

**PREVALENCE OF GASTROINTESTINAL PARASITES IN RHESUS
MACAQUES (*Macaca mulatta*, Zimmermann 1780) AND HUMAN
COMMUNITY IN BIJAYPUR, DHARAN, NEPAL**



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DECLARATION

I hereby declare that the research project entitled “**PREVALENCE OF GASTROINTESTINAL PARASITES IN RHESUS MACAQUES (*Macaca mulatta*, Zimmermann 1780) AND HUMAN COMMUNITY IN BIJAYPUR, DHARAN, NEPAL**” submitted by myself to Institute of Science and Technology, Tribhuvan University, as per the provision for mini-research project.

I further declare that the work reported in this research report has been solely done by myself and has not been submitted in any other institute, university, and organization for academic and non-academic purpose.



.....

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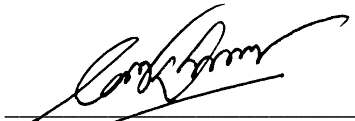
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RECOMMENDATION

This is to certify that Teaching Assistant **Ms. Manisha KC** has completed the mini research project entitled “**PREVALENCE OF GASTROINTESTINAL PARASITES IN RHESUS MACAQUES (Macaca mulatta, Zimmermann 1780) AND HUMAN COMMUNITY IN BIJAYPUR, DHARAN, NEPAL**” under my mentorship. To my knowledge, this work has not been submitted for any other purpose.



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ABSTRACT

Rhesus macaques (*Macaca mulatta*) are distributed across Nepal in close association with humans and with a high probability of sharing of gastrointestinal parasites. This study aimed to evaluate the occurrence, diversity, and determinants associated with gastrointestinal parasites in rhesus macaques and the people residing in the Bijaypur area of Dharan, Sunsari, Nepal. Microscopic methods, including direct wet mount, floatation, and sedimentation, were used to analyze fecal samples from 50 macaques and 50 humans. The results revealed that among the rhesus macaques, the general prevalence of gastrointestinal parasites was 62%. The most prevalent parasites were *Trichuris* sp. (52%), followed by *Entamoeba* sp. (22%), *Ascaris* sp. and Hookworm (12% each), *Eimeria* sp. (6%), and *Strongyloides* sp. (2%). In contrast, humans exhibited a lower parasitic infection rate of 6%, with *Entamoeba* sp. being the most common (6%), followed by Hookworm (4%) and *Trichuris* sp. (2%). The Sorenson's Coefficient of Similarity for the assessment of similarity in GI parasites between rhesus and humans, was found to be 0.67, indicating a moderate level of similarity. The mean parasite richness in infected macaque samples was calculated to be 1.70 ± 0.64 (SD), highlighting the diversity of parasites present in these primates. The study suggests that the substantial occurrence of GI parasites in rhesus macaques can be linked to their close association with humans, sharing habitats and food sources. This situation increases the potential for the bi-directional flow of parasites between the two species and raises concerns about zoonotic transmission, emphasizing the importance of routine monitoring and effective management strategies to mitigate the risks associated with such interactions.

Keywords: Primates; *Trichuris* sp.; *Entamoeba* sp.; Zoonotic Transmission;

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CHAPTER I

1. INTRODUCTION

1.1 Background and statement of the problem

The *Macaca mulatta* are the widely distributed species of primates and are considered as least concerned with an estimated population of about 100,000 (Jnawali et al. 2011). They are mostly concentrated within the elevation range of 2440 m above sea level including terai and the churia regions (Chalise 2013). Rhesus macaques are widely recognized for their co-existence with human and are commonly found inhabiting different cities, religious sites and villages (Chalise et al. 2005). These are prone to parasitic infection as they reside in a closed group which is characteristics of the frequent social interaction (Stoner, 1996). This makes the group the primary and main carrier of numerous gastrointestinal parasites (Sapkota et al. 2020).

Due to the striking similarity in physiological and genetic characteristics between rhesus monkeys and humans, they also possess shared infectious agents, such as intestinal parasites, due to their dietary habits. It has been proven that several newly emerging parasitic diseases in humans have their origins in primates. Additionally, there is a significant concern regarding the transmission of human pathogens to primates living in natural habitats. (Jones-Engel et al. 2006).

Gastrointestinal (GI) parasites, such as protozoa and helminths, are common in both humans and other primates. These parasites are primarily the intestinal parasites, which are responsible for the widespread parasitic infections worldwide. Protozoan parasites are single-celled organisms capable of multiplying inside the body, whereas helminths are multicellular worms that cannot multiply within the host body. Intestinal helminthic parasites, sometimes referred as soil-transmitted helminths, encompass parasite species such as *Ancylostoma duodenale*, *Ascaris lumbricoides*, Hookworms and *Trichiuris trichiura*, (Haque 2007).

Human and non-human primates have a long history of coexistence, leading to the development of intricate connections encompassing behavior, ecology, and epidemiology. The cohabitation of humans and non-human primates in the same geographical area facilitates spatial overlap and interactions, giving rise to a shared environment. Consequently, this shared environment can lead to the mixing and transmission of infectious agents between the two populations. (Fuentes 2006).

