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ARTICLE

Gastrointestinal helminth and protozoan infections of wild mammals in four major national parks in Sri Lanka

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Abstract: A cross-sectional, coprological survey of gastrointestinal (GI) parasites of wild mammals in four major National Parks in Sri Lanka: Wilpattu, Udawalawe, Wasgamuwa, and Horton Plains was carried out during November 2016 to August 2017. Fresh fecal samples were collected and analyzed using sedimentation technique, iodine & saline smears, and Sheather's sucrose flotation for morphological identification parasite eggs, cysts, and larvae. A modified salt flotation was carried out for egg counts. Seventy samples from 10 mammal species: Asian Elephant, Spotted Deer, Water Buffalo, Sambar, Indian Hare, Asian Palm Civet, Sloth Bear, Wild Boar, Grey Langur, Leopard, and four unknown mammals (two carnivores, one herbivore and one omnivore) were analyzed. Most were infected (94.3%) with more than one GI parasites. The highest prevalence of infection was recorded in Horton Plains (100%), followed by Wasgamuwa (92.8%), Wilpattu (90.4%) and Udawalawe (75.0%) with a significant difference among four parks (Chi square test; χ^2=35.435; df=3; p<0.001). Nineteen species of GI parasites were recorded, of which *Entamoeba*, *Isospora*, *Balantidium*, *Fasciola*, *Moniezia*, *Dipylidium*, strongyles, *Toxocara*, *Trichiurus* and hookworms were the most common. Strongyles (62.1%) and *Entamoeba* (80.3%) were the most prevalent helminth and protozoan infections, respectively. Overall, there was no difference in the prevalence of protozoans (84.3%) and helminths (87.1%; χ^2=1.0; df=1; p=0.317). In carnivores, *Entamoeba*, *Balantidium*, *Moniezia*, strongyles and *Strongyloides* were common and in herbivores, *Entamoeba*, strongyles, *Strongyloides* and *Toxocara* were common. The quantitative analysis showed strongyles (17.639 EPG) and *Isospora* (18,743 OPG) having the highest infection intensity among helminthes and protozoans, respectively. This study provides baseline information of GI parasites and their distribution in wild mammals in the four national parks. Although the prevalence of GI infections was high, their intensity shows that they could be incidental infections. When the prevalence of an infection is high but the intensity is low, it is unlikely to be a major health problem leading to the endangerment of a species. Parasitic diseases can not only affect conservation efforts, but they are also natural selection agents and drive biological diversification, through influencing host reproductive isolation and speciation.

Keywords: Cysts, gastrointestinal parasites, helminthes, identification, protozoans, wild mammals.

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Author contribution: CSS—carried out the field and laboratory work, analysed data and wrote the manuscript; RSR—designed the study protocols, supervised the field and laboratory work, edited the manuscript

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INTRODUCTION

National parks are established in many countries to protect and conserve nature while also serving for education, tourism and entertainment (Kaffashi et al. 2015). National parks in Sri Lanka were first established 100 years ago to conserve valuable natural environments (Dahlberg et al. 2010) and are distributed over three climatic zones; dry zone, wet zone and intermediate zone. Today, there are 35 national reserves consisting of three strict nature reserves, 26 national parks, five nature reserves, and one jungle corridor. In Sri Lanka, the Department of Wildlife Conservation (DWC) is the main government authority which has the legal power to control national reserves and natural forests. In these national reserves, a total of 95 species and subspecies of mammals have been described consisting of 21 endemic species and 12 introduced species (Weerakoon 2012).

Endoparasites are an important part of studying the disease ecology of wild animals as the abundance and diversity of parasites can determine the health of a particular ecosystem (Sallows 2007). Especially, in a natural ecosystem carnivores occur in lower densities than ruminants, therefore, parasitic infection of carnivores is a good indicator to understand the health of a specific national park (Stuart et al. 2017). Moreover, parasitic infections can vary between sexes, for example male ungulates are more susceptible to parasitic infections than the females (Dunn 1978; Apio et al. 2006). Environmental conditions like monsoon rains and soil moisture affect parasitic transmission and many parasitic diseases are acquired through contaminated soil and water (Marathe et al. 2002). When food and water are contaminated with infected feces it can easily spread the diseases among wild animals in the park (Coffey et al. 2007; Stuart et al. 2017). Parasites can affect the growth rate, mortality rate, population size and interaction between individuals such as sexual selection and social behaviors of wild mammals (Sinclair & Griffith 1979; Sumption & Flowerdew 1985; Freeland et al. 1986; Marathe et al. 2002).

