

**COMPARATIVE DETERMINATION OF TICK BURDEN AND DIVERSITY IN INTENSIVELY  
MANAGED WILDLIFE ESTATES UNDER THOSE WITH AND WITHOUT  
PRESCRIBED BURNING**

**BY**

**MAAMBO BHAGOOS**

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PUBLIC HEALTH**

**THE UNIVERSITY OF ZAMBIA**

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**DECLARATION**

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## **CERTIFICATE OF APPROVAL**

This dissertation submitted by Maambo Bhagoos is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Ecological Public Health (EPH) at the University of Zambia.

Supervisors Name:.....

Signature: .....Date.....

### **Signature of Examiners**

#### **Internal Examiners**

1. Name: .....Signature: .....Date: .....

2. Name: .....Signature: .....Date: .....

3. Name: .....Signature: .....Date: .....

#### **Chair for Board of Examiners**

1. Name: .....Signature: .....Date .....

## ABSTRACT

Prescribed burning in *ex-situ conservancies* ecosystems significantly reduces tick burden and diversity. In Zambia, the role of ticks in zoonotic disease transmission is not well described, partly, due to limited available information on tick burden and diversity in *ex-situ conservancies*. This study aimed to compare three management systems that are currently used to control ticks in *ex-situ conservancies*. Tick samples were collected between October 2021 and April 2022, a total number of 267 ticks were collected from the ground/vegetation in three tick management systems early burning, late burning and no burning in 36 transects across 3 *ex-situ conservancies* in Central, Lusaka and Southern provinces. These ticks were morphologically identified at the University of Zambia, School of Veterinary Medicine, parasitology laboratory. Collected ticks belonged to 11 species: *Rhipicephalus* species, ( $n=6$ ), (*Rhipicephalus appendiculatus*, *Rhipicephalus evertsi*, *Rhipicephalus microplus*, *Rhipicephalus decoloratus*, *Rhipicephalus sanguineus*, *Rhipicephalus pulcherus*, *Rhipicephalus zambeziensis*); *Amblyomma* species ( $n=2$ ), (*Amblyomma variagatum*, *Amblyomma poposum*), and *Hyalomma* species ( $n=2$ ) (*Hyalomma Rufipes* and *Hyalomma truncatum*). The most common species were *R. evertsi* (19.4 %), *Amblyomma variagatum* (14%), and *Hyalomma truncatum* (11%). The highest species diversity, and burden was found to be highest in no-burn management system ( $p<0.01$ ), whilst no significant differences were observed between late and early burning systems ( $P>0.776$ ) based on Bartlett's test for equal variance. To a large extent, these results have elucidated for the first time in Zambia that the use of fire as a management tool effectively reduces tick diversity and burden in closed *ex-situ* conservancy areas. Additionally, the results intimate a reduction of ticks in both early and late burning, despite the differences being not significant. The findings of this study have far reaching policy implications when it comes to tick management in *ex-situ conservancies*, when it comes to adoption of fire as a preferable method in *ex-situ conservancies*.

## **DEDICATION**

This work is dedicated to my sisters' and brothers for supporting me during my early academic journey. My parents Mr. Maambo Bornface and Winnie Mweene Maambo for supporting me during this academic journey.

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## **ACRONYMS AND ABBREVIATIONS**

<b>ANOVA</b>	Analysis of Variance
<b>ArcGIS</b>	Aeronautical Reconnaissance Coverage Geographical Information System
<b>DNPW</b>	Department of National Parks and Wildlife
<b>GIS</b>	Geographical Information System
<b>GPS</b>	Global Positioning System
<b>MTBS</b>	Monitoring Trends in Burn Severity
<b>PGR</b>	Private Game Reserve
<b>PPE</b>	Personal Protective Equipment
<b>SRST</b>	Simple Random Sampling Technique
<b>ZMD</b>	Zambia Meteorological Department

# CHAPTER ONE

## 1.0 INTRODUCTION

Ticks pose a significant threat to wild animals in *ex-situ conservancies* as they parasitize every class of terrestrial vertebrates. They are obligate blood-sucking ectoparasites of mammals, birds, and reptiles. They are ranked second after mosquitoes as the most frequent vectors of pathogens causing human and animal diseases (Dantas,2012). The geographical burden of tick species is believed to have expanded due to both the intensification of human and animal activities, socio-economic and environmental changes (Walker et al, 2014). Furthermore, ticks can easily spread and colonize novel regions via host movements and translocations. These species all react to changes in habitat characteristics that may further lead to cascading effects throughout the ecosystem. Therefore, effective environmental management in *ex-situ conservancies* areas must be formulated with an understanding of these changes in order to control tick on wild animals.

The impact of ticks is linked to their ability to transmit diseases to humans and animals (Rajput 2006). Consequently, ticks are responsible for severe economic losses in wild animals and livestock both through direct and indirect effects. Direct effects can occur in several ways, such as causing a reduction in live weight which can limit animal production induction anemia among wild and domestic animals and injection by certain ticks (for example, *Dermacentor andersoni*) of a toxin causing paralysis (Durrey *et al.* 2012). Additionally, ticks are vectors of several pathogens such as viruses, bacteria, protozoa, and filarial nematodes, which can cause diseases in animals and humans worldwide (Dantas, 2008).

## **1.1 Problem Statement**

Ticks pose a significant threat to wild animals in *ex-situ conservancies* as they parasitize every class of terrestrial vertebrates. They transmit the utmost variety of animal diseases as compared to all other hematophagous arthropods (Sonenshine, 2014). Domestic and wild animal diseases occurring in Zambia are presumptuously more important as they continue to be a major public health and economic problem not only in Zambia but in many parts of Eastern, Southern, and Central Africa (Makala, 2003). Tick control in free-ranging wildlife is more complicated as compared to domestic livestock setup. The current tick control methods, which include the use of toxic acaricides to manage ticks, and the virulent sporozoite infection and treatment method have limitations and environmental problems in the natural ecosystem.

## **1.2 Study Justification**

Prescribed burning has a potential to reduce tick population in *ex-situ conservancy* areas, this study has provided knowledge on tick burden and diversity in *ex-situ conservancies*, in relation to the management system. Several chemical acaricides have been synthesized and tick resistance to those chemical pesticides poses a serious threat to most *ex-situ conservancy* farmers. It is against this background that the study aimed at assessing tick burden and diversity in *ex-situ conservancy* between three management system late, early and no burning. To date, no study has investigated the effect of prescribed burning on tick burden and diversity in *ex-situ conservancy* areas in Zambia. Henceforth there was a need of a local study to examine the interaction between prescribed burning and tick diversity in game ranches in Zambia.

### **1.3 Study Objective**

#### **1.3.1 General Objective:**

To determine the effect of prescribed burning as a management tool on the diversity of tick species in ranches with and without management system.

#### **1.3.2 Specific Objectives:**

- i. To compare tick abundance in game areas with and without prescribed burning.
- ii. To assess tick species diversity in game areas with and without prescribed burning.

### **1.4 Study Hypothesis**

**$H_0$ :** There is no significant difference in tick abundance and, diversity between areas that practice prescribed burning to those that don't burn.

**$H_a$ :** There is a significant difference in tick abundance and, diversity between areas that practice prescribed burning with those that don't burn.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Tick Taxonomy

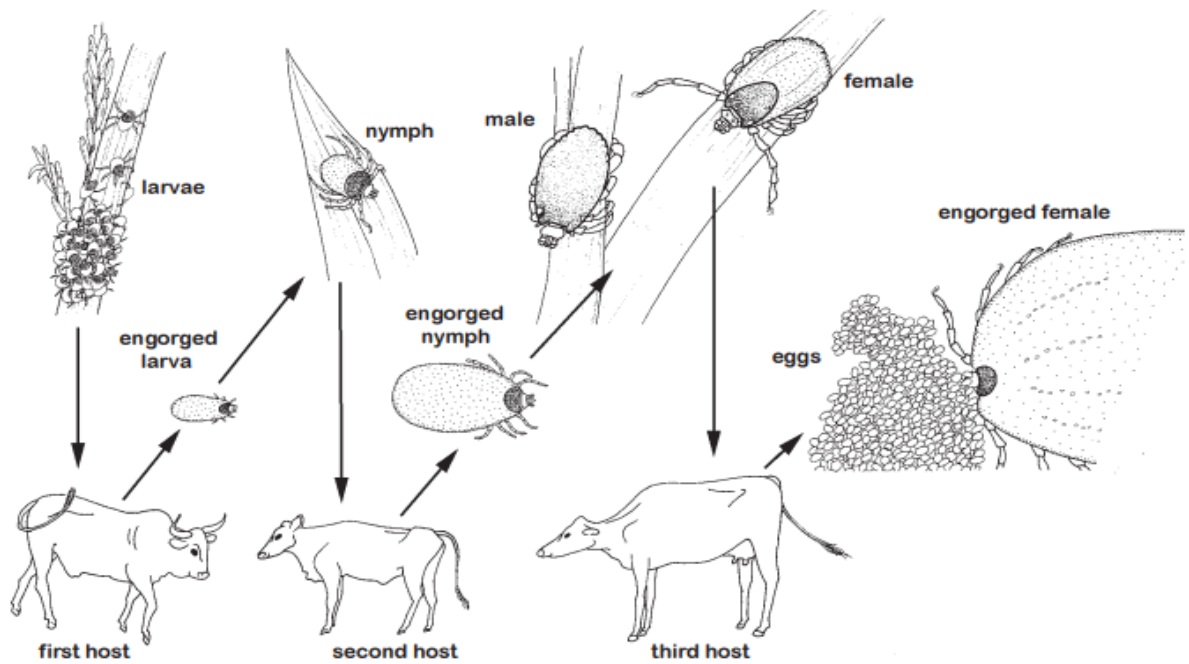
Ticks are ectoparasites of animals, which are classified (together with mites) in the order Acari. All ticks are obligate ectoparasites of vertebrates. They have four pairs of legs as nymphs and adults, and the body is divided into the capitulum (which bears the mouthparts) and the opisthosoma (Walker, et al, 2014). There are at least 840 tick species in two major families, namely the *Ixodidae* or 'hard' ticks (so called by virtue of their hard dorsal shield) and the *Argasidae* or 'soft' ticks (due to their flexible leathery cuticle) (Tandon,1991). The family *Ixodidae* comprises approximately 80% of all known tick species, including the species of greatest economic importance. However, *Argasid* ticks also play a significant role as vectors of diseases, in domesticated and wild animals (Walker, et al, 2014).

