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Prevalence and Intensity of Intestinal Parasites in Mantled Howling Monkeys (*Alouatta palliata*) in Northeastern Costa Rica: Implications for Conservation Biology

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Abstract: *I examined the prevalence and intensity of intestinal parasitic infections in a population of mantled howling monkeys (Alouatta palliata) at La Selva Biological Reserve, a rainforest in northeastern Costa Rica. I collected fresh fecal samples from individual howler monkeys from two focal troops from October 1991 through October 1992. The presence of parasite ova and larvae in samples was determined by using a formalin-ethyl acetate sedimentation technique. Three types of endoparasites were found: (1) a roundworm, Parabronema sp., (2) a physalopterid roundworm, species undetermined, and (3) a fluke, species undetermined. No differences were found in the prevalence of parasitic infections between sexes or troops. No statistical differences were found between the sexes for the intensity of infection. The troop that lived along the river showed a statistically significant higher intensity of nematode infection than the troop that lived mostly in primary forest. Parabronema sp. was found only from individuals in the river group. The prevalence of parasitic infection observed in howlers at La Selva (100%) is higher than has been reported for howlers in a dry deciduous forest at La Pacifica, Costa Rica (47%). Microclimatic factors, ranging patterns, and home-range size are identified as important variables that may affect parasitic infections of howler populations. Data from this study suggest that narrow corridor designs may be inappropriate for conservation of primates and possibly other species of arboreal animals.*

La Ocurrencia e intensidad de parásitos intestinales en los monos Congo (*Alouatta palliata*) en el noreste de Costa Rica: su relevancia para la implicaciones Biología de la Conservación

Resumen: *En este estudio examiné la frecuencia y la intensidad de infecciones de parásitos intestinales en una población de monos congo (Alouatta palliata) en La Reserva Biológica La Selva, ubicada en un bosque húmedo en el noreste de Costa Rica. Colecté muestras frescas de heces de individuos de dos tropas entre Octubre de 1991 y Octubre de 1992. Se determinó la presencia de huevos y larvas de parásitos en las muestras usando una técnica de sedimentación con formalina y acetato de etilo. Se encontraron tres tipos de endoparásitos: (1) un nemátodo, Parabronema sp., (2) un nemátodo, especie indeterminada y (3) uno trematodo, especie indeterminada. No hubo diferencias en la frecuencia de infecciones por parásitos entre los sexos ni entre las tropas. No hubo diferencias significativas entre sexos en la intensidad de infecciones parasíticas. La tropa que vive en la orilla del río tuvo una intensidad de infección significativamente más alta que la tropa ubicada en el bosque primario. Parabronema sp. fue identificado solamente en monos de la tropa del río. La frecuencia de infecciones de parásitos intestinales en los monos congo de La Selva (100%) es mayor que la reportada en el bosque tropical seco de La Pacifica, Costa Rica (47%). Los siguientes factores*

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pueden afectar la frecuencia de endoparásitos en los monos congo: (1) factores microclimáticos, (2) patrones de movimiento y (3) tamaño de área de distribución. Los datos de este estudio sugieren que los diseños de los corredores angostos pueden no ser apropiados para los programas de conservación de poblaciones de primates u otros animales arbóreos.

Introduction

The impact that parasitic infections have on animal populations in the wild has been recognized as an important factor affecting the density and distribution of species (Anderson 1979; Anderson & May 1979, 1982; Price 1980; Holt & Pickering 1985; for a review see Scott 1988). Parasitic infections have been identified as critical components to consider in conservation biology (May 1988; Scott 1988), yet little information is available concerning intestinal parasites of most endangered species in the wild. Primates are particularly vulnerable to the effects of parasitic infections because they often live in close social groups that facilitate parasite transmission.

