EVALUATION OF AWARENESS, BEHAVIORAL PRACTICES AND RISKS ASSOCIATED WITH HUMAN-BAT INTERACTIONS IN KILOMBERO AND MVOMERO DISTRICTS, TANZANIA

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ABSTRACT

Human-bat interactions have been and continue to be a global concern due to their association with several zoonotic disease outbreaks. Such interactions have initiated the infection chains that affect global public health and overburdens the national health care systems leading to high economic losses, increased death rates, and increased food insecurities. Human-bat interactions are insufficiently studied in Tanzania despite the presence of huge bat roosting grounds and past outbreaks of bat-related disease outbreaks and this calls for the need to assess the human knowledge, attitude, practices (KAP), and behavioral risks associated with human-bat interactions. A cross-sectional survey was conducted in Kilombero and Mvomero districts, Tanzania. Four hundred sixty-nine households were interviewed through the use of a semi-structured questionnaire and a simple random sampling technique was employed in the selection of the households. For triangulation purposes, eight Focused Group Discussions (FGD) and eight In-Depth Interviews (IDI) were conducted. Four hundred sixty-nine respondents (n = 469) were interviewed out of which three hundred three were females (n =303) and one hundred sixty-six were males (n = 166). Over 52% of the respondents didn't know that bats were public health threats ($p < 0.05$). More so 19% of the respondents were not aware of the dangers of humans interacting with the bats ($p < 0.05$), 23% of the respondents did not know about any disease that can be passed on from the bats to humans. Furthermore, regarding human practices contributing to bat exposure, results showed, reporting bats to enter houses ($X^2 = 13.85$, $p < 0.001$), reporting touching bats with bare hands either dead or alive ($X^2 = 5.65$, $p < 0.05$), reporting to have used bat guano as an energy source ($X^2 = 16$; $p < 0.001$), consumption of palm sap fed on by the bats ($X^2 = 24.1$; $p < 0.001$) and having used bat manure on their farms ($X^2 = 8.04$, $p < 0.01$). The results showed risk factors for the human-bat interactions being; bats

entering houses (OR = 2.3, CI:1.1-5.1, $p < 0.05$) and palm sap consumption fed on by bats (OR = 1.2, CI: 5.0-22.4, $p < 0.01$). The findings demonstrate low awareness of the bat threats and increased human-bat interactions in the communities near the bat roosts. These are obstacles as this could initiate disease spillover from bats to humans and thus epidemic occurring. Thus, outreach programs and community sensitization on dangers and risks linked to human-bat interaction should be carried out. Further research needs to be done on the seroprevalence of bat pathogens in humans increasingly interacting with the bats in Tanzania.

DECLARATION

I, MARION BYONANEBYE, do hereby declare to the senate of the Sokoine University of Agriculture, that this dissertation is my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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DEDICATION

I dedicate this work to minority especially the girl children with a big version of leadership but are struggling with financial support.

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LIST OF ABBREVIATIONS

COVID-19	Coronavirus disease 2019
DNA	Deoxyribonucleic acid
EBOV	Ebola Virus
FGD	Focused group discusion
HeV	Hendra virus
Hunt	Hunting
ICTV	International Committee for taxonomy of viruses
IDI	Indepth Interview
VEO	Village Executive Officer
WEO	Ward Executive Officer
KAP	Knowledge, Attitude, and Practice
MERS CoV	Middle East Respiratory Syndrome coronavirus
Min	Mining
NiV	Nipah virus
RNA	Ribonucleic acid
SARS CoV	Severe Acute Respiratory Syndrome Coronavirus
WHO	World Health Organisation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Human-bat interactions continue to be a global concern due to their association with several zoonotic disease outbreaks. Such interactions have initiated the infection chains that affect global public health and this overloads the national health care systems. For instance, huge pandemics in the world such as COVID-19 have been associated with increasing human-bat interaction as a risk factor for transmission (Daszak *et al.*, 2020; Li *et al.*, 2020). Apart from bats being a public threat, they are beneficial to the ecosystem they also play ecological roles of pollination of plants, aiding in seed dispersal, reforestation, and provision of guano for fuel and income sources for poor communities (Montecino-latorre *et al.*, 2020).

Over 75% of re-emerging infections have been of zoonotic origin, 70% of which are from wildlife. Among others, bats have been proved to be the natural reservoirs for most viruses resulting in severe outbreaks in the world (Smith and Wang, 2013; Greatores *et al.*, 2016). Over 200 viruses have been associated with the bats and are of RNA origin with a high mutation rate and high adaption rate as compared to DNA Viruses (Allocati *et al.*, 2016). The human-bat interactions are in form of sharing similar space, hunting, and consumption of bats for food and medicine. This enhances transmission of pathogens via scratching, inhalation, hunting, food consumption, guano used as fertilizer, and possible human-to-human interaction. Some of the diseases that have been spilled over from bats include rabies, Marburg, Nipah, Middle East Respiratory Syndrome (MERS) coronavirus, Severe Acute Respiratory Syndrome (SARS) coronavirus, Ebola virus, and Hedra (Smith and Wang, 2013; Li *et al*., 2020). Despite the occurrence of cases of disease outbreaks

due to bat virus spillover, human-bat interactions are insufficiently studied in East Africa. Over 145 species of bats have been reported in East Africa, with Tanzania having a total of over 108 species (Patterson and Webala, 2012). The most abundant species of bats in Tanzania are fruit bats/straw-colored bats that live in proximity with humans (Patterson & Webala, 2012). This calls for the need to examine the human-bat interactions in Tanzania and the associated risk factors. The current study is therefore aimed at covering this knowledge gap and in a way provide useful information that would guide the process of devising control strategies for bat-associated disease outbreaks.

1.2 Problem Statement and Study Justification

Bats are reservoirs of numerous pathogens that are a threat to public health. Outbreaks have been reported globally due to the spillover of the pathogen from bats to humans such as coronavirus disease 2019 (COVID 19) causing over 2.6 million death worldwide (Zhang *et al*., 2021), Ebola virus disease-causing over 15 266 death (Barbiero, 2020) and many more. Despite the presence of huge bat colonies in East Africa, in particular Tanzania, there is limited information on human-bats interactions and their threat to public health. Generating this information is necessary as it would allow risk analysis results which are essential in the development of control strategies for bat-borne diseases. Information obtained from this study will also aid in early warning and detection of zoonotic emergence before large-scale outbreaks. Furthermore, findings from this study will also be useful in devising appropriate strategies for control of human exposure to bats which will indirectly help in the control of re-emerging zoonotic diseases among human populations. This study will contribute to the knowledge on bats through the bat-one health research network.

1.3 Objectives

1.3.1 Overall objective

To evaluate awareness, behavioral practices and risks associated with human-bat interactions in Kilombero and Mvomero districts, Tanzania.

1.3.2 Specific objectives

1. To determine the behavioral risk factors for human-bat interactions among communities in Kilombero and Mvomero districts.
2. To investigate awareness of the threats of bat-related public health threats among communities in Kilombero and Mvomero districts.
3. To determine human knowledge, attitude, and practices towards exposure to the bats among communities in Kilombero and Mvomero districts.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Description of bats: biological and physical attributes

Bats belong to the order Chiroptera and it is the second-largest order of mammals with over 1000 species. The order is subdivided into two suborders that are Megachiroptera (comprising of 166 species) and Microchiroptera (with 759 species). Megachiroptera is found mainly in the regions of Asia, Africa, and Oceania or pacific regions and mainly feed on fruits, seeds, pollen, and other live-in caves, trees, and some buildings and their sizes vary from 40 to 150cm with their wings spread and with the height of 1kg on average. Microchiptera or microbats are distributed throughout the entire planet except for some islands and the poles and their size range from 4 to 16cm and feed mostly on the flowers and fruits and their primary habitats include forests and tropical areas although they are capable of co-existing with humans in the same urban setting. Microbats can travel long distances of up to 2000 km during the migratory season to fulfill their nutritional needs. In addition, bats possess both canines and incisor teeth for chewing and biting, and these aid in feeding. The bats have been classified according to what they feed on such as insectivores, carnivores, piscivores, sanguinivores, nectarivores, and omnivores (Aguirre and Matthysen, 2003).

Bats possess wings that enable them to fly over long distances in search of food during seasonal migration. Their long-distance migration facilities dispersal of pathogens in wide ranges. Throughout the flight, bats eat around four times as much oxygen and they have a very high concentration of red blood cells compared to small terrestrial mammals. The capability of powered flight allows the efficient spread of pathogens. More so bats

have a longlife span of over 25 years, and this has favoured persistent viral infections. The longevity of some bats is attributed to seasonal hibernation with a dramatic drop-in metabolic rate such that small fat reserves can sustain them throughout the entire hibernating season, for instance, the bat family of Rhinolophidae developed hibernation reducing their body temperature down to 8°C (Brüssow Harald, 2012). Under these cold conditions, viral viremia can be maintained for 100 days. Furthermore, the demographic and spatial structure of the bat population also favours viruses to be maintained. Furthermore, bats are extremely social creatures that tend to form dense roosting colonies and their physical proximity creates easy pathogen spread amongst themselves. Lastly, the microptera bats can emit sounds through echolocation. Their larynx is powered by muscles of the abdominal wall triggers the production of loud sound causes the spillover of viruses to inform of droplets (Nziza *et al.*, 2020; Patterson and Webala, 2012; Mandl *et al*., 2018).

2.2 Association of bats and human diseases

Diseases from bats are transmitted directly through direct contact with the body fluids such as saliva, urine, and faeces, hunting, preparation, and consumption of bats. Indirect transmission occurs through intermediate hosts as monkeys, apes, antelopes, livestock blood-feeding arthropods (mosquitoes, fleas, and ticks) infected with the bat-borne pathogens and also through the contaminated environment (Dietrich *et al.,* 2018). Paramyxovirus is a bat-borne virus consisting of Hendra and Nipah viruses which are carried by the flying fox.

2.2.1 Hendra virus (HeV)

Hendra virus causes a sporadic disease and the first outbreak occurred in Australia in 1994 with the case fatality rate of 60% in humans and 75% in horses. The natural reservoir for the Hendra virus is the fruit bat of the genus

Pteropus (family *Pteropodidae).* Sero-epidemiologic studies have demonstrated evidence of infection in all four *Pteropus* species occurring on mainland Australia *(P.alecto P.conspicillatus, P.poliocephalus, P.scapulatus*) across their geographic range (Field *et al.*, 2011)

2.2.2 Nipah Virus (NiV)

Fruit bats of Pteropus spp are natural reservoirs for the Nipah virus (NiV) and can be transmitted from animals to humans through consumption of contaminated foods or directly from humans to humans according to WHO. The first outbreak of NiV was reported in Malaysia with a case fertility rate of 39% in 1998 and this affected 283 persons representing signs and symptoms of encephalitis resulting in 109 deaths (Hossain *et al*., 2016). The subsequent outbreaks of NiV occurred in Bangladesh and India and this was linked to the consumption of fruits (fruit juices) contaminated with urine or saliva from infected fruit bats according to WHO reports on the Nipah virus. From the year 2001 to 2008 half of the reported cases in Bangladesh were due to human-to-human transmission through proving care to infected patients according to WHO and then spread to other countries such as Singapore, India, and Bangladesh. The disease distribution is now in China, Indonesia, Madagascar, Thailand, Vietnam, Cambodia, Taiwan, and New Caledonia (Sun *et al.*, 2018).

2.2.3 Ebola virus

Ebola and Marburg viruses belong to a group filovirus and can cause lethal hemorrhagic fever. The reservoirs for the Ebola virus (EBOV) are fruit bats of *Hypsignathus monstrosus, Epomops franqueti and Myonycteris torquata.* The first outbreak of Ebola occurred in Sudan and Zaire in 1976. In 2000, another outbreak occurred in Uganda leading to massive death. EBOV has continued to emerge within tropical African countries such as Uganda in 2000 and DRC in 2007. The largest outbreak of EBOV

occurred in 2013-2016 in West Africa resulting in massive death and the first case was a 2-year-old boy who was suspected to have played with the colony of insectivorous bats in a hollow tree (Shears *et al.*, 2015; Smith and Wang, 2013).

2.2.4 Marburg virus

Marburg virus is an RNA virus belonging to the family Filoviridae and its natural reservoir is the Egyptian fruit bat Rousettus aegyptiacus and it is a causative agent of Marburg hemorrhagic fever with a case fatality rate of 80%. The first outbreak of Marburg virus disease was reported in Germany and Serbia in 1967 and this was linked to exposure to the African green monkeys that were imported from Uganda. Between 1980 and 1987, a similar incidence was in patients that had a history of visiting caves and mines. More outbreaks have been reported in West Africa, Zimbabwe, Kenya, Russia, the Democratic Republic of Congo, the USA, and Uganda according to WHO reports. A recent outbreak of Marburg has been reported in Kween district, Uganda and this was linked to mining in the caves where the bats lived (Id *et al*., 2019).

2.2.5 Coronaviruses

Coronaviruses most abundantly from the genus Rhinolophus and there are over 39 species under subgenera coronaviridae and out of these 7 are known to cause respiratory infection in humans and these include SARS CoV, MERS CoV, and SARS CoV-2 and some of them are responsible for causing severe acute respiratory syndrome (SARS), middle east respiratory syndrome (MERS) and the recently discovered coronavirus disease during 2019 (Covid-19) (Bonilla-*Aldana et al.*, 2021).

2.2.5.1 Severe Acute Respiratory Syndrome (SARS CoV)

The severe Acute Respiratory Syndrome (SARS) coronavirus outbreak in China in 2002 remains one of the most impactful pandemics in the 21st century and the virus spread to more than 30 countries across the continent resulting in 8000 people being infected with

the virus and 800 deaths. This pandemic lasted for more than 6 months. Studies that were carried out in China stated the SARS outbreak was being linked to contact with wild animals, during slaughter or due to proximity to the wet markets in Guangdong province where some wild animals were consumed as delicacies in South China. SARS CoV natural reservoir is the horseshoe bat in the genus of Rhinolophus. (Fidler, 2004; Bonilla-Aldana *et al*., 2021)

2.2.5.2 The Middle East Respiratory Syndrome coronavirus (MER CoV)

Middle East Respiratory Syndrome coronavirus (MER CoV) first outbreak occurred in 2012 in Saudi Arabia and spread worldwide resulting in massive death. By 2018, 27 countries have been affected with a case fatality rate of 35% (Wang and Anderson, 2019).

2.2.5.3 Corona virus disese 2019 (COVID-19)

Coronavirus diseases 2019 (SARS-CoV-2) outbreak in China remains of the greatest pandemic in the history that the world has ever experienced recently. According to the situation reports by WHO,2020, over 1,341,360 deaths from the disease have occurred. The first COVID 19 outbreak in China has been linked to the consumption of live wild animals and seafood sold at the wet market in the Wuhan province. The disease has been named by WHO and the virus by the international committee for the taxonomy of viruses (ICTV). Researchers from China have reported SARS-CoV-2 in bats of genus Rhinolophus and hence proved to be the natural reservoir (Bonilla-Aldana *et al.,* 2020; Abdel-Moneim and Abdelwhab, 2020).

