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DYNAMICS OF HUMAN-BAT INTERACTIONS: IMPLICATIONS FOR POTENTIAL TRANSMISSION OF CORONAVIRUS INFECTION IN KWAMANG, FORIKROM AND BUOYEM RURAL COMMUNITIES IN GHANA

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DECLARATION

I, Priscilla Anti, hereby declare that this thesis, "Dynamics of human-bat interactions: Implications for potential transmission of Coronavirus infection in Kwamang, Forikrom and Buoyem rural communities in Ghana", consists entirely of my own work produced from research undertaken under supervision and that no part of it has been published or presented for another degree elsewhere, except for the permissible excepts/references from other sources, which have been duly acknowledged.

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ABSTRACT

Evidence of Coronavirus in two species of cave dwelling insectivorous bats: *Hipposideros* aff. *ruber* and *Nycteris* cf. *gambiensis* has been confirmed in Ghana. This raises questions about human health risks since it is unknown whether this virus would potentially cause a zoonotic disease in humans. Human interactions, including livelihood practices that bring people into contact with cave bats are poorly documented. The study had a social survey design. Data was collected using focus group discussions; direct observations; face-to-face interviews with structured questionnaires and a review of available published/unpublished documents. A total of 1274 respondents were interviewed; Buoyem (412), Forikrom (362) and Kwamang (500) from July 2011 to October 2012. The results highlight the existence of human associations with bats, which have the potential to spread zoonotic diseases through complex contact networks. Sources of human-contact with bats identified include caves, farms, homes and schools. Caves were the highest source of contact with bats representing 31%, 45% and 37% in the three communities respectively. Age and gender were major factors that influenced contact with bats at the sources. Community use of bat caves were recreation, religious activities, bat hunting, water fetching, and guano collection. Occurrence of bat exposures included consumption of bat meat, mode of bat hunting and bat bites. Bat consumption was highest among respondents older than 50 years in all the communities representing 95%, 58% and 54% for Buoyem, Forikrom and Kwamang respectively. In Forikrom and Kwamang, men consumed more bat meat than women. Common tools for hunting bats within all three communities were guns, catapult, sticks and hands. Bat bites were highest in Buoyem (24%) followed by Forikrom (2%) and Kwamang (2%). More men than women experienced bat bites at Buoyem and Kwamang. Older respondents and men were the most at risk of bat exposures in all three communities. The study found no association between visiting bat caves and common cold infections. Furthermore, there was no report of any respiratory infections or epidemics from bat bites and bat consumption. As the human-bat interface is essential to the process of potential zoonoses like Coronavirus infection, one of the most important strategies for early detection would be monitoring people who have high exposure to bats. Public education to promote behavioural changes of humans would also enhance the prevention of any potential zoonotic diseases from bats.

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LIST OF ABBREVIATIONS

AAHL	Australian Animal Health Laboratory
BCI	Bat Conservation International
BCV	Bovine Corona virus
CBD	Convention on Biological Diversity
CCV	Canine Corona virus
CDC	Centers for Disease Control
CoV	Corona virus
EBOV	Ebola virus
EIDs	Emerging Infectious Diseases
FAO	Food and Agriculture Organization
HCoV	Human Corona virus
IBV	Avian Infection Bronchitis
IUCN	International Union for the Conservation of Nature
MARV	Marburg virus
PASW	Predictive Analysis Software
SARS	Severe Acute Respiratory Syndrome
SARS-CoV	Severe Acute Respiratory Syndrome Corona virus
TCV	Turkey Corona virus
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background to the Study

With over 4600 currently known species of mammals all over the world, bats represent the second largest order within mammals and have a very diverse diet ranging from plants, insects, animals and even blood (Wilson and Reeder, 1993; Calisher *et al.*, 2006; Wong *et al.*, 2007). They are generally known to be nocturnal and predominantly seek shelter in roosts during the day. They have varied roosting environments ranging from natural to man-made structures which can be temporary or permanent (Kunz and Lumsden, 2003). Natural roosts can be found in caves, rock crevices, nests of birds, ants and termites, cavities in trees, or exposed on tree branches and trunks (Kunz and Lumsden, 2003; Wong *et al.*, 2007). Man-made habitats on the other hand include mines, tombs, buildings, and bridges (Kunz and Lumsden, 2003; Wong *et al.*, 2007).

Recent reviews attribute 75% of all emerging infectious diseases (EIDs) that impact or threaten human health to be zoonotic that is, have an animal origin (Taylor *et al.*, 2001). Majority of these have jumped from wildlife reservoirs into humans either directly or indirectly (Field, 2009). Bats are now recognized as reservoir hosts for viruses which can cross species barriers to infect humans and other domestic and wild mammals (Calisher *et al.*, 2006). Wong *et al.*, (2007) explains that their species diversity and unique biological and ecological features allow them to become hosts for a large number of medically important infectious agents.

The livelihood and behaviour of man as well as the search for foods by bats could bring them into close contact with humans and their livestock thereby facilitating interspecies transmission of infectious agents (Wong *et al.*, 2007). Therefore, human–bat interactions are critical to determining people's exposure to potential zoonotic pathogens they may carry however, this crucial driver of spillover has been insufficiently studied (Wood *et al.*, 2012).

In Ghana, many people may come into contact with bats in several ways including the use of their products such as meat and guano. Although it is believed that well-cooked bat meat is unlikely to pose any risk for transmission of infections, capture and slaughtering of bats could expose the handler to blood and body fluids or bites and scratches (Shakespeare, 2002). Moreover, in situations where live bats are kept in captivity such as in game markets; they may come into close contact with other animals, which are susceptible to viruses carried by bats (Wong *et al.*, 2007). Furthermore, as humans invade further into previously uncultivated environments, new contacts between wild fauna including zoonotic reservoirs such as bats and humans increase the risk of cross-species infection (Patz *et al.*, 2005a).

1.2 Problem Statement

Bats harbour potential pathogenic viruses including Filoviruses (Ebola and Marburg virus), Paramyxoviruses (Hendra and Nipah virus, Tioman virus), Lyssaviruses and the focus of this study; Coronaviruses (CoV) (Taylor *et al.*, 2001; FAO, 2011). Within the past decade interest in bats and their role in Coronavirus transmission have increased around the world. The discovery of the Severe Acute Respiratory Syndrome (SARS) Coronavirus (SARS-CoV), originating from bats in 2003, was key in turning scientific interest towards the study of bats as the most likely reservoir of all known coronaviruses (Li *et al.*, 2005; Poon *et al.*, 2005). This novel zoonotic coronavirus caused an international epidemic but fortunately, effective public health management halted this epidemic (Drosten *et al.*, 2003). Among the most urgent concerns prompted by the SARS epidemic is the likelihood of similar future events (Pfefferle *et al.*, 2009).

In 2009, evidence of Coronavirus in some species of cave dwelling bats (*Hipposideros* aff. *ruber*) was confirmed in two rural communities in Ghana, Buoyem and Kwamang (Pfefferle *et al.*, 2009). The findings from the study strongly suggest that a common ancestor of the human CoV-229E (which causes common cold) and bat CoV existed about 205 years ago. Annan *et al.,* (2013) has also identified a novel bat CoV (*Beta coronavirus*) in *Nycteris* cf. *gambiensis,* another cave dwelling insectivorous bat in these rural Ghanaian communities. This evidence thus, raises pressing questions about human health risks since it is unknown whether the coronaviruses in these bats would potentially cause a zoonotic disease in humans. There is a potential risk of disease transmission when people are in close or regular contact with bats and this is an area of research that requires more attention (Kamins *et al.*, 2014).

Research on how humans interact with cave dwelling bats and the extent of such interactions is virtually lacking in Ghana. As a consequence, understanding the potential impact on public health is limited. To mitigate and manage this risk therefore, requires an appreciation of the interactions between human and wildlife, in this case, bats (Field, 2009). A lot of studies have been conducted to determine the ecology of bat CoVs in terms of diversity, virus prevalence among others. However, it seems highly relevant from a socio-economic perspective to study the potential transmission of coronavirus infection as a result of changing human-bat interactions within rural Ghanaian communities. The potential implications of the bat Coronavirus are particularly not known in Ghana possibly because the caves they inhabit have not been fully explored. Consequently, as human interactions with cave dwelling bats occur characteristically in these communities, it becomes important to study them.

1.3 Justification of the Study

Field (2009) points out that, in order to understand the ecology of wildlife as reservoirs/hosts for pathogens, it is important to first of all, to understand the social and cultural context of wildlife-human interface. In this context, bats provide a critical focus for study at the wildlife-human interface. A lot of research is needed to document the roles of bats of different species in the natural history of the many viruses such as CoV for which these animals can serve as hosts (Calisher *et al.*, 2006). Because of the complexity of wildlife-human disease transmission, a multi-disciplinary scientific approach to studying disease dynamics and emergence becomes necessary (Daszak *et al.*, 2004; Wood *et al.*, 2012).

Tropical developing countries are more vulnerable to infectious diseases due to their greater exposure to the vectors of infectious diseases and environments where they occur (Patz *et al.*, 2005a). This is because of inadequate resources to respond to and cope with them. Furthermore, there is not enough surveillance for wildlife diseases or infections especially in developing countries like Ghana. There is a growing literature on the damaging impact as a result of certain unforeseeable events. In these countries their studies usually are outbreak-driven, that is after an epidemic of a newly recognized virus has emerged (Calisher *et al.*, 2006). It is when such situations arise that leaders and scientists begin to speculate how the virus could have evaded detection. According to Bloom (2005), an essential aspect of the capacity of individuals, communities and societies to develop is their ability to avoid major shocks, mitigate their impact and cope with the consequences of those that occur. This could be linked to how rural communities in Ghana can cope in the advent of any potential zoonotic disease outbreaks. Thus, understanding how, why, where and for whom cave dwelling bats may pose problems, specifically in areas where they are found, is necessary.

In addition, we need to know whether the occurrence of common cold infections (known to be caused by Coronaviruses), is generally believed to be associated with visiting bat caves, collecting bat guano, hunting bats for sale and personal consumption and other anthropogenic activities within these communities. Even though there is little direct evidence to indicate that Coronaviruses in bats can cause severe disease in other domestic animals and in humans, there is an increased possibility of virus variants crossing the species barrier and causing outbreaks in humans as people come into closer contact with wild animals (Shi and Hu, 2007; Pfefferle *et al.*, 2009). Hayman *et al.*, (2012) address the difficulties in quantifying human–bat interactions. This is because these interactions are increasing and occurring in numerous ways including humans encroaching into bat habitats, and bats also utilizing artificial structures as roosts. Unveiling the magnitude of the interactions humans have with bats would be a critical step in identifying potential risk groups for zoonotic transmission. Hence this study reports on general trends with respect to community cave use, and consumption patterns of bats. According to Field (2009), the investigation of emerging infectious diseases (EIDs) associated with wildlife requires a trans-disciplinary approach that includes an understanding of human behaviours that increase risk of exposure.

Therefore, in the wake of the outbreak and spread of SARS in 2003, this study seeks to understand two main issues. The first is the social associations of humans with bats in some rural Ghanaian communities such as how people perceive and interact with bats within their living environment and via livelihoods; bat meat consumption; and ritual practices associated with bats. The second is the complexities/extent of such interactions that may expose them to Coronavirus in bats either from direct or indirect contact with bats through secretions, bites and scratches. The findings from this study would enhance our knowledge about individuals who are most at-risk of bat exposure as a result of regular contact with bats or bat dwellings whether through occupational activities and or other practices. Furthermore, it would describe the occurrence of bat-associated exposures in communities and explore factors associated with bat exposures that are of potential consequence to Coronavirus infections. One important lesson learnt in the aftermath of the SARS epidemic is the need for public health surveillance. According to McMichael (2004), such understanding would therefore assist in the anticipation of any such future risks as the configurations of human ecology, society, environment, technology and behaviour continue to change. This study would therefore, help create awareness and the institution of preventive approaches against potential zoonotic epidemics in these areas.

1.4 Aim, Specific Objectives and Research Questions

The aim of this research was to study the dynamics of human-bat interactions as implications for potential coronavirus infection in humans.

The specific objectives of this study were to;

1. Identify the sources of human-bat contact within the communities
2. Determine socio-demographic characteristics of respondents and sources of contact with bats

3. Determine community use of bats, their caves and the occurrence of bat exposures
4. Identify evidence of common cold infections and disease epidemics from past bat exposures

From the specific objectives the following research questions were derived;

1. What are the sources of human-bat contact within the communities?
2. What socio-demographic characteristics are associated with the sources of human-bat contact?
3. How do the communities use bats and their caves and so shape differential risks of bat exposure?
4. Are there any risks of common cold infections from use of bat caves and contact with bats?
5. Has there been any disease epidemic and from past bat exposure within the last 30 years?

CHAPTER 2: LITERATURE REVIEW

2.1 Classification of Bats

Bats are the only true flying mammals that belong to the order Chiroptera meaning handwing (Greenhall, 1982). They are second only to rodents in numbers of living genera and species, and are the largest order of mammals in overall abundance (Kunz and Lumsden, 2003). They are grouped into two main groups: Flying foxes (Old world fruit bats) and Insectivorous bats (Teeling *et al.*, 2005). Flying foxes are predominantly frugivorous and contain a single family, Pteropodidae (42 genera, comprising 187 species). The insectivorous bats largely feed on insects and they contain 16 families (135 genera, comprising 963 species) (Calisher *et al.*, 2006; Van Der Poel *et al.*, 2006; IUCN, 2010).

2.2 Characteristics of Bats

Bats possess certain characteristics that may explain their importance as reservoir hosts for disease causing pathogens (Luis *et al.*, 2013). These unique characteristics include high species diversity; long life span; the capacity for long-distance dispersal; dense roosting aggregations (colony size); social behaviours and population structure; the use of torpor and hibernation; unique immunology; and spatial population structure (FAO, 2011). These key attributes may contribute to a greater occurrence of infectious diseases they are known to cause (Calisher *et al.*, 2006; FAO, 2011).

2.2.1 Population size

Bats are known to be abundant, widely distributed and highly gregarious (Messenger *et al.*, 2003; Calisher *et al.*, 2006; Chong *et al.*, 2009). Some species aggregate with a density of more than 3,000 bats/m^2 (Calisher *et al.*, 2006; Wong *et al.*, 2007). High population densities of susceptible individuals present opportunities for disease-causing pathogens to invade and spread rapidly (Messenger *et al.*, 2003). The diversity of bat species alone, together with their worldwide distribution, contributes to the biodiversity of their pathogens (Kuzmin *et al.*, 2011).

2.2.2 Life span

Bats are known to have very long life spans (Kunz and Lumsden, 2003; FAO, 2011). For their size, bats are mammals that have a relatively long life span. Many species of bats such as *Rhinolophus ferrumequinum, Plecotus auritus, Myotis lucifus* are recorded to live for at least 30 years (Tuttle and Stevenson, 1982; Calisher *et al.*, 2006). The extreme longevity of bats, together with the possibility that they might develop persistent infections with certain viruses, may help maintain viruses and transmit them to other vertebrates (Calisher *et al.*, 2006; FAO, 2011).

2.2.3 Habitat use and roosting behaviour

Due to similar life histories, many bat species may share the same habitats (Messenger *et al.*, 2003). Several species of bats may roost in a single cave and forage in the same immediate area. In tropical areas, primary or well regenerated secondary forests are used by many taxa; and woodlands are used in temperate areas (Mickleburgh and Hutson, 2001). According to Mickleburgh *et al.,* (2001), aquatic habitats (e.g., rivers, streams, lakes, and canals) are also preferred as feeding areas as they often attract a rich supply of insects that are the main food source for many species particularly insectivorous bats.

Bats use a wide variety of sites for roosting (Kunz, 1982; Mickleburgh and Hutson, 2001). Insectivorous species like *Nycteris thebaica* inhabit holes in trees that have been created naturally or through the activities of other animals such as birds (Hackett *et al.*, 2013). Across both temperate and tropical regions, caves serve as roosting sites for bats. In temperate areas species like Bechstein's bat (*Myotis bechsteinii*) and Hodgson's bat (*Myotis formosus*) have been recorded to hibernate in caves and mines (Kerth and Van Schaik, 2012; Kim *et al.*, 2012). Hibernation is a physiological and behavioural adaptation that enables bats to survive during seasonal periods of energy shortage (Kim *et al.*, 2012). Bats may also use artificial structures such as buildings (Hernandez-Mijangos and Medellin, 2013). The ability of bats to occupy man-made structures is of particular importance, because it increases the opportunities for interactions between bats, domestic animals, and humans. For example, the big brown bat (*Eptesicus fuscus*) and the serotine bat (*Eptesicus serotinus*), both of which are known to harbour Lyssaviruses, commonly roost in man-made structures (Kuzmin *et al.*, 2011).

Bats often inhabit and feed in agricultural areas, which brings them into closer contact with humans and domesticated animals (Kuzmin *et al.*, 2011). Some species have adapted well to urban environments and can be found feeding and roosting within major cities. The presence of fruit bats in Ghanaian cities, for instance, demonstrates their ability to adapt to changing environments. Many bat species also roost together in very large and dense colonies. Mixed species roosts are common in some species of *Pteropus* (Kunz and Lumsden, 2003). Use of a common site by several species therefore, raises the possibility of interspecific transfer of disease-causing agents (Messenger *et al.*, 2003). Moreover, their crowded roosting behaviour increases the likelihood of intra- and interspecies transmission of viral infections (Calisher *et al.*, 2006). For example *Myotis* have been found to harbour a diverse range of rabies virus as a result of high levels of interspecies contact. Bats are known for forming the largest aggregations of all mammals and are thus considered one of the most social groups of mammals. Depending on the species, season, and location of the roost, colony sizes range from a few to millions of individuals (Calisher *et al.*, 2006). For example species like the *Hipposideros caffer* form very large groups with just one colony comprising more than 1000 individuals (Kingdon, 1974). This dense clustering of individuals provides good opportunities for viral exchange within bat populations (Kuzmin *et al.*, 2011).

2.2.4 Capacity for long-distance dispersal

Capacity for long-distance dispersal is the predominant characteristic that distinguishes bats from all other mammals. Bat movements may range from short distances between roosts and foraging areas to long-range migrations between seasonally occupied sites (Fenton, 1997). For example; some insectivorous bats have been tracked travelling 10 to 15 km from their day roost during foraging activities as far as 80 km (Kunz and Pierson, 1994). Fruit bats have been known to travel as far as 87.5 km from their day roost for foraging (Epstein *et al.*, 2009). This extensive foraging flights and seasonal migrations bats exhibit means that they are able to transport disease-causing agents to many different locations per unit time (Bloom, 2005). According to Messenger *et al.,* (2003), migratory habits of some species of bats provide an opportunity for pathogens to cover long distances and bridge gaps between species assemblages that otherwise might not be in contact. This carries obvious implications for infectious disease transmission.

2.3 Ecosystem Services Provided by Bats

Interactions between bats and ecosystems are diverse. This is because of the many services they provide to the ecosystem. Ecosystem services are the benefits obtained from the environment that increase human well-being (Kunz *et al.*, 2011). The Convention on Biological Diversity (CBD) defines ecosystem "as a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit" (Hein *et al.*, 2006). The health and wellbeing of human populations depend on the services provided by ecosystems and their components. Greenhall (1982) highlights that bats and humans have a long and complicated relationship and as a result, many of the negative perceptions people associate with bats are based on myths, fears and misinformation. There are some valid cases where bats pose problems to humans and thus are seen as negative values, but humans also value bats in a number of ways. People benefit from bats both directly and indirectly (FAO, 2011). Direct values are classified as consumptive use value and productive use value such as food and guano which support agricultural crops (Chardonnet *et al.*, 2002). Indirect values are also classified as non-consumptive use value, option value and existence value such as scientific research, bat watching (aesthetic value) and ecological roles in maintaining ecosystems. According to FAO (2011), ecosystem services provided by bats include regulatory services, provisioning services and cultural services.

2.3.1 Regulatory services

Regulatory services refer to the capacity of natural and semi-natural ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes (de Groot *et al.*, 2002; Hein *et al.*, 2006). These include carbon sequestration, regulation of temperature and rainfall patterns (climate regulation). Others include protection against floods by coastal or riparian systems, regulation of erosion and sedimentation, protection against storms, noise and dust, biological nitrogen fixation, soil formation, waste treatment, pollination and biological control. These services provide both direct and indirect benefits to humans such as maintenance of good air quality, provision of water for consumptive purposes (e.g. drinking, irrigation, industrial use), maintenance of arable land, good drainage and natural irrigation.

Bats provide a number of regulatory services including pest suppression, seed dispersal, and pollination of a wide variety of ecologically and economically important plants including *Adansonia sp., Bombax sp., Ceiba sp., Ficus sp.,* Mango, Cashew and Coffee within both agricultural and natural ecosystems (Kunz *et al.*, 2011). According to FAO (2011), about 289 species of plants rely on bats for pollination and seed dispersal, resulting in 448 economically valuable products. This contributes to forest regeneration and maintenance of healthy functioning ecosystems. Insectivorous bats consume large volumes of insects per night, which translates into sizeable economic benefits, as many of the insects eaten are agricultural pests (Whitaker, 1993). According to Bat Conservation International (BCI), bats save farmers in the United States of America between 3.7 and 57 billion dollars every year in pesticide costs.

2.3.2 Provisioning services

Provisioning services are the goods and services produced in the ecosystem (Hein *et al.*, 2006). These include food, fodder (including grass from pastures), fuel (including wood and dung), timber, fibres and other raw materials. Bats provide the primary organic input to cave ecosystems through their faecal material also known as guano (FAO, 2011). Guano are collected or in some parts of the world even mined from caves for personal use as fertilizer on agricultural crops due to the high concentrations of nitrogen and phosphorus (Kunz *et al.*, 2011). Furthermore, because guano is such an effective and valued resource, it is often harvested commercially in larger caves for international trade (FAO, 2011). Human beings are not the only ones who gain but also cave dwelling animals like salamanders and other invertebrates are also highly dependent on the nutrients from bat guano (Fenolio *et al.*, 2006; FAO, 2011).

Bats also provide a direct source of food in many countries. The hunted species are predominantly fruit bats, but a few species of insectivorous bats are also hunted in Asia and Africa (FAO, 2011). In Madagascar, larger species like *Pteropus rufus, Eidolon dupreanum, Rousettus madagascariensis* and *Hipposideros commersoni* are preferred (Jenkins and Racey, 2008).

2.3.3 Cultural services

Cultural ecosystem services refer to the aesthetic, spiritual, psychological, cognitive development, relaxation and other non-material benefits that humans obtain from contact with ecosystems (Butler and Oluoch-Kosura, 2006; Hein *et al.*, 2006). Following Hein *et al.*, (2006), these include nature and biodiversity (provision of a habitat for wild plant and animal species), provision of cultural, historical and religious heritage (e.g., a historical landscape or a sacred forest). Others include provision of scientific and educational information, opportunities for recreation and tourism and also attractive landscape features enhancing housing and living conditions (amenity service) (de Groot *et al.*, 2010).