Howling monkeys, genus *Alouatta* (CITES Appendices I & II, Inskipp & Wells 1979) are large-bodied, mainly folivorous Neotropical primates that are found from tropical Mexico through northern Argentina (Wolfeim 1983; Crockett & Eisenberg 1987). The most serious threat to the survival of these endangered monkeys is habitat destruction (Mittermeier et al. 1986), but other factors contributing to the mortality of howlers include predation, intraspecific aggression, parasites (Smith 1977), and diseases (Stoner 1993). With the exception of habitat destruction and human-caused mortality, parasites and diseases may be the most important factors contributing to howler mortality because aggressive interactions are rare (Neville 1972; Smith 1977; Jones 1980; Milton 1982; for opposing view see Eisenberg 1991) and few natural predators exist (Sherman 1991). As populations of howlers become more concentrated within smaller ranges, the opportunity for parasite and disease transmission rises (Gilbert & Dodds 1987). It is difficult to study many diseases in wild animal populations without invasive procedures, but intestinal parasitic infections can be determined from fecal samples. An understanding of some of the factors that may affect the prevalence (number of individuals infected per number of individuals examined) and intensity (number of parasites of a particular species in each host individual) (Margolis et al. 1982) of intestinal parasites in howling monkeys will be important for long-term conservation efforts.

Several species of intestinal parasites have been described from the alimentary tract of howlers, including (1) protozoans: *Chilomastix* sp., *Entamoeba* (= *Endamoeba*) sp., *Giardia* sp., *Isospora arctoptithecii*, *Retortamonas* sp., *Toxoplasma* sp., and *Trichomonas* sp.

(Hegner 1935; Hendricks 1977; Frenkel & Sousa 1983; Stuart et al. 1990); (2) nematodes: *Ancylostoma* sp., *Ascaris lumbricoides*, *Parabronema bonnei*, *Trypanoxyuris minuta*, and *Vianella* (= *Longistriata*) *dubia* (Diaz-Ungria 1965; Durette-Desset 1968; Thatcher & Porter 1968; Huggins 1969; Stuart et al. 1990); (3) platyhelminthes (digeneans): *Controrchis biliophilus* (= *C. caballeroi*) (Jiménez-Quirós & Brenes 1957; González et al. 1983; Stuart et al. 1990); (4) platyhelminthes (cestodes): *Raillietina* (r.) *multitesticulata*, and *R. alouatta* (Baylis 1947; Perkins 1950; Thatcher & Porter 1968); and (5) acantocephalids: *Prosthenorchis elegans* (Thatcher & Porter 1968; for a comprehensive review see Toft 1986). Most of these studies identified parasites from one sample in isolated individuals, from individuals maintained in the laboratory an unknown amount of time, or from individuals from undescribed localities. One notable exception is the study of Stuart et al. (1990), who analyzed multiple samples from a population of mantled howling monkeys (*Alouatta palliata*) from La Pacifica, a lowland tropical dry forest in northwestern Costa Rica. They suggested that the high prevalence of parasitic infections at La Pacifica may be related to the high density of howlers at that site, yet few comparative data were available to test this hypothesis.

I used multiple fecal samples from each individual and evaluated the prevalence of intestinal parasites in mantled howling monkeys (*Alouatta palliata*) from an area with a relatively low population density (7–15 howlers/km²) in Costa Rica (Stoner 1994). I compared these data with existing data from howlers (Stuart et al. 1990) at a relatively high population density (74 howlers/km²) (Clarke et al. 1986). I hypothesized that howlers found at lower densities will have a lower prevalence of parasites than those found at higher densities because of density-dependent infection. In addition, I compared the prevalence and intensity of parasites between male and female howlers. I hypothesized that females will have a higher prevalence and intensity of parasites than males because all adult female howlers are either lactating or pregnant, and studies on both populations of animals in the wild (O'Sullivan & Donald 1970) and in the laboratory (Lloyd et al. 1983) have shown an increase in parasitic infections for adult females during lactation and pregnancy. Finally, to assess some of the factors that may affect parasitic infections in howlers, I evaluated intratroup variation of parasitic infections from two troops of howlers occupying different habitats within a single reserve.