2.2.6 Rabies virus

Lyssavirus causes rabies disease and the natural reservoir has been proved to the flying fox and insectivorous bats. It is more endemic in developing countries of Asia and Africa. Though rabies is prevalent throughout the globe, many countries and islands have got

rabies-free status due to strict quarantine and excessive vaccination by rabies vaccine (Singh *et al.,* 2017).

2.2.7 Bartonella spp

Bartonellosis is a globally emerging zoonotic bacterial disease and recently two species of Bartonella i.e *B. mayotimonensis* and *B. Naantaliensis* have been detected by previous researchers from the peripheral blood of the bats and hence proved to be the natural reservoir of the pathogen and the arthropods being the intermediate host of the pathogen. Recent researchers have reported the incidence of closely related Bartonella genotypes in fruit bats and their associated bat flies in Madagascar, suggesting the transmission of a potentially zoonotic pathogen by bat fly vectors (Allocati *et al*., 2016).

2.2.8 Pasteurella spp

Pasteurella is spread like a normal microbiota of the oral, nasopharyngeal, and upper respiratory tract and includes a genus of opportunistic pathogens that causes endemic diseases associated with epizootic outbreaks. Some studies that were done by previous researchers from Wisconsin in the USA reported for the first time an outbreak of acute pasteurellosis of *P. multocida* in wild bats (Allocati *et al*., 2016).

2.2.9 Leptospira spp

Leptospira has worldwide distribution and its transmission to humans is mainly through exposure to water contaminated with the urine of infected animals. The presence of Leptospira in bats has been demonstrated in several studies and in some case reports, patients with a history of bat exposure have been reported with human leptospirosis thus proving bats to serve as the reservoir for the bacterium (Allocati *et al.,* 2016).

2.2.10 Enterobacteriaceae spp

Several members of the Enterobacteriaceae family responsible for a variety of human illnesses were isolated from bats and these include salmonella serotypes that have been reported by numerous researchers from the bats with similar characteristics to those found in livestock and humans indicating that bats can be locally important in the epidemiology of salmonellosis in human and domestic livestock. Two of these serotypes, *S. typhimurium* and *S. enteritidis*, are a frequent cause of human and animal diseases. *Escherichia coli* strain has also been frequently isolated from bats (Allocati *et al*., 2016).

A highly resistant strain of *Escherichia coli* has been isolated from the bats by previous researchers and this has posed a global threat. Antimicrobial resistance was also observed in domestic and wild animals, with an increased incidence of resistance in both pathogenic and endogenous bacteria. Several other genera such as Yersinia, Campylobacter, and Vibrio have been identified in bats, but their impact on these animals remains mostly unknown.

2.2.11 Histoplasma capsulatum

Bats have been reported to be the main reservoir for *Histoplasma capsulatum*. *H. capsulatum* is a dimorphic pathogenic fungus of mammals, which causes pulmonary and systemic infections in humans and it is acquired via inhalation of the fungal spores. This microorganism is commonly found in soil associated with great amounts of birds' droppings or bats guano. It has, however, been observed that subjects occupationally exposed to bat sites, such as miners, geologists, or farmers who use bat guano as fertilizer, have a high risk of infection and can develop severe clinical forms of histoplasmosis (Allocati *et al.*, 2016).

2.2.12 Pseudogymnoascus destructans

It has been reported by previous researchers that millions of bats died in North America due to *P. destructans* though implication with human health has not been known *P. destructans* infect the skin of bats-especially the wings – during the winter months while they are in hibernation. Unlike other dermatophytes, which colonize the outer layer of the skin, *P. destructans* can invade the living tissue of the host causing the characteristic severe skin lesions. In addition, *P. destructans* increases the frequency of periodic arousals in bats, resulting in premature consumption of stored fat essential to survive the winter leading to death within 4 months of infection. (Allocati *et al*., 2016).

Recently, it has been observed that bacteria of genus Pseudomonas-isolated from the skin of bats-inhibit the growth of the fungus in vitro. Additional in vivo studies will tell us whether in the future they could be used as biological control agents to protect bats exposed to *P. destructans* (Allocati *et al.*, 2016).

2.3 Human-bat interactions

Increasing hunting, butchering, farming, trading, mining, consumption of the bats and raw sap contaminated with bat excreta, mining of the bat guano for fuel, and use of bat excreta as manure increases the likelihood of pathogen spillover from the bats to the humans (Ayivor *et al.*, 2017). Hunting and consumption of bats have been carried out worldwide. The practice is more common in Africa, Asia, across the islands of Oceania, and to a less extent in central and South America (Mandl *et al*., 2018).

Spillover of viruses from bats such as Nipah and Hedra viruses have been associated with the continuous hunting of the fruit bats and the consumption of palm sap contaminated with bat excreta (Gurley *et al.*, 2017; Openshaw *et al.*, 2017). In addition, Nipah and Hedra viruses (Henipavirus) spillover from fruit bats to humans have been reported in

Africa and this has been associated with increasing butchering of the bats and increasing deforestation leading to the destruction of the natural habitats for the bats (Pernet *et al*., 2014). More so, increasing bat contact with humans has been reported in South China in Yunnan city causing the spillover of coronavirus to the humans (Li *et al.*, 2019). Similar incidence has been reported in Rwanda communities where spillover of coronavirus has occurred due to living in close contact with the bats (Nziza *et al*., 2020).

In a nutshell, many countries worldwide such as Ghana, Congo, Cameroon, Nigeria, Thailand, Brazil, Indonesia, etc have been reported to consume fruit bat which is the natural reservoir for Ebola and Marburg viruses. In Ghana, the bat meat trade has been in high demand in most of the restaurants in the country and even abroad (Suwannarog and Schuler, 2016; Arandjelovic *et al*., 2017; Akem and Pemunta, 2020). Furthermore, spillover of the Marburg virus from Egyptian fruit bats has been reported in some communities in Africa and it has been associated with mining and use of bat guano as the source for fuel. Lastly, Marburg and Ebola disease outbreaks in East Africa have been linked to the mining of gold in the caves where the fruit bats of species *Rousettus aegyptiacus* lived (Marie *et al.*, 2014; Nyakarahuka *et al.*, 2017).

2.4 Preventative measures of bat-related zoonotic diseases

A study by Mantovani, (1992) revealed increased awareness of the dangers of bats especially to those that stay close to the roosts, vaccination (rabies vaccine) of people usually in contact with the bats, exclusion or removal of bats from habited buildings and early warning and surveillance systems on spillage of any novel virus in human populations as some of the measures that can be used to prevent bat-related zoonotic diseases.

Table 1: Emerging and re-emerging viruses harbored by different bat species

Viruses	Bats
Marburg	*Rousettus aegyptiacus*
Ebovirus	*Hypsignathus monstrosus, Epomops franqueti, Myonycteris torquata.; Chaerephon pumilus Mops condylurus; E. helvum; Epomophorus gambianus, Nanonycteris veldkampii, Epomops buettikoferi*
Nipah	*Pteropus hypomelanus, Pteropus vampyrus, Pteropus lylei*
influanza A	*Sturnina lilium, Artibeus planirostris, A. lituratus, Artibeus jamaicensis, Rousettus aegyptiacus*
SARS	*Rhinolophus sinicus, Hipposideros, Chaerophon, Rhinolophus pusillus, R. pearsoni, R. macrotis R. ferrumequinum, Pteropus alecto, Dobsonia moluccensis, Scotophilus heathii*
MERS	*Taphozous perforatus, Rhinopoma hardwickii, Pipistrellus kuhlii*
Hendra	*Pteropus alecto, P. conspicillatus*
Lyssavirus	*Desmodus rotundus, Myotis blythii, Pteropus spp, Saccolaimus flaviventris, Myotis nattereri, Nycteris thebaica, Eptesicus serotinus, Myotis daubentonii, Myotis dasycneme, Pteropus medius, Murina leucogaster Myotis mystacinus, Myotis brandtii, Epomophorus wahlbergi, Rousettus aegyptiacus, Eidolon helvum, Miniopterus schreibersii, Hipposideros vittatus, Miniopterus schreibersii, Pipistrellus abramus*
Rabies	*Desmodus rotundus, Diaemus youngi, Diphylla ecaudata*
Dengue	*Desmodus rotundus, Artibeus jamaicensis, Carollia brevicauda, Myotis nigricans, Glossophaga soricine, Artibeus literatus, Artibeus planirostris, Carollia perspicillata, Myotis lucifugus, Artibeus intermedius, Molossus sinaloae, Molossus pretiosus, Rhogeessa bickhami, Molossus rufus, Eumops glaucinus, Myotis nigricans, Pteronotus parnellii, Natalus stramineus, Artibejus jamaicensis, Artibeus spp., Uroderma spp., Molossus spp., Chaerephon pumilus, Mops condylurus, Anoura geoffroyi, Artibeus cinereus, Artibeus literatus, Carollia perspicillata, Molossus ater, Molossus molossus, Phyllostomus hastatus, Pteronotus davyi, Pteronotus parnellii, Sturnira spp., Pteropus gouldii, Pteropus giganteus, Glossophaga soricina, Artibeus intermedius, Molossus sinaloae, Rhogeessa io, Molossus pretiosus, Balantiopteryx plicata, Molossus rufus, Rhogeessa bickhami, Epomophorus labiatus*
Equine	*Artibeus intermedius, Artibeus jamaicensis, Artibeus literatus, Artibeus turpis, Glossophaga soricina, Rhynchonycteris naso, Sturnira lilium, Carollia.*
Encephalitis	*perspicillata, Phyllostomus hastatus, Vampyrops helleri, Eptesicus fuscus, Myotis lucifugus, Myotis keenii*
Madariaga	*Carollia castanea, Phyllostomus discolor, Carollia perspicillata, Phyllostomus hastatus*

Source: (Bonilla-Aldana *et al.*, 202I)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was conducted in Kilombero and Mvomero districts of the Morogoro region. These two districts were purposively selected because they have the highest number of bat colonies in Morogoro region (Randhawa *et al.*, 2020). The first site was Kilombero district which lies between Kilombero River and Udzungwa mountains and has a population of about 407 880 people (NBS, 2012), the majority of which depend on agriculture as a source of livelihood. This district has over 35 wards, of which only four (Lumemo, Signal, Mang'ula B, and Kidatu) were purposively selected for this study as shown in Figure 1. Lastly, the second site was Mvomero district which is bordered to the North by Tanga Region, North East by Pwani region and the East and Southeast by Morogoro Rural District, and West by Kilosa District. It has a population of about 312 109 people (NBS, 2012) with the majority being agriculturalists. The district consists of 30 wards out of which four (Melela, Doma, Mzumbe, and Kibati) were purposively selected for the study as shown in Figure 1. From each ward, three villages were purposively selected based on the presence of bat colonies making the total number of villages included in this study twenty-four.

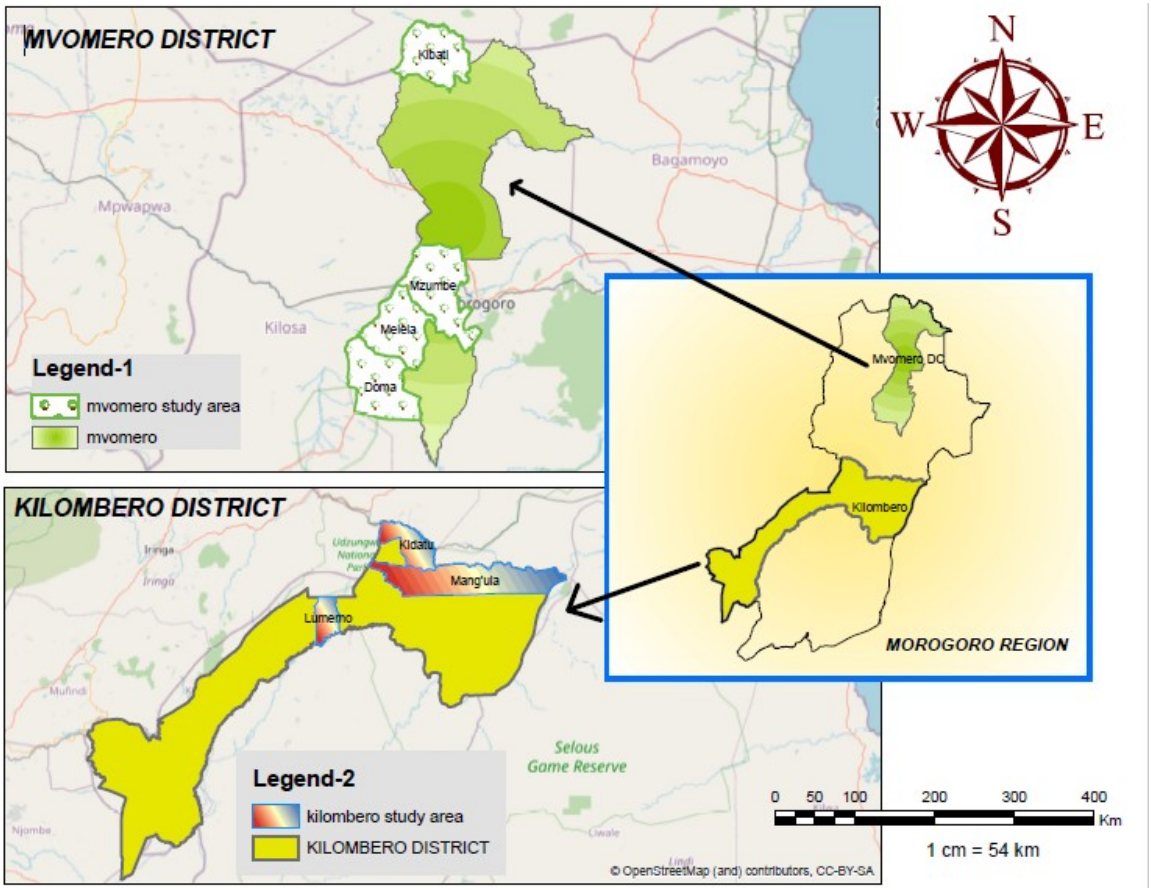

Figure 1: A map showing a study area

3.2 Study design and sample size

A cross-sectional mixed method survey was used to evaluate i) awareness, ii) behavioral risks, human knowledge, attitude, and practice (KAP) and iii) risk factors associated with human-bat interactions.

For questionnaire survey;

The number of individuals exposed to the bats were calculated using the Fischer method for sample size determination at an assumed prevalence of 50% (Fischer *et al.*, 1998).

$$n=\frac{Z_{\alpha}^{2}pQ}{d^{2}}$$ Where: Zα = standard normal deviate = 1.96, p = estimated prevalence. =

0.5 (50 %), q = (1 − p) = 0.5, d = (Precision) = 0.05 $n=\frac{1.96^2\times0.5\times0.5}{0.05^2}$ n = 384 participants; 384 × 1.2 (design effect) = 461 participants were the minimum sample size required for this study.

From the two districts $n=\frac{461}{2}$ = 230 households, therefore, two hundred and thirty household questionnaire interviews were conducted per district.

From eight wards $n=\frac{461}{8}$ = 58 households, therefore, a total of fifty-eight households per ward were included in the questionnaire survey.