Ecologists have recently begun to understand the importance of diseases and parasites in the dynamics of populations (Altizer et al. 2003). Diseases and parasites were probably responsible for some extinctions on islands but also on larger land masses, but the problem has only been identified retrospectively (reviewed in McCallum & Dobson 1995). On the other hand endemic pathogens and parasites might play a crucial role in maintaining the diversity of ecological communities and ecosystems (Karesh et al. 2012). When the hosts are keystone or dominant species with important functions in an ecosystem, the effects of diseases on ecological communities can be particularly pronounced (Preston & Johnson 2010). Patterns of disease emergence in wildlife and integration of parasitism into community ecology provide information for better understanding of the roles of parasites in nature. Among these, their role in food webs, competitive interactions, biodiversity patterns, and the regulation of keystone species, make it clear that parasites contribute to structuring ecological communities (Preston & Johnson 2010).

There is no current literature available on the GI parasites of wild animals in national parks in Sri Lanka. The present study was carried out to obtain baseline information of the types, prevalence and infection intensity of GI parasites in wild mammals in four major national parks located in three climatic zones of Sri Lanka.

MATERIALS AND METHODS

Study site and study animals

Four nature reserves were selected. Wilpattu National Park (8.433N & 80.000E), Wasgamuwa National Park (7.716N & 80.933E) and Udawalawe National Park (6.438N & 80.888E) are located in the dry zone with mean annual temperature of 27.2^{0}C, 27.0^{0}C, and 27.5^{0}C, respectively. Horton Plains National Park (6.800N & 80.000E), located in the wet zone has a mean annual temperature of 13.0^{0}C (Figure 1).

The number of wild mammal species varies among the four parks: 31 species of mammals in Wilpattu National Park, 43 in Udawalawe National Park, 23 in Wasgamuwa National Park and 24 in Horton Plains National Park (DWC, Sri Lanka).

Collection of samples

Fresh fecal samples from wild mammals in the four parks were collected during November 2016 to August 2017. Approximately, 10–15 g of fecal matter was collected from each animal that had defecated in the morning between 07.00 and 10.00 h while samples from those that defecate in the afternoon (e.g., Elephant and Wild Boar) were collected in the late afternoon between 16.00 and 18.00 h. A trained tracker from the DWC identified the fecal samples. Samples were taken to the laboratory in a cooler, stored in a refrigerator at 4^{0}C and were analyzed in the parasitology laboratory in the Department of Zoology at the University of Peradeniya.

