Sokoine University of Agriculture

MSc Dissertation

Effects of Human-Elephant Interactions at Water Sharing Points in Villages Adjacent to Rungwa-Kizigo-Muhesi Game Reserve, Tanzania

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May 2024

EFFECTS OF HUMAN-ELEPHANT INTERACTIONS AT WATER SHARING POINTS IN VILLAGES ADJACENT TO RUNGWA-KIZIGO-MUHESI GAME RESERVE, TANZANIA

Dissertation Submitted to Sokoine University of Agriculture in Partial Fulfillment of the Requirement for the Degree of Master of Science In Wildlife Management and Conservation

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EXTENDED ABSTRACT

The sharing of water sources by humans and elephants is one of the common practices in societies surrounding protected reserves in rural areas across Africa. However, there is little information known about how elephants in Tanzania utilizes water sources beyond formal protected areas and the strategies to manage these challenges. This study was conducted around Rungwa-Kizigo-Muhesi Game reserve in south-western Tanzania to address the following objectives: i) to identify the main types of water sources that are shared by people and elephants on village land, ii) to examine temporal patterns in elephant use of water sources on village land, iii) to assess the number and group composition of elephants that are using village water sources, and iv) to examine community experiences and perceptions resulting from sharing water sources with elephants. Data was collected via camera trapping (n=1,369 camera-trap days between November 2021 and May 2022), key informant interviews (n=25), and questionnaires (n=188 households) among households adjacent to water sources known to be used by elephants. Data from questionnaires and key informant interviews was analyzed by Statistical Package for Social Sciences software. The test statistics used was the chi-square goodness of fit test to test the likelihood of respondents having directly experienced a problem with elephants at a water source. Additionally, logistic regression was used to explore the effect of village habitation, sex, education, age, duration of residency, and experience of respondents on willingness to share the same water sources with elephants. Camera trap images were classified using ExifPro 2.1 software and the *overlap* package in R software was used to generate smoothed non-parametric kernel density distributions showing the timing of elephant visits to water sources over 24 hours. Results showed that shallow wells dug by hand provided the majority of the villager's water needs, and 92% of elephant camera trap detections occurred there. The camera traps detected 24 elephant visits to water sources, all of which occurred at

night. Female-led cow-calf groups were present in 58.3% of visits and male elephants were present in 75.0% of visits. From camera trap photos, we identified at least three distinct cow-calf groups and eleven distinct bulls. Analysis of social-economic data revealed that the majority of households (85.0%) had witnessed elephants at their primary water source and 85.2% of respondents stated they had directly experienced a problem when using a water source that was also being used by elephants. It was further revealed that women were more likely than men to have directly experienced problems with elephants. Generally, around 59.9% of respondents were unwilling to share water sources with elephants. In conclusion, key findings include the prevalence of hand-dug shallow wells as the primary water source for villagers with a high incidence of elephant visits, particularly at night. The main concerns were: elephant damage to shallow wells, delays due to elephant presence at water sources, fear of meeting elephants at water sources, water contamination, elephants being trapped inside wells, and elephants dying inside wells. To address these concerns, community members recommended constructing boreholes and communal water taps and increasing support from Game reserve rangers when elephants are on village land.

Keywords: Human-elephant interactions, water sources, camera trapping, community livelihoods, Tanzania

DECLARATION

I, Irene James Laizer, do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my original work and that it has neither been submitted nor is concurrently being submitted for degree award in any other institution.

Irene James Laizer **(MSc Candidate)**	**Date**

The above declaration is confirmed by;

Dr. Robert Byamungu **(Supervisor)**	**Date**
Dr. Rose Kicheleri **(Supervisor)**	**Date**

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DEDICATION

I dedicate this dissertation to my beloved parents Mary Lekundayo, my late father James Laizer and my Aunt Sr. Adalbera Mukure for their love, support and prayers. Also, to my beloved brother Bosco James, my sisters Joan James and Adalbera Boniventure may God bless you always.

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LIST OF ABBREVIATIONS

AIC	Akaike Information Criterion
CITES	Convention on International Trade in Endangered Species of Flora and Fauna
HEC	Human Elephant Conflict
NBS	National Bureau of Statistics
SPSS	Statistical Package for Social Sciences
STEP	Southern Tanzania Elephant Program
SUA	Sokoine University of Agriculture
TAWIRI	Tanzania Wildlife Research Institute
URT	United Republic of Tanzania

CHAPTER ONE

1.0 General Introduction

1.1 Background Information

The ongoing existence of African elephants (*Loxodonta africana*) is growing increasingly uncertain across various regions of the continent, with over half of their habitat estimated to lie beyond protected areas (Hoare, 2000; Wall *et al*., 2021), occupying semi-arid savannas where water is not widely available (Wato *et al*., 2018). When water is hardly available across the region, wild animals adapt their movement techniques to meet their needs for food and water (Chamaillé-Jammes *et al*., 2013). As a result, elephant movements are thought to be influenced by the distribution and availability of water (Furstenburg, 2018; Wato *et al*., 2018). Elephants visit water sources frequently whether it is a natural or artificial water source to drink but also because they use water-related activities like mud bathing, and splashing to maintain their body temperatures (Dunkin, 2013; Purdon *et al*., 2017).

In their search for water and food resources, elephants use areas outside of formal protected areas and come into contact with people. This can result in elephants damage to water points and water pipes, or injuring/killing people or livestock (Parker *et al*., 2007; Mariki *et al*., 2015; Gross *et al*., 2021). Several studies have described the impacts of elephants using water sources that are also used by people. According to Mayberry *et al*., (2023) respondents in Khumanga, Botswana confirmed that elephants threaten their ability to access water, they mentioned that elephants are often present at the river or on pathways leading to it. When elephants are searching for water can destroy several water facilities and this damage can be expensive and may deprive people of water for days, as it takes significant time to repair pipelines (Mariki *et al.*, 2015). In Chobe National Park, Botswana, Elephants are reported to regularly dig up water lines to reach water during dry seasons, and this brings disturbance to nearby tourist camps (Parker *et al*., 2007). Elephants

may also cause damage to other properties such as fences and water installations (Parker *et al*., 2007). As such, the shared use of water between people and elephants is thought to be one contributing factor to human-elephant conflict.

Tanzania takes the conservation of elephants a top priority as the country is home to the majority of Africa savannah elephants. In Tanzania, they are acknowledged as a significant source of national income through nature and wildlife tourism in addition to playing a critical ecological function as keystone species (Kideghesho, 2016). In 2009, it was estimated that Tanzania had 109,000 elephants, however, in 2015 the population was reported to have declined to an estimated 50,000 elephants (Mduma *et al.,* 2010, Chase *et al*., 2016). This massive decline was primarily a result of poaching for ivory (Thouless, 2016). While poaching levels since 2015 have been lower (Kideghesho, 2016) recovery of elephant populations in Tanzania is increasingly complicated by human-elephant conflicts.

The longstanding challenge of human-elephant conflict (HEC) in Tanzania has endured for decades (TAWIRI, 2010). However, due to an expanding human population and the increasing encroachment of people into the historical elephant range, human-elephant interactions are seemingly on the rise and have become a major concern for the Tanzanian Government (URT, 2020). Elephants are perceived as dangerous and destructive animals, and maintaining coexistence between people and elephants is challenging due to the diversity of people's beliefs and interests (Dublin and Hoare, 2004). To develop management techniques that will protect both people and elephants, it is necessary to understand the dynamics of their interactions (Hariohay *et al*., 2020).

1.2 Problem Statement

All over the world, human-elephant interaction is a big conservation challenge, especially for places within elephant ranges. This is no different when it comes to Tanzania (Mmbaga *et al.,* 2017; Hariohay

et al., 2020). Elephants are highly water-dependent, thus sources of permanent water on the village land are one interface where human-elephant interactions usually arise. Elephants make foray into areas of human settlement and destroy crops, raid food-stores and damage water sources, and occasionally injure or kill people in the process (Hoare, 2000).

Despite these calamities resulting from human-elephants interactions in Tanzania, there is little information on how elephants utilize water sources outside formal protected areas and the approaches to address these challenges. Rungwa game reserve has the largest elephant population in Tanzania, with an estimated 19,884 individuals (TAWIRI, 2022) making this game reserve ideal for addressing the underlying questions. In the Rungwa-Kizigo-Muhesi game reserve, some of the permanent water sources are found outside protected areas, especially on village land. The villagers in Rungwa- reporting problems caused by elephants about (51.9%) mentioned crop damage, followed by damage to infrastructure such as water taps (19.5%). When asked the common reasons for damage by elephants, among others the respondents mentioned elephants searching for water on village land (20.0%)" (Hariohay *et al*., 2020).

Preliminary work has suggested that shared water sources by elephants, people, and livestock can be of concern to local communities because the risk of encountering elephants poses a potential danger to their lives (Smit, 2019). Understanding the dynamics of human-elephants water source sharing is crucial for addressing the ongoing challenges faced by both communities and challenges in villages adjacent to protected areas. In this regard, there is a need to better understand where, when and how elephants use water sources on village land within elephant home range. In addition, there is a need to better understand community perceptions and experiences of human-elephant water source sharing. This in turn will help in forming strategies to enhance water

sharing experience for both people and elephants for sustainable conservation of elephants and coexistence.

1.3 Justification of the Study

This study provides baseline information to guide the formulation of strategies for water access for both people and elephants in an attempt to enhance human-elephant coexistence in the Rungwa-Kizigo-Muhesi game reserve. The study aimed at identifying the main types of water sources that are shared by people and elephants on village land, investigating temporal and seasonal patterns in elephant use of water sources on village land, investigating the number and group composition of elephants using village water sources, and examining community experiences and perceptions around sharing water sources with elephants. In addition, the study will help in understanding periods when elephants are most likely to be using water sources, and how regularly the water sources are being visited by elephants on village land. This information will be useful to advise communities on which water sources are most used by elephants, at what time and what are the safer hours for humans to access and use village water sources.

1.4 Objectives

1.4.1 General Objective

To investigate the pattern of elephant use of water sources, community experiences and perceptions resulting from human-elephants sharing of water sources in villages adjacent to Rungwa-Kizigo-Muhesi Game reserve.

1.4.2 Specific Objectives

i) To identify the main types of water sources that are shared by people and elephants on village land,
ii) To examine temporal patterns in elephant use of water sources on village land,

iii) To assess the number and group composition of elephants using village water sources,
iv) To examine community experiences and perceptions around sharing water sources with elephants in villages adjacent to Rungwa-Kizigo-Muhesi Game reserve.

1.5 Research Questions

1. What are the primary types of water sources utilized by both humans and elephants on village land?
2. How do temporal patterns influence elephant utilization of water sources on village land?
3. What are the demographics and group size of elephants frequenting village water sources?
4. What are the communal perspectives and experiences concerning the cohabitation with elephants in sharing water sources?

1.6 Limitations of the Study

Among others, this study originally aimed at researching both temporal and spatial patterns in elephant use of water sources on village land adjacent to Rungwa-Kizigo-Muhesi Game reserve. Unfortunately, seasonal data was difficult to collect because it was impossible to deploy camera traps at every water source in the villages due to equipment and labor constraints. Five cameras were stolen and this hindered the sampling effort and the collection of data to complete a full year of camera trapping. Therefore the study focused on the daily temporal patterns of elephant water source visits.

Moreover, some respondents refused to participate in the interview and thought they would be subjected to law enforcement, which contributed to a limited dataset.

