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COMMUNICATION

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Comparative cross-sectional survey on gastrointestinal parasites of captive, semi-captive, and wild Elephants of Sri Lanka

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Abstract: Parasites can influence the fitness of individuals particularly of small populations of endangered species. An island-wide, cross sectional, coprological survey was carried out from 03 January to 30 October 2015, to determine the gastrointestinal (GI) parasites of the Sri Lankan Elephant *Elephas maximus maximus*. Fresh fecal samples from wild, captive and semi-captive elephants were collected and analyzed using a modified salt floatation, Sheather's sucrose floatation, direct iodine smears, and sedimentation methods. Species identification was done morphologically. Intensity of parasite infections was determined using McMaster technique. A total of 85 fecal samples (wild = 45, semi-captive = 20, captive = 20) were analysed; 58 (68.2%) samples were positive for GI parasites. Overall, helminth infections (60.0%) were more common than protozoan (37.6%) infections (Chi square test, $\chi^2 = 8.499$; $p < 0.001$). In the captive elephants, however, more protozoan infections were observed than helminthes, which could be due to anthelminthic treatment. A significantly higher prevalence of infection was observed in the wild elephants (93.3%) compared to semi-captive elephants (55.0%; $\chi^2 = 13.516$; $p < 0.001$) and captive elephants (25.0%; $\chi^2 = 32.289$; $p < 0.001$) but there was no significant difference in the prevalence between captive and semi-captive elephants ($\chi^2 = 3.750$; $p = 0.053$). Ten types of GI parasites were observed, nine of which were recorded in wild elephants. Among them the most common infection was strongyles (34.1%) with high intensity (440.1±295.2 EPG). Semi-captive elephants harbored five types of GI parasites, while captive elephants had only three types. One captive elephant at the Temple of the Tooth was infected with the tapeworm *Anoplocephala* sp. at low intensity of 50 EPG. Some of the GI parasites recorded are highly pathogenic while others are incidental.

Keywords: Gastrointestinal parasites, Elephants, Sri Lanka.

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Author Contribution: NA: Collected and analysed the fecal samples, Analysed data, wrote the manuscript; RPVJR: Supervised the parasite egg identification; RSR: Designed the study, supervised and edited the manuscript.

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INTRODUCTION

Globally, the Asian Elephant is listed as 'Endangered' in the IUCN Red List of Threatened Species (IUCN 2008) and is protected under the Convention on International Trade in Endangered Species (CITES) Act. Three subspecies of the Asian Elephant are currently recognized: the Sri Lankan Elephant *Elephas maximus maximus*, the Indian Elephant *Elephas maximus indicus* from the Asia mainland, and the Sumatran Elephant *Elephas maximus sumatranus* from the island of Sumatra in Indonesia (IUCN 2017). Among these, the Sri Lankan elephant has the highest genetic diversity (Fernando 2000; Fleischer et al. 2001). Sri Lanka has the highest density of elephants with over 10% of the global Asian Elephant population in less than 2% of elephant range (Leimgruber et al. 2003). In Sri Lanka, as in the rest of Asia, the elephant has been closely associated with humans and has played a central role in the country's economy, conflicts, religion, and culture for many millennia (Jayewardene 1994). It also holds an important position in the religious and cultural traditions of the country and plays a significant and high profile role in the country's conservation efforts (Jayewardene 1994).

Elephants in the wild are susceptible to many gastrointestinal (GI) parasites (Watve 1995; Dharmarajan 1999; Vidya & Sukumar 2002); in captivity they have enhanced susceptibility as they are often confined to small enclosures and/or maintained in damp unhygienic conditions (Chandrashekaran et al. 1995). Strongyles have been observed in African (Scott & Dobson 1985) and Asian wild elephants as the most common GI parasite (Vidya & Sukumar 2002). In the Asian elephant the helminthes, such as *Parabronema, Brumptia*, *Pseudodiscus*, *Paramphistomum*, and *Fasciola* and *Anoplocephala,* have been recorded (Bhalerao 1933; Gupta 1974; Chandrashekaran et al. 2009). The most common protozoans recorded are *Entamoeba* and coccidian cysts. Injuries, parasitism, and gastrointestinal disease were reported as the most common syndromes responsible for elephant morbidity (Miller et al. 2015). In Kenya, necropsy of 11 fresh wild elephant carcasses revealed the death of the elephants were due to pathological lesions on the intestinal mucosa and haemorrhages which were linked to gastrointestinal parasitism (Obanda et al. 2011).

Studies carried out on Sri Lankan elephant GI parasites record many nematodes: *Murshidia murshidia, M. falcifera, M. longicaudata, Quilonia renniei, Equinubria sipunculiformis, Decrusia additictia* (Seneviratna 1955; Fernando & Fernando 1961; Fowler & Mikota 2008), *Grammocephalus hybridatus, Parabromina smithi* (Seneviratna & Jayasinghe 1968; Perera et al. 2014), *Q. travancra, Choniangium epistomum, Amira pileata, Bathmostpmum sangeri* (Kuruwita & Vasanthathilake 1993), and trematodes: *Cabboldia elephantis* (Seneviratna & Jayasinghe 1968), liver fluke *Fasciola jacksoni* (Perera & Rajapakse 2009), and schistosome, *Bivitellobilharzia nairi* (Agatsuma et al. 2004). More recent studies report strongyle infections in captive and wild elephants in Sri Lanka (Heinrich 2016; Abeysinghe et al. 2017), and unidentified protozoan cysts in captive elephants (Aviruppola et al. 2016). Except for the studies carried out in the 1950s and 1960s (Seneviratna 1955; Fernando & Fernando 1961; Seneviratna & Jayasinghe 1968), recent reports on elephant parasites are focused either on a specific parasite or a particular group of hosts. Here we carried out an island-wide, comparative, coprological survey of GI parasites collecting samples from the wild, captive, and semi-captive elephants of Sri Lanka.

