MAPPING OF HUMAN WILDLIFE CONFLICT HOTSPOTS IN SILOWANA COMPLEX OF WESTERN PROVINCE IN ZAMBIA

By

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DECLARATION

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CERTIFICATE OF APPROVAL

This dissertation by **Chilambe Brian** has been approved as partial fulfillment of the requirements for the award of the Degree of the Master of Science in Geo-Information Science and Earth Observation by the University of Zambia.

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ABSTRACT

This dissertation is about a study conducted on mapping HWC hotspots in Silowana Complex of Western Province in Zambia. Spatially identifying HWC (hotspots) and possible mitigation measures is necessary to inform HWC management in order to facilitate a nonviolent coexistence of humans and wildlife. This study used Earth Observation techniques, Geographic Information Systems and spatial modelling to identify areas at risk of HWC and possible mitigation measures to address the conflict, based on the Silowana Complex (SC) as a case study area. The study achieved three (3) specific objectives: it analysed forms of HWC; modelled HWC hotspots and established possible HWC mitigation measures in the case study area

The study achieved its objectives through a total of 200 HWC incident records covering 2020 to 2021 acquired from the Department of National Parks and Wildlife (DNPW). To supplement this dataset, a semi-structured questionnaire was administered to 100 respondents. The study modelled HWC occurrences together with environmental predictor variables extracted from the land cover map. The land cover map was classified from sentinel 2 Level 1C satellite images using the Supported Vector Machine (SVM) algorithm in ArcGIS Pro (Version 2.4.1). Maximum Entropy (MaxEnt) software (Version 3.4.1) was used to model HWCs. The outputs were analyzed and mapped using ArcGIS Pro (Version 2.4.1).

Further, the study found that, HWC is caused by the following species of wildlife in their order of magnitude; African elephants (*Loxodonta Africana*) at 47%, Common Hippopotamus (*Hippopotamus amphibius*) at 24%, Nile crocodile (*Crocodylus niloticus*) at 21%, Blue wildebeest (*Connochaetes taurinus*), African buffalo (*Syncerus caffer*) and Spotted Hyena (*Crocuta crocuta*) at 2% each, Lions *(Panthera Leo)* at 1% and Common duiker (*Sylvicapra grimmia*) at 1 %. Further, the study analyzed seasonal patterns of HWC and found that HWC occurred throughout the year with peaks in March and October.

Further, the study found that a total of 550 km^2 or 55,000 hectares of SC (5% of its area) was at risk of HWC. The results showed that of the total HWC hotspot areas, 60% were in the GMA, 22% were in the Open area, and 18% were in the National Park. The study also established that community members practiced exclusionary and deterrent methods to mitigate HWC. The practice of these methods show that community members had knowledge of how to mitigate HWC.

The study concluded that Lower West Zambezi GMA experienced more HWC than Sioma Ngwezi National Park. Further, human communities in the GMA are the most affected by HWC than those in the National Park. The study recommended that, DNPW and its conservation partners should consider promoting community-based HWC management, conservation education, livelihood diversification, and prioritize integrated land use planning in addressing HWC in both the National Park and GMA. In addition, future studies on this topic could largely replicating this model in other landscapes in Zambia. Further research is needed focused on quantifying the impacts (Physiological, Social and Economic) of HWC on local human communities.

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DEDICATION

To my beloved wife Dorothy M. Chilambe and my son- Brian Chilambe, and to my parents, Mr. George Chilambe and Ms. Vivian Chatyoka for their support and inspiration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS & ACRONYMS

CITES	Convention On International Trade In Endangered Species Of Wild Fauna And Flora
COVID-19	Coronavirus Disease 2019
DNPW	Department Of National Parks And Wildlife
FRA	Food Reserve Agency
GIS	Geographic Information Systems
GMAs	Game Management Areas
GMP	General Management Plan
H^1	Alternative Hypothesis
Ha	Hectares
HHC	Human-Human Conflicts
H^o	Null Hypothesis
HWC	Human Wildlife Conflict
ID	Identifier
KAZA TFCA	Kavango Zambezi Trans-Frontier Conservation Area
KG	Kilograms
LWZ GMA	Lower West Zambezi Game Management Area
MoA	Ministry Of Agriculture
MOTA	Ministry Of Tourism And Arts
NGOs	Non-Governmental Organizations
PAC	Problem Animal Control
PHs	Professional Hunters
SC	Silowana Complex
SNNP	Sioma Ngwezi National Park
WWF	World Wide Fund For Nature
ZAWA	Zambia Wildlife Authority

CHAPTER ONE: INTRODUCTION

1.1 Background

Human-wildlife conflict (HWC) also interpreted as wildlife-human conflict, is one of the global problems faced by conservationists and decision-makers worldwide (Torres et al., 2018). It occurs when people compete with wildlife for food and resources. Often HWC is driven by habitat loss, due to anthropogenic factors, such as the construction of transport networks, human encroachment, and the conversion of forests to arable land (Acharya et al., 2017; Koirala et al., 2015). Other drivers of HWC include increasing human and wildlife populations, and climate variability/change. Climatic changes affect wildlife's habitat composition, availability of forage, and water accessibility, triggering conflict beyond protected areas (Cushman et al., 2018; Mallick, 2012). It, therefore, becomes imperative to map areas at risk of HWC, and analyze the drivers, and possible mitigation measures, in order to better inform conservation efforts.

HWC has contributed to the extinction of numerous species and caused immeasurable loss of human life, crops, livestock, and property. Further, HWC has indirect consequences for the livelihoods of communities, their psychological and economic well-being, and food security (Barua et al., 2013). On the other hand, the retaliatory killing of wildlife by humans contributes to the loss of biodiversity and to changes in ecosystem structures as a whole (Nyhus, 2016).

In Africa, the co-existence of wildlife and human communities in protected areas has led to HWC and contributed to the high cost of living (Chase et al., 2016; de Boer et al., 2013). In Zambia, Chomba et al, (2012), found that during the period 2002 to 2008, a total of 347 people were killed (that is 49 people killed annually) by five species of wildlife; crocodile, elephant, hippo, lion, and buffalo. The Nile crocodile killed the largest number of people 174 (54 %), seconded by the hippos 65 (19 %), with the elephant 63 (18 %) in third place (Chomba et al., 2012). The above is an indication that HWC is common in protected areas in Zambia including the study area, Sioma Ngwezi National Park (SNNP), and Lower West Zambezi Game Management Area (LWZ GMA) collectively called Silowana Complex (SC).

The SC presents a unique case for this study because the SNNP has since 1971 when it was gazzeted incorporated human settlements inside the park. The villages that are inside the park include Dihele, Imusho, Ngweze, Mbao, and Mbala. These villages are sparsely distributed within the national park, hosting sub-villages and communities. It was estimated that about 5,000 people live in the national park (Ministry of Tourism and Arts (MOTA), 2019). Despite this, the SNNP also has a Game Management Area (GMA) around it, with some communities living in the GMA. It could be expected that HWC would be more in the national park than in the GMA. Therefore, this study used a geospatial approach to better understand the dynamics of the conflicts in the area, as communities continue to reside in the national park.

The HWC geographical patterns are not documented in most parts of Africa (Gross, 2019). There are several challenges that exist in mapping and quantifying the extent of HWC, mostly due to the fact that existing data and information hardly give an indication of how widespread HWC is spatially. In addition, Hanks (2006) indicated that community members tend to exaggerate the extent of their losses because they see reporting damage as an opportunity to express frustration or anger about their helplessness in dealing with conflicts with wildlife. In some areas, HWC is underestimated because each incident may not be reported and/or reports may lack pertinent information vital for geospatial analysis of HWC. Hence, the use of Earth Observation, Geographical Information Systems, and spatial modeling systems by this study will help fill up these gaps in knowledge and overcome the above challenge.

Muyoma, (2016) noted that several studies on HWC are reactive in nature largely focusing on understanding the drivers of HWC, mitigation measures, perceptions and attitudes of community members towards wildlife and the visible direct and hidden costs of HWC. There are few studies taking a geo-spatial approach to delineate areas at risk of HWC (Hotspots) and identify possible mitigation measures.

1.2 Statement of the Problem

The causes, and consequences of HWC in Zambia are well documented (Chomba et al, 2012). However, geographical patterns of HWC are not documented in most parts of Africa (Gross, 2019). The SC is no exception to this trend, due to the lack of comprehensive and uniform HWC data collection methods and systems. This presents difficulties in defining science-led management decisions and developing sound and smart land-use-led HWC mitigation programs since mitigating HWC requires an understanding of how HWC varies in space and time (Gastineau et al.,2019). Previous studies in SC have focused on ecological connectivity (Brennan et al, 2020; Chibeya et al, 2021; Naidoo et al, 2022).

The central location of SC within KAZA TFCA makes it a critical connectivity landscape for elephants and other large carnivores. The transboundary flow of wildlife traversing the ecosystem from Namibia and Angola increases the risk of HWC and has tremendous impacts on the local community. Despite of SC's transboundary geographical nature, there are no studies in SC that have focused on quantifying the damage of HWC, analyzing geographical patterns, examining its relationship with habitat use, and mapping HWC. In addition, SC is a unique landscape in that, it hosts about 5,000 people inside the national park (Ministry of Tourism and Arts (MOTA), 2019). Therefore, spatially mapping HWC (hotspots) will provide new insights with respect to human wildlife coexistence and inform innovative HWC management strategies.

1.3 Aim

The aim of this study was to map areas at risk of HWC to inform mitigation measures in Sioma Ngwezi National Park and parts of Lower West Zambezi Game Management Area collectively called Silowana Complex.

1.4 Objectives

The objectives of the study were:

i. To analyze forms of HWC in Silowana Complex
ii. To model HWC hotspots in the Silowana Complex and
iii. To establish community led HWC mitigation measures in Silowana Complex

1.5 Research Questions

The study answered the following questions:

i. How does HWC manifests itself in Silowana Complex?
ii. When does HWC occur in Silowana Complex?
iii. Where are HWC hotspots be in Silowana Complex?
iv. How is HWC mitigated in Silowana Complex?
v. How can existing HWC mitigation measures be enhanced?

1.6 Significance of the Study

The results of this study will contribute to the preparation of HWC mitigation strategies for the Silowana Complex (SC) that would guide HWC management responses that are currently lacking in the SC. Secondly, this study will provide HWC SC specific information, which will help in the prioritization of areas for conservation. Lastly, this study will also enhance coexistence between humans and wildlife specifically by moving the human community to a situation where they consider the benefits over the consequences of living with wildlife.

1.7 Organization of the Report

This thesis is structured into six chapters. Chapter 1 introduces the study. Chapter 2 presents a summary of the literature reviewed and the theoretical framework of HWC. Chapter 3 describes the study area. Chapter 4 presents the research methodology. Chapter 5 highlights the findings, results, and discussion. Chapter 6 presents the conclusion and recommendations of the study based on the findings.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction to Literature Reviewed

This chapter gives a review of relevant literature. It defines HWC, discusses HWC as a global conservation challenge, a global opportunity for biodiversity and communities. Further, it gives an overview of HWC in Africa and Southern Africa and it further highlights mitigation measures and factors influencing HWC. It also presents constraints and challenges for mapping and analyzing HWC. It ends with a theoretical and conceptual framework of HWC.

2.1 Human Wildlife Conflict

HWC denotes situations where wildlife affects humans negatively (physically, economically, or psychologically), and where humans likewise negatively affect wildlife (Draheim et al. 2015). This definition includes the fact that interactions between wildlife and people can cause damage and costs to both sides and even result in disagreements between different groups of people "Human-Human Conflicts" (HHC) (Jacobsen and Linnell 2016). Ngcobo et al. (2018), suggested that HWC occurs when human actions cause an adverse effect on wildlife or vice versa. For instance, if elephants compete with humans for space and resources, significant conflict can arise. If HWC occurs, not only is there a risk of property loss, but human safety may also be jeopardized. The outcomes for humans are often the destruction of crops and/or property, injuries, or loss of human life, while wildlife may suffer injuries and retaliatory killings (Muyoma, 2016).

2.2 Human Wildlife Conflict: A Global Conservation Challenge

According to IUCN (2023), wildlife continues to pose a direct threat to the safety, livelihoods and well-being of people. Further, that retaliation against the wildlife species by humans is often blamed, hence conflict between groups of people about what should be done to resolve the situation. Although this is not a new phenomenon, people and wildlife have lived in proximity to each other since time in memorial. However, this relationship is becoming much more of a global concern for conservation (IUCN, 2023).

In addition, conflicts over wildlife, commonly called human-wildlife conflict involve many different terrestrial and aquatic species, ranging from large cats, bears, elephants, deer, primates, sharks, seals, crocodilians, snakes, rhinos, otters, to invertebrates and plants, and many more (Scholes and Mennell, 2008: Muyoma 2016; Mukeka et, al, 2019: Barnes, 1982: Bell,1984: Hoare & du Toit, 1999: Hoare, 2001: Parker & Osborn,2001: Parker, 2006 and Pool 1996). HWC also negatively affects human communities, which need to support and benefit from the wider conservation goals (IUCN SSC HWCTF, 2020). Further, HWC poses serious challenges to governments and organizations trying to align wildlife conservation with sustainable development, among other pressures. Where conservation ‘successes’ have resulted in wildlife population increases, or species have recovered and expanded their ranges, HWC’s often follow (IUCN SSC HWCTF, 2020).

Globally, extensive efforts to understand and manage HWC’s have revealed that the conflict tend to be complex, dynamic and multi-layered. Effective and practical methods for preventing the impacts of wildlife on people and their livelihoods (such as livestock predation or crop raiding) are, in many cases, difficult to find (IUCN,2020). Retaliatory or preventative persecution of wildlife by people is often complicated by past experience, fears, perceptions or wider underlying social tensions.

World over, it has been realized that, efforts to manage HWCs often do not sufficiently seek to understand and address the underlying social conflicts that shape these situations (IUCN SSC HWCTF, 2020). Faced with urgent pressures to address the visible damage or threat, organizations and governments trying their best to alleviate the situation are often pressured into rushed physical interventions to control damage and retaliation. However, HWC’s involve tensions among the underlying values of the parties involved, which requires entirely different approaches for which there is often insufficient expertise (IUCN,2020).

In addition, the position of IUCN (IUCN, 2020) is that, the management of HWC is best pursued through sustained, collaborative and process-driven efforts, with the technical support of interdisciplinary expertise, including Indigenous and/or community leaders, peacebuilding practitioners, animal behavior specialists, geographers, social scientists, biologists, development economists and others, to develop more integrated and sustainable approaches to addressing this global challenge. Some HWC's involve situations where lives and livelihoods are at very serious risk, requiring urgent attention that cannot wait for the outcomes of research, dialogues and conflict mediation.

2.3 Human Wildlife Conflict: A Global Opportunity for Biodiversity and Communities

Again, HWC presents not only a global challenge, but also an opportunity for biodiversity and communities. It is an opportunity in that, it calls for global and collect action. Making it a crucial part of the global conservation agenda. For instance, it aligns with the, UN Convention on Biological Diversity's vision for the planet in which "humanity lives in harmony with nature and in which wildlife and other living species are protected." (IUCN SSC HWCTF, 2022).

Globally, it has been acknowledged that, the ever increasing HWC, if not addressed will hinder achievement of many of the Global Sustainable Development Goals (SDGs), such as SDGs Goal 1: No poverty; Goal 2: Zero hunger; Goal 3: Good health and well-being; Goal 5: gender equality; Goal 8: Decent work and economic growth; Goal 9: Industry, innovation and infrastructure; Goal 12: Responsible consumption and production; Goal 14: Life below water and Goal 15: Life on land (United Nations, 2023).

Recognizing that, Sustainable Development Goals (SDGs) are part of 2030 Agenda for Sustainable Development (SD) that aim to eradicate poverty, achieve economic prosperity, gender equality, ensure social well-being, promote sustainable management and use of natural resources, and protect the Earth's natural ecosystems. However, the occurrence of HWC may impair SDGs to be achieved in developing regions where people and wildlife co-occur frequently (Yeshey, et al, 2023). Certainly, Social and ecological effects of HWC such as; a) Crop, Property & Livestock damage, b) Food & Livelihood insecurity, c) Loss of human life and Injuries, d) Retaliatory killing of wildlife, e) Extinction of Species and f) Changes in ecosystem structure and function if not addressed or mitigated, they have the potential to perpetuate poverty, hinder economic prosperity for community members, affect the social well-being of people and lastly, promote unsustainable management and use of natural resources. Surprisingly, there are few studies which have examined how HWC impedes achievement of SDGs (Yeshey, et al, 2023).

At a global scale, HWC is an opportunity for biodiversity conservation and affected communities, since HWC needs to be addressed at relevant scales that often transcend jurisdictional boundaries, and that it suggests an urgent need to create a global enabling environment that ensures a safer and more beneficial coexistence of people and wildlife, focused on empowering affected communities, ensuring that they have the knowledge, skills, resources, resolve and capacity to protect their own lives, crop, livestock and their property (IUCN Resolution (WCC 2020 Res 101), 2020).

2.4 Human Wildlife Conflict in Africa

Humans and wildlife have co-existed in Africa, having a long history of cohabitation (Scholes and Mennell, 2008). Literature indicates that the increase in human population is a driver of HWC since, it results in the degradation of wildlife habitats and reduced landscape connectivity (Mukeka et, al, 2019). Another driver is the significant increase in wildlife populations relative to their historical range (Tiller et al, 2020). As a result, wildlife gets forced into closer contact with people leading to frequent and severe competition between people and wildlife over natural resources and space. The above situation is also observed in Southern Africa.

2.5 Human Wildlife Conflict in Southern Africa

Southern African countries and particularly, Angola, Botswana, Namibia, Zimbabwe, and Zambia are still predominantly agrarian societies with more than 50 percent of the human population relying on agriculture for income and livelihood (Muyoma, 2016). In countries where agriculture serves as the backbone of the economy, the conflict between people and wildlife is consistently present. In southern Africa, HWC has become an issue of regional concern and is frequently deliberated by national parliaments and community local meetings (Muyoma, 2016).

The most commonly cited conflicts are loss of human lives, crop depredation, attacks on humans, and wildlife roaming very close to human settlements (Jadhav & Barua, 2012). Crop depredation is the most common form of HWC cited in Angola, Botswana, Namibia, Zimbabwe, and Zambia (Muyoma, 2016). Further, Matseketsa et al, (2019) confirmed that crop raiding, particularly by elephants and other wild ungulates, is more common followed by livestock depredation and disease transmission to domestic livestock. Further, his findings were also consistent with other studies, for instance in India and Nepal, where Karanth and Nepal (2012) found crop damage to be the most prevalent and persistent form of HWC than livestock loss, human injury and death. In addition, (Malugu et al., 2011) seems to suggest that the high incidences of crop damage recorded relative to other conflict types might be attributable to the proximity of crop fields to protected areas.

Less cited but important aspects of HWC are the hidden costs associated with guarding crop fields, forgoing activities due to fear, psychological disturbance, and transaction costs incurred when the property is damaged or even loss of human life is experienced (Jadhav & Barua, 2012). This situation is worsened by the fact that most of the countries in southern Africa do not provide any form of compensation arising from the loss of lives or property due to wildlife damage except for a few localized interventions in Namibia (Gross, 2019).

In as much as, the increase of HWC has been acknowledged as one of the threats due to both increasing wildlife populations and expansion of their range, most countries in southern Africa except for Namibia have not developed national strategies for dealing with HWC (Gross, 2019). To address this gap, governments in southern Africa should mobilize resources required to develop national HWC management strategies. Therefore, this study will contribute consolidated and updated information on HWC in the study area that could inform the development of the HWC management strategy that DNPW is planning to develop.

Regarding wildlife populations in Southern Africa, it could be indicated that, Southern Africa continues to hold by far the largest number of elephants on the continent nearly 75% of these elephant's form part of a single population in the Kavango Zambezi Trans-Frontier Conservation Area (KAZA TFCA), some 520,000 km² in extent (Thouless, et, al, 2016). The recent elephant survey in the KAZA TFCA estimated that, the TFCA held more than 50% of the remaining African savanna elephants (*Loxodonta africana*) found on the continent and is the largest contiguous transboundary elephant population globally, with prior estimates between 184,000 and 243,000 elephants (Thouless et al., 2016).

