museu de
ciències naturals
de Barcelona

Animal Biodiversity and Conservation 48.1 (2025)
DOI: 10.32800/abc.2025.48.0005

Research paper

Home range, diet pattern and parasite's burden of the wild Bornean orangutans in Sebangau National Park Indonesia

A. Panda[1], T. S. Djohan[2], W. T. Artama[3], D. Priyowidodo[4]

Author affiliations:
[1] University of Palangka Raya, Indonesia
[2] Universitas Gadjah Mada, Indonesia
[3] OHCC/Eco Health, Indonesia
[4] Universitas Gadjah Mada, Indonesia

Corresponding author:
A. Panda
apanda@mipa.upr.ac.id

Handling Editor:
Juan Carlos Serio-Silva

Received: 09/01/2025
Cond. acceptance: 24/02/2025
Final acceptance: 07/04/2025
Published: 14/04/2025

Cite:
Panda A, Djohan TS, W. T. Artama WT, Priyowidodo D, 2025. Home range, diet pattern and parasite's burden of the wild Bornean orangutans in Sebangau National Park Indonesia. *Animal Biodiversity and Conservation* 48.1, e0005. DOI: http://doi.org/10.32800/abc.2025.48.0005

ISSN: 1578-665 X
eISSN: 2014-928 X

Summary

Home range, diet pattern and parasite's burden of the wild Bornean orangutans in Sebangau National Park Indonesia. Fecal samples from five representative age classes of *Pongo pygmaeus ssp. wurmbii* were collected between 18/02/2022 and 29/11/2022. Intestinal parasites were screened using the MiniFlotac technique. We hypothesized that home range reflects the energy budget while the burden of intestinal parasites may influence the fitness of orangutans across age group. Variations in behavior were predicted to affect parasite species richness, prevalence, and intensity of infection, measured as egg per gram (EPG)/oocyst per gram (OCG)/cyst per gram (CPG) in fecal samples. We identified a variety of Protozoa (including *Entamoeba*, *Endolimax*, and *Giardia*) and nematode (such as *Trichuris*, *Ascaris*, *Enterobius*, and hookworms). One un-identified larval form was also observed. The highest prevalence was recorded for *Entamoeba coli* (100 % of individuals), followed by hookworm egg (70 %), *Ascaris lumbricoides* (50 %), *Dientamoeba fragilis* (40 %), *Entamoeba hartmanni* (20 %) and *Giardia* sp. (10 %). The CPG of *E. coli* ranged from 50 to 120 in all orangutan fecal samples. Site-specific differences were observed between sites Punggualas (PA) vs. Natural Peat Laboratory (NPL), hereafter referred to as NPL-CIMTROP, and between male and female orangutans. However, no significant differences were detected in parasite burden relative to home range size. To our knowledge, this is the first report documenting the parasite burden of wild orangutans in Punggualas. Notably, a high prevalence of *Ascaris lumbricoides* eggs was detected (p-value = 0.0000). Our findings imply that environmental disturbances such as the 2021 flooding event and subsequent pseudo-gaharu collection activities in Punggualas may have contributed to this elevated prevalence of *Ascaris* spp. Further investigation is urgently needed to elucidate the dynamics of zoonotic transmission between humans and orangutans and to assess risks related to emerging and re-emerging infectious diseases.

Key words: Home range, MiniFlotac, *Ascaris lumbricoides*, Sebangau National Park, One health, Orangutans

Resumen

Área de campeo, pauta de alimentación y carga parasitaria de los orangutanes silvestres de Borneo en el Parque Nacional Sebangau, en Indonesia. Se recogieron muestras fecales de cinco clases de edad representativas de *Pongo pygmaeus* ssp. *wurmbii* entre el 18 de febrero y el 29 de noviembre de 2022. Los parásitos intestinales se cribaron mediante la técnica MiniFlotac. Formulamos la hipótesis de que el área de campeo refleja el balance energético, mientras que la carga de parásitos intestinales puede influir en la aptitud de los orangutanes de todas las clases de edad. Se predijo que las variaciones en las áreas de campeo afectarían a la riqueza y la prevalencia de especies parasitarias y a la intensidad de las infecciones, medidas como el número de huevos por gramo (EPG)/ovocitos por gramo (OCG)/quistes por gramo (CPG) de las muestras fecales. Se identificaron varios géneros de protozoos (como *Entamoeba*, *Endolimax* y *Giardia*) y nematodos (como *Trichuris*, *Ascaris*, *Enterobius* y anquilostomas). Asimismo, se observó una larva no identificada. La mayor prevalencia fue la de *Entamoeba coli* (100 % de los individuos), seguida de huevos de anquilostoma (70 %), *Ascaris lumbricoides* (50 %), *Dientamoeba fragilis* (40 %), *Entamoeba hartmanni* (20 %) y *Giardia* sp. (10 %). Los quistes por gramo (CPG) de *Entamoeba coli* se situaron entre 50 y 120 en las muestras fecales de todos los orangutanes. Existen diferencias entre los sitios Punggualas (PA) y el Laboratorio de Turba Natural (NPL-CIMTROP) y entre machos y hembras de orangután. Sin embargo, no hemos encontrado diferencias significativas en la carga parasitaria relacionada con la superficie del área de campeo. Hasta donde sabemos, en el presente artículo se informa por primera vez de la carga parasitaria de los orangutanes silvestres en Punggualas. Cabe señalar que se detectó una alta prevalencia de huevos de *Ascaris lumbricoides* (p = 0,0000). El resultado del estudio implica que las perturbaciones ambientales, como las inundaciones de 2021, seguidas de las actividades de búsqueda de pseudo-gaharu en Punggualas, pueden haber favorecido esta alta prevalencia del género *Ascaris*. Se necesitan urgentemente más estudios para comprender la dinámica de la transmisión entre humanos y orangutanes y evaluar los riesgos relacionados con la aparición y reaparición de enfermedades infecciosas.

Palabras clave: Home range, MiniFlotac, *Ascaris lumbricoides*, Parque Nacional de Sebangau, One health, Orangutans

Introduction

Over recent decades land-use policies have emerged as significant threats to great apes, contributing to population decline. Hunting pressure, habitat fragmentation, and anthropogenic development –such as the construction of a massive hydropower dam and planned roads in Batang Toru, North Sumatera (Wich et al 2019, Laurance et al 2020), pose substantial risks to both recently identified *Pongo tapanuliensis* (Nater et al 2017, Sloan et al 2018) and the nearby human population. Although the project has been temporarily halted without further notice, it may be resumed. In response, the IUCN called for a moratorium on further construction until the impact of the dam, road, earthworks, and powerline infrastructure is evaluated.

Logging activities are yet another major driver of habitat fragmentation and loss. Beyond physical fragmentation, primates are also exposed to a range of edge effects and other stressors (Murcia 1995, Fagan et al 1999, Fahrig 2003, Ries et al 2004, Foley et al 2005, Simler-Williamson et al 2021). These stressors can increase the risk of inter-species parasites transmission (Gillespie et al 2005, Mul et al 2007). Despite this, the relationship between habitat disturbance, primate health (Gillespie and Chapman 2006, Martínez-Mota et al 2018), and intestinal parasite prevalence in orangutans remains poorly understood (Mbora and Munene 2006, Mbora and McPeek 2009). Nevertheless, research has shown that logging activities create a fragmented patchy landscape, leading to the so-called compression effect, where displaced primates are forced into smaller habitats (Husson and Morrogh-Bernard 2004, Cheyne et al 2016). Overall, human-induced biodiversity loss not only increases disease risks for both wildlife and humans but also threatens agricultural and forest productivity as seen following the long-term decline of *Pongo pygmaeus* populations over the past 45 years.

Despite improvements in population estimation techniques, ranging from conventional ground-truthing to line-transect methods (van Schaik et al 2005, Buckland et al 2015) aerial surveys (Ancrenaz et al 2005, Simon et al 2019), unmanned aerial drones (Burke et al 2019), and computer simulation and modelling, orangutan populations located outside protected areas continue to show steady decline (Wich et al 2012, Santika et al 2017, Voigt et al 2018). Recent findings have contributed to new insight into the orangutan behavior repertoire, particularly in terms of terrestrial locomotion (Loken et al 2013, Ancrenaz et al 2014, Ashbury et al 2015), which appear to be strongly influenced by changes in habitat structure. These findings challenge earlier assumptions that orangutans primarily avoid canopy gaps (Davies et al 2017) and that their ranging patterns are strictly determined by food availability (Manduell et al 2012). Consequently, the potential for soil-borne nematode transmission warrants further consideration. It is widely reported that land-use changes can significantly alter the dynamics of infectious diseases in many ways by modifying the niches vector communities, host, and pathogen, and changing the composition of host and vector community; thereby influencing the behavior or movement of vectors and/or hosts, altering vectors and/or hosts spatial distribution, and introducing environmental contamination and socioeconomic stressors (Gottdenker et al 2014, Rondón et al 2017). Furthermore, host population density, a critical factor of parasite spread in many epidemiological models, has been consistently associated with overall parasite species richness and the diversity of helminths, protozoa, and viruses.

In 1916, research on orangutan parasites, particularly gastrointestinal parasites, was initiated (Nurcahyo et al 2017). Since then, various diagnostic methods have been developed and improved to detect a wide range of parasite taxa in wild, free-ranging, and captive orangutans, including those in zoological settings. Notably, approximately 27.5 % of primate parasites have also been detected in humans (Huffman et al 2013). Host movements, including migration, range expansion, and transition to captivity, are known to influence parasite community structure. Transition to captivity -a rarely studied yet widespread human-driven host movement- can also change parasite communities, sometimes resulting in pathogen spillover between wildlife species or between wildlife and humans (Herrera et al 2019). Previous studies suggest that ranging behavior of wild orangutans, overcrowding in captivity, and a demographic shift toward younger age groups are key factors contributing to parasite transmission and diversity (Labes et al 2010). The complex interactions between humans, pathogens, and the environment have increasingly been addressed through a one health approach, which emphasizes integrated strategies for understanding and mitigating zoonotic disease risks (Buttke et al 2015, Mackenzie and Jeggo 2019, Ghanbari et al 2020). This research, however, was projected specifically towards the parasite burden in orangutans inhabiting logged peat swamp forest within Sebangau National Park (SNP), Central Kalimantan, Indonesia. A previous study implied that wild male orangutans exhibit a significantly higher risk of hookworm infection than females, a pattern likely driven by differences in ranging behavior (Labes et al 2010). Building on these findings, we hypothesized that variations in ranging areas affect the diversity of microscopic parasitic species, their prevalence, and eggs per gram (EPG) found in orangutan fecal samples.

