

RESEARCH ARTICLE

Habitat fragmentation and population size of the black and gold howler monkey (*Alouatta caraya*) in a semideciduous forest in Northern Argentina

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A population of black and gold howler monkeys (*Alouatta caraya*) living near the southern limit of its distribution in a semideciduous forest located in northern Argentina was studied in 2003 to evaluate the possible effects of habitat fragmentation – owing to logging – on its density and social organization within it. Aerial photographs taken in 1982, 1992, and 2001 were used to compare maps of vegetation. These maps were used to evaluate changes in the area covered by forest fragments. From March to June 2003, 10-day monthly surveys of howlers were made in each fragment. A total of 232 individual howlers were counted, belonging to 34 groups plus a solitary adult female. Groups ranged from 2 to 19 individuals (mean = 6.82, $SD = 4.23$), and 21% of the groups contained more than one adult male. Adults accounted for 55% of the individuals, immatures for 45%, and infants represented 13% of the total. Data obtained were compared with information available for the same population for 1982 and 1995. Results revealed no significant changes in the area of fragments, the crude and ecological density of howlers, and group composition. Group sizes and group composition of howlers suggest that the population remained stable over the past 22 years. The density, number of groups, and individuals appears not to be affected by fragmentation and logging, but crude density was low compared with other less-disturbed habitats. The status of the population remains uncertain owing to isolation, and because there are no protected areas to ensure its stability for the future. *Am. J. Primatol.* 69:1–10, 2007. © 2007 Wiley-Liss, Inc.

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INTRODUCTION

Howlers have been characterized as opportunistic feeders and are reported to colonize a variety of different forest types. Populations are found in different

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types of tropical and subtropical forests including evergreen, semideciduous, gallery, montane, woodlands, and flooded forest [Chapman & Balcomb, 1998; Crockett & Eisenberg, 1987; Eisenberg, 1979]. Howler population densities and group sizes vary considerably, ranging from 0.8 to 1,050 individuals/km², and 2–23 individuals/group [Crockett & Eisenberg, 1987]. However, studies on *Alouatta seniculus* [Crockett, 1996; Rudran & Fernandez Duque, 2003], *Alouatta palliata* [Chapman & Balcomb, 1998; Clarke et al., 2002], and *Alouatta caraya* [Arditi & Placci, 1990; Dvoskin et al., 2004] suggest that factors other than broad ecological differences among howler habitats might influence population density and group size. The factors include diseases, catastrophic events, and habitat modification by human activities [Chapman & Balcomb, 1998; Crockett & Eisenberg, 1987].

Habitat alteration and fragmentation owing to deforestation for agriculture and cattle grazing, and selective logging for timber and fuel wood, are likely to influence the density and group composition of howler monkeys [Clarke et al., 2002; Estrada et al., 2002; Fedigan et al., 1998]. Logging can have different effects on different primate species. Some primate species such as *Ateles paniscus* decline after logging [Gilbert, 2003], whereas *A. palliata* appears to persist in forests with moderate or selective logging, agricultural areas, or around human settlements [Clarke et al., 2002; Estrada et al., 2006; McCann et al., 2003]. Under certain conditions, a reduction in tree species diversity owing to selective cutting might represent a benefit for some primate species. For example, Ganzhorn [1995] found that low-intensity logging resulted in increased sunlight entering lower levels of the canopy and led to higher protein concentrations in leaves, and fruit production for seven Lemur species, in particular for *Microcebus* spp, *Cheirogaleus medius*, *Phaner furcifer*, and *Propithecus verreauxi*. But in other cases such as *Cercopithecus aethiops*, declines in primate populations are evident only several years after logging [Struhsaker, 1976].

Northern Argentina comprises the boundary of the southern distribution of black and gold howler monkeys [Brown & Zunino, 1994]. The study of a population in the extreme part of its range may offer important insight into questions of the species' adaptability. Most of the field studies of *A. caraya* in Argentina have been of short duration and have focused on questions of population density and group composition [Pope, 1966; Thorington et al., 1984]. However, a study initiated in 1982 by Rumiz [1990] in the northwest of Corrientes province, northern Argentina, was continued over the course of several years by other researchers [see DeLuycker, 1995; Kowalewski & Zunino, 1999]. Kowalewski and Zunino [1999] reported a reduction of approximately 32% of the suitable habitat for howlers in five fragments in the study area between 1982 and 1995. This appears to have occurred with a reduction in the crude density but without a major change in howler ecological density and group size.