The spread of GI parasites is influenced by the intensity and type of anthropogenic disruptions

to the environment. Anthropogenic disturbances, such as habitat fragmentation, can heighten the vulnerability of primate populations to infection risks. In certain instances, these disturbances can even result in mortality among primates (Chapman et al., 2005).

The transmission of parasites is primarily attributed to two key factors. Firstly, the rise in soil and water pollution resulting from the disposal of food waste and garbage, contributes to the spread of parasites. Additionally, use of forest areas and near water sources for occasional open defecation plays a vital role. In such instances, macaques often come into contact with contaminated soil and water and consume discarded food, increasing the likelihood of successful transmission of gastrointestinal parasites (Sapkota et. al., 2020).

The extent of parasitism among *Macaca mulatta* in Dharan remained uncertain, primarily because of insufficient scientific research on the subject. Therefore, this study aims to fill that knowledge gap by examining the occurrence of gastrointestinal parasites in rhesus macaques. Furthermore, it will investigate the similarities in parasitic prevalence between the macaques and the human community in Dharan. The findings of this study will contribute valuable information regarding the presence and potential overlap of parasitic infections between humans and rhesus macaques in the region. The lack of comprehensive data on the prevalence, species composition, and potential zoonotic transmission of parasites of gastro-intestine between macaques and humans hinders our understanding of the overall public health risks associated with these infections.

1.2 Rationale of the study

Gastrointestinal parasite infections pose a significant public health concern, leading to morbidity and mortality in both animals and humans. Understanding the prevalence and potential zoonotic transmission of these parasites is crucial for implementing effective control and prevention strategies, reducing the burden of disease, and safeguarding human health. Rhesus macaques and humans share genetic similarities, and there is growing evidence of zoonotic transmission of certain gastrointestinal parasites between these populations. Investigating the prevalence and species composition of parasites in both macaques and humans can help identify the specific parasites with zoonotic potential, allowing for targeted interventions to minimize transmission and prevent human infections.

This study compared the prevalence and species composition of gastrointestinal parasites in rhesus macaques and humans living near macaque habitats, revealing both similarities and differences between the two populations. These findings provide valuable insights into the

potential for zoonotic transmission and the importance of understanding the dynamics of parasitic infections. Such comparative analysis provides valuable insights into the transmission dynamics, potential risk factors, and health consequences associated with these infections in both species. By conducting this study, we gained a deeper understanding of the occurrence of gastrointestinal parasites and its transmission in rhesus macaques and humans, enabling informed decision-making and promoting the health and well-being of both species and the ecosystems they inhabit.

1.3 Objective of the study

The study aims to assess the frequency of intestinal parasites in the rhesus and humans in Bijaypur, Dharan, Sunsari.

The specific objectives include:

- To analyze the occurrence and species composition of intestinal parasites in the rhesus macaques and human populations residing in close proximity at Bijaypur.
- To compare the gastrointestinal parasite species found in rhesus macaques and humans.

1.4 Limitation of the study

The study was governed by various limiting factors that influenced the result of the study. The factors included the sampling biases, sample size and availability, appropriate diagnostic techniques, inherent temporal and spatial variability of the parasites. However optimum care was provided to ensure the impact of the factors to be minimal. Also, the study was a single cross sectional study that may not well resemble the variations completely which requires a longitudinal study or repeated sampling as future prospect of the study.

CHAPTER II

2. LITERATURE REVIEW

2.1 Gastrointestinal parasites prevalence in rhesus macaques

Parasites being the integral part of natural history of mammal forms an important (usually overlooked) aspect of the biodiversity of the ecosystem. Every living organism are somehow affected by parasites where the primates cannot get rid of it (Jha et al. 2011). The coexistence between the human and monkey makes it more vulnerable to pathogen exchange (Cheng 1999).

Sapkota et al. (2020) highlighted the high prevalence and diversity of intestinal parasites among the rhesus macaque population in the Bajrabarahi Temple area. The study identified various parasites and their respective infection rates. The infection rate was found to be maximum for *Entamoeba* sp. (66.7%), followed by *Balantidium coli* (59.5%), *Entamoeba coli* (57.1%), *Ascaris* sp. (21.4%), *Strongyloides* sp. (21.4%), hookworm (19%), *Trichuris* sp. (14.3%), *Cryptosporidium* sp. (11.9%), *Strongylid* sp. (9.5%), *Eimeria* sp. (7.1%), *Giardia* sp. (4.8%), and *Trichomonas* sp. (2.4%).

