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Intestinal Parasites of Free-ranging, Semicaptive, and Captive *Pongo abelii* in Sumatra, Indonesia

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Abstract We collected fecal samples from 32 free-ranging, 19 semicaptive, and 54 captive Sumatran orangutans on Sumatra from 1998 until 2004 and screened them for gastrointestinal parasites. Our objectives were to compare the intestinal parasites of free-ranging, semicaptive, and captive orangutans and to evaluate the risk of parasite transmission in orangutan reintroduction programs. We identified 4 genera of Protozoa, 7 genera of nematodes, 1 trematode sp., and 1 cestode sp. The prevalence of *Balantidium coli* in free-ranging orangutans was significantly higher than in captive individuals. However, the prevalence of *Strongyloides* sp. was higher in captive than in free-ranging orangutans. Free-ranging female orangutans had a significantly higher total prevalence of intestinal parasites than that of males. We found no significant difference between parasite prevalences in different age groups. Compared to gorillas and chimpanzees, orangutans carry a smaller variety of protozoan and nematode species. *Strongyloides* sp. infections form the highest risk in reintroduction programs as crowding, ground-dwelling, and poor hygiene in captive and semicaptive orangutans may cause a constant reinfection.

Keywords intestinal parasites · great ape · *Pongo abelii* · reintroduction · Sumatran orangutan

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Introduction

Orangutans (*Pongo* spp.) are the only great ape species to inhabit Southeast Asia. At present, their distribution is restricted to Sumatra and Borneo in Indonesia, and the Malaysian states of Sabah and Sarawak. Unfortunately their numbers in the wild are decreasing rapidly. In 1997 the orangutan population estimate for Bornean orangutans (*Pongo pygmaeus*) was only 7% of the population in 1900. The estimated Sumatran population in 2002 was 4% of the population in 1900 (Rijksen and Meijaard 1999; Wich *et al.* 2003). On the IUCN Red List Sumatran orangutan (*Pongo abelii*) are critically endangered (IUCN 2004). The main threats to their survival are hunting, trade, and habitat loss (Rijksen 1974; Rijksen and Meijaard 1999; Robertson and van Schaik 2001; Singleton *et al.* 2004).

To enhance the survival of free-ranging orangutans in Indonesia, reintroduction programs were started on Borneo in the mid-1960s and on Sumatra in the early 1970s to release wild-caught, captive orangutans back into the wild. In the past, researchers reintroduced orangutans into the forest that free-ranging orangutan populations still inhabited. The Indonesian Ministry of Forestry effectively terminated the rehabilitation role of all centers that release animals into existing wild populations in its newest Ministerial Guidelines for Rehabilitation (Keputusan Menteri Kehutanan No. 280/kpts-II/1995), which state that every effort should be made to find suitable areas with no existing wild populations for all rehabilitation projects. Reintroduction is allowed only into areas that are within the historic specific range but without remnant wild individuals to prevent disease spread, social disruption, and introduction of alien genes (IUCN 2004).

Orangutans are susceptible to most human pathogenic organisms, and transmission of parasitic infections has occurred (Chitwood 1970; Hegner 1928; Orihel 1970; Ott-Joslin 1993). Important sources of parasite exposure to captive, semicaptive, and free-ranging great apes are tourists, researchers, guides, rangers, animal keepers, and unintentional human contact such as villagers, poachers, and loggers (Woodford *et al.* 2002). Reintroduced orangutans, carrying parasititic infections, may introduce uncommon parasite species in naïve free-ranging primate populations, including orangutans. In addition, captive orangutans could be exposed to parasites common in free-ranging primate populations. In both cases, alien parasitic infections may cause serious illness or even death in a naïve host. Most intestinal parasites are commensals, but because of stress, pregnancy, bad condition, old age, or disease, defense mechanisms could fail and the parasitic infection may cause sickness or death (Collet *et al.* 1986; Cummings *et al.* 1973; Harper *et al.* 1982; Jaskoski 1960; McClure *et al.* 1973; Patten 1939; Rijksen 1978; Uemera *et al.* 1979; Warren 2001).