Material and methods

This research was conducted in two distinct forest habitats within Sebangau National Park: The Natural Peat Laboratory (NPL), managed by the Centre for International Co-operation and in sustainable Management of Tropical Peatland (CIMTROP) at the University of Palangka Raya (UPR), hereafter referred to as CIMTROP, and Punggualas Area (PA).

Descriptions of the studied locations

The Natural Peat Laboratory-CIMTROP UPR is located in the north-eastern part of Sebangau National Park. This site is a former logging concession previously managed by PT Setia Alam Jaya and it has been designated as a Research Centre since 1998. It covers an area of 50,000 ha. It is situated adjacent to Kereng Bangkirai, the only village bordering the NPL-CIMTROP area. In contrast, the Punggualas forest (PA) lies in the western part of Sebangau National Park and is surrounded by more than 40 villages that are scattered along the Katingan river (fig. 1). Currently, the Punggualas is designated as a focal point for the development of eco-tourism focused on wildlife observation, particularly orangutans. From January to December 2018, Punggualas was visited by 260 tourists (Suyoko, PEH TN Sebangau: pers. comm. 2021), primarily from Italy, the Netherlands and Sweden.

Permit letter

We obtained genetic access to protected orangutan samples through official approval from the Ministry of Forestry and Environment, Sub-Directorate of Natural Resources and Ecosystem, Republic of Indonesia: SK.14/KSDAE/SET.3/KSA.2/1/2022. Ethical clearance was

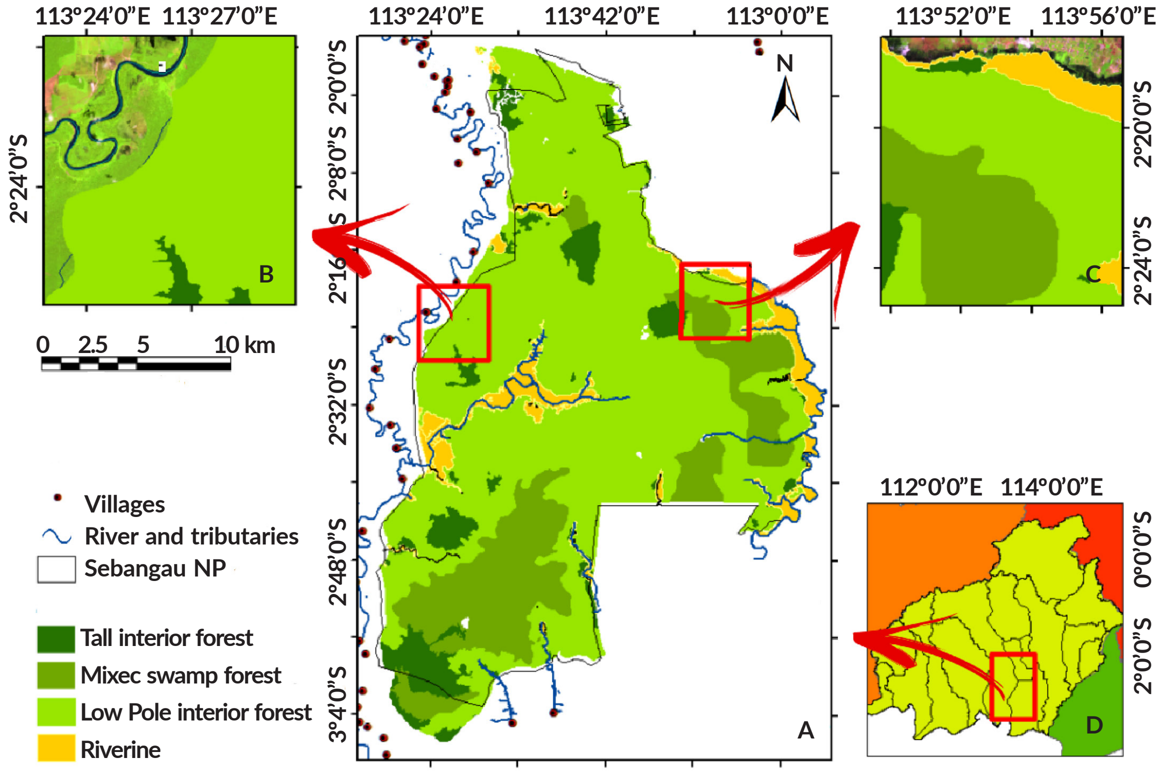


Fig. 1. Study location in Sebangau National Park: A, Sebangau NP; B, Punggualas; C, NPL-CIMTROP UPR; D, inset of Central Kalimantan map.

Fig. 1. *Lugar del estudio en el Parque Nacional Sebangau: A, Parque Nacional Sebangau; B, Punggualas; C, Laboratorio NPL-CIMTROP de la Universidad Palangka Raya (UPR); D, recuadro del mapa de Kalimantan Central.*

granted from the Ethical Commission of the Faculty of Veterinary Medicine, Gadjah Mada University (UGM), with Letter No. 00145/EC-FKH/Eks./2021. In addition, permits for conducting research within the protected area of Sebangau National Park were issued by the park authority under Permit No. SI. 1/BTNS-1/SIMAKSI/2022 (01/02/2022-31/08/2022) and No. SI. 17/BTNS-1/SIMAKSI/2022 (09/09/2022-09/12/2022).

Consideration of orangutan sample size

To contextualize the sample size in this study, we conducted a meta-analysis using a forest plot, incorporating published data on gastrointestinal parasites in wild, semi-captive, and captive orangutans from 1978 to 2011 (fig. 2). The analysis evaluated both the number of parasites detected (events) and sample size (total), comparing them against a no-effect reference line within the 95% confidence interval. The results showed high heterogeneity among studies ($I^2 = 89\%$, $t^2 = 2.3460$) and a statistically significant overall effect ($p < 0.01$). The p-value derived from the chi-square test indicated that the observed heterogeneity is unlikely to have occurred by chance under the random-effects model. Hence, we suggest that sample size alone does not solely determine the likelihood of detecting a higher diversity or prevalence of parasites. We consider that other contributing factors must be involved. In this study, we especially examined the influence of orangutan ranging behavior and diet on parasite burden.

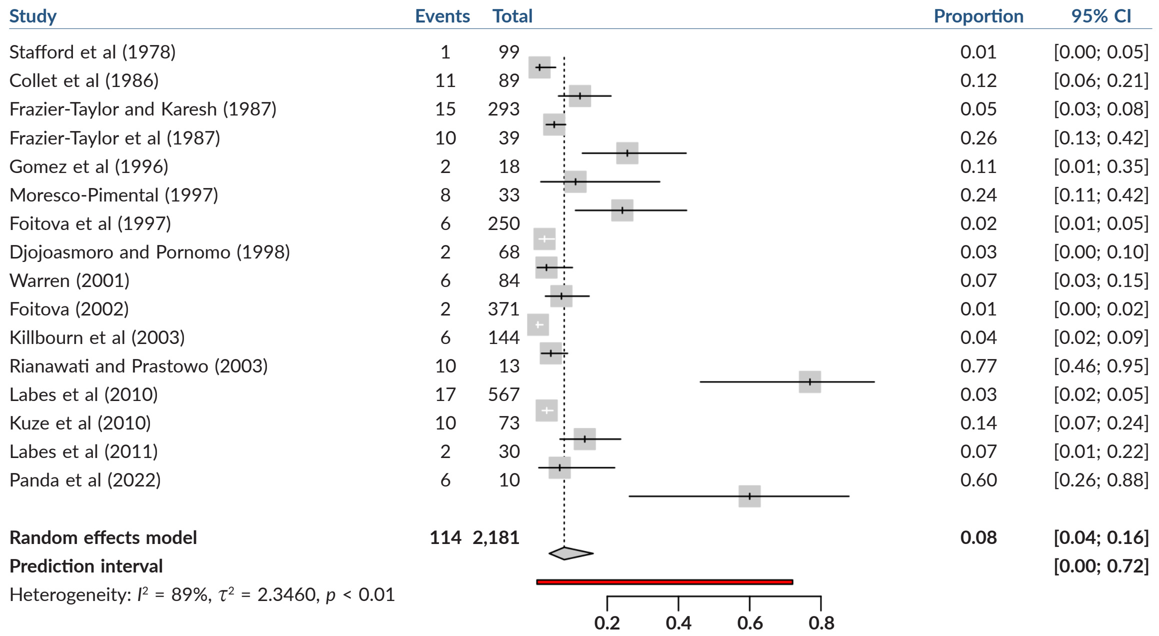
Orangutan fecal collection

At both locations, we used an individual-based single sampling approach (Miller et al 2018). Fecal samples were collected from five sex-age classes of habituated orangutans: flanged males, infants, mothers, juveniles, and adolescents (both male and female). An orangutan follow-up protocol was conducted in accordance with a standardized method for orangutan field studies (Morrogh-Bernard et al 2002). The schematized sampling strategy is presented in figure 3.

Orangutan home range and behavior data

Ranging data within the area of interest (AOI) were collected from February 18th to November, 2022. We used a standardized method for orangutan studies, emphasizing the orangutans follow protocol. Following this standardized protocol, behavioral data were gathered during nest-to-nest focal follows using two-minute instantaneous sampling intervals to record activity and feeding behaviors. Behavioral observations were recorded at two-minute intervals until the focal individual built its night nest. Observation teams consisted of two to three personnel.