Methods

Study Site and Troops

La Selva Biological Reserve is located at the confluence of the Sarapiquí and Puerto Viejo rivers in the Atlantic lowlands of northeastern Costa Rica, Province Heredia (coordinates 10°26'N 83°59'W; Hartshorn 1983). La Selva contains two major Holdridge life zones: tropical wet forest on the west side and tropical premontane wet forest to the east (Holdridge 1967). Average yearly rainfall is 3962 mm \pm 723 with no effective dry season, but a less wet period usually occurs between January and April (Sanford et al. 1994). Average monthly temperatures vary between 25 and 27°C (McDade & Hartshorn 1994). The 1500-ha La Selva Reserve is connected to a much larger protected area, Braulio Carrillo National Park, on the south side via the narrow Zona Protectora. These two areas together encompass an area of over 46,000 ha of protected rainforest and span an altitudinal range of 35 to 2900 m.

La Selva is composed of approximately 56% primary forest (including many swamp areas) and 23% regenerating secondary forest of various ages; the remainder of the reserve consists of regenerating pastures and managed areas (Clark 1990). The reserve is bordered on two sides by large rivers and is crossed by numerous small streams. The variety of habitats available at this site was appropriate for comparing parasite prevalence and intensity between troops inhabiting different areas. Furthermore, I established previously that the density of howlers at La Selva is approximately 7-15 howlers/km² (Stoner 1994); therefore, these data can be compared with parasite data from howler populations with a higher density.

In conjunction with a 16-month ecological project designed to study foraging patterns, two focal troops of howlers were chosen to sample for intestinal parasitic infections. The two troops inhabited different areas within the reserve, with exclusive home ranges (Fig. 1). Troop 1 spent the majority of time in primary forest (forest group), whereas troop 2 spent the majority of time in alluvial habitat along a large river and a small stream (river group) (Stoner 1996). Both groups had individuals with natural markings, allowing several animals to be identified unambiguously. At the beginning of the study troop 1 consisted of 5 adult males, 10 adult females, 3 subadults, and 2 infants; during the study period 3 births occurred. Troop 2 consisted of 2 adult males, 5 adult females, 3 subadults, and 1 small infant (< 1 month old); during the study period 3 births occurred, 1 subadult male emigrated from the troop, and 1 female immigrated.

Fecal Sampling and Analysis

Fresh fecal samples were collected from two focal troops from October 1991 through October 1992. Sam-

ples were collected from individual monkeys immediately after defecation and placed in 10% formalin Para-Pak plastic transport vials (Meridian Diagnostics, Cincinnati, Ohio 45244, U.S.A.). Because it often takes several samples to isolate parasitic infections, fecal sampling was repeated for each individual to assure that parasitic infections would be identified. The presence of ova and larvae was determined after sedimentation using a formalin-ethyl acetate centrifugation technique (Long et al. 1985). After centrifugation two drops of concentrate and one drop of iodine were placed on a microscope slide, and all ova and larvae under a 22 x 30 mm glass coverslip were counted. Four slides were systematically scanned for each fecal sample, and the total number of ova and larvae for the four slides was summed to represent the intensity of infection for that fecal sample. Because not all the parasite life stages were collected, identification of the parasite from eggs and larvae is tentative. Several factors limited the number of samples collected: (1) individually identified monkeys were not always visible because of the height at which they were found, combined with poor visibility in the tall evergreen forest; (2) fecal matter often became stuck in the canopy and could not be collected; and (3) rainy weather precluded the collection of fecal samples because the material was washed away too quickly.

