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Predicted and verified distributions of *Ateles geoffroyi* and *Alouatta palliata* in Oaxaca, Mexico

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Abstract Primate conservation requires a better knowledge of the distributions and statuses of populations in both large areas of habitat and in areas for which we currently have no information. We focused on spider monkeys (*Ateles geoffroyi*) and howler monkeys (*Alouatta palliata*) in the state of Oaxaca, Mexico. This Mexican state has protected large tracts of forest, and has historical records for both primates, although very little is known about them. To update our knowledge of the distributions of these primates and identify potential areas in which they are present, we modeled their geographic distributions by characterizing their ecological niches using the genetic algorithm for rule-set production (GARP), performed interviews and carried out field surveys. The predicted distributions, surveys and interviews indicate that the distributions of these primates are restricted to northeastern Oaxaca. The results suggest that spider monkeys occupy a wider area and elevational range than howler monkeys. Throughout that range there is a wide variety of suitable habitats for these primates. Most of the sites where monkeys were recorded in the field are not officially protected and there was evidence of hunting and habitat destruction. It is important to improve protection, economic alternatives and environmental education as we move towards an integral solution for the conservation of these species. Validation of the GARP model was done for *A. geoffroyi*, since we had obtained enough field data for this species; this validation indicated that the predicted distribution of the species was statistically better than expected by chance. Hence, ecological niche modeling is a useful approach when performing an initial assessment to identify distribution patterns, detecting suitable areas for future exploration, and for conservation planning. Our findings provide an improved basis for primate conservation and productive fieldwork in Oaxaca.

Keywords *Alouatta palliata* · *Ateles geoffroyi* · Geographic distribution · Ecological niche modeling · Mexico · Oaxaca

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Introduction

Spider (*Ateles geoffroyi*) and howler monkeys (*Alouatta palliata* and *Alouatta pigra*) are the only primates in Mexico, and are the northernmost representatives of neotropical non-human primates. Although the first two species are widely distributed throughout Mesoamerica, they have only been studied in a relatively small proportion of their range (Estrada and Mandujano 2003; Estrada et al. 2006). Historical records for spider monkeys in Mexico indicate that this primate ranged along the Pacific coast from the state of Jalisco and along the Gulf of Mexico from southern Tamaulipas in their northernmost limits (Villa 1957; Hall 1981) down to the southern states into the Yucatan peninsula (Estrada and Coates-Estrada 1984; Watts and Rico-Gray 1987; Ford 2006; Rylands et al. 2006). Within this range, two subspecies of spider monkeys exist; *A. geoffroyi yucatanensis* is restricted to the Yucatan peninsula, while *A. geoffroyi vellerosus* occurs throughout the rest of the aforementioned distribution. The mantled howler monkey (*A. palliata*) was originally found in the states of Veracruz, Tabasco, Oaxaca and Chiapas, while the Mexican black howler monkey (*Alouatta pigra*) inhabited Tabasco and Chiapas as well as the Yucatan peninsula (Rylands et al. 2006). At present, these species are known to occur in forest remnants throughout their historical range, but they have not been sighted north of the state of Oaxaca on the Pacific side and north of Los Tuxtlas in the state of Veracruz on the Gulf side (e.g., Estrada and Mandujano 2003; García-Orduña 2003; Méndez-Cárdenaz 2003; Navarro Fernández et al. 2003; Serio-Silva et al. 2006; Anzures-Dadda and Manson 2007; Ortiz-Martínez and Rico-Gray 2007).

The removal of almost one third of the original forested areas in Mexico (Ricker et al. 2007) has reduced and fragmented the natural forest habitat of these species (Estrada and Coates-Estrada 1996; Mandujano et al. 2006; Anzures-Dadda and Manson 2007). The resulting depletion of primate populations is being hastened by hunting and capture for pet trading (Duarte-Quiroga and Estrada 2003; Cuarón 2005), and they are now considered critically endangered species (IUCN 2007). A recent study underlined our limited knowledge of primates in Oaxaca and the importance of increasing our understanding of them in order to aid the conservation of these primates (Estrada and Mandujano 2003).