For Focused Group Discussion and in-depth Interviews

According to Carson *et al.* (2002), 6-10 participants were the required sample size for focused Group discussion. Eight focused group discussions were conducted purposively based on the availability of key informants and proximity to the bat roosts.

For the 8 focused group discussions, a total of 80 participants (¿$10*8$ = 80) were engaged. For each ward $n=\frac{80}{8}$ = 10 participants per ward were interviewed. One participant per ward was required for the In-depth Interview (IDI) (Tarimo and Mashoto, 2019). For 8 wards $n=1*8=8$ participants, therefore 8 participants were the required sample size for In-depth Interviews in the two districts

Per district $n=\frac{8}{2}$ = 4, four participants per district for IDI were interviewed

3.3 Selection of the study villages and individual units

Twenty-four villages were purposively selected from the two districts based on the abundance of bat colonies and the high number of households interacting with the bats. A Simple random sampling technique was applied in the selection of the households from each village for quantitative data collection. An equal number of households were selected from each district. One individual per household was interviewed after consenting to take part in the study using a semi-structured questionnaire (Appendix 2).

3.4 Data collection

Questionnaire survey, In-depth interviews (IDI), Focused Group Discussions (FGD), and household observation forms were used to collect both the qualitative and quantitative data for assessment of awareness, behavioral practices, and risks associated with human-bat interactions. This was done in 24 selected villages from the two districts. Different qualitative and quantitative approaches were employed for triangulation to cross-check research findings by using multiple data collection methods (Denning *et al*., 2013). Furthermore, the assessments were standardized to avoid researcher bias. Household questionnaire surveys were conducted in the two districts to assess the potential risk factors, awareness of bat threats to the public, and also to determine human knowledge, attitude, and practice (KAP) towards exposure to the bats.

In addition, in-depth interviews (IDI) and Focused Group Discussions (FGD) were used to assess the potential risk factors associated with human-bat interactions, awareness of bat threats to the public, and to determine human knowledge, attitude, and practice (KAP) towards exposure to the bats.

3.5 Questionnaire survey

A household survey was conducted through the use of a semi-structured questionnaire. The questionnaire was digitized into Kobo collect software version 1.28.0 (Nampa *et al.,* 2020). Pilot testing of the questionnaire survey was done in Morogoro municipal. This digitized questionnaire survey was then used by the enumerators for data collection and mapping through capturing the Global Positioning System. The semi-structured questionnaire survey was translated from English to Kiswahili and back to English by a team of social scientists and statisticians. A random sampling technique was employed in the selection of the households for the interviews in the two districts. One person per household was interviewed after meeting the inclusion criteria and after getting consent on taking part in the exercise (See Appendix 3). The inclusion criteria were people that were eleven years and above, with a sound mind and have lived in the region for over 2 years and above. The questionnaire survey consisted of both close-ended and open-ended questions relating to people's demography, social-economic activities, history of past infections, Knowledge, Attitude, and Practices (KAP), and awareness of bat threats to the public, and this captured quantitative data (See Appendix 3). At the end of the interviews, the participants were sensitized on various health issues and a bar of medicated soap was given to each of them.

3.6 In-depth Interviews (IDI)

The purposive sampling technique was used in the selection of the key informants for the in-depth interviews. The key informants were health officers, community development officers, local government leaders, agricultural officers, livestock officers, and environmental officers. The IDI guide was developed, pre-tested, and modified accordingly and then translated from English to Kiswahili and was then used on the selected key informants in various aspects. The In-depth Interview (IDI) guide consisted

of questions on risks of human-bat interactions, questions on Knowledge, Attitude, and Practices (KAP) with regards to bats, and questions on health education on bats (See Appendix 3) from which qualitative data was obtained. IDI guide was used in exploring risks of human-bat interactions, beliefs, and practices on bat exposure and also on the awareness of the dangers of bats, and this aided in exploring the insights of the real issues regarding human-bat interactions and associated risk factors from the key informants. Discussions were then recorded using digital voice recorders while transcription and analysis were done manually using Microsoft word (George *et al.,* 2021).

3.7 Focus Group Discussion (FGD)

Purposive sampling technique was used to select the participants for the FGD and these included the primary and secondary school students, health practitioners, business people, farmers, and pastoralists. Focused Group Discussion (FGD) guide captured questions on risks of human-bat interactions, Knowledge, attitude, and practices (KAP) with regards to bats and questions on health education on bats (Appendix 3). FGD guide was used in exploring risks of human-bat interactions, beliefs, and practices on bat exposure and also on the awareness on the dangers of the bats and this helped in exploring the insights of the real issues regarding human-bat interactions and the associated risk factors. To capture the data, digital voice recording and note-taking in the Kiswahili language were done. The themes and sub-themes were used to probe the members while the note-takers were recording gestures, expressions, and non-verbal communication.

3.8 Household observation survey

A household observation survey was conducted through the use of a standard observation form together with capturing of photos to assess the behavioral risks associated with human-bat interactions. Premises such as schools, offices, and households were examined for the presence of bats, tree shades that would attract the bats, structure of the door, and

windows for bat entry. The presence of bat roosts in towns and the possible interactions with the bats were also examined (Appendix 3).

3.9 Quality Assurance

Different qualitative and quantitative approaches were employed for triangulation of the data and this ensured validity of the results by minimizing the researcher's bias. The data collection tools were pretested before the data collection and this enabled having better collection tools free from ambiguous questions. The enumerators were trained on the survey instruments such as how to use kobo collect for household questionnaire survey and also the note takers and audio records for IDI and FGD. The team of enumerators was also engaged in reviewing the questionnaire to correct any inconsistencies that would occur during the data collection.

3.10 Data analysis

The data from the questionnaire survey were entered into Microsoft Excel for cleaning. The R version 4.1.0 software was used to analyze the data. Descriptive statistics were computed to determine the frequencies of responses. The significance of differences in frequencies of responses was then determined by computing the Chi-square. The variables with significant association were subjected to multiple logistic regression to quantify risk factors and Odds Ratios were reported. The data from the Focused Group Discussion and in-depth Interviews (audio recorders) were transcribed into MS word and manual coding was done to create main themes from the discussant (George *et al.,* 2021). The main themes were categorized as (i) channels of transmission of bat spillovers, (ii) practices contributing to human-bat interactions, (iii) prevention of risks associated with human-bat interactions, (iv) perception on bats, (v) diseases from bats and (vi) existence of government donor projects.

3.11 Ethical issues

Permission to conduct this study was granted by Sokoine University of Agriculture Ethical Committee Reference Number SUA/DRRTC/R/12 (Appendix 1).

CHAPTER FOUR

4.0 RESULTS

4.0 Demographic characteristics

Out of the 469 participants interviewed, there were more females (303; 64.6%) than males (166; 35.4%). As reported by the respondents, participants with ages of 41 and above were the majority (219; 46.7%) followed by the age group of 26-33 (95; 20.3%). Over 70.6% of the participants had attended primary education and were the majority followed by those who had attended secondary education (14.9%). More mothers (268; 57.1) than fathers (136; 29%) were reported in this study. The economic activities of most of the participants were crop farming (369; 78.9%) as shown in Table 2.

Table 2: Demographic summary of the study participants

Category	N	%
Sex		
Female	303	64.6
Male	166	35.4
Age		
11-18	13	2.8
18-25	55	11.7
26-33	95	20.3
34-41	87	18.6
>41	219	46.7
Level of education		
No formal education	58	12.4
Primary education	331	70.6
Second education	70	14.9
Tertiary education	9	1.9
Family position of the respondents		
Father	136	29
Mother	268	57.1
Son/Daughter	61	13

Others	4	0.9
Economic activities		
Fishing	1	0.21
Crop growing	368	78.9
Animal keeping	5	1.1
Others	94	20

4.1 Awareness of the dangers of bat-related interactions to public health in Kilombero and Mvomero districts

To gain an understanding of what participants knew, understood, and believed regarding bat dangers and associated risks of human-bat interactions, participants were asked to supply information based on their level of awareness. The majority of the respondents were unaware of the spillover of diseases from the bats to humans and these included 53.48% of those who were practicing mining/farming and 60% of those practicing mining/ agriculture/hunting. Awareness of disease spillover from bats to humans was significantly associated with mining, agriculture, and hunting ($p < 0.05$).

Over 18.69% of those who practiced agriculture and 23.25% of those who practiced agriculture/mining were not aware that interactions with bats were a public health threat. Awareness of risks associated with human-bat interactions was significantly associated with those respondents practicing agriculture/mining ($p < 0.05$). The results further showed low awareness of bat dangers in respondents practicing agriculture and those carrying out more than two practices giving 35.98% and 52% respectively. Awareness of bat dangers was significantly associated with those practicing agriculture and those with more than two practices ($p < 0.05$) as shown in Table 3.

Table 3: Awareness of the dangers of bat-related public health among communities studied

Explanatory factor	Responses					
	Agricultural practice		**Mining/ Agriculture**		**Mining/ Agriculture/ Hunting**	
	N (%)	*p* - value	N (%)	*p* - value	N (%)	*p* - value
Awareness of bat threats						
No	71(16.58	**0.03**	6 (13.95)	0.14	4 (16)	**0.04**
Yes	203 (47.42)		17 (39,53		8 (32)	
I don't know	154 (35.98)		20 (46.51)		13 (52)	
Dangers of humans-bat interactions						
No	326 (76.16)	**0.03**	30 (69.76)	**0.04**	15 (60)	0.2
Yes	220 (5.14)		3 (6.97)		2 (8)	
I don't know	8 (18.96)		10 (23.25)		8 (32)	
If the use of bat manure is good						
No	363 (84.81)	**0.01**	38 (88.37)	0.58	3 (12)	0.63
Yes	63 (14.71)		4 (9.30)		21 (84)	
I don't know	2 (0.46		1 (2.32)		1 (0.63)	
Awareness of any bat disease transmission to humans						
No	30 (7)	0.06	3 (6.97)	**0.02**	4 (16)	**0.02**
Yes	188 (43.92)		17 (39.53)		6 (24)	
I don't know	210 (49.06)		23 (53.48)		15 (60)	
Awareness of natural encroachment dangers						
No	7 (1.63)	0.83	---	1	--	1
Yes	379 (88.55)		38 (88.37)		23 (92)	
I don't know	42 (9.81)		24 (55.81)		2 (8)	
Heard about Ebola, Murburg, Rift valley						
No	23 (5.37)	0.17	4 (9.3)	0.56	3 (12)	1
Yes	405 (94.62)		39 (90.69)		22 (88)	
Heard about Ebola						

No	147 (34.34)	0.54	19 (44.18)	1	11 (44)	1
Yes	281 (65.65)		24 (55.81)		14 (56)	

4.1.1 Health education

The majority of the respondents reported having no intervention programs relating to bats as a public health threat in the study area as shown in Figure 2.

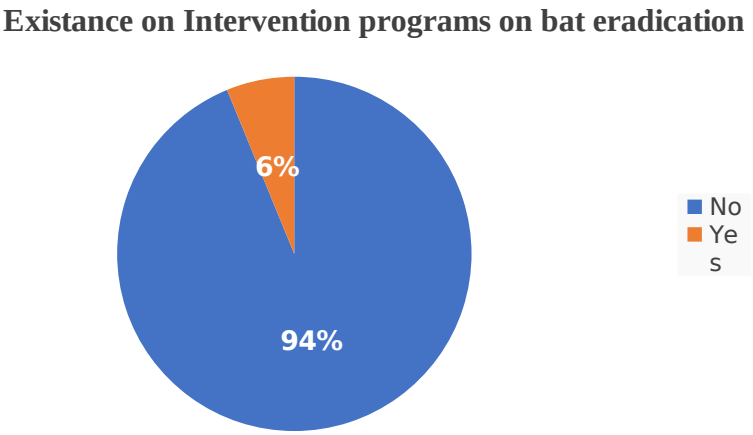

Figure 2: People's response on projects existing on bats in the study area

Most of the interviewed respondents preferred to learn about the dangers of bats through village meetings followed by listening to radios as shown in Figure 3.

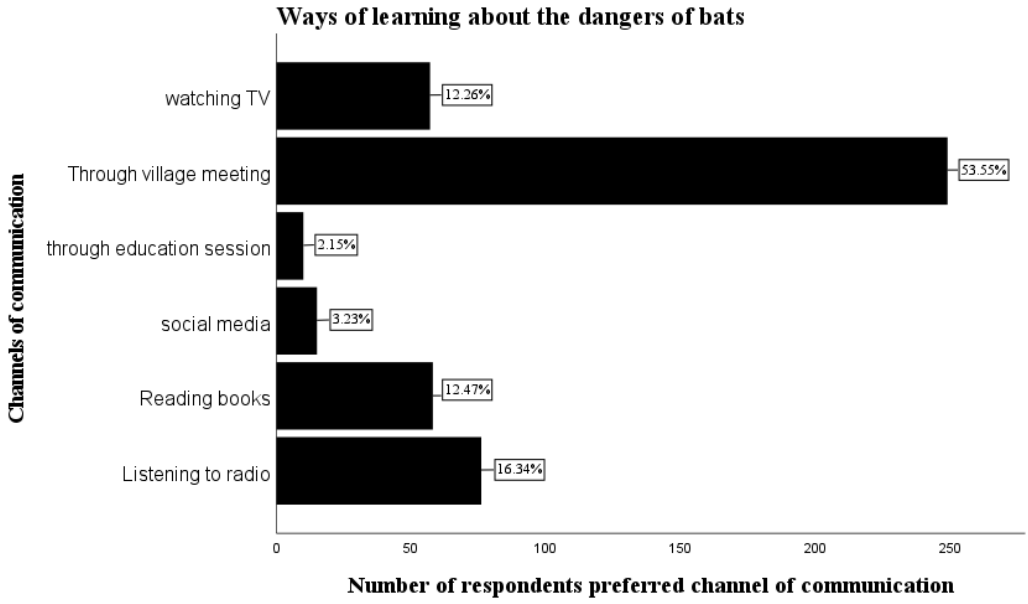

Figure 3: Preference on how to learn about the dangers of bats

4.1.2 Qualitative presentation of awareness of the risks of bat-related public health among communities in studied areas

The information from the key informants' interviews showed limited low awareness of bat threats and disease spillover from bats to humans. From the FGDs with the farmers in Signal ward, it was said, "*There are some disease conditions commonly talked about by experts such as Tuberculosis, HIV, and many others but unfortunately for us, we don't have enough information on bat diseases that can spillover to human beings."* Another FGD interview with one of the business groups at Kidatu ward said, *"I knew nothing about bats being dangerous to humans. In fact, in one of the villages known as Mngeta, there was a church where I used to worship that had so many bats in the ceiling board and they would sometimes drop their feces on us during worship services. We never bothered about it, because we didn't know the associated risks."*

The information from most of the key informants in both the FGD and IDI revealed that no project on bat danger awareness had been in place and that we were the first ones to come on the ground and let them know of the risks associated with bats. The livestock officer of the Doma ward said, "*Since I started living in this village, I have not witnessed any projects/programs/campaigns dealing with bats. But I have heard of researchers from SUA who came to do issues related with tsetse flies but not bats."*

According to the information revealed by the key informants from the IDI and FGD, the project on bats was only at Mang'ula B ward in Kilombero district. However, one of the health practitioners at Mang'ula B ward said, *"I even participated in that study to collect their (bats) swabs, saliva, blood, and fecal samples which were used to investigate possible zoonotic microorganisms from bats. Later on, we had feedback from them (researchers) on the samples collected. Various experts in the Kilombero district were*

invited that day. They (researchers) found Ebola virus families, and also discussed modes of spread of other various pathogens from them (bats) to humans such as direct contact with bat's skin and consumption of contaminated fruits. Respiratory diseases were also discussed to be caused by some organisms isolated from them (bats). Also, bats were associated with prostate cancer in men. However, no information was passed to the community through the VEO and WEO, (Village Executive Officer and Ward Executive Officer) respectively.*"*

Concerning the prevention of bat associated health risk factors, the information from the key informants for both the IDIs and FGDs revealed solutions that included removal of abandoned houses, proper housing infrastructure, avoiding bat consumption, creating a suitable environment for the bats to live, education on bat dangers, use of bat repellants to stop bats from entering houses, thorough understanding of the kinds of bat interactions, involvements by the government in bat control, cutting down trees and pruning of the trees.