Researchers have investigated intestinal parasites of free-ranging, semicaptive, and captive orangutans. Several authors examined free-ranging and semicaptive orangutans in Sumatra, Borneo and Malaysia (Collet *et al.* 1986; Djojosudharmo and Gibson 1993; Djojoasmoro and Purnomo 1998; Kilbourn *et al.* 2003; Rijksen 1978; Warren 2001; Frazier-Taylor *et al.* 1984, *unpublished*; Moresco-Pimentel, *unpublished*). We obtained captive orangutan data from zoos in the United States (Cummings *et al.* 1973), in Java, Indonesia (Collet *et al.* 1986), Spain (Gómez *et al.* 1996), and Borneo, Indonesia (Djojoasmoro and Purnomo 1998; Warren 2001). The results of the studies in Table I. Rijksen (1978), Collet *et al.* (1986), Djojosudharmo and Gibson (1993), and Moresco-Pimentel (*unpublished*) were the only authors who studied free-ranging and semicaptive Sumatran orangutans. To our knowledge, researchers have never reported endoparasitic infections in captive Sumatran orangutans before.

There are numerous reports on the intestinal parasites of the other great apes: *Gorilla* spp. (Ashford *et al.* 1990, 1996; Durette-Desset *et al.* 1992; Freeman *et al.* 2004; Hastings *et al.* 1992; Kalema 1995; Kalema-Zikusoka *et al.* 2002; Landsoud-Soukate *et al.* 1995; Lilly *et al.* 2002; Mudakikwa *et al.* 1998, 2001; Nizeyi *et al.* 1999; Rothman *et al.* 2002; Sleeman *et al.* 2000; van Waerebeke *et al.* 1988) and *Pan* spp. (Ashford *et al.* 2000; File *et al.* 1976; Hasegawa *et al.* 1983; Holmes 1980; Huffman *et al.* 1997; Hugot 1993; Kawabata and Nishida 1991; Kim *et al.* 1978; Landsoud-Soukate *et al.* 1995; Lilly *et al.* 2002; McGrew *et al.* 1989; Murray *et al.* 2000; Schmidt and Prine 1970; Smith *et al.* 1996; van Waerebeke *et al.* 1988; Wrangham 1995).

We surveyed fecal parasites from 3 groups of Sumatran orangutans, with 2 objectives: First, we compared the overall prevalence of intestinal parasites in

Table I Intestinal parasites in fecal samples of captive, semicaptive, and free-ranging orangutans reported in previous studies

	Captive orangutans	Semicaptive orangutans	Free-ranging orangutans
Protozoa			
Entamoeba sp.	4, 6	3, 4	3, 4
Entamoeba histolytica	4	4	4
E. chattoni	6		
Iodamoeba butschlii	6		
Blastocystis hominis	6		
Balantidium coli	1, 4, 6, 8	4, 8, 9	2, 4, 5, 8, 9
Cyclospora sp.	8		
Giardia lamblia	1		
Enteromonas hominis	6		
Nematodes			
Strongyloides sp.	1, 4, 7, 8	3, 4, 7, 8, 9	2, 3, 4, 5, 7, 8, 9
Strongylida sp.	1, 4, 8	3, 4, 8	3, 4, 5, 8, 10
Mammomonogamus sp.		4	
Ancylostoma sp.		2	2
Ternidens sp.			5
Oesophagostomum sp.	7	7	2, 7
Trichostrongylus sp.			2, 7
Pithecostrongylus alatus			2
Abbreviata caucasica			2
Enterobius sp.	1	4, 7, 9	2, 5, 7, 10
Ascaris sp.	1, 4, 7, 8	2, 4	5
Trichuris sp.	1, 7, 8	2, 3, 4, 8, 9	2, 3, 4, 7, 9, 10
Trematodes			
Dicrocoeliidae sp.	4	4	4, 5
Gasterodiscoides sp.			2
Cestodes	1		
Bertiella sp.		4	

1, Cummings *et al.* (1973); 2, Rijksen (1978); 3, Frazier-Taylor *et al.* (1984 , *unpublished*); 4, Collet *et al.* (1986); 5, Djojosudharmo and Gibson (1993); 6, Gómez *et al.* (1996); 7, Djojoasmoro and Purnomo (1998), 8, Warren (2001); 9, Kilbourn *et al.* (2003); 10, Moresco-Pimentel (*unpublished*).