MATERIALS AND METHODS

An island-wide collection of fecal samples from wild, captive, and semi-captive elephants was carried out from 03 January to 30 October 2015. According to the most recent island-wide survey of wild elephants in Sri Lanka carried out in 2011, a minimum of 5,879 animals was estimated (Dissanayake et al. 2012; Santiapillai & Wijeyamohan 2013). There are about 150 captive elephants and 45 semi-captive elephants in Sri Lanka (Fernando et al. 2011).

Wild Elephants

The wild elephants once found throughout Sri Lanka are restricted mainly to the lowland dry zone, which is approximately 60% of the island. Wild elephants are found in protected areas such as national parks including Wilpattu, Yala, Udawalawe, Maduru Oya, Minneriya, Wasgamuwa and Lunugamwehera. Some are not limited to protected areas and are found outside where food and water is plentiful. Wild elephants are free grazers or browsers and do not receive any veterinary care.

Captive Elephants

Elephants that are kept permanently under human control are known as captive elephants. In Sri Lanka, captive elephants are kept by temples, private owners, Pinnawala Elephant Orphanage (PEO), Millenium

Elephant Foundation (MEF) in Kegalle, and National Zoological Gardens at Dehiwala. In addition, at the Temple of the Tooth in Kandy there are 12 elephants, all of which are males and consisting of two tuskers from India, two tuskers from Myanmar, one tusker from Thailand, and four tuskers and three non-tuskers from Sri Lanka. These elephants do not interact with wild ones. They have a great cultural and economic importance (Fernando et al. 2011). Elephants are used in religious festivals and parades; in the past they were used in the transport of timber. Elephants are of great economic value mainly for tourism. The MEF is a private enterprise, which serves as a retirement home for working elephants. Currently there are 10 elephants at MEF; the National Zoo in Dehiwala has eight elephants, while there are about 93 elephants in PEO. Veterinary care for captive elephants is provided and they are dewormed at least twice a year. Febantel (Rintal®) is a first line drug for deworming elephants and Mebendazole is also commonly used.

Semi-captive Elephants

The Department of Wildlife Conservation (DWC), Sri Lanka, has established the Elephant Transit Home (ETH) in Udawalawe where semi-captive elephants are kept (Santiapillai & Sukumar 2006). The aim is to conserve elephants outside the protected areas. Mostly, wild baby elephants that are orphaned due to the death of the mother or abandonment are brought to the ETH which takes care of them until they are fit enough to be released back to the wild, usually after 5–6 years. They do not interact with wild elephants while they are at the ETH. These elephants receive regular veterinary care (e.g., deworming, vaccinations), a standard diet, and bathing. Currently, there are 45 elephants in the ETH. They remain as a group during the day and are kept in a stall at night. All the elephants are bottle fed seven times throughout the day.

Study sites

Fecal samples of wild elephants were collected from four national parks: Minneriya, Udawalawe, Maduru Oya, Yala, and from Mannar District closer to Wilpattu National Park. All the samples from semi-captive elephants were collected from the ETH in Udawalawa. Fecal samples from captive elephants were collected from the elephants in the Temple of the Tooth in Kandy, MEF in Kegalle, and from a private elephant owner in Biyagama (Fig. 1).

Udawalawe National Park contains 400 elephants and lies on the boundary of Sabaragamuwa and Uva provinces in the Wet Zone of Sri Lanka. The park has an annual rainfall of 1,500mm, most of which falls during the months of October to January and March to May. The average annual temperature is about 27–28 ^{0}C, while relative humidity varies from 70% to 82%. This national park spans approximately 31,000ha. Yala National Park is the most visited and second largest national park in Sri Lanka with 97,880ha and 350 elephants. It is located in Uva province with an elevation of 64m. It is situated in dry semi-arid climatic region and rain is received mainly during the northeast monsoon. The mean annual rainfall ranges between 500–775 mm while the mean temperature ranges between 26.4^{0}C in January to 30^{0}C in April. Maduru Oya National Park is located in Eastern and Uva provinces in the dry zone with about 200 elephants. Altitude ranges from 20–60 m. The northeast monsoon is instrumental in the mean annual rainfall of 1,650mm, and the mean annual temperature is 27^{0}C. Maduru Oya National Park is spread over 58,850ha with a special feature of an 8km long rocky range of hills to the southwest of the park. Mannar District is closer to Villpatthu National Park and is one of the 25 districts of Sri Lanka with 29^{0}C annual temperature. The mean annual rainfall ranges between 550–580 mm whereas the area only experiences the tail end of the northeastern monsoon (Department of Wildlife Conservation 2015).

Sample collection

About 50g of fresh fecal samples were collected in a zip-locked plastic bag by inverting the bag and scooping the needed amount into the bag, and then samples were stored in a cooler. The collection was done soon after defecation whenever possible and each site was visited only once and each elephant was sampled once. Samples were labeled and brought to the laboratory and were stored at 4^{0}C until processed. Information on the study animals was recorded using a questionnaire.

