APPROACHES AND TECHNIQUES FOR MANAGING HUMAN-ELEPHANT CONFLICTS IN WESTERN SERENGETI, TANZANIA

ISAAC YOHANA CHAMBA

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ABSTRACT

Human-elephant conflicts (HEC) have been persistent in Ikorongo-Grumeti Game Reserves (IGGRs) and the adjacent communities of Bunda and Serengeti districts, Mara region. This study aimed to identify factors leading to HEC, examine losers and gainers, determine barriers to applied measures and suggest new approaches and techniques for effective mitigation of HEC. Data collection involved direct observations, key informant interviews and household survey using questionnaires. The analysis was done using R, SPSS and MS Excel computer softwares. Results showed that factors that significantly influenced HEC occurrence ($P<0.05$) were crop raiding incidences, increasing elephant population, encroachment, lack of clear buffer zone, lack of compensation plan, infrastructure damages and direct elephant attack. Major effects of HEC in the study villages were crop damage (99%), infrastructure damage (36%), domestic animal killings (18.7%) and human killings and injury (18.3%). Farmers were the main losers, whereas in 2017 about 46.6% of cultivated farms were destroyed and none of which was compensated. On the other hand, corrupt village leaders seemed to gain from the conflicts. The major barriers to HEC mitigation measures included few and large distance between scout camps, use of poor tools like handheld torches, inadequate manpower in HWC mitigation units, and ability of elephants to adapt to most of the detterents used by farmers. A number of non- conventional mitigation measures were identified and recommended; namely construction of trench (95.3%), electric fencing (92.7%), establishment of buffer zone management units (BZMUs) (92.7%), geo-fencing system (92.3%), Wireless Sensing Network (WSN) (85.3%), translocation of problem elephants (11.7%), and evacuation of people near PAs boundaries (22%) as HEC prevention and mitigation measures with long-term impacts. Generally, no single solution is effective as different approaches need to be intergrated to address the problem proactively. Hence, it is recommended that community involvement in decision-making and policy formulation should be emphasized for effective implementation of proposed mitigation measures.

DECLARATION

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

_____ _____

Isaac Yohana Chamba Date

(MSc. Candidate)

The above declaration is confirmed by;

_____ _____

Dr. Gimbage E. Mbeyale (PhD) Date

(Supervisor)

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DEDICATION

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LIST OF ABBREVIATIONS AND SYMBOLS

BZMUs	Buffer Zone Management Units
CBNRM	Community Based Natural Resource Management
CDR	Conflict Detection and Resolution
COP	Community Outreach Programs
COSTECH	Tanzania Commission for Science and Technology
CPU	Central Processing Unit
CRT	Conflict Resolution Theory
DGO(s)	District Game Officer (s)
FZS	Frankfurt Zoological Society
GPS	Global Positioning System
GSM	Global System for Mobile communication
ha	Hectares
HEC	Human-elephant Conflict (s)
HH	Household
HNT	Human Needs Theory
HWC	Human-wildlife Conflict (s)
HWCMU(s)	Human-wildlife Conflict Mitigation Unit (s)
IGGRs	Ikorongo and Grumeti Game Reserves
NBS	National Bureau of Statistics
PAC	Problem Animal Control
PAs	Protected Areas
RDB	Rwanda Development Board
SENAPA	Serengeti National Park
SMS	Short Message Service

SPGSC	Senate Postgraduate Studies Committee
SPSS	Statistical Package for Social Science
SUA	Sokoine University of Agriculture
TANAPA	Tanzania National Parks Authority
TZS	Tanzanian Shillings
URT	United Republic of Tanzania
USD	United States Dollar
VEO(s)	Village Executive Officer(s)
VHF	Very High Frequency
WCA	Wildlife Conservation Act
WD	Wildlife Division
WMA	Wildlife Management Area
WSN	Wireless Sensing Network

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Human-wildlife conflict (HWC) is one among the major problems of global concern (Anon, 2005), which in many cases results into negative impacts on people, their properties and wild animals or their habitats (Hedges and Gunaryadi, 2010). Specific impacts include loss of life for both human and wild animals, injuries and properties damage to humans and crop destruction (Barua *et al.*, 2013). According to Estes *et al.* (2012) increased anthropogenic activities close to the protected areas influence the magnitude and intensity of the conflicts. Conflicts can result from shortage of food to wild-animals within their habitats hence naturally forced to migrate to community lands to feed on crops cultivated by local people living in areas adjacent to protected areas (Mayberry, 2015). Primack (2014) reported that not only elephants but also other animals such as birds and primates are known to raid crops. It has been found by Teel *et al*. (2010) that lack of consensus on the main cause of human-wildlife conflicts has intensified negative attitudes among people towards wildlife conservation. Generally, human-wildlife conflict results when wild animals from protected areas damage crops, infrastructure, human properties and attack people where they cause injuries, or deaths (Chomba *et al*., 2012). The conflicts can inculcate revenge behaviour among the people and thus threaten wildlife in return (Okello, 2005; Røskaft *et al*., 2012).

Human-elephant conflicts mark one of the greatest challenges of conservation in many countries around the world (Burn *et al*., 2011). Asian elephants for example (*Elephas maximus*) are one of the principal source of human-wildlife conflicts in some of Asian countries as they have consistent impact on the livelihoods of local populations (Nyhus

and Tilson, 2004). In Indonesia, 12 elephants were reported to be poisoned to death by farm workers as they were trying to enter and feed on oil palm plantations (Nyhus and Sumianto, 2000). In China, in the mountainous area of Simao, near Xishuang Banna Nature Reserve, property damages and crop raiding by Asian elephants has been reported to be done by a group of about 19 to 24 elephants (Chen *et al*., 2016; Distefano, 2005).

Moreover, in African countries such as Cameroon, Zimbabwe and Namibia, African elephants (*Loxodonta Africana*) were seen to be the most aggressive animals once they enter into communal lands compared to lions and other predators, as they attacked a large area and raided crops (Hedges and Gunaryadi, 2010; O'Connel-Rodwell *et al.*, 2000; Sarker and Røskaft, 2010a; Sukumar, 1991). In particular, human-elephant conflict (HEC) affects humans socio-economically and culturally as people spend much of their time in crop fields guarding their farms from raiding elephants while threatens survival of elephants through revenge (AfESG, 2007; Fungo, 2011; Kumar *et al*., 2011; Archie and Chiyo, 2012; Jadhav and Barua, 2012). In Kenya about 50 to 120 problematic elephants are shot dead by wildlife authorities each year as a measure to control them from killing human beings (Wanyingi, 2014). As a result, HEC together with other factors such as poaching and habitat degradation, have caused decline in African elephant population from around 3-5 million to between 470 000 and 690 000 in the last 100 years (WWF, 2014b).

Every year, Tanzania loses its elephants due to poaching, human-elephant conflicts and habitat degradation. For example a census survey conducted across six ecosystems across the country in 2009, namely Tarangire-Manyara, Serengeti, Selous-Mikumi, Ruaha-Rungwa, Katavi-Rukwa and Moyowosi-Kigosi covering 229 318 km^2 showed the

elephant population fell from 142 788 by 2006 to 109 051 in 2009 (CITES, 2010; TAWIRI, 2010). In the past five years from 2014, Tanzania has lost 60% of its elephants, as the population fell from an estimated 109 051 in 2009 to about 43 330 in 2014 (EIA, 2014; WildAid, 2014). Results from an aerial survey conducted in the Serengeti-Mara ecosystem in 2014, showed that about 192 elephant carcasses were counted, of which 117 were found in the northern part while 75 in the southern part of the ecosystem with 84% and 27% of it outside the protected area respectively (WWF, 2014a).

There is a decentralization approach on the administrative organizations with different jurisdiction over management of wildlife in different areas (Hoare, 2007). The Tanzanian wildlife policy of 1998 introduced a Community Based Natural Resource Management (CBNRM) approach that has been revised to 2007 under section 3.2.1 (c) that states "*Village communities living adjacent to protected areas, wetlands or in wildlife corridors will be encouraged to establish Wildlife Management Areas (WMAs) in order to secure habitat for wildlife and halt wetlands degradation*" to promote the management of wildlife resources outside the protected areas by establishing Wildlife Management Areas (WMAs). The approach aids at enforcing wildlife law and facilitating the application of various techniques for protecting wildlife resources such as elephants against illegal uses (URT, 1998). WMAs aid in mitigation and prevention of conflicts between human and wildlife as the approach enables the local communities to have authority and a participation platform for managing wildlife in their land (Wilfred, 2010). This makes it easier to implement strategies such as awareness raising, chilli fencing and human-wildlife conflict mitigation units. Part VIII of the Tanzania's Wildlife Conservation Act of 2009, describes the management of human-wildlife conflict by suggesting a number of approaches including problem animals control (PAC)

and consolation for loss of life, crops or injury caused by wild animals (URT, 2009). Although not to a point where there are no more conflicts, these approaches have been reducing the intensity of human-wildlife conflicts and especially human-elephant conflicts to many local communities around protected areas in the country (Benjaminsen *et al*., 2013).

However, despite all these efforts there is an ongoing dissatisfaction among local communities, farmers and herders on the way wild animals are managed, and the way destruction and losses are compensated and treated. This dissatisfaction has in many cases resulted into the human-elephant conflicts (Shemwetta and Kideghesho, 2000; Fernando *et al.*, 2008; WWF, 2014a).

1.2 Problem Statement

Human-elephant conflict is a growing problem to most of African and Asian countries and Tanzania in particular. It is a major concern of most people living close to the protected areas (Baardsen 2011). According to Perea (2009) elephants consume approximately 150kg of food daily, causing crop raiding by elephants a major problem to local communities around protected areas (Bitala, 2004). Absence of an effective buffer between protected areas and human settlements or farmlands in Ikorongo-Grumeti Game Reserves is a major source of conflicts (Kideghesho *et al.,* 2006; Nelson, 2012; Fridolin, 2014). In 2003/04 season about 323ha (732 tons) of crops were damaged by elephants while about four people were reported to be killed by elephants (Walpole *et al*., 2004). Mwakatobe *et al.* (2014) found that in the 9 surveyed villages around Serengeti National Park, and Ikorongo and Grumeti Game Reserves the mean estimated costs of crop damaged per household by raiding elephants in 2014, were about USD 31.49 (Closest villages), USD 14.06 (Medium villages) and USD 12.1 (Far away villages).

All these cause dissatisfaction and in the long run have inculcated hatred of animals and in many cases with revenging behaviour (Chang'a *et al.,* 2016). With the ongoing wildlife conservation efforts, recent spatial observation trends have shown that the elephant population in Ikorongo-Grumeti Game Reserves has been increasing from 355 to 1320 elephants from 2003 to 2014, fueling the existing human-elephant conflicts (Nelson, 2012; Goodman, 2014; WWF, 2014a).

Despite the rise in human-elephant conflicts, there is little information that is known on the (i) factors that lead to human-elephant conflicts (HEC) in western Serengeti, (ii) losers and gainers in the HEC, (iii) barriers toward HEC prevention and mitigation approaches and techniques applied and (iv) new approaches to be applied in addressing the problem. This is because most of traditional techniques such as chilli essence (Malugu, 2011), guarding farms (Walpole *et al.,* 2004), scaring elephants using noise and pungent materials (Pittiglio *et al*., 2014), planting alternative crops and buffer crops around fields (Hoare, 2012), and benefit sharing (Gross *et al*., 2016; RESOLVE *et al.*, 2016) have shown short-term impacts leaving a security gap to be filled.

1.3 Justification of the Study

This study aimed at making a detailed study and contributing to knowledge regarding approaches and techniques with long-term impacts required to mitigate human-elephant conflicts in Ikorongo-Grumeti Game Reserves and the surrounding villages. Results obtained from this research will add to the understanding of long-term measures, opening the chance of preventing and combating existing human-elephant conflicts in western Serengeti area and other protected areas having similar problem. Moreover, the study will add knowledge on the management of socio-ecological systems.

1.4 Objectives

1.4.1 Main objective

The main objective of the study was to identify and recommend approaches and techniques for managing human-elephant conflicts (HEC) in western Serengeti area, Tanzania.

1.4.2 Specific objectives

The specific objectives of the study were:

i. To identify factors that lead to human-elephant conflicts (HEC) in western Serengeti
ii. To examine losers and gainers in the human-elephant conflicts (HEC)
iii. To determine barriers toward the different approaches and techniques for prevention and mitigation of human-elephant conflicts (HEC) applied in western Serengeti
iv. To identify novel approaches and techniques to be applied for prevention and mitigation of human-elephant conflicts (HEC) in western Serengeti.

1.5 Research Questions

i. What are the factors that lead to human-elephant conflicts (HEC) in western Serengeti?
ii. Who are the losers and gainers in the existing human-elephant conflicts?
iii. What are the barriers toward applied approaches and techniques for managing human-elephant conflicts (HEC) in western Serengeti area and how can be addressed?
iv. What are the novel approaches and techniques to be applied for prevention and mitigation of human-elephant conflicts (HEC) in western Serengeti area?

1.6 Theoretical Framework

Conflict refers to a situation arising from two or more parties that have incompatible goals about something (Mwagiru, 2000). In understanding sources of conflicts that occur within socio-ecological systems and conflict management techniques, a theoretical framework is developed. The framework is bases on two theories, Human Needs Theory (HNT) and Conflict Resolution Theory (CRT). Abraham Maslow through his Maslow's hierarchy of needs applied human needs theory by urging that, in order to live and attain well-being, humans need certain essentials. These are called human needs or basic human needs. Humans will struggle to ensure they meet these needs. At the base of the pyramid he places food, water, and shelter followed by need for safety and security. Human needs theorists argue that conflicts and violent conducts are caused by unmet human needs. In socio-ecological systems wild animals damage human properties, and cause injury and deaths to people when their ability to meet needs is compromised resulting into conflicts with human beings (Danielsen, 2005). On solving conflicts, in 1949 Morton Deustch developed a theory of Conflict Resolution. He urged that in order to solve an existing conflict the two parties involved should cooperate in solving the conflict. They should work together in finding the constructive measures rather than working separately and come up with destructive ideas. It is considered to be "Cooperation-Constructive; Competition-Destructive" theory (Hansen, 2008).

1.7 Conceptual Framework

The study is based on the concept that conflict analysis and resolution is the systematic study of identifying the profile, causes, actors, dynamism of conflict and effective measures that can be applied to manage the existing conflicts. It helps conflict managers to get a clear insight on understanding the context of management of both social and ecological systems. Conflict management is thus a central component of managing the

contradicting parties or systems, as it provides the foundation to inform managers on the consideration of needs to both social and ecological systems. Fig. 1 highlights the common features for human-elephant conflicts, which will contribute in understanding the interaction between the context and future prevention and mitigation approaches and techniques.