Adhikari & Dhakal (2018). Signifies the presence of a variety of intestinal parasites in both Rhesus Macaques and Hanuman Langurs in the Devghat area Chitwan, indicating a significant parasitic burden in these primate populations. The highest infection rate was reported for *Balantidium coli* (27.95%). This was followed by *Trichuris* sp. (23.65%), *Eimeria* sp. (16.12%), *Entamoeba* sp. (13.97%), *Ascaris* sp. (11.82%), *Strongyloides* sp. (10.75%), *Oesophagostomum* sp. (5.37%), Hookworm (3.22%), *Trichostrongylus* sp. (3.22%), and *Hymenolepis* sp. (1.07%). The overall incidence of parasitic infections was reported to be 74.20%. On the other hand, in the same district Dhakal et al. (2018) reported the highest rate incidence of *Cryptosporidium* sp. in the macaque with prevalence of 80%.

Pokhrel & Maharjan (2014) identified the presence of various parasitic infections among Assamese Macaques in the Shivapuri Nagarjun National Park, highlighting the importance of studying and managing the health of wildlife populations in the area. The study revealed a parasitic infestation rate of 28.24% among the macaque population. Among the parasites detected, *Balantidium coli* was reported to be the most prevalent one. Other identified parasites in the study included *Entamoeba* sp., *Trichuris* sp., *Ascaris* sp., *Oesophagostomum* sp., *Strongyloides* sp., *Isospora* sp., Hookworm, *Moniezia* sp., and *Physeloptera* sp.

Jha et al. (2011). shed light on the high burden of various intestinal parasites among rhesus monkeys residing in temple environments in Kathmandu. The authors highlighted that *Oesophagostomum* infection had the highest prevalence rate. This was succeeded by *Balantidium coli*, *Strongyloides* sp., *Entamoeba histolytica*, *Entamoeba coli*, *Trichuris* sp., and *Trichostrongylus* sp. The general occurrence rate of intestinal parasitic infections in the temple rhesus monkey population was reported to be 76.86%.

2.2 Gastro-intestinal parasites prevalence in humans

Intestinal parasitic infection represents a significant health as well as socio-economic concern, particularly in developing countries (Shrestha et al., 2012). It has been reported that these infections are a leading cause of illness among human communities in such countries. Close interaction with animals and open defecation were identified as major predictors of intestinal parasitic infections in the human (Rajoo et al. 2017). Multiple studies conducted in Nepal have consistently concluded that several factors contribute to the increased risk of intestinal parasitic infections. These factors include low socio-economic status, inadequate housing conditions, contact with domestic animals, unhealthy and poor personal hygiene (Adhikari et al. 2021; Sapkota et al. 2017; Sah et al. 2013; Shrestha et al. 2012;).

Ascaris lumbricoides, *Giardia lamblia*, and *Entamoeba histolytica* have been identified as the most commonly occurring intestinal parasites in various regions of Nepal. These findings have been reported in multiple studies conducted in several parts of the country (Das et al. 2006; Ghimire et al. 2014, Chongbang et al. 2016). These parasites pose a significant public health concern and understanding their prevalence is crucial for implementing effective control and prevention measures.

A research study conducted within school students in the eastern region of Nepal revealed the following occurrence rates of intestinal parasites: *Giardia intestinalis* (30.9%), hookworm (18.6%), *Ascaris lumbricoides* (15.5%), *Hymenolepis nana* (6.2%), and *Entamoeba histolytica* (5.2%) (Ghimire et al. 2014). Meanwhile some comparable investigation carried out among patients of specialized hospital in the same area reported the subsequent prevalence rates: *Giardia intestinalis* (3.34%), *Entamoeba histolytica* (1.96%), and hookworm (0.97%) (Baral et al. 2017). These findings highlight the presence of *Giardia intestinalis* as the most common intestinal parasite in both studies, followed by other significant parasites including hookworm, *Entamoeba histolytica*, *Ascaris lumbricoides* and, *Hymenolepis nana*. However Shrestha & Maharjan (2013) reported that *Ascaris lumbricoides* (22.63%) was found to be the most

prevalent parasite, while others parasites were found to occur with following respective occurrence rate: *Taenia* sp. (1.01%), *Trichuris trichiura* (6.06%), *Hymenolepis nana* (0.81%), Hookworm (1.62%), *Strongyloides stercoralis* (1.82%), and *Enterobius vermicularis* (0.40%) in Bhaktapur district.

The distribution of the GI tract parasites in the rhesus monkey and the humans needs to be well assessed and their status along with the pathogen exchange needs a critical attention.

CHAPTER III

3. MATERIALS AND METHODS

3.1 Study area

The study area lies along the northeast corner of the Dharan City (Fig.1). Geographically it is located between $26^{\circ} 48' 41''$ to $26^{\circ} 50' 09''$ N latitude and $87^{\circ} 17' 11''$ to $87^{\circ} 18' 06''$ E longitude. The area is north south trending elevated land surface consisting of forests, settlements and cultivated lands that connects the higher hills in north and plain in south. The population of the area is 4803 including 2286 male and 2517 female (NPHC, 2021). The area is also well known for the pilgrimage sites. The famous temples like Panchakanya, Budhasubba, Dantakali and Pindeshowri lies within the area. The community forest of Panchakanya and the forest of Hattisar also lies within the area. These forests are well known for their diverse flora and fauna as well. The population of the Rhesus macaques within the study area is reported to be 203 individuals scattered in different troops of varying size (Tamang et al., 2020).