Observations were discontinued when individuals moved beyond the established observation grid. When follows extended beyond four consecutive days -particularly in Punggualas- the observed individual was



Study	Events	Total	Proportion	95% CI
Stafford et al (1978)	1	99	0.01	[0.00; 0.05]
Collet et al (1986)	11	89	0.12	[0.06; 0.21]
Frazier-Taylor and Karesh (1987)	15	293	0.05	[0.03; 0.08]
Frazier-Taylor et al (1987)	10	39	0.26	[0.13; 0.42]
Gomez et al (1996)	2	18	0.11	[0.01; 0.35]
Moresco-Pimental (1997)	8	33	0.24	[0.11; 0.42]
Foitova et al (1997)	6	250	0.02	[0.01; 0.05]
Djojoasmoro and Pornomo (1998)	2	68	0.03	[0.00; 0.10]
Warren (2001)	6	84	0.07	[0.03; 0.15]
Foitova (2002)	2	371	0.01	[0.00; 0.02]
Killbourn et al (2003)	6	144	0.04	[0.02; 0.09]
Rianawati and Prastowo (2003)	10	13	0.77	[0.46; 0.95]
Labes et al (2010)	17	567	0.03	[0.02; 0.05]
Kuze et al (2010)	10	73	0.14	[0.07; 0.24]
Labes et al (2011)	2	30	0.07	[0.01; 0.22]
Panda et al (2022)	6	10	0.60	[0.26; 0.88]
Random effects model	**114**	**2,181**	**0.08**	**[0.04; 0.16]**
Prediction interval				**[0.00; 0.72]**

Heterogeneity: I^2 = 89%, τ^2 = 2.3460, p < 0.01

Fig. 2. Forest-plot depicting number of parasites recovered (events) and the sample size (total) from various authors from 1978 to 2022.

Fig. 2. Diagrama de bosque en el que se muestra el número de parásitos recuperados (events) y el tamaño de la muestra (total) observados por varios autores desde 1978 hasta 2022.

assigned a name. Otherwise, individuals were referred to by their sex-age class as indicated in the datasheets. Orangutans encountered at the CIMTROP site during the study period had already been individually identified and named, having been studied continuously since 1999 (Morrogh-Bernard 2020 pers. comm.). A detailed method to calculate home range size and movement patterns is provided in a separate manuscript (Panda et al 2023). However, results for the individuals followed during this study are presented here. Ranging data were collected using a handheld GPS unit (Garmin GPS78) that recorded the focal point at 60-minute intervals. For range analysis, we included only complete nest-to-nest followings rather than imposing criteria such as a minimum of 1,000 observation hours. Orangutan positional data were extracted and cross-referenced with previously published datasets.

Orangutan fecal examination

Parasite data were collected using the MiniFlotac procedure (Barda et al 2014, Catalano et al 2019). Sample preparation and examination followed the standardized MiniFlotac protocol, with a multiplication factor of 10 applied to estimate egg/oocyst/cyst counts per gram (EPG/OCG/CPG) in fresh and fixed fecal samples (Cringoli et al 2017). In individual-based methods, prevalence ($\hat{p}$) was calculated by dividing the number of individuals observed to be infected (i) by the total number of individuals that were sampled (n):

$$\hat{p} = i/n \qquad (1)$$

After defecation, fecal consistency and collection time were examined for each sample (Garcia et al 2018, Garcia 2007). Samples were then transferred into the 10 mL modified syringe, used as a pipette gauge, and transported to the field camp for further analysis.

Statistical analysis

To determine whether the proportions of infested hosts were significantly different between samples, we compared ECG/OCG/CPG values for each parasite across orangutan sex-age classes using 2×2 contingency tables, followed by chi-square test or Fisher's exact test in Minitab v. 2019 for Windows. To examine the relationships between sites (PA vs CIM), sex (male vs female), and range size (HR < 68 Ha vs HR > 68,1 Ha), we applied a zero-inflated model to better fit the data. All GLM calculations were performed using the 'MASS' and 'pscl' in R 4.2.2 for windows.

Results

Orangutan home range

Following standardized orangutan tracking protocols, we estimated the home ranges of all individuals observed during the study, focusing on those representing each sex-age class for which fecal samples were collected (table 1). Table 1 presents the home range estimates for representative individuals per sex-age class. Based on these estimates, mothers with infants had the largest home ranges in both CIMTROP (151.175 Ha) and Punggualas (104.167 Ha), followed by male juveniles in

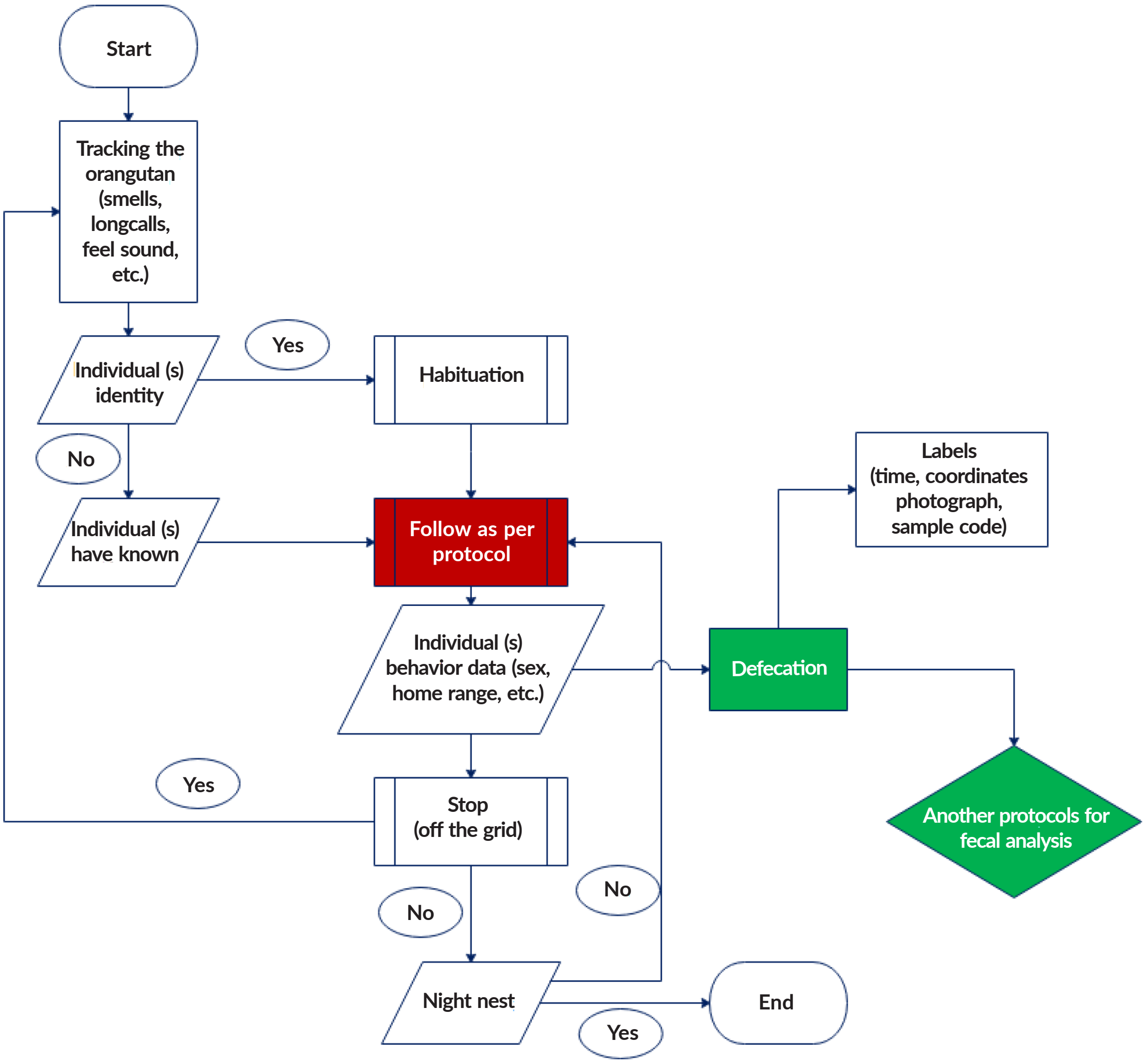


Fig. 3. The schematized sampling strategy for individual-based single sampling for fecal sampling collection of orangutans.

Fig. 3. Estrategia esquematizada para la toma de muestras de materia fecal de los orangutanes mediante muestreo simple.

Punggualas (85.029 Ha), adolescent females in CIMTROP ('Gretel') (61.339 Ha), adolescent females in Punggualas (58.532 Ha), an unidentified flanged male in Punggualas (58.532 Ha), and an unidentified flanged male in CIMTROP (2.302 Ha).

Intestinal parasites recovered and their prevalence

We recovered five protozoans, four nematodes (fig. 4) and one unidentified larva. Among protozoans, *Endolimax nana* trophozoites (6-8 µm) were the most frequently observed. These trophozoites typically contained a single nucleus with a large central karyosome, no peripheral chromatin, and numerous small vacuoles. The cysts of *E. nana* measured 5-10 µm and had up to four nuclei in the mature form (Sleeman et al 2000). *Cysts of Entamoeba coli* ranged from 20-50 µm in diameter, typically containing 4-8 nuclei. *Dientamoeba fragilis* cysts measured 7-15 µm, commonly around 10 µm, with thin walls and a spherical shape. *Endolimax nana*, *Entamoeba coli*, and *E. hartmanni* are considered non-pathogenic protozoans, while *Dientamoeba fragilis* and *Giardia sp.* are classified as potentially pathogenic (Labes et al 2010, Mehlhorn 2016). Although originally thought to be non-pathogenic, recent molecular studies have shown that *D. fragilis* is closely related to *Trichomonas* species and possesses a high pathogenic potential. Moreover, *D. fragilis* is suspected to be transmitted via the eggs of *Enterobius vermicularis* (Mehlhorn 2016). The eggs of *E. vermicularis* measured 50-60 x 20-32 µm. They were oval with a thin shell, and asymmetrical in shape. Hookworm eggs, though not identified to genus level, measured 60-75 x 30-40 µm, were oval in shape, with the morula (8-16 cells) and smooth, thin shell (Mehlhorn 2016). *Trichuris* sp. eggs measured 50-56 x 21-25 µm, displayed bipolar plugs, had thick shell, and were brown.

Table 1. The home-range size per orangutan followed (2019-2022) for mother-infant (MI); also known as dyads so we merged HR size.

Tabla 1. La superficie del área de campeo por orangután es la misma (2019-2022) para las madres y sus hijos (MI), lo que también se conoce como díadas, por lo tanto, se unificaron las superficies de ambos.

Location	Sex-classes	Individual	HR (Ha)	Bar-Chart
CIM	FM	Unknown flanged male	2,302	
	MI	Indy-Icarus	151,175	
	FA	Gretel	61,339	
	MJ	Gara	22,792	
PA	MJ	Male_Juv	85,029	
	MI	Mother_infant007	104,167	
	FA	Female_001	58,532	
	FM	Unknown flanged male2	58,532	

Nuclear structure was not visible, possibly due to the flotation solution used. All the nematodes recovered in this study are considered highly pathogenic. Of particular note, *Ascaris* species are recognized human pathogens, with infection rates as high as 45 % in Central and South America (Mehlhorn 2016).

