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Research paper

Diversity of parasites in two captive chimpanzee populations in southern Gabon

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ABSTRACT

Captive chimpanzees living in confined environments like sanctuaries or primatology centers are frequently affected by gastrointestinal parasites. Some of these are likely to be transmitted to humans and may seriously affect public health. However little information is currently available on the gastrointestinal parasites of primates living in such environments. Here, we characterize the diversity and prevalence of gastrointestinal parasites in two populations of captive chimpanzees living in south-eastern Gabon. Our study reveals that at least nine parasite species infect the chimpanzees with high prevalence, including several helminths (*Ascaris* spp., *Enterobius* spp., *Strongyloides* spp., *Trichuris* spp., *Hymenolepis* spp., *Mammomonogamus* spp), three protozoa (*Balantoides* spp., *Entamoeba* spp. and *Troglodytella* spp) and several unidentified parasites. All the parasite taxa we identified had previously been identified in other primates, including humans. Age, sex and site type may influence infection rates and/or parasite diversity found in a particular host.

1. Introduction

Habitat destruction, logging, and bushmeat trade are significant threats to wild primates (Estrada et al., 2017; Etiendem et al., 2013). Once their habitats destroyed, primates are easily killed and survivors are occasionally taken for sale (Nellemann et al., 2010). Sanctuaries offer protection to these survivors (Beck et al., 2007; Macfie and Williamson, 2010) and various species of non-human primates are maintained in captivity in primatology centers and sanctuaries (Harrison et al., 2008; Hosey, 2005).

Parasitic infections are the most common causes of gastrointestinal diseases in captive nonhuman primates (McPherson, 2013; Tangtrongsup et al., 2019). Because these animals are receptive to gastrointestinal parasites which naturally infect humans (Wolfe et al., 1998), they are potential reservoirs for human parasites (Mafuyai et al., 2013; Soulsby, 1982). Great apes maintained in captivity cannot easily be reintroduced to the wild safely (Guynup, 2017; Robins et al., 2019); living in close contact with humans and in confined environments

facilitates the exchange of infectious agents (Nunn and Hare, 2012). This makes it important to assess gastrointestinal parasite prevalence and diversity in such animal populations.

In this preliminary study we investigate two populations of rescued chimpanzees: one housed in a primatology center and the other in a sanctuary, both in south-eastern Gabon. We evaluated the diversity and prevalence of gastrointestinal parasites in these two confined environments. As far as possible, we also assessed the influence of sex, age, season and site on the presence of intestinal parasites.

2. Material and methods

2.1. Ethics statement

All faecal samples were collected outside national parks and protected areas, using non-invasive methods, as recommended by the National Ethics Committee of Gabon and with the authorization of the Gabonese Ministries of Water and Forestry, Higher Education, Scientific

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2.2. Study sites

We conducted research on gastro-intestinal parasites from February 2017 to March 2018 (13 months) on two populations of chimpanzee: the primatology center at CIRMF (CDP) and the private Lékédi park, both in the Haut-Ogooué province in south-east Gabon (Fig. 1).

Close to the city of Franceville, the CDP environment is strongly impacted by human activities. The CDP houses more than 350 non-human primates of 10 different species, including 54 chimpanzees, 250 mandrills (*Mandrillus sphinx*) and other species of Cercopithecidae. A team of 30 permanent employees and volunteers takes care of the animals, feeding and monitoring them. At night, security agents and dogs guard the center. During this study, we collected faecal samples from 47 chimpanzees during routine health surveys. The other 7 were not included in this study because of their health status: 3 were in quarantine and 4 in retirement.

Lékédi Park is near the town of Bakoumba, approximately 100 km from Franceville; the park covers about 14,000 ha and is completely fenced. Three different types of vegetation are found there: primary forest, secondary forest and savannah, making it a suitable site to receive

chimpanzees and gorillas (*Gorilla gorilla*) seized by the Ministry of Waters and Forest during anti-poaching operations. Three groups of reintroduced chimpanzees being rehabilitated for release into the wild, live there in semi-free ranging conditions. They share the space with wild gorillas and chimpanzees living and circulating freely in the Park. A team of workers takes care of the animals (feeding, nursing, monitoring) from 08:00 h to 17:00 h every day; we collected faecal samples from a group of 23 young semi-free chimpanzees.