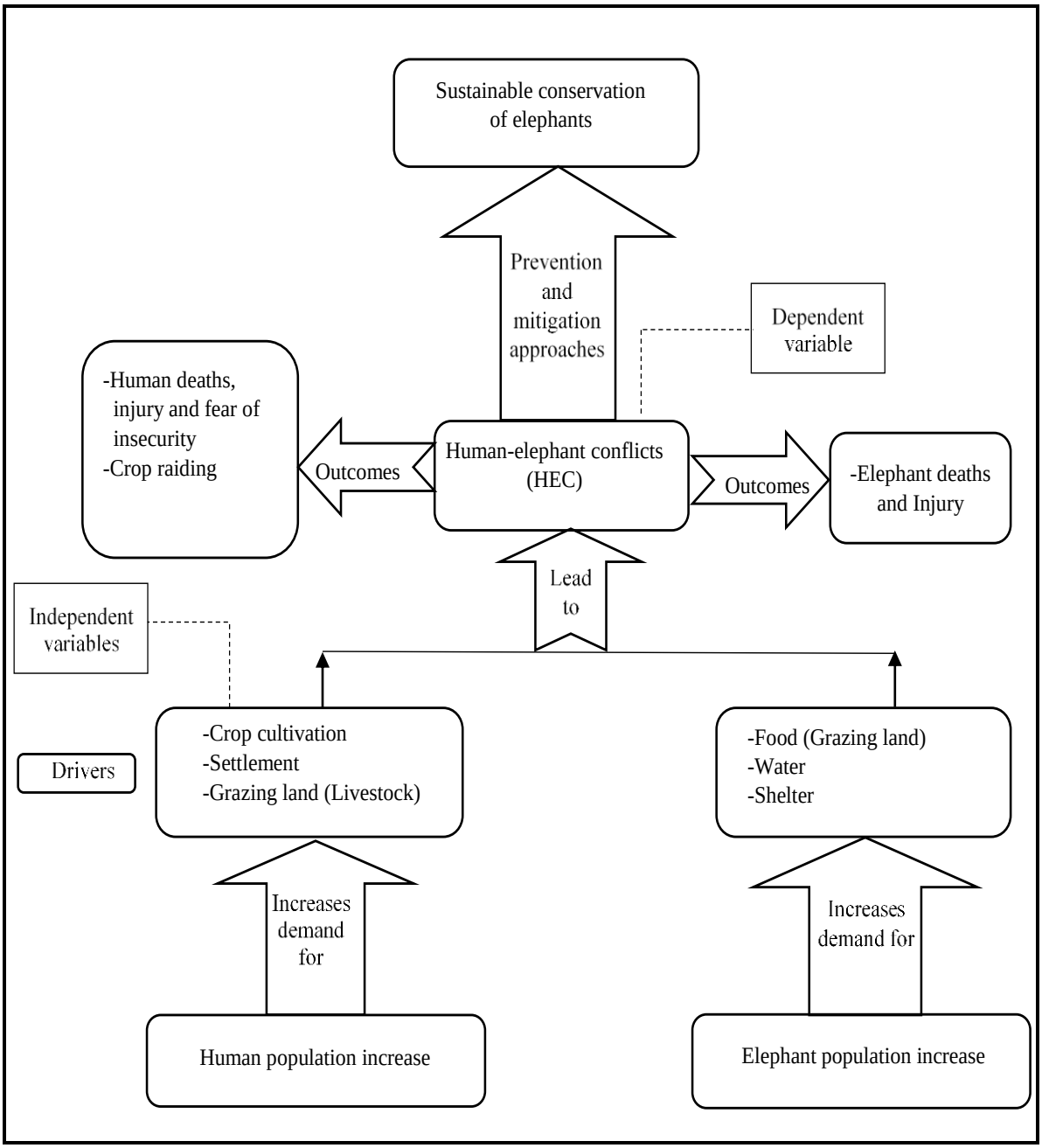

Figure 1: Conceptual framework for understanding human-elephant conflicts management

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The concept of Conflicts

In understanding and avoiding confusion in this study various concepts were defined. There are actually several ways to define conflict due to how it is used in different settings. Hence, to keep it simple for the purpose of this study, conflict pertains to the opposing ideas and actions of different parties, thus resulting in an antagonistic state. It can also be described as a disagreement among groups or individuals characterized by hostility (Thomas, 1992). This is usually fueled by the opposition of one party to another, in an attempt to reach an objective different from that of the other party. The elements involved in the conflict have varied sets of principles and values, thus allowing such a conflict to arise. According to Mwagiru (2000) conflict refers to a situation arising when two or more parties have incompatible goals about something. Solving the conflicts require strategies necessary to ensure there is a balance between the two parties on meeting their goals. The challenge of conflict management therefore is not how to do away with conflicts but how to deal with them so that their harmful effects do not impact the society and ruin relationships. Conflict Management refers to any process by which parties in conflict are encouraged to come together and do something to resolve the conflict (Sandle and Merwe, 1993).

On the other hand, conflict prevention is referred to strategies that are implemented when the conflict is certain to happen or to avoid the conflict occurrence at first place. Mitigation are strategies attempting to reduce the level of impact and lessen the problem (Thomas, 1992). Protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to ensure there is long-

term conservation of nature with associated ecosystem services and cultural values (IUCN, 2008). Furthermore, human-elephant conflict (HEC) refers to any human-elephant interaction which results into negative effects on human social, economic or cultural life, on elephant conservation or on the environment (AfESG, 2007). Looser can be reffered to a person who is bound to failure on obtaining something, whereas gainer is a person bound to benefit from existing conflicts.

2.2 Human-Elephant Conflicts

Conflicts between people and elephants are increasing as both human and elephant populations continue to expand and natural habitats shrink (Kideghesho, 2006). The conflicts can be real or perceived, economic, social or political and may be associated with some ecological, social, economic and political factors. In order to manage elephants moving from protected areas to human dominated landscapes there is a need to strike a balance between conservation priorities and the needs of people who live adjacent to protected areas (Galvin *et al*., 2008). The problems caused to humans especially crop raiding and destruction of properties need to be known (Malima *et al*., 2005). Understanding the causes, timing and distribution of attacks on people and their crops is a step toward reducing the problem and hence prevent it (Fridolin, 2014). Conservation of wildlife outside protected areas cannot be achieved merely by protecting animals while avoiding the issues of human needs, their rights and their conflicts with wildlife (AfESG, 2007; FAO, 2009).

2.3 Causes of Human-Elephant Conflicts

A set of global trends have contributed to the increase of human-elephant conflicts (HEC) worldwide (Burn *et al*., 2011). These can be grouped into human population growth, land use transformation, species habitat loss, degradation and fragmentation,

growing interest in ecotourism and increasing access to nature reserves and increasing wildlife population as a result of conservation programmes (Estes *et al*., 2012). Invasion of human beings and conversion of natural habitats to human dominated land use causes fragmentation and loss of elephant habitat (Chartier *et al*., 2011). With increased contact, elephants progressively raid crop fields and break down houses to get stored crops (Fungo, 2011; Webber *et al*., 2011). Chance encounters between elephants and people living to areas adjacent to protected areas, as well as efforts of people guarding food crops in their farms against raiding elephants result in injury and death of humans (DeMotts and Hoon, 2012; Pant *et al*., 2016). Harmful methods employed by people in the process result in death and injury of elephants thereby escalating human-elephant conflicts (HEC) (Mijele *et al*., 2013; Fernando *et al*.,2005; Wittemyer *et al*., 2014).

In Africa, human population growth has led to encroachment into wildlife habitats, constriction of species into marginal habitat patches and direct competition with local communities (Barua *et al*., 2013; Siex and Struhsaker, 1999). Crop damage by elephants is one of the most common causes of human-elephants conflicts in southern Africa, where rural people are dependent on traditional agriculture for their livelihoods (Osborne and Parker, 2003; Barnes *et al*., 2005; Malima *et al*., 2005). The study done at Arabuko Sokoke forest (2001) in Kenya found that there was a correlation between water availability, rainfall, food availability and crop raiding by elephants. Occurrence of crop raiding was due the movement of elephants from one area to another area in search of suitable habitats having enough water and food, particularly during dry seasons (Muoria, 2001).

2.4 Human-Elephant Conflicts Intensity

The intensity of human-elephant conflict varies among different protected area segments such as inside, edge and outside the protected areas (Hartter *et al*., 2011). In addition,

roads and settlements close to protected areas are mostly affected by elephant attacks (Saaban *et al*., 2011). Intensity of deaths and injuries were highest in settlements close to protected areas, corridor enclosed settlements, and protected areas' edges. This is due to the short distances between settlements which have been constructed illegally and forests or other protected areas, food scarcity inside the forest and extreme disturbances by people (Beyers *et al*., 2011). The human-elephant conflicts intensity rate are remarkable high near the edges of protected areas because of more agriculture related practices and illegal settlements (Joshi *et al*., 2011). In addition, human-elephant conflict intensity is high inside the protected areas due to illegal human entrances. According to Sukumar (1989), 55% of human deaths which occurred in the forests comprising the Biligirirangans of Tamil Nadu were during the day, while 45% of the deaths occurred in settlements at night from a total of 123 human deaths caused by elephants in India. Moreover, factors which are more responsible for the increased deaths and injuries among the people inside the forests are weak forest management system and lack of awareness to most local people adjacent to protected areas (Ramkumar *et al*., 2014). Human-elephant conflicts are increasing outside the forests due to crop raiding in the crop fields and raiding for stored grains in houses (Sarker and Røskaft, 2011; Sukumar, 1990).

In India around 300 humans are killed by elephants and around 200 elephant deaths are found every year (Bist, 2002). Similarly, in Sri Lanka around 150 elephant deaths are found every year due to human and elephant conflicts (Perea, 2009). According to Lee *et al.* (1986) negative interactions between humans and elephants have escalated dramatically over the last 30 years. Encroachments of forest land and establishment of new illegal settlements are the dominant causes behind the increasing intensity of human-elephant conflicts. Poor people are being driven out from their original land to

forest land due to financial crisis, lack of livelihood opportunity and excess of land cost. Human-elephant conflicts intensity also varied significantly between different seasons which mainly are due to crop availability in the fields (Bal *et al*., 2011; Gunn *et al*., 2014). The conflicts seem to increase at extreme levels during the winter and rainy seasons, when crops cultivated by local people living adjacent to the protected areas are in harvesting stage (Sarker and Røskaft, 2010b; Sukumar, 1990).

2.5 Control, Prevention and Mitigation Measures for Human-Elephant Conflicts (HEC)

Mitigation and prevention of human-elephant conflicts require a complete understanding of the problem, its locality, specific causes and attempts to solve it, in order to develop effective management strategies for local communities (Redpath *et al*., 2013; Sitati *et al*., 2003). Various techniques employed in mitigation of human-elephant conflicts (HEC) range from chasing elephants by shouting, drum-beating, noise-making, use of fire crackers, lights, use of chilli pepper and torches (Hill and Wallace, 2012; King, 2011). Furthermore, engaging approaches such as koonkies (trained elephants), specially trained and equipped teams of people, construction of elephant barriers such as rubble walls, ditches and canals, biological and electric fences have been employed in various countries (Joshi, 2010). According to Bandara (2010) and Fernando *et al.* (2005) deployment of alarms, development of communication systems, capture, translocation and culling of problem animals, use of highly sophisticated technology such as satellite telemetry, and compensation and insurance schemes have been suggested.

In Ontario Canada, different ways to mitigate the problem of human-wildlife conflicts such as involvement of stakeholder especially local community in the development and implementation of management tools are used (Estévez *et al*., 2015). Promoting

conservation of biodiversity among people through community based conservation (CBC), where local communities own and manage the area (Derocher *et al*., 2013). Encouraging local communities to initiate discussions on conflict issues tend to increase public understanding and awareness about human-wildlife conflicts (OMNR, 2005).

The study suggesting the killing of elephants as a routine method of problem animal control (PAC) was illustrated by Hoare (2001) who showed experimental data on a crop-raiding group of bull elephants. In 2011, the wildlife authorities of Botswana stated that the legal hunting quota for elephants (27 animals) was to be made up entirely of male crop raiders, believing that, this would help control these problem animals (Bungu, 2011). Use of bees as an elephant deterrent is the other way of preventing elephants from entering the villages. Kenya uses African honey bees (*Apis mellifera*) as a deterrent to crop-raiding elephants where the sound of bees had previously caused elephant groups to either apparently retreat from the source of sound or make alarm calls (King *et al*., 2010, 2011).

Monetary compensation has been used as another way of mitigating human-elephant conflicts where it was tried at many scales but has never been successful in practice (AfESG, 2000). Botswana remains the only of African countries which is still paying across the board wildlife damage compensation to local communities surrounding protected areas (DeMotts and Hoon, 2012). Recently in Uganda, a study conducted suggested that the actual compensation of crops and properties damaged by elephants and other wildlife species is not affordable by protected area authorities (Babaasa *et al*., 2013). Furthermore, the study insisted that it is not sustainable towards conservation as the conflict seems to increase. In turn, Mackenzie and Ahabyona (2012) suggested the best way of using obtained funds to prevent and mitigate the human-elephant conflicts

among local people living adjacent to protected areas, is through promotion and increase awareness on crop raiding control measures.

O'Connell-Rodwell *et al*. (2000) found that, electrical fencing was effective in controlling crop damage caused by elephants, hence reducing costs at the community level in the East Caprivi Region of Namibia. The large number of crop raiding incidences was due to high population densities of both people and elephants in an area, resulting into an increased human-elephant conflict compared to other areas within the country (Lindeque, 1995). Local communities were encouraged to use chilli-based olfactory repellents to deter elephants from entering crop fields or human habitats (Hoare, 2015; Le Bel *et al*., 2015). Although large quantity of chilli aerosols was needed in order to reach elephants to some distance where they are, once reached them the chilli started to make them hot hence deter from an area (Osborn, 2002). For example, four years of monitoring the use of chilli in western Serengeti, showed increasing uptake by farmers reduced the total elephant crop raids in 22 villages by 89% (Malugu, 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Ikorongo-Grumeti Game Reserves and the surrounding villages lie between latitudes 1º30' and 2º45' S and longitudes 33º00' and 35º30' E. The area covered by Ikorongo and Grumeti Game Reserves is 563km^2 and 416 km^2 respectively (Fig. 2) (Kideghesho *et al.*, 2006; Kideghesho and Mtoni, 2008).

