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Cover: Oil painting of Humpback Whale *Megaptera novaeangliae*. © R. Mahesh.

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COMMUNICATION

Occurrence and prevalence of gastrointestinal parasites in herbivores in Dampa Tiger Reserve, Mizoram, India

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Abstract: Gastrointestinal parasite (GI) infection causes serious illnesses, reproductive impairment, and fitness problems in animals. Animals in the wilderness are not given prophylactic measures against parasites. A study was undertaken to recognize the prevalence of gastrointestinal parasites in herbivores at Dampa Tiger Reserve. Different species of herbivores belonging to the families Cercopithecidae, Sciuridae, Elephantidae, Cervidae, and Bovidae were considered for this study. Fresh faecal samples were collected from individuals in the field during January–March 2019, processed to isolate various stages of GI parasites, and examined for the presence of parasite categories and stages. A total of 70 samples were collected and analyzed, 59 samples found positive for gastrointestinal parasite ova. The overall prevalence level was 84.29% of the positive samples. Thirteen parasite species were found, which belong to four groups of parasites, namely, Nematodes, Trematodes, Protozoa, and Cestodes. *Ascaris* sp. had the highest prevalence, followed by Strongyle and *Dicrocelium* sp. exhibited the lowest prevalence. The prevalence of *Ascaris* sp. and Strongyle were 47.68% and 30.23%, respectively. The overall prevalence level was highest in family Cervidae (54.65%), followed by Cercopithecidae (43.02%), and Sciuridae (31.39%). The family Cervidae showed a high prevalence of *Ascaris* sp., whereas the family Cercopithecidae exhibited a high prevalence of Strongyle compared with other families.

Keywords: Cestodes, faecal pellet, footprint, herbivores, nematodes, parasites, protozoa, terei forest range, trematodes, zoonotic.

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Author details: G.S. Solanki, professor of Zoology, and dean, School of Life Sciences, Mizoram University, Aizawl. Thrust area for research was Biodiversity & Conservation Biology, Wildlife Ecology and Resource Management. After a long experience, he has been superannuated from active service of Mizoram University. Lalrinkimi was a PG student in the Department of Zoology and completed her M.Sc. degree. She did her dissertation under the supervision of Prof. Solanki. Phoebe Lalremruati was a research scholar in the Department of Zoology and completed her PhD degree under the supervision of Prof. Solanki on captive primates.

Author contribution: GSS-conceptualization of the study, arrangement of funds, finalizing the data analysis, writing and reviewing the final draft, and correspondence with the journal. Kimi collected the data and faecal samples from the field and performed preliminary screening of the samples. PL-helped in the final sample preparation of parasites and assisted in the identification of species. She also initiated the first draft of the manuscript.

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INTRODUCTION

Parasites are integral components of ecosystems, influencing host population dynamics, regulation, and community biodiversity (Hochachka & Dhondt 2000; Hudson et al. 2002). The intensity of parasitic infection can affect host fitness by reducing survival and reproductive success (Behnke 1990; Despommier et al. 1995; van Vuren 1996; Hilser et al. 2014). Intrinsic host features, together with environmental factors and parasite transmission mechanisms, shape overall vulnerability (Gibb et al. 2020). Primates, like other species, inhabit diverse environments and are exposed to variations in temperature and rainfall (Nunn & Altizer 2006; Solanki & Parida 2022). Many parasites are sensitive to these climatic factors; for instance, the eggs and larvae of several nematodes require adequate humidity to complete their development (Anderson 2000).