Statistical Analyses

The average intensity of infection for each individual monkey sampled for each species of parasite was calculated based on the total number of samples collected for each individual. This average provided an unbiased estimator of the intensity of infection because it considered several random samples of the same individual over time (Sokal & Rohlf 1981). A fixed-effect two-way analysis of variance (ANOVA; SAS Institute 1990) was used to determine if there was a difference in the intensity of infection between groups or sexes. Unfortunately, a statistical comparison of the intensity of infection over time could not be conducted because the number of samples available for many individuals was limited.

Results

Eighty-four fecal samples were collected from 13 individuals from two focal troops, with a minimum of four samples from each individual (Table 1). Five adult females and one subadult and adult male were sampled from the forest troop (troop 1), and three adult females, two adult males, and one subadult male were sampled from the river troop (troop 2).

No differences were found in the prevalence (number of individuals infected per number of individuals examined) of parasitic infections between sexes or between

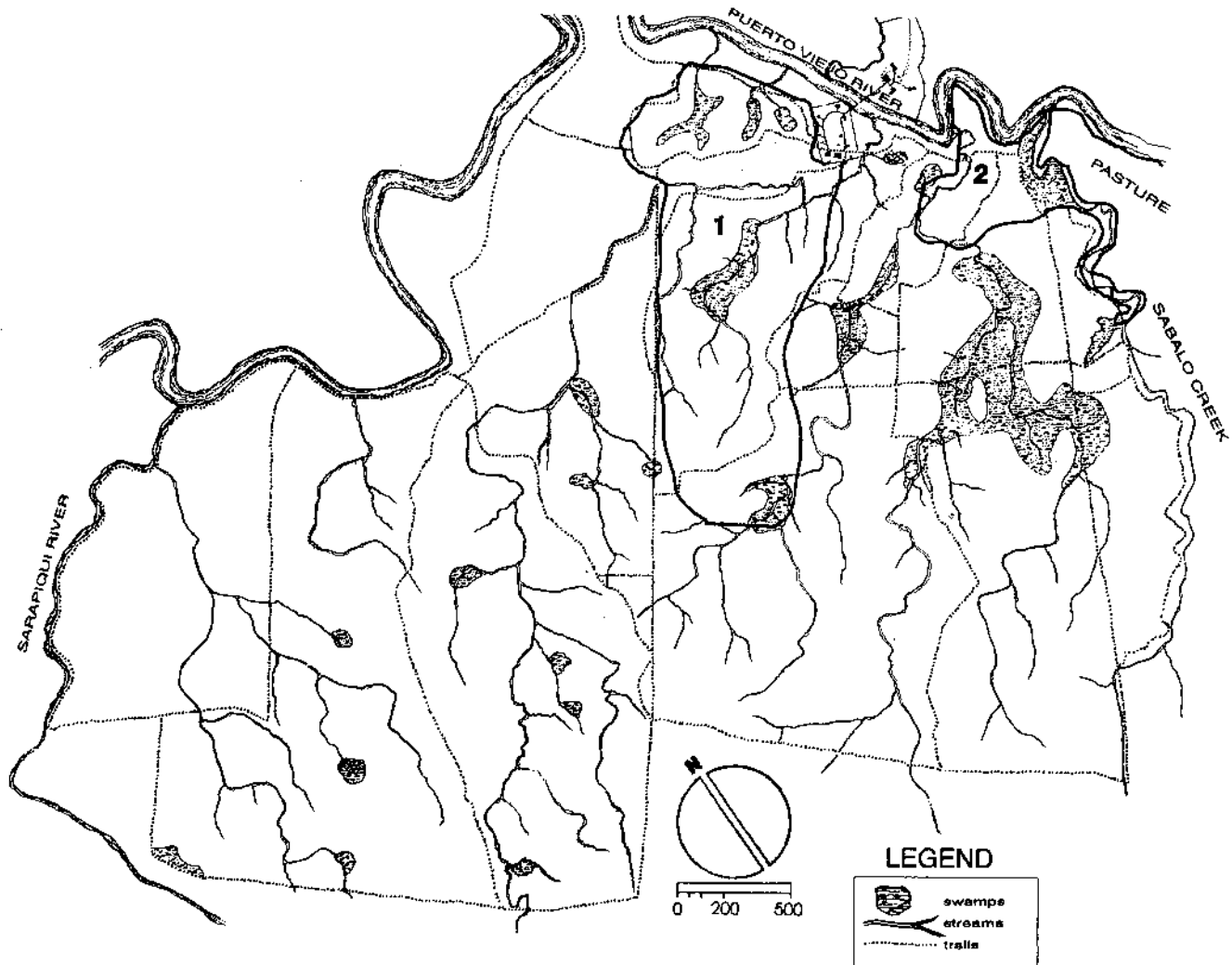


Figure 1. Home ranges of the focal troops within La Selva Biological Reserve from September 1992 through December 1993. Troop 1 is the forest troop and troop 2 is the river troop.

troops because parasites were observed in all individuals sampled from each troop. Intestinal parasites, including one species of nematode (roundworms) and one species of digenean (flukes), were found in the forest troop; the river troop had the same species of nematode and digenean found in the forest troop and one additional species of nematode.

Each howling monkey sampled contained thin-shelled, fully embryonated eggs with an average size of $55 \mu\text{m} \pm 4.7 \times 38 \mu\text{m} \pm 4.7$ ($n = 50$). The characteristic thin-shelled egg and the size unambiguously identifies these as nematode eggs (Ash & Orihel 1990), but the species could not be determined because the eggs were found associated with two larval types and one adult worm. First-stage rhabdiform larvae were found in several samples, suggesting that the nematode eggs may be from the orders Rhabditida or Strongylida (Class: Secernentea), but these larvae could not be identified to species. Fliari-