Since 1980 we have been working in the northwest of Corrientes province, and have no evidence that hunting, disease, or climatic events have affected the population. Hunting pressure in this area is extremely low and has remained low in the last 24 years. Logging appears to be the most important variable influencing this howler population. During 2003, the same population was surveyed to study the behavior, ecology, and demography of the howlers. If deforestation is affecting the habitat of howlers, we expect to find a progressive change in the population size and changes in group composition. We present a comparison evaluating the possible effects of deforestation on this population of black and gold howler monkeys over a period of 22 years.

METHOD

The study site is located in private lands, the northwest of the Corrientes Province, Argentina (27° 30'S, 58° 41'W) in the basin of the Riachuelo River. Mean annual temperature is 21.7°C, and the annual average precipitation is 1,230 mm. Rainfall decreases slightly in the winter (July to August). Vegetation in the area is characterized by tall, dense, semideciduous upland and riparian forests, open lowland forests with palm trees, and grasslands. The original tall dense forest was characterized by the presence of valuable hardwood tree species [Carnevali, 1994], including *Astronium balansae* (Anacardiaceae), *Schinopsis balansae* (Anacardiaceae), and *Tabebuia* spp. (Bignoniaceae). These forests have been heavily modified by logging, the presence of cattle, and burning. The remnant fragments of forest where logging continues to the present constitutes the habitat of black and gold howler monkeys [Rumiz, 1990; Zunino et al., 2001].

We constructed maps of the study site using aerial photographs of 1982, 1992, and 2001 to analyze changes in forest cover, forest fragment size, and distribution of fragments. Forest fragments were defined as discrete forest masses separated by grasslands. Forest fragments separated by 20 m or less were considered as one fragment, because trees with crown diameter of about 20 m usually form bridges connecting forest islands [Zunino et al., 2001]. During the survey of howlers, we used a GPS Garmin 12 (Garmin International Inc.) to establish the location of each fragment. With the help of maps, each fragment was reviewed in 2003 and the shape was adjusted if changes were detected after 2001. Changes in the area of fragments between 1982 and 2003 were analyzed using Students *t*-tests.

Surveys of howlers were carried out in a total of 4,800 ha during 10-day periods, over four consecutive months at the end of the rainy season (March–June 2003). The limits of this area were defined as the outer borders of the peripheral fragments. Because fragments were small (the largest was 29.31 ha), each forest fragment was completely surveyed by a team of three to four field workers walking in two groups separated by a distance of about 40 m. Once the howlers were located, the observers made a count of all individuals in the group. As each group had been observed for 2–4 days, when there were differences in the counts for a given howler group in different surveys, the largest count was considered for the analysis. We considered the largest number of individuals per group because in a survey some individuals could have been separated from other group members or out of sight in the canopy.

Groups were recognized by their location and composition, including the estimated age, sex, and natural markings on each group member. Age groups were assigned following Rumiz [1990] criteria based on genitalia, estimated body size, and coloration. The observed animals were classified into the following categories: adults (males and females) and immatures (subadult males, subadult females, juvenile males, juvenile females, and infants).

We compare the results of surveys with the information reported for June–July 1982 covering a total area of 3,000 ha by Rumiz [1990], and for October 1994–March 1995 in 1,496 ha by DeLuycker [1995] in the same area. We calculated crude density using the area that included all of the surveyed fragments of forest, and ecological density using the area covered only by fragments of forest. We compared group size and composition among years using tests (one-way ANOVA) for independent samples because logging has continued since 1982, surveys were conducted almost 10 years

apart, and the area varied among studies. When average values are shown standard deviations are included in parentheses. All tests are two-tailed with $\alpha = 0.05$.

RESULTS

The complete survey comprised a total of 224.1 ha of forest (Fig. 1) belonging to 24 identified fragments (mean size = 9.24 ha, $SD = 7.62$). Comparison of maps between 1982 and 2003 indicated an increase of 7.2% in the area covered by the forest, but this difference was not significant (t -test, $t = 1.64$, $P = 0.11$, $df = 22$). We detected a reduction in the area of eight fragments and an increase in the area of 16 fragments. One fragment of 3.12 ha with a group of howlers that had been cleared between 1982 and 1992 was replaced completely by a secondary forest in 2003, and one group of howlers was observed using it during our survey. The rest of the fragments showed evidence of selective logging. Selective logging resulted in gaps inside the fragments, and around the oldest tree stumps the gaps were covered by a dense mass of low trees and shrubs of secondary forest.