2.3. Faecal sample collection and examination

We collected samples at each site twice a year, once during the rainy season and once during the dry season. We collected samples <1 h after defecation and examined them the same day. We noted the site, age, sex and season for each sample. Overall, we collected and examined 140 faecal samples. Faecal samples were analyzed via sodium nitrate flotation and faecal sedimentation following the protocol described in Gillespie (2006). As previously described (Boundenga et al., 2018) the detection and counting of parasite eggs, larvae, and cysts was performed using a compound microscope (x10 objective). Egg pictures were captured using a microscope (Leica ICC50 HD) coupled with a computer and using the x40 and x100 objectives. Identification of parasites is based on the morphology and size of the egg shell, nucleus and larvae as

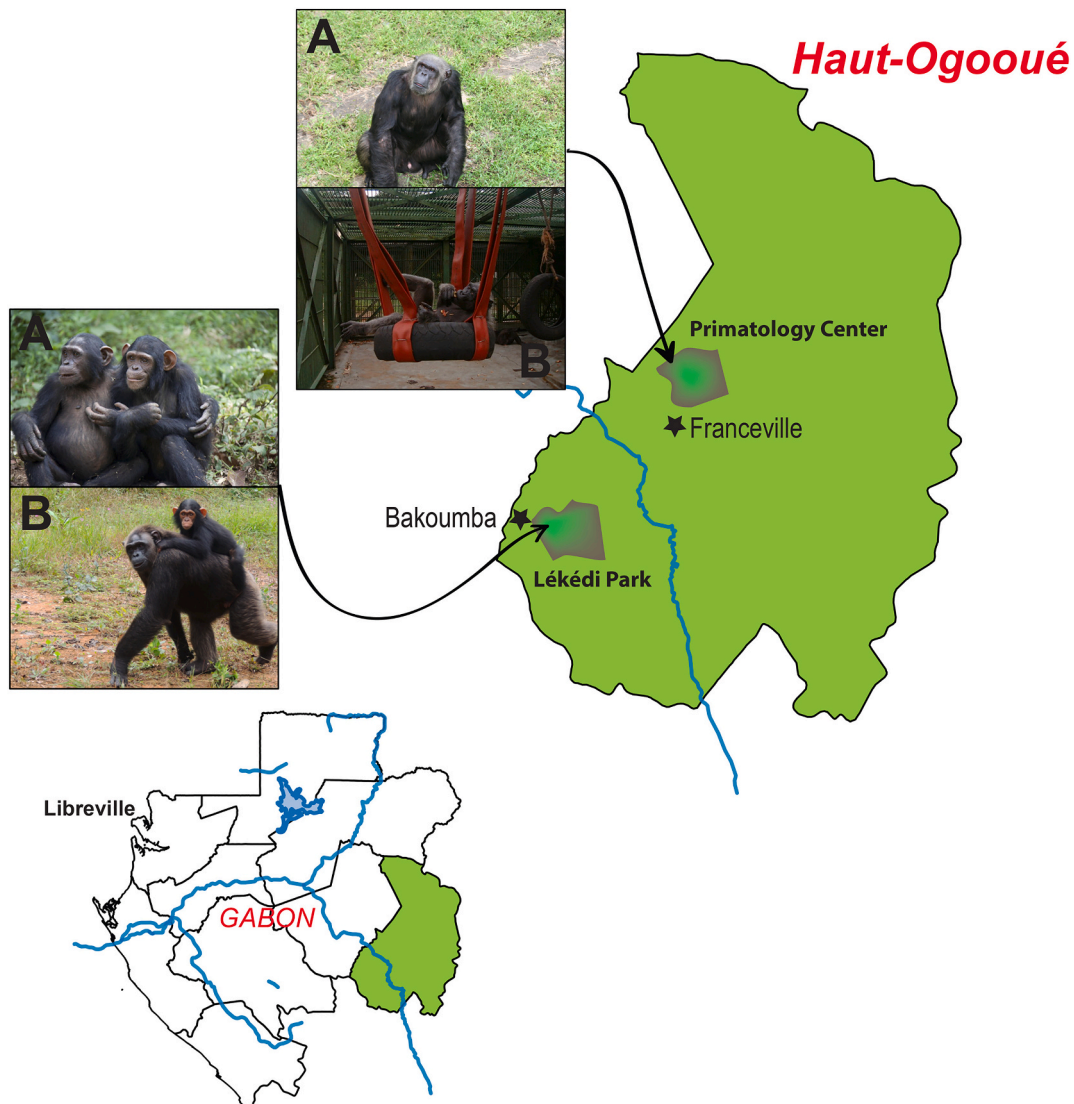


Fig. 1. Map of the study sites in South-east Gabon. This figure shows the different chimpanzees in their environments.

described by Chitwood and Chitwood (1950), Golvan (1990), Ashford and Crewe (2003) and Gillespie (2006). Information about the parasite biology and their host spectrum was obtained from the same sources and from Anderson (2000) and Combes (1996).