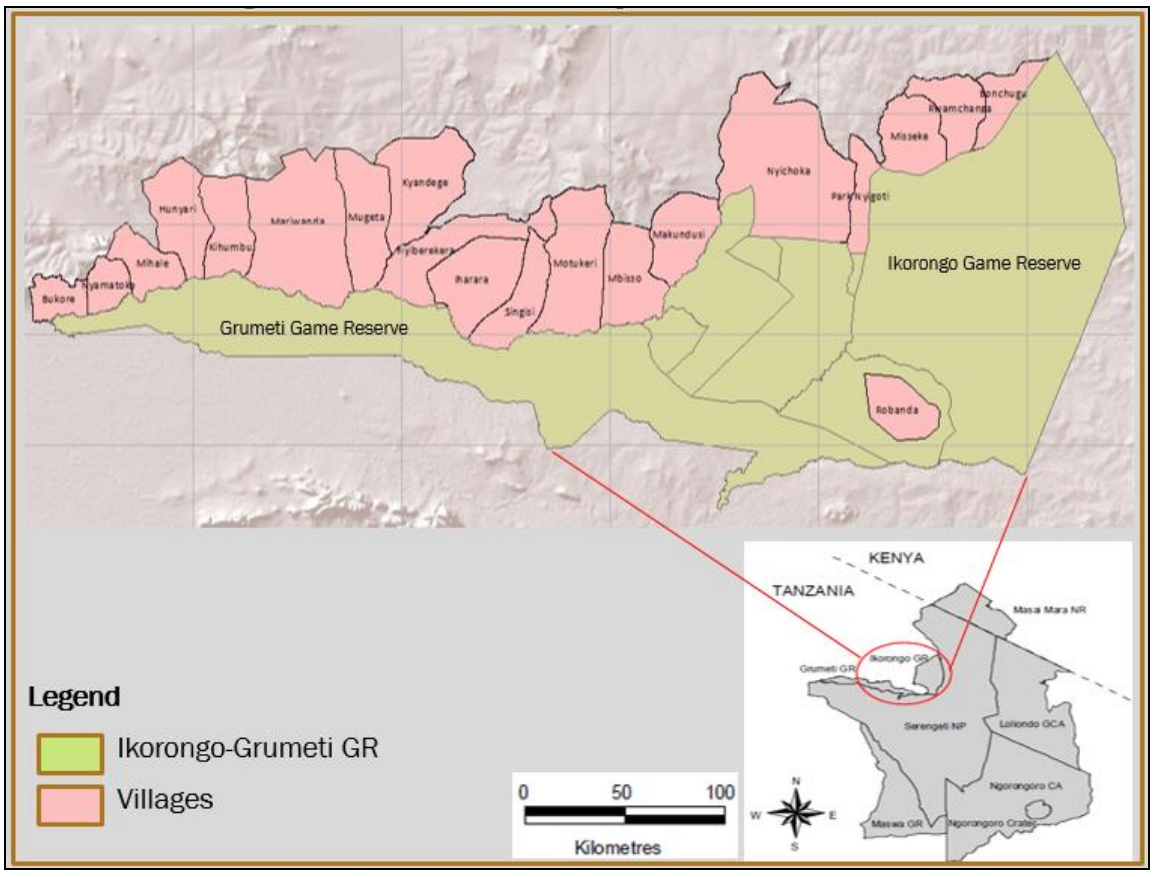

Figure 2: Map of Serengeti Ecosystem, with the study area cycled in red.
Source: Singita Grumeti Fund

3.1.2 Climate

The area experiences two rainy seasons occurring in March to May (long rains) and November to January (short rains). It is characterized by an average annual rainfall approximated to range between 500 mm and 1200 mm declining towards the park boundary and increasing towards Lake Victoria and an annual temperature range of between 21°C and 27°C (Goodman, 2014).

3.1.3 Vegetation

Vegetation cover of an area is a highland savannah with thorn tree woodlands and plains ranging from approximately 900 to 1500 meters above sea level. Singita Grumeti is an integral part of the Serengeti-Mara ecosystem, known as the home of the Great Migration as it protects the path of the annual wildebeest migration (Kideghesho *et al*., 2006).

3.1.4 Ethnic groups

The Ikorongo-Grumeti Game Reserves are bordered by diverse ethnic groups which are approximately to be more than 20 tribes in the area. The major ones being Ikoma, Taturu, Ikizu, Nata, Isenye, Zanaki, Sukuma, Kurya, Zizaki, Ngoreme and Jita. Almost all of them engage into crop cultivation as well as livestock keeping for sustaining their living. Crops cultivated are maize, cassava, millet and sorghum as food crops and cotton as a cash crop. Livestock include goats, donkey, cattle and sheep (Kideghesho, 2006; Galvin *et al.,* 2008).

3.2 Research Design and sampling Procedure

3.2.1 Research design

A cross-sectional research design was used in collecting primary data from the study area. According to Olsen and George (2004), this type of research design either the

entire population or a sample is selected, and from these individuals, data are collected to help answer research questions of interest. Furthermore, it is clarified that it is called a cross-sectional because the information about the subject is gathered only at one point in time. This research design is chosen because it is more flexible and less costly (Babie, 1990; Bailey, 1994).

3.2.2 Sampling procedures

3.2.2.1 Sampling unit

The target population for the study involved communities bordering Ikorongo and Grumeti Game Reserves. The sampling frame was the village registry books containing list of households that served as sampling units.

3.2.2.2 Sampling methods and Sample size

Six sample villages were purposely selected from villages adjacent to Ikorongo and Grumeti Game Reserves based on the nearest distance from the protected area boundary and number of human-elephant conflict incidents reported. The villages selected were *Nyamatoke, Hunyari, Iharara, Makundusi, Nyichoka and Bonchugu*. Simple random sampling method was used to select 50 households from the village registry book of each sampled village in order to keep the sample size above 30 households. Bailey (1994) found that a sample size of 30 from one observation unit is considered adequate to which statistical analysis can be applied.

Generally, a total representative sample of 300 households for the study from the target population of 3004 households was obtained of which 55.7% were female and 44.3% were male. Age distribution of respondents from all six villages varied from 18 to ≥66 years with majority being in the age group of 18-35 years. Most of the surveyed

households depended on crop farming (43.7%) and mixed farming (38.7%) as their prime source of income, whereas 53.7% had an approximate annual income of less than TZS. 800 000/=, those with an annual income ranging from TZS. 800 000/= to 1 600 000/= were (27.7%), followed by those having an approximate annual income of TZS. 1 600 001/= to 2 000 000/= and above TZS. 2 000 000/= who comprised of 9.7% and 9.0% respectively. Moreover, twelve (12) key informants who were District Game Officers (DGOs), SGF staffs, Village Executive Officers (VEOs) and elderly villagers both men and women were purposively chosen.

3.3 Research Instruments

A researcher is required to design instruments that will be used for data collection from respondents. Hence, in this study the researcher used questionnaires and key informant interview guides as the tools for data collection. A questionnaire entailed questions which are either close-ended or open-ended. Kothari (2004) asserted that structured items denote questions with a list of all likely substitutes where respondents select the answer that describes their circumstances. Alternatively, open-ended questions refer to questions which grant respondents a comprehensive freedom of response where they describe their circumstances in their own words. A questionnaire enables the researcher to obtain a large quantity of data inexpensively from a wide range of participants sometimes spread extensively in a geographic space.

Household questionnaires were used in this study. The questionnaires were divided into five parts. Part A covered particulars of respondents, part B covered respondent's land use and property rights, part C covered information on human-elephant conflicts, part D covered HEC prevention and mitigation measures and part E covered respondent's willingness to contribute to the new approaches and techniques. The key informant

interview guides were used to collect information on background information, the status and trends of human-elephant conflicts for the past eight years (2008-15) and conservation measures on human-elephant conflicts.

3.3.1 Pilot testing

A pilot study or pre-testing as a primary test was carried out before embarking to the study to ensure that questionnaires are working properly (Polit *et al*., 2001). According to Mugenda and Mugenda (2008) cited by Machoka (2017), a pilot test comprises of about 1 to 10 percent of the total targeted population. Therefore, a pilot testing for this study was carried out and comprised of 30 households 5 from each surveyed village who did not play part in the study sample. Pilot study was carried out to check whether the data collection tools were valid and reliable and the data to be obtained were of acceptable and standard quality. The pilot study responded to various matters, including; (i) offered the researcher the chance to measure importance of the data by testing the validity and reliability of the questionnaires; (ii) ensuring the enumerators are adequately trained in the process; (iii) checked the presentation of questionnaire, precision and significance; (iv) checked that guidelines are understandable and; (v) ensuring that statistics and analysis process is correct (Van Teijlingen *et al*., 2011).

Following the pilot study some changes were made in the questionnaires to minimize the chances and vagueness of some questions before administered to the respondents. At piloting, the items in the questionnaires were made to be acceptable in terms of word, format and meaning. The amended questionnaires were then used for data collection during the final survey.

3.3.2 Validity of the instrument

Thatcher (2010) asserts that validity of a measuring instrument indicates its ability to measure what it is intended to measure. That is the extent to which the obtained variance in the measuring instrument imitates the true variance among the individuals being tested (Kothari, 2004). The validity test was done using the content validity test to test the tool for accuracy and adequate coverage of the topic under study. To improve content validity the researcher sought out an expert judgement and help from the supervisor to assess whether the questions were perfectly formulated and represented the topic under study. The items that were less adequate and inaccurate in regards to the topic under study were removed while some were changed.

3.3.3 Reliability of the instrument

Reliability can be referred to the ability of a measuring instrument to provide consistent results over time. Therefore, it is the degree to which measures are free from error and in effect yield consistent results (Kothari, 2004). The researcher employed the internal consistency reliability test to measure how consistently participants responded to a set of items. The researcher aimed at determining the coefficient of internal consistency using Cronbach's alpha (sometime called coefficient alpha) whose value varies between 0.00 (indicating no reliability) and +1.0 (indicating perfect reliability). The Cronbach's alpha was used to measure the reliability of tested items. A coefficient of 0.89 was obtained which according to Nitko and Brookhart (2011), a correlation of ≥ 0.80 is determined to be necessary to establish internal consistency reliability.

3.4 Data Collection Procedures

3.4.1 Primary data collection

Data were collected using various techniques including direct observations, key informant interviews and household survey using questionnaires.

3.4.1.1 Direct observation

Direct observation is the collection of information from the environment without altering that environment. Therefore, the researcher visited Ikorongo-Grumeti Game Reserves and their bordering villages observing different anthropogenic activities taking place within surrounding communities. Moreover, the researcher used direct observation to obtain information on the new approaches and techniques with long-term impacts on human-elephant conflicts (HEC) prevention and mitigation in western Serengeti area. Direct observation provides best information because the researcher has opportunity to observe by himself the incidences directly from the environment.

3.4.1.2 Key informant interviews

Key informant interviews are interviews with people who have access to information valuable for the researcher such as insights about the functioning of society and their problems. The researcher used face-to-face interview as a technique of key informant interviews to ask questions and receive response from the respondents in order to obtain and record information. In the study area key informants were District Game Officers (DGOs), SGF staffs, Village Executive Officers (VEOs) and old people who had first-hand knowledge about the losers and gainers in the human-elephant conflict, and new approaches and techniques with long-term impacts that could be applied to prevent and mitigate human-elephant conflicts (HEC) in the area. Checklist was used to collect this information from key informants. This technique was used as it provided information from knowledgeable people, opportunity to explore unanticipated ideas due to free-exchange of ideas and the method was inexpensive and easy to conduct (Brookes, 2007).

3.4.1.3 Household survey

Household survey involved administration of questionnaires. A questionnaire is a document containing questions designed to solicit information appropriate for analysis

(Babie, 1990). In this study questionnaires with both closed and open-ended questions were administered to the respondents from selected households of each sampled village (Kothari, 2004). Questionnaires were used to seek information on factors that lead to human-elephant conflicts (HEC) in the area, and barriers towards the applied mitigation measures based on local knowledge people have and how can be addressed. Moreover, they were used to obtain information on the new measures with long-term impacts on prevention and mitigation of human-elephant conflicts (HEC) in the area.

3.4.2 Secondary data collection

Secondary data were obtained from different sources including books, journals, research papers, pamphlets, web-based literature and relevant reports from Singita Grumeti Fund, Bunda and Serengeti District Game Offices and Village Government Offices. Secondary data provided information that was complementary to the primary data. Secondary sources provided up to eight (8) years period information on the status and trend of human-elephant conflict incidences, number of people affected, number of elephants suffered from the conflict and information on applied measures to prevent elephants from damaging crops, infrastructure and killing and/or injure human beings and other domestic animals.

3.5 Data Analysis

Qualitative data obtained from the survey were analyzed using content analysis. Content analysis involved summarizing through breaking down the recorded dialogue into the smallest meaningful units of information and opinions of respondents over the study topic (Kajembe, 1994). Quantitative data were verified, compiled, summarized, coded and analyzed using R version 3.3.3, Statistical Package for Social Science (SPSS) and MS Excel computer softwares. Descriptive statistics including frequencies, percentages

and cross-tabulation were generated. Binary logistic regression model was used to regress factors influencing occurrence of HEC in western Serengeti as shown in Equation 1 (Tranmer and Elliot, 2008).

To determine losers and gainers from the conflicts, descriptive statistics was employed to give frequencies and percentages of responses from the respondents. Also, the descriptive statistics was used to summarize and analyze the respondents' opinions on the applied measures to prevent and mitigate HEC together with their barriers by giving frequencies and percentage of the responses. In the analysis of information on new approaches and techniques to be applied for effective prevention and mitigation of human-elephant conflicts in surveyed area, both content analysis and descriptive statistics were employed and results were summarized in tables and graphs.

$$\mathbf{Y_1 = Exp(\beta_o + \beta_1 X_1 + \ldots + \beta_n X_n)/1 + Exp(\beta_o + \beta_1 X_1 + \ldots + \beta_n X_n)} \quad \text{(Equation 1)}$$

Where;

Y_1= Occurrence of HEC

Exp= Exponent of the variables

β_o= Constant

β_1= Regression coefficient of predictor variable 1 (or 1st factor)

β_n= Regression coefficient of predictor variable n (or 7th factor)

X_1= Predictor variable 1 (or 1st factor)

X_n= Predictor variable n (or 7th factor)

3.6 Ethical Considerations

Ethical considerations are crucial for any research. Research ethics were revised by the Research and Publications Committee of the Sokoine University of Agriculture (SUA)

to make sure ethical guidelines for carrying out the research and ethical values are not dishonored (Matovelo *et al*., 2010). The respondents were guaranteed of discretion of the information to be provided and concealment of the source of data as the questionnaire did not call for revelation of identity. To enable independence in the study, measures were taken to make sure that individual bias of the researcher did not interfere with the research process and that all parties were given a fair consideration. In reporting the findings, the researcher accurately represented data collected and it was used only for the purposes of this study.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

This chapter includes results and discussions of the research findings. In addition to that, it presents a conflict analysis and strategy design that describes various causes of conflicts between human and elephants. Moreover, the Chapter addresses losers, gainers, barriers towards the applied techniques and the measures and approaches that can be done to resolve the HEC conflicts within the Serengeti Ecosystem particularly in IGGRs, Ikona WMA and the surrounding communities.

4.1 Factors Influencing Human-Elephants Conflicts in Western Serengeti Area

Identifying factors that lead to the occurrence of human-elephant conflicts is the key point towards identification of appropriate measures that can have a long-term impact over the existing human-elephant conflicts. Table 1 presents the logistic regression output of the factors. The identified factors with significant relationship with the response variable were crop damage, increased elephant population, encroachment, lack of clear buffer zone, infrastructure damage and lack of compensation plan (Table 1).

Table 1: Significant variables in the binary logistic regression model

Factor (*X*)	**Estimate (β)**	**Std. Error**	***Z* value**	**Pr(>|*z*|)**
Crop damage	1.69999	0.34138	4.980	6.37e-07 ***
Increased elephant population	0.76957	0.34385	2.238	0.02521 *
Encroachment	-0.16176	0.07854	-2.059	0.03945 *
Lack of buffer zone	0.99572	0.33418	2.980	0.00289 **
Infrastructure damage	0.94550	0.34051	2.777	0.00549 **
Lack of compensation plan	1.07835	0.32979	3.270	0.00108 **
Human attack	1.71306	0.33800	5.068	4.02e-07 ***
Constant	-4.24727	0.73689	-5.764	8.22e-09 ***

*Significance codes: '***' 0.001 '**' 0.01 '*' 0.05*

4.1.1 Crop raiding incidences

Crop raiding incidences showed a significant relationship with the occurrence of HEC in the study area (β=1.69999, $P<0.05$). This indicates that, holding other factors constant, for every one unit change in crop raiding incidence the log odds of HEC occurrence increases by 1.7 in western Serengeti area. Moreover, findings from the survey showed that 99% of the respondents considered crop raiding caused by elephants one among the factors influencing conflicts between human and elephants. This is an indication that crop damage done by raiding elephants contributes to conflict between elephants and people of western Serengeti area. The extent to which crop raiding incidences caused by elephants had an influence on the occurrence of HEC is presented in the Table 2 below.