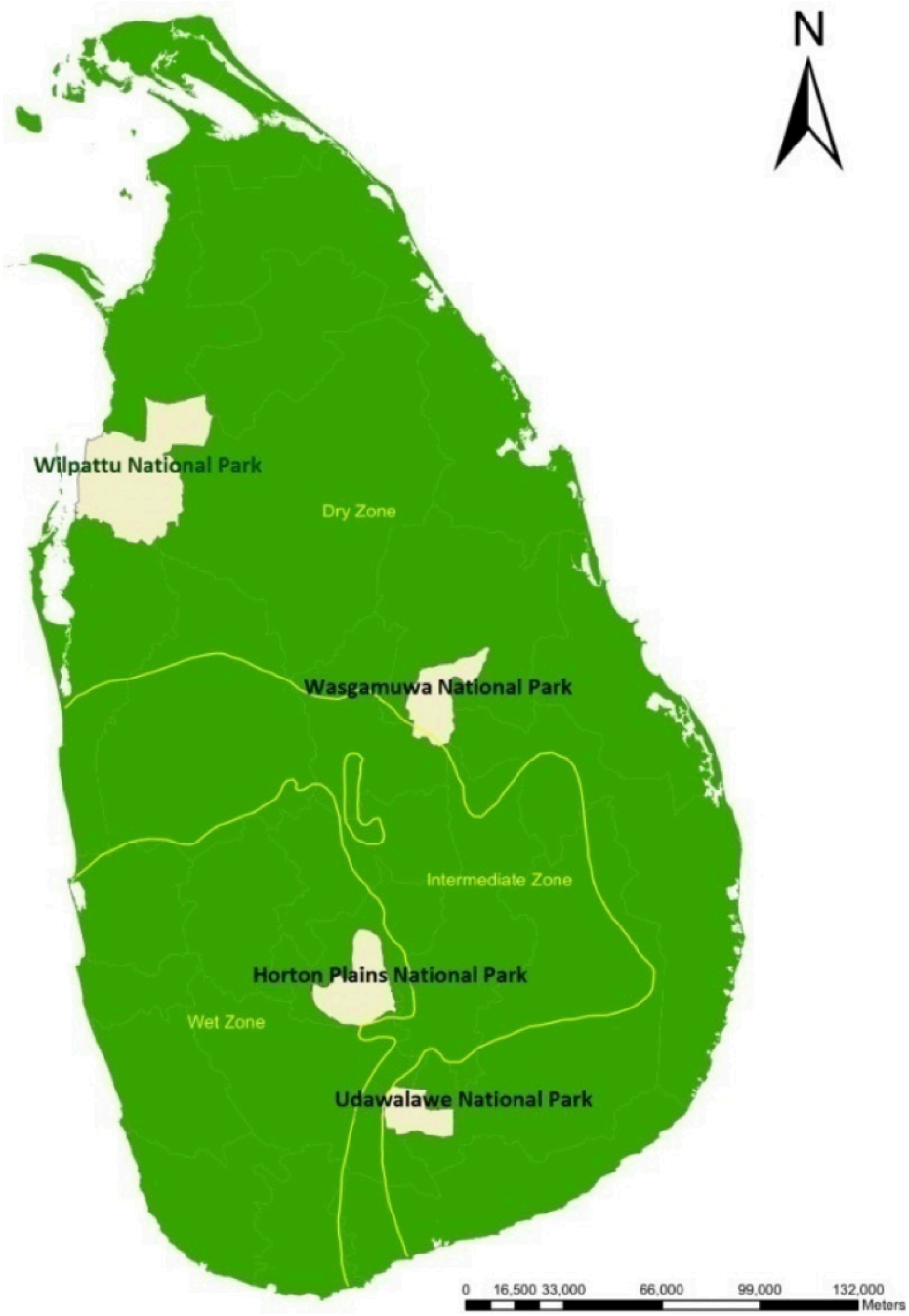

Figure 1. The four national parks in Sri Lanka.

Sample analysis

Fecal samples were analyzed using four methods: (a) sedimentation technique, (b) direct iodine and saline smears, (c) Sheather's sucrose flotation, and (d) modified salt flotation. The eggs of different species were identified morphometrically under a microscope under 10X ocular lens and objective lens of 40X (total magnification 400x). The number of eggs, cysts/oocysts in 0.5ml were calculated as eggs per gram (EPG) in helminthes and cysts per gram (CPG) or oocysts per gram (OPG) in protozoans. The length and width of the eggs were measured under the same 400x magnification (10×40).

Sedimentation technique (Zajac & Conboy 2012; page 13)

Since the trematode eggs are relatively large and heavy they were qualitatively isolated using the

sedimentation method. Approximately, 3g of feces was measured (for elephants 50g was measured due to the high fiber content in their feces) and mixed with 50ml distilled water. Then the suspension was poured into a test tube and allowed to settle for 5 min. The supernatant was removed and the pellet was re-suspended in 5ml of distilled water and then allowed to set for another 5 min. Finally, the supernatant was removed and the sediment layer collected in the bottom of the test tube was examined after adding one drop of Methylene Blue under 400x magnification.

Direct iodine and saline smears (Zajac & Conboy 2012; pages 12–13)

A drop of Lugol's iodine was placed on a microscopic slide and a small portion of fecal matter (~ size of head of a match) was picked up by using a cleaned toothpick and mixed thoroughly with iodine. Then a drop of saline (1% solution) was added to the smear, covered using cover slip and was observed under light microscope at 400x magnification.

Sheather's sucrose flotation technique (Zajac & Conboy 2012, pages 4–11)

This method was used to identify nematode and cestode eggs, coccidian oocysts and other protozoan cysts in the fecal sample. Approximately, 3g of fecal sample was measured (again 50g was used for elephant dung samples) and mixed with 50ml of freshly prepared Sheather's sucrose solution (SPG 1.2–1.25) to make a suspension. The suspension was filtered and poured into cleaned test tube and filled until a convex meniscus formed at the top of the tube. A cover slip was placed over the meniscus and left for 20 min. The cover slip was then placed on a slide and examined under the microscope at 400x magnification.

Modified salt flotation technique (Zajac & Conboy 2012; pages 4–11)

Modified salt flotation is a quantitative method to count eggs of nematodes, trematodes and cestodes and cysts of protozoa. Approximately, 3g of the sample was transferred into a 15ml clean centrifuge tube and 14ml of distilled water were added. For elephant dung samples, 50g was transferred into a 50ml centrifuge tube and 45ml of distilled water were added. Then the fecal solution was stirred well with using a glass rod, the tube was centrifuged at 3000G (N/kg)for 20 min. After that, the supernatant was removed, and the tube was filled again with 14ml (or 45ml) of distilled water and was centrifuged at 3000G for 20 min. This procedure was repeated until a clear solution of the supernatant was obtained. Then the supernatant was removed and salt solution was added to the butt of the centrifuge tube up to 14ml (or 45ml) level. Again, the tubes were centrifuged at 3000G for 20 min. Then the supernatant with the floating parasitic eggs was transferred into a 15ml clean centrifuge tube and distilled water was added up to the 15ml level and was centrifuged at 3000G for 10 min. Then the supernatant was removed and the sediment was pipetted out into microcentrifuge tubes (Eppendorf®). These tubes were then centrifuged at 3000G for 10 min. The supernatant was removed leaving about 0.5ml of solution. This was mixed thoroughly and about 0.1ml of the suspension was placed on and a microscopic slide. Five such smears were prepared from each sample and examined using a light microscope. Eggs of different species were identified and counted and the number of eggs per gram in each sample was calculated. Intensity of infections was calculated using CPG (cysts per gram), OPG (oocysts per gram) and EPG (eggs per gram) of feces.