According to Bussire and Potgieter (2023), the KAZA Elephant Survey (2022), estimated a total population of 227,900 (±16,743) elephants in the KAZA TFCA, with a PRP of 7.34%. Comparing the results of this survey with those of recent former surveys, the overall elephant population in the KAZA TFCA appeared to be stable, with some areas showing population increases, others remaining stable, and some possibly experiencing a decrease. However, the Zambian Component of the KAZA TFCA (Sioma and Kafue Ecosystems together), indicated a decline in the number of elephants from 6,688 in the 2014/2015 elephant survey to 3,840 in 2022 representing 2% of the total population of elephants in the KAZA TFCA.

In addition, the KAZA Elephant Survey (2022) also estimated populations for other surveyed wildlife species in the KAZA TFCA survey area are as follows: buffalo 78,264 (±18882), giraffe 12,771 (±1789), hartebeest 10,905 (±2538), hippopotamus 17,006 (±2940), impala 100,028 (±12695), roan 7,428 (±1917), sable 39,966 (±7386), wildebeest 22,245 (±8496) and zebra 88,250 (±28059). (Bussire and Potgieter, 2023). Therefore, as both human populations increase and as conservation efforts become successful in reversing population declines in wildlife that were experienced between 1980 to the early 2000s in southern Africa and Africa in general, the interaction of humans and wildlife is expected to increase, leading to increased HWC.

There is no doubt that HWC is triggered by increased populations of both wildlife and humans interacting on a finite spatial terrestrial. The Zimbabwean component of KAZA for instance holds 65,028 (±9457) elephants representing 29% of the elephant population in KAZA (Bussire and Potgieter, 2023). In the same region, Hwange National Park is a classical reference in Zimbabwe. The park has an ecological carrying capacity of 15, 000 elephants, in 2008 the park held over 45,000 elephants (Chamaillé-Jammes et, al, 2008). This has resulted in an alarming rate of loss of natural habitat, mainly mature trees, savanna woodlands, and other animal species in local communities surrounding Hwange. Protected areas like Hwange in southern Africa have not been spared from high wildlife densities, with human and wildlife conflicts becoming more prominent. Dozens of people have lost their lives while others are permanently disabled and are being disabled by wildlife while crops are destroyed. Simply put, thousands of peasant farmers are impoverished because their crops are destroyed daily, their livestock is killed and their property is destroyed (Nyashadzashe, 2017).

In addition, protected areas in Botswana are experiencing a similar intensity of HWC as Hwange National Park. Botswana for instance, holds 58% of elephants in the KAZA TFCA translating in 131, 909 (±11933) elephants (Bussire and Potgieter, 2023. The eastern Okavango Panhandle is considered both a conservation stronghold for elephants in Botswana as well as a (HWC) hotspot. However, literature has shown that 16,000 people in that region compete for space and resources with over 18,500 elephants (Songhurst, 2017). The current situation in Southern Africa is no exception to Zambia and the study area inclusive. HWC will continue increasing as the human populations and settlements expands, and wildlife populations increase.

2.6 Institutional Framework Relevant to Human-Wildlife Conflicts in Zambia

In the Zambia Wildlife Act No.14 of 2015[1], the term 'human-wildlife conflict' is not expressly defined in the legal framework. However, it can be assumed that the management of HWC is part of the non-specified functions of DNPW. It seems to appear that, the management of HWC, is an important role played by the authorized officers, who can be a wildlife police officer, a police officer of the rank of inspector or above, a community scout or an honorary wildlife police officer, to whom one reports the killings or conflict with wildlife for self-defense or property defense, and by the Wildlife Management Licensing Committee to which the report is submitted within 48 hours.

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[1] Section 5 (extract)- "(1) There is established in the Ministry responsible for tourism the Department of National Parks and Wildlife which shall be responsible for the administration of this Act under the general direction of the Permanent Secretary of the Ministry. (2) Subject to the other provisions of this Act, the functions of the Department are to — (k) assist and advise the boards in the management of human and natural resources in Game Management Areas and open areas which fall under their jurisdiction; (m) ensure the systematic management of financial, human and natural resources for wildlife conservation so that the abundance and diversity of species is maintained at optimum level; (n) advise the Minister on the regulations required to conserve, protect and manage wildlife in National Parks, Community Partnership Parks, bird and wildlife sanctuaries, Game Management Areas, open areas and private wildlife estates;

Section 32 (extract). "(1) A local community along geographic boundaries contiguous to a chiefdom in a Game Management Area, an open area or a particular chiefdom with common interest in the wildlife and natural resources in that area, may apply to the Minister for registration as a community resources board."

Section 33 (extract)- "(1) The functions of a board are to promote and develop an integrated approach to the management of human and natural resources in a Community Partnership Park, Game Management Area or an open area falling under its jurisdiction.

Section 75(1): Notwithstanding anything to the contrary in this Act, a person may, if it is necessary, kill a wild animal in defence of oneself or in defense of another person.

An authorized officer may arrest a person, without warrant, where he or she has reasonable grounds to believe that he or she has committed an offence or is about to commit an offence, and there is no other way to prevent the commission of the offence, or is willfully obstructing the authorized officer in the execution of the officer's duties. An authorized officer who makes an arrest shall, without undue delay, have the person arrested brought to a police station (The Zambia Wildlife Act No.14 of 2015).

The law in Zambia does not provide for preliminary strategies to manage or prevent human-animal conflict, nor does it specifically provide for financial compensation of wildlife damage in human-animal conflict. When an animal that has caused damage to property is killed in line with the provisions of the law, its carcass or trophy can be given to the victim as compensation for the damage suffered. Therefore, the law in Zambia does not provide for specific functional coordination to manage, prevent or control HWC other than what is permissible within the broader discretion of the Minister

2.7 Factors Contributing to Human Wildlife Conflict in Zambia.

Zambia has a mosaic of overlapping Protected Areas (PAs) with different levels of classifications and protection. Gross, (2018) suggested that areas of overlap, where interaction between wildlife and people takes place, are prone to negative interactions, particularly when; (a) highly attractive crops are farmed, (b) species are being driven out of their native habitats for anthropogenic usage, (c) there is close proximity of farms to boundaries of national parks or community ranches (d) corridors connecting protected areas lie outside. Other factors such as habitat loss, fragmentation, and climate change exacerbate the situation (Gross 2018). In addition, climate variability which affects the availability of food and water for both humans and wildlife is another hidden factor expected to contribute towards increasing HWC (Hanks, 2006).

2.7.1 Habitat Loss

According to Nyirenda and Tembo (2016), HWC occurrences are influenced by competition for space and land resources between humans and wildlife. They suggested a wide array of parameters that could explain HWC including proximity to *refugia*, proximity to water, crop/livestock types, farm size, vegetation type and countermeasures. In addition, the availability of forage is also one of the factors determining wildlife movements (Thouless, et al 2016). Forests feed wildlife and contain more than 50% of plant species, rendering it the most important pillar in the ecosystem (Mayaux, et al 2005). The overexploitation of forests raises numerous questions regarding the survival of wildlife. Therefore, habitat loss constitutes a relevant factor contributing to HWC (Ngcobo et, al, 2018). In addition, habitat loss results from habitat degradation and fragmentation as discussed below.

2.7.1.1. Habitat Degradation

Vinya et, al (2011) suggest that, Zambia is currently experiencing high levels of deforestation between 250, 000 and 300 000 ha/year mainly caused by shifting cultivation. This also applies to the area under study. Habitat degradation remains a major contributor to habitat loss and can take place when human activities bring about structural changes in forests rendering them unsuitable for wildlife. In addition, land available for wildlife declined to ±15% in 2007 (Blanc et, al 2007). Further, between 2007 and 2015, a substantial decrease of 52 to 82% in Africa was reported. This decline in habitats is caused mainly by the increasing pressure on natural areas from mining, logging and the transformation of land for agricultural use (Thouless, et al 2016). As a result, wildlife gets forced to migrate in search for *refugia*, in the end, increasing its interaction with humans (Nyirenda and Tembo, 2016).

2.7.1.2. Habitat Fragmentation

Wildlife has increased contact with humans due to changes in land use (i.e., fragmentation of habitats because the land is converted for crop cultivation, settlement, and livestock grazing) (Nelson et al. 2003). As a result, of fragmentation, the human-wildlife interface expands and creates a land-use pattern not conducive to wildlife foraging (Lahm 1996 & Hoare 1999).

2.7.2 Increasing wildlife Populations

In Zambia, the major threats to the wildlife populations are the increasing human-wildlife conflicts as the population recovers from the heavy poaching scourge of the early 1970s (with over 200, 000 elephants) to the late 1980s (18,000 elephants) (CITES, 2019). As wildlife populations start to increase country-wide, more range will be reclaimed and most wildlife traditional movement routes that have been overtaken by human settlements are reclaimed. The projected increase in wildlife populations in Zambia is expected to contribute to increasing HWC, resulting in crop, and property damage, livestock depredation and loss of human life and injury caused by raiding wildlife. Therefore, the effects of HWC cannot be ignored particularly in areas with high wildlife densities like the SC (CITES, 2002).

2.7.3 Climate Variability

General Management Plans (GMPs) for the Lower west Zambezi Game Management Area and Sioma Ngwezi National Park and (2016 and 2019 respectively) collectively recorded that, climate variability has affected the supply of water in the SC resulting in wildlife spending more time in settled areas along the Kwando and Zambezi rivers, thereby increasing HWC, which has resulted in fatalities for both humans and wildlife. This study will validate the above record by mapping the spatial distribution of HWC hotspots in the SC. Further, climate variability affects temperature and water availability that may contribute to HWC trends and patterns (Ngcobo et, al, 2018). Further, literature shows that the movement of wildlife is affected by the availability of water (Dunkin, et al 2013). For instance, elephants tend to congregate in areas with sufficient water to drink and in which to bathe and play, especially in coastal lowlands and along river valleys (Kerley & Landman, 2006).

2.8 Mitigation Measures of Human Wildlife Conflict from Selected Countries in Africa

In most countries in southern Africa and Zambia inclusive, the authority to manage HWC lies in state authorities in most cases the state's ways of controlling HWC have resorted to lethal and non-lethal methods (Gross, 2019). Non-lethal methods also known as passive methods include (a) taking no action, (b) enlarging the range available to wildlife, (c) fencing to contain or exclude wildlife, (d) the use of repellents, (e) manipulating water supplies and (f) scaring away problem animals by lighting fires, use of chili guns, beating drums, or necessarily making noise. These methods are non-lethal and therefore favored by many on ethical grounds (Cumming & Jones, 2005). Sometimes countries in southern Africa embark on expensive but effective management options available to redress HWC which include the capture and translocation of wildlife from areas high to areas with low wildlife populations like what Zimbabwe and its partners did in 2018 when 100 elephants were moved from the South East Lowveld (Save Valley, Masvingo) to Rifa in Hurungwe (Mashonaland Central) (Sango Wildlife Conservancy, 2018).

Lethal control methods also known as active methods include (a) driving/disturbance of wildlife by creating areas of fear through targeted hunting or killing, and (b) culling and cropping (Cumming & Jones, 2005). These methods are limited to the elimination or destruction of the problem animals mostly by shooting (Treves and Karanth, 2003). This Problem Animal Control (PAC) method is executed by professional hunters (PHs) and law enforcement officers under the authority of government agencies responsible for wildlife. For instance, in Zimbabwe, between 2002 and 2006, more than five thousand cases of damage by elephants were recorded, of which around three thousand cases were attended to, resulting in 774 elephants being controlled (Le Bel et al. 2011). Community action in forms of retaliatory killing or elimination of problem animals is a criminal offense in most southern African countries including Zambia (Zambian Wildlife Act No. 14 of 2015). Under normal PAC circumstances, communities benefit from meat handouts of edible species, ivory, and other trophies that are taken to national stockpiles by appropriate authorities.

Another lethal control method is culling, literature suggests that culling of wildlife is legal in southern Africa and Zambia inclusive. Culling is mainly done for the conservation of wildlife themselves and the preservation of their habitat, which if destroyed takes time to recover, especially the natural vegetation (Gross, 2019). Most southern African countries initiated culling in the 1960s, Uganda did it in 1965, Zambia (1965-69), Namibia (1983-85) South Africa (1968), and in Zimbabwe, it was done in 1965, 1969, 1970, 1972, and 1988. Zimbabwe culled more than 50 000 elephants between 1965 and 1988 (Cumming & Jones, 2005)

2.9 Mapping Human Wildlife Conflict

Potential risks of HWC specifically conflict between lions, elephants and humans in Africa have been highlighted. However, Di Minin et al, (2021) reviewed that a database on the spatial distribution of conflict locations between humans and lions and elephants is not available across Africa.

Further, HWC has been mapped in the context of ecological connectivity and human and wildlife Interface. Lamb et al, (2020) reviewed that conflict and connectivity are clearly emerging as interconnected challenges for wildlife conservation across multiple-use landscapes. While connectivity and coexistence with people are crucial for species persistence in heterogeneous landscapes, they present a conservation paradox: connectivity enhances wildlife viability, but dispersal through human spaces can elevate conflict and mortality risk (Lamb et al, 2020). Therefore, studying HWC and ecological connectivity jointly yields greater insights and predictive accuracy, which would have broad implications for science and conservation in coupled human–natural systems

In addition, the determinants for HWC have not been fully understood in most parts of Africa (Gross, 2019) and to address HWC effectively, geographical, ecological and social factors have to be taken into consideration and comparable HWC data needs to be produced. Currently, geographical patterns of HWC are not documented in most parts of Africa (Gross, 2019). In the case of Zambia and the study area, NGOs and authorities collect data on HWC. The collected data is patchy due to constraints of labor, tools, and transportation. In addition, authorities are slow to respond and to analyze collected HWC data. No maps and analysis can be conducted on most available data due to the lack of geo-referencing. Therefore, earth observation, geographical information systems, and spatial modeling systems were used in this study to overcome the above challenge. In addition, multiple studies in southern Africa and Zambia inclusive have been carried out, using modified research designs and methods**.** Several research and conservation organizations have developed their own monitoring schemes and tools to evaluate HWCs. However, most of them have been developed without using comparable formats (Gross et al, 2022).

Current HWC data collection systems in Southern Africa include, Event Book Systems in Namibia and part of the study area in Zambia. This system is very brief, it does not give details on how the conflict occurred, the stage of growth, and the area classification of where the conflict occurred. Further, given that it is paper-based, it takes too long to report conflict, and its labor intensive in that it requires digitalization if any data would have to be analyzed. The Spatial Monitoring and Reporting Tool (SMART) application is used in Zambia by law enforcement officers to monitor HWC. This system is cost-intensive with respect to the tool itself and the transportation costs required to access farming areas that may be limited during the rainy season. In addition, Management Oriented Monitoring System (MOMS) is used in Angola and Mozambique to capture data on HWC and its limitations are not different from the above systems indicated (Gross, 2021). Therefore, there is a need to modernize these systems based on improved satellite imagery systems, digital data collection, and GPS tracking technology.

2.10 Challenges for Mapping of Human Wildlife Conflict

Although the importance of HWC monitoring data and visualization is obvious, most countries and programs on the African continent seem to be facing constraints as discussed in the subsections below.

2.10.1 Lack of comparable data on Human Wildlife Conflict

The lack of comparable data on HWC decreases the possibility of analyzing factors and drivers of HWC between different regions and species, thus making a regional and global understanding impossible (Sitati et al. 2003). Hence, the need for a uniform system of data collection and a standardized database nationally to support management decisions to reduce damage by wildlife (Nyhus and Tilson 2004, Goodrich 2010, Poessel et al. 2013, Poledníková et al. 2013). In Kenya, the lack of reliable data on crop damage caused by wildlife led to the development of an unrealistic compensation scheme. This compensation scheme was implemented with promising results, but it was suspended because the system had become unworkable (Muruthi, 2005).

2.10.2 Gaps in the existing data

There is a large number of unreported HWC cases in Africa and Zambia inclusive. In Hwange District in Zimbabwe for instance a significant proportion of farmers do not report damage to anyone, as they just do not know whom to report to or would have to travel far (Gross, 2019). This may not be different from the situation in the study areas as well.

2.11 Theoretical Framework

This study is based on; the Social-Ecological Systems (SES) developed by Berkes and Folke (1998). The theory holds that humans are a part of and not separate from nature. Further, that the delineation between social systems and natural systems are arbitrary and artificial. Recent studies have applied the SES theory to understand Human-Wildlife Interactions (Chomba et al 2012; Lischka et al 2018; Salerno et al, 2020)

In Zambia for instance, Chomba et al. (2012) applied the SES theory to determine causes, consequences, and management responses of HWC in Zambia during the period 2002 to 2010. They found that, during the period of 2002 to 2008, a total of 347 people were killed or 49 people killed annually by five species of wildlife; crocodile, elephant, hippo, lion, and buffalo. This theory therefore, holds that the interactions between humans and wildlife can be positive or negative and that people compete with wildlife for food and resources (Lischka et, al, 2018). It further indicates that people have innovated and adapted to become a dominant ecological force on the planet to the point that this conflict has contributed to the extinction of numerous species, changes in ecosystem structure and function, and immeasurable loss of human life, crops, livestock, and property. This theory was recently used to study wildlife impacts and vulnerable livelihoods in a trans-frontier conservation landscape in Southern Africa by Salerno et, al (2020).

Lastly, applied to this study, the SES theory holds that HWC occurrences would inform areas prone or at risk of HWC and forms of HWC specifically; damage to (crops, human life, and properties) because of proximity to and competition for *refugia*, water, and land cover/use type which tend to exacerbate the frequency of HWC.

2.12 Conceptual Framework

Figure 1 depicts the conceptual framework, highlighting drivers, effects, mitigation measures of HWC and adaptive management. In addition, figure 1 shows the conceptual framework model for HWC based on cyclical process, which involve a closed loop system of interaction and feedback within the human and natural system, this is applicable to the study in that the ultimate goal is to support co-existence of humans and wildlife in a dynamic and interconnected ecological landscape.

The study used the notion of a set to describe the model, such as, (Drivers and Factors of HWC) that would exacerbate Human and Wildlife interactions that would have effects on humans and ecosystems (Social and Ecological Effects of HWC). Further to mitigate the effects of HWC the study categorized two sets of measures {Social and Ecological Mitigation Measures} that could prevent and mitigate the effects of HWC. In addition, for the purpose of adaptive management HWC mitigation measures, factors and drivers have to be monitored and evaluated if interventions would have to remain relevant (Social and Ecological Monitoring, Evaluation, Adaptation and Learning (MEAL)) MEAL is relevant in influencing a set of adaptive actions towards HWC.

In addition, Figure 1. explains the linkages among the sets described above;

Firstly, it starts by defining the problem in this case (HWC) that is driven by social and ecological factors listed as follows. a) Human and Wildlife Population dynamics, b) Habitat Loss, c) Blocking Wildlife corridors, d) Climate variability and e) Anthropogenic activities.

Secondly, HWC drivers exacerbate Human and Wildlife interaction resulting into social and ecological effects of such as; a) Crop, Property & Livestock damage, b) Food & Livelihood insecurity, c) Loss of human life and Injuries, d) Retaliatory killing of wildlife, e) Extinction of Species and f) Changes in ecosystem structure and function.

Thirdly, these effects of HWC could be mitigated and prevented by implementing two sets of social and ecological measures categorized as a) Lethal and b) Non-lethal HWC mitigation measures.

Finally, the above drives, effects and mitigation measures should be monitored and evaluated to support adaptive management.