Table II Intestinal parasites in faecal samples of captive and free-ranging gorillas and chimpanzees reported in previous studies

	Captive gorillas	Free-ranging gorillas	Captive chimpanzees	Free-ranging chimpanzees
Protozoa				
Entamoeba coli	18	12, 15, 21, 25, 28	18	8, 15, 20, 23, 24, 28
E. histolytica		12, 15, 21, 25, 28		15, 28
E. hartmanni		12, 15, 21, 25		15, 23
E. chattoni	18		18	23
Iodamoeba butschlii	18	12, 21, 25, 28	18	8, 20, 23, 28
Endolimax nana	18	15, 21, 25	18	15, 20, 23
Blastocystis hominis	18		18	23
Balantidium coli	18	28, 30	4, 18	3, 8, 28
Cyclospora sp.				19
Prototapirella gorillae		15, 17, 30		
Troglodytella sp.		15, 30		3, 6, 8, 15
Gorillophilus thoracatus		30		
Chilomastix mesnili	18	15, 21, 25, 28		15, 28
Giardia sp.		12, 21, 22, 25	18	20, 23
Enteromonas hominis	18			
Trichomonas intestinalis	18			
Pentatrichomonas hominis		28		
Nematodes				
Strongyloides sp.		9, 14, 15, 17, 25, 27, 28, 30	1,4	3, 6, 8, 15, 20, 23, 24, 28, 30
Strongylida sp.		15		6, 15

Mammomonogamus sp.	30		
Necator sp.	14		3, 8
Oesophagostomum sp.	9, 12, 14, 17, 25, 26, 27	1	3, 6, 8, 20, 23, 24, 30
Trichostrongylus sp.	12, 14, 21, 25, 26, 30		
Paralibyostrongylus kalinae	11, 17		8
Hyostrongylus sp.	11, 17, 25		
Murshidia devians	12, 25		
Spirurida/Abbreviata caucasica	30		3, 8, 15, 24
Streptopharagus sp.		1	8
Enterobius sp.		2, 5	3, 6, 8, 13, 23
Probstmayria sp.	7, 9, 12, 21, 25, 29, 30		3, 7, 8, 23, 24
Ascaris sp.	14, 15, 25, 27, 28		15, 28
Trichuris sp.	14, 21, 25, 28, 30	1, 5, 18	3, 6, 8, 10, 20, 23, 24, 28
Trematodes			
Unidentified sp.	25, 30		
Dicrocoeliidae sp.	15		6, 15, 20, 23
Cestodes			
Bertiella sp.		16	7, 10
Anoplocephala gorillae	9, 12, 14, 17, 25, 26		

1, Jessee *et al.* (1970); 2, Schmidt and Prine (1970); 3, File *et al.* (1976); 4, Kim *et al.* (1978); 5, Holmes (1980); 6, Hasegawa *et al.* (1983); 7, Waerebeke *et al.* (1988); 8, McGrew *et al.* (1989); 9, Ashford *et al.* (1990); 10, Kawabata and Nishida (1991) ; 11, Durette-Desset *et al.* (1992); 12, Hastings *et al.* (1992); 13, Hugot (1993); 14, Kalema (1995); 15, Landsoud-Soukate *et al.* (1995); 16, Wrangham (1995); 17, Ashford *et al.* (1996); 18, Gomez *et al.* (1996); 19, Smith *et al.* (1996); 20, Huffman *et al.* (1997); 21, Mudakikwa *et al.* (1998); 22, Nizeyi *et al.* (1999); 23, Ashford *et al.* (2000); 24, Murray *et al.* (2000); 25, Sleeman *et al.* (2000); 26, Mudakikwa *et al.* (2001); 27, Kalema-Zikusoka *et al.* (2002); 28, Lilly *et al.* (2002); 29, Rothman *et al.* (2002); 30, Freeman *et al.* (2004).

free-ranging, semicaptive, and captive Sumatran orangutans of different sexes and ages and to compare the parasite species between the 3 groups. In addition, we compared the results of previous studies on the intestinal parasites of other great apes (*Gorilla* spp. and *Pan* spp.) in Africa (Table II). Second, we evaluated the risk of parasite transmission in orangutan-reintroduction programs.