The number of parasitic and nematode species found in this study is consistent with previous studies conducted on wild, semi-wild and captive orangutan in zoological settings (Mul et al 2007, Labes et al 2010, Hilser 2011). Specifically, the study of Hilser et al (2011) revealed 11 parasite species found in fecal samples of nine orangutans in CIMTROP forest habitat. These included three protozoan species (*Entamoeba coli*, *Entamoeba histolytica/dispar*, and *Troglodytella abrassarti*) and seven nematode species (*Ascaris lumbricoides*, *Enterobius vermicularis*, Strongyloides sp., *Trichostrongylus* sp., *Trichuris trichiura* hookworm eggs), and one unidentified helminth species. The relative density of protozoan cysts found in feces collected in CIMTROP varied across individual orangutans and age classes. The cysts of *E. coli* were detected in 100 % of fecal samples from both alpha male and infant individuals, while the relative density of *E. coli* trophozoites were detected at 100 % prevalence in maternal individuals. In contrast, fecal samples from the Punggualas forest habitats showed 100 % prevalence of *E. coli* cysts across nearly all age classes, except for maternal individuals (fig. 5). *Giardia* sp. trophozoites were found exclusively in infants. The relative density of cysts and trophozoites ranged from 20-100 % across all sex-age class fecal samples, although trophozoites were only detected in mothers, juveniles, and infants in the Punggualas population. A similar pattern was observed in CIMTROP, where trophozoites were absent in samples from infants, the alpha male, and, juvenile males. Cysts represent the infective stage in the life cycle of certain protozoa, including *E. coli*. The presence of *E. coli* cysts in all fecal samples from individuals of various age classes in the Punggualas forest habitat is likely associated with overlapping home ranges among primate groups. In addition, the genus *Entamoeba* is also often associated with the accidental ingestion of parasitic entities, typically via mechanical vectors (Mehlhorn 2016). Similarly, the presence of *Giardia* sp. suggests the potential pathogen transmission from humans to wildlife. This finding is an important indicator of cross-species transmission among primates. Comparable cases have been documented, such as the presence of *Giardia* sp. in *Alouatta pigra* (black howler monkey) groups in Mexico, and in orangutan fecal samples from the Nyaru Menteng Reintroduction Center in Central Kalimantan and the Wanariset Center in East Kalimantan (Vitazkova and Wade 2007, Labes et al 2010).

Ascaris lumbricoides eggs were found in two stages: fertilized and unfertilized eggs. Fertilized eggs were present in all fecal samples collected from orangutans from different age classes in the Punggualas forest habitat (fig. 6). The presence of *A. lumbricoides* eggs in fecal samples suggests that parasitic contamination may have occurred during the successive flood events of 2020 and 2021. Nematode density per 5-gram fecal sample also indicated the presence of *Enterobius vermicularis* eggs in samples from female orangutans categorized as the mother class in both the CIMTROP and Punggualas forest habitats. The presence of infective-stage *E. vermicularis* eggs in these samples is likely related to the parasite's preferred habitat -the perianal folds. However, vulvovaginitis transmission cannot be ruled out. Due to the parasite's location and the accessibility of the area, self-inoculation often occurs when eggs are transferred by hand after scratching the itchy perianal area (Cook 1994, Chhetri et al 2023).

The Mini-FLOTAC technique revealed a high prevalence of *Entamoeba coli* cysts (100 %), followed by hookworm eggs (70 %), *Ascaris lumbricoides* (50 %), *Dientamoeba fragilis* (40 %), *Entamoeba hartmanni* (20 %), and *Giardia* sp. (10 %). The cyst per gram (CPG) count for *E. coli* ranged from 50 to 120 across all orangutan fecal samples. An interesting finding in this study was the exclusive identification of *A. lumbricoides* in orangutans from Punggualas, leading to a highly significant site-specific difference (*p*-value: 0,00000). All parasites recovered in this study are consistent with previous studies conducted on wild, semi-wild and captive

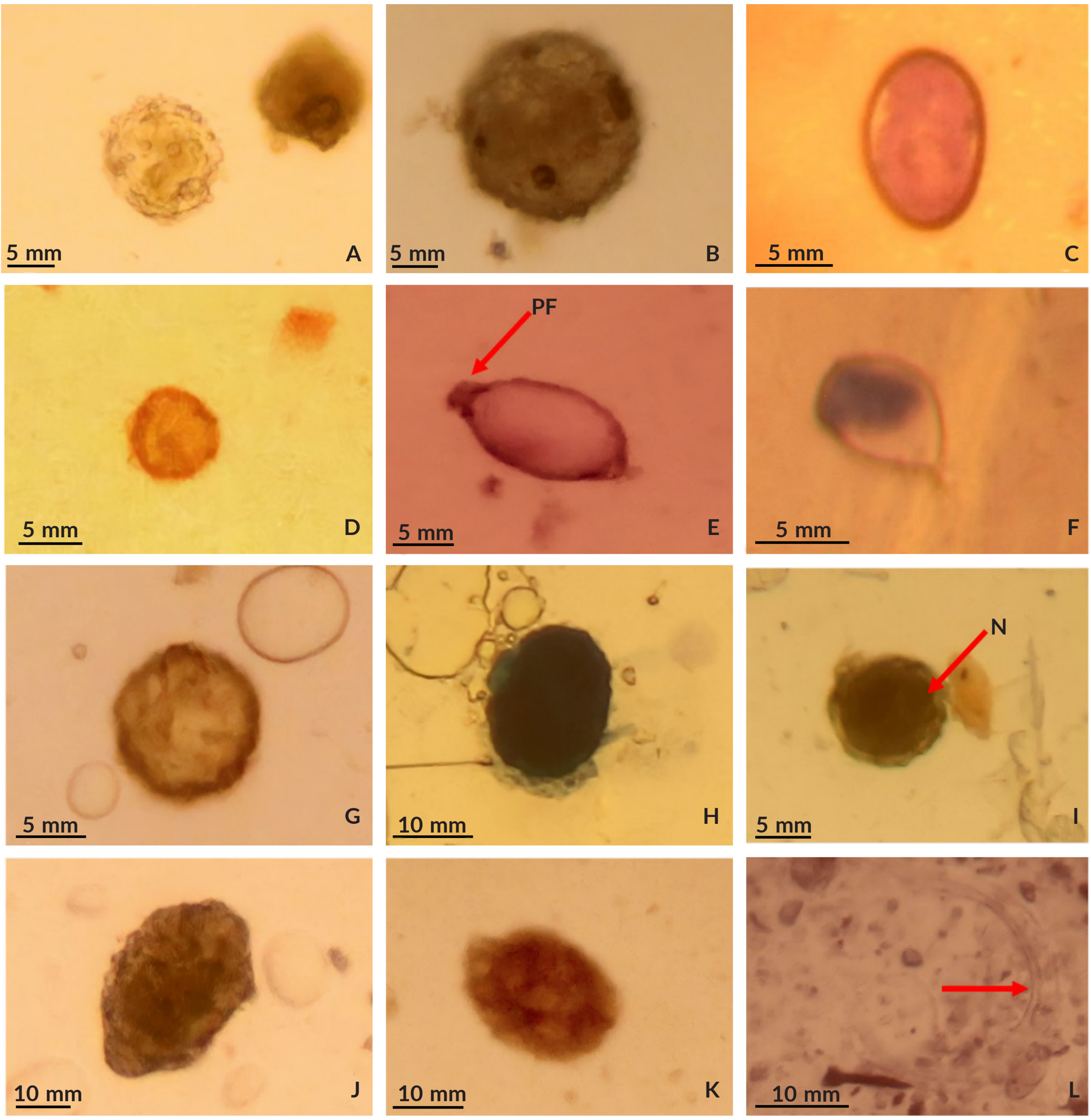


Fig. 4. Parasite richness recovered from orangutan fecal samples: A, cyst *Endolimax nana*; B, trophozoite: *Endolimax nana*, 6-15 mm; C, *Enterobius vermicularis*, 50-60 mm; D, trophozoite *Entamoeba hartmanni*, 5-12 mm; E, *Trichuris trichura* (PF, polar filament); F, *Giardia* sp. 10-20 mm; G, cyst of *Entamoeba coli* (20-50 mm); H, hookworm egg; I, trophozoite with two nuclei of *Dientamoeba fragilis* 7-15 mm; J, *Ascaris lumbricoides* (unfertilized egg: 50-75 x 40-50 mm); K, *Ascaris lumbricoides* (fertilized egg); L, larva (red arrow pointed at unidentified larvae).

Fig. 4. Riqueza de los parásitos recuperados de las muestras de materia fecal de los orangutanes: A, quiste de Endolimax nana; B, trofozoíto de Endolimax nana, 6-15 mm; C, Enterobius vermicularis, 50-60 mm; D, trofozoíto de Entamoeba hartmanni, 5-12 mm; E, Trichuris trichura (PF, filamento polar); F, Giardia sp., 10-20 mm; G, quiste de Entamoeba coli, 20-50 mm; H, huevo de anquilostoma; I, trofozoíto con dos núcleos de Dientamoeba fragilis, 7-15 mm; J, Ascaris lumbricoides (huevo no fecundado: 50-75 x 40-50 mm); K, Ascaris lumbricoides (huevo fecundado); L, larva (la flecha roja apuntando a larvas no identificadas).

orangutan (Mul et al 2007, Labes et al 2010, Hilser 2011). This indicates that no new parasites were identified based on morphological characteristics. However, this is the first report documenting parasite prevalence and species distribution in the Punggualas forest habitat.

The zero-inflated regression model showed no significant relationship between sex (male vs. female), and had a coefficient of -0.968 (*p*-value: 0.333). Similarly, no significant relationship was found between home range categories (HR68 vs HR > 68.1 Ha), where the intercept coefficient was -1.51018 (*p*-value: 0.343) and the predictor coefficient was -0.02317 (*p*-value: 0.682). However, regression analysis of parasite loads by sites (CIM vs. PA) could not be calculated within zero-inflated model (table 2).