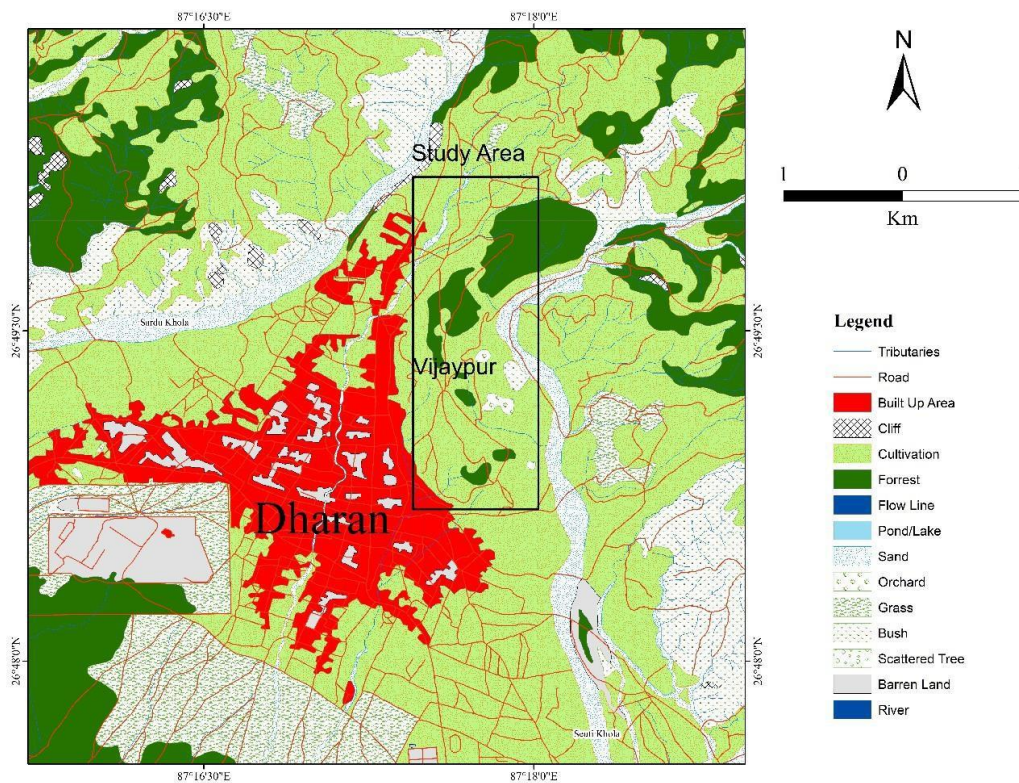


Figure 1 Landuse map of the Dharan showing the study area.

3.2 Materials

Following apparatus and Chemicals were utilized for sample collection and storage, sample

preparation, and their microscopic examination and identification.

3.2.1 Apparatus

- Personal Protective Equipment (PPE)
- Sterile Vials
- Weighing Machine
- Stainer
- Centrifuge Machine
- Dropper
- Coverslip
- Slides
- Trinocular Microscope

3.2.2 Chemicals

- Solution of 2.5 % $K_2Cr_2O_7$
- Iodine solution
- Solution of Sodium Chloride
- 10% Formalin
- Ether
- $ZnSO_4$
- Distilled Water

3.3 Methods

3.3.1 Sample collection and preservation

All together 50 fecal samples of rhesus monkey was collected from November 2023 to January 2024. Fresh fecal samples of the macaques were collected opportunistically within the study area (forest and temple area). During the collection of fecal samples, the troops were followed mostly during the morning (7:00–11:00 A.M.). Collected semisolid or solid fecal samples were placed in a vial containing solution of 2.5% ($K_2Cr_2O_7$)for preservation.

For the collection of Human stool sample, sterile vials were handed out to the potential participants including the temple care taker, forest care taker, local shop vendors, and local inhabitants. The participants were provided with the guidelines for the use of collection vials. The collected samples in the vials were received the next day and were marked, and stored in solution of 2.5% Potassium dichromate for later analysis. The fecal samples from human (n=50) were collected

from 39 adults (22 male, 17 female) and 11 children (age below 15 years). All the participants were informed about the research purpose and provided consent for their involvement, and steps were taken to guarantee the unanimous nature of the study.

Altogether 100 fecal samples (50 from rhesus monkey and 50 from human individuals) were collected and preserved. The samples were transported to the lab of the Central Campus of Technology, Dharan for further evaluation and examination.

3.4 Sample Preparation and microscopic examination

The microscopic analysis of fecal samples aimed to identify trophozoites, oocysts, eggs, cysts, and larval stages of gastrointestinal parasites. This involved employing direct wet mount techniques, including both saline wet mount and iodine wet mount methods, along with concentration methods such as floatation and sedimentation.

The examination process began with observing the slides under a microscope at low magnification (10x) to locate potential parasites and gain an overview of the sample. Subsequently, switching to high magnification (40x) enabled a detailed examination and identification of specific parasite stages, aiding in accurate diagnosis and treatment planning for gastrointestinal parasitic infections.