1.7 Dissertation Structure

This work is organized into publishable manuscripts format comprising four chapters. Chapter one presents the introduction to the general context, objectives, problem statement and the contribution of the study. Chapter two presents the first manuscript, which focuses on the assessment of repercussions of human and elephant water source sharing in village land adjacent to Rungwa-Kizigo-Muhesi Game reserve. Chapter three presents the second manuscript which focuses on the pattern of elephant's use of communal waters sources in villages adjacent to Rungwa-Kizigo-Muhesi Game reserves. In chapters four and five, the study's general discussions, conclusions and recommendations are presented simultaneously.

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CHAPTER TWO

Manuscript One

2.0 Assessment of Repercussions of Human and Elephants Water Source Sharing in Village Land Adjacent to Rungwa-Kizigo-Muhesi Game reserve in south-central Tanzania[1]

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Abstract

Human-elephant interactions that result in conflicts appear to be on the rise because of growing human populations, and expansion of agriculture and settlements into elephant range. This study examined human-elephant interactions around water sources on village land adjacent to Rungwa-Kizigo-Muhesi Game reserve in south-central Tanzania. Data was collected via questionnaires involving households adjacent to water sources known to be used by elephants between November and December 2021 (n=188 households). Respondents indicated that elephants used village water sources seasonally and nocturnally. The majority of households (85.0%) had witnessed elephants at community primary water sources, and (85.2%) of respondents stated that they had directly experienced a problem when using a water source that was also used by elephants. The result from chi-square statistic revealed that women were more likely than men to have experienced a problem directly. Most respondents (82.4) stated that they accessed water sources in the morning or afternoon. The majority of respondents (59.9%) said that they were unwilling to share water sources with elephants. The main concerns were elephant damage to shallow wells, being unable to access water on time due to elephant presence at water sources, fear of meeting elephants at water sources, and water contamination. The findings underscore the need for proactive measures to manage human-elephant interactions, particularly around water sources. Community perspective reveal significant challenges and underscore the collaborative efforts between villagers and conservation authorities to implement sustainable solutions such as constructing boreholes and communal water taps and increasing support from Game reserve rangers when elephants are on village land to promote coexistence between human and elephants.

Keywords: African savanna elephants, water sources, human-elephant interaction, community livelihoods, Tanzania

2.1 Introduction

Human-elephant interactions that result in conflicts appear to be on the rise because of growing human populations, and expansion of agriculture and settlements into elephant range (URT, 2020). As elephants are highly water-dependent, sources of permanent water on village land can be an interface for human-elephant interactions. Elephant distribution is strongly influenced by water availability, as elephants require approximately 160 liters of water per day (Parker *et al*., 2007). Over half of the African elephant population lives in semi-arid regions, where water is particularly scarce (Wato *et al*., 2018). The shared use of water between people and elephants is thought to be one factor contributing to human-elephant conflicts. In Tanzania, the elephant population declined from an estimated 109,000 individuals in 2009 to 50,000 individuals in 2015 as a result of poaching for the ivory trade (Mduma *et al*., 2010; Chase *et al*., 2016; Kideghesho, 2016; Thouless *et al.*, 2016). While poaching for ivory has declined since 2015 (CITES, 2020), the recovery of Tanzania's elephant population is complicated by increasing concerns over human-elephant conflict (URT, 2020).

A handful of previous studies have described the impacts of elephants using water sources that are also used by people, such as damage to water points and water pipes, attacks on people and livestock, and restricted access to water sources (Thouless, 1994; Parker *et al*., 2007; Mariki *et al*., 2015; Mayberry *et al*., 2023). This damage can be expensive and can deprive people of water for days, as it can take significant time to repair pipelines (Mariki *et al*., 2015). Access to water can be a key issue between pastoralists and conservationists as elephants and livestock may compete for the same water sources and elephants sometimes kill livestock (Thouless, 1994; Kagwa, 2011; Kangwana, 2011). The presence of elephants can also restrict people's access to water sources for domestic use or fishing (Mayberry *et al*., 2023).

Nevertheless, previous studies on human-elephant interactions have focused on crop damage (Kaswamila, 2009; Munuo, 2016; Smit *et al*, 2023). To our knowledge, studies on community perceptions and experiences of sharing water with elephants are limited in Tanzania. This study examined the repercussions of human and elephant water source sharing in village land adjacent to Rungwa-Kizigo-Muhesi Game reserve in south-central Tanzania. The objectives of this study were 1) to identify the main types of water sources that are shared by people and elephants in the focal villages, and 2) to examine community experiences and perceptions around sharing water sources with elephants. We used questionnaires to gain insight into how household members living adjacent to water sources that are also used by elephants accessed water, and how many household members had directly witnessed elephants at their primary water sources. We also asked respondents about the types of problems they directly or indirectly experienced as a result of sharing water sources with elephants, and if and how their experiences had changed their use of water sources. We also assessed which factors predicted respondents' willingness to use the same water sources with elephants.

2.2 Materials and Methods

2.2.1 Description of the study area

The study was conducted in Rungwa and Doroto villages adjacent to Rungwa-Kizigo-Muhesi Game reserves (>17,000 km^2) in Itigi District, central Tanzania (Figure 2.1). The villages were selected based on the fact that they are in close proximity to Rungwa-Kizigo-Muhesi Game reserves and they have the large number of elephant visits per year (Smit *et al*., 2016). The study area falls within the Central Zambezian miombo woodlands ecoregion (Olson *et al*., 2001). The area experiences a dry season from May to November and a wet season from January to April (Bjornstad, 1996). The mean annual temperature is 28°C, and rainfall ranges from 500 to 700 mm (Hariohay *et al*., 2019). The greater Ruaha-Rungwa game reserve, which encompasses the Rungwa-Kizigo-Muhesi Game reserves,

was home to an estimated 19,884 elephants in 2022 (TAWIRI, 2022).

The human population was estimated at 14 849 people in Doroto village and 9 666 people in Rungwa village (NBS, 2022). The dominant ethnic groups are Sukuma and Nyaturu. Farming and livestock keeping are the major economic activities in the study area (National Bureau of Statistics, NBS (2016). The main crops grown in the study area are maize, sunflower, rice, sweet potatoes, pumpkin, millet, and groundnuts. These villages rely primarily on hand-dug shallow wells for their water supply. Access to tap water is very limited; the main source of piped water is public taps (NBS, 2016).

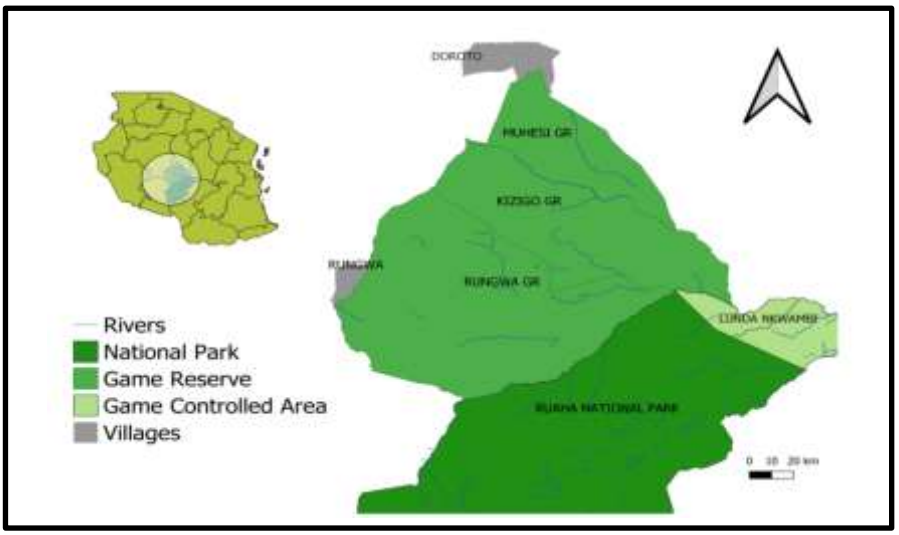

Figure 2.1: Map showing the location of the study area in Tanzania (top left) and the location of Doroto and Rungwa villages adjacent to Rungwa and Muhesi Game reserves (right)

2.2.2 Data collection

Data on elephant use of water sources, community perceptions and experiences of sharing water sources with elephants was collected via household surveys. Prior to data collection, village leaders,

elders, and local elephant monitors (community-based enumerators who collect data on human-elephant interactions) were contacted to explain the goals and obtain consent for the study.

A total of 376 (N) households were identified through a reconnaissance survey conducted by the local elephant monitors stationed at the study area by STEP. The survey included the households occurring near the identified water source within a radius of 1000 meters. Given the limited time and financial resources the sample size was determined from the identified households by applying the standard method as proposed by Krejcie and Morgan (1970) as follows:

$$n = \frac{x^2 * N * p * q}{d^2 * (N-1) + x^2 * p * q} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where n = sample size, χ^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (at 95% confidence level, χ^2 = 3.84), N = total number of households occurring near the identified water sources, p = population proportion considered to be 0.5 to provide maximum sample size, q = (1-p) = 0.5 and, d = degree of accuracy expressed as a proportion (d = 0.05). By applying the formula above, the sample size for the study was 188 households. Household surveys were conducted at households occurring next to water sources known to be used by elephants. A simple random selection of 188 sample proportionately to the total number of identified households was drawn as seen in Table 2.1.

Table 2.1: Sampling Protocol for the surveyed villages

Village-land	Total Identified Households	Weight	Sampled Household in Village-land (Weighted)	Percent (%)
Doroto	284	0.7554	142	75.54
Rungwa	92	0.2446	46	24.46
Total	**376**	**1.0000**	**188**	**100.00**

A total of 188 questionnaires were administered; in Rungwa (n=46) and Doroto (n=142) in November and December 2021. Questionnaires were only conducted in Swahili language and only if

respondents provided their prior informed consent. Questionnaires were both open and closed-ended. Information about household water source use, including the types of water sources used, the identity of the household's primary water source (the water source used most often by the household), and whether the water source was also used by elephants, the times of day at which the household used water sources were collected. Questionnaires were also used to gather local knowledge on the types of water sources used by elephants and elephant visitation patterns to water sources (time of day and seasonality).

2.2.3 Data analysis

The collected data was analyzed using Statistical Package for Social Sciences (SPSS, version 16.0). Qualitative data from open-ended questions was analyzed using content analysis (Zarestky, 2023). Descriptive and inferential statistics were also used to analyze quantitative data (Kiondo *et al*., 2019). We used descriptive statistics to summarize the socio-economic characteristics of respondents. The chi-square goodness of fit tests, on the other hand, was used to test whether the likelihood of having directly experienced a problem with elephants at a water source varied with village (Doroto or Rungwa), sex (male or female), education (no formal education or some formal education), age (youth 15-24 years or adult 25 years and older), or years of residency (0-4 years, 5-9 years, >10 years) (Munuo, 2016). Logistic regression was used to explore the effect of village, sex, education, age, duration of residency, and experience (having direct experience or no direct experience of a problem with elephants at a water source), on whether or not a respondent said they agreed with the statement "able to share the same water sources with elephants". We modeled the probability of someone agreeing or disagreeing with this statement as a function of the following covariates: sex (categorical with two levels, with male as the reference level), age (categorical with two levels, with youth as the reference level), education (categorical with two levels, with no formal education as the reference level), village (categorical with two

levels, with Doroto as the reference level), years of residency (categorical with three levels, with 0-4 years as the reference level), and experience (categorical with two levels: with direct experience as the reference level). We fitted a global model with all covariates but with no interactions and removed covariates that did not contribute to the model fit (Smit *et al.*, 2022). We used a backward stepwise regression whereby the least significant variable (as determined from chi-squared p-values) was dropped at each step (Buchholtz *et al.*, 2021). Model selection was done using AIC, whereby all models within ΔAIC of 2 were considered the most fit (Burnham and Anderson, 2004). We expressed model coefficients as odds ratios to compare the effect of each level of a covariate on the probability of a respondent agreeing to the statement that they were willing to share water sources with elephants (Burnham and Anderson, 2004).