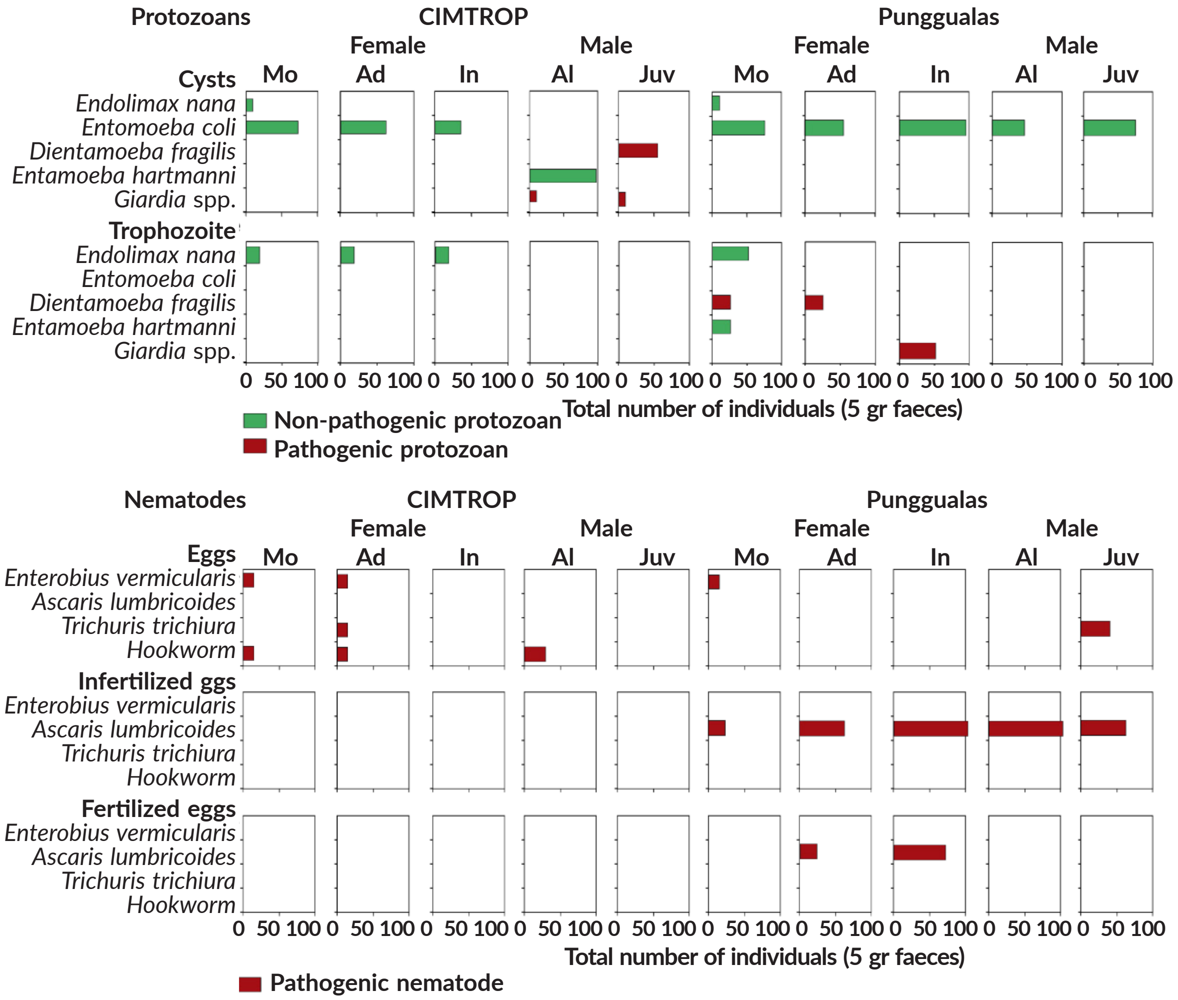


Fig. 5. Numbers of protozoans and nematodes recovered per orangutan age-class and sex in CIMTROP and Punggualas, Sebangau National Park: Mo, mother; Ad, adolescent female; In, infant; Al, alpha male; Juv, juvenile male.

Fig. 5. *Número de protozoos y nematodos recuperados por clase de edad y sexo de los orangutanes en el CIMTROP y en Punggualas, en el Parque Nacional Sebanguau: Mo, madre; Ad, hembra adolescente; In, lactante; Al, macho alfa; Juv, macho juvenil.*

Orangutan diets

Based on individual orangutan following data, Figure 7 shows the percentage of time spent on various behavioral activities. The proportion of time allocated to feeding ranged from 2 % to 18 % of the total daily activity period, equivalent to 38-347 minutes over a 12-hour active period. In the CIMTROP forest habitat, the order of the individuals from lowest to highest feeding percentage was: infant (2 %), juvenile male (5 %), adolescent female (7 %), alpha-male (12 %), and mother (18 %). In the Punggualas forest habitat, the order was: infant (4 %), adolescent female (10 %), mother (12 %), alpha male (15 %), and juvenile male (16 %). Traveling behavior accounted for 8 % to 15 % of total daily activity, equivalent to 115.3-231 minutes. The travel pattern showed relatively little variation, particularly in mother-infant dyads. Infants, typically 1-2 years old, are highly dependent on their mothers and are usually observed clinging to them during movement. As a result, the infant's movement mirrors that of the mother, and their ranging data were analyzed as a single unit.

Resting behavior varied between individuals in each forest habitat. In CIMTROP, the average resting time ranged from 5 to 10 %, or equivalent to 25-32 minutes per active period of each individual. In contrast, individuals in the Punggualas habitat showed greater variation with resting time ranging from 7 to 33 % or equivalent to 22.7-110 minutes per active period. Notably, juvenile males at both sites exhibited no resting behavior during observations. Instead, they spent 32 % of their time moving and 68 % feeding during the 12-hour active period.

Adolescent female individuals exhibited feeding behavior with the highest total percentage, this being of 54.7 % of the total daily feeding period and consisting primarily of semi-ripe fruit from *Madhuca motleyana*

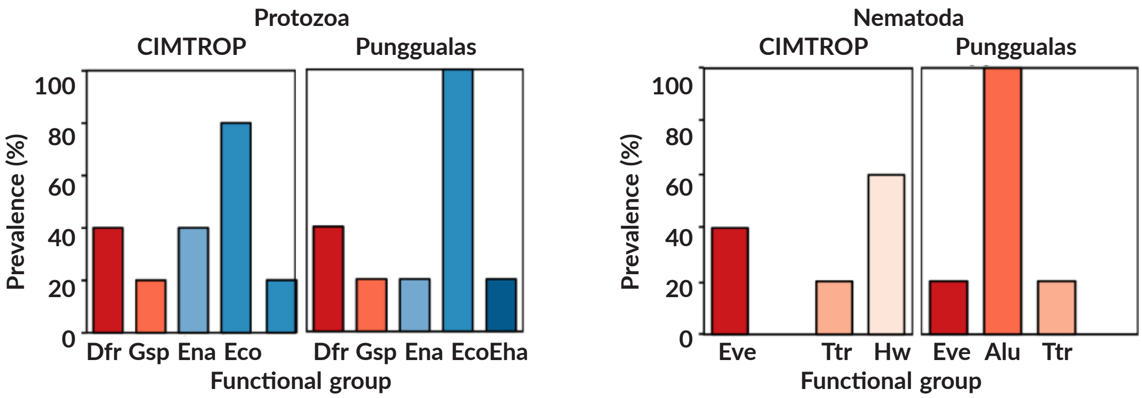


Fig. 6. Prevalence of parasites from fecal sample collected from representativeindividual orangutan age class at two forest habitats for both functional group: protozoan (Dfr, *Dientamoeba fragilis;* Gsp, *Giardia* spp.; Ena, *Endolimax nana;* Eco, *Entomoeba coli;* Eha, *Entamoeba hartmanni*), and nematodes (Eve, *Enterobius vermicularis;* Ttr, *Trichuris trichiura;* Hw, *Hookworm;* Alu, *Ascaris lumbricoides).*

Fig. 6. Prevalencia de parásitos en la muestra de materia fecal tomada de las clases de edad representativas de orangután en dos hábitats forestales de ambos grupos funcionales: protozoos y nematodos. (Para las abreviaturas de protozoos y nematodos, véase arriba).

(44.2 %) and leaves (10.5 %). This behavior accounted for 10 % of their total 12-hour active period. Meanwhile, alpha males showed a feeding preference of 60.4 % for flowers from the *M. motleyana* tree, and 15.8 % for insects, with the remainder divided among termites, unripe fruit, and leaves of varying maturity levels. Similarly, mothers spent 60.4 % of their feeding time eating flowers from *Katiau* and *Madhuca motleyana* species, 15.8 % on insects, and the rest on leaves at various stages of maturity.

A similar pattern was observed in infants and juvenile males, with 53.5 % and 74.9 %, respectively of their diet consisting of flowers, unripe fruit (24 %), and insects 23.8 % over the total 12-hour active period. Based on this observation, the dietary patterns observed among orangutans in the Punggualas forest included flowers, unripe fruits, insects, and leaves. In contrast, dietary patterns in CIMTROP forest habitats showed differences in plant parts consumed, these mainly being ripe fruits, inner bark, and insects. As in Punggualas, individuals in CIMTROP displayed age-specific preferences in plant part consumption.

Adult males in CIMTROP demonstrated a strong preference for ripe fruit, with consumption reaching 100 % of their total active period (minutes per day). Across both habitats, dietary variations were evident among individuals. The food choices observed suggest reliance on fallback foods, highlighting the orangutans' adaptive capacity to shift dietary preferences in response to fruit scarcity, such as that in the Sebangau region.

Table 2. Zero-inflated model regression coefficient for regression EPG/OPG/CPG data: SE, standard error; nc, not computed; *p*-value < 0.05.

