Uttar Pradesh Journal of Zoology

Volume 44, Issue 1, Page 56-66, 2023; Article no.UPJOZ.2404
ISSN: 0256-971X (P)

Prevalence and Distribution of Endoparasites in Carnivorous Primates from Thrissur Zoological Garden

M. Jaya [a#*], K. J. Sandra [a†], M. Aja [b‡], C. B. Prasanth [c#], R. Brinesh [b#] and M. Krishna [d#]

[a] Department of Zoology, Sree Kerala Varma College, Thrissur, Kerala, India.
[b] Department of Zoology, Sree Krishna College, Guruvayur, Thrissur, Kerala, India.
[c] Department of Statistics, Sree Kerala Varma College, Thrissur, Kerala, India.
[d] Department of Mathematics, Sree Kerala Varma College, Thrissur, Kerala, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.56557/UPJOZ/2023/v44i13391

Editor(s):
(1) Dr. Belisario Dominguez-Mancera, University Veracruz, Mexico.
Reviewers:
(1) Tariku Geinoro Alleyo, Ethiopia.
(2) Aseel Mohammed Hamzah, Baghdad University, Iraq.
(3) Kholik Kholik, Universitas Pendidikan Mandalika, Indonesia.

Original Research Article

Received: 25/10/2022
Accepted: 30/12/2022
Published: 18/01/2023

ABSTRACT

The animals selected for the endoparasitic observation are four species of carnivorous mammals specifically, Asiatic lion (*Panthera leo persica*), Bengal tiger (*Panthera tigris tigris*), Indian leopard (*Panthera pardus fusca*) and Indian jackal (*Canis aureus indicus*) that have been captivated in Thrissur zoo. By using direct smear inspection, conventional sedimentation, and flotation procedures, the faecal samples were subjected to a thorough routine parasitological study to

[#] Assistant Professor;
[†] M.Sc Student;
[‡] Guest Lecturer;
**Corresponding author: Email: jayamanazhy@gmail.com;*

determine the presence of parasite eggs and oocysts. The current analysis revealed that helminth and protozoan parasites infest four species of carnivorous mammals. *Ancylostoma, Toxascaris leonina, Toxocara*, Strongyle type and the trematode eggs of the species of *Paragonimus* as well as the coccidian genera *Isospora* of protozoa, were all observed to be abundant in the gastro intestinal tract of chosen mammals as a result of the study. By statistical analysis, according to the most recent observations it is noticed that*Toxocara* makes upon 25% of wild mammals, and any of the parasites infects 60% of wild mammals.

Keywords: Carnivore; mammals; Ancylostoma; Toxascaris; Toxocara; strongyle; Paragonimus; isospora.

1. INTRODUCTION

Zoos are an ex-situ form of conservation wherein animals are displayed in cages or enclosures for esthetic, academic and conservation purposes [1]. Some researchers have found out that gastrointestinal parasites of animals under captivity may incorporate zoonotic species to humans and raise public health concerns [2,3]. In captivity wild animals may succumb to parasitic infections because of environmental pressure consisting of trade within the dwelling situations and space barriers [4,5]. The steady stress of captivity makes animals more at risk of parasitic contamination as the immune mechanism of these captive animals becomes vulnerable [6,7]. In wild situations, animals have some natural resistance towards parasitic sicknesses and there is a nation of equilibrium among the parasite and the host and it seldom led to harmful infection until burdened. Parasitism is one of the essential constraints proscribing farm animals' productions [8]. In wild animals of loose life, parasitism exists certainly and frequently has no clinical signs of disease or parasitosis [9]. The spectrum of parasitic sicknesses in wild animals is of top-notch importance both in human and veterinary medicinal drug. Under captivity, the fitness status of zoo animals varies with various factors inclusive of control, feeding, surroundings, sanitation and seasonal variation.

Several endoparasitic studies in captive mammals are available from literature [10-14]. Delprá-Cachulo et al. [15] 2022 concluded that the parasitic infection can be potential risk to the health of animals in particular to the ones are at the verge of extinction and additionally presence of the zoonotic parasites might also pose a risk to health of care givers. Moreover, for the reason that some wild mammals are reservoirs for parasites, they will function resources of infectious sicknesses which can have an effect on home animals and/or people [16,17]. Endoparasitism in several mammals including equines, bovines, beavers, wild dog, spotted hyaena etc. were reported by various authors [18-23]. Recently, Figueiredo et al. [24] summarised endoparasite diversity of the wild ungulates. Studies by Abraham et al. [25], Nimisha et al. [26], Abhijith et al. [27], Benedict et al. [28] and Thankachan et al. [29] are some of the recent reports from Kerala. From these studies it is clear that, endoparasitic infections may prove severe threat to the health of animals.

Kerala, India is domestic to many charismatic huge mammals; a lot of those species are indexed as nationally and globally threatened species. But there is a severe paucity of statistics on GI parasites of wild mammals. Consequently, this study changed into finished with the purpose of determining the superiority, load and richness of intestinal parasites (protozoa and helminths) in the faecal samples of untamed mammals accrued from Thrissur Zoo. The prevailing examines targeted on four exclusive species of carnivorous mammals specifically, Asiatic lion (*Panthera leo persica*), Bengal tiger (*Panthera tigris tigris*), Indian leopard (*Panthera pardus fusca*) and Indian jackal (*Canis aureus indicus*) that have been captivated in Thrissur zoo.