2.3 Results

2.3.1 Characteristics of respondents

The result in Table 2.2 shows that the majority of respondents (52.7%) had received no formal education, while 45.7% had attended primary school and only 1.6% had attended secondary school. Most respondents (85.2%) were not born in the village they were living in. Over a quarter of respondents (27.1%) had been resident in the study area for four years or less, while 25.0% had been resident in the area between five and nine years. Respondents who had moved to the study area had done so primarily for farming (62.2%) and livestock-keeping (16.0%) opportunities. Most respondents (96.3%) stated that agriculture was one of their economic activities, with 61.7% of respondents also practicing livestock keeping. The most common crops cultivated in the study area were sweet potatoes, maize, sunflower, rice, pumpkins, millet, and groundnuts. On the other hand, cattle were the most familiar livestock kept by the majority as they were also used for ploughing the fields. Most of the labour for these economic activities is provided by household members, with 33.5% of households having

six to eight members and 33.0% of households having nine or more members.

Table 2.2: Characteristics of questionnaire respondents (n=188).

Characteristics of respondents	Frequency	Percentage
Age		
Youth (15-24 years)	40	21.3
Adult (25-64 years)	142	75.5
Senior (65+ years)	6	3.2
Sex		
Male	94	50.0
Female	94	50.0
Residency		
0-4 years	51	27.1
5-9 years	47	25.0
>10 years	90	47.9
Education		
No formal education	99	52.7
Primary education	86	45.7
Secondary education	3	1.6
Household size		
1-2	17	9.0
3-5	46	24.5
6-8	63	33.5
9+	62	33.0
Livelihoods		
Farming	181	96.3
Livestock keeping	116	61.7
Trade	14	7.4
Ethnic group		
Sukuma	72	38.3
Nyaturu	55	29.3
Taturu	25	13.3
Nyamwezi	12	6.4
Gogo	5	2.7
Nyiramba	10	5.3
Iraq	1	0.5
Others	8	4.3

2.3.2 Main types of water source used by village residents

Five types of water sources were found being used by household members in the study area, including shallow wells, boreholes, dams, public water taps, and rivers/streams. All households surveyed used water sources for domestic use and 63.8% of households also used water sources for livestock watering. Households primarily used shallow wells for domestic use and both shallow wells and dams for livestock watering. In Doroto village, the most used water source was shallow wells (92.3% of households). In Rungwa village, the most used water source was shallow wells (97.8% of households) as well, with 23.9% of households also using public water taps. Most of the shallow wells were man-made, that is to say, they had been dug by hand or were the result of quarrying. Most shallow wells were ten to twenty meters wide and around one meter deep. For 55.3% of respondents, the water source closest to their household was their primary water source.

Almost half of all households (46.8%) relied on adult women and/or female children to fetch water from the primary water source, while 17.6% of households relied on adult men and/or male children. About 20.2% of households, both adult men and women collected water, and in 15.4% of households, any family member collected water from the primary water source. The average travel time to and from a household's primary water source was 22 minutes (median 15 min, range 1-120 min), with 39.9% of respondents traveling a minimum of 30 minutes to access water sources. Most respondents (63.3%) indicated that they fetch water from their primary water source in the morning, 25.5% in the evening, and 19.1% in the afternoon. Only 1% of respondents stated they used water sources at night.

2.3.3 Local knowledge of elephant water source use on village land

A large proportion of respondents (85.0%) stated that they had directly witnessed elephants at their household's primary water

source. The remaining 15.0% of respondents stated that they had not directly witnessed elephants at their primary water sources, but that they had heard or witnessed elephants using another water source on village land. Respondents who had heard about or witnessed elephants at their primary water sources were asked about elephant use of these water sources. The majority of respondents (75.6%) in both villages stated that elephants use water sources seasonally (Doroto 70.2%, Rungwa 92.3%). Most respondents (81.4%) stated that elephant use of village water sources is most common in the wet season, especially in the months of April and May. Most respondents (88.9%) reported that elephants tend to visit village water sources at night during both the wet and the dry season (Figure 2.2). In Rungwa, most respondents (87.2%) reported that the frequency of elephant visits to village water sources had declined between 2019 and 2021, while in Doroto village, most respondents (86.8%) stated the frequency of elephant visits had increased between 2019 and 2021. The majority of respondents (73.4%) believed the main reason that elephants used village water sources is that elephants visit water sources while also searching for crops in village farms. A minority (14.4%) of respondents thought elephants used village water sources due to a lack of water in the Game reserves, and others stated this may be due to their homes being close to the Game reserve (11.2%) or farms being near water sources (5.3%).

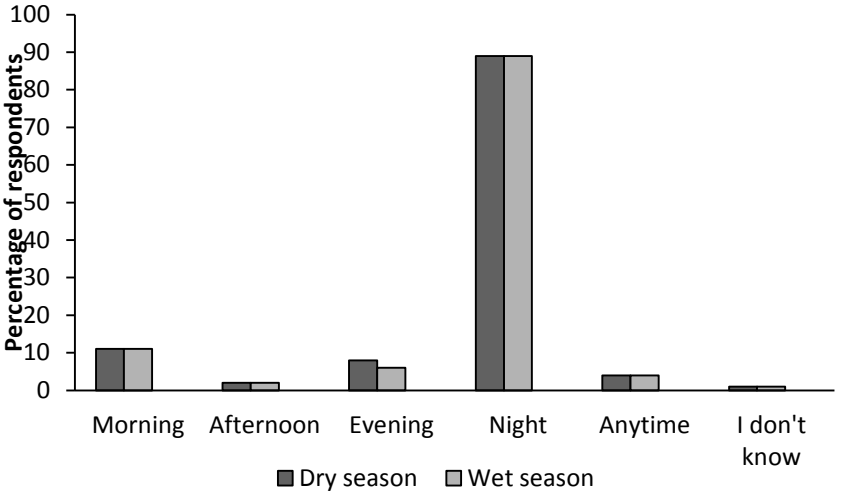

Figure 2.2: Seasonal elephants visit at water sources

2.3.4 Community experience and perception of sharing water sources with elephants

Most respondents (85.2%) stated that they had directly experienced a problem as a result of sharing water sources with elephants, while 11.5% stated that they had not directly experienced a problem but had heard about someone else experiencing a problem (we consider this as an indirect experience). Only 3.3% of respondents had neither experienced a problem directly nor heard about someone else experiencing a problem as a result of sharing water sources with elephants. Women were more likely than men to have directly experienced a problem as a result of sharing water sources with elephants, $X^2(1, N=156) = 12.78, p<0.005$).

The most common problem that respondents had experienced directly because of sharing water sources with elephants was damage to water sources (87.7% of respondents; Figure 2.3). Other problems that respondents had experienced directly included being unable to access water on time (14.1%), fear of meeting elephants (9.0%), people being attacked by elephants (5.8%), and livestock being attacked by elephants (0.6%). Of those respondents with

indirect experience, 85.7% had heard about damage to water sources, and 14.3% had heard about people being attacked by elephants.

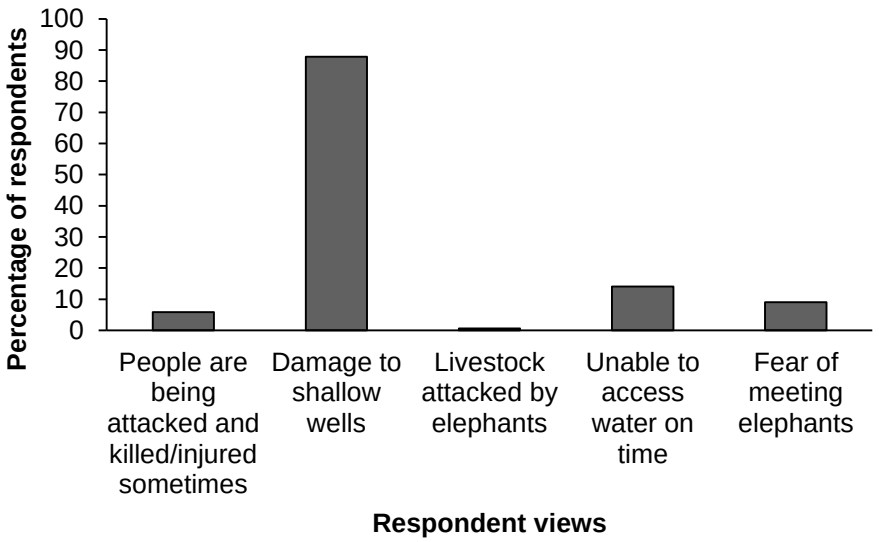

Figure 2.3: Percentage of respondents indicating different types of problems as a result of sharing water sources with elephants

Of the respondents who had directly experienced a problem as a result of sharing their primary water source with elephants, 57.6% said that they stopped using the water source where the problem occurred, 42.4% changed the time at which they visit the water source where the problem occurred, 25.0% of respondents stated that they had changed their primary water source, and 24.7% said that they changed how they visit the water source, such as by walking in groups and not going at night or early in the morning (Figure 2.4).

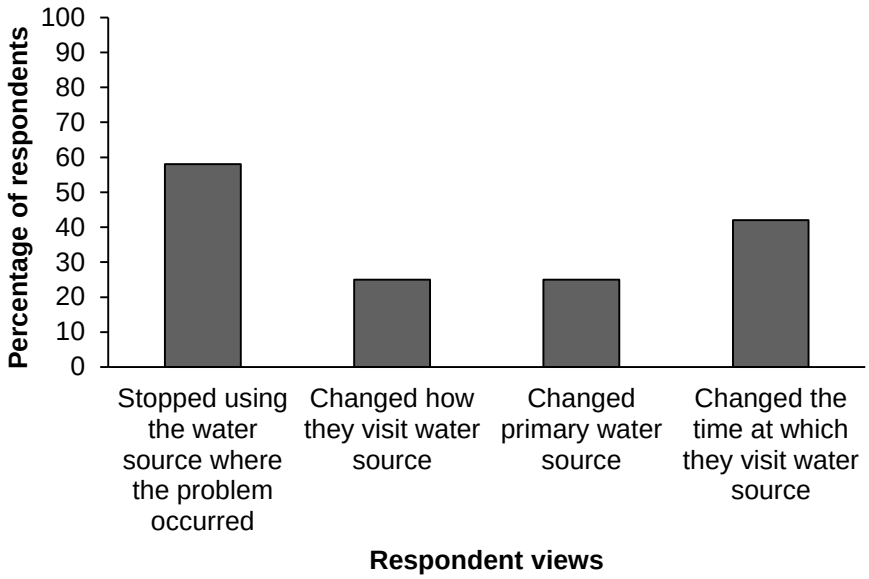

Figure 2.4: Percentage of respondents who changed their behavior in response to directly experiencing a problem because of sharing a water source with elephants.

Of the respondents who had heard about someone else experiencing a problem as a result of sharing water sources with elephants (indirect experience, n=21), 52.4% stopped using the water source after they had heard that the problem had occurred, 9.5% stated that they had changed their primary water source, 47.6% said they changed the time at which they visit water sources, and 47.6% changed approaches on how they visit water sources. Of the respondents who had neither directly nor indirectly experienced problems due to sharing water sources with elephants (n=11), 36.4% said that as a result of knowing that elephants use water sources in the village, they had stopped using a particular water source in the village.