Materials and Methods

Subjects

We studied the quarantine of the Sumatran Orangutan Conservation Program (SOCP) in North Sumatra, Indonesia. We collected samples from free-ranging (wild), semicaptive (wild-caught orangutans that are released into the wild after a reintroduction program), and captive (orangutans in zoos and reintroduction programs) Sumatran orangutans from 5 different locations. Captive orangutans lived at Medan Zoo in Medan, North Sumatra (3° 35′N, 98° 41′E) and at the SOCP quarantine in Batu Mbelin, North Sumatra. Semicaptive orangutans lived at the reintroduction site of the SOCP in Jambi, Central Sumatra (1° 9′S, 102° 33′E) and at the former rehabilitation site Bohorok, North Sumatra (3° 30′N, 98° 12′E), which closed for rehabilitation in 1996. We followed free-ranging orangutans at the Ketambe research station (3° 41′N, 97° 39′E) in the Gunung Leuser National Park, Leuser Ecosystem in North Sumatra.

The reintroduction site in Jambi has an area of 1200 km^2 and does not currently contain a resident wild orangutan population. The last report of the presence of a (dead) orangutan in Jambi was roughly 165 yr ago by Schlegel and Müller (1839–1844). At the time of our study, *ca.* 20 orangutans had already been released into this National Park. Both Bohorok and the Ketambe Research Station, are located in the Leuser Ecosystem in Northern Sumatra. The Leuser Ecosystem covers *ca.* 25,000 km^2 and encompasses the designated Gunung Leuser National Park covering *ca*. 9000 km^2 (van Schaik *et al.* 2001). In 2004 *ca.* 7300 orangutans remained in the wild in Northern Sumatra (Singleton *et al.* 2004).

Sample Collection and Analysis

We collected fecal samples from free-ranging, semicaptive, and captive Sumatran orangutans in 1998 and from 2002 until 2004. Based on data from Kilbourn *et al.* (2003), Rijksen (1978), and Moresco-Pimentel (*unpublished*), we considered orangutans ≤ 8 yr as young and orangutans > 8 yr as adult. Of each freshly passed fecal specimen we mixed 1 part feces with 3 parts of SAF fixative (sodium acetate-acetic acid-formaldehyde) directly after collection. We concentrated the samples via the Ridley method with ethyl acetate instead of ether (Polderman and Rijpstra 1993), using the Faecal Parasite Concentrator kit (FPC®, Evergreen Scientific, International Medical Products BV, Zutphen, the Netherlands).

We scanned the sediments via light microscopy for protozoan cysts, helminth eggs, and larvae at ×10 objective power and conducted detailed examination at ×45 objective power. We identified the cysts and helminth ova with the assistance of published keys (Arcari *et al.* 2000; Bowman *et al.* 1999; Collet *et al.* 1986; Jessee *et al.* 1970; Polderman and Rijpstra 1993; Thienpont *et al.* 1979). We stored unidentified eggs and identified them later in consultation with other experts.

Statistical Analysis

We used nonparametric tests for statistical analysis, as the data were not normally distributed. We compared the total prevalence of intestinal parasites from captive, semicaptive, and free-ranging orangutans with the Friedman test and the Kruskal-Wallis test. We tested the individual prevalence of all parasites with the χ^2 test, to determine if there were significant differences between captive, semicaptive, and free-ranging orangutans. We compared data from young and adult and male and female orangutans via the Wilcoxon signed ranks test.

Results

We examined fecal samples of 105 individuals—54 captive, 19 semicaptive, and 32 free-ranging—for parasite cysts, eggs, and larvae. The 105 orangutans comprised 50 males and 55 females. We considered 52 individuals as young and 51 as adult orangutans, but did not know the ages of 2 orangutans. We took multiple fecal samples per orangutan; the results per individual are in Table III.