The IDIs at Lumemo ward, Mzumbe ward, and Kidatu ward and the FGDs at Mzumbe ward, Signal ward, and Mang'ula B ward revealed educating the mass on the dangers of human-bat interaction and their associated risk factors as the way of raising awareness. An officer at Mzumbe ward said, "*You as researchers need to advise the government to provide education on human-bat interactions particularly on the associated risks so that people will be aware that a bat can either be a friend or an enemy*." An FGD by farmers at Signal ward said, "*Education should be provided first on how to deal with bats at the village level via village meetings."* A secondary school student at Mongola secondary school in Mzumbe ward said, "*Proper education has to be provided to the groups at risk of bat exposure such as miners to take all the precautional measures including wearing of*

proper personnel protective equipment that should be adhered to during their daily activities to avoid their associated risks."

Improving housing infrastructure was mentioned by most of the key informants from FGD at Kibati ward and Mang'ula B ward and IDIs at Mang'ula B ward, Mzumbe ward, Lumemo ward, Signal ward, and Doma ward. The community development officer at Mzumbe ward said, "*housing infrastructures should be well set with no holes to prevent bats from entering our homes*." A Livestock officer at Doma ward said, "*housing environment should be improved* by *sealing off all possible open spaces that will allow bats to enter homes*."

The use of drugs to kill the bats was mentioned by the FGDs at Mang'ula B ward and Signal ward. It was also mentioned by the IDIs at Signal ward, Kidatu ward, Melela ward, and Lumemo ward as a way of preventing human exposure to the bats. The community development officer at Kidatu ward said, "*Maybe bats can be controlled through the use of drugs/poisons which can be sprayed onto them, or through the use of hormones, I do not remember its name but it induces sterility in female bats and kills male bats."* One of the farmers at Signal ward said, "*the availability of drugs which can be used to kill the bats can make it possible to kill bats especially the resting points of farmers under the trees."* A farmer at Kidatu ward said, "*Based on research findings, if truly bats will be found to be harmful to humans, then the best action will be to kill them by the use of strong drugs as we normally do with other harmful creatures like mosquitoes*."

The use of repellant to stop bat entry into the houses was reported by the IDI at Signal ward. Also the FGDs at Kidatu ward and Signal ward reported it as another way of preventing human-bat exposure. An FGD with the business group at Kidatu ward said,

"*Thanks, I advise the use of drugs like those used to kill mosquitoes and other insect repellants which will be used to chase away bats that are normally found in the human residence."*

Cutting down trees and pruning of the trees was reported by the IDIs at Doma ward, Mang'ula B ward, Lumemo ward, and Mzumbe ward as a way of preventing human-bat exposures and its associated risk factors. The health environmental officer at Lumemo ward said, "*we have to cut down trees, and actually the trees were cut down during a season and the bats reduced but the following season the bats again increased in number, a Forest officer advised the killing of bats as a way of reducing their numbers, so people opted to use any means to kill the bats, for instance, those with guns decided to use them to accomplish their mission. That was the feedback we received from the ward development meeting by the chairperson*." The community development officer at Mzumbe ward said, "*Keeping the environment dirty with many trees will attract them to invade human residences hence, we need to keep the environment clean and without a lot of trees that will create a dark environment for bats and trees present in farms should be pruned. I mean we should not cut down trees but just prune them to avoid a dark environment that will attract bats. Bats dislike open areas, they prefer dark environments.*"

4.2 Risk factors for human-bat interactions

The risk of exposure to bats was over 10 times greater among people who touched bats with bare hands either alive or dead (OR 10.5; 95% CI 5.0-22.4; $p < 0.001$) and over two times higher among people who reported bats entering the houses (OR 2.3; 95% CI 1.1-5.1; $p < 0.05$). The odds of Palm sap consumption contaminated with the bats was higher in those that practiced mining (OR 3.2; 95% CI 1.2-4, $p < 0.001$) as shown in Table 4.

Table 4: Logistic regression analysis of the risk factors for human-bat interactions

Explanatory factors	**Responses**					
	Mining practice		**Hunting or mining**		**Agriculture or hunting practice**	
	OR (95% CI)	**p -Value**	**OR (95% CI)**	**p -Value**	**OR (95% CI)**	**p -Value**
Bats enter houses						
Yes	2.3 (1.1-5.1)	**0.03**	6.8 (0.0-NA)	0.99	1.1 (0.5- 2.5)	0.79
No	Ref		Ref		Ref	
Bats consumption						
Yes	0.2 (0.00-1.0)	**0.03**	0.7 (0.1-2.7)	0.63	--	--
No	Ref		Ref			
Touch bats with bare hands						
Yes	--	-	8.8 (NA)	0.99	10.5 (5.0-22.4)	**1.13 x** 10^{-09}
No			Ref		Ref	
Palm sap consumption						
Yes	-	-	3.2 (1.2-4.1)	**3.8 x** 10^{-05}	--	---
No			Ref			

4.2.1 Risk factors for the human-bat interactions

The FGDs and the IDIs showed that having poor housing infrastructure was a risk factor for increased bat exposure as this would allow bat invasion in people's houses. This was shown in both the IDI and FGD by the health practitioners and health officers of Mang'ula B health Centre, the IDI by the environmental health officer of Lumemo ward, and the agricultural officer of Melela ward. The health officer at Mang'ula B together with the health practitioner said, "*For those homes with low standards, they may create chances for bats to go in easily and hence causing interaction with human beings because any open space in the house may attract bats from one place to go in and cause danger*

associated with them; some people construct their homes and leave holes that will attract bats to go in." The farmers at Doma ward elaborated more on poor housing infrastructure by saying, "*In case of holes in the building, they (bats) will use them to go in."* Furthermore, the environmental officer at the Lumemo ward said, "*I would like to say that most of the information I have received from the ward development meeting, is that the bats are the ones invading human residence."*

Another risk factor for the interaction was having trees at homesteads that attract bat roosts and this was mentioned in both the IDI and FGD at Signal ward, Mang'ula B, Kidatu ward, and Mzumbe ward. The community development officer at Kidatu said, "*For example in agricultural activities, we normally see many bats in mango trees. Even in homes, there are so many bats hence, we interact with them in those scenarios.* One of the farmers at Signal said, "*In our farms, there are trees that provide shade for resting but there is a likelihood of bats being in it, hence it's difficult to prevent, interactions with bats.*" The clinical officer at Mang'ula B said, "*Some tree species called Indian almond (Mkungu in Swahili) are most preferred by the bats and hence having them at home might increase the risk of the interaction."*

Having fruit farms such as mangoes, bananas, and coconut trees was also another risk factor associated with human-bat interaction. Bats especially the fruit bats feed on fruits that are later fed on by humans hence increasing the risk of exposure. This was mentioned by the FGDs and IDIs held with the class at Kidatu ward, students of Mongola secondary school, and with community development officers of both Kibati and Kidatu ward. The community development officer of Kidatu ward said, "We *also interact with bats in business centers and via consumption of fruits that may have been contaminated by bats"*. A student at Mongola secondary school said, "*Agricultural activities, like fruit farming in*

most cases, attract bats, hence creating a chance for human beings to be exposed to bats.”. The business person at Kidatu ward said,” I *am a farmer and during my farming activities I normally encounter bats in the farm because of the fruits there, and also in the farm we normally leave our utensils for carrying food un-covered which end up being contaminated with bats´ excreta.”*

The use of bat manure is also another risk factor that can make one get exposed to the bats. This was mentioned from an interview held with the community development officers of MZumbe and Kidatu ward and the agriculture and livestock officer of Signal ward. The community development officer of Kidatu ward said, “*Their feces are very good manure to crops. Some years back I used it in tomato production and I experienced increased yield.”* The agriculture and livestock officer of Signal said, “when *I collect bat droppings from my house ceiling board normally, I would sell to farmers as manure and they would have high demand*.”

Mining activities can get one exposed to the bats since bats live in caves where mining is done and this was mentioned in two FGD with the pastoralists at Melela and secondary school students in Mzumbe ward. One of the pastoralists at Melela said, “*As I said before, activities like gold mining, where you will find many bats in caves where the activity is done expose involved people to bats.”* The secondary school students at Mongola secondary school said, “*In mining activities, bats are coming from the caves down the ground, so for people working they have high chances of being exposed to them easily. “*

Consumption of bat meat was another risk factor that caused humans to get exposed to the bats. This was mentioned by the IDI in Kidatu and the FGD at Kibati and Mzumbe wards. The IDI with the community development officer connected us to his maid who has been

consuming bats for a long time and she said, "*Bat's meat is sweet and has good nutrients and has no health problems, I have consumed bats meat and it is soo tasty."* And the FGD interview by students of Mongola secondary school in Mzumbe ward said, "*Some people use bat meat as a source of food and without knowing their associated risks, this results into increased exposure*." The health practitioner at Kibati ward said, "*In our society, there are no people who consume bats but generally one may get health problems like this corona pandemic which was believed to have originated from the consumption of bat meat.*"

Chasing the bats and killing them was another risk factor associated with human-bat interaction and this was mentioned by the FGD at Signal and Melela wards. The farmer at Signal ward said, "*One day I was trying to chase a bat that had entered my home and it released a small quantity of fluid (while flying) which I think can cause health problems."* The pastoralists at Melela said, "*they say once a bat enters into a home and you beat it using a stick, you will acquire some disease conditions. So as Masai people, we normally use our clothes to beat them or the tail of slaughtered cattle.*

4.2.2 Observations on Risk factors for human-bat interactions

Figure 4: 1-showing bats feces on the house ceiling, 2- showing feces of bats on the banana leaf, 3-showing bats urine on the houses

Figure 5: Houses showing: A and B- housing structures near bat roosts, C-showing bats roosting inside the house, and D-showing a house with trees around for bat roost

4.3 Knowledge, attitude, and practice (KAP) towards exposure to the bats.

4.3.1 Knowledge towards exposure to the bats

Knowledge on the spillover of diseases from bats to humans was poor in the studied regions. The majority of the respondents did not know how pathogen spillover from bats to humans would occur as shown in Figure 6.

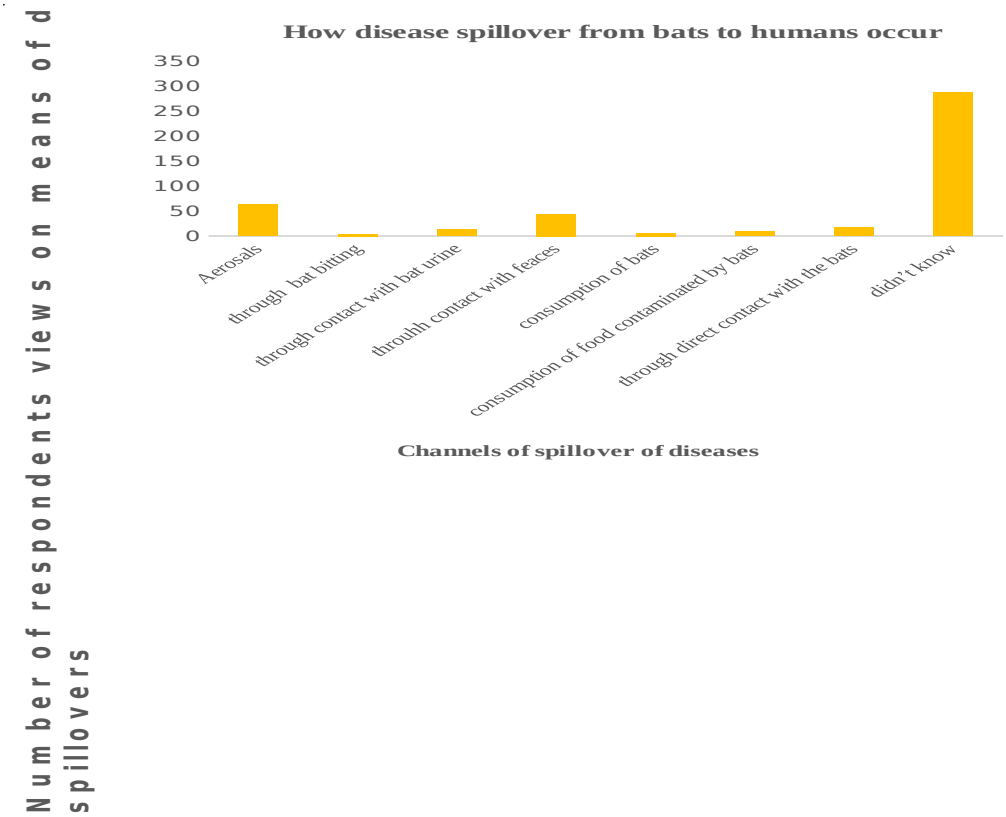

Figure 6: Knowledge on how disease spillover from bats to humans occurs

Knowledge of signs and symptoms of Ebola was poor among the respondents. The majority did not know how Ebola presented itself in humans [284; 60.5%] as shown in Figure 7.

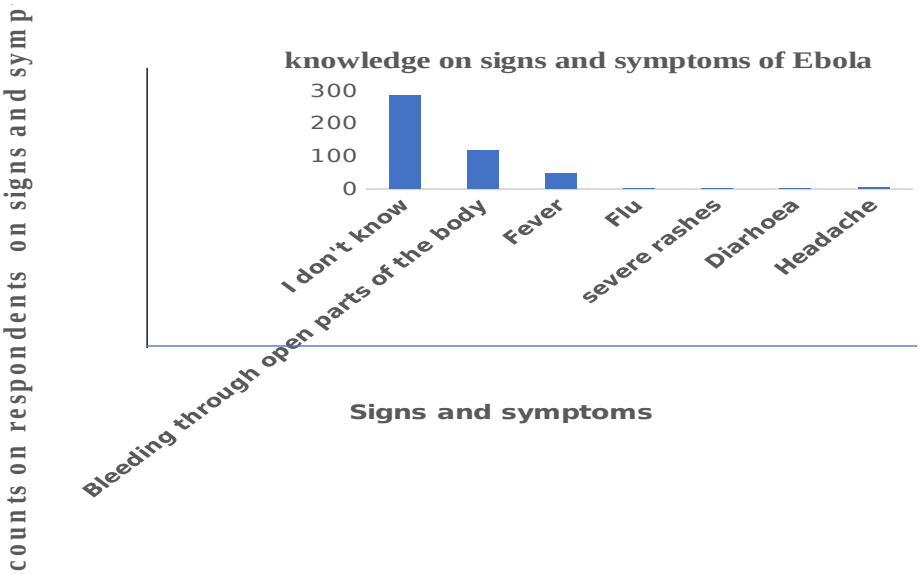

Figure 7: Knowledge on signs and symptoms of Ebola

Knowledge of signs and symptoms of rabies was poor since the majority did not know how the disease present itself. Barking was reported by most respondents followed by fever as shown in Figure 8.

