

**Sokoine University of Agriculture**



**MSc Dissertation**

**Assessment of Wildlife Road Kills  
Along Urbanization Gradient in  
Morogoro Municipality, Tanzania**

**Heavenlight Livingstone Mariki**

**May 2024**

**ASSESSMENT OF WILDLIFE ROAD KILLS ALONG  
URBANIZATION GRADIENT IN MOROGORO MUNICIPALITY**

*This dissertation is submitted to Sokoine University of  
Agriculture in fulfillment of the requirements for the Master  
Degree of Science in Forestry*

*By*

**Heavenlight Livingstone Mariki**

**Supervisors**

**Dr. Robert M. Byamungu  
Prof. Alfian A. Rija**

**Department of Ecosystems and Conservation  
College of Forestry, Wildlife and Tourism  
Sokoine University of Agriculture, Morogoro, Tanzania**

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## EXTENDED ABSTRACT

Roads can adversely affect wildlife in two main ways: indirectly, by destroying or dividing their habitats, and directly, by influencing animal collisions with vehicles. There is insufficient of studies regarding wildlife road killing in urban areas, particularly in Morogoro municipal. In order to assess the extent and context of road kill among urban wildlife. The study examined (i) how wildlife road kill composition changes across the urban zones and how road features impact the occurrence of road kills within the municipality. (ii) Assessing conservation awareness among drivers on wild animal kills incidences. Systematic counts of all road kills was conducted along five roads transects cutting across the urbanization gradient in the study area from November to May 2024. Further, questionnaires were administered to drivers within Morogoro municipal to understand the experiences and knowledge on wild animals.

A descriptive analysis was employed to show kill abundance across the urbanization zones. Analysis of Variance (ANOVA) was used to compare roadkills between urban zones and within animal taxa respectively. The results showed that, insects had the highest kill abundance and birds had the lowest. There was no significance difference in the overall abundance of road kills between the urban zones. Nevertheless, there was a notable variation in taxa abundance across the urban zones. Speed and animal taxa had a significant positive influence on the number of road kills.

Binomial GLM modeling was employed descriptive analysis supported with to understand the factors the mostly influence the perceptions and conservation awareness on the wildlife and animal road kills in urban landscapes. The results revealed that animal collisions occurring outside urban areas (55%) were the most prevalent form of accidents, with mammals being the primary affected group (35.7%). Further, outside of urban areas, the statistical model revealed that the likelihood of animal collision on

the road increased as driving hours decreased, whereas inside urban areas, the likelihood of animal collisions increased as driving hours increased.

Overall, this study emphasizes the substantial impact of road kills on diverse taxa(classes) and identifies key contributors to these incidents. Three major environmental concerns emerge: the threat posed to urban ecosystem functioning by the significant number of animals killed on roads, including crucial pollinators and seed dispersers like fruit bats and insects; the negative impact of designated road over-speeding on wildlife and the lack of conservation status data for a large proportion of road kills, particularly among insects, underscoring the need for increased efforts in investigating invertebrates(insects) biodiversity in urban landscapes.

.

## IKISIRI KUU

Utafiti huo ulilenga kutathmini vifo vya wanyama barabarani katika maeneo ya mijini, hususan Manispaa ya Morogoro. Uchunguzi ulijumuisha kufahamu jinsi muktadha wa vifo hivyo unavyobadilika kati ya maeneo ya mijini na jinsi vipengele vya barabara vinavyoathiri ajali hizo. Pia, madereva ndani ya Manispaa ya Morogoro walipimwa ufahamu wao kuhusu uhifadhi wa wanyama pori. Hesabu za vifo vya wanyama barabarani zilifanywa kwenye barabara tano kuu zinazopita mijini kuanzia Novemba hadi Mei 2024.

Matokeo yalionyesha kuwa wadudu ndio walioadhiwa zaidi na vifo vya barabarani kuliko ndege. Tofauti kubwa ya vifo vya wanyama ilionekana katika maeneo ya pembezoni ya miji kuliko maeneo ya mijini. Kasi ya uwendeshaji magari ilionyesha ushawishi mkubwa wakuongezeka kwa idadi ya vifo vya wanyama barabarani. Pia, Matokeo yalionyesha kuwa ajali za wanyama nje ya maeneo ya mijini (55%), mamalia wakiongoza kati ya makundi yaliyoathiriwa (35.7%). Kasi kubwa iligunduliwa kuwa sababu kuu ya ajali hizi. Masaa ya kuendesha na aina za magari ziliathiri hatari ya ajali na wanyama nje ya maeneo ya mijini. Washiriki waliripoti kupungua kwa ajali za wanyama wanapotumia magari binafsi nje ya miji, lakini kuongezeka wanapotumia magari binafsi ndani ya miji. Zaidi ya hayo, wengi wa madereva (57%) walionyesha nia ya kushiriki katika programu za elimu.

Utafiti unasisitiza athari kubwa ya vifo vya wanyama kwenye makundi mbalimbali ya wanyama na kubainisha wachangiaji muhimu wa matukio haya. Masuala matatu muhimu ya mazingira yanajitokeza: tishio kwa mifumo ya ikolojia ya mijini kutokana na kundi kubwa ya wanyama wanaouawa barabarani, ikiwa ni pamoja na wachavushaji muhimu wa maua na wanaosambaza mbegu kama popo na wadudu.

## DECLARATION

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

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Heavenlight L. Mariki  
(MSc. Candidate)

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Date

The above is confirmed by;

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Dr. Robert M. Byamungu  
(Supervisor)

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Date

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Prof. Alfani A. Rija  
(Supervisor)

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Date

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## **DEDICATION**

I would like to dedicate this work to my lovely family, Mr. and Mrs. Livingstone Mariki and siblings Jackson, Godlove and Johnson Mariki. Your consistent support and motivation have served as my enduring drive during this venture. I appreciate you for being the foundation of my resilience and inspiration.

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## CHAPTER ONE

### 1.0 GENERAL INTRODUCTION

#### 1.1 Background Information

Wildlife roadkill, as defined by Williams *et al.* (2019), occurs when animals are fatally impacted by collisions with vehicles. This phenomenon is often a result of wildlife using road borders, and it is exacerbated when vehicles fail to anticipate wildlife movements (Muluaem, 2016). The presence of roads has diverse ecological repercussions on terrestrial ecosystems, a trend that is increasing in continental areas (Forman *et al.*, 2003). Recognizing the adverse impacts of roads on wildlife is crucial for enhancing current management strategies and mitigating the detrimental effects of roadways on biodiversity, as emphasized by Lyamuya *et al.* (2021). Despite the acknowledged economic benefits of roads, their negative consequences are frequently overlooked (Crane *et al.*, 2010).

Roads have detrimental effects on wildlife populations both during construction and in the post-construction phases (van der Grift *et al.*, 2013). The impacts encompass habitat fragmentation, the introduction of invasive species, and alterations in animal behavior, occurring during and after the construction process (Mantyka-Pringle *et al.*, 2012). Acting as barriers, roads hinder animal movements, substantially diminishing population connectivity and gene flow, leading to increased inbreeding and a loss of genetic diversity, ultimately contributing to extinctions (Crispo *et al.*, 2011; Delibes *et al.*, 2001). Furthermore, roads play a role in vehicle-wildlife collisions, a significant threat to wildlife survival and traffic safety globally, with the United States alone estimating an annual range of 725,000 to 1.5 million wildlife vehicle collisions (Van Der Ree *et al.*, 2011; Huijser *et al.*, 2007).

Moreover, roads are regarded as independent variables with potential direct and indirect consequences on both vertebrate and

invertebrate animals. Instances of injury or fatality resulting from physical encounters with vehicles are categorized as direct effects (Jochimsen *et al.*, 2004). Among the most conspicuous impacts of roads on wildlife is the direct mortality of individuals due to collisions with vehicles (Abra *et al.*, 2019), particularly affecting reptiles and amphibians. This susceptibility arises from their high adaptability, enabling them to inhabit various environments, including roadside habitats with remnant vegetation (Pickett *et al.*, 2011). In Africa, the likelihood of road kills increases in regions surrounded by dense vegetation, as noted (Kioko *et al.*, 2015). Highways, cutting through the natural habitats of species, disrupt their regular range of movement, leading to collisions (Bager and Rosa (2010). The factors contributing to animal road kills vary significantly among species and taxa (Santos *et al.*, 2011). Understanding and explaining the spatial patterns of road-kill aggregations are crucial for comprehending the significance of these causes and processes (D'Amico *et al.*, 2015).

In addition, the attraction of raptors and scavengers to roadkill carcasses tends to rise in areas with diverse habitats and nearby land uses, implying that landscape spatial patterns significantly influence the risk of new collisions, creating an ongoing cycle of biodiversity impact (Schaub, 2012). Specific behaviors of certain species and taxa, such as snakes and other ectotherms basking along roadsides, can also heighten the risk of road kills (Christian, 2017). Additionally, at night, some animals may become immobile when exposed to bright artificial lights, as (McBride, 2017). Ecological factors like dense vegetation attract herbivores for feeding purposes, while biophysical factors, including road type and vehicle attributes, contribute to collision (Collinson *et al.*, 2019).

Number of road kill incidences are increasingly reported in the Northern part of Tanzania (Kioko, Kiffner, Phillips *et al.*, 2015). Most of the road kill (77.3%) were observed on road side adjacent to Protected Areas in Manyara ranch and Lake Manyara National Park

(Kioko *et al.*, 2015). In Serengeti ecosystem–Northern Tanzania, a total of 51 wildlife road kills were observed consisting of 26% species including 18% birds and 8% mammal species (Lyamuya *et al.*, 2021). In Tarangire – Manyara ecosystem, a total of 161 wildlife road kills incidences were noted consisting of 60 species, including birds 49%, mammals 23%, reptiles 18% and amphibians 9% (Kioko *et al.*, 2015).

Within the Morogoro region of Tanzania, the Tanzania–Zambia highway traverses through Mikumi National Park, resulting in the reported death of 183 animals due to vehicle collisions. These incidents involved 52 different species, including two endangered species: the African elephant (*Loxodonta Africana*) and the African hunting dog (*Lycaon pictus*), as documented by Drews (1995).

This study focused on the patterns and composition of wildlife road kills between urban zones and perceptions and knowledge of driver on wildlife vehicle collisions in urban landscape. The information generated will be of great use to the management of wildlife in urban area of the different part of the county. To support efforts of mitigating road impacts at all levels of species organization, management needs to be able to identify where particular wildlife communities (both vertebrates and invertebrates) are susceptible to high road-kill rates along the road gradients of Morogoro Municipality.

## **1.2 Problem Statement**

In Tanzania, Studies have been conducted on incidences, magnitude and pattern on wildlife mortality in various areas. For instance, a study conducted in Serengeti-Manyara ecosystem have shown that the major factors affecting road kills are road conditions and time whereby good roads have spotted more kills and morning time also has more kills than afternoon (Lyamuya *et al.*, 2021). Moreover, urban areas in Karatu showed that night kills are higher than day kills and major roads have significance effects on pattern of

road kills (Kioko *et al.*, 2015). Despite the fact that road kills is one among the threat in wildlife survival, and are most common reported in different protected areas. There is insufficient information that has been documented on wildlife roadkill in urban areas especially Morogoro municipal, this result to local extinction of some species and fragmentation will results to HWC. The missing essential information is important to lessen the effects of highways on animals in the urban environment of Morogoro Municipal Council.