Sample analysis

Fecal samples were analyzed in the parasitology laboratories of the Department of Veterinary Pathobiology in the Faculty of Veterinary Medicine and Animal Science at the University of Peradeniya. Qualitative and quantitative analysis were carried out to determine the types of gastrointestinal parasites (GI) and their intensities. Under qualitative analysis, direct saline and iodine mounts, modified salt flotation, Sheather's modified sucrose flotation method, and sedimentation techniques were carried out for each of the samples simultaneously (WHO 1991). Intensity of infection in

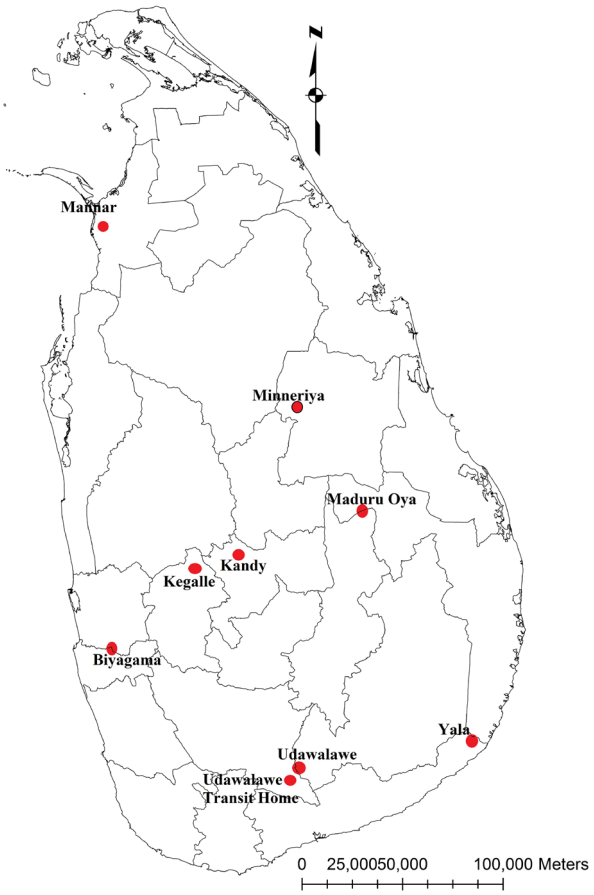

Figure 1. Sample collection sites of elephants in Sri Lanka

the positive samples was calculated using McMaster counting technique; number of eggs or cysts/oocysts per gram (EPG/CPG/OPG) of feces was calculated.

Modified salt floatation method

About 50g of feces was measured and transferred into a 50ml capped centrifuge tube with 45ml distilled water. Feces were mixed thoroughly using a wooden applicator to get a clear solution. This suspension was centrifuged at 2,016g for 20min. The supernatant was removed using a suction pump. Again 45ml of distilled water was added and it was centrifuged for 20min at 2,016g. The supernatant was discarded. Once the supernatant was removed, 45ml of salt solution was added in to the pellet in the butt of the tube. This was centrifuged at 2,016g for 20min. Approximately, 5ml of the supernatant with floating parasitic eggs was removed in to a 15ml centrifuge tube. The total volume was made up to 15ml by adding distilled water and the tube was centrifuged at 2,016g for 10min at 16^{0}C. Supernatant was removed and pipetted in to a 1.5ml Eppendorf® microfuge tube using a Pasteur pipette. Distilled water was added to make it up to 1.5ml and the tube was centrifuged for 10min at 2,744g at 16^{0}C in the micro centrifuge. The supernatant was decanted and the pellet was mixed thoroughly with 0.5ml of the supernatant. Microscope slides were prepared using about 0.1ml of the suspension and covered with a cover slip without staining. Three smears were observed from each sample under ×10 and ×40 objectives (WHO 1991).

Different stages of parasites (eggs, larvae, cysts) were morphologically identified with the aid of experts, standard keys, and literature (Soulsby 1982; Fowler & Mikota 2008). All stages were photographed and measurements were taken using Primostar Zeiss trinocular microscope.

Statistical analysis

The prevalence of parasitic infection in wild, semi-captive, and captive elephants was calculated using the following formula: Prevalence = (Infected number ÷ Individuals examined) x 100%. The prevalence of infections in wild, semi-captive, and captive elephants and the difference in helminth and protozoan infections were compared using a Chi squared test.

RESULTS

A total of 85 fecal samples were collected: 45 from wild elephants, 20 from semi captive elephants, and 20 from elephants in captivity.

Prevalence of GI parasites

Of the samples collected 58 (68.2%) were infected with one or more GI parasites of nematodes, trematodes, cestodes, and protozoans. Overall, helminth infections (60.0%) were significantly more common compared to the protozoan (37.6%) infections (Chi square test, $\chi^2 = 8.499$, $p < 0.001$; Fig. 2). Among the three host categories, the wild elephants had the highest prevalence (93.3%) of GI infections where 42 out of 45 individuals were infected. They all had helminth infections (93.3%) which were significantly higher than the protozoa infections (51.1%; $\chi^2 = 19.994$, $p < 0.001$). All the wild elephants sampled from Minneriya National Park, Udawalawe National Park, and from Mannar District were infected with GI parasites (Table 1). The second highest prevalence of GI infections was recorded from semi-captive elephants (55.0%) where 11 elephants were positive. There was no difference between the helminths (40.0 %) and protozoan (25.0 %) infections ($\chi^2 = 1.026$, $p = 0.311$). When the prevalence of GI parasites

