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Survey of Helminth Parasites in Populations of *Alouatta palliata mexicana* and *A. pigra* in Continuous and in Fragmented Habitat in Southern Mexico

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Abstract The 2 howler species that occur in southern Mexico, *Alouatta palliata mexicana* and *Alouatta pigra* are endangered, mainly as a result of habitat loss and fragmentation from human activity. Little is known about the gastrointestinal parasite communities affecting their populations, and lack of baseline information for populations of howler species in continuous forest habitats, makes evaluations of gastrointestinal parasite prevalence in populations in fragmented landscapes difficult. We report the results of a one-time broad survey of gastrointestinal parasites in fecal samples of individuals from several demographically stable populations of *Alouatta palliata mexicana* and *A. pigra* existing in continuous and/or protected forests. We further report similar data for populations of both species in human-fragmented landscapes. We detected 6 parasites for each howler monkey species, but only 3 of them (Trematode I, *Controrchis biliophilus, Trypanoxyuris* sp.) were common to both species. While parasitic prevalence in populations of both howler species was, in general, higher in the fragmented habitat than in continuous and/or protected forests. The difference is only marginally significant in *Alouatta pigra*. Some parasites (Coccidia and Strongylid) only appeared in populations in fragmented landscapes. Preliminary data suggest that adult males tended to have higher parasite prevalence values than those of adult females in both howler species. Parasite prevalence is associated to average group size, but not to population density in *Alouatta pigra*.

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Introduction

Parasites are an important part of the biological diversity of tropical forests, and investigation of them can enhance our understanding of ecological and evolutionary processes and interactions. Parasite-host associations may also be indicators of nutritional preferences and patterns, of host migration patterns and of trophic relations in the ecosystem (Pérez-Ponce de León and García Prieto 2001). The study of parasites in wild primate populations provides knowledge for evaluating the health and the infection risk in populations, and it may also enhance the success of management programs (Gillespie *et al*. 2005). Primates are particularly vulnerable to parasitic infections because many species live in cohesive social groups characterized by frequent social interactions that facilitate parasite transmission between individuals (Freeland 1983; Stoner 1996). In many cases parasitic infections may increase host susceptibility to predation or decrease the competitive fitness of the individual (Scott 1998), and maybe more prevalent in populations living in human modified habitats (Nunn *et al*. 2003).

Two howler species (*Alouatta palliata mexicana* and *A. pigra*) and one spider monkey, represented by two subspecies *Ateles geoffroyi vellerosus* and *A. g. yucatanensis*), occur in southern Mexico, and are the northernmost continental Neotropical primates. Information on gastrointestinal parasites for populations of the 2 howler species is particularly scanty. For example, no published information is available on gastrointestinal parasites for wild populations of *Alouatta palliata mexicana*. In the case of *Alouatta pigra* there are very few studies. Stoner and González (2006) reported gastrointestinal parasites for *Alouatta pigra*, based on samples from 3 troops in one locality in southern Mexico. They identified 8 species of parasites (protozoan, nematodes, and trematodes) and found a higher incidence and intensity of infection in the largest of 3 troops, and in females vs. males and juveniles vs. adults. Vitazkova and Wade (2006) report 4 gastrointestinal parasites in *Alouatta pigra* in 2 sites in Mexico. Outside of Mexico, there is a survey of parasites of *Alouatta pigra* in Lamanai (Eckert *et al*. 2006), and in the Community Baboon Sanctuary and Cockscomb reserve in Belize (Eckert *et al*. 2006, Vitazkova and Wade 2006).

Habitat fragmentation may make primate populations more sensitive to infection by parasites, and in some cases it may result in high mortality and morbidity (Shalk and Forbes 1997). Mexican mantled howlers (*Alouatta palliata mexicana*) and the black howlers (*Alouatta pigra*) of southern Mexico are endangered taxa because of habitat destruction and fragmentation caused by human activity (Cuarón *et al*. 2003; Estrada *et al*. 2006; Van Belle and Estrada 2006). Little is known about the gastrointestinal parasitic communities affecting their populations, and there is no baseline information for populations in continuous forest habitats, making evaluations of gastrointestinal parasitic prevalence in populations in fragmented landscapes difficult.

