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Gastrointestinal Parasites in Bali's Long-tailed Macaque (*Macaca fascicularis*): A Zoonotic and Public Health Concern

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ABSTRACT

In Bali, monkeys and humans share a close relationship that presents both opportunities and challenges. While this proximity enhances tourism appeal, it also raises concerns about disease transmission, particularly parasitic infections. This study aimed to identify the types and prevalence of parasites in monkey habitats across Bali, considering variations in location, altitude, and habitat characteristics. A total of 1,011 fresh fecal samples from long-tailed macaques were analyzed using the formol-ether method. The findings revealed the presence of various gastrointestinal parasites, including nematodes, trematodes, cestodes, and protozoa. The most prevalent parasite was *Entamoeba* spp. (83.44%), followed by *Isospora* spp. (31.6%), *Balantidium* spp. (29.87%), *Strongyloides* spp. (14.07%), *Dicrocoelium* spp. (9.31%), *Diphyllobothrium* spp. (8.23%), *Ascaris* spp. (3.25%), *Taenia* spp. (3.03%), and *Trichuris* spp. (1.84%). Altitude significantly influenced infections by *Strongyloides* spp., *Ascaris* spp., *Dicrocoelium* spp., *Taenia* spp., *Diphyllobothrium* spp., *Entamoeba* spp., *Balantidium* spp., and *Isospora* spp. Similarly, urbanization was found to affect infections of *Strongyloides* spp., *Dicrocoelium* spp., *Taenia* spp., *Diphyllobothrium* spp., *Entamoeba* spp., *Balantidium* spp., and *Isospora* spp. However, *Trichuris* spp. infections appeared unaffected by these factors. In conclusion, long-tailed macaques in Bali are hosts to a diverse range of parasitic infections, with altitude and urbanization playing key roles in influencing infection prevalence. These findings provide essential baseline data emphasizing the need for prevention and control strategies and increased public awareness of zoonotic gastrointestinal parasites from long-tailed macaques to reduce the risk of transmission to other animals and humans.

Key words: Bali, Gastrointestinal parasite, Long-tailed macaque, *Macaca fascicularis*, Monkey.

INTRODUCTION

The long-tailed macaque (*Macaca fascicularis*), also known as the crab-eating macaque, is native to Southeast Asia and is one of the most widespread primate species in the region. This adaptable species inhabits various environments, including tropical forests, mangroves and even urban areas (Gamalo et al. 2024). It has a distinctive long tail, which it uses for balance in its arboreal lifestyle. Long-tailed macaques are omnivorous and opportunistic feeders, consuming a diet that includes fruits, seeds, leaves, and small animals (Ritonga et al. 2022). They are highly social and live in groups known as troops, with complex social structures led by dominant males (Fitriana et al. 2024).

The interaction among humans, monkeys, and Hindu traditions in Bali constitutes a vital element of the island's cultural and spiritual heritage. Monkeys residing near

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temples are often perceived as spiritual guardians, believed to maintain a special connection with the spiritual realm and the sacred sites they inhabit. As a result, their presence is deeply respected by the Balinese, who frequently offer food as a gesture of reverence (Fuentes 2010). This intricate relationship is particularly significant in settings where human-wildlife boundaries are blurred, such as wildlife reserves and areas surrounding temples or tourist attractions (Schell et al. 2021). However, the association between long-tailed macaques and humans is multifaceted and carries critical implications for zoonotic disease transmission (Kaewchot et al. 2022). As highly adaptable primates often coexisting closely with human populations, long-tailed macaques serve both as subjects of scientific research and potential vectors for zoonotic pathogens, highlighting the need for careful management of these interactions (Jiang et al. 2023).