Table 2: Extent to which crop raiding incidences enhanced HEC

Extent	Frequency (n=297)	Percentage	Rank
Very high extent	262	88.2	1
High extent	31	10.4	2
Moderate extent	1	0.4	4
Not applicable	3	1.0	3
Total	297	100	

Majority of the respondents indicated that crop raiding by elephants contributed to HEC at a very high extent as it was ranked the first (Table 2), high extent (2) and medium extent (4). This finding concurs that encroachment of crop cultivation near protected area boundaries increases pressure on wild animals such as elephants forcing them to move outside the protected area into village land (Naughton-Treves, 1998).

From year 2008 to 2014 approximately 8954.5 acres of crops were damaged by elephants in Serengeti district, whereas about 6438.5 acres were damaged in villages from Bunda District leaving majority of farmers without food. Results obtained from

300 respondents in the surveyed villages showed that in 2017 cropping season about 1819 acres were cultivated, of which 847.5 acres were raided by elephants that accounting 46.6% of cultivated land (Table 3). Major crops which were destroyed are maize, cotton, millet, cassava, rice and sweet potatoes. This resulted into an increased sense of food insecurity among the people.

Table 3: Crop damage by elephants in the surveyed households in 2017

Village Name	Nyamatoke	Hunyari	Iharara	Makundusi	Nyichoka	Bonchugu	**Total**
Cultivated farms (Acres)	286.5	292	218.5	391.5	315	315.5	**1819**
Damaged farms (Acres)	140.5	138	124	166.5	112	166.5	**847.5**

4.1.2 Increased elephant population

Increased elephant population showed a significant relationship with the occurrence of HEC in the study area (β=0.76957, $P<0.05$). This means that an increase in one unit of elephant population, the log odds of HEC occurrence increases by 0.77. Successful conservation initiatives implemented in IGGRs concession has resulted into massive increase in the population of elephants (Goodman, 2014). This increase in elephant population exerts pressure on grazing land within the protected areas resulting into the elephants to move in and out of the protected area boundary in search of resources such as food and water. Fig. 3 shows that elephant population in Ikorongo and Grumeti Game Reserves has been changing substantially over the eleven years since 2003 to 2014. However, since 2011 onwards the trend has been increasing gradually suggesting the persistence of elephant invasions into the human dominated land around the reserves.

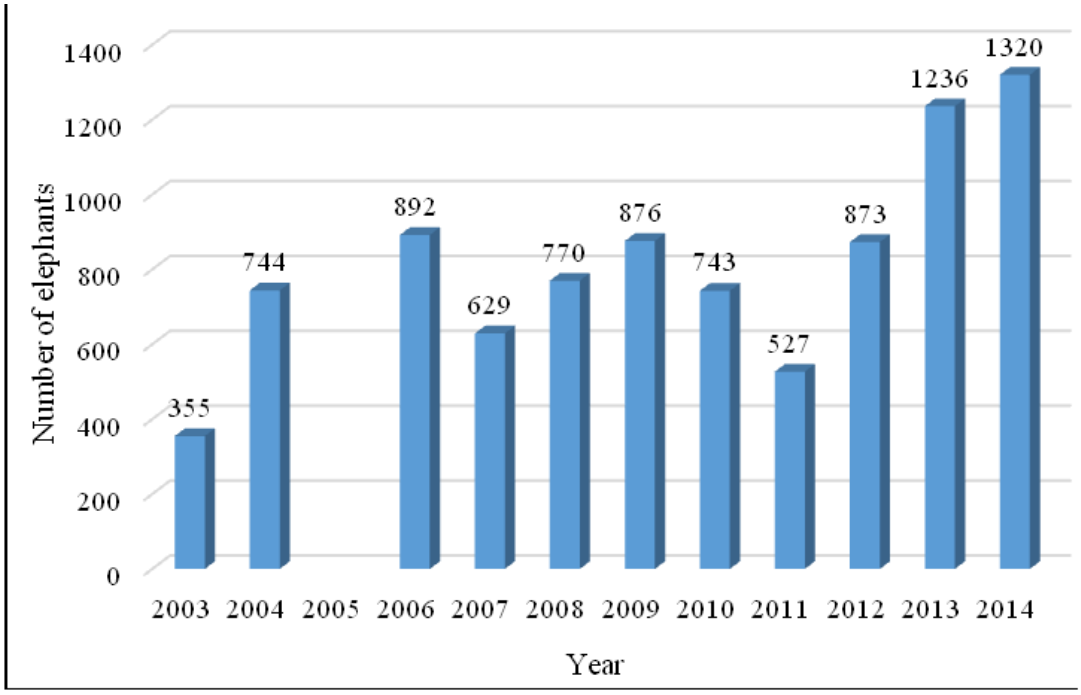

Figure 3: Trend in the size of the elephant population in IGGRs
(Source: Goodman, 2014)

The results show that almost all respondents (99%) indicated that elephant population has been increasing in the study area causing it to be one among the factors influencing HEC in their villages. Whereas, in the past they had never seen elephants in the village land but later on few elephants started to invade and raid crops within the villages. Some of the respondents added that, they had never seen elephants within the village since they were born until 2000s where the invasion started and has been increasing temporally. This was further evidenced by a report from WWF showing a general increasing trend in the elephant numbers within the Serengeti –Mara ecosystem (WWF, 2014a).

About 73.7% of the respondents indicated that an increase in elephant population within the neighboring PAs contributed to the occurrence of HEC to a very high extent (1), whereas to a high extent (2) and 2.7% considered it to a moderate extent (3) (Table 4).

Table 4: Extent to which increased elephant population enhanced HEC

Extent	Frequency (n=297)	Percentage	Rank
Very high extent	219	73.7	1
High extent	67	22.6	2
Moderate extent	8	2.7	3
Not applicable	3	1.0	4
Total	**297**	**100**	

4.1.3 Encroachment

Ikorongo and Grumeti Game Reserves are encroached by human settlements and farms. The human population in Serengeti and Bunda Districts was over 249 420 and 335 061 in the 2012 national census, and has been rising at an annual rate of around 3.52% and 2.59% respectively (NBS, 2012). This exerted more pressure on protected areas land for settlements and agricultural activities. In the sampled villages, about 3% of the surveyed households were found within 500 meters from the protected area boundary. This increased vulnerability and exposure of human beings and crop fields to elephants once moving near or outside the protected areas. Areas that were highly encroached by human settlements and farms were considered to be high conflict zones, as log odds for HEC occurrence decreased significantly with a single unit increase in distance between households and PAs boundary (β=-0.16176, $P<0.05$).

This was further evidenced by the intensity of crop damage occurred in the surveyed households from the sampled villages. The intensity being higher in Makundusi village which had 166.5 acres damaged with an average distance of 1.6km from PAs boundary, followed by Bonchugu village (166.5 acres damaged with 1.7km average distance from PAs boundary), Nyamatoke village (140.5 acres damaged with 2.1km average distance from PAs boundary), Hunyari village (138 acres damaged with 3.6km average distance

from PAs boundary), Iharara village (124 acres damaged with 4.7km average distance from PAs boundary) and Nyichoka village (112 acres damaged with 5.7km average distance from PAs boundary) (Fig. 4).

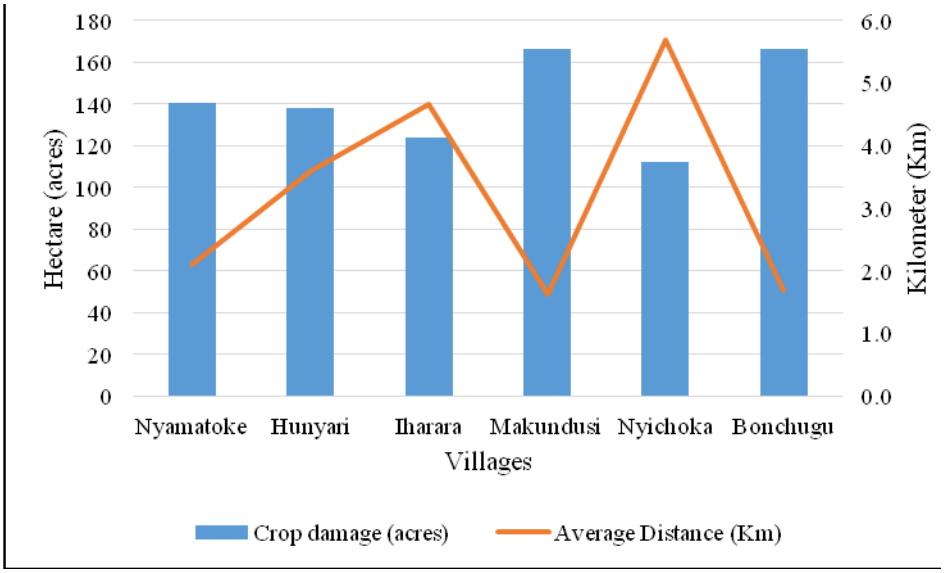

Figure 4: Crop damage against village average distance

Furthermore, about 98% of the respondents from the surveyed households considered the short distance from households to protected area boundary to be among the factors influencing the HEC. Although, the respondents argued that, the protected area boundary has been moving from the previously established boundary towards the village land. Findings on the extent to which encroachment contributed to the occurrence and increasing of the HEC are summarized in the Table 5. The test shows that, 51.4% of respondents suggested that encroachment influenced HEC to a high extent (1) followed by 40.1% who suggested that it influenced to a very high extent (2).

Table 5: Extent to which Encroachment enhanced HEC

Extent	Frequency (n=294)	Percentage	Rank
Very high extent	118	40.1	2
High extent	151	51.4	1
Moderate extent	19	6.5	3
Low	3	1.0	4
Not applicable	3	1.0	4
Total	**294**	**100**	

(Source: Field data)

4.1.4 Lack of clear buffer zone

One among the long-term challenges facing IGGRs is the absence of large enough and clear buffer zone. To the north of Grumeti Game Reserve is the Robana River forming the boundary between the reserve and surrounding villages, where at one side is the protected area and the other side is the village land (Plate 1). Same goes to Ikorongo Game Reserve and surrounding villages where the established boundary is made up of small pillars (beacons) with no clear buffer zone between the two lands. The results showed that there was a significant relationship between absence of a clearly defined buffer zone with the occurrence of HEC within the surveyed area (β=0.99572, $P<0.05$). This tells us that for every one unit change in lack of a clear buffer zone the log odds of HEC occurrence increases by 0.996.

Plate 1: Robana River

Results from the surveyed households showed that 98.3% of the respondents perceived that absence of a clearly defined buffer zone between game reserves and surrounding communities was among the factors escalating the HEC. On assessing the extent to which lack of clear buffer zone influenced the occurrence of HEC, very high extent was ranked the first (1), followed by those who ranked it to a high extent (2) (Table 6).

Table 6: Extent to which Lack of clear buffer zone enhanced HEC

Extent	Frequency (n=295)	Percentage	Rank
Very high extent	148	50.2	1
High extent	128	43.4	2
Moderate extent	12	4.1	3
Low extent	3	1.0	4
Very low extent	1	0.3	5
Not applicable	3	1.0	4
Total	**295**	**100**	

(Source: Field data)

4.1.5 Infrastructure damages

Infrastructure damages caused by problem elephants showed a significant relationship with the occurrence of HEC (β=0.94550, $P<0.05$). This indicates that holding other factors at a fixed value, for every one unit change in infrastructure damages the log odds of HEC occurrence increases by 0.95. Elephants may indulge in infrastructure (e.g. fence, paddock and house) and damage for various reasons such as searching for food grains or to rescue their calves if they have ventured inside.

Findings showed that 7.7% of the respondents indicated that elephants had destroyed their houses, food stores and water wells in the year 2017 only. Moreover, several cases were reported where house fences made up by sisals were destroyed as elephants feed on sisal especially during dry season where they acquire food as well as water from the sisals. Plate 2 below shows the water well that was damaged by elephants in Makundusi village during reconnaissance survey in July, 2017. From 2008 to 2014, at least 61 incidences of infrastructure and other damage were reported to occur in villages adjacent to IGGRs.

Plate 2: Water point damaged by elephants in Makundusi village, western Serengeti

During household survey about 64% of the respondents indicated that infrastructure damage by problem elephants influenced the HEC occurrence within the communities surrounding the IGGRs. Table 7 indicates that among the respondents who suggested that infrastructure damage had an influence on occurrence of HEC majority ranked higher extent first (1), moderate extent (2) and very high extent was ranked sixth (6). This implies that infrastructure damage caused by problem elephants influences and escalates the existing HEC within the study area.

Table 7: Extent to which Infrastructure damage enhanced HEC

Extent	Frequency (n=192)	Percentage	Rank
Very high extent	2	1.0	6
High extent	65	33.9	1
Moderate extent	53	27.6	2
Low extent	50	26.0	3
Very low extent	19	9.9	4
Not applicable	3	1.6	5
Total	**192**	**100**	

(Source: Field data)

4.1.6 Lack of compensation plan

In Tanzania, there is no compensation scheme for damages caused by wild animals as the approach seems to be more costly and challenging in its implementation. Instead there is a consolation scheme titled "*The Wildlife Conservation (Dangerous Animals Damage Consolation) Regulations, 2011*" established under Section 121 of the Tanzania Wildlife Conservation Act of 2009 (URT, 2009). Lack of compensation plan showed a statistically significant relationship with the occurrence of HEC in the study area (β=1.07835, $P<0.05$). This implies that holding other factors at a fixed value, every one unit change in lack of a compensation plan increases the log odds for HEC occurrence by 1.08. Absence of a clearly defined compensation plan for damages done by problem

elephants and other wild animals facilitates and escalates the occurrence of HEC within the study villages. It causes dissatisfaction among the people as the existing consolation plan seems unsatisfactory to local people as the amount being paid does not match to total cost incurred or actual value of the destroyed property. This can be evidenced by 99% of the respondents who indicated that absence of well-defined compensation plan facilitated the conflict between them and elephants in their village.

Findings on Table 8 show that influence from lack of a compensation plan in the management of HEC to the occurrence of conflicts was ranked to a higher extent (1), very high extent (2) and moderate extent was ranked third (3).

Table 8: Extent to which lack of compensation plan enhanced HEC

Extent	Frequency (n=297)	Percentage	Rank
Very high extent	93	31.3	2
High extent	169	56.9	1
Moderate extent	30	10.1	3
Low	2	0.7	5
Not applicable	3	1.0	4
Total	**297**	**100**	

(Source: Field data)

4.1.7 Elephant attacks

Human beings have been threatened whereby some have been injured and killed by the problem elephants. Attack have been occurring when the problem elephants invade in the villages in search of food and water where they can meet with farmers in their farms or homesteads. Human attack showed a statistically significant relationship with the occurrence of HEC within the study villages (β=1.71306, $P<0.05$). This implies that for every one unit change in human attacks, the log odds for HEC occurrence increases by 1.7. This can be evidenced by the 56% of the respondents from the surveyed villages

who indicated that elephant attacks to humans that were reported to occur within their villages increased their hatred to problem elephants.