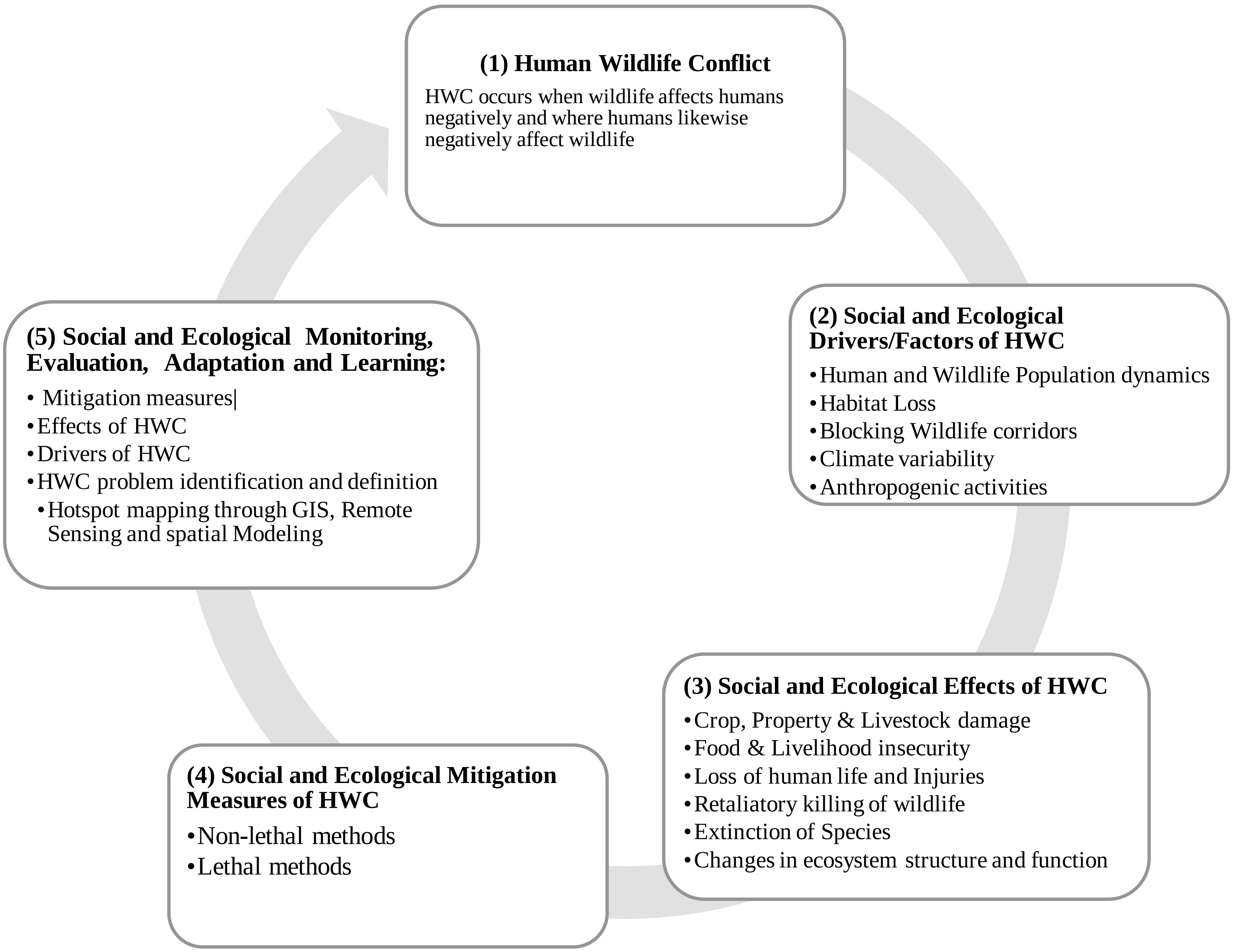

Figure 1: Conceptual Framework for Human Wildlife Conflict Mitigation

Source: Adopted from (Lischka et al, 2018)

CHAPTER THREE DESCRIPTION OF THE STUDY AREA

3.1 Location

The study area lies between latitudes 17°10' south and longitudes 23° 40' east (See Figure.2). In SNNP and the southern portion of the LWZ GMA collectively called Silowana complex (SC). SC is located in the southwest corner of Zambia comprising the SNNP and the southern portion of the LWZ GMA. It traverses parts of the Sesheke, Senanga, and Shangombo Districts. On its north side, SC borders both Angola and Namibia. It is part of the contiguous set of protected areas that includes Luengue-Luiana and Mavinga National Parks in Angola, Bwabwata National Park, and other conservation areas in Namibia that are part of the KAZA-TFCA. The central location of SC within KAZA makes it a critical connectivity landscape for elephants and other large carnivores.

The SC presents a unique case for this study because the SNNP has since 1971 when it was gazzeted incorporated human settlements inside the park. The villages that are inside the park include Dihele, Imusho, Ngweze, Mbao, and Mbala. These villages are spatially distributed within the national park, hosting sub-villages and communities. It was estimated that about 5,000 people live in the national park (Ministry of Tourism and Arts (MOTA), 2019). Despite this, the SNNP also has a Game Management Area (GMA) around it, with some communities living in the GMA. It could be expected that HWC would be more in the national park than in the GMA. Therefore, the presence of settlements within these protected areas as specifically in the national park presented a unique opportunity to map HWC hotspots. The study area is shown in Figure 2.

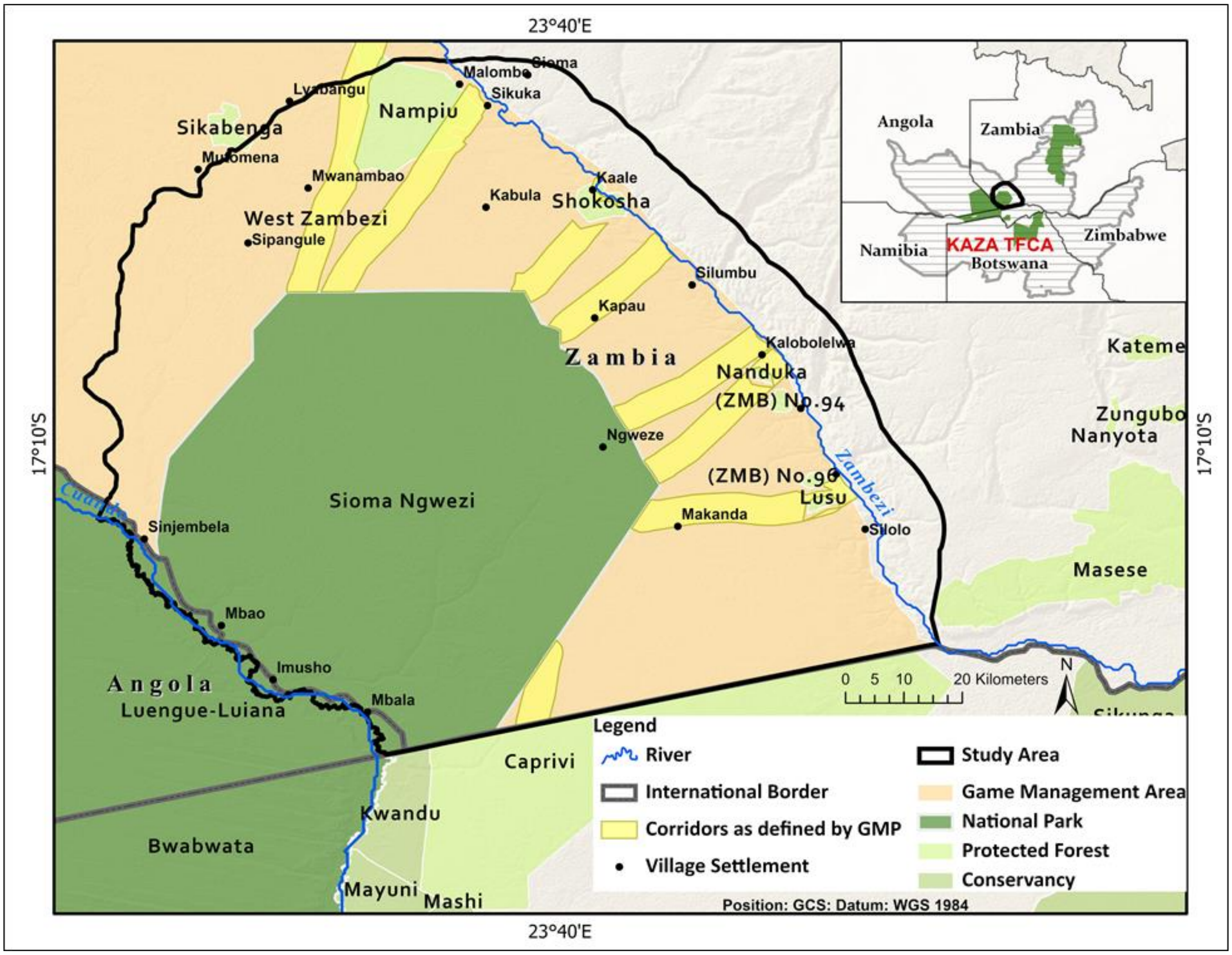

Figure 2: Silowana Complex at the Centre of the KAZA TFCA

Source: Adapted from DNPW (2019)

3.2 Population Size

The study area is inhabited by around 15,000 people (10, 000 in the GMA and 5000 in NP) in a cluster of villages that are spatially distributed, hosting sub-villages and communities. (MOTA, 2019).

3.3 Social Economic Characteristics

The study area is characterized by a mono economy, poor infrastructure, poor access to social & economic amenities, poor water & sanitation conditions, and low levels of economic activity. The economy in the study area is based on natural resources exploitation, subsistence agriculture and livestock rearing as well as small scale trading in groceries. High unemployment levels due to lack of industries is as a result of dependency on the major employer government both the central & local government. The area is also characterized by high illiteracy levels & lack of adequate skilled labor (MOTA, 2019).

Community livelihood activities in this area can be categorized based on three broad categories; Resource exploitation: is carried out through fishing, timber production through the harvesting of timber and non-timber products, handicrafts by carving mortars, stools and chairs, axe handles, cooking sticks and doors. Weaved products include baskets, reed mats, and hats. Blacksmith products are mainly axe, hoes and pots. Subsistence Agriculture: the study area has farmers most of whom are small and medium scale with very few if any commercial farmers. Maize, sorghum, millet, groundnuts, cassava, cow peas, rice, etc are some of the food crops grown within the study area and Livestock Rearing: Cattle, goat, pig, chicken and duck rearing are the most common form of livestock rearing in the area (MOTA, 2016).

3.4 Climate

The climate of SC is characterized by two distinct seasons. The rainy season (November to April) and the dry season (May to October). The dry season could further be subdivided into the cool dry season (May to August), and the hot dry season (September to October). The rainy season is rather unreliable. Annual rainfall is less than 750mm, erratic, and of high intensity such that drought and moisture stresses are frequent (MOTA, 2019). The cropping season is 60-90 days. It is characterized by very high temperatures (up to 40 0C) in September-October. Frost is regularly experienced between June and August. Based on the average annual rainfall, length of the growing season, and soil characteristics, the larger part of the SC falls under Agro-ecological region IIb.

3.5 Soils

The national soil map of Zambia (Ministry of Agriculture,1991) generally classified the soils in SC as Orthi-Ferrallic Arenosols. Implying that they are excessively drained, very deep, very pale brown to yellowish brown, and loose to very friable sandy soils. Its physical structure is almost single to massive grain, loose and very friable in lower subsurface horizons of the soil profile with a low capacity to hold water and nutrients. The study area has a high soil acidity (pH 4.0-4.7) (MOTA, 2019). Chemically, the soils contain very low amounts of plant nutrient elements. Generally, these soils are of very low soil fertility status and are of low and poor arable agriculture potential.

3.6 Vegetation

According to General Management Plans (GMPs) for the Sioma Ngwezi National Park and Lower west Zambezi Game Management Area (2019 and 2016 respectively). The SC is endowed with many different tree species and grasslands. The flora is composed of diverse habitat types such as Zambezi teak *Baikiaea plurijuga* forests, grasslands, termitary associated bushland, and woodlands classified as *'kalahari' Brachystegia specie (sp)., Julbernardia sp., Isoberlinia sp., 'munga' Acacia sp., Combretum sp., Terminalia sp, 'mopane' Colophospermum mopane*, which are interspersed with flood plains and seasonal water pans on generally flat terrain and porous soils associated with Kalahari sand deposits. Forest cover in the SC is estimated at 30-35 %. (MOTA, 2016 & 2019).

3.7 Hydrology and Drainage

SC lies in a region drained by two river systems, the Kwando River on the southwest and the Zambezi River on the northeast. The Kwando River rises in the central plateau of Angola on the south-eastern slopes of Mount Tembo (Mepham, 1992; Mendelsohn & Roberts, 1997; Peel et al, 2012), then flows southeastward along the Zambian border and enters the Silowana plains (Peel et al., 2012). Seasonally inundated areas form due to lack of drainage of rainfall creating several pans due to the relatively shallow water table. Pans or small water bodies that are formed are either seasonal or perennial. Some of these small water bodies get connected to either the Kwando or the Zambezi during periods of high floods but when the water recedes they get cut off from the channel and some dry up before another rain season starts while others retain the water until the next rain season.

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This chapter describes the methods used for data collection, the sources of data, and how data were analyzed, including both primary and secondary data. Due to the complexity of the topic, a mixed methods approach was used whereby both quantitative and qualitative data were collected. This was done to facilitate cross-validation of findings and results.

4.2 Data Collection

4.2.1 Primary Sources of Data and sampling

Primary data were collected using a semi-structured questionnaire and key informant interviews. To further analyze forms of HWC and establish community led HWC mitigation measures in SC, this research used non-probability sampling when selecting respondents to a semi-structured questionnaire.

A total of 100 respondents were purposively sampled using homogenous sampling technique from a total population of 200 HWC incidents / victims for the period 2020 to 2021 acquired from DNPW. This technique was used on the basis that, the targeted population and sample involved people who had previously been involved in HWCs. Therefore, findings were expected to be clearer, accurate, precise and valid (Bornstein et al.,2013). As such, the details of the target population were accessed through the HWC incidence reports obtained from DNPW. These reports had the following attributes; Conflict species, Date, Year, Month, Complaints Name, Chiefdom, District, Latitude, Longitude, Forms of HWC, Conflict type, Number, Sex, Age, Activity and Action taken. Apart from household interviews, key informant interviews were also conducted.

4.2.1.1 Household Survey

A semi-structured questionnaire (Appendix 1) was administered to 100 households. The questionnaire contained questions organized around these themes; causes of HWC, settlement preference, common conflict species, forms of HWC, perceived impacts, mitigation measures, courses of action when HWC occurs, and distribution of HWC (Newing et al, 2011). The survey results helped to validate the findings from HWC hotspot spatial modeling and provided further insights into the lived experiences of respondents with wildlife.

42.1.2 Key-Informant Interviews

A total of 10 unstructured interviews were conducted to collect data from key informants (KI) who had extensive knowledge and experience by virtue of their position in the community and government. Those interviewed were: Staff from Conservation Non-Governmental Organizations which included the Elephant Connections and WWF Zambia. Others were representatives of Sesheke West and Mufulani Community Resources Boards, Sioma and Sesheke district agriculture extension officers in the Ministry of Agriculture, and staff from the Department of National Parks and Wildlife (Research, Law Enforcement, and Community Extension Officers). Appendix 2 shows a sample of the Interview Guide for Key Informants

4.2.2 Secondary Sources of Data

Secondary data in this study were collected from literature sources which included over 20 monthly HWC reports covering (2020 – 2021) from DNPW. HWC incidents were reported to DNPW by community members from different locations in the SC. About 200 HWC incidents were reported in the 20 reports.

Further, the study used 100 × 100 km^2 tiles of sentinel 2 (Level 1C) satellite images with a ground sampling distance (GSD) of 10 m. The images were downloaded from the Earth Explorer USGS image database (https://earthexplorer.usgs.gov/). The downloaded images were sensed in May 2022 as they were less cloudy. Specifically, the tiles L1C T34KFG, T34KHF, T34KGF, T34KGG, T34KHG, T34KFF, T35KKA, T34LGH, and T34KFG were used. The collected reports data were used to inform conflict incidents, while the satellite images were used to derive environmental variables (Land use and Land cover). This data was thus useful for modeling the response variable HWC probability. Outputs of the model were mapped for HWC hotspots and analyzed further as described under the data analysis section.

4.3 Data Analysis and Processing

4.3.1 HWC Incidence Data Analysis and Processing

The study treated all HWC incidents reported from 2020 to 2021 as the population of the study. HWC incident reports were subjected to further cleaning by confirming the conflicts using place names. The researcher worked with key informants and HWC victims to confirm incidents recorded and geo-located the incidents to known places. HWC incidents recorded by DNPW were assigned a unique identity and considered once as a single observation and assigned to only one category of damage (crop, livestock, and property damage) in a data schema that was developed by the researcher. The study used proportions to describe common conflict species and forms of HWC. Descriptive statistics were used to show the distribution of HWC incidents according to seasons, using Microsoft data analysis toolpak (Microsoft Excel Inc., 2013). In addition, responses from the household surveys and key informant interviews informed HWC mitigation measures. Responses from respondents were analyzed using a thematic approach and presented by tables and charts.

4.3.2 HWC Hotspot Data Analysis and Processing

The study modeled HWC occurrences obtained from DNPW together with three environmental predictors extracted from the land cover map (classified sentinel 2 imagery). Maximum Entropy MaxEnt software *(Version 3.4.1)* was used to model the probability of HWC. Hotspots were then extracted from the probability of HWC model output. It was imported into ArcGIS Pro *(Version 2.4.1)* in ASCII format, where the probability values were classified into ten classes based on equal intervals. The range 0.6 to 1 probability of HWC was considered as 'Human-Wildlife Conflict hotspot areas' and extracted as HWC hotspots then mapped using Geographical Information System platforms ArcGIS Pro (*Version 2.4.1*) and ArcMap (*Version 10.7*) creating two classes of Non- HWC Hotspot area for probability values below 0.6 and HWC Hotspot area for values above 0.6 using the Natural Breaks (Jenks) classifier its outputs informed the results which were then analyzed. The flow chart in Figure 3 depicts the process and a detailed exposition of how predictor and response variables were obtained

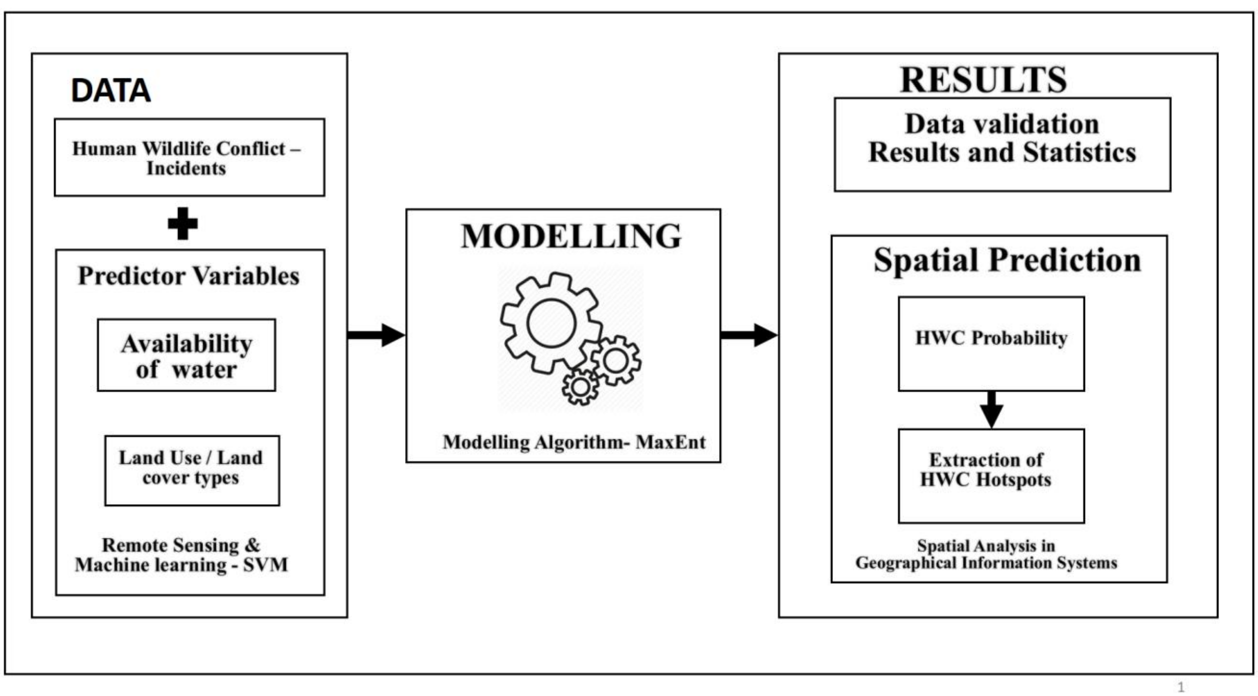

Figure 3: Schematic flowchart showing the methodological approach used in hotspot mapping

Source: Adapted from Mallick (2012)

4.3.2.1 Environmental/predictor variables data

Three environmental variables considered important for predicting HWC were selected. The major factors considered were anthropogenic pressure (settlements and cropland/Farms), land cover (vegetation), and availability of water (Mateo-Tomas et al., 2012; Naha et al., 2019). Research as shown that, foraging decisions made by animals are the underlying driver of the observed patterns of many forms of HWC (Hill, 2015). Foraging decisions typically involve tradeoffs between risks in accessing a food item and the net profitability of the food item (Baruch-Mordo et al., 2013). Therefore, it could be indicated that those be the major parameters considered. Hence the prioritization of land cover as a predictor variable. In addition, increased human-wildlife interface is largely driven by two factors: Firstly, the change in land use patterns that allows humans to spread into areas inhabited by wildlife (Warrier, 2021). Secondly, changes in the distribution patterns of wildlife species causing them to come into closer contact with human societies (Baruch-Mordo et al., 2013). Further, it should be stated that, these two aspects can, and often do, also influence each other, while also being influenced by other ultimate drivers such as climate change, although the impacts of this is not yet well studied (Warrier, 2021).