Identification using morphometric analysis precludes precise determination at the species level, so we identified positive samples to the genus level when possible. The genus name used is that of the parasite of the same type (order, suborder, family) found in other primates, including humans. When several diagnoses were possible, we chose the most probable based on the parasite's lifecycle and host taxonomy. For most of the parasites, the genus is likely to include several species, so we use the abbreviation "spp". The Strongyloidea are a special case; when Strongyloidea eggs are detected they are likely to be *Strongyloides* spp., *Oesophagostomum* spp., *Necator* spp. or other members of this group. Among these different taxa only the first one may be identified unambiguously and is therefore designated in the following as *Strongyloides* spp. Without any possibility of identification at the generic level the other Strongyloidea are categorized as "strongylid" eggs.

2.4. Statistical analyses

All statistical analyses were performed using R software. Prevalence between sites and sexes were compared using Chi-square (χ^2) tests. We compared seasons using the McNemar test. Differences were considered statistically significant at 0.05 confidence level.

3. Results

3.1. Diversity and prevalence of parasite taxa

After examination of 140 faecal samples from chimpanzees, several genera of gastrointestinal parasites were identified (Fig. 2). **Helminths:** *Ascaris* spp., *Enterobius* spp., *Strongyloides* spp., *Trichuris* spp., *Hymenolepis* spp., *Mammomonogamus* spp.; strongylid eggs; unidentified eggs very similar to the eggs of *Toxocara* spp. **Protozoa:** *Balantioides* spp., *Entamoeba* spp. and *Troglodytella* spp.

Among the helminths, *Strongyloides* spp. was the most frequent with an overall prevalence of 67%, followed by "other" strongylid eggs, 57%, *Ascaris* spp. 44% and *Trichuris* spp. 24% (Table 1). For the other taxa, the overall prevalence varied 1–17% (Table 1). Among the protozoans, *Balantioides* spp. had the highest prevalence (66%), followed by *Entamoeba* spp. (48%), while *Troglodytella* spp. was found in 7% of samples (Table 1).

3.2. Effect of site, season and host sex and age on infection prevalence

Infection levels (Table 1) are generally higher at Lékédi Park than at the CDP. Three parasite groups were significantly more frequent in LEK Park than in CDP: strongylid eggs, *Trichuris* spp. and *Mammomonogamus* spp. Two groups found at Lékédi Park, *Hymenolepis* spp. and *Troglodytella* spp., were not found in samples from the CDP. Conversely: *Ascaris* spp. was more frequent in samples from the CDP than from Lékédi Park. *Enterobius* spp. was identified only in samples from the CDP.

A significant difference in infestation rate was observed between the rainy and the dry season ($p < 0.05$). At the CDP, six parasites had a higher prevalence during the rainy season: *Ascaris* sp. ($p = 0.005$), *Strongyloides* spp. ($p = 0.009$), *Enterobius* spp. ($p = 0.004$), *Mammomonogamus* spp. ($p = 0.023$), *Balantioides* spp. ($p = 0.006$) and a group of strongylid eggs ($p = 0.003$) (Table 2). At Lékédi Park, the same difference was observed for four parasite taxa: *Strongyloides* spp. ($p = 0.006$); *Ascaris* spp. ($p = 0.004$); *Trichuris* spp. ($p < 0.001$) and *Mammomonogamus* spp. ($p = 0.015$) (Table 2).

At the CDP, prevalence was significantly higher in males than females ($p < 0.05$) for strongylid eggs, *Balantioides* spp., *Strongyloides* spp. and group of unidentified parasites (Table 3). At Lékédi Park, prevalence was generally higher in males than females but the differences were not

statistically significant (Table 3).

