MAKERERE UNIVERSITY

PREVALENCE OF TAPEWORM PARASITES IN MOUNTAIN GORILLAS (*GORILLA BERINGEI BERINGEI*) AND OLIVE BABOONS (*PAPIO ANUBIS*) IN BWINDI-MGHAHINGA CONSERVATION AREA

BY

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DECLARATION AND APPROVAL

I, **Amuge Gertrude Esther**, declare that this research project report is original and has never been submitted to any academic institution of higher learning for any academic award. Reference citations are included where work of other people has been used.

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DEDICATION

I dedicate this book to my dear mother Ajanga Joyce Icumar, my late father Ajanga Max, my brothers Okiror Felix, Ajanga Alexander Max and Olupot Ivan, my sister Asio Cynthia and my uncle Ochan Joseph for their financial, emotional and moral support towards achievement of my university education. To the Gorilla doctors for their financial and emotional support towards the completion of this project.

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LIST OF ABBREVIATIONS

BMCA	Bwindi_Mgahinga Conservation Area
BINP	Bwindi Impenetrable National Park
MGNP	Mgahinga Gorilla National Park
EPG	Eggs Per Gram
DNA	Deoxyribonucleic acid
NHPs	Non-Human Primates
GIT	Gastrointestinal tract
CITES	Convention of International Trade in Endangered species
IUCN	International Union for Conservation of Nature
DRC	Democratic Republic of Congo
UWA	Uganda Wildlife Authority
WHO	World Health Organisation
WWF	World wildlife fund
ADF	adult female
SB	silver back
JUV	juvenile
SA	subadult
INF	infant
BB	black back
Cm	centimeter
g	gram
STATA	Statistics and Data

ABSTRACT

Cestode are common gastrointestinal parasites of non-human primates and may influence wildlife health and conservation. Cestodes are gastrointestinal parasites that infect a wide range of vertebrate hosts, including rodents, ungulates, primates, elephants, and hyraxes. Although the epidemiology of cestode infections has been well documented in some host species, information on free-ranging primates remains limited. This cross-sectional study was conducted in the Bwindi–Mgahinga Conservation Area (BMCA), Uganda, between November and December 2025 to determine the prevalence, diversity and egg burden of tapeworm infestations among mountain gorillas (Gorilla beringei beringei) and olive baboons (Papio anubis). A total of 273 fecal samples were collected, comprising 245 samples from mountain gorillas obtained from fresh night nests and 28 samples from olive baboons collected during daytime by following troop trails. Tapeworm eggs per gram (EPG) were quantified using the Mini-FLOTAC® technique, and cestode eggs were identified morphologically to the genus level. Mountain gorillas exhibited a markedly higher prevalence of tapeworm infection than olive baboons. Overall prevalence was 94.1% (222/236) in BINP and 100% (9/9) in MGNP for gorillas, compared with 25.0% (7/28) in olive baboons. Within BINP, gorilla prevalence ranged from 87.0% in Buhoma to 98.0% in Rushaga. Adults showed the highest prevalence (95.7%), while females had slightly higher prevalence (97.0%) than males (93.6%). Three tapeworm genera—Anoplocephala, Moniezia, and Bertiella—were identified in mountain gorillas, whereas only Bertiella species were detected in olive baboons. Mean tapeworm egg counts were significantly higher in gorillas from MGNP than BINP (319.20 ± 39.51 vs. 162.17 ± 11.80 EPG; $p = 0.011$). Within BINP, gorillas had significantly higher mean EPG than olive baboons (162.17 ± 11.80 vs. 4.29 ± 2.91; $p < 0.001$). Tapeworm egg burdens also differed significantly among gorilla sectors, with Rushaga recording the highest median EPG ($p < 0.0001$), while differences by age and sex were not statistically significant. These findings indicate a higher occurrence of tapeworm infections in mountain gorillas than in olive baboons and provide information on the distribution of cestode genera in sympatric primate populations within BMCA. However, because parasite identification was based on morphological characteristics of eggs, future studies incorporating molecular techniques are recommended to enable species-level identification and improve understanding of cestode diversity and transmission dynamics.

CHAPTER ONE: INTRODUCTION

1.1 Background

Mountain gorillas (*Gorilla beringei beringei*) and other primates such as chimpanzees (*Pan troglodytes*) and bonobo (*Pan paniscus*) are regarded as the closest living relatives to humans sharing a remarkably high percentage of their DNA, with estimates ranging from 98-99% similarity (Prüfer et al., 2012; Ventura et al., 2011). The mountain gorilla (*Gorilla beringei beringei*) subspecies is currently classified as an endangered by the International Union for Conservation of Nature (IUCN), (Hickey et al., 2018), warranting several many measures as possible to safe guard their health and survival. Mountain gorillas are naturally found in two habitats of Bwindi Impenetrable National Park (Bwindi) and Virunga massif shared amongst three countries; Uganda, Rwanda and Democratic Republic of Congo (Hickey et al., 2018). In Uganda mountain gorillas are naturally found in two habitats of Bwindi Mgahinga Conservation Area (BMCA) that represents Bwindi Impenetrable National Park (BINP) and Mgahinga Gorilla National Park (MGNP).

BMCA is a natural afro-montane forest located in southwestern Uganda, 32,092 hectares in size, is famous for vast biodiversity in flora and fauna. For example, it is home to almost half of the world's remaining mountain gorilla population (McNeilage et al., 2006). Mountain gorillas share this habitat with other primates like olive baboons, chimpanzees, l'hoest monkeys, blue monkeys and black and white colobus monkeys among others. In this Park, the constant interaction between gorillas and the highly sedentary (migratory) olive baboons (*Papio anubis*) has been reported to pose a conservation and health challenge, particularly regarding the transmission of several parasites and infectious organisms (Hope et al., 2004). This could consequently lead to gorilla and mortality.

A number of these primates, chimpanzees, blue monkeys, colobus monkeys, olive baboons, and humans, share a sympatric relationship with mountain gorillas. The propensity for zoonotic and anthrozoonotic disease transmission between these primates is overwhelming (Larbi et al., 2020). Baboons forage from both inside and outside the park, therefore can be a source of pathogens to mountain gorillas, which also increases the risk of ill health as they are in continuous contact with the olive baboons (Larbi et al., 2020). Due to their interactions with humans (through crop raiding and scavenging on human refuse for food), in addition to their large populations, transmission of parasites from baboons to humans has long been identified as a particular zoonotic threat(Ebbert et al., 2015).

In Bwindi, olive baboons have been documented to harbor a lot of cestodes such as *Hymenolepis* sp, along with multiple other intestinal parasites (Hope et al., 2004). In the recent years, mountain gorillas have been diagnosed with a high prevalence of helminthes, such as Strongyloides spp, Probstmayria spp, and *Probstmayria gorillae,* strongyles, other nematodes and tapeworms (Červená et al., 2024; Petrželková et al., 2022; Klara J. Petrželková et al., 2021; Sirima, Bizet, Hamou, Červená, Lemarcis, Esteban, Peeters, Mpoudi Ngole, et al., 2021),.

Tapeworms including *Echinococcus granulosus, Echinococcus multilocularis, Taenia solium, Taenia multiceps, Taenia serialis (Chanove et al., 2019).* However, the predominant tapeworm species, *Anoplocephala gorillae,* has been detected in the night nest samples and individually known gorillas in the Virunga (Červená et al., 2024).

