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GASTROINTESTINAL PARASITES OF PUBLIC HEALTH IMPORTANCE IN *CERCOPITHECUS MONA* OF TAFI ATOME MONKEY SANCTUARY IN THE AFADJATO SOUTH DISTRICT OF GHANA

BY

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DECLARATION

I do hereby declare that apart from references to the work of other investigators, which have been duly acknowledged, the work presented in this thesis is original and was carried out by me under the joint supervision of Dr. Bethel Kwansa–Bentum and Dr. Isaac Frimpong Aboagye of the Department of Animal Biology and Conservation Science, University of Ghana.

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DEDICATION

This piece of work is dedicated to the memory of my beloved sister Abigail Success Amu-Asempa.

ACKNOWLEDGEMENTS

My greatest appreciation is to God Almighty for seeing me through to the end of this work. I am highly indebted to my supervisors for their outstanding mentorship and unflinching commitment to seeing to work completed. To my wife Gladys Hlodze and my children for the spiritual and moral support; your prayers worked. Sincerely, I am grateful to my brothers for their encouragement and financial support. In addition, I thank Madam Marian Esi Jackson for the opportunity granted me, not forgetting the Headmaster and entire Staff of Jim Burton Memorial Agricultural Senior High School, Logba Adzakoe for their warm reception. My appreciation to the Chiefs and Opinion Leaders of Tafi Atome, Tafi Abuife, Tafi Mador, Avatime Dzokpe New Town and Avatime Dzokpe Old Town for their warm welcome. Finally, to the management and staff of the Tafi Atome Forest Reserve and Monkey Sanctuary and the Staff of the basic schools in Tafi and Avatime Dzokpe, without whom there would have been no samples collected for this study.

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LIST OF ABBREVIATIONS

HIV	Human Immunodeficiency Virus
TAFRMS	Tafi Atome Forest Reserve and Monkey Sanctuary
TACV	Tafi Atome Cultural Village
PCV -	Peace Corps Volunteer
NCRC	Nature Conservation Resource Centre
USAID	United States Agency for International Development
IUCN	International Union of Conservation of Nature
NT	Near Threatened
SARS Cov-2,	Severe Acute Respiratory Syndrome Corona Virus Strain 2
MERS :	Middle East Respiratory Syndrome
HMRV	Human-Transmitted Respiratory Viruses
AIDS	Human Immune Deficiency Syndrome
ISDS	International Society for Disease Surveillance
TACV	Tafi Atome Cultural Village
FEAST	Formalin-Ethyl Acetate Sedimentation Technique
NHP	None Human Primate

ABSTRACT

Transmission of pathogens from animals to humans accounts for over 60% of infectious diseases in humans and 75% of all zoonotic diseases emanate from wild rather than domestic animals. Tafi Atome monkey sanctuary is a conserved grove that surrounds human population and serves as a habitat for many troops of habituated *Cercopithecus mona* (mona monkeys) that welcome many tourists annually and generate revenue for the district assembly. The habitat sharing bridges the human animal interface, providing avenue for pathogen trade-off between cohabited human and mona monkeys populations. This study aimed at characterising gastrointestinal parasites of public health importance in these monkeys at the Tafi Atome monkey sanctuary in the Afadjato South District of Ghana. Stool samples of school-aged children and faecal samples of mona monkeys were collected, processed and examined microscopically for parasite infection status. Using morphological characteristics, three genera of helminths and one protozoan were identified in both humans and mona monkey. The helminths were Hookworm, *Strongyloides* and *Ascaris*, while the protozoan was *Giardia lamblia*. Prevalence of gastrointestinal parasites in humans (47.6%) and mona monkeys (26.4%) was statistically significant (χ^2(df) = 12.96(1); p= 0.0003), but prevalence was insignificant between the two sampling areas of Tafi And Avatime Dzokpe (χ^2(df) 2.944 (1); p=0.077). The highest gastrointestinal prevalence in humans was hookworm (21.09%) while in mona monkeys, *Ascaris* and *Strongyloides* (8.05%) were most prevalent. The sharing of parasites between humans and mona monkeys of the sanctuary could be indicative of possible zoonotic transmission. Regular administration of anthelminthic to the vulnerable groups in the catchment area of the sanctuary would be necessary to ameliorate the effects of gastrointestinal parasites in the human animal interface of Tafi Atome.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Mona monkeys are old world monkeys of the Genus *Cercopithecus*, having a downward nose with thin septum characteristic of humans (Napier & Groves, 2021). They are endemic to Sub-Saharan Africa, mainly found in forest zones of Ghana, Togo, Benin, Nigeria and Cameroon. These non-human primates live in troops of about 12 to 35 (Myers, 2008) mostly along river bodies in the rainforest. The International Union of Conservation of Nature (IUCN) classify *mona* monkeys as near threatened (NT) (Fatsuma *et al*., 2020), attributing their risk of extinction to land use for agriculture, construction, logging and hunting for bush meat among others.

Rising human population growth has resulted in increased pressure on the carrying capacity of the habitat as demand for farmland, human settlement development and other activities for survival increases. The upsurge in land use, occasioned by rapid population growth, has destroyed the habitat of wild animals, bridging the gap between wild animals and human populations (Fatsuma *et al*., 2020; Quraishi *et al*., 2017).

Habitat destruction by human activities has a remarkable adverse impact on other animals and the ecosystem as a whole. As a result, many animal habitats have been either completely or partly destroyed threatening the survival and development of such species. These threatened animal species include non-human primates such as chimpanzees, bonobos, baboons and mona monkeys. Efforts to preserve threatened animal species have resulted in keeping them ex-situ in zoological gardens, where they serve as tourist attractions thereby generating revenue for local and national development.

In Ghana, the Accra zoological garden is home to spot nosed monkeys (*Cercopithecus petaurista*), Patas monkey (*Erythrocebus patas*), White naped mangabey (*Cercocebus torquatus)* and Diana monkey (Stephen, 2015). The Kumasi zoo houses up to eight (8) green monkeys (*Cercopithecus aethiopicus*), 6 chimpanzees, (*Pan troglodytes)* 6 olive baboons (*Papio Anubis*) and a mona monkey (*Cercopithecus mona*) (Dra, 2015).

Despite challenges of habitat depletion, many troops of free-ranging mona monkeys can be found in wild forest reserves across Africa, including Omo Forest Reserve and Afi Mountain Private Conservation Area in Nigeria (Uloko & Lameed, 2019), Lama Forest Reserve in Benin (Matsuda, *et al*., 2020). Besides these reserves, protected sacred groves and sanctuaries like Buabeng Fiema and Tafi Atome in Ghana serve as habitat for mona monkeys where they live closely with human populations. Because Mona monkeys are beautiful and easy to habituate, these sanctuaries and reserves now serve as centres for ecotourism, welcoming thousands of local and international tourists annually, generating revenue for local community development.

Transmission of pathogens from animals to human accounts for over 60% of infectious diseases in human (Al-Tayib, 2019) and 75% of zoonotic pathogens of public health concern originates from wild rather than domestic animals (Chakraborty *et al*., 2019). Zoonotic pathogens inhabit animal reservoirs, such as birds, livestock, pets and wildlife (Teshome, 2019), including non - human primates which act carrier agents for pathogen transmission to humans (Ekwem, 2016), and have been implicated in public health disease outbreaks in recent years.

Animals infected with parasites may be clinically ill, however, a large proportion of zoonotic parasite-infected animal reservoirs are asymptomatic (Bauerfeind *et al*., 2016) and are the least suspected agents of parasite transmission. Identification and prevention of contaminants in human environments is, therefore, a top priority in public health control. According to Teshrom

(2019), the basic principles of prevention, control and eradication of zoonotic disease transmission involve reservoir neutralization, reducing contact potential and increasing host resistance. Disease prevention is easier, cost-effective and harmless as compared to expensive and sophisticated approaches to disease treatment that may cause morbidity and mortality.

1.2 Justification of the study

Tafi Atome monkey sanctuary is a conserved sacred grove of about 49 ha of semi-deciduous forest in the Afadjato District that serves as a habitat for many troops of habituated *Cercopithecus mona* monkeys. The sanctuary attracts thousands of local and international tourists annually, and these tourist visitations generate revenue for community development and create employment for the local Tafi communities. The sacred grove however encircles the Tafi Atome human settlement allowing for close daily interaction between cohabited species of humans, mona monkeys and also domestic animals like sheep goats and domestic fowls.

Apart from Tafi Atome, the mona monkeys of the sanctuary regularly interact with residents of Avatime Dzokpe township. On the fringes of the Tafi Atome monkey sanctuary and forest reserve are two communities; Tafi Mador, Tafi Abuife. Though *mona* monkeys of the sanctuary are seldom seen in these human settlements, they frequently raid farm crops like maize from these communities, creating interactions with local farmers.

Despite the economic benefits derived from the mona monkeys in the sanctuary, the location of a human settlement in the middle of the sanctuary provides for persistent visitation of monkeys to Tafi Atome and Avatime Dzokpe townships. This interaction bridges the human-wildlife interface, creating an avenue for the trade-off of pathogenic organisms and molecules between the populations. In habitats where non-human primates are habituated, the opportunities for transmission of pathogens to and from the primates are enormous (Cibot *et al*., 2015).

When human communities share habitat with non-human primates, the potential of transmission of zoonotic pathogens between the two populations is significantly high (Klaus *et al*., 2017; Larbi *et al*., 2020). This is because many human communities living in close association with non-human primates are mostly oblivious of viable anthroponotic and or zoonotic parasite transmission between the two populations. These communities therefore do very little to protect the non-human primates from gastrointestinal parasite infections (Teklemariam *et al*., 2018) with associated threat to public health control measures.

It has been established that ruminants, livestock (Squire *et al*., 2018), non-human primates like baboons (Larbi *et al*., 2020) *mona* monkeys (Mbaya & Udendeye, 2011) carry a significant number of gastrointestinal parasites, which cause morbidity and mortality (Devaux *et al*., 2019; Medkour *et al*., 2020). Parasite infestation of non-human primates reduces reproductive potential among female monkeys and also causes spontaneous abortion leading to the death of pregnant individuals (Akpan *et al*., 2010) with a potential of derailing conservation efforts. These parasites produce eggs, cysts and larvae, which are released through faeces of their host onto the environment with long periods of viable infective stages in dumb soil and fomites, infecting unsuspecting hosts.

In communities where these non-human primate habitats serve as tourist centres, people become preoccupied with increasing income generation from tourist activities without recourse to potential health hazards of zoonotic transmission posed by their close interaction with the primates. The phenomenon of the transmission of pathogens between non-human primates and humans has accounted for emerging zoonoses that currently threaten public health (White & Razgour, 2020).

With many zoonotic disease outbreaks in recent times, maintenance of public health calls for collaborative action on pathogens across boundaries of animals, humans and the environment. Establishing the prevalence of parasitic zoonotic diseases in animals that frequently interact with human settlements is therefore necessary to ascertain challenges posed by these pathogens to communities in the habitat. With knowledge of the biology of prevailing parasites, robust effective and preventive or control measures could be developed to minimize their transmission to mitigate their impact on animal and human populations.

The search for zoonotic pathogens in non-human primates has been, on many occasions, focused on viral and bacterial pathogens (Kebede *et al.*, 2020; Mossoun *et al.*, 2017), due to complex epidemiology, rapid transmission and immediately quantifiable devastations associated with such outbreaks such as SARS Cov-2, MERS and Ebola, with precipitate implications to the global economy. Mona monkeys are particularly susceptible to parasitic infections because they exist in sympatric troops that allow for regular social interactions within the troop that facilitates parasite transmission among individuals (Dawet, 2013; Mbaya *et al.*, 2011). *Ancylostoma duodenales, Trichuris trichuira, Ascaris lumbricoides* have been identified in mona monkey populations in Nigeria (Adegbulu, 2015; Dawet, 2013).

There exists a plethora of research on gastrointestinal parasite prevalence in captive and wild mona monkeys (Adegbulu, 2015; Mbaya & Udendeye, 2011), in Nigeria, baboons in Ghana (Larbi *et al.*, 2020; Van Lieshout *et al.*, 2005). Non-human primates (NHP) existing in several wild habitats, forest reserves and venerated local sanctuaries across Africa (Gery *et al.*, 2019;

Kamani *et al*., 2020; Klaus *et al*., 2017; Mbaya & Udendeye, 2011) have been found to host wide diversity of gastrointestinal parasites.

Despite these findings, available researches on the Tafi Atome Monkey Sanctuary however, focused on tourism potential and economic premium derived from the forest reserve for the indigenous human community (Mensah, 2012; Quraishi *et al*., 2017). More so, no published work is available on gastrointestinal parasite infection of *Cercopithecus mona* monkeys of the sanctuary. This research has therefore provide reliable information on the parasite load of the wild habituated mona monkeys of Tafi Atome monkey sanctuary and forest reserve and the potential of transmission of zoonotic parasites between the human populations and their interacting *Cercopithecus mona* of the Tafi Atome monkey sanctuary. It has also provide useful information for the care of the monkeys of the sanctuary to harness its tourism potentials to generate enough revenue and create jobs for the development of Tafi Atome.

1.3 Study Objectives

The objectives for the study are as follows:

1.3.1 General Objective

To identify gastrointestinal parasites of public health concern in mona monkeys of Tafi Atome monkey sanctuary in the Afadjato South District in the Volta Region of Ghana.

1.3.2 Specific objectives

The specific objectives for the study are the following

1. To determine the prevalence of gastrointestinal parasites in *Cercopithecus mona* in Tafi Atome monkey sanctuary

2. To determine the prevalence of gastrointestinal parasites in human populations of Tafi Atome, Tafi Mador, Tafi Abuife and Avatime Dzokpe.
3. To determine possible source of exposure to gastrointestinal parasites present in mona monkeys of Tafi Atome monkey sanctuary and the human populations of Tafi and Avatime Dzokpe.
4. To assess the knowledge, attitudes, beliefs and perceptions of the people of Tafi Atome about the mona monkey sanctuary.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Brief History of the Tafi Atome Monkey Sanctuary

Tafi Atome monkey sanctuary is located in the Afadjato South District of the Volta Region. History indicates that the people of Tafi migrated from Sene, currently in the Bono East Region of Ghana, to their current location about 250 years ago. Tafi is made up of three rural communities, Abuife, Mador and Atome, the three form the paramountcy. Soon after arrival at their current location, they began to sight some monkeys in the forest, where their ancestral god was enshrined, similar to those in their ancestral home, Sene (Bobuafor, 2013) in the Bono Region of Ghana.

It was believed that the monkeys were sent by their ancestors for protection and prosperity. Subsequently, the monkeys were declared sacred messengers of the gods after traditional religious rights were performed to welcome the monkeys. The monkeys became totems for the inhabitants therefore the whole community of Tafi did not hunt or feast on these revered non-human primates.

The protection and worship of the monkeys and their sacred habitat were solidly foundational on strong traditional and cultural beliefs for several generations. Cutting down of forest trees and killing of monkeys were taboos. Penalties ranged from hefty fines to total banishment from Tafi Township. These traditional believes and practices preserved the forest and provided suitable and sustainable habitat for the protection, reproduction and proliferation of the monkey population in the forest for several years.

With the advent of Christian Religious belief in mid - 20th century, many inhabitants converted to Christianity, plummeting adherence to traditional religion and its outmoded principles. Many inhabitants of the community lost interest in their century-old cultural belief in their ancestral gods. Significance and adherence to traditional doctrines and beliefs waned significantly due to their newly discovered faith. Consequently, the revered spiritual adoration for the monkeys and their forest habitat declined. Care for the forest and the non-human primates dwindled, and the once sacred forest with ancestral mona monkey messengers were treated with contempt, disdain and tagged devilish.

The monkeys were thereafter hunted for bush meat by some adjoining communities due to a lack of protection and diminished reverence for the species. Young feeble mona monkeys were caught and trading in monkey pets boomed outside Atome and its surrounding communities during the breeding season. The forest trees, which served as habitat for the monkeys, were cut indiscriminately for timber, and portions of the conserved forestland were cultivated for agricultural purposes. Residential facilities now occupied the originally revered forest of the ancestral gods and the monkey habitat encroachment was carried out with impunity. These practices mounted significant pressure on the forest boundaries and the monkey population significantly reduced together with many species of plants and animals of the forest.