2. METHODOLOGY

2.1 Statement of Ethics

No live animals were used in the study's experiments. We haven't hurt or killed any animals either. As a result, no licences are needed in India from any ethical bodies or authorities on conservation. The zoo authorities in Thrissur gave permission to perform experiments using captive carnivorous animals.

2.2 Sampled Animals

The IUCN Red List categorises the Asian lion and Bengal tiger as endangered species, while the Indian leopard is listed as vulnerable. It is

regarded as a member of the amazing megafauna. They typically prefer hunting huge ungulates like chital, sambar, wild boar, hog deer, and Indian muntjac because they are carnivores. Porcupines, hares, and peafowl are just a few examples of the small prey species that make up relatively little of its diet. It also preys on domestic livestock due to human encroachment on tiger habitat. Along with the Asiatic lion, Bengal tiger, snow leopard, and clouded leopard, the Indian leopard is one of the large cats that can be found on the Indian subcontinent. The leopard has an extremely diverse diet and is a skilled, opportunistic hunter. Indian jackals are essentially scavengers who live off of trash and offal. Insects, fruit, and rodents are used to enhance its diet. When wild prey is in short supply, it typically resorts to consuming plant stuff, such as maize and jujube fruit.

2.3 Site Description

The study was carried out in the 13.5-acre (5.5 ha) Thrissur Zoo, which was founded in 1885 and is located in the city of Thrissur, Kerala, India having 10.5302^0N Longitude and 76.2229^0 E Latitude. One of the nation's oldest zoos, it is home to a huge variety of animals, reptiles, and birds. The zoo complex houses a natural history museum, an art museum, a zoological garden, and a botanical garden that all highlight the socio-cultural past of the area.

2.4 Description of Cage

The Asian lion, Bengal tiger, Indian leopard, and Indian jackal are all kept in separate enclosures, cleaned frequently, and given the appropriate prophylaxis. Beef is used to feed these creatures.

2.5 Faecal Sample Collection

With the help of an official, a total of 60 fresh faecal samples from four distinct mammal species were taken from the Thrissur Zoo. Each test animal had fifteen fresh stool samples taken from it. The faeces samples were transported to the Department of Agriculture laboratory at Mannuthy, Thrissur, for parasitological analysis in correctly labelled plastic bottles.

2.6 Preservation of Faecal Samples

It is always preferable to take samples directly from the rectum. Fresh faeces may be retrieved off the floor if this is not practicable. The ideal amount of faeces to collect is five grammes. Since the eggs develop quickly, the samples should be kept chilled unless they will be examined within a day. The samples can be preserved by adding twice as much 10 percent formalin if they are going to be sent to the lab for processing.

2.7 Processing of Samples

By using direct smear inspection, conventional sedimentation, and flotation procedures, the faecal samples were subjected to a thorough routine parasitological study to determine the presence of parasite eggs and oocysts. To diagnose parasite infections of the digestive system, faeces samples are typically examined by standard protocols [30]. The processed faeces sample is examined for the presence of protozoan and helminthic eggs.

2.8 Concentration Method

By using concentration techniques or direct smear inspection, faecal sample analysis is qualitatively assessed for the identification of parasite infection. In the direct smear technique, a small amount of faeces is mixed with an equal amount of water and viewed via the microscope's low-power objective. This approach is only useful for identifying relatively severe infections. Therefore, the concentration approach was used in the current investigation. The helminthic ova found in the sample, however, are concentrated using concentration procedures either through sedimentation or flotation (Fig. 2). This approach is simpler since it effectively removes most of the waste from the faeces.

2.9 Sedimentation Method

According to this approach, 1 gramme of faeces is combined with 15 ml of water or 10% formalin in a mortar and pestle, and the coarse particles are then filtered off. After that, the filtrate is put into a centrifuge tube and spun at 2000-3000 rpm for 2-3 minutes. The parasite eggs will fall to the test tube's bottom. The sediment is next studied under a light microscope after the supernatant has been drained off.

2.10 Flotation Technique

Faeces suspended in a liquid with a specific gravity greater than an egg forms the basis of

flotation. The egg will rise to the top of the water. A saturated solution of sodium chloride, zinc sulphate, or sugars is a frequently used flotation solution. 10 ml of flotation solution are combined with 1 gramme of faeces before being well mixed. Saline solution is the floating medium employed in this technique (NaCl). The filtrate is carefully transferred to a test tube and filled to the top without overflowing with extra flotation solution. The liquid surface is covered with a coverslip, and the tube is left unattended for 15 to 30 minutes. After that, the coverslip is removed vertically and placed upside down on a glass slide for microscopic analysis. More than 30 minutes should not be spent mixing the sample with the flotation solution because doing so will cause the sample to shrink and affect the eggs' morphology. Eggs floating in a flotation medium can be accelerated by centrifugation.

2.11 Statistical Analysis

The data was statistically analysed for the hypothesis's scientific validation. Population Proportion of the presence of *Toxocara* species in wild animals is estimated and tested under 95% confidence. Also the proportion of the presence of anyone of the parasites in wild mammals also tested.