##### 2.1.1 Tick Life Cycle and Ecology

##### 2.1.2 Three-Host Tick Life Cycle

The life cycle for the three-host ticks, the larvae develops in the eggs until ready to hatch, usually in several weeks. Larvae feed once on a host, then detach from the host and hide in sites such as soil or vegetation (Walker, et al 2014). They moult to nymphs, where these nymphs feed once and moult in the same way as larvae. From the nymphal moult either a female or male hatches. The female feeds once and lays one huge batch of eggs. The depleted female then dies. The male may take several small feeds, mate and then die. Ticks that have recently hatched from eggs or from moulting have soft bodies and are inactive for

one to two weeks until the external body wall hardens. The life cycle of three-host ticks is slow, from six months to several years (Walker, et al 2014). The illustration below shows the sequence of feeding and moulting during the life of individual ticks of a typical three-host species. This is the commonest type of life cycle.

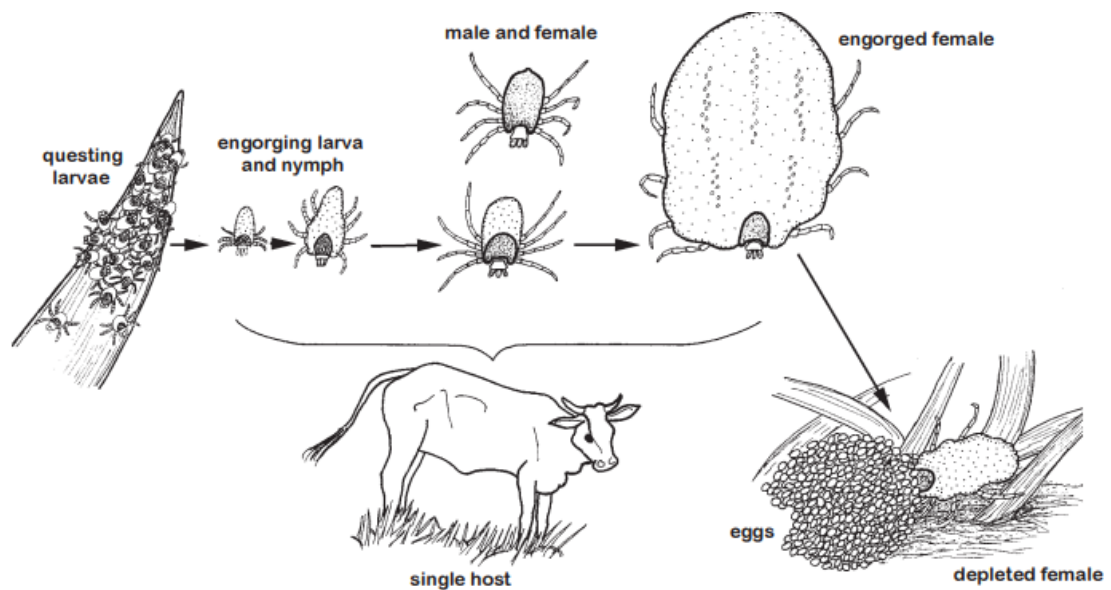


Source (Walker, et al 2014)

### 2.1.3 One and Two-Host Tick Life Cycles

This is a less common type of life cycle but it occurs in all the *Boophilus* sub-genus of the *Rhipicephalus* genus and in other genera. During reproductive system eggs are laid on soil/ground. Where larvae hatch after several weeks of development and crawl onto vegetation to quest for a host. When they have completed feeding they remain attached to the host and moulting occurs there. The nymphs then feed on the same host and also remain attached (Walker, et al 2014). After another moult the adults hatch and then feed on the same host. The adults will change position on the same host for mating. Thus all

three feedings of any individual tick occur on the same individual host. The life cycle of one-host ticks is usually rapid, for *Rhipicephalus (Boophilus)* it takes three weeks for the feedings on one host and two months for egg laying and larval development (Walker, et al 2014). The two-host life cycle is similar but only the larvae and nymphs feed on the same individual host, and the adults will feed on another host, such as *Hyalomma detritum* and *Rhipicephalus evertsi* have two-host life cycles. In cooler temperatures, they may live without food for up to six months. Adults' pursuit on forest floor vegetation and in leaf litter from fall to spring with an ambient air temperature tolerance of 4°C (Hung, 2001). The illustration overleaf shows the sequence of feeding and moulting during the life of individual ticks of a typical one-host species.



Source, (Walker et al, 2014)

#### **2.1.4 Multihost Tick Life Cycle**

The life cycle for *Argasid* multihost tick's family *Argasidae* have two or more nymphal stages, each of which requires a blood meal. This pattern is referred to as the multihost life cycle. Mating usually occurs, and egg-laying always occurs, off the host in a sheltered area (usually an animal nest) (Sonenshine, 1991). Eggs hatch into six-legged larvae in the parents' sheltered area. They quest for a host in the vicinity of the sheltered area. Once a suitable host is found, they feed for anywhere from one hour to several days, depending on the species. After feeding, the larvae leave the host and molt into the first nymphal instars in the sheltered area (Balashov, 1972).

The nymphs quest for, and feed on, the second host rapidly (usually about an hour). The second host is usually the same species, and often the same individual, as the first host (Uilenberg, 1992). The first nymphal instars leave the host and molt into the next nymphal instars in the sheltered area. This cycle can continue to accommodate up to seven nymphal instars depending on the species. After the last nymphal instar has fed, it leaves the host and molts into an adult in the sheltered area (Gould, 2008).

#### **2.2 Preferred Tick Habitat**

A tick's habitat is composed of the variety of living and non-living things in the space in which it lives that are good or bad for its survival. Ticks are adapted to two extremely contrasting components of their habitat: the physical environment and their host. When ticks are moulting and then questing in the physical environment they are in danger of drying out, starving and freezing. They are also exposed to predators such as ants and to pathogens such as fungi (Walker, et al 2014). These adverse factors limit the type of

habitats that a species will be found in and knowledge of the typical physical habitat of a species is an aid to identification. Additionally, Otsfeld et al., (2006) in their study they observed that ticks spent most of their life hidden in grass, leaf litter under forest floor molting, and overwintering. Larval and nymph ticks can minimize water storage capacity and permeable cuticles making them sensitive to changes in relative humidity leading to potential desiccation (Smith, 2002). Researchers concluded that changes in habitat such as reductions in leaf litter, duff, or understory cover, that increase light penetration and reduced humidity, can lead to a substantial reduction in tick abundance (Ginsberg and Stafford, 2005).

The ecological characteristics that regulate an area's potential habitat suitability for ticks include humidity, seasonal temperature, soil conditions, and vegetative cover and composition (Wasser *et al*, 2006). Principally, areas of high humidity and variable seasonal temperature are known to have high tick population presences in-game areas. Soils that are too dry leads to tick desiccation and death, while soils of high moisture can lead to negative effects on overwintering capabilities in leaf litter and upper horizons of soils, ruling out much wetland habitat (Guerra *et al.*, 2002). Interestingly, Guerra, *et al* (2002) found that coarse soils, such as sandy barrens, are more likely to harbor high tick density populations than thicker clays where water drainage is minimal.

Grippingly, (Trip,2017) found that higher densities of shrub layers stabilize temperature and increase humidity by limiting airflow between forest strata, as well as reducing predation on ticks and their host species. Therefore, culmination of these environmental characteristics can lead to general patterns of tick burden, diversity and distribution. Classic studies on tick burden in New Jersey found that tick diversity was more prevalent

in areas with habitat fragmentation, hardwood tree dominance, higher shrub density, and higher leaf litter depth (Schulze and Jordan, 2005). Therefore, researchers concluded that proportional pine forest areas of the study exhibited undesirable comparatively high temperatures and low humidity, limiting tick survival (Schulze and Jordan, 2005). This study formed a useful basis of research but it was far too limited in scale and complexity to draw a useful conclusion on the relationship between prescribed burning and tick distribution.

### **2.3 Economic Importance of Ticks**

The medical and economic importance of ticks has long been recognized due to their ability to transmit diseases to humans and animals. Ticks cause great economic losses to livestock, and wild animals in several ways. Blood sucking by large numbers of ticks causes reduction in live weight and anemia among animals, while their bites also reduce the quality of hides (Zahid, et al 2006).

However, the major losses caused by ticks are due to their ability to transmit protozoan, rickettsial and viral animal diseases, which are of great economic importance world-wide. Diseases such as Theileriosis, Babesiosis, Anaplasmosis, cowdriosis and tick-associated dermatophilosis are major health and management problems of livestock and wild animals in many developing countries. The economically most important ixodid ticks of livestock in tropical regions belong to the genera of *Hyalomma*, *Boophilus*, *Rhipicephalus* and *Amblyomma* (Frans, 2000).

### **2.4 Current tick control methods**

There are various ways to control ticks, but every method of tick control has certain shortcomings. Chemical control with acaricides was considered as one of the best methods,

but it has been seen that ticks have developed resistance against a range of acaricides (Martins *et al.*, 1995). Moreover, these chemicals are toxic and costly. Problems of acaricide resistance, chemical residues in food and the environment and the unsuitability of tick resistant cattle for all production systems make the current situation unsatisfactory, especially on wild animals in *ex-situ conservancy* areas which is why there is debate on the development of an alternate and absolute control method such as vaccines.

A complex of problems related to ticks and tick-borne diseases of cattle created a demand for methods to control ticks and reduce losses of cattle (George *et al.*, 2004). Control of tick infestations and the transmission of animal diseases remain a challenge for the cattle and game ranch industry in tropical and subtropical areas of the world. Tick control is a priority for many countries in tropical and subtropical regions (Lodos *et al.*, 2000).

These losses can be cut considerably by adopting effective tick control measures in *ex-situ conservancies*. There are three major reasons for controlling ticks in animals: disease transmission, tick paralysis or toxicosis, and tick-caused physical damage. The main weapon for controlling ticks at present in game ranches is prescribed burning (Gleim, *et al.* 2014).