### **1.2.1 Justification of the Problem**

Morogoro is surrounded by different protected areas such as forest reserves and national parks; therefore we expect to see movement of animals within the city settings. This will later results to wildlife vehicle collision. Therefore the findings from this study will be useful in urban planning, managing and save urban wildlife population.

## **1.3 Objectives**

### **1.3.1 General objective**

Determining the Patterns of wildlife roads kills in relation to landscape mosaic in Morogoro Municipality.

### **1.3.2 Specific objectives**

- i. To assess species composition and species richness of wildlife killed along the roads.
- ii. To assess spatial distribution of wildlife kills along the roads.
- iii. To assess conservation awareness among driver on wildlife collision on roads.

## **1.4 Limitations of the Study**

Limited Resources: Due to time and money constraints, our study couldn't cover everything. To get a better understanding of how roadkill affects different animals, we'd need more time and funding. Some animals remain unidentified because it's expensive to do DNA tests for their identification.

### **1.5 Dissertation Structure**

This dissertation is consist of five chapters with two manuscript publishable chapters. The first chapter provides an introduction of the study, including background information, the problem statement, study objectives and limitations of the study. Chapter two assesses how wildlife road kill composition changes across the urban-rural gradients in Morogoro municipality. Chapter three results presents drivers reasons for drivers involvement in animal collision. Chapter four is the general discussion of the study finding and chapter five provides summary on conclusions and recommendations.

**CHAPTER TWO****MANUSCRIPT I****Pattern and composition of wildlife road kill across urban-rural gradient in an African expanding city<sup>1</sup>**

Heavenlight L. Mariki<sup>1\*</sup>, Stella T. Kessy<sup>2,3</sup>, Robert M. Byamungu<sup>2</sup>,  
Alfan A. Rija<sup>2</sup>

<sup>1</sup>Department of Ecosystem Science and Conservation; College of Forestry, Wildlife and Tourism, Sokoine University of Agriculture, Morogoro, Tanzania

<sup>2</sup>Department of Wildlife Management, Sokoine University of Agriculture, P. O. Box 3073, CHUO KIKUU, Morogoro, Tanzania

<sup>3</sup>School of Life Science and Bio-Engineering (LiSBE), Nelson Mandela African Institution of Science and Technology, P. O. Box 447, Arusha, Tanzania

**\*Correspondence:marikiheavenlight886@gmail.com**

**Abstract**

Urban roads have been widely recognized as having a significant impact on wildlife fauna. However, most of the research conducted on the effects of roads has been focused on cities. Unfortunately, there are few comparable studies that investigate the patterns of road kill in rapidly expanding cities. This gap precludes the ability of the city management authorities in designing the appropriate mitigation and conservation measures especially during this era where the road networks in African cities is expanding steadily. We surveyed 48 km of roads pattern transcending an urban-rural gradient in Morogoro city, Tanzania. To understand on the pattern, composition and ecological, environmental factors mostly influence

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<sup>1</sup> Status: The materials contained in this manuscript has been submitted to European Journal of Wildlife Research

road kill abundance of wildlife road kill. We analysed the data using descriptive analysis, analysis of variance and generalized linear modeling respectively. We also assessed the conservation status of the road kills to propose measures to improve biodiversity conservation in this urban landscape bordering a global biodiversity hotspot. We found 930 killed animals belonging to 62 families and 23 orders and 5 classes with the majority kills being insects. Further, there was no significant difference in the kill abundance across the urbanization gradient on a pooled kill data neither was differences when taxa (classes) kill data were analysed individually across the urban zones. Further, we found designated road speed and taxa the strongest predictors of the abundance of road kills in the study area with most kills positively predicted with the increasing road speed and insects. Furthermore, we found three species involved in the animal-vehicle collision were among threatened species under IUCN status and over 50% of the recorded road kills lacking information on their conservation status on the red list at all. These data may be useful in improving the strategies to reducing the animal-vehicle collisions and to inform the potential biodiversity monitoring in the study area and elsewhere in Africa's cities faced with similar urbanization challenges.

**Keywords:** Animal-vehicle collision; environmental justice; road attributes; road kill; urban ecosystem; wildlife.

## 2.1 Introduction

Cities are growing and expanding outward and shrinking natural areas. Although the growth is considered positive to the development, however, it transforms natural to built-up areas often leading to fragmentation of the wildlife habitat and loss of biodiversity (Faeth *et al.*, 2011; Vallejo Jr *et al.*, 2009). Studies have consistently shown that urbanization does affect biodiversity in various ways including inducing biological homogenization within cities (Devictor *et al.*, 2007), increasing phenotypic change in animal and plant species (Alberti *et al.*, 2017) and inducing trait divergence for plants and trait convergence for birds (Concepción *et al.*, 2015) as well as influencing the genetic diversity, distribution and behaviours of animals (Kilwanila *et al.*, 2022; (Biseko and Rija, 2022). However, the impact of urbanization on biodiversity is not uniform and varies across the cityscape due to varying levels of disturbances at different city zones. As predicted by the intermediate disturbance hypothesis (Connell, 1978), within a landscape, areas faced with moderate disturbances are expected to have the highest biodiversity. Consistent with the hypothesis, several studies have demonstrated that across the urban landscapes, sub-urban areas with intermediate disturbances often show high species richness of animals and plants (McKinney, 2008; Rija *et al.*, 2014). Further, roads infrastructure are an important feature characterizing the urbanization process. Road impacts on biodiversity are well studied with the majority of the scientific literature documenting roads as threats than enhancers to biodiversity, see, Morelli *et al.* (2014) for a review. Furthermore, most studies assessing road impacts on biodiversity have covered vertebrates (Morelli *et al.*, 2014; Devictor *et al.*, 2007; Lode, 2000) and fewer literature on invertebrates (Muñoz *et al.* 2015; Baxter-Gilbert *et al.*, 2015; Rao and Girish, 2007) and most these literatures cover wild landscapes and few in urbans of the developed regions (Kent *et al.*, 2021; Riley *et al.*, 2014). There still thus, a limited understanding of how roads impact biodiversity in urban landscapes particularly of metropolitan cities of the tropical developing countries. Such data, if available could help

the designing of the appropriate strategies for planning sustainable biodiversity conservation in the growing cities.

African cities are expanding their road networks supporting the rapidly growing businesses and human population (Arimah, 2017; Sietchiping *et al.*, 2012). While, the roads infrastructures are improving and increasing in numbers (Gibbons *et al.*, 2019), our effort to understanding their impacts on the biodiversity is not matching comparable literature in the developed countries (Benett *et al.*, 2017). A review of the road science in Africa (Collinson *et al.*, 2019) for example, shows that most existing literature have documented road impacts on wildlife in the wilderness areas covering mostly vertebrate animals (Dean *et al.*, 2006; Bullock *et al.*, 2011; Newmark *et al.*, 1996) and there is currently no research that has investigated how roads within cities impact on biodiversity. Further, most existing studies on road ecology only quantify animal kill abundances without detailing the factors influencing the kills on particular roads. However, elsewhere outside Africa, studies indicate animal kill abundance on roads are associated with road attributes: that high traffic volume and roadside trees increase and decrease road kills respectively (Denneboom *et al.*, 2023; Lin, 2016) while species traits such as foraging near roads increases the likelihood of road mortality (Fahrig and Rytwinski, 2009). Understanding the ecology and conservation impacts of roads in urbanizing African cities is thus important to assisting the development of the mitigation conservation strategies.

Urbanization in Tanzania is gaining pace with most cities sprawling and the roads upgrading with tarmac and interconnecting all the administrative regions across the country. Such roads transcend across the urban landscapes, the wilderness and protected areas and are a gate way to the neighboring countries in the East and Southern Africa. Similar to other areas elsewhere, the road network poses threat to the wildlife although the full range of impacts of the road is less well documented. The available studies have been

conducted mostly on roads passing through the protected areas such as Tarangire-Lake Manyara National Parks (Njovu *et al.*, 2019; Kioko *et al.*, 2015) and the Serengeti National Park (Lyamuya *et al.*, 2021; Nkwabi *et al.*, 2018) in northern Tanzania, and Mikumi National Park (Newmark *et al.*, 1996; Drews 1995) in eastern Tanzania. These studies collectively report wildlife kill abundances (vertebrate animals: mammal, amphibians, reptiles and birds) due to vehicle collision associated with the traffic volumes and only one study in Serengeti reports on how road width is associated with the kill abundance (Lyamuya *et al.*, 2021). Further, one study investigating urbanization impacts on biodiversity in a Tanzania's city found plant richness increases in peri-urban than core urban and rural areas (Rija *et al.*, 2014) consistent with results from the temperate regions (McKinney 2008). There is yet no research that has looked at how the urban roads and their attributes influence animal-vehicle collision and how road kill patterns vary across the urban- rural gradients. Such studies are crucial as the urban world is losing substantial animal populations due to roads collision (Jones and Leather, 2013), thereby threatening the ecological functioning and ecosystem services the species perform within the urban ecosystem (Muñoz *et al.*, 2015; Baxter-Gilbert *et al.*, 2015).

In this study, we aimed to assess the patterns and composition of wildlife (vertebrate and invertebrates) killed along the urban-rural gradient in Morogoro municipality. Specifically, we aimed to understand how taxa composition of road kills varies along this gradient and how road characteristics (road shape, road type, road size, designated road speed and habitat type and road locality in the city) influence the abundance of road kills in Morogoro municipality. We finally assessed the conservation status of each individual killed using the current IUCN red list (IUCN, 2022). We expected number of road kills to increase from urban core to peri-urban due to presences of high patches (remnant vegetation) of vegetation acting as habitat and forage areas for different animal species including the threatened species consistent with the intermediate disturbance

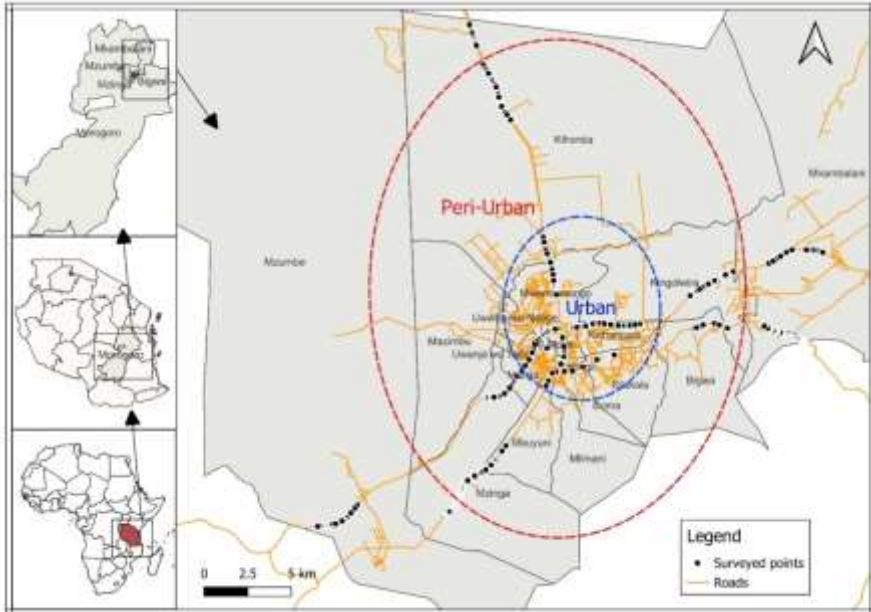
theory. Also, we predicted that the lesser-known taxon particularly invertebrates will have the highest road kill abundance over other well-known animal taxa to the vehicle drivers on the roads. Additionally, we predicted that road characteristics such as speed, habitat, road shape and road type will have stronger influences on the overall number of road kills recorded along the surveyed roads and that this effect should be modulated along the gradient of urbanization i.e. decreasing towards the rural zone in the study area. These findings may be useful for planning managing and save urban wildlife population.