The effect of age could not be evaluated at the CDP because only adult individuals were examined. At Lékédi Park, the prevalence of *Trichuris* spp. and group of unidentified parasites were significantly higher among adults than young animals (Table 4). For other parasites, adults at Lékédi tended to have higher infection rates than young animals, although the comparison was not statistically significant (Table 4).

4. Discussion

Several recent studies have reported wide gastrointestinal parasite diversity in African non-human primates (Clough et al., 2010; Howells et al., 2011; Kalousova et al., 2014). With the exception of *Mammomonogamus* spp. all the gastro-intestinal parasites identified in this study had previously been recorded in chimpanzees.

4.1. Helminth parasites

4.1.1. *Strongyloides* spp.

With 67%, the highest prevalence was for *Strongyloides* spp. This prevalence is similar to that found in studies of wild chimpanzees, where *Strongyloides* prevalence was 74–100% (Gillespie et al., 2010; Krief et al., 2005) and higher than reported in several studies of captive chimpanzees (Howells et al., 2011; Landsoud-Soukate et al., 1995; Mbaya and Udendeye, 2011; Petrášová et al., 2010). The parasites identified in our study may be *Strongyloides fuelleborni*, recorded in chimpanzees from Gabon (Hasegawa et al., 2016); but because strongylid eggs are morphologically similar and overlap in size, they may also belong to *Oesophagostomum*, *Necator* or *Trichostrongylus*, which have also been identified in chimpanzees (Pafčo et al., 2019; Krief et al., 2005).

4.1.2. *Ascaris* spp.

With a prevalence of 44%, *Ascaris* spp. has a higher prevalence than previously observed (Mbaya and Udendeye, 2011; Mul et al., 2007). Recent studies suggested the presence of two different species in captive chimpanzees: *A. lumbricoides*, primarily a human parasite, and *A. suum*, a pig parasite likely to be transmitted to humans (da Silva et al., 2003; Nejsun et al., 2010; Zhou et al., 2012). However, recent molecular evidences suggests that these two taxa may be a single species (Leles et al., 2012). Whatever the taxonomy, *Ascaris* spp. seems to be very common among captive chimpanzees, but rare in the wild (Mbaya and Udendeye, 2011; Mul et al., 2007). This could be due to the mode of contamination: ingestion of mature eggs present in soil, and water or food contaminated with human or animal feces (faecoral contamination).

4.1.3. *Trichuris* spp.

Trichuris spp. have been reported in captive and wild chimpanzees (Drakulovski et al., 2014; Mbaya and Udendeye, 2011; Petrášová et al., 2010) and are the third most prevalent parasite in our study. For this parasite our results suggest a higher infection rate in captive (23.6%) than wild chimpanzees (between 0 and 5% in Drakulovski et al., 2014; Petrášová et al., 2010). This may be due to higher proximity to humans in captive animals and support the zoonotic potential of this parasite. In all cases in the literature, the parasite was identified as *T. trichiura* (Ghai et al., 2014; Gillespie et al., 2010), which is known to be a common parasite of humans and non-human primates (Barriga, 1982) and sometimes implicated in the death of chimpanzees (Hennessy et al., 1994; Toft, 1982).

4.1.4. *Enterobius* spp.

Enterobius spp. have previously been identified in African primates (Ebbert et al., 2015; Gillespie et al., 2010) and infect chimpanzees in captivity (Hasegawa and Udono, 2007; Hugot et al., 1996; Hugot, 1993). The specific parasite species found in wild or captive chimpanzees is *Enterobius anthropopithecii* (Hasegawa and Udono, 2007; Hugot, 1993). However, recent studies reported the presence of *E. vermicularis*, the