We report the results of a one-time broad survey of helmith parasites in several demographically stable populations (ones subjected to no human induced disturbance in > 50 yr) of *Alouatta palliata mexicana* and *Alouatta pigra* in continuous and/or protected forests (C/P forests) within their distributional range in southern Mexico. We further report similar data for populations of both howler species in human-fragmented landscapes adjacent to some of the C/P forests sampled. From examination of fecal samples of the howler populations, we specifically report the taxonomic identity of the parasites, parasitic species richness and parasitic prevalence: number of individuals of a host species infected with a particular parasite species/number of hosts examined. We also report for each howler species preliminary data on patterns of parasitic prevalence in adult males and in adult females. We further tested for the existence of a relationship between population density and group size and parasitic prevalence. We compared populations of each species in C/P forests with those in fragmented habitat, and predicted that because of close proximity to humans and domestic animals, populations of both howler species in fragmented landscapes would have a higher prevalence of parasites than those in C/P forests.

Materials and Methods

Study Sites

We collected fecal samples from *Alouatta palliata mexicana* and *A. pigra* in C/P forests and in fragmented habitats between January and October 2003, in August 2005 and in February 2006. For *A. p. mexicana*, we sampled groups from a stable population inhabiting the C/P forest of the biosphere reserve Los Tuxtlas (ca 15,000 ha) in southern Veracruz, and groups in a fragmented landscape northeast of the biosphere reserve (Estrada and Coates-Estrada 1996) (Table I, Fig. 1). For *Alouatta pigra*, we sampled groups of populations in 5 C/P forests ranging from 1,400 ha to 700,000 ha, in the states of Campeche (N=2; Barrueta *et al.* 2003; Estrada *et al.* 2004a, b) and Chiapas (N=3; Estrada *et al.* 2002, 2004a, b) (Fig. 1). We also sampled black howler groups at 3 sites in a fragmented landscape adjacent to the C/P forests of the Montes Azules biosphere reserve in Chiapas (Estrada *et al.* 2004b) (RMA in Table I and Fig. 1).

Collection of Fecal Samples

Because howlers defecate after resting for long periods and before shifting foraging areas, a team of 4–6 people monitored individuals in selected groups for defecation. We collected samples in the morning and on dry days immediately after defecation to avoid contamination. The samples are mainly from adult males and females and fewer are from juveniles.

We placed samples into 30 ml vials with 10 ml of 10% formalin, and we placed the same quantity of feces in each vial to reach 15 ml (Stoner and González 2006). Within the constraints of time and logistics, we attempted to sample as widely as possible within each population in the C/P forest sites and in forest fragments.

Table I Features of study sites and of populations of *Alouatta palliata mexicana* and *A. pigra*

Habitat	Area (ha)	Average group size	Number of groups	Ind/km^2
Alouatta palliata mexicana				
C/P forest Los Tuxtlas*	15,000	9	18	23
Fragment F1B	3.5	13	1	371
Fragment F2LE	6.0	8	2	266
Fragment F3PE	40.0	7	6	105
Alouatta pigra				
C/P forest CLK *	700,000	7.50	8	15.2
C/P forest ET	1,400	6.65	26	12.7
C/P forest RA	1,700	5.08	12	25.6
C/P forest RMA *	300,000	5.54	13	44.1
C/P forest PNP	1,771	6.74	20	23.0
Fragment F1(CE)	1.0	7	1	700
Fragment F2 (CL)	20.0	11	2	110
Fragment F3 (V)	8.0	7	1	88

* Sampling of groups found in an area ca 1000 ha within the reserve
C/P forest stands for continuous and/or protected forest

Processing of Fecal Samples

We processed samples at the parasitological laboratory of Universidad Autónoma Metropolitana-Xochimilco in Mexico City. Via fecal flotation using a sodium-chloride solution (Foreyt 2001) we recovered parasite eggs. We systematically scanned 2 slides for each fecal sample and recorded and photographed each unique helminth parasite for later identification. We also took measurements to the nearest 0.1 μm of each parasite with an ocular micrometer fitted to a compound microscope, and used them to discriminate parasitic species.

