Population status and identification of potential habitats for the conservation of the Endangered black howler monkey *Alouatta pigra* in northern Chiapas, Mexico

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Abstract In the Mexican state of Chiapas the rainforest has been cleared, to make way for crops and extensive cattle ranching, at an annual rate of 12.4% since 2002. The conservation status of the Endangered black howler monkey *Alouatta pigra* in these fragmented landscapes in north-eastern Chiapas has not previously been examined. We therefore surveyed *A. pigra* populations in the municipality of Playas de Catazajá during 2004–2006 to obtain population and habitat data for this species in 115 fragments of remnant vegetation. A geographical information system was used to determine the variables (fragment size, and distances to the nearest fragment, human settlement and water body) that could be used to generate an index of habitat potential for *A. pigra*. We estimated a population of 659 individuals and a mean troop size of 5.0 ± SE 2.3. The adult male : female ratio was 1 : 1.4, the adult female : juvenile ratio 1 : 0.6 and adult female : immature ratio 1 : 0.8. The index of habitat potential indicates that 12% of the fragments have a high conservation potential for *A. pigra*. This index is a valuable tool for evaluating the conservation status of this species and its habitat, and can be expanded to include additional variables, thus allowing for a more comprehensive assessment.

Keywords *Alouatta pigra*, black howler monkey, index of habitat potential, Playas de Catazajá, Mexico, population

Introduction

The rainforests of Mexico are biologically productive and diverse ecosystems (Challenger, 1998) but are being transformed by human activity at an increasing rate. For example, the annual deforestation rate during 1990-2000 in north-eastern Chiapas, near the Palenque National Park, was 12.4%, in central Chiapas 4.5%, and on the southern Yucatan Peninsula 7.7% (Estrada et al., 2004; Cayuela, 2006; Serio-Silva et al., 2006). Deforestation has resulted in the local and regional extinction of plant and animal species, including the black howler monkey *Alouatta pigra* of Mesoamerica, specifically Mexico (Tabasco, Chiapas and the Yucatan Peninsula), Guatemala and Belize (Horwich, 1998; Pavelka, 2003; Estrada et al., 2004; Serio-Silva et al., 2006). *A. pigra* is protected by the laws of each Mesoamerican country in which it occurs (Mexico: Mexican Ecological Norms, NOM-059-SEMARNAT, 2001; Guatemala: Appendix II of the wildlife Red List, CONAP 2001; Belize: Wildlife Protection Act, WPA, 1982), and is categorized as Endangered on the IUCN Red List (IUCN, 2008) and listed in Appendix I of CITES (CITES, 2009).

Recent studies of *A. pigra* in Chiapas have highlighted the lack of information on the conservation status of the species in protected rainforests and fragmented sites (Estrada et al., 2002a, 2004; Van Belle & Estrada, 2005). There are only a few studies of this species in fragmented sites in Mexico: in the Palenque National Park in the state of Campeche and in Balancan, Tabasco (Estrada et al., 2002b; Pozo-Montuy et al., 2008). Only in Belize, where the species has been studied in more detail, is there information on the impact of fragmentation, both anthropogenic and natural, on the demography, ecology, behaviour and physiology of *A. pigra* (Ostro et al., 2001; Horwich et al., 2001; Marsh, 2003; Pavelka, 2003; Pavelka et al., 2003).

Studies in fragmented landscapes report high densities of *A. pigra* compared to the density of the species in unfragmented rainforest. This may be the result of (1) the crowding of *A. pigra* into small fragments (an area effect), (2) the tolerance of these animals to habitat reduction, and/or (3) flexibility in diet (Estrada et al., 2002b; Pozo-Montuy et al., 2008). Under such conditions howler monkeys face the risk of increased parasite transmission as well as an overall increase in risk to their health because they have to descend to the ground and move between forest fragments to meet their nutritional needs (Stuart et al., 1990; Stoner, 1996; Ascencio et al., 2009).