2.2 Conservation of Tafi Atome Forest Reserve and Monkey Sanctuary (TAFRMS)

The ecological and socio-economic importance of the TAFRMS was initiated by a Peace Corps Volunteer (PCV), in conjunction with Nature Conservation Resource Centre (NCRC), a local non-governmental organization (NGO). In collaboration with the Ministry of Tourism, Forestry Commission together with traditional rulers and opinion leaders of Tafi Atome, the monkey sanctuary was established in 1993 as a community-based ecotourism project (United Plant

Savers, 2018). United States Agency for International Development (USAID) and other international NGOs provided funding for restoration and habitat protection of the true mona monkeys to provide an avenue for sustainable community development and job creation (Mensah, 2012).

TAFRMS is now situated on a 29 Ha sacred grove of semi-deciduous forest within the Forest-Savannah Transitional Zone of the Volta Region. The groove is bordered by a savannah transition zone of low grassland cultivated for crops (United Plant Savers, 2018). The area is protected by a 2006 bylaw of the Hohoe Municipal Assembly to conserve the flora and fauna of the forest, including birds and butterflies, with habitat preservation for the mona monkeys being central. Currently, it is estimated that about seventeen (17) troops of habituated mona monkeys occupy the conserved forest and serve as a tourist destination for thousands of local and international visitors annually. Figure 1 is the arial view of Tafi Atome Monkey Sanctuary surrounding the human community settlement.

Figure 1: Arial view of Tafi Atome Monkey Sanctuary with the human community surrounded by the forest

2.3 Old World Monkeys (Cercopithecoidea)

Primates are a very diverse group of mammals made up of almost 80 genera and over 800 known species of which anthropoids, made up of monkeys, apes and humans, are the most diverse and distributed worldwide (Fleagle & Seiffert, 2016). Old World monkeys (*Cercopithecoids*) are distinguished from Hominoids by having bilophiodont teeth and long arms that are equal to their body length or in some cases shorter than their leg (Fleagle & Seiffert, 2016). Old World monkeys are found primarily in Africa and Asia, both on the continental mainland and islands. They possess tails that vary significantly in their lengths.

Cercopithecoids are divided into two clades, the leaf-eating Colobines and the more fruit-eating Cercopithecines (guenons) (Napier & Groves, 2021). Cercopithecines are omnivorous, having simple stomachs and pouched cheeks for storing food. They mostly feed on fruits, seeds, flowers, leaves and insects. They include baboons, macaques, mona, rhesus patas and vervet monkeys.

The Colobinae have a multi-chambered complex stomach made up of the *saccus gastricus*, with or without a *presaccus*, foregut fermentation chamber, where bacterial fermentation occurs. Also, they have *pars pylorica* and *tubus gastricus* (Nijboer & Clauss, 2006), sites where digestive enzymes break down food into simpler forms (Myers, 2000). They are folivorous, feeding on forest forage, supplemented with fruits, flowers and insects. Colobinae lack check pouches characteristic of their Cercopithercine cousins.

Guenons live primarily in the tropical rainforest belt in Africa to the south of the Sahara Desert, but a few species have adapted to the forests along principal African rivers. They have body sizes ranging from 1.5 kg to about 30 kg (Fleagle & Seiffert, 2016), having slim body lengths ranging between 16 to 22 inches on average (Britannica, 2021). Their face is short, points downward with close nostrils (Myers, 2000) because of the reduction in the septum that separates the nostrils.

Tails of old-world monkeys are relatively long compared to their body size but are non-prehensile (Britannica, 2021). Cercopithecoids are agile four-footed animals with grasping cheiridia (Gilbert & Frost, 2009). They walk on all four limbs with slightly lifted wrists and ankles sometimes. Generally, guenons are omnivorous, having simple stomachs and pouched cheeks for storing food. They mostly feed on fruits, seeds, flowers, leaves and insects. They include baboons, macaques, mona, rhesus patas and vervet monkeys.

2.4 The Mona Monkey Classification

Mona monkeys are Old World monkeys, guenons, belonging to the family Cercopithecidae. The mona monkey is classified as follows:

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Primate

Family: Cercopithecidae

Genus: Cercopithecus

Species: mona

2.4.1 Geographical Distribution of mona monkeys

Mona monkeys are naturally endemic to forest areas of Ghana, Togo, Benin, Nigeria and Cameroon. They occupy forest ranges from the Eastern part of the Volta River in Ghana to the South of the Sanaga River in Cameroon (Matsuda, *et al*., 2020), with their natural distribution being restricted by the two large river bodies. Mona monkeys have, however, as a result of slave trade ships, been introduced to Granada, Caribbean island where they inhabit mangrove and marshy forests (Starr, 2018) and also in São Tomé and Príncipe (Matsuda, *et al*., 2020). Living in lowland forests, mona monkeys are therefore tolerant to depleted zones but are generally connate to forests with river bodies (Starr, 2018).

2.4.2 Body description of Mona monkey

Mona monkeys have deep brown dorsal fur that runs from the neck region to the bridge of the hind limb and abdomen. A blotch of white surrounds the genito-anal region, extending to the dorsal base of the tail. They have a blue-black tail that is longer than the entire length of the body. The head bears a white brow that bounds a light brown crown. The face is downwards, bearing no hair, but a dark grey skin that covers around the eyes and the nose. The snout is pink with grey sparse hair. The prominent large pouch is covered by a light cream bushy fur, mostly at maturity, which spreads dorsally to the base of the crown but does not cover the pinnae. The ventral body is creamy white to the interior of the limbs but is black exteriorly.

Male mona monkeys are larger and taller, with mature adults measuring about 51cm tall on average and weighing about 5kg. Females are relatively smaller, weighing 4kg on average and body length of 41 cm tall (Starr, 2018).

Figure 2: Mona monkey of Tafi Atome Monkey Sanctuary

2.4.3 Behaviour of Mona Monkey

The mona monkey is an arboreal primate, actively forages during the day mostly in the mornings and evenings, intercepted by a midday rest characterized by grooming, playing, and other forms of socialization in the forest canopy. They leap in forest canopy from tree to tree with accuracy though they may miss targets which normally does not result in injury (Fatsuma *et al*., 2020). Mona monkeys live in sympatric groups of about 12 to 35 with a dominant male leader, many females and young adults. Fully grown adult male bachelors form uni-male groups and forage together while waiting for an opportunity to overthrow a leader, seize and take over their territory (Matsuda, *et al*., 2020).

Living in sympatric groups, mona monkeys are very social with the advanced evolution of sound communication (Uloko & Lameed, 2019). Troops produce squeaking sounds to maintain contact and cohesion while foraging. High pitch alarm sneezes are sound, mostly by females, for an alert when danger looms.

Two unique calls sounds are produced by the male. Dominant males make low hacking calls to regroup their troops after disruptions. However, they are noted for producing loud low pitch "booming" sounds, once or in multiples, to affirm their territory, every dawn and dusk (Goodwin, 2007). Boom sounds are also produced when their territory is threatened by invading bachelor males. According to Goodwin (2007), mating sounds of continuous querulous warbles of males and choppy low tone groans have been recorded in copulating individuals during the breeding season.

2.5 Zoonotic Pathogens of Non-Human Primates

Pathogenic infectious diseases are highly prevalent in tropical and subtropical regions where climatic conditions of suitable temperature together with predictable annual rainfall distribution facilitate survival and transmission of infective stages of pathogens, especially of soil-transmitted parasites to their host (Hailu & Ayele, 2021; Medkour *et al.*, 2020). The outbreaks of infectious diseases have occurred not only in human populations but also in domestic and wild animals with severe morbidity and pathology, with a significant impact on the conservation and survival of wild animals including non-human primate populations.

Humans and non-human primates share a close genetic relationship such that information about identified diseases in non-human primates is useful to humans, and vice versa (Davoust *et al.*, 2018). Owing to close genetic compatibility, humans and non-human primates share common microflora, hence, non-human primates have been frequently responsible for emerging diseases and infections in humans. They are therefore among the first animals suspected of becoming a source of one of the next emerging zoonotic diseases outbreak (Olivier *et al.*, 2010).

The Human Immunodeficiency Virus (HIV) emergence has been widely attributed to the Simian Deficiency Viruses in chimpanzees and gorillas (Barbian *et al.*, 2015, 2017; Keele *et al.*, 2008). Several studies have shown that Enzootic Simian Immuno- Deficiency Viruses can infect other non-human primates such as West African green monkeys (*Chlorocebus sabaeus*) (Davoust *et al.*, 2018) and humans. Available data indicates that HIV-1 originated in some chimpanzees (*Pan troglodytes troglodytes*), found in central Africa and HIV-2 is suggested to have originated in the sooty mangabey (*Cercocebus atys*) (Barbian *et al.*, 2017).

These viruses may have probably been transmitted to humans intermittently over the centuries. Outbreaks of a respiratory disease caused by human-transmitted respiratory viruses (RSV, HMPV) (Goldberg, 2008) and anthrax have caused a substantial decline of the chimpanzee population in Taï National Park, Cote D'Iviore (Metzger, 2015).

Bacterial pathogens of wild non-human primates include *Streptococcus pneumonia*, *Klebsiella Bordetella bronchiseptica*, *Haemophilus influenzae*, and various species of Streptococci, Staphylococci, and Pasteurellae. Infant non-human primates are highly susceptible to the cross-species transfer of respiratory pathogens from human populations (Parrott, 2020). Though all non-human primates are predisposed to tuberculosis infection (Matz-Rensing, & Kaup, 2010), old world species such as rhesus monkeys are more susceptible, compared to new world monkeys (Parrott, 2020).

Furthermore, parasites are pervasive in all habitats affecting the life and development of their hosts. Diseases caused by parasite infections are very common in non-human primates. About

68% of all primate infections are caused by parasites (Klaus *et al*., 2017) and have been widely studied (Barelli *et al*., 2019; Calvignac-Spencer *et al*., 2012; Gillespie *et al*., 2004; Narat *et al*., 2017; Quraishi *et al*., 2017), and have been known to cause morbidity and mortality in their host populations. *Ascaris lumbricoides*, hookworm, *T. trichiura*, *Strongyloides stercoralis*, *E. histolytica*, *D. latum*, *Iodamoeba buetschlii*, and *Entamoeba coli* invasion of the gastrointestinal tract of non-human primates are major causes of gastroenteritis, diarrhoea, haemorrhage, and extra-intestinal infection such as liver abscess and may result in death.

Entamoeba histolytica, *Balantidium*, *Gardia sp* and *Cryptosporidium* infections are known to reduce growth in young baboons and proboscis monkeys, *Nasalis larvatus* (Larbi *et al*., 2020; Quraishi *et al*., 2017) chimpanzees (Mertz, 2016) proboscis monkey (Klaus *et al*., 2017) and mona monkey (Dawet, 2013; Egbetade *et al*., 2014; Frias *et al*., 2019; Goodchild, 2007; Quraishi *et al*., 2017) *marcaque marcaca* (Kurniawati *et al*., 2020) among others. The gorillas have been a major source of human infection of *Plasmodium falciparum* parasite, the most prevalent and virulent form of malaria (Calvignac-Spencer *et al*., 2012; Duval *et al*., 2010; Liu *et al*., 2010), a major cause of infant mortality in Sub-Saharan Africa.

2.6 Potential Risk of zoonotic transmission in Tafi Atome

Transmission of zoonotic diseases are considered a major public health concern (Quraishi *et al*., 2017). Zoonoses are contagious diseases that are transmissible from non-human vertebrate animals to humans (Obanda *et al*., 2019) and have been recognized as a major cause of emerging and re-emerging public health diseases (WHO, 2020). Zoonotic pathogens, mainly viruses, bacteria, fungi and parasites, have been known to cause severe pathology in both humans and animals (Quraishi *et al*., 2017). These pathogens are mainly transmitted from animal hosts to unsuspecting human populations by contact, soil, fomites, or through invertebrate mechanical vectors such as ticks, black flies and mosquitoes (Bauerfeind *et al.*, 2016).

Wild animals harbour endogenous flora that are pathogenic to humans (Teshome, 2019) (Teshome, 2019), making them effective conduits for the transmission of pathogenic parasites to humans, in most cases, where these animals closely interact with human populations. Spatial human-animal interaction has been implicated as a major facilitator of zoonotic pathogen disease transmissions (Klaus *et al.*, 2017; Mossoun *et al.*, 2017; Quraishi *et al.*, 2017).

Studies on large and threatened non-human primate species such as orangutans and chimpanzees (Carne *et al.*, 2017) have established a significant prevalence of rabies, measles, Ebola virus, tuberculosis, polio-like diseases and parasite infections. Zoonotic viral disease outbreaks such as human immune deficiency syndrome (AIDS) in 1986, Ebola virus disease of 2014 in Guinea and Liberia (Redding *et al.*, 2019), Middle East Respiratory Syndrome (MERS) and global severe acute respiratory syndrome (SARS) CoV-19 have caused severe and significant pathology to human populations.

The zoonotic origin of HIV has been connected to chimpanzees (Glynn, 2008), since the immunodeficiency virus is intimately linked with simian virus SIV-cpz; an immunodeficiency virus occurring in chimpanzees (Bauerfeind *et al.*, 2016), causing severe clinical illness in macaque monkeys (VDH, 2021). With SARS cov-2 of 2019 outbreak, which crumbled many world economies, including Great Britain, Germany, China and the USA, suggested to have started from an animal market in Wuhan, Hubei Province in China, attention of the world is now focused on wild animals and their role in the outbreak of emerging and re-emerging diseases.

Ectoparasites, helminths and protozoan parasitic infections in humans and non-human primates have been recorded to cause monumental effects of disease resulting in morbidity and mortality (White & Razgour, 2020). Many human parasites have been identified in small non-human primates including *Nasalis larvatus* (Klaus *et al.*, 2017) *Cercopithercus mona* (Adegbulu, 2015; Kamani *et al*., 2020; Klaus *et al*., 2017) over the years. Human parasites such as *Ancylostoma*, *Strongyloides*, *Teania*, *Trichuris* (Medkour *et al*., 2020; Squire *et al*., 2018; Uloko & Lameed, 2019), *Schistosoma mansoni* and *Plasmodium* (Teklemariam *et al*., 2018; Weber *et al.*, 1992) have been found in non-human primates.

It has been established that ruminant, livestock (Squire *et al.*, 2018), non-human primates like baboons (Larbi *et al*., 2020) *mona* monkeys (Mbaya & Udendeye, 2011) carry a significant number of gastrointestinal parasites. These parasites produce eggs, oocysts and larvae which are released through faeces of their host onto the environment. Humans, chimpanzees and old-world monkeys have close evolutionary relationships, such that these non-human primates share over 90% of genes common to humans (VDH, 2021). The closeness in genetic composition between humans and old-world monkeys could promote the easy adaptation of human parasites to infect their cohabited non-human primate cousins (VDH, 2021) and serve as a potential reservoir host for infection and reinfection of human populations.

In modern times, there have been efforts of capital injection into ecotourism infrastructure in the Tafi Atome monkey sanctuary due to predictions of ecotourism becoming a major driver in the socioeconomic development of many communities where such facilities exist (Bansah-kagambega, 2019). Traversing the conserved forest and monkey sanctuary is a seasonal stream, Dedi, which serves as the basic source of drinking water for the monkeys. Not only is the stream of economic value to the monkeys but also many farmers. Farmers fetch the water for drinking, watering farm crops and also for the application of insecticides and herbicides. This practice could provide an avenue for the transmission of faecal-oral transmitted parasites between humans and mona monkeys.

During dry seasons, the stream dries up and *mona* monkeys rely heavily on stored water in homes of the human community. Monkeys, therefore, drink water from cooking utensils and water storage tanks. The close location of these human settlements, together with high level of activity between the two species of humans and *mona* monkeys of the sanctuary suggests possible bridges in the human-animal interface. This interaction could provide a suitable avenue for transmission of zooanthroponotic and zoonotic parasites between *mona* monkeys and human community.