3. RESULTS AND DISCUSSION

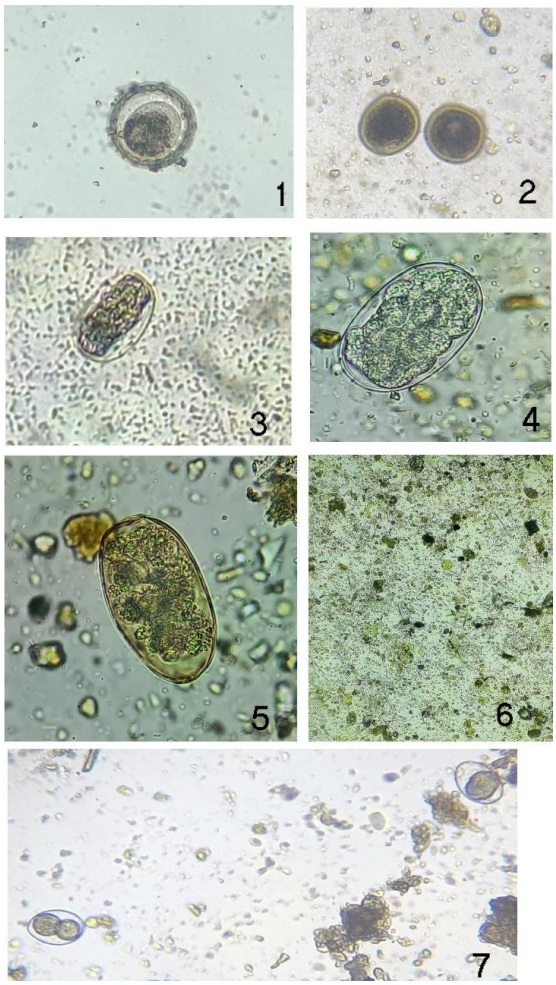
The investigation showed that four species of carnivorous mammals kept in the Thrissur Zoo have helminth and protozoan parasites.

Table 1. The demeanour of gastrointestinal parasitic eggs in carnivorous mammals observed, +/- indicates the presence/absence of eggs

Animals studied	Appearance of parasitic eggs in five different days					Parasitic eggs
	Day 1	Day 2	Day 3	Day 4	Day 5	
Asiatic lion	+	-	-	+	-	*Toxocara*
(Panthera leo	-	-	-	-	-	*Paragonimus*
persica)	-	-	-	+	-	*Toxascaris leonina*
	-	-	-	-	-	*Strongyle*
	+	-	-	-	-	*Ancylostoma*
	-	-	-	+	-	*Isospora*
	-	-	-	-	-	*Diphyllobothrium latum*
Bengal tiger	-	+	-	+	-	*Toxocara*
(Panthera tigris tigris)	-	-	-	-	+	*Paragonimus*
	-	-	-	-	+	*Toxascaris leonina*
	-	-	-	+	-	*Strongyle*
	-	-	-	-	-	*Ancylostoma*
	-	-	-	-	-	*Isospora*
	-	-	-	-	-	*Diphyllobothrium latum*
Indian leopard	-	-	-	-	-	*Toxocara*
(Panthera pardus	-	-	+	-	+	*Paragonimus*
fusca)	-	-	-	-	-	*Toxascaris leonina*
	-	-	-	-	-	*Strongyle*
	-	-	-	-	-	*Ancylostoma*
	-	-	-	-	+	*Diphyllobothrium latum*
	-	-	-	-	-	*Isospora*
Indian jackal (Canis	-	-	-	-	-	*Toxocara*
aureus indicus)	-	-	-	-	-	*Paragonimus*
	-	-	-	-	-	*Toxascaris leonina*
	-	-	+	-	-	*Strongyle*
	-	-	-	-	-	*Ancylostoma*
	-	-	-	-	-	*Diphyllobothrium latum*
	-	-	-	-	-	*Isospora*

Table 2. Richness and prevalence of the gastrointestinal parasites in four large mammal taxa in the Thrissur Zoo, Kerala, India

Species	Total samples analyzed	Total positive samples	parasitic richness	Prevalence (%)
Asiatic lion (Panthera leo persica)	15	15	*Toxocara* *Toxascaris leonina* *Ancylostoma* *Isospora*	100
Bengal tiger (Panthera tigris tigris)	15	15	*Toxocara* *Toxascaris leonina* *Strongyle* *Paragonimus*	100
Indian leopard (Panthera pardus fusca)	15	9	*Paragonimus* *Diphyllobothrium latum*	60
Indian jackal (Canis aureus indicus)	15	3	*Strongyle*	20



Figs. 1-7. Representing the eggs of parasites collected from faecal samples of selected mammals under captivity

1-Toxocara; 2- Toxascaris leonina; 3 – Ancylostoma;
4- Strongyle; 5- Paragonimus; 6- Diphyllobothrium latum ; 7- Isospora