Wildlife, particularly macaques, plays a significant role in the transmission and spread of zoonotic diseases, acting as reservoirs for parasites that can infect both humans and livestock. Studies on macaques, such as the lion-tailed macaque (*Macaca silenus*) in the Western Ghats of India, have demonstrated that habitat fragmentation and human proximity significantly increase parasitic loads. For instance, research found that lion-tailed macaque groups near human settlements exhibited higher prevalence and species richness of gastrointestinal parasites, including nematodes like *Strongyloides* and *Trichuris*, as well as cestodes and protozoans. This is attributed to increased host density, environmental stress, and cross-species transmission facilitated by livestock grazing in fragmented habitats (Hussain et al. 2013). Similarly, macaques in Southeast Asia, such as the long-tailed macaque, are critical reservoirs for zoonotic malaria parasites like *Plasmodium knowlesi* and *P. cynomolgi*. These parasites are increasingly transmitted to humans in regions where macaques and humans coexist closely, highlighting the ecological complexity of zoonotic disease dynamics (Yusuf et al. 2022; Putaporntip et al. 2025). The persistence of these infections in macaques over long periods, as observed in longitudinal studies, underscores their role as sustained reservoirs, complicating disease control efforts (Putaporntip et al. 2025). The long-tailed macaque also known as a carrier of gastrointestinal parasites like *Strongyloides* and *Entamoeba*, which pose significant zoonotic risks to human populations, particularly in regions where human-wildlife interactions are frequent (Chrismanto et al. 2022). Understanding the dynamics of zoonotic disease transmission from macaque especially to humans is essential for developing effective surveillance, prevention, and control strategies to mitigate public health risks and prevent future pandemics (Kaewchot et al. 2022).

The long-tailed macaque is highly susceptible to a range of gastrointestinal parasites, many of which are shared with humans (Schurer et al. 2019). These parasites include protozoa, nematodes, cestodes, and trematodes (Yang et al. 2022). Transmission commonly occurs through the ingestion of contaminated food or water, inadequate sanitation, or close contact with infected hosts (Adhikari et al. 2023). This study aims to investigate the prevalence and diversity of gastrointestinal parasites in long-tailed macaque populations across various habitats in Bali Province, Indonesia.

MATERIALS AND METHODS

Ethical statement

This study was conducted in accordance with ethical guidelines and approved by the Research Ethics Committee of the Faculty of Veterinary Medicine, Udayana University, under approval number B/47/UN14.2.9/PT.01.04/2024.

Research design

This study employed an observational design with a cross-sectional sampling method. The habitats of long-tailed macaques were categorized based on location, altitude and proximity to human settlements. Samples were collected from five districts in Bali: Buleleng, Karangasem, Tabanan, Badung and Gianyar, with locations identified by the names of the places or villages where the macaques reside. Altitude was classified into three categories: lowlands (<400 meters above sea level), midlands (400–700 meters above sea level) and highlands (>700 meters above sea level). Habitat characteristics were further divided into three types: urban, semi-urban and forest (wild).

Sample collection

Fresh monkey feces were collected early in the morning by sampling 1–5 fecal deposits beneath the trees where the monkeys rested overnight. To minimize the likelihood of sampling feces from the same individual, each location was sampled only once. Samples were stored in labeled tubes containing a 10% sodium acetate-formaldehyde (SAF) solution for preservation.

Fecal examination

Parasitological analysis of the fecal samples was conducted using the formol-ether concentration method. Briefly, fecal samples were homogenized with SAF solution by vigorous shaking. The homogenized mixture was filtered through gauze or a fine sieve to remove large debris and insoluble material, allowing the parasite-containing liquid to pass through. Approximately 3–4mL of ether was added to the filtrate to aid in the separation of lighter contaminants. The mixture was centrifuged at 2,000rpm for 2–3min to concentrate parasites at the bottom of the tube. This process resulted in four distinct layers: an upper ether layer, a layer of lighter fecal debris, a formalin layer, and a sediment layer containing parasites. Following centrifugation, the upper layers (ether and lighter debris) were discarded, leaving only the sediment containing parasite elements. The sediment was transferred to a glass slide and examined under a microscope at low to medium magnification to identify parasite eggs, larvae, or cysts (Agustina et al. 2021).

Data Analysis

Collected data were tabulated and subjected to descriptive statistical analysis. Crosstabulation and Pearson's chi-square tests were performed to evaluate the relationships between habitat characteristics and the incidence of gastrointestinal parasitic infections.