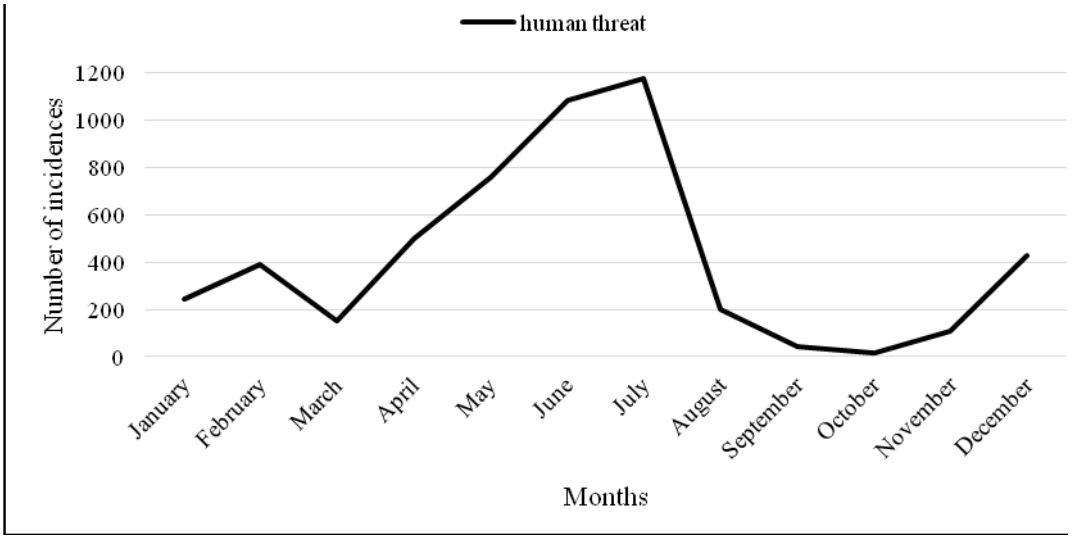

Figure 5: Trendline showing elephant threats to human in Serengeti District

In 2014 and 2015, 1 man from Iharara village and 2 people (1 man and 1 woman) from Changuge village respectively were reported to be killed by problem elephants. According to data recorded from year 2008 to 2015 in villages of Serengeti District, human threats were higher in the months of February, June, July, November and December (Fig. 5). Whereas data recorded from year 2012 to 2015 in villages of Bunda District showed that human threats were higher in the months of February and June (Fig. 6). This increase in threats from elephants was aligned with seasonal increase in crop raiding incidences within the villages.

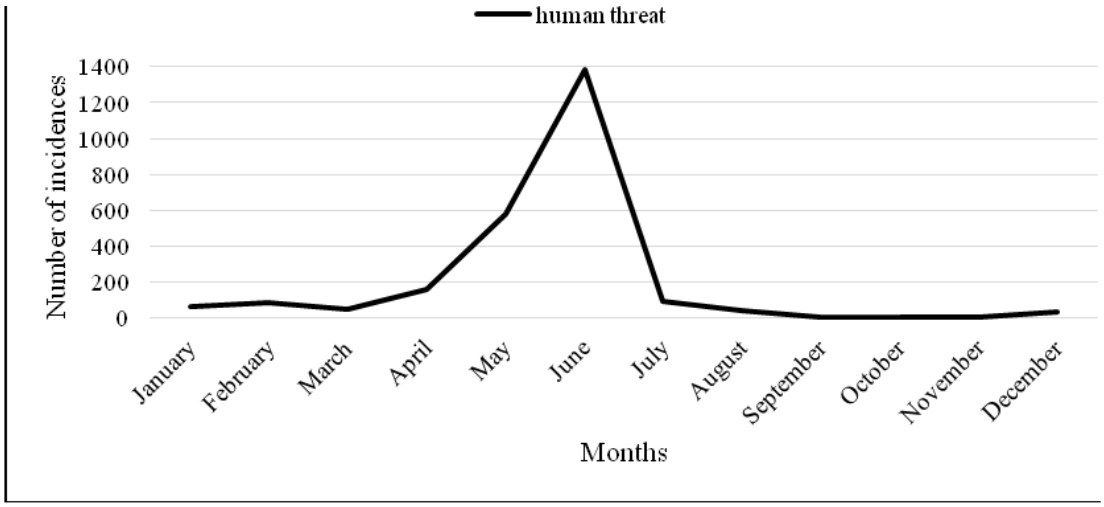

Figure 6: Trend-line showing elephant threats to human in Bunda District

Moreover, reported incidences where people killed and injured by problem elephants were considered to have an influence to the occurrence of HEC by majority of the respondents and ranked at a higher extent (1), followed by moderate extent (2) and very high extent (3) (Table 9).

Table 9: Extent to which elephant attacks enhanced HEC

Extent	Frequency (n=168)	Percentage	Rank
Very high extent	34	20.2	3
High extent	76	45.2	1
Moderate extent	51	30.4	2
Low	6	3.6	4
Not applicable	1	0.6	5
Total	**168**	**100**	

(Source: Field data)

4.1.7.1 Time when conflicts occur

4.1.7.1.1 Time of the day when conflicts occurred

Findings from this study revealed that most raiding happens at night. This concurred with the general notion that elephants spend most of their time eating and sleep for about two hours a day (Archie and Chiyo, 2012). Majority of the respondents (94.3%)

indicated that elephant conflicts occurred at night. On the other hand, 5% reported that they occurred at any time of the day, whereas 0.7% of the respondents suggested that conflict occurred during the day (Table 10). Respondents further indicated that due to the nature of most of elephant invasions being in the night they are forced to spend most of their night time in farms guarding their crops against raiding elephants. This in turn increases risk of being injured or killed by problem elephants.

Table 10: Time when conflicts occurred

Time of Day	Frequency (n=300)	Percentage
During the Day	2	0.7%
At Night	283	94.3%
All the Time	15	5%

(Source: Field data)

4.1.7.1.2 Time of the year when conflicts occur

From January 2008 to December 2014 there were 5102 HEC incidences reported in Serengeti District from villages adjacent to IGGRs (Fig. 7). The highest number of incidents were recorded in July, with a mean of 168.4 incidences per month whereas the lowest recorded incidences were in October with a mean of 2 incidents per month (Table 11). There are certain times of the year when the elephants from IGGRs begin moving into the farms (Malugu, 2011). Though there isn't a precise timing, mostly the farm incursions happen when most parts of the reserves and the Serengeti National Park are beginning to dry, and the elephants are looking for additional nutrition (Kangwana, 1996).

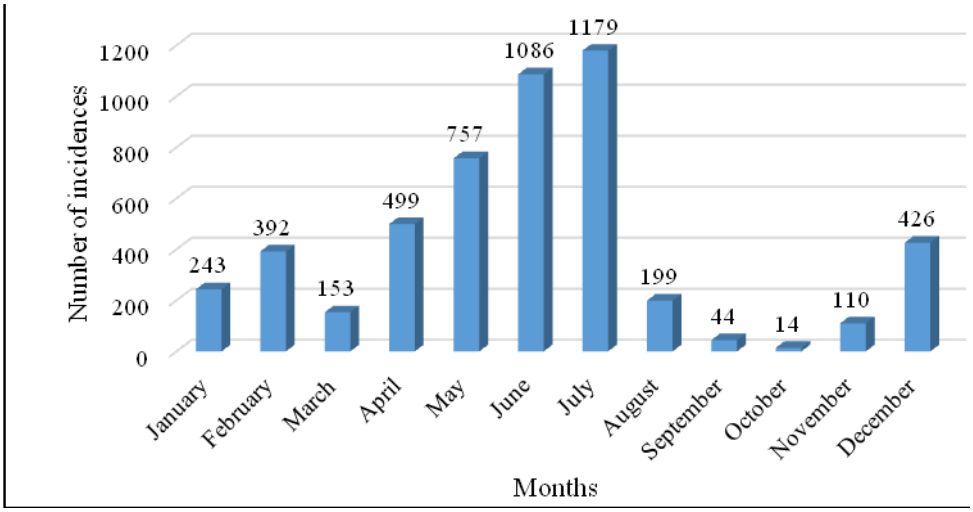

Figure 7: Monthly number of HEC incidences for Year 2008-14

Table 11: Mean ±SE monthly number of HEC incidents in Serengeti District for Year 2008-14

Month	Jan*	Feb	Mar*	Apr*	May*	Jun	Jul	Aug	Sep	Oct	Nov*	Dec*
Mean incidence No.	34.7	56	21.9	71.3	108.1	155.1	168.4	28.4	6.3	2	15.7	60.9
Conflict Season rate	Low	High	Low	High	High	High	High	Low	Low	Low	High	High

*Shaded regions are the rainy months of the year. The rate of conflict was determined by comparing the present month with the previous month.

In the villages from Bunda District, about 2490 incidences were reported from January 2012 to December 2015 (Fig. 8). The highest number of incidences were recorded in June, with a mean of 345 incidences per month whereas the lowest recorded incidences were in November with a mean of 0.5 incidence per month (Table 12).

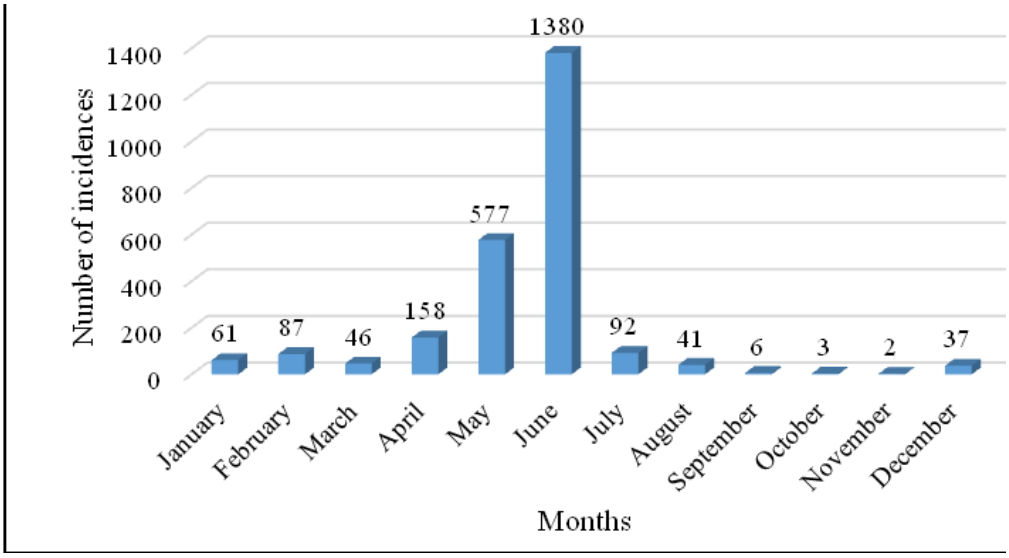

Figure 8: Monthly number of HEC incidents for Year 2012-15

Table 12: Mean ±SE monthly number of HEC incidents in Bunda District for Year 2012-15

Month	Jan*	Feb	Mar*	Apr*	May*	Jun	Jul	Aug	Sep	Oct	Nov*	Dec*
Mean incidence No.	15.3	21.8	11.5	39.5	144.3	345	23	10.3	1.5	0.8	0.5	9.3
Conflict Season rate	Low	High	Low	High	High	High	Low	Low	Low	Low	Low	High

*Shaded regions are the rainy months of the year. The rate of conflict was determined by comparing the present month with the previous month.

4.2 Losers and Gainers in the Human-Elephant Conflicts

There was a general consensus that farmers were the ones who lose the most from the human-elephant conflicts. They experienced crop damage, livestock killings, infrastructure damage and exposure to threat where several individuals have been injured and killed by problem elephants. Most of the human killings and injured were reported to occur when individuals were in their farms cultivating or guarding for their crops. On other hand, elephants suffer from the revenging behaviour of affected

individuals and several have been shot dead accidentally by rangers. Between 2006 and 2014 about 26 problem elephants were killed in the villages surrounding the IGGRs and Ikona WMA, posing a great loss to PAs authorities and government in general (Fig.9).

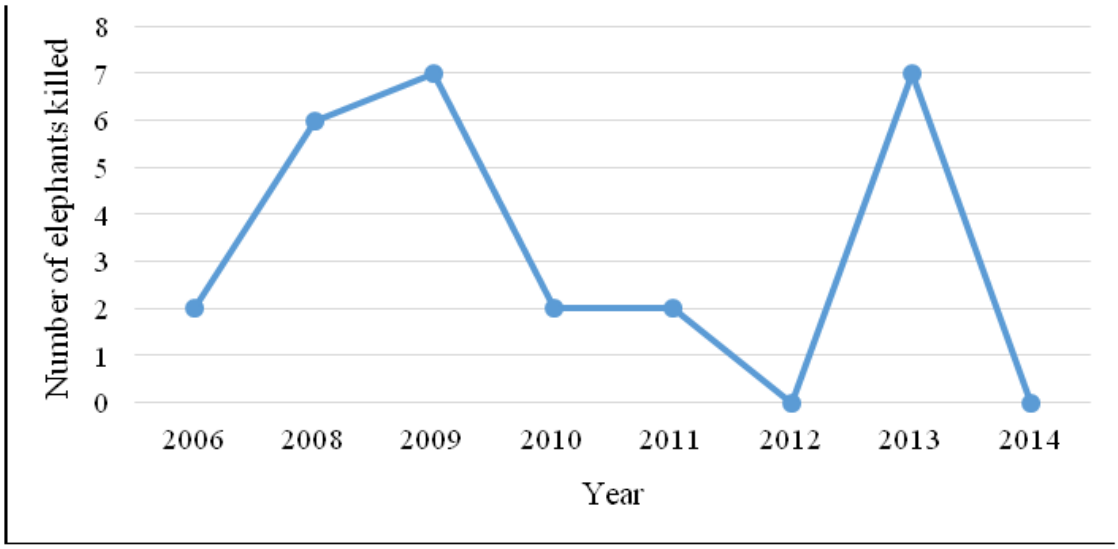

Figure 9: Elephants killed in the communities for Year 2006-14
(Source: Singita Grumeti Fund)

Moreover, a further observation was that 15% of the respondents suggested that some corrupt village government officials together with their relatives were the one benefited from the conflicts. They further explained that the perception came from the existing compensation plan made by Wildlife Division (WD) as upon registering as affected individuals from damages made by elephants, the ones who ended up being compensated are some of relatives of those corrupt officials who were not affected at all. The summary of these findings are further summarized in Table 13 below.

Table 13: Identified losers and gainers in HEC in the Western Serengeti

	INVOLVED PARTIES	IMPACT
LOSERS	The villagers (Famers)	➢ Majority of farmers lose cultivated crops following raiding from problem elephants.
	Livestock keepers	➢ Sometimes livestock are injured and/or killed by elephants once found grazing or in paddock.
	Mixed farmers (The ones who do both farming and livestock keeping)	➢ Lose in the conflicts through both crop damages and livestock killing and/or injury.
	Protected Areas Management (i.e. IGGRs, SENAPA)/Government	➢ Lose once wild animals are injured and/or killed by Villagers who revenge upon incursions.
	District council	➢ Lose through loss of revenue that could be obtained from damaged commercial crops.
	Tour companies (e.g. Singita)	➢ Following HEC people rejected to cooperate with tour companies on supplying visitors with cultural tourism experiences.
GAINERS	Corrupt village leaders	➢ Inappropriate consumption of money provided to console affected Villagers i.e. Farmers and livestock keepers by problem elephants.
	Non-Governmental Organizations (NGOs) (e.g. FZS)	➢ Majority of NGOs particularly the ones involved in research activities benefited from the conflict as they get a ground from which a number of researches are conducted.