#### **2.4.1 Application of chemicals**

Various methods including dipping, land spraying, spraying, ear tagging or pour on, have been used to apply chemicals to protect livestock against ticks. Direct application of acaricides to animals is the most popular method of controlling ticks on livestock (Drummond, 1983). Applications of acaricide to tick-infested cattle via dipping or sprayer can be equally effective under ideal conditions with proper handling of equipment's without injuring animals and subsequent dilution of the product (George, 2000). Intensive

dipping proved extremely effective in the control of *Amblyomma hebraeum*, the main vector of heartwater. (Ndavambi, 2012). Tick control programmes normally target the accessible host (cattle), which cannot be possible for wild animals. This has its own challenges from drug selection to spraying and dipping techniques.

## **2.5 Non Acaricides Tick Control methods**

### **2.5.1 Effects of prescribed burning on tick diversity**

Globally, one of the most common non-acaricides methods for controlling ticks is prescribed burning in *ex-situ* and *in-situ conservancies* (Gleim *et al.* 2014). Most studies on the impact of prescribed burning on tick burden and abundance agree that there is an immediate decline in ticks following fire impact (Adams *et al.*, 2013). This could be caused by direct mortality when temperatures exceed 150-165°C for at least 15 seconds or because tick refugia within the field layer are reduced or eliminated (Polito *et al.* 2013). Importantly, Gleim *et al* (2014) did not observe temporary reductions in tick populations after prescribed fire but rather sustained reductions in tick abundance for a period of two years. The need to interrogate the impact of prescribed burning on tick populations was highlighted by Gleim *et al* (2014).

Captivatingly, another study by Klemmedson *et al* (2000) showed that the time for prescribed burning should ideally be planned to occur when the top layer of the vegetation floor is dry enough to burn and lower layers are still moist. This helps in maximizing the benefits of fire while minimizing its destructive ability to the environment. Change in vegetation composition caused by prescribed burning at a certain time of the year has the potential to decrease habitat viability of ticks; who depend on low light penetration and

high humidity by reducing leaf litter depth and clearing shrub layers that provide shading (Ginsberg and Stafford, 2005).

Interestingly, Gleim *et al* (2014) found that long-term prescribed burning significantly had reduced tick abundance and altered species composition. Though, very few studies have scrutinized whether fire could directly impact pathogens prevalence in-game areas (MacDonald, 2018). Despite some studies have indicated that habitat and ecological variables can affect pathogen's dynamics in-game areas (Manangan *et al*, 2007).

Grippingly, the study done by Nowacki and Abrams (2016) showed that long-term forest change is directly related to the ecophysiological factors of the species within them. The role each species fills changes through space and time-dependent on these factors. The primary objective of prescribed burning is usually to alter the vegetative characteristics of the environment without reducing the quality or quantity of the desirable ecological characteristics.

Few classic studies conducted in forested areas in Georgia, Florida, Pennsylvania, and South Carolina, revealed that long-term prescribed burning has a noteworthy impact in reducing tick counts than in unburned counterparts (Gleim *et al.*, 2019 and Hodo *et al.*, 2019). Large area burn reduces tick and host repopulation while repeated and consistent prescribed burn may deplete tick source populations for increased long-term results (Gleim *et al.*, 2014). Most of these reviewed studies on prescribed burning did not account for spatial and temporal variation in host abundance, microclimate, and vegetation structure as these are known to contribute to tick burden as much as any human actions. Long-term burning was found to reduce ticks by seventy-eight (78) percent (Gleim *et al.* 2014).

One study conducted in Southern Africa investigated the relationship between prescribed burning and grassland conservation in the area. This is typically undertaken to optimize available grazing by removing dominant rank grasses thereby allowing new growth of more palatable species (Hardy *et al.* 1999). This ecological system creates heterogeneity in space and time that is sometimes termed mosaic patch pyrodiversity (Andersen 2006). Anderson's study focused much on the importance of fire in maintaining grazing patterns in the area. The study did not scrutinize whether prescribed burning could directly reduce tick burden and diversity in *ex-situ conservancy*.

Allan (2009) suggested that modern prescribed burning in the environment could reduce tick burden in the ecosystem because of its various effects. This is true especially regarding to fires effect on ticks and their hosts. Any organism that spends part of its life cycle on the ground or in low vegetation is vulnerable to properly timed burns, including ticks (Blumler 2003). Fascinatingly, the study done by Padgett (2009) showed that prescribed burning can reduce the abundance of black-legged ticks, *Ixodes scapularis*, locally once practiced every year. In this study, the researcher concluded that the tick populations seem to rebound after one year.

The findings of the previous studies conducted in the past have largely been vague and inconclusive on the relationship between prescribed burning, tick diversity and distribution. Most sites for tick selection were only burnt once for experimental purposes, which are small in geographical size, while some areas were previously unburnt for a long period making it inappropriate for gauging the effectiveness of prescribed burning for tick management. Moreover, most studies focused much on forested areas with less attention on game areas with wetlands and floodplains. Generally, in the Zambian context, there is

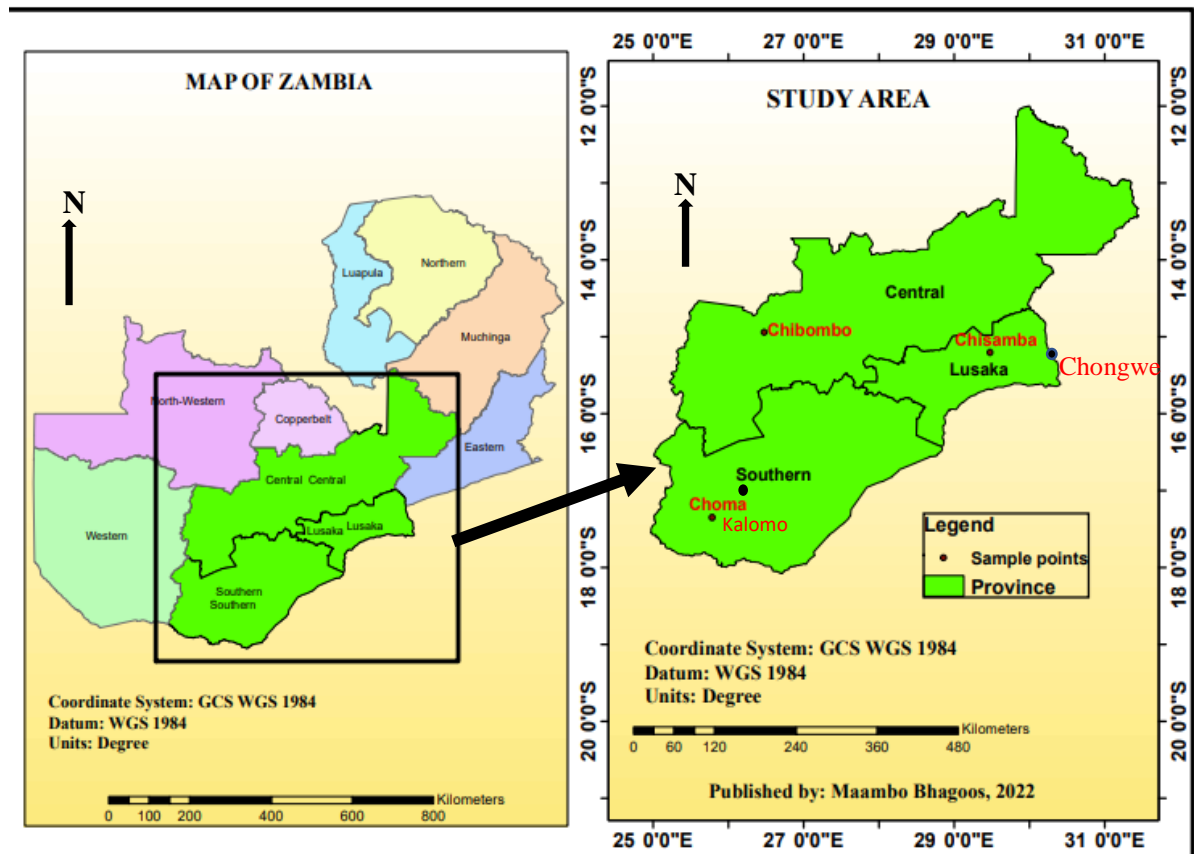
barely any scientific study on the impact of prescribed burning in determining tick diversity and burden in game ranches. This study thus, aimed at assessing the effective burning regime to control ticks in *ex-situ conservancies* the information obtained in this study has potential to inform game ranchers the suitable way of controlling ticks.

## CHAPTER THREE

### 3.0 MATERIALS AND METHODS

#### 3.1 Study Area

This study was conducted in three *ex-situ conservancy* reserves in Zambia. The first *ex-situ conservancy* is located in Chibombo district ( $28^{\circ}1446^{\circ}$  E,  $15^{\circ}0431$  S) it practices early burning from April to late May. The second one is located in Chongwe area ( $28.4987^{\circ}$ N,  $15.1549^{\circ}$ S) this does not practice any burning. The third *ex-situ conservancy* is located in Choma district Southern province ( $16.641471^{\circ}$  S,  $27.009580^{\circ}$ N) this *ex-situ conservancy* does late burning from October to November before rain season. The figure below shows all three study areas Chongwe, Chibombo, and Choma respectively.