The main questions that we address here are: (1) What is the population size and density of *A. pigra* in Playas de Catazajá, Chiapas? (2) How are troops distributed and what

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are the age and sex composition and size of the troops? (3) Which vegetation fragments are more suitable for the conservation of *A. pigra* in this region?

Study area

The municipality of Playas de Catazajá is in north-east Chiapas, Mexico, at an altitude of 20 m. The site studied covers c. 621 km^2 (Fig. 1). Playas de Catazajá is part of a system of wetlands in the Usumacinta River basin. The bloodwood tree *Haematoxylon campechianum* is typical of this region of low sub-perennial rainforest and riparian and secondary vegetation (Pennington & Sarukhán, 1998). The remnant vegetation in Playas de Catazajá is mainly managed, secondary and riparian vegetation surrounded by a matrix of pastures.

Methods

A complete census of *A. pigra* was carried out in each of the 115 forest fragments in 46 *ejidos* (communal land for agriculture under the stewardship of rural inhabitants). We assumed that we are able to locate all *A. pigra* groups present in these small fragments. This was accomplished by a team of 3–4 people walking slowly to cover the entirety of each fragment; this method has been used by other authors working with *Alouatta* under similar conditions (Zunino et al., 2007; Pozo-Montuy et al., 2008). Surveys were conducted over 17 months (October 2004 to March 2006), from 06.00 to 17.00. The *ejidos* were randomly selected from among the 52 *ejidos* in Playas de Catazajá, each of which contains 1–6 forest fragments. Each *ejido* was surveyed on consecutive days until all chosen fragments had been censused. *Ejidos* with 1–3 fragments were sampled in a single day, those with 4–5 fragments in 2 days and those with six fragments in up to 3 days.

When a troop of *A. pigra* was sighted the animals were observed for at least 30 minutes and the age/sex composition of the troop and any other features of note (e.g. body scars) recorded. Each fragment in which *A. pigra* was encountered was georeferenced using a global positioning system, and the data transferred to orthophotos (1:20,000) using the geographical information system *ArcView v. 3.2* (ESRI, Redlands, USA). Collection of detailed information on each troop ensured that we did not repeat observations on individual troops. Density was calculated as the number of individuals in the total area surveyed (691.2 ha).

We drew distribution maps for *A. pigra* and identified habitats for conservation based on five factors that have been identified as important for the species in fragmented habitat (Marsh, 2003; Rodríguez-Toledo et al., 2003; Anzures-Dadda & Manson, 2007): vegetation type (recorded for each fragment visited: rainforest, riparian vegetation, secondary vegetation) and fragment size, and distances to the nearest fragment, human settlement and water body from fragment edge. Variables other than vegetation type were calculated using *ArcView*.

For fragments that contained *A. pigra* multiple linear regression was used to evaluate the relationship of abundance and troop size with area of fragment and distances to the nearest fragment, human settlement and water body. A non-parametric one-way ANOVA (Kruskall-Wallis) was used to identify any significant differences in these characteristics between fragments with and without *A. pigra*.

For each fragment inhabited by *A. pigra* we calculated an index of habitat potential (also known as the ecotourism

