ticks in the island is inevitable as it is infested heavily with ticks. Ticks being vector of parasitic, bacterial, viral and other pathogen diseases, risk of transmission of such pathogens from animals to humans can be a stumbling block for tourist to visit the park.

The study which was carried out by (Mdetele, 2011) identified three tick species in Saanane Island National Park including *Ambryoma marmereum, Rhipicephalus evertsi* and *Rhipicephalus appendiculatus.* This is an observation which requires further studies on the identification of the species of tick species available in the island and the effects they may have on wild animals suggest better method to control the ticks in the island.

This research, therefore, aims to introduce Guinea fowl in the park as biological control which has shown positive result in Shelter Island and islands of Martha's, Vineyard, Nantucket and Massachusetts New York-USA (Wilson, 1992 as cited in Duffy *et al.* 1992). The experiment was used to test whether guinea fowl would reduce adult tick population and did not measure the density of birds needed for effective control of ticks. The results will help the organization to carry similar study in Rubondo National park which suffers similar problem and unsolved problem of Sitatunga and Bushbuck deaths as these two parks are isolated with no corridor where animals can get relief (Lyaruu unpub. 2014). The method is cheap, simple technique, yields the highest number of adult ticks with less impact to the environment as is the matter of translocation of the Guinea fowls to the Saanane Island.

1.4 Objective of the Study

1.4.1 General Objective

The main objective of this study was to investigate the effectiveness of guinea fowl as biological control of ticks in the Mwanza Region.

1.4.2 Specific Objectives

The specific objectives of the study were:

(i) To assess tick species presence in the island.

(ii) To examine the feeding habits of guinea fowl in the island.

(iii) To evaluate potential hosts for ticks in the island.

1.5 Hypothesis

H_0: There is no significant difference between presence and absence of Guinea fowls as biological control of ticks.

H_a: There is significant difference using guinea fowl as biological control of ticks.

1.6 Research Questions

(i) Which tick species are found at SINP?

(ii) What are the potential host for ticks at SINP?

(iii) Does the introduction of guinea fowl have any significant impact as biological control of ticks at SINP?

1.7 Significance of the Study

The result on tick species identification and distribution in the island is useful for both academicians and park management. The results shows no new tick species identified apart from the three known species regardless of additional number of animals and if any they could add up new finding to existing knowledge. This knowledge on distribution of ticks keep the park management informed with areas infested with ticks. This is very useful for decision making, areas to take initiatives so as to solve the problem of ticks including putting warning sign for visitors.

The feeding habit for guinea fowl proves that they have ability to reduce ticks in the island therefore is justifiable for the introduction in the island as biological control of ticks. Biological controls minimize cost as compared to chemical control of ticks and less or minimal impact to the environment. The identification of potential host for ticks was important since the management aim to reduce tick load and not to add problem to the existing. The guinea fowl proves not to be carriers for ticks and since the intention is not to feed or confine them, then cannot attract other birds or rodents.

1.8 Scope of the Study

The study focuses on the assessment of effectiveness of guinea fowl as biological control of ticks in the SINP. The parameters investigated in the study are the tick species present, their distribution, density, animals affected; the reasons of high population ticks and the rate of tick reduction by guinea fowl within the study area.

The study area is small isolated and animals are at risk of tick infestation. The findings of this study therefore can be replicable to other PAs of Tanzania with similar or facing the same challenges.

1.9 Limitation of the Study

High frequency of larvae ticks in comparison to nymph and adults. Larvae tend to show aggregated distribution with large population usually arising from one egg batch. Therefore by not considering they may have effect to population estimate but not the measurers of effectiveness of guinea fowl as a number of studies have proved not to be effective to such stage. Some areas within the study area grasses were tall such that may affect the chances of ticks to come into contact with dragging cloth.

1.10 Organization of the Study

This study is organized into five chapters; Chapter One presents Introduction and Background of the study, Chapter Two presents both a critical Theoretical and Empirical Literature Review, Chapter Three presents the Methodology used in the study, Chapter Four presents the Findings and Discussion, and Chapter Five gives Conclusion and Recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section focuses on the review of the related studies such as publications, reports and researches done about guinea fowl as the biological control of ticks and similar discipline. Since the study is about the assessment of the effectiveness of guinea fowl as biological control of ticks in Tanzania, therefore literature used (Theoretical and Empirical review) are those, which are related to the topic and objectives of the study for the purpose of providing a base for this study.

2.2 Conceptualization of Key Terms

2.2.1 Ticks

Ticks are small arachnids, part of the order Parasitiformes, and along with mites they constitutes the sub-class Acari (Latif *et al.* 2004). Ticks are obligate blood-feeding ecto-parasites (external parasites), feeding on blood of mammals, birds and reptiles and amphibians (https://en.wikipedia.org/wiki/Tick). Ticks feed by inserting piercing mouthparts into the skin of the host, avoiding detection by using a salivary pharmacopeia of anti- inflammatory, analgesics, antihistamines and anticoagulants (Ribeiro *et al.*1985, Sonenshine 1993, as cited in Ostefeld *et al.* 2006). Ticks are closely related to arthropods such as spiders and insects, which have no spine (invertebrates). They belong to a group called Arthropoda. In the world there are 866 species of tick that have been described (Latif *et al.* 2004). There are two main groups of ticks called the family Argasidae and the family Ixodidae. Argasidae ticks are often called soft ticks because they do not have hard plates on their bodies. The Ixodidae are often called hard ticks because they have hard plates and difficult to crush. Ticks are important parasites because of their voracious blood feeding activity (Latif *et al*. 2004). It is the feeding of ticks that makes them important in the health of domestic animals, wild animals and humans (Latif *et al*. 2004). During feeding, ticks transmit disease pathogens to their hosts by taking blood, injuring the skin, causing irritation and pain, and sometimes by causing poisoning (Latif *et al*.2004). More serious health problem is often caused when ticks are infected with microorganisms. These are transmitted to humans or animals while sucking blood and may weaken or cause fatal disease to the hosts. This type of microorganism is known as a pathogen and when a tick transmits it the tick is known as a vector of the pathogenic microorganism (Latif *et al.* 2004).

They are also important because they are capable of transmitting many parasitic, viral, rickettsial, and other pathogenic diseases such as borreliosis (Lyme disease) to animals and humans. Ticks are also important because the salivary secretions of some female ticks are toxic and can produce a syndrome known as tick paralysis in animals and human. However human cases are rare and usually occur in children under the age of 10 (Latif *et al.*2004). Symptoms include paralysis of the arms and legs, followed by a general paralysis which can be fatal if not reversed. The victim may recover completely within a few hours of the removal of the ticks. Tick paralysis is frequently associated with attachment of ticks at the base of the victim’s skull; however the illness occurs from the attachment to the other part of the body as well (Latif *et al*.2004).

The onset of Lyme disease (in temperate climate) is usually characterized by the development of a large red rash which may develop a characteristic clear central area (“bulls eye”), one to two weeks after a tick bite, often the rush occur at the site of the tick bite as the central red spot surrounded by clear spot with an area of redness on the edge (Sullivan, 2017). Other symptoms include joint pains, flu –like symptoms such as chills, fever, enlarged lymph nodes, sore throat, vision changes, fatigue, muscle aches and headaches all this occur if no treatment at early stage (Sullivan, 2017). Rocky Mountain spotted fever (RMSF) is a bacterial disease spread through the bite on an infected tick (Sullivan, 2017).

Both Lyme disease and Rocky Mountain spotted fever are transmitted after the tick feed for several hours. Prompt removal of attached ticks greatly reduces the chances of infection. Both diseases are successful treated with antibiotics in their initial stages. Therefore early diagnosis is imperative. For this reason it is recommended that the date of a tick bite be marked on a calendar. If any unexplained disease symptoms occur within two or three weeks, physician should be consulted (Integrated Pest Management Manual cited by Mdetele, unpub. data). Periodic surveys of potential or known ticks can reveal the presence of low –level tick infestations. This permits the application of management procedures to prevent or retard further population.

2.2.2 Biological Control

The most promising alternatives to chemical pesticides are biological control (biocontrol) agents, which are species that consume target pest organisms via predation, herbivory, or parasitism (Ostefeld *et al*. 2006). Biocontrol agents typically are nontoxic to humans and to non-target wildlife (with few exceptions). Moreover, biocontrol agents are expected to co evolve with their target organisms, reducing the likelihood that resistance will evolve. Although biocontrol programs have a mixed record of success and include some spectacular failures (e.g. the decimation of island endemic birds by mongooses [*Herpestes javanicus*] released to control introduced rats). Biological control appears promising, but understudied, for the control of ticks. The predominant form of biocontrol is “classical biocontrol,” whereby non -native predators, herbivores, or parasites (including parasitoids and pathogens) are introduced to control nonnative pest species. The vast majority of classical biocontrol efforts have been directed at exotic plants and insect pests of agricultural products (Ostefeld *et al*. 2006).

The most widely recognized danger of classical biocontrol is that may attack non-target organisms, particularly native taxonomic relatives of the exotic target species (Stiling, 2004, Louda *et al.* 2005). Attacks on non-target species are expected to be minimal when the biocontrol agent is a specialist on the target species, and much effort is devoted to confirming that a potential biocontrol agent is indeed a specialist on the target pest.

2.2.3 Guinea fowl

Guinea fowl is a large African game bird with slate – colored white- spotted plumage and a loud call. Guinea fowl are birds of the family Numididae in the order of Galliformes. They are social and typical live in small groups or large flocks.

There is some evidence to suggest that guinea fowl are known as far back to ancient Greek around the 5^{th} C BC. The Roman brought them from African Campaigns and tried to domesticate them. Some were taken to Jamaica about 200 years ago during the Slave trade era and become part of landscape (Olson, 2019).

The home of Guinea fowl is Africa were they run in large flocks. Guineas are experts at hunting down pests like ticks, fleas, Japanese beetles, and tomato horn worms without tearing up garden plants. They can even chase down small snakes and won't lose interest in chasing grasshoppers. (Arne *et al*, 2000) "They're not going to get rid of every kind of insect, but they're very helpful with certain types of insects," says Gibson.

2.2.4 Protected Areas

Protected Area is defined as a geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IUCN) 2008. The criteria used to define protected areas vary widely, depending on the objective and on the mechanisms behind the establishment of the protected area. They are usually locations of significant environmental, cultural or natural value that in most cases has some form of management authority in place for their protection.