The current analysis elucidate the occurrence and prevalence of seven different parasitic eggs from four different carnivorous mammals. *Toxocara* (Nematoda: *Toxocaridae*) infection occurs by the ingestion of eggs containing an infective second stage larva. The cervical alae are very broad and are striated (Fig. 1). *Toxascaris leonina* (Nematoda*: Toxocaridae*) eggs are slightly oval, with smooth sides (Fig. 2). *Ancylostoma* (Nematoda: *Ancylostomatidae*) egg is small in size and oval in shape. It is thin shelled and contain about eight celled embryo (Fig. 3). *Strongyles* (Nematoda : Strongylidae) egg is oval in shape and thin shelled with a smooth surface. It contains embryonated mass inside (Fig. 4). *Paragonimus* (Platyhelminthes: *Paragonimidae*) egg is large in size and oval in shape. They are yellowish-brown in colour. It is provided with an operculum, and the shell is thickened at the pole opposite this (Fig. 5). *Diphyllobothrium latum* (Platyhelminthes: *Diphyllobothriidae*) egg is oval in shape. It is thin shelled yellowish tint and have round shaped ends. Shell with operculum and have an unsegmented embryo inside (Fig. 6). *Isospora* (Apicomplexa :*Eimeriidae)* egg is large in size. It has spherical or ellipsoidal shape. Each oocyst contains two sporocysts with four sporozoites. It also contains residual bodies (Fig. 7).

As shown in Table 2, 44 of the 60 total samples, analysed and tested positively for gastrointestinal parasite infection. In addition to the eggs of the cestode *Diphyllobothrium latum*, the presence of nematode eggs of the genera *Ancylostoma, Toxascaris leonina, Toxocara, Strongyle* type, and trematode eggs of the species *Paragonimus* (Table 1, Figs. 1-7) were also found. The parasitic richness for the group of protozoa included oocysts of the genera coccidia (Fig. 7). Only Asiatic lions have reported positive for parasitic egg tests on day 1 of the study (Table 1). The protozoan parasite, *Isospora* and the nematode, *Ancylostoma* has been reported only for Asiatic Lion and *the cestode, Diphyllobothrium latum* for Indian Leopard (Table 1). A striking feature is that only the egg of one parasitic species has been observed in our study for Indian Jackal. Table 2 showed that parasite prevalence in the faeces of Bengal tiger and Asiatic lion was 100%, 60% in Indian Leopard, and 20% in Indian Jackal.

Among the 44 positive samples, faeces from four carnivorous mammals contained the eggs of 16 *Toxocara*, 8 *Paragonimius*, 6 *Toxascaris leonina*, 5 *Strongyle*, 4 *Ancylostoma*, 2 *Isospora*, and 3 *Diphyllobothrium latum* (Fig. 8).

Albendazole and fenbendazole will be given 15 mg/kg as three consecutive days every three months to these four mammals. *Diphyllobothrium latum,* a common fish tapeworm found in *Panthera pardus fusca*, was one of the standout characteristics noted. It is uncertain where this parasite originated in beef-eating leopards kept in captivity. Four different parasitic eggs were found in Asian lions and Bengal tigers, two in leopards, and one in Indian jackals (Table 3).

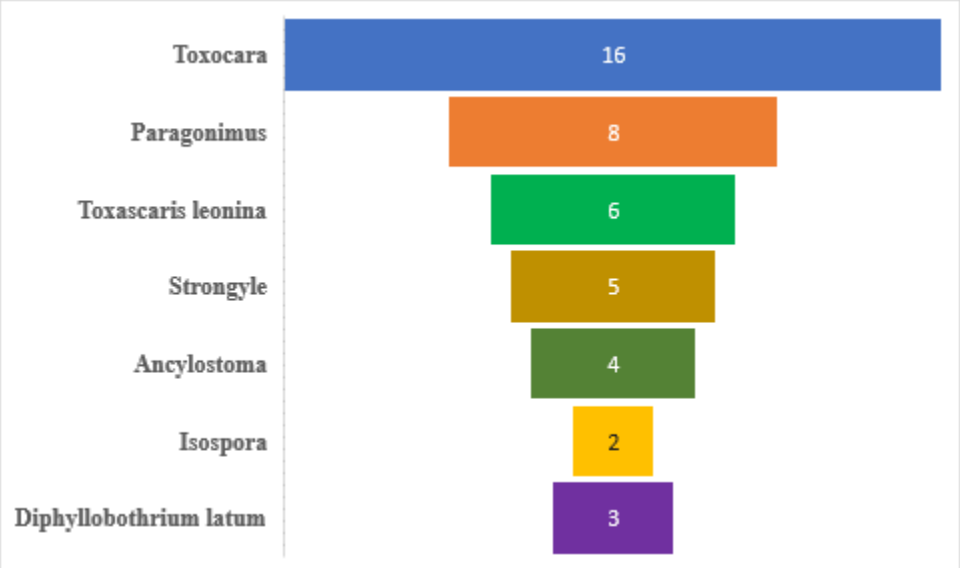


Fig. 8. Representation of parasitic richness from 60 samples collected from four different mammals

Table 3. Number of positive samples and the distribution of parasitic eggs in Four different mammals