RESULTS

Prevalence of parasites

A total of 70 mammals were examined (Wilpattu = 21, Udawalawe = 8, Wasgamuwa = 28 and Horton Plains = 13) of which 66 (94.3%) were infected with more than one GI parasite of protozoans, trematodes, nematodes and cestodes. Among the four parks, the highest prevalence of GI parasites was observed in the Horton Plains where all the mammals were infected (100%), followed by Wasgamuwa (92.8%) and the lowest was Udawalawe (75.0%) with a significant difference in the prevalence among parks (Chi square test; $\chi^2 = 35.435$; df = 3; $p<0.001$). Overall, there was no difference in the prevalence of protozoans (84.3%) and helminths (87.1%; $\chi^2 = 1.0$; df = 1; p = 0.317).The highest protozoan prevalence was observed in Horton Plains(100%), followed by Wasgamuwa (85.7%), Wilpattu (80.9%) and Udawalawe (62.5%). The highest helminth prevalence was observed from Horton Plains (92.3%), followed by Wasgamuwa (89.3%), Wilpattu (85.7%) and Udawalawe (75.0%).

Types of gastrointestinal parasites

Parasites belong to 19 genera were observed in mammals in the four national parks. Out of which 14 species were identified (Table 1; Figure 2). The most common protozoan was *Entamoeba* (80.3%) observed

Table 1. Prevalence of gastrointestinal parasites of wild mammals in four national parks in Sri Lanka.

Parasite	National Park			
	Wilpattu	Udawalawe	Wasgamuwa	Horton plains
Entamoeba	71.4%	83.3%	85.7%	92.3%
Isospora	52.4%	50%	35.7%	84.6%
Balantidium	14.3%	16.7%	-	-
Moniezia	19.0%	16.7%	39.3%	53.9%
Fasciola	38.1%	33.3%	39.3%	-
Schistosoma	4.8%	-	10.7%	-
Dipylidium	-	-	32.1%	-
Diphyllobothrium	-	-	14.3%	-
Ascaris	14.3%	-	32.1%	-
Strongylus	57.1%	83.3%	57.1%	61.5%
Strongyloide	-	33.3%	10.7%	-
Trichostrongylus	19.0%	16.7%	10.7%	-
Trichiurus	-	-	10.7%	15.4%
Toxocara	-	-	10.7%	-
Hook worm	-	50%	-	7.7%
Pin worm	23.8%	-	7.1%	-
Unknown sp 1	4.8%	-	-	3.8%
Unknown sp 2	-	-	-	15.4%
Unknown sp 3	-	-	3.6%	15.4%