Wild animals are subjected to human exploitation or interventions, such as hunting and the wildlife trade, often experience heightened stress (Clark et al. 2008; Dickens et al. 2010) and are used in therapeutic activities and sociocultural & religious purposes (Solanki & Chutia 2009; Solanki et al. 2016). The growth of human populations, particularly in herbivore habitats, has further increased the risk of zoonotic transmission (Devaux et al. 2019). Chronic stress can suppress immune function, making animals more vulnerable to parasitic infections, leading to declining health and ultimately, death (Glaser & Kiecolt-Glaser 2005; Clark et al. 2008; Coe 2011). Habitat fragmentation and the resulting inbreeding have also been linked to higher parasite prevalence (Schad et al. 2005), although fragmentation may in some cases reduce parasite diversity (Anderson & May 1982). Human encroachment in natural habitats facilitates contact between people and wild herbivores, thereby increasing the chances of disease spillover and is viewed as a potential zoonotic agent for human wellbeing (de Thoisy 2001; Graczyk et al. 2001; Johnson et al. 2015; McLennan et al. 2018; Keatts et al. 2021).

Increasing anthropogenic activities are heightening contact between humans, domestic animals, and wildlife. These increases have been linked to changing human ecology, a growing human population, and its demand for bushmeat, wild animals as pets, agricultural land, natural resources, and the shrinking of wildlife habitats (Jones et al. 2008; Herrera & Nunn 2019; Gibb et al. 2020a; Plowright et al. 2021). However, the impact of human-herbivore interactions, both legal and illegal, on zoonotic pathogens remains insufficiently explored in the Dampa Tiger Reserve (DTR). Along the periphery of DTR, twelve villages practice shifting cultivation, which often attracts herbivores and other mammals into farmland areas (Gouda et al. 2020). Nath et al. (2021) provided a concept of "one health moment" and recognised wildlife as a major source of zoonotic infections, highlighting the need for further research in wildlife pathogen detection. In light of these implications, an attempt was made to study the occurrence and prevalence of parasites among wild herbivores in the Dampa Tiger Reserve, Mizoram, India.

MATERIALS AND METHODS

Dampa Tiger Reserve is located between 92.220–92.4566^0 E and 23.545–23.693^0 N, encompassing 500 km² of core area and 488 km² of buffer zone at elevations ranging 200–1,200 m. Situated within the Indo-Myanmar biodiversity hotspot, the reserve supports rich floral and faunal diversity, including numerous herbivore species. The climate is moderately seasonal, with winter temperatures ranging from 11–21 ^{0}C and summer temperatures from 19–37 ^{0}C. Twelve villages lie within the buffer zone, where shifting cultivation is the primary livelihood practice. The study site map is presented in Figure 1.

Dampa Tiger Reserve (DTR) supports 23 herbivore species (Table 1) representing the families Cercopithecidae, Sciuridae, Elephantidae, Cervidae, and Bovidae. Owing to this diversity, faecal samples were collected from multiple individuals within each family rather than from all species. The sampling area was the Terei range of DTR. As only one Asian Elephant was recorded, repeated samples were collected from the same individual at different time intervals. Faecal samples were identified in the field based on pellet morphology (shape, size, colour, and consistency) following Gopal (1993), with species confirmation through footprints and associated field signs (Apeldoorn et al. 1993). Fresh samples were collected between January and March 2019 from active sites within the known distribution of individuals, with assistance from the local forester. This study is a part of the fulfilment of the Master's degree program; therefore, the study was conducted for a limited period. Approximately, 10 g of each sample was preserved in 10% formalin and transported to the laboratory (Gillespie 2006). In total, 70 samples were obtained from 21 individuals (Table 2).

Samples were processed to detect enteric parasitic eggs and oocysts using direct smear, sedimentation,