According to the World Database on Protected Areas (WDPA) there are over 210,000 protected areas around the world. The proportion of areas protected globally (percentage of terrestrial area and territorial waters up to 12 nautical miles) amount to 11.9%. The proportion of terrestrial areas protected amounts to 12.9% and marine areas to 6.3%, as recorded in WDPA for 2009.

Tanzania is one of the largest countries in Africa with the surface area of about 945,000 square kilometers. Protected areas in Tanzania are extremely varied, ranging from sea habitats over grasslands to the top of the Mount Kilimanjaro, the tallest mountain in Africa. Over 28% of the county area is devoted to wildlife conservation under different PAs categories depending on permissible use. The Protected Areas network includes National Parks, Game reserves, Marine parks, Forest reserves, Game Controlled Areas and Open Areas. Saanane island National Park is among the 19 National Parks in Tanzania mainland, which is the highest category of PA's where active consumptive utilization of resources in restricted. Well-managed protected areas provide a variety of benefits: protection of healthy ecosystems and their associated services, support for the recovery of threatened species, control of invasive species, and maintenance of traditional ecological knowledge among indigenous communities. The goods and services delivered by protected areas can have effects well beyond their boundaries, for example where they provide protection of watersheds resulting in river flow outside the boundary of the park. (WDPA, 2009).

2.3 Review of Theoretical Frameworks

2.3.1 Sequence Theory of Multiple Importations

Multiple introductions provide a series of natural enemies that can attack a sequence of host stages in any one habitat. Here environmental changes may adversely affect one natural enemy yet favor another, so that the latter natural enemy may tend to compensate for the reduced efficiency of the former (Howard and Fiske, 1911).

The analysis of past successes suggests that multiple species importation, whether made simultaneously or sequentially, have nearly always resulted in enhanced biological control. When several natural enemy species are established on a common host, they are more likely to parasitize that host over a greater geographic range than a single species of natural enemy. Multiple introductions increase the chances of obtaining a species of natural enemy that can use alternate hosts to overcome difficulties associated with seasonal fluctuation in pest abundance. Multiple importations favor the chance of establishing a truly superior species of natural enemy.

2.3.2 Classical and Augmentative Biocontrol Theory

Biological control or biocontrol is a method of controlling pests such as insects, mites, weeds and plant diseases using other organisms. It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role. The most promising alternative to chemical pesticide are biological control (biocontrol agents, which are species that consume target pest organisms via predation, hebivory and parasitism (Ostefeld *et al*. 2006).

2.3.2.1 Use of Biological Agent to Control Ticks

Natural enemies of ticks include insectivorous birds, parasitoid wasps, nematodes, *Bacillus thuringiensis* bacteria, and deuteromycete fungi (largely *Metarhizium* *anisopliae* and *Beauvaria bassiana*) (Samish *et al*. 1999 as cited in Ostefeld *et al*. 2006).

Mammals and birds typically consume ticks during self-grooming. For example, laboratory studies demonstrate that significant numbers of larval blacklegged ticks is consumed by white-footed mice (*Peromyscus leucopus*) during self-grooming (Shaw *et al.* 2003 as cited in Ostefeld *et al.* 2006). Nevertheless, a high proportion of ticks encountering mice survive and feed to repletion, and abundance of blacklegged ticks is positively correlated with that of mice (Ostfeld et al. 2001). Some vertebrates attack ticks in the environment. Wild turkeys (*Meleagris gallopavo*) consume a very high proportion of the immature blacklegged ticks they encounter while grooming (Ostfeld *et al.* 1999), and might reduce tick numbers. In the case of host species, such as turkeys, that groom a high proportion of ticks that attempt to feed from them, abundance of ticks could be suppressed by high host abundance. To our knowledge, such negative correlations between the abundances of specific hosts and ticks have not been explored. Unfortunately, enhancing the numbers or distribution of turkeys as biocontrol agents seems infeasible. Moreover, turkeys are an important host for lone star ticks (*Amblyomma americanum*) (Kollars *et al.* 2000), and high abundance of turkeys could facilitate populations of this tick species, which is a vector of human monocytic ehrlichiosis.

Other birds also consume host-seeking ticks in the environment. On the basis of a modest study using small enclosures and exclosures to manipulate helmeted guinea fowl (*Numida meleagris*) on lawns (Duffy *et al.* 1992), this bird has reached cult status as a biocontrol agent for blacklegged ticks and is credited with reducing the transmission of Lyme disease bacteria to people. However, tick reduction by Guinea fowl was restricted to the adult stage (Duffy *et al.* 1992), which transmits a small minority of Lyme disease cases to people (Barbour and Fish, 1993), and to lawns, which maintain far smaller populations of ticks than do brushy and wooded habitats (Ostfeld *et al.* 1996). Duffy *et al, (*1992) numbers of adult and nymph blacklegged ticks on properties with and without free-ranging Guinea fowl in a highly Lyme disease–endemic zone in southeastern New York State.

They established that although reduced abundance of adult ticks in the presence of Guinea fowl suggested that the birds do attack this life stage, the presence of Guinea fowl did not significantly reduce the density of nymphs (Barbour and Fish 1993). It was hypothesized that the provision of food (grain) to guinea fowl attracted small rodents, which might have imported immature ticks onto properties containing the birds, and that this might counteract the suppressive effects of predation by fowl on adult ticks.

The most obvious vertebrate consumers of ticks are ox-peckers, pan-African birds that specialize on ticks feeding on both wild and domestic large mammals. The daily intake of ticks by ox-peckers is reported to be in the hundreds (adult ticks) to thousands (nymphs) (Samish, 2000). However, neither a reduction in tick populations by natural populations of ox-peckers nor the feasibility of augmenting their numbers has been demonstrated.

The researcher used guinea fowl as biological means to control ticks in the island. Regardless of oxpecker which has proven to be more efficient in tick reduction it may be difficult to retain them in island as the area is too small with few herbivores. Guinea fowl are inexpensive, easy to capture in the wild and add value in tourism but they are too noise.

2.3.2.2 Predators

The efficiency of predators in controlling tick populations in different habitats varies and may reach up to 100% (67, 131, 210, and 211). In Kenya, predation was lower in tall grass areas than in short grass areas (144). In Texas, predation was two to eight times higher in open areas than in a post-oak thicket pasture habitat (67). In Russia, up to 100% of the ticks were preyed on in a woody area, whereas about half were in small open areas and none in intensive pasture or agricultural areas (114). Predators contribute greatly to a reduction in the tick population. Because none of them (except oxpeckers) are tick specific, their importation is generally not recommended. Local predators should, however, be conserved and augmented. Among the natural predators yellow- and red-billed oxpeckers (*Buphagus africanus)* and *B. erythrorhynchus* are known to feed on ectoparasites and especially on ticks.

However, some authors are not convinced of the benefit of having oxpeckers in the close vicinity of cattle as they create wounds and increase the size of existing wounds (Weeks, 2000). Chemical control of ticks has, however, resulted in drastic declines in the populations of these birds during the last century. This decline has resulted from the birds ingesting ticks that have been treated with an acaricide and also because the pool of ticks required by the birds to feed on in order to reproduce has been drastically reduced because of the use of effective acaricides.

2.3.2.3 Behavioral Variation in Natural Enemies

The variation and changes in behavior of natural enemies that can be caused by rearing conditions are manifold. The main questions whether erratic behavior of natural enemies can be prevented or cured. Most ecologists are aware that variability in natural-enemy behavior occurs frequently. It is important to know how natural enemies function in agro ecosystems because such understanding may help in designing systems where natural enemies can play an even more important role in inundative and seasonal inoculative releases. The core of natural enemy behavior, host-habitat and host-location behavior, shows great variability, which often leads to Inconsistent results in biological control. Most studies aimed at understanding such variability has focused on extrinsic factors as causes for any inconsistencies seen in foraging behavior. By understanding this will help to understand well when to measure for effectiveness of introduced biological control agent.

2.4 Empirical Review

This part presents the information based on how different scholars have written about ticks and biological control of ticks in different places.

2.4.1 Biological control of ticks worldwide Experience

Ticks are of considerable importance to wildlife and livestock health due to their role as vectors of an impressive array of infectious agents, as well as direct injury caused by piercing the host's skin (Allen, 1994 cited by Anderson *et al,* 2012). Tick-borne diseases affect 80% of the world's cattle population and are widely distributed throughout the continents, particularly in the tropics and subtropics. It is in fact widely accepted that tick-borne haemoparasitic diseases are – and will likely continue to be – among the most important cattle diseases in the world, with higher impact in tropical and sub-tropical countries. It has been estimated that the annual global costs associated with ticks and TBDs in cattle amounted to between US$ 13.9 billion and US$ 18.7 billion, (Meneghi *et al*,2016). Wildlife are known to have in born immunity which are resistant to ticks such as ranging African buffalo (*Syncercus caffer*).

Since the beginning of the 20th century investigators have documented numerous potential tick biocontrol agents, including pathogens, parasitoids and predators of ticks (Samish & Rahacek, 1999; Kaaya, 2003). A worldwide review from 1977 provides data about the use of natural enemies in the USSR (on 10 million ha), China (1 million ha), West Europe (< 30,000ha) and North America (< 15,000 ha). Since that review, many new natural enemies have become available (Anon, 2000) and activities have strongly increased in Latin America (van Lenteren and Bueno, 2002).

In Africa most of wild animals in protected areas survive by self-grooming, innate immune, and habitat manipulation by use of fire, predatory birds and few weak animals are removed in the ecosystem by carnivore. Wild mammals in Africa mostly have high levels of innate resistance to haemoparasites and the tick vectors that transmit them. Occasionally though, biotic and abiotic factors combine to alter this relationship and tick-borne disease is diagnosed in wildlife (Fyumagwa *et al.* 2007).

2.4.2 Importation and use of Biological Control Agency in Tanzania

National Biological Control Programme (NBCP) is a unit under Plant Health Services in the Directorate of Crop Development in the Ministry of Agriculture Food

Security and Cooperatives. It was established at Kibaha Sugarcane Research Institute in 1990 following the invasion of Cassava mealy bug, *Phenacoccus manihoti* (Matile Ferero). NBCP coordinates importation and use of biological control agents in the country. Activities involved include: Importation of biological control agents in the country is guided by Plant Protection Act 1997 and Regulations, 1998. Importers of biological control agents include Research Institutions, universities, private companies and private farmers. There is continuous interaction between NBCP and importers to ensure that the existing regulations are adhered to. According to the Act, approval for importation of bio logical control agents is given by National Plant Protection Advisory Committee (NPPAC). Importers are required to prepare dossiers for biological control agents intended to be introduced and submit to Secretary of Biological Control Agents Subcommittee (BCAS). The dossiers are evaluated in BCAS meetings, and recommendation for approval made to NPPAC.