Many indigenous people have spiritual bonds with sacred landscapes, groves, and species of flora and fauna. Many farmers form emotional bonds with the herds and flocks they depend upon for their livelihood (Zinsstag, 2001). Bats are used for medicinal purposes; in ancient magic to induce desire and drive away sleep and also to treat ailments of patients such as baldness and paralysis by witchdoctors (Mickleburgh *et al.*, 2009). They also provide aesthetic value through cave visits thereby promoting ecotourism. According to Kunz *et al.*, (2011), bat watching is a growing recreational activity although it is not as widely practised as bird watching. The majority of bat viewing takes place at cave entrances where nightly emergences are viewed (Kunz *et al.*, 2011). These activities provide adventure and life memories for the public and generate revenue for the communities and stakeholders involved (Norberg, 1999).

2.4 Potential Negative Services

Bats in the process of providing these ecosystem services of highly economic benefits to man may also have some negative effects on man either directly or indirectly. The threat of pathogen transfer from bats to people is of growing concern as more bat species (cave bats) have been identified in Ghana as vectors of emergent viral diseases (Pfefferle *et al.*, 2009; Annan *et al.*, 2013). In fact, virtually little work has documented the modes of capture, preparation and consumption of these bats in Ghana which may also risk potential pathogen transmission to humans from eating their meat or through direct handling.

2.4.1 Infectious diseases

According to the World Health Organization (WHO), infectious diseases account for close to one quarter of the global burden of disease and majority of these are of zoonotic origin (Taylor *et al.*, 2001; Patz *et al.*, 2005a). In the early part of the 20th century, some scientists in Western Europe believed two primary disciplines were enough to explain and control infectious diseases: microbiology and epidemiology. Though there were others who knew social factors also played a major role, the discovery of vector-borne diseases in transmission led to the agent-host-environment model of infectious disease (Figure 2.1), which still serves as the central model for examining emergence of specific diseases. The process of emergence usually begins with a novel physical contact between a potential pathogen and humans (McMichael, 2004). Contact event may arise naturally or through cultural, social, behavioural or technological change on the part of humans (McMichael, 2004). The infectious agent mostly derives from an animal source or soil and an important requirement is that the potential pathogen should be able to enter and survive in the human host (McMichael, 2004; Siegel *et al.*, 2007).

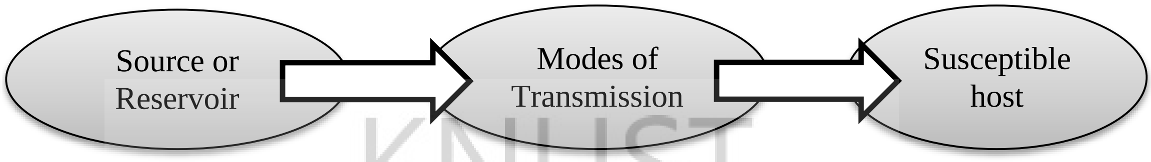

Figure 2.1: Dynamics of infection after McMichael (2004)

Parkes *et al.,* (2005a) argues that, this model fails to throw light on the social and ecological settings in which the phenomenon of the disease emergence takes place and therefore provides a comprehensive review of adopting a trans-disciplinary approach to studying emerging infectious diseases. Using the Nipah outbreak as an example, a social science perspective was not incorporated in the investigation though interdisciplinary teams of medical, ecological, molecular and genetic researchers conducted the investigation. Although their findings indicated the contributing factor to the outbreak, the argument still remains that there was a need for better understanding of the significant role that socio-economic and cultural factors played in Nipah's emergence. Hence innovative research projects such as this that seeks to engage in place-based knowledge sets of communities vulnerable to EIDs is critical to preventing potential emerging infections (Parkes *et al.*, 2005).

2.4.2 Zoonoses

Zoonoses are diseases and infections that are naturally transmitted between vertebrate animals (wild or domestic) and man (Leggat and Goldsmid, 2001; Meslin, 2006). Zoonotic pathogens are significant causes of historical diseases (including HIV and tuberculosis) and newly emerging infectious diseases affecting humans such as

SARS, West Nile virus, and Hendra virus (Patz *et al.*, 2005a). These pathogens consist of a very diverse collection of organisms such as Arthropods, Bacteria, Fungi, Helminths, Prions, Protozoa, Rickettsia and Viruses (Shakespeare, 2002).

Over the years, bats have increasingly played significant roles as reservoirs of highly pathogenic viruses for emerging infectious diseases (EIDs) (Calisher *et al.*, 2006). Ebola virus, Hanta virus, Henipa virus, Severe Acute Respiratory Syndrome (SARS) Coronavirus are examples of bat-associated zoonoses that have had a significant impact on human health globally (Field, 2009)

2.4.3 Drivers of zoonoses

Zoonotic infections are generally associated with anthropogenic forces involving high contact rates with the wild animal host (Patz *et al.*, 2004; Slingenbergh *et al.*, 2004). Example of such anthropogenic forces include global travel, trade, agricultural expansion, deforestation/habitat fragmentation, and urbanization (Morse, 2004; Patz *et al.*, 2004). Katare and Kumar (2010) categorize the factors under either an agrarian or an industrialized setup (Table 2.1).

Table 2.1: Drivers of zoonoses after Katare and Kumar (2010)

Agrarian	Industrialized
Sharing the same environment with livestock	Leisure time activities (camping, hunting),
Movement of animal populations	Ownership of pets
Limited human medical and veterinary medical facilities	Intensive animal production
Low literacy rate	Cultural trends
Poor sanitation/hygiene	Socio-economic conditions

Chomel *et al*., (2007) group these factors under the following: human behaviour, modifications to natural habitats, and changes in agricultural practices. The impacts of these factors are amplified by human demographics and socio-economic advancement from poverty towards middle income (FAO, 2011). These increase the interface and/or the rate of contact between humans, domestic animals, and wildlife populations, thereby creating increased opportunities for spill-over events to occur (Daszak *et al.*, 2000; Field, 2009).

2.5 Importance of Zoonoses

The importance of zoonoses in terms of human health and well-being cannot be overemphasized (Shakespeare, 2002; Vaske *et al.*, 2009). Zoonotic diseases pose a threat to both the physical and social environment of man (FAO, 2011). These include animal welfare (both domesticated and wild); food/water safety and public health. Three major trends have made zoonoses a critical issue (Vaske *et al.*, 2009). These comprise:

1. Human population growth
2. Globalization of travel and trade
3. Increased participation in outdoor activities.

Increasing human population growth and mobility have enhanced transfer of pathogens and as a result intensified disease spread (Butcher and Ulaeto, 2005). Moreover, this has increased fragmentation of wildlife habitats and proximity of wildlife to humans and consequently, an increase in the potential for humans to contract diseases from wildlife.

Globalization of travel and trade has led to increasing rates of disease transmission and the spread of diseases (Vaske *et al.*, 2009). Furthermore, increased participation in outdoor recreation activities has also amplified the proximity of wildlife to humans (Vaske *et al.*, 2009). Ecotourism and adventure tourism for instance have increased the exposure of wildlife and humans to diseases not common in their respective home environments (FAO, 2011). Impact of zoonoses on human society include illness, monetary loss; unfavourable publicity; man-hours lost; food scares with boycotts; dietary change; consumer/producer costs; fear; anxiety; morbidity and mortality (UC Santa Barbara Office of Research, 1996; Shakespeare, 2002). These have major socio-economic implications through direct impact of the disease and also through collective and international costs incurred in their prevention and control. An example is the SARS, which caused economic losses in tourism due to fear of rapid disease transmission (Drosten *et al.*, 2003).

2.5.1 Transmission of bat associated zoonoses

Zoonoses can be transmitted through direct and indirect contact with wildlife or domesticated animals (Shakespeare, 2002; Vaske *et al.*, 2009). The pathways for zoonotic disease emergence are determined by nature and frequency of human interactions with animals (LeBreton *et al.*, 2012).

For a zoonotic disease to emerge, it has to first of all be introduced into the human population, followed by subsequent human-to-human transmission. A wide range of factors determine the probability of spread of an infectious pathogen from an animal to human (Swift *et al.*, 2007). Among these include; the number of animal–human interactions; number of different species to which humans are exposed; the probability that any animal is carrying a pathogen; the nature of the human–animal interaction; the genetic susceptibility of the human hosts; the infectiousness of the pathogen for humans, and its virulence and geographical remoteness (Swift *et al.*, 2007).

Wildlife such as bats often harbour microbes and parasites that are not pathogens for them but become disease agents for other species (Mahy and Brown, 2000). Therefore, human infections may sometimes occur through contact with other species and not necessarily the bats. In other words, contact between humans and other animals can provide the opportunity for cross-species transmission and thus facilitate the emergence of new pathogens into the human population (Patz *et al.*, 2005a).

2.6 Modes of Transmission of Zoonotic Infectious Agents

Though bats do not normally prey on humans, transmission of the viruses they carry to humans can occur in a variety of ways (Wong *et al.*, 2007). These include direct and indirect modes of transmission (Kagan *et al.*, 2002; Siegel *et al.*, 2007). The modes of transmission are categorized under the following Brachman (1996) Sattenspiel and Slonim (2000):

1. Respiratory or Airborne
2. Physical contact with animal secretions and excretions

} Direct transmission

3. Food-borne and or Water-borne
4. Vector-borne

} Indirect transmission

Direct transmission occurs when microorganisms are transferred from an infected animal (primary host) to another person without a contaminated intermediate object or person (Shakespeare, 2002; Siegel *et al.*, 2007). This occurs mainly through bites or contact with infectious fluids from saliva or tissues (UC Santa Barbara Office of Research, 1996; Kagan *et al.*, 2002; Siegel *et al.*, 2007). An example of zoonotic infection associated with bats that occurs through direct transmission is Rabies (Kuzmin *et al.*, 2011).

Indirect transmission occurs when an intermediate host or agent transfers pathogens from one primary host to another (Kagan *et al.*, 2002; Siegel *et al.*, 2007). Examples of occasions for indirect contact transmission to occur are individuals who come into contact with contaminated water or soil, or inhaling airborne pathogens (Shakespeare, 2002).

2.6.1 Respiratory or Airborne

According to Sattenspiel and Slonim (2000), this is the most common mode of transmission of human diseases. Respiratory transmission of infectious agents such as bacteria or viruses occurs through aerosols, respiratory droplets and spores (Kruse *et al.*, 2004). Aerosols refer to fine droplets or particles that remain stable for relatively long periods of time in the air and are capable of carrying infectious agents (Roberto and Rodi, 2009). Respiratory droplets are aerosols from the lungs that are released when people sneeze, cough, laugh, and exhale (Siegel *et al.*, 2007). This mode of transmission is also known as droplet transmission (Sattenspiel and Slonim, 2000). Spores of fungi like *Aspergillus spp* are common in the environment and may cause disease in individuals who inhale aerosolized construction dust (Tang *et al.*, 2006).

Another example is Histoplasmosis, a fungal infection transmitted by exposure to bat droppings that contain spores infected with *Histoplasma capsulatum* has been contracted in the USA from inhaling dust in caves where bat droppings accumulate (Calisher *et al.*, 2006; Snell, 2008; FAO, 2011). The infected spores contaminate the soil and become airborne when the soil is disturbed. Inhalation of these spores causes lung infection that may present as fever, cough, and chest pain while breathing, which may be fatal if left untreated (Ferguson, 2001). Microorganisms carried in this manner may be dispersed over long distances by air currents and inhaled by susceptible individuals who have not had face-to-face contact with the infectious animals (Siegel *et al.*, 2007). For example, the Hantaviral disease, a rare but fatal disease that causes cough, fever, shortness of breath, decreased blood pressure, and kidney failure is transmitted through inhaling air contaminated with rodent urine and droppings infected with the Hantavirus (Kruse *et al.*, 2004). According to Roberto and Rodi (2009) however, the mere presence of infectious organisms in the air is generally insufficient to cause a disease.

2.6.2 Physical contact

Some zoonotic infections may spread through physical contact with animal secretions and excretions (Kruse *et al.*, 2004). An example is Ebola haemorrhagic fever, a severe viral disease that causes high fever, external and internal bleeding, low blood pressure, and shock (Leggat and Goldsmid, 2001; Shakespeare, 2002). This disease is spread by contact with infected blood, tissues, secretions, or excretions of bats, primates (chimpanzees and gorillas), and forest antelopes (Muyembe-Tamfum *et al.*, 2012). Another example is rabies, which may be transmitted through a bite of an infected animal or after an open wound or mucus membrane is exposed to infected fluids such as blood or saliva (Leggat and Goldsmid, 2001; Shakespeare, 2002; Maine Rabies Workgroup, 2012).

2.6.3 Food-borne and/or water-borne

Contamination of food and water by faecal matter or urine may cause zoonotic infections (Shakespeare, 2002). Certain bacteria such as *Salmonella spp*, *Leptospira spp.* and *Escherichia coli* cause intestinal infections (Uraemic Syndrome) which are acquired through the consumption of contaminated meat and water from infected animals such as poultry, pigs, or cattle (Brachman, 1996; Kruse *et al.*, 2004; Morse, 2004). Other examples are parasites such as *Cryptosporidium* and *Giardia*, which cause intestinal infections, are transmitted through the consumption of water contaminated with faeces from infected animals such as dogs, cats, cattle, bats, and waterfowls (Leggat and Goldsmid, 2001).

2.6.4 Vector-borne

Vectors like ticks, fleas, mosquitoes, and lice may also cause transmission of zoonosis (Sattenspiel and Slonim, 2000; Shakespeare, 2002). A vector is an insect or any living carrier that transports an infectious agent from an infected animal/individual or its wastes to a susceptible individual, its food or immediate surrounding (Leggat and Goldsmid, 2001). Lyme disease (a zoonotic disease common in Europe and the USA) caused by the bacteria *Borrelia burgdorferi*, is transmitted by Ixodid ticks (Leggat and Goldsmid, 2001). Transmission occurs after a tick that is carrying the bacterium bites a person. These ticks are often found on deer, weasels, bats, and rodents. Another example is Plague, a potentially fatal bacterial disease, that is transmitted through the bite of an infected flea *Xenopsylla cheopis*; it is often found on animals such as rodents, and rabbits (Sattenspiel and Slonim, 2000; Carniel, 2008).

2.6.5 Risk factors of zoonosis

A risk factor is defined as an aspect of personal behaviour or lifestyle, an environmental exposure, or an inborn or inherited characteristic that is associated with an increased risk of a person developing a disease (Leggat and Goldsmid, 2001). Certain individuals may be at greater risk for contracting zoonoses (Shakespeare, 2002). Individuals who are at increased risk of contracting zoonotic diseases include veterinarians, farmers, slaughterhouse workers or butchers, poultry workers, zoo employees, food-industry operatives, animal handlers, wildlife scientists or researchers working in animal laboratories, children, and elderly persons (Shakespeare, 2002; Vaske *et al.*, 2009). According to Kuzmin *et al.*, (2011), a recent study linked the index case of Ebola virus (EBOV) outbreak in the Democratic

Republic of the Congo (DRC) in 2007 to a contact with freshly killed fruit bats, which were migrating in close proximity to the outbreak villages and thus represented an important food source for the local people. Other groups at risk include individuals who participate in outdoor recreational activities, such as hunting (Vaske *et al.*, 2009). It has been demonstrated that the majority of human cases of Marburg virus (MARV) infection could be linked to visitation of caves and mines in Uganda (Kuzmin *et al.*, 2011).

2.7 Sources of Potential Human-Bat Contact

Due to the wide variety of roosting sites used by bats, there are increased opportunities for interactions between bats and humans. Contact zones between systems are sites for potential transfer of pathogens to susceptible human populations (Patz *et al.*, 2005b). These sites can both be natural or artificial. Different types of systems may harbour a unique set of infectious diseases (Table 2.3). Bats reveal their presence through different forms such as faecal droppings, odours from urine, faeces, and glandular body secretions (Greenhall, 1982). Human contacts with systems containing foci of infections therefore increase the risk of human infections (Patz *et al.*, 2005b). Hence it is important to identify where bats may come into contact with humans in the communities.

Table 2.2: Sources of some viral infections from bats after Wong *et al.*, (2007)

Virus	Natural reservoir host	Possible source of transmission
SARS Corona virus	Bats	Wet markets
Ebola virus	Bats	Forests
Hendra virus	Bats	Farms
Nipah	Bats	Farms, abattoirs
Rabies virus	Bats	Rural residents
Marbug virus	Bats	Caves

2.8 Socioeconomic Aspects of Understanding Zoonotic Disease Transmission

In Ghana bats play a vital role in the economy and contribute in various ways to the well-being of their inhabitants (Kamins *et al.*, 2011). Bats provide a lot of consumptive goods such as animal protein in human diets and organic fertilizer. In most rural communities, livestock and other animals live in close proximity to humans, therefore any potential contagious disease in these animals is transmissible to people representing a direct threat to human health (Meslin, 2006). Zoonotic diseases, therefore, create permanent direct and indirect threat for livestock keepers, rural dwellers and consumers.

Despite the aforementioned ways of how zoonoses occur or are transmitted, there is a clear indication of how rarely socioeconomic aspects to understanding zoonotic disease transmission at especially the human-bat interface are studied. Wood *et al* (2012) therefore, propose a framework using bat-related disease threats as an example (Figure 2.2). The framework shows that in order to fully address the risks of bat-derived zoonoses, there should be a social science perspective. One of the thematic areas of research they proposed was studying human-bat interactions. They suggested that such thematic research should be based on livelihood approaches, which seek to understand human–bat interactions in their bio-cultural context.

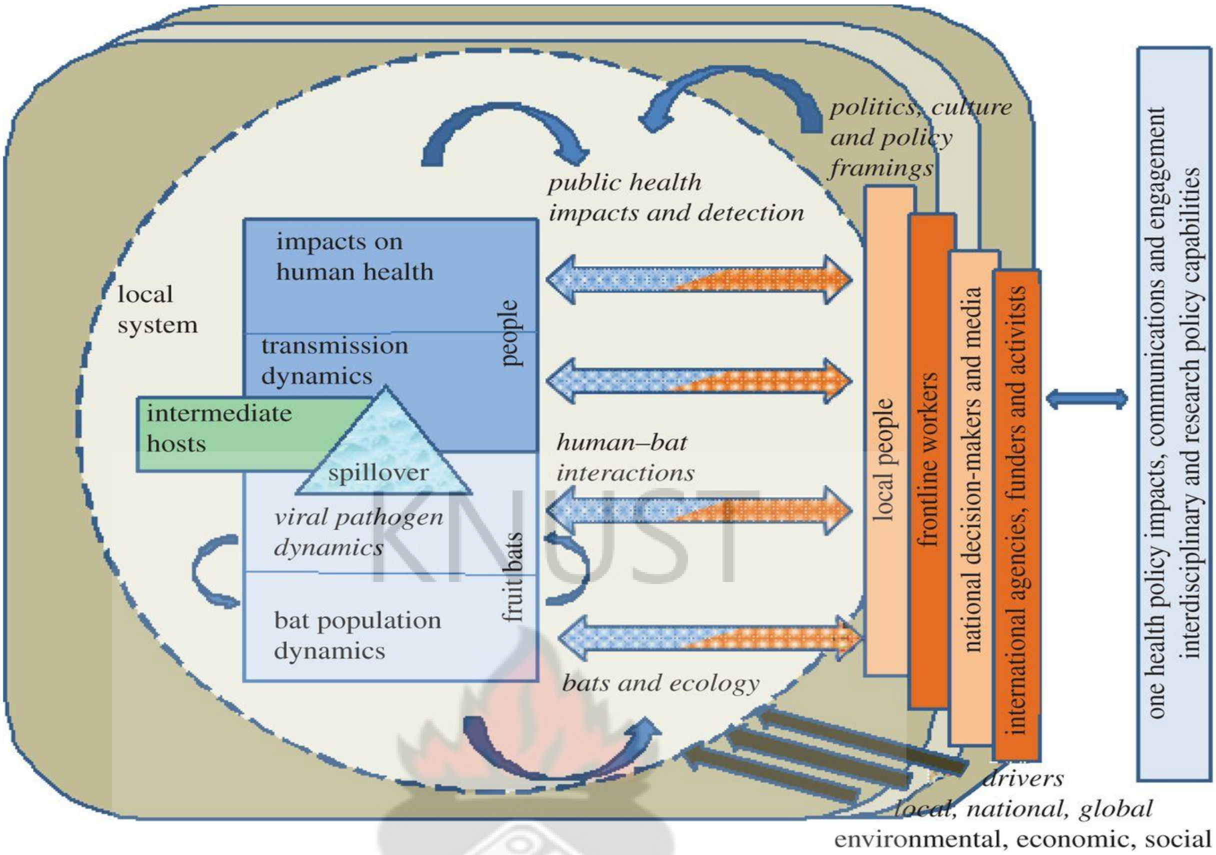

Figure 2.2: A conceptual framework for the study of wildlife derived zoonoses, focused on bat infections after Wood *et al.*, (2012)

The livelihoods of rural communities often depend on natural resources through primary production activities, indicating a high reliance on ecosystems and bio-cultural resources (Suneetha *et al.*, 2010). Examples of such bio-cultural sites in Ghana include caves, which serve as shrines for humans and sanctuaries for bats. The caves in Forikrom for instance receive about four hundred visitors per month who come to hold prayer camps there (Guri, 2010). The dependency of local communities on biological resources thus, cannot be overemphasized.

Community use of bat caves in Ghana however, is virtually understudied. Therefore, any risks associated with visiting these caves and using resources from the caves that may induce potential spillover infections are unknown. According to Hayman *et al.*, (2012), human–bat interactions are difficult to quantify, however, such interactions are increasing and occurring in numerous ways including humans encroaching into bat habitats, and bats also utilizing artificial structures as roosts. Unveiling the extent of the interactions humans have with bats would be the first step towards the identification of potential risk groups for zoonotic transmission.

2.9 Coronavirus (CoV)

Viruses are biological agents or living organisms capable of replicating after release (Roberto and Rodi, 2009). They usually require a permissive host to replicate or grow and having established an active infection in a permissive host, they are transported by the host, creating a new source for release (Roberto and Rodi, 2009). Viruses are responsible for a variety of diseases in humans as well as animals of economic importance (Sattar *et al.*, 1987). They cause an estimated 60% of human infections (Barker *et al.*, 2001).

All coronaviruses belong to the genus *Coronaviruses*, order Nidovirales and within the family Coronaviridae (Lai and Cavanagh, 1997). The name for the group was adopted to describe the characteristic crown-like (corona) projections seen around the viruses under electron microscope (Monto, 1974; Van Der Hoek *et al.*, 2006). They are enveloped, more or less spherical; approximately 120 nm (nanometres) in diameter with a prominent fringe of 20 nm long petal-shaped surface projections made up of different types of proteins also known as spikes (Figure 2.3) (Lai and Cavanagh, 1997).