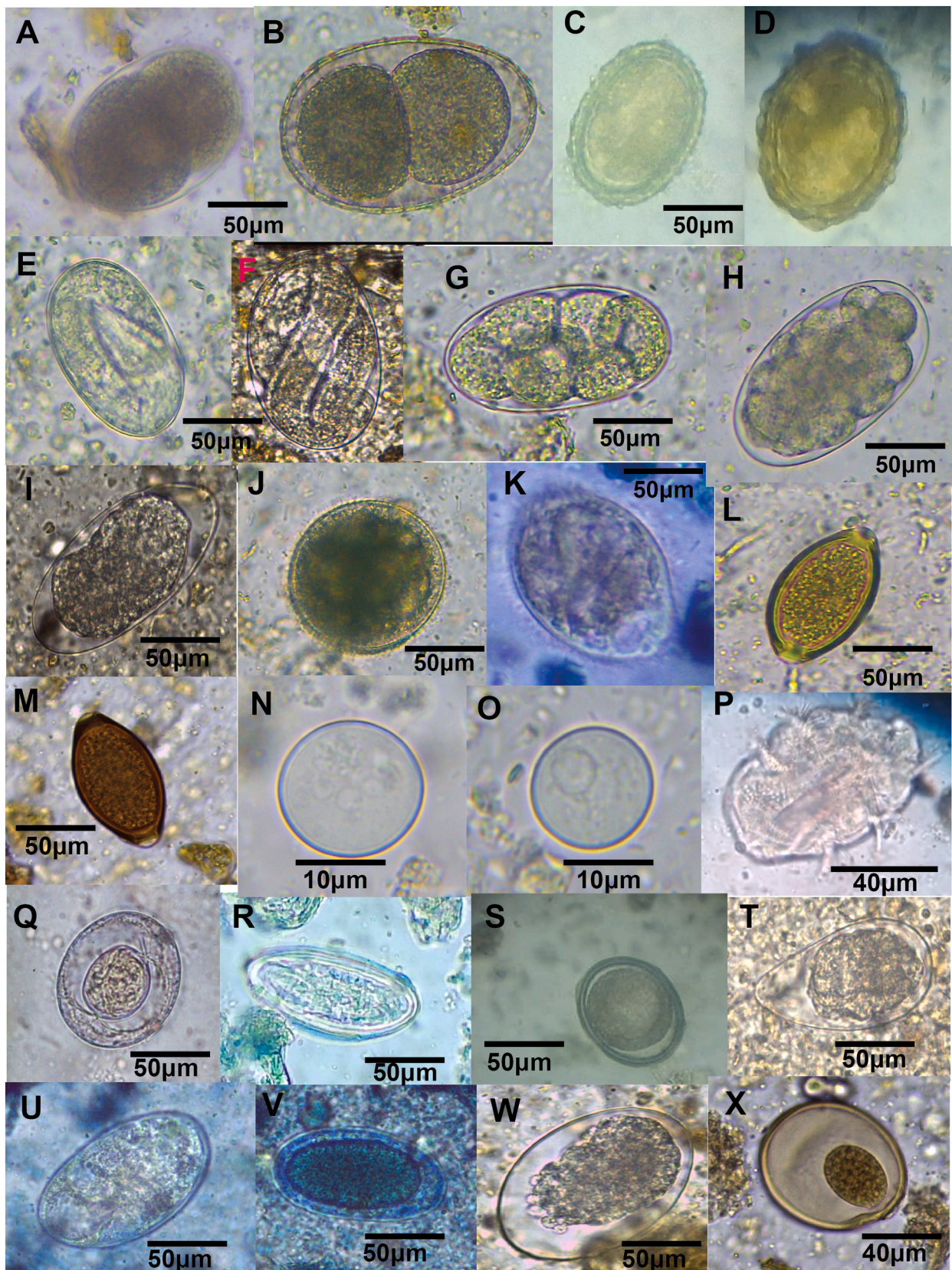


Fig. 2. Intestinal parasites genus found in captive chimpanzees. *Mammomonogamus* spp. (A, B); *Ascaris* spp. (C, D); *Strongyloides* spp. (E,F); strongylid eggs (G,H,I); *Balantioides* spp. (J,K); *Trichuris* spp. (L,M); *Entamoeba* spp. (N,O); *Troglodytella* spp. (P); *Hymenolepis* spp. (Q); *Enterobius* spp. (R) and unidentified parasites (T, U, W, X).

Table 1

Prevalence of gastrointestinal parasites taxa identified during the period of study following the site of collection.