4.3 Barriers to Human-Elephant Conflicts Mitigation Strategies

A multitude of traditional methods have been developed to reduce and prevent crop raiding by elephants in conflict prone areas. The escalation of human-elephant conflict in the past few years has resulted in development of traditional methods together with the efforts from Human-wildlife Conflict Mitigation Units (HWCMUs) and PAs

authorities to address the problem. In general, traditional methods are easy to use, have low costs and are somehow effective at low levels of conflict. The following are various techniques employed in human-elephant conflict mitigation by farmers and PAs management in villages adjacent to Ikorongo and Grumeti Game Reserves (Fig. 10).

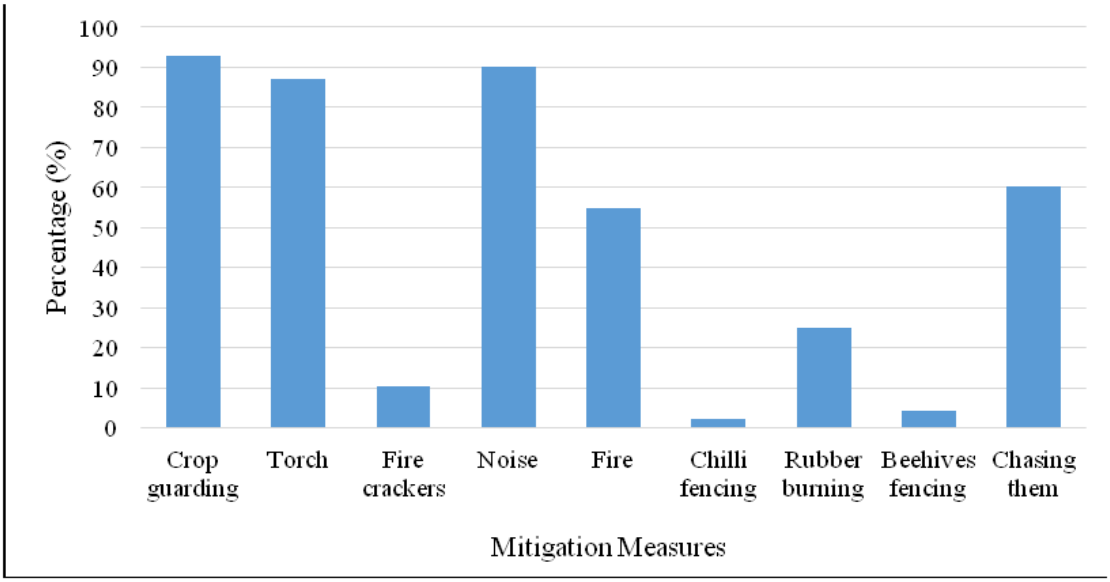

Figure 10: Prevalence of current HEC mitigation measures

4.3.1 Crop guarding

Guarding of crops by farmers is conducted with different levels of organization ranging from guarding isolated fields by individual farmers to guarding the peripheries of contiguous fields by village societies. Farmers individually or collectively scare away elephants relying on the fear elephants have over people, especially herds of females and young. The mere presence of farmers in huts located within the crop fields may discourage elephants from raiding crops. According to respondents (92.7%) in the surveyed villages guarding is accompanied by several means (e.g. whistles and sling). Human effigies (scarecrows) are also used in places although elephants quickly become habituated.

Barrier

The method seemed more of a risk as farmers spend their time outside while exposing themselves to the problem elephants hence they bear a risk of being killed. Moreover, the quickly habituation of elephants to the scarecrows reduce the effectiveness of the approach hence subjected to failure. The respondents indicated no permanent solution to enhance the effectiveness of this approach.

4.3.2 Noise

Noise-making which involves beating on drums, shouting and use motorcycle horns is one of the common used strategies by famers. Farmers (90.3%) living in communities adjacent to Ikorongo and Grumeti Game Reserves, and Ikona WMA used noise made by drumming on tins and pots to frighten off elephants. They further indicated that the method seems to be less effective as it somehow works when the problem elephants are not in the crop fields as they usually refuse to come out once in the crop fields.

Barrier

Although the approach was considered somewhat effective in controlling the elephant incursions it was among the most dangerous approach as sometimes the problem elephants charged back to people. Moreover, the strategy showed less effectiveness in prevention of elephants attack due to the fact that most farmers used poor tools to frighten off the problem elephants (e.g. drumming on tins and pots). The use of more sophisticated tools such as non-lethal explosives was suggested as means to address the barriers to the technique.

4.3.3 Lights and torches

Although elephants graze almost any time of the day they are partial to feasting by night, hence rigging up lights or use of torches might scare them off. Quite a number of

farmers (87%) along the surveyed communities adjacent to IGGRs and Ikona WMA were using torches and other light sources to scare the problem elephants trying to prevent the crop raiding and other damages associated with elephants incursions in the village land.

Barrier

The strategy resulted into fairly less effective impacts due to a number of reasons such as use of poor torches having no capacity to flash very bright lights that can be sufficient to scare them off and change habituation of the strategies by problem elephants. Furthermore, majority of the people due to low income level cannot afford battery costs and repair of the tools when needed to do so. The possible solutions that were addressed by the respondents were provision of torches with long range flashlight and other sophisticated equipments to enhance the approach.

4.3.4 Fire

Most wild animals avoid fire. Fires at crop field boundaries, or at elephant entry points to fields, serve as a short-term deterrent. The technique deters elephants hence reduces the intensity of elephants attack especially when fire is lit at the entry points of the problem elephants into the crop fields or villages. Fairly moderate number of respondents (54.7%) indicated that they were applying the strategy this could be due to the fact that the strategy was unsustainable for any length of time without large amount of materials to be burnt to increase the deterrent effect of fire (Hoare, 2001).

Barrier

The unsustainability of fire without large amount of wood materials to be burnt so as to increase the effect of fire was one among the causes of its less effectiveness and application as it was considered not environmental friendly approach. Another reason

could be the negative effect of using fire as sometimes elephants charge back in the direction of fire once frightened. No means to address the barriers as the approach was considered destructive.

4.3.5 Rubber burning

Smoke from plastic and rubber burning is one among the elephants deterrent used in communities surrounding IGGRs. Farmers may burn plastic and rubber to create noxious smoke that deter elephants from entering the crop fields (Fernando *et al*., 2008). About 25% of the respondents from the surveyed villages indicated that they have been using this technique for some time and the method seemed to become effective. The noxious smoke that comes out of the burnt rubber or plastic materials had a chocking smell which deter elephants and prevent them from raiding crops.

Barrier

The respondents faced several challenges during application of the techniques as the noxious smoke affected the farmers as well causing them to not stay near or in the crop fields. Furthermore, the burnt rubber or plastic material can start fire which can burn crops while in the crop fields as the crop raiding peaks were in the months of July, November, December and January where the vegetation cover is almost dried. The respondents indicated no possible solution to improve the technique and increase its effectiveness as the method considered destructive and lethal.

4.3.6 Chasing elephants away

The official approach where elephants are chased by human-wildlife conflict mitigation unit or Rangers is for villages to request assistance from TANAPA or Ikorongo and Grumeti Game Reserves through Village Executive Officers (VEOs) and DGOs. The

HWC mitigation unit is sent with Game Wardens or a person authorized to use gun loaded with ammunition. The HWC mitigation unit uses the vehicle to chase elephants, using its horn and firing ammunition to scare them away. About 60.3% of respondents revealed that they have been received assistance from the HWC mitigation unit from IGGRs in collaboration with TANAPA, Ikona WMA and DGOs from both Bunda and Serengeti Districts through their VEOs.

Barrier

The method had an effective impact although due to several challenges there has been limitations to its effectiveness. In the study villages, three barriers affecting the technique were identified. These were inadequate workforce (83.3%), inadequate equipments like vehicles and firearms (82.7%), few scout camps and large distance between them (80.3%). Respondents further indicated that the barriers have been inhibiting the technique as there are times where the HWCMUs are not reached or when reached are already in other villages chasing the elephants back into the PAs.

Moreover, several possible solutions were pointed out by the respondents in the surveyed villages. First, was to increase the number of Village game scouts (VGS) in the HWCMUs (85.3%), second, was to increase the supply of equipments (85.7%) and lastly was to construct more scout camps where at least one camp should be within or near each village (86.7%).

4.3.7 Use of firecrackers

Following a donation of firecrackers from Frunkfurt Zoological Society (FZS), about 10.3% of the respondents from the six surveyed villages reported to use the fire crackers to deter elephants from incursions into farms. Majority being from Nyichoka (38%,

n=50) followed by Iharara (8%, n=50), Makundusi (8%, n=50) and Bonchugu village (8%, n=50). They further indicated that the method seemed more effective than other traditional methods such as the use of torch and shouting. The method seemed as the alternative to the HWC mitigation units who use guns loaded with ammunition as the firecrackers emitted fire, smoke and sound which scared the problem elephants as they confuse the technique with firearms.

Barrier

The technique is fairly and newly employed in few villages within the western Serengeti area and most people seemed to not have knowledge over its application. Moreover, majority of the respondents didn't apply the technique as very few firecrackers were supplied among the community hence limited coverage and application. The only solution that could be employed to increase the efficiency of this technique is to promote and increase the supply of firecrackers among the people and provision of knowledge on its application for effective HEC mitigation.

4.3.8 Beehives fencing

Several respondents indicated that the beehives fencing had a positive impact towards deterring the elephants from crop field incursion. The method considered one among the biological deterrent of elephants as African honey bees (*Appis melifera*) produces sound and sting elephants on soft body parts making them to move away from farms. This was pinpointed out by 4.3 % of the respondents from the surveyed villages who were found applying the beehives fences supplied by SGF to prevent crop raiding by problem elephants in their crop fields (Plate 3).

Plate 3: Beehives fencing in Makundusi Village

Barrier

The low number of individuals applying the method (4.3%) was due to its limited effectiveness in deterring the elephants, as according to farmers the problem elephants have been used and adapted to the stinging of bees hence can tolerate and sometimes they use their trunk to swipe away the bees by blowing air onto them. There was no solution to the technique that was suggested by the respondents as the method was regarded to be a failure.

4.3.9 Chilli – based deterrents

Chilli-based deterrents have been used to prevent elephants from entering the crop fields across the global (Osborn & Parker, 2002; Parker & Osborn, 2006). The method can be applied through several ways namely; pepper grease (chilli-grease), which is applied to rope fences around crop fields (Chang'a *et al*., 2016), pepper dung (chilli-dung), which is burnt to produce a noxious smoke (Parker *et al*., 2007), and pepper plants, which are planted as buffer crop at the boundary of crop fields. Such uses of chillies (*Capsicum frutescens*) were reported by the 2.3% of the respondents in the surveyed villages

adjacent to IGGRs. The reason for few respondents to apply the method was due to its limited effectiveness over elephant deterrence as it was indicated by the respondents (97.7%) who happened to not use the technique.

Barrier

Sisal rope fences covered in chilli oil, pepper dung and pepper planted as buffer crop do not work all the time as some elephants have figured out how to walk into farms backwards or knock them down with branches and tolerate the hotness from pepper. The method was regarded to be a failure hence no solution that was depicted by the respondents.

4.4 Novel Approaches and Techniques for HEC Mitigation

Following the less effectiveness of the applied HEC mitigation measures in the western Serengeti which resulted into short term impact, there has been an increased demand for more effective measures with long-term impact to prevent and mitigate the HEC. Due to an advance in technology the use of un-conventional mitigation measures together with traditional techniques showed fairly positive results in the management of HEC. According to Dhanaraj & Sangiah (2017) and Sheela *et al*. (2016) application of advanced techniques in the management of HEC across the global showed positive impacts with long-term results.

Following the study survey that was conducted in the sampled villages from Bunda and Serengeti Districts, respondents from the surveyed households suggested new six measures namely; Construction of Trench (95.3%), Electric fencing (95%), Buffer Zone Management Units (BZMUs) (92.7%), Geo-fencing system (92.3%), Wireless Sensing Network (WSN) (85.3%), Translocation of problem elephants (11.7%), and Evacuation

of people near protected area boundary (22%) (Fig. 11). Moreover, the proposed measures were ranked in regard to the number of respondents who opted particular measures. In which the ones with large number of respondents who opted them were ranked higher, followed by those with small numbers (Table 14).

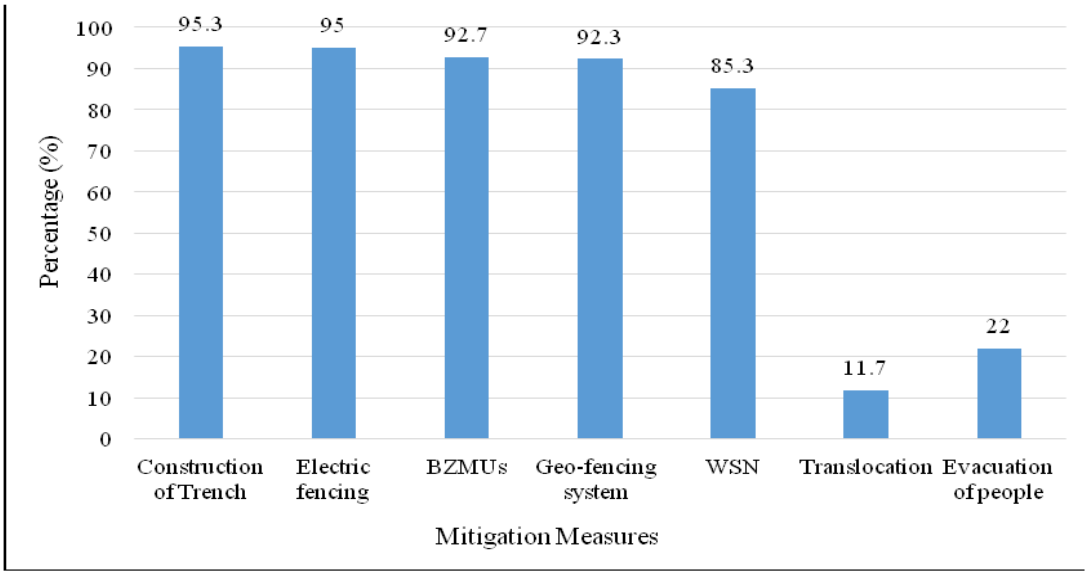

Figure 11: Unconventional HEC mitigation measures

Table 14: Ranking of the unconventional HEC mitigation measure

Measure	Percentage	Rank
Construction of Trench	95.3	1
Electric fencing	95	2
BZMUs	92.7	3
Geo-fencing system	92.3	4
WSN	85.3	5
Evacuation of People	22	6
Translocation	11.7	7

4.4.1 Construction of trench

A trench, about 20ft wide and 8ft deep is excavated at the reserves edge (Fig. 12). It is a deterrent to non-jumping animals like elephants. The soil excavated from the trench is

heaped on top of one side of the bank, making the trench to appear deeper limiting the problem animals to cross from PAs into villages. The technique has been applied in majority of National parks in India, Sri Lanka and Uganda (Babaasa *et al*., 2013; Fernando *et al*., 2008; Mackenzie and Ainebyona, 2012).