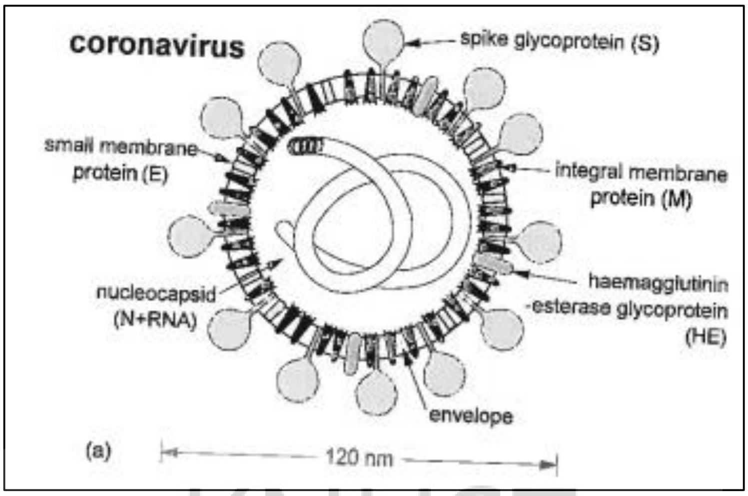

Figure 2.3: Morphology of Coronavirus after Lai and Cavanagh (1997)

Coronaviruses are a group of RNA-containing agents which have been associated with respiratory illnesses in man and with a number of other conditions in laboratory and domestic animals (Monto, 1974; Leggat and Goldsmid, 2001). Coronaviruses are known to infect mammals and birds (Wong *et al.*, 2007). Coronaviruses are classified into 4 genera: *Alpha coronavirus*, *Beta coronavirus* (grouped further into clades 2a–2d), *Gamma coronavirus*, and *Delta coronavirus* (Annan *et al.*, 2013). *Gamma coronaviruses* are found exclusively in birds, whereas *Alpha coronavirus* and *Beta coronavirus* have mammals as their host (Van Der Hoek *et al.*, 2006). CoVs are responsible for a range of disease, including respiratory and gastro enteric disease in humans and animals (Van Der Hoek *et al.*, 2006). These include Nephritis caused by Avian Infectious Bronchitis Virus (IBV); Enteritis caused by Bovine Coronavirus (BCV), Turkey Coronavirus (TCV) and Canine Coronavirus (CCV) (Lai and Cavanagh, 1997; FAO, 2011). Humans are also known to suffer from different coronaviruses like human coronavirus (hCoVs) 229E, NL63, OC43, and HKU1 (Van Der Hoek *et al.*, 2006). Among these, 229E and OC43, identified in 1960, cause predominantly mild respiratory disease (common cold) endemic worldwide (Annan *et al.*, 2013).

Pfefferle *et al*., (2009) have identified a group 1 bat CoV (*Alpha coronavirus*) in a cave dwelling insectivorous bat *Hipposideros* aff. *ruber*. The study showed that this virus shares 92% sequence similarity to the human CoV 229E. The authors suggest that this was as a result of interspecies transmission about 208 to 322 years ago, but postulated that direct transmission from bats to humans would have been difficult (Pfefferle *et al.*, 2009). However, their findings also suggest that bats are likely to be the natural reservoir host for all known CoVs, including human cold CoVs because the CoVs identified in the bats have great genetic diversity and are older than any CoVs previously identified in other animals.

Annan *et al.*, (2013) have also identified a novel CoV (*Betacoronavirus*) in *Nycteris* cf. *gambiensis,* another cave dwelling insectivorous bat. Presently, it appears that the likelihood of coronaviruses spillover into humans is limited. Dynamics at the human–bat interface is a neglected area of research and this gap must be addressed if we are to understand spillover risks (Hayman *et al.*, 2012). Therefore, this study is critical to increasing public awareness and keeping health authorities informed on the documented presence of Coronaviruses in bats and their potential pathogenicity in causing zoonotic diseases in humans.

CHAPTER 3: METHODOLOGY

3.1 Study Area

Rural people are usually organized into social groups on the basis of shared ethnicity, religion, interests and activities (Guri, 2010). Their livelihoods often depend on natural resources through primary production activities, showing a high reliance on ecosystems and bio-cultural resources (Suneetha *et al.*, 2010). The dependency of local communities on biological resources cannot be overemphasized. Thus, the study was conducted in three rural communities in Ghana where the local people generally relied on such resources namely; Kwamang, Forikrom and Buoyem. These are farming communities governed by traditional authorities. The elders in these communities make by-laws to keep off encroachers; the youth and women provide manual labour and volunteer as bat caves tour guides and the spiritual leaders provide guidance on spiritual issues (Guri, 2010). Some of the indigenous fruit trees and plants that constitute the major food crops in these areas include mango, tomatoes, maize, cocoa, cashew, cassava and yams

3.1.1 Buoyem

Buoyem is located 15 km from Techiman, the District Capital in the Brong Ahafo Region of Ghana (Figure 3.1). Its geographical coordinates are 7^0 40’ 0” North, 1^0 57’ 0” West. The entire Buoyem area is largely hilly with scattered mountains hence the name 'Buoyem', meaning in the belly of the stone. Buoyem is located in the transitional zone between high forests and savannah habitats. The area experiences both semi-equatorial and tropical conventional or savannah climates, characterized by moderate to heavy annual rainfall. The major rains are between April to July and the period of minor rains lasts from September to October. The only dry season follows between November and March. The annual rainfall is between 1250 mm-1650 mm.

The area experiences an annual average temperature of 28ºC and a relative humidity of 75-80% in the rainy season and 70-72% for the rest of the year.

Buoyem is composed primarily of Brong inhabitants. Most of the population speak Brong as their mother tongue and the vast majority of the population are Christians (Guri, 2010). The population of Buoyem is about 3,500 (Ghana Statistical Service, 2000). Historically, Nana Owusu Kwakuru II founded Buoyem after the Bono-Manso/Ashanti war of 1722. During this war, the Ashantis destroyed Bono-Manso and captured the Queen (Gyamerawa) and the king (Ohene Ameyaw) and took them to Kumasi. Nana Owusu-Kwakuru II and few royals from Bono-Manso took the ancestral stool and hid themselves in some caves in the Mpirisi forest, now known as Mprisi cave and Bats colony. The other cave is known as the Dwamerawa cave, named after the Queen (Gyamerawa). Later they moved from that site to the present site which is about 11km south of the Mpirisi forest (Habitat for Humanity Ghana, 2011). The Mprisi cave and Dwamerawa cave are 0.58 km apart. The vegetation around the caves is dominated by shrubs and grass, and shows patches of regenerating forests and cultivated croplands.

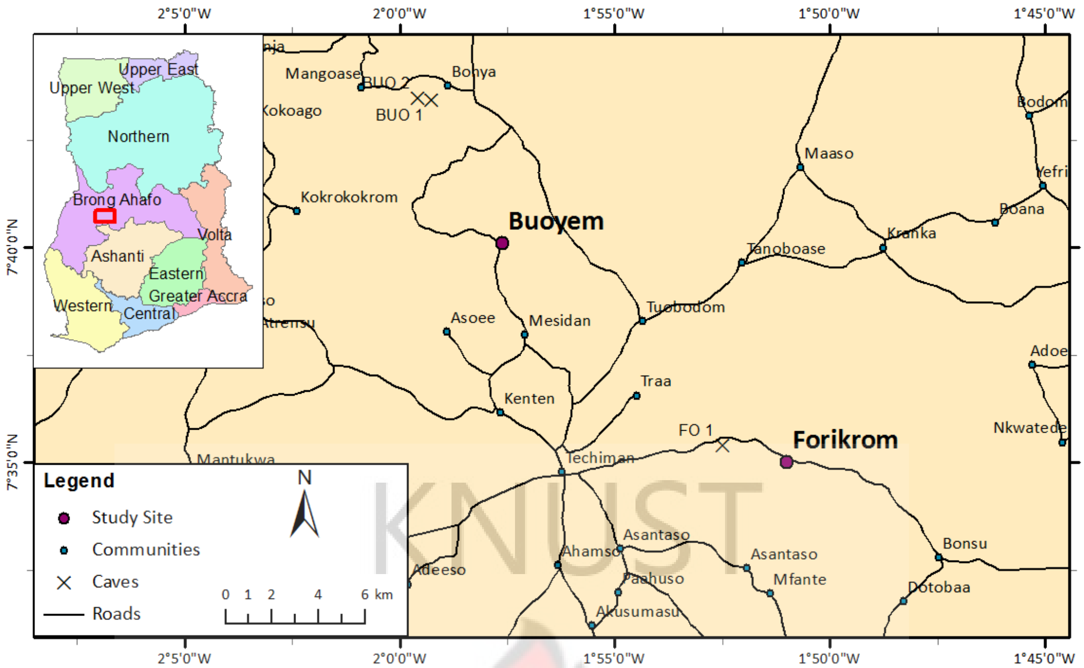

Figure 3.1: Map of Buoyem and Forikrom, Techiman District of Ghana

3.1.2 Forikrom

Forikrom is a farming community of about 6,500 people located in the savannah transitional zone, occupying an area of 60 km^2 (Guri, 2010). It is 25 km away from Buoyem and situated also in the Techiman District of the Brong Ahafo region (Figure 3.1). Its geographic coordinates are 7^0 36’ 0” North, 2^0 36’ 0” West. Forikrom has a very similar climate as Buoyem. The people of Forikrom are of the "bono”speaking group. The most important cultural events in the community are the "Kwamene festival (yam festival), the "Appoh" festival (accountability festival) and the “Bakor” rituals (traditional bath rituals) (Guri, 2010). Forikrom has sites of both historical and cultural significance that promote eco-cultural tourism. These sites include a magic cave (Nkonyayibuo), Boten shrine, a royal burial ground for chiefs, holy mountains which serve as a place of worship and also a bat sanctuary (Guri, 2010). These sites are of cultural importance because they represent sacred, magic and mystique relationships between people, the environment and their ancestors (Guri, 2010). This cave is situated in an agricultural landscape. The area is characterised by cultivated croplands comprising of annual crops like maize, millet, yam and cassava. Teak, and cashew plantations surround the cave. The landscape is also flat and rocky.

3.1.3 Kwamang

Kwamang is located 50 km northeast of Kumasi in the Sekyere Central District situated in the Ashanti region (Figure 3.2). This is a hilly area with an elevation of 530 m above sea level. Its geographic coordinates are 6^0 58’ 0” North, 1^0 17’ 0” West. Kwamang is located within the moist semi-deciduous rainforest ecological zone of Ghana. The landscape is characterized by a complex mosaic of numerous patches of indigenous crops mostly annuals and large perennial crops (Nkrumah, 2011). The population of Kwamang is about 6,500 (Ghana Statistical Service, 2000) and Twi is the spoken local dialect. Kwamang also has sites of both historical and cultural significance that promote ecotourism. These sites include a shrine cave called “Mmframabuom” meaning “windy rock”, which serves as a place of worship and also a bat sanctuary, and “Ohene Abutia”, which serves as one of the major water sources in the community and also as a bat sanctuary. These caves are 3.75 km apart.

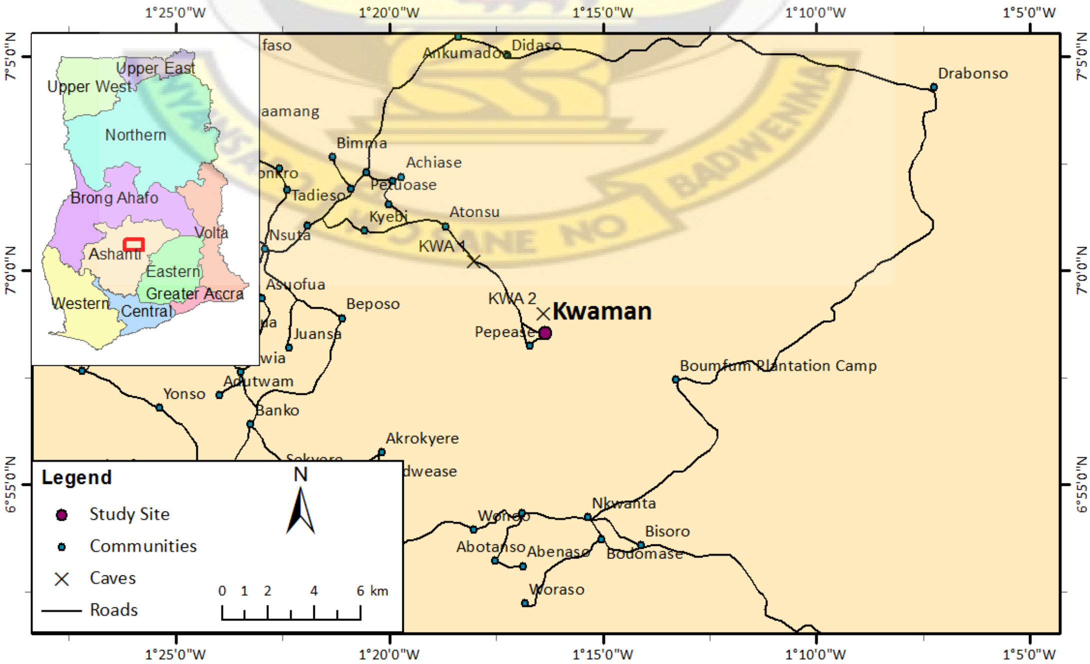

Figure 3.2: Map of Kwamang, Sekyere Central District of Ghana

3.2 Research Design

A research design is the blueprint that enables an investigator to come up with solutions to problems and provides guides in the various stages of the research (Frankfort-Nachmias and Nachmias, 1996). In designing any research, Robson (2002) defines five key components of a design. These are purpose, theory, research questions, methods and sampling strategy.

Robson (2002) identifies two broad approaches in the design of research; Fixed and Flexible designs. The former requires considerable pre-planning before data collection and mainly involves quantitative data while the latter evolves as the study progresses, involves qualitative data (non-numerical usually in the form of words) or both.

Since previous studies on this subject area were unavailable, following Robson (2002), a combined strategy design; in other words mixed method design with an initial flexible design stage of primarily exploratory purpose was employed for this study. Mixed methods research is defined as a combination of quantitative and qualitative research techniques, methods, approaches and concepts fused into a single study (Johnson and Onwuegbuzie, 2004).

Recent arguments advocate that combining approaches provide an in-depth interpretation of the situation being studied (Denscombe, 2008). However, for this study the choice of using a mixed method approach was not necessarily to provide a balance between the shortcomings of one approach and the strengths of another but rather to best address the research questions (Morrison, 2007).

The study participants had various roles such as traditional authorities, chief priests as well as different occupational backgrounds. Therefore, the flexible design was used in the early stage of this study to collect in-depth interview data by exploring how bats helped or hindered members of the communities in their various day-to-day activities, work and health. This was achieved through discussions with stakeholders such as traditional authorities, village leaders, local project committees, assemblymen and older members of the community. The responses helped determine the data to be collected in the second phase, which employed a fixed design using the survey approach. The survey questions were almost entirely close-ended with a few being open-ended. These comprised individualized questions intended to describe particularly interesting bat related activities such as use of bat caves, bats as source of food, rituals and medicine as well as any evidence on common cold infections.

3.2.1 Research purpose

Robson (2002) classifies the purpose of any research as exploratory, descriptive and explanatory. The purpose of this study was to carry out an investigation involving human interactions with bats in rural communities to draw attention to some complexities that may arise from such interactions. Virtually very little is understood about such interactions and their potential implications. This study can therefore be classified as exploratory, descriptive, and explanatory since it seeks to explore and describe the interactions humans have with bats and eventually provide explanations about the phenomenon and also identify relationships between aspects of the phenomenon.

3.2.2 Research strategy

Strategy or approach refers to the general broad orientation for addressing research questions (Robson, 2002). According to Yin (2003) there exist five primary research strategies which are specific to situations, best answer the research questions and also show whether there is control over behaviours or focus on contemporary events.

Following Robson (2002), a case study (flexible design) strategy was employed in this study. Case study is an empirical inquiry which focuses on a contemporary phenomenon within its real-life context using multiple sources of evidence (Yin, 2003). The 'case' is defined as a phenomenon that occurs in a bounded context (Miles and Huberman, 1994). According to Yin (2003) a case study design should be considered when the focus of the study is to answer 'how' and 'why' questions; the behaviour of those involved in the study cannot be manipulated; the study seeks to cover contextual conditions relevant to the phenomenon under study; and also when the boundaries are not clear between the phenomenon and context.

The main focus of this study was to investigate how and why humans and bats interact including how such interactions may influence the potential transmission of CoV within the context; human communities. Moreover, this occurred in a natural setting and therefore could not be manipulated. The design of a case study could be a single case or multiple cases (Robson, 2002; Yin, 2003).

A multiple case study design was adopted in this study to explore differences in human-bat interactions within and between three rural communities; Buoyem, Forikrom and Kwamang. This allowed useful comparisons to be made in order to predict similar or contrasting conditions across the communities. Once the case was determined, it was important to define boundaries in terms of definition, context, time and place/ activity which would inform what would and would not be studied in the scope of the research (Baxter and Jack, 2008).

Based on place/activity, the study sought individuals who may have contact with bats through their daily activities such as occupation; through certain areas in the community such as households, workplaces, school, bat caves and farms. Furthermore, based on definition and context, the study sought to find out the implications of potential CoV infections by interviewing individuals who had symptoms of common cold and to establish how they perceived they contracted the infection. Although case studies have various advantages such as presenting data of real-life situations and better insights into the detailed behaviours of the subjects of interest, they are also criticised for their inability to generalise results and the tendency for a researcher to have a biased interpretation of the data (Zainal, 2007). Hence, a survey approach was adopted to manage the limitations of the case study approach.

The survey approach was used in the second phase to answer the 'what', 'who', 'where', 'how many' and 'how much' questions of the study. According to Robson (2002), surveys are carried out for descriptive purposes rather than exploratory by providing a wide range of information about the characteristics of people and the relationships between such characteristics.

This facilitated the description of interactions people had with bats and how such interactions were related to socio-demographic characteristics such as age, gender and education. The survey also provided a snapshot of what the situation was in the various communities at a specific point in time and also allowed the data to be collected in a standardized form (Kelley *et al.*, 2003). The survey informed the study about the common cold situation within the communities. It sought to establish associations between the common cold infections and interactions humans had with the bats. This allowed acquiring useful information in order run analysis on correlation.

Survey research uses a range of methods including mail questionnaires, personal/face-to-face interviews and telephone interviews (Frankfort-Nachmias and Nachmias, 1996; Kelley *et al.*, 2003). Personal interviews were employed for this study. The personal interview is a face-to-face, interpersonal role situation in which an interviewer asks respondents questions designed to elicit answers pertinent to the research hypotheses (Frankfort-Nachmias and Nachmias, 1996).

3.3 Sampling Design and Selection of Respondents

Respondents were selected using probability and non-probability purposive sampling Probability sample designs allow the researcher to specify the probability of each sampling unit to be included in the sample in a single draw from the population (Frankfort-Nachmias and Nachmias, 1996). There are four common designs of probability samples: simple random sampling, systematic sampling, stratified sampling and cluster sampling (Frankfort-Nachmias and Nachmias, 1996; Kelley *et al.*, 2003). In this study, cluster sampling was used. This was because a sampling frame for the resident population was unavailable (Fogelman and Comber, 2007). Following Frankfort-Nachmias and Nachmias (1996), a map was created for each community with boundaries marked excluding areas that did not include dwelling units. Each map was divided into four blocks and individuals were randomly sampled from each block. Since all three communities are farming communities it was difficult to get the participants to become actively involved in the study. This was because they set out early in the morning to their farms and returned in the evening.

Thus, this design did not yield much information, hence, the adoption of a non-probability purposive sampling method.

In a non-probability sample, units are deliberately selected to reflect particular features of groups within the sampled population (Kelley *et al.*, 2003). Furthermore, the sample is not intended to be statistically representative meaning the chances of selection for each element are unknown but, instead, the characteristics of the population are used as the basis of selection (Yin, 2003). There are three main techniques including Purposive Sampling, Convenience sampling and Snowballing (Frankfort-Nachmias and Nachmias, 1996; Kelley *et al.*, 2003; Ruane, 2005). Purposive sampling and Snowballing were employed in this study.

The characteristics of individuals are used as the basis of selection, most often selected to reflect the diversity and breadth of the sample (Wilmot, 2005). According to Wilmot (2005), the sample criteria used may be based on demographic characteristics or behaviours or attitudes and other characteristics based on the researcher's judgment. Socioeconomic characteristics defined occupation, including individuals who farmed and hunted around caves. Health characteristics defined people who showed symptoms of common cold such as running nose, headaches and sore throat. Behaviours and attitudes defined people who visited the caves for recreational purposes, collected guano or fetched water from caves as well as people who engaged in religious activities inside the caves. Experiences and knowledge defined people who had been bitten by bats and also people who may have contracted infections from consuming bats or from bat bites.

The inclusion criteria for participation included individuals who were 13 years or older and had lived in the community within the last 20-50 years. This criterion was used as the sampling frame for the study. Respondents were also found through referral from existing participants, in other words through snowballing. A similar method was employed to locate bat hunters/trappers in communities where fruit farms are known to attract flying foxes. Recruitment areas were selected based on proximity to bat caves and mass bat roosting sites; and certain community characteristics known to promote bat-associated activities. Village leaders and other local contacts provided assistance in locating individuals who were known to engage in these activities.

3.4 Data Collection

The selection of a method or methods is based on the kind of information sought from whom and under what circumstances. According to Robson (2002) case study employs a wide range of data collection techniques including observation, interview and documentary analysis based on factors such as what people do privately or publicly and also what their thoughts and beliefs are. Data was collected through community fora, direct observation, face-to-face interviews and review of documents. Data collection was conducted over a period of 15 months, from July 2011 to October 2012.

Following Robson (2002), community entry began with workshops conducted in the initial stage of the study to find out what the people thought, felt and/or believed, that is their perceptions regarding bats in the communities. This was however, not targeted for everybody in the community. With the help of the village leaders and assemblymen, some key people from each community were chosen to participate in the workshops to orient the communities about the purpose of the study and what it entailed. The workshops also provided an opportunity for focus group discussions.

This is an informal discussion among a group of selected individuals about a particular topic (Bryman, 2012). It provided a platform for adding depth and dimension to the knowledge being sought and enabled the researcher gain as much information as possible in a relatively short period of time (Sinagub *et al.*, 1996). Using this approach, the people were interviewed on how they felt bats helped or hindered them in their work, community and health based on their perceptions, experiences, beliefs, needs and concerns. A total of 136 people representing Buoyem (28), Forikrom (39) and Kwamang (69) participated in the focus group discussions. This provided an overall picture of how the people interacted with bats in each community and also informed the kind of questions to be asked in subsequent stages of data collection.

The next stage was direct observation, which was used to find out what the people did in public (Bryman, 2012). This involved extended visits to the communities, informal interactions, following up on their day to day activities such as visits to farms, caves, households, churches, markets, health centres and schools. According to Bryman (2012), this gives the researcher a general idea of the information being sought. In other words, it enables the researcher keep an open mind about the contours of what is needed. These observations were done for two weeks in each community. Caution was however taken so that the people did not feel they were being spied on or threatened in anyway.