A total of 232 animals belonging to 34 groups were detected in the entire area surveyed. In addition, one solitary adult female was observed but not included in the analyses. Five groups were observed using more than one fragment of forest separated by grasslands, and these groups occupied the smallest fragments in the area. Crude density of howlers was 0.06 individuals (ind.) per hectare, and the ecological density was 1.04 ind./ha. These values show an increase of 50% in crude density and 30% in ecological density when compared with surveys conducted in 1982 (crude density = 0.04 ind./ha, ecological density = 0.80 ind./ha). In comparison with surveys conducted in 1994–1995, crude density in 2003 was similar, and ecological density showed an increase of 13% (crude density = 0.06 ind./ha, ecological density = 0.92 ind./ha).

Censuses of this howler population in 1982 reported 156 individuals living in 22 groups in 3,000 ha. Based on the location of fragments and groups, we adjusted our study area to cover the same forest fragments, and we surveyed a total of 30 groups and 200 animals currently inhabiting this 3,000 ha area.

Adults accounted for 55% of the individuals, and immatures for 45% (infants represented 13% of the total). There was no significant differences among 1982, 1995, and the current study in group sizes and number of animals categorized by age–sex classes (Table I). Group size ranged from 2 to 19 individuals, 27 groups (79.4%) only one adult male, five groups (14.7%) contained two adult males, and two groups (5.90%) three adult males. The multimale groups averaged 10.86 ($SD = 4.95$) individuals, and unimale groups 5.78 ($SD = 3.41$) individuals showing significant differences in size when the number of adult males is subtracted from the group total size (t -test, $t = 2.40$, $P = 0.02$, $df = 32$).

Significant positive relationships were found between the area of patches and the number of individuals ($r = 0.46$, $P = 0.03$, $df = 32$) (Fig. 2A), between the immature to adult female ratio (IFR) and group size ($r = 0.58$, $P < 0.01$, $df = 32$) (Fig. 2B), and between the number of adult males in a group and the size of the group ($r = 0.50$, $P < 0.01$, $df = 32$) (Fig. 2C). In the last case, considering the broad dispersion of data we re-ran the regression excluding points with values larger than twice the initial standard deviation of residuals (eliminating outliers), resulting again in a significant regression ($r = 0.41$, $P = 0.02$, $df = 30$). No significant relations were found between the area and number of groups in a fragment ($r = 0.39$, $P = 0.06$, $df = 22$), between the number of groups with more