Tabla 2. Coeficiente de regresión del modelo inflado a cero para la regresión de los datos relativos a los huevos por gramo (EPG)/ovocitos por gramo (OCG)/quistes por gramo (CPG) de las heces: SE, error estándar; nc, no calculado; p *< 0,05.*

			Estimate	SE	z-value Pr (>|z|)	
PA vs CIM						
	Coefficients	Intercept	nc	nc	nc	nc
		GLM_R$CIM	nc	nc	nc	nc
Male vs Female						
	Coefficients	Intercept	1.01237	1.33947	0.756	0.45
		GLM_R$FEM	-0.04633	0.04785	-0.968	0.333
HR < 68 vs HR > 68.1 Ha						
	Coefficients	Intercept	-1.51018	1.59259	-0.948	0.343
		GLM_R$`HR > 68.1	-0.02317	0.05647	-0.41	0.682

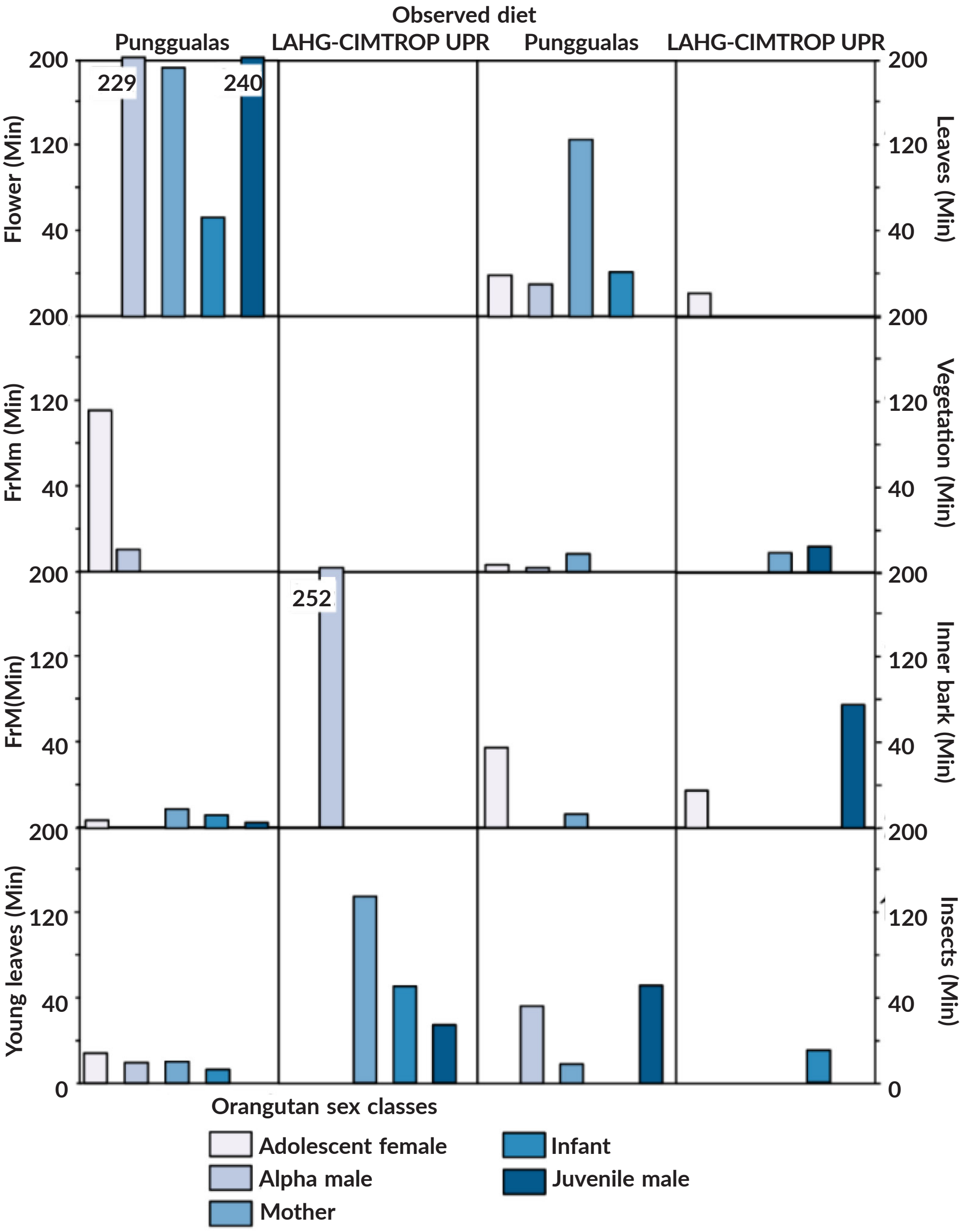


Fig. 7. Total feeding time of each individual in the Punggualas and CIMTROP forest habitats: Fr, fruit; Mm, semi-mature; M, mature; FrM, orangutan feed on fruit (Fr) mature (M); FrMm, orangutan feed on fruit (Fr) semi mature (Mm); Min, minutes (total minutes spent in feeding items per 12 hours-active period).

***Fig. 7.** Tiempo total de alimentación de todos los ejemplares en los hábitats forestales de Punggualas y el CIMTROP: Fr, fruta; Mm, en proceso de maduración; M, madura; FrM, orangután alimentado con fruta (Fr) madura (M); FrMm, orangután alimentado con fruta (Fr) en proceso de maduración (Mm); Min, minutos (total de minutos dedicados a alimentarse en las 12 horas de período de actividad).*

Discussion

Our data analysis revealed that some individuals were consistently observed while others were not. This suggests that individuals with larger ranging areas are more likely to be encountered during observation. In other words, utilization distribution estimates the probability of an animal being located at any randomly selected time point (Powell and Mitchell 2012). Although range estimates for flanged males appear comparatively low in this study, this does not necessarily indicate that their actual ranges are smaller. Instead, it is likely due to limitations in observation coverage. Female home ranges are generally assumed to be influenced by environmental factors, particularly the distribution and availability of food sources (Singleton and van Schaik 2001, Singleton et al 2009). In contrast, male orangutan ranges are typically several times larger than female ranges and often extend beyond the grid trails used in the study area (Wartmann et al 2010). Compared to mixed-dipterocarp forests, orangutans in peat swamp forests spend approximately half of their active time feeding. Additionally, the 'compression effect' may lead orangutans to prefer fine-scale habitats (Morrogh-Bernard et al 2014).

We also examined parasite loads in male and female orangutans. All nematodes identified in this study (*E. vermacularis*, *A. lumbricoides*, *T. trichiura* and hookworm egg) showed significant differences between males and females (*p*-value: 0,00000). This finding contradicts previous studies, which often reported higher parasite loads in male orangutans. Among the five protozoan species analysed, two (*Entamoeba nana*, both cyst and trophozoite stages) did not show significant differences between sexes (*p*-value: 0,536934). However, three protozoa did show significant differences: *Dientamoeba fragilis* (*p*-value: 0,000007), *E. hartmanni* (*p*-value: 0,010993), and *Giardia* sp. (*p*-value: 0,000436). This discrepancy may relate to the larger ranging behaviour of males, as previously discussed. Males often travel beyond the grid trails of the study area (Wartmann et al 2010), potentially exposing them to a greater variety of habitats and, consequently, a broader range of parasites (Wartmann et al 2010).

To better understand the relationship between orangutan range size and parasite load, we calculated the mean data for individuals grouped based on their estimated range size. We categorized the home range (HR) into two groups: HR < 68 Ha and HR > 68.1 Ha. The results revealed no significant differences between these categories; in fact, some 2 x 2 contingency tables were not computable due to data limitations. Negative binomial regression indicated a high level of significance for sites (PA vs CIM), gender (male vs female), and home range size (HR < 68 Ha and HR > 68,1 Ha). However, we could not draw firm conclusions from these results as the regression coefficients showed a tendency to produce Type I errors. To address this, we applied a zero-inflated regression model, which confirmed that there were no significant relationships between parasite load and either sex or home range. The relationship between site and parasite load could not be computed in this model. This suggests that parasite load may be a site-specific phenomenon, with each count being independent of the others. The CIM and PA sites differ in their management objectives and classification under the Sebangau National Park (SNP) Zonation Plan (2018-2027). While CIM has been designated as a special zone and has accommodated research activities since 1999 (prior to SNP's formal establishment in 2004) it is subject to stricter controls, including the requirement of research permits and limited access. In contrast, the PA site is part of the Sebangau National Park's utilisation zone, developed for ecotourism and the provision of ecosystem services. This showed that there are some restrictions on community access to the natural resources. Previous studies have identified multiple potential sources of parasitic infection, including tourists, researchers, and incidental contact with community activities such as hunting and logging (Woodford et al 2002). Additionally, orangutan translocation and release programs have further implications for disease transmission, regardless of zonation differences (Kilbourn et al 2003, Mul et al 2007).

We explored additional activity logs to better understand the factors mentioned earlier, particularly community access to natural resources. During the study period, we observed villagers (mostly from Karuing) frequently entering and exiting the forest to collect *gaharu* (agarwood). We recently found the product originating from *Gonystylus bancanus* (Miq.) Kurz, a species in the Thymelaeaceae family. This wood has been in high demand during logging concessions in the Sebangau ecosystem. A product claimed to be *gaharu* was previously verified by Nordahlia and Lim (2017), who concluded that it belonged to a different species from the commonly known *Aquilaria* genus, referring to it as pseudo-*gaharu*. Although aromatic, its mechanical structure differs from that of the true *gaharu* species *Aquilaria beccariana* van Tiegh and *Aquilaria filaria* (Oken.) Merr. The frequent movement of villagers in and out of the Sebangau forest likely influences orangutan ranging patterns and increases the risk of human-orangutan pathogen transmission, particularly in the Punggualas area.

The presence of two functional groups (protozoa and nematodes) in the feces of wild orangutans in their natural habitat serves as indicators of two key factors. First, it suggests potential sources of pathogen transmission, with the fecal-oral route being the most commonly reported pathway between humans and orangutans. Second, the findings suggest that orangutans may possess resistance mechanisms to limit parasite load or tolerance mechanisms so as to minimize the negative impacts of infection. Overall, parasite burdens were categorized as low, with < 500 EPG/CPG in orangutan fecal samples from both study sites. However, further research is needed to better understand the complex relationships between humans, orangutans, and parasites, as well as broader aspects of animal disease ecology.