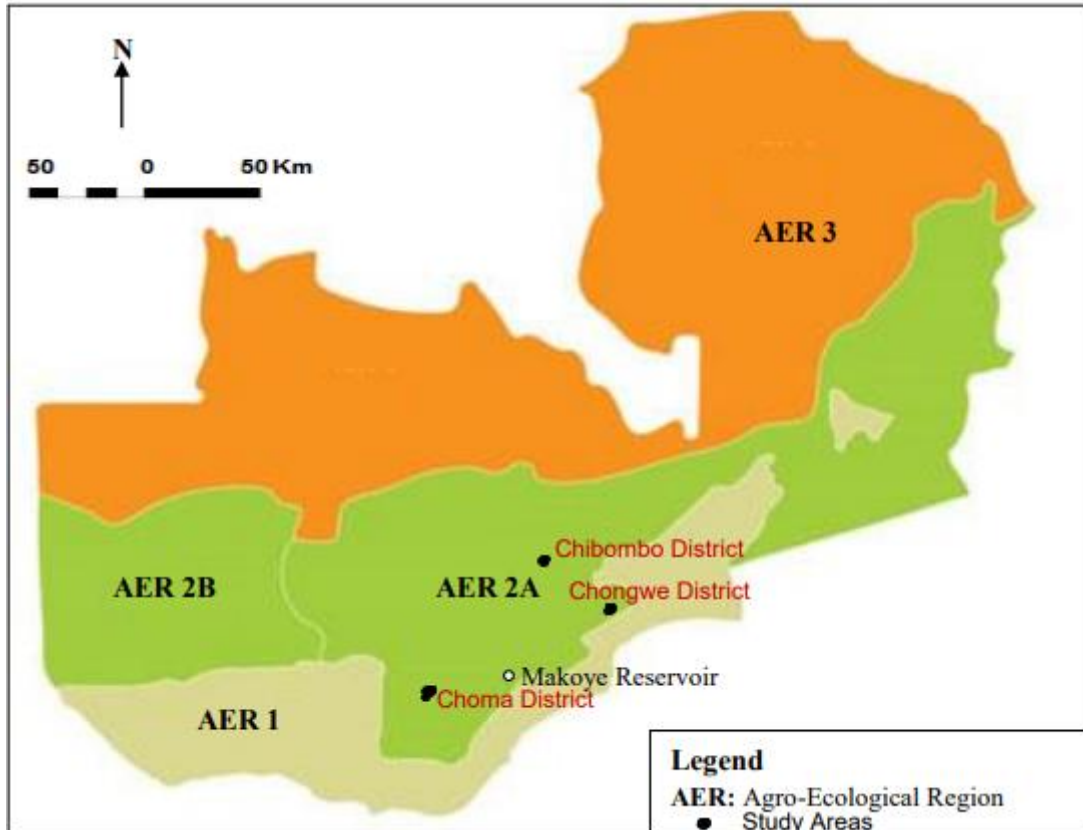


*Figure 3.1* geographical set up of all three study areas Chongwe, Chibombo and Choma (Source, Maambo, 2022).

### **3.2 Ecological Zoning and Climate**

Two ex-situ conservancy are located in agro ecological zone IIa, this zone has three main seasons namely, cool-dry from May to August, hot and dry from September to October and the hot-wet from November to April (Zambia Meteorological Department, 2020). The average midday maximum temperatures are generally high close to 31<sup>0</sup>C to 45<sup>0</sup> C in October especially in the southern fringes (ZMD, 2013). The average midday minimum temperatures in these districts oscillate between 4<sup>0</sup> C to 20<sup>0</sup> C in June (Zambia Meteorological Department, 2020).

The hot season in Chongwe last from September to November with an average daily temperature above 30<sup>0</sup> C. The hottest month in Chongwe (ranch A) is November with an average temperature of 30<sup>0</sup> C and low of 19<sup>0</sup>C. The cool season lasts for two months from May to August with an average daily high temperature below 24<sup>0</sup> C. The coldest month of the year in Chongwe is July with an average low of 9<sup>0</sup> C and high 23<sup>0</sup>C (Zambia Meteorological Department, 2020).



**Figure 3.2:** General location of study areas in Zambia Agro-Ecological Zones. Adopted from MTENR (2012)

### 3.2 Study Design

A cross-sectional descriptive study design was employed in this study, where all ticks samples were collected between October, 2021 and January 2022.

### 3.3 Vegetation Surveys

To justify the potential differences of vegetation's in selected private game reserves, vegetation surveys were performed in all mapped transects. In order to determine tree compactness, a singular point-centered quarter survey utilizing the equivalent of 10 points per transect was performed with a quarter being considered empty if there were no trees within 10 meters from the center point of the transect. Thus, these points were marked for

open woodland vegetation surveys. Open grassland vegetation and tree compactness closure was measured using ecological assessment index surveys (Daubenmire,1959).

### **3.4 Study Setting**

The study was done in three *ex-situ* conservancies in Central, Lusaka and Southern Province of Zambia. These three *ex-situ* conservancies with satisfactory tick samples were; in Chibombo ticks were collected in August, 2021, in Chongwe tick samples were collected in January 2022, lastly in Choma tick samples were collected in November 2021. All these *ex-situ conservancies* have mixed feeders, browsers and grazer type of animals.

### **3.5 Field Station Set-Up**

Different laboratory materials were used during tick sample collection in the field such as, white work surface for sorting ticks, the waste bucket was used for putting waste and papers. The falcone tube model 352099 were used to store (housing of engorged larvae, flat and engorged nymphs, flat adult ticks). The snap cap lid was used for storing ticks once collected. The one-meter rule, was used to measuring sort distances in mapped clusters; the scissors was used to cut a drag cloth. as a tool for collecting ticks. White tray was used to store collected ticks and falcon tubes in the field, the masking tape was used to capture and disposing of escaped ticks. Lastly the Global Positioning System (GPS) was used to mapping clusters/transects with coordinates for examination of spatial patterns.

### 3.6 Collection of Tick Samples

The tick samples were collected from three selected *ex-situ conservancies* areas, where 12 transects [50×50] were formed per ranch. These transects were formed in areas where wild animals congregate and graze from. Tick samples were collected directly by visiting the selected *ex-situ conservancies* and collecting samples from each mapped transect (cluster) unit. The primary dependent variable of tick density was collected by a drag cloth method in selected ecological zones in each private game reserve in which a 50×50 m<sup>2</sup> block transect were formulated in cluster.

As shown in the picture below a drag cloth method was used during tick sample collection, this method is an elegant tool for collecting questing ticks (Zimmerman and Garris, 1985). The figure below shows tick collection process picture (a) shows tick blanket swiping over grass and picture (b) ticks in falcon tubes.



Figure 3.3 Tick blanket during sample collection

The method was conducted by dragging a white flannel material over vegetation abutting trails in mapped clusters. (Cohnstaedt *et al*, 2012). In a distance of 20 meters, attached

ticks were picked using a forcep. At the edge of the transect the flannel was flipped over to reverse the side faces to the ground and flagging continued along the opposite side, yielding a total flagged area of 100 meters per transect (Cohnstaedt *et al.*, 2012).

Collected tick samples were put in falcon tubes with small holes on the lid to allow air to circulate. Freshly cut, green grass was placed in the falcon tube to keep the environment humid and to protect the ticks from damage during tick sorting, the engorged female ticks were separated and all eggs that were laid during sample collection were separated and stored separately.

The second tick collection method that was used during the survey involved the use of carbon dioxide (CO<sub>2</sub>) baited pitfall traps. This method was effective for the ticks that were active in the soil and leaf-litter especially the soft ticks, CO<sub>2</sub> trapping was conducted daily in each transect (Petersen *et al.*, 2015). Five white enamelware pans (18×29×5 cm) were buried at 20-meter intervals along mapped ecological zones so that they function as pitfall traps (Lane *et al.*, 1985). Five to 10 grams of dry ice were added to the center of each pan, elevated by two small wooden strips, during the warm part of the day (10:00 hours to 12:00 hours in grazing sites and 12:00 hours to 14:00 hours in animal resting sites). This method was to capture soft ticks.

### **3.7 Tick Identification**

Collected tick samples were classified and morphologically identified using existing Walker *et al.* 2014 taxonomic keys and Olympus DF Plapo 1×4 SN5G 08128 stereomicroscope. All tick species, sex, and instar were recorded for each specimen in parasitology laboratory (Bakkes, 2020). Detailed morphological keys for ticks and their

nymphal stages were documented. Photographs of adult ticks and nymph specimens were captured on Olympus DP72 stereomicroscope with an external Euromex EK-1 fiber optic light source and cellSens Standard version from *Bioevopeak* Japan. After identification ticks were stored in falcon tubes containing 70 percent ethanol where they are stored as tick banks.

### **3.8 Data Analysis**

Field data cleaning, editing, and coding was done with Microsoft Excel 2019. The Excel file was then imported into Stata 15.0 software to test each hypothesis. Using a Bartlett's test of equal variances to determine which management had more number of ticks. A - value less than 0.05 was considered to be statistically significant. Descriptive statistics were calculated for categories created for the hypothesis. Analysis of Variance (ANOVA) was used to compare tick means of each management tool. The correlation comparison of adult ticks was determined using the Bonferroni test. To determine the association between prescribed burning, tick burden and diversity the data was quantified for both variables. The association was then quantified by measuring the association using correlation coefficient in order to determine the strength of the relationship (Sylvia, 2004).

## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 Descriptive Results

##### 4.1.1 Major vegetation types by study area

The vegetation was assessed using ecological observation assessment in all three *ex-situ* conservancies, the following major vegetation types were identified, open grassland, miombo woodlands, sedge, *hyperrhenia sp*, munga woodland, termitaria, damboo and deciduous thicket. Table 4.1 below shows overall vegetation types by proportion in all three study areas combined (Chibombo, Chongwe and Choma).

**Table 4.1** Vegetation maintained by the given burning regime (*Number of transects with vegetation type*)

Vegetation type	Ranch A Chongwe No-burning	Ranch B Choma Late burning	Ranch C Chibombo Early burning
Open Grassland	1	2	1
Miombo woodlands	5	2	3
Sedges	2	0	1
<i>Hyperrheniah sp</i>	1	0	1
Munga Woodland	0	1	1
Termitaria	3	2	2
Dambo	4	1	1
Deciduous thickets	0	1	1
<b>Total no of vegetation type</b>	<b>16</b>	<b>9</b>	<b>11</b>

Table 4.2 below displays the quantity of vegetation type by proportions per study area in selected *ex-situ* conservancies.

**Table: 4.2** Overall major vegetation types in mapped transects in all study areas

<b>Vegetation Type</b>	<b>n (36)</b>	<b>Frequency (%)</b>	<b>95% CI</b>
1 Open Grassland	4	11	3-21
2 Miombo woodlands	10	27.8	12-43
3 Sedges	3	8	0-18
4 <i>Hyperphenia</i> sp	2	5.6	0-13
5 Munga Woodland	2	5.6	0-13
6 Termitaria	7	19	5.8-33
7 Dambo	6	16.7	3.8-27
8 Deciduous Thickets	2	5.6	0-13

Key: N=[number of transects] and CI= [Confidence Interval]

Of the major vegetation types determined, Miombo woodlands (*Combretum* and *Brachystegia* species of trees were abundant), accounted for 27.8%.