Parasites taxa	Global Prevalence	Chimpanzees				Comparison test					
		CDP		LEK		χ^2	df	p-value	S	CDP	LEK
		N/94 (%)	P	N/46	P (%)						
Helminths											
<i>Ascaris</i> spp	43.57	51	54.26	10	21.74	4.94	1	0.026	+	+	
Strongylid eggs	57.14	34	36.17	46	100	7.62	1	0.000620	+	-	+
<i>Strongyloides</i> spp	67.14	64	68.08	30	91.30	1 ² .4	1	0.99	-	-	+
<i>Enterobius</i> spp.	7.14	10	10.64	0		3.31	1	0.0684	+	+	-
<i>Trichuris</i> spp.	23.57	13	13.83	20	43.47	7.58	1	0.0059	+	-	+
<i>Hymenolepis</i> spp	1.43	0		2	4.34	0.050	1	0.8219	-	-	+
<i>Mammomonogamus</i>	12.86	7	7.44	11	23.91	4.36	1	0.0367	+	-	+
Unidentified eggs	3.57	5	5.31	0	0		1	0.2424	-	-	+
Protozoas											
<i>Balantioides</i> spp	65.71	53	56.38	39	84.78	1.78	1	0.1818	-	-	+
<i>Entamoeba</i> spp	47.86	36	38.30	31	67.39	2.94	1	0.0865	-	-	+
<i>Troglodytella</i> spp	7.14	0	0	10	21.73	15.2	1	9.522 ^{e-05}	+	-	+

Comparison of the prevalence between two sites computed using the chi-square test.

Table 2

Distribution of infection by parasite taxa according seasonal pattern.

Primates center	Rainy season		Dry season		Comparison test						
	N/47	P (%)	N/47	P(%)	χ^2	df	p-value	S	Rs	Ds	
<i>Ascaris</i> spp	36	76.59	15	31.91	4.916	1	0.0266	+	+		
Strongylid eggs	24	51.01	10	21.28	3.492	1	0.0617	-	+		
<i>Strongyloides</i> spp	45	95.74	19	40.42	5.65	1	0.0175	+	+		
<i>Enterobius</i> spp	10	21.28	0		7.21	1	0.00722	+	+		
<i>Balantioides</i> spp	37	78.72	16	34.04	4.653	1	0.031	+	+		
<i>Entamoeba</i> spp	24	51.06	12	25.53	2.284	1	0.130	-	+		
<i>Trichuris</i> spp	8	17.02	5	10.63	0.234	1	0.628	-	+		
<i>Mammomonogamus</i> spp	7	14.86	0	0	4.69	1	0.030	+	+		
Unidentified parasites	2	4.25	0	0	0.46	1	0.4934	+	+		
Lékédi Park											
	N/23	P (%)	N/23	P(%)	χ^2	df	p-value	S	Rs	Ds	
<i>Ascaris</i> spp	10	43.47	0	0	6.56	1	0.0105	+	+		
Strongylid eggs	23	100	21	91.30	0.138	1	0.7099	-	+		
<i>Strongyloides</i> spp	23	100	7	30.43	4.35	1	0.037	+	+		
<i>Balantioides</i> spp	23	100	16	69.56	0.371	1	0.54	-	+		
<i>Entamoeba</i> spp	23	100	8	34.78	3.6	1	0.059	+	+		
<i>Trichuris</i> spp	19	82.60	1	4.34	10.33	1	0.0013	+	+		
<i>Troglodytella</i> spp	4	17.39	6	26.08	0.0504	1	0.822	-	-	+	
<i>Mammomonogamus</i> spp	10	43.47	1	4.34	4.5	1	0.033	+	+		
<i>Hymenolepis</i> spp	2	8.69	0	0	0.4392	1	0.508	-	+		

(N = number of positive specimens; P = prevalence; S = +, test significant; + higher prevalence in Rainy season (Rs) or Dry season (Ds).

human pinworm, in captive chimpanzees with a prevalence similar to that observed in our study (Mbaya and Udendeye, 2011). Moreover, infection by *E. vermicularis* in captivity can persist for more than 20 years (Hasegawa and Udono, 2007). Our results show that *Enterobius* spp. was present only at the CDP, where apes are most exposed to humans. Further studies are needed to determine which species are present in our samples.

4.1.5. *Hymenolepis* spp.

Hymenolepis spp. occurred in chimpanzees at Lékédi only (1%). The very low prevalence reflects a previous study reporting that it was relatively rare in semi-captive chimpanzees (Mbaya and Udendeye, 2011). Because this parasite is common in humans (Shahnazi et al., 2019), the possibility of host-switching between apes and human must be considered, but needs to be confirmed by further investigations, including molecular studies.

4.1.6. *Mammomonogamus* spp.

Mammomonogamus spp. had a prevalence of 13%. This result was unexpected because this parasite is uncommon in chimpanzees and had never been reported before in wild or captive chimpanzees (Mul et al., 2007). Thus, as suggested by Freeman et al., 2004, it is probable that chimpanzees acquire this parasite through ecological interactions with other mammals. Cases of primates infected with *Mammomonogamus* have been observed (Mul et al., 2007; Setchell et al., 2007; Valenta et al., 2017), as well as exchange of this species between gorillas and elephants (Červená et al., 2017).