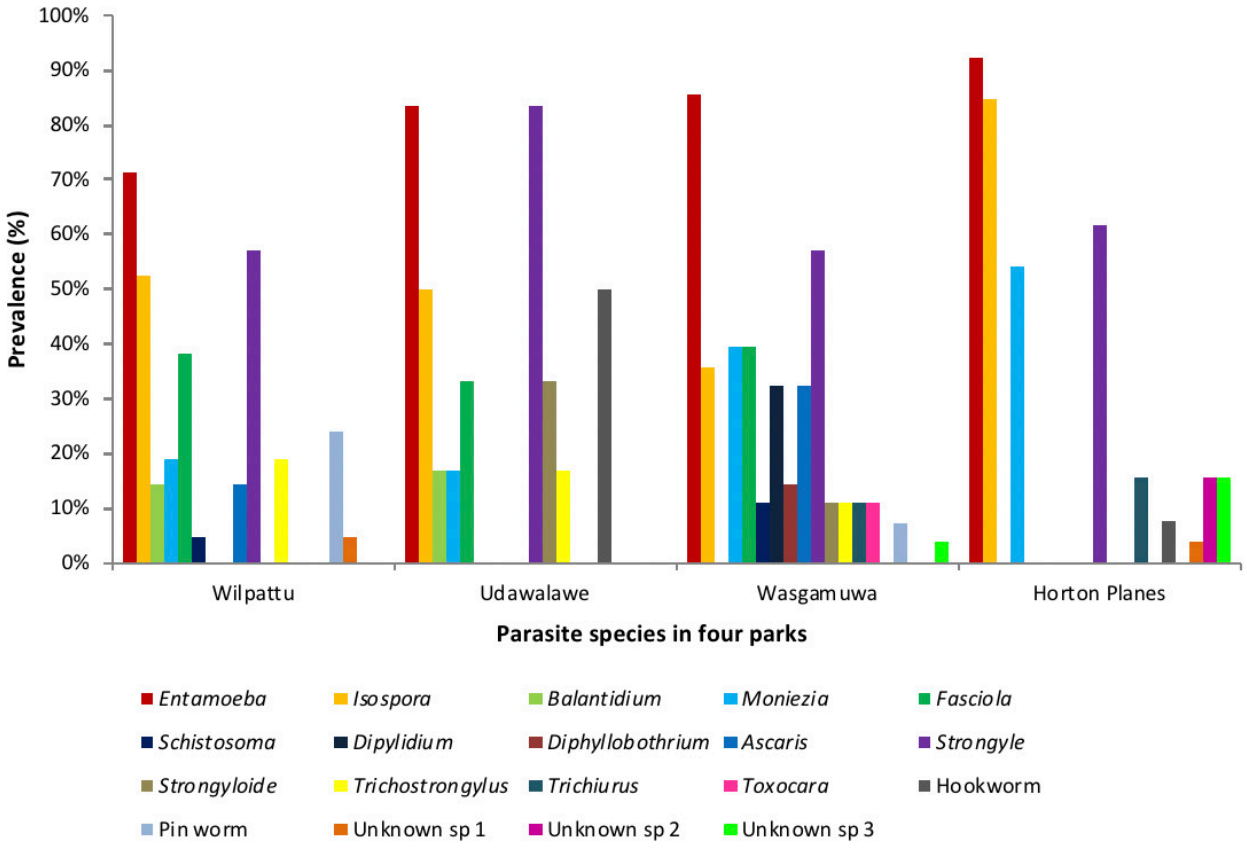

Figure 2. Percentage prevalence of gastrointestinal parasites in wild mammals of four national parks in Sri Lanka.

in the Asian Elephant, Water Buffalo, Spotted Deer, Asian Palm Civet, Indian Hare, Sloth Bear, Sambar, Wild Boar, and Grey langur. The most common helminth were strongyles (62.1%) observed in the Asian Elephant, Water Buffalo, Asian Palm Civet, Leopard, Sloth Bear, Sambar, Indian Hare, and Grey Langur. The least

common parasite infections were pinworm, *Toxocara*, *Diphyllobothrium* and *Balantidium*.

Intensity of Infections

Overall, the intensity of infection was not high in any GI parasite observed in the four parks (Table 2). The highest protozoan infection was observed in the Horton Plains (23.811 CPG) and the highest helminth infection was observed in Wasgamuwa (18.743 EPG; Table 2).

DISCUSSION

Results show that the prevalence of GI infections in wild mammals in the four national parks was high (94.3%). High prevalence of GI infections are recorded in many national parks: Masai Mara National Reserve (100%) in Kenya (Engh et al. 2003), Kibale National Park (84%) in Uganda (Bezjian et al. 2008), Serengeti and the Ngorongoro Crater (97.3%) in Tanzania (Muller-Graf, 1995), Langtang National Park (88.9%) in Nepal (Achhami et al. 2016). There was a significant difference in the prevalence among the four parks. Udawalawe had the lowest prevalence GI infections while Horton Plains had the highest. This could be due to the period of sampling where it was carried in the dry period in Udawalawe and in the rainy season in Horton plains. During rainy periods, the transmission of parasitic infections is high. The environmental conditions such as rainfall patterns have a significant influence on the parasitic transmission in mammals and there is a strong relationship between the rainfall and the pathogenecity of GI infection (Marathe et al. 2002; Rosenthal 2010; Turner et al. 2012; Chattopadhyay & Bandyopadhyay 2013; Stuart et al. 2017). On the contrary, Wasgamuwa Park was also sampled during the dry season but had a higher prevalence of infection. Some studies, however, show that the prevalence of certain GI parasites is not correlated with rainfall pattern (Gillespie et al. 2004, 2005). For example, *Oesophagostomum* is a common infection in baboons in the dry season in Kibale National forest (Bezjian et al. 2008). The authors point out that this parasite may resist desiccation due to the lush habitat of the Kibale National Forest and the presence of the Dura River. It has also been noted that during the dry season, *Oesophagostomum* sp. larvae can avoid adverse weather conditions by arresting their development (Pettifer 1984). Nevertheless, the sample size in the Udawalawe Park was small (n = 8) and therefore comparing across parks and drawing conclusions cannot be done uncritically. The prevalence of infection did not show any marked seasonal variation among the four parks.