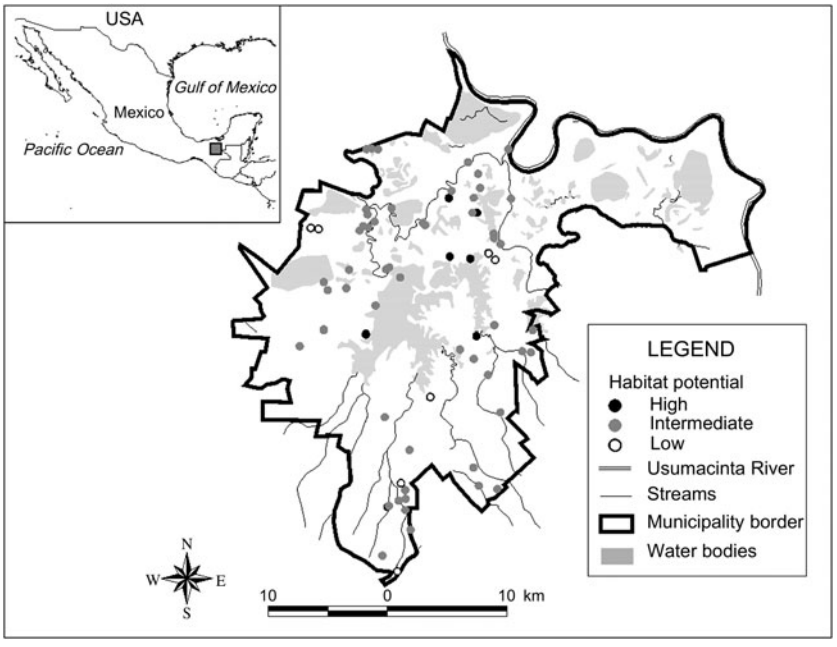

FIG. 1 The study area of Playas de Catazajá, Chiapas, illustrating the distribution of the studied forest fragments and the index of habitat potential (see text for details) for conservation of black howler monkey *Alouatta pigra* in Playas de Catazajá, Chiapas. The rectangle on the inset indicates the location of the main figure in Mexico.

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potential index; Berovides-Álvarez, 2000) for conservation. Each independent variable was scored in the range 1–3, where 3 represents the most favourable condition of the variable for conservation of the species, 1 the least favourable and 2 an intermediate condition (Table 1). These scores are summed for the five variables, giving an index with a potential range of 3–15. Fragments with an index in the range 13–15 are considered to have high potential suitability for the conservation *A. pigra*, those with 9–12 moderate potential, and fragments with ≤ 8 low potential (Table 2).

Results

A. pigra was present in 70 of the 115 vegetation fragments surveyed. We recorded 659 individuals in 118 troops, and 11 solitary individuals, giving an overall density of 95.3 km^{-2}. Mean troop size was 5.0 ± SE 2.6 (range 2–13), and there were 435 adults, 137 juveniles and 87 infants (Table 3). The most common social unit was single male–multi-female (50 troops, 42%), followed by multi-male–multi-female (39, 33%), single male–single female (16, 14%), and single female–multi-male (10, 8%). The remaining 3% (n = 3) were same sex pairs.

The mean number of adult males per group was 1.4 ± SE 0.7, with 2.0 ± SE 0.1 adult females, 0.6 ± SE 0.1 juvenile males, 0.6 ± SE 0.1 juvenile females, 0.4 ± SE 0.6 male infants, and 0.3 ± SE 0.04 female infants. Two troops had no adult males, one had no adult females and 13 had no immatures. The adult male to female ratio was 1 : 1.4, the adult female to juvenile ratio 1 : 0.55 and the adult female to immature ratio 1 : 0.87.

The distribution of *A. pigra* in the municipality of Catazajá is limited to low-lying areas that are prone to flooding, such as riparian vegetation, and rainforests with trees of low to medium height near the municipality of Palenque, Chiapas. Of the individual *A. pigra* recorded, 46.7% (n = 308) were sighted in areas with riparian vegetation, 34.6% (n = 228) in secondary vegetation and 18.7% (n = 123) in rainforest (Table 3).

Mean fragment size was 6.01 ± SE 1.2 ha, mean distance to the nearest fragment was 112.4 ± SE 8.4 m, and mean distance to the nearest water body was 271.5 ± SE 61.5 m. Vegetation type of 53.9% of the fragments was riparian, 37.4% was secondary vegetation and only 8.7% was rainforest. The analysis between fragments with (n = 70) and without (n = 45) *A. pigra* revealed significant differences with respect to fragment size and distances to the nearest fragment and water body ($P < 0.05$; Table 4).

A multiple linear regression revealed no statistically significant relationship between mean troop size and fragment size and distances to the nearest fragment, human settlement or water body ($R^2 = 0.04$, $F = 0.83$, $P = 0.50$). A multiple linear regression of abundance and all independent variables was significant ($R^2 = 0.248$, $F = 5.36$, $P \leq 0.001$) but there was a significant relationship only with fragment size ($R^2 = 0.253$, $t = 3.842$, $P < 0.001$; Table 5).