Therefore, this study derived the major factors considered; anthropogenic pressure (settlements and cropland/Farms), land cover (vegetation), and availability of water from the satellite imagery through land use and land cover classification and mapping as described under 4.3.2.1.1

4.3.2.1.1. Land use and land cover

The study used both supervised and unsupervised classification to classify a mosaicked, atmospheric and geometric corrected Sentinel imagery from ArcGIS Pro (*Version 2.4.1*) image classification wizard. The mosaic was then segmented using the inbuilt maximum likelihood unsupervised classification algorithm to classify the spectral data into a thematic map using the segmentation tool with the spectral detail set at 15.50, spatial detail set at 15, and the minimum segment in pixel size set at 20.

Segmentation provided a methodological framework for the machine-based interpretation of complex classes, using both spectral and spatial information, and generated better classification results with a higher degree of accuracy than pixel-based methods (Chettri et al., 2013). The algorithm helped to merge pixels with their neighbors having relative homogeneity criteria based on defined minimum mapping threshold units. Information about the spectral values of image layers, slope, and texture was used in the land cover mapping. Additional data relating to vegetation indices, for example, the normalized difference vegetation index (NDVI), and a land-water mask were also used for the mapping procedure. These indexes were calculated from the mosaicked image using the indices tool from ArcGIS Pro *(Version 2.4.1).*

To enhance the accuracy of the segmented classes, supervised classification was conducted using researcher-generated training samples based on the segmented image. A total of about 1.1 million pixels were trained based on five broad themes, Water, Forest cover, Wetlands, Settled/cultivated, and Shrub/grassland. The segmented image was classified using Support Vector Machines (SVM) classifier. SVM are one of the most robust and accurate methods of well-known Machine Learning algorithms (Bui, 2021). SVM Machine learning tool was applied because it aims at finding separating hyperplanes and separate pixels as reliably as possible into the distinct data classes. It has also been found reliable for predictive modeling in ecology and spatial data modeling. Appendix 3, shows a land use/ cover classification map of the study area.

In addition, the land use / cover classification accuracy was assessed using a confusion matrix based on the independent dataset generated from the google earth observations. The overall accuracy was 94% with Kappa statistics of 0.9 as shown in Appendix 4. User's accuracy ranged from 92% to 100% while producer's accuracy ranged from 83% to 100%.

4.3.2.2 Spatial Prediction/Response variables data

4.3.2.2.1 Spatial modeling of Human Wildlife Conflict Probability

MaxEnt software (version 3.4.1) was used for risk modeling of HWC risk areas. Data points regarding the incidence of conflicts were extracted from 20 HWC reports obtained from DNPW based on their coordinates (latitude and longitude) and saved in the CSV format. The derived land cover map (Appendix 3) was clipped to the study area and converted into an ASCII format as an input into MaxEnt. The MaxEnt model was run for 1000 iterations. A default setting of 10,000 maximum background points was accepted for the model run. The model's output was generated using the default format of Cloglog. This format provides an estimate of the probability of presence between 0 and 1, which is from the lowest to the highest probability of distribution (Phillips et al., 2006).

4.3.2.2.2 Predictive accuracy and validation of the Model

The predictive accuracy of the model was accessed on the basis of the area using the Receiver Operating Characteristics (ROC) curve and the Area Under the Curve (AUC) (Phillips et al., 2017). The Area Under the Curve (AUC) was considered for both training and actual data, plotted against sensitivity (correctly classified presences in the y-axis) and specificity (correctly classified absences in the x-axis) for all possible thresholds. The AUC value ranks between 0 and 1, in which <0.5 means no discrimination, 0.5 to 0.69 poor, 0.7 to 0.79 reasonable, 0.8 to 0.89 excellent, and >0.9 exceptional prediction (Vilar et al., 2016). HWC hotspot areas were then extracted from the probability ranges and analyzed with respect to protected areas in the study area. The model was trained on using 40 % of the actual HWC occurrence data from study area.

4.4 Limitations of the Study

The major limitation of this study was the geographical extent of the study area and the widely distributed hotspot areas, this made it difficult to verify each of the HWC incidents reported to DNPW and hotspot areas extracted from the model. In addition, not all incidents reported to DNPW had location information, to overcome this challenge some incident records were assigned known near places coordinates after consultations with community members and the predictive power of the model overcame this limitation. Further, the study only considered water availability and Land use/cover types, geographical and seasonal movement patterns and distribution of wildlife (based on expert knowledge from key informants) as predictor variables. However, the model did not consider elevation and the population density of livestock in the area. Elevation was not considered because the study area is relatively flat, therefore, it would not be a significant predictor of HWC.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1. Introduction

This chapter presents and discusses the results of the study. It begins by highlighting the population characteristics, common wildlife conflict species and then it focuses on describing forms of HWC observed in the study area, temporal and spatial distribution of HWC and HWC mitigation measures in SC.

5.2 Population Characteristics

This section of the chapter focuses on describing the population characteristics of the respondents interviewed, these could as well be referred to as the HWC victims.

5.2.1.1 Gender and Age

The results indicated that 58 % of the respondents were males and 42 % were females. This corresponds, with Munyao et, al (2020) who concluded that in Africa, most of those killed in HWC are men and that many of these incidents occur during the night. Further, 58 % of the respondents were between the age of 36-50 years, followed by 30 % representing 18-35 years, then 10 % represented 51-65 years and 2 % represented those that were above 65 years and 0 % for those that were below the age of 18 years. Therefore, it could be indicated, that the responses were based on experience, and maturity based on the fact that all the respondents were above the age of 18 years and below the age of 65 years.

5.2.1.2. Geographical Distribution of Respondents

With respect to the geographical location of respondents, findings show that 82 % of the respondents were in Lower West Zambezi Game Management Area (LWZ GMA)[2], 12 % were in the Sioma Ngwezi National Park (SNNP)[3], and 6 % were in the Open Area (OA)[4]. The results are not surprising because it is expected that you would find more HWC incidents in LWZ GMA and not in SNNP based on human density variations within these protected areas.

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[2] Game Management Areas comprise mostly communally-owned land that is used primarily for the sustainable utilization of wildlife, through hunting and/or non-consumptive tourism concessions for the benefit of local communities and the wildlife resource, but which can also be used for other land uses such as settlement, agriculture, forestry, mining etc. In addition, GMAs are jointly managed by The Department of National Parks and Wildlife and the Local Communities through Community Resource Boards (MOTA, 2018)

[3] National Parks in Zambia are mainly established to conserve faunal biodiversity, protecting the integrity of one or more ecosystems for present and future generations. National Parks exclude exploitation or occupation and provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities (MOTA, 2018)

[4] Open Area these are communally-owned lands used primarily for settlement, agriculture, etc. In addition, open areas are managed by Traditional / local authorities and the Local Communities (MOTA, 2018)

5.3 Common Conflict Wildlife Species

The total number of HWC incidents was 200 recorded between 2020 to 2021 by DNPW. The records indicated that the common conflict wildlife species in order of magnitude was as follows; African elephants (*Loxodonta Africana*) at 47 %, Common Hippopotamus (*Hippopotamus amphibius*) at 24 %, Nile crocodile (*Crocodylus niloticus*) at 21 %, Blue wildebeest (*Connochaetes taurinus*), African buffalo (*Syncerus caffer*) and Spotted Hyena (*Crocuta crocuta*) at 2 % each, Lions *(Panthera Leo)* at 1 % and Common duiker (*Sylvicapra grimmia*) at 1 % (See Appendix 6). These results indicated that, Elephants are the major conflict species within the study area. This was also validated by responses from 100 participants interviewed, where 76 % of the respondents identified African Elephants as the common conflict species within the study area.

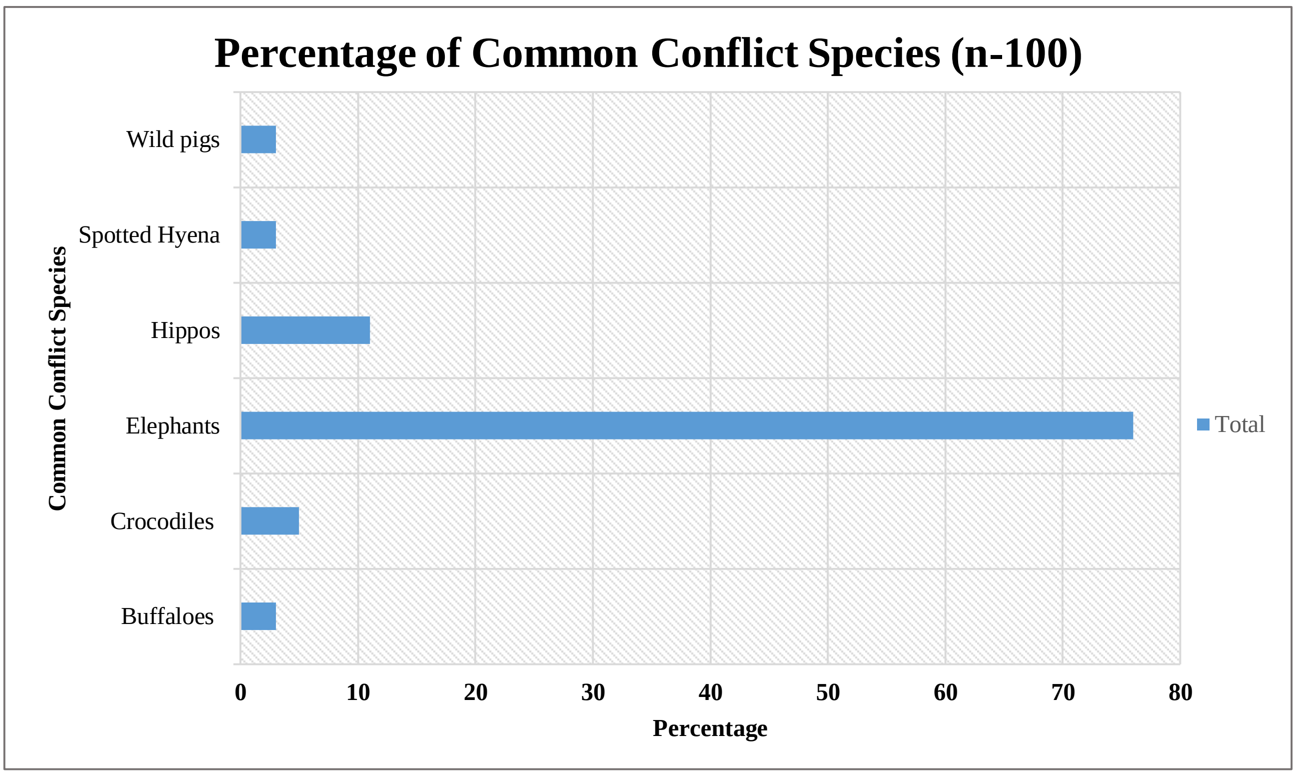

Figure 4: Common conflict wildlife Species based on respondent's responses

Source: Field data, 2022

These results on common wildlife conflict causing species slightly differ with what Chomba et al, (2012), found during the period 2002 to 2008 in Zambia were they categorized wildlife species that caused human injury and loss of life from a total of 347 human deaths (this translated in 49 people killed annually). This paper highlighted five common wildlife conflict causing species in the following order of magnitude; Nile crocodile, Elephant, Hippo, Lion, and Buffalo. However, these results suggest the following common conflict species in this order of magnitude; African elephants, Common Hippopotamus, Nile crocodile, Blue wildebeest, African buffalo and Spotted Hyena, Lions and Common duiker. Equally, in Zimbabwe, a case of Save Valley Conservancy (SVC), Matseketsa et, al (2019) found that there were 10 common conflict wildlife species in SVC, of which the top three species in terms of number of reports were African elephant, Lion and Spotted hyena. Correspondingly, Gandiwa et al. (2013) listed African elephant, Lion and Spotted hyena among the most disturbing species as reported by respondents living adjacent to northern Gonarezhou National Park in Zimbabwe.

Therefore, it could be suggested that, ecosystem structures and dynamics poses influence on the type and species of wildlife causing conflict. Further, these results suggest that large herbivores and carnivores are highly involved in HWC and this could be attributed to the fact that, they require a large home range, and due to their high energy requirements they need to consume large quantities of food each day (Matseketsa et, al, 2019). Therefore, based on foregoing needs and range it can be deduced that large-bodied terrestrial mammal species are likely to traverse far, beyond protected areas borders onto human inhabited lands in their quest to satisfy daily dietary requirements thus making them important contributors to HWC.

5.4 Forms of Human Wildlife Conflict in the Silowana Complex

Four forms of HWC emerged in this order of magnitude; Crop damage, Livestock depredation, Loss of human life or injury, and Property damage. As Figure 5 indicates that, 90 % of the respondents interviewed, they all identified crop damage as the most common form of HWC within the study area. Further, during the period 2020 to 2021, a total of 200 HWC incidents were recorded by DNPW, of the incidences, 59 % were for crop damage, 1 % for property damage, 16 % for livestock depredation, and 24 % for loss of human life or injury (See Appendix 7). These findings conform with similar studies (Barnes, 1982: Bell,1984: Hoare & du Toit, 1999: Hoare, 2001: Parker & Osborn,2001: Parker, 2006 and Pool 1996) that have shown that crop damage is the most common form of HWC. This potentially threatens household income and food security of the affected communities.

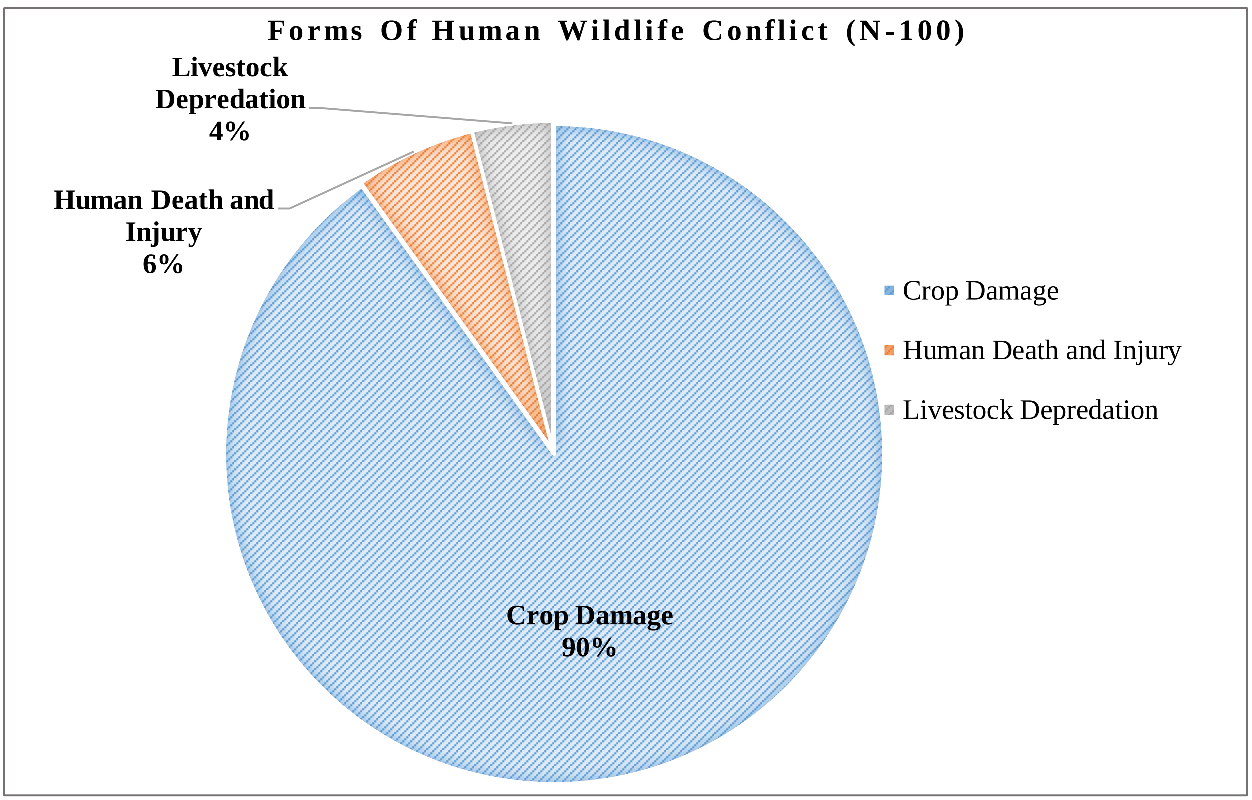

Figure 5: HWC by form based on respondent’s responses

Source: Field data, 2022

5.4.1. Forms of Human Wildlife Conflict by Conflict Species and Type

Further, the study went on to analyze conflict species and type against each form of HWC. Table 1; presents forms of HWC and corresponding conflict species and type.

Table 1: Forms of HWC by conflict species and type

Form	Conflict species	Conflict Type
Crop Damage	66 % African elephants (*Loxodonta Africana*) , 28 % Common Hippopotamus (*Hippopotamus amphibius*), 3 % blue wildebeest (*Connochaetes taurinus*), 2 % Common Duiker (*Sylvicapra grimmia*) and 1% African buffalo (*Syncerus caffer*)	Crops raided represented 82 % Maize , 1 % Millet & 2 % Sorghum other crops 15%
Livestock Depredation	67 % Nile crocodile (*Crocodylus niloticus*) , 10 % spotted hyena (*Crocuta crocuta*) 10 % lion *(Panthera leo)* and 14% Other species	Livestock depredated included; 67 % Cattle, 19 % Goats & & 14 % other species
Human Life Loss / Injury	38 % Common Hippopotamus (*Hippopotamus amphibius*), 30 % Nile crocodile (*Crocodylus niloticus*), 27 % African elephants (*Loxodonta Africana*) and 5 % African buffalo (*Syncerus caffer*)	Humans Injured 57 % and 43 % loss of human life

Source: Field data, 2022

5.4.1.1 Crop damage

Crop damage was the most common form of HWC threatening household income as well as food security. Maize was the most raided crop by elephants. Respondents indicated that when elephants come in a large group, they destroyed large areas of crops in a single night. The analysis based on HWC incident reports obtained from DNPW further indicated that, crops were raided by the following species in their order of magnitude 66 % African elephants (*Loxodonta Africana*), 28 % Common Hippopotamus (*Hippopotamus amphibius*), 3 % Blue wildebeest (*Connochaetes taurinus*), 2 % Common Duiker (*Sylvicapra grimmia*) and 1 % African buffalo (*Syncerus caffer*). The most raided crops were Maize at 82 %, 1 % Millet with 2 % Sorghum other crops such as vegetables accounted for 15 %. These findings show that large mammals are the most damaging species to crops targeting especially the maize crop. Given that maize is the most raided crop in the study area. It could be that maize is the most preferred crop by animals.