Because of the dynamic nature and interaction of Bwindi's primate population, it is important to do continuous monitoring of the primate health and disease transmission (Lonsdorf et al., 2022). There's a gap in continuous monitoring and surveillance of the transmission of internal parasites such as zoonotic tapeworms and other helminths. This requires more research to inform future mountain gorilla health and conservation efforts. This study will establish the relationship between the prevalence of tapeworms (cestodes) in mountain gorillas and baboons.

1.2 Problem statement

The current status of the predominant gorilla tapeworm (*Anoplocephala gorillae*) recently identified in the gorillas of the Virunga population (Červená et al., 2024) remains uncertain in BINP. Additionally, no recent literature exists on the prevalence of tapeworm infestation in the olive baboon, a common and adaptable primate that frequently traverses human and gorilla habitats and may serve as a transmission host for these helminths. The interaction among olive baboons, habituated mountain gorillas, and humans within the Bwindi landscape creates a conducive environment for the transmission of several zoonotic helminths. This in turn increases the risk of worm burden within the endangered mountain gorilla (Drewe et al., 2012).

1.3 Objectives

1.3.1 General objective

To compare the prevalence of tapeworms (cestodes) in olive baboons and mountain gorillas in BMCA.

1.3.2 Specific objectives

1. To determine the prevalence of fecal tapeworms in habituated mountain gorillas and olive baboons in BMCA.
2. To determine the diversity of tapeworm species that affect both mountain gorillas and olive baboons in BMCA.
3. To determine the parasite load of faecal tapeworms in habituated mountain gorillas and baboons in BMCA.

1.4 Research questions

1. What is the relationship between fecal tapeworms found in mountain gorillas and olive baboons in BMCA?
2. What is the parasite load of faecal tapeworms in habituated mountain gorillas and baboons in BMCA?

1.5 Study justification

Although tapeworms of the genus Taenia are globally distributed and inflict enormous socioeconomic costs on their human hosts, little is known about taenid tapeworm effects on wildlife (Schneider-Crease et al., 2017). Previous studies on baboons and mountain gorillas have determined several shared endoparasites, for example, cryptosporidium, Trichuris, and strongyloides (Hope et al., 2004) but there are few or no reports on tapeworms in the two primate species.

The study will therefore provide more information on the tapeworm species affecting these species in the study area as well as provide insights on treatment. It will also provide data for future research and continuous monitoring of the trends in the endangered mountain gorillas.

1.6 Study significance

Habituation of mountain gorillas for wildlife tourism and ecological research has increased interactions among wild animals, humans, and livestock at the human-livestock-wildlife interface. This study will therefore;

1. Provide the first recent direct comparative data on the prevalence of tapeworms in olive baboons and mountain gorillas.
2. Contribute information on species-specific parasite ecology and parasite implication for wildlife conservation and One Health.
3. Contribute information on cross-species transmission and zoonotic potential of tapeworms (cestodes) at the human-livestock-wildlife interface.

1.7 Scope of study

This study covered the prevalence and morphological identification of tapeworm (cestodes) in the family Anoplocephalidae isolated from mountain gorillas and olive baboons at BMCA, Uganda. It was a cross-sectional study, seeking to understand parasitic dynamics at the human-wildlife interface, and it was carried out in the months of November and December 2025 with relevant institutional approval.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview

Mountain gorillas (Gorilla beringei beringei) are one of the world's endangered great apes, with more than half of the global population occurring in BINP. This makes BINP a critical habitat for mountain gorilla conservation. Although conservation efforts seem to have contributed to the gorilla population growth, natural threats such as infectious diseases remain key determinants of their reduced survival rates (Robbins et al., 2011). For instance, gastro-intestinal helminths, including tapeworms (cestode), can adversely affect the health of mountain gorillas by causing chronic physiologic stress, reducing host fitness, impairing nutrient absorption, compromising immune function, and predisposing the gorillas to secondary infections. These effects are usually subclinical in healthy adults, but can become clinically significant and more pronounced in the young, elderly and immunocompromised individuals (Ryan & Walsh, 2011).

On the other hand, within the mountain gorilla landscape in BINP is an ever-increasing population of olive baboons (*Papio anubis*). The presence of these vermin animals is a significant risk factor in the transmission of many parasitic diseases including helminthiasis (Larbi et al., 2021).

Tapeworms are helminth of veterinary and public health importance that can cause significant weight loss, poor body condition, intestinal irritation, and reduced reproductive performance in animals. Although there are many studies that have documented gastrointestinal parasites in non-human primates (NHPs), most have focused on protozoa and nematodes. There is comparatively scarce information on the occurrence and prevalence of cestode infestation in free-ranging and habituated NHPs (Esteban-Sánchez et al., 2024). This lack of epidemiological information limits understanding of the burden of tapeworm infections and their potential impact on gorilla health and conservation.

A comparative investigation of tapeworm prevalence in mountain gorillas and olive baboons in BMCA is therefore timely and important. Such a study would generate epidemiological data on cestode infections in two sympatric primate species, identify potential differences in parasite burden associated with ecology and behavior, and provide insights into possible cross-species transmission pathways. The findings would contribute to wildlife disease surveillance, support evidence-based conservation management, and strengthen the implementation of the One Health approach by addressing the interconnected health of wildlife, humans, livestock, and the environment in and around Bwindi Impenetrable National Park.

2.2 Conservation status

The mountain gorillas are placed in Appendix 1 by the Convention of International Trade of Endangered Species (CITES) and are classified as ‘endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2023).

This is based on the fact that gorillas face a very high risk of extinction in the wild in the near future if current threats do not subside. The mountain gorilla lives in two isolated regions the BINP, in Uganda and the Virunga Volcanoes Conservation Range bounded by Uganda, Rwanda and the DRC (Figure 1).

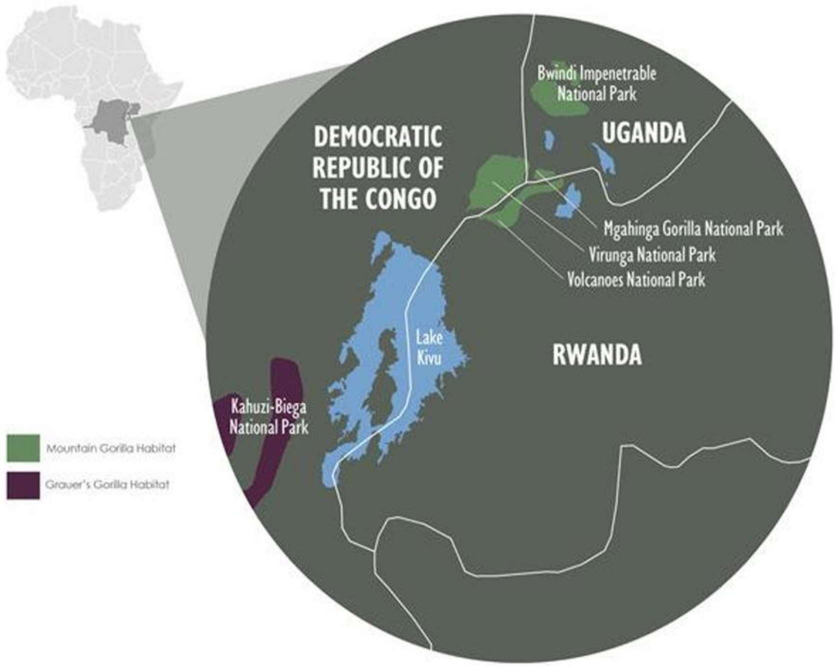


Figure 1: Location of the entire global population of mountain gorillas (Gorilla beringei beringei) in Uganda, Rwanda, and the DRC. *(Gilardi et al. 2022)*