There was no difference in the prevalence of helminthes and protozoans in the four national parks. The two groups have developed different adaptive strategies for their survival. Protozoans release large number of cysts with feces, compared to helminthes. But helminth egg is resistant to various environmental conditions like high temperature, high rainfall, desiccation etc (e.g., *Toxocara*, *Trichiurus*) (Okulewicz et al. 2012) as they have a thick egg shell. Wilpattu and Udawalawe parks are located in the dry zone of the country that has high temperatures but the helminth eggs and protozoan cysts were able to survive those conditions. Some studies however, show high prevalence of helminthes than protozoans, have been reported in wild lions in Tanzania (Muller-Graf 1995) and spotted hyenas in Masai Mara Reserve, Kenya (Engh et al. 2003) whereas in captive conditions such as zoological gardens, the protozoan prevalence is higher than helminthes due to regular anthelmintic treatments (Dawet et al. 2013) but may not be the case always (Adeniyi et al. 2015; Aviruppola et al. 2016).

Prevalence of parasite infections can lead to evolution of tolerance or resistance in the host. Tolerance to parasites, or infection tolerance is the ability of a host to limit the health or fitness effect of a given infection intensity whereas resistance is the ability of the host reduce risk of infection. Both resistance and tolerance are host traits that have evolved to alleviate the health and fitness effects of infection, but they represent two fundamentally different strategies to deal with parasites. The main difference of the two is that resistance reduces the risk of infection and/or the replication rate of the parasite in the host, whereas tolerance does not. Tolerance and resistance lead to different ecological and evolutionary interactions between hosts and their parasites (Roy & Kirchner 2000; Rausher 2001; Best et al. 2014; Vale et al. 2014). Roy & Kirchner (2000) show that if hosts evolve resistance, this should reduce the prevalence of the parasite in the host population and if hosts evolve tolerance instead, this will have a positive effect on parasite prevalence.

Among the GI parasite species observed *Entamoeba*, *Isospora*, and *Balantidium* were the most common protozoans while *Moniezia*, *Fasciola*, *Schistosoma*, *Dipylidium*, *Diphyllobothrium*, *Ascaris*, strongyles, *Strongyloides*, *Trichostrongylus*, *Trichiurus*, *Toxocara*, hookworm, and pinworm infections were the common helminthes. The diversity of parasite species was highest in the Wasgamuwa Park and the lowest in the

Table 2. Prevalence and the intensity of parasites found in wild mammals in four national parks in Sri Lanka.

National Park	Mammal species (n)	Parasite	Prevalence	Intensity (CPG/EPG/OPG)
Wilpattu	Asian Elephant *Elephas maximus* (1)	*Entamoeba*	100%	0.020
		Fasciola	100%	0.060
		Strongyles	100%	0.300
	Water Buffalo *Bubalus arnee* (5)	*Entamoeba*	40%	0.334
		Balantidium	60%	0.734
		Isospora	60%	3.467
		Fasciola	40%	0.201
		Moniezia	20%	0.067
		Schistosoma	20%	0.067
		Strongyle	40%	0.400
	Spotted Deer *Axis axis* (4)	*Entamoeba*	50%	0.417
		Isospora	75%	0.084
		Moniezia	75%	0.084
		Ascaris	75%	0.084
		Trichostrongylus	50%	4.834
	Indian Palm Civet *Paradoxurus hermaphroditus* (1)	*Entamoeba*	100%	6.670
		Isospora	100%	1.334
		Strongyle	100%	0.334
	Sloth Bear *Melursus ursinus* (1)	*Entamoeba*	100%	0.334
		Isospora	100%	14.000
		Dipylidium	100%	10.000
		Strongyle	100%	14.668
	Indian Hare *Lepus nigricollis* (1)	*Entamoeba*	100%	1.334
		Moniezia	100%	0.334
	Sambar *Rusa unicolor* (3)	*Entamoeba*	100%	0.778
		Isospora	100%	1.222
		Fasciola	100%	2.889
		Ascaris	66.7%	0.222
		Strongyle	66.7%	0.778
		Trichiurus	33.4%	0.222
	Wild Boar *Sus scrofa* (4)	*Entamoeba*	50%	0.333
		Isospora	25%	0.416
		Fasciola	50%	0.416
		Moniezia	25%	0.084
		Dipylidium	25%	0.084
		Strongyles	75%	1.000
		Unknown sp1	100%	2.084
	Unknown omnivore (1)	*Isospora*	100%	1.000
		Dipylidium	100%	7.334
		Unknown sp 1	100%	4.334
		Unknown sp 2	100%	0.334