## **2.2 Methodology**

### **2.2.1 Study area**

The study was conducted in Morogoro Municipality which is known for its rich biodiversity. The city lies between 37° and 38° E and latitudes 5° and 7° S, at the base of the Uluguru Mountains which is part of the Eastern Arc Mountains global biodiversity hotspot. The area experiences bimodal annual rainfall of 750 mm to 1050 mm with shorter rains in October and December and a longer rainy season in March and May and the average monthly temperature varies between 21 and 27 degrees Celsius (Rija *et al.*, 2014).

Due to increasing construction of roads connecting different region within Tanzania and neighboring countries the traffic volume is poised to increase with the increasing human population (Biseko and Rija, 2022). In this study, we used the urban zonation from previous studies (Rija *et al.*, 2014; Biseko and Rija, 2022) to assess the patterns of road kills along the urban core-rural gradient on five road sections radiating from the city center (Figure 2.1).



**Figure 2.1: Map of Morogoro municipality, eastern Tanzania showing the study areas and surveyed transects along the five roads radiating from the city center to the rural areas**

### 2.2.2 Study Design

The sampling used five transects that connect the major highways to Dar-es-salaam, to Iringa, to Dodoma, to Bigwa and Mzingwa roads, covering urban-rural gradient. The five roads transects were surveyed covering various distances that traversed from the urban core, sub or peri-urban and rural areas. With the road speed limit of 30,50 and 80km/h respectively. These transects were Dodoma road (9.6 km), Iringa road (9.6 km), Dar-es-Salaam road (9.6 km), Mzingwa road ( 9.6 km) and Bigwa road (9.6km) (Fig. 21). In which each major transect was divided into three sub transects covering urban zone. Therefore we had one sub transect per urban zone in each major transect.

### **2.2.3 Data Collection**

We walked along a 48 kilometer road between November 2022 and May 2023 during early wet season covering the five road transects to record the animals killed on road. During the sampling along each road transect, two observers walked in the same direction on different sides of the road to record and identify each kill on the road. When a kill was observed, a GPS point of its location was recorded to identify potential road kill hotspots. Further, to understand how road attributes were associated with the overall kill abundance, we recorded the weather conditions (whether sunny or cloud day), road shape (straight or winding), road type (tarmac or gravel), surveyed road length and road width and designated vehicle speed by reading speed signboards erected along the road. Further, we also recorded vegetation type available along the location where a kill was observed as well the urban zone (urban core, peri-urban and rural). All kills were collected or photographed and later identified and categorized at the order level, and whenever possible, species-level identification was achieved using field guides books in the laboratory: mammals such as hedgehogs and bats (Kingdon, 2014a), rodents (2014b) birds (Stevenson and Fanshawe, 2004) reptiles (Nussbaum, 2002) butterflies (Martins, 2016), and other invertebrates (Meuwissen, 2016). The road survey was performed twice per week on each transect throughout the entire data collection period. To avoid double counting, kills were removed from the road. Animals were classified into classes such as mammals, aves, reptiles, amphibians, insects. Domestic animal kills were removed during analysis.

### **2.2.4 Data Analysis**

We conducted descriptive analysis to understand the relative kill abundance for each taxon (class) recorded across the study area and urbanization zones. To assess how the number of road kills differed between the urban zones we employed analysis of variance (ANOVA) using pooled data separately and individually for each taxon that had enough data. Further, to assess how the road

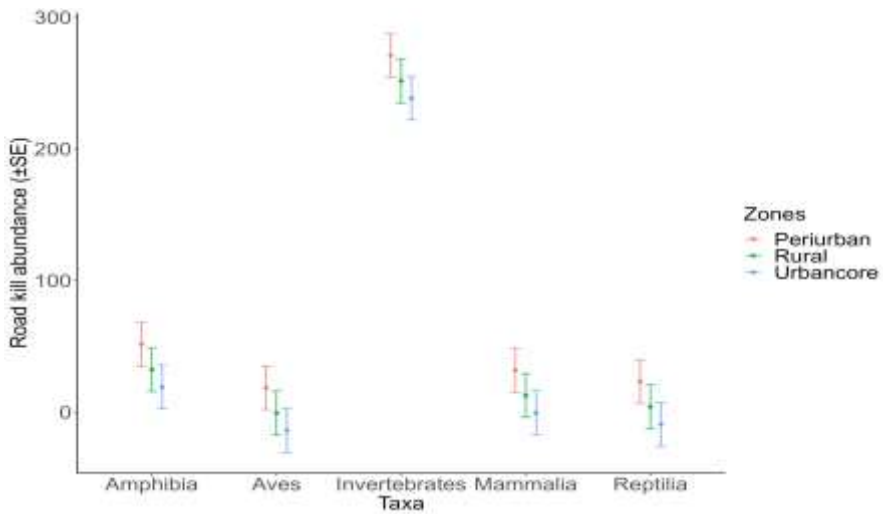
attributes influenced the number of road kills, we built a negative binomial generalized linear model (GLM) using the package MASS in R program as data were over-dispersed. The global model included six covariates: road type, road shape, designated road speed, urbanization zone, habitat type, and road width. To assess the relative influence of each variable on the model performance, we used the drop1 function, stepwise dropping single non-significant model term from the model at each modelling stage. The model fit was assessed using the chi-square test (Kamil, 2018) and the Akaike Information Criterion (AIC) used to assess the most plausible model that best fitted the data for the potentially competing models. Further, we calculated the squared correlation between the response variable and the predicted values to get a measure of variance explained by the models. Squared R was calculated in MuMIn (Barton, 2009). Furthermore, we used the predict function to build a prediction model for the final model predictors to understand the relative predictive power of each variable on the road kill abundance. Visualization and graphing of the model performance were done using the package "ggplot2". Finally, we assessed the conservation status of each kill based on the IUCN red list (IUCN, 2022) to understand how the roads pose threats to the species in this urbanizing landscape.

## **2.5 Results**

### **2.5.1 Taxonomic Composition of Road Kills and Pattern Across the Urbanization Zones**

During this study, we recorded 930 killed individual animals classified into five taxonomic groups: mammals (n = 44), aves (n = 4), reptiles (n =18), amphibians (n =103), insects (n =756). These kills fall into 62 families and 23 orders. Insects accounted for the highest abundance, representing (64.15%) of the total, with 10 orders and 38 families. Birds were the least (0.43%) represented in the recorded kills. Further, wild species accounted for 98.40% of the total kills, while 1.61% were domestic species including cat and dog. Pooled together, the road kill abundance was not significantly

different across the studied urban zones (DF=2, F=1.27, p=0.32). However, there was a significant difference in class abundance between the urban zones (DF=5, F=19.39, p<0.001; Table 2.1). The difference was largely contributed by the most abundant insects (p<0.05; Figure 2.2).



**Figure 2.2: Mean number of kills of individual taxa(class) recorded across the urbanization zones.**

**Table 2.1: Composition of road kills in various animal taxa (Classes) across the city zone in Morogoro, Tanzania recorded during this study**

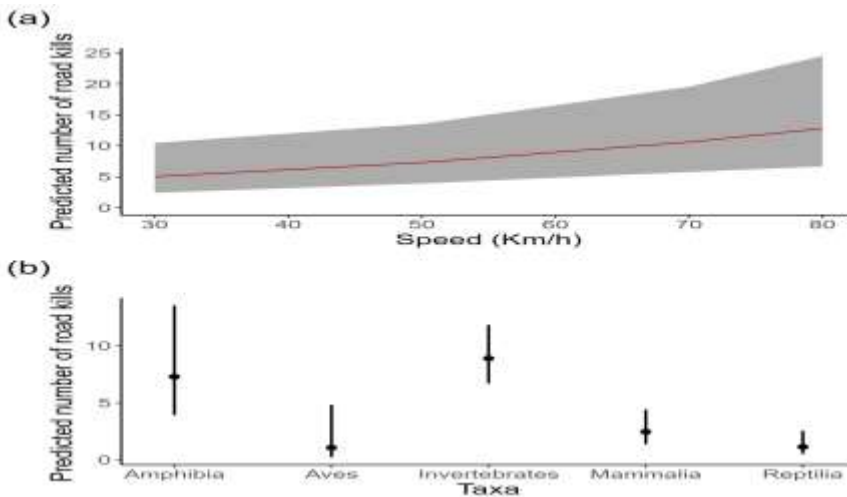
<b>Urban zone</b>	<b>Taxa</b>	<b>Number of road kills</b>	<b>Percentage</b>
<b>Peri-urban</b>	Amphibia	92	23.23
	Aves	3	0.76
	Arthropods	263	66.41
	Mammalia	29	7.32
	Reptilia	9	2.27
		<b>396</b>	<b>42.58</b>
<b>Rural</b>	Amphibia	10	3.33
	Aves	0	0
	Arthropods	279	93.00
	Mammalia	2	0.67
	Reptilia	9	3.00
		<b>300</b>	<b>32.26</b>
<b>Urban-core</b>	Amphibia	1	0.43
	Aves	1	0.43
	Arthropods	219	93.59
	Mammalia	13	5.56
	Reptilia	0	0
		<b>234</b>	<b>25.16</b>

### **2.5.2 Factors Influencing Animal Kills on Urban Roads**

Assessing the road and environmental characteristics influencing the kill abundance, we found designated road speed and the animal classes had significant effect on the overall kill abundance on the road (Table 2.2). Designated road speed tended to significantly positively increase with the number of road kills. Also, further analysis shows that kill abundance was predicted to increase with in some classes, particularly insects than others. In addition kill abundance tended to significantly decrease in aves, mammalia and reptile (Figure 2.3).