Of the fragments in which *A. pigra* was found 12.9% (n = 9; total area 2.76 km^2) had a high index of habitat potential, 77.1% (n = 54; 3.43 km^2) an intermediate value and 10% (n = 7; 0.20 km^2) a low value (Fig. 1). Most of the fragments with low potential for conservation of *A. pigra* are small in area and with secondary vegetation on the edges of highways or smaller roads (Table 2).

TABLE 1 The five criteria used to generate the index of habitat potential (see text for further details) for the conservation of *Alouatta pigra*.

Variable	Category	Value
Predominant vegetation type in the fragment	Rainforest	3
	Riparian vegetation	2
	Secondary vegetation	1
Fragment size	>5 ha	3
	1.1–5 ha	2
	0.06–1 ha	1
Distance to the nearest fragment	1–200 m	3
	201–500 m	2
	>500 m	1
Distance to the nearest human settlement	>5,000 m	3
	1,001–5,000 m	2
	0–1,000 m	1
Distance to the nearest water body	0–500 m	3
	501–1,000 m	2
	>1,000 m	1

Discussion

The density of *A. pigra* (95.3 km^{-2}) in the fragments surveyed is similar to that reported for *A. pigra* in other fragmented sites such as around Palenque in Chiapas, Mexico (119 km^{-2}), and the Community Baboon Sanctuary (100 km^{-2}), Monkey River (102 km^{-2}) and the Cockscomb Basin Wildlife Sanctuary (47–257 km^{-2}) in Belize (Horwich & Lyon, 1998; Ostro et al., 2001; Estrada et al., 2002b; Pavelka, 2003). The highest densities reported have been attributed to the crowding of *A. pigra* into small areas, where they survive as a consequence of their feeding and behavioural flexibility (Estrada et al., 2002b; Pavelka, 2003; Pozo-Montuy & Serio-Silva, 2007). A high density of primates in disturbed areas is likely to result in a higher parasite load and greater physiological stress than would occur in preserved areas, as well as changes in foraging strategies (Stoner, 1996; Martínez-Mota et al., 2007; Pozo-Montuy & Serio-Silva, 2007). However, some reports of high densities of *A. pigra* could be a result of the small number (< 30) of fragments surveyed (five fragments, Ostro et al., 2001; 22 fragments, Estrada et al., 2002b; 26 fragments, Rosales-Meda et al., 2007).

Mean troop size in Playas de Catazajá falls within the expected range for the species and did not vary with fragment size. This range is similar in fragmented and

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TABLE 2 Example calculations of the index of habitat potential (Table 1) for 15 of the 115 fragments surveyed in Playas de Catazajá, north-east Chiapas, Mexico (Fig. 1).

Fragment	Vegetation type	Area	Distance to closest fragment	Distance to closest human settlement	Distance to closest water body	Index of Habitat Potential	Potential*
Rancho El Piñal	3	3	3	2	3	14	High
Álvaro Obregón	3	3	3	1	3	13	High
Cuauhtémoc Quemado	2	3	3	2	3	13	High
El Naranjo	2	3	3	2	3	13	High
La Paila	3	3	3	1	3	13	High
Boca de Rio Chico	2	2	3	1	3	11	Moderate
El Tintillo	2	3	2	1	3	11	Moderate
Fco. J. Grajales	2	1	3	1	3	10	Moderate
Linda Vista	2	1	3	1	3	10	Moderate
Agua Fria	1	3	3	1	1	9	Moderate
Carretera al Cuyo A. Obregón	1	1	3	1	2	8	Low
Carretera Palenque a Catazajá	1	1	3	2	1	8	Low
El Rosario A	1	3	2	1	1	8	Low
El Rosario B	1	2	3	1	1	8	Low
Puesto Militar de Control	1	1	3	1	1	7	Low

*≤8, low potential; 9–12, moderate potential; 13–15, high potential

unfragmented sites (González-Kirchner, 1998; Ostro et al., 2001; Estrada et al., 2002b; Pavelka, 2003; Van Belle & Estrada, 2005; Rosales-Meda, 2007).