All but 6 orangutans tested positive for ≥ 2 different intestinal parasites. We found cysts of 4 species of Protozoa, eggs of 7 different nematode species, 1 trematode species (measuring 42.5×25 μm, brown, thick-shelled, smooth surface, operculum), and 1 unknown cestode species (measuring 44×30 μm, brown, thin shell, smooth surface, oncosphere; Table III). *Entamoeba* sp. (range 7.5–37.5 – 7.5–37.5 μm, spherical, 1–8 nuclei), *Balantidium coli* (range 30–50×27.5–50 μm, spherical brown cysts and brown trophozoites containing cilia), *Strongyloides* sp. (range 45–57.5×25–37.5 μm, oval, smooth thin shell, morula) and species of Strongylida (range 62.5–75×32.5–50 μm, oval, smooth thin shell, morula) were the most common intestinal parasites, irrespective of whether orangutans were free-ranging, semicaptive, or captive (Table III). We found *Chilomastix* sp. (range 6–10×5–8 μm, lemon shaped, large nucleus) and eggs of Spirurida (47.5–55×22.5–32.5 μm, dark brown, thick-shelled, irregular surface, morula) in fecal samples of captive and free-ranging orangutans. We discovered eggs of *Mammomonogamus* sp. (range 67.5–77.5×40–42.5 μm, oval, thick shell, morula), *Enterobius* sp. (range 52–56×25–30 μm, oval, thin shell, asymmetrical shape, contain larva) and *Trichuris* sp. (range 50–52.5×20–25 μm, barrel shaped, bipolar plugs, thick shell) in free-ranging, semicaptive, and captive orangutans. *Giardia* sp. (measuring 10×6 μm, ellipsoid) and *Ascaris* sp. (range 45–52×35–38 μm, oval, brown, thick wall, irregular surface) were present only in fecal samples of captive orangutans.

There is no significant difference for the overall prevalence of intestinal parasites among captive, semicaptive, and free-ranging individuals. Significant differences in prevalence occur only for *Balantidium coli* (χ^2=26.8, p<.01), which is higher in free-ranging than in captive orangutans (Table III) and *Strongyloides* sp., which is significantly higher in captive than in free-ranging orangutans ($\chi^2=11.2$, $p<.05$). There is a significant difference between free-ranging males and females; females had a higher overall prevalence of intestinal parasites than males (Wilcoxon, $N=17$, $p=.008$). There is no significant difference between young and adult orangutans.

Discussion

We investigated whether there are variations in the overall prevalence of intestinal parasites and whether or not there are differences in parasite species between captive, semicaptive, and free-ranging orangutans. We found no significant differences for the overall prevalence of intestinal parasites and no great differences in the parasite species between captive, semicaptive, and free-ranging orangutans. Except for *Chilomastix* sp., *Giardia* sp., *Spirurida* sp., *Ascaris* sp., Dicrocoeliidae sp., and a cestode sp., all parasites were present in fecal samples, irrespective of whether orangutans were free-ranging, semicaptive, or captive (Table III).

To our knowledge, there is no previous report on intestinal parasites in captive Sumatran orangutans. Compared to data from captive Bornean orangutans (Collet *et al.* 1986; Djojoasmoro and Purnomo 1998; Warren 2001), this is the first report of *Chilomastix* sp., *Giardia* sp., *Mammomonogamus* sp., *Enterobius* sp., a spirurid species, and a cestode species in captive orangutans. Collet *et al.* (1986) reported the presence of trematode eggs of the Dicrocoeliidae in captive orangutans in Surabaya

Table III Number of parasitic infections detected on fecal examination of 54 captive, 19 semicaptive, and 32 free-ranging male and female Sumatran orangutans

	Captive orangutans			Semicaptive orangutans			Free-ranging orangutans		
	Total (n=54)	Male (n=31)	Female (n=23)	Total (n=19)	Male (n=6)	Female (n=13)	Total (n=32)	Male (n=13)	Female (n=19)
Protozoa									
Entamoeba sp.	47	27	20	11	4	7	22	6	16
Balantidium coli	10	5	5	7	2	5	24	9	15
Giardia sp.	1	1	0	0	0	0	0	0	0
Chilomastix sp.	10	8	2	0	0	0	4	0	4
Nematoda									
Strongyloides sp.	44	24	20	9	2	7	15	6	9
Strongylida sp.	18	9	9	5	0	5	12	5	7
Mammomonogamus sp.	5	3	2	4	1	3	6	1	5
Spirurida sp.	1	1	0	0	0	0	3	1	2
Enterobius sp.	3	3	0	1	0	1	1	0	1
Ascaris sp.	6	3	3	0	0	0	0	0	0
Trichuris sp.	16	10	6	2	1	1	6	2	4
Larva indefinable	7	6	1	1	1	0	6	2	4
Trematoda									
Dicrocoeliidae sp.	0	0	0	1	0	1	0	0	0
Cestoda	1	1	0	0	0	0	0	0	0
Negative examinations	1	1	0	2	2	0	3	3	0

Zoo in Java, Indonesia. Djojoasmoro and Purnomo (1998) reported the presence of *Strongyloides fulleborni* and *Oesophagostomum* sp. in Borneo. We did not identify the parasites in captive orangutans.