These results are consistent with (Naughton 1998; Nyhus 2016; DeMotts & Hoon 2012; Salerno et al. 2018; Ravenelle & Nyhus 2019;) that, suggested that, crop damage by wildlife is a widely reported form of HWC. However, crop damage effects on people's livelihoods are insufficiently measured (Gross, 2019).

5.4.1.2 Livestock Depredation

The findings indicate that cattle are the most attacked livestock in the study area followed by goats. The results showed that, they are three common apex and predator species in the ecosystem in the following order of magnitude, Nile crocodile (*Crocodylus niloticus*) at 67 %, 10 % Spotted hyena (*Crocuta crocuta*) 10 % Lion *(Panthera leo)* and 14 % Other species.

5.4.1.3 Loss of Human Life or injury

The findings showed that 57 % of the cases were injury related and 43 % were related to humans losing their lives. Four species were responsible for this form of conflict in the following order of magnitude 38 % Common Hippopotamus (*Hippopotamus amphibius*), 30 % Nile crocodile (*Crocodylus niloticus*), 27 % African elephants (*Loxodonta Africana*), and 5 % African buffalo (*Syncerus caffer*).

To address the future research areas highlighted by (Chomba et al, 2012), where it was indicated that, future research should determine gender and age group of people killed, time of the day and activity conducted by the victims at the time of the fatality incidence. The study investigated victim activities during attack by human life threatening conflict species. The results indicated that, community members were attacked when performing the following activities; 25% were attacked while crossing the river going to school and walking at night between neighboring villages. 38 % were attacked while fishing, 13% were attacked while protecting their crops and herding cattle, 12 % were attacked while drinking water and washing from the river and others were attacked when disrupting African elephants from drinking water from the river.

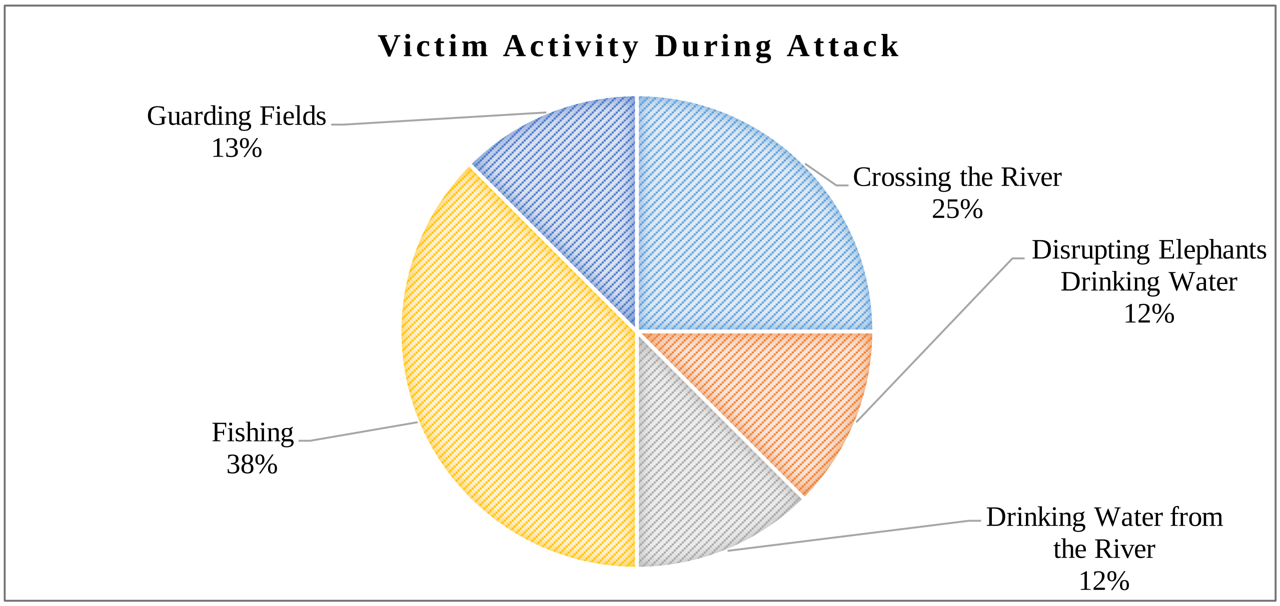

Figure 6: Victims Activity During Attack

Source: Field data, 2022

5.4.1.4 Property damage

Property damage cases were very rare. Only one isolated incident was recorded in the period under study.

5.2.4 Seasonal Distribution of Human Wildlife Conflict in SC

The study found that rainy season accounted for 52% of HWC incidents, 36% for of HWC incidents occurred in the hot dry season and 12% occurred in the cool dry season. These findings indicated that HWC occurred across all seasons in the Silowana complex.

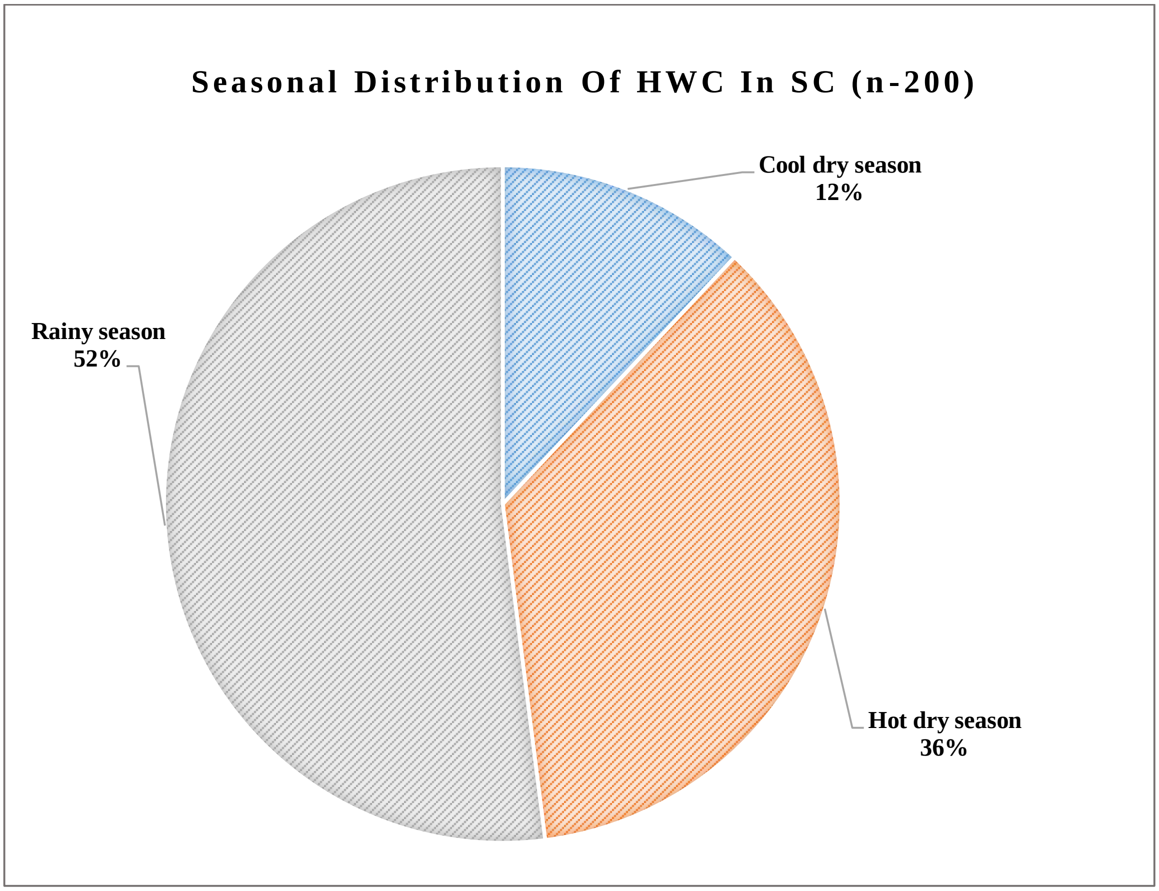

Figure 7: Seasonal distribution of Human Wildlife Conflict in SC

Source: Field data, 2022

5.2.4.1 Monthly Distribution of Human Wildlife Conflict in SC

On a monthly basis, the study observed that, the highest HWC incidences occurred in October at 31 %, followed by March at 18 % and January at 13 %. The months of August and May had the lowest proportions of incidents. The highest proportions of incidents happened during harvesting periods with 39 % of incidents taking place from January to March. These results conform with other studies which concluded that, crop-raiding usually peaks when crops are mature because of a lessening in the nutritive quality of grasses (Barnes, 1982: Bell,1984: Hoare & du Toit, 1999: Hoare,2001: Parker & Osborn,2001: Parker, 2006 and Pool 1996) As shown in Figure 5. The month of March had the highest percentage of crop damage incidents. This showed that, raiding occurred when crops were near maturity and during the harvesting period.

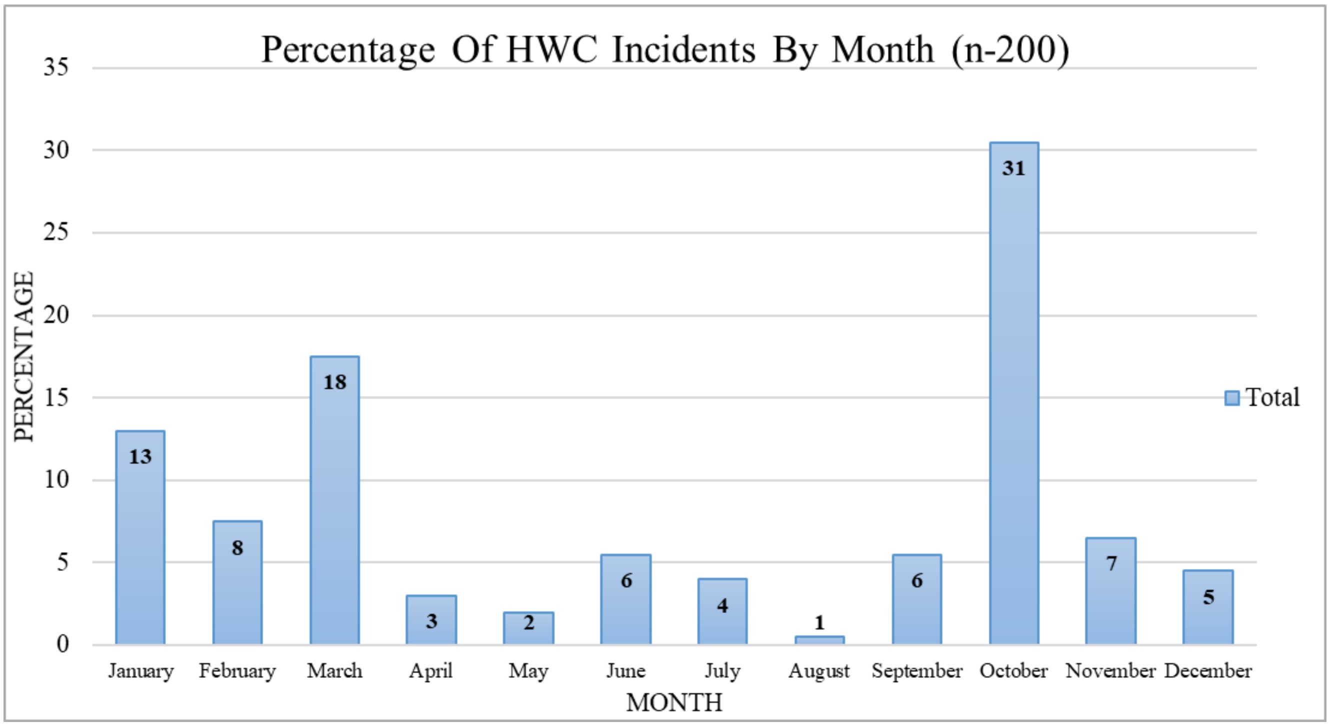

Figure 8 : Percentage of HWC by Month

Source: Field data, 2022

Further, the results have also indicated that, HWC incidents peaks during the driest period of the year in October representing 31 % of HWC incidents as shown in figure 9. The study area is in a water stressed ecosystem that, experience early dry-ups of water pans forcing wildlife out of the National Park in search of food and water. Scarcity of resources brought by seasonality may result in high levels of animal aggregation and interference competition can occur in such a scenario and play a role in resource acquisition for both wildlife and people (Chamaillé-James, Valeix, & Fritz, 2007).

Further, literature shows that the movement of wildlife is affected by the availability of water (Bonenfant, et al., 2009 & Dunkin, et al 2013). For instance, elephants tend to congregate in areas with sufficient water to drink and in which to bathe and play, especially in coastal lowlands and along river valleys (Kerley & Landman, 2006). The increased potential risk of competition for space and resources (food and water) between humans and wildlife brings about conflict especially in the driest parts of the year such as October

5.5. Human Wildlife Conflict Hotspots in the Silowana Complex

5.5.1 Probability of Human Wildlife Conflict in the Study Area

This section presents the modeled HWC probability based on the Maximum Entropy software. The study obtained an AUC value of 0.908 from the training data, with a regularized training gain of 1.398 and an unregularized training gain of 1.666. When the maximum achievable AUC is less than 1. If the actual data is drawn from the same as the training distribution itself, then the maximum possible test AUC would be 0.871 rather than 1; in practice, the test AUC may exceed this bound (Phillips et al., 2017). Refer to Appendix 9.

The study obtained an AUC value of 0.840 when the model was run on the actual sample data (HWC Occurrence data), representing the high accuracy of the model as predicted by the training data. The AUC value indicates the model's predictive power. In this case, a value of 0.84 for the AUC means that, for 84 % of the time, a random selection from the positive group (sensitivity) will have a score greater than a random selection from the negative class (specificity) (DeLeo,1993). Hence, the results from this model can accurately predict the probability of HWC incidents in the study area. Refer to Appendix 9.

The model showed that, HWC is linearly distributed in the landscape, following the river network systems. The Kwando River on the southwest and the Zambezi River on the northeast showed higher probability values for HWC compared to the central region. Figure 10 shows the spatial probability of HWC in the study area. In addition, the probability of HWC was found to be highest in areas with moderately dense concentrations of water, grassland, settlements, and crop fields. This is possible as communities living along rivers mostly practice livestock rearing and small-scale agriculture, mainly for subsistence (Bargali and Ahmad, 2018).

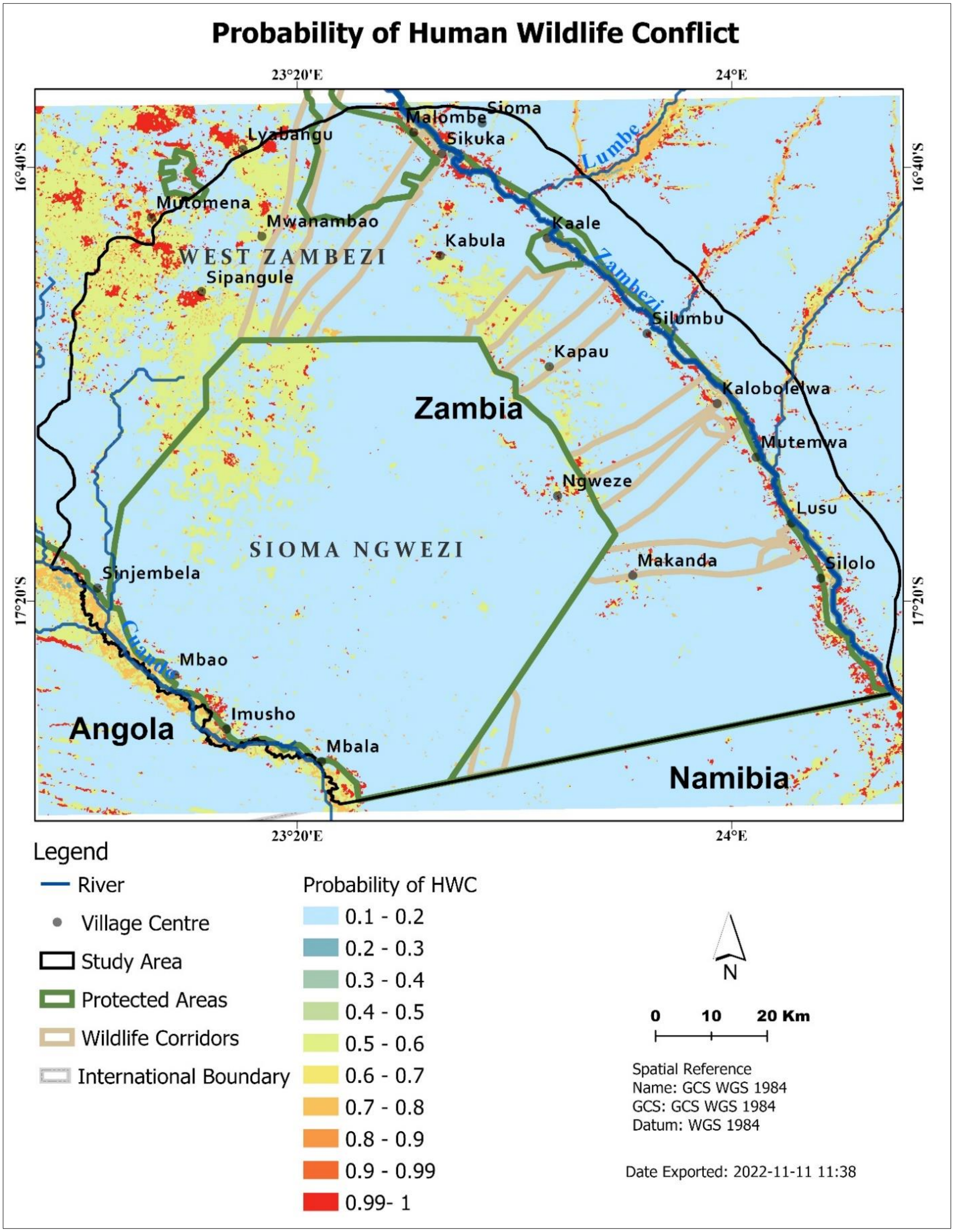

Figure 9 : probability of human wildlife conflict in the study area

Source: Field data/ Modeled Results, 2022

According the model results presented in Figure 10, River line areas showed higher probability values for HWC compared to the central region of the study area. This indicated that river line areas should be prioritized for HWC management due to the higher risk of conflicts that prevails in these areas within a buffer of 2 to 5 kilometers from the rivers running through the study area. These results align with (Dunkin, et al 2013) which suggested that, the movement of wildlife is affected by the availability of water. Further, Kerley & Landman, (2006) added that elephants for instance, tend to congregate in areas with sufficient water to drink and in which to bathe and play, especially in coastal lowlands and along river valleys.

5.5.2 Human wildlife conflict hotspot areas

HWC hotspot areas were extracted from probability ranges in figure 10 above and analyzed with respect to protected areas in the study area. The range 0.6 to 1 probability of HWC was considered as 'Human-Wildlife Conflict hotspot areas' based on literature reviewed and validation with key informants.

5.5.2.1 Human wildlife Conflict Hotspot Extraction and Validation

The range used for visualizing and extracting HWC hotspots was based on a conclusion from a consultative process with key informants based on their expert knowledge and experience in the landscape. Conservation grounded institutions and staff from the study area were consulted with the aim of validating the output of the model. The range of 0.4 to 1 was proposed by the researcher based on (Mallick, 2012) who treated 0.4 to 1 as HWC hotspot areas in his research. However, key informants consulted suggested that the range of 0.6 to 1 probability of HWC be considered as 'Human-Wildlife Conflict hotspot areas'.

The basis for considering the range of 0.6 to 1 is hinged on the probability theory. This theory deals with the analysis of random events. Probability is defined as a numerical assessment of likelihood on a scale from 0 (impossibility) to 1 (absolute certainty) (Prasanna, 2015). Therefore, on the basis that the higher the probability the higher the likelihood of occurrence. Hence, the range was adopted, this range implies that all areas modelled with a probability of HWC equal to and above 0.6 or 60% was treated as a hotspot area by this study.

Further, this was also adopted on the basis of enhancing the accuracy of results as compared to Mallick (2015) Who used the range of 0.4 to 1, His analysis was based on a number of ecosystems at a transboundary level. Therefore, it could be suggested that, the range used in this study presents a higher distribution accuracy when extracting HWC Hotspot areas at the level of one ecosystem that was considered in this study.