Data Analysis

Because in a few cases individual recognition was not certain, it is likely that we sampled some individuals more than once. We defined parasitic richness as the number of unique intestinal parasitic species documented from the host's fecal sample (Chapman *et al*. 2006), and we assessed parasitic specific and diversity via of Shannon's diversity index ($H'=-\Sigma pi \ln pi$). We measured parasitic prevalence as the percent of individuals of a host species infected with a particular parasitic species relative to the number of hosts examined. Because repeated samples may have occurred, this should be considered as an index of prevalence (Gillespie *et al*. 2005). Because multiple-species infections may be associated with a greater potential for morbidity and mortality (Gillespie *et al*. 2005), we recorded multiple species infection:proportion of individuals in the population with more than one species of parasite. We also tested for the existence of a relationship between parasitic infection and population density and group size in the populations of *Alouatta pigra*, but not in the case of *A. palliata mexicana* because of the small number of populations sampled.

Fig. 1 Map showing the approximate location of study sites for *Alouatta palliata mexicana* and *A. pigra*. 1=Los Tuxtlas biosphere reserve (ca 15,000 ha) and adjacent fragmented landscape; 2=PNP (Palenque National Park - 1,771 ha); 3=ET (forestry reserve - 1,400 ha); 4=CLK (Calakmul biosphere reserve - 700,000 ha); 5=RMA (Montes Azules biosphere reserve - 300,000 ha); 6=fragmented landscape adjacent to RMA; 7=RA (Reforma Agraria community reserve - 1,700 ha).

Results

Parasites Detected in the Fecal Samples

Four Platyhelminthes, 3 Nematoda, 1 Protozoa and 1 unidentified parasite were in the feces of the howler populations (Table II and Fig. 2). We detected Coccidia (protozoa) while scanning the fecal samples for helminth parasites. Six parasites occurred in each howler taxon, but only 3 of them (Trematode I, *Controrchis biliophilus, Trypanoxyuris* sp.) were common to both species (Table II; Fig. 2).

Alouatta palliata mexicana

Of 101 Mexican mantled howler fecal samples (C/P forests n=38; fragmented habitat n=63) 51 are from adult individuals of known sex (59% males and 41% females).

Table II List of parasites detected in fecal samples of *Alouatta palliata mexicana* and *A. pigra*

	A. p. mexicana	*A. pigra*			
Parasite	Present study	Present study	Chajul, Mexico*	Lamanai, CBS (Belize)**	CBS, CWR (Belize); Campeche, Palenque (Mexico)***
Platyhelminthes					
Trematode I	X	X			
Trematode II	X				
Controrchis biliophilus	X	X			X
Raillietina sp.		X			
Digenean			X	X	
Nematodes					
Trypanoxyuris sp.	X	X			X
Parabronema sp.	X				
Strongylid		X	X	X	
Ascarid				X	
Nematode					
Trichostrongyloides sp.			X		
Enterobius sp.			X		
Oxyurid				X	
Protozoa					
Coccidia	X				
Blastocystis sp.			X		
Giardia sp.					X
Entamoeba sp.			X	X	X
E. coli			X		
Isospora sp.			X		
Iodamoeba bütschlii				X	
Unidentified parasite "I"		X			

Shown also are parasites reported by others for *A. pigra* at other sites.
*Stoner and González 2006
**Eckert *et al*. 2006
***Vitazkova and Wade 2006

Parasitic Richness and Diversity

In the groups in the C/P forest we detected eggs of 5 parasitic species (Platyhelminthes and Nematoda) (Table II), and parasitic specific diversity was H′=1.35. In the groups in the fragmented habitat, we found eggs of two helminth parasites (Platyhelminthes and Nematoda) and we also detected a Coccidia (phylum Myzozoa) (Table III). Average parasitic specific diversity in this habitat is H′=1.01 (± 0.39) (range H′=0.56 –1.24). Howler populations in the C/P forest and fragmented habitats shared 3 parasitic species (Trematode I, *Controrchis biliophilus* and *Trypanoxyuris* sp.) (Table III). Population in the C/P forest had 2 parasitic species that we did not detect in the fragmented habitats (Trematode II and *Parabronema* sp.), while those in the fragmented habitat had one species not present in the continuous habitat (Coccidia) (Table III). The fragmented habitat had a greater percentage of individuals (10.34%) with more than one parasite than in the C/P forest (5.26%), but the difference is not significant (P=0.21).