RESULTS

A total of 1,011 fecal samples from long-tailed macaques were collected and examined from 11 distinct habitats across Bali Province. In the study, we identified a diverse range of parasitic organisms in the examined samples, including three species of nematodes: *Strongyloides* spp., *Ascaris* spp., and *Trichuris* spp. (Fig. 1). Additionally, we detected one species of trematode, *Dicrocoelium* spp. (Fig. 2) and two species of cestodes, *Taenia* spp., and *Diphyllobothrium* spp. (Fig. 3). Furthermore, three types of protozoa were observed: *Entamoeba* spp., *Balantidium* spp., and *Isospora* spp. (Fig. 4). The overall prevalence of intestinal parasitic infections observed in this study is presented in Table 1. *Entamoeba* spp. was the most frequently detected parasite, with a prevalence of 83.44%, followed by *Isospora* spp. (31.6%), *Balantidium* spp. (29.87%), *Strongyloides* spp. (14.07%), *Dicrocoelium* spp. (9.31%), *Diphyllobothrium* spp. (8.23%), *Ascaris* spp. (3.25%), *Taenia* spp. (3.03%), and *Trichuris* spp. (1.84%). In this study, we also observed single and mixed infections (Table 2). A total of 34.2% of the cases were single infections caused by a single parasite. Meanwhile, the prevalence of mixed infections involving two, three, four and five parasites were 34.1, 15.8, 3.4, and 1%, respectively.

Table 1: Distribution of gastrointestinal parasites in long-tailed macaques by habitat location

Sample location	Regency	N	Nematodes			Trematode	Cestodes		Protozoa		
			A	B	C	D	E	F	G	H	I
Labuan lalang	Buleleng	60	20	3	1	0	0	0	43	0	28
Pulaki	Buleleng	150	16	4	4	18	8	17	118	55	28
Mekori	Tabanan	16	0	0	0	1	0	3	15	2	0
Sangeh	Badung	83	7	2	4	9	0	7	79	41	20
Gumang	Karangasem	152	19	0	0	35	0	12	145	51	32
Batu Pageh	Badung	75	7	4	2	0	0	5	45	22	14
Uluwatu	Badung	149	18	0	0	0	0	2	106	21	91
Bedugul	Buleleng	45	6	1	1	1	2	2	15	4	13
Alas Kedaton	Tabanan	155	19	7	2	21	11	19	127	70	44
Lempuyang	Karangasem	39	13	7	1	0	5	7	12	1	6
Monkey forest	Gianyar	87	5	2	2	1	2	2	66	9	16
Total		1011	130	30	17	86	28	76	771	276	292
P (%)			14.07	3.25	1.84	9.3	3.03	8.2	83.4	29.9	31.6

Description: A: *Strongyloides* spp.; B: *Ascaris* spp.; C: *Trichuris* spp.; D: *Dicrocoelium* spp.; E: *Taenia* spp.; F: *Diphyllobothrium* spp.; G: *Entamoeba* spp.; H: *Balantidium* spp.; I: *Isospora* spp.; N: Sample numbers; P: Prevalence

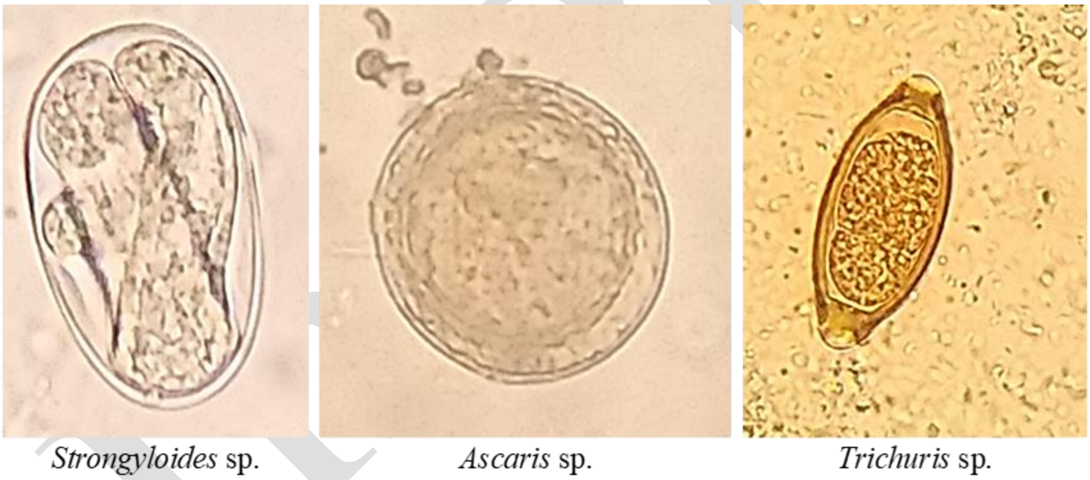

Fig. 1: Nematode eggs from long-tailed macaque in Bali.