These shared infectious parasites betwixt non-human primates and human populations could have a detrimental effect on the quality of life of the *mona* monkeys and humans, including anaemia, malnutrition, reduced immunity (Cibot *et al*., 2015) leading to increased susceptibility to other pathogenic infections. These infections can therefore lead to severe morbidity and pathology among non-human primates and human populations (Medkour *et al*., 2020) of the conserved sacred sanctuary. More so, gastrointestinal infections of the *mona* monkey could potentially affect the tourism potential of the sanctuary, resulting in loss of revenue for local development.

2.7 Common Gastrointestinal Parasites of Humans and Mona Monkeys

Mona monkey is an old-world monkey occupying forest zones of Ghana to Cameroon. They are very beautiful with the body made up of different colours and also are easy to habituate as compared to many other guenons. As a result, many wild habitats of mona monkey serve as tourist attractions such as sacred grooves of Buabeng Fiema and Tafi Atome, Ghana

Emerging zoonotic diseases pose a severe threat to public health and animal conservation. Many gastrointestinal parasites have been identified in humans and non-human primates including mona monkeys. Human parasites that can potentially undergo complete development in multiple hosts are difficult to control because reservoir hosts may be unsuspected and serve as sources of re-infection for other populations in which the parasite has been eliminated.

Multi-host parasites species are of particular concern because they are more likely to emerge than single-host parasites (Ghai *et al.,* 2014). In many instances shared hosts have close phylogenetic relationship providing a conducive environment for the total development of parasites (Teklemariam *et al*., 2018) in their unnatural host. Most infectious diseases that recently emerged in humans have been found to originate in wild animals (Cibot *et al*., 2015).

Mona monkeys and old-world monkeys share a common phylogenetic relationship with humans hence there is a high potential of parasite sharing between the two populations and their role in ecotourism development presupposes continuous encounters with the human population resulting in probable cross parasite transmission. Where non-human primates and humans share common habitats, there exists high parasite prevalence in both species (Gizaw *et al*., 2018) with the associated risk of disease emergence.

Helminths and protozoans inhabit the gastrointestinal tract, blood and body tissues of mona monkeys, causing severe pathology leading to mortality and morbidity. Gastrointestinal parasites such as Hookworm, *Trichuris trichiura, Strongyloides stercoralis* have been identified in mona monkey of Agriculture Zoological Park, Abeokuta, Ogun State, Nigeria (Adegbulu, 2015; Egbetade *et al*., 2014). Gery, (2021), identified two helminths (*Capillaria and Strongyloides*) and protozoans (*Balantidium coli* and *Entamoeba*) in captive mona monkeys in Cameroon. Furthermore, Dawet *et al*., (2013) identified *Trichuris*, Hookworm, *E. coli* and

Entamoeba histolitica in mona monkey in Jos Zoological Garden, Nigeria. In their study of worm burden in captive and free-ranging non-human primates of Afi Mountain Primate Conservation area in Calabar, Nigeria, Mbaya and Udendeye (2011) isolated Ascaris *lunbricoides, Ancylostoma duodenale* and *Trichuris trichuira* in free-ranging mona monkeys. *Ancylostoma, Strongyloides* and *Trichuris* were prevalent in mona monkey of Jos and Kano Zoos and Jos and Abuja National Parks (Kamani *et al*., 2020).

2.8 Treatment and control of gastrointestinal parasites

Even though many individual hosts infected with gastrointestinal parasites remain asymptomatic, very mild cases of infections need to be treated to prevent complications. Historically, treatment of gastrointestinal parasites has been by herbal preparations for many centuries and is still in practice in many parts of the developing world. Aqueous extract of *Anethum graveolensat* plant, administered at a dose of 1 ml x 3 times for 5 days considerably improved symptoms in pediatric patients diagnosed with giardiasis. *Triticum vulgarea* and *Mentha crispaat* dose of 2 g/day for 7 to 10 days has been found to considerably reduced both cyst passage and copro-antigen levels in diseased and asymptomatic giardiasis patients (Alnomasy *et al*., 2021).

Chemical treatment of gastrointestinal parasites case of acute or chronic infection with *S. stercoralis* is by using albendazole and mebendazole. Although albendazole is also effective, it may not be preferred due to the adverse side effects. Several chemotherapeutic preparations have been adopted for the treatment of gastrointestinal parasite infections and these preparations have proven to be more specific and effective than the broad-spectrum herbal preparations. Chemical drugs most commonly used for the treatment of giardia infection is oral administration antibiotic therapy of Metronidazole (Flagyl). Tinidazole (Tindamax) and Nitazoxanide (Alinia) have also proved to be effective against the flagellate parasite (Delgado, 2018).

At present, ivermectin is the routine drug for the treatment of strongyloidiasis. World health organization (WHO) recommends either albendazole or ivermectin at a dose of 400 mg daily for three days and a single dose of 200 µg/kg body weight respectively. A single dose of 5 – 10mg/Kg body weight to 1g of Pyrantel and Piperazine 75mg/Kg body weight to a maximum of 4g for adults and 2g for children blocks the neuromuscular system of Ascarid worm, which instantly immobilize the worm leading to their expulsion (Ore *et al*., 2021). Levamisole is the drug of choice for Ascaris treatment. Administration of 40 mg levamisole tablets and 40 mg/5 ml suspensions interferes with ascaris nerve ganglia, paralysing the worm which is then ejected by host peristaltic movement in less than 24 hours.

2.9 One Health Approach

Humans and animals live in an amalgamating interdependence of health ecosystems where human health is affected by changes and effects in the health of animals and their environment (Galvani *et al*., 2016). Pathogens are ubiquitous, having evolved distinct adaptions to infect multiple hosts in shared habitats to ensure survival. As a result, human and animal diseases have been closely linked and until recently studies of animal and human medicine were together (Mackenzie & Jeggo, 2019). The idea that humans, animals and their environments are closely linked gave birth to the One Health Concept.

One Health Approach or Concept involves proactive designing and implementation of programmes, policies, regulations and standard research across all sectors of health, to collaborate and communicate findings to improve public health. This concept recognises the interconnectedness of global health problems and, as such, promotes the importance of collaboration among local, national, international, interdisciplinary, and cross-sectoral efforts in tackling public health concern (Macfie *et al*., 2015).

The One Health Approach is therefore a deliberate attempt to deviate from the traditional divisive and several contracted opaque health approaches to an all-inclusive integrated transparent system which requires a new set of skills to implement. A sustainable healthy human, animal and environmental health, therefore, calls for dedicated leadership, team building, effective communication, and multidisciplinary projects and research management instead of the skewed traditional discipline-based training. Thus, the One Health approach is a long-term strategy that requires the development of future global health leaders with the skills, knowledge, and experience in collaborating across disciplines and sectors to solve pressing and complex global health problems (Travis *et al*., 2014)

Human population increase and complexities associated with emerging diseases resulted in the disjunction of human and animal medicine. However, the One Health concept, carved in 2008, denotes that animal, environment and human health cannot be separated because of the urgent need for effective sustainable health care systems (Couto & Brandespim, 2020). The concept is foundational on the awareness that major opportunities exist to protect public health through prevention and control of pathogenic diseases in animal populations (World Organisation For Animal Health (OIE), 2013). One Health, therefore, calls for a framework of structured regular surveillance of the environment, human and animal populations for possible transmission of pathogens.

The International Society for Disease Surveillance (ISDS) defines One Health surveillance as 'the collaborative, on-going, systematic collection and analysis of data from multiple domains (at local, national and global levels) to detect health-related events and produce information which leads to actions aimed at attaining optimal health for people, animals, and the environment (Mor *et al.*, 2019). According to OIE (2013). Over sixty percent of all human pathogenic diseases originated from animals (Al-Tayib, 2019) therefore, the most effective way of protecting human populations is to combat zoonotic pathogens at their animal host sources.

In modern times, the frequent outbreak of certain zoonoses, such as bird flu, the Ebola and Zika viral epidemics, SARS Cov-2 have emphasized the interdependence of human health, animal health, and ecosystem health. This has called for continued attention and concern for domesticated animal and wildlife health for sustainable human health system building. Conservationists have therefore recognised and endorsed the principle of "Manhattan" which states that 'the health and sustainable maintenance of wildlife in nature reserves are mutually interdependent with the health of communities and the livestock surrounding them' (Peiris, 2009). Undermining animal health for humans could provide a fertile niche for the growth and proliferation of parasites that could become supply contacts for human infections and the emergence of new diseases in human populations.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Study Site

The study was carried out in Tafi Atome monkey sanctuary located in the Afadjato South District of the Volta Region of Ghana. Afadjato South District was carved out of Hohoe Municipality in 2012, and it is one of the eighteen (18) Municipalities and Districts in the Volta Region. The District has a total land area of 553 km^2, forming about 3.06% of the Volta Region. Ve-Golokwati is the administrative capital located about 20 km from Hohoe, 58 km from Ho, and 200 km from Accra. The geographical coordinates of Ve Golokuati are 6°59'49.1"N 0°26'20.7"E. Other major communities include Logba, Have and Leklebi.

Afadjato South District is the hub of tourism in the Volta Region having a large number of attractive sites – Afadjato, the highest mountain in Ghana, Wli Waterfalls, Aflabo Falls, Tagbo Falls, Tafi Atome Monkey Sanctuary and Logba Tota Caves are located in Afadjato South District. The District borders Hohoe Municipality to the north, Ho West and South Danyi Districts to the south. The Republic of Togo and Kpando Municipality share its boundaries to the east and west respectively.

Afadjato south experiences a maximum amount of 1747.6 mm and a minimum 808.1 mm rainfall annually (Nyatuame *et al.*, 2014) with an average of four months of dry season per year, normally experienced between November and April. The population of the District according to the 2010 population and housing census stands at 95,030 with 46,272 males and 48,758 females.

The research was conducted in wild habituated mona monkeys of Tafi Atome Monkey Sanctuary which do not only interact with the human population of Tafi Atome but also sparingly with the people of Tafi Mador and Abuife all of Afadjato South District. The geographical coordinates of the Tafi Atome monkey sanctuary and human settlement is 6°54'19.7"N 0°23'12.0"E, Tafi Abuife is 6°51'41.6"N 0°21'11.3" and Tafi Mador is 6°51'56.9"N 0°23'59.9"E.

The monkeys also interact with people of Avatime Dzokpe Old Town and Avatime Dzokpe New Town, are in the Ho West District of the Volta Region. These communities lie close to the geographical boarder between the two districts of Afadjato South and Ho West, close to the Tafi Atome monkey Sanctuary. The geographical coordinates of Avatime Dzokpe Old Town are 6°53'45.4"N, 0°24'46.9"E and that of Avatime Dzokpe New Town is 6°53'01.1"N and 0°25'16.8"E. Ho West District has Dzolokpuita as the administrative capital. Other notable communities in the district include Saviefe, Kpedze, Tsito, Abutia and Avatime. Figure 3 is the map of Afadjato South District showing the study communities.

The sacred reserve is a semi-deciduous forest surrounded by a forest-savannah transitional zone (Ormsby & Edelman, 2012), with a large number of lianas on tall to medium-height trees, which sustains the forest and provides support for the climbing activity of the monkeys. The conserved landmass of the sanctuary, including the Tafi Atome Cultural Village (TACV) which is 48.63 Ha (UPS, 2018) has a well-demarcated boundaries that protect the forest from encroachment. These features make Tafi Atome Forest Reserve a safe habitat, not only for the true mona monkeys but also a large number of birds, insects, mammals and reptiles.

Traversing the forest is a stream, Didi, which only become inundated with water during the rainy season, serving as the principal source of water for the monkeys and some community members. River Ahavor also runs through the north to the western fringe of the forest and can swell up considerably during the rainy season, flooding adjacent landmass. The river, therefore, is another source of drinking water for the habituated mona monkeys when the Didi stream dries out.

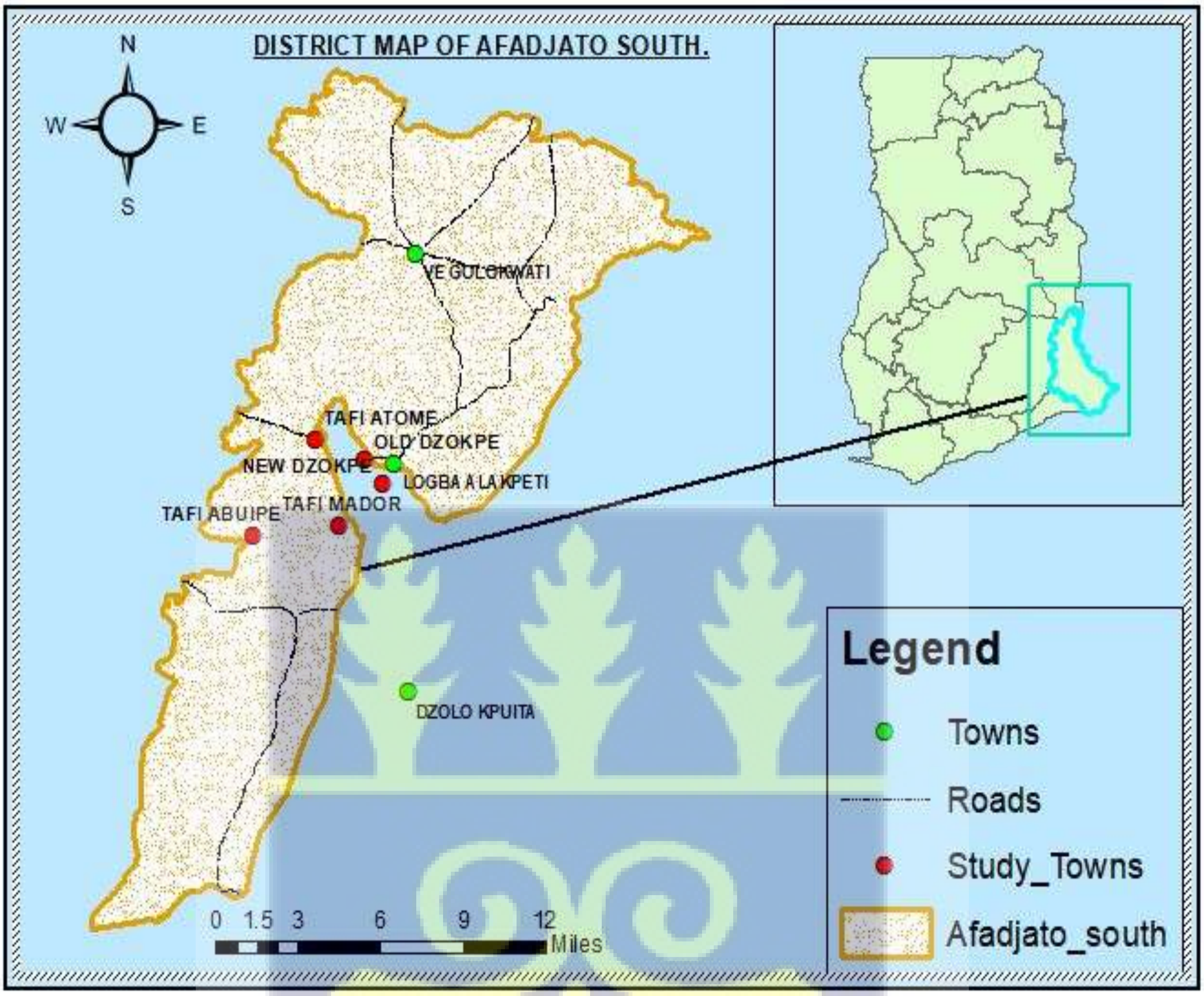

Figure 3: Map of Afadjato South district showing the study areas

3.2 Permission for the Study

Permission to conduct the study was sought from Ghana Tourism Authority, the mother agency managing the sanctuary, and the management board of Tafi Atome monkey Sanctuary for the non-invasive collection of faecal samples from the mona monkey of the sanctuary. Permission was also granted by Ghana Education Service, Afadjato South District for collection of stool samples from school children between six (6) and eighteen (18) years in Tafi Atome, Tafi Mador and Tafi Abuife basic schools. Same clearance was issued by Ghana Education Service, Ho West District for sample collection from school children in Avatime Dzokpe Old Town and New Town basic schools. Traditional authorities and opinion leaders of Tafi Atome, Tafi Mador, Tafi Abuife and Avatime Dzokpe were duly notified. The identity of participants and data collected was ethically protected.