Given this situation, there is a need for studies that determine the current situation of these primates. One approach that has been increasingly used in conservation assessment and planning to evaluate the current and potential distribution of species is ecological niche modeling (ENM), sometimes also called species distribution modeling or bioclimate envelope modeling (Anderson and Martínez-Meyer 2004; Engler et al. 2004). ENM uses the points of occurrence of a species together with environmental variables of the region to identify nonrandom associations between the two and determine suitable conditions for the species to persist (i.e., its ecological niche). It then looks for these conditions on a map, producing a potential distribution model of the species (Peterson 2001; Guisan and Thuiller 2005). Although this approach has been used successfully in a diverse array of taxonomic groups for analyzing different biogeographical aspects, such as conservation prioritization (Sanchez Cordero et al. 2005), discovery of new populations and species (Raxworthy et al. 2003), and climate change (Pearson and Dawson 2003), no previous efforts has been made to use it to analyze the distribution patterns of primates.

In this study we present the results of ecological niche modeling, interviews, and surveys of *A. geoffroyi* and *A. palliata* in the state of Oaxaca. ENM was used to identify the distribution patterns of the species, while the interviews and surveys were used to obtain data on their current and historical ranges, as well as their conservation statuses in the region.

Methods

Study area

The state of Oaxaca is located in southern Mexico (18°39′–15°39′N and 93°52′–98°32′W) and has an area of 95,364 km^2. It has 12 physiographic provinces, of which the Sierra Madre mountains of Oaxaca, the Western Oaxacan Mountains and Valleys, and the Sierra Madre del Sur mountain range cover 55% of the state's area, reaching the highest altitudes (2,500–3,500 m a.s.l.) in the state (Ortiz-Pérez et al. 2004). For northern and eastern Oaxaca there are historical records of the presence of primates (Paray 1951; Goodwin 1969), and this area also has the largest areas of moist montane forest, tropical rain forest, and dry forest (Torres-Colin 2004).

Primate distribution

The records and localities for this research were obtained in three phases. During the first we compiled occurrence data of *Ateles* and *Alouatta* in southern Mexico from museum collections in Mexico and the USA (Lopez-Wilchis and López-Jardines 1998), as well as from the scientific literature (see the "Appendix").

During the second phase we did 55 interviews with scientists, government and NGO staff as well as the local villagers who work in forested areas of Oaxaca. We recorded information on monkey sightings, hunting, and pet trading, as well as knowledge about the current statuses of and the laws protecting these species. Whenever possible, sightings were georeferenced to the nearest minute of latitude and longitude using vegetation and land-use maps (Palacio-Prieto et al. 2000).

The third phase consisted of field surveys of spider monkeys and howler monkeys in northeastern Oaxaca. This region was selected because the historical distributions, the results from our interviews and the ecological niche models indicated that the primate distributions were limited to this area. We conducted surveys from March to July and in November 2003, from January to May 2004, and in May and July 2005. The mountainous and complex character of the terrain, as well as the poor condition of the roads and transport services presented challenges, and some difficulties in gaining permission from local authorities to do the surveys were encountered. These limitations determined the locations we were able to visit. Surveys were done by at least two observers, one of whom guided on foot using existing trails. On sighting either primates or evidence of their presence we recorded the location and elevation using a GPS. We also recorded the vegetation type and its degree of preservation. Because of the topography and the rapid movement of the animals, our attempts to record their numbers were often unsuccessful. Therefore, we used an encounter rate survey as an indicator of relative monkey abundance, by dividing direct sightings of monkeys (one individual or a subgroup counted once)/km (Carrillo et al. 2000; Radhakrishna et al. 2006).