Sl. No.	Species selected	Identified endoparasites	Number of positive feacal sample
1	*Asiatic lion (Panthera leo persica)*	*Toxocara*	8
		Toxascaris leonina	3
		Ancylostoma	4
		Isospora	2
2	*Bengal tiger (Panthera tigris tigris)*	*Toxocara*	8
		Toxascaris leonina	3
		Strongyle	2
		Paragonimus	2
3	*Indian leopard (Panthera pardus fusca)*	*Paragonimus*	6
		Diphyllobothrium latum	3
4	*Indian jackal (Canis aureus indicus)*	*Strongyle*	3

Table 4. Showing proportion analysis of *Toxocara* species

Sample Size (n)	Sample proportion	Calculated Z	$Z_{(\alpha/2)}$ α =0.05	P value	Conclusion
60	0.27	0.37	1.96	0.71	not significant

Table 5. Showing proportion analysis of anyone of the parasites in wild mammals

Sample Size (n)	Sample proportion	Calculated Z	Z α α=0.05	P value	Conclusion
60	0.70	1.58	1.645	0.06	not significant

From the sample observation it is observed that 27% of wild mammals having the presence of *Toxocara*. Hence, we are setting a null hypothesis H_o as in 25% of wild mammals the *Toxocara* species is present against the alternate H_1 it is not equal to 25%, at a level of significance α = 0.05 and Critical Region IZI > Z_α where IZI =.37 and Z_α =1.96, P value = 0.71138 and finally accepted the H_o (Table 4).

Also, from the real sampling data, it is found that in 70% of wild mammals - there is a presence of anyone of the parasites. Hence, in general, we are setting the null hypothesis H_o as in 60% of wild mammals there is a presence of anyone of the parasites (*Toxocara*, *Paragonimius*, *Toxascaris leonina*, *Strongyle*, *Ancylostoma*, *Isospora*, and *Diphyllobothrium latum)* against the alternate H_1 it is greater than 60%, at a level of significance α = 0.05 and Critical Region IZI > Z_α where IZI =1.58 and Z_α=1.645, and finally accepted the H_o (Tables 4 & 5).

From this it can be concluded that *Toxocara* makes up 25% of wild mammals, and any of the parasites infect 60% of wild mammals, according to the most recent observations. A parasitic helminth species, *Toxocaridae* have reported from the small intestines of family Cats and other wild Felidae. Infection is brought on by eating eggs that contain an infectious second stage larva. Heavy infections are most frequently found in kennels and catteries, and young animals may become severely infected in these settings if hygiene standards are not upheld. Zoo staff members give medication for the care and control of animals. In kennels and catteries, proper hygiene is essential. In the case of *Toxocara*, where oral infections immediately result in a patent infection, the parasite can be removed with routine therapy and periodic thorough cleaning of the surroundings. The infective stage is the egg harbouring a second stage larva, much like *Toxocara* species. The *Toxocarid* egg shell is thick and pitted. Unless there are numerous parasites present in young animals or animals that are otherwise weakened, infections are often moderate. It is advised to thoroughly clean or replace anything the animal has come into touch with to avoid the spread of parasitic roundworms, including bedding and kennels. Additionally, it is strongly advised to clean up any potential defecation sites outside and to regularly remove any waste from outdoor pet runs, crates, and the yard.

Ancylostoma, which belongs to the family Ancylostomatidae, can be found in the small intestine of canines, wolves, coyotes, foxes, and other wild carnivores, as well as very rarely in humans. Faeces contain eggs that have been secreted into the environment as a result of sexual reproduction [31-33]. The egg is small in size and oval in shape. It is thin shelled and contain about eight celled embryos when passed in the faeces.

Strongyles being categorised as a family Strongylidae are frequently parasitic in mammals' digestive tracts, particularly grazers like deer, sheep, cattle, and horses. Strongyle eggs have an oval form, a thin shell, and a smooth exterior. Inside, there is embryonated mass. Deworming frequently is essential.

Paragonimus is a trematode 'lung fluke' coming under the family Paragonimidae occurs in the lungs and more rarely in the brain, spinal cord and other organs of the pig, dog, cat, goat, cattle, fox etc. The *paragonimus* egg is big and oval in shape. Their colour is a yellowish-brown. It has an operculum, and the shell is thicker at the pole across from it. A cestode worm belonging to the family Diphyllobothriidae called *Diphyllobothrium latum* can be found in the small intestine of several animals, including humans, dogs, cats, pigs, polar bears, and others. An oval-shaped egg is produced by *Diphyllobothrium latum*. It has a thin, yellowish-tinted shell and spherical ends. Inside the operculum-covered shell is an unsegmented embryo. *Diphyllobothrium latum* is a parasite that causes the disease diphyllobothriasis.

Different larval cestode infections have been reported in previous studies, most of the cases mortality rates were high, showing that the control of these infections might be of critical importance in maintaining the well-being of National parks [34].

In this investigation, eggs of *Isospora* was found in faeces sample collected from Asiatic lion. *Isospora* eggs that have sporulated are big in size. It is ellipsoidal or spherical in shape. Each oocyst contains two sporocysts with four sporozoites. Good hygiene, correct effluent disposal, isolating affected people, and preventing crowding are all examples of control strategies. These are especially important in circumstances involving intense husbandry, such as breeding facilities, kennels, and rescue facilities.