Table 2: Mixed infection of gastrointestinal parasites in long-tailed macaques

Variables	Frequency	Percentage
Single infection	346	34.2
Co-infection by two parasites	345	34.1
Co-infection by three parasites	160	15.8
Co-infection by four parasites	34	3.4
Co-infection by five parasites	10	1.0

Table 3 shows that altitude has a highly significant effect (P<0.01) on the infection rates of *Ascaris* spp., *Dicrocoelium* spp., *Entamoeba* spp., *Balantidium* spp., and *Isospora* spp. It also has a significant effect (P<0.05) on the infection rates of *Strongyloides* spp., *Taenia* spp., and *Diphyllobothrium* spp. However, it did not have a significant effect (P>0.05) on the infection rate of *Trichuris* spp.

Fig. 2: Trematode egg: *Dicrocoelium* sp. from long-tailed macaque in Bali.

Table 3: Distribution of gastrointestinal parasites in long-tailed macaques according to altitude

Altitude	N	Nematodes			Trematodes	Cestodes		Protozoa		
		A	B	C	D	E	F	G	H	I
Lowland	434	61	11	7	18	8	24	312	98	161
Medium	477	50	11	8	66	13	40	417	171	112
Highland	100	19	8	2	2	7	12	42	7	19
P value		0.42*	0.00**	0.9	0.00**	0.018*	0.05*	0.00**	0.00**	0.00**

Description: A: *Strongyloides* spp.; B: *Ascaris* spp.; C: *Trichuris* spp.; D: *Dicrocoelium* spp.; E: *Taenia* spp.; F: *Diphyllobothrium* spp.; G: *Entamoeba* spp.; H: *Balantidium* spp.; I: *Isospora* spp.; N: Sample numbers; *: P<0.05; **: P<0.01

Table 4: Distribution of gastrointestinal parasites in long-tailed macaques based on habitat characteristics

Characteristics of the area	N	Nematodes			Trematodes	Cestodes		Protozoa		
		A	B	C	D	E	F	G	H	I
Urban	491	47	15	12	50	21	48	405	177	108
Semi urban	269	31	5	3	1	2	9	166	47	118
Wild	251	52	10	2	35	5	19	200	52	66
P value		0.00**	0.35	0.6	0.00**	0.01*	0.00**	0.00**	0.00**	0.00**

Description: A: *Strongyloides* spp.; B: *Ascaris* spp.; C: *Trichuris* spp.; D: *Dicrocoelium* spp.; E: *Taenia* spp.; F: *Diphyllobothrium* spp.; G: *Entamoeba* spp.; H: *Balantidium* spp.; I: *Isospora* spp.; N: Sample numbers; *: P<0.05; **: P<0.01

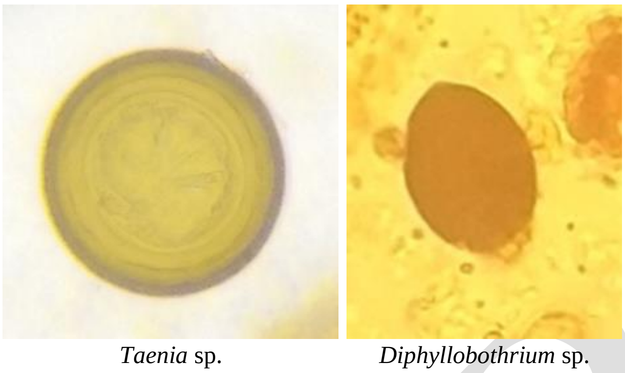

Fig. 3: Cestode eggs from long-tailed macaque in Bali.

Fig. 4: Protozoa from long-tailed macaque in Bali.

Table 4 shows that habitat characteristics have a highly significant effect (P<0.01) on the infection rates of *Strongyloides* spp., *Dicrocoelium* spp., *Diphyllobothrium* spp., *Entamoeba* spp., *Balantidium* spp., and *Isospora* spp. It also has a significant effect (P<0.05) on the infection rate of *Taenia* spp. However, it did not have a significant effect (P>0.05) on the infection rates of *Ascaris* spp. and *Trichuris* spp.