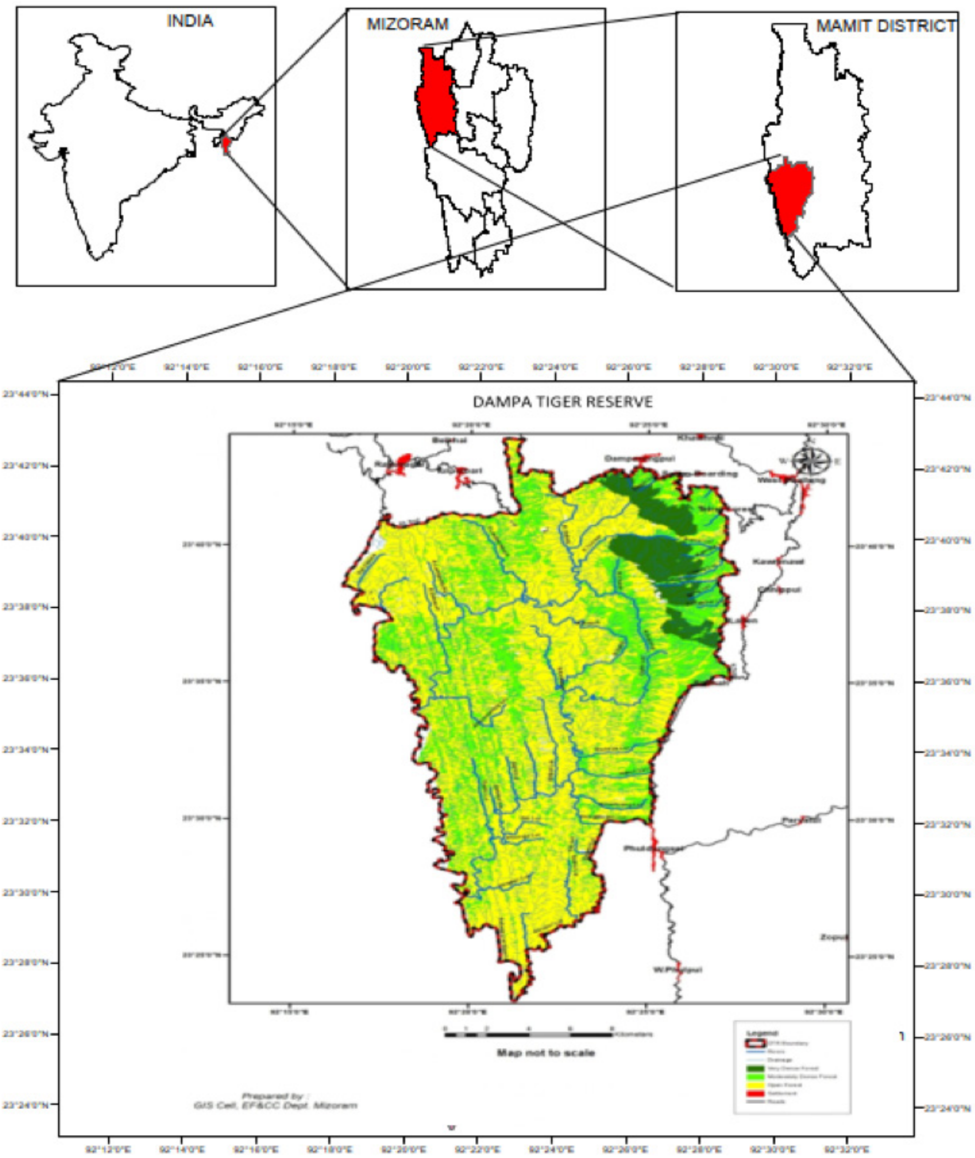

Figure 1. Map of Dampa Tiger Reserve.

and flotation techniques (Gillespie 2006). Prepared slides were systematically examined under a compound light microscope at varying magnifications. Parasite identification and confirmation were conducted at the College of Animal Husbandry and Veterinary Sciences. The data were compiled and organized for further analysis and graphical representation. Differences in gastrointestinal (GI) parasite prevalence among host families were assessed using the Kruskal-Wallis test. Pairwise comparisons between families were performed using the Mann-Whitney U test and the Wilcoxon rank sum test to evaluate variations in GI parasite prevalence.

RESULTS

Of 70 samples, 59 samples were found to be positive with ova or other stages of gastrointestinal parasites (GI). These parasite species include *Spirometra* sp., *Balantidium coli, Capillaria* sp., *Eimeria* sp., *Paragonimus* sp., *Giardia* sp., *Opisthorchis* sp., *Toxocara* sp., *Dicrocelium* sp., *Trichuris* sp., *Isospora* sp., Strongyle and *Ascaris* sp. In total, 84.29% of samples were found to be positive for the prevalence of GI parasites, and 15.71 % of the samples were found to be negative (Table 2).