Olive baboons in contrast, are classified as Least Concern on the IUCN Red List owing to their wide distribution throughout sub-Saharan Africa, large population size, and remarkable ecological adaptability (Kiffner et al., 2022; Kingdon et al., 2008). Olive baboons occupy diverse habitats, including tropical forests, woodland, savannah, riverine forests, and agricultural landscapes. Although they are not considered globally threatened, local populations are affected by habitat fragmentation, persecution arising from human–wildlife conflict, hunting, and disease. Their opportunistic feeding behavior and frequent movement between protected forests and surrounding human settlements increase contact with humans, livestock, and other wildlife species, including mountain gorillas. Consequently, olive baboons are considered potential reservoir hosts and useful sentinel species for monitoring environmentally transmitted parasites and zoonotic pathogens (Kingdon et al., 2008; Nabuule et al., 2024).

2.3 Major Wildlife conservation threats

Mountain gorillas like other wildlife are threatened by a number of anthropogenic and natural disasters. Human poverty and high human population growth rates affect the environment sustainability including survival of gorillas (Kalema-Zikusoka et al., 2018). The biggest danger to the existence of mountain gorillas is posed by the destruction and alteration of their habitat by human activities. Habitat loss due to agriculture or modification, through logging, collecting fuel wood, and nontimber forest product collection, as well as grazing domestic animals all contribute to degradation of the gorilla habitat, which is an issue that will only get worse as the human population in Africa continues to rise (Plumptre et al. 2003). It was predicted that more than 90% of African great ape habitats will experience moderate to high impacts by 2030 as a result of anthropogenic factors (Consolee et al., 2024). Only about 20% of gorillas live inside protected areas where in theory they are safe from habitat modification by encroaching humans. The remaining 80% are severely threatened by human-induced habitat modification (Plumptre et al. 2003). As the number of humans living around mountain gorilla habitats grows exponentially, so does their need for land to cultivate, which is why the forest in which the gorillas live are being reduced to virtual islands in the midst of expanding human settlements. (WWF 2022b).

Not only are mountain gorillas threatened by loss of habitat due to human encroachment, they have also become victims of human violence. As civil war rages in Africa, efforts to conserve mountain gorilla populations have been curtailed. Mountain gorillas have also been killed or captured by poachers. Their body parts are sold to collectors, and baby gorillas are sold illegally as pets, research subjects, or private zoo animals (WWF 2022a).

Other threats to gorilla conservation are caused by natural circumstances such as floods, heavy rains with lightning and hailstones, and diseases. These natural occurrences can also be precipitated by human activities. For instance, with human encroachment into gorilla habitats, disease spread becomes a common scenario, and morbidity and mortality events have been reported (Kalema-Zikusoka et al., 2018). Gorillas are highly susceptible to human diseases and where they are immunologically naïve, the influx of poachers, soldiers, local communities, and domestic animals facilitate the spread of pathogens in small communities (Plumptre et al. 2003).

2.4 Diseases of non-human primates

Gorillas are susceptible to human diseases and with small populations of gorillas any infectious disease would devastate the population (Plumptre et al., 2003). Habituation of gorillas for ecotourism could cause increased disease transmission between human and the wildlife they have come to visit and additionally the presence of humans may cause stress to the animals making them susceptible to disease (Kalema-Zikusoka et al., 2005). Some diseases that usually disturb mountain gorillas are; common colds, pneumonia, paralytic poliomyelitis, tuberculosis, and influenza (Butynski, 2001), shigella and salmonella species, trypanosome, Giardia, Cryptosporidium, sarcoptic mange or scabies, Ebola, and a variety of gastro-intestinal helminths (Kalema-Zikusoka et al. 2018).

2.4.1 Helminths in non-human primates

Helminths are among the most common parasites infecting NHPs and include nematodes (roundworms), cestodes (tapeworms), and trematodes (flukes), many of which are transmitted through contaminated soil, water and pasture or vegetables or intermediate hosts (WHO, 2023). Wild NHPs are continuously exposed to helminth parasites because of their terrestrial activities, social behavior, and frequent contact with contaminated environment (Fitri-Suhaimi et al., 2026; MacIntosh et al., 2012).

Factors such as factors, host species, age, sex, diet, habitat characteristics, climate, population density, and degree of anthropogenic disturbance greatly influence the diversity and prevalence of helminth in NHPs (K. J. Petrželková et al., 2021). Terrestrial and omnivorous primates generally exhibit higher helminth burdens than their arboreal relatives, and this is because they spend more time on the ground where infective parasites stages accumulate (Klein et al., 2024; Sirima, Bizet, Hamou, Červená, Lemarcis, Esteban, Peeters, Mpoudi Ngole, et al., 2021). Habitat fragmentation, ecotourism, agricultural expansion, and increasing overlap between wildlife, humans, and livestock have further increased opportunities for parasite transmission at the human–wildlife interface (Jori et al., 2021; Madzingira et al., 2025).

Numerous GIT helminth is reported in NHPs are Strongyloides, Trichuris, Oesophagostomum, Ascaris, hookworms, Trichostrongylus, and several cestodes such as Hymenolepis. Table 1 provides more details on helminth of NHPs.

While many infections remain subclinical, heavy parasite burdens may result in malnutrition, anaemia, reduced body condition, impaired nutrient absorption, chronic inflammation, suppressed immune function, and increased susceptibility to secondary infections. These adverse effects are particularly pronounced in infants, juveniles, elderly animals, and immunocompromised individuals, ultimately reducing survival and reproductive success (Hughes & Kelly, 2006; Morales et al., 2023).

Among the great apes, gastrointestinal helminths have received considerable attention because of their implications for conservation and public health. Studies in gorillas, chimpanzees, and baboons have demonstrated that several helminth species are shared among sympatric wildlife, livestock, and humans, suggesting that environmental contamination and cross-species transmission occur where these populations interact (Gery et al., 2019; Mohamed-Djawad et al., 2025; Obanda et al., 2019).

Table 1: Common helminth species in non-human primates

	Host	Importance	Reference
Tapeworm (cestodes)			
Anoplocephala species	Mountain gorillas, equids, elephants,	Zoonotic	(Červená et al., 2024)
Bertiella species	Mountain gorillas, humans, rodents, marsupials, dermopterans, olive baboons	Zoonotic	(Červená et al., 2024) (Bakuza, 2020)
Echinococcus species	Olive baboons, dogs, humans,	Zoonotic, ccausative agent of cystic echinococcosis and Echinococcus multilocularis, which causes alveolar echinococcosis.	(Chanove et al., 2019)
Taenia species	Olive baboons, rodents, humans, pigs, cattle	Zoonotic, Emaciation, Cause taeniasis and cysticercosis.	(Chanove et al., 2019)
Moniezia species	Olive baboons, goats, sheep	Zoonotic	(Obanda, 2015)
Dipylidium species	Canines, olive baboons,	Zoonotic	(Ofori et al., 2024)
Hymenolepis species	Rats, humans, baboons, chimpanzees,	Zoonotic	(Yao C, 2023)
Round worms (Nematodes)			
Strongylid species	Man, mountain gorillas, olive baboons, cattle, sheep and goats	Zoonotic, chronic wasting	(Rothman et al., 2006)