The study extracted HWC hotspot areas and mapped them using Geographical Information System platforms such ArcGIS Pro (*Version 2.4.1*) by creating two classes of Non- HWC Hotspot areas for probability values below 0.6 and HWC Hotspot areas for values above 0.6 using the Natural Breaks (Jenks) classifier. Further, HWC hotspot areas outputs were then analyzed by area classification.

The results in Figure 11, show variations in the distribution of HWC hotspot areas across the study area. The emerging spatial pattern presented was that hotspots had a linear spatial pattern following river line areas along the Zambezi river and its tributaries in the north and the Kwando river on the southern portion of the study area. The linear distribution of HWC hotspots along river lines is responsive to Human-Wildlife Interactions as theorized by the Social-Ecological Systems (SES) theory. Lischka et, al (2018) advanced that, the interactions between humans and wildlife can be positive or negative and that people compete with wildlife for food and resources. Applied to these results, the SES theory explains the distribution of areas prone or at risk of HWC along the river line areas in this study due to, competition between wildlife and humans for resources specifically water along the river line areas from the Zambezi and Kwando rivers.

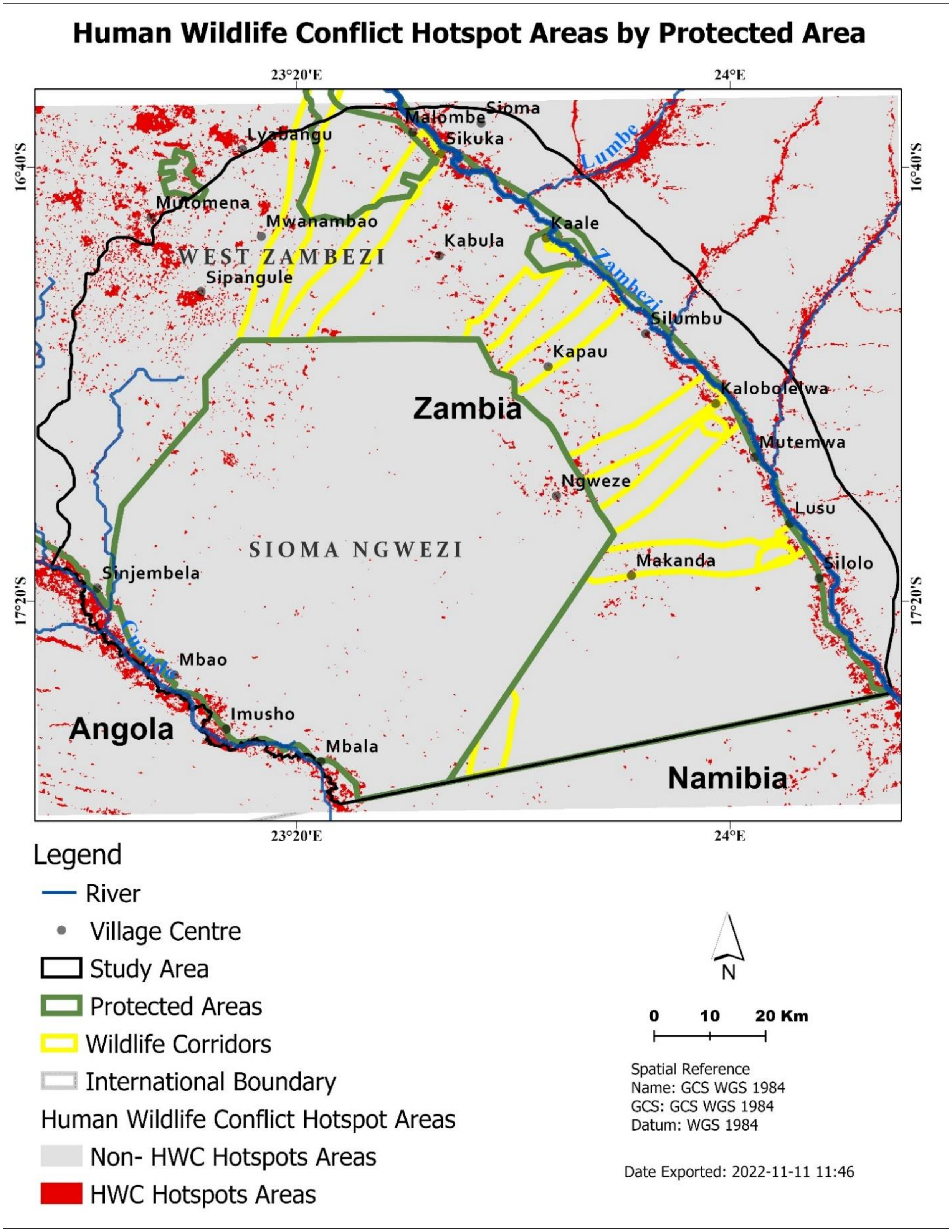

Figure 10: Human wildlife conflict hotspot areas by protected area

Source: Field data/ Modeled Results, 2022

In addition, the river line areas offer refugia, forage, fertile agricultural soils and water for wildlife and the human population hence the distribution of HWC hotspots. The hydrological regimes of the study area also explain the distribution of HWC hotspots, it is observed that small water bodies in the Sioma Ngwezi National Park get connected to either the Kwando or the Zambezi during periods of high floods but when the water recedes they get cut off from the channel, some dry up before another rain season starts while others retain water until the next rain season (General Management Plans (GMPs) for the SNNP and LWZ GMA, 2019 and 2016 respectively). Key informants added that, reduced availability of water in the park during the dry season forces wildlife to alter their movement patterns and concentrate their movements and distribution along river shores for a period of 6 months. These results are justified given that the reduced availability of water in park enhances competition for water between humans and wildlife along river line areas.

In addition, modelled HWC hotspot areas from the results coincide with those of previous studies indicating that human-inhabited areas, highways, rivers, water plans, wetlands, plains and agricultural fields as hotspots areas (Dasgupta and Ghosh, 2015; Naha et al., 2018, 2019; Roy and Sukumar, 2017). These results are supported by other studies that also found that conflict with wildlife increases in intensity with proximity to rivers and protected areas (Kiiru, 1995; Nath & Sukumar, 1998; Naughton et al., 1999; Nyhus et al., 2000; Lahkar et al., 2007; Riddle, 2007).

5.5.2.2 Analysis of Human Wildlife Conflict Hotspot Areas

This analysis was based on Zambia's protected area classification and specifically National Park**,** Game Management Area and Open Area. About 550km^2 or 55,000 hectares of Silowana Complex (5% of its area) was estimated as the HWC Hotspot Area. The results showed that, of the total HWC hotspot areas, 60% were in the GMA, 18 % were in the National Park and 22 % were in the Open area. It could, therefore, be concluded that the GMA would experience more HWC than the National Park.

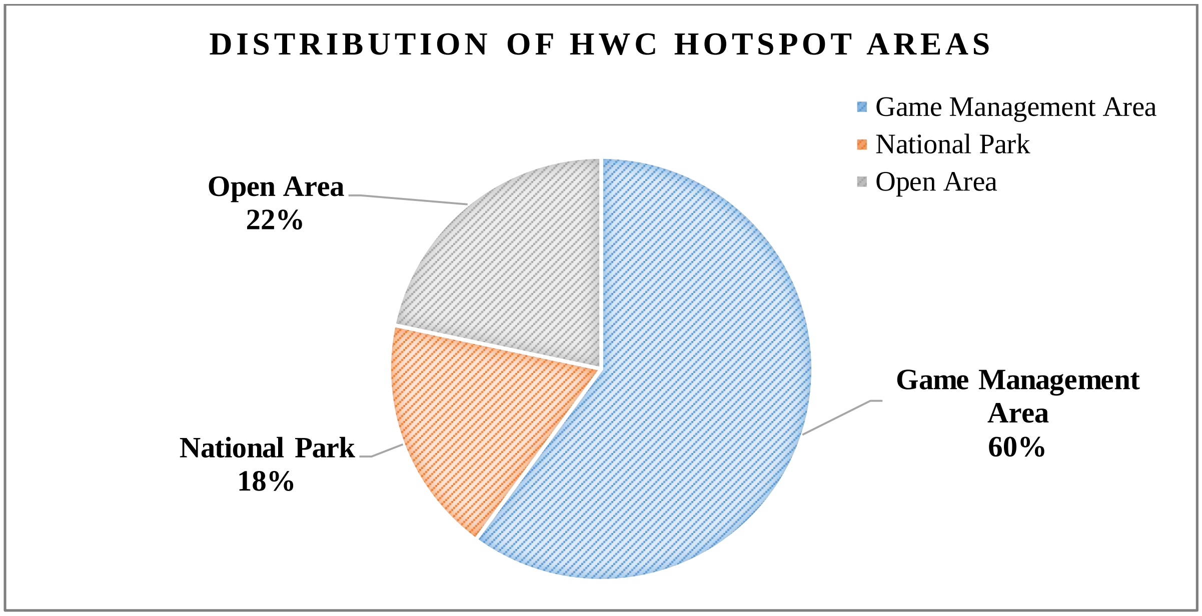

Figure 11 : Human wildlife conflict hotspot areas by protected area

Source: Field data/ Modeled Results, 2022

These results indicate that, most of the hotspot areas were in the LWZ GMA, followed by the SNNP and then OA. The GMA was found to have the highest proportions of hotspot areas (Further, analysis is presented in Appendix 8). This is not surprising as Gross, (2018) observed that, areas of interaction between wildlife and people, such as GMA are prone to negative interactions.

5.5.2.3 Reason for Settlement Preference by Area Classification

The study further explored reasons why community members settled in areas prone to HWC knowing they were at risk of conflict. Two themes emerged specifically land heritage and soil fertility. The results indicated that, 70 % of the respondents indicated that, they had no way else to go, since it was the only land they have known since time in memorial, their absolute responses included; "*The park found us, it's our motherland", "It has been our land for ages", "It's our God given land", "It's being our home since time in memorial", "That's where we have been living since our birth" and others said, "It is our heritage land from our forefathers".* The rest, 30% of the respondents indicated that, they settled and cultivated in HWC prone areas because of fertile soils and proximity to water. Their absolute responses included; *"That's where there is fertile land", "That's where we grow food" and "That is where we can only do gardening from"*.

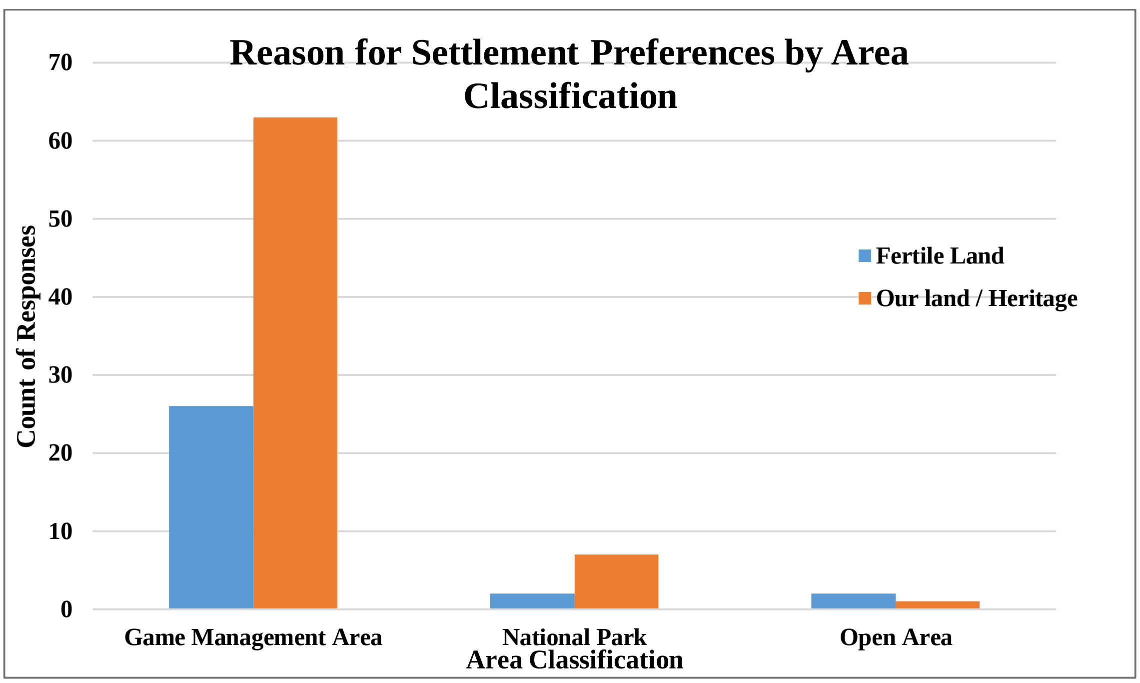

Figure 12: Reason for Settlement Preference by Area Classification

Source: Field data, 2022

5.6 Human Wildlife Conflict Mitigation Measures in SC

The study has documented, existing and proposed community responses to HWC as presented below.

5.6.1 HWC Mitigation Strategies Implemented by the Authorities

This study reviewed the current strategies implemented by the government through the Department of National Parks and Wildlife in the study area in mitigating HWC. According to the General Management Plans (GMPs) for the Sioma Ngwezi National Park and Lower west Zambezi Game Management Area (2019 and 2016 respectively), authorities have set two objectives against HWC (i) to enhance cost effective and efficient HWC restraining measures, and (ii) to reduce incidences of HWC. These objectives are to be achieved through the following three main strategies. (a) restraining measures and community sensitization, (b) protection of people, wildlife and corridors and (c) judicious control of problem animals.

A review of the GMPs cited above showed that, state strategies excluded community gain from wildlife. Simply stated, existing strategies and activities proposed by the state do not promote economic incentives to communities aimed at increasing their tolerance to wildlife and moving them to a situation where they consider the benefits over the consequence's and costs of living with wildlife (Leslie et al. 2019). This could be detrimental for the conservation of wildlife since state strategies specifically, control of problem animals is a lethal method and unethical, it brings about destruction of an animal itself and little benefits to communities (Treves and Karanth, 2003). Lastly, communities that see less value in wildlife are more likely to retaliate by killing wildlife as a response to conflict, and poach wildlife as a response to the lack of economic beneficiation (Leslie et al. 2019).

5.6.2 Current Community Led Human Wildlife Conflict Mitigation Measures

The study found that, most of the respondents did nothing and had no local knowledge of how to mitigate HWC (Figure 14). Further, some of the respondents responded to HWC by guarding their fields and livestock, others fenced their fields and property (This included, erecting predator proof kraals, fencing houses, food storage facilities, water points, farms and gardens) and others scared wildlife by beating drums and throwing Chilli bombs at elephants for instance as shown in Figure 14.

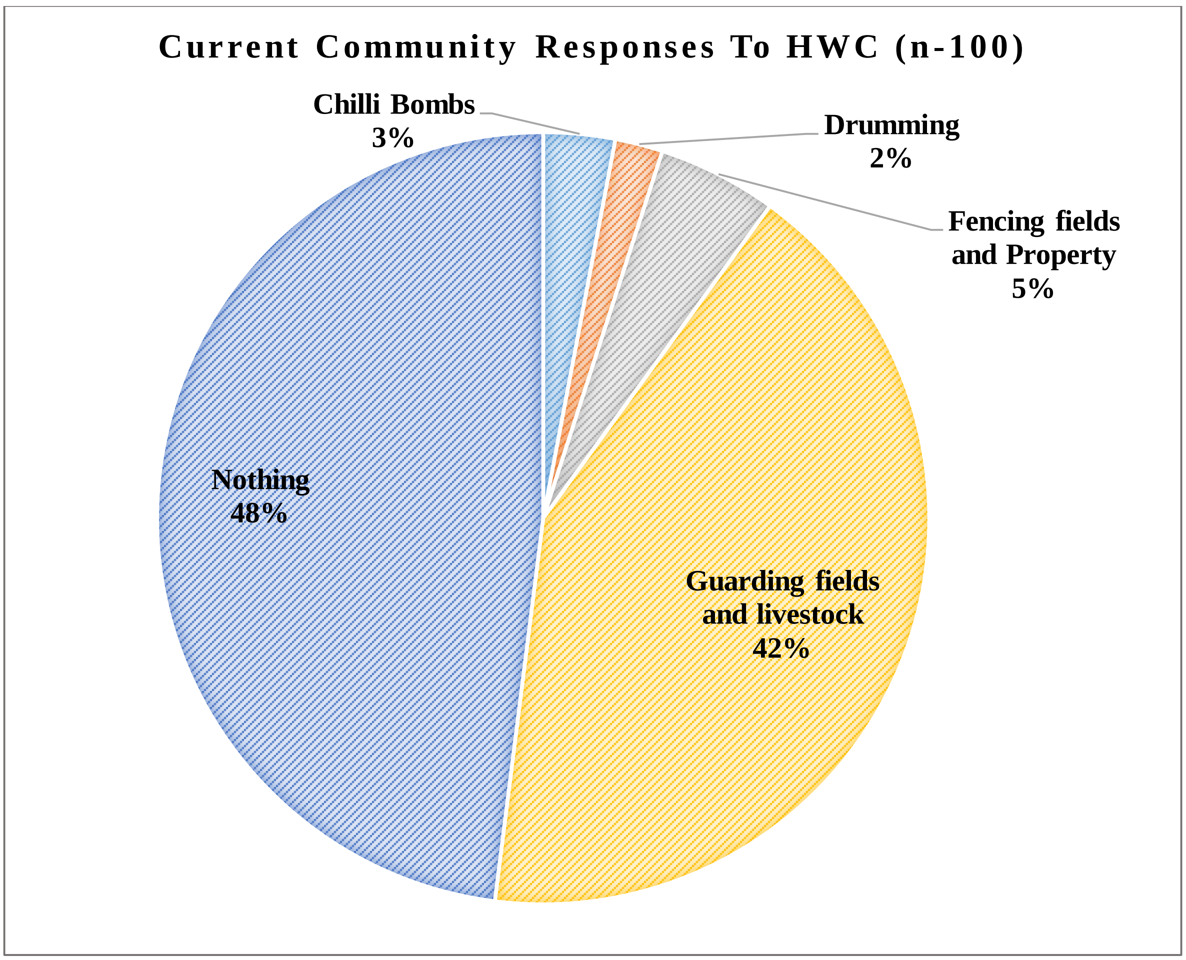

Figure 13: Current community responses to HWC

Source: Field data, 2022

It was concerning that 48% of the respondents did nothing and had no knowledge of how to mitigate HWC. At the same time this presents an opportunity to co-create solutions with the community and pilot mitigation measures on a clean slate. This calls for capacitation and community sensitization. This situation is what may be contributing to the huge data gaps in the existing data. In that, a large number of these HWC incidents go unreported. In the case of Hwange District in Zimbabwe for instance a significant proportion of farmers do not report damage to anyone, as they just do not know whom to report to or would have to travel far to get knowledge on how to mitigate HWC (Gross, 2019).

Further, 42% of the respondents indicated that, they guarded their fields and livestock, this was concerning as well in that, it presents a range of hidden costs and implications as documented by (Jadhav & Barua, 2012 and Muyoma, 2016). They cited important aspects of HWC hidden costs associated with guarding crop fields and domestic animals namely, fear, psychological disturbance, given up opportunities of schooling by children and transaction costs incurred when HWC is experienced, loss of health both psychological and physical, brought on by the stressors of guarding fields and homes. Jadhav & Barua, (2012) added that, the fear of encountering wildlife is a constant stressor leading the farmers who guard their crops and livestock to suffer from a significant lack of sleep and fatigue, this often means less productivity during the day. This therefore, justifies the accession that, the ever increasing HWC, if not addressed will hinder achievement of many of the Global Sustainable Development Goals (SDGs) as depicted in section 2.3 above (United Nations, 2023).

In addition, 5 % of the respondents erected wood and grass fences around their fields and property to mitigate against herbivore related conflicts and to mitigate carnivore related conflicts respondents interviewed, indicated that they set up stronger kraals to prevent lions and spotted hyenas. Basically, fences work by separating people and livestock from wildlife through a barrier to avoid negative impacts on both sides (Gross, 2019). However, barriers can also alter people’s relationship with nature.

Again, a number of respondents interviewed indicated that, they scared animals using drums and Chili bombs.