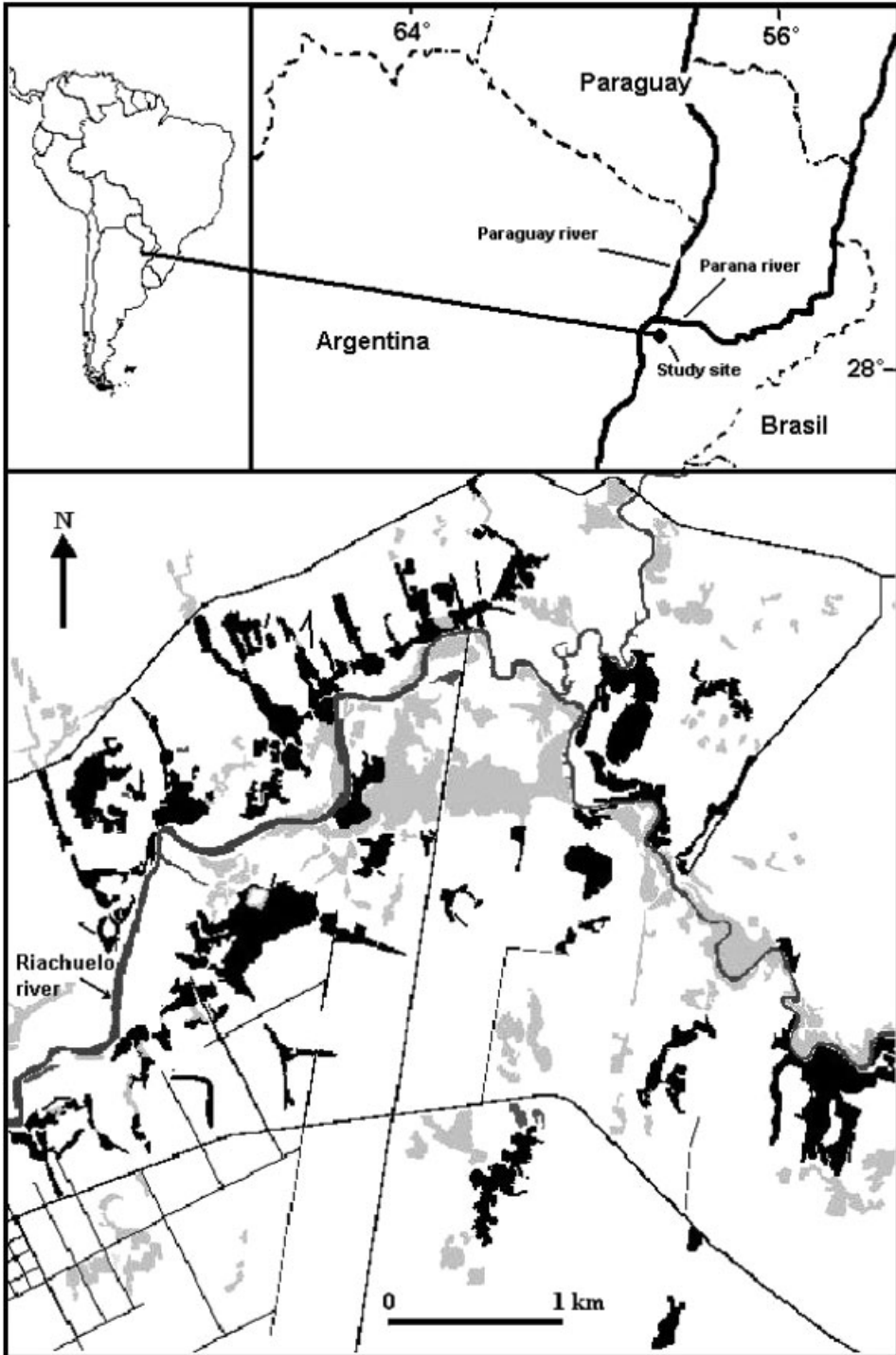


Fig. 1. Location and map of the study site. Dark gray are the fragments of tall forest, and light gray include palms and open lowland forest surrounding the Riachuelo River. Straight lines are roads in the lower left corner is the city of San Cayetano.

TABLE I. Groups surveyed, number of individuals and mean group composition

	1982	1995	2003	ANOVA P values
Groups	11*	14	34	
Individuals	70	88	232	
Adult males	1.36 (0.50)	1.71 (0.99)	1.26 (0.57)	0.124
Adult females	2.00 (0.77)	2.43 (0.76)	2.50 (1.33)	0.445
Subadult males	0.45 (1.21)	0.36 (0.50)	0.38 (0.70)	0.949
Subadult females	0.54 (0.68)	0.21 (0.42)	0.26 (0.45)	0.201
Juvenile males	0.54 (0.69)	0.28 (0.47)	0.79 (1.12)	0.229
Juvenile females	0.82 (0.60)	0.57 (0.65)	0.73 (0.99)	0.755
Infants	0.64 (0.67)	0.71 (0.61)	0.88 (1.15)	0.719
Total	6.36 (2.54)	6.28 (2.13)	6.82 (4.23)	0.866
Immatures	3.00 (1.84)	2.14 (1.46)	3.06 (3.08)	0.526
Adults	3.36 (0.92)	4.14 (1.03)	3.76 (1.71)	0.416

References: 1982 [Rumiz, 1990], 1995 [DeLuycker, 1995], and 2003 (this study).

*Rumiz [1990] surveyed 22 groups but gives the composition for 11 groups.

Standard deviation in parentheses

than one adult male and the area of patches ($r = 0.25$, $P = 0.23$, $df = 22$), and between the number of multimale groups in a fragment and the number of groups in the fragment ($r = 0.14$, $P = 0.52$, $df = 22$).