Table 1. Prevalence of helminths and protozoans in the fecal samples of captive, semi-captive, and wild elephants collected from different sites in Sri Lanka

Collection site (n)		Prevalence (%)		
		Overall	Helminths	Protozoans
Wild	Yala NP (8)	87.5	87.5	62.5
	Maduru Oya NP (10)	80.0	80.0	50.0
	Minneriya NP (10)	100	100	40.0
	Udawalawe NP (10)	100	100	50.0
	Mannar (7)	100	100	57.1
Semi-Captive	Udawalawe ETH (20)	55.0	40.0	25.0
Captive	Kandy - TTR (7)	28.6	14.3	14.3
	Kegalle - MEF (10)	20.0	0.0	20.0
	Biyagama (3)	33.3	0.0	33.3
	Total (85)	**68.2**	**60.0**	**37.6**

NP = National Park; TTR = Temple of Tooth Relic; ETH= Elephant Transit Home; MEF= Millennium Elephant Foundation

in the two groups was compared, a significantly higher prevalence of infection was observed in the wild elephants compared to the semi-captive elephants (χ^2 = 13.516, $p < 0.001$). The captive elephants had the lowest GI infections (25.0%) among the three groups where only five elephants out of 20 were positive for GI parasites. Protozoan infections were more common (20.0 %) in captive elephants than helminth (5.0%) infections, but this difference was not statistically significant (χ^2 =2.057; p = 0.151). Among the captive elephants, only one elephant sampled from Kandy (14.3%) had a helminth infection only (Table 1). There was a highly significant difference of parasitic prevalence between captive and wild elephants (χ^2 = 32.289; $p < 0.001$) but not between the captive and the semi-captive elephants (χ^2 = 3.750; p = 0.053).

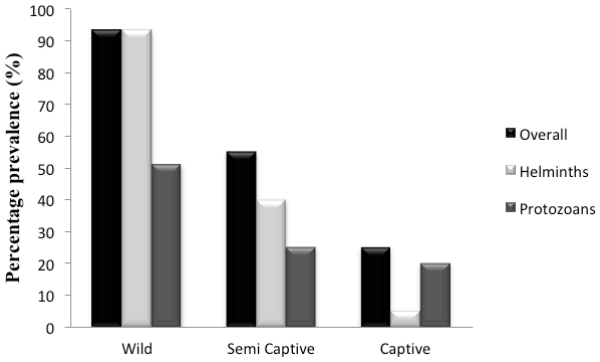

Figure 2. Percentage prevalence of gastrointestinal parasites in wild, semi-captive, and captive elephants; wild=45, semi-captive=20, captive=20

Types of GI parasites

A total of 10 parasite species were found in the elephants (Table 2). Among them the most common helminth infection was strongyles (34.1%) followed by *Ascaris* sp. (22.9%). Among the protozoans, *Entamoeba* sp. (18.8%) was the most prevalent followed by coccidia cysts (15.3%). Wild elephants harbored more parasite species than the other two groups. Overall nine types: strongyles, *Strongyloides* sp., *Ascaris* sp., *Fasciola* sp., *Paramphistomum* sp., unidentified helminth eggs, *Entamoeba* sp., coccidian cysts, and unidentified protozoan cysts were recorded (Table 2). In semi-captive and captive elephants five types and three types of parasites were recorded, respectively. The wild elephants had all the parasites recorded in the present study except *Anoplocephala* sp., which was recorded only from one captive elephant from the Temple of the Tooth in Kandy. All the samples from Minneriya National Park were positive for strongyles. All three elephant groups had *Entamoeba* sp. infections. Among helminths, strongyles, *Ascaris* sp., and *Fasciola* sp. were recorded from both semi-captive and wild elephant categories (Table 2). Unidentified protozoan cysts were found in semi-captive and wild elephants (Image 1). The captive elephants harbored three parasite species (*Anoplocephala* sp., *Entamoeba* sp., and coccidia cysts; Table 2). None of the elephants in MEF and from private owners in Biyagama had GI helminths. Four samples were positive (20.0%) for protozoans (*Entamoeba* sp., coccidia cysts). *Entamoeba* sp. was found only in two elephants from MEF in Kegalle. None of the other captive elephants were positive for *Entamoeba* infection. Coccidia cysts were positive in 1 sample from Temple of

Table 2. Types of parasites and their prevalence in wild, semi-captive, and captive elephants in Sri Lanka (n =85)

Parasitic group	Parasite species	Prevalence of infection (%)			
		Overall	**Captive**	**Semi captive**	**Wild**
Helminths	Strongyles	34.1	-	20.0	55.6
	Strongyloides sp.	16.5	-	-	31.1
	Ascaris sp.	22.9	-	10.0	37.8
	Anoplocephala sp.	1.2	5.0	-	-
	Paramphistomum sp.	3.5	-	-	6.7
	Fasciola sp.	12.9	-	10.0	20.0
	Unknown eggs	5.9	-	-	11.1
Protozoans	*Entamoeba* sp.	18.8	10.0	20.0	22.2
	Coccidia cysts	15.3	10.0	-	24.4
	Unknown cysts	5.9	-	10.0	6.7
	Total	68.2	25.0	55.0	93.3