In most regions of the world, *Toxascaris leonina*, a member of the Toxocaridae family, is found in the small intestine of domestic and wild felid and canid animals as well as dogs, cats, and foxes [35]. Their eggs are slightly oval with smooth sides. The gastrointestinal parasite species discovered in this study have already been observed in confined animals in a number of zoological gardens and National parks by other authors [36,9,37,1,38,39]. In six different captive mammals, Hewavithana *et al*., 2021 found eight forms of GI parasites, including protozoan cysts, nematode ova (*strongyle, strongyloid, ascarid*, and *trichuroid* varieties), and rhabditiform larvae. According to Martin-Solano *et al*., 2017 the only genus common to captive and free-ranging individuals was *Strongyloides* sp. The current study also identified *Strongyle* species and *Toxocara* sp. in Bengal Tigers and Indian Jackals, *Toxocara* sp. and *Toxascaris leonina* in Asian Lions. *Toxocara* sp. and *Toxascaris* sp. infection is via oral-faecal due to their direct biological cycle, therefore it is tied to appropriate hygiene and cleaning standards of the enclosures, even though it may require a paratenic host. According to Mir et al. [40] both helminth and protozoan infection were observed in 48% of animals in captivated mammals. In the current investigation, six different helminth egg types were found in four different mammals, and the protozoan parasite was only found in Asiatic lions. Similar results were reported by Lim et al. [41], Fagiolini et al. [21], and Houssain et al. [9], who also noted a higher helminth infection than protozoan infection in an Italian zoo.

However, it is contrary to the studies of Levecke et al. [42], and Hewavithana et al. [43] who reported higher protozoan infection compared to helminthic infection. Such information would also assist in identifying potential dangers to domestic animals and humans living in areas adjacent to natural habitats further contributing to assist the process of preventing zoonotic outbreaks [44,15]. Investigating the disease burden of wildlife is therefore an important aspect of wildlife conservation and management [16].

The high incidence of gastrointestinal parasites found in this study is suggestive of subclinical infection since there were no overt clinical symptoms of disease or mortality. The widespread prevalence and transmission of GI parasites are typically severely controlled in caged animals. It has been reported that individual differences in infection loads and the variety of co-infecting parasite taxa may also exist [45,43].

Through captive breeding and reintroduction operations, zoo populations are a special and crucial source for research on wildlife and their habitats as well as for the preservation of endangered species [44]. In nature, almost no species is immune to parasite infection, yet they frequently develop resistance to illnesses of lower severity. By paying close attention to proper feeding, watering, hygiene upkeep, husbandry practises, disease prophylaxis, and treatment in captivity, it is possible to get rid of these parasites.

4. CONCLUSION

Zoological gardens are designed to preserve endangered animal species and assess the need for biodiversity protection. From the present study, it can be concluded that *Toxocara* makes up 25% of wild mammals, and any of the parasites infect 60% of wild mammals, according to the most recent observations. The presence of *D. latum* in meat-eating *Panthera* species is being investigated further. It is beneficial to become knowledgeable about the various illnesses that affect wild and exotic animals in captivity. The research will be used to develop the best deworming procedure for these captive animals in order to control parasites. Although the overall management of the zoo, including nutrition, sanitation, and deworming practises, was adhered to, the study finds room for improvement in the management of the zoo through re-standardizing/re-investigating or re-scheduling the anthelmintic programme, regular examinations for parasitic infections, and early season treatments to prevent infection.

ACKNOWLEDGEMENT

We would like to express our great gratitude to Dr. Dhanya V. R. Veterinary Surgeon, State Museum and Zoo, Chembukavu, Thrissur, for providing samples and to Dr. Bindu Lakshmanan, Head of Parasitology Department, College of Veterinary and Animal Science, Mannuthy, Thrissur, for the parasitological investigations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Thawait VK, Maiti SK, Dixit AA. Prevalence of gastro-intestinal parasites in captive wild animals of Nandan Van Zoo Raipur Chhattisgarh. Veterinary World. 2014;7(7): 448–451.
2. Otegbade AC, Morenikeji OA. Gastrointestinal parasites of birds in zoological gardens in south-west Nigeria. Trop. Biomed. 2014;31(1):54–62.
3. Opara MN, Osuji CT, Opara JA. Gastrointestinal parasitism in captive animals at the zoological garden Nekede Owerri Southeast Nigeria. Rep. Opin. 2010;2(5):21–28.
4. Rana MA, Ahmad I, Jabeen F, Naureen A, Shabnam M. Comparative study of endo-parasites from faecal samples of sambar (*Rusa unicolor*) and goral (Naemorhedus goral) in captivity. Journal of Biodiversity and Environmental Sciences. 2015;6(5): 399-408.
5. Atanaskova E. Endo-parasites in wild animals at the zoological garden in Skopje Macedonia. Journal of Threatened Taxa. 2011;3(7):1955–1958.
6. Gracenea M, Gomez MS, Torres J, Carne E, Fernadez-Moran J. Transmission dynamics of Cryptosporidium in primates and herbivores at the Barcelona Zoo: A long-term study. Veterinary Parasitology. 2002;104:19–26.
7. Cordon GP, Prados AH, Romero D, Moreno SM, Pontes A, Osuna A, Rosales MJ. Intestinal parasitism in the animals of the zoological garden “Pena Escrita” (*Almunecar Spain*) Veterinary Parasitology. 2008;156:302–309.
8. Kabir BHM, Eliyas M, Hashem AM, Mohiuddin M, Miazi O. Prevalence of zoonotic parasitic diseases of domestic animals in different abattoir of Comilla and Brahman Baria region in Bangladesh University. Journal of Zoology Rajshahi University. 2010;28:21-25.
9. Houssain NM, Dey RA, Begum N, Farjan T. (Parasitic infection in captive wild mammals and birds in Bangabandhu Sheikh Mujib Safari Park. Cox’s Bazar Bangladesh Journal of Threatened Taxa. 2021;13(3):17889-17894.
10. Darabus G, Afrenie M, Hotea I, Imre M, Morariu S. Endoparasites in mammals from seven zoological gardens in Romania. Journal of Zoo and Wildlife Medicine. 2014;45(2):239-246.
11. Gonzalez-Ramirez LC, Vazquez CJ, Chimbaina MB, Djabayan-Djibeyan P, Prato-Moreno JG, Trelis M, Fuentes MV. Occurrence of enteroparasites with