None of the calculated ratios showed significant differences among years (ANOVA, $P > 0.05$, $df = 2, 56$). The mean adult female to adult male ratio in 2003 (average = 2.06; $SD = 1.05$) was similar to previous surveys (1982: average = 1.64, $SD = 0.84$; 1995: average = 1.88, $SD = 1.08$). The immature to IFR reached average values (average = 1.19, $SD = 0.84$) with the lowest in 1995 (average = 0.82, $SD = 0.49$) and the highest in 1982 (average = 1.45, $SD = 0.79$). The infant to adult female ratio (InfFR) was equal among years (2003: average = 0.28, $SD = 0.33$; 1982: average = 0.27, $SD = 0.32$; 1995: average = 0.27, $SD = 0.22$).

DISCUSSION

Contrary to our expectations, the population studied showed consistent values of density and group composition during the last 20 years. Such consistency in group size and density suggests that between 1982 and 2003 this population was not affected significantly by deforestation, diseases, or climatic events, remaining stable. This lack of fluctuation is supported by similar results obtained in a smaller sample in the same site between 1988 and 1995 [Kowalewski & Zunino, 1999]. The ecological density at the study site was within the range of density values for *Alouatta* in other sites [see Chapman & Balcomb, 1998; Crocket & Eisenberg, 1987]. Current levels of deforestation do not appear to affect the density, group size, and composition of *A. caraya*.

During this 20-year period, there were twice as many adult females as adult males. This ratio was within the range reported for other study sites and species of howlers and suggests a competition of males for mates [Chapman & Balcomb, 1998]. The sex ratio in subadults was approximately 1 (Table I). This suggests that males have a higher rate of mortality or emigration than females during the transition from subadult to the adult age. Because all the forest fragments were occupied by groups and these fragments are small, groups tend to be territorial and emigrants do not form new groups [Zunino & Rumiz, 1986]. Immigration is

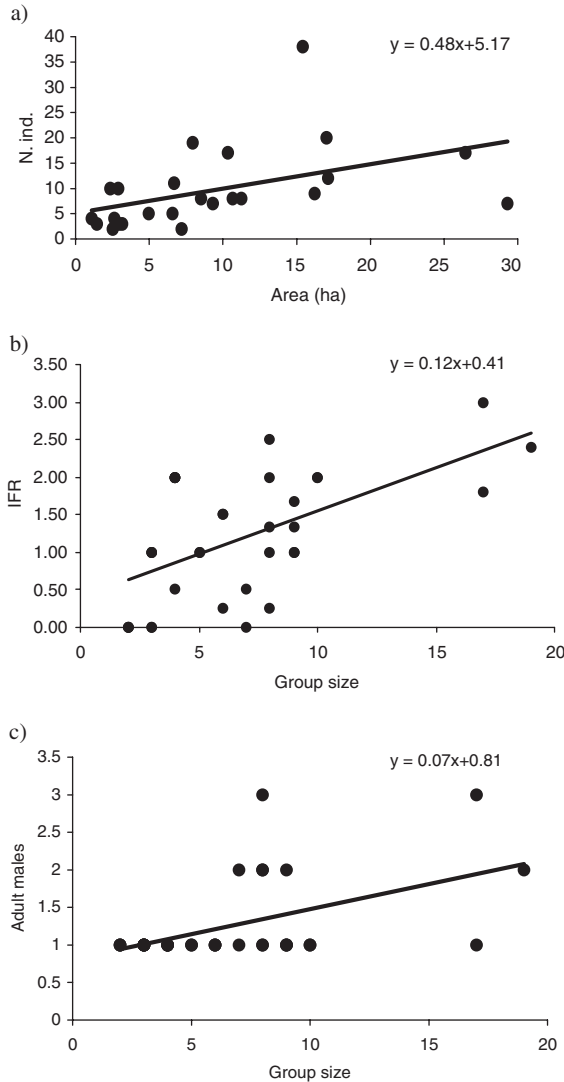


Fig. 2. Relationships between (a) number of individuals and area of fragment forests; (b) immature to adult female ratio (IFR) and group size; (c) number of adult males and group size.

rare, and detected solitaries were never seen forming new stable groups [Kowalewski et al., 1995; Rumiz, 1990]. However, based on the slight increase detected in the area of the fragments and in the number of groups between 1982 and 2003, we expect that secondary forest growth in the future would favor the establishment of new groups.