References

Ancrenaz M, Gimenez O, Ambu L, Ancrenaz K, Andau P, Goossens B, Payne J, Sawang A, Tuuga A, Lackman-Ancrenaz I 2005. Aerial surveys give new estimates for orangutans in Sabah, Malaysia. *Plos Biology* 3(1), e3. DOI: 10.1371/journal.pbio.0030003

Ancrenaz M, Sollmann R, Meijaard E, Hearn AJ, Ross J, Samejima H, Loken B, Cheyne SM, Stark DJ, Gardner PC, Goossens B, Mohamed A, Bohm T, Matsuda I, Nakabayasi M, Lee SK, Bernard H, Brodie J, Wich S, Fredriksson G, Hanya G, Harrison ME, Kanamori T, Kretzschmar P, Macdonald DW, Riger P, Spehar S, Laurentius N, Ambu LN, Wilting A, 2014. Coming down from the trees: Is terrestrial activity in Bornean orangutans natural or disturbance driven? *Scientific Reports* 4, 3-7. DOI: 10.1038/srep04024

Ashbury AM, Posa MRC, Dunkel LP, Spillmann B, Atmoko SSU, van Schaik CP, van Noordwijk MA, 2015. Why do orangutans leave the trees? Terrestrial behavior among wild Bornean orangutans (Pongo pygmaeus wurmbii) at Tuanan, Central Kalimantan. *American Journal of Primatology* 77(11), 1216-1229. DOI: 10.1002/ajp.22460

Barda BD, Rinaldi L, Ianniello D, Zepherine H, Salvo F, Sadutshang T, Cringoli G, Clementi M, Albonico M, 2013. Mini-FLOTAC, an Innovative Direct Diagnostic Technique for Intestinal Parasitic Infections: Experience from the Field. *PLoS Neglected Tropical Diseases* 7(8). DOI: 10.1371/journal.pntd.0002344

Buckland ST, Rexstad EA, Marques TA, Oedekoven CS, 2015. *Desingning*

Surveys in Distance Sampling: Methods and Applications. Springer Cham, USA. DOI: 10.1007/978-3-319-19219-2

Burke C, Rashman MF, Longmore SN, McAree O, Glover-Kapfer P, Ancrenaz M, Wich SA, 2019. Successful observation of orangutans in the wild with thermal-equipped drones. *Journal of Unmanned Vehicle Systems* 7(3), 235-257. DOI: 10.1139/juvs-2018-0035

Buttke DE, Decker DJ, Wild MA, 2015. The role of one health in wildlife conservation: A challenge and opportunity. *Journal of Wildlife Diseases* 51(1), 1-8. DOI: 10.7589/2014-01-004

Catalano S, Symeou A, Marsh KJ, Borlase A, Léger E, Fall CB, Sène M, Diouf ND, Ianniello D, Cringoli G, Rinaldi L, Bâ K, Webster JP, 2019. Mini-FLOTAC as an alternative, non-invasive diagnostic tool for Schistosoma mansoni and other trematode infections in wildlife reservoirs. *Parasites and Vectors* 12(1). DOI: 10.1186/s13071-019-3613-6

Cheyne SM, Gilhooly LJ, Hamard MC, Höing A, Houlihan PR, Kursani Loken B, Phillips A, Rayadin Y, Capilla BR, Rowland D, Sastramidjaja WJ, Spehar S, Thompson CJH, Zrust M, 2016. Population mapping of gibbons in Kalimantan, Indonesia: Correlates of gibbon density and vegetation across the species' range. *Endangered Species Research* 30(1), 133-143. DOI: 10.3354/esr00734

Chhetri S, Al Mamari AH, Al Awfi MM, Al Khaldi NHN, Abed NM, Pandak N, Khamis F, Al Balushi Z, Alalawi RMK, Al Lawati S, Ba'Omar M, Shukaili N, Al-Abri S, 2023. *Enterobius vermicularis* related acute appendicitis: A case report and review of the literature. *Infectious Disease Reports* 15(4), 417-424. DOI: 10.3390/idr15040042

Cook GC, 1994. *Enterobius vermicularis* infection. *Gut* 35(9), 1159-1162. DOI: 10.1136/gut.35.9.1159

Cringoli G, Maurelli MP, Levecke B, Bosco A, Vercruysse J, Utzinger J, Rinaldi L, 2017. The mini-FLOTAC technique for the diagnosis of helminth and protozoan infections in humans and animals. *Nature Protocols* 12(9), 1723-1732. DOI: 10.1038/nprot.2017.067

Davies AB, Ancrenaz M, Oram F, Asner GP, 2017. Canopy structure drives orangutan habitat selection in disturbed Bornean forests. *Proceedings of the National Academy of Sciences of the United States of America* 114(31), 8307-8312. DOI: 10.1073/pnas.1706780114

Fagan WF, Cantrell RS, Cosner C, 1999. How habitat edges change species interactions. *American Naturalist* 153(2), 165-182. DOI: 10.1086/303162

Fahrig L, 2003. Effects of Habitat Fragmentation on Biodiversity. *Annual Review of Ecology, Evolution, and Systematics* 34(2003), 487-515. DOI: 10.1146/annurev.ecolsys.34.011802.132419

Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N, Snyder PK, 2005. Global consequences of land use. *Science* 309(5734), 570-574. DOI: 10.1126/science.1111772

Garcia LS, 2007. *Diagnostic Medical Parasitology*, 5th ed. ASM Press.

Garcia LS, Arrowood M, Kokoskin E, Paltridge GP, Pillai DR, Procop GW, Ryan N, Shimizu RY, Visvesvara G, 2018. Laboratory diagnosis of parasites from the gastrointestinal tract. *Clinical Microbiology Reviews* 31(1), 1-81. DOI: 10.1128/CMR.00025-17

Ghanbari MK, Gorji HA, Behzadifar M, Sanee N, Mehedi N, Bragazzi NL, 2020. One health approach to tackle brucellosis: a systematic review. *Tropical Medicine and Health* 48(1), 1-10. DOI: 10.1186/s41182-020-00272-1

Gillespie TR, Chapman CA, 2006. Prediction of parasite infection dynamics in primate metapopulations based on attributes of forest fragmentation. *Conservation Biology* 20(2), 441-448. DOI: 10.1111/j.1523-1739.2006.00290.x

Gillespie TR, Chapman CA, Greiner EC, 2005. Effects of logging on gastrointestinal parasite infections and infection risk in African primates. *Journal of Applied Ecology* 42(4): 699-707. DOI: 10.1111/j.1365-2664.2005.01049.x

Gottdenker NL, Streicker DG, Faust CL, Carroll CR, 2014. Anthropogenic land use change and infectious diseases: A review of the evidence. *EcoHealth* 11(4), 619-632. DOI: 10.1007/s10393-014-0941-z

Mehlhorn H (Ed), 2016. *Encyclopedia of Parasitology*. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-662-43978-4

Herrera JP, Chakraborty D, Rushmore J, Altizer S, Nunn C, 2019. The changing ecology of primate parasites: Insights from wild-captive comparisons. *American Journal of Primatology* 81(7), e22991. DOI: 10.1002/ajp.22991

Hilser H, 2011. An Assessment of Primate Health in the Sabangau Peat-Swamp Forest, Central Kalimantan, Indonesian Borneo. MSc thesis, Oxford Brookes University, UK.

Huffman M, Nahallage C, Hasegawa H, Ekanayake S, De Silva L, Athauda I, 2013. Preliminary survey of the distribution of four potentially zoonotic parasite species among primates in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka* 41(4), 319. DOI: 10.4038/jnsfsr.v41i4.6246

Husson S, Morrogh-Bernard H, 2004. *Orang-utan population dynamics in the Sebangau Ecosystem, Central Kalimantan Distribution, Population Size and Trends. June*, 1-18.

Kilbourn AM, Karesh WB, Wolfe ND, Bosi EJ, Cook RA, Andau M, 2003. Health evaluation of free-ranging and semi-captive orangutans (*Pongo pygmaeus pygmaeus*) in Sabah, Malaysia. *Journal of Wildlife Diseases* 39(1), 73-83. DOI: 10.7589/0090-3558-39.1.73

Labes EM, Hegglin D, Grimm F, Nurcahyo W, Harrison ME, Bastian ML, Deplazes P, 2010. Intestinal parasites of endangered orangutans (*Pongo pygmaeus*) in Central and East Kalimantan, Borneo, Indonesia. *Parasitology* 137(1), 123-135. DOI: 10.1017/S0031182009991120

Laurance WF, Wich SA, Onrizal O, Fredriksson G, Usher G, Santika T, Byler D, Mittermeier R, Kormos R, Williamson EA, Meijaard E, 2020. Tapanuli orangutan endangered by Sumatran hydropower scheme. *Nature Ecology and Evolution*, 4(11), 1438-1439. DOI: 10.1038/s41559-020-1263-x

Loken B, Spehar S, Rayadin Y, 2013. Terrestriality in the bornean orangutan (*Pongo pygmaeus morio*) and implications for their ecology and conservation. *American Journal of Primatology* 75(11), 1129-1138. DOI: 10.1002/ajp.22174

Mackenzie JS, Jeggo M, 2019. The one health approach-why is it so important? *Tropical Medicine and Infectious Disease* 4(2), 5-8. DOI: 10.3390/tropicalmed4020088

Manduell KL, Harrison ME, Thorpe SKS, 2012. Forest Structure and Support Availability Influence Orangutan Locomotion in Sumatra and Borneo. *American Journal of Primatology* 74(12), 1128-1142. DOI: 10.1002/ajp.22072

Martínez-Mota R, Pozo-Montuy G, Bonilla Sánchez YM, Gillespie TR, 2018. Effects of anthropogenic stress on the presence of parasites in a threatened population of black howler monkeys (*Alouatta pigra*). *Therya* 9(2), 161-170. DOI: 10.12933/therya-18-572

Mbora DNM, McPeek MA, 2009. Host density and human activities mediate increased parasite prevalence and richness in primates threatened by habitat loss and fragmentation. *Journal of Animal Ecology 78*(1), 210-218. DOI: 10.1111/j.1365-2656.2008.01481.x

Mbora DNM, Munene E, 2006. Gastrointestinal parasites of critically endangered primates endemic to Tana River, Kenya: Tana River red colobus (*Procolobus rufomitratus*) and crested mangabey (*Cercocebus galeritus*). *Journal of Parasitology* 92(5), 928-932. DOI: 10.1645/ge-798r1.1

Miller IF, Schneider-Crease I, Nunn CL, Muehlenbein MP, 2018. Estimating infection prevalence: Best practices and their theoretical underpinnings. *Ecology and Evolution* 8(13), 6738-6747. DOI: 10.1002/ece3.4179

Morrogh-Bernard HC, Husson SJ, Harsanto FA, Chivers DJ, 2014. Fine-scale habitat use by orang-utans in a disturbed peat swamp forest, central Kalimantan, and implications for conservation management. *Folia Primatologica* 85(3), 135-153. DOI: 10.1159/000358251

Morrogh-Bernard H, Husson S, McLardy C, 2002. Orangutan Data Collection Standardisation. In: *Orangutan Culture Workshop, February 2002, San Anselmo, USA*. Available online at: https://www.aim.uzh.ch/dam/jcr:00000000-31fd-16f1-ffff-fffff64ca75e/method_standardisation_fina_II.pdf