There are more females than males at Playas de Catazajá, which is typical of a species with a single male–multi-female social organization. However, the number of immatures per female is low (0.8 : 1), as also reported for other fragmented sites in Mexico and Belize (immature : female = 0.9 : 1 ± SD 0.23; Horwich et al., 2001; Ostro et al., 2001; Estrada et al., 2002b; Pavelka, 2003; Pavelka et al., 2003; Pozo-Montuy et al., 2008). This suggests a decrease in reproduction compared to large areas of preserved forest such as Yaxchilán, Calakmul and Palenque National Park in Mexico and Tikal in Guatemala (immature : female 1 : 1.9 ± SD 0.22; González-Kirchner, 1998; Estrada et al., 2004; Van Belle & Estrada, 2005). The low proportion of immatures in fragmented sites could be attributed to mortality of juveniles and infants from predation (mainly by domestic dogs when monkeys descend to the ground to feed or to move between fragments; Pozo-Montuy et al., 2008), and/or to increases in malnutrition, stress and parasitic diseases as a result of crowding (Bonilla-Moheno, 2002; Martínez-Mota, 2004).

Although the social unit of *A. pigra* has been presumed to be single male–multi-female (Horwich et al., 2001), Van Belle & Estrada (2005) found that social units are related to site size, with multi-male–multi-female social units observed with greater frequency in large protected areas and single male–multi-female groups in fragmented sites. The latter was the most frequent type of group in our study, and occurs with a similar frequency in fragmented sites in Palenque (Estrada et al., 2002a,b, 2004; Van Belle & Estrada, 2005).

The abundance of *A. pigra* in Playas de Catazajá is related to fragment size, as recorded at other sites (Pozo-Montuy et al., 2008) and for *Alouatta palliata mexicana* at Los Tuxtlas, Veracruz and in northern Chiapas (Estrada & Coates-Estrada, 1996; Anzures-Dadda & Manson, 2007). An analysis for *A. palliata mexicana* suggested that the risk of extinction is lowest when the area of the fragment is maintained or increased (Escobedo-Morales, 2005). This indicates the need to preserve the remaining fragments by

TABLE 3 Total area, area surveyed and area in which *A. pigra* was present, and abundance, by age and sex, in Playas de Catazajá (Fig. 1).

				Age and sex[2]								
Vegetation type	Total area (ha)[1]	Area surveyed (ha)	Area with *A. pigra* (ha)	AM	AF	JM	JF	IM	IF	SM	SF	Total
Secondary	780	182.3	157.8	63	82	27	25	15	14	2	0	228
Riparian	4,694	286.9	259.7	83	117	29	30	23	19	4	3	308
Rainforest	428	222.0	222.0	31	48	11	15	10	6	1	1	123
Total	5,902	691.2	639.5	177	247	67	70	48	39	7	4	659

[1]Total area in the municipality
[2]AM, adult male; AF, adult female; JM, juvenile male; JF, juvenile female; IM, infant male; IF, infant female; SM, Solitary male; SF, solitary female

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TABLE 4 For fragments in which *A. pigra* were and were not located, the mean of four characteristics, determined by a geographical information system (and the non-parametric Kruskall-Wallis ANOVA between the two groups of fragments), and the number of fragments of each of the three vegetation types.