Thirteen species of gastrointestinal parasites (GI) were recorded from herbivores of five different families (Table 3, Images 1 & 2). The highest level of

Table 1. List of herbivorous species present in Dampa Tiger Reserve.

Family	Common name	Scientific name
Cercopithecidae	i) Stump-tailed Macaque ii) Assamese Macaque iii) Northern Pig–tailed Macaque iv) Rhesus Macaque v) Phayre's Leaf Monkey vi) Capped Langur	i) *Macaca arctoides* ii) *Macaca assamensis* iiii) *Macaca leonina* iv) *Macaca mulatta* v) *Trachypithecus phayrei* vi) *Trachypithecus pileatus*
Sciuridae	i) Hairy-footed Flying Squirrel ii) Parti-coloured Flying Squirrel iii) Red-bellied Squirrel iv) Red Giant Flying Squirrel v) Orange-bellied Himalayan Squirrel vi) Black Giant Squirrel vii) Hoary-bellied Squirrel viii) Himalayan Striped Squirrel	i) *Belomys pearsonii* ii) *Hylopetes alboniger* iii) *Callosciurus erythraeus* iv) *Petaurista petaurista* v) *Dremomys lokriah* vi) *Ratufa bicolor* vii) *Callosciurus pygerythrus* viii) *Tamiops macclellandi*
Elephantidae	i) Asian Elephant	i) *Elephas maximus*
Cervidae	i) Hog Deer ii) Northern Red Muntjac iii) Brow-antlered Deer iv) Sambar	i) *Axis porcinus* ii) *Muntiacus muntjak* iii) *Rucervus eldii* iv) *Cervus unicolor*
Bovidae	i) Gaur ii) Red Serrow iii) Himalayan Serrow iv) Chinese Goral	i) *Bos gaurus* ii) *Capricornis rubidus* iii) *Capricornis thar* iv) *Naemorhedus griseus*

prevalence of *Ascaris* sp. was reported, followed by Strongyle whereas the prevalence of *Dicrocelium sp*. was the least. The prevalence of *Ascaris* sp. and Strongyle was 47.68% and 30.23%, respectively (Figure 2). Among the four categories of gastrointestinal parasites, nematodes and protozoans were predominant with 38.5% and 30.8% prevalence of GI parasites, followed by trematodes with 23.1%. These two categories of parasites, nematodes, and protozoans, together showed a prevalence of 69.3%, with heavy infection in herbivores in DTR. Occurrence of the cestode (*Spirometra* sp.) was also recorded. Five species of nematodes found in herbivores were: *Ascaris* sp., Strongyle, *Capillaria* sp., *Trichuris* sp., and *Toxocara* sp. Of these species, *Ascaris* sp. and Strongyle were the most common parasites found in almost all samples. The level of prevalence of gastrointestinal parasites in herbivores in the DTR, in general, is given in Figure 2.

Parasites from different families

Ascaris sp. and Strongyle are family specific; *Ascaris* prevailed more in members of the Cervidae family, and the Strongyle exhibited high prevalence in members of the Cercopithecidae family. Gastrointestinal parasites were highest in Cervidae (54.65%) followed by Cercopithecidae (43.02%) and Sciuridae (31.39%). The overall level of GI parasites in different herbivore families is given in Figure 3. The variations in prevalence in different families of herbivores were tested using the Kruskal-Wallis test and revealed that variations in the number of parasites in different families were significant ($\chi^2 = 36.822$, df = 5, $P < 0.01$). The Mann-Whitney test was then performed for pairwise variation on the infection with different families. The pairwise analysis of the different families of the herbivore is given in Table 4 The pair-wise variation in GI prevalence level showed a significance at $P < 0.001$ between Ceropithecidae vs. Elephantidae, Cercopithecidae vs. Bovidae, Sciuridae vs. Elephantidae, Bovidae vs. Cervidae, and Sciuridae vs. Bovidae (Table 4. This indicates that the level of infection