3.4.1 Saline wet mount method

A small amount of fecal sample was placed onto a clean glass slide and combined with normal saline. A cover slip was then delicately positioned over the mixture. Any surplus liquid was eliminated using a cotton filter before the sample was scrutinized under a microscope, employing both 10× and 40× magnification lenses. This method is used for detection of cysts of protozoa and larvae and eggs of Helminthes (Zajac & Conboy 2012).

3.4.2 Iodine wet mount method

A glass slide received two to three drops of stool sample, followed by the addition and mixing of a drop of Lugol's iodine. After placing a cover slip, any surplus liquid was eliminated with cotton filter and resulting specimen was then examined under a microscope at magnification of 10× and 40×. This method facilitates the examination of protozoans' internal structure and aids in their identification (Zajac & Conboy 2012).

3.4.3 Formalin-ether sedimentation method

A quantity of half a teaspoon of the sample undergoes homogenization in 10 ml of water and is subsequently filtered through a double layer of gauze using a funnel. The resulting filtrate is processed through centrifugation at 2000 rotation per minute (rpm) for 2 minutes. The liquid

above the sediment is poured off, and the resulting residue is reconstituted in 10 ml of physiological saline solution before undergoing another round of centrifugation. Following the removal of the supernatant, the sediment is resuspended in 7 ml of formalin saline and allowed to undergo fixation for a period of 10 minutes. Subsequently, 3 ml of ether are introduced into the suspension, which is vigorously agitated before sealing of the tube. The tube is then subjected to centrifugation at 2000 rpm for 2 minutes.

Upon allowing the tube to stand undisturbed, distinct layers become visible. The uppermost layer comprises ether, followed by a layer of debris, a clear stratum of formalin saline, and finally, the sediment at the bottom. The debris is carefully dislodged from the tube wall using a glass rod, and the liquid component is decanted, leaving a residual volume of formalin saline for sediment suspension. This suspension is transferred onto a glass slide, covered with a coverslip, and subjected to microscopic examination. Microscopic scrutiny is performed utilizing both low-power (10×) and high-power (40×) objectives to detect and characterize various parasites such as cysts, eggs, or larvae, as outlined by Arora & Arora (2014).

3.4.4 Zinc sulphate floatation method

Approximately 3 gm of fecal samples were placed in a beaker and homogenized with approximately 20 ml of water. The resulting mixture was filtered through cotton gauze and transferred into a centrifuge tube, filling it up to a volume of 12 ml, then centrifuged at 1000 rpm for 5 minutes. After centrifugation, the upper layer of water was removed from the tube, and the tube was refilled with ZnSO₄ solution up to 12 ml before undergoing another centrifugation at 1000 rotation per minute (rpm) for 5 minutes. Afterward, additional ZnSO₄ solution was introduced to form an upper meniscus. A coverslip was carefully positioned atop the centrifuge tube in such a way that the solution touched the coverslip, and this setup was left undisturbed for 5 minutes. Subsequently, the coverslip was gently removed and mounted onto a slide for examination, as described by Jain and Maharjan (2023). Microscopic analysis was carried out using both low-power (10×) and high-power (40×) objectives. This technique facilitated the detection of helminth eggs and protozoan cysts in the prepared solution, with the exception of eggs from *Ascaris* sp., *Taenia* sp., and *Strongyloides* sp.

3.5 Identification of eggs, cysts and larvae

The examination process involved thorough scrutiny of developmental stages of GI parasites, including oocysts and cysts of protozoans, as well as immature and mature (eggs and larvae) form of helminths. These stages were meticulously observed, documented through

photography, and their dimensions were accurately determined using a precise oculo-micrometer. Identification of parasites was based on their morphological characteristics, which encompassed factors such as shape, size, color, structure of cyst/oocyst walls and shells, and the contents within these structures. This identification process adhered to established descriptions found in a variety of authoritative sources, including reference books and research papers such as Soulsby (1982), Sapkota et al. (2020), and Zajac & Conboy (2012).

3.6 Data analysis

Parasite occurrence was established by determining the ratio of infected stool specimens to the total number of specimens under consideration. Parasite intensity was determined by dividing the count of a particular parasite in samples by the number of hosts infected with that parasite. Parasite richness was quantified by identifying the diversity of parasite species present in every individual specimen (Turgeon et al., 2018). Collected information then underwent coding and entry in a Excel File. Analysis and interpretation of the data were conducted using simple tables and bar diagrams to provide visual insights

Furthermore, to gauge the similarity in gastrointestinal parasites between macaques and humans, Sorenson's Coefficient of Similarity (SCS) was calculated using the formula:

$$SCS = \frac{2c}{a + b + 2c}$$

Here, 'c' represents the number of common parasite species shared between macaques and humans, 'a' denotes parasite exclusively found in macaques, and 'b' indicates parasite exclusively found in humans. This coefficient provides a quantitative measure of the similarity in gastrointestinal parasite composition between the two populations.