	Fragments with *A. pigra* (mean ± SE / no. of fragments)	Fragments without *A. pigra* (mean ± SE / no. of fragments)	Kruskall-Wallis ANOVA
Fragment size (ha)	9.1 ± 1.8	1.1 ± 0.2	$H = 34.841$, $df = 1$, $P < 0.001$
Distance to nearest fragment (m)	131.3 ± 12.0	83.2 ± 9.2	$H = 8.295$, $df = 1$, $P < 0.004$
Distance to nearest human settlement (m)	909.5 ± 143.0	617.9 ± 75.9	$H = 0.090$, $df = 1$, $P = 0.343$
Distance to nearest water body (m)	395.0 ± 96.8	79.4 ± 28.2	$H = 12.108$, $df = 1$, $P < 0.001$
Secondary vegetation	30	13	
Riparian vegetation	30	32	
Rainforest	10	0	

assigning them a protected status, using them only in sustainable ways, and promoting connectivity between them.

Human activities, including large-scale deforestation, agriculture and cattle ranching, are the main causes of habitat loss and fragmentation in the range of *A. pigra* in Playas de Catazajá. However, several other factors explain why we found the species in only 70 of the 115 fragments surveyed. The fragment size, distance to the nearest fragment and distance to the nearest water body were significantly different between fragments with and without *A. pigra*. Other authors have reported similar results, and attribute this to the tree composition and structural quality of the fragments for arboreal primates (Anzures-Dadda & Manson, 2007).

Hunting by people for food, fire, extreme weather events and the history of habitat disturbance cause *A. pigra* to be absent in particular fragments on the Yucatan Peninsula and in Tabasco, Mexico (Watts & Rico-Gray, 1987; Serio-Silva et al., 2006; Pozo-Montuy & Serio-Silva, 2007). We found that fragments without *A. pigra* were mainly in *ejidos* that are close to rivers and lagoons, where local people sometimes hunt *A. pigra* for food and the species is also more exposed to predation by domestic dogs and coyotes *Canis latrans*, particularly when moving on the ground to another fragment (Pozo-Montuy & Serio-Silva, 2007).

The index of habitat potential is a useful tool, providing an effective instrument for making decisions and creating conservation areas, and can include any number of variables, depending on what one wishes to evaluate for particular fragments. Our data indicate that the availability of habitat is critical for *A. pigra* at Playas de Catazajá because only 12% of the fragments properly meet the species' needs (i.e. areas ≥ 5 ha that are < 200 m to the nearest fragment and $\geq 1{,}000$ m from roads and settlements). Using these data we can now guide conservation efforts for forest fragments. For example, fragment size could be increased, habitat restored, connectivity with other fragments established, and environmental education programmes could be developed and taken to the settlements near those fragments with the greatest potential for conservation of the species.

Through the establishment of environmental education programmes, local people, researchers and authorities could join together in efforts to use fragments with conservation potential as a sanctuary for *A. pigra*. Fragments with low to moderate conservation potential could be incorporated into a conservation plan based on community ecotourism, with *A. pigra* the flagship species for Playas de Catazajá. This strategy has been successfully applied elsewhere for other primate species (Horwich, 1998; Horwich & Lyon, 1998; Goldsmith, 2001; Serio-Silva, 2006) but prior to any implementation it will be necessary to evaluate an area's potential for ecotourism and any threats this may represent for the species (Grossberg et al., 2003; Bonilla-Sánchez, 2006). The study reported here has been used as supporting evidence

TABLE 5 Evaluation of the relationships of abundance and mean troop size of *A. pigra* with area of fragment and distances to the nearest fragment, nearest human settlement and nearest water body. The only significant relationship is in bold.

Independent variable	Dependent variable	Coefficient (R^2)	SE	*t*	P
Area	**Abundance**	**0.253**	**0.0659**	**3.842**	**< 0.001**
	Mean troop size	0.0230	0.0143	1.601	0.114
Distance to nearest fragment	Abundance	-0.0120	0.0100	-0.200	0.235
	Mean troop size	-0.00131	0.00218	-0.602	0.550
Distance to nearest human settlement	Abundance	0.00134	0.000691	1.933	0.058
	Mean troop size	0.0000547	0.000150	0.364	0.717
Distance to nearest water body	Abundance	-0.0000159	0.00125	-0.0127	0.990
	Mean troop size	-0.0000667	0.000271	-0.246	0.806

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