form larvae that resembled physalopterans (Secernentea: Spirurida: Physalopteridae) were also identified in several samples. Adult nematodes, *Parabronema* sp. (Secernentea: Spiruridae) were observed in the fresh feces from three individuals from the river troop. Because the two larval types and the adult worm were found in samples with the nematode eggs, it was not possible to distinguish which was associated with the egg. It is most likely that the nematode egg is associated with the rhabdiform larvae or the adult *Parabronema* sp. because physalopteran eggs have thick hyaline shells (Ash & Orihel 1990), and the nematode egg observed in the samples was very thin. Although most species of Rhabditida and Strongylida are described as laying eggs that are passed from the host in the stage of early cleavage (Noble et al. 1989), the advanced larval development observed in the eggs, as well as the presence of larvae in uncultured fecal samples, could be a consequence of the

Table 1. Individuals sampled within each troop, sex, number of samples collected, and the months during which the samples were collected.

Individual	Sex	Number of samples	Year: Months of samples
Troop 1			
1	M	4	1992: 10,12 1993: 2
2	M	12	1992: 11,12 1993: 1,2,3,4,6,8,9
3	M	12	1992: 11,12 1993: 1,2,3,4,6,7,9
4	F	8	1992: 11 1993: 2,4,7,8,9,10
5	F	8	1993: 5,6
6	F	4	1993: 9,10
Troop 2			
7	M	12	1992: 10,11 1993: 1,2,3,5,7
8	M	5	1992: 10
9	F	4	1992: 10
10	F	4	1992: 10,11
11	F	5	1992: 10 1993: 3,5,6
12	F	4	1993: 1,7
13	F	4	1993: 9,10

large relative surface area of the intestinal tract (Milton 1980), combined with slow gut-passage rates characteristics of howling monkeys (Milton et al. 1980).

A dark-staining digenean egg (Platyhelminthe: Digenea) with an average size of $41 \mu\text{m} \pm 5.8 \times 22 \mu\text{m} \pm 4.3$ was found in all individuals except for one male from the river troop. Accurate species identification of fluke eggs is difficult because the morphology and size of many species are similar (Ash & Orihel 1990).