National Park	Mammal species (n)	Parasite	Prevalence	Intensity (CPG/EPG/OPG)
Udawalawe	Asian Elephant *Elephas maximus* (1)	*Fasciola*	100%	0.020
		Strongyle	100%	0.960
	Water Buffalo *Bubalus arnee* (1)	*Entamoeba*	100%	2.000
		Balantidium	100%	1.000
		Isospora	100%	4.667
		Strongyle	100%	1.334
	Grey Langur *Semnopithicus priam* (1)	*Entamoeba*	100%	1.000
		Isospora	100%	5.334
		Strongyle	100%	18.668
		Strongyloide	100%	7.334
		Hook worm	100%	0.334
	Unknown carnivore (1)	*Entamoeba*	100%	1.000
		Isospora	100%	1.667
		Strongyle	100%	8.334
		Strongyloide	100%	1.667
		Hook worm	100%	0.334
	Spotted Deer *Axis axis* (1)	*Entamoeba*	100%	2.000
		Fasciola	100%	0.334
		Hook worm	100%	0.334
		Trichostrongylus	100%	1.000
	Indian Hare *Lepus nigricollis* (1)	*Entamoeba*	100%	2.000
		Moniezia	100%	4.000
		Strongyle	100%	8.000
Wasgamuwa	Asian Elephant *Elephas maximus* (6)	*Entamoeba*	100%	2.667
		Isospora	25%	0.166
		Fasciola	50%	0.334
		Moniezia	100%	1.083
		Strongyle	50%	1.883
	Water Buffalo *Bubalus arnee* (6)	*Entamoeba*	100%	3.050
		Isospora	50%	0.555
		Moniezia	66.7%	0.611
		Schistosoma	50%	0.167
		Ascaris	83.3%	0.889
		Strongyle	66.7%	0.833
	Spotted Deer *Axis axis* (6)	*Entamoeba*	83.3%	0.833
		Isospora	83.3%	0.833
		Unknown sp3	16.7%	0.055
		Fasciola	66.7%	0.444
		Moniezia	50%	0.167
		Dypylidium	33.3%	0.222
		Diphyllobothrium	33.3%	0.166
		Ascaris	16.7%	0.167
		Trichostrongylus	50%	0.500

National Park	Mammal species (n)	Parasite	Prevalence	Intensity (CPG/EPG/OPG)
Wasgamuwa	Asian Palm Civet *Paradoxurus hermaphroditus* (7)	*Entamoeba*	100%	1.048
		Isospora	14.2%	0.528
		Fasciola	85.7%	3.667
		Dipylidium	71.4%	1.000
		Diphyllobothrium	28.5%	0.190
		Strongyle	100%	19.667
		Strongyloide	42.8%	1.381
		Trichiurus	42.8%	1.714
		Toxocara	28.5%	0.809
		Pinworm	14.2%	0.407
	Leopard *Panthera pardus kotiya* (1)	*Dipylidium*	100%	0.334
		Strongyle	100%	9.334
		Toxocara	100%	5.000
	Sloth Bear *Melursus ursinus* (1)	*Dipylidium*	100%	2.000
		Strongyle	100%	1.668
	Unknown herbivore (1)	*Entamoeba*	100%	2.000
		Ascaris	100%	0.667
		Strongyle	100%	0.667
Horton Plains	Indian Hare *Lepus nigricollis* (4)	*Entamoeba*	100%	15.755
		Isospora	100%	45.697
		Moniezia	75%	2.647
		Strongyle	75%	12.521
		Trichiurus	50%	3.014
		Unknown sp 3	25%	6.500
	Asian Palm Civet *Paradoxurus hermaphroditus* (1)	*Entamoeba*	100%	16.000
		Strongyle	100%	4.000
		Unknown sp 3	100%	2.000
	Wild Boar *Sus scrofa* (2)	*Entamoeba*	50%	0.333
		Isospora	100%	4.667
		Strongyle	100%	0.667
		Unknown sp 1	100%	2.000
	Sambar *Rusa unicolor* (5)	*Entamoeba*	100%	1.401
		Isospora	100%	0.734
		Moniezia	60%	0.200
		Strongyle	20%	0.067
		Hook worm	20%	0.067
	Unknown carnivore (1)	*Entamoeba*	100%	6.000
		Moniezia	100%	2.000
		Strongyle	100%	4.000

Horton Plains. Although the prevalence of infection was highest in the Horton Plains National Park, the diversity of infection was the lowest. The common GI parasites for both herbivores and carnivores were *Entamoeba* and strongyles. Fecal samples of herbivores such as the Asian Elephant *Elephas maximus*, Water Buffalo *Bubalus arnee*, Spotted Deer *Axis axis*, Sambar *Rusa unicolor*, Grey Langur *Semnopithecus priam*, and Indian Hare *Lepus nigricollis* were infected with *Entamoeba*, *Balantidium*, *Moniezia*, *Fasciola*, *Trichiurus*, strongyles, *Strongyloides*, and *Trichostrongylus*. Carnivorous such as Leopard *Panthera pardus kotiya* and other unknown carnivorous species were infected with *Entamoeba*, strongyles, *Strongyloides,Toxocara*, and hookworm.