3.3 Study Design

This study was a multi-site study that involved a cross-sectional survey of five different human communities of Tafi Atome, Tafi Mador and Tafi Abuife Avatime Dzokpe Old and New Town and mona monkeys of Tafi Atome Monkey Sanctuary. The study was to establish the current prevalence of the most important gastrointestinal parasite species of zoonotic potential in the Tafi Atome monkey sanctuary that threaten the public health of the participating communities and many tourists that visit the monkeys as well as posing a threat to the tourism potential of the sanctuary.

To achieve the objectives of the study, faecal samples of school children in participating communities and mona monkeys were subjected to microscopic analysis for the prevalence of gastrointestinal parasites of public health importance. Structured questionnaires were also administered to targeted groups to determine the potential risk of zoonotic transmission between humans and cohabited monkey populations. The questionnaires were administered to all randomly sample school children in participating communities for stool gastrointestinal parasite analysis and adult human population above 18 years in Tafi Atome to determine respondent's attitudes, perceptions and knowledge of the mona monkeys of the sanctuary to establish the potential risk of parasite transmission between mona monkeys and human populations.

3.4 Sample size determination

The human faecal sample size was determined by Cochran's Formula ($N0 = Z^2 pq / e^2$) using an infection rate of 45.0% (Orish *et al*., 2019), a 5% margin of error and 95% confidence interval. The final sample size was determined to be 384 excluding 10% non-response rate.

Mona monkey faecal sample size guided by recommendations of Gillespie, (2006) who suggest that for wild non-human primates a minimum of 60 sample could be reflective of the population.

3.5 Sampling methods

The participating school children were selected by systematic random sampling using the school roll as a sampling frame. Proportional allocation was made to select the study subjects from each class level in the school. The number of school children sampled from each class and school was based on the school population and class size. Selection of mona stool samples was by convenient sampling.

3.6 Questionnaire Administration

Semi-structured questionnaires were administered to two categories of respondents. Firstly, all randomly selected school pupils in participating communities for stool sample collection responded to a questionnaire. This was to determine respondents' knowledge of gastrointestinal parasites and prevailing practices that predispose young children of school-going age within the study area to potential zoonotic parasite transmission between humans and mona monkey populations. Apart from demographics, questions varied from records of gastrointestinal parasite infestation, intestinal parasite treatment regime, place of defecation, hand washing practices and nail cutting habits.

The second questionnaire targeted adult residents of Tafi Atome who were above 18 years. The Tafi Atome monkey sanctuary surrounds the human community, permitting frequent interaction between human and *Cercopithecus mona* monkey populations. This questionnaire was to assess respondents' knowledge, attitudes and perceptions of *mona* monkeys of the sanctuary, more so to ascertain risk factors that could facilitate the transmission of gastrointestinal parasites between humans and mona monkeys of the sanctuary. These respondents were selected by non-probability sampling from homes, the mini market, streets and the Monkey Sanctuary and Cultural Village.

Both questionnaires were administered between 28th February and 15th March 2021. All questions were in English and translated to the local Ewe language for individuals who were not proficient in English.

3.7 Faecal Sample Collection from Mona Monkeys

Different troops (hereafter called "families") of mona monkeys of the Tafi Atome monkey sanctuary were identified by tour guides who were very familiar with the monkeys based on their occupied territorial micro habitations within the forest reserve. Each mona monkey family characteristically has an alpha male who defends the territory from other bachelor male invaders though range allopathy is rare in mona monkey behaviour.

Identified families were traced to their nesting site between 17:30 and 18:30 GMT. At 5:00 GMT, families were trailed from their sleeping site to the feeding site where *mona* monkeys were fed large quantities of bananas to minimize their movement. While eating, *mona* monkeys dropped faeces. Freshly void faecal sample was collected using a sterile spatula to pick about 5g from the central portion into labelled sterile cryovials to reduce soil contamination. Samples were then transported to the field laboratory where they were analysed for gastrointestinal parasite larvae, eggs and cyst within six hours.

Overall, Eighty-seven (87) mona money faecal samples were collected for examination; twenty-nine (29) samples between 28th February and 13th March 2021 and fifty-eight (58) samples were collected between 16th and 23rd June 2021. Sample collection was non-invasive because no mona monkey was harmed throughout the process. Each identified mona monkey troupe was targeted and trailed only once. Figure 4 shows the researcher collecting mona monkey faecal samples with assistance of a tour guide.

Figure 4: Researcher collecting mona monkey faecal samples

3.8 Stool Sample Collection from Humans

Apart from Tafi Atome, and Avatime Dzokpe, the *mona* monkeys of the sanctuary casually interact with two other communities; Tafi Mador, and Tafi Abuife. Three hundred and forty-seven (347) stool samples were collected from randomly selected school children from six (6) to seventeen (17) years. Pupils from seven Primary and Junior High Schools within the study area were sampled randomly by systematic random sampling using school roll as a sampling frame. Before specimen collection, demographic information such as sex, age and class of each participating pupil was recorded. Labelled sterile leak-proof vials with applicator sticks, together with plastic sheets, toilet paper and zip-lock bags were distributed to participants who were requested to bring sizeable stool samples. The entire school was educated on stool sample collection procedures to reduce stool contamination and infection of participants. Each sampled participant received a Parental Assent form which was signed and submitted together with fresh morning faecal samples at 8:00 GMT the following morning. Each school was sampled once. Received fresh stools were transported to the field laboratory where they were analysed microscopically for the presence of gastrointestinal parasites eggs and cysts.

Figure 5: A section of one school from where stool samples were collected at Tafi

3.9 Field Laboratory

A field laboratory was set up in the premises of Jim Burton Memorial Agricultural Senior High School, Logba Adzakoe, six kilometres from Tafi Atome. All samples transported to the laboratory were analysed microscopically by a qualified medical laboratory professional.

Figure 6: Field laboratory set up at Jim Burton Memorial Agricultural Senior High School, Logba Adzakoe

3.10 Formalin-Ethyl Acetate Sedimentation Concentration

Formalin-Ethyl Acetate Sedimentation technique (FEASC) as recommended by Manser *et al*., (2016) was employed to analyse freshly collected mona monkey and human faecal samples for the presence of gastrointestinal parasite eggs and cyst. About 1 g of faecal sample was mixed well in 10% formalin water and sieved using a mesh with 0.5 mm pores into a 15 ml Eppendorf tube. Formalin (10%) was added through the strainer to bring the volume to 15 ml and the tube caped.

The mixture was placed in a centrifuge and spanned at 3000 rpm (revolutions per minute) for 3 minutes. The supernatant was decanted and 10% formalin water was added to the sediment up to the 10 ml mark of the Eppendorf tube and mixed thoroughly using a wooden applicator. Four millilitres of ethyl acetate was then added and the stopper placed on. The mixture was homogenized vigorously for about 1 minute and centrifuged at 3000 rpm for 3 minutes.

The plug at the top of the Eppendorf tube was removed by ringing with an applicator stick and the supernatant decanted. Debris was removed by using cotton buds before the Eppendorf tube was inverted. Two drops of normal saline were added to the sediment using a pipette and mixed thoroughly to suspend the residue. One drop of the suspension was placed on a cleaned glass slide using disposable pipette tip and covered with a cover slip. The slide was observed under Optika DM-10 digital microscope using x 10 objective and shifting to high power for detailed identification of parasites. The entire cover slip was systematically examined.

Identification of parasite egg, cyst and larvae was guided by standard parasitological criteria (Soulsby, 1982) and WHO bench aids in the laboratory (1994). Any parasite, egg or oocyst that was observed was recorded as positive.

The formalin used in this method destroyed parasite eggs and larvae such that they are no longer infective after concentration. More so, the addition of ethyl acetate to the sediment before the second centrifugation removes debris from the tool sample for a clearer image of parasite eggs and oocyst under the microscope, thereby reducing false-negative results. Formalin is, however, a mutagen and extra caution had to be taken in handling it.

3.11 Statistical Analysis

Data on gastrointestinal parasites identified in monkeys faecal and human stool samples together with questionnaire responses were entered into MS-excel spread sheet to create a database. The overall prevalence of gastrointestinal parasites infection in humans and mona monkeys was calculated by dividing the proportion of positive samples with gastrointestinal helminths and protozoan infestation (n) by the total sample size (N), multiplied by 100% in each case. Chi-squared (χ^2) test was carried out to determine differences in gastrointestinal parasite prevalence in school children in *Cercopithecus mona* of the Sanctuary using the Statistical Package for Social Sciences (SPSS).

Questionnaire responses were summarized using descriptive statistics and chi-squared (χ^2) tests was used to determine differences in the categories of responses. Statistical tests were considered significant at $p < 0.05$ and confidence interval of 95%.

CHAPTER FOUR

4.0 RESULTS

4.1 Prevalence of gastrointestinal parasites in mona monkeys of Tafi Atome Monkey Sanctuary

Eighty-seven (87) mona monkey faecal samples were non-invasively collected from the Tafi Atome Monkey Sanctuary and examined microscopically under the light microscope for helminth egg, larvae and protozoan cyst. Overall, five (5) gastrointestinal parasites of public health importance, made up of cyst of a protozoan (*Giardia)* and eggs of four (4) helminths (Hookworm, *Ascaris*, *Schistosoma*, and *Strongyloides)*, were identified morphologically and the parasite prevalence is shown in Figure 7.

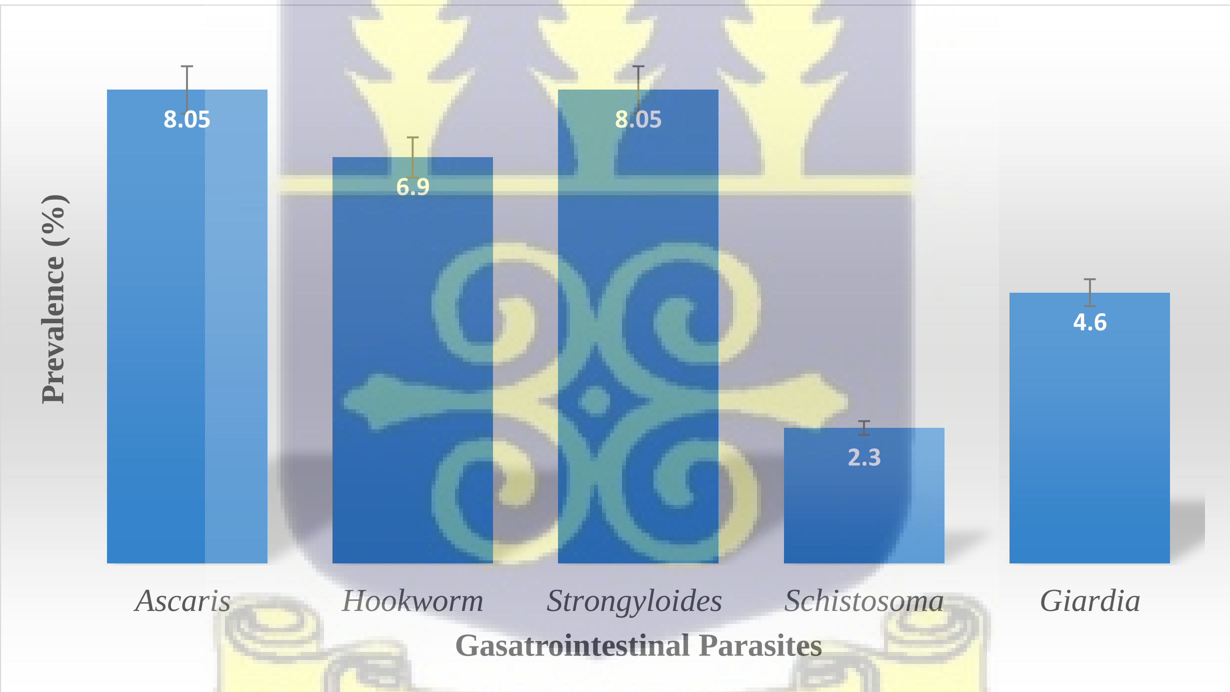

Figure 7: Gastrointestinal parasites prevalent in mona monkeys of Tafi Atome Monkey Sanctuary

The dominant gastrointestinal parasite species in the mona monkeys of the sanctuary were *Ascaris lumbricoides* (8.05%) and *Strongyloides* (8.05%) while *Schistosoma mansoni* (2.29%) was the least prevalent.

4.2 Demographic characteristic of school children sampled

Three hundred and forty-seven (347) stool samples were collected from randomly selected school pupils, from 6 to 17 years in seven basic schools present in the study communities of Tafi in the Afadjato South and Avatime Dzokpe in the Ho West Districts of the Volta region of Ghana. Overall, 171 representing 49% of the pupils sampled were boys while the remaining 178 representing 51% were girls. Table 1 shows the various schools with the demographic characteristics of pupils sampled.

Table 1: Study districts and schools, sample size and demographic characteristics

Variable	Classification	Sample size	Percentage %
Ho West	Avatime Dzokpe New Town E.P. Primary	35	10.1
	Avatime Dzokpe New Town D/A JHS	45	13.0
	Avatime Dzokpe Old Town E.P. Primary	40	11.2
Afadjato South	Tafi Abuife United D/A JHS	39	11.2
	Tafi Atome D/A JHS	86	24.8
	Tafi Atome R.C. Primary	65	18.7
	Tafi Mador D/ A Primary and JHS	37	10.7
Age	6-8	15	4.3
	9-11	60	17.3
	12-14	174	50.1
	15-17	98	28.2
Gender	Male	171	49.3
	Female	176	50.7

4.3 Prevalence of Gastrointestinal Parasites in Humans

Overall, six (6) genera of gastrointestinal parasites made up of two protozoans; *Entamoeba* (3.7%) and *Giardia* (3.5%) and four helminths; *Ascaris* (9.51%), Hookworm (21.9%), *Strongyloides* (14.7%) and *Trichuris* (9.2%) were microscopically identified by using their morphological features from human stool samples of school children. Most of the parasites were helminths. The highest prevalent gastrointestinal parasite in the human population was Hookworm (21.9%) while the least prevalent was *Giardia* (3.5%) as shown in figure 8 below.