Table 3. Mean Eggs per gram (EPG) or Oocysts per gram (OPG) counts of different parasites in the captive, semi-captive, and wild elephants

Parasite species		**Mean EPG or OPG counts (±SD)**		
		Captive	**Semi-captive**	**Wild**
Eggs	Strongyles	-	50.0±9.1	440.1±295.2
	Strongyloides sp.	-	-	225.8±157.7
	Ascaris sp.	-	95.0±7.1	251.2±225.1
	Anoplocephala sp.	40	-	-
	Paramphistomum sp.	-	-	123.3±94.5
	Fasciola sp.	-	60.0±14.1	152.2±97.7
	Unknown eggs	-	-	82.5±34.9
Cysts	*Entamoeba* sp.	75.0±35.4	58.0±22.2	169.8±125.4
	Coccidia cysts	55.0±7.1	-	92.7±52.1
	Unknown cysts	-	30.0±14.1	65.0±35.4

*Note -SD = Standard Deviation.

the Tooth and in 1 sample from Biyagama.

Mixed infections

Mixed infections were more common (47.1%) than single infections (21.2%). The percentages of elephants having mixed infections of 2, 3, and 4 parasites were 24.7%, 17.6%, and 4.7%, respectively. Multiple infections of helminthes (30.6%) were more common than those of protozoans, which were found only in three elephants (3.5%). Multiple helminth infections were not recorded in semi-captive and captive elephants. Twenty-three wild elephants were infected with both helminth and protozoan infections. Eight semi-captive elephants were infected with single GI infection (40.0%) and three were infected with mixed infections (15.0%). Among the eight single infections, six samples were positive for helminths and two samples were positive for protozoans.

Intensity of GI parasites

A high intensity of infection was recorded for strongyles in wild elephants (Table 3). The highest helminth egg count of 1,100 EPG of strongyles was recorded in a wild elephant from Minneriya National Park. In general, all the infections in wild elephants had a higher intensity than those in the captive and semi-captive animals. Highest number of cysts (340 OPG) of *Entamoeba* sp. was recorded from a wild elephant in Maduru Oya National Park. The intensity of all the infections in the wild elephants was higher compared to semi-captive and captive elephants. The intensity of common helminth and protozoans infections was lower in captive and semi-captive elephants than in wild

Table 4. Percentage prevalence of single and mixed infections of gastrointestinal parasitic groups in wild, semi-captive, and captive elephants in Sri Lanka

Parastic group	Infection Type	Prevalence of infection (%)			
		Overall	Captive	Semi captive	Wild
Helminths	Single	29.4	5.0	40.0	35.6
	Mixed	30.6	-	57.8	-
Protozoans	Single	34.1	20.0	20.0	46.7
	Mixed	3.5	5.0	4.4	-