#### 4.2 Animal species in selected *ex-situ* conservancies

During tick sample collection animal species in selected *ex-situ* conservancies were recorded for the purpose of determining partial burden of ticks. Animal species from the three *ex-situ* conservancy were divided into three categories namely mixed feeders, browsers and grazers. Table 4.3 below shows the overall animal species common in all three selected *ex-situ* conservancies.

**Table 4.3:** Animal species in selected *ex-situ* conservancies

<b>Animal Species</b>	<b>Ranch A Chongwe No burning</b>	<b>Ranch B Choma Late burning</b>	<b>Ranch C Chibombo Early burning</b>
Mixed Feeders	-Elephants ( <i>Elephantidae</i> ) -Impalas ( <i>Aepyceros melampus</i> )	-Impalas( <i>Aepyceros melampus</i> )	-Impalas ( <i>Aepyceros melampus</i> )
Browsers	-Giraffes ( <i>Giraffa</i> )		-Goats ( <i>Capra aegagrus hircus</i> )

Grazer	<ul style="list-style-type: none"> <li>-Zebras (<i>Equus quagga</i>)</li> <li>-Buffaloes (<i>Bubalus bubalis</i>)</li> <li>-Kudu <i>Tragelaphus strepsiceros</i>)</li> <li>-Eland (<i>Taurotragusoryx</i>)</li> <li>-Sable Antelope (<i>Hippotragus niger</i>)</li> <li>-Waterbuck (<i>Kobus ellipsiprymnus</i>)</li> <li>-Impala (<i>Aepyceros melampus</i>)</li> <li>-Wildebeest (<i>Connochaetes</i>)</li> <li>-Warthogs (<i>Phacochoerus Africanus</i>)</li> <li>-Cattle (<i>Bos Taurus</i>)</li> <li>-Horses (<i>Equus caballus</i>)</li> <li>Tsessebe (<i>Damaliscus lunatus</i>)</li> </ul>	<ul style="list-style-type: none"> <li>-Zebras (<i>Equus quagga</i>)</li> <li>-Buffaloes (<i>Bubalus bubalis</i>)</li> <li>-Wildebeest (<i>Connochaetes</i>)</li> <li>-Warthogs (<i>Phacochoerus Africanus</i>)</li> <li>-Cattle (<i>Bos Taurus</i>)</li> <li>-Horses (<i>Equus caballus</i>)</li> <li>-Impala (<i>Aepyceros melampus</i>)</li> </ul>	<ul style="list-style-type: none"> <li>-Zebras (<i>Equus quagga</i>)</li> <li>-Buffaloes</li> <li>-Sebo</li> <li>-Wildebeest</li> <li>-Warthogs</li> <li>-Waterbuck (<i>Kobus ellipsiprymnus</i>)</li> <li>-Impala (<i>Aepyceros melampus</i>)</li> <li>-Tsessebe (<i>Damaliscus lunatus</i>)</li> <li>-Sable Antelope (<i>Hippotragus niger</i>)</li> </ul>

There were more grazers in all selected *ex-situ conservancies*. No burning regime had more number of grazers, such as Zebras (*Equus quagga*), Buffaloes (*Bubalus bubalis*), Kudu *Tragelaphus strepsiceros*), Eland (*Taurotragusoryx*), Sable Antelope (*Hippotragus niger*), Waterbuck (*Kobus ellipsiprymnus*), Impala (*Aepyceros melampus*), Wildebeest (*Connochaetes*), Warthogs (*Phacochoerus africanus*), and Cattle (*Bos taurus*).

#### 4.3 Overall tick samples across the three management systems

A total of 267 individual ticks were collected across the three tick management systems (Early, late and no-burning systems). A total of 256 ticks were collected using a tick blanket and 11 ticks were collected from carbon dioxide tick pans. Carbon dioxide traps captured several life stages of *Amblyomma variagatum* tick which is very active and is considered to be fast-moving while aggressively hunting for hosts. Table 4.4 below is shows the overall tick burden across the three management system.

**Table 4.4:** Total number of tick burden by management system

Tick Management System	Total number of Ticks ( <i>n</i> =267)	%	MSD
Late Burning	52	19.5%	44.8
Early Burning	22	8.2%	23.3
No Burning	193	72.3%	98.6

*Key: MSD=[Mean Standard Deviation]*

Results in table 4.4 indicates that high tick diversity and burden was in the area where the management system did not apply any burning control measures, as this accounted for 72.3% of the tick burden across the different management systems, this was followed by late burning with 19.5%, this management system had more number of ticks as compared to early because it is done in late November before the onset of rain season. Lastly, early burning had the lowest number of tick burden at only 8.2% of the total tick burden.

#### **4.2 Correlation comparison of adult ticks by location using Bonferroni correlates**

From the three tick management systems computed, the comparative significances are indicated in table 4.4 below.

**Table 4.5:** Correlation comparison of adult ticks by location using Bonferroni correlates

	Early Burning	Late Burning
Late Burning	-30 <i>P</i> = 0.776	
No Burning	141.167 <i>P</i> <0.001	171.167 <i>P</i> <0.001

Significant differences were seen between the early burning management system against no burning management system (*P* < 0.000). Significant differences were also seen between the late burning management system against the management system where no

burning was practiced ( $P < 0.001$ ). No significant differences were observed between early and late burning.

### 4.3 General tick species identification by proportions

In total, eleven (11) tick species were collected from 36 transects across all the three study areas in Chibombo tick samples were collected in August 2021, in Choma tick samples were collected in November 2021 and in Chongwe samples were collected in January 2021. Table 4.6 below shows the abundance of tick species across the three *ex-situ* conservancies by burning regime.

**Table 4.6:** Identified tick species diversity, abundance and burden by burning regime

Tick species	Ranch A Chongwe No-burning	Ranch B Choma Late burning	Ranch C Chibombo Early burning
<i>Rhipicephalus evertsi</i>	27	7	2
<i>Rhipicephalus B microplus</i>	38	14	4
<i>Amblyomma variagatum</i>	30	8	6
<i>Rhipicephalus pulcherus</i>	9	6	0
<i>Hyalomma marginatum rufipes</i>	23	4	1
<i>Hyalomma truncatum</i>	3	0	1
<i>Rhipicephalus appendiculatus</i>	18	5	2
<i>Rhipicephalus zambeziensis</i>	10	4	3
<i>Amblyomma pomposum</i>	8	0	2
<i>Rhipicephalus decoloratus</i>	19	4	1
<i>Rhipicephalus sanguineus</i>	8	0	0
<b>Total number of ticks</b>	<b>193</b>	<b>52</b>	<b>22</b>

Key, [NB=No burning, LB=Late burning, EB=Early burning]

There was more tick abundance in the no burn management system of about 193 ticks out of 267 collected ticks, this was followed by late burning management system with 52 tick samples and lastly early burning with 22 ticks.

Table 4.6 below shows the overall collected tick species across all the study areas by proportionate in early, late and no burning regime in selected *ex-situ* conservancies.

**Table 4.7:** Overall ticks collected in mapped transect

<b>Species</b>	<b>(n=36)</b>	<b>Percentage (%)</b>	<b>95% CI</b>
1 <i>Rhipicephalus evertsi</i>	7	19.4	5.8-33%
2 <i>Rhipicephalus B microplus</i>	1	2.8	0-8.4 %
3 <i>Amblyomma variagatum</i>	5	14	2-25
4 <i>Rhipicephalus pulcherus</i> (Zebra Tick)	3	8	0-17
5 <i>Hyalomma marginatum rufipe</i>	2	6	0-13
6 <i>Hyalomma truncatum</i>	4	11	0-21
7 <i>Rhipicephalus appendiculatus</i>	4	11	0-21
8 <i>Rhipicephalus zambeziensis</i>	3	8	0-17
9 <i>Amblyomma pomposum</i>	1	2.8	0-8.4
10 <i>Rhipicephalus decrolatus</i>	3	8	0-17
11 <i>Rhipicephalus sanguineus</i>	3	8	0-17

These species were: *R.b. microplus*, *R. evertsi*, *A. variagatum*, *R. pulcherus*, *H. rufipe*, *H. truncatum*, *R. appendiculatus*, *R. zambeziensis*, *A. pomposum*, *R. decoloratus* and *R. sanguineus*. Table 4.6 has indicated the proportion of overall abundance in three *ex-situ* conservancies where *Rhipicephalus evertsi*, representing 19.4% at 95% CI (5.8-33%),

*R.B. microplus*, representing 2.8% at 95%CI (0;8.4%) and *A. variagatum*, representing 14% at 95% CI (2-25%) these species accounted for the majority among those that were identified at the laboratory.

#### 4.5 Bartlett’s test for equal variances across the 36 transects

The Bartlett’s test for equal variance produced a chi-square of 19.7402 and a *p* value of *p*<0.001. This was an indication of a significant differences across and within transects in the three management systems as shown in table 4.7.