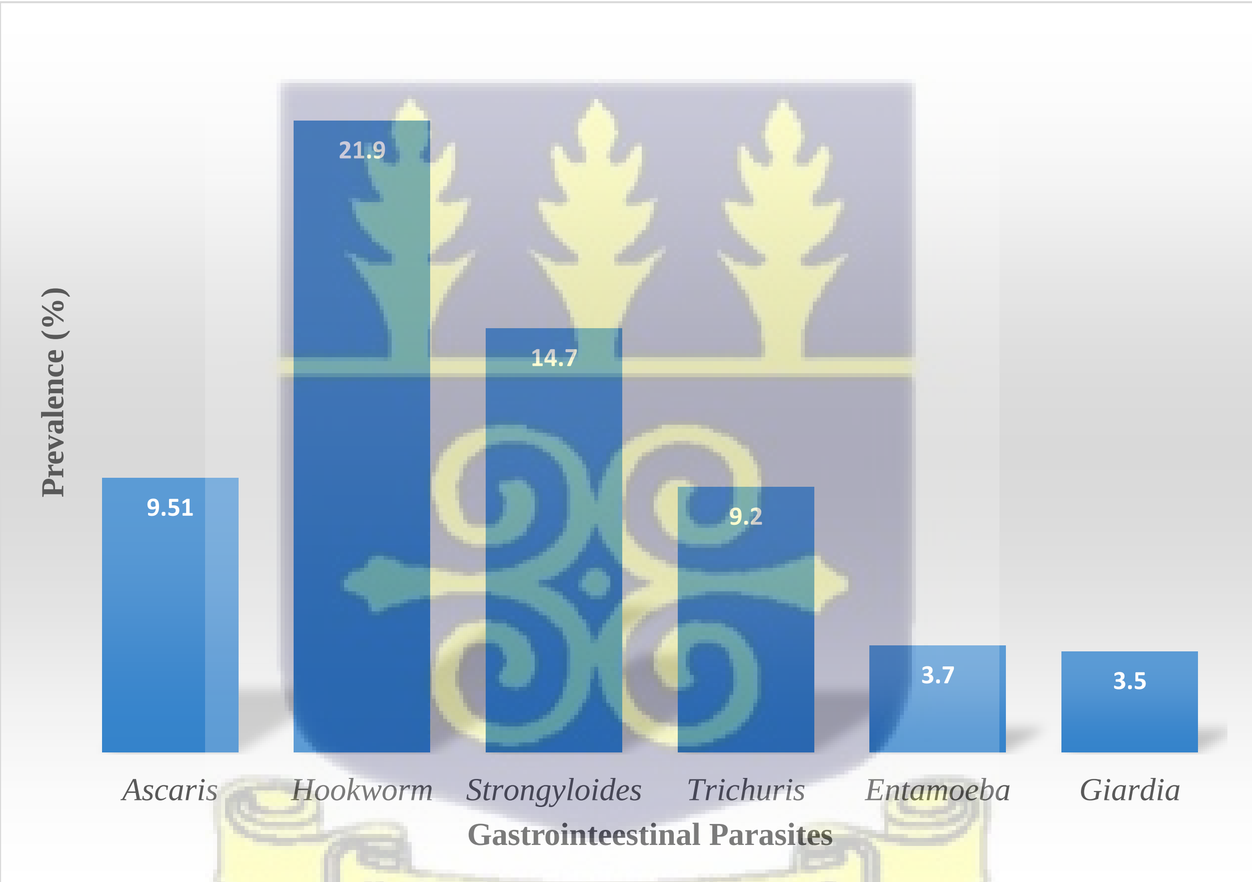

Figure 8: Prevalence of Gastrointestinal Parasites in School children

4.4 Prevalence of gastrointestinal parasites prevalent in school children of Tafi and Avatime Dzokpe

Hookworm was the dominant gastrointestinal parasite prevalent in school children in Tafi (26.7%) and Avatime Dzokpe (19.2%). Prevalence of *Strongyloides* in Tafi and Avatime Dzokpe schools were 16.7% and 13.7% respectively. The least prevalent gastrointestinal parasite in Tafi was *Entamoeba* (1.8%) while *Giardia* (2.5%) and *Entamoeba* (2.5%) were least prevalent in Avatime Dzokpe. A chi square test was conducted to determine possible differences in common gastrointestinal parasites prevalence between Tafi and Avatime Dzokpe. Results show no difference in *Ascaris, Trichuris, Strongyloides,* hookworm, *Entamoeba and Giardia,* in the adjoining communities of Tafi and Avatime Dzokpe ($p > 0.05$) as presented in Table 2.

Table 2: Comparison of gastrointestinal parasites prevalent in school children of Tafi and Avatime Dzokpe

Parasites Identified	Number of pupils infected at Tafi (*NPS)	Percentage prevalence (95%CI)	Number of pupils infected at Avatime Dzokpe (*NPS)	Percentage prevalence (95%CI)	χ^2 (df); p-value**
Protozoa					
Entamoeba	4(223)	1.8 (4.58; 0.07)	3(117)	2.5(2.42; 0.14)	0.22 (1); 0.64
Giardia	7(220)	3.1 (6.54; 0.03)	3(117)	2.5(3.46; 0.06)	0.10 (1); 0.76
Helminth					
Ascaris	17(210)	7.5 (20.93; 0.74)	15(105)	12.5(11.07; 1.4)	2.4 (1); 0.12
Hookworm	44(183)	19.3(49.72; 0.66)	32(88)	26.7(26.28; 1.24)	2.43 (1); 0.12
Strongyloides	31(196)	13.7(33.36; 0.17)	20(100)	16.7(17.64; 0.32)	0.57 (1); 0.45
Trichuris	21(206)	9.3 (20.93; 0)	11(109)	9.2 (11.07; 0)	0.001 (1); 0.98

**= p-values of parasite prevalence comparisons; NPS = no parasites seen; Sample = 347

Overall prevalence of gastrointestinal parasites in school children of Tafi and Avatime Dzokpe was analysed using chi-square test and there was no difference in gastrointestinal parasites prevalence in Tafi and Avatime Dzokpe, (χ^2 ***(df)*** 2.944 (1) ***p*** = 0.077) as presented in Table 3.

Table 3: Comparison of gastrointestinal parasite prevalence in Tafi and Avatime Dzokpe

Community	Number of pupils sampled	Number infected(NPS)	Percentage prevalence (95% CI)	***χ^2 (df)** p-value***
Tafi	227	**101** (126)	44.5 (108.59) [0.53]	
Avatime Dzokpe	120	**65** (55)	54.2 (57.41) [1]	2.944 (1) 0.077

**= Chi-square (degrees of freedom); NPS = no parasites seen

4.5. Common Gastrointestinal Parasites in Humans and mona Monkeys.

Overall, four genera of gastrointestinal parasites were found common in both human and cohabited mona monkeys in the Tafi Atome monkey sanctuary. These parasites were *Giardia*, *Strongyloides*, Hookworm, and *Ascaris*. In humans, the most prevalent gastrointestinal parasite was hookworm (21.90%), while *Ascaris* (8.05%) and *Strongyloides* (8.05%) were the most prevalent in mona monkeys (Table 3). Out of the various parasites shared between humans and cohabited mona monkey species, only hookworm infection was significantly different by Chi-square test (χ^2 (df); 10.22 (1); P = 0.00) as presented in Table 4.

Table 4: Comparisons of gastrointestinal parasites prevalent in humans and *Cercopithecus mona* of Tafi Atome Monkey Sanctuary

Parasite Identified	Mona monkeys infected (*NPS)	Prevalence (95%CI)	Humans infected (*NPS)	Prevalence (95%CI)	χ^2 (df)p-value
Giardia	4 (83)	6.6 (2.81, 0.51)	10 (337)	2.9 (11.19; 0.13)	0.656 (1) 0.43
Ascaris	7 (80)	8.0 (7.82, 0.09)	32 (315)	9.2 (31.18; 0.02)	0.1176 (1) 073
Hookworm	6 (81)	6.8 (316.44, 6.63)	76 (271)	21.9 (65.56; 1.66)	10.2207 (1) 0.00
Strongyloides	7 (80)	8.0 (11.63, 1.84)	51 (296)	14.7 (46.37; 0.46)	2.658 (1) 0.10

***= Chi-square (degrees of freedom); *NPS = no parasites seen.**

A comparison of total gastrointestinal parasite prevalence in *Cercopithecus mona* of the Tafi Atome Forest Reserve and Monkey Sanctuary and cohabited human populations of Tafi and Avatime Dzokpe was significantly different (χ^2 (df) 12.96 (1); p = 0.000318) as presented in Table 5

Table 5: Relationship of gastrointestinal parasite prevalence between *Cercopithecus mona* and interacting human population

Parasite Host	Total sampled	Number infected (NPS)	Percentage prevalence (95% CI)	χ^2 (df); p-value
Mona monkey	**87**	**23 (64)**	**47.8 (37.89; 5.85)**	
Human	**347**	**166 (181)**	**26.4 (151.11; 1.47)**	**12.96 (1); 0.000318***

= Chi-square (degrees of freedom)*; ****NPS = no parasites see*

4.6 Knowledge, Attitudes, Beliefs and Perceptions of human inhabitants towards Mona monkeys

4.6.1 Demographic Characteristics of Adult Respondents to the Questionnaire

A total of 167 adults made up of 38.9% males and 61.6% females from Tafi Atome responded to the questionnaire. Generally, there were marginal differences in the representation of age groups of respondents. Respondents between 46 – 45 years formed the largest group representing 22.2% while those above 65 years were the least, representing 9%. The other ages groups of respondents were 18 – 25 years (15.6%), 26 – 35 years (18.6%), 36 – 45 years (20.4%) and 14.4% were between 56 -65 years.

The highest level of education of respondents was secondary education (38.3%) followed by basic education (36.5%). Only 4.2% of respondents had tertiary education while the remaining 21.0% had no formal education. The main occupation of the people of Tafi Atome was farming (49.1%), followed by petty trading (32.9%) whilst 6.0% of respondents are employed in the formal sector. Other occupations include kente weaving, driving and motor riding.

4.6.2 Knowledge of mona monkeys

It was common knowledge among adult respondents of Tafi Atome that mona monkeys eat banana and all respondents were aware of their banana diet. They were however generally oblivious of other food items preyed upon by mona monkeys as 65.3% believed they relied exclusively on bananas. Only 19.8% of respondents believed mona monkeys eat other fruits such as palm, mangoes and yellow berries, while 13.8% believed they complement bananas and fruits with wild insects for their protein needs. Awareness of trend of Mona monkey population was high among respondents as a majority (92.2%) described them as increasing as against

3.6% and 2.4% describing the trend as stable and decreasing in the forest respectively. Many respondents had no idea of other socio-ecological benefits derived from the presence of the monkeys in the sanctuary apart from tourism. On the health of mona monkeys, only a minority (12%) believed they do fall sick with some passing watery faeces (6.0%) and looking dull. (3.0%). A number of respondents (38.9%) believed the monkeys are always healthy.

Though respondents had never seen a dead mona monkey, many (77.8%) assumed that dead monkeys are buried by the troops while others (22.2%) asserted mona monkeys could be cannibals, eating dead members of their troops as shown in Table 6

Table 6: Proportion of Respondent's answering questions on knowledge of *Cercopithecus mona* of TAFRMS

Question	Answer	Frequency	Percent
What do the monkeys eat?	Banana	109	65.3
	Insects	23	13.8
	Fruits	33	19.8
	Others	2	1.2
Trend of monkeys numbers in the forest	Increasing	154	92.2
	Stable	6	3.6
	Decreasing	4	2.4
	No Idea	3	1.8
Importance derived from the monkeys apart from tourism?	No	85	50.9
	No Idea	82	49.1
Do the monkeys fall sick?	Yes	20	12.0
	No	65	38.9
	No Idea	82	49.1
How do you know a mona monkey is sick?	Pass Watery Stool	10	6.0
	Looks Dull	5	3.0
	No Idea	152	91.0

What do you think happen to naturally dead monkeys	Eaten by the troop	37	22.2
	Buried by the troops	130	77.8

4.6.3 Attitudes and Perceptions of human inhabitants towards mona monkeys

Human attitudes and perceptions of wild animals they interact with are sentinel to potential transmission of zoonotic parasites in the human - wildlife interface. The people of Tafi Atome revered mona monkeys of the Sanctuary and none of the respondent would either kill or eat the meat of the non-human primates. A majority (64.7%) thought the monkeys could not be captured for any purpose as against 22.8% who believe they are captured as pets (16.2%) and for sale (7.2%). An overwhelming 91% of respondents considered the mona monkeys to be friendly and value their close association.

Generally, respondents' perception of benefit derived from their association with the mona monkeys ranged between bringing of good luck (15.6%), protection for the community (34.7 %) with tourism accounting for only 31.1%. Overall, a significantly high proportion of respondents (79%) supported the continuous visitation of the primates to their homes against a minority (18.6%) who would be happy if the monkeys could be restricted from visiting their homes on grounds of mona monkey being a nuisance (14.4%), scary (4.8%) and also littering their homes (1.8%). Respondents' responses on their attitudes and perceptions of the mona monkeys with the descriptive statistics are shown in Table 7.

Table 7: Respondents' attitudes and perceptions of the mona monkeys in the sanctuary

Question	Answer	Frequency	Percent
Do you kill *mona* monkey?	Yes	0	0.0
	No	167	100
Do you know if people capture *mona* monkeys?	Yes	38	22.8
	No	108	64.7
	No Idea	21	12.6
If yes, what are captured monkeys used for?	No Idea	128	76.6
	As Pet	27	16.2
	For Sale	12	7.2
Will you eat monkey meat if given chance?	Yes	0	0
	No	167	100
Should the monkeys be relocated by the wildlife society?	Yes	15	9.0
	No	152	91.0
If yes, give one reason?	Answered No	152	91.0
	Pollute my stored water	2	1.2
	Are evil	1	0.6
	Bring bad luck	8	4.8
	Steal eggs and food items	4	2.4
If no, give one reason?	Answered Yes	15	9.0
	Bring good luck	26	15.6
	Protect the community	58	34.7
	Employment creation	16	9.6
	Tourism	52	31.1
Should the monkeys be prevented from coming to your house?	Yes	31	18.6
	No	132	79.0
	No Idea	4	2.4
If yes, give one reason?	Answered No	132	79.0
	They are nuisance	24	14.4
	They scare me	8	4.8
	They litter my house	3	1.8

4.6.4 Knowledge of Zoonotic Disease Transmission

Overall, respondents of Tafi Atome' awareness of presence pathogens in both wild and domestic animal populations was significantly high (68.3%) but ironically 68.3% of respondents did not believe their revered mona monkeys could be a host of gastrointestinal parasites. More so, only 24% believed gastrointestinal parasites, if present in mona monkeys, could be transmitted to human populations.

Though 68% of respondents believed humans in the Tafi Atome community could be carrying gastrointestinal parasites, only 27.5% had ever tested for gastrointestinal parasite infection and only a small fraction, 10.2% believed these parasites in humans could be transmitted to the mona monkey population of the sanctuary. Responses of respondents are presented in appendix III.

4.6.5 Risk of parasite transmission between human and mona monkey population

All though 57.3% of school children regularly wash their hands before eating, general hands washing practices were poor as 50.1% do not frequently wash hand with soap. Again, 44% of school children did not have toilet in their homes but there were available public toilet facilities in the communities sampled. Despite available public toilet facilities 18.9% of school children practiced open defecation as shown in Table 8.

It is also worth noting that of the 167 adult respondents at Tafi Atome, 18.6% see mona monkey faecal matter in their homes after the visitations of the non-human primates and 6.6% have seen children play with these mona faecal matter, a situation that provides an avenue for faecal-oral zoonotic disease transmission. From the data, it was a common practice for people to walk barefooted as confirmed by 64.1% of respondents. Children of Tafi Atome also play barefooted while a significant number of the population drinks untreated water from the two water bodies, Ahavor (94.6%) and Didi (42.5%), which runs through the conserved forest and serve as a source of drinking water for mona monkeys of the sanctuary as shown in Appendix III.

Table 5: Risk of zoonotic parasite transmission in Tafi Atome among School children of Tafi and Avatime Dzokpe

Questions on Practice		Frequency	Percent
Do you wash hands before you eat food at home or in school	Yes	200	57.3
	No	5	1.4
	Sometimes	144	41.3
Do you wash hands with soap before you eat food at home or in school	Yes	129	37.0
	No	45	12.9
	Sometimes	175	50.1
Do you wash your hands after visiting the toilet	Yes	208	59.6
	No	26	7.4
	Sometimes	115	33.0
Do you have toilet in your house	Yes	194	55.6
	No	155	44.4
Where do you go to toilet?	Public Toilet	93	26.7
	Bush	66	18.9
	At Home	126	36.1
	Home and public toilet	31	8.9
	Home and Bush	22	6.3
	Bush and Public Toilet	11	3.2
How often do you wear shoes at home or to school	Always	172	49.3
	Sometimes	177	50.7
Do you cut your nails regularly?	Yes	281	80.5
	No	68	19.5
What do you use to cut your nails?	I bite my nails	107	30.7
	I use a blade or Knife	242	69.3

CHAPTER FIVE

5.0 DISCUSSION

The human-animal interface is an established link for the transmission of pathogens across human and animal species. This interface has sustained horizontal transmission of pathogenic agents to humans resulting in the emergence and re-emergence of diseases with varying magnitude and impact on human and animal lives (Reperant *et al*., 2012). The concept of zoonoses has received heightened interest in the past few years following the outbreak of SARS-Cov-2 in 2019, with immeasurable public health and socio-economic impact on the entire world. The influence of zoonotic disease transmission is not limited to public health and socio-economics of humans but also affects the survival of domestic and wild animal species with its associated bearing on ecosystem sustenance and transfer of energy in food webs.

This study sought to underpin possible zoonotic transmission of gastrointestinal parasites between cohabited species of *Cercopithecus mona* monkeys and humans in the Tafi Atome Forest Reserve and Monkey Sanctuary using the formalin-ethyl acetate sedimentation.