Hyostrongylus species	Pigs, mountain gorillas	Zoonotic	(Pafco et al., 2026)
Oesophagostomum species	Mountain gorillas, cattle, olive baboons	Chronic wasting, alopecia,	(Sambucci et al., 2026)
Trichuris species	Mountain gorillas, olive baboons, cattle	Zoonotic, chronic wasting	(Kalema-Zikusoka et al., 2005)
Strongyloides species	Mountain gorillas, olive baboons,	Zoonotic, chronic wasting	(Kalema-Zikusoka et al., 2005)
Toxocara species	Mountain gorillas, olive baboons, chimpanzees	Cause zoonotic parasitic infections such as toxocariasis. Cause asymptomatic infections which are costly to treat.	(Strube et al., 2013)
Galoncus species	Baboons	blood loss caused by the worms' feeding activity in the gut is a contributing factor in the development of poor iron status leading to iron deficiency anemia.	(Larbi et al., 2021)
Flukeworms (Trematodes)			
Paragonimus	Rhesus monkeys,	used for research purposes to help better understand trematode infections. Cause paragonimiasis. Can cause asymptomatic infections hence difficult diagnosis.	(Rabone et al., 2021)

2.4.2 Life cycle of tapeworms

Cestodes or tapeworms belong to the class Cestoidea of the phylum platyhelminthes. Tapeworms loke other flatworms are bilaterally symmetric, flattened dorsoventrally, and lack a body cavity (Schantz, 1996). Cestodes of the family Anoplocephalidae typically use mites as their intermediate host parasitise various vertebrates including rodents, ungulates, primates, elephants and hyraxes (Červená et al., 2024). After ingestion of the affected mites during grooming or microscopic eggs from grass or soil during feeding, the eggs hatch in the small intestines and attach to the intestinal wall of their final host by a scolex, which is followed by a neck behind which grows the proglottids. Each proglottid has both male and female reproductive organs. The oldest proglottids are located farthest from the scolex and contain the tapeworm eggs (Bowman et al., 2006). These are then released through faecal matter into the environment, where they are picked up by the intermediate hosts, e.g. mites, rodents, which migrate to tissues to form cysts. Later the final hosts ingest the intermediate hosts and get infected and the cycle continues.

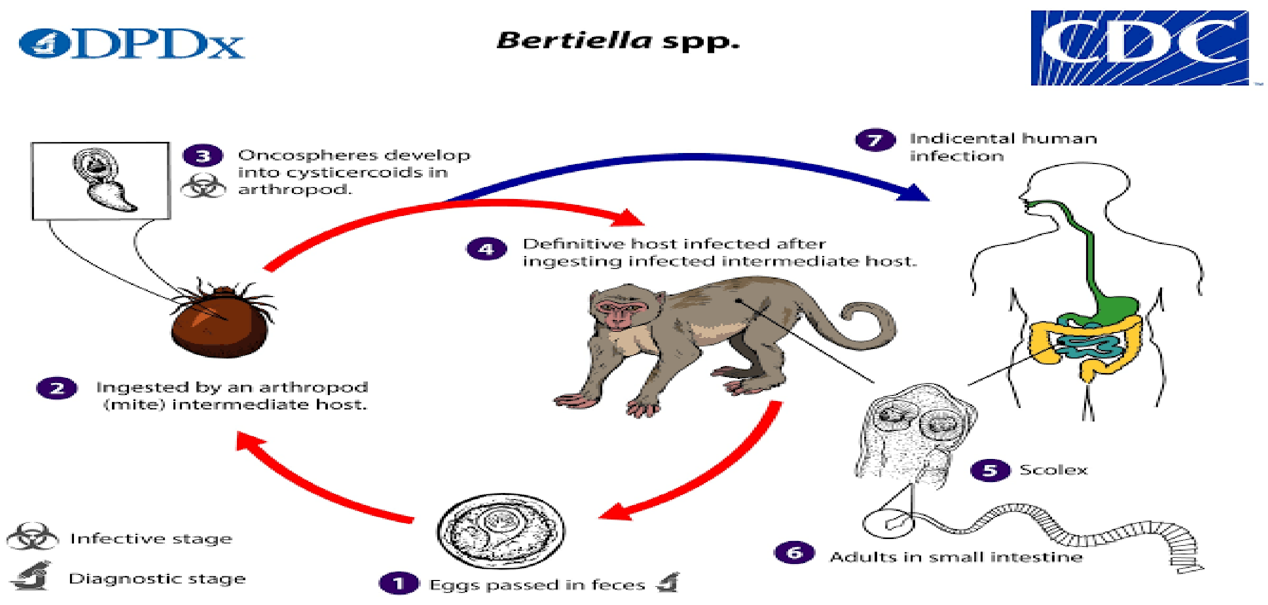


Figure 2: Lifecycle of tapeworm. Adapted from *https://www.cdc.gov/dpdx/bertiella/index.html*.

CHAPTER THREE:MATERIALS AND METHODS

3.1 Study area

The study was conducted from both Bwindi_Mgahinga Conservation Area. BINP is located at latitude 0°53′ and 1°08′S and longitude 29°35 and 29°50′E in Uganda (Figure 2). The national park covers 32,092 ha and is located along the Albertine Rift Valley, in the South-Western region of Uganda. The park is home to 120 species of mammals, 350 species of birds, 310 species of butterflies, 27 species of frogs, chameleons, geckos and a host of endangered species. MGNP is located in Kisoro district and has an area of 33.7km^2.