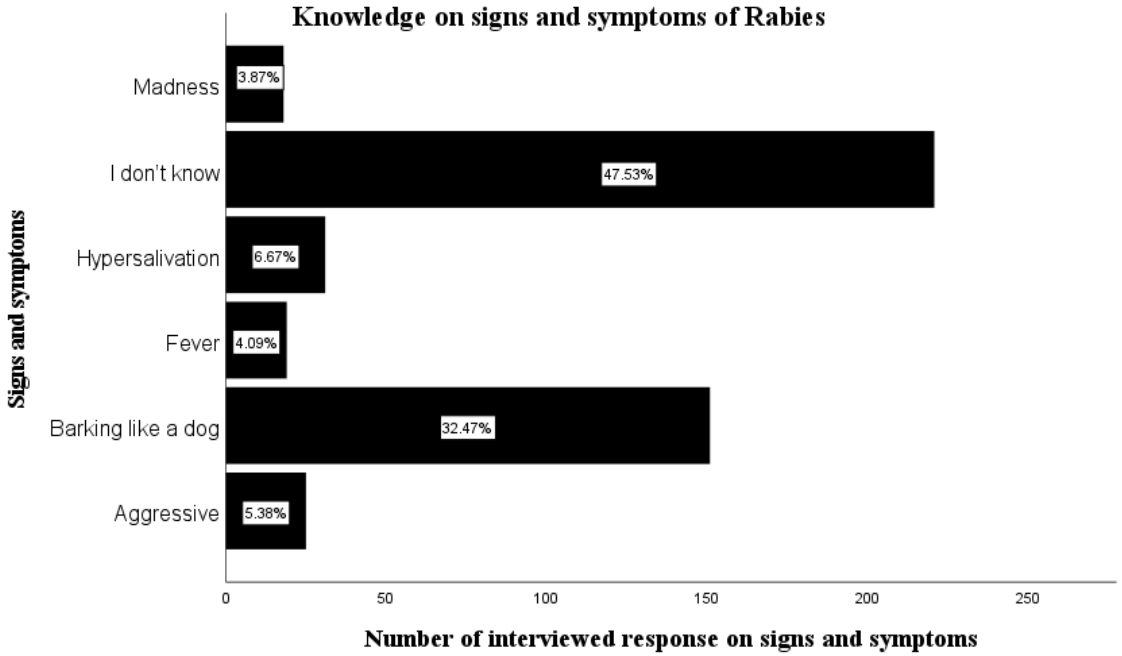

Figure 8: Knowledge on signs and symptoms of rabies

4.3.1.1 Awareness on exposure to bats

The interviews of key informants in the IDIs revealed that some of the key informants had some knowledge on how spillover of diseases from bats to humans occurs. The ways on how diseases from bats spillover to humans as per the interviews included bat consumption, aerosols, contact with bats excreta such as urine and feces, living with the bats in the house, consumption of contaminated fruits, living in close proximity with the bats, bats bites direct and indirect contact with the bats.

Some of the interviews with the key informants from both IDI and FGD revealed that some had no knowledge on disease spillover from the bats to humans. The FGD of Kigamboni primary school in Lumemo ward, FGD of the farmers at Doma ward, IDI of the community development officer at Kibati ward, and IDI of community development officer at Kidatu revealed that knowledge on disease spillover from the bats to the human population was poor. The community development officer of Kibati ward said, "*First of all, I am not aware that bats can spread some diseases to humans"*. While the community development officer at Kidatu ward said, "*From my understanding, I was not aware that bats can spread diseases, so this is news to me."*

A few diseases were being mentioned in the interview during IDI and FGD and these included corona and ebola. Ebola as a disease that spreads from bats to humans was revealed by one of the health practitioners at Kibati ward, a health practitioner at Mang'ula B, an environmental health officer at Lumemo ward, and a secondary school student at Mongola secondary school in Mzumbe ward. The environmental health practitioner said, "One *can get Ebola by consuming bats."*

Corona and respiratory diseases were mentioned by the key Informants from Kibati ward, Mzumbe ward, Mang'ula B, and Melela ward. The livestock officer at Melela ward said, "*bats are wild animals hence their proximity to humans can cause serious diseases, and when you have domesticated animals, there is a possibility of them acquiring diseases from bats in case the bats are infected with a disease that may pass to domesticated animals. I have heard of corona pandemic that bats were the source but I have no proof about that to me it's just a theoretical idea*."

However, aerosols as a way of spillover of diseases from bats to humans were mentioned in the IDIs with the agricultural officer at Doma ward, with the chairman at Mzumbe ward, with livestock officer at Melela ward, community development officer at Kidatu ward, and FGDs with Mongola secondary students at Mzumbe ward, farmers at Signal ward and health practitioner at Mang'ula B ward. During the IDI, the chairman of Mzumbe ward said, "*During their (bats) movement from one location to the other they contaminate air so that when someone comes into contact with it, they may end up getting an infection."*

Through their excreta such as urine and feces, the disease from bats would spillover from bats to humans and this was mentioned by FGDs at Mang'ula B ward, at Kidatu ward, at Signal ward, at Mzumbe ward and Doma ward, and IDIs at Kidatu ward, at Mang'ula B ward and Melela ward. The community development officer of Kidatu said, *"People walking down trees infested with bats normally get contaminated with bat's stool, so if their feces contain viral pathogens then the transmission can be facilitated in this way."* The health practitioner at Mang'ula B ward said, "*Through their feces, for example, paddy may be contaminated, and once someone prepares and consumes that rice, they may end up getting infected."*

The students at Mongola secondary school Mzumbe ward said, "*Bats prefer to live in a dark environment at home, so in case of contact with their feces one may get diseases due to presence of bacteria in their feces."* Farmers at Signal ward said, "*Through their excreta in human residence someone may end up getting diseases during cleaning because someone may not take precautions like wearing gloves and hence can end up in contact with their feces and urine which will expose one to the risk of getting diseases*."

The FGD of the business group at Kidatu ward said, "*Also, we had a case of one person somewhere else who got fever and blisters after being in contact with bat's urine."*

Bites as another way through which diseases can spillover to humans were mentioned in the interviews of FGDs at Kibati ward and Mang'ula B ward, and IDI at Mzumbe ward. The chairman at Mzumbe ward said, "*some aggressive bats can bite someone and hence predisposes them to infections*. "While a health practitioner at Mang'ula B ward said, "*the bats normally have ectoparasites so in close proximity with them increases the chances of an individual to get bitten and if they (bats) are infected, it will be easy to pass the infection to human*."

Bat consumption was also revealed as another way on how spillover of diseases from bats to humans can occur. This was revealed in the FGD at Kibati ward, Mang'ula B ward, Doma ward, and Mzumbe ward, and the IDIs at Kidatu ward and Melela ward. The livestock officer at Melela ward said, "*What I know is that bats are mammals hence they share many things in common with humans so in case the bats have been infected in one way or another, they may pass the infection to humans via eating their meat."*

Consumption of contaminated fruits fed on by the bats was reported in the interviews of IDI with the livestock officer at Melela ward, the community development officer at Kidatu ward, and the FGD of farmers at Signal ward. An FGD of the farmers at Signal ward said, "*bats may spread diseases to humans via contaminated fruits because bats normally consume a variety of fruits like mangoes. A bat can consume a bit of mango and the rest of it can be ingested by a human, this can be a means for the human to acquire infections from bats."*

Close interaction was another way how diseases from bats can be spilled over to humans. This was revealed in the IDI at Doma ward, Melela ward, and Kidatu ward and FGDs at Kidatu ward, Signal ward, and Mang'ula B ward. The chairman at Mzumbe ward said, "*Curiosity and ignorance of people make them go to bat habitats to play with them hence, this close interaction may cause someone to acquire diseases from bats*." The community development officer at Kidatu ward said, "*Under normal circumstances, bat's habitats are not in homes but trees and if trees make their habitats, human beings found in close proximity to their surroundings may easily be in contact with their feces and if these feces have negative side effects, there are high chances of someone getting infected with diseases though am not yet aware of any diseases associated with bats."*

Furthermore, living with the bats was a form in which spillover of diseases from bats to humans would occur and this was mentioned in the FGD at Kidatu ward and Signal ward. The community development officer at Kidatu ward said, "*And through that process of bats going into homes at night, their excreta may contaminate the utensils, and one may get diseases after using the contaminated utensils"*

Direct contact and indirect contact with the bats were the ways on how spillover of diseases from bats to humans would occur and this was also revealed in the IDI at Lumemo ward and FGD at Mzumbe ward and Signal ward. An FGD of farmers at Signal ward said, "*Direct contact with bats for example by school children who usually play with bats and kill them, may facilitate the spread of diseases."* The environmental officer at Lumemo ward said, "*Therefore, the presence of bats near the human residence can facilitate getting infected with Ebola through indirect contact with contaminated surfaces or objects*."

4.3.2 Practices towards exposure to the bats

Over 6.4% of the respondents were miners and the minerals being mined included, diamond, ruby, quartz, feldspar, and gold while 3.2% practiced hunting/agriculture practices and 80.9% were the majority who had mixed practices. Issues of bats entering into the houses were significantly associated with agriculture practices (X^2 =10.40; $p < 0.001$) and mining-hunting practices (X^2 =13.85; $p < 0.001$). Touching bats with hands either dead or alive was significantly associated with hunting practice (X^2 =5.65; $p < 0.05$). Being bitten or scratched by a bat was significantly associated with mining practices (X^2 = 4.64; $p < 0.05$). The use of bat manure was significantly associated with agriculture practice (X^2 =8.04; $p < 0.01$). Use of bat guano as the energy source was significantly associated with mining practices (X^2 =16; $p < 0.01$), agriculture practices (X^2 =10.15; $p < 0.01$) and hunting/mining (X^2 =10.71; $p < 0.01$). Consumption of palm sap was significantly associated with mining practices (X^2 =4.70; $p < 0.05$) and mining/hunting (X^2 = 24.01; $p < 0.001$) as shown in Table 5.

Table 5: Association between explanatory factors and hunting, mining, agriculture practices, and both hunting/mining practices

Explanatory factor	**Responses**							
	Hunting practice		**Mining practice**		**Agricultural practice**		**Mining/hunting**	
	X^2	***p* - value**	**X^2**	***p* - value**	**X^2**	***p* - value**	**X^2**	***p* - value**
Bats enter houses	1.54	0.21	3.42	0.06	10.40	**0.001**	13.85	**0.000**
Touch bats with bare hands	8.16	**0.004**	0.62	0.42	119.8	**2.2x 10^{-16}**	5.65	**0.02**
Bitten by bats	---	---	4.64	**0.03**	---	---	---	---
Use of bat guano	0.20	0.65	16	**0.000**	10.15	**0.001**	10.71	**0.001**
Palm sap consumption	0.01	0.92	4.70	**0.03**	--	---	24.01	**0.000**
Bats consumption	1.65	0.43	5.42	0.06	1.86	0.39	8.11	**0.02**

Use of bat manure	1.14	0.28	3.42	0.06	8.04	**0.004**	1.57	0.21
Killing bats as pests	0.94	0.33	0.01	0.91	0.02	0.86	2.14	0.14

The majority of the respondents reported that fruits are highly attacked by the bats followed by the coconut plants as shown in Figure 8.

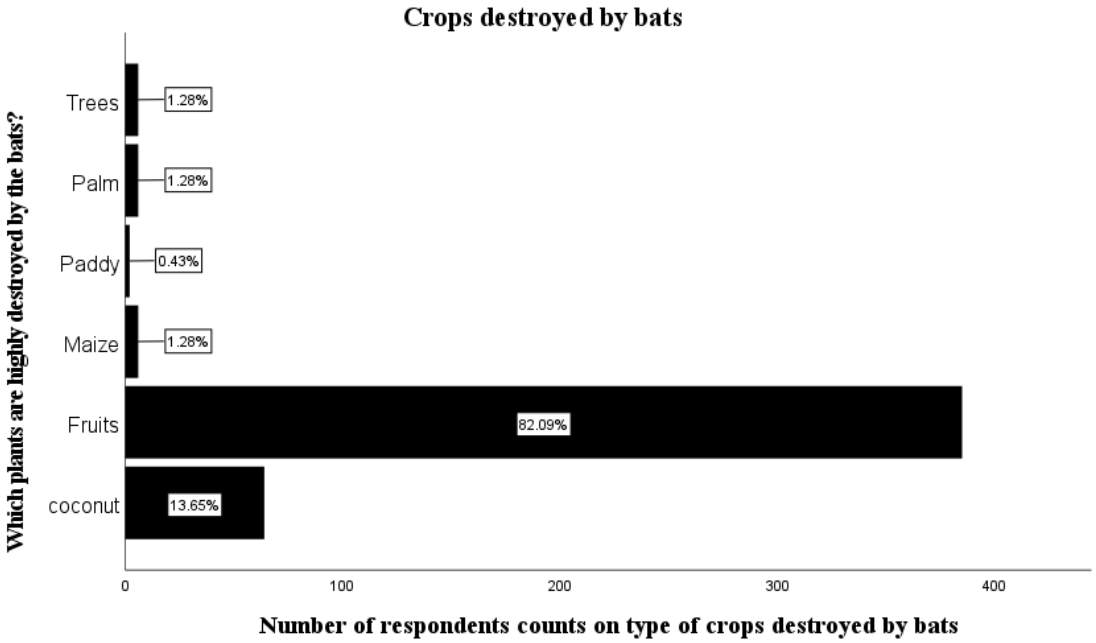

Figure 8: Crops destroyed by bats

4.3.3 Risk perceptions towards exposure to the bats

The majority of the respondents in the studied region perceived bats as being destructors as shown in Figure 9.