Overall, 39.9% of respondents agreed with the statement “I am able to use the same water sources with elephants” while 60% of

respondents disagreed. Of the covariates tested, only experience had a statistically significant effect on whether respondents agreed with this statement (Tables 2.3 and 2.4). Respondents who had direct experienced of a problem with elephants at a water source were more likely to say that they were able to use the same water sources with elephants than respondents with no direct experience. The covariates of education and age were each included in one top model (Table 2.3 - 2.4), but neither covariate was statistically significant.

Table 2.3: Top model set from logistic regression analysis of covariates on the probability of whether respondents agreed with the statement "I am able to use the same water sources with elephants"

Model	AIC	ΔAIC
Experience	245.8	0
Experience + Age	246.8	1
Experience + Education	246.9	1.1

Note: Top model set (all models within ΔAIC < 2) from logistic regression analysis of covariates on the probability of whether respondents agreed with the statement "I am able to use the same water sources with elephants". The top models included the covariates experience (direct experience of a problem as a result of sharing a water source with elephants or no direct experience), age (youth or adult), and education (no formal education or some formal education).

Table 2.4: Estimated regression parameters, standard errors, P-values, and odds ratios for the covariates in the top model set (values are for the highest-ranked model in which the covariate appears).

Covariate	Beta	SE	P-value	Odds ratio
Constant	1.25	0.46	0.007	3.5
Experience (direct vs. no direct)	-0.97	0.49	0.048	0.38
Age (youth vs. adult)	0.36	0.38	0.35	1.43
Education (no formal vs. formal)	-0.31	0.31	0.32	0.73

2.4 Discussion

The future of African elephants increasingly depends on their ability to persist in landscapes that they share with humans, and on the willingness of humans to coexist with elephants (Poole *et al.,* 2011). Sources of permanent water are often shared by people and elephants and are therefore an interface for potentially hostile human-elephant interactions (Kangwana, 2011). In this study, we examined community knowledge, perceptions, and experiences of sharing water with elephants in the Tanzanian context.

Village residents in Rungwa and Doroto relied primarily on hand-dug shallow wells for their water supply. In a related study by Laizer *et al.,* (unpublished), it was found that these shallow wells were also the water sources that elephants used most on village land. Most respondents indicated that elephants visit village wells primarily during the wet season, particularly in the months of April to May because there is plenty of water in the wells. Respondents also indicated that elephants visited village water sources at night, corresponding to findings from other sites where elephants were reported to use water sources in human-dominated areas at night (Buchholtz *et al*., 2019). Similarly, elephants have been widely reported to engage in risky crop foraging at night (Graham *et al.*, 2009; Chamba, 2018; Smit *et al.*, 2019). In areas where elephants are relatively safe, such as inside protected areas, elephants tend to access water during the day (Guy, 1976; Leggett, 2008; Smit *et al*., 2022). It is therefore likely that elephants are avoiding the village water sources during the day because of human activity and to reduce the risk of encountering humans. As only 1% of respondents indicated that they visit water sources at night, there may be little temporal overlap in water source use between people and elephants. The greatest risk for overlap is likely at dusk and dawn when elephants can be moving through village land at times when humans are also active.

The study revealed that there has been an increase in elephant visits in Doroto and a decrease in Rungwa, this is due to the fact that there has been a significant increase in population and urbanization in Rungwa. Consequently, many residents have shifted from using wells to using tap water because many wells have been silted up with soil which led elephants not to visit those wells again. Furthermore, in Rungwa village, several respondents reported that the fake beehive fencing supplied by the Southern Tanzania Elephant Program (STEP) had a positive impact on reducing the number of elephants from entering in their residences. The findings are in line with Chamba (2018) who found that 4.3 % of the respondents from the surveyed villages were found applying beehive fences to prevent crop raiding by problem elephants in their crop fields.

Moreover, respondents perceived that elephants visit wells when they are looking for crops in the village, as many farms are located close to village wells. In a study of crop damage risk in villages around Rungwa-Kizigo-Muhesi Game reserves, Hariohay *et al*. (2020) found that households that shared water sources with elephants were significantly more likely to experience crop damage than households that did not share water sources with elephants. Elephants can reduce travel time by drinking at waterholes that are close to where they forage (Chamaillé-Jammes *et al*., 2013). There was a high degree of overlap in the types of water sources used by people and elephants, as both elephants and people relied primarily on shallow wells and small dams (Laizer et al., unpublished). It was common for people living near water sources to have direct experience of elephants at their primary water sources. Most respondents (85%) had directly experienced a problem because of using a water source that was also used by elephants, with women more likely than men to have directly experienced a problem. This could be due to the fact that almost half of households, women or girls were responsible for fetching water. Dillip *et al.* (2018) similarly reported that the majority of household chores are traditionally

performed by women in Tanzania. The two most common problems mentioned by respondents were damage to shallow wells (elephants pushing sand or soil into the wells and making the water dirty) and being unable to access water on time. Respondents also raised concerns about water being contaminated with elephant urine and dung, causing stomach pain when ingesting such water. Although not mentioned by primary respondents, the village leaders that were interviews related incidents of elephants falling into and/or getting stuck in village wells, with several elephants dying in this manner.

More than half of respondents who had direct or indirect experience with elephants as a result of sharing water sources said that they stopped using the water source after the encounter. Respondents also said that they changed how they use water sources, such as by visiting village wells after sunrise and before sunset, walking to water sources in groups, washing clothes at home rather than at the well, men collecting water instead of women from water sources that are far away, and reducing the number of visits to wells. Studies from Botswana and Kenya have reported how direct and indirect encounters with elephants caused people to abandon activities such as collecting water for cooking and prevented access to rivers for fishing, or caused people to guard their artificial livestock watering points against elephants (Kagwa, 2011; Mayberry *et al*., 2023). Interestingly, while in Kenya elephants are reported to kill livestock around water sources (Thouless, 1994), in our study area, no one reported livestock being killed by elephants. One respondent mentioned that an elephant had injured, but not killed, a sheep at a water source.

Overall, a majority of respondents (59.1%) said they were unable to share the same water sources as with elephants. Interestingly, respondents with direct experience of a problem as a result of sharing water sources with elephants were significantly more likely to say they were able to use the same water sources with elephants than respondents with no direct experience. Respondents who said

that they were able to share water sources with elephants explained that they were used to sharing water sources with elephants and that they had no alternative source of water. Respondents who stated that they were unable to use the same water sources with elephants said this was because elephants are dangerous, that elephants damaged wells and contaminate water with their urine and dung, and that elephants usually prevent people from getting water when they need it. Notably, there was no difference between Rungwa and Doroto villages in the percentage of respondents who said they are able to use the same water sources with elephants, though there were no elephant visits reported in Rungwa during the study period (Laizer *et al.,* unpublished).

2.5 Conclusions and Recommendations

Our findings suggest that even in areas where elephant use of village water sources is relatively infrequent (Laizer et al., unpublished), the majority of people felt that they were unable to use the same water sources with elephants. Notably, women were found to be more likely than men to have encountered such problems directly. The reluctance of a majority of respondents to share water sources with elephants highlights the urgent need for intervention to address the main concerns such as damage to shallow wells, contamination of water sources by elephant urine and dung, as well as not being able to get water on time and fear of meeting elephants at village wells. Respondents recommended that government authorities together with relevant stakeholders invest in alternative water infrastructure for the villages in the study area, such as public water taps and boreholes to ensure safe supplies of water for domestic use. It should be noted that our sample of questionnaire respondents were households that are found near water sources known to be used by elephants, therefore their knowledge, experience and perception may not be representative of the wider village community. In addition, some households did not agree to participate in the survey as they thought they may be subjected to law enforcement. We recommend that future studies also engage

households found further away from water sources to ensure a more comprehensive and understanding of community perspectives and needs regarding human elephant interactions and water sources management.

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CHAPTER THREE

Manuscript Two

3.0 Pattern of Elephants Use of Communal Water Sources in Villages Adjacent to Rungwa-Kizigo-Muhesi Game Reserve in Tanzania[2]

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Abstract
Shared water sources by people and elephants is a social-economic issue of concern among communities living adjacent protected areas in Tanzania. This study aimed to investigate patterns of elephant water source use based on views of key informants and camera trapping in Rungwa and Doroto villages. The data was collected via camera trapping (n=1369) camera-trap days between November 2021 and May 2022, as well as through key informant interviews (n=25). Camera traps detected 24 elephant visits at water sources, all of which occurred at night. Female-led cow-calf groups were present in 58.3% of visits and male elephants were present in 75.0% of visits. Village leaders stated that the main types of problems reported to them by village residents are that elephants cause water scarcity, pollute water in wells through their dung and urine and that villagers fear being harmed by elephants. They also reported several incidents of elephants getting trapped in and dying in wells. The most common recommendation from village leaders was that, to better manage the sharing of water between village residents and elephants, the Central Government in collaboration with relevant stakeholders should provide boreholes and communal tap water for village residents. Other suggestions included building a reservoir inside the Game reserve and increasing support from rangers to prevent elephants from entering the villages. While these suggestions provide a starting point for understanding possible mitigation options acceptable by communities, before any actions are taken, it is essential that future work should thoroughly assess each option with regard to its feasibility, sustainability, advantages and disadvantages.

Keywords: Human-elephant interactions, water sources, camera trapping, village leaders, Tanzania

3.1 Introduction

Growth in human populations with the associated socio-economic activities has led to changes in the ranges, resource access, and

movement patterns of elephants. For example, in the search for water resources in human-dominated areas, previous researchers have found that elephants use water more at night or at other times of less human activity, or in larger groups (Kangwana, 2013; Buchholtz *et al.,* 2019). Contrary, within protected areas, elephants typically visit water sources during the day or at dusk (Guy, 1976; Legget, 2009). This suggests that elephants try to reduce the chances of meeting people in their attempt to access water sources in human-dominated landscapes.

Due to their water-dependence nature, more often elephants use community water sources outside of protected areas, resulting in hostile interactions with farmers who need access to water and fertile land for their domestic and agricultural activities (Hariohay *et al.,* 2020). It is thus important to comprehend the dynamics of human-elephant interaction on water resources, looking into how people and elephants are impacted respectively, as well as options for managing the shared resources for the benefit and coexistence of the two. In a related study Laizer et al., (unpublished), used questionnaires to explore community experiences and perceptions of the shared resources in two villages adjacent to Rungwa-Kizigo-Muhesi Game reserves. It was found that a significant percentage of community members are willing to share water sources with elephants. However, coexistence with elephants comes with opportunity costs as well as indirect costs. People feel insecure while going about their regular lives, and the time needed for guarding reduces the amount of time available for tasks like going to school, getting water, and firewood, and visiting stores (Hariohay *et al*., 2020; Mayberry *et al*., 2023). In Zimbabwe's National Parks, villagers and conservationists worry that competition for water resources would result in fatalities of locals and elephants; whereby at least 20 people have already died this year in encounters with elephants (Marima., 2022). Elephants can also seriously damaged water infrastructure, and they can even kill animals. For example, in Zimbabwe's Zambezi Valley, cattle were killed at night close to the

water source (Parker *et al.,* 2007). Here, we present camera trap data on temporal patterns of elephant use of village water sources, and views of key people residing in the area in an attempt to build up a comprehensive source of information to help in addressing key issues emanating from the sharing of water resources between elephants and humans.