2.4.3 Threshold for Ticks

Mount (1981) as cited by Mdetele (unpub.2011) proposed an arbitrary tolerance threshold of one tick/per dry –ice sample, based on several years of study in recreation in Oklahoma. Mount and Dunn (1983) as cited in Mdetele unpub.data (2011) recommend that a count of 0.65 per one hour of Co2 exposure (dry-ice-traps) be considered the economic threshold in lone star tick management (equivalent to one tick per visitor per day, based on assumption that most human visitors to recreational activities will not spend more than one hour per day in tick habitats). Suitable threshold level can be established by conducting regular Co2 survey and plotting tick count against the number of tick bites complaints received. This will permit selection of a complainant threshold level for each site surveyed. Treatment should be conducted to keep tick population below the selected threshold.

2.4.4 Feeding Habit of Guinea Fowl

Wild guineas eat mainly insects and domestic guineas can eat exactly the same feed as the chickens get and they seem to ignore the layers pellets entirely. My birds have an all seed scratch that includes 4% sunflowers seeds 4% safflower seed, wheat, cracked maize and millet. https://guinea-fowl.com/guineas/Feeding-Guineas.

Adult guineas forage for themselves with little tendency to laziness and are able to meet most of their nutrition requirements provided they have enough land to cover. They consume a variety of insects and arachnids, seeds, slugs, worms, small rodents and have been known to attach snakes (Jacob, 2015). Guineas need to consume some greens in order to maintain good digestion and so eat grass, dandelions, weeds and other vegetations. Guineas can reduce keeper’s risk of Lyme disease by consuming deer ticks which carry disease. If they are kept as pest control restricting their feed encourage them to spend more time eating insects (Jacob, 2015).

2.4.5 Potential Hosts for Ticks

Ticks detect their hosts in a wide variety of ways, including; Breath, body odors, body heat, body moisture and vibrations. Some species of ticks even hunt for hosts by simply seeing or recognizing shadows of potential hosts that are approaching. Ticks may survive for up to a year without feeding and spend approximately 95% of their life off-host (Klompen, 2005). In Ixodidae, the process of finding a host is known as questing behavior. Ixodids typically climb to host-height on vegetation and wait for a host to brush up against the foliage. When this occurs, the tick grabs onto the host attaches it. Detection of host is accomplished with the use of Haller's organs located on the first tarsus of the forelegs. Haller's organ detects both co_2 and kairomones emitted by potential host (Klompen, 2005). Below is the summary of the potential host for ticks. (See Figure 2.1).

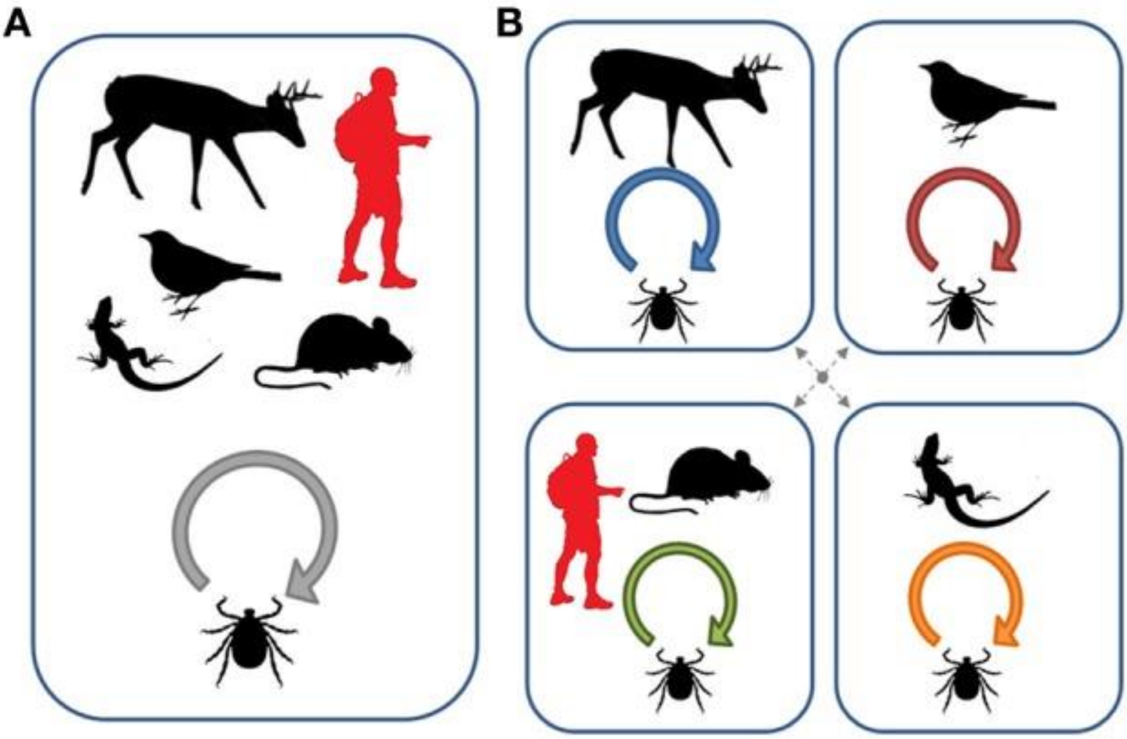

Figure 2.1: Common Ticks' Host Species are Available Locally

Source: McCoy (2008)

2.5 Conceptual Framework

Ticks are widely distributed in a range of habitat types, including heath, coniferous and deciduous woods, grassland and rough pastures. The presence or absence of ticks is highly dependent on local microclimate conditions, which are largely determined by sward height and humidity. Ticks have a diverse range of vertebrate hosts from which they feed, affecting ∼240 species of wild and domesticated mammals, many species of birds and reptiles. The presence of ticks in the island may be due to introduction of wildlife species not indigenous to the place without prior treatment.

Tick presence was closely related to soil moisture, light levels and humidity throughout the park. Ticks require moderate temperatures and adequate moisture especially during quiescent periods between molts. When all conditions are favorable tick load increases to the ecosystem.

Saanane being a small park suffer similar problem of ticks were animals during dry season appear stressed. The more affected species are zebra, and in 2017 a young zebra died of anemic case due to high infestation of ticks and in 2018, three adult zebra died of heat water (Personal observation 2017, TVLA Lab. analysis 2018). Since there were only five zebras in the island, the tourism attraction has reduced. Incase death occur to species of interest to the tourists then tourist number may reduces and if no further intervention the end result is low income to the park.

Tick control on wildlife in nature reserves encompassing more than 20 000 ha should not be necessary, particularly if a sustainable number of large carnivores are present to remove stressed, weak, sick or injured animals. Problems with ticks usually occur in small wildlife reserves or on game farms, especially those under 1 000 ha in size, on which it is not practical to also keep the larger wild carnivores. Biological tick controls in wildlife include self- and all grooming: impalas can frequently be seen grooming themselves or by sliding their loose pairs of incisor teeth through the hair.

The third and fourth incisors of impalas and the inner toe of hind feet of daisies have been "adapted" to facilitate grooming. Oxpeckers scissor their beaks through the hair of animals to which they cling collecting lice and the immature stages of ticks. They also prefer engorged females of the short mouthpart ticks such as *R. (B.) decoloratus (*www.afrivip.org/sites/default/files/Ticks_control/html*)*. The ox-peckers are appropriate but difficult to contain them in the island since is close to the city. Therefore guinea fowl are appropriate for biological control and has no effect to the ecosystem.

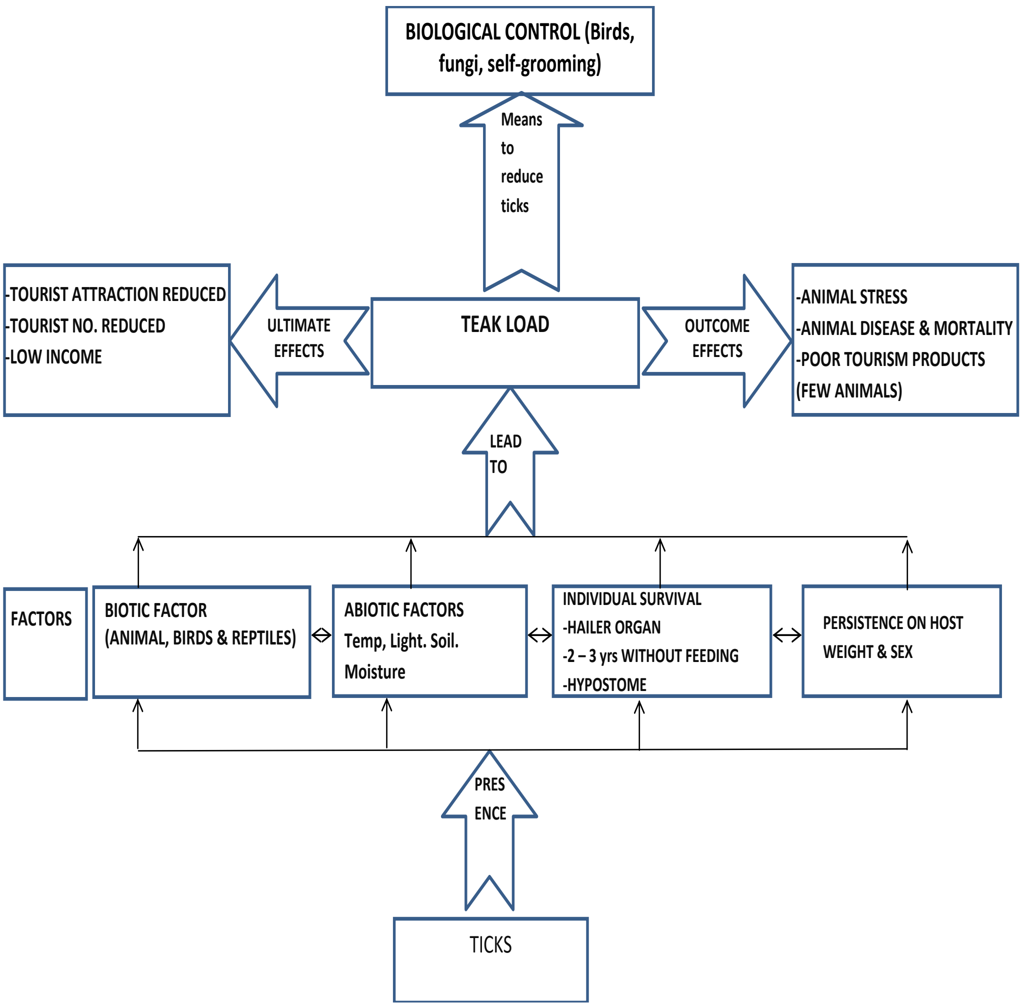

Figure 2.2: Conceptual Model on Ticks

Source: Literature (2018)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

Research methodology refers to the procedures by which researchers go about their work of describing; explaining and predicting phenomena (Rajasekar, 2013).It offer the theoretical underpinning for understanding which method, set of methods or best practice can be applied to a specific case. This chapter presents the procedures that will be used to conduct the research.