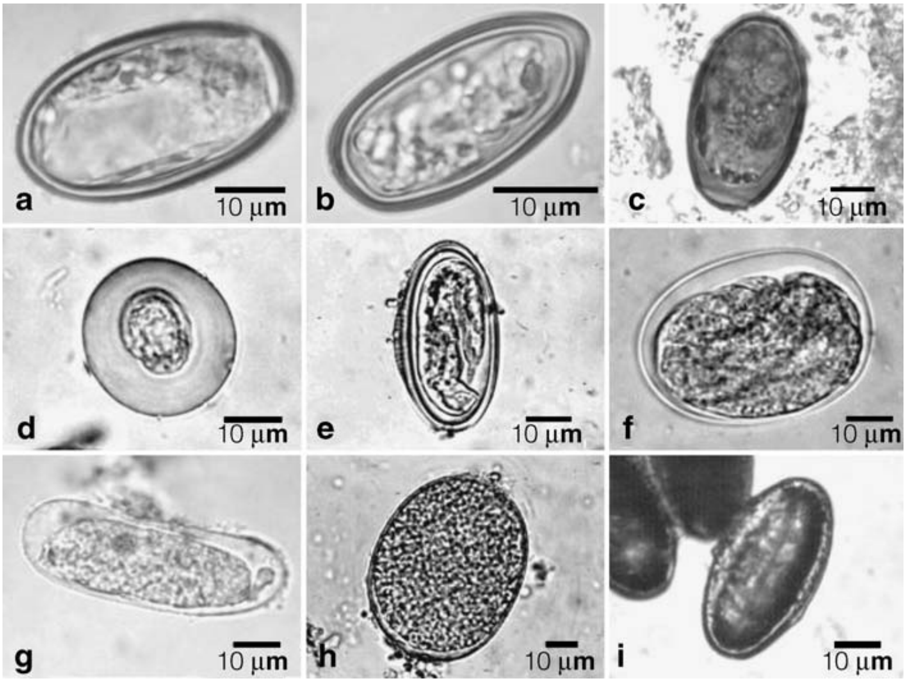

Fig. 2 Parasite eggs found in fecal samples of *Alouatta palliata mexicana* and *A. pigra*. a: Trematode I (*A. palliata* and *A. pigra*); b: Trematode II (*A. palliata*); c: *Controrchis biliophilus* (*A. palliata* and *A. pigra*); d: *Raillietina* sp. (*A. pigra*); e: *Trypanoxyuris*sp. (*A. palliata* and *A. pigra*); f: unidentified strongylid (*A. pigra*); g: *Parabronema* sp. (*A. palliata*); h: unidentified coccidia (*A. palliata*); I: unidentified parasite (*A. pigra*).

Prevalence of Parasites

Parasitic prevalence for the population of *Alouatta palliata mexicana* in the C/P forest was 23.68%, and twice as high in the fragmented habitat (45.74±13.05%). The difference is significant (X^2=7.01, df 1, P=0.0081; Fig. 3). While prevalence of specific parasites ranged from 2.63% to 13.16% in the C/P forest, the average in the forest fragments ranged from 4.22% to 25.26%. Prevalence of Trematode I, *Controrchis biliophilus,* and *Trypanoxyuris* sp. was, on average, higher in the fragmented habitat than in the C/P forest (Table III).

Differences Between Adult Females and Adult Males

Adult males displayed generally higher prevalence values for parasites than those of adult females in both the C/P forest and in the fragmented habitat (Fig. 4a). While the difference between the sexes is marginally significant for the C/P forest (X^2= 3.27, df 1, P=0.070), in the fragmented habitat it is significant (X^2=5.38, df 1, P= 0.020; Fig. 4a). In the C/P forest, adult females of *A. palliata* displayed similar prevalence values (11.11%) for Trematode I and *Trypanoxyuris* sp. Trematode I has