5.6.3 Community Proposed Additional HWC Mitigation Measures

The community members interviewed, proposed additional mitigation measures, a mixture of responses is presented in Figure 15. Largely the responses included; relocating people from wildlife corridors, recruiting and deploying more community scouts in communities, compensation for HWC related damages, limited hunting of common conflict species and fencing.

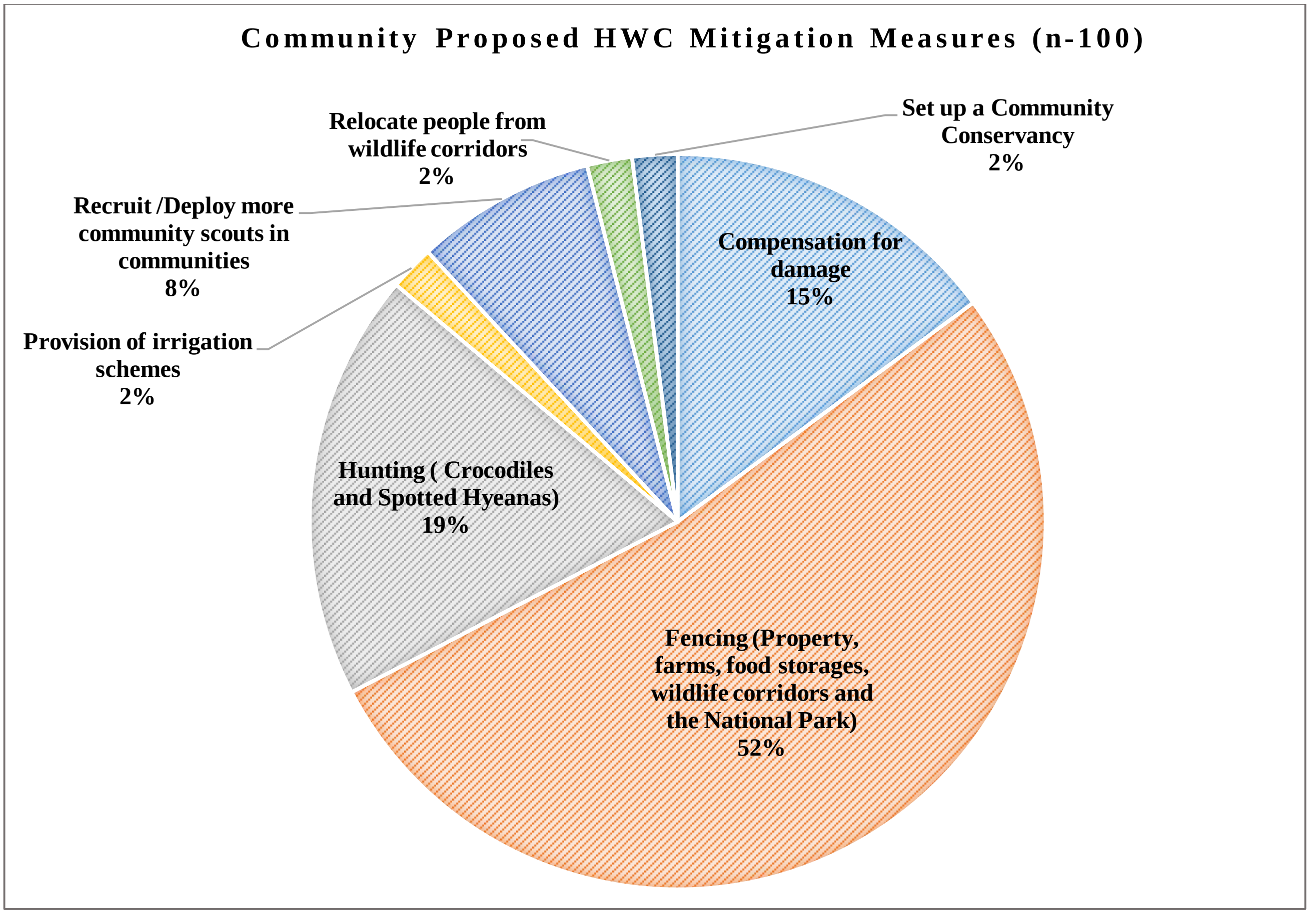

Figure 14: Community proposed additional HWC mitigation measures

Source: Field data, 2022

5.2.6.3.1 Fencing

Figure 15 shows that 52% of the respondents or community members highly recommended erecting fences around fields, property, storage facilities, wildlife corridors, water points, the national park and erecting stronger kraals. This recommendation was highly favored has been effective. Three types of fencing emerged from these respondents a) Restraining Fences for Elephants and Crocodiles b), Predator Proof Kraals and c), High tension wire fences for National Parks. However, this study would not recommend some of these measures based on (Graham and Ochieng, 2008), since some these methods are exclusionary in nature, they prevent the free movement of wildlife. Below is a detailed elaboration on each of these three types of fencing that emerged.

5.6.3.1.1 Restraining Fences for Elephants and Crocodiles

Restraining fences for elephants; community members highly recommended erecting poly electric wire fences around fields and property. This recommendation was highly favored for been effective. But, results from a comprehensive study by Thouless and Sakwa (1995) revealed a myriad of constraints ranging from design, construction to maintenance. It is obvious that the specifications of poly electric fences were beyond the reach of local communities, unless supported by international and external agents.

In addition, Graham and Ochieng (2008) concluded that the effectiveness of electrified fences depends on their delivery of a short high-voltage, low current, electric shock when touched and the circuit between the wires, the earth and the body of animal touching the fence is completed. Power is generated by solar panels, and stored in lead acid accumulators. Further, these fences are easily broken if the posts are weak, the wires poorly attached to the post, or if voltage falls and the fences been recommended are made of poly wire. The most frequent cause for low voltage is short circuiting caused by vegetation, for example long grass, or from badly connected wires because of poor repair. These fences therefore need to be well built, and well-maintained, with regular clearance of growing vegetation and timely and efficient repair. Simply stated, sustainability of this intervention is difficult for community members.

In addition, some respondents recommended the installation of crocodile restraining fences, they indicated that in some places within the study area were pilots have been done, crocodile restraining fences have proved effective in reducing human and livestock attacks by crocodiles. These fences also help in providing safe access to river lines and water. The Crocodile Specialist Group (2011), have documented that crocodile restraining fences work well in combination with crocodile disturbance, and more effectively, where problem sites have been identified. The noise made by humans will continuously affect the activities of crocodiles, reducing chances of attacks. However, ecologically this negatively affect the crocodile population, as the nesting sites are affected, and breeding rates will decrease. Further, the challenges of crocodile restraining fences come with flooding regimes of rivers. Fluctuations in water levels requires that the fence be mobile for it to remain effective. In addition, river erosion and burrowing effects of crocodiles may rend them ineffective. Therefore, these fences require regular maintenance due to a number of factors which includes rusting of the wire material usually used.

5.6.3.1.2 High tension wire fences for National Parks

High tension wire fences were recommended for Sioma Ngwezi National Parks. However, this study would not recommend this measure based on (Graham and Ochieng, 2008). Fencing a national park is exclusionary in nature preventing the free movement of wildlife. Generally, high wildlife fences are used around national parks and other protected areas. Varying successes have been recorded in most parts of Africa. The bottom line is that this measure is difficult to maintain by the community as well as National Parks Authorities. Lessons in Zambia could be drawn from Mosi-Oa-Tunya and Lusaka National Parks, were animals severely damage fences knocking them down or burrowing underneath, resulting in a failure to keep wildlife in the park. Over time, they become so damaged that in many places it is nonexistent or is so mangled that they become a threat to wildlife as they get caught in the fence. Widespread fence damage also provides no poaching deterrent, thus providing few benefits to wildlife and people.

5.6.3.1.3 Predator Proof Kraals

Community members also recommended erection of stronger predator proof kraals as a mitigation against livestock depredation. Predator proof enclosures (called either "corrals", "pens", "paddocks", "bomas", "stockades", or "kraals") are designed to stop or reduce livestock attacks at nights. However, it has to be mentioned that, livestock/predator conflict is very complex and no single solution has proven to be effective yet including predator proof kraals. However, good results have been obtained from zero visibility predator proof kraals (Lichtenfeld et al., 2015), its known that predators only attack what they can see and therefore, if kraals are designed to make livestock invisible at night, then they would be effective.

Literature has shown that where predator proof kraals have shown effectiveness they have also changed predator behavioral patterns, predators start attacking less at night and more during the day time when livestock is out of enclosures. This complexity can be addressed by applying good daytime animal husbandry practices in conflict areas such as communal herding instead of individual as observed in the study area, and adult human herders should guard livestock instead of children (Lichtenfeld et al., 2015). Further, if the state has to use lethal control of problem predators. It could be recommended that, detailed identification of individual predator animals through collaring and behavior studies be done to allow for targeted control instead of indiscriminate killing by both the state and communities.

5.6.3.2 Limited Hunting of Common Conflict Species

The results showed that, 19% of the respondents advocated for wildlife cropping. Respondents suggested that the Government of Zambia through the DNPW should consider lifting the ban on hunting in Lower West Zambezi GMA where the effect of HWC were being felt the most. They recommended limited hunting of predator species for instance crocodiles and spotted-hyenas. However, if this has to be considered there is need to conduct detailed wildlife counts to justify hunting quotas. Usually, hunting is often the only or most viable solution to mitigating conflict, supporting community livelihoods, and creating conservation incentives. Further, hunting provides communities, with the resources and incentives to tolerate HWC and wildlife. Some key informants interviewed indicated that the current hunting ban in the GMA should be supplemented with alternative solutions and that coexistence initiatives are complicated.

5.6.3.3 Compensation for Human Wildlife Conflict related Damages

Further, 15% of the respondents proposed that compensation for damages caused by wildlife should be considered as a mitigation measure. Basically, community members are interested in compensation because it mitigates HWC impacts through the provision of a financial buffer and, in turn, reduce the likelihood of victims seeking to kill wildlife in retaliation (Leslie et al. 2019). In addition, the authorities and community members in the area have acknowledged that the situation is worsened by the fact that Zambia's legal framework does not provide for compensation arising from raiding wild animals (Zambian Wildlife Act No. 14 of 2015). Respondents observed that the law provides for actions and punishing measures when the community kills or injures wildlife, while nothing is done when wildlife damages people's crops, and threatens and destroys human life. Further, due to the lack of compensation, community members are discouraged to assess, accurately reporting damaged crop fields, and participating in conservation efforts, since assessments do not lead to compensation for loss suffered (MOTA, 2016).

However, this study does not recommend compensation from the authority. Since, most compensation programs reviewed by this study lack adequate incentives for communities and they encourage disregard for preventative measures (Dyar and Wagner, 2003; Swenson and Andren, 2005). Compensation schemes for instance in Botswana, Namibia and around the globe must include a variety of factors to be effective (Nyhus et al., 2005). The most critical factors include: correct and speedy confirmation of losses; timely and fair payments; clear protocols, rules, and guidelines that connect payment and appropriate conservation management practices; and an understanding of the cultural and socio-economic systems. This study underscores the importance of investigating HWC incidents as a part of compensation programs.

5.6.3.4 Recruit/ Deploy more Community scouts in Communities

Again 8% of the respondents proposed that, the government should consider increasing the presence of wildlife police officers and community scouts in the area for them to have a rapid response effect to control HWC in their area. This recommendation was made on the basis that, it would translate into conservation based long term employment for a select few qualified community members, this in turn would benefit the community at large.

5.6.3.5 Relocating People from Wildlife Corridors

Further, 2% of the respondents indicated that, some community members have settled in traditionally known wildlife corridors and they were of the view that if HWC has to be resolved in some hotspots there was a need to intensify wildlife corridor management and maintenance with the aim of reducing and preventing human encroachment on wildlife corridors. They suggested that people have to be relocated away from wildlife corridors and that people should not farm in wildlife corridors. This study advocates for voluntary relocation of people from wildlife corridors as an ethical measure rather than forced relocation.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter begins with conclusions of the study in line with the aim and objectives of the research and then presents a summary of the key findings. The chapter further presents the proposed recommendations and applications based on the conclusion of the study. The chapter ends with recommending areas were future research related to this study could be undertaken.

6.2 Conclusion

The aim of this study was to map areas at risk of HWC and establish mitigation measures in Sioma Ngwezi National Park and Lower West Zambezi Game Management Area (Silowana Complex). The objectives of this study were to analyze forms of HWC, model HWC hotspots and establish community led HWC mitigation measures in SC

The study found that, they were four forms of HWC in the study area presented in their order of occurrence from high to low; Crop damage, Livestock depredation, Loss of human life or injury and property damage. These forms of conflict were caused by four common conflict wildlife species in the area in the following order of magnitude; African elephants (*Loxodonta Africana*) at 47 %, Common Hippopotamus (*Hippopotamus amphibius*) at 24%, Nile crocodile (*Crocodylus niloticus*) at 21%, Blue wildebeest (*Connochaetes taurinus*). The study also concluded that, HWC occurred throughout the year.

The modelled HWC probability in the study found that, HWC hotspots are linearly distributed in the Silowana complex, following the river network systems, specifically the Zambezi in the north and the Kwando on the southern portion of the study area. Therefore, the study concluded that, the river line areas should be prioritized for HWC management due to the higher risk of conflicts that prevails in these areas within a buffer of 2 to 3 kilometers from the rivers running through the study area. The study further concluded that most of the hotspots were in the GMA, therefore, the GMA experienced more HWC than the National Park.

The study established the prevailing HWC community led mitigation measures. It concluded that community members have knowledge of how to mitigate HWC and therefore, their best practices should be scaled up. Further, the study concluded that the existing HWC mitigation strategies and activities implemented by both the community and state do not promote economic incentives to communities aimed at increasing their tolerance to wildlife and moving them to a situation where they consider the benefits over the consequence's and costs of living with wildlife.

Overall, this study concluded that areas at risk of HWC in SNNP and parts of LWZ GMA are around river line areas where there is a high density of settlements, fertile soils and constant availability and access to water. It further concluded that most of the conflict is caused by African elephants (*Loxodonta Africana*) coming to river line areas to drink water and forage in agricultural lands along the rivers. In addition, conflicts with Common Hippopotamus (*Hippopotamus amphibius*), Nile crocodile (*Crocodylus niloticus*), are also along the river particularly along the Zambezi river and Kwando river where people get their water, fish and water their livestock.

6.3 Recommendations

The study recommends the following;

Implementation of species-specific Mitigation Measures: Conservation players (NGOs and government departments) should facilitate the implementation of species-specific mitigation measures focusing on addressing all the four forms of HWC identified in the study area.

Integrated land use planning and zonation: Key stakeholders in the landscape should prioritize integrated land use planning and zonation. Based on the results of this study it is clear that HWC is complex, and it requires appropriate, evidence-based land use planning that takes the needs of both people and wildlife into consideration on a Micro and Macro level. On a Micro or community level, there is a need for a detailed understanding of spatial needs for both people and wildlife in the study area. This will assist with the development of detailed land use plans accommodating both needs of people and wildlife through detailed zonation of different land uses. On a Macro or the SC level, HWC should be managed by land use planning and zoning based on wildlife abundance, movement patterns, and habitat availability intertwined with the following specific interventions aimed at; (i) incentivizing community members for maintaining and managing wildlife corridors, (ii) promoting cluster farming along river line areas and away from validated wildlife corridors. Cluster farms should be supplemented with water appended conservation agriculture techniques. This will increase productivity through increased yields and all year round production. Thereby, fostering food security for communities and (iii) facilitating the flow of community economic benefits from wildlife such as the improvement of social amenities like schools, clinics, markets, etc. This will in turn increase the communities' tolerance to wildlife and move to a situation where they consider the benefits over the consequence's and costs of living with wildlife.

Promoting Conservation Education: DNPW under its community extension section should consider promoting conservation education in the 24 schools within the study area. This will create a basis for future HWC mitigation activities and strong effect on knowledge and tolerance towards wildlife at an early stage in future community members

Upscaling effective community led HWC mitigation strategies: Lastly, DNPW and its conservation partners should facilitate the upscaling and implementation of effective community led HWC mitigation strategies as suggested by respondents.

6.4 Future Research

This study presents a framework of analysis that constitutes a unique methodology in mapping HWC hotspot areas at the landscape level based on intensive literature survey and existing data. The methodology is unique in that it overcomes the lack of comprehensive and uniform HWC data collection methods and systems in most protected areas. The integration of earth observation, geographical information systems with spatial modelling systems in mapping HWC hotspots should be a replicated in other landscapes in Zambia. Therefore, the study recommends that future research may focus on

a. Replicating this framework in other landscapes in Zambia.
b. Quantifying the impacts (Physiological, Social and Economic) of HWC on local human communities in the study area
c. Evaluating the effectiveness of current HWC mitigation measures implemented in the landscape.
d. Conducting community participatory identification, validation and marking of wildlife corridors to allow for easy management and maintenance of corridors which will enable free movement of wildlife in turn reducing HWC and
e. Investigating the true orientation of wildlife corridors in the study area, using scientific approaches for at least over two seasons.

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APPENDIXES

Appendix 1 : Showing a sample of the Semi Structured Questionnaire deployed on HWC Victims

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT GEOGRAPHY AND ENVIRONMENTAL STUDIES

I am a postgraduate student from the University of Zambia. I am conducting interviews for my research. The aim of the research is to map areas at risk of HWC to inform mitigation measures in Sioma Ngwezi National Park and parts of Lower West Zambezi Game Management Area

You are kindly invited to voluntarily participate in an interview, which will require approximately 45 minutes of your time.

The information you provide will only be used for this research and will be treated with strict confidentiality.

Your participation is also anonymous – your name is not required and will not be recorded.
You do not need to answer any questions that you would prefer to not answer.
Your help with this research would be greatly appreciated.
Do you agree to participate in the interview?

GENERAL INFORMATION OF THE HOUSEHOLD HEAD

* Required

1. Gender *

Mark only one oval.

- Male
- Female

2. Age (years) *

Mark only one oval.

- <18
- 18-35
- 36-50
- 51-65
- >65

3. Village Name *

4. Village Action Group Name *

Causes of Human Wildlife Conflict

5. What are the primary causes of HWC? *

Mark only one oval.

- Habitat Loss
- Habitat Degradation (Deforestation and forest conversion)
- Habitat fragmentation (crop cultivation, settlements, livestock grazing)
- Elephant Population (increased number of elephants in the area)

6. Why do you stay or use areas where HWC is severe? *

Protected Area Classification

7. Protected Area Classification *
Mark only one oval.

- National Park
- Game Management Area
- Open Area

8. Nearest Village Centre * *Mark only one oval.*

Forms of Human Wildlife Conflict

9. Common Conflict Species *

Impacts of Human Wildlife Conflict

10. What are the physical impacts associated with HWC on livelihoods in the Silowana complex*?

Mark only one oval.

- Crop Damage
- Human Death and Injury
- Elephant Damage to food stores and Other Properties
- Livestock Depredation

11. Which of the above physical impacts of HWC has the most severe impact on you*?

Mark only one oval.

- Crop damage
- Human Death and Injury
- Elephant Damage to food stores and Other property
- Livestock Depredation

12. Economic impact of HWC - How much money did you lose when the damage happened? (in Kwacha) *

Check all that apply.

- [ ] <1000
- [ ] 1000 -5000
- [ ] 5000 -10000
- [ ] 10000 - 20000
- [ ] >20000

Other: [ ] ______________________

13. When HWC happens to you or someone else in the community how do you feel? *

____

____

____

____

____

14. Psychological impacts of HWC - When HWC happens to you or someone else in the community how do you feel? * *Mark only one oval.*

- Fear of moving around and encountering elephants
- Threatened by elephants
- Anger towards wildlife (Elephants)
- Anger towards authorities

Human Wildlife Conflict Mitigation Measures

15. What immediate actions do you take when HWC happen? *

16. What traditional methods do you use that reduce HWC? *

17. What local practices do you think increase HWC? *

18. What would you suggest as solutions to HWC in your area? *

Reporting Human Wildlife Conflict

19. Who do you report to when HWC arise? *

20. Do you get a response or reactions from the DNPW when you report HWC cases? *

Mark only one oval.

- Yes
- No

21. How helpful is DNPW on this issue? *

Mark only one oval.