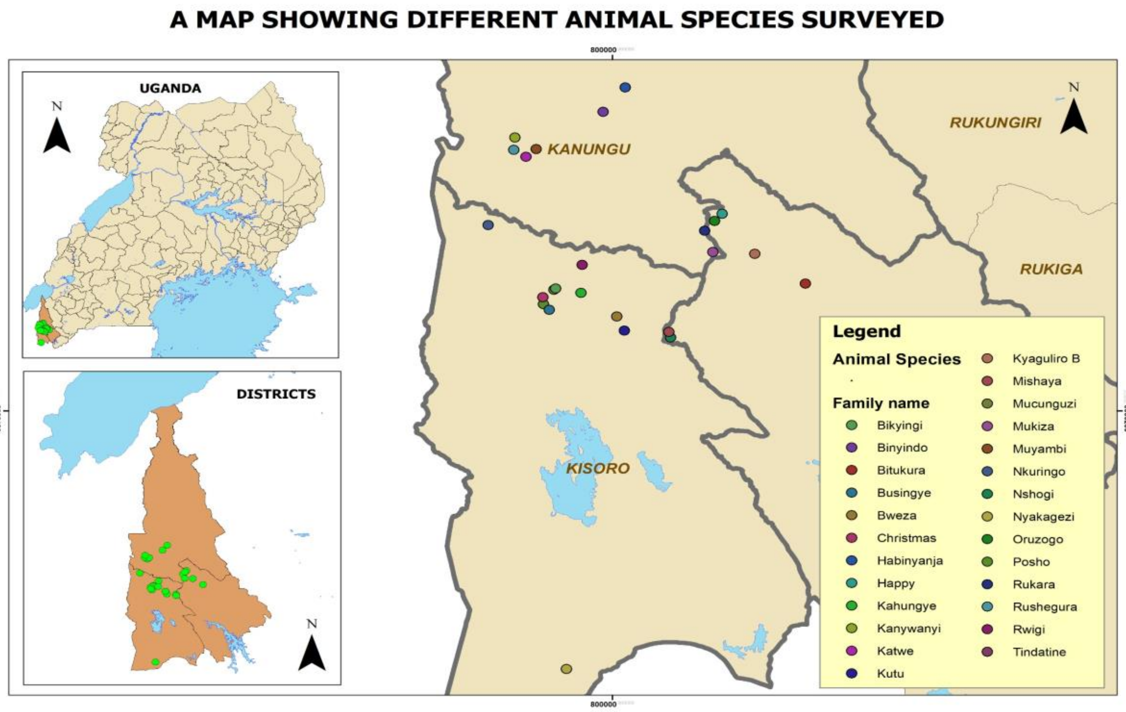


Figure 3: Study area

3.2 Study population

BINP is home to over 26 habituated mountain gorilla groups spread across four administration sectors, Buhoma, Ruhija, Rushaga and Nkurigo as indicated below (Table 2). BINP is also home to a large population of olive baboons that range within and out of the fore mentioned sectors. The study was conducted on 25 mountain gorilla families ranging within BINP and 1 mountain gorilla family within MGNP, while olive baboon samples were collected from baboons in the Buhoma sector of BINP.

3.3 Study design and sampling strategy

This was a cross-sectional study carried out in BINP and MGNP to collect gorilla and baboon fecal samples between November 2025 and December 2025.

The gorilla faecal samples were collected purposively and conveniently from each gorilla night nest in the gorilla groups found free ranging in the different sectors found within BINP as well as MGNP (Table 2). These gorilla groups commonly interact with humans, baboons and other animals. The age of the animal was estimated by measuring the diameter of the gorilla faecal material using the standardized method (Kalema-Zikusoka, Rothman, and Fox 2005) (table 3). A total of 245 fecal samples were collected from the different gorilla groups.

The olive baboon fecal samples were equally collected non-invasively from the baboon troop ranging around the Gorilla Doctors field station in Buhoma.

Table 2: **Target Mountain gorilla and olive baboon groups**

Location	Group description	Samples collected
Buhoma		
Habinyanja	6 fecal samples found, 1SB, 1BB, 1INF, 3ADF	6 samples
Binyindo	8 fecal samples found, 1SB, 3SA, 4ADFs	8 samples
Katwe	7 fecal samples found, 2SB, 1BB, 2JUV, 1ADF, 1SA	7 samples
Muyambi	5 fecal samples found, 1SB, 1JUV, 3ADF	5 samples
Rushegura	16 fecal samples found, 2SB, 6ADF, 4INF, 1JUV, 1SA, 2BB	16 samples
Kanywanyi	5 fecal samples, 1SB, 4ADF	5 samples
Olive baboons	28 fecal samples found	28 samples
Ruhija		
Rukana	2 fecal samples found, 1SB, 1BB	2 samples
Kyaguliro	7 fecal samples found, 1INF, 1SB, 5ADF	7 samples
Happy	9 fecal samples found, 1SB, 2INF, 1JUV, 5ADF	9 samples
Oruzogo	11 fecal samples found, 3SB, 1ADF, 3BB, 2INF, 1SA	11 samples
Mukiza	13 fecal samples found, 1SB, 4INF, 8ADF	13 samples
Bitukura	14 fecal samples found, 3SB, 1INF, 3JUV, 3BB, 4ADF	14 samples
Rushaga		
Rwigi	14 fecal samples found, 3SB, 6ADF, 1BB, 3INF, 1SA	14 samples
Busingye	13 fecal samples found, 1INF, 1JUV, 1SA, 1SB, 9ADF	13 samples
Mucunguzi	13 fecal samples found, 1SB, 4ADF, 4JUV, 1SA, 2INF	13 samples
Kahungye	14 samples found, 3BB, 1SB, 6ADF, 3INF, 1JUV	14 samples
Bikyingi	8 fecal samples found, 2SB, 1ADF, 4BB	8 samples
Kutu	8 fecal samples found, 1BB, 1SB, 1JUV, 2INF, 3ADF	8 samples
Mishaya	9 fecal samples found, 1SB, 1SA, 3INF, 4ADF	9 samples
Bweza	5 fecal samples found, 1SB, 2ADF, 1BB, 1JUV	5 samples
Shong	11 fecal samples found, 2BB, 2SA, 1SB, 3ADF, 1JUV, 2INF	11 samples
Tindatine	7 fecal samples found, 1BB, 1JUV, 3SA, 1SB, 1ADF	7 samples

Nkuringo		
Posho	18 fecal samples found, 1INF, 1SB, 3JUV, 4SA, 9ADF,	18 samples
Christmas	6 fecal samples found, 1SB, 2INF, 1BB, 2ADF	6 samples
Nkuringo	8 fecal samples found, 2SB, 1JUV, 3ADF, 1SA, 1INF	8 samples
Mgahinga		
Nyakagezi	9 fecal samples found, 3SB, 1BB, 1JUV, 4ADF	9 samples
Total Samples		273

Table 3: Faecal lobe measurements

Age	Estimated fecal lobe measurement
Infant	3.0 to 4.0cm
Juvenile	4.0 to 4.5 cm
Subadult	4.5 to 5.5cm
Black back	5.4 to 6.0cm
Adult female	6.5 to 7.0cm
Silver back	7.5 to 8cm

Upon collection, each gorilla and baboon faecal sample was examined carefully before collection for consistency, shape, size color, parasite presence or any clinical manifestation (e.g. diarrhea, mucus, blood) (Table 4).

Samples were collected into sterile fecal tubes using tongue depressants, labelled with the first letter of the group name, followed by the nest number, age category and finally date e.g.: M – N1 – SB 12/11/25 (SB- Silverback) and then put in a cool box and transported to the lab and put in a refrigerator. The samples collected were analyzed within an 8 to 24hr period.

Table 4: examination of fecal samples

Family	Consistency	Shape	Color	Clinical manifestation	Parasite presence
Habinyanja	Firm	Lobed	Greenish	None	Absent
Binyindo	Firm	Lobed	Greenish	None	Absent
Katwe	Soft	Lobed	Greenish	None	Absent
Muyambi	Firm	Lobed	Greenish	None	Absent
Rushegura	Soft	Lobed	Greenish	None	Absent
Kanywanyi	Firm	Lobed	Greenish	None	Absent
Olive baboons	Firm	Lobed	Greenish	None	Absent
Rukana	Firm	Lobed	Greenish	None	Absent
Kyaguliro	Firm	Lobed	Greenish	None	Absent
Happy	Firm	Lobed	Greenish	None	Absent
Oruzogo	Firm	Lobed	Greenish	None	Absent
Mukiza	Firm	Lobed	Greenish	None	Absent
Bitukura	Firm	Lobed	Greenish	None	Present
Rwigi	Firm	Lobed	Greenish	None	Absent
Busingye	Firm	Lobed	Greenish	None	Absent

Mucunguzi	Firm	Lobed	Greenish	None	Absent
Kahungye	Firm	Lobed	Greenish	None	Absent
Bikyingi	Firm	Lobed	Greenish	None	Absent
Kutu	Soft	Lobed	Greenish	None	Absent
Mishaya	Soft	Lobed	Greenish	None	Absent
Bweza	Soft	Lobed	Greenish	None	Absent
Shong	Soft	Lobed	Greenish	None	Absent
Tindatine	Soft	Lobed	Greenish	None	Absent
Posho	Loose	Squashed	Greenish	Diarrhea	Present
Christmas	Firm	Lobed	Greenish	None	Absent
Nkuringo	Firm	Lobed	Greenish	None	Absent
Nyakagezi	Firm	Lobed	Greenish	Mucus	Absent

3.4 Eligibility Criteria

Inclusion criteria

- Free ranging and habituated gorillas were considered.
- All age groups were considered
- Gorilla faecal samples were fresh and from identified nesting sites as identified by the UWA tracking/ field staff.
- Fresh baboon faecal samples from free ranging troops with an overlapping range with the gorillas were considered.