4.2. Protozoa parasites

Three genera were identified: *Balantioides* spp., *Entamoeba* spp. and *Troglodytella* spp.

4.2.1. *Balantioides* spp.

This parasite is the most prevalent protozoan (66%). and infects a

Table 3

Distribution and prevalence of parasite species reported to the gender of chimpanzees collected during the period of study.

Primatology center										
Parasites taxa	Males		Females		Comparison test					
	N/46	P (%)	N/48	P(%)	χ^2	df	p-value	S	M +	F+
<i>Ascaris</i> spp	33	71.73	18	37.5	2.71	1	0.09972	-	+	
<i>Strongylid</i> eggs	29	63.04	10	20.83	6.2475	1	0.01244	+	+	
<i>Strongyloides</i> spp	45	67.40	18	18.75	6.9358	1	0.0085	+	+	
<i>Enterobius</i> spp	2	4.34	8	16.66	1.9921	1	0.1581	-	+	
<i>Balantoides</i> spp	39	84.8	13	27.08	8.3092	1	0.00394	+	+	
<i>Entamoeba</i> spp	22	47.82	14	29.16	1.0972	1	0.2949	-	+	
<i>Trichuris</i> spp	9	19.56	4	8.33	1.158	1	0.2818	-	+	
<i>Mammomonogus</i> spp	7	15.21	0	0	4.918	1	0.027	+	+	
unidentified parasites	3	6.52	0	0	1.334	1	0.248	+	+	

Lékédi Park										F+
Parasites taxa	N/24		P (%)		Comparison test					
	N/24	P (%)	N/22	P(%)	χ^2	df	p-value	S	M +	F+
<i>Ascaris</i> spp	7	29.17	3	13.64	0.458	1	0.498	-	+	
<i>Strongylid</i> eggs	24	100	18	68.18	0.0641	1	0.8001	-	+	
<i>Strongyloides</i> spp	20	83.33	10	45.45	1.02	1	0.311	-	+	
<i>Balantoides</i> spp	19	79.16	20	90.90	0.01	1	0.9223	-	+	+
<i>Entamoeba</i> spp	16	66.67	15	68.18	0	1	1	-	+	+
<i>Trichuris</i> spp	13	54.16	7	31.81	0.4831	1	0.48	-	+	
<i>Troglodytella</i> spp	5	20.83	5	22.72	0	1	1	-	+	
<i>Mammomonogus</i> spp	6	25	5	22.72	0	1	1	-	+	
<i>Hymenolepis</i> spp	2	8.33	0	0	0.365	1	0.5458	-	+	

(N = number of positive specimens; P = prevalence; S = +, test significant; + higher prevalence in males (M) or females (F).

Table 4

Distribution of the prevalence of parasites taxa reported to the age of chimpanzees collected during the period of the study.

Lékédi Park											Y
Parasites taxa	Adults (>12 years)		Young (<12 years)		Comparison test						
	N/26	P (%)	N/20	P (%)	χ^2	df	p-value	S	A	Y	
<i>Ascaris</i> spp	10	38.46	0	0	0.759	1	0.384	-		+	
<i>Strongylid</i> eggs	23	73.07	20	100	0.0055	1	0.9408	-		+	
<i>Strongyloides</i> spp	24	92.31	8	40	2.055	1	0.151	-	+		
<i>Balantoides</i> spp	24	92.31	15	75	0.0611	1	0.8048	-	+		
<i>Entamoeba</i> spp	11	42.30	20	100	2.45	1	0.1142	-		+	
<i>Trichuris</i> spp	18	69.23	2	10	5.6046	1	0.018	+	+		
<i>Troglodytella</i> spp	9	34.61	1	5	2.62	1	0.1049	-	+		
<i>Hymenolepis</i> spp	2	7.69	0	0	0.239	1	0.625	-	+		
<i>Mammomonogus</i> spp.	11	42.30	0	0	5.5825	1	0.0181	+	+		

(N = number of positive specimens; P = prevalence; S = +, test significant; + higher prevalence in adults (A) or young (Y).

variety of hosts (Barbosa et al., 2018; da Silva Barbosa et al., 2017), including captive primates (Mbaya and Udendeye, 2011; Pomajbikova et al., 2013). The prevalence observed here matches the results of a study by Pomajbiková et al. (2010) but is higher than in another study in Nigeria which reported an infection rate of 8.7% (Mbaya and Udendeye, 2011). Because this parasite is unknown in wild chimpanzees (Pomajbiková et al., 2010), the difference could be related to the captive conditions. Finally since our method does not allow identification at the specific level, we cannot exclude the possibility that our observation corresponds to another parasite in this group: *Neobalantidium coli*, recently identified in captive primates, including chimpanzees (Pomajbiková et al., 2010).