The third stage was the face-to-face interviews to find out what they did in private using questionnaires (Bryman, 2012). Structured questionnaires, which were very clear, were administered. This was first tested on a pilot sample of the target population (Ruane, 2005). The purpose of this was to determine respondents' understanding of the questions and also to identify whether the meanings of questions were the same for all respondents (Frankfort-Nachmias and Nachmias, 1996; Kelley *et al.*, 2003; Ruane, 2005).

An 18-item structured questionnaire was developed in English and administered in Twi, which is the local dialect in all three communities via face-to-face interviews. The questionnaire was developed based on socio-ecological reasoning about sources of contact with bats, use of bats and caves, traditional knowledge on disease epidemics in the past, and whether the occurrence of common cold infections is generally believed to be associated with visiting bat caves and consuming bat meat (Robertson *et al.*, 2011). For respondents who indicated visiting bat caves, the purpose, frequency and duration of visits was elicited. Data was collected on demographics; cave-associated activities; contact with bats; bites and scratches from bats and bat consumption. Awareness of the particular species of bat respondents preferred to eat, the mode of capture as well as any infections from consuming bats was also elicited.

To know the health practices following bat exposures, participants were asked about actions they took when they visited the caves, captured bats and when bitten by a bat (Robertson *et al.*, 2011). Participants were also interviewed away from other people so others did not influence their responses. Interviews lasted an average of 30 minutes and conducted in such a way that questions were not asked in a leading manner and also allowed as much time as necessary for participants to respond (Ruane, 2005).

The final stage was reviewing of available published and unpublished documents. Visits were paid to the local ecotourism centres as well as the health centres in the communities to obtain information on the history of bat caves and any information of disease epidemics in the past. For communities without ecotourism or health centres, stakeholders such as the chief priests, traditional leaders, tour guides and older people with in-depth knowledge about the bats were interviewed for this information. A total of 1274 people were interviewed in all three communities; Buoyem (412), Forikrom (362) and Kwamang (500).

3.5 Ethics Statement

Research may directly or indirectly harm people's lives and relationships through unwanted publicity and influence hence the need for ethics statement. Research ethics ensures that the principles of justice, respect and avoidance of harm are upheld by using agreed standards (Bryman, 2012). The Committee on Human Research, Publications and Ethics, School of Medical Sciences, Kwame Nkrumah University of Science and Technology approved consent for the study. All participants were verbally informed of the study's purpose and assured that their responses would be kept anonymous. The consent was read with the purpose explained extensively to the respondents to enable them understand and also decide whether or not to partake in the study. The respondents having understood everything then either appended their signature or thumb printed the form. Under no circumstance were any of the respondents forced to partake in the study. Those that did not partake in the study were either merely uninterested or busy at the time.

3.6 Statistical Analysis

The software Epi Info version 3.4.3 was used for computerizing data collected during the survey (CDC, 2007). This software was used to create questionnaires and data entry forms. This software is user friendly as it automatically creates the database from the questionnaire; enables the user place data entry fields on one or many pages and tailors the data entry process with skip patterns (CDC, 2007). Data were then transferred into the software Predictive Analysis Software (PASW) Statistic version 18 (formerly SPSS Statistics) for statistical analysis (SPSS Inc, 2009). This software has a statistics base that offers a wide range of statistical tools for basic analyses like counts, crosstabs and descriptive statistics. Data collected from qualitative surveys were subjected to a descriptive statistical analysis including a bivariate analysis using contingency tables. The Pearson Chi-square test indicated the strength of associations between variables (SPSS Inc, 2009). Differences were considered to be significant at p-values less than 0.05. Graphs (bar charts) were created with Microsoft Excel.

3.7 Limitations

Some of the respondents were widely dispersed geographically for example at Kwamang and Buoyem therefore the cost involved was higher in those areas compared to Forikrom. This was managed by interviewing respondents at a central point through radio announcements. Some questionnaires were left at the health centres for people who presented with symptoms of respiratory infections such as common cold. These questionnaires were administered by community health workers, which could have influenced respondents' answers due to differences in interviewer techniques. This was managed by training community health workers on how to conduct the interviews. Finally, there were some instances where respondents felt intimidated due to the presence of the interviewer. This was because some respondents were not familiar with the process of being interviewed. In such instances, respondents were asked to calm down and further explanations were given to them.

CHAPTER 4: RESULTS

4.1 Socio-demographic Characteristics of Respondents

The highest number of respondents interviewed was at Kwamang (500), followed by Buoyem (412) and Forikrom (362). Socio-demographic characteristics of the respondents are described in Table 4.1. Generally, 59%, 52% and 58% of respondents at Kwamang, Buoyem and Forikrom respectively were women. Across all three communities, 79%, 85% and 76% of respondents respectively had completed at least primary education. Generally, 90% of respondents in all three communities were Christians. In Kwamang (38%) and Forikrom (25%) of respondents were above 50 years. This is in contrast to Buoyem where most of the respondents representing 30% were between 12 and 20 years.

Table 4.1: Socio-demographic characteristics of respondents

	Communities					
Characteristics	Kwamang	%	Buoyem	%	Forikrom	%
Sex						
Female	297	59.4	214	51.9	208	57.5
Male	203	40.6	198	48.1	153	42.5
Level of Education						
Educated	393	78.6	348	84.5	274	75.7
Uneducated	107	21.4	64	15.5	88	24.3
Religion						
Christian	476	95.2	385	93.5	312	86.2
Muslim	9	1.8	17	4.1	10	2.8
Traditional	1	0.2	1	0.2	10	2.8
None	14	2.8	9	2.2	30	8.2
Age (years)						
11-20	73	14.6	124	30.1	83	22.9
21-30	73	14.6	76	18.5	75	20.7
31-40	60	12	65	15.8	68	18.8
41-50	104	20.8	50	12.1	47	13
>50	190	38	97	23.5	89	24.6

Kwamang (n=500); Buoyem (n=412); Forikrom (n=362)
Total number of respondents (n) =1274

4.1.1 Occupational distribution of respondents

The occupational distribution of all the respondents indicated that farming was the most important occupation in all three communities (Figure 4.1). This was followed by student, dressmaking and secondary occupations classified as "other". In Kwamang, farming was reported by 50% of respondents, this was highest in Buoyem and Forikrom with 44% of respondents. Secondary occupations mentioned included butcher, security guard, palm wine tapper, electrician, shoemaker, pastor, credit officer, painter, barber and labourer.

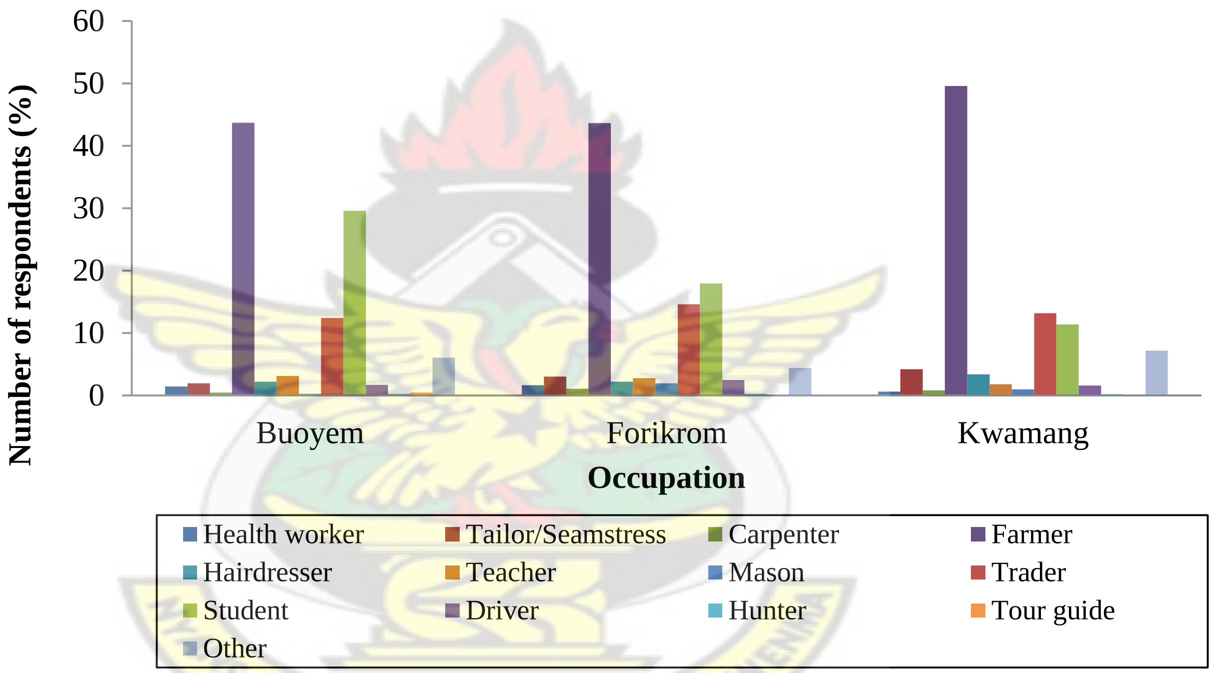

Figure 4.1: Percentage distribution of respondents' occupation

4.2 Sources of Human-Bat Contact within Communities

Source of human-bat contact in this study was defined as a place from which any form of contact (direct or indirect) with bats is obtained. For instance, finding a bat in a room or an area where there are young children, elderly persons, or where people are sleeping or not alert were considered as forms of contact with bats. Direct contact was described as any physical contact with a bat; or when a bat is observed to land on a person, fly into a person or was touched when a person reached into its roosting place. Indirect contact was also described in the study as when a bat is observed from a distance such as roosting on trees, hanging on ceilings without any form of physical contact.

Sources of human contact with bats in the communities include homes, schools, farms and caves (Figure 4.2). The caves were the highest source of contact with bats in all three communities representing 31%, 45% and 37% for Buoyem, Forikrom and Kwamang respectively. The least source of human contact with bats was schools representing 6% for Buoyem and 1% for Forikrom and Kwamang respectively. There was no significant difference between the communities in terms of contact with bats in homes (x^2=2.63, df=2, p>0.05) and farms (x^2=5.46, df=2, p>0.05). However, there was a significant difference between the communities and human-contact with bats in caves (x^2=14.26, df=2, p<0.05). Similarly, human-contact with bats at schools (x^2=27.33, df=2, p<0.05) was also highly significant between the communities.

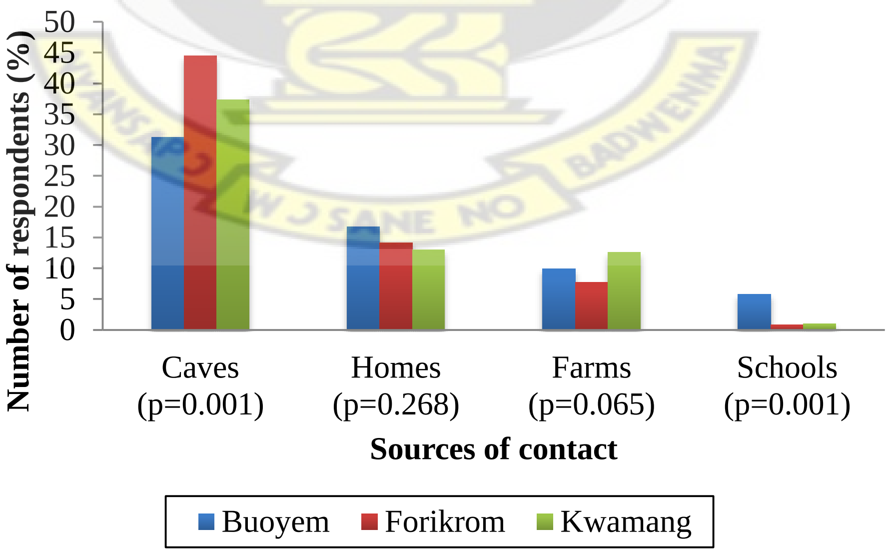

Figure 4.2: Sources of human-bat contact cited by respondents at study area
Buoyem (n=263), Forikrom (n=243) and Kwamang (n=320)

Bat species mentioned by respondents at the identified sources included both flying foxes and insectivorous bats. Respondents were however unable to identify the particular species but from personal observations, the following were identified: *Hipposideros gigas; Hipposideros abae; Hipposideros* aff. *ruber; Hipposideros jonesi; Nycteris* cf. *gambiensis; Rhinolophus landerii; Coleura afra* and *Rousettus aegyptiacus* (Table 4.2). Potential human contact (direct and indirect) with the focal species (*H.* aff. *ruber*) occurred at all the sources. Contact with *Nycteris* cf. *gambiensis* occurred only in caves and farms.

Table 4.2: Species identified from personal observation

Species	Group	Community	Source
H. gigas	Microchiroptera	B, F, K	Caves
H. abae	Microchiroptera	B, F, K	Caves
H. aff. *ruber*	Microchiroptera	B, F, K	Caves, homes, farms, schools
H. jonesi	Microchiroptera	F, K	Caves, farms
Nycteris cf. *gambiensis.*	Microchiroptera	B, F, K	Caves, farms
Rhinolophus landerii	Microchiroptera	F	Caves
Coleura afra	Microchiroptera	B, F	Caves
Rousettus aegyptiacus	Megachiroptera	B, F, K	Caves, farms, homes, schools

Legend: B= Buoyem; F=Forikrom and K= Kwamang

4.3 Socio-demographic characteristics of respondents and sources of contact with bats

Within each community the associations between socio-demographic characteristics of respondents and contact with bats were explored. Human contact with bats at identified sources; caves, homes, farms and schools were grouped according to age, gender and education. According to age, the following groups were defined; young (<30 years), middle age (31-40 years), elderly group (41-50 years) and old group (>50 years). Sex was defined as either male or female.

4.3.1 Age and sources of contact with bats

Results of statistical testing indicated a statistically significant difference between age and contact on farms in all three communities; Buoyem (*x^2=26.63, df=4, p<0.05*), Forikrom (*x^2=22.82, df=4, p<0.05*) and Kwamang (*x^2=17.06, df=4, p<0.05*) (Figure 4.3; Appendix B). These findings therefore suggest that older respondents had the highest contact with bats on farms. There was however, no significant difference between age and contact in homes in all the communities; Buoyem (*x^2=0.83, df=4, p>0.05*), Forikrom (*x^2=4.70, df=4, p>0.05*) and Kwamang (*x^2=5.78, df=4, p>0.05*).

In Buoyem, there was a strong significant difference between age and contact in caves (*x^2=129.85, df=4, p<0.05*). This also suggests that older respondents had the highest contact with bats in caves. This was in contrast to Kwamang (*x^2=5.36, df=4, p>0.05*) and Forikrom (*x^2=8.47, df=4, p>0.05*), where there were no significant difference between age and contact in the caves.

At Buoyem (*x^2=52.53, df=4, p<0.05*) and the results showed a significant difference between age and contact at schools. Based on the evidence of this data, it would appear that younger respondents had the highest contact with bats at school. However, this was also in contrast to Kwamang and Forikrom where there was no significant association between age and contact with bats at school (*x^2=9.62, df=4, p>0.05*), (*x^2=4.46, df=4, p>0.05*) respectively.

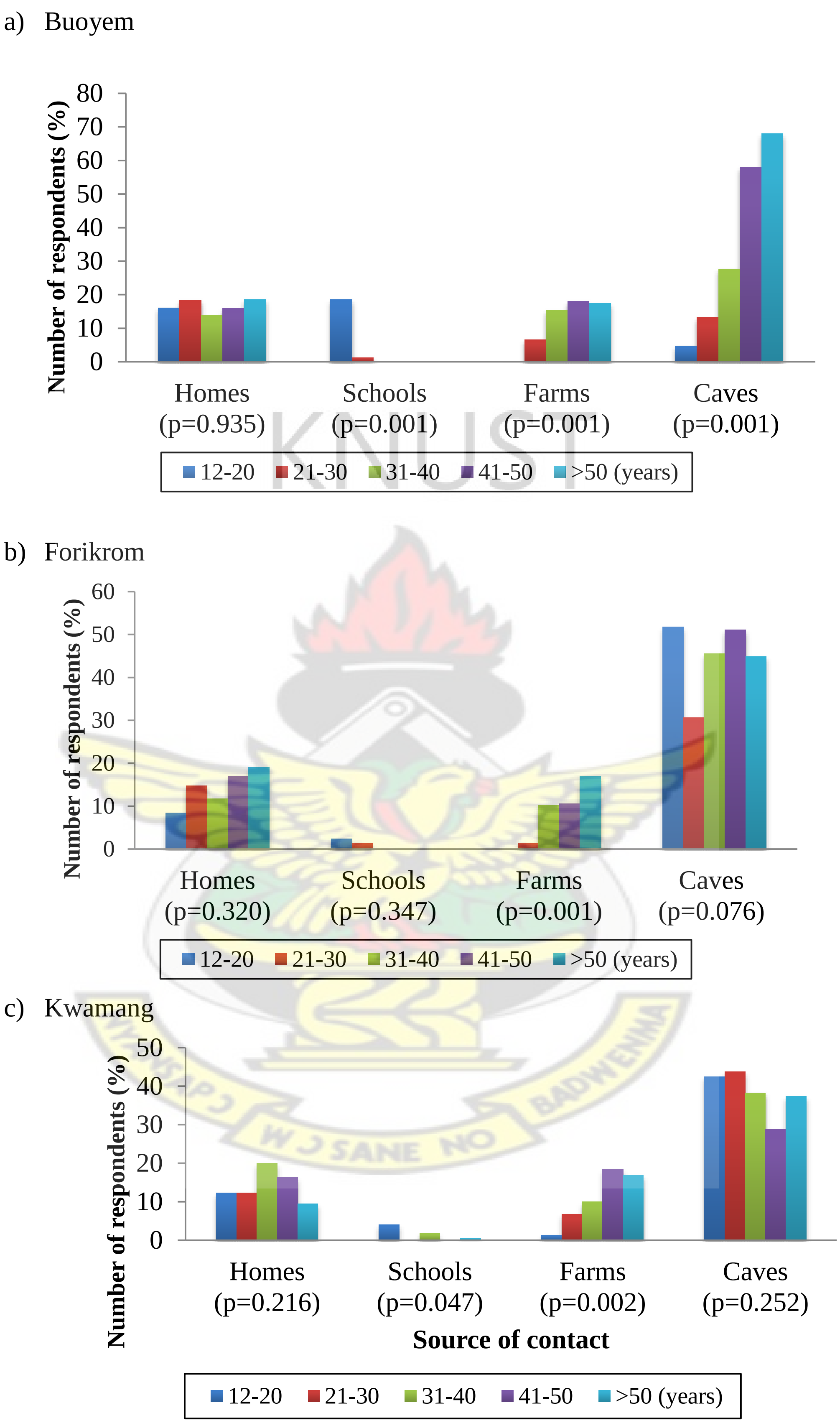

Figure 4.3: Age distribution of respondents who have contact with bats at identified sources at study area
Buoyem (n=263), Forikrom (n=243) and Kwamang (n=320)

4.3.2 Gender and sources of contact with bats

The differences between gender and contact with bats at identified sources; homes, schools, farms and caves were also explored (Figure 4.4). At Forikrom and Kwamang, there was a strong significant difference between gender and contact with bats in homes ($x^2=16.15$; $x^2=6.77$, $df=1$, $p<0.05$ respectively), farms ($x^2=16.15$; $x^2=13.58$, $df=1$, $p<0.05$ respectively) and caves ($x^2=6.65$; $x^2=6.06$, $df=1$, $p<0.05$ respectively). The findings therefore suggest that significantly more men had contact with bats at these sources than women. However, in these two communities, there were no significant differences between gender and contact with bats at schools (Appendix B). At Buoyem, there were no significant differences between gender and contact with bats at all the sources (Appendix B).

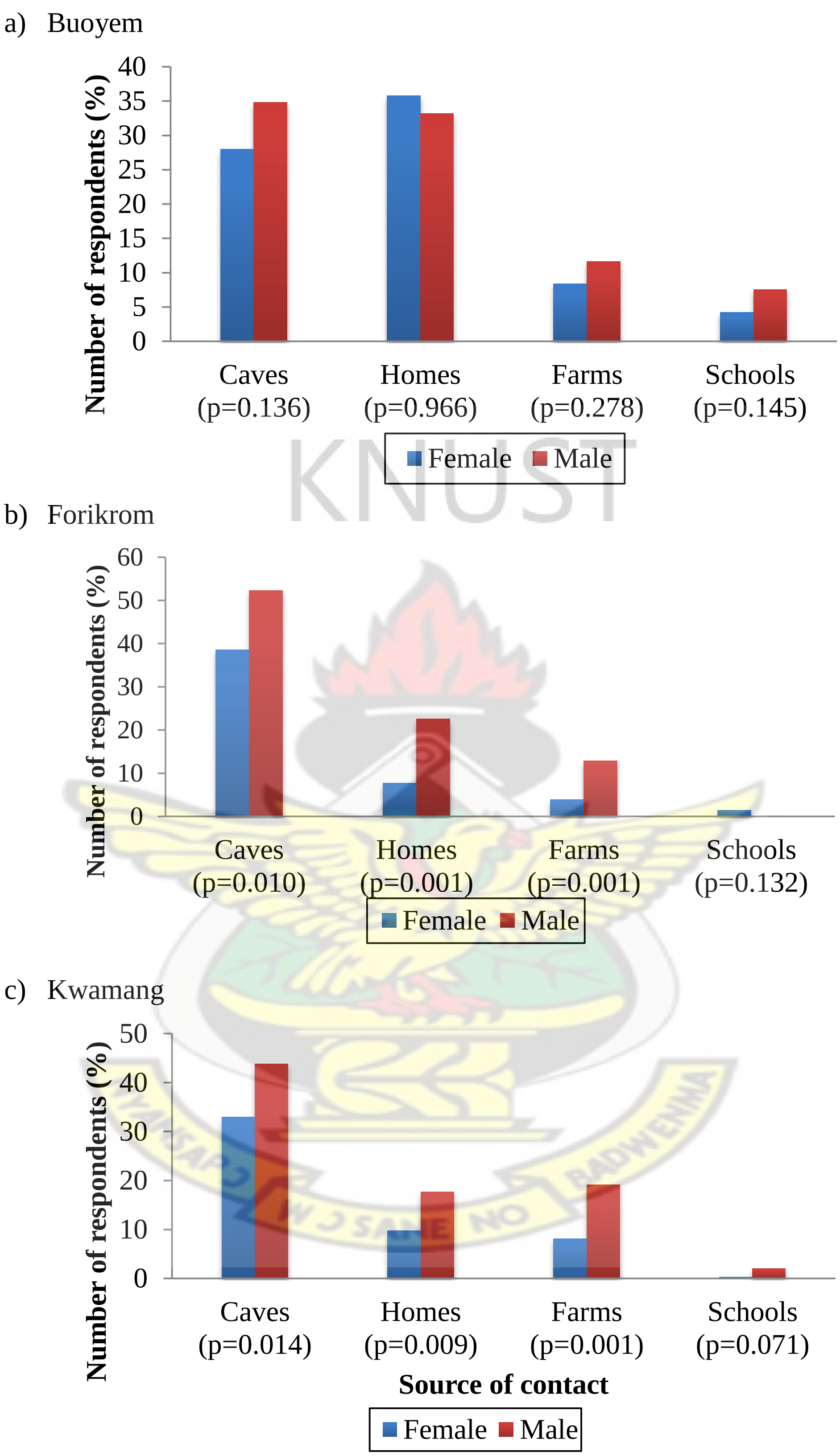

Figure 4.4: Gender distribution of respondents who have contact with bats at identified sources at study area

4.4 Community Use of Bats and Caves

A total of 181 respondents in Buoyem visited the bat caves out of which 51% were males and 38% were females (Figure 4.5). In Forikrom, 178 respondents visited the bat caves out of which 60% were males and 42% were females. In Kwamang, 222 respondents visited the bat caves and this comprised 51% males and 40% females. The relationship between gender and use of caves was explored. Analysis confirmed a strong positive association between gender and use of caves in all the communities Buoyem ($x^2=6.69$, $df=1$, $p<0.05$), Forikrom ($x^2=11.70$, $df=1$, $p<0.05$) and Kwamang ($x^2=5.56$, $df=1$, $p<0.05$). This suggests that more men visited the bat caves than women in all three communities.