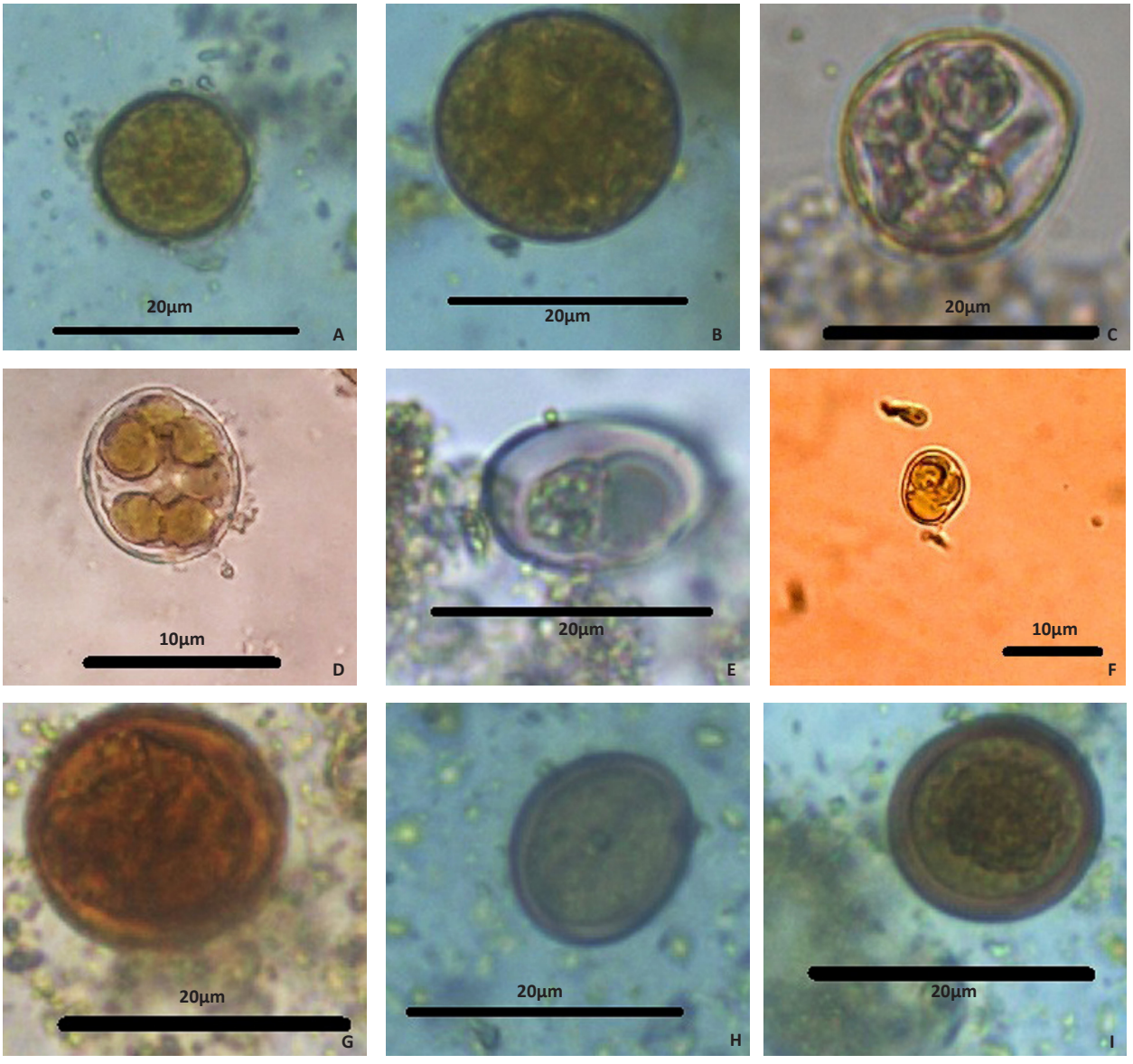

Image 1. Types of protozoan cysts recorded during fecal analysis of wild (B, D, F, H, I), Semi-captive (A, G), and Captive (E, C) elephants, using modified salt flotation (A, B, E, F, G, I) and direct iodine smear (C, D, H) methods. A, B, C - Amoeboid parasites (*Entamoeba* sp.) D, E, F - Coccidian cysts G, H,I - Unknown cysts

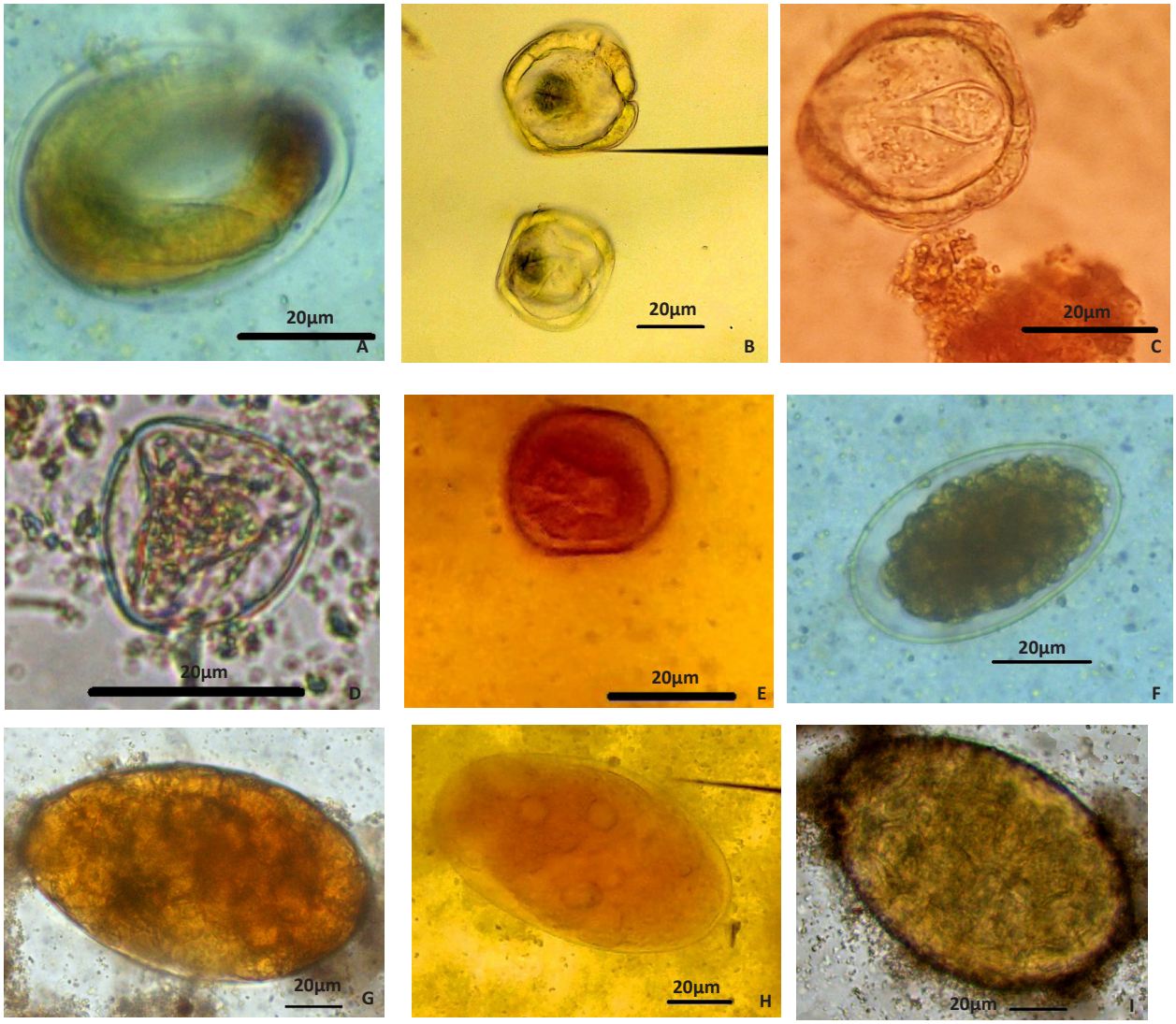

Image 2. Helminth eggs recorded from captive and wild elephants using modified salt flotation (A, B, C, D, F), sedimentation - (G, H) and direct iodine smear (E, I) method. (A) *Strongyloides* sp., (B, C) *Anoplocephala* sp., (D, E) Unknown eggs, (F) Stongyles, (G) *Paramphistomum* sp., (H) *Fasciola* sp., (I) *Ascaris* sp.