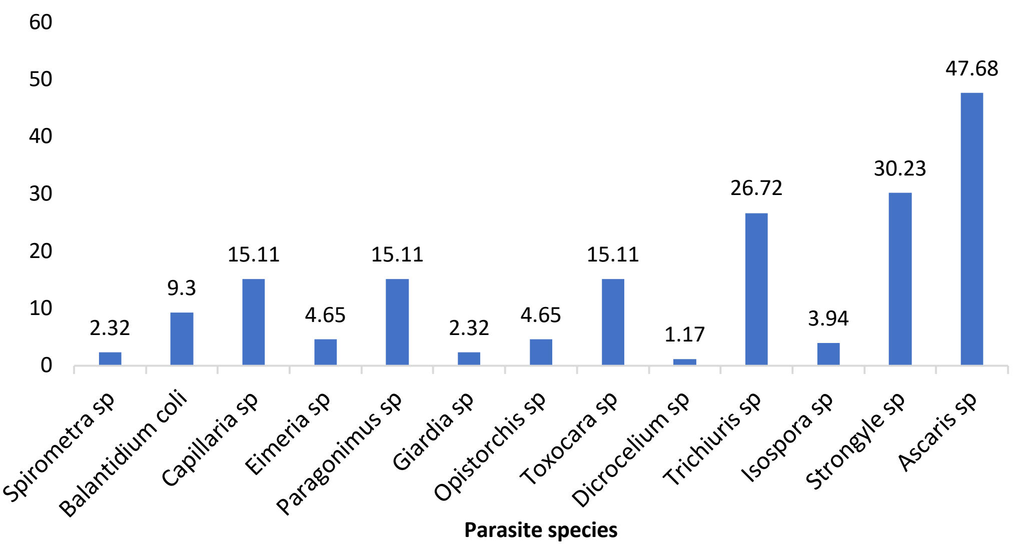

Figure 2. Prevalence (%) of gastrointestinal parasites in herbivores.

Table 2. Number of samples showed the prevalence of parasites in different families.

	Name of the family	No. of samples collected	No. of positive samples	No. of negative samples
1	Cercopithecidae	25	23	2
2	Sciuridae	12	12	0
3	Elephantidae	01	01	0
4	Cervidae	31	23	8
5	Bovidae	01	0	1
	Total	**70**	**59**	**11**
	Percentage		**84.29**	**15.71**

Table 3. Class of gastrointestinal parasites.

Nematodes	Trematodes	Protozoan	Cestode
Ascaris sp. Strongyle *Capillaria* sp. *Trichuris* sp. *Toxocara* sp.	*Opisthorchis* sp. *Paragonimus* sp. *Dicrocelium* sp.	*Isospora* sp. *Balantidium coli* *Giardia* sp. *Eimeria* sp.	*Spirometra* sp.

Table 4. Comparison of different families using the Mann-Whitney 'U' test.

	Different families	Mann-Whitney U	Wilcoxon W	P
1	Cercopithecidae vs. Sciuridae	136.5	227.5	0.818
2	Cercopithecidae vs. Elephantidae	23	114	0.001
3	Cercopithecidae vs. Bovidae	23	114	0.001
4	Cercopithecidae vs. Cervidae	78	169.5	0.753
5	Sciuridae vs. Elephantidae	30.5	121.5	0.001
6	Sciuridae vs. Bovidae	30.5	121.5	0.001
7	Sciuridae vs. Cervidae	69	160	0.411
8	Elephantidae vs. Bovidae	84.5	175.5	1
9	Bovidae vs. Cervidae	23	114	0.001

Image 1. Ova of gastrointestinal parasites: A—*Ascaris* sp. | B—Strongyle | C—*Trichuris* sp. | D—*Capillaria* sp. | E—*Toxocara* sp. | F—*Opisthorchis* sp.