Mul IF, Paembonan W, Singleton I, Wich SA, Van Bolhuis HG, 2007. Intestinal parasites of free-ranging, semicaptive, and captive *Pongo abelii* in Sumatra, Indonesia. *International Journal of Primatology* 28(2), 407-420. DOI: 10.1007/s10764-007-9119-7

Murcia C, 1995. Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution* 10(2), 58-62. DOI: 10.1016/S0169-5347(00)88977-6

Nater A, Mattle-Greminger MP, Nurcahyo A, Nowak MG, de Manuel M, Desai T, Groves C, Pybus M, Sonay TB, Roos C, Lameira AR, Wich SA, Askew J, Davila-Ross M, Fredriksson G, de Valles G, Casals F, Prado-Martinez J, Goossens B, Verschoor EJ, Warren KS, Singleton I, Marques DA, Pamungkas J, Perwitasari-Farajallah D, Rianti P, Tuuga A, Gut IG, Gut, M, Orozco-terWengel P, van Schaik CP, Bertranpetit J, Anisimova M, Scally A, Marques-Bonet T, Meijaard E, Krützen M, 2017. Morphometric, behavioral, and genomic evidence for a new orangutan species. *Current Biology* 27(22), 3487-3498.e10. DOI: 10.1016/j.cub.2017.09.047

Nordahlia AS, Lim SC, 2017. Verification of products sold as Gaharu. *Timber Technology Bulletin* 71, 139-258. Available online at: https://chrome-extension://dbkidnlfklnjanneifjjojofckpcogcl/pdf-viewer.html?file=https%3A%2F%2Finfo.frim.gov.my%2Finfocenter%2Fbooksonline%2Fttb%2FTTB71.pdf

Nurcahyo W, Konstanzová V, Foitová I, 2017. Parasites of orangutans (Primates: Ponginae): An overview. *American Journal of Primatology* 79(6). DOI: 10.1002/ajp.22650

Panda A, Meididit A, Simon O, Artama WT, Priyowidodo D, Djohan TS, 2023. Orangutan (*Pongo pygmaeus* ssp. *wurmbii*) range pattern in Punggualas, Sebangau National Park, Central Kalimantan Indonesia. *Biotropia* 30(3), 282-296. DOI: 10.11598/BTB.2023.30.3.1901

Powell RA, Mitchell MS, 2012. What is a home range? *Journal of Mam-*

malogy 93(4), 948-958. DOI: 10.1644/11-MAMM-S-177.1

Ries L, Fletcher RJ, Battin J, Sisk TD, 2004. Ecological responses to habitat edges: Mechanisms, models, and variability explained. *Annual Review of Ecology, Evolution, and Systematics* 35(2004), 491-522. DOI: 10.1146/annurev.ecolsys.35.112202.130148

Rondón S, Ortiz M, León C, Galvis N, Link A, González C, 2017. Seasonality, richness and prevalence of intestinal parasites of three neotropical primates (*Alouatta seniculus*, *Ateles hybridus* and *Cebus versicolor*) in a fragmented forest in Colombia. *International Journal for Parasitology: Parasites and Wildlife* 6(3), 202-208. DOI: 10.1016/j.ijppaw.2017.07.006

Santika T, Ancrenaz M, Wilson KA, Spehar S, Abram N, Banes GL, Campbell-Smith G, Curran L, D'Arcy L, Delgado RA, Erman A, Goossens B, Hartanto H, Houghton M, Husson SJ, Kühl HS, Lackman I, Leiman A, Llano Sanchez K, Makinuddin N, Marshall AJ, Meididit A, Mengersen K, Musnanda, Nardiyono, Nurcahyo A, Odom K, Panda A, Prasetyo D, Purnomo, Rafiastanto A, Raharjo S, Ratnasari D, Russon AE, Santana AH, Santoso E, Sapari I, Sihite J, Suyoko A, Tjiu A, Utami-Atmoko SS, van Schaik CP, Voigt M, Wells J, Wich SA, Willems EP, Meijaard E, 2017. First integrative trend analysis for a great ape species in Borneo. *Scientific Reports* 7(1), 4839. DOI: 10.1038/s41598-017-04435-9

Simler-Williamson AB, Metz MR, Frangioso KM, Rizzo DM, 2021. Wildfire alters the disturbance impacts of an emerging forest disease via changes to host occurrence and demographic structure. *Journal of Ecology* 109(2), 676-691. DOI: 10.1111/1365-2745.13495

Simon D, Davies G, Ancrenaz M, 2019. Changes to Sabah's orangutan population in recent times: 2002-2017. *Plos One* 14(7), 1-14. DOI: 10.1371/journal.pone.0218819

Singleton I, van Schaik CP, 2001. Orangutan Home Range Size and Its Determinants in a Sumatran Swamp Forest. *International Journal of Primatology* 22(6), 877-911. DOI: 10.1023/A

Singleton I, Knott CD, Morrogh-Bernard HC, Wich SA, van Schaik CP, 2009. Ranging behavior of orangutan females and social organization. In: *Orangutans: Geographic Variation in Behavioral Ecology and Conservation*: 205-214 (SA Wich, SSU Atmoko, TM Setia, CP van Schaik, Eds). Oxford University Press, New York, USA. DOI: 10.5167/uzh-31342

Sloan S, Supriatna J, Campbell MJ, Alamgir M, Laurance WF, 2018. Newly discovered orangutan species requires urgent habitat protection. *Current Biology* 28(11), R650-R651. DOI: 10.1016/j.cub.2018.04.082

van Schaik CP, Wich SA, Utami SS, Odom K, 2005. A simple alternative to line transects of nests for estimating orangutan densities. *Primates* 46(4), 249-254. DOI: 10.1007/s10329-005-0134-z

Vitazkova SK, Wade SE, 2007. Effects of ecology on the gastrointestinal parasites of *Alouatta pigra*. *International Journal of Primatology* 28(6), 1327-1343. DOI: 10.1007/s10764-007-9229-2

Voigt M, Wich SA, Ancrenaz M, Meijaard E, Abram N, Banes GL, Campbell-Smith G, d'Arcy LJ, Delgado RA, Erman A, Gaveau D, Goossens B, Heinicke S, Houghton M, Husson SJ, Leiman A, Sanchez KL, Makinuddin N, Marshall AJ, Meididit A, Miettinen J, Mundry R, Musnanda, Nardiyono, Nurcahyo A, Odom K, Panda A, Prasetyo D, Priadjati A, Purnomo, Rafiastanto A, Russon AE, Santika T, Sihite J, Spehar S, Struebig M, Sulbaran-Romero E, Tjiu A, Wells J, Wilson KA, Kühl HS, 2018. Global Demand for Natural Resources Eliminated More Than 100,000 Bornean Orangutans. *Current Biology* 28(5), 761-769.e5. DOI: 10.1016/j.cub.2018.01.053

Wartmann FM, Purves RS, van Schaik CP, 2010. Modelling ranging behaviour of female orang-utans: A case study in Tuanan, Central Kalimantan, Indonesia. *Primates* 51(2), 119-130. DOI: 10.1007/s10329-009-0186-6

Wich SA, Fredriksson G, Usher G, Kühl HS, Nowak MG, 2019. The Tapanuli orangutan: Status, threats, and steps for improved conservation. *Conservation Science and Practice* 1(6), e33. DOI: 10.1111/csp2.33

Wich SA, Gaveau D, Abram N, Ancrenaz M, Baccini A, Brend S, Curran L, Delgado RA, Erman A, Fredriksson GM, Goossens B, Husson SJ, Lackman I, Marshall AJ, Naomi A, Molidena E, Nardiyono, Nurcahyo A, Odom K, Panda A, Purnomo, Rafiastanto A, Ratnasari D, Santana AH, Sapari I, van Schaik CP, Sihite J, Spehar S, Santoso E, Suyoko A, Tiju A, Usher G, Atmoko SSU, Willems EP, Meijaard E, 2012. Understanding the Impacts of land-use policies on a threatened species: Is there a future for the Bornean Orang-utan? *Plos One* 7(11). DOI: 10.1371/journal.pone.0049142

Woodford MH, Butynski TM, Karesh WB, 2002. Habituating the great apes: The disease risks. *Oryx* 36(2), 153-160. DOI: 10.1017/S0030605302000224

Acknowledgments

We thank Head of Sebangau National Park, Ir. Andi M. Khadafi, M.Sc., for the opportunity to conduct orangutan study in Punggualas. We also give our highest gratitude to Atheng Achmad, Candra, Hera Hidayat, Suprianto, Rahmad Hidayat, Nuryakin, Yanu, Tomi, Arif Faldy and all associates from Karuing Village. Your ability, willingness to manifest the instructions for data collections along with nest to nest follow, have yielded first orangutan parasites manuscript for Punggualas. The Borneo Nature Foundation biodiversity staff: Azis Ou, Azis Kelasi, Jali, Iwan Shinyo, Santiano, Tommy Sanjaya, Adul 'Camera Trap', Hendri 'Ucu' and Rustam 'Unyil' Efendy. Your experiences in recognizing orangutan individual have made the follow procedure much easier. Thank you.

Author contributions

A Panda, **WT Artamna**, **TS Djohan** and **D Priyowidodo** initiate to wrote paper. **D Priyowidodo** review on parasites, especially their microscopic features. **A Panda**, collect, identify and analyzed the data, finalized the paper. **A Panda**, **WT Artamna**, **TS Djohan** and **D Priyowidodo** read the final draft of manuscript. **A Panda** submit the paper and correspond to any communications.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

No funding provided.

Complete affiliations

Adventus Panda, Dept. of Biological Science, Faculty of Mathematic and Natural Science, University of Palangka Raya, Central Kalimantan Indonesia 73111 A

Tjut Sugandawaty Djohan, Laboratory of Ecology and Conservation, Dept. of Tropical Biology, Faculty of Biology, Universitas Gadjah Mada, Jalan Teknika Selatan, Senolowo, Sinduadi, Mlati Sleman, Yogyakarta, Indonesia 55281

Wayan Tunas Artamna, One Health Collaborating Centre (OHCC)/Eco Health, PAU UGM, Jalan Teknika Utara, Kocoran, Caturtunggal, Kec. Depok, Kabupaten Sleman, Yogyakarta Indonesia 55281

Dwi Priyowidodo, Dept. of Parasitology, Faculty of Veterinary Medicine, Universitas Gadjah Mada, Jl. Fauna No. 2 Karangmalang, Yogyakarta, Indonesia 55281