**Table 2.2: Results from GLM model indicating the relative effect of road speed and taxa(class) identity as most predictors of overall kill abundance of the urban roads**

Predictors	Mean $\pm$ SE	Z-value	P-value
Intercept	1.05 $\pm$ 0.52	2.01	<b>0.04</b>
Road speed	0.02 $\pm$ 0.01	2.71	<b>0.01</b>
TaxaArthropods	0.20 $\pm$ 0.33	0.6	0.55
TaxaAves	-1.91 $\pm$ 0.82	-2.34	<b>0.02</b>
TaxaMammalia	-1.08 $\pm$ 0.43	-2.54	<b>0.01</b>
TaxaReptilia	-1.84 $\pm$ 0.50	-3.73	<b>&lt;0.01</b>



**Figure 2.3: Predicted number of road kills influenced by the designated vehicle speed and animal taxa(classes) as shown in the final most parsimonious model. The shaded area around the prediction line (a) indicates the 95% confidence interval of the mean while in (b) error bars indicate mean with standard errors**

### 2.5.3 Conservation Status of Road Kills Recorded Across the Urban Landscape

Of the 930 recorded road kills, 0.22% (n=2 species) are listed Vulnerable (Vu) and 0.11% (n=1 species) is listed Near Threatened (NT). The majority (2.15%) road kills are classified Least Concern (LC), 0.97% as Data Deficient (DD), 0.43% (n=4) are listed as Not Evaluated (NE) and the rest (4.95%) have not be classified on the red list. The Vulnerable species (Long horned grasshopper- *Tettigoniidae* and small striped swordtail butterfly- *Graphium policeses*) were recorded on core urban road and on the peri-urban road respectively, while the Near Threatened species (Fruit bat- *Pteropodidae*) was record on the roads across all the urban zones.

### 6.6 Discussion

The aim of the study was to assess composition of wildlife kills on the roads traversing across the city, the factors influencing them and how animal kills changes across the urban-rural gradients in Morogoro municipality. We found the highest kills were arthropods and least numbers of aves. There was no significant difference in the kill abundance across the urbanization gradient on a pooled kill data neither was differences when taxa(class) kill data were analysed individually across the urban zones. Further, we found designated road speed and taxa the strongest predictors of the abundance of road kills in the study area with most kills positively predicted with the increasing road speed and arthropods. Furthermore, we found three species involved in the animal-vehicle collision threatened with extinction and over 50% of the recorded road kills lacking information on the conservation status from the red list at all.

Highest abundance of arthropods in the road kills is suggestive of greater biodiversity richness of the study area which is within a global biodiversity hotspot consistent with reports from elsewhere that high abundant road kills are significantly correlated with high species density an area possesses (D'Amico *et al.*, 2015; Morelle *et*

*al.*, 2013; Gehrt, 2002). On the other hand, however, the arthropods were most abundant perhaps because of the rich roadside green vegetation that provide foraging resources and subtle habitats for the flying and crawling species across the urbanization zones, although habitats as whole was not detected to influence kill abundance in the model. Previous research in this study area (Rija *et al.*, 2014) reported rich plant biodiversity across the urban zones which may have supported high diversity of arthropods and increased activity patterns during foraging, rendering them more susceptible to collisions with moving vehicles as the invertebrates cross road in flight. Abundant road-side vegetation has been reported to increase incidence of species-vehicle collision on roads in New South Wales (Taylor and Goldingay, 2004) and Southern Dakota (Gleason and Jenks, 1993) with consequent management of roadside vegetation being advocated for to reduce animal kills on roads (Rea, 2003). An alternative explanation could be that the smaller size of invertebrates increases their risks of being knocked on roads as they are less visible to the drivers than larger animals or that the drivers are less aware about them and their importance to nature making these species most prone to vehicle collision. For example, in a separate assessment (Mariki *et al.*, *in prep*) investigating drivers' awareness of the wildlife species on roads we found that only less than one percent of the 180 drivers assessed were aware about invertebrates being animals that require protection and mostly reported large mammals as the most at-risk taxon on the vehicle-animal collision incidences they have involved with before. This discrepancy may suggest persistent potential risks of arthropods deaths on roads, thus calls for new strategies to improve the conservation awareness among drivers in the study area.

Aves were the least abundant animals in the kill record. This could be because most urban birds are excellent urban exploiters, they are more worrisome of potential dangers than other animal species when foraging and their visual acute enable them to quickly escape

dangers. In the present study, all the three bird species killed were distributed in the peri-urban areas and two of them were mostly rural birds that are not excellent flier to escape vehicles on road. Biseko and Rija (2022) investigating the flight behaviours of urban birds in Morogoro municipality found that birds inhabiting urban core areas had quicker and longer flight distances when approached by a potential danger. This bird trait enables the urban birds to avoid deaths as they forage across the urban landscape (Kent *et al.*, 2021). Furthermore, not finding the difference in kill abundances across the urbanization gradient is not surprising as road kill risks is expected to be species density-dependent and distribution across the urban zones (Kent *et al.*, 2021; Riley, 2014) and it appears most taxa (class) investigated in our study could be evenly distributed across the urban-rural gradient, although further studies are required to confirm this assertion in this urbanizing landscape.

Designated road speed and insect class were the most predictors of overall kill abundance on road. Road kills tended to increase with increasing road speed. During fieldwork we observed higher number of kills at speed ranging from 50 to 80 km per hour, with most of these kills observed in peri-urban and rural zones. Increased road speed is well known to reduce ability of drivers to avoid moving animals on road and also high speed reduces visual ability to detect small animals in motion and also reduces time for the driver to react to moving animals thereby increase animal-vehicle collision risks (Chambers *et al.*, 2010; Rendall *et al.*, 2021). The insects were mostly associated with the kill abundance mostly likely reflecting invertebrate population density in the study areas as observed in other areas elsewhere (D'Amico *et al.*, 2015; Morelle *et al.*, 2013). Further, we found species threatened with extinction represented in the road kills, reflecting the greater impacts roads have on the species survival (Lowton, 2018). The threatened species are insects which are likely to continue to be killed on the roads given their poor conservation awareness among the vehicle drivers in the study areas. Furthermore, the high proportion (>50%) of road kills in this

study have unknown conservation status. This is concerning because the continued road kill patterns in this urban landscape as yet present even more risks to those species as some could disappear before they are described given the increasing anthropogenic activities facing the study area as biodiversity hotspot.

## **2.7 Implications for Biodiversity Conservation in Urban Landscapes**

This study highlights the impact of road kills across various taxonomic groups and identifies the factors influencing kill incidents. Our results shed light on three important conservation and environmental concerns. First, the high number of animals killed on the urban roads undermine the ecological roles the species perform in ecosystem functioning and services provision such as pollination in urban landscapes. The road kills included some mammal species (e.g. fruit bats), bird species (e.g. Speckled mouse bird) and diverse insects which are known to be important pollinators and seed dispersers in several ecosystems. Reducing their numbers may have far reaching impacts on the environmental health of the urban ecosystem and will directly affect horticultural productivity, its economic potential to the urbanites and wane environmental justice in the study area (Rija and Augustino, 2023; Lima *et al.*, 2023). Second, our data show designated road speed is negatively impacting animal lives in this urban landscape, suggesting that management of traffic speed and volume by the local authority could improve the situation for better. Our results are useful in informing the city planners on devising the appropriate measures to reduce the wildlife-vehicle collision incidences in the urban landscape. Third, with the large proportion of the road kills lacking conservation status suggests that appropriate data for most invertebrate species such as population size, distribution and species-specific biology are still missing for these species. This gap may suggest that more effort is needed to investigate the biodiversity richness of the insects in this urban landscapes. Furthermore, the threatened species being killed

on roads yet casts more concerns on their future population trend given that their current population trend is unknown. A monitoring program of their population as the road network expands in this sprawling city is a growing priority.

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**Appendix 1. List of animal road-kill found along urban-rural gradient in Morogoro municipality.**

<b>Name</b>	<b>Taxon</b>	<b>IUC N</b>	<b>urban</b>	<b>peri-urban</b>	<b>rural</b>	<b>No. of count</b>
Dragon fly	Insecta	NIL	√	√	√	25
Dung beetle	Insecta	NIL	√	√	√	85
Dust bug	Insecta	NIL		√		1
Earwing	Insecta	NIL			√	1
Eastern Carpenter bee	Insecta	DD		√		3
Elegant acraea	Insecta	LC			√	2
Elegant grasshopper	Insecta	DD		√		5
Emerald fruit chaffer	Insecta	NIL	√	√		26
Diadem	Insecta	LC	√	√		3
Female rhinocerus beetle	Insecta	DD	√	√		5
Flower chafer	Insecta	NIL	√	√	√	10
Flower cutting bees	Insecta	NIL		√		1
Frog	Amphibia	NIL		√	√	5
Fruit bat	Mammalia	NT	√	√	√	4
Gecko	Reptilia	LC	√			1
Giant rat	Mammalia	LC	√	√		7
Giant red-legged millipede	Arthropoda	NE	√	√	√	139
Gold banded forester	Insecta	NIL		√		1
Grass yellow butterfly	Insecta	NIL	√			2
Grasshopper	Insecta	NIL	√	√	√	50
Ground beetle	Insecta	LC		√		2
Hedgehog	Mammalia	LC	√	√	√	19
Heron	Aves	NIL		√		1
Honey bee	Insecta	DD	√	√		10
Housefly	Insecta	NIL	√		√	7
Indian house crow	Aves	NIL	√			1
Leaf cutting bee	Insecta	NIL	√			1
Lizard	Reptilia	LC			√	1
Long horn beetle	Insecta	NIL		√		2
Long horn grasshopper	Insecta	VU	√			16

Nile monitor lizard	Reptilia	NE	√	√		2
Moth	Insecta	NIL	√	√	√	9
Olive haired swift	Insecta	LC	√			1
Orange antenna wasp	Insecta	NIL			√	1
Pray mantis	Insecta	NIL	√	√		5
Small striped sword tail butterfly	Insecta	VU	√			7
Snail	Arthropoda	NIL			√	2
Snake	Reptilia	NIL	√	√		8
Southern banded groundling dragonfly	Insecta	LC	√			1
Speckled mouse bird	Aves	LC	√			1
Spider	Arthropoda	NIL	√	√		5
Spider hunting wasp	Arthropoda	NIL	√	√	√	24
Termite (Swarmers)	Insecta	NE			√	70
Toad	Amphibia	NIL	√	√		99
Wandering glider	Insecta	LC	√			4
Wasp	Insecta	NIL	√	√	√	12
White barrel acraea	Insecta	NIL	√			2
White-barred Charaxes	Insecta	LC			√	1
Yellow belted fruit chafer	Insecta	NE	√	√	√	14
Harvester termites	Insecta	NIL			√	2
African Armoured Ground Cricket	Insecta	NIL		√	√	3
African civet	Mammalia	LC	√			1
African joker	Insecta	DD	√		√	4
African migrant	Insecta	LC	√	√	√	16
African monarch	Insecta	DD	√	√		3
Angled grass yellow	Insecta	LC			√	2
Ant	Insecta	NIL	√	√	√	27
Assassin bug	Insecta	NIL			√	2
Banded groundling	Insecta	LC		√		2
Bee	Insecta	NIL	√	√		3
Beetle	Insecta	NIL	√	√	√	27
Big-snouted Lanternfly	Insecta	DD		√		1

Black and white manikin	Aves	LC		√		1
Blister beetle	Insecta	DD	√			3
Blue Spangled Charaxes	Insecta	NIL			√	1
Bombadier beetle	Insecta	NIL		√		2
Brown house snake	Reptilia	NIL		√		2
Bug	Insecta	NIL	√	√	√	7
Burrower bug	Insecta	NIL		√		1
Butterfly	Insecta	NIL	√	√	√	12
Caper white	Insecta	LC			√	1
Carpenter bee	Insecta	DD	√	√	√	40
Centipede	Arthropoda	NIL		√	√	11
Chameleon	Reptilia	NIL		√	√	4
Cicada	Insecta	NIL		√		1
Citrus swallowtail	Insecta	LC	√	√	√	5
Cockroach	Insecta	NIL	√	√	√	4
Common grass yellow	Insecta	LC	√			4
Cotton stainer	Insecta	NIL		√	√	13
Cricket	Insecta	NIL		√	√	5
Dancing acraea	Insecta	LC			√	1
Domesticated cat	Mammalia	NIL	√	√		3
Domesticated dog	Mammalia	DD	√	√	√	11

A mark '√' shows animal killed in a particular zone.