3.2 Materials and Methods

3.2.1 Description of the study area

The study was conducted in two villages, namely Rungwa and Doroto, adjacent to Rungwa-Kizigo-Muhesi Game reserves (>17,000 km^2) in Itigi District in central Tanzania (Figure 3.1). The villages were selected based on the fact that they are in close proximity to Rungwa-Kizigo-Muhesi Game reserves and they have a large number of elephants visit per year (Smit *et al*., 2016). The District falls within the Central Zambezian Miombo Woodlands Eco Region (Olson *et al.,* 2001). The area experiences one dry season from May to November, and a wet season from January to April (Bjornstad, 1996). The average annual temperature is 28°C and rainfall ranges from 500 to 700 mm (Hariohay *et al.,* 2019). Rungwa, Kizigo, and Muhesi Game reserves fall within the wider Ruaha-Rungwa game reserve, which was home to an estimated 19,884 elephants in 2022 (TAWIRI, 2022). In 2022, the human population was reported by village leaders to be 14 849 people in Doroto village and 9,666 people in Rungwa village (NBS, 2022). The dominant ethnic groups are Sukuma and Nyaturu. Both Doroto and Rungwa had three sub-villages respectively during the time of study. Farming and livestock-keeping are the major economic activities (NBS, 2016). Village residents rely primarily on shallow wells, and secondarily on dams and boreholes for their water supply. Access to piped water via communal water taps is very limited (NBS, 2016).

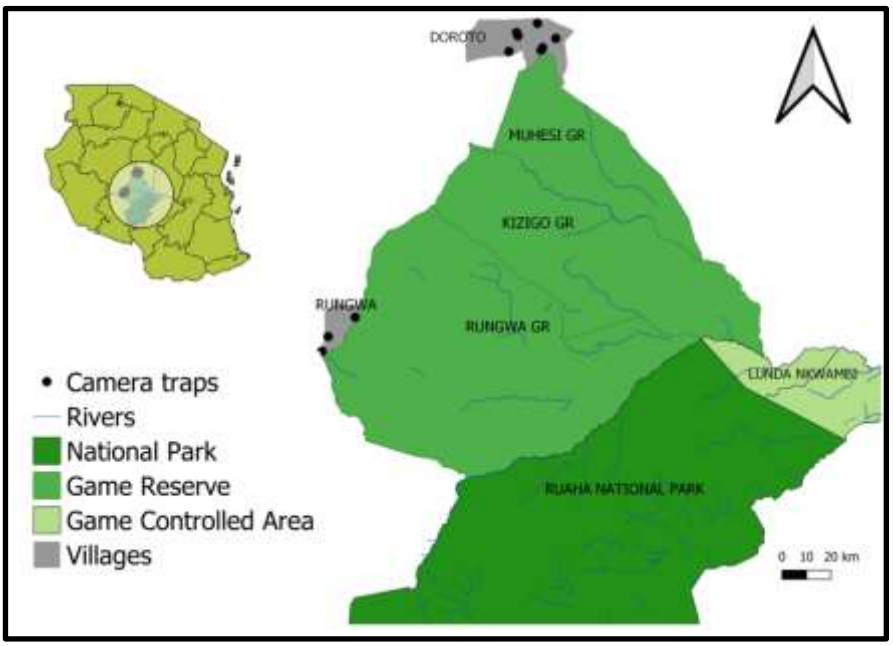

Figure 3.1: A map showing the study area location in Tanzania (top left) and the locations of camera traps at water sources in Doroto and Rungwa villages adjacent to Rungwa and Muhesi Game reserves (Right).

3.2.2 Data collection

3.2.2:1 Key informant interviews

We collected data on elephant use of water sources on village land and village leaders' perceptions of sharing water sources with elephants via key informant interviews. A total of 25 face-to-face interviews were conducted with key informants in Rungwa (n=12) and Doroto (n=13) villages. Interviews were only conducted if respondents provided their prior informed consent. We interviewed two village chairpersons, eight sub-village chairpersons, nine village elders, and six local elephant monitors who were working with the NGO Southern Tanzania Elephant Program from November to December 2021. These interviews were used to gather information on village leaders' views on elephants and people sharing the same

water sources, including identifying problems arising from this sharing of water sources and the views of village leaders on possible mitigation measures.

3.2.2.2 Camera trap data

Camera traps were used to gather data on elephant group composition and visitation patterns to water sources on village land. Camera traps were deployed at water sources that were known to be used by elephants, as indicated by local knowledge and/or the presence of elephant dung and tracks. Camera traps were only placed at a water source if consent was obtained from nearby residents. A total of 15 camera traps (a combination of Browning Dark Ops and Cuddeback Pro Color 1347 cameras) were deployed from November 2021 to May 2022 (n=1,369 camera-trap sampling days). Camera traps were set at five water sources in Rungwa village and ten water sources in Doroto village. Camera traps were set to take three photos per trigger with a five-second delay between triggers. Over the course of the study, five camera traps were lost to theft. Camera traps were checked every four weeks to replace batteries, download images, and ensure correct camera placement. Camera trap images were used to estimate the number of cow-calf groups and bulls using water sources, and their group composition, and to analyze temporal patterns of elephant visits to water sources on village land.

The study received approval from the Tanzania Wildlife Research Institute, the Tanzania Commission for Science and Technology and from Sokoine University of Agriculture.

3.2.3 Data analysis

3.2.3.1 Key informant interviews

Data from key informant interviews were analyzed in the Statistical Package for Social Sciences (SPSS, version 16.0). Qualitative data from open-ended questions were analyzed using content analysis.

The descriptive statistics results were generated from questionnaire data in SPSS software (Kiondo *et al*., 2019).

3.2.3.2 Camera trap data

We classified camera trap images using ExifPro 2.1 software (Smit *et al*., 2022). Images of elephants were grouped into independent detection events, which were defined as images of elephants that were separated by more than 15 minutes (Gaynor *et al*., 2018; Smit *et al.*, 2022). Camera trap images were visually inspected to assess group type, group size, and direction of movement (towards the water source or away from the water source). Group types were coded as cow-calf group, lone bull, bull group, mixed group or unknown following the definitions in (Smit *et al*., 2022) and group size was coded as 1, 2-4, 5-9, 10-14, 15-19, >20 individuals. Group type and group size were classified independently from camera trap images by two observers. If there was disagreement between observers, we reviewed camera trap images again until an agreement was reached. The *overlap* package Ridout & Linkie, (2009) in R software (version 4.1.2) was used to generate smoothed non-parametric kernel density distributions showing the timing of elephant visits to water sources over a 24-hour period. We also calculated the coefficient of overlapping (the total percentage of area that is shared by two activity distributions) between the activity curves for elephant movement towards and away from water sources. Data on elephant events were used to analyze elephant group types and sizes at village water sources. We also identified individual elephants using features of their ears and tusks (Bedetti *et al*., 2020) to estimate how many unique cow-calf groups and bulls visited water sources during the sampling period. Individual identification of elephants was verified by a second observer.

3.3 Results

3.3.1 Key informant views on elephant use of village water sources

Most key informants (76%) stated that people and elephants using the same water sources was a big problem, 8% said that it was a minor problem, while 16% said it was not a problem at all. Furthermore, 24% of key informants reported that sharing water sources with elephants is a serious issue and doing so is putting their lives in danger and it is not healthy for both people and elephants.

Village leaders reported that currently, the most popular techniques for enabling village residents to access the same village water sources that are also frequented by elephants are collecting water after sunrise or before dusk, walking in groups, and using a torch if walking in the dark. Key informants also suggested several options for lessening issues brought on by the sharing of water sources between elephants and people (Figure 3.2). Most of the key informants (56%) suggested drilling of boreholes and 24% suggested provision of communal tap water in the village. Key informants in the surveyed villages indicated that these approaches could help reduce people's reliance on shallow wells (which may still be used by elephants) and therefore may reduce the risk of people and elephants meeting each other at water sources. Some of the key informants (24%) suggested that a beehive fence along the border between the Game Reserve and villages could prevent elephants from moving from the Reserves towards the village wells.

In addition, 20% of the key informants thought that increasing ranger presence and efforts to scare elephants out of village land might be used as a mitigation mechanism to keep elephants from damaging village wells and raiding crops. About 56% of the key informants suggested excavating dams in the Game Reserves as a potential method, as they thought that by providing an alternate water source

inside the Reserves, elephants might be less likely to use the village wells and springs.

Finally, the education of village leaders was suggested by 20% of the key informants as a strategy for encouraging people to share the same water sources with elephants. They suggested increasing leaders' protection awareness, educating them about conservation issues and actively encouraging them to get involved, such as by joining the ecological patrol team at the village-level.

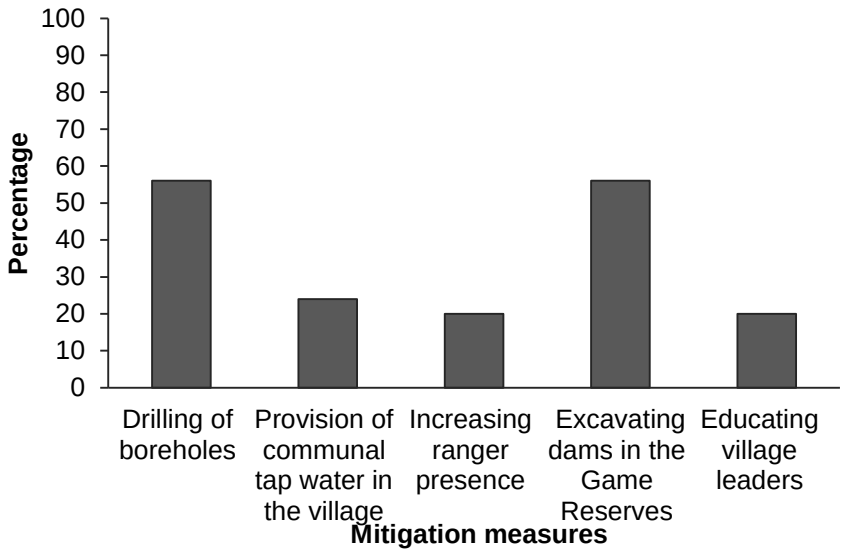

Figure 3.2: Percentage of key informants who mentioned each of the mitigation measures

3.3.2 Patterns of elephants use of communal water sources

Camera traps captured 24 elephant events, all of which occurred in Doroto village. Elephant visits were detected by camera traps at four village water sources (three shallow wells and one stream). Most elephant visits to water sources were detected during April and May (camera traps were active between November 2021 and May 2022). Most elephant detections occurred at shallow wells (92% of events).

Elephant events occurred between 19:00 and 03:00, with a peak between 22:00 and 23:00 (Figure 3.3). There was a high degree of overlap (coefficient of overlap of 0.85, 95% CI 0.52-1.0) between the activity curves of elephants moving towards and away from water sources.

The results shown in Figure 3.3 indicate (a) activity profile of all elephant events at water sources (n=24 events) and b) elephant activity curves by direction of movement, either towards (In, n=6 events) or away from water sources (Out, n=13 events). The density of elephant events over a 24-h period is represented by the solid and dotted lines. Each black line in the rug at the bottom of Figure 3.3a indicates the time at which an elephant event occurred and the shaded area in Figure 3.3b is the area that is shared between the two activity curves and is equal to the coefficient of overlapping.