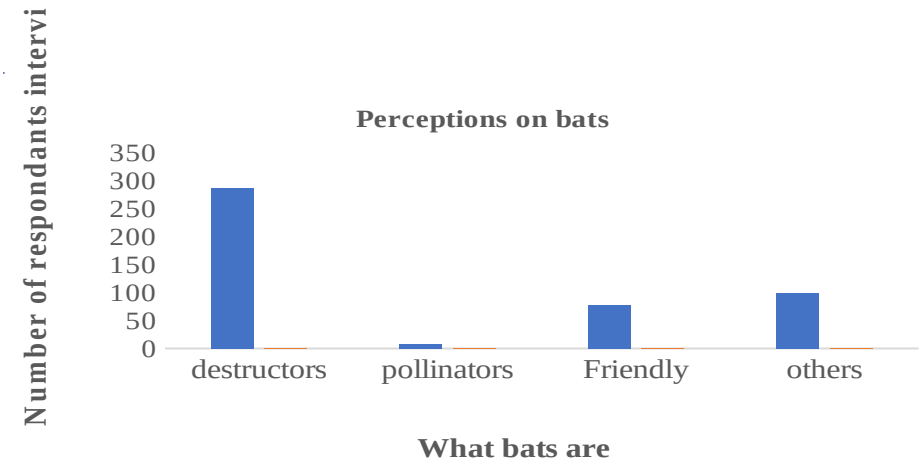

Figure 9: Perceptions of people on bats

The majority of respondents perceived bats as being a nuisance with no importance as shown in Figure 10.

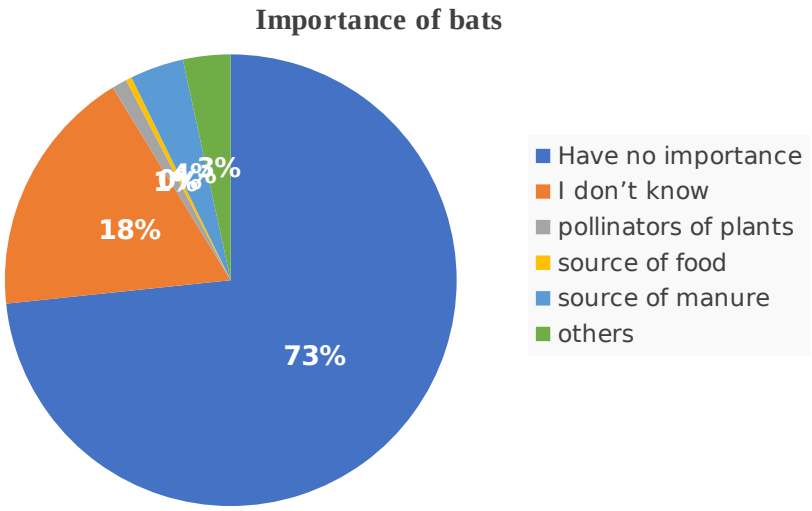

Figure 10: Respondents perception of roles of bats

Knowledge on which sex is highly at risk of bat exposure was poor as the majority reported that they didn't know which sex was at high risk. This was then followed by those that reported both sexes to be at risk as shown in Figure 11.

Knowledge on which sex is highly at risk of bat exposure

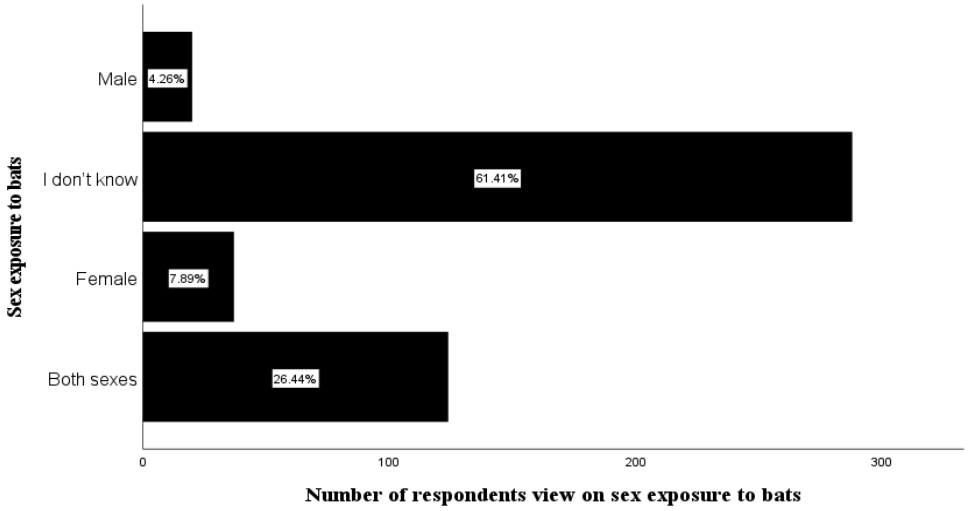

Figure 11: Sex that is highly at risk of bat exposure.

4.3.3.1 Qualitative presentation on perceived attitude towards exposure to the bats

The majority of key informants IDI (environmental officer, farmers, community development officers, livestock officers, health officers, and agricultural officers) had different perceptions on human-bat interactions with associated risk factors. Some of the key informants believed that bats didn't have any importance and hence just a nuisance because they would cause pollution of the environment with the bad smell of their excreta, destruction of farms and ceilings, being a source of bad omen, disturbance, and noise pollution. Others perceived bats as important since they would help in pollination of the plants, mosquito control, source of food, source of medicine, learning purpose, and tourist attraction.

One of the FGD of the pastoralists at the Melela ward perceived bats as the cause of fever once it dies in the house and hence said, "*Once you use a stick to chase the bat it will die in the house and will cause fever, this is what we believe here so we instead use a cloth so that we do not kill the bat but just chase it away from the home."* The student at Mongola secondary school in Mzumbe ward perceived bats as a sign of bad omen and said, *"Bats*

in our tradition, is a very dangerous creature, and we believe when you hear the bat's sound or see a bat in your village/street it might be the sign that someone has died." The same student further said that bats are believed to be used by the witch doctor and they cause blindness by saying, "*With the people in my society, we believe that bats are dangerous and are used in witchcraft especially at night and cause blindness to a human being when they come in contact with them."*

A farmer at Signal ward believed that bat's urine damages the coconut trees and he said, "*Their urine causes damage to the coconut trees*." The chairman at Mzumbe ward perceived bats as being medicinal and he said, "*I have heard that bat's urine is used as potential medicine but, I hate bats. I have also heard that the urine is used as pest's repellant especially when applied in farms."* The agricultural officer at Doma ward believed that the excreta from bats harm someone who is asthmatic and said, "*The smell of their bat excreta in the home has a negative impact on people with asthma, I have heard about this in another village."*

Perception of the bats as birds was being stated in the interviews at Kidatu (FGD) and Doma (FGD) while at Lumemo (IDI) as a disease vector. One of the FGD with the business people at Kidatu ward said, *"I am not certain to which category the bats fall in, what I know is bats are birds that normally fly here and there but I know less about their details."* While the environmental health officer at Lumemo ward said, "*The way I know, a bat is the vector for some diseases and has no any importance, they do possess only negative side effects*."

Perception of bats as being used for mosquito control was being mentioned by the IDIs at Signal ward, Melela ward, and Mzumbe ward and FGDs at Mang'ula B ward and Signal

ward. An FGD interview by the farmers at Signal ward said, "*I know a bit about the importance of bats, for example, they eat mosquitoes in homes after getting in, to me, this is important because I usually stay in a house without a mosquito net but I do not encounter mosquitoes when the bats are in the house. After this simple observation, I concluded that bats were eating mosquitoes as the source of food."* The agricultural officer at Signal ward said, "*bats like to eat mosquitoes by doing so they reduce Malaria cases in one way or another."*

Bats perceived as being destructors were being reported in the FGD at Kidatu and Doma wards and the IDIs at Signal ward and Mzumbe ward. The IDI at Mzumbe ward with the chairman said, "*The bats are destructors of properties in homes for example the ceiling boards are destroyed by their excreta. They also cause damage to mango fruits."*

Being environmental pollutants was being mentioned by the FGDs at Kibati ward, at Doma ward, and Signal ward, and IDI at Lumemo ward. One of the farmers at Signal ward said, "*Bats pollute the home environment after their invasion this is because their urine and feces have a foul smell. The same I experienced in the warehouse by the foul smell coming from them (warehouse) particularly from the bats' urine."*

Manure from the bats being perceived good was mentioned in the IDI at Signal ward, IDI at Mzumbe ward, FGD at Lumemo ward, FGD at Doma ward, and FGD at Kidatu ward. The chairman at Mzumbe ward said, "*bat's manure is very good and I have tried to use it before and it showed good results."*. The agricultural officer at Signal ward said, *"their feces are used as manure, and when I collect bat droppings from my house ceiling board, I sell it to farmers and there is always a high demand for it. As an agricultural expert, to begin with, the quality of any feces used as manure depends on what the animal*

consumes. Secondly, you cannot compare the bats' manure and artificial fertilizers for example it has been said that one tonne of cattle manure is almost equivalent to fifty kilograms of artificial fertilizers. So, I can say the bats' manure will help farmer "A" as compared to farmer "B" who will not apply anything to his/her farm."

Perception of bats as being food was mentioned by the IDI at Kidatu ward, IDI at Doma ward, and FGD at Doma ward. The farmers at Doma ward said, "*Bats are used differently depending on the society. In Some places, they are used as food and at the end of the day they get some health problems for example fever, like how pigs get infected with African swine fever and accompanied with banning of pig consumption."*

Pollination of the plants was being mentioned by the IDI at Kidatu ward and FGD at Mang'ula B ward as one of the importance of bats. The community development officer at Kidatu ward said, "*But I think they are used in pollination just like bees because they move from one plant to the other hence by considering this function, they can be beneficial to the environment."*

The perception of bats being friendly and living in harmony with human beings was mentioned during IDI at Kibati ward, FGD at Signal ward, and FGD at Mang'ula B ward. The community development officer at Kibati ward said, "*What I know with bats in this village is that we are living in harmony with them. There are no any risks associated with them."*

CHAPTER FIVE

5.0 DISCUSSION

The present study reveals proof of human-bat interactions in Kilombero and Mvomero districts, Tanzania that may increase the potential of disease spillover from bats to humans resulting in great pandemics and thus the suggested opportunities for risk mitigation. A previous study done in China on novel bat origin coronaviruses outbreak was proved to be linked with increased human-wildlife interaction (Daszak *et al.*, 2020). Results from the current study further show that the majority of the respondent's highest level of education is primary education level and this possibly contributed to their low level of awareness on bat threat and knowledge towards bat exposures. Furthermore, the finding from the current study shows the main occupation of the respondents being agriculture and possibly this could put them more at risk of bat exposure.

Results from the previous study generally indicate low awareness of bat dangers and disease spillover from bats ($p < 0.05$). Knowledge regarding whether it is good to interact

with the bats according to the study findings is poor amongst the participants ($p < 0.05$). Findings are in agreement with the study done in Nigeria on assessing the KAP and behavioral risks regarding zoonotic infections which also showed 42.9% of the population being ignorant of zoonotic infections from the wild ($p < 0.05$) (Ozioko *et al.*, 2018). This possibly can increase risk behaviors and thus the population remaining vulnerable to zoonotic diseases from bat spillover like coronavirus disease, Ebola disease, Marburg. Moreso could initiate disease spillover and thus the need for more intervention studies to be done. Furthermore, results from the focused group and in-depth interviews show adequate knowledge on how spillover from bats to humans can occur. Various ways on how spillover of diseases from bats to humans can ok through direct and indirect contact with the bats, living in close proximity with the bats, contact with their excreta (urine and feces), biting from the bat, through aerosols, and consumption of contaminated foods by the bats. Studies by previous researchers have reported similar ways of spillover occurring through the same modes of diseases spread from bats to humans (Akem and Pemunta, 2020; Kohl and Kurth, 2014; (Saéz *et al.*, 2015).

The results of this study also show some of the risk factors associated with human-bat interactions. From the current study, the odds of bats entering into houses being high amongst the study communities (OR = 2.3, CI: 1.1-5.1, $p < 0.05$). The cause of bats entering into houses could probably be due to poor housing standards with cracks and holes that allow bats entry. More so having lots of trees in the home sounding (mangoes, coconut Palm trees etc) could increase the chances of bats entering the houses. Carrying out house chores under the bat roosting trees has been observed such as preparing meals, laundry activities, washing plates, and resting under the tree shades could lead to direct interaction with the bats. This possibly put people at high risk of spillover of diseases from bats. The previous study was done in Ghana on examining human-bat interaction

and the potential risks of disease transmission from bats to humans, results showed living with the bats directly exposes people to spillover of pathogens from the bats (Ayivor *et al*., 2017).

Furthermore, the results from the current study demonstrate odds of touching bats with bare hands either alive or dead being high among the study population (OR = 11, 95% CI: 5.0–22.4, $p < 0.001$). This could increase the risk of exposure to the bats and disease spillover. The finding more suggests that indirect contact with bats occurring through the consumption of food fed on by bats. From the current study, the results show that the odds of consumption of contaminated palm sap by bats being high in miners (OR = 3.2, 95% CI: 1.2-4.1, $p < 0.001$). The palm sap consumed is probably contaminated with bats' saliva or excreta. The findings further suggest that consumption of palm sap be associated with an increased risk of pathogen spillover from the bats. Previous studies done in Bangladesh and India prove that the outbreak of Nipah virus disease to be linked with the consumption of fruits (fruit juices) contaminated with urine or saliva from infected fruit bats (Openshaw *et al.,* 2017; Gurley *et al.,* 2017). No Nipah virus disease outbreak has been reported in Tanzania even though there is continuous consumption of palm sap and fruits by humans possibly fed on by bats as was the case in Bangladesh and India.

From the current study, some of the behavioral practices in the study population contributing to bat exposure is killing off bats as pests management ($p < 0.05$). This is due to the process of chasing and hunting down bats some spillover of pathogens may occur in form of aerosols and excreta. Killing bats as pests management is the direct way one interacts with the bats and thus could lead to chances of disease spillover to humans.

A Previous study was done in West Africa to investigate the zoonotic origin of Ebola and it was revealed that the first case outbreak was to be linked to a 2-year-old boy who was suspected to have played with the colony of insectivorous bats in a hollow tree (Saéz *et al*., 2015). Furthermore, the results from the current research show having been bitten or scratched by a bat as one of the practices that could lead to human exposure to the bats ($p < 0.05$). Being bitten or scratched by the bat could initiate spillover of lyssavirus/rabies viruses directly to the exposed. A relatively similar study done in Thailand on rabies-related KAP among persons at risk of bat exposure, reported 27% of participants to have a history of bat exposure through a bite or scratch ($p < 0.05$) (Robertson *et al*., 2011). More so more previous studies done on bat exposure have also shown direct transmission of lyssavirus through similar mechanisms (Pape *et al*., 1999; Moran *et al.*, 2015), thus in agreement with the current study. Moreso the current findings shows the use of bat guano as an energy source to be among the practices in the study communities that may risk them to bat exposure ($p < 0.01$). The finding suggests that the practice of collecting and harvesting bat guano may pose a potential exposure to bat-borne pathogens. The findings are in agreement with what was reported earlier by Dietrich and other researchers on bat pathogens hit the road and revealed the possible transmission of diseases through bat guano (Dietrich *et al.,* 2018). The results from the current research further express some crop husbandry practices such as the use of bat manure as the risk of bat exposure ($p < 0.01$). Findings from ethnographic interviews revealed high crop yield with the use of bat manure as a comparison to other sources of manure. This may pose a considerable health threat to communities as this will lead to spillover of the bat-borne pathogen.