Exclusion criteria

- Fecal samples that were old, degraded or suspected to be contaminated were not considered.
- Contaminated samples from human action were not considered.

3.5 Laboratory analysis

This was accomplished by using the Mini-FLOTAC (MiniFLOTAC©, FLOTAC Group USA), a specific, highly advanced type of flotation technique. The Mini-FLOTAC provides the EPG (Eggs Per Gram of feces) through a simple four-step process of suspension, filtration, flotation, and direct counting.

Five hundred grams (500g) of Sodium chloride was dissolved in in 1000ml warm water (specific gravity 1.2). Then 3g of faecal sample was mashed with distilled water using a mortar. Thereafter the suspension was strained using a sieve into the flotation tube and distilled water was added up to the 15ml mark. The suspension was then centrifuged at 3500rpm for 5 minutes and the supernatant discarded. Then the flotation solution was added up to the 15ml mark on the flotation tube. Thereafter, using a pipette, approximately 2ml was taken and used to fill the two MiniFLOTAC chambers after which the sample was left to stand for 5 minutes. The dial was then turned and the upper section of the MiniFLOTAC was viewed using a light microscope and starting in the left upper corner, eggs were counted while following the grid lines until both chambers had been counted. After counting the eggs, a multiplication factor: 2.5 was used to obtain the total EPG of eggs in the fecal sample analyzed.

Parasite identification

Identification of parasite eggs seen was confirmed on the basis of morphological descriptions of Modrý (Modrý et al. 2018).

3.6 Data analysis

The data collected was entered into Microsoft Excel software and thereafter analyzed using a statistical package Statistics and Data (STATA) software. Descriptive statistics were conducted and tables of frequency and graphs drawn.

3.7 Ethical considerations

An official permission to enter BINP issued by Uganda Wildlife Authority to collect fecal samples from the mountain gorillas and olive baboons was sought. Fecal samples were collected non-invasively from the night nests of the mountain gorillas and after following the baboons respectively.

CHAPTER FOUR: RESULTS

4.1 Demographics of the sampled mountain gorillas and olive baboons

Out of the 245-mountain gorilla fecal samples collected, 36 were from infants, 24 from juveniles, and 185 from adults. Additionally, 62 samples were from males, 101 from females, and 82 were of unknown gender. The gender identities for infants, juveniles, and subadults were not ascertained. Of the 28 olive baboon samples collected, 9 were from infants, and 19 from adults. The gender identities of the baboon samples were not determined. Furthermore, from the samples collected, 236 mountain gorilla fecal samples were collected from Bwindi Impenetrable National Park (BINP) and 9 mountain gorilla fecal samples were collected from Mgahinga Gorilla National Park (MGNP). Additionally, 46 gorilla samples were collected from Buhoma, 56 from Ruhija, 102 from Rushegura, 32 from Nkuringo, and 9 from Mgahinga. All 28 olive baboon fecal samples were collected from BINP and from Buhoma sector.

Table 5: Demographics of sampled mountain gorillas and olive baboons

Characteristic	Species, n (%)	
	Mountain gorillas (n=245)	Olive baboons (n=28)
Age group		
Infant	36 (14.7)	9 (32.1)
Juvenile	24 (9.8)	0 (0.0)
Adult	185 (75.5)	19 (67.9)
Sex		
Male	62 (25.3)	0
Female	101 (41.2)	0
Unidentified	82 (33.5)	28 (100.0)
Site		
BINP	236 (96.33)	28 (100.0)
MGNP	9 (3.67)	0 (0.0)
Sector		
Buhoma	46 (18.78)	28 (100.00)
Ruhija	56 (22.86)	0 (0.00)
Rushaga	102 (41.63)	0 (0.00)
Nkuringo	32 (13.06)	0 (0.00)

4.2 Tapeworm Prevalence and diversity in sampled animals

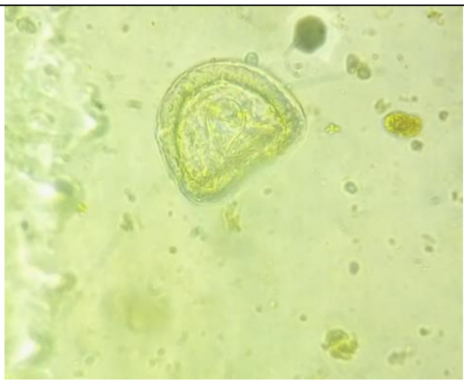
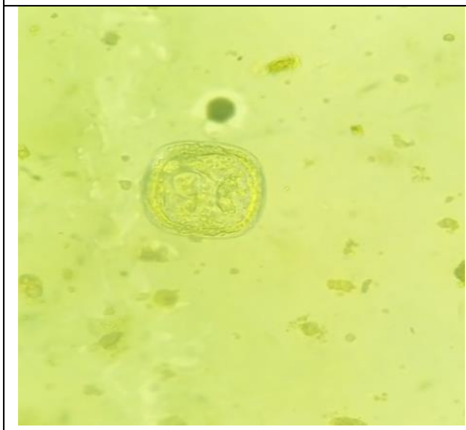
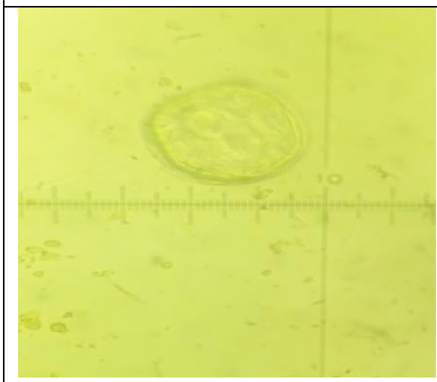
Overall, gastrointestinal helminths were highly prevalent among mountain gorillas, with an overall prevalence of 94.1% (222/236) in BINP and 100% (9/9) in MGNP. Within BINP, prevalence varied slightly across sectors, ranging from 87.0% in Buhoma to 98.0% in Rushaga, with Ruhija and Nkuringo recording prevalences of 91.1% and 96.9%, respectively. Across age groups, infection prevalence was lowest among infants (86.1%) and highest among adults (95.7%), while juveniles had a prevalence of 95.8%. By sex, females had the highest prevalence (97.0%), followed by males (93.6%) and gorillas of unidentified sex (91.5%).