DISCUSSION

Gastrointestinal parasites are prevalent in long-tailed macaques, which inhabit diverse environments across Southeast Asia (Phosuk et al. 2024). Studies have demonstrated a high prevalence of these parasites, including nematodes, trematodes, cestodes, and protozoa, primarily due to the macaques' omnivorous diet and their frequent proximity to human habitats (Fernando et al. 2022). The crowded living conditions and social behaviors of these macaques, such as foraging and social grooming, facilitate the transmission of parasites within groups (MacIntosh et al. 2012). Research suggests that factors such as habitat degradation, urbanization, and seasonal changes influence the diversity and intensity of parasitic infections in these primates, posing health risks not only to the macaques but also to surrounding ecosystems and human populations (Cable et al. 2017; Damrongsukij et al. 2021).

Multiple gastrointestinal parasitic infections in monkeys refer to a condition in which a monkey is infected by more than one type of parasite within its digestive tract. This condition is commonly observed in monkey populations living in densely populated environments or with limited access to clean water. Multiple infections can exacerbate symptoms such as diarrhea, weight loss, and nutrient malabsorption, potentially leading to a significant decline in the overall health of the affected monkeys (Adhikari et al. 2023).

Nematode infections were detected in all long-tailed macaque habitats across Bali, with *Strongyloides* spp. being the most prevalent, followed by *Ascaris* spp. and *Trichuris* spp. The prevalence of these parasites in long-tailed macaques is a significant concern in parasitology, particularly due to their implications for both primate health and zoonotic transmission (Schurer et al. 2019). Studies have reported considerable infection rates of *Strongyloides* spp. in various macaque populations, often associated with exposure to contaminated environments and fecal matter. The life cycle of *Strongyloides* spp. involves both direct and indirect transmission pathways, which can facilitate rapid spread within macaque groups, particularly in areas with high population density or where human activities intersect with natural habitats. Factors such as seasonality, dietary habits, and stress levels in macaques may further influence parasite prevalence (White et al. 2019). Transmission of *Ascaris* spp. and *Trichuris* spp. occurs through the ingestion of eggs present in contaminated soil, food, or water and the high fecundity of these parasites contributes to their widespread distribution (Schurer et al. 2019). Research has shown that habitat degradation, poor sanitation, and the dietary habits of macaques can exacerbate infection rates. Infected macaques may exhibit symptoms such as malnutrition, growth retardation, and gastrointestinal disturbances, which can affect their overall health and social behavior (Schurer et al. 2019). The presence of these nematodes not only affects the health of long-tailed macaques, leading to gastrointestinal distress, but also raises public health concerns regarding potential transmission to humans and other animals within the same ecosystem (Cable et al. 2017; Damrongsukij et al. 2021).

The prevalence of *Dicrocoelium* spp. was notably high across various long-tailed macaque habitats in Bali. While the prevalence of *Dicrocoelium* spp., particularly *Dicrocoelium dendriticum*, in long-tailed macaques is relatively underexplored compared to other gastrointestinal parasites, it remains a subject of significant interest in parasitological research (Cringoli and Rinaldi 2014). These trematodes typically require intermediate hosts, such as snails and ants, to complete their life cycle, complicating the transmission dynamics within primate populations. Long-tailed macaques primarily inhabit forested and urban environments, which offer abundant foraging opportunities, yet their exposure to these intermediate hosts can result in incidental infections (Köse et al. 2015). Although infection rates of *Dicrocoelium* spp. may not reach the levels observed in nematodes or cestodes, their presence in these macaques can still pose significant health risks, including liver and gastrointestinal complications. Moreover, the complex ecological interactions between long-tailed macaques, their habitat, and other animal species highlight the necessity for continued monitoring to better understand the epidemiology of *Dicrocoelium* spp. infections and their potential implications for both wildlife and human health (Cringoli and Rinaldi 2014).

The prevalence of cestodes in long-tailed macaques holds significant ecological and health implications (Greigert et al. 2019). These parasitic organisms, which typically inhabit the gastrointestinal tract, can lead to a range of health issues in infected macaques, including malnutrition, abdominal discomfort, and stunted growth. Cestode transmission predominantly occurs through the ingestion of contaminated food or intermediate hosts, such as rodents or other animals, thereby making the foraging behaviors of long-tailed macaques a critical factor in their exposure. Elevated prevalence rates of cestodes may reflect environmental stressors or inadequate sanitation, as such conditions can facilitate the transmission of infections within macaque populations. Understanding both the prevalence and impact of cestodes is crucial, not only for the health management of long-tailed macaques but also for conservation efforts, as these parasites can negatively affect the overall fitness, survival, and reproductive success of individuals (Younis et al. 2021).