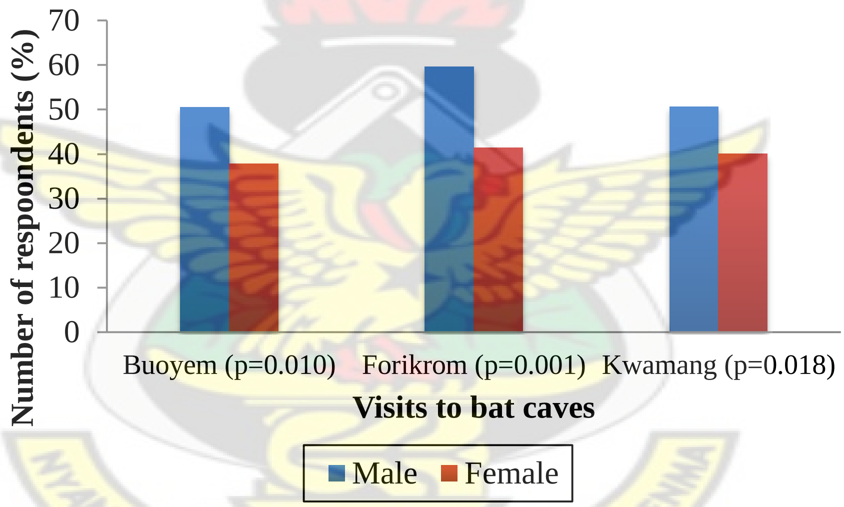

Figure 4.5: Gender distribution of respondents who visit bat caves at study area

There was also a significant difference between age and visits to bat caves in all the communities; Buoyem ($x^2=137.94$, $df=4$, $p<0.05$), Forikrom ($x^2=12.19$, $df=4$, $p<0.05$) and Kwamang ($x^2=9.995$, $df=4$, $p<0.05$) (Figure 4.6). In Buoyem, the highest visits to bat caves were by older persons. However, this was in contrast to Kwamang and Forikrom where visits to bat caves were somewhat evenly distributed across all age groups.

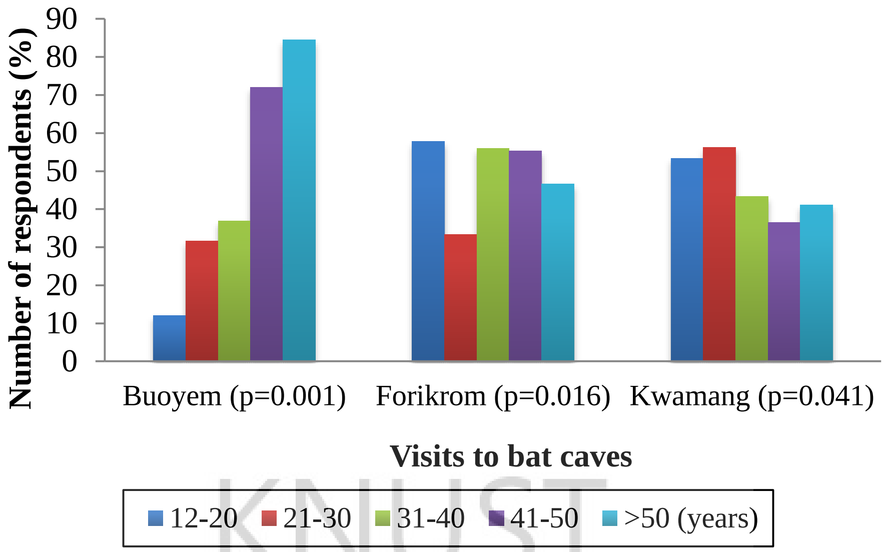

Figure 4.6: Age distribution of respondents who visits bat caves study area

4.4.1 Purpose, frequency and duration of visits to bat caves

In total six reasons were mentioned for visiting bat caves in all the three communities; religious activities (x^2=*132.4, df=2, p<0.05*), recreation (x^2=*21.12, df=2, p<0.05*), hunting (x^2=*173.99, df=2, p<0.05*), farming (x^2=*9.976, df=2, p<0.05*), water fetching (x^2=*207.05, df=2, p<0.05*) and guano collection (x^2=*28.1, df=2, p<0.05*) (Figure 4.7). In Buoyem, the main purpose for visits to the bat caves was hunting representing 25% of respondents. Religious activities were the main purpose cited by respondents who visited the caves in Forikrom representing 22%. In Kwamang, the main reason mentioned by respondents was water fetching representing 25%. Generally, two activities were the least mentioned in all three communities, these were water fetching and guano collection. The former was only mentioned in Buoyem and Kwamang and the latter Forikrom and Kwamang respectively.

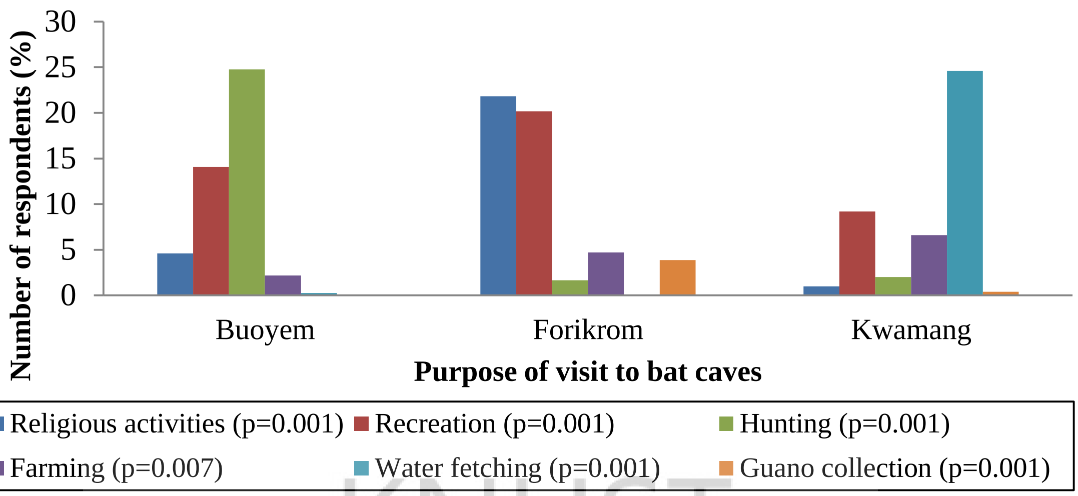

Figure 4.7: Respondents' purpose of visiting bat caves at study area
Buoyem (n=189), Forikrom (n=189) and Kwamang (n=219)

4.4.2 Age of respondents, gender and purpose of visiting bat caves

The effect of age was significant for some of the reasons cited but not all (Figure 4.8). In Buoyem there was a significant difference between age and hunting (x^2=*176.45, df=4, p<0.05*), and religious activities (x^2=*10.61, df=4, p<0.05*). This suggests that older persons visited the caves predominantly for hunting and religious activities. In Forikrom, there was a strong difference between age and only recreation (x^2=*13.22, df=4, p<0.05*). This suggests that younger persons visited the caves primarily for recreation. At Kwamang, there was a significant difference between age and farming (x^2=*11.715, df=4, p<0.05*), water fetching (x^2=*15.02, df=4, p<0.05*) and recreation (x^2=*22.172, df=4, p<0.05*). This suggests that older respondents visited the caves mostly for farming whereas younger persons visited the caves predominantly for recreation and water fetching.

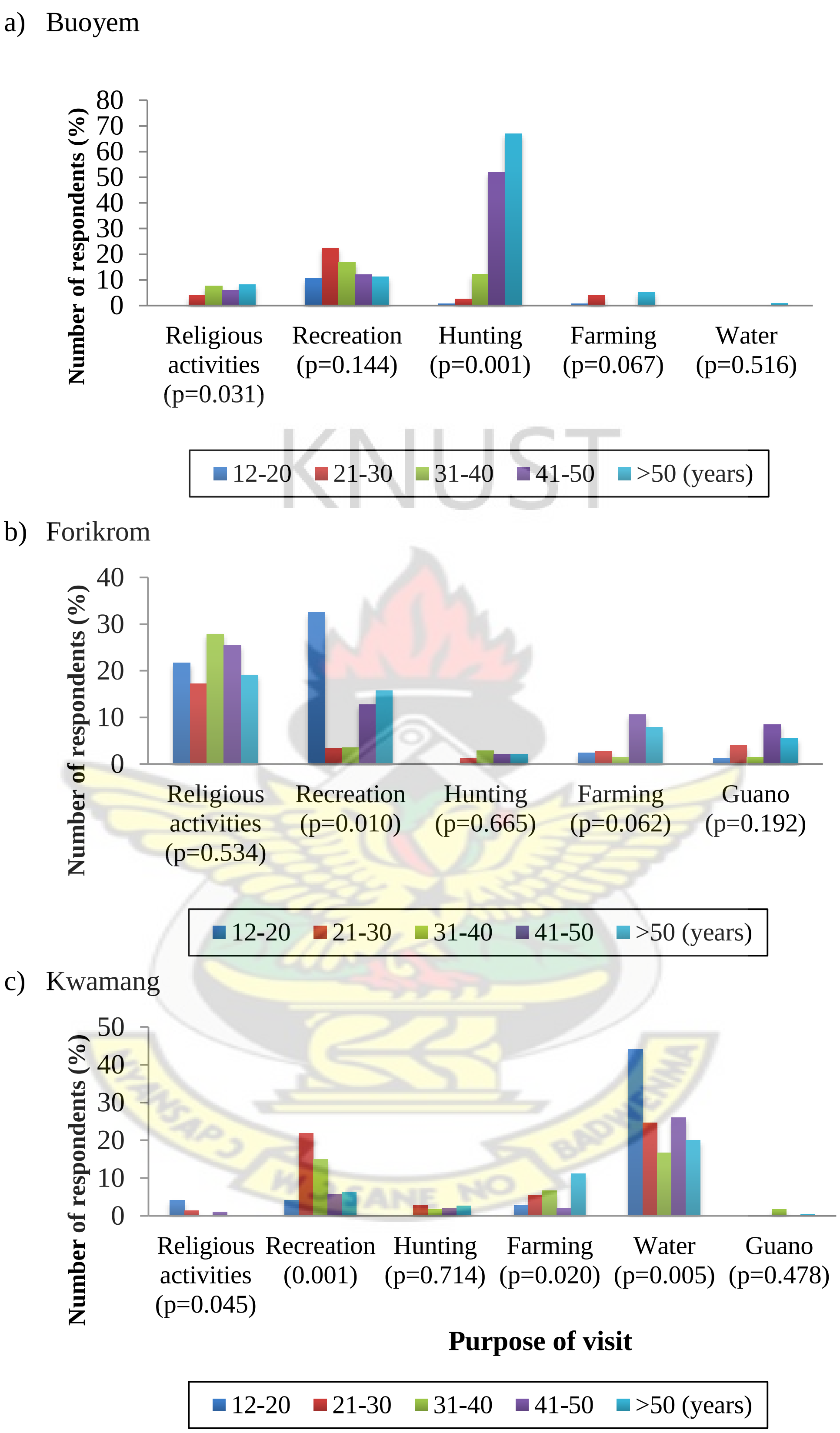

Figure 4.8: Age of respondents and purpose of visiting bat caves at study area
Buoyem (n=189), Forikrom (n=189) and Kwamang (n=219)

The effect of gender and purpose of visiting bat caves was explored (Figure 4.9). In Buoyem, there were significant differences between men and women with respect to religious activities (x^2*=7.61, df=1, p<0.05*), recreation (x^2*=29.41, df=1, p<0.05*) and hunting (x^2*=6.34, df=1, p<0.05*). Bat hunting was predominant among women than men. However, recreation and religious activities were higher among men than women.

In Forikrom, there were significant differences between men and women with respect to all the purposes mentioned; religious activities (x^2*=12.64, df=1, p<0.05*), recreation (x^2*=36.25, df=1, p<0.05*), hunting (x^2*=8.15, df=1, p<0.05*) and guano collection (x^2*=7.604, df=1, p<0.05*), with the exception of farming (x^2*=1.89, df=1, p>0.05*). Religious activities were higher among women than men. However, recreation, hunting and guano collection was more predominant among men than women.

In Kwamang, there were significant differences between men and women with respect to hunting (x^2*=12.73, df=1, p<0.05*) and recreation (x^2*=18.25, df=1, p<0.05*). Bat hunting and recreation were higher among men than women.

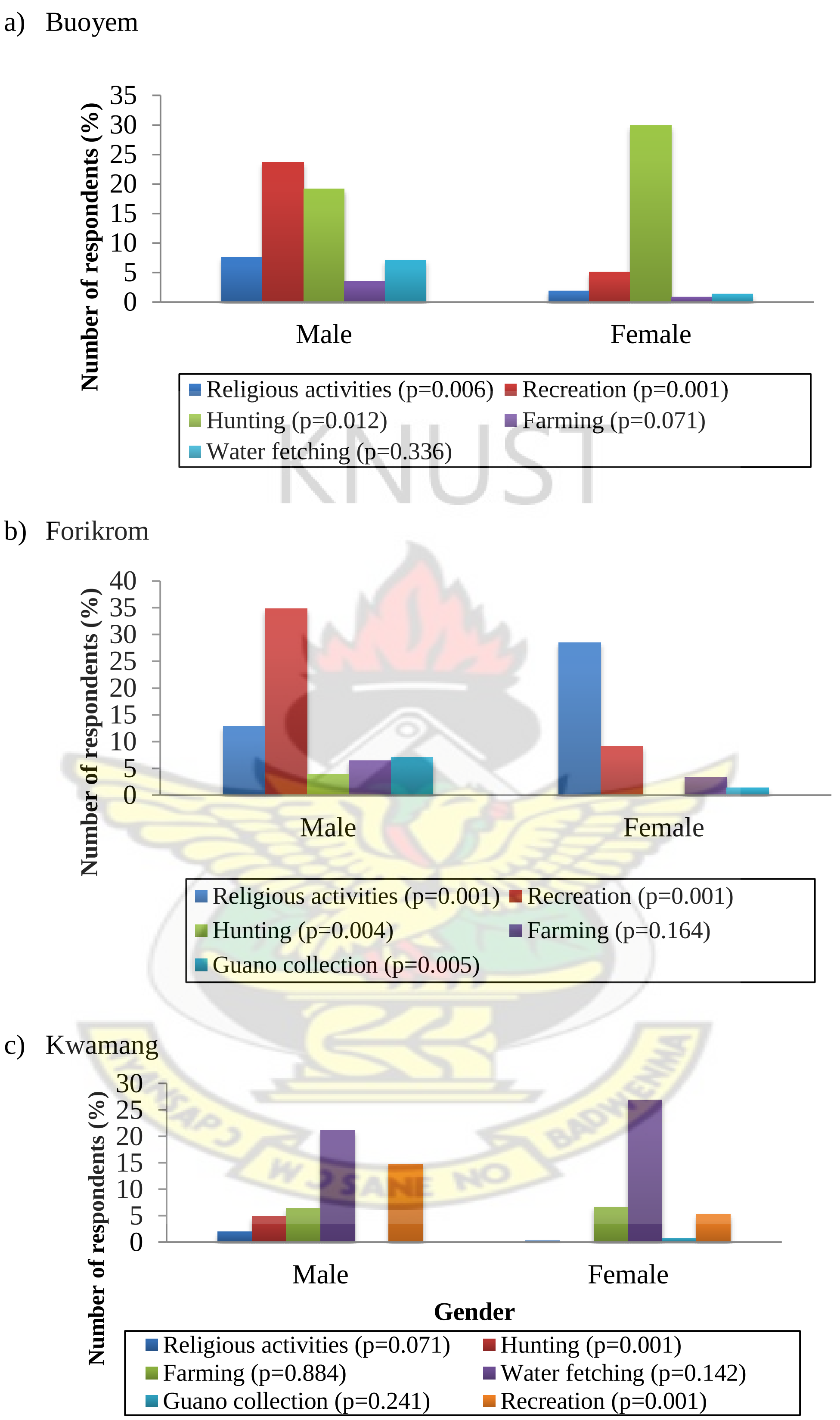

Figure 4.9: Gender of respondents and purpose of visiting bat caves at study area
Buoyem (n=182), Forikrom (n=176) and Kwamang (n=222)

4.4.3 Frequency of visits to bat caves between the communities

Frequency of visits to bat caves were classified into six categories namely once in a while, daily, weekly, monthly, annually, 2-5 years ago and more than five years ago (Figure 4.10). Annual visits to bat caves were highest in Buoyem representing 22% of respondents. This was in contrast to Forikrom and Kwamang where visits were mostly on a weekly basis representing 19% and a daily basis representing 17% of respondents respectively. With $p<0.05$, there were significant differences between the communities with respect to frequency of visits to bat caves.

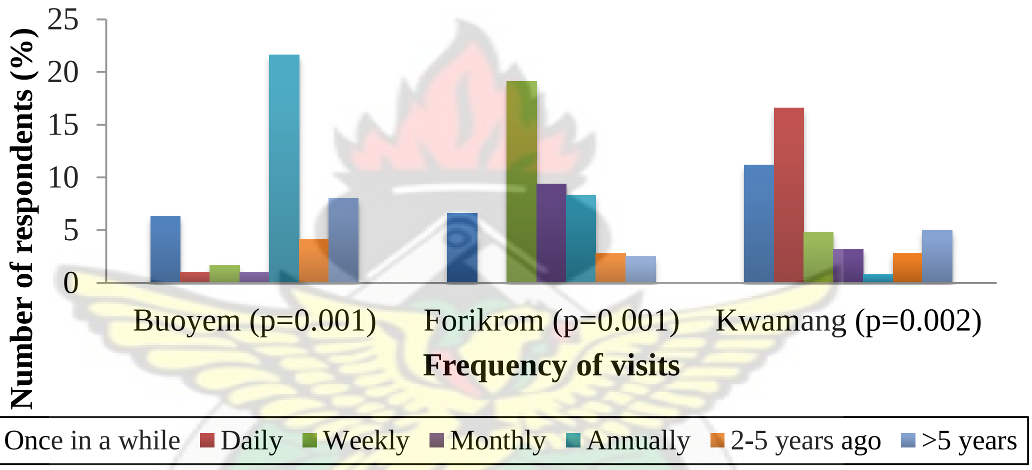

Figure 4.10: Respondents' frequency of visits to bat caves at study area
Buoyem (n=180), Forikrom (n=176) and Kwamang (n=222)

4.5 Occurrence of Bat Exposure

Any direct contact with a bat represents a potential exposure to bats. An exposure to bats in this study was classified as a bite or scratch from a bat or circumstances such as direct skin contact with a bat. In this study, situations that qualified as exposures included techniques used in capturing bats, bat bites, modes of preparation and consumption of bat meat.

4.5.1 Bat consumption

Generally, bats are used for food ($x^2=75.195$, $df=2$, $p<0.05$) in all three communities. A total of 257 respondents in Buoyem ate bats out of which 60% were males and 65% were females (Figure 4.11). In Forikrom, 141 respondents ate bats out of which 60% were males and 23% were females. In Kwamang, 183 respondents ate bats and this comprised 49% males and 28% females. Statistical testing confirms a significant difference between gender and bat consumption at Forikrom ($x^2=50.88$, $df=1$, $p<0.05$), and Kwamang ($x^2=21.80$, $df=1$, $p<0.05$). This suggests that in these communities, men consumed bat meat more than women. However at Buoyem, there was no significant difference between gender and bat consumption ($x^2=1.40$, $df=1$, $p>0.05$).

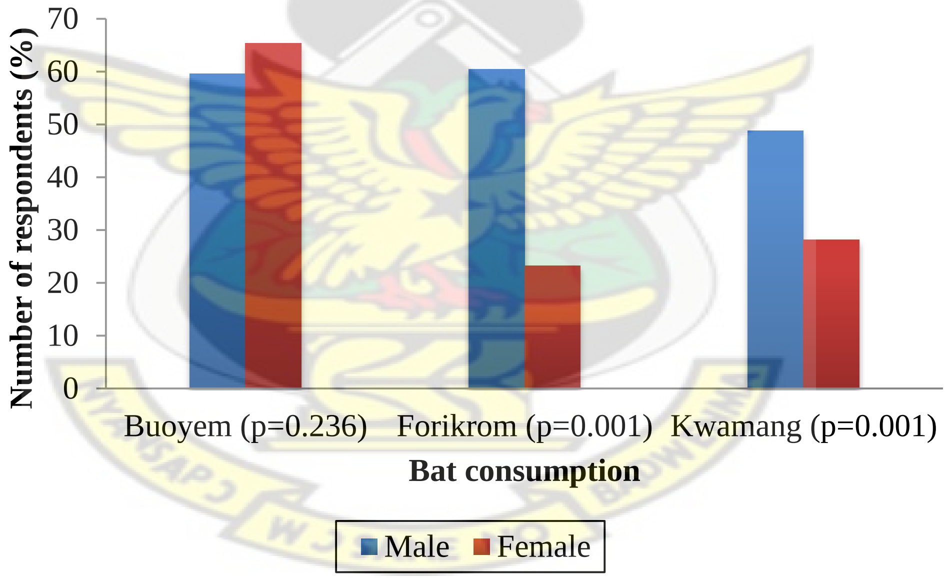

Figure 4.11: Gender of respondents who eat bats at study area
Buoyem (n=257), Forikrom (n=141) and Kwamang (n=183)

Bat consumption was highest among respondents older than 50 years in all the communities representing 95%, 58% and 54% for Buoyem, Forikrom and Kwamang respectively (Figure 4.12). Statistical testing also confirms a strong association between age and bat consumption in all the communities; Buoyem ($x^2=126.09$, $df=4$,

$p<0.05$), Forikrom ($x^2=27.893$, $df=4$, $p<0.05$) and Kwamang ($x^2=55.48$, $df=4$, $p<0.05$). This suggests that older respondents consumed more bat meat than younger persons.