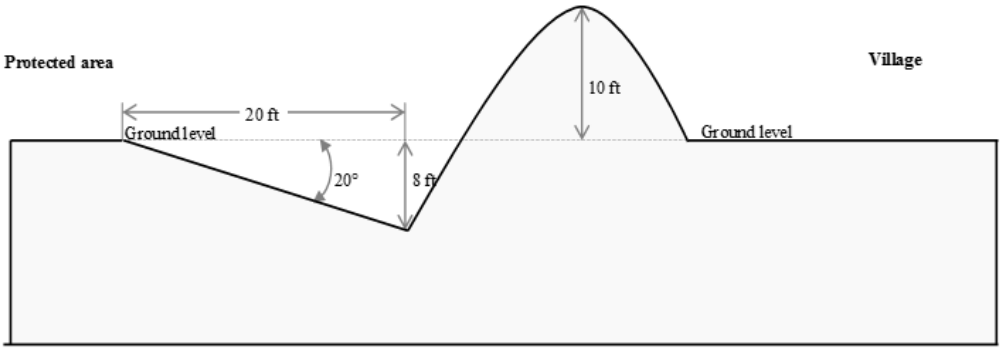

Figure 12: Schematic diagram of the proposed trench construction

The results from the study found that 95.3% of respondents in the surveyed villages indicated that trench construction could be applied as an unconventional mitigation measure to the HEC. This led for the technique to be ranked first (1) as the technique of choice among the respondents (Table 14). They further considered the technique to be more effective as a physical barrier that will prevent elephants moving out of the protected areas boundary into village land. Moreover, the researcher assessed the level of prioritization of this technique among the respondents who suggested the measure and results are presented in Table 15.

Table 16 shows that (41.6%) of the respondents indicated that construction of trench along the protected areas boundary was given a very high priority as a measure that will result into positive and long-term prevention of elephant incursions into the village land,

followed by those who highly prioritized it (40.6%). This indicates that construction of a trench along the PAs boundary will have a long-term impact on mitigating the HEC within the communities surrounding the IGGRs.

Table 15: Prioritization of Trench construction as a desired measure

Priority	Frequency (n=286)	Percentage
Very high	119	41.6
High	116	40.6
Medium	33	11.5
Low	15	5.2
Very low	3	1.1
Total	**286**	**100**

(Source: Field data)

4.4.2 Electric fencing

Electric fences have been quite effective in preventing problem animals, particularly habitual raiding elephants in majority of countries facing the HEC (Babaasa *et al*., 2013). The technique acts as the physical barrier preventing the elephants from invading farms in the village land bordering the protected areas. The erection of electric fence powered by solar energy was considered an alternative measure following the failure and short term effectiveness of the traditional measures (Plate 4).

Majority of the respondents in the surveyed villages (95%) indicated that erection of electric fence along the boundary between IGGRs and villages will have a positive impact over the conflict as it will restrict elephants' movement from PAs into farmlands located along the reserves boundary. The technique was ranked the second (2) as a technique with long-term solution to elephant menace within the communities surrounding the IGGRs.

Plate 4: An electric fence limiting elephant crossing from PAs into villages.

(Source: RDB, Rwanda)

The respondents were asked the priority to which the electric fencing was considered an alternative HEC mitigation measure and results are presented in Table 16. Results in Table 16 show that majority of the respondents (42.5%) presented high priority to electric fence as a mitigation measure with long-term impact followed by the ones presented a very high priority to the technique (27.4%) and medium priority (23.5%). This finding concurs with; Wanyingi (2014) that erection of electric fence in areas with persistent HEC prevents problem elephants incursion into village land hence prevents and reduces the intensity of the conflicts.

Table 16: Prioritization of Electric fencing as a desired measure

Priority	**Frequency (n=285)**	**Percentage**
Very high	78	27.4
High	121	42.5
Medium	67	23.5
Low	10	3.5
Very low	9	3.2
Total	**285**	**100**

(Source: Field data)

4.4.3 Buffer zone management units (BZMUs)

Buffer Zone Management Units comprise of specialized personnel dedicated to respond quickly upon elephant's invasion or when about to cross from PAs into village land. Majority of the respondents (92.7%) from the surveyed villages suggested that a clearly delineated buffer zone should be established between the IGGRs, Ikona WMA boundary and its adjacent villages. It was ranked third (3) as the technique of choice among the respondents. They further indicated upon creation of a clearly defined buffer zone, there should be establishment of Buffer Zone Management Units (BZMUs) dedicated to the protection and management of the buffer zone. Moreover, establishment of the BZMUs should be in line with establishment of permanent ranger posts along the buffer zone across the villages.

The respondents were asked to indicate the level of prioritization on the establishment of BZMUs as an alternative measure to mitigate the HEC in the study site and results were presented in Table 17. The findings show that majority of the respondents presented a very high priority (76.6%), whereas 19.8% indicated high priority to the approach. This indicates that the approach was considered effective to mitigate HEC by the respondents to a great extent.

Table 17: Prioritization on establishing Buffer zone Management Units as a desired measure

Priority	Frequency (n=278)	Percentage
Very high	213	76.6
High	55	19.8
Medium	9	3.2
Low	1	0.4
Total	**278**	**100**

(Source: Field data)

4.4.4 Geo–fencing system

Geo-fencing system was among the unconventional mitigation measures identified during the study survey. The system involves a virtual fence line within a computer GIS and programmed in GPS positions into the tracking collar of crop raiding elephants, which creates a Geo-fence around the particular animal. If the elephant strays outside of its known range or tries to enter a local village to raid crops, GSM elephant collars with installed SIM cards send a SMS text message to the control center or BZMUs manager alerting them of the immediate problem, and the location of the elephant, enabling rangers, VGS and reserve staff to locate and drive back the elephant into the reserve boundaries. Majority of the respondents (92.3%) indicated that the technique will have an effective and long-term impact to the mitigation of HEC in the conflict zones of IGGRs. It was ranked fourth (4) as the technique of choice among the respondents.

Moreover, the researcher asked the farmers to indicate the level at which they prioritized the measure, whereas majority of the respondents (47%) indicated a very high priority, followed by those indicated a high priority to the technique (40%) (Table 18). This indicates that the technique was believed to have a long-term and effective solution to the HEC within the IGGRs and adjacent communities.

Table 18: Prioritization of Geo-fencing system as a desired measure

Priority	Frequency (n=277)	Percentage
Very high	131	47.0
High	114	40.9
Medium	30	10.8
Low	4	1.4
Total	**277**	**100**

(Source: Field data)

4.4.5 Wireless sensing network (WSN)

Wireless Sensing Network (WSN) based systems are widely used for various purposes such as warning system against different hazard scenarios (e.g. fire) and research on detection of movement and distribution patterns of wild animals (Dhanaraj and Sangiah, 2017). Such WSN based system can also be effective to generate an early warning against the presence of elephant near the village land and thus can prevent potential human-elephant conflict scenarios. The proposed technique uses the Very High Frequency (VHF) transmitters embedded in the collar fitted on elephant body that are connected to track the location of the animal while approaching the restricted area. The VHF transmitters attached to the problem elephant emit a pulsed radio signals which when the animal is within the range the signals are detected by the receivers erected on poles or towers. The signals taped by receivers are sent to a gateway node having a signal processing unit to filter specific signal of particular frequency. Signals from gateway node will be received by a central processing unit (CPU) (Ramkumar *et al*., 2014; Sheela *et al*., 2016). This processing unit will look for a pattern match of incoming signal with a reference signal to detect and confirm the presence of elephant within range. Once the CPU confirms the presence of an elephant it will generate warnings and send the information to the nearby HWCMU office with specific location codes through GPS. Functioning of the proposed WSN system has been shown in the below Fig. 13.

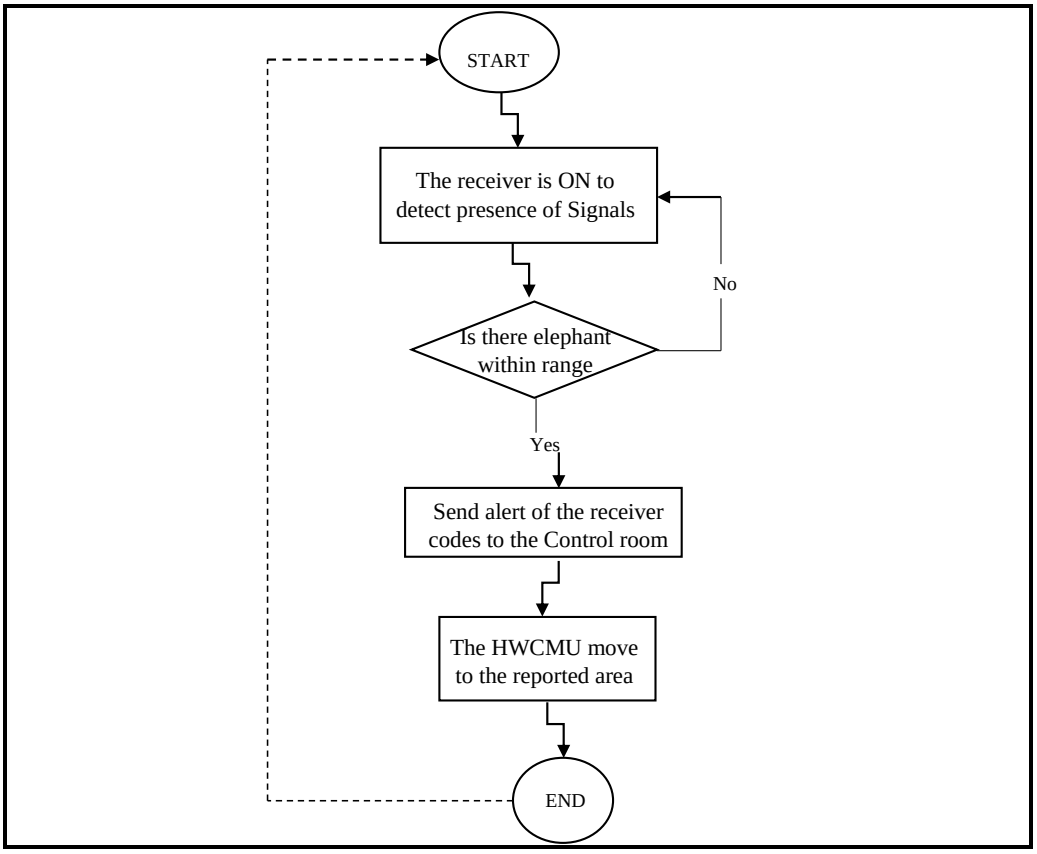

Figure 13: Schematic diagram of the proposed integrated WSN for Elephant Detection (Modified from Ramkumar *et al., 2014*)

Results from the surveyed households indicated that 85.6% of respondents considered this technique as a mitigation measure which upon implementation could have an effective and long term impact solution to HEC within the western Serengeti. Furthermore, the researcher assessed the level of prioritization to which the WSN system was considered an alternative solution to HEC scenarios, whereas majority of the respondents (78.5%) gave very high priority to the technique, followed by 17.6% who opted high priority and 3.5% medium priority (Table 19).

Table 19: Prioritization on establishing Wireless Sensing Network as a desired measure

Priority	Frequency (n=256)	Percentage
Very high	201	78.5
High	45	17.6
Medium	9	3.5
Low	1	0.4
Total	**256**	**100**

(Source: Field data)

4.4.6 Translocation of problem elephants

Translocation is the removal of a problem animal by tranquilizing and transporting it to a new location where they are released, using specially designed vehicles and specialists' expertise. Translocation of animals has been undertaken in Kenya (Litoroh *et al*., 2001; Njumbi *et al*., 1996) and South Africa (Garai and Carr, 2001), among other countries. Translocation may appeal more to conservation organizations because it has a number of advantages, including saving elephants from being killed, stabilizing the elephant population within the habitat carrying capacity, and taking obvious action that satisfies local communities who are normally confronted with conflicts (Nelson *et al*., 2003). Before translocations can be undertaken, preliminary studies of the social structure of the elephants need to be conducted so as to avoid disruptions that can affect family and other elephants. About 12% of the respondents in the surveyed villages indicated that the approach could help in the reduction of problem elephants hence incursions and raiding pressure on crop fields from nearby villages.

Moreover, majority of the respondents pinpointed out that the measure was considered and given a medium priority (38.9%) as an alternative approach to mitigate HEC following the growing numbers of elephants in IGGRs and other nearby PAs, followed by those who indicated a high priority (13.9%) to the approach (Table 20). This indicates

that PAs management needs to consider elephant translocations as the growing numbers of the species are threatening local habitats together with the local communities adjacent to PAs boundary.

Table 20: Prioritization of Translocation as a desired measure

Priority	Frequency (n=36)	Percentage
Very high	5	13.9
High	11	30.6
Medium	14	38.9
Low	5	13.9
Very low	1	2.8
Total	**36**	**100**

(Source: Field data)

4.4.7 Evacuation of people

Results revealed that distance from PA to settlements showed a significant relationship with intensity of conflict. These results are not surprising because elephants are known to move distances from day to day, in search of suitable habitat where they can obtain basic needs such as food and water (Harris *et al*., 2008). This can be evidenced as the amount of crop damaged varied in the study villages with the change in the average distance of the surveyed households and farms in each village (c.f. pg. 31). As the encroachment of PAs by settlements together with human cultivated land seemed fueling the damage of crops and increase in threats to both human and domestic animals, relocation of people living near protected areas is inevitable.

People should be evacuated in the areas which are reported to be conflict zones and those which are very close (<0.5km) to the IGGRs and Ikona WMA boundary. In the study villages about 22% of the respondents considered the approach as an alternative

measure that will have effective and long-term solution to the conflicts. The approach was given a medium priority by majority of the respondents (40.9%) as a suggested measure of interest, followed by those who indicated a high priority (30.3%) and 7.6% indicated a very high priority (Table 21).

Table 21: Prioritization of Evacuation of people near protected area as a desired measure

Priority	Frequency (n=66)	Percentage
Very high	5	7.6
High	20	30.3
Medium	27	40.9
Low	13	19.7
Very low	1	1.5
Total	**66**	**100**

(Source: Field data)

4.5 Conflict Analysis and Strategy Design

Human-elephant conflict mitigation cannot be solved by the Wildlife Department alone. It requires multidisciplinary collaborations ranging from Ministries responsible for managing natural resources and social welfare to local communities living in the conflict zones. Designing a conflict analysis tool to put together the conflicting parties, discussing each of the party's interests and issues influencing the conflict is a necessity towards reaching consensus. The researcher adapted conflict analysis and strategy design tool to describe the nature of HEC and measures that can be done to resolve the conflict between local communities, Ikorongo and Grumeti Game Reserves (IGGRs) and Ikona WMA (Table 22).

Table 22: Conflict Analysis and Strategy Design Table

CONFLICTING PARTIES	ISSUES	IMPORTANCE OF ISSUES*	INTERESTS	OPTIONS	WILLINGNESS TO SETTLE	NEXT STEPS
Local communities (farmers & Pastoralists)	-Crop damage -Human threats (killing & injure) -Infrastructure damage -Domestic animals threats (killing & injure)	**VH** **L** **M** **VL**	– Protect crops from damage – Security from being killed or injured by elephants – Greater access to decision making – Maintenance of Customary rights of occupancy – Access to pasturage and water sources	– Would contribute to support the new mitigation measures (53.4%), provide manpower (35.3%) and ready to be relocated (22%)	– Distrust of government and PAs management (bad experiences) – Would talk if process perceived as fair	– Conduct conflict resolution meeting at village level to address the issues and strategies among villagers
Elephants (Represented by PAs management)	- Blocking migratory routes -Loss of habitat (food, water & shelter) -Elephants killing & injure	**VH** **H** **L**	– Prevent degradation of habitats (food, water & shelter) – Prevent elephants killing and injure – Environment in which humans live in harmony with nature	– Provision of conservation education – Use of more effective mitigation measures	– Prefer to use Community Outreach Programs (COP) rather than force – Would use force when necessary	– Conduct conflict resolution meetings and forums to develop strategies to address the issues

Source: Adapted from Conflict Detection and Resolution (CDR)

***Key: VH**=Very high priority**, H**=High priority**, M**=Medium priority**, L**=Low priority**, VL**=Very low priority

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

According to the findings it can be concluded that crop raiding incidences, increasing elephant population, encroachment, lack of clear buffer zone, infrastructure damage, lack of compensation plan and direct elephant attacks were significant predictors of human-elephant conflicts prevalence between local communities and elephants from IGGRs and Ikona WMA. Majority of the villagers particularly farmers were the most losers in the HEC conflicts due to effects like crop damage, human killings and injuries, domestic animal killings, and infrastructure and other damage, whereas very few corrupt leaders were the ones gaining from the conflicts.