Mona monkeys of the sanctuary frequently interrelate with the human community creating an interface for pathogen transmission. Results of analysis of faecal samples of the mona monkeys of the sanctuary showed a prevalence of Hookworm (6.9%), *Ascaris* (8.05%), *Strongyloides* (8.05%), *Schistosoma* (2.3%) and *Giardia* (4.6%). These gastrointestinal parasites are pathogenic and could cause significant damage to their host, mostly in high infections (Feasey *et al*., 2010). The prevalence of these gastrointestinal parasites therefore, has the potential of impeding conservation efforts and subsequently impact adversely on the tourism potential of the sanctuary.

The presence Hookworm, *Ascaris*, *Strongyloides*, *Schistosoma* and *Giardia* in mona monkeys of the Tafi Atome Monkey Sanctuary are similar to gastrointestinal parasites found in mona monkeys of Abeokuta zoological gardens, Nigeria (Adegbulu, 2015). Dawet, (2013), found mona monkeys of Jos Zoological Garden to have hookworm (33.33%), *Trichuris* (66.67%) and *Entamoeba histolitica* (66.67%), however, *Trichuris* and *Entamoeba histolitica* were absent in the current study. Gery *et al*., 2019 identified two helminths *Capillaria* and *Strongyloides* in captive mona monkeys in Cameroon.

Findings are also in agreement with those of Houmsou *et al*., (2019), who found intestinal parasites made up of *Giardia* (6.7%), *Ascaris* (50%) *Strongyloides stercoralis* (20%) and *Trichuris trichuira* (28.6%) prevalent in mona monkeys of the Gumti National Park in Northern Nigeria.

The high prevalence of gastrointestinal parasites observed in this study could be a result of mona monkeys living in large sympatric troupes of up to 35 members (Matsuda, *et al*., 2020) with close interactions including grooming which facilitates parasite and other pathogen exchange among individuals (Gillespie, 2006). Also, the conserved forest is wet, providing an enabling condition that promotes the growth and development of infective stages of soil-transmitted helminths and protozoans in the environment.

In the current study, the prevalence of *Strongyloides* (8.05%) *Ascaris* (8.05%) and Hookworm (6.9%) in the *Cercopithecus mona* of the Tafi Atome monkey sanctuary were lower than those found by Adegbulu, (2015) and Dawet, (2013) in the *Cercopithecus mona* in Nigeria. Again, these findings are lower than the gastrointestinal parasites found in Baboons (*Papio anubis)* in the Shai Hill Reserve in Ghana (Larbi *et al.*, 2020). The lower prevalence in the mona monkeys of the current study could be attributed to variations in ecological niches as mona monkeys are arboreal, spending more time in the forest canopy as against the baboons which spend most of their time on the land, having regular contact with the soil.

The dominant gastrointestinal parasites in the mona monkeys of the TAFRMS were helminths. The higher prevalence of helminth parasites in this study agrees with results of Quraishi *et al*., 2017 who identified helminth as the most prevalent intestinal parasites in non-human primates in the Gumti National Park, North-East Nigeria. This high helminth prevalence could be associated with humid conditions in the Tafi Atome forest reserve. Humid environmental conditions are suitable for the development of infective stages of larvae of soil-transmitted helminths; *Ascaris, Strongyloides* and Hookworm. Teichrobe *at al.*, 2009 established a strong positive correlation between a humid environment and intestinal parasite prevalence in Ghana.

The presence of these parasites in the mona monkey populations of the Tafi Atome monkey sanctuary is a source of concern since heavy gastrointestinal parasite infections have been associated with anaemia leading to iron deficiency, malnutrition, intestinal mucosal inflammation leading to ulceration, weight loss, and death in primates (Feasey *et al.*, 2010).

It was also observed that *Schistosoma mansoni* was prevalent in only 2.29% of mona monkeys of the TAFRMS. This situation could be attributed to the fact that mona monkeys of the sanctuary only partially rely on water from Didi and Ahavor streams since drinking water was readily available at the cultural village. The hatched miracidia of the *Schistosoma* require a suitable fresh water snail host for development to the infective *Cercariae* stage. Sample collection in this study, however, was at a time when water was not readily available in the columns of the two main water bodies, Didi and Ahavor, hence parasite infective stages might not be readily available in the environment, accounting for the very low prevalence.

There was high prevalence of gastrointestinal parasites of public health importance in school children in Tafi and Avatime Dzokpe within the catchment of the Tafi Atome monkey sanctuary. The parasites identified in the current study were helminths Hookworm (21.9%), *Strongyloides* (14.7%), *Ascaris* (9.2%) and *Trichuris* (9.2%) and protozoans *Entamoeba* and *Giardia*. In a similar study using combined techniques of Kato-Katz and Formol–ether concentration, Teklemariam *et al*, 2018 reported the prevalence of *Schistosoma mansoni* (35.7%), *Trichuris trichuira* (26.9%), and *Ascaris lumbricoides* (24.1%) in school children in the Ziway area in Ethiopia.

The high prevalence of gastrointestinal parasites in school children of Tafi and Avatime could be attributed to pervasive risk practices such as open defaecation (19.6%), irregular hand washing before meals and walking around barefooted (49.9%). Kefale & Teklemichael, 2021 attributed source of drinking water, latrine availability, defecation habit, hand washing habit before meals and after visiting toilet and fingernails hygiene to gastrointestinal parasite prevalence in children of Grade School Complex, Ethiopia. These practices could facilitate the transmission of soil-transmitted helminths and protozoans. According to Assemie *et al*., (2021), individuals who do not wear shoes regularly are 2.7 times more susceptible to contracting gastrointestinal parasites as compared to those who wear shoes but irregular shoe wearing behaviour was pervasive among school children (50.9%) in the study area.

Also, Dessie *et al*., 2019; Forson *et al*., 2017; Gelaw *et al*., 2013; Gizaw *et al*., 2018 established strong positive correlation between transmission of gastrointestinal parasites in school children and practices such as hand washing before eating, family size, drinking water sources, shoe-wearing habit and fingernail cleanness, being major risk factors in children.

Overall, gastrointestinal parasite prevalence in school children in Tafi and Avatime Dzokpe was 47.6 %. Although this prevalence was higher than findings in some other studies in the Volta Region (Kpene *et al*., 2020; Orish *et al*., 2019), findings are similar to the 40% prevalence in children of Grade School Complex (Kefale & Teklemichael, 2021) and 46.9% in primary school children (Assemie *et al.*, 2021) in Kenya. Findings are however, lower than over 80% identified in school children in Burkina Faso (Erismann *et al*., 2016) and 65.8% in school children aged 5 – 15 years in Egypt (El-Sherbini & Abosdera, 2013).

Furthermore, gastrointestinal parasite prevalence in school children in the current study could be attributed to favourable environmental conditions that facilitate the development and survival of infective stages of the parasites. *Ascaris*, Hookworm and *Strongyloides* are transmitted through the soil hence larvae survival depends largely on environmental conditions.

From the study, four gastrointestinal parasite genera were found prevalent in mona monkeys of the TAFRMS and school children in the catchment areas of the conserved groove. The parasites were helminths; *Ascaris*, hookworm and *Strongyloides* and a protozoan *Giardia*. The sharing of common habitat between non-human primates and humans could account for the prevalence of common parasites (Gizaw *et al*., 2018) with the associated risk of disease emergence.

The prevalence of common gastrointestinal parasites between mona monkeys and the human population agrees with those of Teklemariam *et al*., (2018), in Ethiopia where *Trichuris*, *Ascaris*, hookworm, *Strongyloides spp*, *Giardia lamblia* and *Schistosoma mansoni* were prevalent in interacting human and vervet monkey populations. *Trichuris* species were found in humans and different species of non-human primates (NHP) in Kibale National Park, Uganda (Ghai *et al*., 2014). Even though *Trichuris* was prevalent in non-human primates (NHP) of zoological gardens of Ibadan Nigeria, there was no evidence of cross-transmission between the NHP and their human handlers (Adetunji, 2014).

The gastrointestinal parasite sharing between humans and mona monkeys of the Tafi Atome sanctuary suggests a possible parasite-host sharing within the area, hence the habitat could be sentinel for zoonotic transmissions. Parasites are pervasive, occurring in virtually all food webs at all trophic levels with complex life cycles that rely on trophic interactions for transmission (Marcogliese, 2005). Humans and non-human primates share close genetic information (Medkour *et al*., 2020) and this could account for parasite-host sharing between mona monkeys and humans in the study area. Host sharing increases parasite niche and improves ecological success (Teklemariam *et al*., 2018).

Furthermore, based on the results from this study it could be deduced that the mona monkey population of the Tafi Atome monkey Sanctuary is not threatened by the presence of the interacting human community. There was good awareness of the benefits the community derives from tourism and its subsequent role in the development of the Tafi Atome community. Apart from tourism, the monkeys also serve as the spiritual link between the people and the gods, bringing good luck to the community. These findings agree with those of (Mensah, 2012), in the Tafi Atome community. The continuous increase in the mona monkey population would increase parasite hosts, thereby increase the chances of zoonotic gastrointestinal parasite spill-over to the interacting human population.

According to Ankamah, (2020), in wildlife conservation, local communities should be allowed to participate in the decision-making and policy formulation and given some level of control and powers within the management system for the sustenance of such policies and this exactly was the case in Tafi Atome Monkey Sanctuary. Though the mona monkey population in the sanctuary was increasing with the potential of the emergence of interspecies conflict between humans and mona monkeys, the people of Tafi Atome share their homes and other recourses with the monkeys for the sustenance of the forest, conceivably because of the tourism and other benefits the community derive from this interaction. These perceptions are similar to suburban residents in Msunduzi and Ekwini municipalities in South Africa toward vervet monkeys (Patterson *et al*., 2017).

Despite the cherished interaction, residents were oblivious of the potential of pathogen transmission between them and cohabited mona monkey populations as many inhabitants did not believe that mona monkeys of the sanctuary could host some gastrointestinal parasites. Generally, attitude towards testing and control of gastrointestinal parasites within the human population was poor although there was awareness of their presence. This could be attributed to a lack of knowledge on transmission of the parasites and high belief that non-human primates of the sanctuary are without pathogens and over-reliance on the tourism potential of the forest. Teklemariam (2021) suggests that in areas where non-human primates serve as drivers for tourism and resource development, inhabitants tend to direct attention toward income generation.

5.1 Challenges Encountered in the Study

Every research is characterised by limiting factors and this study was no exception. The first factor was the outbreak of Covid- 19. After the covid-19 disease outbreak, all educational institutions including basic schools in Ghana were closed. As a result, sample collection from school children in the project area was put on hold until Basic Schools resumed on January 15th, 2021

In addition, sample collection from school children took place around the inception of covid vaccination in Ghana. This activity was characterised by misconceptions leading to vaccine resistance. Pupils and parents, therefore, believed stool samples were to be used for the covid-19 test and subsequently, children would be administered the covid vaccine. As a result, the targeted sample size of 384 was not achieved as children and parents refused to participate in the project.

It would have been better if advanced identification techniques such as PCR and other molecular tools were used to identify parasites to the species level to be able to establish gastrointestinal parasite host sharing between mona monkeys and the human populations of the interacting communities of Tafi and Avatime Dzokpe. This was however not possible due to lack of funding.

Furthermore, the management board of the Tafi Atome Forest Reserve and Monkey Sanctuary was reluctant in giving clearance for the non-invasive collection of faecal samples of mona monkey of the sanctuary. This is because management was not sure of the effects of the findings of the research on the tourism potential of the sanctuary. Resources had been spent on building infrastructure that had been achieved since the inception of the ecotourism centre in 1993.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From the study, it can be concluded that gastrointestinal parasites are still pervasive in rural communities in the Volta Region, a phenomenon that could hamper the WHO goal of reducing intestinal parasite prevalence in vulnerable groups to < 2 % by 2030.

Five gastrointestinal parasites of zoonotic potential and public health concern were found prevalent in the *Cercopithecus mona* of the Tafi Atome monkey sanctuary. They were made of four helminths, *Strongyloides*, Hookworm**,** *Ascaris* and *Schistosoma* together and one protozoan**,** *Giardia*.

A total, six gastrointestinal made of four helminths *Strongyloides,* Hookworm, *Ascaris*, and *Trichuris* and, two protozoans *Giardia* and *Entamoeba* parasites were identified in the school children in Tafi and Avatime Dzokpe.

Four gastrointestinal parasites of public health importance made of *Strongyloides*, hookworm and *Ascaris* and *Giardia* were identified in both school children and cohabited *Cercopithecus mona* of the Tafi Atome monkey sanctuary. The *Cercopithecus mona* - human interaction in the sanctuary may be giving rise to the exposure to these gastrointestinal parasites.

Furthermore, the human community of Tafi Atome lives in harmony with the *Cercopithecus mona* of the sanctuary but generally lacks knowledge of gastrointestinal parasite transmission despite pervasive transmission risk factors which could facilitate pathogen host sharing between the cohabited species of human and *Cercopithecus mona* monkeys of the sanctuary in Tafi Atome.

6.2 Recommendations

The identification of gastrointestinal parasites in the human and monkey populations suggests a potential threat to public health. It is therefore suggested that government and other agencies institute regular deworming exercises in the catchments of the Tafi Atome Monkey sanctuary to ameliorate the effects of these parasites on the development of school children.

Further research is also recommended to establish any possible transmission and direction of gastrointestinal parasites between the human populations and the *Cercopithecus mona* of the Tafi Atome Monkey Sanctuary.

Furthermore, there should be public education on the prevalence of pathogens and behaviours that could minimise exposure to gastrointestinal parasites to prevent outbreak of zoonoses within the Tafi Atome Monkey Sanctuary.

REFERENCES

Adegbulu, Y. T. (2015). A Preliminary Survey of Gastrointestinal Parasites of Animals in Federal University of Agriculture Abeokuta Zoological Park, Ogun State, Nigeria. *Journal of Biology, Agriculture and Healthcare*, *5*(11), 195–202. http://www.iiste.org/Journals/index.php/JBAH/article/view/23253

Akpan, P., Abraham, J., & Ekwetiong, P. (2010). Survey of Gastro-Intestinal Parasites of Chimpanzees and Drill Monkeys in Drill Ranch, Calabar, Cross River State-Nigeria. *African Research Review*, *4*(3), 334–340. https://doi.org/10.4314/afrrev.v4i3.60196

Al-Tayib, O. A. (2019). *An Overview of the Most Significant Zoonotic Viral Pathogens Transmitted from Animal to Human in Saudi Arabia*. https://doi.org/10.3390/pathogens8010025

Alnomasy, S., Al-Awsi, G. R. L., Raziani, Y., Albalawi, A. E., Alanazi, A. D., Niazi, M., & Mahmoudvand, H. (2021). Systematic review on medicinal plants used for the treatment of Giardia infection. *Saudi Journal of Biological Sciences*, *28*(9), 5391–5402. https://doi.org/10.1016/j.sjbs.2021.05.069

Bansah-kagambega, P. F. (2019). *ANALYSIS OF POOR PATRONAGE OF TOURISM DESTINATIONS IN THE VOLTA REGION OF GHANA*. *VII*(12), 347–359.

Barbian, H. J., Decker, J. M., Bibollet-Ruche, F., Galimidi, R. P., West, A. P., Learn, G. H., Parrish, N. F., Iyer, S. S., Li, Y., Pace, C. S., Song, R., Huang, Y., Denny, T. N., Mouquet, H., Martin, L., Acharya, P., Zhang, B., Kwong, P. D., Mascola, J. R., … Hahn, B. H. (2015). Neutralization properties of simian immunodeficiency viruses infecting chimpanzees and gorillas. *MBio*, *6*(2), 1–22.

https://doi.org/10.1128/mBio.00296-15

Barbian, H. J., Jackson-Jewett, R., Brown, C. S., Bibollet-Ruche, F., Learn, G. H., Decker, T., Kreider, E. F., Li, Y., Denny, T. N., Sharp, P. M., Shaw, G. M., Lifson, J., Acosta, E. P., Saag, M. S., Bar, K. J., & Hahn, B. H. (2017). Effective treatment of SIVcpz-induced immunodeficiency in a captive western chimpanzee. *Retrovirology*, *14*(1), 1–9. https://doi.org/10.1186/s12977-017-0359-0

Barelli, C., Gonzalez-astudillo, V., Mundry, R., Rovero, F., Hauffe, H. C., & Gillespie, T. R. (2019). *Altitude and human disturbance are associated with helminth diversity in an endangered primate , Procolobus gordonorum*. 1–18.