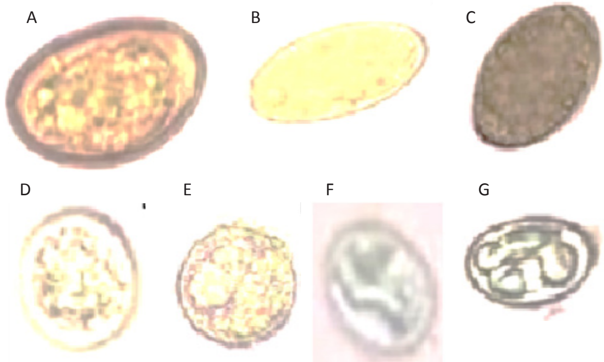

Image 2. Ova of gastrointestinal parasites: A—*Dicrocelium* sp. | B—Paragonimus sp. | C—*Spirometra* sp. | D—*Isospora* sp. | E—*Balantidum coli* | F—*Giardia* sp. | G—*Eimeria* sp.

by GI parasites was high in family Cercopithecidae (92% [23/25 samples]), Sciuridae (100% [12/12 samples]), and Cervidae (74% [23/31 samples]) (Table 2).

DISCUSSIONS

This study provides the first systematic assessment of gastrointestinal (GI) parasite occurrence and prevalence in herbivores of Dampa Tiger Reserve. *Ascaris* sp. had the highest prevalence (47.68%), followed by Strongyle (30.23%), and *Trichuris* sp. (26.72%). *Capillaria* sp., *Paragonimus* sp., and *Toxocara* sp. had a prevalence level of 15.11% each. Similar patterns have been reported in herbivores across different habitat conditions by Cisek et al. (2004), Santin et al. (2004), Pilarczyk et al. (2005), and Lim et al. (2008). Although prevalence rates varied among the studies reported, the ranges were 40%–18%, 52%–27.5%, 67%–35%, and 34.5%- 21.8% for helminths and protozoans, respectively. The prevalence of the cestode parasite (*Spirometra* sp.) was found in the present study (Table 3).

Nematodes are primarily transmitted through faecally contaminated soil, water, and forage, particularly in agricultural landscapes (Bethony et al. 2006). Grazing herbivores inadvertently ingest infective eggs or larvae while feeding, making them highly susceptible to infection. In DTR, primates of the family Cercopithecidae frequently forage in adjacent jhum (shifting cultivation) fields, increasing contact at the wildlife-agriculture

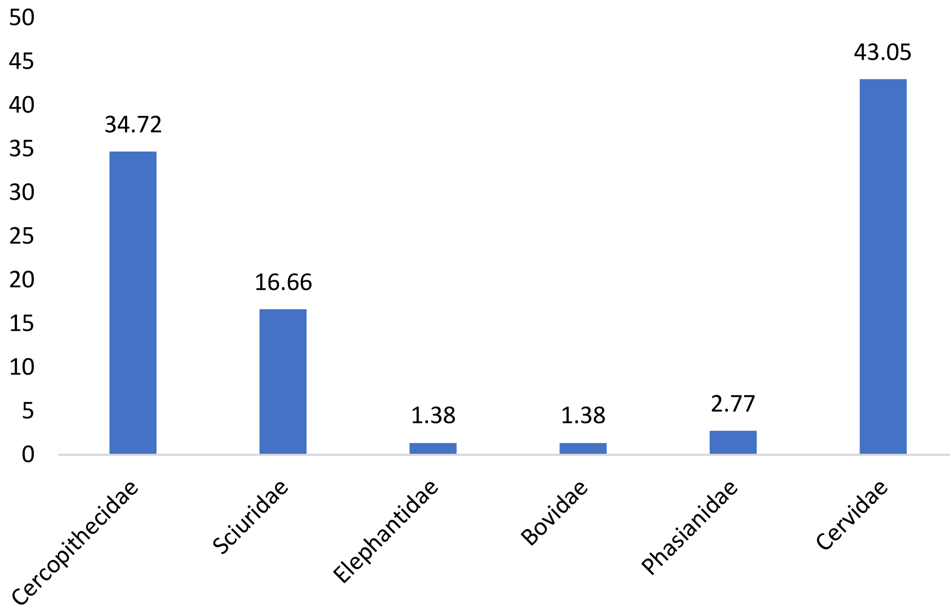

Figure 3. Overall prevalence level (%) of parasites in different families of herbivores.