CHAPTER IV

4. RESULT

4.1 GI parasites prevalence in rhesus macaques

All total 50 fecal specimen analyzed, 31 tested positives for gastrointestinal parasites indicating a positivity rate of 62 %. Different six species, comprising 2 protozoans and 4 helminthes parasites, were identified among rhesus macaques of Bijaypur area (Figure 2). These parasites include *Trichuris* sp., *Entamoeba* sp., *Ascaris* sp., *Strongyloides* sp., Hookworm, and. *Eimeria* sp.,

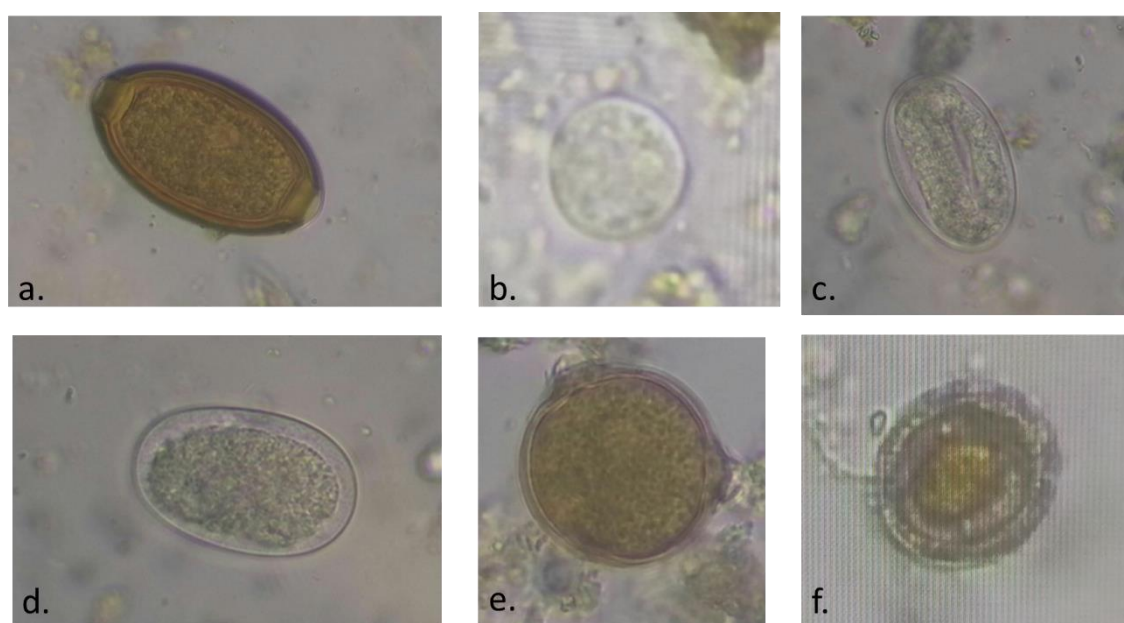


Figure 2 a. Egg of *Trichuris* sp. (55µm × 23 µm, X 400); b. Cyst of *Entamoeba* sp. (15 µm × 15 µm, X 400); c) Egg of *Strongyloides* sp. (50µm × 27 µm, X 400); d) Egg of Hookworm (72µm × 37 µm, X 400); e) Cyst of *Eimeria* sp. (19µm × 17 µm, X 400), and f) Egg of *Ascaris* sp. (55µm × 23 µm, X 400).

4.1.1 Richness of GI parasites in rhesus macaques

Among the 31 fecal specimens tested positive for the gastrointestinal infection, 12 fecal specimens of rhesus macaque were tested to be positive with a single parasite species, 16 were harboring with two different parasite species, and 3 were found to host with three different species of parasite. This indicates that single, double, and triple infection of parasites were observed at rates of 38.7%, 51.6 % and 9.67% respectively, demonstrating a mean richness of GI parasites of 1.70 ± 0.64 (SD).