3.2 Study Area

Saanane National Park, is one of the rocky islands in Lake Victoria which was named after its former owner Saanane Chawandi, who was a farmer and fisherman. To pave way for conservation, in 1964 the Government took the island and established the first Zoo in Tanzania through the Government Notice 567/64, and was managed by Mwanza Municipality. Mr. Saanane was compensated and shifted with his family to the nearby island. Between 1964-68 the island was stocked with an array of wild animals such as impala (*Aepyceros melampus*), elephant (*Loxodonta africana*), dikdik (*Madoque kirkii*), topi *(Damaliscus korrigum*), bushbucks (*Tragelaphus scriptus* wildebeest (*Connochaetes taurinus*), velvet monkey (*Chlocebus pygerythrus),* buffaloes (*Syncerus caffer*), giraffe (*Giraffa camelopardalis*), lion (*Panthera leo*), and nile crocodiles (*Crocodylus niloticus*), (Kataliwa, 1981 as cited by Nanyoro *et al* 2008).The dangerous animals were kept in enclosures and others were released into the island to roam freely. The area became famous and prime tourist attraction where thousands of visitors paid visit every year. The island was also used as a holding ground for dislodged animals. For example, 2000 the island received dislodges 10 De brazas monkey. Gradually, the status of the zoo deteriorated year after year due to inadequate management and lack of investment (Nanyoro *et al*. 2008).

The move to promote the Saanane Island Game Reserve into a National Park started at the end of 2006. Elevating the status of Saanane Island included annexing the adjacent two islands of "Chakende Kubwa and Chakende Ndogo" respectively in order to improve the conservation status of the existing Saanane Island. Saanane island was fully fledged as the 16th National Park in July 2013 covering an area of 2.18km^2 including aquatic environment. Wildlife conservation, photographic tourism, spot fishing, lake excursion and research are the only land use and human activities permitted in Saanane Island National Park (Koroso pers.com.2018).

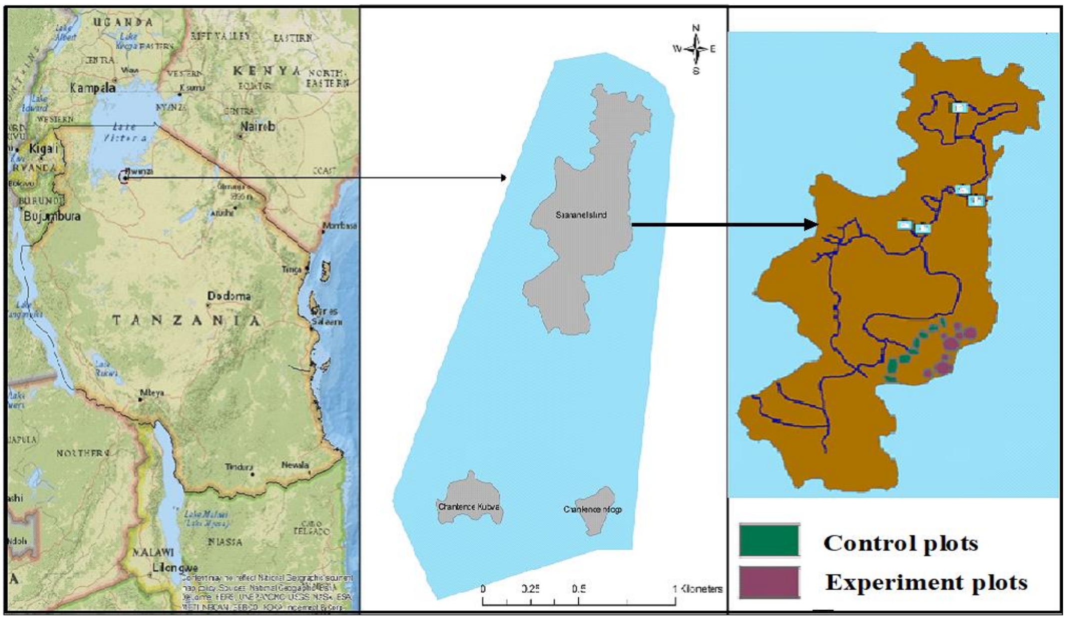

Figure 3.1: A Map of Saanane Island National Park showing the Location of the Study Area

3.2.1 Location

The study was conducted in Saanane Island National Park (SINP), which is located 2 kilometers south west of the city centre of Mwanza, lying in the gulf of Lake Victoria with an area of 2.18 km^2. This national park is located between Latitude: 2.5° S and Longitude: 32° E.

3.2.2 Vegetation

The major vegetation of the island are open grassland, small patches of dry forest of tree stands dominated by various species of Ficus, Haplocoelom and Tremaspecies. Large parts of the rocky hills are covered by Combretum woodlands degrading to thicket covers on the kopjes and swamp vegetation in areas touching Lake Victoria. Dominant species on the Kopjes include species of Ficus, Combretum and Grewia. (Nahonyo *et al*, 2008).

3.2.3 Wildlife Species

Wildlife species found in the park are categorized into two major groups, native and introduced species. Native species are Rock hyrax (*Procavia capensis*), Nile crocodiles (*Crocodylus niloticus)*, snakes, and Lizards and Spotted necked otter (*Hydrictis maculicollins)*. The island is also rich in avian -life of which the majority are resident (70 species identified) including malachite kingfisher (*Alcedo cristata*), cattle egret (*Bubulcus ibis*), Maccoa duck (*Oxyyura maccoa*), Namaque dove (*Oena capensis*),Superb starling(*Lamprotornis superbus*) and few are migratory birds .Originally introduced species include Impala (*Aepyceros melampus*), plain zebra (*Equus burchelli*), De-brazas monkey (*Cercepithes neglectus)* (but have gone extinct study carried out in 2017),velvet monkey (*Chlorocebus pygerythrus*) ,Leopard tortoise (*Stigmochelys pardalis*) and caged lions(*Panthera leo*) .In June 2018 more herbivores were introduced including Wildebeests (*Connochaetes taurinus*), Dikdik (*Madoqua kirkii*), Klip springer (*Oreotragus oreotragus*), two lions (*Panthera leo*), and four birds i.e. pea fowls(Mtui Per.comm.*2018*).

3.3 Research Design

The study used informal experimental design for data collection. Data was collected before-and after-with control design. In this design the two areas were selected and the depended variable was measured in both areas for identical period of time before the treatment. Then, treatment was introduced into the test area only and the dependent variable was measured in both for identical period of time after introduction of treatment (guinea fowl). The treatment effect was determined by subtracting the change in the dependent variable in the test area. The design is shown on Table 3.1.

Table 3.1: Before- and after with Control Design

Time Period 1		**Time period 11**
Test area: Level of ticks before Treatment (X)	Treatment introduced →	Level of ticks After treatment(Y)
Control area: Level of ticks without treatment (A)		Level of ticks without treatment (Z)

Treatment effect = (Y-X)-(Z-A)

3.4 Data Collection

In determining the status of ticks and effectiveness of guinea fowl as biological control the following methods was used. There were experimental block/fenced with guinea fowl and control block (without guinea fowl) and prior dragging was conducted in the study area and population of ticks was established and the effect of treatment in the plot was obtained.

Two transect of 100m @ were identified using the GPS coordinates. The effect of guinea fowl presence on tick densities was evaluated using 8 paired plots/cages of 2m by 2m. Eight experimental plots was located by fulfilling the following criteria guinea fowl were introduced in plots @ 2 for about 2 months and no activity by other fowls to ensure no removal of ticks by other species. Each treatment plot was paired with control plot located 35m apart. The plots were located at entrance gate towards Director's loop and small Serengeti ndogo i.e. similar habitat. Sampling on each plot involved dragging once per week for 8 weeks. The ticks were counted and returned in the cage and all death of individual was taken care in the field. All plots were within an area of 3500 M^2 (100m x 35m).

3.4.1 Ticks Collection

Ticks were collected using three methods, that is, dragging, visual searching and ccollection of litter.

3.4.1.1 Dragging

Dragging consist of passing a white cotton material over the plant litter or grasses on the ground (Azrua & Brescovit, 2006). Tick dragging method was utilized by using a

1m width by 1m length flannel cotton cloth. Dragging was conducted over vegetation for adult questing tick species and immature ticks was collected and stored in tube with ethanol 70% for laboratory identification and counting. This method usually targeted to collect immature ticks that were questing for hosts over vegetation.

3.4.1.2 Visual Searching

A visual searching method was employed to search for questing ticks on tree leaves, grass leaves and stem and nocturnal species, which are cryptic and stay in grass litter cover, crevices or fallen dead wood. This method collected mostly adult tick though immature was also collected as described by other workers (Gray, 1985; Labruna *et al.*, 2005; Szabo *et al,* 2009; Tarassing *et al*., 2010).In visual search trained observer looks for questing ticks on the tips of leaves along animal trails and collects them (Tarassining *et al.*, 2010).

Active searching was conducted randomly in 10*10m established plots in study habitats and involved turning over logs, leaf litter, tree holes, rocks, and other potential site. This was undertaken for maximum of eight days within an area of 1600m^{2}so as to establish population density. Each plot was searched for 30 minutes.