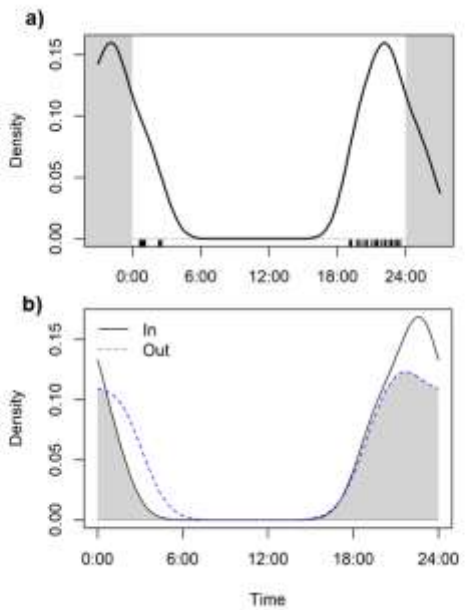

Figure 3.3: Activity profile of all elephants events at water sources and elephant activity curves by direction of movement.

3.3.3 Elephant group types and size

Most elephant events at water sources involved mixed groups (a cow-calf group with one or more bulls, 37.5% of events), followed by lone bulls (20.8%), cow-calf groups (20.8%), and bull groups (16.7%) (Figure 3.4). Most mixed group events had a group size of 5-9 (44.4% of mixed group events) or 10-14 (33.3%) individuals, while the two bull groups detected comprised between 2-4 individuals and the cow-calf groups detected comprised either 2-4 (60.0%) or 5-9 (40.0%) individuals. We identified a minimum of three different cow-calf groups and 11 different bulls from camera trap photos. Repeat use of water sources was observed for one cow-calf group on three occasions and two bulls on two occasions.

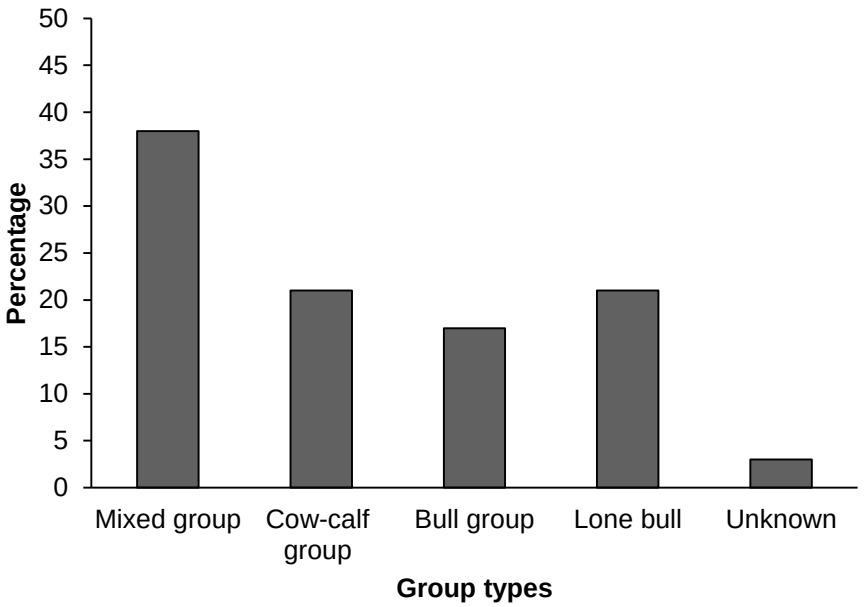

Figure 3.4: Percentage of camera trap events by group type (n=9 mixed group events, 5 cow-calf group events, 5 lone bull events, 4 bull group events, and 1 unknown group type event).

3.4 Discussion

While many studies on human-elephant interactions have mainly focused on crop damage (Kaswamila, 2009; Munuo, 2016), relatively few researchers have looked at the interactions arising from the sharing of water sources between people and elephants. Previous researchers have argued that maintaining coexistence between people and elephants is difficult since different people have different ideas or interests and because elephants are perceived as dangerous and destructive animals (Mayberry et al., 2023; Dublin & Hoare, 2004). Thus, the findings of this study can help to better understand interactions between people and elephants around water sources in an attempt to plan mitigation measures.

Under the current study, key informants from Rungwa and Doroto villages suggested that reservoirs or artificial water holes could be built inside the Game reserves, which could perhaps provide a supply of water to the elephants, thus deterring them from visiting village water sources. However, in South Africa, the establishment of artificial waterholes inside protected areas caused a variety of ecological problems that led to a decline in wildlife population and habitat degradation (Pienaar, 1983; Beale, 2013) further complicating the issue.

On the other hand, the findings from the camera trap study provide valuable insight into the patterns of elephant behavior and group dynamics around communal water sources in Doroto village. The fact that all 24 elephant events were recorded within Doroto village highlight the significance of this location as a key area for the elephant activity. Camera trap data collected in the current study indicated that elephants visited village water sources at night, corresponding with other studies such as that by Bucholtz *et al.,* (2021). It was also noted that there was a high degree of overlap in the types of water sources used by people and elephants, as both relied primarily on shallow wells and small dams. Female-led cow-calf groups were present in 58.3% of elephant visits to water

sources captured by camera traps, and males were present in 75% of visits. As females are thought to be more risk-averse than males (Sukumar & Gadgil, 1988), it is usually more common for male elephants to use human-dominated areas and enter farmlands to forage on crops (Graham *et al*., 2009; Butler, 2019). However, in the context of access to water, it appears that both females and males use risky water sources outside of formal protected areas (Buchholtz *et al*., 2021). Although we are unable to say how widespread the use of village water sources is among the local elephant population, we identified eleven bull groups and three cow-calf groups from just 24 events. The varying group size observed, along with the identification of cow-calf groups and individual bulls, suggest a diverse and potentially stable elephant population utilizing water sources in Doroto village. Camera trap photos showed that elephants used these village water sources not only for drinking but also for wallowing, bathing, and social interactions (e.g., sparring by males). This is a health risk to people using the water sources as there is a high chance of disease transmission. Humans can contract diseases like cholera and typhoid, from contaminated water when they utilize it for drinking and other domestic activities (State, 2013).

In conclusion, the study found that the main concerns of residents in the study area regarding sharing water sources with elephants were; elephants causing water scarcity and polluted water, fear of being harmed by elephants, and elephants getting trapped in wells. Although there was a formal plan to provide water for domestic use in both villages as well as to distribute water from villages to their sub-villages, no progress had been made at the time of the study. The key informants recommended several options to manage the sharing of water resources between villagers and elephants, including for the Central Government in collaboration with relevant stakeholders to provide boreholes, and communal tap water, increasing support from rangers, and educating the community on available mitigation methods. While these suggestions may serve as

a useful starting point, it is crucial that the feasibility, sustainability, advantages/disadvantages, and potential consequences of each option are assessed further, including through consultation with more members of the community before any actions are taken.

This study had several limitations; since all the respondents from this study were the key informants, the sample size should be increased in future research to enhance the generalization of the issues. We recommend that future studies should include a focus group discussion method to bring together the community that shares the same experience and to hear a wider diversity of perspectives on mitigation methods. Furthermore, it was not possible to deploy camera traps at every water source in the villages of Doroto and Rungwa due to equipment and labor constraints. We also lost five cameras due to theft and this affected our sampling effort. Future research should aim at sampling a whole year around to better understand seasonal patterns in elephant visits to water sources and to determine whether the types of problems experienced vary seasonally.

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CHAPTER FOUR

4.0 General Discussion

This study assessed elephant use of water sources on village land as well as community experiences and perceptions of sharing water sources with elephants in village land adjacent to Rungwa-Kizigo-Muhesi Game Reserve. The study found that shallow wells dug by hand play a crucial role in meeting the water needs of villagers. Additionally, the study found that the presence of elephants at water sources is significant with 92% of the elephant camera trap detections occurrence at the shallow wells. All 24 elephant visits captured by the camera traps took place during the night, suggesting a distinct behavioral pattern of elephants in accessing water sources. Elephants' behavior is influenced by humans, and we anticipated that the distributions of elephants would vary in connection to human development and land usage (Buchholtz *et al., 2019)*.

The camera trap data also indicated the group composition of elephant visits to water sources with female-led cow-calf being observed in 58.3% of the visits, indicating the importance of these water sources for their survival and the well-being of the young elephants. Male elephants were present in 75.0% of the visits, suggesting that water sources are critical for their needs as well. Elephants are water-dependent animals, as indicated by their movement patterns in relation to surface water (Dunkin, 2013). The identification of multiple cow-calf groups and distinct bulls emphasizes the significance of these water sources as a communal gathering point for elephants to conduct activities like mud bathing, swimming, and wallowing, as well as drinking.

Furthermore, the study found that a significant proportion of respondents had witnessed elephants at their primary water source, and a substantial number of them (85.0%) reported direct problems associated with sharing water sources with elephants. Interestingly,

women were more likely than men to have direct experiences of such problems. This difference might be attributed to different gender roles (Dillip, 2018) and responsibilities within the villages around Rungwa-Kizigo-Muhesi Game reserves.

In regards to addressing the problems posed by elephants, household members reported various adjustments to their water source access patterns. The majority of respondents reported accessing water sources in the morning or afternoon, while some even changed their primary water sources and visiting times as strategies to avoid encountering elephants. These adjustments reflect the adaptive measures taken by villagers to ensure their water needs are met while minimizing encounters with elephants. The study also found that some villagers were unwilling to share water sources with elephants. The majority of respondents (59.9%) expressed concerns regarding sharing the same water sources with elephants including; elephants damaging shallow wells, the potential for delays in accessing water due to elephant presence, fear of encountering elephants at water sources, and water contamination. Similarly, elephants have been reported to threaten villagers to access food and water in Khumanga, Botswana (Kagwa, 2011; Mayberry *et al.,* 2023). Additionally, reports of elephants being trapped in wells and dying further reinforced the concerns voiced by village leaders and community members.

Based on interview results the current study highlights some possible mitigation measures for better management of people and elephants on shared water sources. Potential strategies could include implementing protective measures such as developing alternative water sources for villagers such as boreholes and communal water taps, increasing support from Game reserve rangers when elephants are on village land and raising awareness about elephant behavior and conservation among local communities. One of the efforts aiming at reducing the movement of elephants outside protected areas in Kruger National Park, South

Africa is through the provisioning of artificial water sources, especially in water-scarce areas, though this has effects of increasing local elephant densities with knock-on negative effects on vegetation and other wildlife species (Purdon *et al*., 2017; Ndlovu *et al.*, 2018). Another alternative is to build water infrastructure for people away from areas used by elephants, as this could potentially reduce the spatial overlap of elephants and people (Jackson *et al*., 2008).

Generally, the use of water sources on village land adjacent to the Rungwa-Kizigo-Muhesi Game Reserve presents a complex and delicate interplay between human communities and elephants. As communities rely on these shared water sources for their livelihoods, coexistence with elephants becomes both a challenge and an opportunity. Thus, finding a balance that addresses the needs of both elephants and humans while ensuring the preservation of vital water resources remains a critical task for researchers, communities, and conservation stakeholders.