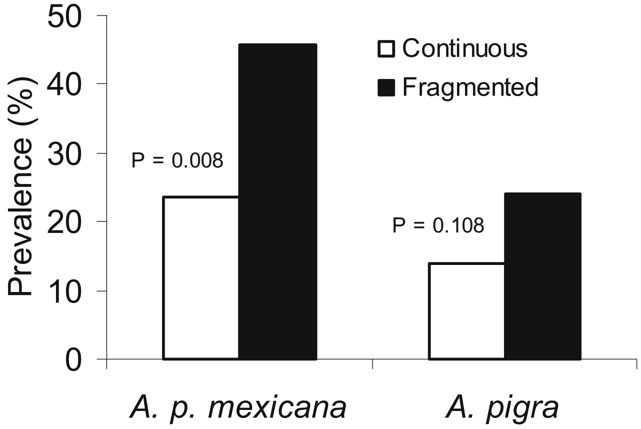

Fig. 3 Prevalence of parasites in *Alouatta palliata mexicana* and *A. pigra* living in continuous/protected forests and in fragmented habitats. Differences in *A. p. mexicana*.

higher prevalence values in the fragmented habitats than in the C/P forest for females, and the converse was true for *Trypanoxyuris* sp (Table IV). Adult females were also infected with 2 additional parasites in the fragmented habitats, *Controrchis biliophilus* and Coccidia (Table IV). Adult males were affected by the same 2 parasites in the C/P forest, but *Trypanoxyuris* sp., had higher prevalence values (14.29%) in males than Trematode I (Table IVa). Prevalence values for these 2 parasites were higher in adult males in the fragmented habitat than in the C/P forest, and samples from adult males also contained *Controrchis biliophilus* and Coccidia (Table IVa).

Table III Prevalence (percent of individuals) of parasite eggs in fecal simples of *Alouatta palliata mexicana* in continuous/protected forest (C/P forests) and in fragmented habitats

Habitat	Parasites						Richness
	Trematode I	Trematode II	*Controrchis biliophilus*	*Trypano-xyuris* sp.	*Parabro-nema* sp.	Coccidia	
C/P forest (N=38)	13.16	2.63	2.63	10.53	2.63	0	5
Fragments							
F1B N=32	6.25	0	18.75	12.50	0	3.13	4
F2LE N=21	9.52	0	4.76	23.81	0	9.52	4
F3PE N=10	60	0	20	0	0	0	2
Average fragments N=63	25.26	0	14.50	12.10	0	4.22	4*

* Total richness

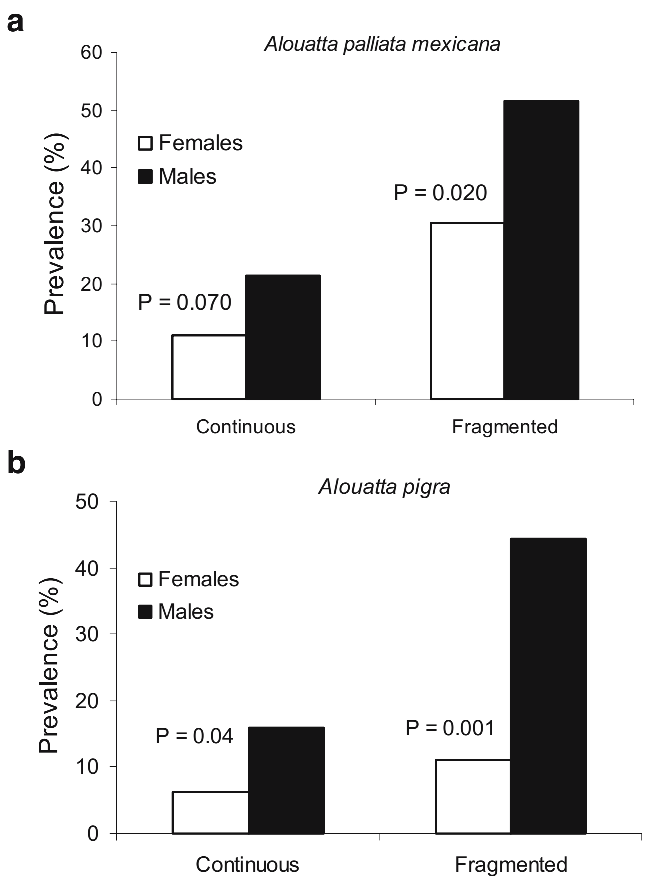

Fig. 4 Prevalence of parasite eggs in adult males and in adult females in populations of (a) *A. palliata mexicana* (Males n=30; Females n=21) and (b) *A. pigra* (Males n=59; Females n=49) in continuous/protected forests and in fragmented habitats.