4.2.2. *Entamoeba* spp.

With 48% prevalence this parasite is the second most prevalent protozoan in our samples. Parasites of this group have been observed in captive chimpanzees in Nigeria and in Japan (Mbaya and Udendeye, 2011; Mul et al., 2007; Tachibana et al., 2000). In both cases, however, prevalence was much lower than observed in our study, although an outbreak was associated with severe mortality in chimpanzees (Mbaya and Nwosu, 2005). Recent studies have reported the presence of at least three species of *Entamoeba* (*Entamoeba histolytica*, *E. hartmanni* and

E. coli) infecting chimpanzees living in captivity or in the wild (Jirku-Pomajbikova et al., 2016). This suggests that the parasites identified here may belong to different species, and molecular approaches are needed to identify these protists. Because humans are considered the main reservoir for this pathogen, our observations suggest exchanges of parasites between humans and apes.

4.2.3. *Troglodytella* spp.

With a prevalence of 7%, *Troglodytella* spp. have the lowest rate among the protozoa. Two species of Entodiniomorphida have been recorded in captive and wild apes: *Troglodytella abrossarti* and *Troglodytella cava* (McLennan et al., 2017; Modry et al., 2009; Mul et al., 2007; Petzelkova et al., 2012; Ruzicova et al., 2014). In captive apes, infection by *T. cava* tends to gradually disappear (Modry et al., 2009), which may explain why only *T. abrossarti* was observed in our work (Fig. 2). This hypothesis is reinforced by a study showing that chimpanzees at Lope Park (Gabon) had a prevalence of *Troglodytella* spp. around 4 times higher than we observed in our study (Landsoud-Soukate et al., 1995).

5. Conclusion

Our work reveals very similar parasite diversity in two groups of

captive chimpanzees in Gabon. Factors as habitat, season, sex and host age may affect parasite prevalence and diversity. The lower prevalence observed at the CDP could be due to the fact that animals living there are treated with antiparasitic medication more often, while the animals at Lékédi live in almost natural conditions. Our study shows that the rainy season seems to have a significant influence on parasite prevalence. This result is consistent with previous studies (Altizer et al., 2006; Huffman et al., 1997), showing higher parasite prevalence in monkeys during the rainy season or parasite lowest egg abundance and prevalence during the dry season (Setchell et al., 2007). Four parasite genera (*Strongyloides*, *Balantioides*, *Mammomonogamus* and an unidentified strongyloid), have a significantly higher infection rate in males than in females; dissimilarities that are probably related to differences in behavior or physiology between the sexes (Poulin, 1996). For two parasites (*Trichuris* spp. and *Mammomonogamus* spp) a higher occurrence rate was observed in adults than in young animals. This observation suggests an age effect for these parasites, as proposed by MacIntosh et al. (2010) and Mbaya and Udendeye (2011).

All parasite taxa identified in our study were previously found in other primate hosts including captive or wild apes, and/or humans. This suggests that some parasites found here could be zoonotic; to confirm this hypothesis we need a precise identification of the parasites at the species level, which is not feasible using coprological analyses based on morphological examination. Determination of the parasites could be improved through the use of molecular analysis but these methods were not accessible in the context of the present study. This study must therefore be considered preliminary and additional observations are needed to confirm our conclusions. This study also suggests the interest that there might be to periodically monitor the intestinal parasites of staff and other animals working and/or living close together.

Conflicts of interest

The authors declare no conflict of interest.

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Authorship contribution statement

LB: Conceptualization; Data curation; Writing - original draft
NB: Resources; Supervision; Writing - review & editing
NM: Data curation, Investigation; Writing - review & editing
SD: Methodology, Investigation
CM: Formal analysis, Validation
JPH: Writing - review & editing

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