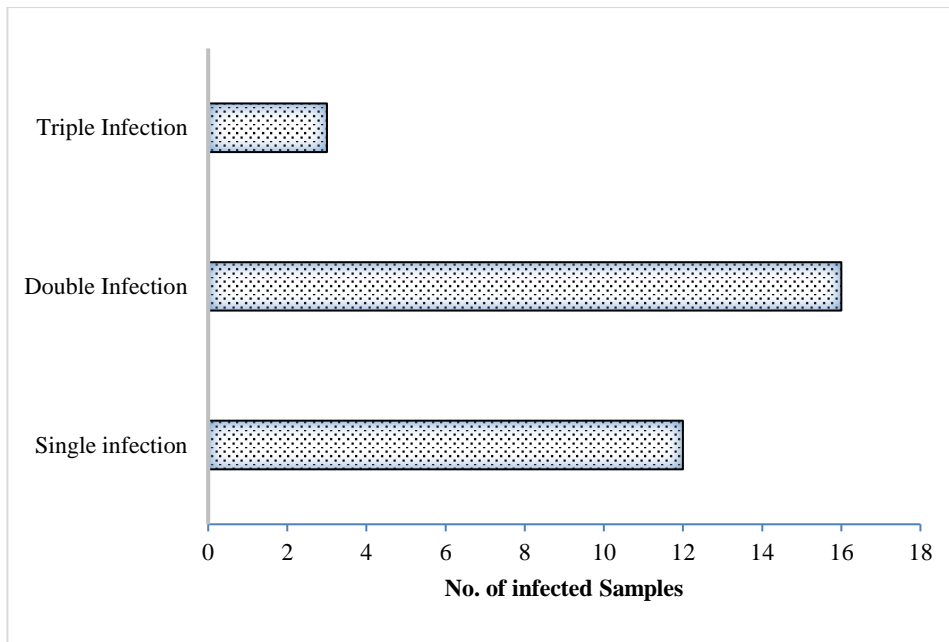


Figure 3 GI parasites infection status in rhesus macaques

4.1.2 GI parasites intensity in rhesus macaques

Out of the six parasite species, *Trichuris* sp. has highest prevalence at 52% with an intensity level of 4.62, followed by *Entamoeba* sp. with a prevalence of 22% and an intensity level of 3.36. Hookworm and *Ascaris* sp. were found to be prevalent at 12% each, with intensity levels of 1.67 and 1.5 respectively. *Eimeria* sp. had a prevalence rate of 6% and an intensity of 2, while *Strongyloides* sp. was found in only in 1 sample, accounting for a prevalence rate of 2% and an intensity level of 1 (Table 1).

Table 1 Prevalence of parasites and intensity of infection in rhesus macaque

Parasites	Infected samples	Prevalence (%)	Mean Intensity
<i>Entamoeba</i> sp.	11	22	3.36
<i>Eimeria</i> sp.	3	6	2.00
<i>Trichuris</i> sp.	26	52	4.62
Hookworm	6	12	1.67
<i>Strongyloides</i> sp.	1	2	1.00
<i>Ascaris</i> sp.	6	12	1.50

4.2 Prevalence of GI Parasitic in human

Among 50 samples from human, 6 were found to be infected with the prevalence of 12%. Three parasite species *Entamoeba* sp., *Trichuris* sp., and Hookworm were detected in human samples. All the 6 samples that were tested positive for the GI infection were found to harbor a single species of parasite. Within the three parasite species,

Entamoeba sp. has highest prevalence at 6% with an intensity level of 2.67, followed by Hookworm sp with a prevalence of 4% and an intensity level of 1.50. *Trichuris* sp. was found only in 1 sample, accounting for a prevalence rate of 2% and an intensity level of 2.00 (Table 3).

Table 2 Prevalence of parasites and intensity of infection in human

Parasite species	Infected samples	Prevalence rate (%)	Mean Intensity
<i>Entamoeba</i> sp.	3	6	2.67
<i>Trichuris</i> sp.	1	2	2.00
<i>Hookworm</i>	2	4	1.50

4.3 Similarity in GI parasites between macaques and humans

The similarity in GI parasites between macaques and humans has been assessed using the Sorenson's Coefficient of Similarity (SCS) as discussed earlier. The number of common parasite species shared between the rhesus and human consists of all 3 parasite species reported from the humans. Further 3 parasite species were reported exclusively from the rhesus and no any exclusive parasite species has been reported from the humans (Figure 4). The SCS value (0.67) indicates good overlap between the common shared parasite species.

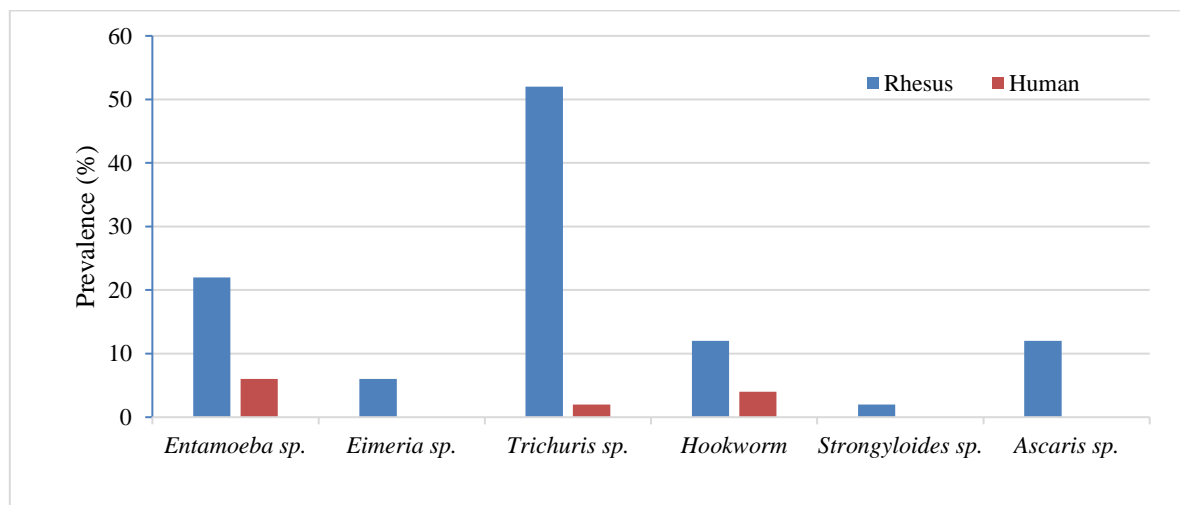


Figure 4 Prevalence percentage of the reported parasite species in the rhesus and human samples.