3.4.1.3 Collection of litter

Collection of litter was done on woodland kopjes where dragging was difficult to apply. The depth of litter was determined in the field and cryptic ticks were collected. Fieldwork was conducted early in the morning and evening when temperatures were cool and wind was not strong. Collected ticks were counted and recorded on data sheet and preserved under 70% Ethanol in a 50ml silicone (Falcon) tubes.

3.4.2 Capture –recapture Technique

This method was used on experimental and control blocks only. Dragging was conducted on the plot of (2m*2m) before the introduction of guinea fowl using 1m by 1m flannel cloth to establish presence/absence of ticks. All the ticks encountered were counted and returned to the plot. After the introduction of guinea fowl dragging was done once per week so as to establish the trend of tick reduction. The exercise was conducted for two months from mid September towards early November. 2018. This is the period after long rain season which is favorable for tick's activities due to increased humidity. The chances of capturing nymph are high towards September it is normally very dry and many of immature ticks die naturally due to desiccation (Fyumagwa *et al.,* 2007).

3.4.3 Removal Sampling

This technique was used for species identification where all collected ticks were kept in special tubes with 70% ethanol for laboratory analysis as described by Fyumagwa *et al. (*2007). In order to get enough samples the plots were of size of10mx10m, the one plot was randomly located in the previous area in grassland while the other one was located in woodland kopjes so as to compare the distribution of tick in two different habitats and the exercise was repeated randomly eight times in each habitat.

3.4.4 Experimental Birds (Guinea Fowls)

The domesticated guinea fowl was used during the studies of which were 20 and each cost 30,000Tshs.Prior to the experiment 4 birds was released in the ecosystem while 16 were confined in the peafowl cage. Unfortunately the released guinea fowl were eaten by predator (wild cats).This was a lesson to the researcher and since the experimental cage was made of chicken wires, the situation forced to hire a research assistant who could bring the guinea fowl in the experimental cage early in the morning and late evening return then in pea fowl cage for the whole study period.

3.4.5 Secondary Data from Various Documents

Captured individuals from all techniques were identified up to genus level. Specimens were preserved in 70% ethanol in the field and few ticks were then transferred to another bottle with 70% ethanol for preservation in Saanane museum after identification.

3.5 Data Analysis

3.5.1 Population Size of Ticks

The population size obtained from the sampled area was established and extrapolated to the total area (Terrestrial environment).

3.5.2 Population density of ticks

$$\text{Population density} = \frac{\text{No. of individuals per plot}}{\text{Area}}$$

3.5.3 Determine Effectiveness of Guinea fowl as Biological Control

Testing hypothesis was done using Wilcoxon Matched –pairs Test (or Signed Rank Test) using 5% level of significance. When the table value of T at 5% is less than 25 we reject Null hypothesis (Kothari, 2004).

3.5.4 To Determine Feeding Habits of Guinea Fowl using Spearman's Rank Correlation Coefficient

The formula returns the value between 1 and -1.

Where 1 indicate strong positive correlation

-1 indicate negative correlation and 0 no correlation.

$$r = \frac{1-6\sum d^2}{n^3-n}$$

Where

r= rho

n= No. of observation

$\sum d^2$= Sum of rank squared.

Lastly the distribution of the ticks in the grassland and rocky woodland habitats was calculated in the study area. The population on each habitat was established and comparison was made using percentage.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings gathered after collection of data. It also discusses critically the findings basing on the analysis of data. The chapter presents answers of the research objectives and questions stated in chapter one as per methodology, which has been employed.

4.2 Tick species Present in Saanane Island National Park

In order to determine the tick species present in two habitats, ticks were collected through dragging, tick removal on wild animals, litter collection on woodland vegetation and visual search at the interval of one week for two months. Then, laboratory analysis of tick species was performed as illustrated in (Table 4.1).

Table 4.1: Laboratory Analysis of Tick Species Present in the Island

Date	Rh.appendiculatus		A.marmerium		Rh.avertsi	
	♀	♂	♀	♂	♀	♀
17/9/2018	159	63	1	0	10	2
24/9/2018	96	32	7	0	36	11
1/10/2018	101	42	0	0	8	5
8/10/2018	71	28	1	0	23	12
15/10/2018	35	21	0	0	31	9
22/10/2018	24	18	0	0	16	4
29/10/2018	31	19	0	0	0	0
4/11/2018	21	10	0	0	0	1
TOTAL	**538**	**233**	**9**	**0**	**124**	**44**

Source: Field Data 2018

The results (Table 4.1) identified three species namely, *Ambryomma marmerium, Rhipicephalus appendiculatus* and *Rhipicephalus avertsi*. The results further show that *Rhipicephalus appendiculatus* was the dominant tick species in the SINP. The *Rhipicephalus appendiculatus* made 80.3% of the ticks in the island, 18.6% was *Rhipicephalatus avertis* and least species 1.1% which is *Amblyomma marmereum.*

Furthermore, results indicate that in each species there are more number of female than males which indicate the population of ticks is increasing in the island. In the entire population 671 are female and 277 are males equal to 71% and 29%, respectively. It was important to re-identify species in the SINP following the plan which was in place to add to new species of wild animals such as two lions (caged), 6 Dik dik, 5 Klipspringer, two wildebeest and 4 Indian peafowl from SENAPA and Tabora Zoo.

Following the additional number of wildlife yet no new tick species identified apart from the three species i.e. *Ambryomma marmerium, Rhipicephalus avertsi* and *Rhipicephalus appendiculatus (*Mdatele, 2011 unpublished data) which is similar to the current finding (Table 4.1). ln other words treatment provided prior to the introduction of new species using pour on acaricides (Deltamethlin) was effective.

Also SINP is the smallest park in Tanzania and the only Park found in town. This attracts a good number of tourists to visit the Park for recreation and education purposes. By not having new species of ticks it means there are no new threats identified.

4.3 Tick Species Distribution by Habitats in the Island

A total of 1,108 ticks were collected in immobilized animals and two different vegetation habitats. The results (Table 4.2) shows, 948 ticks were collected in grassland and rocky wood vegetation, while the remaining 160 were obtained from immobilized animals.

Table 4.2: Tick Species in Relation to the Habitat (10m x10) Plots

Habitat type	**Tick species**			**Total**	**Percent age**
	Rh.appendiculatus.	**Rh.avertsi**	**A.marmereum**		
Grassland	752	166	5	923	97
Rocky woodland	19	2	4	25	3
Total	**771**	**168**	**9**	**948**	**100**

Source: Field Data (2018)

The results (Table 4.2) show that the distribution of ticks in the study area vary greatly among the two habitats. The spatial distribution and abundance of ticks vary accordingly depending on biotic and a biotic factor such as temperature, humidity, vegetation type and the host. Through this study, number of ticks were captured and preserved for counting and identification.

However, there were several developmental stages of ticks including tiny and difficult to handle (larvae stage) thus concentrating on nymph and adult. The nymph stages were many than adult ticks basing on 10m x10m and those collected from immobilized animals (appendices 1, 2 & 6). Total ticks were 1,108, adult were 187 and nymph 921.Compared to nymph stage, adult did not exhibit wide range in population. Given high reproductive potential of a single female (Daniel 1999 cited by Daniel *et al*. 2000) population level can apparently be maintained with few adults successively producing offspring. Therefore if no any control measures taken the population of ticks will double in the ecosystem thus posing more burdens to the environment due to the fact that one female of *Rh.appendiculatus* can lay 5000 -7000 eggs. Knowing the distribution of ticks in the island will enable the management to take effective tick control in respective areas but also be used to alert visitors.

Although this was not part of my study it was observed during the study abrupt decrease number of ticks in the control plots in the start of rain season. Fortunately enough manage to see and prove that when the conditions are harsh they do hibernate in grass sheath (personal observation 2018, Figure 2.1). Grassland play dual role for ticks as attachment when looking for host and as shelter when condition are not favorable.

During this period ticks have ability to stay 2-3 years without feeding. The haler organ is used to detect external stimuli such as temperature, carbon dioxide level and humidity (Greenfield, 2011). When the condition is favorable get out of grass sheath. Grassland vegetation support more ticks than the rocky woodland vegetation because animal spend less time in those area for shelter when it is too hot.

Plate 4.1 shows opened grass sheath as the proof that ticks have ability to hibernate when the condition are harsh using their sense of haler. This ability increases the chance of survival as an individual species.

Ticks

Plate 4.1: Tick Quest on Grass Sheath when Condition are not Favorable

The total area for Saanane is 2.18squre kilometer. The terrestrial environment covers an area of 0.76 square kilometer

1square meter = 1x10^{-6} square kilometer.

? = 0.76 square kilometer

= 760000 square meter

948 Ticks were obtained 1600 square kilometer

? Ticks are in 760,000 square meters

$$\frac{948 \text{ ticks x } 760{,}000 \text{ square meter}}{1600 \text{ square meter}}$$

= 450,300 Ticks in the terrestrial environment of Saanane.

The possibility of height of vegetation may have influenced results or chances of ticks to come into contact with the dragging cloths is also possible (Plate 4.2) shows some tall grasses lie over the other grasses. The total population of 948 ticks was obtained from small sample area of 1600 square kilometer (Grassland and rocky woodland vegetation). The terrestrial environment in Saanane Island covers an area of 760,000 square meters while the rest is covered by water. From the simple calculation this area will have 450,300 ticks. This number of ticks is too high for a small area which is also covered by rocks.

Plate 4.2 shows how the exercise of dragging was carried out but also the impact of dragging on tall grasses as the ticks under long grasses might have not been collected hence affecting the estimates of ticks population in the habitat. To minimize the effect two stones were on top the dragging cloth material.

Plate 4.2: Collection Ticks on Grasses by Dragging

4.4 Distribution of Tick Species on Wild Animals

The distribution of tick species by wild animals is given in Table 4.3. The adult ticks collected was 160 from immobilized three animals species i.e. Zebra, Wildebeest and impala and non immobilized reptile which were three leopard tortoises. Both animals were highly infested with ticks relative to their body size (Table 4.3). The results (Table 4.3) shows animals were mostly affected by ticks followed by reptile while birds had no ticks.