A space without '√' indicates the absence of animal roadkill within the zone. IUCN category VU=Vulnerable, NT= Near threatened, LC= Least Concerned, NE=Not evaluated, DD= Data Deficient. NIL means the species is not currently listed on the red list.

## CHAPTER THREE

### MANUSCRIPT II

#### 3.0 Experience and knowledge of drivers on wildlife roadkill, Tanzania

Heavenlight L. Mariki<sup>1\*</sup>, Robert M. Byamungu<sup>2</sup>, Alfian A. Rija<sup>2</sup>

<sup>1</sup>Department of Ecosystem Science and Conservation; College  
of Forestry, Wildlife and Tourism, Sokoine University of  
Agriculture, Morogoro, Tanzania

<sup>2</sup>Department of Wildlife Management, Sokoine University of  
Agriculture, P. O. Box 3073, CHUO KIKUU, Morogoro, Tanzania

\*Correspondence: marikiheavenlight886@gmail.com

#### Abstract

Roads are a major factor contributing to wildlife collision due to road expansion networks and increasing number of vehicles. We conducted questionnaire survey in Morogoro municipality to assess experiences and knowledge of drivers who frequently use the roads on the wildlife species they encounter on roads, road kill incidences and their views on conservation of wildlife in urban landscapes. Animal collisions outside urban (55%) were perceived by drivers to be the most common Animal Vehicle Collisions (AVCs), with wild mammals perceived to be the major affected taxon. About (35.7%) reported that high speed was the most causative factor in Animal Vehicle Collisions., Increase in driving hours was mostly likely to be associated with the animal-vehicle collision. Further, there was a contrasting pattern on the animal-vehicle collision within and outside the urban landscape: whereas the likelihood of hitting an animal outside the urban areas decreased with increasing in driving hours, road whereas inside urban areas the likelihood of hitting an animal increased as driving hours increased. Furthermore, respondents reported a significant decrease in animal collision when driving private vehicles outside urban areas whereas a significant increase was reported when driving private vehicle inside urban areas. Moreover, 57% of drivers were willing to attend education programs

patterning road killing incidences. The study underscores the significance of collaboration between wildlife conservation managements and road authorities in promoting responsible driving for the safety of both humans and wildlife. Also,

More efforts should be invested in conservation of neglected group of organisms for proper functioning of an ecosystem

**Key Words:** Animal Vehicle Collisions (AVCs), Drivers, Roads killing

### 3.1 Introduction

Transportation infrastructures play a crucial role in our economy and daily lives, providing essential mobility and connectivity (Borza *et al.*, 2023). However, the expansion of road networks and the increasing number of vehicles have led to significant environmental impacts, particularly on wildlife populations (Ibisch *et al.*, 2016). The fragmentation of habitats caused by roads has resulted in genetic loss through collisions, posing a serious threat to animal globally (Van Der Ree *et al.*, 2011). Hence, conducting studies on the factors contributing to wildlife-vehicle collisions and understanding drivers' behaviors towards wildlife is essential for fostering conservation efforts, implementing effective mitigation measures and promoting the coexistence of humans and wildlife in an increasingly urbanized world.

The consequences of roadkill are felt on a global scale, with millions of birds being killed annually on U.S. roads alone (Loss *et al.*, 2014). Recent studies have also highlighted cases of intentional killings by drivers purposely running over invasive species like Cane toads in Australia and American bullfrogs in the Pacific Northwest (Collinson, 2013). Similarly, deliberate killings of snakes have been reported in

Brazil (Secco *et al.*, 2014). Interestingly, the decision to hit or avoid an animal can be influenced by its size, with smaller animals such as snakes and frogs more likely to be purposefully killed due to fear and cultural belief (Rodrigues, 2005). Also, the frequency of intentional and unintentional snake killings can be attributed to their horizontal movement across roads (Whitaker & Shine, 2000). On the other hand, drivers tend to avoid collisions with larger animals due to the potential for significant vehicle damage and the associated costs of maintenance (Conover *et al.*, 1995). Example, collisions with large animals, such as deer, in the United states result in substantial financial losses, injuries, and mortalities each year (Donaldson & Lafon, 2008).

In Africa, the field of ecology has primarily focused on assessing the biophysical effects of roads on wildlife (Lyamuya *et al.*, 2021; Mkanda & Chansa, 2011; Nkwabi *et al.*, 2018). However, there remains a scarcity of research on psychosocial factors that influence wildlife-vehicle collisions. For instance, Ashley *et al.* (2007) observed a higher incidence of intentional object striking among males compared to females, which they linked to greater levels of aggression in males. Also, Ozel *et al.* (2009) found that female students exhibited more unfavorable attitudes toward snakes, with fear being reduced among students who had pets in their homes. For this case, evaluating the attitudes and intentions of drivers regarding wildlife can greatly improve our ability to predict the frequency of wildlife-vehicle collisions and gain insights into the broader impacts of roads on wildlife (Crawford & Andrews, 2016). However, these specific relationships have not been extensively studied within the specific context of wild life- vehicle collisions.

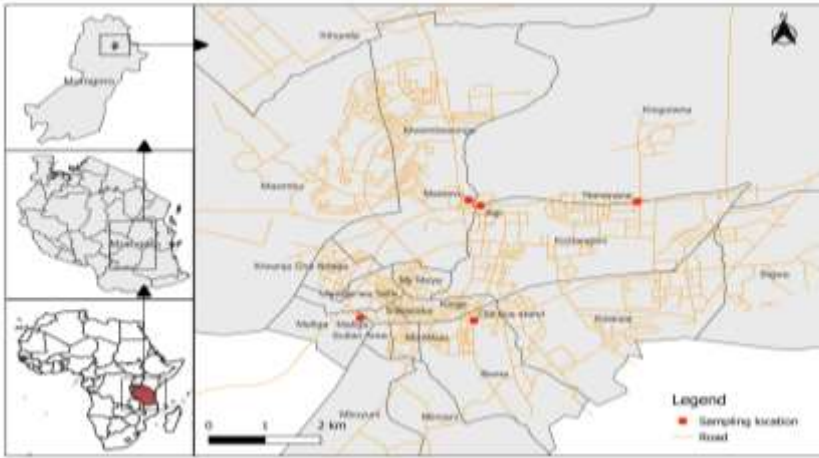
Under this study we aimed at understanding why drivers are involved in wildlife collision. Specifically, we aimed at understanding (i) To what extent are drivers' contributiong to animal collision? (ii) why are drivers involved in animal collision? (iii) which types of animals are mostly involved in vehicle collision? and (iv) If drivers

are sufficiently informed about conservation education?. We hypothesized that smaller animals such as reptiles, amphibians and insects would be more reported in road kill incidence due to their lower visibility and increased likelihood of intentional killing. Also, we predicted that the majority of animal collision on roads would be caused by driving hours, due to fatigue and low concentration. Moreover, we predicted that drivers' involvement in animal collision both outside and inside urban areas, would be influenced by factors such as vehicle categories and lack of road signage.

## **3.2 Methodology**

### **3.2.1 Study Area**

This study was conducted in Morogoro, a region in eastern Tanzania experiencing rapid growth and development. The region is situated at the base of the Uluguru Mountains and is surrounded by key natural features such as the Uluguru Mountains, Udzungwa Mountains National Park, Mikumi National Park, and Kilombero Game Controlled Area. These areas serve as vital wildlife corridors. The region's growth and development are driven in part by a network of interconnected highways that link various regions, leading to an increase in the population. Geographically, Morogoro is located between latitudes 5° to 7° S and longitudes 37° to 38° E. The region experiences a climate characterized by two distinct rainy seasons. The shorter rains occur in October and December, while a long rainy season takes place from March to May and with an annual rainfall ranging from 750mm to 1050mm. The average monthly temperature in this Morogoro varies between 21 and 27 degrees Celsius, (Rija *et al.*, 2014).



**Figure 3.1: Map of Morogoro municipality showing the bus stations**

### 3.2.2 Data collection

A total of 215 questionnaires were addressed to drivers who were travelling both within and outside the surveyed regions. The survey took place at five stations: Msamvu, Itigi, Nanenane, Old Bus Stand, and Mafiga Station, between August 2023 to September 2023. The questionnaire consisted of 28 questions divided into three sections. The questionnaires were in closed-ended and open-ended format. A number of 43 questionnaires were distributed in each bus station.

The respondent questionnaires included inquiries about drivers' daily driving hours, the types of animals they commonly encounter on the road, and the time of day or night when these encounters typically occur. Participants were asked if they had ever hit any wildlife animal, if so, whether the incidents happened inside or outside the city. The questionnaire further investigated the causes behind hitting or not hitting animals and the drivers' feelings towards specific type of wild animal.

In addition, drivers were asked about causes of collisions and reactions (such as hitting, stopping, swerving, or slowing down) when encountering wild animals while crossing the road and factors influencing their decision making process. The questionnaire also asked whether drivers considered body size as factor when making decision related to wildlife encounters. Furthermore, participants were asked whether they believed that lack of conservation education contributed to wildlife-vehicle collisions and if they would be interested in participating in a wildlife conservation seminar. The questionnaire was in Kiswahili and its design aimed at gaining a comprehensive understanding of why drivers get involved in animal crashes.

### **3.2.3 Data Analysis**

The data was entered in the excel sheet and organized for further analysis. To understand the extent of drivers 'contribution on animal killing, types of animals that are mostly involved in animal vehicle collision, and driver's knowledge about conservation education' we used descriptive analysis. To identify locations that are particularly prone to animal collisions, both inside and outside urban areas, we used word cloud (DePaolo & Wilkinson, 2014). To assess the likelihood of animal-vehicle collisions within and outside urban areas, we build generalized linear model (GLM) with function binomial. We first build a global model that included six variables, gender, education status, vehicle category, driving hours, drivers' duration and age as predictors. The response variables were "yes" and "no" to indicate the occurrence or absence of collisions. Further, the relative influence of each variable in the model was evaluated by deleting non-significant model term in a backward step-wise process until the final models were reached. The best model fitting the data was chosen using the Akaike Information Criterion (AIC) lowest value (Portet, 2020). Further, a "ggplot2" package was used to visualize the relative magnitudes of effect for each predictor variable from the final model, as well as to identify which predictor variables

have statistically significant effects on the response variable (Greenwell *et al.*, 2018).