This is the first report of *Chilomastix* sp. and *Mammomonogamus* sp. in free-ranging orangutans. Other parasites found in Sumatran free-ranging orangutans corresponded to previous studies (Collet *et al.* 1986; Djojosudharmo and Gibson 1993; Rijksen 1978; Moresco-Pimentel, *unpublished*), with the exception of some parasites not found in our subjects: Djojosudharmo and Gibson (1993) reported the presence of eggs of *Ascaris* sp. and trematodes and Rijksen (1978) identified the trematode *Gasterodiscoides* sp., the strongylid *Oesophagostomum blanchardi*, the trichostrongylids *Pithecostrongylus alatus* and *Trichostrongylus colubriformis*, and the spirurid *Abbreviata caucasica* in free-ranging Sumatran orangutans (Table I). It was impossible to identify the eggs of the *Strongylida* and *Spirurida* to specific level via the techniques we used. We detected trematode eggs of the Dicrocoeliidae for the first time in semicaptive orangutans. Rijksen (1978) and Collet *et al.* (1986) reported the presence of *Ascaris* sp. in semicaptive orangutans and Collet *et al.* (1986) also reported the presence of *Bertiella* sp. in semicaptive orangutans; we found neither.

We found eggs of *Mammomonogamus* sp. in the semicaptive orangutans at Bohorok, similar to the findings of Collet *et al.* (1986), but we also found eggs of the species in feces of free-ranging and captive orangutans. The parasite may be transmitted to free-ranging individuals by other primate species, which live in overlapping areas. *Mammomonogamus* sp. can also infect humans, who might have transmitted the parasite to the orangutans in the zoo in Medan. Collet *et al.* (1986) reported *Mammomonogamus* sp. for the first time in Sumatran orangutans. *Mammomonogamus* sp. is a nematode parasite that inhabits the respiratory tract. In 1980, 5 young orangutans died after symptoms of dyspnea and listlessness caused by the parasite. In some circumstances, the parasite is easily transmissible and a definite health hazard to orangutans (Collet *et al.* 1986).

We found a significant difference among the 3 groups of orangutans with regard to *Balantidium coli*, which had a significantly higher prevalence in free-ranging than in captive orangutans. The prevalence of *Strongyloides* sp. was higher in captive than in free-ranging orangutans. *Balantidium coli* is a ciliate in the cecum and colon of pigs (Bowman *et al.* 1999; Hegner 1928; Lee *et al.* 1990; Levine 1970; Nelson 1934). Wild pigs in Sumatra share their habitat with orangutans (Rijksen 1978). The feces of wild pigs may contaminate the food and water of orangutans when they share the same habitat, which may explain the high prevalence of *Balantidium coli* in free-ranging orangutans in our sample. *Strongyloides* sp. can live primarily in humans or nonhuman primates depending on the subspecies (Bowman *et al.* 1999; Hegner 1928; Hira and Patel 1980; Kelly *et al.* 1976). In our study the prevalence of *Strongyloides* sp. was higher in captive than in free-ranging orangutans. The *Strongyloides* sp. we found could be *S. stercoralis*, which is transmitted by human contact, but without culture, it was not possible to identify to specific level. Crowding, ground dwelling, and bad hygiene, which may occur in populations of captive and semicaptive orangutans, can cause a constant reinfection with *Strongyloides stercoralis*. When the cell-mediated immunity is suppressed, as in the case with young or sick individuals, the disease may become fatal (Cummings *et al.* 1973; Harper *et al.* 1982; McClure *et al.* 1973; Uemura *et al.* 1979; Warren 2001).

One should administer a good anthelmintic medication such as ivermectin or mebendazole (Datry *et al.* 1994; Leeflang and Markham 1986; Warren 2001) to infected individuals. We found only *Giardia* sp. and *Ascaris* sp. in the captive orangutans. Both parasites are primarily parasites of humans (Bowman *et al.* 1999; Chitwood 1970; Landsoud-Soukate *et al.* 1995; Orihel 1970; Ott-Joslin 1993; Pawlowski 1982; Polderman and Rijpstra 1993) and were probably transmitted to orangutans at a time when they were living in close proximity to humans.