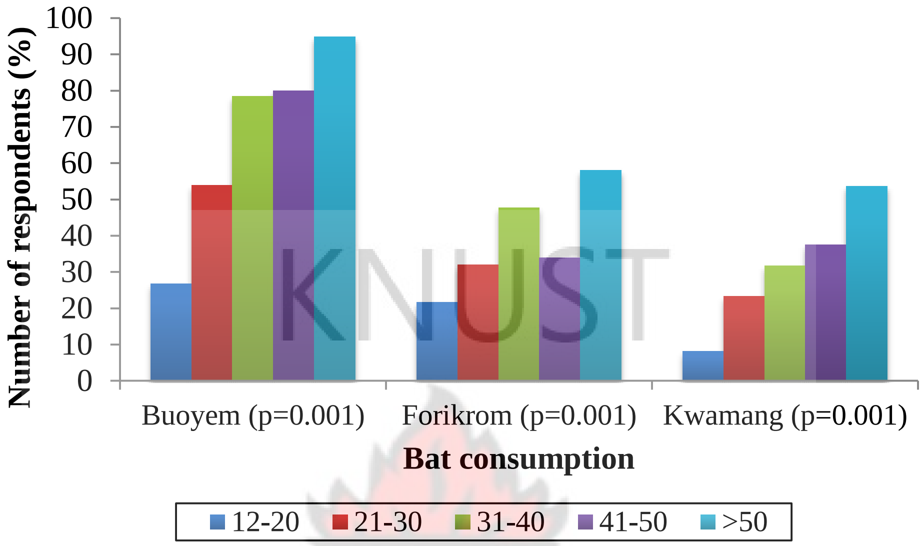

Figure 4.12: Age distribution of respondents who eat bats at study area
Buoyem (n=257), Forikrom (n=141) and Kwamang (n=183)

4.5.2 Frequency of bat consumption

Frequency of bat consumption was also classified into six categories namely once in a while, daily, weekly, monthly, annually, 2-5 years ago and more than five years ago (Figure 4.13). Majority of respondents in Buoyem, representing 29% had eaten bat meat more than five years ago. In Kwamang and Forikrom, 20% and 14% respectively of respondents ate bats once in a while. Generally, less than 0.2% of respondents in all three communities ate bats on a daily basis. There was a significant difference between the communities in terms of frequency of bat consumption ($x^2=198.76$, $df=14$, $p=0.000<0.05$).

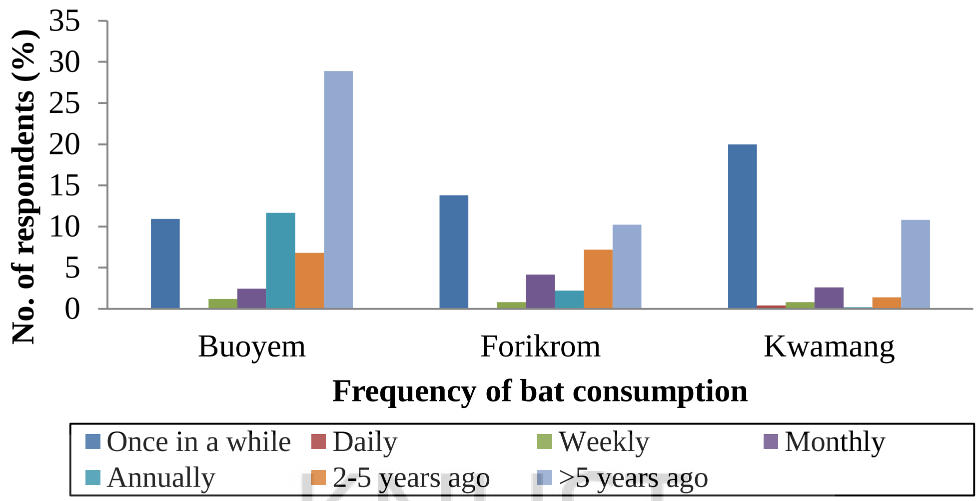

Figure 4.13: Respondents' frequency of consuming bats at study area
Buoyem (n=255), Forikrom (n=139) and Kwamang (n=181)

4.5.3 Mode of preparation and consumption of bat meat

Bats were generally boiled or roasted before consumption. Majority of respondents in Buoyem (53%) and Kwamang (29%) preferred roasted bats whereas boiling was more common at Forikrom (35%). Across all three communities, bats were largely consumed in soups.

4.5.4 Source of bat meat

Sources of bat meat in the communities include caves, markets, farms, homes, chop bars and others (Figure 4.14). The highest source of bat meat in Buoyem came from the caves (43%). In Forikrom the major source of bat meat was from farms (17%). Other areas mentioned by respondents in Buoyem and Forikrom were Tuobodom and Techiman. In Kwamang, the highest source of bat meat came from markets (14%). The sources of bat meat extended beyond the study areas. Information obtained from respondents showed other sources of bat meat include Duamo (3km away from Kwamang), Adobomam, Kyekyebon, Kumawu, Deduako, Agogo, and Kumasi (Zoo), all located in the Ashanti region; Techiman, Nkoranza, Tanoso and Tuobodom in the Brong Ahafo region; Afram Plains and Akuapem in the Eastern region, Accra (37 military hospital) in the Greater Accra region; Northern region and Cote d'Ivoire. There were significant differences between the communities with respect to caves, markets, farms, and homes ($p<0.05$).

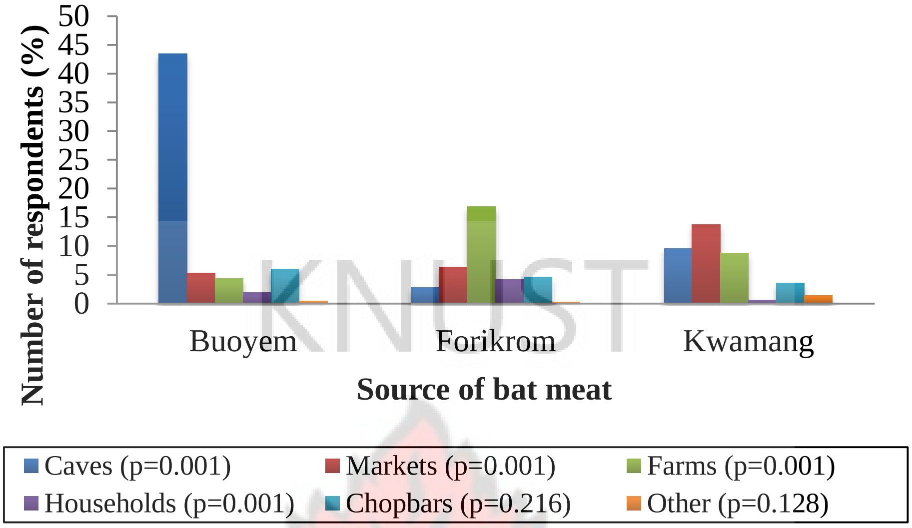

Figure 4.14: Respondents' source of bat meat at study area
Buoyem (n=254), Forikrom (n=127) and Kwamang (n=189)

4.5.5 Modes of hunting bats

The common techniques used in hunting bats within all three communities include guns, catapult, sticks and hands (Figure 4.15). In Buoyem, the major modes of hunting bats were the use of bare hands (picking live bats from roosts) followed by sticks representing 33% and 13% respectively. Catapults, guns and nets were the most preferred modes of capture in Forikrom representing 9%, 7% and 6% respectively. In Kwamang however, guns were most preferred modes of capture representing 11% of respondents.

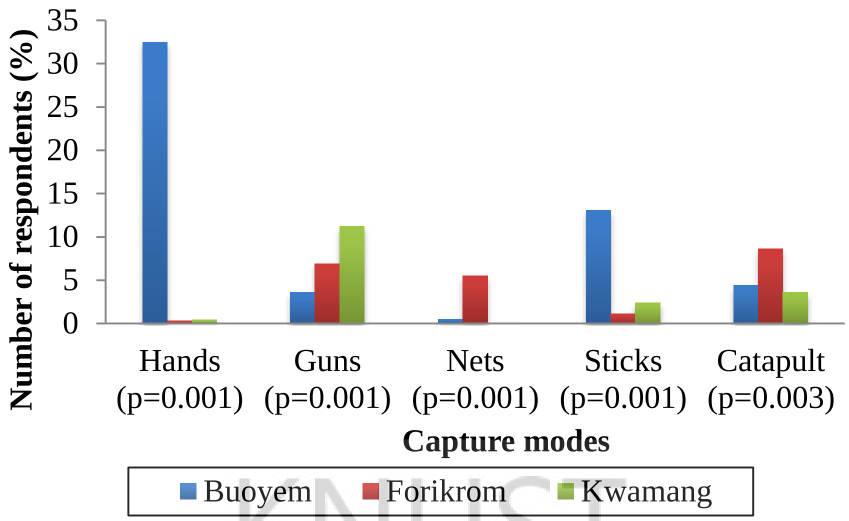

Figure 4.15: Respondents' modes of hunting bats at study area
Buoyem (n=412), Forikrom (n=362) and Kwamang (n=500)

4.5.6 Age and mode of capturing bats

At Buoyem, there was a strong difference between age and capturing of bats with hands ($x^2=144.290$, $df=4$, $p=0.001<0.05$) and sticks ($x^2=27.339$, $df=4$, $p=0.001<0.05$) (Figure 4.16). This suggests that older respondents predominantly used these hunting modes. At Forikrom, there was a significant difference between age and capturing of bats with nets ($x^2=22.555$, $df=4$, $p=0.001<0.05$) and guns ($x^2=16.718$, $df=4$, $p=0.002<0.05$). This suggests that older respondents (above 50 years) used nets to capture bats whereas the middle age persons (31-40 years) used guns. At Kwamang, there was a significant difference between age and capturing of bats with guns ($x^2=19.540$, $df=4$, $p=0.001<0.05$). This suggests that older respondents predominantly used these modes to capture bats more than the young people.

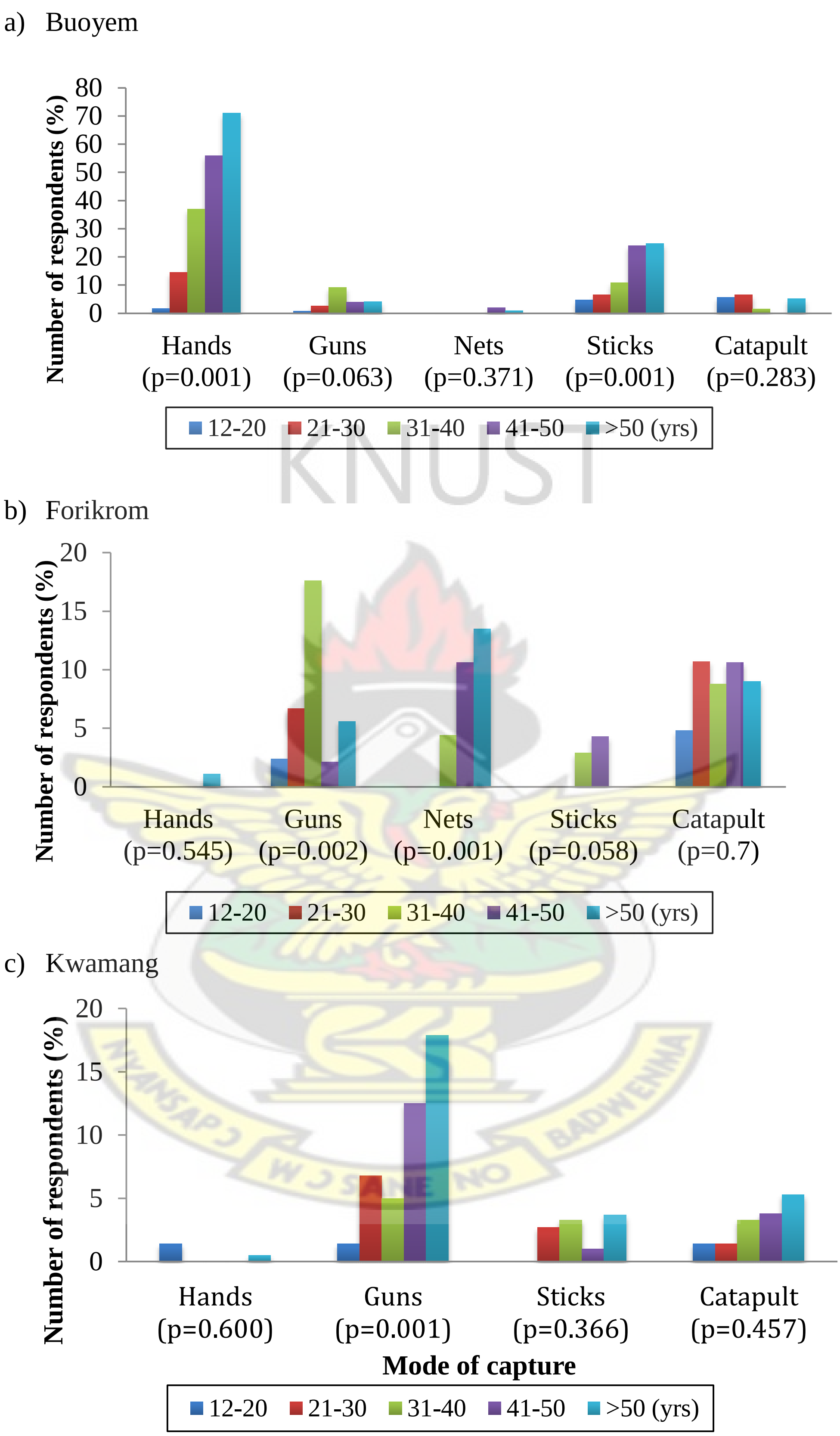

Figure 4.16: Age distribution of respondents and mode of capturing bats at study area

Buoyem (n=412), Forikrom (n=362) and Kwamang (n=500)

4.5.7 Bat bites

At Buoyem, 48 respondents had been bitten by bats and this comprised 19% males and 5% females (Figure 4.17). In Kwamang, only three males representing 2% had been bitten. Statistical testing confirms a significant difference between gender and bat bites at Buoyem (x^2=*21.062, df=1, p<0.05*) and Kwamang (x^2=*0.614, df=1, p<0.05*). This suggests that men experienced more bat bites than women in these communities. In Forikrom, five respondents had been bitten and this comprised 2% males and 1% females. However, there was no significant difference between gender and bat bites (x^2=*4.401, df=1, p>0.05*).

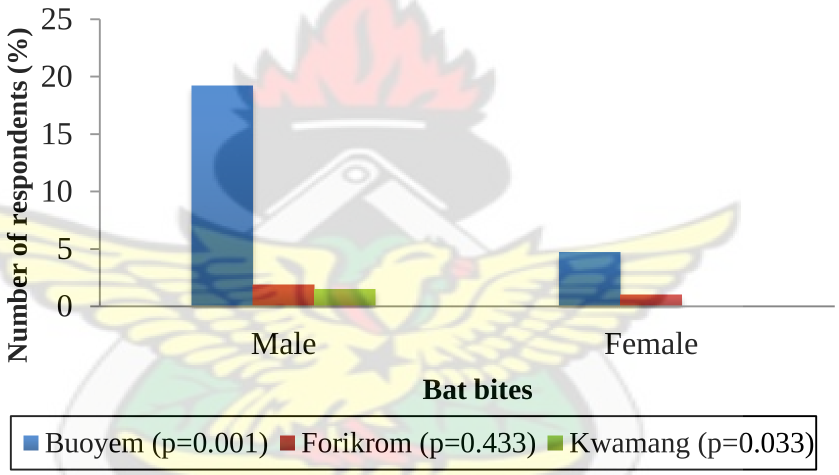

Figure 4.17: Gender of respondents who have been bitten by bats at study area Buoyem (n=48), Forikrom (n=5) and Kwamang (n=3)

Statistical testing also confirms a significant difference between age and bat bites at Buoyem (x^2=*59.625, df=4, p=0.001<0.05*) and Kwamang (x^2=*17.613, df=4, p=0.001<0.05*) (Figure 4.18). At Buoyem, older respondents experienced more bat bites than younger persons but at Kwamang only younger persons had experienced bat bites. At Forikrom however, there was no significant association between age groups and bat bites (x^2=*6.778, df=4, p=0.148>0.05*). Generally, there were no reports of bat bites for persons between the ages of 12 and 20 years in all three communities.

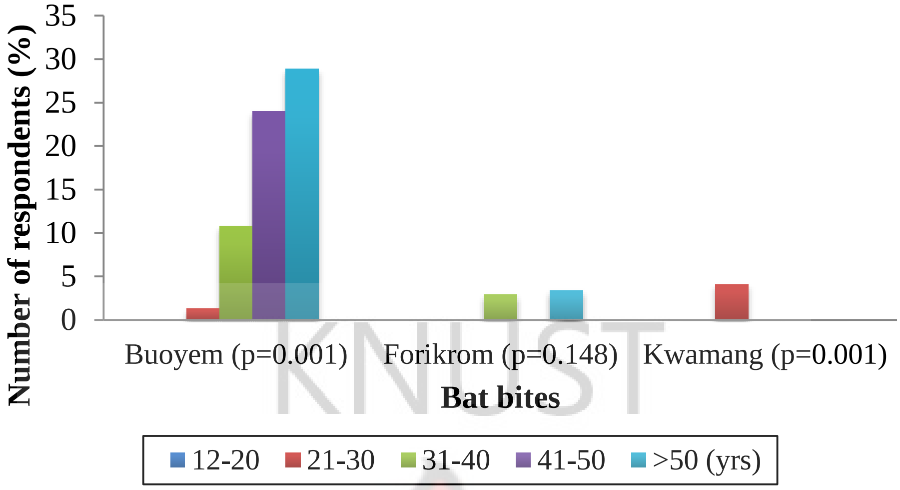

Figure 4.18: Age distribution of respondents who have been bitten by bats at study area
Buoyem (n=48), Forikrom (n=5) and Kwamang (n=3)

4.5.8 Treatment of bat bites

Respondents mentioned a range of treatments for bat bites. These include antibiotics, a mixture of antibiotics and palm kernel oil, soap, hot water, and sterillium (an alcohol based hand disinfectant) (Figure 4.19). In Buoyem, 10% of respondents who reported bat bites applied no treatment. Only 1% however, reported using hot water, antibiotics and a mixture of antibiotics and palm kernel oil. In Forikrom, 1% of respondents who had been bitten also applied no treatment. At Kwamang, 4% of respondents bitten washed injuries with soap.

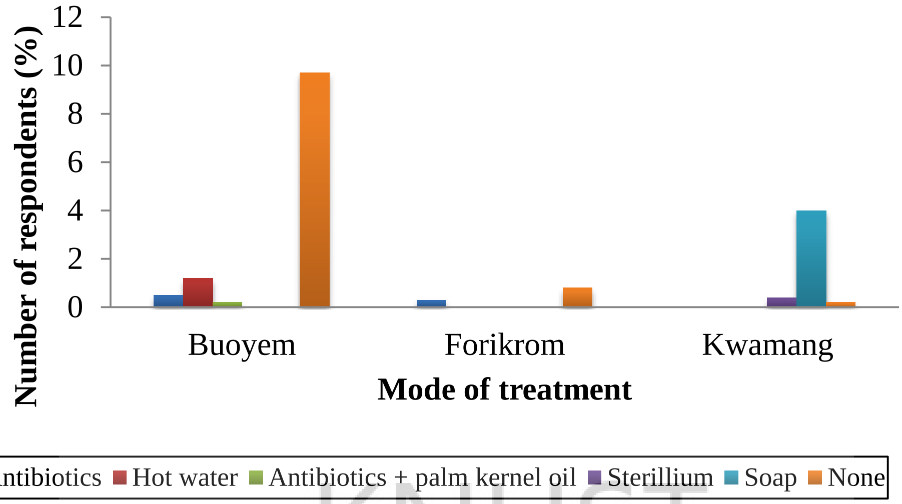

Figure 4.19: Respondents' modes of treating bat bites at study area

4.5.9 Infection from bat bites

More than 90% of respondents who had been bitten by bats in all three communities reported that they did not get any infections from bat bites (Figure 4.20). Less than 9% were not sure while 0.2% representing only one person from Buoyem reported getting an infection as result of a bite.

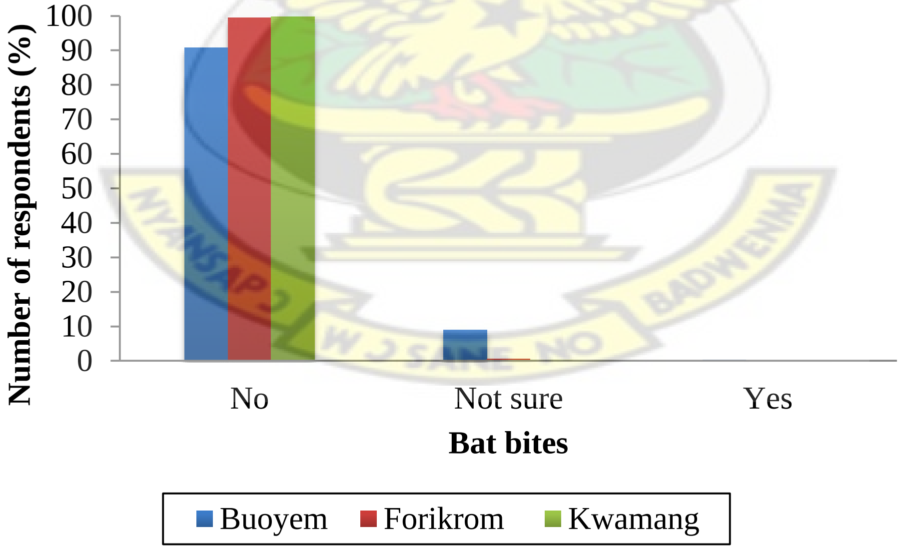

Figure 4.20: Respondents' views on infection from bat bites at study area
Buoyem (n=48), Forikrom (n=5) and Kwamang (n=3)

4.6 Visits to Bat Caves and Symptoms of Common Cold Infections

Generally, about 85% of respondents in all the communities who visited bat caves did not experience any symptoms of a common cold (Figure 4.21). However, 13% of respondents in all the communities who go to the caves experienced symptoms of common cold. Only about 2% were not sure of contracting symptoms of common cold from the caves. With a *p-value=0.197>0.05*, there was no association between visiting bat caves and common cold infections. This suggests that one is not likely to get symptoms of common cold from visiting bat caves.