elephants. Unknown cysts were found in semi-captive and wild elephants; among them the lowest cyst count (50 OPG) was recorded from a semi-captive elephant in ETH (Image 1). *Anoplocephala* sp. was recorded at low EPG (40) in only one captive elephant at the Temple of the Tooth in Kandy. Coccidia cysts were found in wild and captive elephants; among them the lowest OPG (45) was recorded from a captive elephant in Biyagama (Image 2).

DISCUSSION

The present study reports an overall prevalence of 68.2% of GI parasites in elephants of Sri Lanka; the infection in wild elephants (93.3%) was significantly higher than that of the captive (55.0%) and semi-captive elephants (25.0%). Unlike the wild elephants, the captive and semi-captive elephants receive regular deworming which is the main reason for having a low prevalence of GI parasites in these two groups. In general, oral deworming treatments are given two to three times per year with special treatments if elephants show clinical symptoms. Febantel and Mebendazole are the commonly used anthelminthics for both captive and semi-captive elephants in Sri Lanka (personal communication with the veterinarian). Febantel is a broad spectrum anthelminthic used against GI parasites including *Giardia*, roundworms, hookworms, whipworm, ascarids, and tapeworms (Tiwari & Rao 1996). Deworming of

both adult elephants and calves is done with Febantel twice a year @ 5–10 mg/kg body weight. Mebendazole is a highly effective, broad-spectrum anthelmintic for the treatment of nematode infestations, including roundworm, hookworm, whipworm, threadworm, and the intestinal form of trichinosis prior to its spread into the tissues beyond the digestive tract (Tiwari & Rao 1996). The prevalence of helminth infections was higher in wild elephants than the other two groups. This could be because the anthelminthic drugs mainly target the helminths. Irrespective of regular deworming treatments, one third of Biyagama captive elephants were infected. This could be attributed to the method of deworming where individuals were treated separately, while the other captive elephants were treated simultaneously. Moreover, sampling of elephants in Biyagama was done five months after the last deworming while sampling of other two sites was carried out within 2 to 3 months after deworming. Furthermore, in Biyagama the space limitation for the captive animals can aggravate the prevalence of GI parasites. All the wild elephants sampled from Minneriya and Udawalawe National Parks were infected. Due to the water scarcity in these national parks, many elephants congregate and depend on a single water hole. This tends to increase the contamination rate as they defecate on the ground and there is a higher possibility of infection of the whole herd when one individual is infected. Potential factors determining the transmission of GI parasites in the wild include environmental conditions that affect the viability and behaviour of parasite propagules, as well as feeding, movement, and defecation patterns of the host, which determine the parasites encountered (Watve 1995; Vidya & Sukumar 2002).

A total of 10 species of GI parasites was found in the elephants. All the helminth species except *Anoplocephala* were recorded in wild elephants. None of the captive elephants had any helminths except *Anaplocephala*. Semi-captive elephants had strongyles, *Ascaris*, and *Faciol*a infections. All three protozoans recorded were found in wild elephants. *Entamoeba* was reported both in captive and semi-captive elephants. Strongyles was the most common infection. The most common helminth was strongyle followed by *Ascaris*. A recent study carried out in Sri Lanka at Pinnawela Elephant Orphanage (PEO), Galgamuwa wild elephants, and with some privately owned elephants by Abeysinghe et al. (2017) reported that 100% of wild elephants and 90% of privately owned captive elephants were infected with strongyles, while only 38% of elephants in PEO harbored that infection. Vanitha et al. (2011) reported the prevalence of strongyles as 37% in captive elephants in Tamil Nadu, India. They show that the prevalence varies significantly across seasons, with the highest rate during summer (49%) followed by monsoon (41%) and the lowest rate during winter (15%). Furthermore, they have shown that male elephants have a lower parasite prevalence compared to females, and the age classes show no difference. Previous studies from India also record strongyles as the most comment type of GI parasite (Watve 1995; Chandrasekharan et al. 1995; Vidya & Sukumar 2002; Chandrasekharan et al. 2009). Saseendran et al. (2003) reported 10% of captive elephants had strongyles in Kerala, India. There is a correlation between the pathogenecity of the parasite and the number of eggs that they produce. In the present study, the strongyles were not found in captive elephants. Anthelminthics against strongylosis in captive elephants are effective (Chandrasekharan 1992; Suresh et al. 2001).

Ascaris infections were recorded in wild and semi-captive elephants. *Ascaris* sp. is known to evolve anthelminthic resistance, which could be a possible reason for the presence of the parasite in semi-captive elephants, even with regular anthelmintic treatments. It may also be due to treating with broad-scale anthelminthics at sub-curative dosages, which eventually leads to the development of resistance. Resistance has been recorded in both Asian and African Elephants in India (Bapu 1936), Nigeria (Mbaya et al. 2012), and Bangladesh (Rahman et al. 2014). The other helminth infections recorded were *Strongyloides* sp., *Paramphistomum* sp., *Fasciola* sp. These have also been reported in elephants in India (Varadharajan & Kandasamy 2000) and in Borneo (Hing et al. 2013).