Taenid eggs were identified in several fecal samples from long-tailed macaques. While *Taenia* spp. infections in long-tailed macaques are infrequently reported, they can occur under specific circumstances (Deplazes et al. 2019). Long-tailed macaques, which typically inhabit tropical forests, urban areas, or regions near human settlements, may be exposed to *Taenia* eggs in their environment (Schurer et al. 2019). It is well-established that certain species of *Taenia*, which have complex life cycles, may involve primates, including monkeys, as definitive or intermediate hosts, although such occurrences are exceedingly rare and are more commonly associated with humans or livestock (Deplazes et al. 2019). *Taenia serialis* is capable of infecting primates, including long-tailed macaques, though these cases are extremely uncommon. The larvae of this species, known as *coenuri*, may form cysts in the muscle tissue or other organs of the intermediate host (Deplazes et al. 2019; Strait et al. 2012). Similarly, *Taenia crassiceps*, a tapeworm species primarily found in rodents and dogs, has been rarely reported to infect primates, including long-tailed macaques, particularly in laboratory settings or environments where macaques are in contact with infected dogs (Bleyer et al. 2018; Deplazes et al. 2019).

The prevalence of *Diphyllobothrium* spp. was also found to be relatively high. Infections caused by *Diphyllobothrium* spp. in primates, including long-tailed macaques, are rarely reported, although they can occur under specific circumstances (Kumar et al. 2018). Long-tailed macaques residing in proximity to water sources or frequently interacting with humans who consume fish are considered to be at an increased risk of *Diphyllobothrium* infection (Scholz et al. 2019). We hypothesize that the presence of dogs around the habitat of long-tailed macaques may contribute to the presence of *Diphyllobothrium* spp. eggs in macaque feces. Our assumption is that the macaques might be ingesting feces from dogs infected with this cestode. However, this hypothesis requires further investigation and substantiation.

Protozoan infections are frequently reported in long-tailed macaques and can involve various protozoan species that impact their health. Protozoa are single-celled organisms that commonly cause gastrointestinal, systemic, or blood infections in primates (Athaillah et al. 2021). The burden of gastrointestinal protozoan infections in Bali's long-tailed macaques is notably high, with *Entamoeba* spp. being highly prevalent, followed by *Isospora* spp. and *Balantidium* spp. Several species of *Entamoeba*, including *E. histolytica*, *E. coli*, *E. dispar*, *E. polecki*, *E. chattoni*, and *E. nuttalli*, are known to infect primates, including long-tailed macaques (Regan et al. 2014; Tuda et al. 2016; Stensvold et al. 2018). Infected macaques may serve as reservoirs, potentially transmitting these protozoan infections to humans and other animals, particularly in environments where they share food, water, and habitat resources (Balasubramaniam et al. 2020).

We found that altitude plays a significant role in influencing the prevalence of gastrointestinal parasite infections in long-tailed macaques in Bali (Table 3). In lowland areas characterized by warm, humid climates, nematodes are more likely to thrive, as these conditions support their life cycle stages, including the survival of eggs and larvae in the environment. Elevated temperatures and humidity levels allow parasite eggs to remain viable outside the host for extended periods, thereby increasing the likelihood of infection among monkeys in these regions (Aleuy and Kutz 2020). In contrast, at higher altitudes, where cooler temperatures and lower humidity prevail, nematode development is impeded, resulting in lower infection rates among long-tailed macaque populations (Narzullayev 2022). Thus, environmental factors associated with altitude, such as temperature and humidity, are critical determinants in the distribution and intensity of nematode infections in long-tailed macaques (Cohen et al. 2020).

Both trematodes and cestodes typically require intermediate hosts to complete their life cycles before infecting primates (Cringoli and Rinaldi 2014; Greigert et al. 2019). In lowland areas with warmer and more humid climates, these intermediate hosts are more abundant, thereby increasing the likelihood of cestode transmission to macaques. The favorable environmental conditions in the lowlands support both the survival and development of the parasites and their intermediate hosts, leading to a higher prevalence of infection. However, at higher altitudes, cooler temperatures and reduced biodiversity can limit the availability and survival of these intermediate hosts, disrupting the cestode life cycle and reducing infection prevalence in macaque populations (Heyneman 1996). Consequently, altitude-related environmental factors, including temperature, humidity, water availability, and biodiversity, play a crucial role in the distribution and infection rates of trematodes and cestodes in long-tailed macaques (Cringoli and Rinaldi 2014; Kumar et al. 2018).