Alouatta pigra

We analyzed 159 black howler fecal samples (C/P forests n=137; fragmented habitat n=22): 105 of them were from adults of known sex (53% males and 47% females).

Parasite Richness and Diversity

Fecal samples from black howler populations in the C/P forests had eggs of 2 helminth parasites, (Platyhelminthes and Nematoda), one of which we could not identify specifically (Table V). Average parasitic specific diversity in C/P forests is H′=0.69 ± 0.26 (range H′=0–1.39). In the fragmented habitat, fecal samples had 2 helminth and 1 Trematode parasites (Table V), and average parasitic specific diversity is H′=0, because groups in forest fragments had only one parasite each. Populations in the C/P forests and in the fragmented habitats only shared 1 parasitic

Table IV Prevalence (%) of parasite eggs in *Alouatta palliata mexicana* adult females (F) and adult males (M) in continuous/protected forest (C/P forest) and in fragmented habitats

Habitat	Sex	Trematode I	*Controrchis biliophilus*	*Trypanoxyuris* sp.	Coccidia	Richness
C/P forest	F (N=9)	11.11	0	11.11	0	2
	M (N=14)	7.14	0	14.29	0	2
Fragments						
F1B	F (N=6)	0	0	16.67	16.67	2
	M (N=6)	16.67	66.67	16.67	0	3
F2LE	F (N=4)	25.00	25.00	0	0	2
	M (N=7)	14.29	0	42.86	14.29	3
F3PE	F (N=2)	50.0	0	0	0	1
	M (N=3)	0	0	0	0	0
Average	F (N=12)	25.00	8.33	5.56	5.56	*4
	M (N=16)	10.32	22.22	19.84	4.76	*4

* Total richness

species (*Raillietina* sp.; Table V). Three parasitic species (*Controrchis biliophilus, Trypanoxyuris* sp., and unidentified parasite (“I”) in the populations in C/P forests were absent in the fragmented habitats, and 2 species (Trematode I and Strongylid) in howler populations in fragmented habitat were undetected in the populations of the C/P forests (Table V). No individual with >1 parasite occurred in the sample populations.

Parasitic Prevalence

Average parasitic prevalence for the black howler population in the C/P forests is 13.93± 7.10%, which is almost twice as high as that in the fragmented habitat (23.99±22.76%), but the difference is marginally significant (X^2=2.67, df 1, P=0.10; Fig. 3). The only parasite shared by populations in C/P forests and in fragmented habitat is *Raillietina* sp., whose prevalence is similar in both habitats (Table V). While parasitic prevalence was not associated with population density, it is significantly associated with average group size (r=0.645, P=0.01, N=8).

Differences Between Adult Females and Adult Males

Adult males displayed generally higher prevalence values for parasites than those of adult females in both the C/P forests (X^2=4.16, df 1, P=0.04) and in the fragmented habitats (X^2=19.10, df 1, P<0.0001) (Fig. 4b). In adult females in the C/P forests, *Trypanoxyuris* sp. had higher prevalence values (3.45%) than *Controrchis biliophilus* (2.86%) (Table VI). In the C/P forest RMA, we detected no parasites in the adult females, but a Strongylid occurred in females in the adjacent fragmented habitat (Table VI). In RMA, fecal samples from adult males had 3 parasites, with the highest average prevalence values for *Trypanoxyuris* sp. (6.67%) and the lowest for *Raillietina* sp. (3.83%) (Table VI).

Table V Prevalence percent of individuals of parasite eggs in fecal simples of *Alouatta pigra* in continuous/protected forests (C/P forests) and in fragmented habitats

Habitat	Parasites						Richness
	Trematode I	*Controrchis biliophilus*	*Raillietina* sp.	*Trypanoxyuris* sp.	Strongylid	Unidentified "I"	
C/P forests							
ET N=39	0	2.56	0	2.56	0	0	2
CLK N=29	0	3.45	3.45	0	0	3.45	3
PNP N=29	0	0	3.45	17.24	0	0	2
RMA N=23	0	17.39	4.35	0	0	0	2
RA N = 17	0	5.88	0	5.88	0	0	2
Average N=137	0	5.86	2.25	5.14	0	0.69	4**
Fragments*							
F1 (CE) N=7	0	0	0	0	14.29	0	1
F2 (CL) N=2	50	0	0	0	0	0	1
F3 (V) N=13	0	0	7.69	0	0	0	1
Average N=22	16.67	0	2.56	0	4.76	0	3**