4.1 General Conclusions

This study investigated elephant use of water sources on village land as well as community experiences and perceptions of sharing the same water source with elephants on village land adjacent to Rungwa-Kizigo-Muhesi Game Reserve. The specific objectives of this study were to identify the main types of water sources that are shared by people and elephants on village land, to investigate temporal patterns in elephant use of water sources on village land via local community knowledge, to investigate the number and group composition of elephants using village water sources, and to understand community experiences and perceptions around sharing water sources with elephants. The study came out with useful key findings regarding the interaction between villagers and elephants in relation to water sources. Shallow wells dug by hand served as the primary water source for the majority of the villagers, and these wells were found to be heavily utilized by elephants accounting for 92% of

elephant camera trap detection. Over the study period between November 2021 and May 2022, camera traps detected 24 elephant visits at water sources, all of which occurred at night. Female-led cow-calf groups were present in 58.3% of visits (as cow-calf groups or in mixed groups) and male elephants were present in 75.0% of visits (either occurring alone, in bull groups, or mixed groups). This information provides insights into the number and group composition of elephants in relation to water sources.

On the other hand, it was further revealed that the majority of respondents had seen elephants at their primary water source. The majority of respondents reported using water sources in the morning or late in the day and 85.0% of respondents stated they had directly experienced a problem when using a water source that was also used by elephants. With regard to problems associated with water source sharing, women were more likely than men to be affected. Furthermore, the research found that household members had changed their water source preferences and the timing of their visits in an attempt to avoid encounters with elephants. Additionally, a significant majority of respondents (59.9%) expressed their unwillingness to share water sources with elephants due to various concerns, including damage to wells, fear of encounters, water contamination, and instances of elephants getting trapped and dying in wells.

Excitingly, the result shows that camera trap data, household questionnaires and key informants data provided similar results in most cases, regarding the main types of water sources shared between people and elephants, and temporal patterns in elephant use of village water sources.

4.2 Recommendations

Households and village leaders suggested that government authorities and relevant stakeholders invest in alternative water infrastructure for the villages in the study area, such as public water

taps and boreholes, or improving access to existing sources may help alleviate conflicts between villagers and elephants to ensure safe supplies of water for domestic use. Also, community awareness programs should be increased to educate villagers about elephant behavior, safety measures, and the importance of coexistence, these programs should target both adults and children to foster a deeper understanding of elephant movements and reduce fear. Special attention should be given to addressing the concerns of women, who appear to be more directly affected by the presence of elephants by considering their specific needs and perspectives in conflict resolution and infrastructure development. Initiatives that enhance their safety and empowering them with knowledge and resources to deal with elephant encounters can have a significant positive impact. This study suggests that year-round research be conducted to better understand seasonal trends in elephant trips to water sources and to ascertain whether households living further away from water sources are likewise affected by problems that fluctuate annually. By addressing the concerns and needs of both villagers and elephants, it is possible to find practical solutions that promote peaceful coexistence and ensure sustainable water resource management in the study area.

Finally, the study suggests that addressing the concerns and needs of both villagers and elephants is essential for achieving peaceful coexistence and ensuring sustainable water resource management in the study area. By investing in alternative water infrastructure, improving access to existing sources, conducting community awareness programs, paying special attention to women's concerns, and conducting ongoing research, it is possible to develop practical solutions that benefit both the human and elephant populations. Ultimately, these efforts contribute to a harmonious coexistence between communities and elephants while safeguarding vital water resources.

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APPENDICES

Appendix 1: Household Survey Questionnaire

SOKOINE UNIVERSITY OF AGRICULTURE

COLLEGE OF FORESTRY, WILDLIFE AND TOURISM
DEPARTMENT OF WILDLIFE MANAGEMENT

Dear participant,
My name is Irene James Laizer a student from Sokoine University of Agriculture. I am conducting a study on the **Effects of human-elephant interactions at water-sharing points in villages adjacent to Rungwa-Kizigo-Muhesi Game Reserve, Tanzania.** Participation in this research is purely voluntary. Your answers will not be disclosed to anyone. They will be combined with those of other respondents to guide me in the evaluation process.

Questionnaire for households living near water sources visited by elephants (Rungwa and Doroto)

Section A: Personal information
Respondent number _____ Date _____
Name _____
Village Name _____ Subvillage Name _____
Coordination: Latitude _____ Longitude _____

1. Gender:
Male ( ) Female ( )

2. How old are you?
Age:_____

3. Name of the tribe?
_____

4. Were you lucky enough to study formal education (in the classroom?)
□ Yes
□ No

5. To what extent did you succeed in getting an education?
□ I did not finish primary education
□ I finished elementary school
□ I did not finish high school
□ I finished high school
□ Vocational training
□ University degree

6. How many people in your household eat together at least five times a week?
(1) 1 - 2 (….) (2) 3 - 5 (….)
(3) 6 - 8 (….) (4) 9 and above (….)

7a. Were you born in this village?
□ Yes
□ No

7b. If not, why did you decide to move here?
_____
_____

8. How much time do you have in this area?

_____

9. What activities do you do each day to cover the daily needs of the family?

Select all the activities he mentions:

□ Cultivation of various crops
□ Livestock grazing
□ Business
□ Civil Servant
□ Retired
□ Burning charcoal
□ Other

_____

10. Are you engaged in animal husbandry?

□ Yes
□ No

Part B: The nature and type of water sources used by elephants and villagers on village land.

1. For what purpose do you use water?

□ Home use (cooking, washing, drinking, hygiene)
□ Livestock use (drinking and treatment)
□ Use of garden / agricultural irrigation
□ Other uses (Specify):

2a.What type of water source do you take for home use?

(Select all that apply)

□ Natural springs _____
□ Rivers _____
□ □ Dams _____
□ □ Tap water _____

□ □ Shallow wells (drilling) _____
□ Other sources (Specify) _____
2b. For livestock use, what kind of water source do you get?
(Select all that apply):
□ Natural springs _____
□ Rivers _____
□ □ Dams _____
□ □ Tap water _____
□ □ Shallow wells (drilling) _____
Deep wells _____
□ Other sources (Specify) _____

2c. What kind of water source do you take for agriculture / irrigation?
(Select all that apply):
□ Natural springs _____
□ Rivers. _____
□ □ Dams _____
□ □ Tap water _____
□ □ Shallow wells (drilling) _____
□ Deep wells _____
Other Sources (Specify) _____

2a. What is the source of the water that you use most for home / livestock use?

_____
_____

2b. What kind of water source do you use ?
□ Natural springs
□ □ Rivers
□ □ Dams
□ Tap water
□ □ Shallow wells (drilling)
□ Deep wells

□ Other sources (Specify) _____

2c) Is the water source you use the most the closest (show nearby)?
□ Yes
□ No

3. For the water source you use the most how often do you spend most of your time arriving, fetching water for domestic / livestock use, and returning home?

_____
_____

4. For the water source you use the most what time do you go per day?
□ Morning
□ Daytime
□ Evening
□ Night
□ All day long
I do not know
□ Another time

_____
_____

5. For the water source you use the most who in the household draws the water for home use / which water the animals most often?
□ Adult woman (over 15 years)
□ Adult male (over 15 years)
□ Child / girls (under 15)
□ Child / boys (under 15)
□ I do not know

6. For the water source you use the most, have you ever heard of elephants using / visiting?
□ Yes

□ No
□ I do not know
7. For the water source you use the most have you ever witnessed with your eyes that elephants use / visit?
□ Yes
□ No
□ I do not know

Section C: When and where are the water sources visited by elephants on village land.

Ask only 8 to 12 questions if the answer to question 6 or 7 is yes.
8. For the water source you use the most is water use for elephants seasonal or year-round?
□ Seasonal
□ All year
□ I do not know

9a. For the water source you use the most what season do elephants visit the most?
□ □ Dry season (months) _____
□ wet season (months) _____
All year _____
□ □ I do not know

9b. For the water source you use the most what season do elephants rarely visit?
□ □ Dry season (months) _____
□ □ wet season (months) _____
□ All year _____
□ I do not know

10a. For which water source do you use the most at what time of day do elephants spend most of their time in the dry season?
□ Morning

□ Daytime
□ Evening
□ Night
□ All day long
□ I do not know

10b. For the water source you use the most what time of day do elephants spend most of the □ wet season?
□ Morning
□ Daytime
□ Evening
□ Night
□ All day long
□ I do not know

11. For the water source you use the most how often do elephants visit?
For this year (2021): _____
For the last year (2020): _____
For the year (2019): _____
I do not know

12. From the water sources you use the most do you think the events of elephants visiting this source from 2019 until now?
□ Decreased
□ Increased
□ It is OK
□ I do not know

Ask only 13 to 21 questions if the answer to questions 6 and 7 is no.

13. Unlike your most common water source have you ever heard of elephants using / visiting a water source in a village?
□ Yes
□ No
□ I do not know

14. Unlike the water source you use the most have you ever witnessed that elephants use / visit a water source in the village?
□ Yes
□ No
□ I do not know

15a. What is the source of the water that you have ever heard / witnessed that an elephant has visited?

_____
_____

15b. What kind of water source have you ever heard / witnessed being visited by elephants?
□ Natural springs
□ Rivers
□ □ Dams
□ Tap water
□ □ Shallow wells (drilling)
□ Deep wells
□ Other sources (Specify) _____

16a. Do you use this water source ?
□ Yes
□ No

(ask 16b if the answer is yes to 16a)
16b. What do you use this water source for?
□ Home use (cooking, washing, drinking, hygiene)
□ Livestock use (drinking and treatment)
□ Use of garden / agricultural irrigation
□ Other uses (Specify):

_____
_____

17. In a water source that you have ever heard of or witnessed an elephant visit , is the water use for elephants seasonal or year-round?
□ Seasonal
□ All year
□ I do not know

18a. In a water source that you have ever heard / witnessed being visited by elephants, what season do elephants visit the most?
□ □ Dry season (months) …….
□ □ wet season (months) .....
□ All year …….
□ I do not know

18b. In a water source that you have ever heard / witnessed being visited by elephants , what season do elephants visit the least?
□ □ Dry season (months) …….
□ □ wet season (months) .....
□ All year …….
□ I do not know

19a. In a water source that you have ever heard / witnessed being visited by elephants , what time of day do elephants spend most of their time in the dry season?
□ Morning
□ Daytime
□ Evening
□ Night
□ All day long
□ I do not know

19b. In a water source that you have ever heard / witnessed being visited by elephants , what time of day do elephants spend most of their time in the wet season?
 Morning
 Daytime
 Evening
 Night
 All day long
 I do not know

20. In a water source that you have ever heard / witnessed being visited by elephants , how often do elephants visit?
For this year (2021):
……
For the last year (2020):
……
For the year (2019):
……
I do not know

21. In a water source that you have ever heard / witnessed being visited by an elephant , do you think the elephant events to visit this source from 2019 until now?
 Decreased
 Increased
 It is OK
 I do not know

Section D: Understanding community perceptions about shared use of elephants, and the impact of people and elephants on using equitable water sources in villages

22. Why do you think elephants use water sources in the village?

_____

_____

And choose the following reasons if he mentions them:
□ Water sources in the village are located near the reserve
□ A field near or along an elephant corridor / path
□ A field near the reserve
□ A field near water sources
□ Housing near the reserve
□ Lack of water in the reserve

23. How do you feel about using water sources like elephants? Please explain.

_____
_____

24a. In your opinion, people using water sources like elephants is a big problem, a small problem or not a problem?
□ A big problem
□ A little problem
□ Not a problem
□ I do not know

24b. Why?

_____
_____

25. Have you ever had trouble sharing water sources with elephants?

Also, select the following problems if he mentions them:
□ People were attacked and killed
□ People were attacked and injured
□ Water infrastructure is damaged
□ Livestock were attacked by elephants
□ Not being able to use water on time
□ Fear
□ I don't know

Ask questions 26 to 29 if she has answered that she has ever had a problem (question 25)

_____

_____

26. How often has this problem occurred? (see problem question above)

_____

_____

27a) Has this problem caused you to stop using the water source when the problem arises?