Similarly to protozoan infections, we found that in lowland areas with high temperatures and humidity, protozoa are more likely to survive and reproduce outside the host environment (Fletcher et al. 2012). These environmental conditions facilitate the spread of protozoa through contaminated water, soil, or food, thereby increasing the risk of infection in macaques. Additionally, the higher population density of macaques in lowland areas may further accelerate the transmission of infections (Kooros et al. 2022). In contrast, in highland areas with lower temperatures and reduced humidity, the life cycle of protozoa may be disrupted, leading to a lower prevalence of protozoan infections in macaque populations.

Characteristics of the area, such as urbanization, have a significant impact on infections with *Strongyloides* spp., *Dicrocoelium* spp., *Taenia* spp., *Diphyllobothrium* spp., *Entamoeba* spp., *Balantidium* spp., and *Isospora* spp. in long-tailed macaques (Table 4). In areas with high levels of interaction between macaques and humans, coupled with access to contaminated food sources, the risk of infection with these parasites is elevated. Poor waste management and inadequate sanitation, common in densely populated urban areas, create favorable conditions for the spread of *Strongyloides* spp. larvae and protozoal cysts (Fernando et al. 2022). Furthermore, macaques that frequently forage in locations such as waste disposal sites are more likely to encounter parasite larvae or cysts, which may enter the host through the skin or be ingested with food (Pebsworth et al. 2012).

Urbanization exerts a significant influence on trematode and cestode infections in monkeys through various environmental and behavioral factors. Habitat alterations resulting from urbanization often lead to the loss of natural ecosystems, compelling monkeys to inhabit areas with higher population densities and increased interactions with humans and domestic animals (Schell et al. 2021). This environment heightens the risk of parasite transmission due to more frequent contact with intermediate hosts and other potential sources of infection. Additionally, changes in the monkeys' diet, as they begin consuming human food scraps, increase their exposure to contaminated food (Agostini et al. 2023). Urban environments, often characterized by poor sanitation and inadequate hygiene, also promote the proliferation of intermediate hosts such as insects, rodents, and snails, further increasing the risk of infection. Collectively, these factors create more favorable conditions for the spread of trematode and cestode infections in macaques, particularly in areas with higher human population densities (Thompson 2013).

These findings highlight the significant parasitic diversity present in the studied population, underscoring the potential zoonotic risks and the importance of monitoring and controlling parasitic infections in both wildlife and human-inhabited areas (Banda et al. 2024).

Conclusion

This study conclusively demonstrates that a diverse range of gastrointestinal parasites is present in long-tailed macaques in Bali, with the following prevalence rates observed: nematodes *Strongyloides* spp. (14.07%), *Ascaris* spp. (3.25%), and *Trichuris* spp. (1.84%); trematodes *Dicrocoelium* spp. (9.31%); cestodes *Diphyllobothrium* spp. (8.23%) and *Taenia* spp. (3.03%); and protozoa *Entamoeba* spp. (83.44%), *Isospora* spp. (31.6%), and *Balantidium* spp. (29.87%). The study further identifies that altitude and urbanization factors significantly influence the prevalence of most parasitic infections, with the exception of *Ascaris* spp. and *Trichuris* spp.; notably, *Ascaris* spp. infections are exclusively influenced by altitude. These findings underscore the complex interplay between environmental factors and parasitic infections in primates, highlighting the comprehensive measures must be implemented to control, manage, and prevent gastrointestinal parasitic infections in order to mitigate the risk of transmission to other animals or humans. This study provides essential baseline data that can serve as a foundation for future epidemiological investigations and the development of management strategies for gastrointestinal parasites in long-tailed macaques in the region.

Conflict of interest: All authors declare that there is no conflict of interest regarding to this research and article.

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Author's Contribution: KKA, IMS, NAANS, IWMT, RMDM and IBMO conceptualized the research, conducted sample collection, and performed examinations. KKA and IMS analyzed the data. KKA, AHW, DHS, and MM contributed to the writing and review of the manuscript.

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