The findings from the current study show 16% of the participants perceiving bats as being friendly and having no associated bad benefits like public health threats. This incorrect belief may spread to other people within the study region could increase the risk of human

interaction with the bats and could increase disease spillover to the public from the bats. The finding more so suggests the mindset of the public needs to be changed in regards to bats with associated risk factors. This could indirectly help in the risk reduction of bat hazards which will further help in the mitigation of pandemics that can outweigh the health systems and cause high economic losses and deaths. Furthermore, the findings from the current study revealed 60% of the respondents perceiving bats as being distractors. The ethnographic interviews revealed bats believed bats a nuisance with no importance due to destruction of crops, home ceiling, making disturbance noise, and polluting the environment with their smelly excreta. This calls for the need of employing one health strategy focusing on the bats' control without interfering with their ecology since bats have some advantages like insect control and pollination of the plants.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

From this study, it can be concluded that the level of knowledge, attitude, awareness, and behavioral risks associated with human-bat interactions in Mvomero and Kilombero districts, Tanzania were evaluated. The results revealed that awareness of bats as public health threats was poor in Kilombero and Mvomero districts despite the abundance of bat roosts in these didtricts. Low awareness of bats as public health threats could be an obstacle in risk mitigation of bat pathogen spillover to humans resulting in epidemics. This could further be a hindrance in the efforts to control bat-borne diseases thus having a great impact on Sustainable Development Goal (SDG 3) 2063 to ensure healthy living which is free from any diseases like zoonotic diseases.

More so from the results, practices that increase the likelihood of bat exposure are; use of bat manure, the use of bat guano for energy sources, killing of bats as pest management, and having been bitten or scratched by the bat. The risk factors for human-bat interactions is concluded to be; consumption of palm sap fed on by the bats, bats entering in the houses, touching bats with bare hands either dead or alive.

Targeted health education is needed to change these behavioral risks that increase human-bat interactions. This can be done through village meetings, media, hand-outs or leaflets, and other written materials on the dangers of bats and their associated risk factors and this can have an important role in increasing awareness of the risks associated with increased human-bat interactions. There is also a great need for health intervention programs and community sensitization on control of human-bat interactions with associated risk factors. Good housing infrastructure should be put in place and any cracks in the ceiling or wall must be sealed off to avoid bat entry into houses.

6.2 Recommendations

It is recommended that

i. Further research is to be established on quantification of the seroprevalence of bat-related pathogens among humans increasingly interacting with the bats in the study population. This will further assist in planning for better strategies for the control of bat-borne diseases.
ii. strong enforcement of strong surveillance systems to be put in place in monitoring zoonotic spillover diseases from bats to humans.
iii. More studies need to be done on the detection of pathogens that may be associated with the use of bat guano as manure.

iv. More studies need to be done in risk assessment of individuals by comparing individuals exposed and non-exposed to the bats.

REFERENCES

Abdel-Moneim, A.S. and Abdelwhab, E.M. (2020). Evidence for SARS-CoV-2 infection of animal hosts. *Pathogens* 9(529): 1 – 22.

Aguirre, L. F., Herrel, A., Van Damme, R. and Matthysen, E. (2003). The implications of food hardness for diet in bats. *Functional Ecology* 17(2): 201 – 212.

Akem, E. S. and Pemunta, N. V. (2020). The bat meat chain and perceptions of the risk of contracting Ebola in the Mount Cameroon region. *BioMed Central Public Health* 20: 1 – 10.

Allocati, N., Petrucci, A. G., Di Giovanni, P., Masulli, M., Di Ilio, C. and De Laurenzi, V. (2016). Bat–man disease transmission: zoonotic pathogens from wildlife reservoirs to human populations. *Cell Death Discovery* 2(1): 1 – 8.

Amman, B. R., Nyakarahuka, L., McElroy, A. K., Dodd, K. A., Sealy, T. K., Schuh, A. J. and Nichol, S. T. (2014). Marburgvirus resurgence in Kitaka Mine bat population after extermination attempts. Uganda. *Emerging Infectious Diseases* 20(10): 1761.

Ayivor, J. S., Ohemeng, F., Tweneboah Lawson, E., Waldman, L., Leach, M. Ntiamoa-Baidu, Y. (2017). Living with bats: the case of Ve Golokuati township in the Volta region of Ghana. *Journal of Environmental and Public Health* 2017: 1 – 12.

Barbiero, V. K. (2020). Ebola: A Hyperinflated Emergency. *Global Health: Science and Practice* 8(2): 178 – 182.

Bonilla-Aldana, D. K., Jimenez-Diaz, S. D., Arango-Duque, J. S., Aguirre-Florez, M., Balbin-Ramon, G. J., Paniz-Mondolfi, A. and Rodriguez-Morales, A. J. (2021). Bats in ecosystems and their Wide spectrum of viral infectious potential threats: SARS-CoV-2 and other emerging viruses. *International Journal of Infectious Diseases* 102: 87 – 96.

Brüssow, H. (2012). *On Viruses, Bats and Men: A Natural History of Food-Borne Viral Infections*. Springer Science + Business Media, Dordrecht, Switzerland. 23pp.

Chen, N., Zhou, M., Dong, X., Qu, J., Gong, F., Han, Y. and Yu, T. (2020). Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *The Lancet* 395(10223): 507 – 513.

Daszak, P., Olival, K. J. and Li, H. (2020). A strategy to prevent future epidemics similar to the 2019-nCoV outbreak. *Biosafety and Health* 2(1): 6 – 8.

Fidler, D.P. (2004). *Brief History of the Global SARS Outbreak of 2002–03*. Palgrave Macmillan, London. 35pp.

Field, H., de Jong, C., Melville, D., Smith, C., Smith, I., Broos, A. and Zeddeman, A. (2011). Hendra virus infection dynamics in Australian fruit bats. *PloS One* 6(12): e28678.

Fischer, A. A., Laing, J. E. and Strocker J E. (1998). *Handbook for Family Planning, Operation Research Design in Sampling.* (Second Edition), Population Council. New York. 85pp.

George, J., Häsler, B., Komba, E., Sindato, C., Rweyemamu, M. and Mlangwa, J. (2021). Towards an integrated animal health surveillance system in Tanzania: making better use of existing and potential data sources for early warning surveillance. *BioMedical Central Veterinary Research* 17(1): 1 – 18.

Greatorex, Z. F., Olson, S. H., Singhalath, S., Silithammavong, S., Khammavong, K., Fine, A. E. and Gilbert, M. (2016). Wildlife trade and human health in Lao PDR: an assessment of the zoonotic disease risk in markets. *PloS One* 11(1371): 1 – 17.

Gurley, E. S., Hegde, S. T., Hossain, K., Sazzad, H. M., Hossain, M. J., Rahman, M. and Khan, S. U. (2017). Convergence of humans, bats, trees, and culture in Nipah virus transmission, Bangladesh. *Emerging Infectious Diseases* 23(9): 1 – 8.

Islam, M. S., Sazzad, H. M., Satter, S. M., Sultana, S., Hossain, M. J., Hasan, M. and Gurley, E. S. (2016). Nipah virus transmission from bats to humans associated with drinking traditional liquor made from date palm sap, Bangladesh, 2011–2014. *Emerging Infectious Diseases* 22(4): 664 – 670.

Joffrin, L., Dietrich, M., Mavingui, P. and Lebarbenchon, C. (2018). Bat pathogens hit the road: But which one? *PLoS Pathogens* 14(8): 1 – 5.

Kohl, C. and Kurth, A. (2014). European bats as carriers of viruses with zoonotic potential. *Viruses* 6(8): 3110 – 3128.

Krueger, R. A. (2002). *Designing and Conducting Focus Group Interviews*. University of

Minnesota, USA. 18pp.

Li, H. Y., Zhu, G. J., Zhang, Y. Z., Zhang, L. B., Hagan, E. A., Martinez, S. and Daszak, P. (2020). A qualitative study of zoonotic risk factors among rural communities in southern China. *International Health* 12(2): 77 – 85.

Mandl, J. N., Schneider, C., Schneider, D. S. and Baker, M. L. (2018). Going to bat (s) for studies of disease tolerance. *Frontiers in Immunology* 9: 1 – 13.

Mantovani, A. (1992). Zoonoses control and veterinary public health. *Review Science Technology* 11(1): 205 – 218.

Marí Saéz, A., Weiss, S., Nowak, K., Lapeyre, V., Zimmermann, F., Düx, A. and Leendertz, F. H. (2015). Investigating the zoonotic origin of the West African Ebola epidemic. *European Molecular Biology Organization Molecular Medicine* 7(1): 17 – 23.

Marié, J., Berenger, J. and Edouard, S. (2014). Marburgvirus resurgence in kitaka mine bat population after extermination attempts, Uganda. *Emerging Infectious Diseases* 20(10): 1761 – 1764.

Montecino-Latorre, D., Goldstein, T., Gilardi, K., Wolking, D., Van Wormer, E., Kazwala, R. and Mazet, J. A. (2020). Reproduction of East-African bats may guide risk mitigation for coronavirus spillover. *One Health Outlook* 2(1): 1 – 13.

Moran, D., Juliao, P., Alvarez, D., Lindblade, K. A., Ellison, J. A., Gilbert, A. T. and Recuenco, S. (2015). Knowledge, attitudes, and practices regarding rabies and exposure to bats in two rural communities in Guatemala. *BioMed Central Research Notes* 8(1): 1 – 7.

Nampa, I. W., Mudita, I. W., Patrick, N., Bire, L. and Kaho, R. (2020). The kobocollect for research data collection and management (an experience in researching the socio- economic impact of blood disease in Banana). *Jurnal Sosial Ekonomi Pertanian* 14(3): 545–556.

National Bureau of Statistics (2012). *Tanzania Population and Housing Census.* National Bureau of Statistics, Dar es Salaam, Tanzania. 56pp.

Nyakarahuka, L., Shoemaker, T. R., Balinandi, S., Chemos, G., Kwesiga, B., Mulei, S. and Lutwama, J. J. (2019). Marburg virus disease outbreak in Kween District Uganda, 2017: Epidemiological and laboratory findings. *PLoS Neglected Tropical Diseases* 13(3): 1 – 19.

Nyakarahuka, L., Skjerve, E., Nabadda, D., Sitali, D. C., Mumba, C., Mwiine, F. N. and Kankya, C. (2017). Knowledge and attitude towards Ebola and Marburg virus diseases in Uganda using quantitative and participatory epidemiology techniques. *PLoS Neglected Tropical Diseases* 11(9): 1 – 20.

Nziza, J., Goldstein, T., Cranfield, M., Webala, P., Nsengimana, O., Nyatanyi, T. and Mwikarago, I. E. (2019). Coronaviruses Detected in Bats in Close Contact with Humans in Rwanda. *EcoHealth* 17: 152 – 159.

Openshaw, J. J., Hegde, S., Sazzad, H. M., Khan, S. U., Hossain, M. J., Epstein, J. H, andLuby, S. P. (2017). Bat hunting and bat–human interactions in Bangladeshi villages: Implications for zoonotic disease transmission and bat conservation. *Transboundary and Emerging Diseases* 64(4): 1287 – 1293.

Ordaz-Németh, I., Arandjelovic, M., Boesch, L., Gatiso, T., Grimes, T., Kuehl, H. S. and Junker, J. (2017). The socio-economic drivers of bushmeat consumption during the West African Ebola crisis. *PLoS Neglected Tropical Diseases* 11(3): 1 – 22.

Ozioko, K. U., Okoye, C. I., Obiezue, R. N. and Agbu, R. A. (2018). Knowledge, attitudes, and behavioural risk factors regarding zoonotic infections among bushmeat hunters and traders in Nsukka, southeast Nigeria. *Epidemiology and Health* 40: 1 – 6.

Pape, W. J., Fitzsimmons, T. D. and Hoffman, R. E. (1999). Risk for rabies transmission from encounters with bats, Colorado, 1977–1996. *Emerging Infectious Diseases* 5(3): 433 – 437.

Patterson, B. D. and Webala, P. W. (2012). Keys to the bats (Mammalia: Chiroptera) of east Africa. *Fieldiana Life and Earth Sciences* 2012(6): 1 – 60.

Pernet, O., Schneider, B. S., Beaty, S. M., LeBreton, M., Yun, T. E., Park, A. and Daszak, P. (2014). Evidence for henipavirus spillover into human populations in Africa. *Nature Communications* 5(1): 1 – 10.

Randhawa, N., Bird, B. H., VanWormer, E., Sijali, Z., Kilonzo, C., Msigwa, A. and Mazet, J. A. (2020). Fruit bats in flight: a look into the movements of the ecologically important Eidolon helvum in Tanzania. *One health outlook* 2(1): 1 – 14.

Robertson, K., Lumlertdacha, B., Franka, R., Petersen, B., Bhengsri, S., Henchaichon, S. and Rupprecht, C. E. (2011). Rabies-related knowledge and practices among persons at risk of bat exposures in Thailand. *PLoS Neglected Tropical Diseases* 5(6): 1 – 7.

Shears, P. and O'Dempsey, T. J. D. (2015). Ebola virus disease in Africa: Epidemiology and nosocomial transmission. *Journal of Hospital Infection* 90(1): 1 – 9.

Singh, R., Singh, K. P., Cherian, S., Saminathan, M., Kapoor, S., Manjunatha Reddy, G. B. and Dhama, K. (2017). Rabies–epidemiology, pathogenesis, public health concerns and advances in diagnosis and control: A comprehensive review. *Veterinary Quarterly* 37(1): 212 – 251.

Smith, I. and Wang, L. F. (2013). Bats and their virome: An important source of emerging viruses capable of infecting humans. *Current Opinion in Virology* 3(1): 84 – 91.

Sun, B., Jia, L., Liang, B., Chen, Q. and Liu, D. (2018). Phylogeography, transmission, and viral proteins of Nipah virus. *Virologica Sinica* 33(5): 385 – 393.

Suwannarong, K. and Schuler, S. (2016). Bat consumption in Thailand. *Infection Ecology and Epidemiology* 6(1): 1 – 6.

Tarimo, E. A. and Mashoto, K. O. (2019). A qualitative study of perceived risk of occupational exposure to HIV and use of post exposure prophylaxis services among health-care workers in Tanzania. *East Africa Health Research Journal* 3(2): 96 – 104.

Wang, L. F. and Anderson, D. E. (2019). Viruses in bats and potential spillover to animals and humans. *Current Opinion in Virology* 34: 79 – 89.

Wynne, J. W. and Wang, L. F. (2013). Bats and viruses: friend or foe? *PLoS Pathogen* 9(10): 1 – 4.

Zhang, F., Karamagi, H., Nsenga, N., Nanyunja, M., Karinja, M., Amanfo, S., Chase-Topping, M., Calder-Gerver, G., McGibbon, M., Huber, A. and Wagner-Gamble, T. (2021). Predictors of COVID-19 Epidemics in Countries. World Health Organization, Geneva. 28pp.