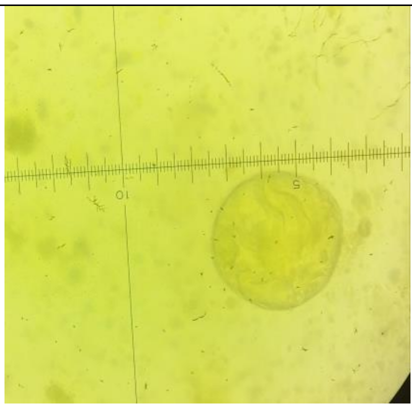
In olive baboons, helminth prevalence was considerably lower, with an overall prevalence of 25.0% (7/28), all detected in the Buhoma sector of BINP. Among baboons, prevalence was higher in adults (31.6%) than infants (11.1%), while all positive cases were from individuals of unidentified sex (25.0%).

Table 6: tapeworm prevalence

	Gorillas	Olive baboons
Overall prevalence n (%)		
BINP	222 (94.1)	7 (25.0)
MGNP	9 (100.0)	
Prevalence by sector n (%)		
Buhoma	40 (87.0)	7 (25.0)
Ruhija	51 (91.1)	
Rushaga	100 (98.0)	
Nkuringo	31 (96.9)	
Prevalence by age group n (%)		
Infant	31 (86.1)	1 (11.1)
Juvenile	23 (95.8)	
Adult	177 (95.7)	6 (31.6)
Prevalence by sex n (%)		
Male	58 (93.6)	
Female	98 (97.0)	
Unidentified	75 (91.5)	7 (25.0)

Table 7: tapeworm diversity

Species	Cestode egg	Description
Mountain gorillas	 Magnification*40 Anoplocephala species	• Measured 50 to 80 nm • Rectangular or polygonal in shape • very thick shell, oncosphere relatively smaller, and bifurcated pyriform apparatus • common to many individuals within the different families
	 Magnification*40 Moniezia species	• measured 50 to 60 nm • eggs are usually squared to cuboidal in shape • contain well developed pyriform apparatus
	 Magnification*40 Bertiella species	• round shape, thick shell, relatively bigger oncosphere and brush-like pyriform apparatus. • Measured 50 nm • Found within a few individuals

Olive baboons	 Magnification*40 Bertiella species	• round shape, thick shell, relatively bigger oncosphere and brush-like pyriform apparatus. • Measured 40 nm. • Observed in one individual

4.3 Tapeworm egg loads in Mountain gorillas and Olive baboons

EPG in Bwindi-Mgahinga Conservation Area

From *Table 8* , the mean EPG of tape worm eggs in mountain gorillas in MGNP was significantly higher than BINP (p=0.011).

Table 8: EPG of tapeworms by site

Site	Mean (SE)	*P value*
BINP	162.17 (11.80)	0.011
MGNP	319.20 (39.51)	

EPG in Bwindi Impenetreble National Park

From *Table 9*, the mean EPG of tapeworm eggs in olive baboons is significantly lower than that in the mountain gorillas ($p < 0.001$)

Table 9: Mean EPG of tapeworms

	BINP		
species	mean	se	*p value*
mountain gorillas	162.17	11.8	< 0.001
olive baboons	4.29	2.91	

EPG of tapeworms in mountain gorillas by sector

From the study findings, mountain gorillas in Rushaga sector recorded the highest median EPGs of tapeworm eggs compared to other sectors. Overall the median EPG of tapeworm eggs in mountain gorillas varied significantly by sector by (p<*0.0001*).

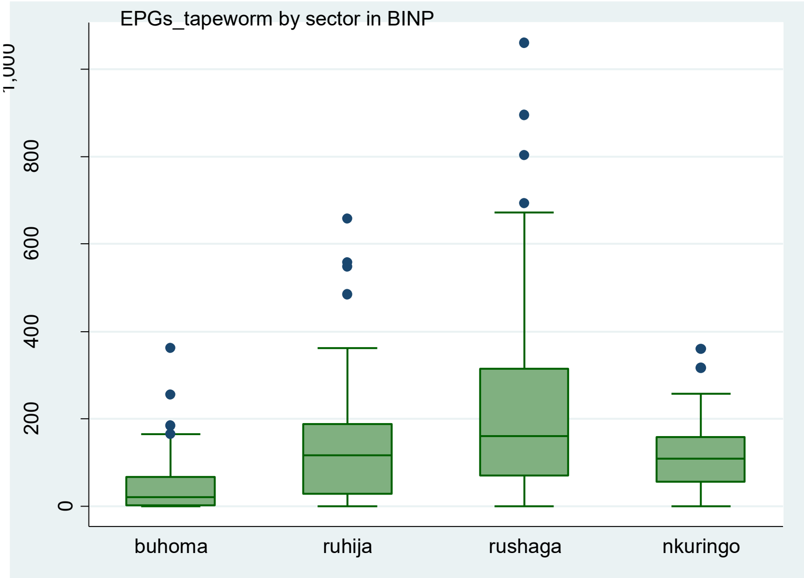


Figure 4: EPG of tapeworms in mountain gorillas by sector

EPG of tapeworms by age in mountain gorillas

In this study, the median EPG of tapeworms in adults was higher than in other age groups. However, the difference in the median EPGS was not statistically significant.

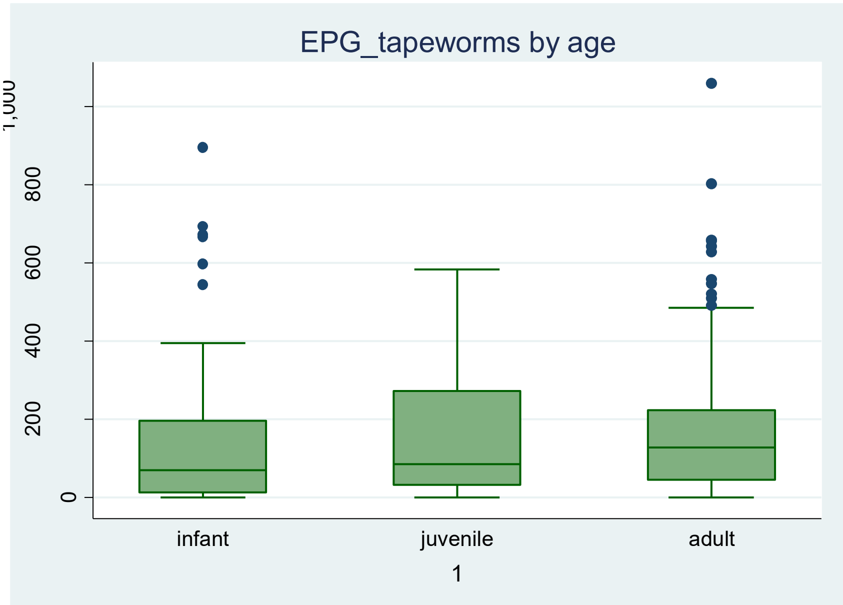


Figure 5: EPG of tapeworms by age in mountain gorillas

EPG of tapeworm eggs by sex of mountain gorillas

In the study, the median EPG of tapeworms was higher in males than in the other sexes. However, the difference in the median EPGs was not statistically significant.