*Forest fragments in landscape adjacent to the RMA continuous forest
** Total richness

Discussion

The presence of different types of parasites in the fecal samples of *Alouatta palliata mexicana* and *A. pigra* do not necessarily imply morbidity and pathology in the infected individuals. Further, parasite impact on the individuals may range from fatal diseases to asymptomatic infections (Foreyt 2001). Accordingly, it is difficult, without the appropriate data, to issue clinical statements at the population level. Bearing this in mind, and in view of the fact that our surveys were not exhaustive on temporal and spatial scales, they nonetheless contribute new baseline information on gastrointestinal parasites present in populations of *Alouatta palliata mexicana* and *A. pigra*.

Our study showed the presence of 6 parasites in each howler taxon, but that only 3 were common to both of them. It also showed that populations in C/P forests and in fragmented landscapes had similar parasitic specific richness (*Alouatta palliata mexicana* 5 vs. 4; *A. pigra* 4 vs. 3) but some parasites (e.g., Strongylid, Coccidia) only occurred in populations in fragmented habitat. Populations of *Alouatta palliata mexicana* and *A. pigra* in C/P forests had a higher diversity (Shannon's H′) of parasites than populations of the same species in fragmented habitats. Habitat fragmentation results in important changes in the relations among community members, and it can cause the loss of species (Altizer *et al.* 2003), including those that act as

Table VI Prevalence (%) of parasite eggs in *Alouatta pigra* adult females (F) and adult males (M) in continuous/protected forests (C/P forests) and in fragmented habitats

Habitat	Sex	Prevalence					Richness
		Trematode I	*Controrchis biliophilus*	*Raillietina* sp.	*Trypano-xyuris* sp.	Strongylid	
C/P forests							
	F (N=21)	0	0	0	4.76	0	1
ET	M (N=14)	0	7.14	0	0	0	1
	F (N=4)	0	0	0	0	0	0
CLK	M (N=8)	0	0	12.50	0	0	1
	F (N=8)	0	0	0	12.50	0	1
PNP	M (N=6)	0	0	0	33.33	0	1
	F (N=4)	0	0	0	0	0	0
RMA	M (N=15)	0	20	6.67	0	0	2
	F (N=7)	0	14.29	0	0	0	1
RA	M (N=8)	0	0	0	0	0	0
Average	F (N=44)	0	2.86	0	3.45	0	*2
	M (N=51)	0	5.43	3.83	6.67	0	*3
Fragments							
	F (N=3)	0	0	0	0	33.33	1
F1CE	M (N=4)	0	0	0	0	0	0
	F (N=1)	0	0	0	0	0	0
F2CL	M (N=1)	100	0	0	0	0	1
	F (N=1)	0	0	0	0	0	0
F3V	M (N=3)	0	0	33.33	0	0	1
	F (N=5)	0	0	0	0	11.11	*1
Average	M (N=8)	33.33	0	11.11	0	0	*2

* Total richness

intermediate hosts for some parasitic species. While loss of specific hosts suggests loss of parasitic species, lowering parasitic specific diversity, habitat fragmentation may favor some parasites, especially those that have a direct life cycle and/or those that predominate in anthropogenic environments (Nunn *et al*. 2003; Chapman *et al*. 2005; Stoner and González 2006), thus changing patterns and the dynamics of host-parasite relationships (Nunn *et al*. 2003; Altizer *et al*. 2003).

Our survey showed a general trend for parasitic prevalence to be higher for populations of both howler species in the fragmented habitat than in C/P forests. This pattern is consistent with the premise that in habitats fragmented by humans, primate populations are subjected to greater contamination from humans and domestic animals, than populations in continuous habitats (Michaud *et al*. 2003; Chapman *et al*. 2005, 2006; Gillespie and Chapman 2006).