APPENDICES

Appendix 1: Ethical Approval letter

SECTION P : FOR OFFICIAL USE

(i) APPROVAL

Date received : Click here and arrow to enter a date. 03/12/2020	Received by: Click here to type names. L. Madalla
Date of approval: Click here and arrow to enter a date. 07.01.2021 **Name**: Akwilina W. Director **Title**: Coordinator Approving authority in capital letters (example: SRPC, Departmental /College/Centre R&PC **Click here to enter the name of approving authority.**	Approval reference number: Click here to enter number. SUA/DRRIC/R/12 Approval is valid from Click here and arrow to enter a date. 07.01.2020 To: Click here to enter a date. —

Postgraduate studies, Research, Technology Transfer and Consultancy
Sokoine University of Agriculture
P. O. Box 3151, Morogoro
TANZANIA

*All undergraduate studies shall be evaluated and/or approved by the College/Centre R&PC and Reports submitted to the chair Research Ethica Committee, DPRTC

(ii) **NOT APPROVED**

☐ The applicant is required to revise the application by addressing reviewer's concerns (Reviwer's comments are provided to the applicant)

☐Other reasons (Describe briefly)

Click here to enter text.

Appendix 2: Consent forms used; questionnaire survey, IDI and FGD

A questionnaire survey

Principal Investigator Marion Byonanebye Msc

Sokoine University of Agriculture (SUA),

Morogoro Tanzania

Name of Organization Sokoine University of Agriculture (SUA),

Morogoro, Tanzania

Title: EVALUATION OF BEHAVIORAL PRACTICES AND RISKS ASSOCIATED WITH HUMAN-BAT INTERACTIONS IN KILOMBERO AND MVOMERO DISTRICTS, TANZANIA

Introduction

we are from Sokoine University of Agriculture and we are studying behavioural risks associated with human-bat interactions in Kilombero and Mvomero districts. The aim of this study is to assess the human knowledge, attitude, practices and behavioural risks associated with human-bat interactions. There will be no money or anything offered to take part in this study. No samples will be collected and no administration of any drug will be done. The data collected will be used for risk analysis which will guide development of control strategies for bat borne diseases. Information obtained from this study will also aid in early warning and detection of zoonotic emergence before large scale outbreak. More so it will contribute to the worldwide knowledge on bats through the bat-one health research network.

Confidentiality

The information that we will collect from this research project will be kept confidential and will be stored in a file which will not have the participants name on it, but a number

assigned to it. Which number belongs to which name will be kept under lock and key, and will not be divulged to anyone except the scientists and representatives of the Sokoine University of Agriculture (SUA).

“I have read, understand this information and agree to take part in this study”

Name: Interview.....Signature.....Date.....

“I have agree to abide by the above condition”

Name: Interviewer.....Signature.....Date.....

IDI AND FGD

Principal Investigator Marion Byonanebye Msc
Sokoine University of Agriculture (SUA),
Morogoro Tanzania

Name of Organization Sokoine University of Agriculture (SUA),
Morogoro, Tanzania

Title: Evaluation of Behavioral Practices and Risks Associated with human-bat Interactions in Kilombero and Mvomero Districts, Tanzania

we are from Sokoine University of Agriculture and we are studying behavioural risks associated with human-bat interactions in Kilombero and Mvomero districts.

The purpose of the focus group discussion is to understand risks associated with human - bat interactions. The information acquired will help us to understand people’s altitude, knowledge, practices and risk factors that may occur due to the interaction with the bats the discussion will take approximately 60 minutes. One can choose whether or not to participate in the focus group and stop at any time. The focus group will audio record and all responds remains anonymous. There are no right or wrong answer to focus group questions. We want to hear many view points and we would like to hear from everyone.

In respect for each other, we ask that only one individual speaks at a time in the group and that responses made by all participants to be kept confidential. We hope you can be honest even when your responses may not be in agreement with the rest of the group.

“I have read, understand this information and agree to take part in this study”

Name: Interview.....Signature.....Date.....

“I have agreed to abide by the above condition”

Name: Interviewer.....Signature.....Date.....

Appendix 3: Data collection tools ; questionnaire survey, IDI form, FGD forms and observation form

A: Questionnaire Form

A questionnaire to explore people's Knowledge, Attitude and Practices (KAP), public awareness on human-bat interaction and associated risk factors in Kilombero and Mvomero district in Tanzania

To be filled in by research team:
Date_____ Interview_____
District_____Ward_____Village_____sub-village_____
GPS co-ordinates: longitude N _____ latitude E _____ altitude_____

ID Number _____

Age _____

Sex Female ☐ Male ☐ Telephone number_____

Part 1: Background and Village

1. How long have you been living in this village?

   One month ☐ 6 months and above ☐

   Above 1 year ☐ others specify_____

2. Do you spend some time in this village?

   Yes ☐ No ☐

3. If Yes, how much time do you spend in this village**?**

4. How long has your family been living in this village**?** _____

5. Position of the respondent in the household

Father ☐ Mother ☐ Daughter/son ☐

Others (Mention)_____

6. How many people (including yourself) are there in your household?

_____

7. Do you have a village health committee?

Yes ☐ No ☐

8. According to you, what's the biggest problem in your village?

Bat invasion in homes ☐ malaria ☐

Accidents ☐ Typhoid ☐

Others specify_____

9. What's the most serious health concern in the village in the last 10 years (Please rank 5 out of these 12. The biggest problem ranked with 1)

Diarrhoea ☐ Malnutrition ☐

Heart diseases ☐ Breathing problems ☐

Flu ☐ High blood pressure ☐

Chest pain ☐ Abdominal pain ☐

Red eyes ☐ Tuberculosis ☐

Several rashes ☐ bleeding ☐

Others (specify) _____

Part 2: Socio-Economic Status

10. Level of Education

No formal education ☐

Primary school education ☐

Secondary school education ☐

Tertiary school education ☐

11. Occupation_____

12. How many people (including yourself) in your immediate family earn an income?

_____

13. Where does most of your family income come from and which activities are you involved in? (Choose one answer)

Fishing ☐ crop production ☐

Animal raising ☐ Mining ☐

Business ☐ Hunting ☐

Others specify_____

14. Do you have any land for farming?

Yes ☐ No ☐

15. Does your family own any animals / livestock?

Yes ☐ No ☐

16. If yes, which animals / livestock and how many? _____

Part 3: Knowledge On Spillover

Please tell what you have heard and what you know about bats. You may also write down:" I don't know." if you do not know

17. What do you know about bats?

There friendly ☐ destructors ☐

Plant pollinators ☐ others specify _____

18. What is the local name of bats in your language?

19. What is the importance of bats?

Source of manure ☐ source of fuel ☐

Source of food ☐ pollination of plants ☐

Others specify

_____

20. Do you think bats are dangerous?

Yes ☐ No ☐ I don't know ☐

21. Do you think it is good to interact with the bats?

Yes ☐ No ☐ I don't know ☐

22. If yes why? _____

23. Do you think manure from bats dropping is good?

Yes ☐ No ☐ I don't know ☐

24. If yes give reasons

_____

25. Do you think bats can transmit disease?

Yes ☐ No ☐ I don't know ☐

26. If Yes, mention some of them and how there are transmitted

27. Have you heard about Ebola, Marburg, rabies, rift valley fever?

Yes ☐ No ☐

28. Have you heard of cases of Ebola?

Yes ☐ No ☐

29. What are signs and symptoms of Ebola?

_____

30. What are signs and symptoms of rabies?

_____

31. Are there some communities that consume bush meat?

Yes ☐ No ☐ I don't know ☐

32. If yes which bush meat do, they consume

_____

33. Are there some communities that consume bats?

Yes ☐ No ☐ I don't know ☐

34. If yes, which species of bats are consumed

_____

35. Give ways in which encroachment on natural reservoirs for wild life has been done?

_____

36. Do you think there must be dangers to humans that may occur through encroachment on natural reservoirs for wildlife?

Yes ☐ No ☐ I don't know ☐

Part 4: Practices

37. Do you practice mining?

Yes ☐ No ☐

38. Which minerals are mined?

_____

39. Do you collect bat guano for energy source?

Yes ☐ No ☐

40. Do you practice some agriculture?

Yes ☐ No ☐

41. If yes which crops do you plant?

_____

42. Do you have palm trees?

Yes ☐ No ☐

43. Have you ever consumed palm sap?

Yes ☐ No ☐

44. Do you use manure on your farm?

Yes ☐ No ☐

45. Which sources of manure do you use?

_____

46. Where do you get your manure?

_____

47. Have you ever used manure from Bats?

Yes ☐ No ☐

48. If yes how often do you use the bat manure

Occasionally ☐ after a month ☐

Seasonal ☐

Others specify_____

49. Are you involved in manure collection from bats?

Yes ☐ No ☐

50. If yes how do you collect the manure?

Use bare hands ☐ use gloves ☐

Others specify _____

51. Do you face problems of bats invasion in your farms?

Yes ☐ No ☐

52. If yes which measures do you use to protect your crops from being attacked by the bats?

_____

53. Which plants are highly destroyed by the bats?

_____

54. Do you sometime kill bats as pest's management?

Yes ☐ No ☐

55. Do you face issues of bats entering into your houses?

Yes ☐ No ☐

56. If yes how often do they enter in the houses

_____

57. Which seasons or periods do you experience a lot of bat invasion?

_____

58. Have you ever touched dead bats with bare hands?

Yes ☐ No ☐

59. If yes where do you put the dead bats

_____

60. Have you ever been bitten or scratched by the bat?

Yes ☐ No ☐

61. If yes what actions did you take once bitten or scratched by the bat?

_____

62. Do you think bats have a healing property?

Yes ☐ No ☐ I don't know ☐

63. If yes, which diseases are prevented with use of bats as medicine?

_____

64. Which part of the bat is used for medicine?

---

65. Do you practice hunting?

Yes ☐ No ☐

66. If yes which animals are more hunted and why?

---

67. Which kind of bush meat is highly consumed here? _____

68. Do you have pet animals?

Yes ☐ No ☐

69. If yes which pet animals _____

Part 5: Attitude / Belief

70. Which sex is more at risk for bat exposure?

Male ☐ Female ☐ Both Male and Female ☐

I don't know ☐

71. If yes give reason_____

72. I think bats are friendly

Yes ☐ No ☐ I don't know ☐

73.Which age group is at risk of being exposed to the bats?

0-25 ☐ >36 ☐

26-35 ☐ I don't know ☐

74. I think bats are highly rich in proteins?

Yes ☐ No ☐ I don't know ☐

76. I think bat remedies can heal people

Yes ☐ No ☐ I don't know ☐

78. I think bats are nuisance

Yes ☐ No ☐ I don't know ☐

Part 6: Awareness/ Health Education

79. Was there any bat project carried out in this place?

Yes ☐ No ☐

80. If yes by whom

Government ☐ NGO ☐ Others specify_____

81.Were the bats eradicated in this project / program?

Yes ☐ No ☐

82.What were the success and failures of the project / program?

Success	*Failures*

83. How would you want to learn about bats?

Listening to radio ☐ through education session ☐

Reading books ☐ watching TV ☐

Through village meeting ☐ social media ☐

84.Which one do you prefer?

Thank you for successfully completing the questionnaire

B: Observation Form

To be filled in by research team:

Date _____Interviewer _____

District _____Village _____sub village_____

GPS co-ordinates: longitude N _____latitude E

1. Bats roosting sites to find and establish human-bat interaction

2. Structure of doors and windows for the bat entry into the household

3. Outskirts of town to determine the occurrence of bats outside households where there is less protection

4. Schools and office premises for tree shades that provides shade to the bats

C: In-Depth Interview Guide

To be completed by the agricultural officer, veterinarians' officer, medical officer and community officers in Kilombero and Mvomero district.

Risks of human-bat interactions

1. According to you, how does diseases from the bat's spillover from the bats to humans occur?
2. Please tell us which activities or risk behaviors that cause people to be exposed to the bats. (Probing questions; why? where? give example? How to prevent? your advice?)

Knowledge on dangers of human-bat interactions, belief and practices

3. What is your perception on the bats? Do you think bats are important in the environment? Are there any risks that are associated with bats (probing question)? If yes what are the risks involved?
4. Please tell us if there is any disease that you know that can be sprayed from bats to humans? Is there are any health problems for human beings consuming bat's meat? (probing question: What are the problems, how to prevent)
5. Has there been any government/donor bat related projects /program /campaign carried out in this area? (Probing question: What was it about? What did it include? How was it implemented? What were the success and failure of the project?)

Health Education on bats

6. Please tell us the most important measures to be taken to reduce bats from interacting with people. (Probing questions; why? where? give example? How to prevent? your advice?)
7. Please tell us if there is any similar health education program /campaign put in place in this village. If no, do you have any plan to introduce the health education program? (Probing questions; how, when, who will be responsible, what will be the challenges)
8. If yes, what is it that you are addressing in health education at your village? (Probing questions; how? what is covered?)
9. Please tell us what you think about introducing health education on human-bat interactions to the affected areas (Probing questions; who should be in charge? what should it include? What should be the target age? methods of implementation? For how long? how often?

Thank so much for successfully completing the questions

D: FGD Form

Focused group discussion (FGD) for hunters, farmers, school going children, health care workers, veterinary officers, agricultural officers and those who live and work close to the bat roots in Kilombero and Mvomero districts, Tanzania.

Date_____ Village_____

Division_____district_____

Group Composition and Description

Name	Age	Sex	Occupation	Experience	Education	Family size
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Questions:

<u>Introduction</u>

After a brief self-introduction then lead to them rules to follow during discussion

"Before we start, I would like to remind you that there are no right or wrong answers in this discussion. We are interested in knowing what each of you think, so please feel free to share your points of view, regardless of whether you agree or disagree with what you hear. It is very important that we hear all your opinions. Please, do not interrupt when others are talking even if you disagree with their opinion. Let's start by going around the circle and having each person introduce her/himself."

(*Copies of informed consent and confidentiality forms should be provided to each participant and read aloud for the benefit of those who cannot read. Participants should be provided an opportunity to ask any questions. Verbal agreement should be taped*).

Risks of human-bat interactions

1. According to you, how does diseases from the bats spillover from the bats to humans occur?
2. Please tell us which activities or risk behaviors that cause people to be exposed to the bats. (Probing questions; why? where? give example? How to prevent? your advice?)

Knowledge on dangers of human-bat interactions, belief and practices

3. What is your perception on the bats? Do you think bats are important in the environment? Are there any risks that are associated with bats (probing question)? If yes what are the risks involved?
4. Please tell us if there is any disease that you know that can be sprayed from bats to humans? Is there are any health problems for human beings consuming bat's meat? (probing question: What are the problems, how to prevent)
5. Has there been any government/donor bat related projects /program /campaign carried out in this area? (Probing question: What was it about? What did it include? How was it implemented? What were the success and failure of the project?)

Health Education on bats

6. Please tell us the most important measures to be taken to reduce bats from interacting with people. (Probing questions; why? where? give example? How to prevent? your advice?)
7. Please tell us if there is any similar health education program /campaign put in place in this village. If no, do you have any plan to introduce the health education program? (Probing questions; how, when, who will be responsible, what will be the challenges)
8. If yes, what is it that you are addressing in health education at your village? (Probing questions; how? what is covered?)
9. Please tell us what you think about introducing health education on human-bat interactions to the affected areas (Probing questions; who should be in charge? what should it include? What should be the target age? methods of implementation? For how long? how often?