**Table 4.8:** Analysis of variance for Bartlett’s test for equal variances across the 36 [50×50] transects (12 from each management system)

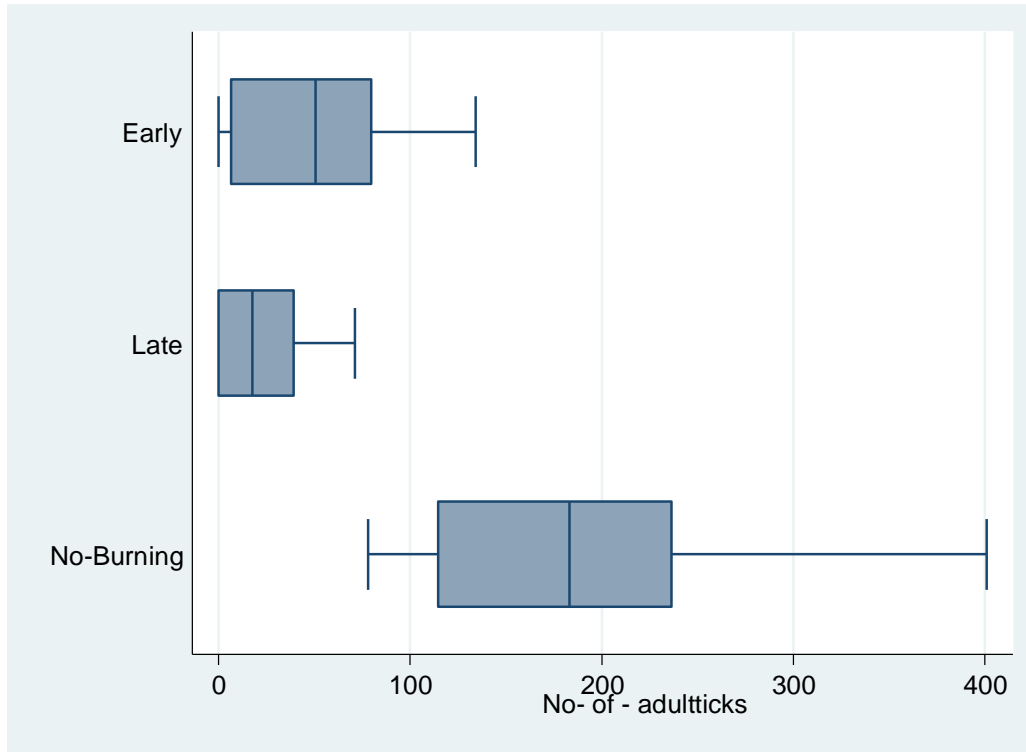
Sources	Sum of Square	Degrees of Freedom	Mean Square	F	<i>P</i> value
Between groups	200504.222	2	100252.111	24.52	<i>P</i> <.0001
Within groups	134923.417	33	4088.58838		
Total	335427.639	35	9583.64683		

*Bartlett’s test for equal variances:  $\chi^2=19.7402$  Prob>chi2=0.000*

#### 4.6 Tick burden determination across the three management systems

##### 4.6.1 Adult tick burden determination

The box whisker plot showed the significant difference of adult ticks in all three management system. The figure below shows the burden of adult ticks collected in 36 transects indicating variations between the three management systems, late burning, early burning and no burning.

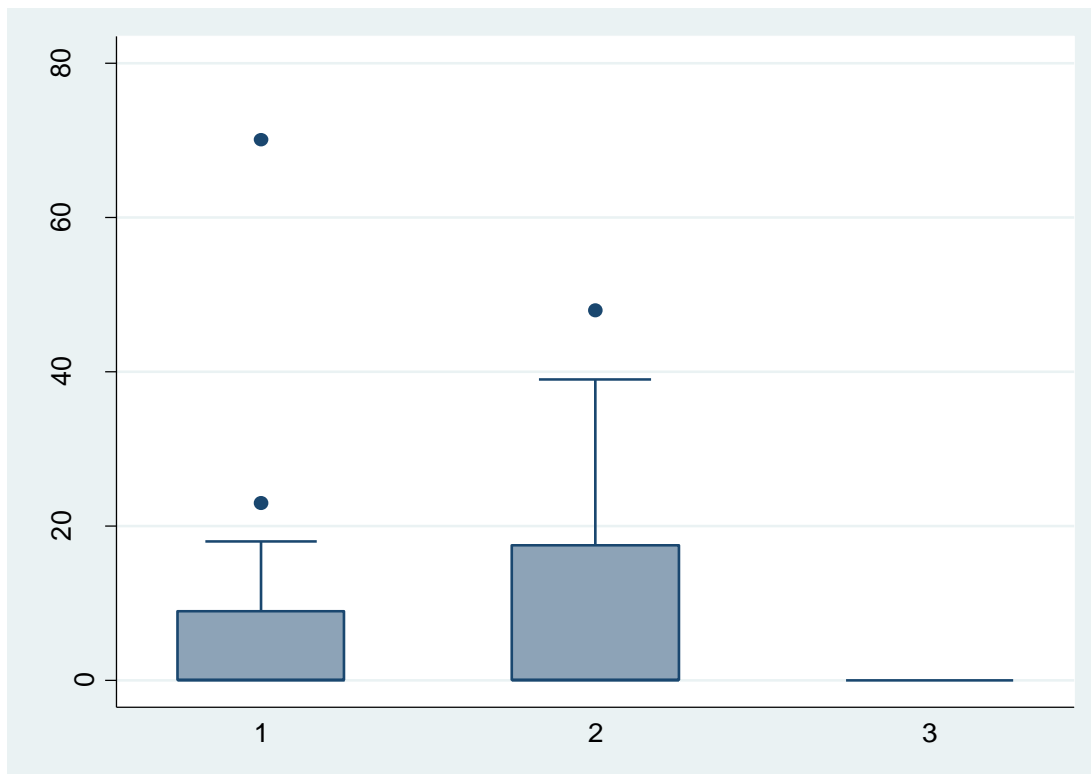


**Figure 4.1:** Tick burden by management system showing burden across the system for **adult ticks**

The heaviest burden observed was 195 ticks per transect in no-burning management system (fig 4.1). This was followed by early burning with a tick burden of (0-50 ticks per transect) at 95% CI and Late burning with a lower showed a lower burden at an average of 45 ticks at 95% CI (0-35 ticks per transect) (fig 4.1).

#### **4.6.2 Immature ticks burden determination**

The box whisker plot showed the significant difference of immature ticks in all three management system. The figure below showed the burden of immature ticks collected in 36 transects indicating a variance between the three management systems: Late burning, early burning and no burning.

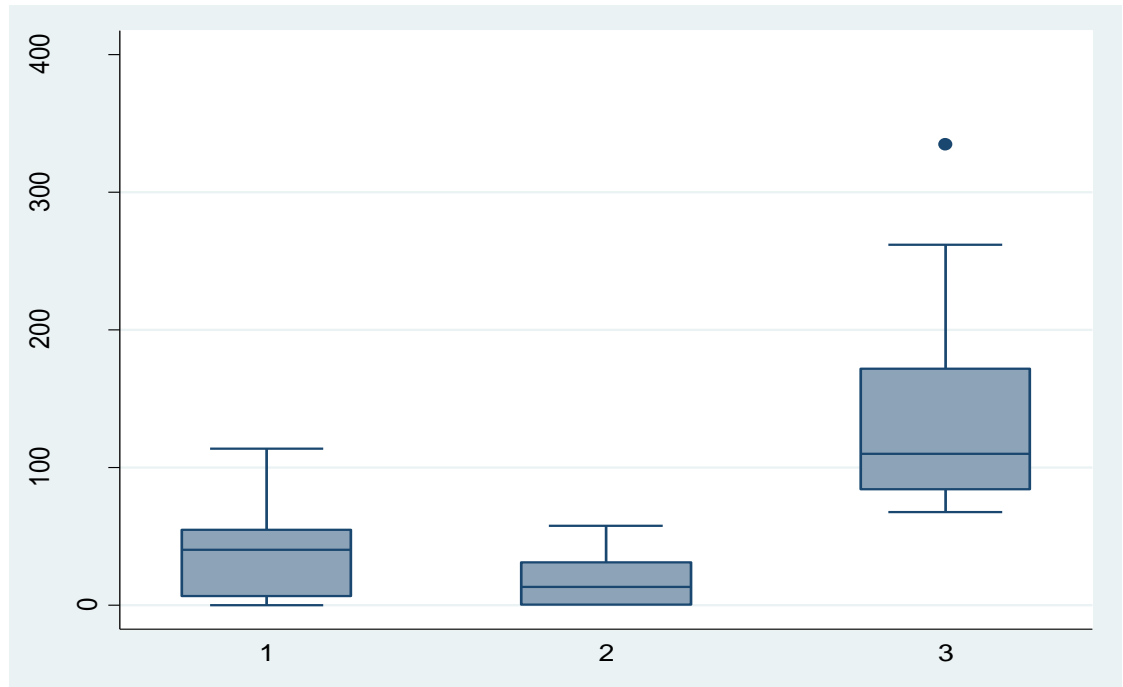


**Figure 4.2:** Tick burden by management system showing burden across the system for *immature ticks*\*[\*Note: 1 = Late Burning, 2= Early burning, 3= No burning]

The heaviest burden of immature ticks was observed in early burning management system (fig 4.2) This was followed by late burning with a tick burden of 10 at 95% CI (0 -18 immature ticks per transect). Negligible numbers of immature ticks were accounted for under the no - burning management system in all transects (fig 4.2).

#### 4.6.3 Female ticks burden determination

The box whisker plot showed the significant difference of female ticks in three management system. The figure below showed the burden of female ticks collected in 36 transects indicating a variance between the three management systems.

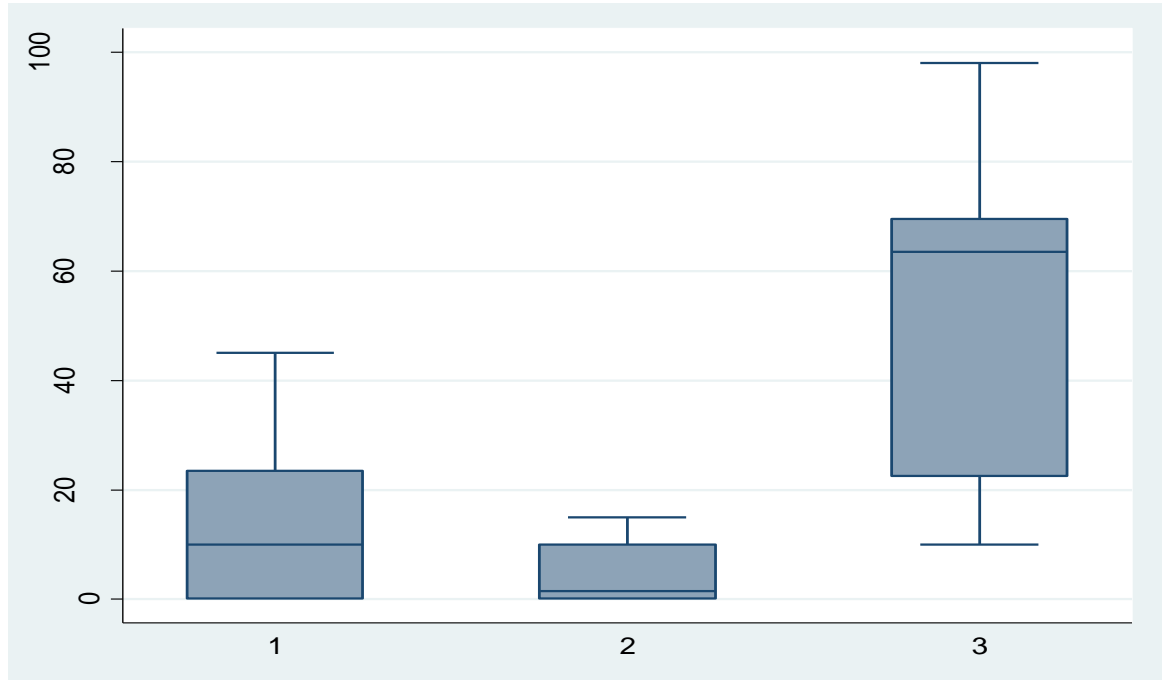


**Figure 4.3:** Tick burden by management system showing burden across the system for *female adult ticks* [\*Note: 1 = Late Burning, 2= Early burning, 3= No burning]

The heaviest burden of female ticks was in the range of 180 female ticks per transect in no-burning management system (fig 4.3). This was followed by late burning with a tick burden of 40 at 95% CI (0 -40 female ticks per transect) and early burning showed a lower burden at an average of 20 female ticks per transect at 95% CI (0 – 20 female ticks per transect) (fig 4.3).