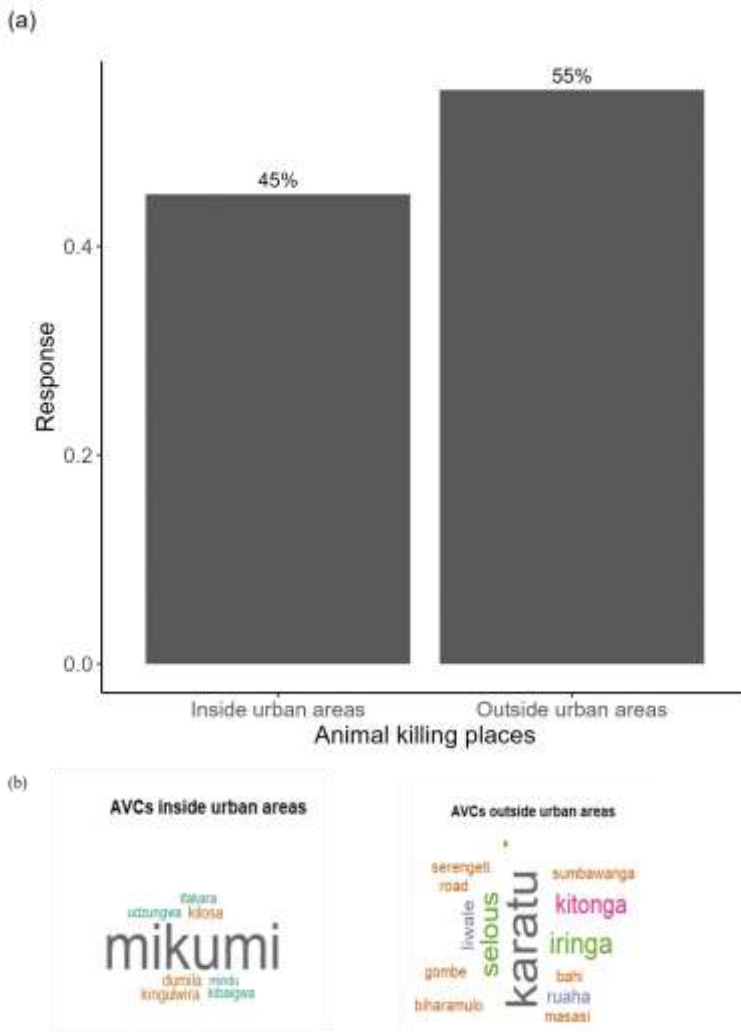
### **3.3 Results**

#### **3.3.1 Demographic Information**

A total of 215 responds were collected from Morogoro municipal. Out of the total respondents, 97% were male, and 3% were female. The age range of the participants was between 22 to 56years. The educational background of respondents varied, with the majority (48%) having completed secondary level. Around 45% had completed primary school, and 17% had attained a university level education.

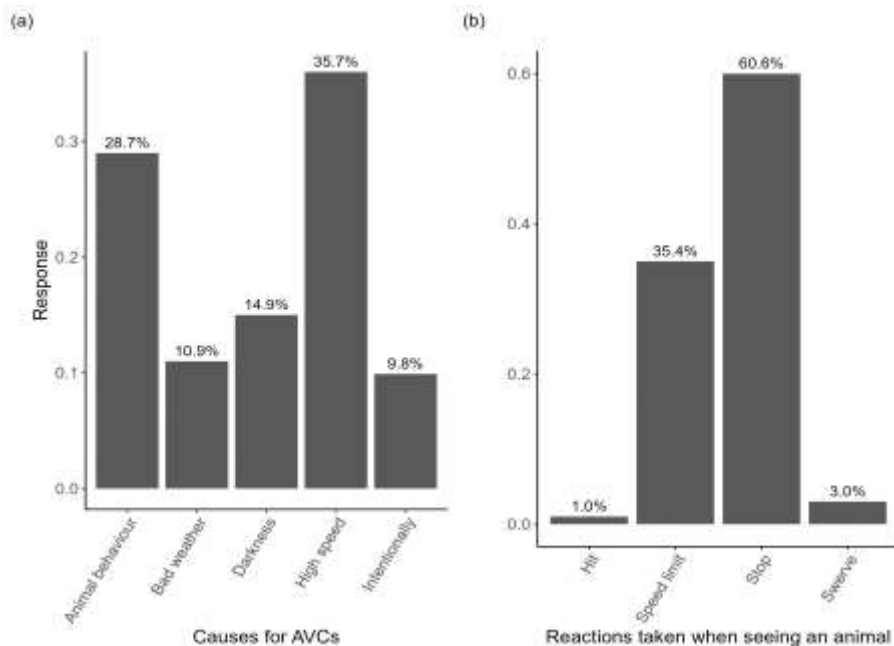
#### **3.3.2 Extent of drive's Contribution in Animal Collision**

The extent of drivers' contribution to animal collision was assessed based on the responses obtained from the participants. About 55% of the respondents reported hitting animals outside cities while 45% reported hitting animals inside urban areas (Fig. 3.2a). To further gain insight, participants were asked to specify areas where they experienced a higher frequency of animal collision, both inside and outside urban areas. The majority of the drivers reported a higher frequency of animal collision within urban areas of Mikumi and outside urban areas of Karatu (Fig. 3.2b).



**Figure 3.2:** A bar plot showing the percentage of animal collisions inside and outside urban areas (a), and a word cloud representing locations mostly mentioned by respondents in relation to animal collisions. The size of each location name in the word cloud represent its relative frequency of mention, highlighting the areas where collision occurred more frequently, both inside and outside urban areas (b).

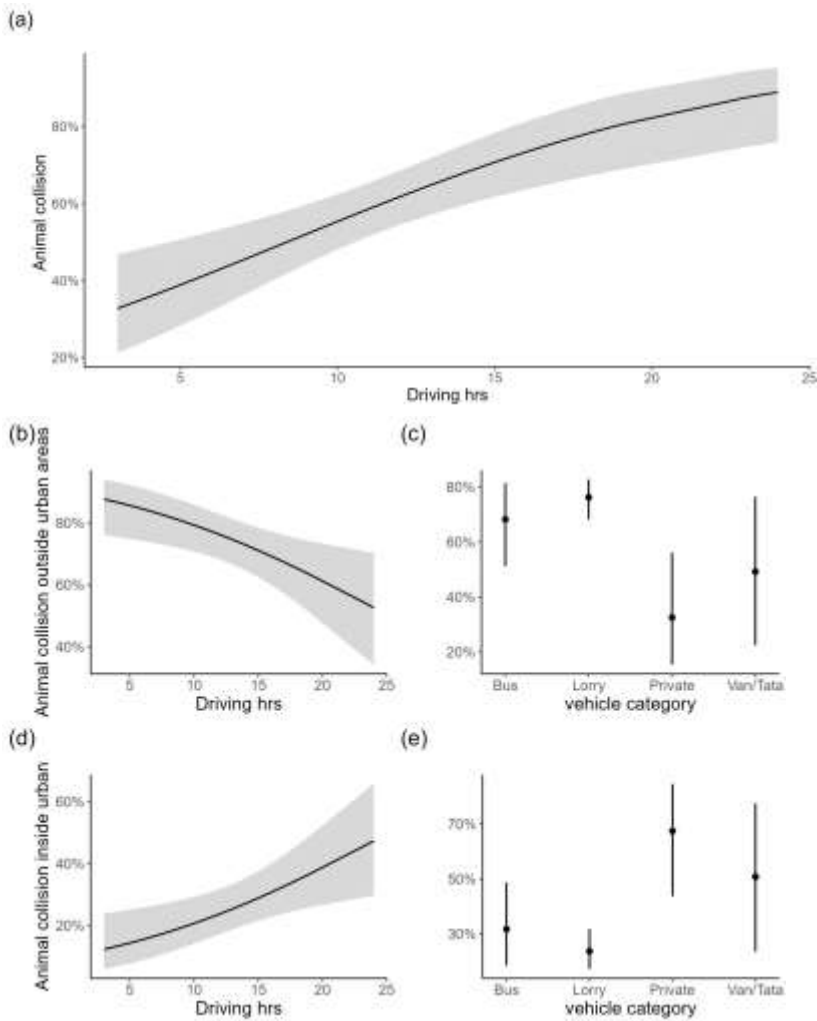
Additionally, majority of respondents agreed that vehicle speed was the major contributor to road fatalities (35.7%). This was followed by animal behavior (28.8%), darkness (14.6%), bad weather (10%) and intentionally (9.9%) (Fig. 3.3a). Also, regarding the timing of accidents involving wildlife approximate 60% of the respondents reported that such accidents mostly occurred during day time, while 20% reported they occurred during night time and the remaining 20% reported that they took place both during day and night time. Further, about 60.6% of the respondents reported that they would stop the vehicle when seeing an animal. Also, 35.4% reported to reduce the speed, 3% said they swerved and 1% reported to hit the animal (Fig 3.3b).