The social organization appears to be related to the size of fragments, as more individuals per group were found in the largest forest fragments, largest groups tend to be multimale, and in large groups the IFR was higher than in small groups. According to Heltne et al. [1976], for mantled howler monkey populations to remain stable requires a minimum group size of 11–15 animals, an IFR value of

1.5, and an infant to female ratio (InfFR) of 0.75. From 1982 to 2003, the mean values of group size, IFR, and InfFR for *A. caraya* were lower than those proposed by Heltne et al. [1976] and the population remained stable. These ratios are in the range of values observed for other sites and species of howler with stable populations [Zucker & Clarke, 2003]. Lower values than hypothesized for *A. caraya* could be associated with infant mortality, mortality or emigration of immatures, and a concentration of births in the dry season observed in the study site [Kowalewski & Zunino, 2004; Zunino, 1996; Zunino et al., 2001]. But in the current study, 38% of the groups showed a IFR value higher than hypothesized (Fig. 2C), which suggests lower rates of mortality and/or emigration in largest groups. Largest groups contained more than one adult male, and the presence of two or more adult males possibly prevented the invasion of solitary males and infanticide, which caused 20% of the infant mortality in the study site [Zunino et al., 1986].

Selective logging was the most common modification detected in the fragments. From 1982 to the present, the reductions of some forest fragments were compensated by an increase in the area of other fragments that were abandoned and allowed to regenerate after clearing. These patches were replaced by secondary forest. As a result, there was evidence of a minor increase in total forest area. Logging was heavy for trees of economic value, and tall trees of *A. balansae*, *S. balansae*, and *Tabebuia* spp. were absent. Other species of trees eaten by howlers, such as *Myrcianthes pungens* (Myrtaceae), *Chlorophora tinctoria* (Moraceae), *Ficus monckii* (Moraceae), and *Patagonula americana* (Boraginaceae) [Rumiz et al., 1986; Zunino & Rumiz, 1986] were logged for fuel wood, timber, or brought down to extract honey.

Howlers are characterized as opportunistic and pioneer monkeys [Eisenberg, 1979]. The floristic composition change caused by logging might represent a benefit for howlers in the study site because secondary forest is more productive in terms of food for howlers [Peres, 1997]. After logging, there was a replacement of tree species with dry fruits by tree species with fleshy fruits characteristic of the secondary forests [Gonzalez et al., 2002; Rumiz et al., 1986; Zunino et al., 2001]. Some of these species included *Celtis* spp. (Ulmaceae), *Myrcianthes uniflora*, and *M. pungens* (Myrtaceae), all of them consumed by howlers. There is evidence that howlers prefer to eat fleshy fruits when they are available, being frugivorous when possible and folivorous when necessary [Silver et al., 1998]. In addition, howlers appear to be adaptable and flexible in their dietary selection [Bicca-Marques, 2003]. Like other primates, howler persistence may be compatible with moderate and selective logging [Chapman et al., 2000; Clarke et al., 2002; Jones, 1995].

Even though the population in the study site appears to be healthy, logging must not be considered a benefit. Productivity of secondary forests might compensate for the effect of logging and fragmentation, but the forest fragments in this study represent only 5.2% of the total area surveyed, and most of the fragments were small and separated by grassland. The crude density of 0.06 ind./ha was very low compared with the crude density of 0.69 ind./ha found in 1,200 ha of flooded forest of the Parana River located in the same latitude and 28 km away from the study site [Zunino et al., 2001]. The lack of connection or corridors among fragments could make dispersal and range expansion difficult [Crockett, 1998]. A study based on microsatellite analysis [Oklander et al., 2006] suggests that a recent genetic differentiation among groups in this population is a result of possible reduction in gene flow. Groups with less genetic variability were found in more isolated fragments. On the other hand, Santa Cruz et al.

[2000] found a higher diversity and prevalence of intestinal parasites in the study site than groups living in less disturbed habitats. According to our results, these aspects did not affect the population in the last 20 years. Although howlers appear not to be affected by recent fragmentation and selective logging in the study site, the future of this population remains uncertain. Forest fragments are located in private lands and the persistence of the forests is linked to the management plans of each owner.

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