A two-way ANOVA (SAS Institute 1990) revealed that the river troop had a significantly higher intensity of nematode infection (based on the number of eggs) than did the forest troop (Tables 2 & 3). The intensity of digenean infection also was higher in most individuals from the river troop, but this difference was not statistically significant (Tables 2 & 3). The intensity of infection was not statistically different between males and females for either nematode or digenean infections (Table 3). The intensity of *Parabronema bonnei* infection could not be compared because only one adult worm was found in three fecal samples from different individuals.

Discussion

Howler Density and Parasitic Infections

This study does not support the hypothesis that intestinal parasitic infections of howlers would be relatively low at La Selva because of the low density of howlers in

Table 2. Mean intensity of nematode and digenean infection separately and collectively for individual howler monkeys from two troops over a 12-month period.

Individual	Nematode egg	Digenean egg
Troop 1		
	$\bar{X} \pm \text{SE}$	$\bar{X} \pm \text{SE}$
Male 1	34.75 ± 1.11	0.00
2	31.25 ± 7.84	0.92 ± 0.45
3	22.58 ± 10.84	1.08 ± 0.58
Female 4	37.48 ± 19.10	2.88 ± 1.17
5	13.25 ± 3.55	0.50 ± 0.27
6	23.00 ± 14.14	1.00 ± 1.00
Total	27.05 ± 9.43	1.06 ± 0.58
Troop 2		
Male 7	1.92 ± 0.62	0.25 ± 0.17
8	10.40 ± 2.73	0.20 ± 0.2
Female 9	13.67 ± 3.67	1.00 ± 0.99
10	10.75 ± 5.38	0.75 ± 0.48
11	8.80 ± 5.34	0.20 ± 0.20
12	4.50 ± 3.50	0.50 ± 0.50
13	14.00 ± 5.51	1.00 ± 0.58
Total	9.15 ± 3.82	0.56 ± 0.45

this area. One hundred percent of the 13 individuals sampled were infected with at least two species of parasites, whereas a recent survey of intestinal parasites of howlers from the lowland tropical dry forest at La Pacifica revealed that 48% of the individuals sampled ($n = 155$) had intestinal parasitic infections (Stuart et al. 1990). A study of woolly spider monkeys (*Brachyteles arachnoides*) in Brazil also detected no relationship between host population density and the prevalence of parasitic infections (Stuart et al. 1993). An important factor contributing to the observed difference between La Pacifica and La Selva may be the constant humid environment encountered in the rainforest at La Selva that may provide optimal conditions for larval survival, thus increasing the chances of infection compared to the drier environment at La Pacifica. Stuart et al. (1990) similarly found a significantly higher intensity of infection in

Table 3. Results from two-way fixed-effect ANOVA with sex, troop, and their interaction.*

	DF	MS	F	p
Nematode eggs				
Sex	1	0.43	0.01	n.s.
Troop	1	1034.42	19.69	**
Sex \times Troop	1	61.05	1.16	n.s.
Error	9	52.54		
Digenean eggs				
Sex	1	1.16	2.42	n.s.
Troop	1	1.08	2.25	n.s.
Sex \times Troop	1	0.08	0.17	n.s.
Error	9	.48		

*The response variables are the average intensity of infection for nematode eggs and digenean eggs for each individual (** $p < 0.05$).

howlers at La Pacifica in the more humid, riverine environments than those in dry forest at this site. In addition, the study of woolly spider monkeys in Brazil found that monkeys in more humid environments had a higher prevalence of parasitic infection (Stuart et al. 1993). In sum, these studies indicate that the prevalence of parasitic infections in monkeys is not determined by the density of the population; rather, the environment is likely one of the most important factors.