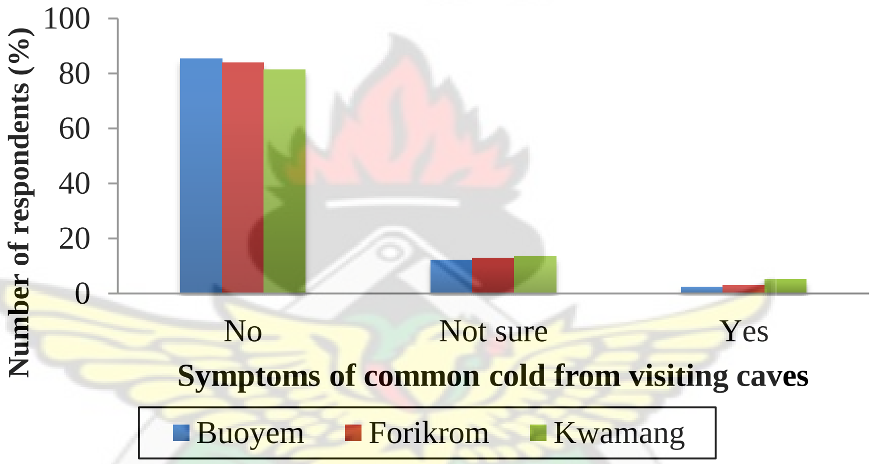

Figure 4.21: Respondents' perceptions on symptoms of cold from visiting bat caves study area

Respondents were asked how they contracted common cold infections and these were mentioned; coming close to infected persons, visiting farms, visiting bat caves, coming into direct contact with bats, and also other causes such as strong scent such as perfumes, cold weather, dust (Figure 4.22). Respondents however, reported no case of any disease epidemic in the past in all the communities.

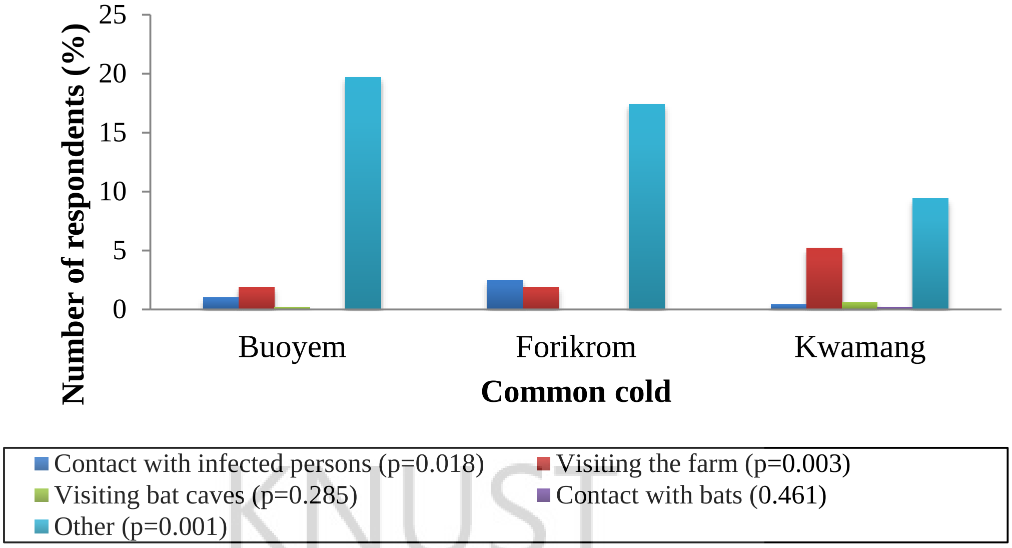

Figure 4.22: Respondents' perceptions on contracting common cold infections at study area
Buoyem (n=94), Forikrom (n=78) and Kwamang (n=79)

4.7 Ecosystem Services Provided by Bats

Respondents were asked about services bats provide in the communities (Figure 4.23). The following were mentioned; food, seed dispersal, fertilizer, tourism, income, employment, recreation, pollination, medicine and reduction of mosquitoes. Food and fertilizer contributed 100% of what people rated as important in Forikrom and Kwamang, and 60% in Buoyem. Dispersal, tourism, income, employment and reduction of mosquitoes contributed up to 80% in Buoyem and Forikrom. The results show that food, fertilizer, employment and pollination were significant.

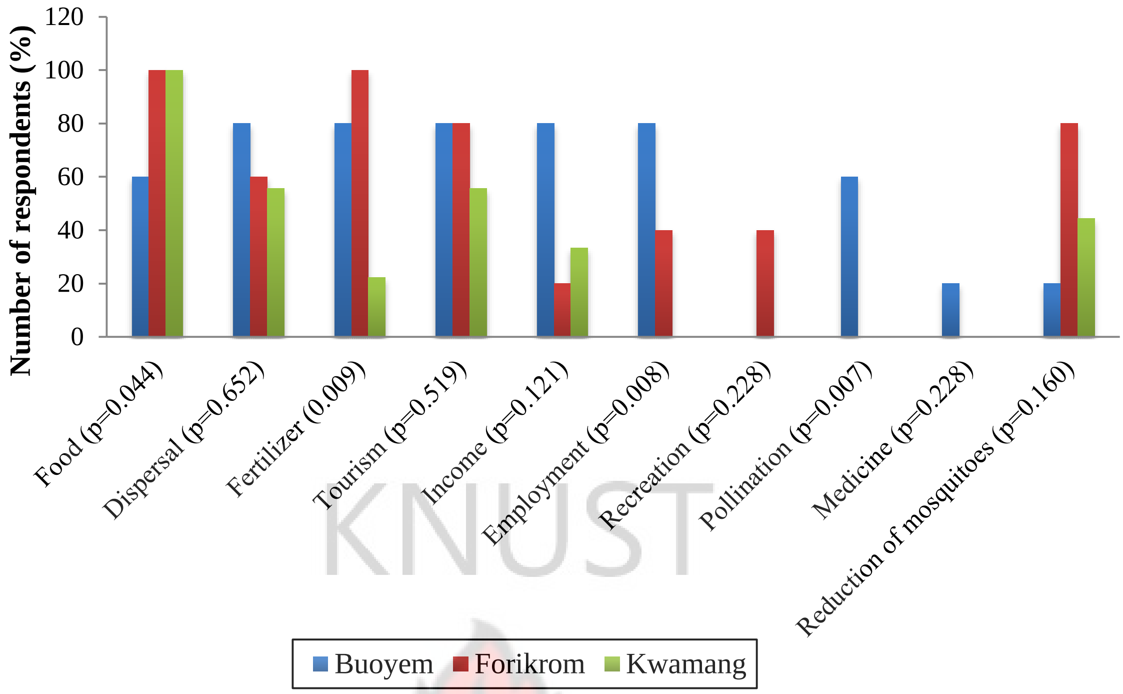

Figure 4.23: Respondents' perceptions on ecosystem services bats provide at study area
Buoyem (n=28), Forikrom (n=39) and Kwamang (n=69)

4.8 Problems Associated with Bats in the Communities

Respondents were also asked about negative services or problems associated with bats (Figure 4.24). Respondents believed that bats destroyed crops, had bad odour, transmit diseases, are noisy, destroyed ceilings, transmit common cold infections, caused conflicts, polluted their water and destroyed electric cables. Crop destruction contributed 100% of what people rated as negative services in all three communities. Bad odour, disease transmission, noise and water pollution contributed up to 80% in Forikrom and Kwamang. The results show that water pollution was statistically significant.

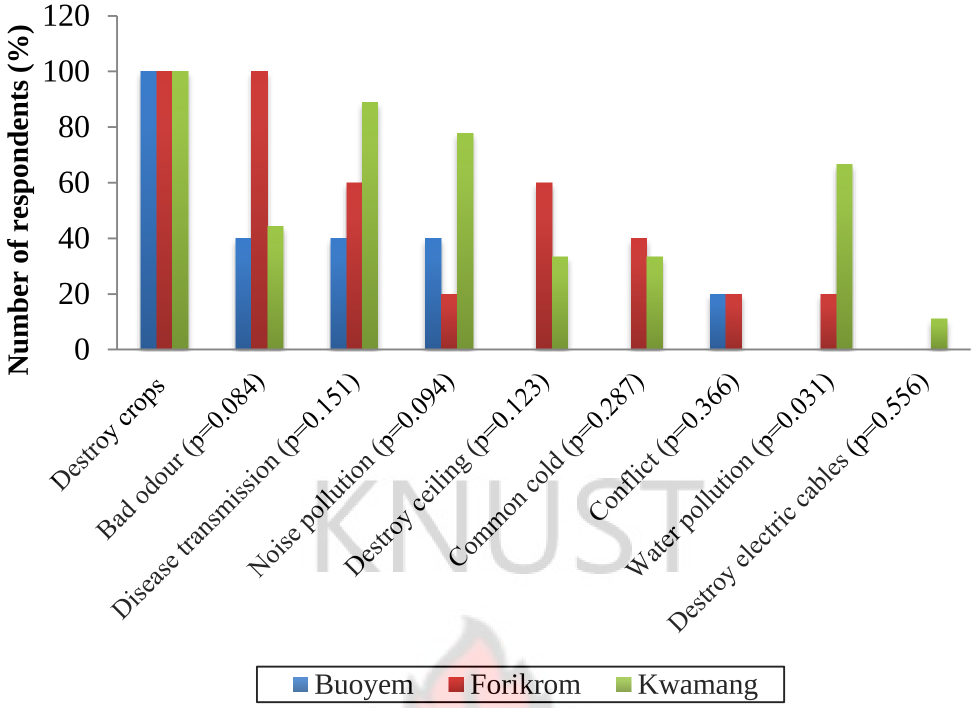

Figure 4.24: Respondents' perceptions on negative services bats provide at study area

Buoyem (n=28), Forikrom (n=39) and Kwamang (n=69)

CHAPTER 5: DISCUSSION

5.1 Sources of Human-Bat Contact within the Communities

The sources of human-bat contact identified in the study include caves, farms, households and schools. These sources corroborate with bats' preference for both natural and man-made/cultivated habitats (Kunz, 1982; Patz *et al.*, 2005a). The caves were the highest source of contact with bats in all three communities and this indicates a high reliance on this bio cultural resource by the local people as reported by (Guri, 2010). Contact sources may enable the process of any infectious disease emergence through physical contact between potential pathogens, in this case CoVs in bats, and humans (McMichael, 2004). This is because they serve as sites for transfer of pathogens and vectors to susceptible human populations (Patz *et al.*, 2005a). Based on the results of the study, the potential for human-bat contact at the sources mentioned can be viewed as a two-way situation.

Contact with bats in the community caves and farms are as a result of human movement into the natural habitats of bats (Katare and Kumar, 2010). FAO (2011) further explains that increasing human population, which cause such movement into and around bat habitats, create opportunities for negative interactions to occur. Such anthropogenic forces generate an enabling environment for high contact rates with bats (Patz *et al.*, 2004; Slingenbergh *et al.*, 2004).

On the other hand, contact with bats in homes and schools are as a result of movement by bats into the habitat of man (Wong *et al.*, 2007). Movement by bats is a very important process through which pathogens and diseases bats potentially carry are spread (Williams *et al.*, 2002; Calisher *et al.*, 2006). Although the origin of the coronaviruses identified in *Hipposideros* aff. *ruber* and *Nycteris* cf. *gambiensis* in

Buoyem, Kwamang and Forikrom is somewhat unknown, the movement by bats either deliberately or accidentally may potentially expand the geographic range of the virus as well as other newly discovered viruses bats are known to carry (Williams *et al.*, 2002; Pfefferle *et al.*, 2009; Annan *et al.*, 2013). For example, according to Williams *et al.*, (2002), the geographic expansion of Rabies occurred by both natural and anthropogenic movements of wildlife. While it is unknown whether the identified sources of contact with bats in this study contain foci of infections, regular human contacts with bats in these systems may increase the risk of human infections from bats (Patz *et al.*, 2005b).

5.2 Socio-demographic characteristics of respondents and sources of contact with bats

Age and gender are known social determinants of health in developing countries (CDC, 2010; Viner *et al.*, 2012). According to WHO, social determinants of health are defined as "the conditions in which people are born, grow, live, work and age". This study identified the link between these social determinants and the sources where humans come into contact with bats. The findings from the study showed that age, and gender of respondents had an effect on the sources where bats and humans come into contact.

Generally, older respondents (>50 years) had the highest contact with bats on farms in all three communities. This is because they engaged mainly in farming as their occupation and therefore, stood a higher chance of coming into contact with bats on farms. Respondents identified some of the bats as "big bats" which fed on their crops. This brings them into closer contact with humans, hence, creating a risk of potential zoonotic pathogens on the farms where humans and bats are in constant close proximity (Kuzmin *et al.*, 2011).

In Buoyem, older respondents had the highest contact with bats in caves because they had high dependency on the caves. Some of this group indicated that their farms were located close to the caves and therefore occasionally sourced this water for irrigation. Others also mentioned that they took shelter in the caves during the rainy season. At Buoyem and Kwamang, younger respondents (<30 years) had the highest contact with bats at school because of the presence of the bats in the schools' compound. They indicated that some trees located on the school's compound served as roosting sites for bats. The focal species (*H. aff. ruber*) from observations were seen to be roosting in the ceilings of a school at Kwamang. There is a clear indication that age of respondents is a major factor that influenced contact with bats at the sources. Therefore, it can be inferred that older respondents are at a higher risk of potential zoonotic infections from caves and farms whereas the youth are at a higher risk at school.

In terms of gender, more men had contact with bats in homes, farms and caves than women at Kwamang and Forikrom. This can be attributed to the fact that the men spend longer hours on farms, hence, leave late and just about the time the bats come out of the caves to forage. The women probably leave earlier to go and prepare the evening meals. Traditionally, men are responsible for outdoor activities and strenuous activities, mostly working on the farm full time while women work part-time since they combine off-farm and household work (Bjørkhaug and Blekesaune, 2008). Therefore, it can be inferred that men are at a higher risk of any zoonotic infections from these identified sources than women.

5.3 Community Use of Bat Caves

Most indigenous societies inhabiting bio-cultural resources rely on such resources to a make a living (Suneetha *et al.*, 2010). Caves are valuable to indigenous people not only because of all the goods (consumptive values) they can get but also because of many other reasons (non–consumptive values) (Erni, 2011). From the study, use of bat caves was significantly different between the communities and the activities include; religious activities, recreation, hunting, farming, water fetching and guano collection. The findings from the study indicate that the caves in all three communities provide both consumptive (food, water and guano) and non-consumptive (recreation and spiritual) values to the people (Erni, 2011; FAO, 2011).

In all three communities, more men visited the bat caves than women. This is because, in traditional indigenous communities, men and older people are more engaged in outdoor activities than women and children (Bjørkhaug and Blekesaune, 2008).

5.3.1 Social and cultural factors influencing use of bat caves

The study showed how social and cultural factors influencing the use of bat caves are associated with potential CoV transmission. People's behaviour may dictate how a disease enters a community and how it spreads (AAHL, 2012). Accordingly, social and cultural factors including physical attributes such as gender and age, general beliefs and cultural practices, which may influence potential health risk from use of bat caves was sought (AAHL, 2012).

In Buoyem the main purpose for respondents' visits to the bat caves was hunting and the older respondents mainly engaged in this activity. In this study, the capturing of bats, dead or alive, irrespective of techniques used for the purpose has been considered as hunting (Chutia, 2010). In the past, the Buoyem community engaged in an annual hunting of bats in the caves to commence the yam festival. This is similar to the report by Chardonnet (2002) in the pacific region where bats are important sources of food and also play important roles in ceremonies, such as the annual yam festival. FAO (2011) also reports that in Carolina Islands of the Federated State of Micronesia, bats are a highly valued delicacy traditionally eaten at celebrations by certain tribes such as the Chamorros and Carolinians. Such cultural celebrations, according to Chomel *et al*., (2007), are a contributing driver of zoonotic infections.

During the hunt in Buoyem caves, only adults went to the caves while the children stayed at home. The men went to the caves on Wednesday evenings with ladders and waited till the bats returned from feeding and then caught them. This corroborates with the report by (Kamins *et al.*, 2011), where only men are generally involved in bat hunting. The women went on Thursdays mainly to collect the night's catch and take them home. According to Chutia (2010), the extraction of animals from the wild for sustenance has been the way of life in many rural communities. Similarly, the bats in Buoyem have been a primary source of food for these people in the past. Following Chardonnet *et al.,* (2002), hunting varies from subsistence to commercial to leisure. Based on this classification, the main type of hunting practised in this community can be described as subsistence for households as this provided a large proportion of the meat eaten by the rural people in the past (Kamins *et al.*, 2011). According to the respondents, each person could catch a minimum of 20 to 30 bats depending on the size of the bag being used. Typically, empty rice sacks were used for collecting the dead bats. Bat hunting may enable the spread of zoonotic infections through physical contact with bat secretions and excretions (Kruse *et al.*, 2004). The culture of cave hunting was still practised in Buoyem until the last three decades. Due to chieftaincy disputes and conflict over the ownership of the cave lands in the community, this practice has been discontinued. According to Bjørkhaug and Blekesaune (2008), in traditional indigenous communities, older people are more engaged in outdoor activities than younger people. This explains why hunting in caves was highest among older respondents. Age was only associated with hunting probably because of the long distance (about 15 km) from the community to the caves. Gender was however, associated with religious activities, recreation and also hunting.

According to FAO (2011), traditional myths and beliefs are associated with the use of bio-cultural resources like caves. In the study, one reason why fewer women visited the caves compared to men is that, women are restricted from going to the caves when they are in their menstrual periods. This is because traditionally, women are considered to be unclean during that period. Furthermore, the caves have spiritual significance and are considered as sacred groves where spirits dwell hence, women who go there during that period are believed to be severely punished by the gods (Erni, 2011). Nevertheless, the emerging modern world and Christianity are gradually weakening these traditional rules and customs, and in many instances the new generations are abandoning the customary rules. Generally, women visited the caves predominantly during the annual hunting since they were largely limited to the collection of hunted bats. It was reported that these hunting activities in the caves were done without any protective covering like nose masks or proper clothing. Lights and shoes were not even allowed since the caves were considered as holy grounds for gods and ancestral spirits (Erni, 2011). Such situations may enable conditions for indirect contact transmission to occur for individuals who come into contact with contaminated water or soil, or inhale airborne pathogens from the caves (Shakespeare, 2002; Siegel *et al.*, 2007).

5.3.2 Traditional rites influencing use of bat caves

Among all indigenous societies, land is worshiped and respected and forms the core of culture and source of identity (Erni, 2011). Many indigenous people form close relationship with other beings (Zinsstag, 2001). In some indigenous societies, all living and non-living things in the universe are closely interlinked and were expressed in traditional ceremonies and rituals (Erni, 2011). From the study, bat caves have a strong cultural and spiritual value which cannot be measured in monetary terms (Butler and Oluoch-Kosura, 2006; Hein *et al.*, 2006). They serve as sacred places which are important for worshiping. According to Erni (2011), the cultural and spiritual values of caves have a strong influence on the preferences of people and their well-being. The caves in all three communities serve as shrines and tourist attraction and the men usually serve as caretakers and tourist guides (Habitat for Humanity Ghana, 2011). The findings from the study also showed that traditional elders responsible for appeasing the "gods" are mostly men. Although the caves serve as a common property for the community, it does not necessarily make it a free-access resource. In Buoyem and Forikrom, use of caves depends on people in powerful positions in the community such as spiritual leaders; chief priests and traditional rulers who have strong responsibilities of ensuring the caves remain a holy ground for the gods (Butler and Oluoch-Kosura, 2006; Hein *et al.*, 2006). Thus, these traditional authorities mainly the chief priest and his elders perform some rituals annually to appease the gods. They do this every year by sacrificing a cow and also pouring libations to the gods. This explains why more men visited the caves mainly for recreation and religious activities than women.

In Forikrom, though the main purpose of visiting the caves was religious activities, there was no significant difference between age and this purpose. The caves (also referred to as Holy caves) serves as a prayer and camping ground for at least 400 people from different religious sects every month (Guri, 2010). The study also showed a significant difference between age and only recreation, which was mostly done by younger respondents.

5.3.3 Livelihood options influencing use of bat caves

In Kwamang, older respondents visited the caves mostly for farming whereas younger persons visited the caves predominantly for religious activities, recreation and water fetching. Water is scarce in this community so members of this community resort to either rainwater or the cave water. Water availability is a major limiting factor in the Kwamang community not only for the survival of bats, agricultural and production systems, but also for human health. This is because human health depends on access to clean water, clean air, and sanitation. According to Patz *et al.,* (2005a), water scarcity and the poor quality of available water can increase the risk of transmission of pathogens associated with bats, leading to zoonotic diseases. These potential infections may be intensified by the already existing physical health problems common in rural communities, such as malnutrition, as well as inadequate medical care, which are often evident in such communities (Katare and Kumar, 2010). There was a high degree of water contact with bats since it is possible that the local people also drink from the cave water, hence, the people especially younger respondents in this community are at a risk of any potential disease transmission from bats (Patz *et al.*, 2005a).

Though water fetching from caves was significantly different with age, there was no significant difference with respect to gender. The men visited the caves mainly for recreation and hunting purposes while women went there mainly for recreation only.

This is because, in traditional indigenous communities, men engage in a lot of outdoor activities than women (Bjørkhaug and Blekesaune, 2008). Generally, the main purpose for men visiting the caves was the same for all the three communities but that of women differed.

5.3.4 Implications of community use of bat caves on human health

Community use of bat caves identified in the study indicates direct anthropogenic drivers of cave ecosystem disturbance that potentially affect infectious disease risk (Patz *et al.*, 2005a). These risk factors underlie social and economic factors that determine the health of a community (CDC, 2010; Viner *et al.*, 2012). For instance, some Christian religious sects hold prayer camps in the bat caves. It was observed that these religious sects especially those in Kwamang spend more than 20 hours each day for a maximum of two weeks inside the caves. They were however unwilling to participate in the interviews. Although the possibility of direct bat-to-human transmission of coronaviruses from *H.* aff. *ruber* and *Nycteris* cf. *gambiensis* is somewhat obscure, there is a possible route of transmission of pathogens through inhalation of infectious particles (aerosols) by humans inside the caves (Wong *et al.*, 2007; Pfefferle *et al.*, 2009; Annan *et al.*, 2013). These potential infective aerosols could arise from secretions such as saliva or guano of the bats. This transmission route is known to possibly occur in Lyssa virus infections (Wong *et al.*, 2007). According to Patz *et al.*, (2005a), these anthropogenic drivers can lead to specific changes in ecosystems that may or may not lead to disease emergence.

5.4 Occurrence of Bat Exposures

According to CDC (2010), any direct contact with a bat represents a potential exposure to bats. An exposure to bats in this study was classified as a bite or scratch from a bat or circumstances such as direct skin contact with a bat. Situations that qualified as exposures included techniques used in capturing bats, bat bites, modes of preparation and consumption of bat meat. The study showed few exposures from unprovoked encounters with bats, suggesting that bats rarely initiated contact with humans in the communities (Dendle and Looke, 2008).