**Figure 3.3: Bar plots presenting the frequency of causes for animal vehicle collision reported by the respondents (a), as well as reactions taken by the respondents when encountering wild animals (b)**

### 3.3.3 Driver's Involvement in Animal Killing

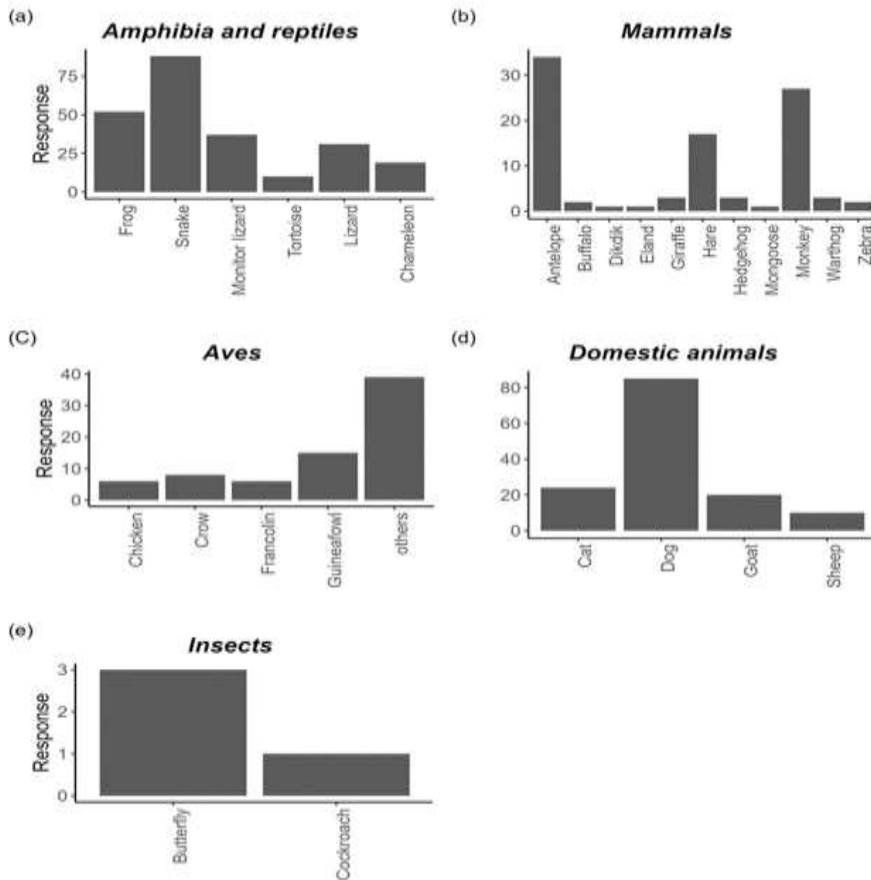
The GLM results indicated that animal collision was mostly likely to increase with increase in driving hours (mean=0.13  $\pm$ 0.03SE,  $p < 0.001$ ) (Fig.3.4a). Further, the probability of animal collision varied based on driving hours and vehicle categories, both inside and outside urban areas. Results showed that the likelihood of hitting the animal outside the urban areas increased as driving hours decreased (mean=-0.088 $\pm$ 0.03SE,  $p=0.007$ ) whereas inside urban areas the likelihood of hitting animal increased as driving hours increased (mean=0.088 $\pm$ 0.03SE,  $p=0.007$ ). On the other hand, respondents reported a significant decrease in animal collision when driving private vehicles outside urban areas (mean=-1.49 $\pm$ 0.61SE,  $p=0.01$ ) whereas a significant increase was reported when driving private vehicle inside urban areas (mean=1.49 $\pm$ 0.61SE,  $p=0.01$ ) (Fig.3.4b - e).



**Figure 3.4:** GLM predictions showing animal collision were mostly likely to increase with increase in driving hours (a). Specifically, the likelihood of animal collisions outside urban areas showed to decrease with increase in driving hours (b) and, animal collision decrease when driving private vehicle (c). Additionally, the probability of animal collision inside urban areas showed to increase with increase in driving hours (d) and increase when driving private vehicles (e)

### 3.3.4 Types of Animals Mostly Involved in Vehicle Collision

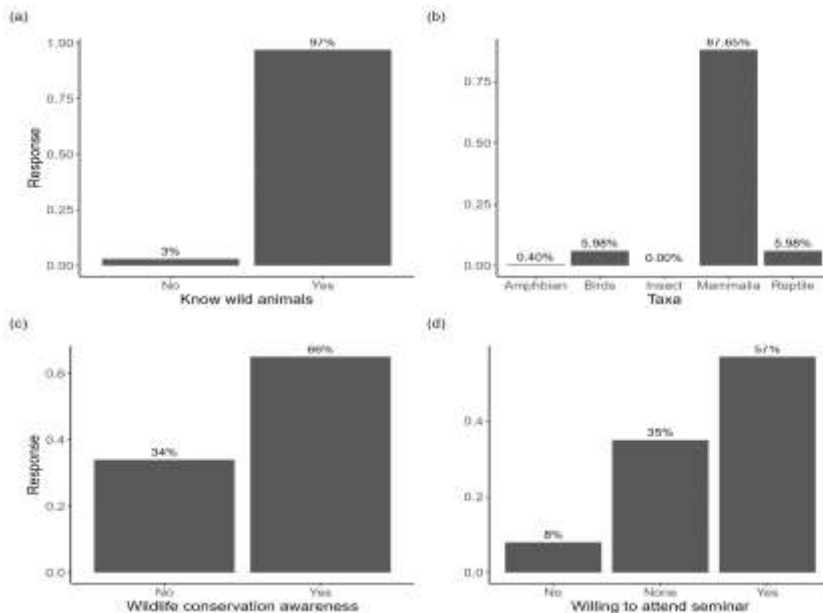
Results on animal collisions by taxa showed that mammal had the highest frequency of collisions, specifically antelope  $n=34$ . The second taxon was reptile  $n=88$  with snakes being the most commonly encountered, followed by amphibian  $n=52$ , aves  $n=39$  and butterflies with only 3 collision incidences (Fig. 3.5).



**Figure 3.5: Responses frequency on different taxon, (a) amphibian and reptile, (b) mammals, (c) aves, (d) domesticated animals (e) and insect**

### 3.3.5 Driver's Wild Animal Awareness

The findings regarding drivers' awareness of wild animals indicated that majority, 96.7% of the respondents were knowledgeable about wild animal, while the remaining 3.3% did not have knowledge about wild animal (Fig.6a). Among the known taxon group, mammals were the most commonly reported by the respondents (87%), followed by reptiles (5.6%), birds (6.4%), and amphibians (0.4%) (Fig.3.6b). In addition, 66% of the respondents reported that animal collision is a result of lack of knowledge on wildlife conservation (Fig.3.6c). Moreover, a proportion 57% of the respondents were willing to attend conservation seminar. However, small proportion of the respondents 8% reported not being willing to attend wildlife seminars (Fig. 3.6d).



**Figure 3.6:** Bar plot showing the percentage of drivers who had knowledge about wild animals (a), mammal was the most frequently mentioned taxa of wild animals by the drivers (b), percentage of drivers reported to be aware of wildlife conservation (c).and percentage of drivers expressed their willingness to attend seminar (d)

### 3.6 Discussion

The aim of the study was to understand drivers knowledge and experience on wildlife-vehicle collision. We observed a higher number of vehicle collision of wild animal to occur outside urban areas. High vehicle speed was mostly reported as a major factors contributing to animal collision. Interestingly, most of the drivers reported to stop when they encountered wild animals. Also, the incidence of vehicle collision was reported to increase with increase in driving hours. In addition, among the different taxonomic groups, mammals, (class mammalia) were the mostly affected by vehicle collisions.

Majority of the respondent reported to hit animals outside urban areas. This may be due to the fact that these kind areas offer more extensive and diverse natural habitats, including forests, wetlands, grasslands, and other ecosystems that provide suitable environments for a wide variety of wildlife species. This is similar to the study conducted by Freitas *et al.* (2013) who found more roadkill incidences involving birds outside urban areas particularly on highways. Also, respondents reported that Mikumi and Karatu had the highest animal vehicle collision compared to other areas. This may be attributed by the presence of wildlife conservation areas around the two locations. Moreover, most respondents reported animal collisions were more associated by vehicle speed. These findings are consistent with previous study conducted by Farmer & Brooks (2012), and Ramp *et al.* (2006). Also, respondents reported that most accidents occurred during day time compared to night time and most drivers reported to stop the vehicle after seeing an animal. Contrary, several studies reports night kills are higher than day kills (Kioko *et al.*, 2015). This contradiction may be due to differences in study methodology. Driver's reports on high animal collision during day time may be due to clear visibility and enough concentration during day time compared to night time. However, there might be a possibility of drivers missing information of animal collision during

night time since it is very rarely for the driver to observe small animal collision during night times.

Additionally, results under the current study indicated that the probability of animal vehicle collision increased with increase in driving hours. This may be due to tiredness and/ or loss of concentration during driving which causes drivers to deviate away from the road. A similar case was reported from Brazil by Secco *et al.* (2014). On the other hand, the findings indicated that animal collision decreased with increase in driving hours outside urban areas whereas inside urban areas, an increase in driving hours was associated with a higher incidence of collisions with wild animals. Also, the likelihood of animal vehicle collision decreased when driving private vehicle outside urban areas .However, there was a high probability of animal collision inside urban areas when driving private vehicles. These findings may be attributed by the different characteristics between locations. For instance, inside urban areas, there are more traffic volume compared to outside, which, combined with driver fatigue from long hours of driving, may contribute to a greater likelihood of animal collisions. In contrast, outside urban areas, where traffic density is lower, even with more driving hours, the risk of collisions with wild animals may remain relatively low. Similar observations were observed in other studies elsewhere (Chodur *et al.*, 2016).

Furthermore, majority of respondents under the current study reported that mammals were the most commonly involved in vehicles collisions. Specifically, drivers mentioned mammals such as antelope to be the most affected animal species due to their tendency of crossing the road very fast without observing vehicles passing along the road. Monkey were also mentioned, likely because of their playful behavior across the road. Additionally, reptiles such as snake were mentioned to be prone to collisions, possibly due to their slow movement across the road and freezing

behavior making them more prone to collision (Andrews & Gibbons, 2005).

On the other hand, majority of respondents had knowledge about wild animals; their understanding was mostly biased towards mammals with very few mentioning amphibians and none mentioning insects. This indicates a lack of comprehensive awareness regarding the various species of wild animal. Moreover, respondents recognized a connection between their lack of knowledge on wildlife conservation and the occurrence of animal roadkill incidents. Interestingly, the majority of respondents expressed their willingness to dedicate time in conservation education programs. This finding suggests that such programs have the potential to promote safer driving habits on the roads.

### **3.7 Conclusion and recommendations**

The study shows that majority of respondents had knowledge about wild animals; their understanding was mostly biased towards mammals with very few mentioning amphibians and none mentioning insects. The study recommends on the implementation of conservation education programs and expands the focus of animal collision studies to include some of overlooked taxa like insects

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## CHAPTER FOUR

### 4.0 GENERAL DISCUSSION

The purpose of this study was to examine the patterns of wildlife roads kills in relation to landscape mosaic in Morogoro Municipality. The study assessed species composition and distribution of road kill along the roads. The study also assessed conservation awareness among driver on wildlife collision on roads. During the study on pattern and composition of wildlife roadkill across urban-rural gradient in an African expanding city, found that the invertebrates, encompassing various insects and arthropods, had the highest abundance of kills. Both Species ground and crawling were particularly affected due to their behavior and habitat preferences it may be due to the roadside surrounding rich vegetation cover. This pattern resonated with prior research conducted in India (Rao & Girish, 2007). In addition, roadkill incidents involving Aves were the least frequent, likely due to their adeptness at navigating urban environments, heightened awareness of potential threats while foraging, and quick escape abilities (Biseko and Rija, 2022). Furthermore, the speed at which vehicles traveled played a pivotal role in roadkill incidents. Higher speeds, especially in the 50 and 80 km/h ranges, escalate the risks of animal-vehicle collisions by reducing visual acuity for the driver on seeing the animal crossing the road (Chambers *et al.*, 2010). Furthermore, The study noted that roadkill extended its reach to endangered species like fruit bats in both urban and rural areas, underscoring the potential threat to local ecosystems. Moreover, more than half of the road kills in the study had unknown conservation status, this pose a risk of some species to disappear before formal description is compounded by escalating anthropogenic activities within the urban environment.