interface and thereby elevating the risk of nematode and protozoan transmission (Dazak et al. 2000). Many nematodes and protozoans have direct life cycles that do not require intermediate hosts; transmission occurs via the faecal-oral route through contaminated feed, water, or soil (Thawait et al. 2014). Local communities draw untreated water directly from streams flowing through the reserve, thereby facilitating zoonotic transmission. Additionally, the reliance of approximately 21% of the local population on wild animals for bushmeat and ethnomedicinal purposes (Sloanki & Chutia 2009; Solanki et al. 2016) increases the likelihood of cross-species parasite exchange between wildlife and humans (Johnson et al. 2015).

Comparable trends for prevalence of helminths and protozoans have been observed in wild captive animals, including elephants, with prevalence rates of 58% & 6% (Varadharajan & Kandasamy 2000), and 50% & 18.8% (Parasani et al. 2001), respectively. The overall prevalence of gastrointestinal parasites in this study (84.29%) (Table 2) was higher than that reported by Corden et al. (2008) at 72.5% and Dahal et al. (2023) at 47.57%. Lower prevalence rates have also been documented as 42.4% (Reddy et al. 1992), 40.4% (Chakraborty & Islam 1996), 48.1% (Modi et al. 1997), 60.7% (Parasani et al. 2001), 56.3% (Lim et al. 2008). Such variations are likely influenced by geographic, climatic, and ecological factors that affect parasite transmission and host–parasite dynamics (Lalremruati & Solanki 2020; Moustafa et al. 2021; Anusha et al. 2025). Parasitic infections are known to be prevalent widely in warm and tropical climates where temperature, humidity, and light conditions favour parasite development and survival (Magona & Musisi 1999). These parasites, particularly trematodes and certain cestodes, require intermediate hosts for completion of their life cycles (Atanaskova et al. 2011). However, due to the limited scope of this study, life history parameters related to the identification of intermediate hosts were not examined.

Dampa Tiger Reserve hosts a rich diversity of carnivores (Singh et al. 2016; Singh & MacDonald 2017; Vandir et al. 2022), which rely on herbivores as their principal prey. This trophic relationship increases the potential for parasite transmission from herbivores to carnivores. Vandir et al. (2022) reported a gastrointestinal (GI) parasite prevalence rate of 90.47% among carnivores in DTR, with most parasite species corresponding to those identified in herbivores. Of the 13-parasite species in herbivores, 10 were common in carnivores in DTR. Frequent human-herbivore interactions also occur in and around the 12 villages adjacent to the reserve (Solanki et al. 2016), where bushmeat consumption poses a significant zoonotic risk (Keatts et al. 2021). The dependency of the local population (21%) on wild animals as sources of bushmeat and as ethnomedicines (Solanki et al. 2016) also increases the possibilities of cross-transmission of zoonotic diseases several-fold. Increasing human encroachment into wildlife habitats further heightens the risk of zoonotic disease transmission between wildlife and local communities

(Gibb et al. 2020; Recht et al. 2020). Agricultural fields surrounding protected areas often function as peri-habitats for several herbivores, increasing the likelihood of exposure to zoonotic pathogens. Increasing landscape modification, greater human intrusion into wilderness areas, habitat fragmentation, the presence of free-ranging domestic animals, and seasonal ecological changes further intensify interactions among wildlife, livestock, and humans. Consequently, zoonotic parasites may eventually breach existing ecological barriers, shifting to new hosts such as livestock and ultimately humans (Otranto et al. 2015; Gibb et al. 2020a,b; Keatts et al. 2021; Plowright et al. 2021).

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