5.4.1 Sources of bat meat and techniques used in capture of bats

The main sources of bat meat in the communities include caves, markets, farms, homes and chop bars. In Buoyem, the main source of bat meat came from the caves. Only *Rousettus aegyptiacus,* a fruit bat known to echolocate and roosts in caves was traditionally hunted, mainly with bare hands (Jenkins and Racey, 2008). Respondents however used sticks to catch those in flight and at higher heights in the caves. This technique involved throwing sticks at roosting bats and collecting the animals that fell, or striking them as they emerged from the cave (Jenkins and Racey, 2008).

In Forikrom bats were mainly caught on farms. These bats are suspected to be fruit bats as well since the farmers mentioned them to be seen roosting in coconut, mango, cashew and other fruit trees on their farms. The respondents could not identify the particular species eaten; though, some identified catching *Hypsignathus monstrosus*. Other respondents identified these fruit bats as *Eidolon helvum.* The bats were caught mainly with catapults and guns. This method of hunting bats is corroborated by Kamins *et al.,* (2014).

There were also reports of collecting scavenged bats similar to the report by Kamins *et al*., (2014). Scavenged bats were collected alive or dead when they got entangled in electricity lines.

In Kwamang however, bat meat could be obtained at markets. Respondents reported buying freshly killed as well as roasted bats from markets. The commodity value chain through which fruit bats are sold extends beyond all three communities. Information obtained from respondents and market vendors in the communities showed the supply route of bat meat extends far beyond the Brong Ahafo region to other regions and neighbouring countries in Ghana. This corroborates with Kamins *et al.,* (2011) on the commodity chain and extent of bat hunting in Ghana.

With regards to hunting techniques, the results from this study are similar to the general picture of hunting cave bats in Madagascar, where sticks and hand collection in sacks were found to be the principal mode of capture (Jenkins and Racey, 2008). Similarly, the use of guns and nets corroborates with Jenkins and Racey (2008) and Kamins *et al.*, (2014), where similar techniques are used for the fruit bats perching on roost trees. Hunting techniques used in trapping bats are generally considered to increase the risk of exposure to zoonotic parasites and pathogens (Schurer *et al.*, 2013). This is because they could expose the handler to the bats' blood and body fluids or bites and scratches creating a risk of potential zoonotic infections (Maine Rabies Workgroup, 2012). However, the findings from the study indicates risk of potential transmission from hunting techniques used in all three communities (Kamins *et al.*, 2014). .

5.4.2 Consumption of bat meat

According to Field (2009), culture underlies wildlife consumption in some countries. Chutia (2010) reported that different groups utilize the kills obtained by hunting for different purposes such as meat (food), traditional medicines, trophies, rituals and socio-cultural celebrations. However in this study, bats are mainly used as food in all three communities. Similar to the report by FAO (2011), the hunted species are predominantly fruit bats (flying foxes). Respondents described the species hunted as "big" bats and based on pictures shown to them; some species identified by the respondents include *Rousettus aegyptiacus, Eidolon helvum, and Hypsignathus monstrosus*. The small insectivorous species were described by the respondents as "smelly" and also did not have enough meat so they were not preferred though they have been reported to be hunted for food in Africa and the Pacific region (Chardonnet *et al.*, 2002; Kamins *et al.*, 2011). Field (2009) reported that many people, particularly in southern China prefer wildlife because they believe that it adds social status, prosperity, and health benefits. In this study some respondents mentioned that bat meat was leaner and healthier similar to the report by Kamins *et al.*, (2014). The consumption of bat meat is practised in many parts of Ghana (Kamins *et al.*, 2011; Kamins *et al.*, 2014). One risk factor known to be associated with the emergence of zoonotic diseases is consumption of bat meat (Chomel *et al.*, 2007).

In Ghana, bat meat is usually preferred roasted or smoked (Kamins *et al.*, 2011; Kamins *et al.*, 2014). Though this was evident in Buoyem and Kwamang, it was in contrast with Forikrom where respondents preferred boiled bat meat. There were however, no reported infections from consuming bat meat in the study. This is possibly because according to Wong *et al.*, (2007), well-cooked bat meat is unlikely to pose any risk for transmission of infections. However, slaughtering of bats could expose the handler to the bats' blood and body fluids or bites and scratches creating a risk of potential zoonotic infections (Maine Rabies Workgroup, 2012). .

Gender is considered as one of the important determinants of exposure to zoonotic disease (Kimani *et al.*, 2012; Kamins *et al.*, 2014). Though gender was not associated with bat consumption in Buoyem, the study showed that in Kwamang and Forikrom, men consumed bats more than women. Bat meat consumption was highest among older respondents because in traditional Ghanaian communities, adults consume more meat than children. Another reason is probably because they have lived together with bats in the communities for a longer period of time and thus was generally more aware of bats. This puts men at a higher risk of potential zoonotic infections than women; and adults at a higher risk than children.

5.4.3 Exposure from bat bites and scratches

According to Dendle and Looke (2008), animal bites especially bat bites are a significant public health problem. From the study, the fact that bat hunting was more common among the older respondents at Buoyem could explain why they experienced more bites than the youth. This is in contrast to Kwamang where younger respondents between 21-30 years had experienced bat bites. The study showed more men experienced bat bites than women at Buoyem and Kwamang. This can be due to the fact that the men did the catching and killing of the bats whereas the women collected and processed the carcass. This also highlights that men engage in a lot of strenuous activities than women in traditional indigenous communities (Bjørkhaug and Blekesaune, 2008). The findings from this study corroborates with Dendle and Looke (2008), where people at risk of animal bites include young people and men.

Bites from animals are considered as an important, yet under recognized problem in countries such as Ghana (Dendle and Looke, 2008). Unfortunately, sometimes bat bites and scratches may go unnoticed. In certain situations it may be impossible to know if contact with a bat has occurred. Given the respondents' level of education and overall familiarity with bats, 90% of respondents who had been bitten by bats in all three communities reported that they did not get any infections from bat bites. Less than 9% were not sure while 0.2% representing only one person from Buoyem reported getting an infection as result of a bite. If so, this would support the hypothesis that people may lack the knowledge to seek medical care if a bat bites them (Gibbons *et al.*, 2002). Moreover, unlike bites from larger mammalian carnivores, lesions resulting from a bat bite usually do not warrant seeking medical care. According to Dendle and Looke (2008), infectious pathogens usually arise from the mouth of the biting animal. According to the Centers for Disease Control, technically, a scratch contaminated with saliva is an exposure, but scratches alone are less likely to transmit infections than a bite. According to Pfefferle *et al.*, (2009), CoVs are almost exclusively detected in bat faeces and not in saliva. Thus any risk of contracting CoVs from bat bites is unlikely in all three communities. Nevertheless, according to CDC, any bite from bats should always be considered a potential for rabies exposure. In fact, all bat bites are of high risk and the greatest health risk associated with bats is Rabies, with direct contact through bites and scratches being the most obvious example (Dendle and Looke, 2008; Maine Rabies Workgroup, 2012). The practical problem therefore, arises in the consideration of bites and scratches from bats; and more importantly, whether a person bitten or scratched by a bat can discern getting any infections from the bite or scratch, particularly under the dark conditions of the bat caves.

5.5 Evidence of Common Cold Infections and Disease Epidemics from Past Bat Exposures

From the study, health complaints attributed to bats by respondents were mainly common cold infections as well as discomfort caused by their smell. However, common cold infections from visiting caves was not reported by respondents. This can be attributed to the fact that, for many animal pathogens, hunters and people occupationally exposed to wild animal species are more likely to have had prior exposure to the pathogens and therefore show presence of antibodies (Swift *et al.*, 2007).

Results from the focus group discussions also indicated that health and hygiene was a major concern. This is because out of the nine negative services mentioned by the groups, five (including bad odour, disease transmission, noise pollution, common cold and water pollution) were related to health and hygiene. In Forikrom, some people perceived that bad odour from bats could transmit diseases. Moreover, though the study only showed water pollution to be statistically significant, the rest cannot be overlooked. In Kwamang, respondents mentioned one major problem they faced with bats was water pollution. As mentioned earlier water is scarce in this community and many of the people either store rainwater or fetch water from the bat caves. Accumulated faeces and urine from bats usually contaminate the stored water (Shakespeare, 2002; Siegel *et al.*, 2007).

In general, direct contact between bats and people in the communities was low except for certain groups, such as people who visit bat caves, hunt, prepare or eat bats. Respondents were not aware of any reported epidemic within the past 30 years and at the time the study was conducted in all three communities. Indeed, no evidence of an epidemic from human associations with bats was found among respondents, most of who had close interactions with insectivorous bats as well as flying foxes and therefore are exposed to potential zoonotic infections. This could be due to the fact that, the magnitude or potential for emergence of zoonotic viruses incidence into a community depends on the susceptibility of human populations, prevalence of the virus in its host species and the degree to which the reservoir host interacts with humans (Patz *et al.*, 2005a). It can therefore be inferred from the study that, there is a low risk of transmission of coronavirus directly from bats though there was no epidemiological data collected in the study to support a link (Pfefferle *et al.*, 2009; Annan *et al.*, 2013). Thus this study suggests possible transmission directly from bats to humans is a rare event.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study extends the number of studies on the interactions humans have with wildlife, principally bats in Ghana and importantly provides comparative data on three rural communities with cave bats. This study was descriptive, exploratory and explanatory since it sought to explore and describe the interactions humans have with bats and eventually provide explanations about the phenomenon and also identify relationships between aspects of the phenomenon. The study shows that interactions between humans and bats, based on a sample from three different communities vary with respect to community, gender and age.

6.1.1 Sources of human-bat contact within the communities

The sources of human-bat contact within the communities were caves, farms, homes and schools. The potential for human-bat contact at these sources can be viewed as a two-way situation; human invasion into the natural habitats of bats and also movement by the bats into human dwellings. The caves were the highest source of contact with bats in all the communities. Interestingly, direct and indirect contact modes with the focal species *Hipposideros.* aff. *ruber* occurred within all the sources whereas contact with *Nycteris* cf. *gambiensis* occurred only at the caves and farms. In Forikrom and Kwamang, *Hipposideros* aff. *ruber* was also reported to roost regularly in ceilings and this was confirmed through personal observations. In addition, respondents in Kwamang mentioned that one major problem they faced with bats in their homes was water pollution due to accumulated faeces and urine from bats, which usually contaminate their stored water. From the focus group discussions, the presence of bats in human dwellings like homes and schools have triggered the fear of possible risk of diseases though this risk seems to be low. However concerns, highlighted are smell, noise and accumulation of droppings.

6.1.2 Socio-demographic characteristics and sources of contact with bats

Age and gender had an effect on the sources where bats and humans come into contact. Generally, older respondents (>50 years) had the highest contact with bats at the farms in all three communities. In Buoyem, older respondents had the highest contact with bats in caves. At Buoyem and Kwamang, younger respondents (<30 years) had the highest contact with bats at school. There is a clear indication that age of respondents is a major factor that influenced contact with bats at the sources. Men had more contact with bats in homes, farms and caves and therefore are at a higher risk of any zoonotic infections from these identified sources than women at Forikrom and Kwamang.

6.1.3 Community use of bats and caves

Community use of bat caves includes the use of bat caves for recreation, religious activities, bat hunting, water fetching and guano collection. Hunting, religious activities and water were the main purposes for visiting the bat caves at Buoyem, Forikrom and Kwamang respectively. The duration of a typical visit by respondents to the bat caves was between 30 minutes and at least 10 hours. The study showed that in all three communities, women and men had different roles and responsibilities regarding use of the bat caves. In all three communities, more men visited the bat caves than women and are therefore at a higher risk of potential zoonotic infections from bat caves. In Buoyem, the highest visits to the bat caves were by older persons. This puts them at a higher risk of potential zoonotic infections. This was in contrast to Kwamang and Forikrom where young people predominantly visited the caves, thus at a higher risk than older people.

Gender was associated with religious activities, recreation and hunting at Buoyem. More men visited the caves mainly for religious activities, recreation and hunting than women. In Forikrom gender was only associated with recreation and hunting. The men visited the caves mainly for recreation and hunting purposes while women went there mainly for recreation only. In Kwamang older respondents visited the caves mostly for farming whereas younger persons visited the caves predominantly for religious activities, recreation and water fetching. Generally, the main purpose for men visiting the caves were the same for all the three communities but the purposes were different for women.

6.1.4 Occurrence of bat exposures

In this study, situations that qualified as exposures included consumption of bat meat, techniques used in hunting bats, and bat bites. Bat consumption was highest among respondents older than 50 years in all the communities representing 95%, 58% and 54% for Buoyem, Forikrom and Kwamang respectively. The study shows that men consume bats more than women in only Forikrom and Kwamang. The common modes of hunting bats within all three communities were guns, catapult, sticks and hands. The use of bare hands in hunting bats was highest in Buoyem. Catapults, guns and nets were the most preferred modes of capture in Forikrom whereas guns were most preferred in Kwamang. Bat bites were highest in Buoyem followed by Forikrom with the least being Kwamang. More men experience bat bites than women. From the study, older respondents are at a higher risk of bat exposures.

6.1.5 Evidence of common cold infections and disease epidemics from bat exposures

Direct contact between bats and people in the communities is low except for certain groups, such as people who visit bat caves, hunt, prepare or eat bats. Furthermore, there was no reported epidemic within the past 30 years and at the time the study was conducted in all three communities from human associations with bats. From the study, there was not enough evidence to suggest that one gets symptoms of common cold from visiting bat caves though some did indicate experiencing symptoms such as running nose, sneezing, headaches and cough. It can therefore be inferred from the study that, there is a low risk of transmission of coronavirus directly from bats though there is no epidemiological data to support a link. Though there were no known cases of disease epidemics, results from the study also indicated that health and hygiene was a major concern.

The study has provided an understanding of the dynamics of human-bat interactions by showing how, why, where and for whom these cave dwelling bats may pose problems. As the human-bat interface is essential to the process of potential zoonotic disease emergence like Coronavirus, it stands to reason that one of the most important strategies to help in early detection would be monitoring people who are highly exposed to the bats. The study has shown that more people are coming into contact with cave bats and the pathogens that they carry, thus, public health measures are necessary.

6.2 Recommendations

Bats and their caves provide a means of sustenance in the research communities. However, there have been relatively few socioeconomic studies on disease trends on human-bat interactions in rural communities in Ghana. One of the greatest challenges associated with this is the ability to balance the needs of people in the midst of the many potential infectious pathogens like CoVs bats carry. This requires:

- Educating the public on measures towards preventing potential disease transmission across species through behavioural changes on the part of humans. These include avoiding direct handling of bats, which will help reduce exposure to blood and body fluids, bites and scratches.
- Another way is educating the people not to hunt or touch bats when they have injuries on their hands.
- Cuts, bites and scratches from bats should be washed immediately with soap.
- Additionally, protective coverings like nose masks, shoes and proper attire should be worn during cave visits to prevent direct contact with aerosols.
- Stored water in homes must be covered at all times to prevent accumulation of bat faeces and urine.
- Finally, there is a need for further study on cave water-use patterns especially in Kwamang where caves are a major source of water for the community.

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APPENDICES

Appendix A: Data Collection Instruments

This appendix describes the questionnaire used for collecting data within the communities.

A.1 Questionnaire for communities

Committee on Human Research, Publications and Ethics
School of Medical Sciences, Kwame Nkrumah University of Science and Technology
Kumasi, Ghana. Tel: 233 51 22301-4 ext 1098. Email: chrpe.knust.kath@gmail.com

CONSENT FORM

Statement of person obtaining informed consent:

I have fully explained this research to ……………….. and have given sufficient information, including that about risks and benefits, to enable the prospective participant make an informed decision to or not to participate.

DATE: …………. SIGNATURE: …..………

NAME: …………

Statement of person giving consent:

I have read the information on this study/research or have had it translated into a language I understand. I have also talked it over with the interviewer to my satisfaction. I understand that my participation is voluntary (optional). I know enough about the purpose, methods, risks and benefits of the research study to judge that I want to take part in it. I understand that I may freely stop being part of this study at any time. I agree to take part in the study.

NAME OF PARTICIPANT: ………………

DATE: …………… SIGNATURE/THUMB PRINT: …………..

WITNESS' SIGNATURE: (if participant could be non-literate): ………..

WITNESS' NAME: ……………….

ASSESSMENT OF HUMAN-BAT INTERACTIONS

Community: Buoyem ☐ Kwamang ☐ Forikrom ☐

Type of Study: Cohort ☐ Cross-sectional ☐

House Number if cohort study: Date of sampling:

Demographic data

1 Respondent Code No: ………. 2 Name : …………….

3 Age : …….(yrs) 4 Gender: Male ☐ Female ☐

5 Are you educated? Yes ☐ No ☐

6 What is the highest level of your education? ☐ Primary ☐JHS ☐SHS ☐ Tertiary ☐Other……..

7 Which religion do you belong to? ☐Christian ☐Muslim ☐Traditional ☐ Other…….

8 Do you have any occupation? Yes ☐ No ☐

9 How many?

10 What kind of occupation are you engaged in?

☐Medical officer ☐Dress maker ☐Carpenter ☐Farmer
☐Teacher ☐Hairdresser ☐Mason ☐Trader
☐Student ☐Driver ☐Chop bar operators ☐Hunter
☐Traditional Authority ☐Tour guide
☐Other (please specify) ………..

a. Which is your primary occupation/major source of income?

11 Which of these areas in your community do you usually come into contact with bats?

☐ Homes ☐ Schools ☐ Farms ☐ Caves

☐ Workplace (please specify)………… ☐ Other……

Use Of Caves

12 Do you visit the bat caves in your community? Yes ☐ No ☐

a. What is the purpose of your visit?

☐ Religious activities ☐ Hunting ☐ Fetch water

☐ Recreation ☐ Farming ☐ Collect guano

☐ Other (please specify)………

b. How often do you visit the caves?

☐ Annually ☐ Monthly ☐ Weekly ☐ Daily ☐ Other …….

c. What time is your visit? Morning ☐ Afternoon ☐ Evening ☐

d. What is the duration of your visit? 1hr ☐ 2hrs ☐ 3hrs ☐ 4hrs ☐

Other……

13 Do you wear any protective covering when inside the cave? ☐ Yes ☐ No

a. What kind of protective gear do you wear?

14 Do you experience any symptoms of cold from your visits? ☐ Yes ☐No

Use of Bats

15 Do you use bats for any of these purposes?

☐ Medicine ☐ Rituals ☐ Food

16 Do you eat bats? ☐ Yes ☐ No

a. How often? ☐ Monthly ☐ Weekly ☐ Daily ☐ Other ……

b. Where do you obtain it?

☐ Caves ☐ Market ☐ Chop bars/food vendors ☐ Hunters

☐ Farms ☐ Households ☐ Other……

c. What is the mode of capture?

☐ Hands ☐ Net ☐ Catapult

☐ Guns ☐ Sticks ☐Other…………..

d. What is the size of the bat? Small ☐ Big ☐

e. What is the mode of preparation? Boiling☐ Roasting ☐ Frying☐ Other…..

f. What is the mode of consumption? Soups ☐ Stews ☐ Other……..

g. Did you experience any infection after consumption? ☐Yes ☐No

h. What kind of symptoms did you experience?

17 Have you been bitten by a bat before? Yes ☐ No ☐

a. How did you treat it?

b. Did you experience any infection from the bite? ☐ Yes ☐No

c. What kind of symptoms did you experience?

Clinical Data

18 Do you have cold? ☐Yes ☐No

a. What symptoms are you experiencing?

☐ Cough ☐ Headache ☐ Feverish ☐ Sneezing

☐ Runny nose ☐ Nasal Congestion ☐ Other …….

b. How do you think you contracted the cold?

☐close contact with an infected person

☐visiting the farm

☐visiting bat caves

☐close contact with bats

☐Other………..

A.1: *Questionnaire for Focus Group Discussions*

1. Discuss what new ways we can think about how Bats can help or hinder us in our;

- Work (Identify various livelihoods)
- Community
- Health

2. Select one person to write outcomes of discussion on flip chart and report
3. Groups Report

Appendix B: Summary data tables for results

Table B1: Age and sources of contact

Age (years)	Homes	Schools	Farms	Caves
Buoyem				
	(p=0.935)	***(p=0.001)***	***(p=0.001)***	*(p=0.001)*
12-20	16.1	18.5	0	4.8
21-30	18.4	1.3	6.6	13.2
31-40	13.8	0	15.4	27.7
41-50	16	0	18	58
>50	18.6	0	17.5	68
Forikrom				
	(p=0.320)	*(p=0.347)*	***(p=0.001)***	*(p=0.076)*
12-20	8.4	2.4	0	51.8
21-30	14.7	1.3	1.3	30.7
31-40	11.8	0	10.3	45.6
41-50	17	0	10.6	51.1
>50	19.1	0	16.9	44.9
Kwamang				
	(p=0.216)	***(p=0.047)***	***(p=0.002)***	*(p=0.252)*
12-20	12.3	4.1	1.4	42.5
21-30	12.3	0	6.8	43.8
31-40	20	1.7	10	38.3
41-50	16.3	0	18.3	28.8
>50	9.5	0.5	16.8	37.4

Table B2: Gender and sources of contact with bats

Gender	Caves	Homes	Farms	Schools
Buoyem				
	(p=0.136)	*(p=0.966)*	*(p=0.278)*	*(p=0.145)*
Female	28	35.8	8.4	4.2
Male	34.8	33.2	11.6	7.6
Forikrom				
	(p=0.010)	***(p=0.001)***	***(p=0.001)***	*(p=0.132)*
Female	38.6	7.7	3.9	1.4
Male	52.6	22.6	12.9	0
Kwamang				
	(p=0.014)	***(p=0.009)***	***(p=0.001)***	*(p=0.071)*
Female	33	9.8	8.1	0
Male	43.8	17.7	19.2	2

Table B3: Education and source of contact with bats

Buoyem	Homes *(p=0.345)*		Schools ***(p=0.032)***		Farms ***(p=0.031)***		Caves ***(p=0.001)***	
	Contact	No Contact	Contact	No Contact	Contact	No Contact	Contact	No Contact
Educated	88.4	83.9	100	83.7	73.2	85.9	75.8	88.7
Uneducated	11.6	16.1	0	16.3	26.8	14.1	24.2	11.3

Forikrom	Homes *(p=0.055)*		Schools *(p=0.420)*		Farms ***(p=0.001)***		Caves ***(p=0.002)***	
	Contact	No Contact	Contact	No Contact	Contact	No Contact	Contact	No Contact
Educated	86.3	73.8	100	75.4	50	77.7	83.2	69.3
Uneducated	13.7	26.2	0	24.6	50	22.3	16.8	30.7

Kwamang	Homes *(p=0.345)*		Schools *(p=0.939)*		Farms *(p=0.618)*		Caves ***(p=0.024)***	
	Contact	No Contact	Contact	No Contact	Contact	No Contact	Contact	No Contact
Educated	83.1	77.9	80	78.6	76.2	78.9	84	75.4
Uneducated	16.1	22.1	20	21.4	23.8	21.1	16	24.6