Modeling predictive distribution

The predicted distributions of both *A. geoffroyi* and *A. palliata* were obtained using a public desktop version (from http://nhm.ku.edu/desktopgarp/) of the genetic algorithm for rule-set prediction (GARP) system (Stockwell and Noble 1992; Stockwell and Peters 1999). This artificial-intelligence-based algorithm is designed to explore nonrandom associations between known occurrences of species and associated environmental parameters through an iterative process of many generations of rule selection, modification, testing, and incorporation or rejection. GARP combines individual approaches that are used to relate the environmental conditions with the presence (and absence) of species, such as climate envelopes (Bioclim) and logistic regression, in order to develop a model consisting of a set of if–then rules describing suitable conditions for the species to persist (i.e., its ecological niche). A full description of the whole process can be found elsewhere (Stockwell and Noble 1992; Stockwell and Peters 1999). GARP has been successfully used to model the distributions of Mexican fauna (Peterson et al. 2002; Illoldi-Rangel et al. 2004; Domínguez-Domínguez et al. 2006), and has proven robust, even with small sample sizes (Stockwell and Peterson 2002).

Datasets used

GARP models for *A. geoffroyi* and *A. palliata* were built using 74 and 20 records, respectively, including data from the scientific literature, unpublished scientific reports, mammal collections, and historical reports (from prior to 2000) obtained from interviews. Of the 74 records obtained for *A. geoffroyi* in Mexico, 38 were drawn from the scientific literature (Paray 1951; Estrada and Coates-Estrada 1984; García-Orduña 1995; Serio-Silva et al. 2006), four from unpublished scientific data (Anzures-Dadda, personal communication), 19 from mammal collections, and 13 from interviews (reports from observations prior to 2000). For *A. palliata*, 14 records were obtained from the scientific literature (Estrada and Coates-Estrada 1984; García-Orduña 1995; Serio-Silva and Rico-Gray 2002; Serio-Silva et al. 2006), one from an unpublished thesis (Méndez-Cárdenaz 2003), four from unpublished scientific data (Anzures-Dadda, personal communication), and one from a mammal collection. We obtained 31 recent reports (since 2000) from interviews regarding the presence of spider monkeys and four reports of howler monkeys for the state of Oaxaca.

We used 22 layers of environmental data including aspects of topography and climate that have been determined as being primary drivers of the species' distributions at regional scales (Pearson and Dawson 2003). Topographic layers included elevation, slope, and a topographic index which reflects the ability of the terrain to pool water in terms of its shape (concave or convex), and were obtained from the USGS TOP30 Hydro 1K dataset (http://lpdaac.usgs.gov/gtopo30/hydro/; original resolution 1 km on a side). Climate layers were obtained from the WorldClim dataset (http://biogeo.berkeley.edu/worldclim/worldclim.htm), which includes 19 variables expressing different limiting aspects of temperature and precipitation for species (mean annual temperature, mean diurnal range, isothermality, temperature seasonality, maximum temperature of the warmest month, minimum temperature of the coldest month, annual temperature range, mean temperature of the wettest quarter, mean temperature of the driest quarter, mean temperature of the warmest quarter, mean temperature of the coldest quarter, annual precipitation, precipitation of the wettest and the driest months, precipitation seasonality, precipitation of the wettest quarter, precipitation of the driest quarter, precipitation of the warmest quarter, and precipitation of the coldest quarter).

Modeling procedure

In GARP, due to the random processes involved in model development, each model produced with a single occurrence dataset may be somewhat different; therefore, to capture this variability we developed 100 replicate models for each species and then we selected the ten models that gave the smallest errors of commission and omission, following the procedures developed by Anderson et al. (2003). These ten models were then overlaid together in a Geographic Information System (ArcView v. 3.2) to produce a consensus map representing the predicted distribution for each species. Pixel values of the consensus map can go from 0 to 10, where 0 represents areas where all models predicted the absence of the species, 1 are areas where one out of ten models predicted the presence of the species, and so on, up to 10, which are those areas where all ten models predicted the species' presence.

To test the model accuracy, we estimated the proportion of predicted and unpredicted areas of primate distribution relative to the area of the entire state of Oaxaca in order to obtain the expected rate of omission (number of observations not predicted by the model) and test it against the actual omission rate calculated from field data. We used chi-square statistics to test whether the observed predictivity departs form random expectations (Anderson et al. 2003). Since we did not detect the presence of *A. palliata* during field work, we only validated the model of *A. geoffroyi*.