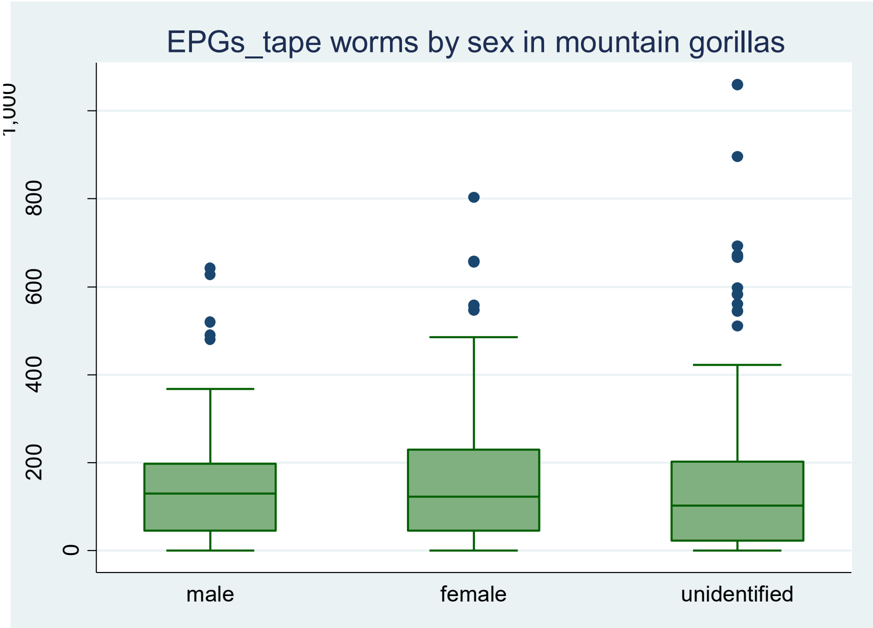


Figure 6: EPG of tapeworm eggs by sex of mountain gorillas

CHAPTER FIVE: DISCUSSION

Increasing habitat overlap between olive baboons and mountain gorillas has raised concerns about the potential transmission of parasites among wildlife species and between humans and non-human primates (Hope et al., 2004,) and particularly in areas where anthropogenic activities have reduced the separation between habitats (Rwego et al., 2008). Although the increased spatial overlap is considered a plausible risk factor, the extent to which it directly influences cross-species parasite transmission remains uncertain because transmission is also shaped by host behavior, environmental conditions, parasite biology, and contact rates (Nunn & Altizer, 2006). Gastrointestinal helminths have increasingly been associated with clinical disease in mountain gorillas, highlighting the importance of continued research on parasite epidemiology and its implications for conservation (Petrželková et al., 2021; Sirima et al., 2021; Rothman, Pell, & Bowman, 2008). Given that mountain gorillas are an endangered species, regular surveillance of parasitic infections is essential for informing conservation and disease management strategies.

This study assessed the current status of tapeworm infestations among all habituated mountain gorilla groups in BINP and MGNP, as well as olive baboons inhabiting BINP. Although several helminth species were identified, cestodes (tapeworms) were the primary focus of the study. Identification of cestodes was performed to the genus level based on morphological characteristics observed in recovered specimens. While morphological identification is widely used in parasitological studies, its ability to discriminate between closely related or morphologically similar species is limited, increasing the possibility of misidentification and the failure to detect cryptic species. The absence of molecular techniques, such as DNA-based analyses, therefore represents a limitation of this study, as these methods would have enabled more accurate species-level identification and improved the detection of cryptic diversity. Consequently, the findings presented should be interpreted within the context of these methodological limitations.

Most mountain gorilla fecal samples were positive for anoplocephalid tapeworms, whereas the majority of olive baboon samples were negative for tapeworm infection. The highest overall EPG count of tapeworms was recorded in MGNP, despite the park containing only one habituated gorilla family. Within BINP, the Rushaga sector recorded the highest tapeworm EPG counts. This finding may be attributed to the extensive home-range overlap among the numerous habituated gorilla families in the sector, which increases opportunities for parasite transmission. Additionally, fewer targeted deworming interventions have reportedly been implemented in Rushaga compared with other sectors.

In contrast, the Buhoma sector recorded relatively lower tapeworm EPG counts as predicted due to previous reports of gorilla mortalities associated with heavy helminth burdens. The lower parasite intensity observed in the present study may reflect the effectiveness of repeated deworming interventions that have been implemented among habituated gorilla groups in this sector. However, because this study was observational, the relationship between deworming efforts and reduced parasite burden cannot be confirmed without further investigation.

Male gorillas exhibited higher tapeworm EPG counts than females, possibly due to behavioural and social factors associated with the dominance hierarchy and movement patterns within gorilla groups, which may increase their exposure to infective parasite stages. Similarly, adult gorillas showed higher tapeworm EPG counts than juveniles and subadults, potentially reflecting cumulative exposure over time and their broader ranging behaviour.

Mountain gorillas generally exhibited higher tapeworm EPG counts than olive baboons. While this difference may partly reflect the higher density of habituated gorilla populations within the study areas, other ecological and behavioral factors, including differences in diet, habitat use, social organization, and exposure to infective stages, may also contribute to the observed variation in parasite burden. Greater home-range overlap and frequent social interactions among gorillas are likely to facilitate parasite transmission through increased environmental contamination and closer contact between individuals (Klara J Petrželková et al., 2021) . In addition, studies of non-human primates have shown that physiological stress can alter immune function and increase susceptibility to parasitic infections, particularly in socially dynamic populations (Muehlenbein, 2006). However, because physiological stress and immune status were not assessed in the present study, their contribution to the higher tapeworm burdens observed in mountain gorillas remains speculative and warrants further investigation.

Three cestode genera were identified in mountain gorillas: *Anoplocephala*, which was the predominant genus and occurred in most infected individuals, *Bertiella*, which was detected only in a few individuals and *Moniezia* which was uncommon to most families. The predominance of *Anoplocephala* in mountain gorillas suggests that this genus may represent the principal cestode of conservation concern within the study population. In olive baboons, only *Bertiella* spp. was identified, and these were detected in a single individual. The detection of *Bertiella* in both gorillas and baboons may indicate shared environmental exposure to infective intermediate hosts or occasional cross-species transmission.

However, because parasite identification was based on morphological characteristics of eggs, future studies incorporating molecular techniques are recommended to enable species-level identification and improve understanding of cestode diversity and transmission dynamics.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study demonstrates that tapeworm infections remain prevalent among habituated mountain gorillas in Uganda, with *Anoplocephala* spp. being the dominant cestode and *Bertiella* species and Moniezia species occurring less frequently. Mountain gorillas exhibited substantially higher tapeworm infection intensity than olive baboons, indicating that gorillas may be at greater risk of cestode transmission within their populations.

Variation in infection intensity among park sectors suggests that ecological factors, including home-range overlap, group interactions, and management interventions such as deworming, may influence parasite transmission dynamics. Higher infection intensities observed in adult and male gorillas further indicate that age and sex may be important determinants of parasite burden.

6.2 Recommendations

- Regular monitoring of gastrointestinal helminths should be incorporated into the routine health surveillance programs for habituated mountain gorillas in the BMCA to facilitate regular early detection of changes in parasite prevalence and infection intensity, allowing timely intervention before infections become clinically significant.

- Since both mountain gorillas and olive baboons were found to harbor cestodes, further studies such as molecular characterization of parasite isolates from different host species would help determine whether cross-species transmission is occurring.

- The comparatively lower tapeworm egg counts observed in sectors where veterinary interventions have been implemented suggest that targeted treatment of clinically affected individuals may contribute to reducing parasite burdens thus the Gorilla Doctors should continue programmed evidence-based deworming and clinical management while ensuring that interventions are guided by routine diagnostic surveillance to minimize unnecessary anthelmintic use and reduce the risk of drug resistance.

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APPENDICES

APPENDIX 1: fecal sample collection

Appendix 2: fecal sample preparation and analysis