Table 4.3: Tick Species Found on Wild Animals

	Rh.appendiculatus		***Rh.avertsi***		***A.marmerium***		
	♀	♂	♀	♂	♀	♂	
Zebra(1)	23	10	20	9	0	0	62
Impala (1)	10	3	6	2	0	0	21
Wildebeest(1)	41	12	-	0	1	0	54
Leopard tortoise(3)	13	7	1	0	1	1	23
Guinea fowl	0	0	0	0	0	0	0
Slender billed weaver	0	0	0	0	0	0	0
Total	**87**	**32**	**27**	**11**	**2**	**1**	**160**

Source: Field study 2018

All sampled animals by immobilization had abundant of ticks which were attached on ears, inguinal region, mane, and under the tail (Plate 4.3) which are soft part of the body and difficult for the animal to remove by grooming or wallowing on mud and/or dust. Except for the leopard tortoise (*Stigmochelys pardalis*) ticks observed on exoskeleton and the soft part like around the neck and legs. Sampled species were treated with pour on acaricide so as to kill the attached ticks on their bodies (Plate.4.5).Also guinea fowl and slender billed weaver proved not to be carrier of ticks as they were sampled on plots but and no tick were found (Table 4.3).

This is contrary to other scholar who suspects guinea fowl that as they wander around the properties they become host to ticks themselves further reducing their value of biological control.

Plate 4.3 billustrates the most affected parts of the host animals after immobilization. Ticks are attached to the body for blood meal and cause irritation, unrest and weight loss due to massive infestation of ticks, direct injury due to tick bites, and loss of blood due to feeding of blood (Drummonds 1983 cited by Raj put *et al.* 2006).

Plate 4.3: High Tick Infestation on Ear and Anal Fold of Plain Zebra after Immobilization

All ticks collected from sampled animals in the field were preserved in small lebbled bottle with 70% ethanol.


Tick removal on leopard tortoise

Plate 4.4: Ticks Attached on Leopard Tortoise

Plate 4.5: Treatment with Pour on Acariside after Tick Removal

Leopard tortoise and all immobilized animals were treated in the field with Deltamethlin to kill the remain ticks in their bodies. This chemical was applied on specific animal in small amount as it has tendency to spread. Control of tick ingestation though use of acaricides is one of the method that can be used to reduce the tick borne diseases it's application of acaricide to tick infessted animal via sprayer can be equally effective under ideal condition with proper handling of equipment without injuring animal and subsequently dilution of product (Gorge, 2000).

4.5 Determination of Tick Density in the Island

The tick density in grassland is between 0.3 – 2.3 ticks per $100m^2$ while the rocky woodland vegetation is from 0 (no ticks) to 0.1 per $100m^2$ (Table 4.4). The mean tick density in grassland is $1/100m^2$ while on woodland vegetation in similar area was 0 or no ticks.

Table 4.4: Tick Density 10mx10m Plots

Plot.	Tick density(grassland)/$100m^2$	Tick density(rocky woodland)/$100m^2$
1	2.26	0.09
2	1.69	0.13
3	1.56	0
4	1.32	0.03
5	0.96	0
6	0.62.	0
7	0.50	0
8	0.32	0
Mean	1.15	0.03

Source: Field Study 2018

The tick densities tended to increase from August to October and decreases towards November as the rains begins. The increasing trend was less in rocky woodland vegetation and more in grassland were tourist spending more time thus causing the threat of tick bites. This is due to fact that presence of ticks require biotic and a biotic factor were in rocky woodland vegetation animals (host) spend less time and no grasses apart from rocks and trees. It was observed that out of eight sites in rocky woodland vegetation only three sites had ticks ranging from 0 (no ticks) ticks/100m^2 to 0.13 tick/100m^2 and grassland vegetation range from 0.3 tick/100m^2 to 2.3 ticks/100m^2.Comparison of the tick densities between this and the former finding of the same localities (Mdelete, 2011 unpublished data) the density decrease from 1 tick/18m^2 to average mean 1 tick/100m^2 in grassland vegetation.

The decreased numbers of ticks in the ecosystem may be due to the effect of fire carried out two consecutive years. But continual use of fire is difficult as the animals suffered a lot due to shortage of pasture and some forced to feed on water hyacinth for their survival but as management we had to buy maize brand for supplement for animals. This scared the management as the few zebra present in the island were exposed to another risk of being eaten by crocodile in Lake Victoria and the current plan of increasing number of herbivores forced me to look for an alternative way to control ticks without causing inconvenience to animals.

4.6 Potential Host for Ticks in the Island

In most cases, the wild animals harbor a good number of ticks on their bodies especially under the tail, ears, inguinal region and mane (Plate 4.3). Although, ticks can attach itself to other parts of animal body, the illustrated parts (Plate 4.3) are the most affected areas. The results (Table 4.5) show that birds were also captured and checked for the presence of ticks especially the experimental birds and weavers found inside the plots.

Table 4.5: Potential Host for Ticks and Level of Infestation

Mammal/bird/reptile	No. ticks on host	Level of infestation
Zebra(1)	62	Abundant
Wildebeest (1)	54	Abundant
Leopard tortoise (3)	23	Moderate
Impala (1)	21	Moderate
Guinea fowl (8)	0	Nil
Slender billed weavers (4)	0	Nil

***Abundant ticks were more in different parts of the body but collected few ticks as the matter of time with animal heath after immobilization.**

From the observations in this experiment the two bird's species proved not to be carriers of ticks. The potential hosts for ticks were zebra, wildebeest, impala and Leopard tortoise to mention just few sampled species in the island due sensitivity of chemical, animal health status and cost associated with darting animal. The overall proportion of tick infested wild animals, it was highest in Zebra (62) equal to 38% followed by wildebeest 54 (34%) while Impala had 21 or 13% of ticks and three leopard tortoise had 23 ticks (14% or 4.7% each). Older and large animal carry more ticks than young animals (Fyumagwa *et al.* 2007).

It was important to prove whether birds are carrier of ticks before the introduction on guinea fowl SINP so that we don't cause more problems but rather try to solve the problem. Provision of food (grain) to guinea fowl attracts small rodents, which might import immature ticks onto properties (cage) containing the birds, and that this might counteract the suppressive effects of predation by the fowl on adult ticks

(Ostfeld *et al.* 2006).During the study only slender billed weaver were attracted with maize brand in cage and they did not carry ticks.

4.7 Feeding Habits of Guinea Fowl in the Island

The feeding habits of guinea fowl were determined using Spearman's Rank Correlation by comparing the level of ticks before treatment and the level after the treatment (Appendix 7). The results (Appendix 7) show that there is a strong significant positive correlation between presence of guinea fowl and tick density reduction as compared by tick in plots with guinea fowl and similar plot with no guinea fowl. The Spearman's Rho test (r = 0.3304) indicate that deployment of guinea fowl was able to explain 33 percent of the reduction in ticks. The answer always is between 1 and -1. This means if you increase guinea fowl rate of tick reduction also increase i.e. positive correlation and vice versa. The reduction in ticks come as guinea fowl consume host seeking ticks in the environment as they are good grazers. The average number of ticks consumed per chicken in a 3 hour period ranged from 28-81 ticks per chicken. With one chicken eating the most impressive 128 ticks! Chickens really are tick eating machines, and the proof is there in this study and some others it cites (http://ticksareforthebirds.com/proof-that-ticks-are-for-the-birds/).In their ancestral homeland of Africa, guineas follow the grazing herds and can reputedly eat four thousand ticks per day! Here, they eat a little chicken grain in the morning and then follow our herd of pygmy goats or just run around aimlessly (Randall, 2012). Therefore, from this proof plus the Crowe unpublished data cited in Duffy 1992 found ticks in the stomach of three guinea fowl l support guinea fowl will play a similar role in tick reduction in the ecosystem and partly add value in tourism as well. Also Predation Hypothesis suggests that guinea fowl and ticks interact in their final stage when adult ticks seek their terminal host, at which they are found and eaten by foraging guinea fowl.

4.8 Testing of Hypothesis

Using Wilcoxon matched- pairs test, an experiment was conducted to judge the effectiveness of guinea fowl, 8 paired of plots were set and the results are given in Table 4.6.

Table 4.6: Wilcoxon Matched – rank test

Pair	Control plot	Experimental plot	Difference Di	Rank of |di|	Rank with sign
1	11	8	3	2	2
2	7	8	-1	1	-1
3	9	9	0	-	-
4	12	9	4	3	3
5	24	11	13	6	6
6	21	4	17	7	7
7	14	7	7	4	4
8	14	6	8	5	5
		Total			**27** **-1**
		Hence , T=1			

Testing hypothesis using Wilcoxon matched- pair test, that there is no significant difference between the presence and absence of Guinea fowls as biological control of tick's .Using 5% level of significance.

Solution:

H_0: There is no significant difference between presence and absence of Guinea fowls as biological control of ticks.

H_a: There is significant difference using guinea fowl as biological control of ticks.

Note: Control and experimental plot represent average number of ticks per plot for the two months. Pair 3 is dropped out as di value for this is zero and as such my n= (8-1) =7 in the given problem. The table value of T at five percent level of significance when n= 7 is 2 (using a two –tailed test because my alternative hypothesis is that there is significant difference using guinea fowl as biological control of ticks. The calculated T is 1(one) which is less than the table value of 2.

As such I reject the Null hypothesis and conclude that there is significant difference using guinea fowl as biological control of ticks. The Predation Hypothesis suggests that guinea fowl and ticks interact at their final – stage when adult ticks seek their terminal host at which time they are found and eaten by foraging guinea fowl. In addition adult ticks mostly likely allow them to be more easily detected by guinea fowl. Guinea fowl have ability to reduce adult ticks but their presence may attract small rodents which might import immature ticks on to properties (cage) containing the birds and counteract the suppressive effect of predation by guinea fowl on adult ticks (Ostfeld *et al.* 2006).

4.9 Measurement of Tick Reduction between the Adult and nymph

A Wilcoxon Signed Ranks Test was used to determine if a statistical difference existed between the number of nymph found in each treatment plot/ cage and its control plot which did not(Table 4.7a).The results revealed that there was significant difference in nymph reduction (table z value is =1 and calculated p- value 2.365).

Table 4.7a: Rate of nymph Reduction in Experimental Block by Guinea Fowl

Pair	Control plot nymph	Experimental plot nymph	Difference di	Rank of di	Rank with sign	
1	9	5	4	3	3	
2	7	4	3	2	2	
3	7	8	-1	1	-1	
4	8	8	0	-	-	
5	21	10	11	6	6	
6	17	4	13	7	7	
7	10	5	5	4.5	4.5	
8	11	6	5	4.5	4.5	
					27	-1

Hence T= 1

We drop out pair 4 since the value of di is zero. The table value of T at 0.05 level of significance when n=7 is 2.365. The rate of nymph removal by guinea fowl is significant since the table value is higher than the calculated value which is 1.