Sexual Differences in Parasitic Infections

The hypothesis that females would have a higher prevalence and intensity of parasitic infections than males was not supported (Table 3). No significant differences were detected in the prevalence or intensity of infection between males and females in this study. No differences were reported between sexes in the number of individuals parasitized in the La Pacifica population, but no information was given for intensity of infection or the distribution of sexes between the riverine and dry forest troops (Stuart et al. 1990). The study of woolly spider monkeys did not evaluate differences between the sexes (Stuart et al. 1993). Future studies should attempt to analyze a larger sample of males and females to determine if gender differences exist in the prevalence or intensity of parasitic infections.

Troop Differences in Parasitic Infections

The river troop had a significantly higher intensity of nematode infection than the forest troop did (Table 3). Individuals from the river troop also showed a tendency toward a higher intensity of digenean infection, but this difference was not statistically significant. Factors that may contribute to the higher intensity of strongylid infections observed in the river troop include microclimate, repeated pathway use, and smaller home range. The river troop spent approximately 75% of the total time observed during the 16 months in alluvial habitat in the northeastern corner of the reserve and outside of the reserve (Fig. 1; Stoner 1993). The alluvial habitat was bordered by water on one side and a pasture on the other, providing the howlers with a narrow corridor. The river habitat restricted the howlers to a limited pathway that they used repeatedly. In addition, the river troop had an overall smaller home range (35 ha) than the forest troop (54 ha) (Stoner 1993), also contributing to repeated path use. Contrary to what has been observed in some studies, that howlers often use the same arboreal pathways (Milton 1980), at La Selva the focal troop in primary forest often traveled quite spread out, moving through many different trees. The forest troop occasionally traveled over the same pathways, but only after several days or weeks; they did not repeatedly use the same trees on a daily basis as did the river troop. Be-

cause many species of Rhabditida and Strongylida are infective by fecal contamination (Noble et al. 1989), repeated use of the same arboreal pathways likely results in a higher contamination rate and thus a higher intensity of infection. In sum, the difference between the two focal troops at La Selva in intensity of parasitic infections indicates that howler troops living in close proximity but within slightly different habitats may experience differences in the intensity of parasitic infections.

Implications for Conservation Biology

This study has important implications for the conservation of howling monkeys and other endangered primate species. First, it shows that the relationship between parasitic infections and populations of wild primates is not simply a function of the density of the species in the area; rather, a complex of factors is likely important in determining the prevalence and intensity of parasitic infections. In particular, the environment inhabited by the species as well as patterns of movement and home range use may have an effect on parasitic infections.

As deforestation continues at an alarming rate in most tropical countries (Brown & Lugo 1984), many primates will be forced into limited protected areas. Although this study and others (Stuart et al. 1993) demonstrate that density alone is not an important factor affecting parasitic infections in primates, deforestation often confines primates to narrow corridors or river edges that limit arboreal pathways and constantly expose them to parasitic infections. This constant exposure, in turn, may result in a high prevalence and intensity of parasitic infections and may have long-term consequences for mortality and the subsequent population density of wild primates.

The importance of corridors to conservation strategies has generated much discussion of their advantages and disadvantages (Noss 1987; Simberloff & Cox 1987; Lindenmayer & Nix 1993). But few data exist that document the possible negative effects corridors may have on particular species (Lindenmayer & Nix 1993). The data from my study indicate that narrow corridor designs may be inappropriate in conservation programs for primates and possibly other arboreal species. Riparian habitats are often recommended as corridor sites (Noss 1987), in part because they are often some of the only areas in which trees remain in a deforested landscape and also because some species of figs (*Ficus*) grow well in riparian habitats, providing an abundant source of fruit for many animals (Terborgh 1983). Riparian corridors, in spite of appearing superficially to provide an "oasis" for many animals, may actually be less effective than wider corridors that potentially provide a greater number of arboreal pathways for primates and other arboreal animals. Wide corridors, which potentially provide a variety of arboreal pathways, may reduce reinfect-

tion by parasites due to contamination. Future plans for corridors in conservation strategies—especially for primate conservation—should account for the effects of the width of corridors on potential arboreal pathways and rates of parasite infection.

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