One captive elephant was infected with the tapeworm *Anoplocephala* sp. at low intensity of 40 EPG. This elephant was the oldest male elephant belonging to the Temple of the Tooth and was in musth condition at the time of sampling, which was done five months after a deworming treatment. Although all the elephants were kept together, none of the six other elephants sampled from the same temple had the infection. The oribatid mite acts as the intermediate host transmitting the infection and can easily spread the infection to other individuals in the vicinity. These six samples however, were collected two months after the last deworming, which may be a reason for the absence of *Anoplocephala* infection among them. Moreover, cestode eggs are not equally distributed in the fecal matter, probably due to the eggs being shed as gravid proglottids detached from tapeworm. Some studies report that *Anoplocephala*

eggs are difficult to find in fecal samples (Ihler et al. 1995; Nilsson et al. 1995) and suggest using modified methods and 30–40 g of feces.

Perera et al. (2014) recorded adult tapeworm *Anoplocephala* sp. from wild elephants in the Udawalawe National Park and the identifications were done using morphometric features and molecular characterization of its 2s and 28s genes. *Anoplocephala* has been found in both Asian and African captive elephants where Obanda et al. (2011) reported that *Anoplocephala manubriata* was common among wild African Elephants. It has been recorded in the Asian elephant in Kerala, India (Warren 1996), and in Tamil Nadu state in Mudumalai, Anamalai, and Sathyamangalam forests in India (Nishanth et al. 2012).

All protozoan parasites recorded in the present study (*Entamoeba* sp., Coccidian cysts, and unknown cysts) have been previously recorded in elephants in South Africa (Eloff & van Hoven 1980; Samuel 2001). Protozoans including coccidian parasites such as *Eimeria* sp., *Isospora* sp. (Mbaya 2013), are commonly found in a wide variety of species but rarely cause disease in free-living elephants (Samuel 2001). In addition, GI protozoans like *Cryptosporidium*, *Cyclospora*, and *Giardia* have been reported in captive African and Asian Elephants (Majewska et al. 1997) but were not found in the present study. There are some non-pathogenic protozoans that can be found in elephants, including in the amoeboid group (Begon 1995). They do not harm elephants, even those with weak immune systems. Symptomatic elephants that are found to have these protozoa in their feces should be examined for other causes of their symptoms.

All the wild elephants had mixed infections. A higher frequency of mixed infections in wild elephants could be due to animal movement and grazing behavior. When there is greater freedom of animal movement, it can result in feeding at a greater variety of locations and on more different types of fodder thus increasing exposure to a greater variety of endoparasites (Nunn et al. 2003). Moreover, the presence of one parasite species may facilitate the presence of the other species (Fontanarrosa et al. 2006) since the elephants that have mixed infections with higher parasite intensities are known to have less immunity. Mixed infections of strongyles and *Strongyloides* sp. are common in wild elephants (Watve 1995; Dharmarajan 1999; Nishanth et al. 2012).

All gastrointestinal parasites are not equal, some are highly pathogenic and some are incidental. The presence of parasites in the fecal samples of elephants does not necessarily mean they are sick, or will be sick, nor does it mean that the animal should be treated. Gaur et al. (1979) stated that wild animals in a free-living state are generally infected with numerous parasites, but these cause little harm to them unless they are physiologically or nutritionally stressed. Understanding the infections in wild animals is important since infections could result in die-offs of elephants during extreme stress conditions. In 1995, three Sumatran Elephants (*Elephas maximus sumatranus*) died suddenly of helminth infection in the Way Kambas National Park, Indonesia. Postmortem examination revealed that the GI tracts of all three animals were infected with *Murshidia falcifera* (Nematoda), *Hawkesius hawkesi*, *Pfenderius papillatus* (Digenea), and *Cobboldia elephantis* (Diptera) (Matsuo et al. 1998).

The baseline information of disease prevalence of already threatened taxa is important in understanding the role of disease in provoking endangerment. Although there are some studies on GI parasites of elephants in Sri Lanka, most of them were focused mainly on one type of elephant group. This study, however, provides a comprehensive survey of wild, captive, and semi-captive elephants in Sri Lanka. All the wild elephants sampled from Minneriya National Park, Udawalawe National Park and from Mannar District were infected with GI parasites and some with very high intensities. Deaths due to parasitism have been reported from elsewhere. Necropsy of 11 fresh wild African Elephant carcasses in Kenya revealed pathological lesions on the intestinal mucosa and haemorrhages, which were linked to parasitism (Obanda et al. 2011). It is likely that starvation and dehydration could have triggered a vicious cycle of host malnourishment, a result of combined inadequate food and nutritional deprivation by intestinal parasites, which lead to emaciation, pathology, and death (Obanda et al. 2011). So it is important to monitor mortalities of wild elephants and carry out post-mortem sampling to determine whether the cause of death was due to GI infections. Estimation of GI parasitic egg burdens is also key for designing appropriate treatment or management regimes in captive host populations. Therefore it is vital to do a fecal egg count prior to deworming semi-captive and captive elephants. As stated by Miller et al. (2015), there is a need to identify strategic investments in Asian Elephant health that will yield maximal benefits for overall elephant health and conservation as prevention is often the most cost-effective approach.

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