- Helpful
- Very-Helpful
- Extremely-Helpful
- Not – Helpful

Thank you for your time and participation

Appendix 2 : Interview Guide For Key Informants

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES
DEPARTMENT GEOGRAPHY AND ENVIRONMENTAL STUDIES

Welcoming remarks:

Thanks you for accepting to be part of this study by accepting to be interviewed. The data collected will be used for academic purposes only.

I. How would you describe the HWC situation in the Silowana Complex?

II. What are the common conflict species?

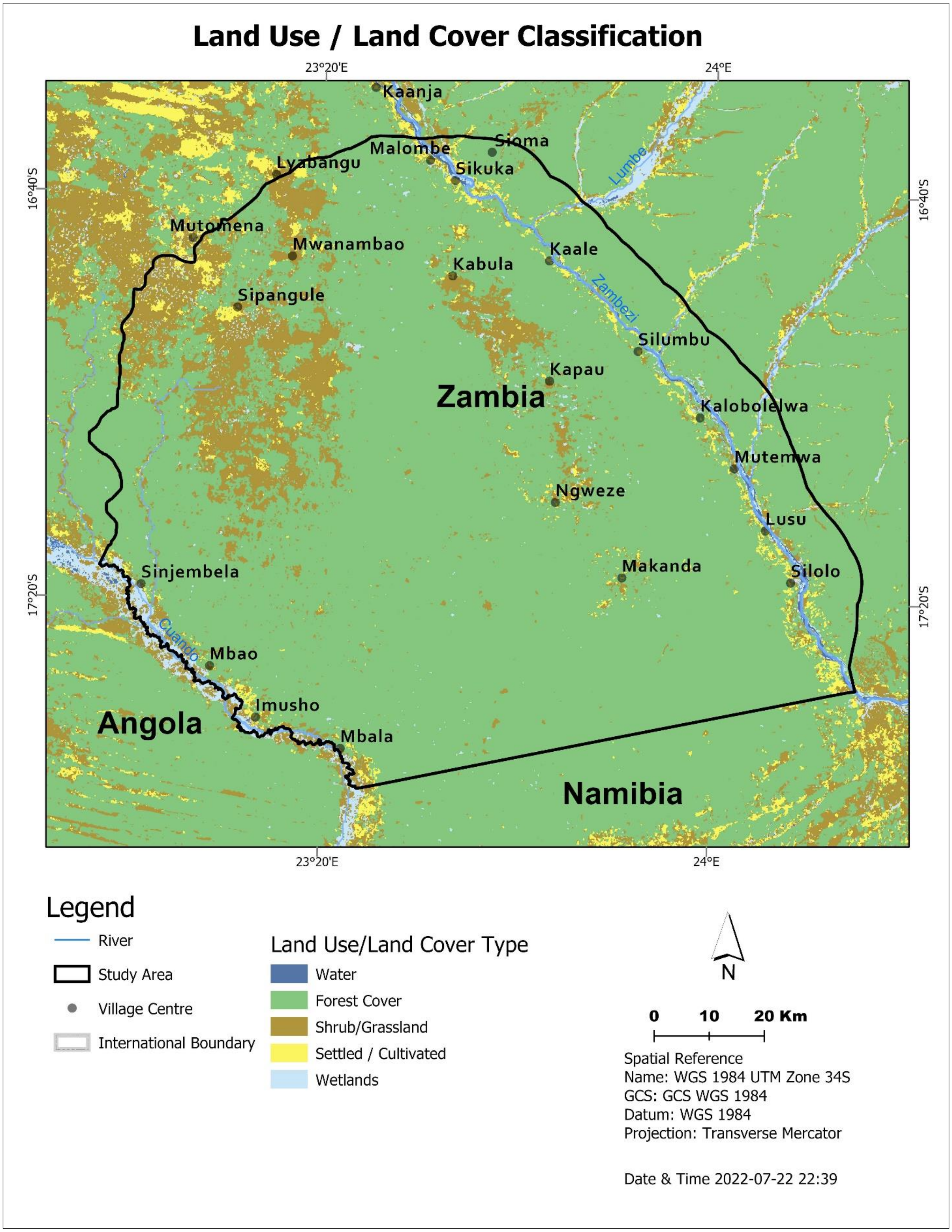
III. What forms of HWC exist in Silowana Complex?

IV. When does HWC occur in Silowana Complex?

V. Where are HWC hotspots in Silowana Complex?

VI. How can HWC be mitigated in Silowana Complex?

Appendix 3 : Showing the Land Use/ Cover Classification Map



Appendix 4 : Land use / Cover Accuracy Assessment

		Referenced Data					
	Classification	Forest	Planted/Cultivated	Shrub land	Water	Wetlands	**Users Accuracy**
Classified Data	Forest	**11**	0	1	0	0	**92%**
	Settled/Cultivated	0	**18**	0	0	0	**100%**
	Shrub/Grassland	0	1	**14**	0	0	**93%**
	Water	0	0	0	**10**	0	**100%**
	Wetlands	0	0	0	2	**19**	**90%**
	Producers Accuracy	**100%**	**95%**	**93%**	**83%**	**100%**	
	Overall Accuracy						**94%**
	Kappa co-efficient						**0.9**

1. **Over Accuracy**

The overall classification accuracy = No. of correct points /Total number of points X 100

= 72/76*100

= 94%

2. **KAPPA Statistic** - (This estimate is a measure of agreement or accuracy)

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_i + Xx_{+1})}{N^2 - \sum_{i=1}^{r}(x_{ii}Xx_{+1})}$$

= **4,307/4,611 = 0.934071**

where;

r = number of rows and columns in error matrix, N = total number of observations (pixels)

X_{ii} = observation in row i and column i,

Xi+ = marginal total of row i, and X+i = marginal total of column i

3. **Users and Producers Accuracy / Errors of commission and Omission**

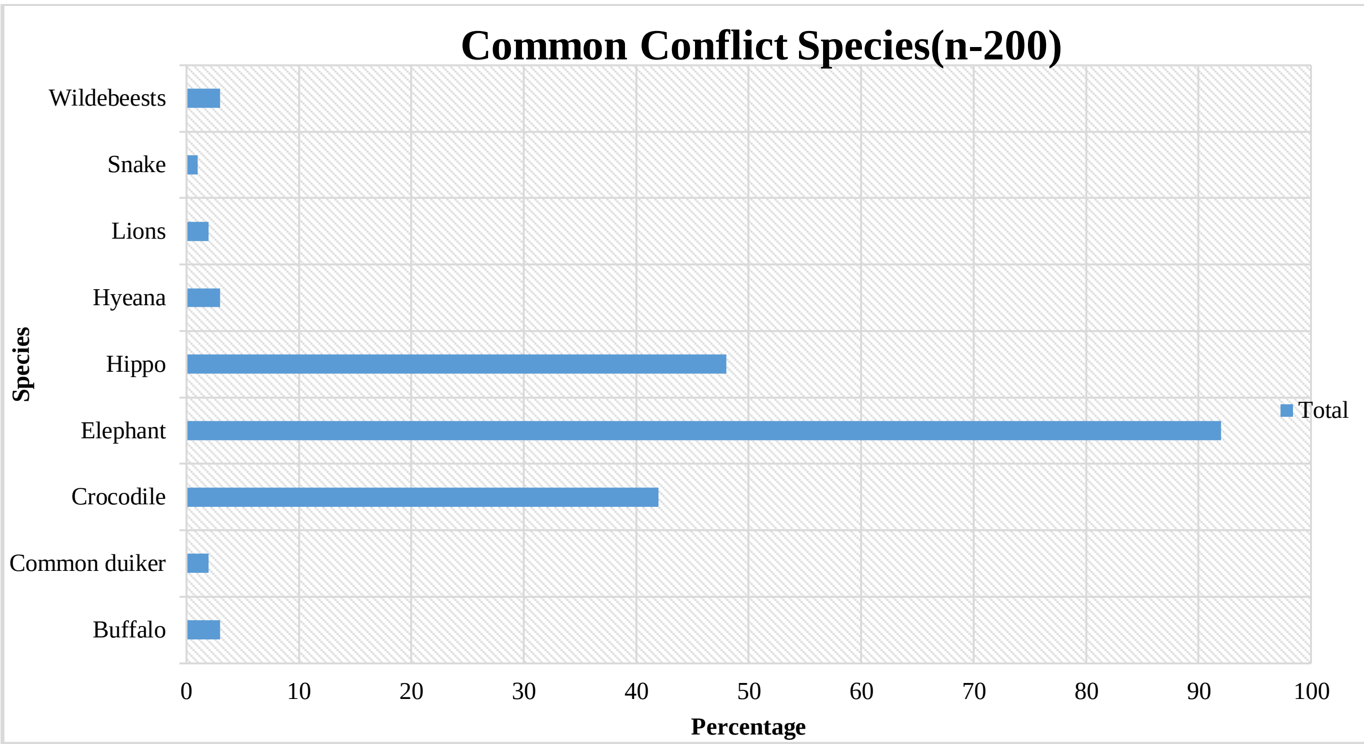
	Classification	Users Accuracy	Commission Error
Users Accuracy	Forest	92%	8%
	Settled / Cultivated	100%	0%
	Shrub/Grassland	93%	7%
	Water	100%	0%
	Wetlands	90%	10%

	Classification	Producers Accuracy	Omission Error
Producers Accuracy	Forest	100%	0%
	Settled / Cultivated	95%	5%
	Shrub/Grassland	93%	7%
	Water	83%	17%
	Wetlands	100%	0%

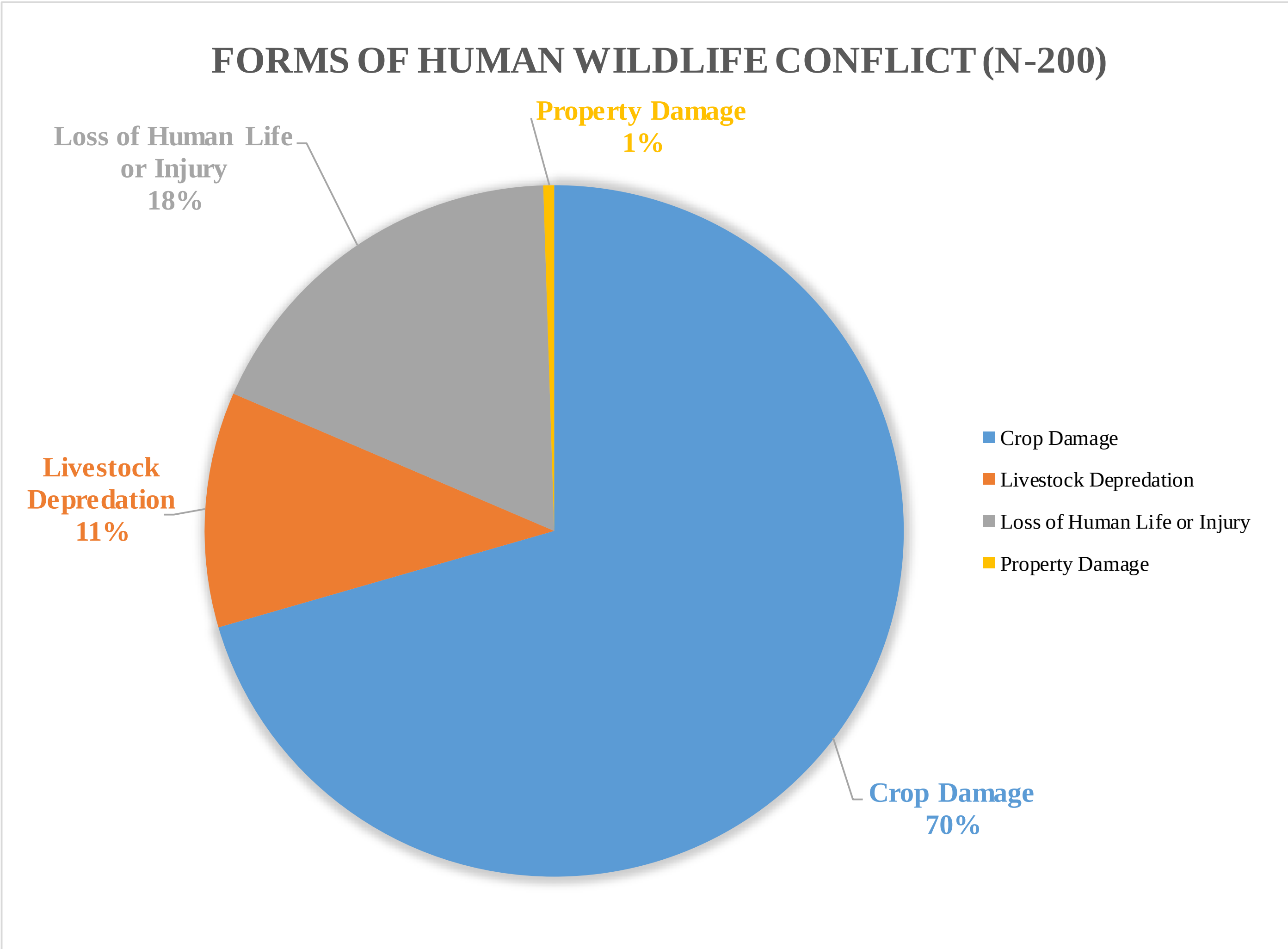
Appendix 5 : Showing an Erected Electric Wire Fence

Source: Image taken by Brian Chilambe (2022) during data collection.

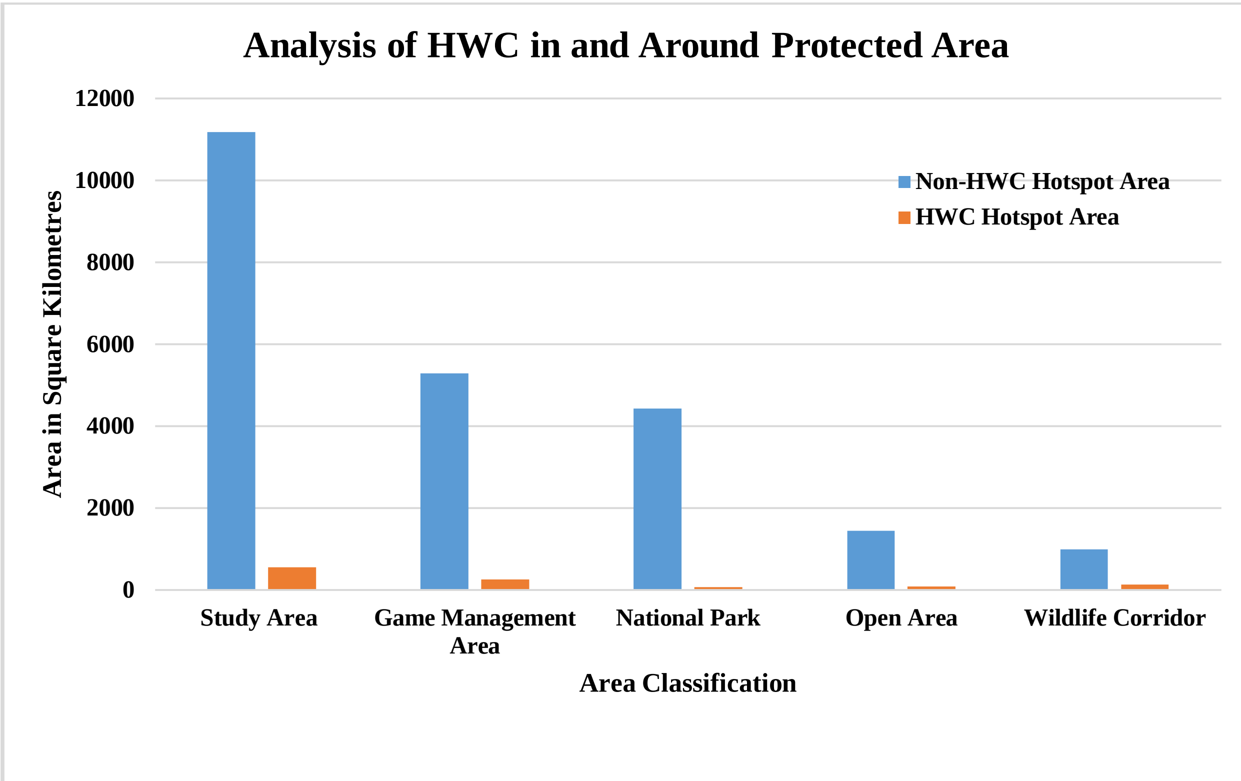
Appendix 6: Common Conflict Wildlife Species based on DNPW HWC Reports



Appendix 7: Forms of HWC based on DNPW HWC Reports



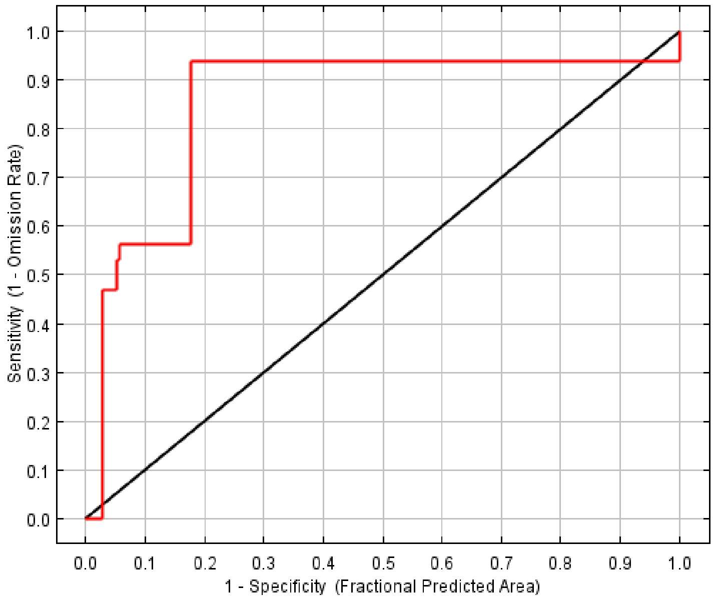
Appendix 8: Analysis of HWC in and Around Protected Area



Appendix 9: Model performance based on the Receiver Operating Characteristic curve (AUC)

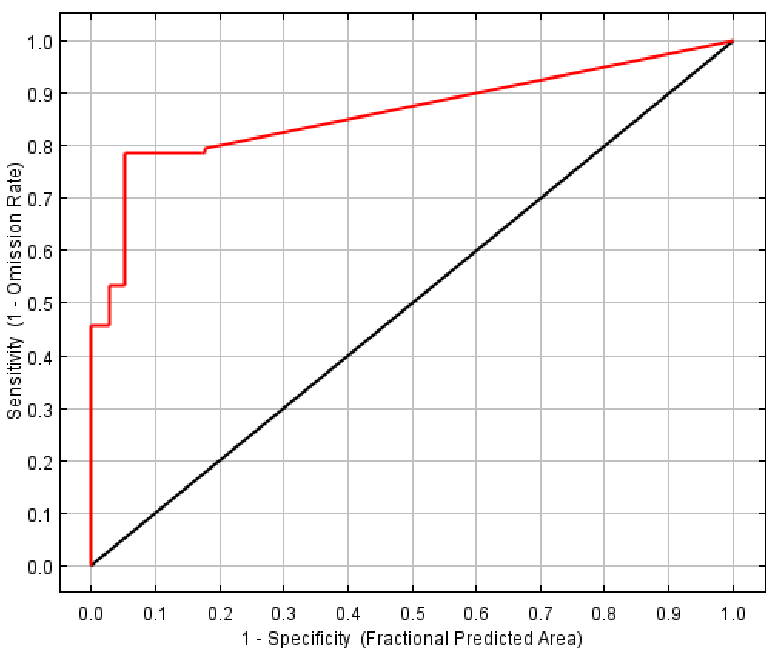
MaxEnt Model validation shows how the model performed based on the under Receiver Operating Characteristic curve (AUC). The red line shows the Receiver Operating Curve compared with the black straight line with ROC value of 0.5.

a) Training Data (40%) of Actual sample data (HWC Occurrence data) model performance (AUC)



Training data had an (AUC) performance of **AUC=0.908**

b) Actual sample data (Human-Wildlife Conflict Occurrence data) model performance (AUC)



Actual data had an (AUC) performance of **AUC=0.840**