zoonotic potential in animals of the rural area of San Andres Chimborazo Ecuador. Veterinary Parasitology: Regional Studies and Reports. 2021;26:100630.

12. Santos IG, Dos, Batista AIV, Silva WSIDa, Oliveira Neto MB, Schettino SC, Oliveira MR, Ramos RA N, Alves LC, Bezerra-Santos M, Lima VFS. Gastrointestinal parasites in captive wild animals from two Brazilian Zoological Gardens. Research Society and Development. 2022;11(4):e2841142663.
13. Kapnisis K, Kassinis N, Papanikolopoulou V, Diakou A. Endoparasites in wild populations of Cyprus mouflon (*Ovis gmelini* ophion). Veterinary Parasitology: Regional Studies and Reports. 2022;34: 100767.
14. Pacifico L, Sgadari MF, D'Alessio N. First description of Eucoleus garfiai (Gallego and Mas-Coma 1975) in wild boar (Sus scrofa) in Italy. Parasitol Res. 2022;121:1683–1689.
15. Delprá-Cachulo J, Labrada-Martagón V, Comas-Garcia M, Ruiz G, González-Hernández M. Endoparasitic infections in captive wild mammals under human care in San Luis Potosí Mexico. Agro Productividad. 2022;15(9):99-107.
16. Peterson MJ, Ferro JP. Wildlife health and disease: surveillance investigation and management. Johns Hopkins University Press. 2012;7:181-206.
17. Marin AM, Moranu Maria MF, An, Dan Popovici, Cirsean CA, Pavlovic I, Kaya A, Georgiana M, Mederle N. Study regarding the endoparasitism in goats from Dolj County. Lucrari Stiintifice Medicina Veterinara. 2022;LV(2):142-151.
18. Hutchens DE, Paul AJ, DiPietro JA. Treatment and Control of Gastrointestinal Parasites. The Veterinary clinics of North America. Equine Practice. 2000;15(3):561-573.
19. Torres J, Miquel J, Casanova JC, Ribas A, Feliu C, Morand S. Endoparasite species richness of Iberian carnivores: influences of host density and range distribution. Biodiversity and Conservative. 2006;15: 4619-4632.
20. Singh A, Gangwar A, Shinde NK, Srivastava S. Gastrointestinal parasitism in bovines of Faizabad. Journal of Veterinary Parasitology. 2008;22(1):31-33.
21. Fagiolini M, Lia RP, Laricchiuta P, Cavicchio P, Mannella R, Cafarchia C, Otranto D, Finotello R, Perrucci S. Gastrointestinal parasites in mammals of two Italian zoological gardens. Journal of Zoo and Wildlife Medicine. 2010;41(4):662-70.
22. Atanaskova E, Kochevski Z, Stefanovska J, Nikolovski G. Endoparasites in wild animals at the zoological garden in Skopje Macedonia. Journal of Threatened Taxa. 2011;3(7):1955–1958.
23. Niranjan A. S, Singh VS, Vatsya S, Singh JL, Bharadwaj Y. Parasitic infection in captive wild animals of Nainital Zoological park India. The Pharma Innovation Journal. 2022;11(7):3308-3313.
24. Figueiredo Ana M, Valente Ana M, Fonseca Carlos, DeCarvalho LMM, Torres Rita Tinoco. Endoparasite diversity of the main wild ungulates in Portugal. Wildlife Biology. 2020;2020(1):1-7.
25. Abraham M, Harshal PT, Ajithkumar KG, Ravindran R. Coprological survey of gastrointestinal parasites of dairy cattle in Wayanad Kerala India. International Journal of Current Microbiology and Applied Sciences. 2017;6(2):899-903.
26. Nimisha M, Pradeep RK, Kurbet PS, Amrutha BM, Varghese A, Deepa CK, Priya MN, Lakshmanan B, Ajith Kumar KG, Ravindran R. Parasitic diseases of domestic and wild animals in Northern Kerala: A retrospective study based on clinical samples. International Journal of Current Microbiology and Applied Sciences. 2017;6(11):2381-2392.
27. Abhijith T. V, Mohanarangan A, Thampy DR, George C. Gastrointestinal parasites of Asian elephants (*Elephas maximus* L. 1798) in south Wayanad forest division Kerala India. Journal of Parasitic Diseases. 2018;42(3):382–390.
28. Benedict DP, Radhika R, Rajagopal A, Devada K. Occurrence of strongylosis in cattle of Thrissur district Kerala India. The Pharma Innovation Journal. 2018;7(8):317-319.
29. Thankachan J, Tresamol PV, Vijayakumar K, Vinodkumar K, Ajithkumar S. Occurrence of gastrointestinal parasites among pigeons in Kerala. Journal of Veterinary and Animal Science. 2022;53(1):39-43.
30. Soulsby EJL. Technique In: Helminths Arthropods and Protozoa of Domesticated Animals. Bailliere Tindall An Imprint of Elsevier. London. 1982;762- 777.
31. Greigert V, Brion N, Lang C, Regnard P, Pfaff AW, Abou-Bacar A, Wanert F,