#### 4.6.4 Male ticks burden determination

The box whisker plot showed the significant difference of male ticks in three management system. The figure below showed the burden of male ticks collected in 36 transects indicating a variance between the three management systems



**Figure 4.4:** Tick burden by management system showing burden across the system for male adult ticks\*[\*Note: 1 = Late Burning, 2= Early burning, 3= No burning]

The heaviest burden was observed in no-burning management system of about 75 male ticks per transect at 95% CI (20-75 male ticks per transect) (fig 4.4). This was followed by late burning with a tick burden of 21 at 95% CI (0 -20 male ticks per transect) and early burning showed a lower burden at an average of 12 ticks per transect at 95% CI (0-15 male ticks per transect) (fig 4.4).

## CHAPTER FIVE:

### DISCUSSION

Based on the thrust of this study, the study findings have been able to elucidate the burden and diversity of tick species across three different management systems with regards the use of fire as a tick control and management tool. From the results, *ex-situ* conservancies that do not practice any fire usage on their ranches had the highest burden of ticks and the widest range of species. In total 11 tick species were identified across the three management systems (late, early and no burning). These tick species were collected directly from mapped transects where wild animals graze from. The species determined under this present study were: *Rhipicephalus microplus*, *Rhipicephalus evertsi*, *Amblyomma variagatum*, *Rhipicephalus pulcherus*, *Hyalomma marginatum ruffipe*, *Hyalomma truncatum*, *Rhipicephalus appendiculatus*, *Rhipicephalus zambeziensis*, *Amblyomma pomposum* and *Rhipicephalus sanguineus*. *Amblyomma variagatum*, *Rhipicephalus microplus*, and *Rhipicephalus evertsi* accounted for the majority of tick species identified in this study.

The finding of these species in various ecological environments in selected *ex-situ conservation* areas has been reported elsewhere although these previous studies did not take into account the different management systems (Bazarusanga et al. 2007; Kalume et al. 2013; Sungirai et al. 2015). The richness of *Rhipicephalus* and *Amblyomma* tick species in continental Africa is reportedly high by (Guglielmone and Nava 2014), and this may in part explain the findings of these species being in greater numbers in our present study than any other tick species. Further, according to Walker et al. (2014), *Rhipicephalus appendiculatus* survives best in woodland and woodland savanna regions

with good vegetation cover. It tends to die out if overgrazing occurs and it does not survive on open plains, it was common in open grasslands (Walker and Bouattour, 2003). This tick specie is common in no-burning regime with more animal grazers like African buffalo (*Bubalus bubalis*), eland (*Taurotragusoryx*), male nyala, greater kudu (*Tragelaphus strepsiceros*) and sable antelope (*Hippotragus niger*). Walker *et al*, (2003) showed that this specie is widely distributed in southern, eastern and central Africa; the burden ranging from South Sudan to the northern parts of South Africa.

Similarly, *R. decoloratus* or African blue tick requires moisture and a warmth environment. This specie is widely distributed in most areas of Sub-Sahara Africa, typically within grasslands and wooded areas used as pasture for wildlife and cattle (Walker et al. 2014). The common host of this tick specie includes cattle as the main host of *Rh. (Bo.) decoloratus* but it also feeds on horses, donkeys, sheep, goats and wild ungulates. This tick specie was common in no burning management and early since these *ex-situ* conservancy keeps cattle, goats, horses and sheep. The suitable habitat and burden of *Rh. (Bo) decoloratus* occurs in regions with savanna and temperate climates, typically in grasslands and wooded areas used as cattle pasture (Walker, et al. 2014). Based on the result of this study this tick specie was common in no-burn management where more dambo and termitaria vegetation types was observed.

*Rhipicephalus microplus*, tick specie in Africa it has established in much of Southern and Eastern Africa and it is widespread in Madagascar. It is also known as Asian invasive tick and considered one of the most widespread ectoparasites of wildlife and livestock. *Rhipicephalus (Bo.) microplus* is a one-host tick with a monotropic type of behaviour. The time spent by the three stages on the host is about three weeks and egg laying can be

completed in about four weeks (Walker, et al 2014). The suitable habitat is in savanna climatic regions where there are habitats of wooded grassland used as cattle pasture. It has been suggested that *Rh. (Bo.) microplus* was introduced into East and South Africa from Madagascar, where it had originally arrived with cattle from south east Asia. Further north it occurs in parts of the eastern and central provinces of Zambia (Mulilo, 2008).

Based on the findings of this study *Rh. (Bo.) microplus* tick species was more in late burning management system in Choma and Chongwe districts, the common host of this species in two *ex-situ conservancies* includes domestic cattle (*Bos taurus*), impalas (*Aepyceros melampus*), eland, nyalas (*Tragelaphus angasii*) bushbuck (*Tragelaphus scriptus*), greater kudu (*Tragelaphus strepsiceros*) and also horses and zebras are hosts of *R. decoloratus* (Walker et al, 2014). *Rhipicephalus microplus* may be present in variable numbers throughout the year, the largest numbers of adult ticks were collected in November. Theoretically, only larvae of this one-host tick should quest for hosts from the vegetation, but male ticks were also collected from the vegetation, implying that they must have detached shortly before or after moulting and were now questing from the vegetation for a second host (Walker et al, 2003).

In this present study, tick abundance in *ex-situ conservancies* indicated variations in relation to the management systems namely late, early and no burning. The management systems that did not practice either early or late burning were found to have the heaviest burden of ticks. This present finding intimates that prescribed burning at certain times of the year has significant impact in reducing, as well as keeping the tick burden to a minimum level in the ecosystem. Despite the benefits of reducing tick burden through prescribed burning this practice has the potential of considerably altering both the abiotic

and biotic factors that govern tick survival and reproduction in the environment as well as affecting other micro and macro fauna and flora that are key for the functional balance of the ecosystem (Keeley *et al.* 2011, Simon and Pennington, 2012). The findings of significantly reduced tick burden in *ex-situ conservancies* that practice both early and late burning, are in strong agreement with, the findings of Gleim *et al* (2014) who did not observe temporary reductions in tick populations after prescribed burning but rather sustained reductions in tick abundance for a period of two years. However, our study was only cross sectional and not longitudinal for us to assess the period or length of time that it takes for the tick species to revert to their normal levels after burning.

Fascinatingly, there was no significant differences observed between early and late burning management systems in this present study. In post burn habitats, there are significant changes in vegetation cover, temperature and humidity regimes (Iverson and Hutchinson 2002), whereas the abundance and diversity of vertebrate tick-hosts also can be greatly affected (Fisher and Wilkinson 2005, Saab and Powell 2005).

Schulze and Jordan (2011), in their early studies showed that vegetation cover in grasslands or forests area is an ecological trait that has serious implications for the conditions of the forest floor, and usage of fire as a management system can seriously alter tick ecological determinants. These conditions are major determinants of microhabitat suitability and actual distributions of immature and adult ticks.

The results of immature tick burden indicated a significant deviation from what the adult ticks showed. What was observed in no-burning transects, was few to no immature ticks, as compared to higher burden of immature ticks in the burn areas, especially in early burning. This observation is difficult to describe in simple terms, however, factors that

disturb were sampling time, the microhabitat's stability and suitability for survival of immature ticks may be partly responsible as they are also a function of the ecosystem. The findings of more engorged females in the no-burning system, just before the rainy season, indicated the normal cycle of tick population and survival. This indicates the changes in tick cycle and survival that fire elicits on the different surviving tick species after burning of the pastures (Gleim *et al*, 2014).

Comparatively, early burning allowed faster regeneration of grass and shrubs compared to late burning. Accordingly, sections which were burnt early were found to hold significantly higher numbers of animals compared to the late burning whilst the no-burning showed an evenly distributed number of animals. This explanation is supported by high herbivore presence in no burn areas and by the positive correlation between herbivore presence and the number of adult ticks. This is congruent with studies by (Allan,2009) and (Adams et al. 2013) in the very different environment of North American woodland that suggests time taken for tick re-invasion of burned areas is around two years' post burning, hence our findings of low tick burden in either early or late burning management systems.

*Rhipicephalus Appendiculatus* (brown ear tick) was found to be abundant in woodland and sedge vegetation types in sampled *ex-situ conservancies*. This finding was in line with those of Walker et al (2014). In early burning management system this tick specie was common at land elevation of 3,590 and in no burning management system it was common at land elevation of 3,096. This study showed that *R. appendiculatus* survives best in woodland and woodland savanna regions with good vegetation cover and it was mostly determined in late burning management system as well as the no burning management

system. The common hosts of this tick specie includes cattle, goats, buffaloes, elands, waterbucks, nyalas, greater kudu and sable antelopes are the main hosts. Dogs and sheep are also infested. This tick has become well adapted to the presence of domestic cattle and can be maintained by all stages feeding on cattle. Immature ticks can feed on smaller antelopes and scrub hares; thus this tick species has a telotropic type of behaviour with a tendency to the monotropic type. The adults prefer to feed on the ear pinna but not in the ear canal (Walker et al, 2014). Based on the findings of this study this tick specie was common in all ex-situ conservancies with browser, mixed feeders, and grazers types of animals.