Likewise in adult tick reduction Table 4.7b (Table z- value is 1 and calculated p-value 2.306. But, the result obtained (Table 4.7a &4.7b) does not show significant difference between the adult and nymph reduction as other scholar finding which showed clear significant difference in adult but not nymph reduction.

Table 4.7b: Adult Tick Rate of Reduction by Guinea Fowl

Pair	Control plot adult	Experimental plot adult	Difference di	Rank of di	Rank with sign	
1	0.5	0.8	-0.3	1	-1	
2	0.6	0.5	0.1	2	2	
3	1	0.6	0.4	3.5	3.5	
4	2.6	0.4	2.2	6	6	
5	1.8	0.8	1	5	5	
6	2	0.6	0.4	3.5	3.5	
7	6	2	4	8	8	
8	3	0.6	2.4	7	7	
					30	-1

Hence calculated T = 1

The value of T at 0.05 level of significance when n= 8 is 2.306 (two tailed). My assumption for the difference could be two month was not enough time for tick adult reduction to impact the nymph numbers. The grass in the experimental plot was short as compared to other areas hence increase grazing efficiency of guinea fowl. The result of experiment on the importance of birds in suppressing of tick population varies considerably for different countries depending on season and type of ground cover (Samish & Rehacek, 1999). It would be worthwhile to conduct another study with enough time to establish active forging of guinea fowl and the density of guinea fowl required for the island.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview

This chapter contains the conclusion and recommendations of the study. The conceptual framework guided the research, the methodology used in the study and the major research findings. Conclusions are then drawn from the study findings. Recommendations for action and further studies are then provided.

5.2 Summary of Major Findings

The researchers observed more ticks in grassland than rocky woodland vegetation, no new tick species identified regardless of additional wildlife species from other PA's. There were decreases in number of ticks towards rain season even in the cage with no guinea fowl which prove the ability of ticks to hibernate in grass sheath when condition are not favorable. There was no significant different between the adult and nymph tick removal in the ecosystem. My assumption was time was short (two month) to get clear differences and tall grass cover in the study area may have affected the result.

5.3 Conclusion

The study aim at investigating the effectiveness of guinea fowl as biological control method of ticks in the Mwanza Region. It highlights the potential host for ticks such as zebra, wildebeest, impala and leopard tortoise and parts with high infestation of ticks such as inguinal region, under the tail, male and ear. The tick does not only cause nauseas to animals but also tourists who are exposed to the same habitat during recreation are likely to be infested by ticks. The analysis of tick species identified three species which were *Rhipicephalus appendicutus, Rhipicephalus avertsi and Ambryomma mamerium.*

The finding identified some important factors responsible for tick's survival such as host (biotic) and biotic factors such as vegetation. It was observed less tick density in woodland rocky vegetation as compared to grassland vegetation were animals spend more time for feeding. Grassland plays dual faction as attachment while looking for host and ad shelter when conditions are harsh. From the study Park management can easy predict areas of 'hotspot' activity of ticks in grassland. This study, demonstrating how research can benefit management, hopefully fulfils a small part of that objective.

The study found that guinea fowl have ability to reduce tick density in small area as it concurs with the alternative hypothesis. Guinea fowl may be most appropriate as one means of controlling ticks in low density public parks were noisy is unlikely to be a problem. Guinea fowl along should not be reliable on for the complete control of ticks but rather should be used as one of a suitable method to reduce ticks or used in hand with other means like habitat manipulation.

They are inexpensive compared to many pesticide treatment and present less potential for direct environmental damage, but they are prone to predation by small wildcat as witnessed in the study domesticated guinea fowl are easily taken by predators as they lack wild survival techniques.

Other studies have shown their ability to reduce arthropods thus minimizing use of pesticides in lawn therefore; having guinea fowl in the ecosystem will add value in tourism and as biological control.

5.4 Recommendations

Based on the finding of the study, the following recommendation aim at assisting Park Ecologists for Saanane as well as Management of other PA's to minimize level of ticks infestation in the park , tourists when visiting the PA's or areas indicated with high risk of ticks, other conservation institutions as implementers and researchers.

5.4.1 Policy Recommendations

(i) The study recommends that the Park Ecologists for SINP instead of burning the whole area during early burning to divide area into plots and slash grasses at different interval while collecting slashed grasses and burn those grasses at one collection point so as to kill ticks. Continue watering of slashed area to allow growth of new and palatable grasses for herbivores. Short grasses allow ultra-violet light penetration hence making less oviposition, tick survival or questing. Also other studies show that guinea fowl are efficient biological control of ticks on short grasses.

(ii) In addition, the study recommends the park ecologists to put enough sand to some points where animal can do dust wallowing to get rid of ticks. This was observed in the field in the children Conner (Playing ground) were zebra used same sand in the ground as wallowing place to get rid of ticks (personal observ.2018). Besides, the parks can plant grasses that are repellant for ticks such as genera cynodon and pennisetum are effective as means to control ticks. On the other hand, cultivation of land (plots) tends to reduce tick life by controlling movement of wild animals as well as creating condition unfavorable for ticks. Cultivated land act as area for dust wallowing and tick removal.

(iii) The park ecologists are recommended to direct kill immature ticks that are abundant during dry season, after dragging kill them with hot water.
Moreover, the park can introduce strategic treatment system based on ecological knowledge of the seasonal cycle of ticks. During the peak season you can immobilize some animals which are worse situation and treat them.

(iv) On other hand, TANAPA and other Conservation Institution like TAWA, TFS, NCAA who wishes to introduce guinea fowl in their areas to translocated wild guinea fowl and not domesticated or from zoos as they lack wild survival techniques. It was also observed during the experiment some were eaten by wild cats. Sufficient budget allocation to ecology department so that they can perform further research of the best option to minimize the problem in different ecosystem. The problem may increase in future as the migratory routes are blocked and animals confined in one place. There is need as wildlife managers to have clear understanding of the consequences of ticks’ infestation especially on small areas like Saanane and Rubondo Islands where active intervention is inevitable so as to rescue animals. It is no longer the time to live nature takes its own course as we may lose potential animals in the ecosystem

(a) Similarly, the study recommend provision of conservation education to the tourist including warning sign to areas with high risk of tick and the way to protect oneself including-:

(b) Wear insect repellent with 10 percent DEET give protection for two hour. Oil of lemon eucalyptus gives the same protection as DEET.

(c) Wear light colored protective clothing that cover the skin, as well as tucking your trousers into your socks.

(d) Be vigilant. Check your pets and yourself for ticks don’t assume you cannot be affected.

(e) Use of ant- tick vaccine. This type of vaccination use of tick gut rather than salivary antigen as a target for immune response.

5.4.2 Suggested further Study

Further research should focus on the evaluation of introduced guinea fowl and multiple habitat manipulation as means to eliminated or minimize tick in National Parks of Tanzania.

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APPENDICES

APPENDIX 1: TICKS FOUND ON IMMOBILIZED AND NON IMMOBILIZED ANIMALS

Herbivore/Birds	Tick species						No. of tick spp.on host
	Rh.appendiculatus		*Rh.avertsi*		*A.marmerium*		
	♀	♂	♀	♂	♀	♂	
Zebra(1)	23	10	20	9	0	0	62
Impala (1)	10	3	6	2	0	0	21
Wildebeest(1)	41	12	-	0	1	0	54
Leopard tortoise(3)	13	7	1	0	1	1	23
Guinea fowl	0	0	0	0	0	0	0
Slender billed weaver	0	0	0	0	0	0	0
Total	87	32	27	11	2	1	160

APPENDIX 2: TICKS FROM EXPERIMENTAL BLOCK

TABLE 2 .EXPERIMENTAL BLOCK							
Plot no.	**Date**	**Co-ordinates**		**Adult**	**Nymph**	**Total**	**Remarks**
		X	Y				
1	17/9/2018	487891.5	9718926.8	2	11	13	
2	17/9/2018	487888.1	9718914.6	2	13	15	
3	17/9/2018	487876.8	9718907.1	2	33	35	
4	17/9/2018	487879.9	9718893.1	1	33	34	
5	17/9/2018	487872.9	9718880.9	4	44	48	
6	17/9/2018	487860	9718847.7	1	18	19	
7	17/9/2018	487860	9718847.7	7	22	29	
8	17/9/2018	487858	9718842.5	0	15	15	
1	24/9/2018	487891.5	9718926.8	3	6	9	
2	24/9/2018	487888.1	9718914.6	0	2	2	
3	24/9/2018	487876.8	9718907.1	1	16	17	
4	24/9/2018	487879.9	9718893.1	0	24	24	
5	24/9/2018	487872.9	9718880.9	0	16	16	
6	24/9/2018	487860	9718847.7	1	3	4	
7	24/9/2018	487860	9718847.7	1	2	3	
8	24/9/2018	487858	9718842.5	0	9	9	
1	1/10/2018	487891.5	9718926.8	0	4	4	
2	1/10/2018	487888.1	9718914.6	0	5	5	
3	1/10/2018	487876.8	9718907.1	1	5	6	
4	1/10/2018	487879.9	9718893.1	1	4	5	
5	1/10/2018	487872.9	9718880.9	0	5	5	
6	1/10/2018	487860	9718847.7	0	1	1	
7	1/10/2018	487860	9718847.7	0	5	5	
8	1/10/2018	487858	9718842.5	0	7	7	
1	8/10/2018	487891.5	9718926.8	0	11	11	
2	8/10/2018	487888.1	9718914.6	0	0	0	
3	8/10/2018	487876.8	9718907.1	1	2	3	
4	8/10/2018	487879.9	9718893.1	1	2	3	