Dirheimer M, Candolfi E, Brunet J. Cestode infections in non-human primates suggest the existence of zoonotic cycles in the area surrounding the Strasbourg primatology center. Parasite. 2019;26:25.
32. Kabir MHB, Eliyas M, Hashem Md. Abul, Mohiuddin M, Miazi OF. Prevalence of zoonotic parasitic diseases of domestic animals in different abattoir of Comilla and Brahman Baria region in Bangladesh. University Journal of Zoology Rajshahi University. 2009;28:21-25.
33. Martin-Solano S, Carrillo-Bilbao AG, Ramirez W, Celi-Erazo M, Huynen M, Levecke B, Benitez-Ortiz W, Losson B. Gastrointestinal parasites in captive and free-ranging *Cebus albifrons* in the Western Amazon Ecuador. International Journal for Parasitology: Parasites and Wildlife. 2017;6(3):209-218.
34. Vonfeld I, Prenant T, Polack B, Guillot J, Quintard B. Gastrointestinal parasites in non-human primates in zoological institutions in France. Parasite. 2022;29 (43).
35. Rostami A, Riahi SM, Fallah Omrani V, Wang T, Hofmann A, Mirzapour A, Foroutan M, Fakhri Y, Macpherson CNL, Gasser RB. Global prevalence estimates of *Toxascaris leonina* infection in dogs and cats. Pathogens. 2020;9(6):503.
36. Dishane K, Hewavithana Mayuri R, Wijesinghe Preethi V, Udagama. Gastrointestinal parasites of six large mammals in the Wasgomuwa National Park Sri Lanka. International Journal for Parasitology: Parasites and Wildlife. 2022;17:1-6.
37. Singh P, Gupta MP, Singla LD, Sharma S, Sandhu BS, Sharma DR. Parasitic infections in wild herbivores in the Mahendra Choudhury zoological park Chhatbir Punjab. Zoo's Print. J. 2006;21(11): 2459–2461.
38. Prykhodko Yu. O, Mazannyy OV. Fedorova OV, Lyulin PV, Nikiforova OV. Endoparasites of carnivores in non-governmental organization "Feldman eco-park"(Kharkiv Ukraine). Journal Article – Scientific Article. 2021;38 (38):174-185.
39. Punya MS, Shyma VH, Reshnu VC, Vijayakumar K, Vinodkumar K, Ambily R, Arun Zachariah. Gastrointestinal parasites of captive Asian elephants in Kerala. Journal of Veterinary and Animal Science. 2021;52(3):312-315.
40. Mir AQ, Dua K, Singla LD, Sharma S, Singh MP. Prevalence of parasitic infection in captive wild animals in Bir Moti Bagh mini zoo (Deer Park) Patiala Punjab. Veterinary World. 2016;9(6):540-3.
41. Lim YAL, Ngui R, Shukri J, Rohela M, Naim HRM. Intestinal parasites in various animals at a zoo in Malaysia. Veterinary Parasitology. 2008;157:154–159.
42. Levecke B, Dorny P, Geurden T, Vercammen F, Vercruysse J. Gastrointestinal protozoa in primates of four zoological gardens in Belgium. Veterinary Parasitology. 2007;148:236–246.
43. Hewavithana DK, Wijesinghe MR, Udagama PV. Gastrointestinal parasites of six large mammals in the Wasgomuwa National Park Sri Lanka. International Journal for Parasitology: Parasites and Wildlife. 2021;17:1-6.
44. Otranto D, Deplazes P. Zoonotic nematodes of wild carnivores. International Journal for Parasitology: Parasites and Wildlife. 2019; 9:370-383.
45. Heitlinger E, Ferreira S, Thierer D, Hofer H, East ML. The intestinal eukaryotic and bacterial biome of spotted hyenas: the impact of social status and age on diversity and composition. Front Cell Infect Microbiol. 2017;7.
46. MacIntosh AJJ, Hernandez AD, Huffman MA. Host age sex and reproductive seasonality affect nematode parasitism in wild Japanese macaques. Primates. 2010;51(4):353–364.
47. Schulte-Hostedde AI, Mastromonaco GF. Integrating evolution in the management of captive zoo populations. Evolutionary Applications. 2015;8(5):413–422.