□ Yes

□ No

Ask 27b if the answer is yes to 27a

27b) Have you stopped using that water source or have you used it again after a problem arose?

□ Yes

□ No

27c) Has this problem caused you to change the water source you use the most?

□ Yes

□ No

28. Has this problem caused you to change what time of day you are going to the water sources?

_____

_____

29. Has this problem caused you to change the way you visit water sources?

_____

_____

Ask questions 30 to 33 if you have never had a problem (question 25)

30. Have you ever heard of someone getting into trouble for sharing water sources with an elephant?

31a). Did hearing this problem make you stop using the water source you heard the problem was about?

□ Yes

□ No Ask 31b if the answer is yes to 31a

31b) Have you stopped using that water source or have you used it again after hearing a problem occur?

□ Yes

□ No

31c) Has hearing this problem caused you to change the water source you use the most?

□ Yes

□ No

32. Has hearing this problem caused you to change the time of day to visit water sources?

33. Has hearing of this problem made you change the way you visit water sources?

Ask questions 34 to 36 if you have never had a problem (question 25) or heard (question 30) someone who has had a problem but has

heard / witnessed elephants using water sources (question 6/7 question 13/14).

34a). Has the elephant's act of using water sources made you stop using any water source?
□ Yes
□ No

Ask 34b if the answer is yes to 34a
34b) Have you stopped using that water source or have you used it again?
□ Yes
□ No

34c) Has the elephant's act of using water sources caused you to change the water source you use the most?
□ Yes
□ No
35. Has the elephant's act of using water sources caused you to change the time of day to visit water sources?

_____
_____

36. Has the elephant's use of water sources caused you to change the way you visit water sources?

_____
_____

Ask everyone
37a. Do you agree or disagree with the following statement: "I can use water sources like elephants"?
□ I agree
□ I do not agree

37b) Why?

_____
_____

38. Do you have any suggestions on people and elephants using the same water sources?

_____
_____

Appendix 2: Checklist for Key Informants

SOKOINE UNIVERSTIY OF AGRICULTURE

COLLEGE OF FORESTRY, WILDLIFE AND TOURISM
DEPARTMENT OF WILDLIFE MANAGEMENT

Dear participant,

My name is Irene James Laizer a student from Sokoine University of Agriculture. I am conducting a study on **Human and Elephant interaction based on water resources sharing in village land adjacent to Rungwa-Kizigo-Muhesi Game reserve.**Participation in this research is purely voluntary. 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.

Checklist for key informants: village / neighborhood leaders / local elephant monitors (Rungwa and Doroto)

Section A: Personal information

Respondent number …… .. Date …… ... …… ..

Name …… .. ……. Village Name …… ..

Subvillage Name …… ..

Coordination: Latitude …… .. Longitude ……

1. What types of water sources are most commonly used by residents of this neighborhood / village for home use?

□ Natural springs ……

□ Rivers. ……

□ Dams ……

□ Tap Water ……
□ Shallow wells (drilling) ……..
□ Deep wells…….
Other sources (Specify) _____

2. What types of water sources are most commonly used by residents of this neighborhood / village for livestock?
□ Natural springs ……
□ Rivers. …….
□ Dams ……
□ Tap Water ……
□ Shallow wells (drilling) …….
□ Deep wells
Other sources (Specify) _____

Questions 3 to 6 ask for leaders only (not LEMs)
3. Do residents here have barriers to access water?
□ Yes
□ No
□ I do not know

4. If yes, what are the local barriers to accessing water? Please explain.
_____
_____

5. What are the challenges that have been reported in the village / neighborhood office regarding water supply? Please explain.
_____
_____

6. Is there a formal water supply plan in the village / suburb? Please explain.
_____
_____

Questions 7 to 12 ask for LEMs only (not leaders)

7. Are there water sources used by the residents of this neighborhood / village that are also used by elephants that are not on the map (see map)?

_____

_____

8. Is the use of elephant water sources in this neighborhood / village seasonal or year-round?
□ Seasonal
□ □ All year
□ I do not know

9. What season do elephants visit the water sources of the village / neighborhood most often?
□ □Dry season (months) ……
□ Wet season (months) .....
□ All year …… ..
□ I do not know

10. In what season do elephants visit the water sources of the village / neighborhood infrequently?
□ Dry season (months) ……
□ Wet season (months) .....
□ All year …… ..
□ I do not know

11. At what time of day do elephants use water sources in the village / neighborhood in the dry season?
□ Morning

□ Daytime
□ □ Evening
□ Night
□ All day long
□ I do not know
□ Another time

12. At what time of day do elephants use water sources in the village / neighborhood in the rainy season?
□ Morning
□ Daytime
□ Evening
□ Night
□ All day long
□ I do not know
□ Another time

13. How do you think the events of elephants visiting water sources here in the village / in this neighborhood from 2019 until now?
□ Decreased
□ Increased
□ It is OK
□ I do not know

Ask everyone

14. Why do you think elephants use water sources in this village / village? Please explain.
_____
_____

15. Do you know what the locals think about sharing water sources with elephants? Please explain.
_____
_____

16. Have the locals ever had any problems with sharing a

water source between humans and elephants in the village? Please explain.?

_____
_____

17. Have elephants ever had any problems with sharing a water source between humans and elephants in the village? Please explain.

_____
_____

18. What are your views / opinions on people and elephants using the same water sources in your village / neighborhood?

_____
_____

19. In your opinion, people using water sources like elephants is a big problem, a small problem, or not a problem.

□ A big problem
□ A little problem
□ Not a problem
□ I do not know

Why?

_____
_____

20. Do you have any suggestions on people and elephants to use the same water sources in your village / neighborhood?_____
_____

Appendix 3: Camera Trap Effort Data

Station	Metimete 1	Metimete 2	Hamisi	Mwanzo	Ruhemesha	Mangola	Matilova
Village	Doroto	Doroto	Doroto	Doroto	Doroto	Doroto	Doroto
Start date	11/11/2021	11/11/2021	11/12/2021	11/11/2021	11/11/2021	11/11/2021	11/11/2021
Check 1							
Check dat e	12/3/2021	12/3/2021	12/4/2021	12/3/2021	12/3/2021	12/3/2021	12/3/2021
Camera on?	STOLEN	STOLEN	OFF	OFF	OFF	OFF	OFF
If off, last photo dat	STOLEN	STOLEN	11/15/2021	12/2/2021	11/23/2021	12/1/2021	11/24/2021
Number of Days	N/A	N/A	3	21	18	20	13
Check 2							
Check date	STOLEN	STOLEN	1/3/2022	1/3/2022	1/3/2022	1/3/2022	1/3/2022
Camera on?	STOLEN	STOLEN	STOLEN	ON	ON	OFF	OFF
If off, last photo dat	STOLEN	STOLEN	STOLEN	1/3/2022	1/3/2022	12/29/2021	12/12/2021
Number of Days	N/A	N/A	N/A	31	31	23	9
Check 3							
Check date	STOLEN	STOLEN	STOLEN	1/30/2022	1/30/2022	1/30/2022	1/30/2022
Camera on?	STOLEN	STOLEN	STOLEN	ON	ON	ON	OFF
If off, last photo dat	STOLEN	STOLEN	STOLEN	1/30/2022	1/30/2022	1/30/2022	1/12/2022
Number of Days	N/A	N/A	N/A	27	27	27	9
Check 4							
Check date	STOLEN	STOLEN	STOLEN	3/3/2022	3/3/2022	3/3/2022	3/4/2022
Camera on?	STOLEN	STOLEN	STOLEN	ON	ON	ON	OFF
If off, last photo dat	STOLEN	STOLEN	STOLEN	3/3/2022	3/3/2022	3/3/2022	2/9/2022
Number of Days	N/A	N/A	N/A	32	32	32	10
Check 5							
Check date	STOLEN	STOLEN	STOLEN	4/4/2022	4/4/2022	4/4/2022	4/4/2022
Camera on?	STOLEN	STOLEN	STOLEN	ON	ON	ON	ON
If off, last photo dat	STOLEN	STOLEN	STOLEN	4/4/2022	4/4/2022	4/4/2022	4/4/2022
Number of Days	N/A	N/A	N/A	32	32	32	31
Check 6							
Check date	STOLEN	STOLEN	STOLEN	5/6/2022	5/6/2022	5/7/2022	5/7/2022
Camera on?	STOLEN	STOLEN	STOLEN	ON	ON	OFF	ON
If off, last photo dat	STOLEN	STOLEN	STOLEN	5/6/2022	5/6/2022	4/23/2022	5/7/2022
Number of Days	N/A	N/A	N/A	34	34	16	33
Total days	0	0	3	177	174	160	166

	Manzanilla	Darajani	Malkoi 2	Malkoi 1	Mwembeni	Athumani	Mwemboni	Nyerere
	Rungwe	Rungwe	Rungwe	Rungwe	Rungwe	Doroto	Doroto	Doroto
	11/16/2021	11/16/2021	11/15/2021	11/15/2021	11/15/2021	11/12/2021	11/12/2021	11/11/2021
	12/11/2021	12/11/2021	12/10/2021	12/10/2021	12/10/2021	12/4/2021	12/4/2021	12/3/2021
	STOLEN	OFF	OFF	OFF	ON	OFF	OFF	ON
	STOLEN	12/4/2021	11/18/2021	DAMAGED	12/10/2021	11/12/2021	11/13/2021	12/3/2021
	N/A	18	3	0	25	0	1	22
	STOLEN	1/6/2022	1/6/2022	1/7/2022	1/7/2022	1/4/2022	1/4/2022	1/3/2022
	STOLEN	OFF	OFF	OFF	OFF	OFF	OFF	ON
	STOLEN	12/27/2021	12/12/2021	12/14/2021	12/29/2021	12/15/2021	12/14/2021	1/3/2022
	N/A	16	2	4	19	11	18	31
	STOLEN	2/5/2022	2/4/2022	2/4/2022	2/4/2022	1/31/2022	1/31/2022	1/30/2022
	STOLEN	OFF	OFF	ON	ON	OFF	OFF	ON
	STOLEN	1/18/2022	1/6/2022	2/4/2022	2/4/2022	1/4/2022	1/18/2022	1/30/2022
	N/A	10	0	28	28	0	6	27
	STOLEN	3/7/2022	3/6/2022	3/6/2022	3/6/2022	3/3/2022	3/3/2022	3/4/2022
	STOLEN	OFF	OFF	OFF	OFF	ON	OFF	ON
	STOLEN	2/23/2022	2/25/2022	2/19/2022	2/20/2022	3/3/2022	2/23/2022	3/4/2022
	N/A	18	21	15	16	31	23	33
	STOLEN	4/6/2022	4/7/2022	4/7/2022	STOLEN	4/5/2022	4/5/2022	4/4/2022
	STOLEN	ON	OFF	ON	STOLEN	ON	ON	ON
	STOLEN	4/6/2022	3/15/2022	4/7/2022	STOLEN	4/5/2022	4/5/2022	4/4/2022
	N/A	32	9	32	0	33	33	31
	STOLEN	5/11/2022	5/10/2022	5/10/2022	STOLEN	5/8/2022	5/8/2022	5/7/2022
	STOLEN	ON	OFF	OFF	STOLEN	OFF	ON	ON
	STOLEN	5/11/2022	4/21/2022	5/7/2022	STOLEN	5/4/2022	5/8/2022	5/7/2022
	N/A	33	14	30	0	29	33	33
1383	0	127	49	109	88	104	108	177