Bauerfeind, R., Graevenitz, A. Von, Kimmig, P., Schiefer, H. G., Schwarz, T., Slenczka, W., & Zahner, H. (2016). Zoonoses: infectious diseases transmissible between animals and humans. In *Choice Reviews Online* (Vol. 53, Issue 10). https://doi.org/10.5860/choice.196232

Bobuafor, M. (2013). *Title : A grammar of Tafi* [Leiden University]. http://hdl.handle.net/1887/20916

Britannica, E. of E. (2021). Guenon. In *Encyclopaedia Britannica* (2015th, Marc ed., pp. 1–5). https://www.britannica.com/animal/guenon

Calvignac-Spencer, S., Leendertz, S. A. J., Gillespie, T. R., & Leendertz, F. H. (2012). Wild great apes as sentinels and sources of infectious disease. *Clinical Microbiology and Infection*, *18*(6), 521–527. https://doi.org/10.1111/j.1469-0691.2012.03816.x

Chakraborty, D., Reddy, M., Tiwari, S., & Umapathy, G. (2019). Land Use Change Increases

Wildlife Parasite Diversity in Anamalai Hills, Western Ghats, India. In *Scientific Reports* (Vol. 9, Issue 1). Springer US. https://doi.org/10.1038/s41598-019-48325-8

Cibot, M., Guillot, J., Lafosse, S., Bon, C., & Seguya, A. (2015). Nodular Worm Infections in Wild Non-human Primates and Humans Living in the Sebitoli Area (Kibale National Park , Uganda): Do High Spatial Proximity Favor Zoonotic Transmission ? *PLOS Neglected Tropical Diseases*, 1–17. https://doi.org/10.1371/journal.pntd.0004133

Couto, R. de M., & Brandespim, D. F. (2020). A review of the one health concept and its application as a tool for policy-makers. *International Journal of One Health*, *6*(1), 83–89. https://doi.org/10.14202/IJOH.2020.83-89

Davoust, B., Levasseur, A., & Mediannikov, O. (2018). Studies of nonhuman primates: key sources of data on zoonoses and microbiota. *New Microbes and New Infections*, *26*, S104–S108. https://doi.org/10.1016/j.nmni.2018.08.014

Dawet, A. (2013). Survey of Gastrointestinal Parasites of Non-Human Primates in Jos Zoological Garden. *Journal of Primatology*, *02*(01), 2–4. https://doi.org/10.4172/2167-6801.1000108

Delgado, A. (2018). *Giardiasis*. https://www.healthline.com/health/giardiasis#complications

Dessie, A., Gebrehiwot, T. G., Kiros, B., Wami, S. D., & Chercos, D. H. (2019). Intestinal parasitic infections and determinant factors among school-age children in Ethiopia: A cross-sectional study. *BMC Research Notes*, *12*(1), 1–6. https://doi.org/10.1186/s13104-019-4759-1

Devaux, C. A., Mediannikov, O., Medkour, H., & Raoult, D. (2019). Infectious Disease Risk

Across the Growing Human-Non Human Primate Interface: A Review of the Evidence. *Frontiers in Public Health*, *7*(November), 1–22. https://doi.org/10.3389/fpubh.2019.00305

Dra, N. (2015). *List of animals in the Kumasi Zoological Garden*. Clearing House Mechanism of Ghana. Convention on Biological Diversity. https://gh.chm-cbd.net/biodiversity/faunal-diversity-ghana/ex-situ-conservation/list-of-animals-in-the-kumasi-zoological-garden

Duval, L., Fourment, M., Nerrienet, E., Rousset, D., Sadeuh, S. A., Goodman, S. M., Andriaholinirina, N. V., Randrianarivelojosia, M., Paul, R. E., Robert, V., Ayala, F. J., & Ariey, F. (2010). African apes as reservoirs of Plasmodium falciparum and the origin and diversification of the Laverania subgenus. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(23), 10561–10566. https://doi.org/10.1073/pnas.1005435107

Egbetade, A., Akinkuotu, O., Jayeola, O., Niniola, A., Emmanuel, N., & Olugbogi, E. (2014). Gastrointestinal helminths of resident wildlife at the Federal University of Agriculture Zoological Park , Abeokuta. *Sokoto Journal of Veterinary Sciences*, *12*(3), 26–31.

Ekwem, D. E. (2016). *Endemic Zoonosis: A One Health Appraoch*. University of Glasgow.

Fatsuma, O., Abiodun, B. O., Egonmwan, G. B. O., Iriowen, R., & Lambert, J. E. (2020). Diet and Nutritional Profile of the Mona Monkey (Cercopithecus mona , Schreber , 1774) in Okomu National Park , Nigeria : Preliminary Study. *African Primates*, *14,* 1–10.

Fleagle, J. G., & Seiffert, E. R. (2016). The Phylogeny of Primates. In *Evolution of Nervous*

Systems: Second Edition (Second Edi, Vols. 3–4). Elsevier. https://doi.org/10.1016/B978-0-12-804042-3.00061-0

Forson, A. O., Arthur, I., Olu-Taiwo, M., Glover, K. K., Pappoe-Ashong, P. J., & Ayeh-Kumi, P. F. (2017). Intestinal parasitic infections and risk factors: A cross-sectional survey of some school children in a suburb in Accra, Ghana. *BMC Research Notes*, *10*(1), 4–8. https://doi.org/10.1186/s13104-017-2802-7

Frias, L., Stark, D. J., Salgado Lynn, M., Nathan, S., Goossens, B., Okamoto, M., & MacIntosh, A. J. J. (2019). Molecular characterization of nodule worm in a community of Bornean primates. *Ecology and Evolution*, *9*(7), 3937–3945. https://doi.org/10.1002/ece3.5022

Galvani, A. P., Bauch, C. T., Anand, M., Singer, B. H., & Levin, S. A. (2016). *Human – environment interactions in population and ecosystem health*. *113*(51), 14502–14506. https://doi.org/10.1073/pnas.1618138113

Gelaw, A., Anagaw, B., Nigussie, B., Silesh, B., Yirga, A., Alem, M., Endris, M., & Gelaw, B. (2013). Prevalence of intestinal parasitic infections and risk factors among schoolchildren at the University of Gondar Community School, Northwest Ethiopia: A cross-sectional study. *BMC Public Health*, *13*(1), 1–7. https://doi.org/10.1186/1471-2458-13-304

Gery, W. (2021). *Gastrointestinal Helminths of Captive Non-human Primates in Cameroon*. 1–8. https://doi.org/10.3923/ecologia.2020.30.37

Gery, W., Mbida, M., Abdoulmoum, M., & Lendzele, S. S. (2019). Gastrointestinal Helminths of Captive Non-human Primates in Cameroon. *Ecologia*, *10*(1), 30–37.

https://doi.org/10.3923/ecologia.2020.30.37

Gilbert, W. H., & Frost, S. (2009). Cercopithecidae. In *Homo erectus: Pleistocene Evidence from the Middle Awash, Ethiopia* (Issue January 2008). https://doi.org/10.1525/california/9780520251205.003.0005

Gillespie, T. R., Greiner, E. C., & Chapman, C. A. (2004). Gastrointestinal parasites of the guenons of western Uganda. *Journal of Parasitology*, *90*(6), 1356–1360. https://doi.org/10.1645/GE-311R

Gizaw, Z., Adane, T., Azanaw, J., Addisu, A., & Haile, D. (2018). Childhood intestinal parasitic infection and sanitation predictors in rural Dembiya, northwest Ethiopia. *Environmental Health and Preventive Medicine*, *23*(1), 1–10. https://doi.org/10.1186/s12199-018-0714-3

Goldberg, T. L. (2008). Commentary on "Pandemic human viruses cause decline of endangered great apes," by Köndgen et al., 2008, Current Biology 18: 260-4. *American Journal of Primatology*, *70*(8), 716–718. https://doi.org/10.1002/ajp.20562

Goodchild, M. F. (2007). Non-Human Primates, Retroviruses, and Zoonotic Infection Risks in the Human Population | Learn Science at Scitable. *GeoJournal*, *69*(4), 211–221. http://www.nature.com/scitable/knowledge/library/non-human-primates-retroviruses-and-zoonotic-infection-59119998

Goodwin, R. M. (2007). *Behavior and Ecology of the Mona Monkey in the Seasonally Dry Lama Forest, Republic of Bénin* [City University of New York (CUNY)]. https://academicworks.cuny.edu/cgi/viewcontent.cgi?article=5329&context=gc_etds

Hailu, G. G., & Ayele, E. T. (2021). Assessment of the prevalence of intestinal parasitic infections and associated habit and culture-related risk factors among primary schoolchildren in Debre Berhan town, Northeast Ethiopia. *BMC Public Health*, *21*(1), 1–12. https://doi.org/10.1186/s12889-020-10148-y

Kamani, J., Yidawi, J. P., Sada, A., Msheliza, E. G., & Turaki, U. A. (2020). Prevalence and morphotype diversity of Trichuris species and other soil-transmitted helminths in captive non-human primates in northern Nigeria. *Journal of Threatened Taxa*, *12*(10), 16239–16244. https://doi.org/10.11609/jott.4552.12.10.16239-16244

Kebede, T., Bech, N., Olivier, R., Erko, B., & Boissier, J. (2020). *Genetic evidence for the role of non-human primates as reservoir hosts for human schistosomiasis*. 1–20. https://doi.org/10.1371/journal.pntd.0008538

Keele, B. F., Heuverswyn, F. Van, Li, Y., Bailes, E., Takehisa, J., Santiago, M. L., Bibollet-ruche, F., Chen, Y., Wain, L. V, Loul, S., Ngole, E. M., Bienvenue, Y., Delaporte, E., John, F., Brookfield, Y., Sharp, P. M., Shaw, G. M., Peeters, M., & Beatrice, H. (2008). *NIH Public Access*. *313*(5786), 523–526.

Klaus, A., Zimmermann, E., Röper, K. M., Radespiel, U., Nathan, S., Goossens, B., & Strube, C. (2017). Co-infection patterns of intestinal parasites in arboreal primates (proboscis monkeys, Nasalis larvatus) in Borneo. *International Journal for Parasitology: Parasites and Wildlife*, *6*(3), 320–329. https://doi.org/10.1016/j.ijppaw.2017.09.005

Kurniawati, D. A., Suwanti, L. T., Lastuti, N. D. R., Kusdarto, S., Suprihati, E., Mufasirin, M., & Pratiwi, A. (2020). Zoonotic potential of gastrointestinal parasite in long-tailed

Macaque Macaca fascicularis at Baluran National Park, Situbondo, East Java, Indonesia. *Aceh Journal of Animal Science*, *5*(1), 47–56. https://doi.org/10.13170/ajas.5.1.15397

Larbi, J. A., Akyeampong, S., Abubakari, A., Offei Addo, S., Okoto, D., & Hanson, H. (2020). Zoonotic Gastrointestinal Parasites of Baboons (Papio anubis) in the Shai Hill Reserve in Ghana. *BioMed Research International*, *2020*(March), 0–6. https://doi.org/10.1155/2020/1083251

Liu, W., Li, Y., Learn, G. H., Rudicell, R. S., Robertson, J. D., Keele, B. F., Ndjango, J. N., Sanz, C. M., Morgan, D. B., Locatelli, S., Gonder, M. K., Kranzusch, P. J., Walsh, P. D., Mpoudi-ngole, E., Georgiev, A. V, Muller, M. N., Shaw, M., Peeters, M., Sharp, P. M., … Beatrice, H. (2010). Liu et al. 2010 Origin of human malaria prasite P. falciparum in gorillas. *Nature*, *467*(7314), 420–425. https://doi.org/10.1038/nature09442.Origin

Macfie, E. J., Travis, D. A., Whittier, C. A., Williamson, E. A., Cameron, C. K., Cranfield, M., Gaffikin, L., Kalema-zikusoka, G., Köndgen, S., & Leendertz, S. (2015). Best practice guidelines for health monitoring and disease control in great ape populations. In *Best practice guidelines for health monitoring and disease control in great ape populations* (Issue January 2016). https://doi.org/10.2305/iucn.ch.2015.ssc-op.56.en

Mackenzie, J. S., & Jeggo, M. (2019). The one health approach-why is it so important? *Tropical Medicine and Infectious Disease*, *4*(2), 5–8. https://doi.org/10.3390/tropicalmed4020088

Manser, M. M., Saez, A. C. S., & Chiodini, P. L. (2016). Faecal Parasitology: Concentration Methodology Needs to be Better Standardised. *PLoS Neglected Tropical Diseases*, *10*(4), 1–16. https://doi.org/10.1371/journal.pntd.0004579

Marcogliese, D. J. (2005). Parasites of the superorganism: Are they indicators of ecosystem health? *International Journal for Parasitology*, *35*(7), 705–716. https://doi.org/10.1016/j.ijpara.2005.01.015

Matsuda, Goodwin R Segniagbeto, G., Nobimè, G., & Imong, I. (2020). *Cercopithecus mona. The IUCN Red List of Threatened Species 2020*. https://www.iucnredlist.org/species/4222/17946672

Matz-Rensing, K.; Kaup, F. J. (2010). Tuberculosis in Nonhuman Primates -the disease. *German Primate Centre*, 1–9. http://www.dpz.eu/fileadmin/content/Infektionspathologie/Bilder/Dokumente/MAETZ-RENSING TB-the diseasse FORMAT COP_Korr.pdf

Mbaya, a. W., & Udendeye, U. J. (2011). Gastrointestinal parasites of captive and free-roaming primates NIGERIA.pdf. In *Pak J Biol Sci* (Vol. 14, Issue 13, pp. 709–713). http://scialert.net/qredirect.php?doi=pjbs.2011.709.714&linkid=pdf

Mbaya, A., Shingu, P., & Luka, J. (2011). A Retrospective Study on The Prevalence of *Fasciola* Infection in Sheep and Goats at Slaughter and Associated Economic Losses from Condemnation of Infected Liver in Maiduguri Abattoir, Nigeria. *Nigerian Veterinary Journal*, *31*(3). https://doi.org/10.4314/nvj.v31i3.68970

Medkour, H., Amona, I., Laidoudi, Y., Davoust, B., Bitam, I., Levasseur, A., Akiana, J., Diatta, G., Pacheco, L., Gorsane, S., Sokhna, C., Hernandez-Aguilar, R. A., Barciela, A., Fenollar, F., Raoult, D., & Mediannikov, O. (2020). Parasitic infections in African humans and non-human primates. *Pathogens*, *9*(7), 1–20. https://doi.org/10.3390/pathogens9070561

Mensah, C. (2012). Residents' perception of socio-economic impacts of tourism in Tafi Atome, Ghana. *Asian Social Science*, *8*(15), 274–287. https://doi.org/10.5539/ass.v8n15p274

Mertz, G. J. (2016). Zoonoses: Infectious Diseases Transmissible From Animals to Humans, Fourth Edition. *Clinical Infectious Diseases*, *63*(1), 148.2-149. https://doi.org/10.1093/cid/ciw234

Metzger, S. (2015). *Gastrointestinal helminthic parasites of habituated wild chimpanzees (Pan troglodytes verus) in the Taï NP, Côte d'Ivoire* [Freien Universität Berlin]. https://doi.org/10.06.2015

Mor, S. M., Wiethoelter, A. K., Massey, P., & Eastwood, K. (2019). One Health surveillance: monitoring health risks at the human–animal–environment interface. *One Planet, One Health*, 179–218. http://www.jstor.org/stable/j.ctvggx2kn.13

Mossoun, A., Calvignac-Spencer, S., Anoh, A. E., Pauly, M. S., Driscoll, D. A., Michel, A. O., Nazaire, L. G., Pfister, S., Sabwe, P., Thiesen, U., Vogler, B. R., Wiersma, L., Muyembe-Tamfum, J.-J., Karhemere, S., Akoua-Koffi, C., Couacy-Hymann, E., Fruth, B., Wittig, R. M., Leendertz, F. H., & Schubert, G. (2017). Bushmeat Hunting and Zoonotic Transmission of Simian T-Lymphotropic Virus 1 in Tropical West and Central Africa. *Journal of Virology*, *91*(10), 1–16. https://doi.org/10.1128/jvi.02479-16

Myers, P. (2000). *Cercopithecidae Old World monkeys*. https://animaldiversity.org/accounts/Cercopithecidae/

Myers, P. (2008). Cercopithecidae (Old World monkeys). In *Encyclopedia of Genetics, Genomics, Proteomics and Informatics* (pp. 315–315). https://doi.org/10.1007/978-1-

4020-6754-9_2701

Napier, J. R., & Groves, C. P. (2021). Primate. In *Encyclopedia Britannica* (31st March). https://www.britannica.com/animal/primate-mammal.