On the other hand, the study aimed to understand the reasons behind drivers' involvement in wildlife collisions. The study found a higher number of wildlife collisions outside urban areas, often attributed to high vehicle speeds. Interestingly, most drivers reported

stopping when encountering wild animals, demonstrating their willingness to respond to wildlife presence. However, the incidence of vehicle collisions increased with extended driving hours, suggesting fatigue and decreased concentration as contributing factors. Mammals, especially antelope and monkeys, were frequently involved in vehicle collisions, alongside reptiles like snakes. These collisions were attributed to factors such as fast animal movements, playful behavior, and slow crossing speeds. The study's findings on drivers' observations of animal collisions during daytime, despite contrasting findings in other studies reporting higher incidents at night (Kioko *et al.*, 2015).

## **CHAPTER FIVE**

### **5.0 CONCLUSIONS AND RECOMMENDATION**

#### **5.1 General Conclusion**

In conclusion, this study showed that insects are the most killed group on wildlife road kills in the study area. Also, peri-urban recorded a large number of road kills than rural and core-urban.

Majority of respondents had knowledge about wild animals; their understanding was mostly biased towards mammals with very few mentioning amphibians and none mentioning insects.

#### **5.2 Recommendation**

The study recommends on the implementation of conservation education programs and expands the focus of animal collision studies to include some of overlooked taxa like insects.

More efforts should be invested in conservation of neglected group of organisms for proper functioning of an ecosystem

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## APPENDICES

### Appendix 1: Questionnaire used in the study

#### Swahili

Jina langu ni Heavenlight Mariki, na mimi ni mwanafunzi wa shahada ya uzamili ninayefanya utafiti kuhusu.Mtazamo wa madereva juu ya ugongwaji wa wanyamapori katika maeneo ya miji.Lengo kuu ni kupima uelewa wa madereva juu ya wanyama pori.Majibu yako ni ya siri kabisa, na data itakayokusanywa itatumika kwa madhumuni ya utafiti pekee. Tafadhali jibu maswali kwa uaminifu na kwa uwezo wako wote.Ushirikiano wenu unathaminiwa sana. Asante sana kwa ushiriki wako.

Heavenlight Mariki

Marikiheavenlight886@gmail.com

#### MTAZAMO YA MADEREVA JUU YA UGONGWAJI WA WANYAMAPORI,TANZANIA.

- 1.Jina la kituo.....
- 2.Jinsia a)Me b)Ke [ ]
- 3.Umri....a)Kijana(miaka 18-25) b)26-33 c)34-41 e)42-49 f)50-60 e) zaidi ya 60 [ ]
- 4.Kiwango chako cha elimu ni kipi?  
a)Elimu ya msingi (b)elimu ya sekondari (c)chuo /chuo kikuu (d)hakuna elimu rasmi [ ]
- 5)Aina ya kikundi cha chombo cha moto?  
a)lori b)busi c)gari la kati(tata/vani) d)gari dogo [ ]
- 6.Una muda gani tangu uwe dereva? .....  
a)chini ya mwaka 1(b) mwaka 1- 5 c) 6 -10 (d)Zaidi ya miaka 10 [ ]
- 8)Je unatumia masaa mangapi kuendesha gari kwa siku?.....
- 9)Ni aina gani ya wanyama huwa unakutana nao barabarani ukiwa unaendesha?

.....  
.....

- 10) Unalinganishaje wingi wa wanyama hao usiku na mchana?  
 a) wengi zaidi mchana b) wengi zaidi usiku c) muda wote sawa
- 11) Je unafahamu wanyamapori ni viumbe vipi?  
 a) ndio b) hapana
- 12) Kama ndio nitajie wanyamapori unaowafahamu unaokutana nao barabarani iwe barabara zipitazo mijini au maeneo yasiyoishi watu.....
- 13) Ni muda gani hasa katika siku huwa unakutana na matukio ya kukanyagwa kwa wanyamapori barabarani?  
 a) mchana b) usiku c) asubuhi
- 14) Je umewahi kugonga au kumkanyaga mnyama pori yeyote barabarani?  
 a) ndiyo b) hapana
- 15) Kama ndiyo ni mara ngapi kwa wiki huwa unakanyaga wanyama pori?.....
- .
- 16) Ni aina gani ya wanyama pori ulishawahi kukanyaga na gari barabarani (tick zote zinaousika  
 a) chura  
 b) nyoka, mjusi, kenge, kobe na kinyonga (taja.....)  
 c) wanyama  
 wakubwa (swala, nyani, nyati, twiga, tembo, pundamilia, pofu) taja.....  
 d) mamalia  
 wadogo (panya, popo, karunguyeye, pimbi, nguchiro) taja.....  
 e) wanyama wa  
 kufuga (mbwa, paka, mbuzi, kondoo) taja.....  
 f) ndege (taja.....)  
 g) wadudu (taja mfano.....)
- 17) Ni maeneo gani au barabara gani HASA (mfano, nje ya mji au mjini) umewahi kukanyaga au kugonga mnyama pori? ( )  
 a) nje mji.....  
 b) ndani mji.....
- 18) Je unapokuwa unaendesha Barabarani nje ya mji na Barabara zinazopitia maeneo ya miji, unahisi ni sehemu gani unauwezekano mkubwa HASA wa kukanyaga/kugonja mnyamapori bila kujali?

a) Barabara zilizo nje ya miji (b) Barabara zinazopitia maeneo ya miji

19. Katika jibu lako hapo juu namba 18(a) au (b)...Unahisi ni nini kinasababisha wewe ufanye hivyo?

a)sababu.....

b)sababu.....

20)Je huwa unajisikiaje unapomkanyaga mnyama pori?

a)kawaida

b)huzuni

c)furaha

21)Kama unajisikia huzuni, Je ni wanyama gani ukiwakanyaga huwa unajisikia huzuni.....

22) Je ni mnyama gani huwa ukimkanyaga huwa hujisikii huzuni yoyote? (Taja kadiri unavyoweza).....

23) Ni njia gani HASA inayoweza kufanyika kupunguza ugongwaji wa wanyama pori barabarani?

a) kupunguza mwendo

b) kutumia vibao vya alama za barabarani

c) kufuata sharia

d) kukwepa wanyama

24)Ni sababu ipi HASA huwa inazopelekea kugongwa kwa wanyama kipindi wanapovuka barabara?

a) giza

b) hali ya hewa

c) makusudi

d) tabia za Wanyama.....mfano tabia gani husababisha mnyama agongwe/akanyagwe na gari?

e) mwendokasi

25)Kama ni tabia,ni tabia gani HASA za wanyama husababisha mnyama agongwe/akanyagwe na gari?

.....

.....

26)Hatua gani unazozichukuwa kipindi ukimwona mnyama akivuka barabara?

a)kupunguza mwendo

- b) kusimama
- c) kumkwepa
- d) kumgonga

27) Sababu ipi inayokupelekea wewe kufanya uamuzi juu ya hatua hiyo iliyotajwa juu?

.....

28) Je unahisi hatua hizo ulizo chukuwa hapo juu zinaweza badilika kulingana na aina ya ukubwa wa wanyama?

- a) ndiyo
- b) hapana

27) Je unahisi kugongwa kwa wanyama kunasababishwa na ukosefu wa elimu ya uhifadhi kwa madereva?

- a) ndiyo
- b) hapana

28) Je kama ni ndiyo, hapo juu unaweza kutenga muda kuhudhuria seminar ya elimu ya wananchi juu uhifadhi wa wanyamapori katika barabara zetu?

- a) ndio
- b) hapana

### English

My name is Heavenlight Mariki, and I am masters student conducting research on Perception and knowledge of drivers on wildlife roadkill. Your valuable insights will contribute significantly to the research findings. Your responses are entirely confidential, and the data collected will be used solely for research purposes. Please answer the questions honestly and to the best of your ability. Your cooperation is highly appreciated. Thank you in advance for your participation.

Heavenlight Mariki

Marikiheavenlight886@gmail.com

1. Name of the station.....

2. Gender... a) Male b) Female [ ]

3. Age.... a) 18-25 b) 26-33 c) 34-41 e) 42-49 f) 50-60 e) above 60 [ ]

4. What is your level of education?

a)Primary education (b)Secondary education(c)University (d)Illiterate

[ ]

5) Type of vehicle category?

a)lorry b)bus c)van d)private car [ ]

6. How long have you been a driver?.....

a)less than1year(b) 1- 5 years c) 6 -10 years (d)above 10 years [ ]

8) How many hours do you spend driving a day?.....

9) What kind of animals do you meet on the road while driving?

.....

.....

10) How do you compare the number of animals at night and day?

a) more during the day b) more at night c) all the time the same

11) Do you know what wild animal are?

a)yes b)no

12) If yes, tell me the wildlife you know that you meet on the road, whether it is the roads that pass through cities or outside the cities area.....

13) What time of the day do you usually encounter incidents of wildlife being crushed on the road?

a) afternoon b) evening c) morning

14 Have you ever hit or stepped on any wild animal on the road?)?

a)yes b)no

15) If yes, how many times a week do you hit on wild animals?

.....

16) What kind of wild animals have you ever run over with a car on the road.

a) frog

b) snake, lizard, monitor lizard, tortoise  
(mention.....)

c) large mammals (antelope, monkey, buffalo, giraffe, elephant, zebra, eland) mention.....

d) small mammals (rat, bat, hedgehog, mongoose)  
mention.....

e) domesticated animals(dog, cat, goat, sheet) mention

.....

f) birds(mention.....)

g) insects (mention example.....)

17) What places or roads EXACTLY (for example, outside the city or in the city) have you ever run over or hit a wild animal? ( )

a) outside the city.....

b) in the city.....

18 When you are driving on roads outside the city and roads that pass through the cities, where do you feel you are most likely to step on/hit a wild animal regardless?

a) Roads outside the cities (b) Roads passing through the cities

19. In your answer above number 18(a) or (b)...What do you feel that causes you to do so?

a) reason.....

b) reason.....

20) How do you feel when you step on a wild animal?

a) normal

b) sadness

c) happiness

21) If you feel sad, what animals do you feel sad when you step on them?.....

22) What type of animal that you never feel sad when you step on it? (Specify as many as you can).....

23) What is the EXACT way that can be done to reduce the collision of wild animals on the road?

a) slow down

b) using road sign boards

c) following the law

d) avoid animals

24) What are the EXACT reasons that lead to animals being hit while crossing the road?

a) darkness

b) the weather

c) intentional

d) Animal behavior.....for example, what behavior causes an animal to be hit/run over by a car?

e) speed

25) If it is behavior, what EXACTLY are the behaviors of animals that cause an animal to be hit/run over by a car?

.....  
.....

26) What steps do you take when you see an animal crossing the road?

- a) slow down
- b) standing up
- c) avoid him
- d) hit him

27) Which reason leads you to make a decision on the action mentioned above?

.....

28) Do you feel that the steps you have taken above can change depending on the size of the animal?

- a)yes b)no

27) Do you think/feel that animal crashes are caused by a lack of conservation education for drivers?

- a)yes b)no

28) If yes, can you spare time to attend a public education seminar on wildlife conservation on our roads?

- a) yes b)no