Herbivores get the infections through contaminated food or water as most of these GI parasite eggs, cysts and larvae are associated with pasture. Digenetic trematodes like *Fasciola,* and *Pharamphistomum* have indirect life cycles where a snail (e.g., *Lymnea, Planorbis*, *Balinus, Oncomelaria*) acts as an intermediate host of parasite who associate with water bodies. Cercariae of these trematodes encyst on vegetation where herbivores feed. *Moniezia* is a common cestode of herbivores and it was recorded from all four parks. It was also recorded in an unknown carnivore in Horton Plains. A recent study on GI parasites of wild cats reported *Moniezia* in four leopards in Horton plains (Kobbekaduwa et al. 2017) and the authors attribute this as an accidental ingestion of oribatid mites, the intermediate host of *Moniezia* by the leopards. The mite lives on the pasture and enters the mammalian host while feeding. *Fasciola*, *Moniezia*, *Strongyloides*, and *Trichuris* obtained from herbivores in Bhutan (Tandon et al. 2005) and strongyles, *Strongyloides*, *Moniezia* observed from Musk Deer in Nepal (Achhami et al. 2016). *Balantidium* is also transmitted through fecal-oral route infection via contaminated pasture (Schuster & Ramirez-avila 2008). Carnivores get infected by GI parasites like *Toxocara* mainly by ingesting the intermediate host (Okulewicz et al. 2012) or by direct penetration like the hookworms. *Toxocara* is a common GI parasite of carnivores worldwide. Studies have shown Grey wolves in Riding mountain National Park of Canada (Sallows 2007; Stuart et al. 2017) wild Lions in Tanzania (Muller-Graf 1995), Wolves in northeastern Poland (Kloch et al. 2005) wild carnivores in Przybyszewskiego (Okulewicz et al. 2012), and Spotted Hyena samples in Masai Marai Reserve in Kenya (Engh et al. 2003) as few examples.

Although the prevalence of infection was high among the mammals, the intensity of most infections were not high enough to cause serious health problems in these mammals. Wild mammals have natural resistance against parasites or live mutually with them, unlike captive stressful conditions where the animals are more susceptible to parasitic infections (Borkovcova & Kopriva 2005; Singh et al. 2006a,b; Adeniyi et al. 2015). Free ranging animals can disperse the parasite throughout the environment, therefore the infections in wild mammals or free living ones occur in low intensities compared to captive or domestic mammals (Stuart et al. 2017). Because of constant stress of captivity makes animals more susceptible to parasitic infection as the immune system of these captive animals become weak (Gracenea et al. 2002; Cordon et al. 2008). Moreover, some infections in most captive and domestic mammals has both transplacental and transmammary transmission which can cause serious damage such as acute and ocular infections of *Toxocara* in cubs (Okulewicz et al. 2012). In some cases parasites can affect the cellulose digestion of host species, increase the rate of morbidity and mortality (e.g., *Oesophagostomum*; Muehlenbein 2005). This may depend on the intensity of infection, where some parasites become less pathogenic even with large number of eggs or cysts (>20,000), but some become high pathogenic with few eggs or cysts.

This study provides baseline information of GI parasites and their distribution in wild mammals in the four national parks. The prevalence of GI infections was high, nevertheless, their intensity shows that they could be incidental infections. When the prevalence of an infection is high but the intensity is low, it is unlikely to be a major health problem to endanger species. Mathematical models have shown that parasitic diseases affecting host mortality maintain equilibrium far below their disease free carrying capacity (Anderson 1979; McCallum & Dobson 1995). Highly pathogenic diseases also have minor effect on host populations. If a disease is detectable at high prevalence, it is probably mild and unlikely to be a major problem to an endangered species. Parasitic diseases can affect conservation efforts, acting as a contributing threat in the endangerment of wildlife hosts, and occasionally causing severe population declines (de Castro & Bolker 2005; Blehert et al. 2009). The maintenance of host-parasite relationships in managed wildlife populations can be ultimately beneficial, and points to a critical role for wildlife parasitologists in conservation efforts (Gomez & Nichols 2013). Parasites are also natural selection agents influencing a variety of host attributes, from phenotypic polymorphism and secondary sexual characters, to the maintenance of sexual reproduction (Wegner et al. 2003; Lively et al. 2004; Blanchet et al. 2009). These

effects ultimately drive biological diversification, through influencing host reproductive isolation and speciation (Summers et al. 2003). Infections are fundamental to the ecological and evolutionary drivers of biological diversity and ecosystem organization (Marcogliese 2004). Wildlife parasites should be considered meaningful conservation targets as important as their hosts as they not only can affect conservation efforts, but they are also natural selection agents and drive biological diversification, through influencing host reproductive isolation and speciation.

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