It is hypothesized that the saliva of *R. appendiculatus* contains a toxin and if large numbers of ticks infest an animal this toxin can interfere with the immune processes of the host resulting in a loss of condition and outbreaks of babesiosis, anaplasmosis and heartwater in animals that were previously immune to these diseases (Balinandi, *et al* 2020). These results are similar with the findings of Trip (2017) this study found that higher densities of shrub layers stabilize temperature and increase humidity by limiting airflow between forest strata, as well as reducing predation on ticks. The major vegetation types in sampled areas was mostly Miombo woodland especially in no burning regime (*combretum* and *brachystegia* species). All study areas also had termitaria vegetation types as well as dambo vegetation type represented, indicating little or no ecological set up differences.

However, this study was limited in scope it was a cross-sectional study where samples were collected from August 2021 to January 2022. Thus, limiting the studies bioclimatic factors across seasons and also determining the re-invasion as well as the lag phase from burning

to full recovery of tick populations in these selected *ex-situ conservancies*. Nevertheless, this study has demonstrated the high burden and abundance of multiple tick species across *ex-situ conservancies*. Early burning management system was found to reduce the tick burden. Based on the findings of this study, operational prescribed burning in *ex-situ conservancies* ecosystems significantly reduces tick populations which supports several previous studies (Cully, 1999). A number of previous studies showed that although burning causes tick mortality, they recolonized the area within a few years (Willis,2012). It was further, observed that early burning from April to May before cold season has an impact of reducing ticks. Further, vegetation and microclimate are ultimately responsible for the long-term reductions in tick populations as observed in this study, land elevation was also seen to have an effect on the abundance of tick species in *ex-situ conservancies*. These findings illustrate another benefit of prescribed in managing ticks in *ex-situ conservancies* and have important implications for public health as it is a time efficient, cost effective method for reducing tick populations in game ranches

## CHAPTER SIX

### CONCLUSION AND RECOMENDATIONS

#### 6.0 CONCLUSION

These findings of this study have exciting implications for ecological public health as it was observed that prescribed burning management, when performed on a regular basis (heedlessly of burn regime), significantly reduces tick burden and diversity in game ranches. The first objective Of this study aimed at assessing tick diversity in *ex-situ* conservancies with and without prescribed burning. There was a tick reduction in early burning management system as compared to other management systems in line with the findings of this study.

Based on the findings of this study, operational prescribed burning in *ex-situ conservancies* ecosystems significantly reduces tick burden which supports several previous studies (Cully, 1999). A number of previous studies showed that although burning causes tick mortality, they recolonized the area within a few years (Willis,2012). It was observed that early burning from April to May before cold season has an impact of reducing ticks. Further, vegetation and microclimate are ultimately responsible for the long-term reductions in tick populations as observed in this study, land elevation was also seen to have an effect on the abundance of tick species in *ex-situ conservancies*. These findings illustrate another benefit of prescribed in managing ticks in *ex-situ conservancies* and have important implications for public health as it is a time efficient, cost effective method for reducing tick populations in game ranches.

## 6.1 RECOMMENDATION

The following are the recommendations from this study:

- i. Based on the empirical evidence elucidated from this study, early burning management system is recommended as an effective tool to control tick burden in *ex-situ* conservancy.
- ii. There is need for a detailed longitudinal study to monitor the lag phase, re-invasion as well as tick burden and abundance on a large scale in both *in-situ* and *ex-situ* conservancies.
- iii. Future studies on prescribed burning as a tick management system should include analyses of individual tick species to account for species-specific seasonality and effects of prescribed burning since some species uses soil refugia to escape fire.

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**APPEDIX 1: FIELD DATA ENTRY FORMS**

**TICK FIELD SURVEY DATA ENTRY FORM 2021-2022 FIELD INDENTIFICATION FORM**

**AREA OF SAMPLING .....**

<b>S/N</b>	<b>Location</b>	<b>Terrain</b>	<b>Elevation</b>	<b>GPS Waypoint</b>	<b>Vegetation</b>	<b>Day</b>	<b>Month</b>	<b>Year</b>	<b>Immature (IMM) Ticks</b>	<b>Adults- Ticks</b>	<b>F</b>	<b>M</b>	<b>Preliminary Identification</b>

## APPEDIX 2: APPROVAL OF RESEARCH PROPOSAL



**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF VETERINARY MEDICINE  
OFFICE OF THE ASSISTANT DEAN (POSTGRADUATE)**

Telephone: 293727  
Telegrams: UNZA LUSAKA  
Telex: UNZALU ZA 44370  
Fax: 293727/253952  
School Fax: 293727  
Vet. Clinic Telephone: 291515

P.O. Box 32379  
Lusaka, Zambia

Your Ref.

Our Ref.

24<sup>th</sup> September, 2021

Maambo Bhagoos  
Department of Disease Control  
School of Veterinary Medicine  
University of Zambia  
P.O. Box 32379  
**LUSAKA**

Dear Maambo Bhagoos,

**RE: APPROVAL OF RESEARCH PROPOSAL**

At the meeting of the School Board of Graduate Studies held on 24<sup>th</sup> September 2021, your research proposal entitled '**Comparative determination of tick burden, diversity and distribution in intensively managed wildlife estates under those with and without prescribed burning**' was tabled and discussed. I am therefore pleased to inform you that the research proposal was subsequently approved by the Board.

On behalf of the Board, I wish you success as you apply for ethical approval and carry on with you research activities.

Yours sincerely

Dr Chisoni Mumba

**ACTING ASSISTANT DEAN (PG), SCHOOL OF VETERINARY MEDICINE**

Cc     Director, DRGS  
       Dean, School of Veterinary Medicine  
       Head, Disease Control  
       File

**APPEDIX 3: RESEARCH ETHICAL APPROVAL**



Plot No. 272, Cit Olive Tree Menwood Road,  
 Menwood llex  
 Lusaka - Zamb  
 Tel: +260 955 155 633  
 +260 955 155 634  
 Call +260 977 493 720  
 Email: eresconverge@yahoo.co.uk  
 I.R.B. No. 00005948  
 F.W.A. No. 00011697

27<sup>th</sup> April, 2022.

**Ref. No. 2022-April -001**

The Principal Investigator  
 Mr. Maambo Bhagoos  
 C/O The University of Zambia  
 School of Veterinary Medicine  
 Department of Disease control  
 P.O. Box 32379  
 Lusaka

Dear Mr. Bhagoos

**RE: COMPARATIVE DETERMINATION OF TICK BURDEN DIVERSITY AND DISTRIBUTION IN INTENSIVELY MANAGED WILDLIFE ESTATES UNDER THOSE WITH AND PRESCRIBED BURNING.**

Reference is made to your protocol submission. The IRB resolved to approve this study and your participation as Principal Investigator for a period of one year.

Review Type	Ordinary	Approval No. <b>2022-April-001</b>
Approval and Expiry Date	Approval Date: 27 <sup>th</sup> April,2022	Expiry Date: 26 <sup>th</sup> April, 2023
Protocol Version and Date	Version - Nil.	26 <sup>th</sup> April, 2023
Information Sheet, Consent Forms and Dates	<ul style="list-style-type: none"> <li>English.</li> </ul>	26 <sup>th</sup> April, 2023
Consent form ID and Date	Version - Nil	26 <sup>th</sup> April, 2023
Recruitment Materials	Nil	26 <sup>th</sup> April, 2023
Other Study Documents	Data Collection Sheet, Focus Group Discussion.	26 <sup>th</sup> April, 2023
Number of participants approved for study	-	26 <sup>th</sup> April, 2023

Specific conditions will apply to this approval. As Principal Investigator it is your responsibility to ensure that the contents of this letter are adhered to. If these are not adhered to, the approval may be suspended. Should the study be suspended, study sponsors and other regulatory authorities will be informed.

### **Conditions of Approval**

- No participant may be involved in any study procedure prior to the study approval or after the expiration date.
- All unanticipated or Serious Adverse Events (SAEs) must be reported to the IRB within 5 days.
- All protocol modifications must be IRB approved prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address.
- All protocol deviations must be reported to the IRB within 5 working days.
- All recruitment materials must be approved by the IRB prior to being used.
- Principal investigators are responsible for initiating Continuing Review proceedings. Documents must be received by the IRB at least 30 days before the expiry date. This is for the purpose of facilitating the review process. Any documents received less than 30 days before expiry will be labelled "late submissions" and will incur a penalty.
- Every 6 (six) months a progress report form supplied by ERES IRB must be filled in and submitted to us.
- A reprint of this letter shall be done at a fee.

Should you have any questions regarding anything indicated in this letter, please do not hesitate to get in touch with us at the above indicated address.

On behalf of ERES Converge IRB, we would like to wish you all the success as you carry out your study.

Yours faithfully,  
**ERES CONVERGE IRB**



Dr. Jason Mwanza  
Dip. Clin. Med. Sc., BA., M.Sc., PhD  
**CHAIRPERSON**

## APPEDIX 4: DATA COLLECTION INTRODUCTORY LETTER



### THE UNIVERSITY OF ZAMBIA SCHOOL OF VETERINARY MEDICINE

Telephone: 293727 Telegrams:  
UNZA LUSAKA Telex: UNZALU  
ZA 44370 Fax: 293727/253952  
School Fax: 293727  
Vet. Clinic Telephone: 291515

P. O. Box 32379  
Lusaka, Zambia

Your Ref:

Our Ref:

November 1<sup>st</sup>, 2021

The Manager,  
Bruce Miller Farm,  
CHOMA, ZAMBIA.

Dear Sir/Madam,

**RE: INTRODUCTORY LETTER: BHAGOOS MAAMBO (MSc Student) – Ecological Public Health**

Reference is made to the above captioned matter.

Mr. Bhagoos Maambo is a first year student at the University of Zambia, School of Veterinary Medicine pursuing an MSc in Ecological Public Health. As part of the requirement towards the fulfilment for the qualification of this MSc degree program, every student is required to undertake a research project relevant to their thematic area of study. Bhagoos' research topic is titled: "*Comparative determination of tick burden, distribution and diversity in intensively managed Game ranches in Zambia, those with and without prescribed burning.*" Your Farm was randomly selected to be part of the study site given its excellent record of one of the forefront runner well managed game ranches in Zambia. Accordingly, we are seeking your authority to allow our student to undertake the above stated research for at least or day or so at your ranch.

Your consideration and guidance in this aspect is highly appreciated.

Yours sincerely

Prof. Musso Munyeme  
**SUPERVISOR**