CHAPTER V

5. DISCUSSION

The investigation focused on the occurrence of GI parasites among the rhesus macaques (*Macaca mulatta*) and individuals from the Bijaypur area of Dharan, located in the Sunsari District in eastern Nepal's foothills. Six distinct parasite species were observed in *Macaca mullata* comprising *Entamoeba* sp., *Ascaris* sp., *Eimeria* sp., Hookworm, *Strongyloides* sp., and *Trichuris* sp. Concurrently, three different parasites- *Entamoeba* sp., *Trichuris* sp., and Hookworm - were identified in human population. The overall prevalence of parasites among rhesus macaques stood at 62%, slightly less than the figures reported for similar areas within Nepal (Sapkota et al. 2020; Adhikari & Dhakal 2018; Jha et al. 2011) but notably higher than findings by Tandan et al. (2023).

The distribution of parasite richness among the 31 macaque samples with infections varied, with 51.6% showing two parasite species, 38.7% displaying one parasite species, and the remaining 9.6% exhibiting three parasite species. This pattern contrasts with studies by Jha et al. (2011) and Sapkota et al. (2020), which found greater parasite abundance, up to five species of parasites, in rhesus macaques at temples of Kathmandu Valley. In contrast, Tandan et al. (2023) reported a maximum of two parasite species in macaques in the Daunne area.

The control of parasite load and diversity in rhesus macaques is attributed to behavioral actions like grooming, licking, and ingesting therapeutic plants (Dhakal et al. 2018; Hart & Hart 2018). Moreover, primate populations in fragmented habitats have higher parasite infection rates than those in continuous, protected forests due to human settlements and interactions with domestic animals, leading to increased transmission risks (Trejo-Macías et al., 2007).

The forest area of Bijayapur are, overseen and safe guarded by local residents, provides a diverse range of vegetations that act as significant seasonal food sources for macaques. These macaques also receive food from visitors and residents near the temple. However, due to shrinking natural habitats and increasing urbanization in Bijaypur, the natural habits and habitats of rhesus macaques are being disrupted, causing them to rely more on food from human settlements. This increased dependence on human-provisioned food raises the risk of infection through contaminated foods and water, leading to a higher prevalence of parasites among macaques in the area (Sapkota et al., 2020).

This interaction is reflected in the higher parasitic loads observed in rhesus macaques within Bijaypur. In contrast, the prevalence of parasites in humans, at 6%, is notably lower than the 62% prevalence in macaques. Factors such as improved awareness and education about parasite infections among humans, as well as access to modern health facilities, may contribute to this difference (Schurer et al., 2019). Common intestinal parasites found in humans in this study include *Entamoeba* sp., *Trichuris* sp., and Hookworm, which are also commonly detected in similar studies involving human populations (Gyawali, 2012; Shrestha and Maharjan, 2013; Acharya et al., 2021).

The potential for parasite transmission between rhesus macaques and human is a significant health issue, highlighting the need for increased and sustained surveillance efforts (Tandan et al., 2023). Identifying shared species of gastrointestinal parasite between rhesus and humans underscores the risk of mutual transmission due to intimate interplay within the study area. Therefore, further investigations with expanded sample number populations are recommended to comprehensively evaluate infection rates of parasites along with the corresponding risk of potential zoonosis.

CHAPTER- VI

6. CONCLUSION

Following conclusion can be drawn from the present study:

- Altogether six different species of GI parasites (*Entamoeba* sp., *Eimeria* sp., *Strongyloides* sp., *Ascaris* sp., Hookworm, and *Trichuris* sp.) were recorded from the rhesus macaques with 62% prevalence rate and three different species (*Entamoeba* sp., *Trichuris* sp., and Hookworm) were recorded from humans with prevalence rate of 6%.
- *Entamoeba* sp. and *Trichuris* sp. were found dominant parasite species in human (6%) and macaques (52%) respectively.
- All the three parasite species reported in human sample are shared in common with the rhesus macaques showing strong interaction and bi-directional as well as unidirectional transmission of GI parasites.
- The parasites identified in rhesus macaques could potentially pose a risk of zoonosis to the residents and tourists. To better understand and mitigate this risk, conducting a thorough study with an expanded sample size of both humans and rhesus macaque residing in this shared environment is crucial. This study would help ascertain the potential zoonotic risk of enteric parasites and facilitate the development of targeted strategies for disease prevention and control.

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ANNEXES

ANNEX 1. PHOTOGRAPHS DURING FIELD SURVEY