The local communities used traditional mitigation measures together with the efforts from HWCMUs and PAs authorities to control elephant attacks. Despite these efforts, there were several barriers needed to be addressed to make the mitigation measures more effective. These included the use of local tools as the primary mean to chase the elephants, low income and education level and large distance between ranger posts and villages. Moreover, elephants showed very high adaptability to most of the applied detterents. Several unconventional mitigation measures were identified and recommended as mitigation mesures with long-term impact to the HEC between local communities and elephants of the IGGRs and Ikona WMA. The measures were construction of trench, electric fencing, buffer zone management units (BZMUs), geo-fencing system, Wireless Sensing Network (WSN), evacuation of people near protected area boundary and translocation of problem elephants. The implementation of these methods requires a long timeframe, financial resources as well as, importantly, political

will. It is essential that human-elephant conflicts mitigation becomes an integral part of the national wildlife conservation policy. Strengthening trans-border cooperation is needed to manage elephant populations across IGGRs, Serengeti National Park, Ikona WMA and other nearby PAs. Development of a rigorous decision-making framework will require the participation of various stakeholders such as government ministries responsible for management of natural resources, social welfare and land-use planners, PAs management authorities, natural and social scientists and economists and local people from communities adjacent to PAs.

There is a need for a clear policy and strategic planning. The current approach to dealing with conflict is largely ad hoc, and predisposed to failure because of inappropriate application of methods, limited involvement of local people, lack of effective monitoring of conflicts and conflict mitigation measures, and inadequate understanding of elephant ecology in deploying mitigation strategies. In the absence of a new and improved wildlife conservation approaches, there will be more conflicts between people and wildlife particularly elephants due to their large home range and free ranging. No single solution is effective and different approaches need to be integrated to address the problem proactively.

5.2 Recommendations

With reference to the study findings it is evident that HEC is the persistent problem to communities living adjacent to IGGRs and Ikona WMA. Therefore the study recommends the following:

5.2.1 Recommendations for local communities

The planting of palatable crops (maize, millet, among others) close to the reserves boundary by farmers has led to the hike in the incidence of elephant crop raids within the

landscape. Therefore, farmers are adviced to engage in cultivation of non-target crops like onions, chili, peanuts and sesame which are mainly commercial crops (Ekanayaka *et al*., 2011). Also, in collaboration with PAs management and other stakeholders, farmers would need to adopt new and sustainable techniques to deter elephants from raiding their crops as suggested in this study. On other hand, livestock keepers should participate in bee keeping projects where they can get and sell honey and beeswax, whereas beehive fences can enhance crop production hence improved rural livelihoods (King *et al.,* 2011). Local people are encouraged to improve village-based guarding efforts to detect and deter elephants prior to their entry into crop fields. This should be in line with the use of more sophisticated tools like long-range flashlight torches, among others as suggested in this study.

5.2.2 Recommendations for PAs management

For effective management of elephants and human-elephant conflicts it is important for local people to have conservation education and an understanding on scientifically-proven drivers of the conflicts particularly HEC. Hence it is recommended that the IGGRs and Ikona WMA should put more emphasis on conservation education among local people at various levels and seek to address the economic aspects of the communities. Community involvement in conservation activities should be among the key and prioritized areas in the General Management Plan (GMP) of the IGRRs and Ikona WMA. The approach increases sense of belonging in the conservation teams among the people hence is a sustainable way and therefore conducive to long-term conservation efforts.

Moreover, it is recommended that the HEC mitigation measures suggested in this study should be put in place by IGGRs, Ikona WMA management in collaboration with the

government of URT for effective and long-term mitigation of HEC in western Serengeti. The IGGRs management should use GPS satellite telemetry to monitor and record the spatial and temporal distribution and movement patterns of elephants and their activities within and outside the PAs boundary. This should focus on identifying individuals and groups and monitoring their movement patterns in relation to crop raiding in order to obtain long-term information for effective operation of the new conflict mitigation measures identified in this study. Also, establishment of comparative conflicts mitigation trials within the conflict zones that can be monitored to assess for their effectiveness should be put in place.

5.2.3 Recommendations for the Government

The current wildlife conservation policy of 2007 should be revised and amended to incorporate and put into action the potential and alternative long-term mitigation measures such as erecting electric deterrents, which are non-lethal to reduce the conflict between people and wildlife as suggested in Section 3.3.12 of the Tanzania wildlife policy of 1998. It is recommended that government should design and establish a compensation and insurance scheme as 54% of the respondents indicated that they are willing to contribute in order to support the new interventions and a government-established trust fund to compensate a greater proportion of the elephant-caused damage. Government should put an emphasis on the greater local communities' involvement in the decision-making processes for HEC mitigation plans. Shared policy changes by the government would enhance people's perception towards and an ownership of those elephants being conserved. It is further recommended for the government to create a clear and well defined buffer zone separating the IGGRs and the surrounding communities.

5.2.4 Recommendations for further research

In order to enhance the sustainability and effectiveness of human-elephant conflicts mitigation strategies, this study suggested several areas for further research. These areas included the following;-

i. Assessment of the spatial and temporal movement and distribution patterns of elephants in the Reserves and its surrounding using GPS radio telemetry for proper implementation of new HEC mitigation measures is recommended as an area of future research interest.
ii. Scientific assessment of the success and failure of the organized crop protection strategies and further economic assessment of the cost and benefit.
iii. Continuous assessment of novel HEC prevention and mitigation measures for effective management of human-elephant conflicts in western Serengeti area.
iv. Collect and collate existing data and information to document change in land use and possible impact on elephant distribution.

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APPENDICES

Appendix 1: Household survey questionnaire

Sokoine University of Agriculture

Department of Ecosystems and Conservation

Dear participant,

I am conducting a survey to help in determine how to improve the management of Ikorongo-Grumeti Game Reserves specifically on preventing and mitigating human-elephant conflicts in adjacent communities. Participation in this research is purely voluntary. Please take a few minutes to answer these questions about your experience on human-elephant conflicts in this area. Your individual answers will not be disclosed to anyone. They will be combined with those of other respondents to guide me in the evaluation process. Your opinions are very important for resolution of the conflicts.

Part A: Particulars of the Respondent

Respondent No…….. Date……. Coordinates…….

Village Name…….....….. Ward……...

1. Sex: 1. Male (….) 2. Female (….)
2. Who is the head of family? 1. Father (….) 2. Mother (….) 3. Other (Mention)…….
3. Age……
4. Education level:
   1. No formal education (….) 2. Primary education (….)
   3. Secondary education (….) 4. College/University (….)
5. Marital status:
   1. Single (….) 2. Married (….)
   3. Divorced (….) 4. Widowed/Widower (….)
6. Total number of people in the household
   1. 1 – 2 (….) 2. 3 – 5 (….)

3. 6 – 8 (….) 4. 9 and above (….)

7. Household income per annum (in TZS).

1. Less than 800,000 (….) 2. 800,000 – 1,600,000 (….)

3. 1,600,001 – 2,000,000 (….) 4. Above 2,000,000 (….)

8. Duration of Residence

1. 0 – 5 years (....) 2. 6 – 10 years (….) 3. 11 – 20 years (....)

4. 21 – 30 years (….) 5. 31 and above years (…..)

9. What is your Occupation?

1. Crop production (…..)
2. Livestock keeping (…..)
3. Hunting (…..)
4. Crop production and livestock keeping (…..)
5. Crop production and business (….)
6. Crop production and hunting (…..)
7. Other (Mention)…….

Part B: Land use and property rights

10. What kind of property right do you have on the land you are using for agriculture?

1. Owning (…..) 2. Owning and using (…..) 3. Renting (…..) 4. Other (Mention)...…..

11. What is the farm size …… (Acres) and how far is it from Game Reserve boundary …… (Meters)?

12. What kind of crops are you producing in your farm?

1. …… 2. ……..

3. …… 4. ……..

Part C: Human-elephant conflicts

13. Are there any human-elephant conflicts in your village? 1. Yes (...) 2. No (...)

14. What are the major factors causing human-elephant conflicts in your village?

S/N.	Factors for human-elephant conflicts	Survey scale (Circle one): 1=Very high 2=High 3=Medium 4=Low 5=Very low						
1.	Increased elephant population		1	2	3	4	5	
2.	Encroachment		1	2	3	4	5	
3.	Crop damage		1	2	3	4	5	
4.	Livestock attacks		1	2	3	4	5	
5.	Human attacks		1	2	3	4	5	
6.	Lack of compensation plan		1	2	3	4	5	
7.	Climate change		1	2	3	4	5	
8.	House/Infrastructure damage		1	2	3	4	5	
9.	Lack of clear Buffer zone		1	2	3	4	5	
10.	Other (Mention)…….		1	2	3	4	5	

15. Please check the activities that the elephants cause to your locality.

Activities	Village	Year/Month	Details/Number/ Amount	Survey scale (Circle one): 1=Very high 2=High 3=Medium 4=Low 5=Very low						
Crop damage					1	2	3	4	5	
House damage					1	2	3	4	5	
Attack to livestock					1	2	3	4	5	
Family member death					1	2	3	4	5	
Family member injury					1	2	3	4	5	
Any other……					1	2	3	4	5	

16. Have you experienced any crop raiding incidence(s) by elephants in your farm this cropping season? 1. Yes (….) 2. No (….)

17. If the answer is yes in Q. 16 above, how many incidences of crop raiding occurred in your farm this cropping season? .....

18. At what time of the day do elephants most often attack and raid crops in the field?

    1. Morning (…..) 2. Afternoon (……) 3. Evening (…..)

    4. Night (…..) 5. Throughout the day (…..)

19. What is the estimate of economic losses resulting from crop damaged caused by elephants in percentage (%) and Tanzania shillings (TZS.) in this cropping season?.....(%) and …….(TZS.)

20. Are you aware about wildlife conservation (especially elephant)? 1. Yes (….) 2. No (….)

21. Should elephants be protected? 1. Yes (….) 2. No (….)

    Why? .....

22. Have you ever seen an elephant killed by human beings within your village?

    1. Yes (….) 2. No (….)

23. What are the possible drivers of elephant killings by people in this area?

    1 …… 2 …….

    3 …… 4 ……..

24. Who are the key players in the conflict scenarios?

    1. People vs Elephants (….) 2. People vs Rangers (….) 3. People vs IGGR Officers (….)

Part D: HEC prevention and mitigation measures

25. How do you relate to Ikorongo-Grumeti Game Reserves? ……

26. Do you know the rules on how to access the resources? 1. Yes (….) 2. No (….)

27. How do you comply with the rules? …….

28. What are limitations to these rules? ……..

29. What coping strategies do you apply to prevent your crops from being destroyed by elephants?

    1 …… 2 …….

    3 …… 4 ……..

30. Are there any measures applied by Ikorongo-Grumeti Game Reserves/Any Protected Area Authorities to prevent and mitigate the existing human-elephant conflicts in your area?

    1. Yes (….) 2. No (….)

31. What are those measures?

    1 …… 2 …….

    3 …… 4 ……..

32. Were they successful for the purpose which was intended?

    1. Very high (...) 2. High (...) 3. Moderate (...) 4. Little (….) 5. Very little (…) 6. Not at all (….)

33. Mention and explain the barriers that facilitated the failure of the applied measures

    1..... 2.....

34. How do you think those barriers in Q. 33 above can be removed to make the applied measures effective? .....

35. What measures apart from the previously applied do you think should be applied in order to effectively prevent and mitigate human-elephant conflicts in the area?

    1. Construction of Trench/Moat (….)
    2. Construction of electric fence (….)
    3. Geo-fencing (….)
    4. Translocation of problem elephants (….)
    5. Buffer zone management units (….)
    6. Other (Mention)…….

36. Who do you think gain in the human-elephant conflict? ……

37. Who bear the most negative impacts (loses) in the human-elephant conflict? ……

Part E: Willingness to pay (WTP) questions

38. Should farmers be compensated for elephant damage to crops? 1. Yes (….) 2. No (….)

39. Do you need better compensation program? 1. Yes (….) 2. No (….)

40. Is the respondent familiar with the WTP scenario?

1. Very new (….) 2. Slightly known (….) 3. Very familiar (….)

41. If a TRUST FUND is established and an appropriate program is implemented to reduce HEC, would you like to be involved in such a program?

1. Not interested (….) 2. Depends on program (….) 3. Very interested (….)

42. For appropriate conservation program, finance is essential. So, if "TRUST FUND" would be established, and the account is transparent to everyone, would you like to donate some money for the program?

1. Not interested (….) 2. Depends on program (….) 3. Very interested (….)

43. How much would you be willing to contribute for the program per month, i.e. '12X' per year following the establishment of the proposed "TRUST FUND" for HEC prevention and mitigation measures?

1. TZS. 1 000/= (….) 2. TZS. 2 000/= (….) 3. TZS. 3 000/= (….)
4. TZS. 4 000/= (….) 5. TZS. 5 000/= and above

THANK YOU FOR YOUR COOPERATION AND TIME!!

Appendix 2: Checklist for key informants

Sokoine University of Agriculture - Department of Ecosystems and Conservation

Dear participant,

I am conducting a survey to help in determine how to improve the management of Ikorongo-Grumeti Game Reserves specifically on preventing and mitigating human-elephant conflicts in adjacent communities. Please take a few minutes to answer these questions about your experience on human-elephant conflicts in this area. Your individual answers will not be disclosed to anyone. They will be combined with those of other respondents to guide me in the evaluation process. Your opinions are very important for resolution of the conflicts.

Respondent No.…… Village……

Date…… Occupation status……..…

1. Are there any human-elephant conflicts in this area?
2. What factors lead to human-elephant conflicts?
3. To what extent the damage caused by elephants affect the communities?
4. What is the trend of these damages for the period between years 2008 to 2015?
5. Which crops are raided by elephants? List them (Starting with No. 1=Most raided crop)
6. How many incidences of crop raiding have been reported to occur in your area for the period of 2008 to 2015 years?
7. What is the number of human injuries and deaths caused by elephants for the period of 2008 to 2015 years?
8. How many elephants were killed/injured as problem animals within or along your area for the period of 2008 to 2015 years?
9. What strategies have been applied to prevent and mitigate the conflicts in this area?
10. Were they successful for the purpose to which was intended ….....?, Why……?
11. Can you suggest other alternative ways of solving the conflicts apart from currently applied?
12. Do you prefer to settle the conflict so that communities and protected area authority could live in harmony?

THANK YOU FOR YOUR COOPERATION AND TIME!!