5	8/10/2018	487872.9	9718880.9	1	3	4	
6	8/10/2018	487860	9718847.7	2	4	6	
7	8/10/2018	487860	9718847.7	0	7	7	
8	8/10/2018	487858	9718842.5	0	9	9	
1	15/10/2018	487891.5	9718926.8	1	7	8	Sampling guinea fowl but no ticks.
2	15/10/2018	487888.1	9718914.6	1	5	6	
3	15/10/2018	487876.8	9718907.1	0	7	7	
4	15/10/2018	487879.9	9718893.1	0	4	4	
5	15/10/2018	487872.9	9718880.9	1	7	8	
6	15/10/2018	487860	9718847.7	0	3	3	Guinea fowl no ticks
7	15/10/2018	487860	9718847.7	0	2	2	
8	15/10/2018	487858	9718842.5	1	1	2	
1	21/10/2018	487891.5	9718926.8	0	0	0	
2	21/10/2018	487888.1	9718914.6	1	3	4	
3	21/10/2018	487876.8	9718907.1	0	2	2	
4	21/10/2018	487879.9	9718893.1	0	0	0	
5	21/10/2018	487872.9	9718880.9	0	3	3	
6	21/10/2018	487860	9718847.7	0	1	1	Weaver birds no tick.
7	21/10/2018	487860	9718847.7	0	2	2	
8	21/10/2018	487858	9718842.5	0	2	2	
1	29/10/2018	487891.5	9718926.8	0	0	0	
2	29/10/2018	487888.1	9718914.6	0	0	0	
3	29/10/2018	487876.8	9718907.1	0	0	0	
4	29/10/2018	487879.9	9718893.1	0	0	0	
5	29/10/2018	487872.9	9718880.9	0	0	0	
6	29/10/2018	487860	9718847.7	0	0	0	
7	29/10/2018	487860	9718847.7	3	3	6	
8	29/10/2018	487858	9718842.5	2	2	4	
1	4/11/2019	487891.5	9718926.8	0	0	0	

2	4/11/2019	487888.1	9718914.6	0	0	0	
3	4/11/2019	487876.8	9718907.1	0	1	1	
4	4/11/2019	487879.9	9718893.1	0	0	0	
5	4/11/2019	487872.9	9718880.9	0	0	0	
6	4/11/2019	487860	9718847.7	0	0	0	
7	4/11/2019	487860	9718847.7	0	2	2	
8	4/11/2019	487858	9718842.5	0	1	1	
Total				42	399	441	

APPENDIX 3: TICKS PRESENT IN CONTROL BLOCK

Plot. No.	Date	Coordinates		Adult	Nymph	Total
		X	Y			
1	17/9/2018	487915.3	9718913.9	0	12	12
2	17/9/2018	487909.8	9718909.3	1	8	9
3	17/9/2018	487919.8	9718899.6	1	9	10
4	17/9/2018	487916	9718890.6	5	9	14
5	17/9/2018	487909.5	9718880.5	6	42	48
6	17/9/2018	487906.7	9718870.1	3	35	38
7	17/9/2018	487904.7	9718856.1	16	10	26
8	17/9/2018	487903.6	9718846	13	9	22
1	24/9/2018	487915.3	9718913.9	1	14	15
2	24/9/2018	487909.8	9718909.3	0	5	5
3	24/9/2018	487919.8	9718899.6	1	12	13
4	24/9/2018	487916	9718890.6	4	5	9
5	24/9/2018	487909.5	9718880.5	3	36	39
6	24/9/2018	487906.7	9718870.1	2	38	40
7	24/9/2018	487904.7	9718856.1	13	19	32
8	24/9/2018	487903.6	9718846	9	10	19
1	1/10/2018	487915.3	9718913.9	0	17	17
2	1/10/2018	487909.8	9718909.3	0	8	8
3	1/10/2018	487919.8	9718899.6	3	14	17
4	1/10/2018	487916	9718890.6	4	12	16
5	1/10/2018	487909.5	9718880.5	0	31	31
6	1/10/2018	487906.7	9718870.1	1	27	28
7	1/10/2018	487904.7	9718856.1	9	22	31
8	1/10/2018	487903.6	9718846	5	6	11
1	8/10/2018	487915.3	9718913.9	1	8	9
2	8/10/2018	487909.8	9718909.3	2	10	12
3	8/10/2018	487919.8	9718899.6	0	8	8
4	8/10/2018	487916	9718890.6	3	16	19
5	8/10/2018	487909.5	9718880.5	3	26	29
6	8/10/2018	487906.7	9718870.1	2	22	24
7	8/10/2018	487904.7	9718856.1	6	11	17
8	8/10/2018	487903.6	9718846	3	8	11
1	15/10/2018	487915.3	9718913.9	0	6	6
2	15/10/2018	487909.8	9718909.3	1	7	8
3	15/10/2018	487919.8	9718899.6	0	5	5
4	15/10/2018	487916	9718890.6	1	4	5
5	15/10/2018	487909.5	9718880.5	2	19	21
6	15/10/2018	487906.7	9718870.1	0	14	14
7	15/10/2018	487904.7	9718856.1	3	5	8
8	15/10/2018	487903.6	9718846	0	9	9
1	21/10/2018	487915.3	9718913.9	2	3	5
2	21/10/2018	487909.8	9718909.3	0	5	5
3	21/10/2018	487919.8	9718899.6	0	3	3
4	21/10/2018	487916	9718890.6	2	5	7
5	21/10/2018	487909.5	9718880.5	1	5	6

6	21/10/2018	487906.7	9718870.1	0	6	6
7	21/10/2018	487904.7	9718856.1	4	8	12
8	21/10/2018	487903.6	9718846	2	18	20
1	29/10/2018	487915.3	9718913.9	0	12	12
2	29/10/2018	487909.8	9718909.3	1	7	8
3	29/10/2018	487919.8	9718899.6	3	4	7
4	29/10/2018	487916	9718890.6	2	9	11
5	29/10/2018	487909.5	9718880.5	0	5	5
6	29/10/2018	487906.7	9718870.1	0	13	13
7	29/10/2018	487904.7	9718856.1	0	7	7
8	29/10/2018	487903.6	9718846	0	5	5
1	4/11/2019	487915.3	9718913.9	0	0	0
2	4/11/2019	487909.8	9718909.3	0	2	2
3	4/11/2019	487919.8	9718899.6	0	1	1
4	4/11/2019	487916	9718890.6	0	0	0
5	4/11/2019	487909.5	9718880.5	0	0	0
6	4/11/2019	487906.7	9718870.1	1	3	4
7	4/11/2019	487904.7	9718856.1	0	1	1
8	4/11/2019	487903.6	9718846	0	0	0
Total				**145**	**710**	**855**

NOTE: *The last two weeks result appeared almost similar to experimental block thus I came to realize during rain reason ticks hibernate in grass sheath.*

TICKS COLLECTED IN DIFFERENT HABITATS IN 10MX10M BLOCKS

APPENDIX 4: TICKS COLLECTED IN 10MX10M PLOTS IN GRASSLAND.

Dates	Dragging	Visual search	Litter collection	Total
17/9/2018	190	36	0	226
24/9/2018	158	11	0	169
1/10/2018	139	17	0	156
8/10/2018	122	10	0	132
15/10/2018	91	5	0	96
21/10/2018	50	12	0	62
29/10/2018	43	7	0	50
4/11/2018	8	23	1	32
Total	**801**	**121**	**1**	**923**

APPENDIX 5: TICKS COLLECTED FROM 10M X 10M PLOT IN ROCKY WOOLAND VEGETATION

Dates	**Dragging**	**Visual search**	**Litter collection**	**Total**
17/9/2018	1	7	1	9
24/9/2018	2	0	11	13
1/10/2018	0	0	0	0
8/10/2018	1	0	2	3
15/10/2018	0	0	0	0
21/10/2018	0	0	0	0
29/10/2018	0	0	0	0
4/11/2018	0	0	0	0
Total	**4**	**7**	**14**	**25**

Note: G*rand total in both habitats 948*

APPENDIX 6: TICKS OBTAINED FROM 10M X10M PLOTS OF DIFFERENT HABITATS

DATE	TYPE OF HABITAT	*Rhipicephatus appendilatus*		*Ambryomma spp*		*Rhipicephatus avertis*		TOTAL
		♀	♂	♀	♂	♀	♂	
17/9/2018	Rocky woodland	5	3	1	0	0	0	9
17/9/2018	Grassland	154	60	0	0	10	2	226
24/9/2018	Rocky woodland	8	3	2	0	0	0	13
24/9/2018	Grassland	88	29	5	0	36	11	169
1/10/2018	Grassland	101	42	0	0	8	5	156
1/10/2018	Rocky woodland	0	0	0	0	0	0	0
8/10/2018	Grassland	71	28	0	0	21	12	132
8/10/2018	Rocky woodland	0	0	1	0	2	0	3
15/10/2018	Grassland	35	21	0	0	31	9	96
15/10/2018	Rocky woodland	0	0	0	0	0	0	0
22/10/2018	Grassland	24	18	0	0	16	4	62
22/10/2018	Rocky woodland	0	0	0	0	0	0	0
29/10/2018	Grassland	31	19	0	0	0	0	50
29/10/2018	Rocky woodland	0	0	0	0	0	0	0
4/11/2018	Grassland	21	10	0	0	0	1	32
Total		**538**	**233**	**9**	**0**	**124**	**44**	**948**

Appendix 7: Spearman's Rank Correlation

Plot	X	Y	R_1 (X)	R_2(Y)	D(R_1-R_2)	d^2
1	**13**	**0**	**8**	**4.5**	**3.5**	**12.25**
2	**15**	**0**	**6.5**	**4.5**	**2**	**4**
3	**35**	**1**	**2**	**2.5**	**-0.5**	**0.25**
4	**34**	**0**	**3**	**4.5**	**- 1.5**	**2.25**
5	**48**	**0**	**1**	**4.5**	**-3.5**	**12.25**
6	**19**	**0**	**5**	**4.5**	**0.5**	**0.25**
7	**29**	**2**	**4**	**1**	**3**	**9**
8	**15**	**1**	**6.5**	**2.5**	**4**	**16**
Total						$\sum d^{2=56.25}$

$$r = \frac{1 - 6\sum d2}{n3 - n}$$

$$r = \frac{1 - 6(56.25)}{83 - 8}$$

r= 1-0.6696

r=0.3304

Appendix 8. Data analysis sheet

Ticks collected	Adult	Immature or nymph
Dragging over vegetation		
Visual search (Tree leaves, barks and stem)		
Litter collection		
From animals		

Appendix 8 Lab analysis data sheet

Date	Type of species identified			
	♀	♂	♀	♂

Appendix 9: Ticks data sheet-Experimental and Control cages

Plot No.	Coordinates N. E.	Adult	Nymph.	Total	Remarks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Note. This form will be used also Removal sampling.

Data sheet No………..

Date …………….

Time: start: ………… Finish………………

Vegetation type……………………