Monkeys in small fragmented habitats may have to come to the ground to move from one patch to another and/or may drink ground water with the possibility of acquiring parasites, and because of proximity to human settlements and to domestic animals, may also be exposed to parasitic vectors or intermediate hosts. For example, *Alouatta palliata mexicana* populations in the fragmented habitats were infected with Coccidia, a microscopic, spore-forming, single-celled parasite that infects the intestinal tracts of domestic animals. Coccidian organisms can infect a wide variety of animals, including humans and livestock. The parasite spreads from one animal to another by contact with infected feces or ingestion of infected tissue or contaminated water. Diarrhea, which may become bloody in severe cases, is the primary symptom. Most animals infected with coccidia are asymptomatic; however, young or immuno-compromised animals may suffer severe symptoms, including death (Foreyt 2001). A survey of parasites in *Alouatta pigra* in a fragmented landscape of the Community Baboon Sanctuary, Belize, showed *Giardia* sp. in fecal samples (Vitazkova and Wade 2006). *Giardia* affects humans and it is one of the most common parasites infecting other mammalian hosts such as cows, dogs, cats, and lambs. Infection causes giardiasis, a type of gastroenteritis that manifests itself with severe diarrhea and abdominal cramps (Foreyt 2001; Thompson 2002).

An important question related to parasite spread in socially structured populations of primates involves identifying individuals that are at greatest infection risk. Parasitism is likely to correlate with dominance rank, age, sex, and mating status because they influence habitat use, the frequency of intraspecific and interspecifc contacts, and the effectiveness of immune defenses. For example, in some mammals, e.g., reindeer, dominant individuals were more frequently exposed to nematode infections because they consumed more vegetation (Altizer *et al*. 2003). Preliminary results on sex differences from our study suggest that parasitic prevalence may be higher, in both howler species and in both continuous and fragmented habitats, in adult males than in adult females, possibly owing to the immunosuppressive effects of testosterone on the accumulation of parasites (Shalk and Forbes 1997; Ezenwa 2002; Klein 2004).

A large number of epidemiological models, supported by data from several empirical and comparative studies, point to strong links between host density or local group size and the spread and diversity of directly transmitted parasites (Altizer *et al*. 2003). A comparative study of parasites in wild primates showed that host density was the most consistent factor predicting increases in the diversity of both macro and microparasite communities (Nunn *et al*. 2003). While our data failed to show such a relationship with density, possibly the result of our small sample size,

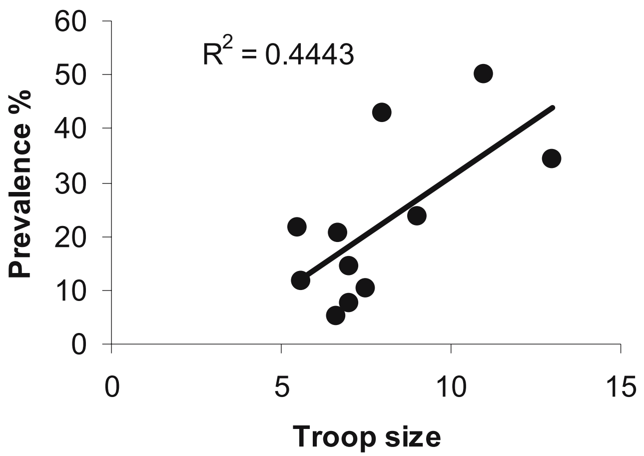

Fig. 5 Relationship between troop size and parasite prevalence in populations of *Alouatta palliata mexicana* and *Alouatta pigra*.

results showed that group size is positively associated with parasitic prevalence in *Alouatta pigra*. Pooled data for *Alouatta palliata mexicana* and *A. pigra* showed a strong correlation between group size and parasitic prevalence (r=0.68, P=0.009, R^2= 0.4709, N=11 sites; Fig. 5).

In summary, we provided first-time data on 6 gastrointestinal parasites for *Alouatta palliata mexicana* to complement databanks on parasites for *A. pigra*. We further reported baseline data on demographically stable populations of them in C/P forests, which will allow comparisons with populations of the same species in fragmented habitats, yielding light on the dynamics of host-parasite relationships, on the impact of anthropogenic disturbance on host-parasite relations, and on the vulnerability of wild primates to such changes.

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