We found only negative parasitic results in males. Free-ranging female orangutans had a significantly higher total prevalence of intestinal parasites than males did, possibly because of the degree of physical contact with other orangutans. Females are accompanied by an infant for most of their lives and they travel relatively often with other females and their offspring. Adult females do not come in contact with each other a great deal, but while the females are feeding, the juveniles often play together; therefore a female effectively has second-hand contact with many other orangutans via her offspring.

Males achieve physical contact with other orangutans only during mating, rapes, or fights, which are rare occurrences (Singleton and van Schaik 2001; van Noordwijk and van Schaik 2005).

Many publications are available about the intestinal parasites of other great apes (*Gorilla* spp. and *Pan* spp.). Besides a few reports of endoparasites in captive great apes, almost all the reports provide data on the intestinal parasites of free-ranging great apes in African countries (Table II). All the parasites we found also occur in both gorillas and chimpanzees, with the exceptions of *Enterobius* sp. and cestode sp., which do not occur in gorillas, and *Mammomonogamus* sp., which do not occur in chimpanzees. In total there were more protozoan and nematode species in gorillas and chimpanzees than in orangutans, possibly because of differences in the techniques used and the conservation method of fecal samples. Another explanation could be the fact that gorillas and chimpanzees live together in groups and spend more time on the ground, in contrast to orangutans, which in general live solitarily in trees. Living on the ground may increase exposure to feces from both conspecifics and other species, and hence increase infection risk in chimpanzees and gorillas. Wich *et al.* (2004) have also argued that a lower risk of disease transmission is one of the possible explanations for the lower mortality of wild orangutans compared to chimpanzees. Dietary habits and differences in seasonal conditions may also cause the differences in parasite loads. Female chimpanzees normally have 2 or 3 offspring around them at 1 time, in contrast to orangutans, which carry only 1 offspring at a time, which could increase the chance of transmission of parasites (van Noordwijk and van Schaik 2005).

Of all the parasites we found, only some *Entamoeba* sp. and *Chilomastix* sp. are nonpathogenic (Bowman *et al.* 1999; Gómez *et al.* 1996; Hegner 1928; Levine 1970, 1973; Rijksen 1978). All the other parasites can become pathogenic when the host defense mechanism fails as a result of stress, pregnancy, poor physical condition, old age, or disease. Only a few of the orangutans in our study experienced diarrhea without any other symptom. We found no other symptom. There is no correlation between the presence of diarrhea and the parasite species in the individuals.

To decrease the risk of released orangutans introducing new parasites into free-ranging naïve populations, one should not release captive orangutans into areas where free-ranging orangutans are living. Also, anthelmintic treatment of captive orangutans may decrease the transmission risk, though anthelmintic treatment never guarantees that the orangutan will be free of parasites. It is also not desirable to release orangutans that are totally free of parasites into the wild because they may be more susceptible to new infections from free-ranging nonhuman primate populations. To reduce the risk that the parasites cause sickness, one should release the captive individuals in optimal physical condition and avoid stress situations around their release as much as possible.

In conclusion, all 3 groups of orangutans had parasitic infections. All free-ranging female orangutans had a significantly higher total prevalence of intestinal parasites than those of males. *Balantidium coli* had a significantly higher prevalence in free-ranging than in captive orangutans, and *Strongyloides* sp. had a higher prevalence in captive than in free-ranging orangutans. *Strongyloides* sp. in particular is a high risk in reintroduction programs. Crowding, ground dwelling, and poor hygiene in captive and semicaptive orangutans cause a constant reinfection, which may become fatal if left untreated, especially in young individuals. To reduce the risk of reintroduction of *Strongyloides* sp. in free-ranging individuals, one should treat released orangutans with anthelmintics just before their release. However, it is not desirable to strive for the reintroduction of orangutans that are completely free of intestinal parasites, as infections with new parasites might become fatal in naïve hosts. Further research is required to identify the unknown species, e.g., *Entamoeba* sp., S*trongyloides* sp., Strongylida sp., and trematode and cestode species, down to the specific level and to evaluate better the health risks of parasite infections and parasite intensities in orangutans.

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