Narat, V., Alcayna-Stevens, L., Rupp, S., & Giles-Vernick, T. (2017). Rethinking Human–Nonhuman Primate Contact and Pathogenic Disease Spillover. *EcoHealth*, *14*(4), 840–850. https://doi.org/10.1007/s10393-017-1283-4

Nijboer, J., & Clauss, M. (2006). The Digestive Physiology of Colobine Primates. *Fibre Intake and Faeces Quality in Leaf-Eating Primates*, *May*, 9–28. https://doi.org/10.5167/uzh-3520

Obanda, V., Maingi, N., Muchemi, G., Ng'Ang'A, C. J., Angelone, S., & Archie, E. A. (2019). Infection dynamics of gastrointestinal helminths in sympatric non-human primates, livestock and wild ruminants in Kenya. *PLoS ONE*, *14*(6). https://doi.org/10.1371/journal.pone.0217929

Olivier, K. J., Price, K. D., Hutto, D. L., Lerche, N. W., Mansfield, K. G., Simmons, J. H., Taylor, K., Myers, L. P., Ouyang, Y., & Evans, E. W. (2010). Naturally occurring infections in non-human primates (NHP) and immunotoxicity implications: Discussion sessions. *Journal of Immunotoxicology*, *7*(2), 138–146. https://doi.org/10.3109/1547691X.2010.480948

Ore, A., Asaolu, S., Ph, D., Ofoezie, O. E., Ph, D., Onyeji, O. C., & Ph, D. (2021). *Ascaris lumbricoides (Ascariasis)*. Infectious Disease and Antimicrobial Agents. www.antimicrobe.org/b17.asp

Parrott, T. (2020). Bacterial diseases of nonhuman primates. *The Comparative Pathology of Zoo Animals*, 197–217.

Peiris, J. S. M. (2009). *One world, one health* (Vol. 184, Issue 8). https://doi.org/10.1016/j.cell.2021.03.021

Quraishi, A. M., . M. K., . T. C., Varatharajalu, R., Kakuturu, R., The University of Melbourne, Title, I., Review, L., April, D. U. E., Review, L., Trinity Washington University, Fong, W.-K., Matsumoto, H., Ho, C.-S., Ng, B. Y. S., Perron, P., Johansen, S. S., Jlrselius, K., Johansen, S. S., … Gonzalez, J. P. (2017). Co-infection patterns of intestinal parasites in arboreal primates (proboscis monkeys, Nasalis larvatus) in Borneo. *International Journal for Parasitology: Parasites and Wildlife*, *6*(1), 320–329. https://doi.org/10.1016/j.ijppaw.2017.09.005

Squire, S. A., Yang, R., Robertson, I., Ayi, I., Squire, D. S., & Ryan, U. (2018). Gastrointestinal helminths in farmers and their ruminant livestock from the Coastal Savannah zone of Ghana. *Parasitology Research*, *117*(10), 3183–3194. https://doi.org/10.1007/s00436-018-6017-1

Starr, E. (2018). *Mona Monkey*. New England Primate Conservancy. https://www.neprimateconservancy.org/mona-monkey.html

Stephen, Af. (2015). *List of Animals at Accra Zoo, Ghana*. Clearing House Mechanism of Ghana. Convention on Biological Diversity. https://gh.chm-cbd.net/biodiversity/faunal-diversity-ghana/ex-situ-conservation/list-of-animals-at-accra-zoo-in-ex-situ-conservation-in-ghana

Teklemariam, D., Legesse, M., Degarege, A., Liang, S., & Erko, B. (2018). Schistosoma mansoni and other intestinal parasitic infections in schoolchildren and vervet monkeys in Lake Ziway area, Ethiopia. *BMC Research Notes*, *11*(1), 1–6. https://doi.org/10.1186/s13104-018-3248-2

Teshome, H. (2019). Review on Principles of Zoonoses Prevention, Control and Eradication. *American Journal of Biomedical Science & Research*, *3*(2), 188–197. https://doi.org/10.34297/ajbsr.2019.03.000660

Travis, D. A., Chapman, D. W., Craft, M. E., Deen, J., Farnham, M. W., Garcia, C., Hueston, W. D., Kock, R., Mahero, M., Mugisha, L., Nzietchueng, S., Nutter, F. B., Olson, D., Pekol, A., Pelican, K. M., Robertson, C., & Rwego, I. B. (2014). One Health: Lessons Learned from East Africa. *Microbiology Spectrum*, *2*(1), 1–13. https://doi.org/10.1128/microbiolspec.oh-0017-2012

Uloko, J. I., & Lameed, G. A. (2019). *Preliminary Study of the Population Density of Mona Monkeys (Cercopithecus mona) in Omo Forest Reserve*. 413–425. https://doi.org/10.4236/oje.2019.910027

United Plant Savers. (2018). *Tafi Atome Monkey Sanctuary and Cultural Village*. https://unitedplantsavers.org/tafi-atome-monkey-sanctuary-and-cultural-village/

Van Lieshout, L., De Gruijter, J. M., Adu-Nsiah, M., Haizel, M., Verweij, J. J., Brienen, E. A. T., Gasser, R. B., & Polderman, A. M. (2005). Oesophagostomum bifurcum in non-human primates is not a potential reservoir for human infection in Ghana. *Tropical Medicine and International Health*, *10*(12), 1315–1320. https://doi.org/10.1111/j.1365-3156.2005.01527.x

White, R. J., & Razgour, O. (2020). *Emerging zoonotic diseases originating in mammals : a* *systematic review of effects of anthropogenic land-use change*. *50*, 336–352. https://doi.org/10.1111/mam.12201

World Health Organization. (2020). *Soil-transmitted helminth infections*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections

World Organisation For Animal Health (OIE). (2013). The OIE PVS Pathway and the WHO IHR Framework: opportunities for joint activities at the humanitarian interface. *OIE Bulletin*, *1*, 2–5. http://www.oie.int/fileadmin/Home/eng/Publications_&_Documentation/docs/pdf/bulletin/Bull_2013-1-ENG.pdf%5Cnhttp://www.oie.int/doc/ged/D12675.PDF

APPENDICES

Appendix I

Structured Questionnaire for Adults in Tafi Atome

I am Israel Kwame Amu and I am conducting a research on the gastrointestinal parasites of public health importance in *mona* monkeys of Tafi Atome Monkey Sanctuary in the Afadjato South District of Ghana. I seek to assess the risk factors that may facilitate transmission of gastrointestinal parasites between humans and monkeys. I also seek to evaluate the beliefs, knowledge, attitudes and perceptions of people of the monkeys of the sanctuary. The assessment will require sincere and personal views from adults on their attitudes, beliefs, knowledge and perceptions of the monkeys.

Personal information

#	Questions	Code	Remark
01	Gender of respondent	01=Male 02=Female	
02	Age of respondent	01=18-25 02=26-35 03=36-45 04=46-55 05=56-65 06=66 and above	
03	Level of education of respondent	01=No formal education 02=Basic 03=Secondary 04=Tertiary	
04	Occupation of respondent	01= Farming 02= Trading 03= Formal sector 04= Others	

Respondent's Knowledge of *mona* monkeys (KM)

#	Questions	Code	Remark
01	What do the monkeys eat?	01=Banana 02=Insects 03=Cassava 04=Chicken 05=Fruits 06=Others	
02	How will you describe the trend in number of monkeys in the forest?	01=Increasing 02=Stable 03=Decreasing 04=No idea	
	Do you know of any other importance derived from the monkeys apart from tourism?	01=Yes 02=No 03=No idea	
04	Do the monkeys fall sick?	01=Yes 02=No 03=No idea	
05	If Yes, how do you know a mona monkey is sick?	01 = Pass watery stool 02 = Looks dull 03 = Refuse to eat bananas	
06	What do you think happen to naturally dead monkeys	01=They are eaten by the troop 02=They are buried by the troops 03=No idea	

Peoples' attitudes and perceptions of the *mona* monkeys in the sanctuary (APM)

#	Questions	Code	Remark
01	Do you kill *mona* monkey?	01=Yes 02=No 03=No idea	
02	If yes, why do you kill mona monkey?	01=Meat 02=Sell for money 03= Other (state) ………………………………	
03	Do you know if people capture *mona* monkeys?	01=Yes 02=No 03=No idea	
04	If yes, what are captured monkeys used for?	01= As pet 02= For sale 03= No idea	
05	Will you eat monkey meat if given chance?	01= Yes 02= No 03= No idea	
06	Should the monkeys be relocated by the wildlife society?	01= Yes 02= No 03= No idea	
07	If yes, give one reason?	01= Pollute my stored water 02= Are evil 03= Are nuisance 04= Bring bad luck 05= Steal eggs and food items	

08	If no, give one reason?	01= Bring good luck 02= Protect the community 03= Employment creation 04= Tourism	
09	Should the monkeys be prevented from coming to your house?	01= Yes 02= No 03= No idea	
10	If yes, give one reason?	01= They are nuisance 02= They scare me 03= They litter my house	

Knowledge of Gastrointestinal Parasites Transmission and Risk Factors (PTRF)

#	Questions	Code	Remark
01	Do some animals carry diseases to human?	01=Yes 02=No 03=No idea	
02	Do mona monkeys have intestinal parasites	01=Yes 02=No 03=No idea	
03	Can *mona* monkeys transmit intestinal parasites to humans	01=Yes 02=No 03=No idea	
04	How can humans get parasites from wild animals like *mona* monkeys?	01=Biting/scratching of body 02=Eating food and taking water contaminated with faeces 03= contaminated soil 04 = contaminated clothes 05= No idea	
05	Can humans transmit intestinal parasites to *mona* monkeys	01=Yes 02=No 03=No idea	
06	Do some humans carry intestinal parasites?	01=Yes 02=No 03=No idea	
07	Have you ever been diagnosed of gastrointestinal parasite infection?	01=Yes 02=No 03=No idea	
08	Do mona monkeys come to your house	01=Yes 02=No 03=No idea	
09	Do you find monkey faeces in your house	01=Yes 02=No 03=No idea	
10	If yes, how often?	01=Every day 02=Every three days 03=Once a week 04=Others	

11	Have you ever seen a crawling child pick monkey faeces	01=Yes 02=No 03=No idea	
12	Do adults walk bare footed at home and in town	01=Yes 02=No 03=No idea	
13	Do children play bare footed	01=Yes 02=No 03=No idea	
14	Do you drink untreated water from Ahavor streams?	01=Yes 02=No 03=No idea	
15	Do you drink untreated water from Didi?	01=Yes 02=No 03=No idea	

Appendix II

Structured Questionnaire for School children

Introduction

I am Israel Kwame Amu and I am conducting a research on **Gastrointestinal Parasites of public health importance in *Cercopithecus mona* of Tafi Atome monkey sanctuary in the Afadjato South District of Ghana.** The assessment will require sincere and personal views from children of school - going age on their knowledge of gastrointestinal parasites and practices that predisposes them to risk of infection of these intestinal parasites

Personal information

#	**Questions**	**Code**	**Remark**
i	Identification Number		
ii	Class		
iii	Age group; ,	**01**= 6 - 8, **02**= 9 -11, **03**= 12 - 14, **04**= 15-17	
iv	Sex.	**01**= Male **02** = Female	

Knowledge

1	Have you ever been diagnosed of intestinal parasites	**01 = Yes** **02= No**	
2	Do you take dewormer (anthelminthic drug)?	**01 = Yes** **02= No**	
3	When was the last time you took dewormer (anthelminthic drug)?	**01=** 1-3 months **02=** 4- 6 months **03=** 7- 9 months **04=** 10-12 months **05=** More than 12 months	

Practices

4	Do you wash hands before you eat food at home or in school	**01**= Yes **02**= No **03**= Sometimes	
5	Do you wash hands **with soap before** you eat food at home or in school	**01**= Yes **02**= No **03**= Sometimes	
6	Do you wash your hands after visiting the toilet	**01**= Yes **02**= No **03**= Sometimes	
7	Do you have toilet in your house	**01**= Yes **02**= No	
8	Where do you go to toilet?	**01**= Public toilet **02**= Bush **03**= At home 04= Home and Public toilet 05= Home and Bush 06= Bush and Public toilet	
9	How often do you wear shoes at home or to school	**01**= Always **02**= Sometimes **03**= Never	
10	Do you cut your nails regularly?	**01**= Yes **02**= No	

11	What do you use to cut your nails?	**01**= I bite my nails **02**= I use blade / knife	

APPENDIX III

Respondents Knowledge of Gastrointestinal Parasites Transmission and Risk Factors (PTRF)

Question	Answer	Frequency	Percent
Do some animals carry diseases to human?	Yes	114	68.3
	No	13	7.8
	No idea	40	24.0
Do mona monkeys have intestinal parasites	Yes	53	31.7
	No	34	20.4
	No idea	80	47.9
Can *mona* monkeys transmit intestinal parasites to humans	Yes	40	24.0
	No	34	20.4
	No idea	93	55.7
How can humans get parasites from wild animals like *mona* monkeys?	Biting/scratching of body	59	35.3
	Eating food and taking water contaminated with faeces	26	15.6
	Contaminated soil	14	8.4
	No idea	68	40.7
Can humans transmit intestinal parasites to *mona* monkeys	Yes	17	10.2
	No	42	25.1
	No idea	108	64.7
Do some humans carry intestinal parasites?	Yes	113	67.7
	No	12	7.2
	No idea	42	25.1
Have you ever been diagnosed of gastrointestinal parasite infection?	Yes	46	27.5
	No	93	55.7
	No idea	28	16.8
Do mona monkeys come to your house	Yes	159	95.2
	No	6	3.6
	No Idea	2	1.2

Do you find monkey faeces in your house	Yes	31	18.6
	No	133	79.6
	No idea	3	1.8
If yes, how often?	Answered No	133	79.6
	Every day	21	12.6
	Every Three Days	6	3.6
	Once a Week	7	4.2
Have you ever seen a crawling child pick monkey faeces	Yes	11	6.6
	No	148	88.6
	No idea	8	4.8
Do adults walk bare footed at home and in town	Yes	107	64.1
	No	52	31.1
	No idea	8	4.8
Do children play bare footed	Yes	162	97.0
	No	5	3.0
Do you drink untreated water from Ahavor streams?	Yes	158	94.6
	No	9	5.4
Do you drink untreated water from Didi?	Yes	71	42.5
	No	94	56.3
	No idea	2	1.2

APPENDIX IV

PARENT / GUARDIAN ASSENT FORM

Project Title: Gastrointestinal Parasites of Public Health Importance in *Cercopithecus mona* of Tafi Atome Monkey Sanctuary in the Afadjato South District of Ghana.

Investigator: Mr. Israel Kwame Amu

Supervisors: Dr. Bethel Kwansa - Bentum

Dr. Isaac Frimpong Aboagye

We are doing a research study about intestinal worms that cause disease in humans and monkeys of the Tafi Atome monkey sanctuary. A research study allows us to learn more about people and the environment to improve human and animal lives in the community. If you decide that your child should be part of this study, they will be asked to bring samples of their stool to school.

There are some things about this study you should know. The study will not cause any harm or pain to your child. The stool sample will be examined for parasite eggs. The remaining stool will be washed away after studying them according to government rules.

The research will provide useful information on the intestinal parasites of the monkeys that can affect humans. It will also indicate the human activities that make it easy for these worms to move between monkeys and humans to prevent their effects in the community.

When we are finished with this study we will write a report about what was learned. This report will not include your child's name or that you were in the study.

Your child should not be in this study if you do not want to.

If you decide your child should be in this study, please sign your name.

I,________________________________ want my child,______________________, to be in this research study.

___________________________________ ____/ ____ / 2021

(Sign your name here) (Date)

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