Finally, we used the latest Mexican forest inventory (Palacio-Prieto et al. 2000) to identify the areas that currently hold primary vegetation, assuming that these are potential areas where the monkeys persist, and to produce a final map representing the best approximation possible to the current distributions of the two species in Oaxaca.

Results

Relative abundance of monkeys

We surveyed a total of 189 km through communal (96.8%) and private land (3.2%), which included localities from 18 municipalities and seven districts in the state of Oaxaca (Table 1). In general, the relative abundance of spider monkeys was similar among sites; there was one exception where it was relatively high, possibly due to the greater accessibility of this site (Table 1).

Predicted and current distributions of *A. geoffroyi*

The model of the potential distribution of *A. geoffroyi* encompassed the NE portion of Oaxaca, including some portions of the Sierra Madre of Oaxaca and the lowlands of the Gulf of Mexico and the Isthmus of Tehuantepec (Fig. 1a). We confirmed the presence of *A. geoffroyi* in 18 of the 31 sites surveyed. These verification points were laid over the predicted distribution to test their correspondence and the result was better than expected relative to a random distribution ($\chi^2 = 6.67$, $P < 0.01$). The area of the predicted distribution was 36,977 km^2, 38.8% of the state of Oaxaca. Of that area, 70.2% was covered by tropical lowland and temperate forests, of which 23.2% was tropical forest mixed with secondary vegetation. Eliminating the remaining 29.8% of cultivated lands, grasslands and urban areas from the predicted area, we produced a final map representing the best approximation to the current distribution of *A. geoffroyi* in Oaxaca (Fig. 1b).

Predicted and current distributions of *A. palliata*

The predicted distribution of *A. palliata* correlated almost completely with that predicted for *A. geoffroyi*. These distributions were mostly restricted to eastern Oaxaca. Howler monkeys were recently reported to inhabit four sites in the municipalities of Santa María Chimalapa and Matías Romero (Fig. 1b). However, we did not detect this species during the surveys conducted in this region, so it was not possible to test the predicted distribution pattern for it. The predicted distribution covered an area of 10,580 km^2, 11.1% of the state of Oaxaca. Of this, 78.9% was covered by tropical lowland and temperate forests, and 27.1% of this was tropical forest mixed with secondary vegetation. These forested areas represent the closest approximation to the potential distributions of these primates.

Discussion

Modeling methods and field surveys

To our knowledge, this is the first time that ecological niche modeling has been used to evaluate primate distribution patterns. Our models estimated the geographic extents of the ecological niches of *A. geoffroyi* and *A. palliata* in Oaxaca. These predicted areas climatically and physically resemble the areas in which we had documented the presence of primates, i.e., the dataset that we used to develop the model. The GARP modeling system does not consider historical aspects (Peterson et al. 1999) and geographical barriers (Soberón and Peterson 2005) that may have limited the occupation of the resulting favorable area, so one must be careful when interpreting the results. In our case, the models agree with the historic distributions for these primates. Maps of the predicted distribution were clipped using the most recent land use/land cover map (Palacio-Prieto et al. 2000), resulting in a map showing the distribution of the species in areas where the primary vegetation is still present. These maps, coupled with the sites where the presence of monkeys was verified and reports from the interviews, provide an improved basis for primate conservation and productive fieldwork in Oaxaca.

Variations in spider monkey subgroup abundance have also been found among habitat types, and are greater in humid than in dry forests (Serio-Silva et al 2006). Although the abundances estimated in our study follow this trend, relative abundances at our study sites were rather low. The resulting absence of spider monkeys and their low relative abundances in a variety of habitat types could have been influenced by a combination of low monkey detectability due to the limitations imposed by the terrain and an actual low presence and abundance of monkeys in Oaxaca. Although we lack previous estimates of monkey abundances in the region, we cannot reject the possibility of a drop in population numbers, as suggested by the interviewees during the study.

Table 1 Sites surveyed for primates in Oaxaca, Mexico

No.	Site name	Municipality	Latitude N	Longitude W	Vegetation type	Distance surveyed (km)	Subgroups or evidence of presence	Type of record	Encounter rate (subgroups/km)
1	S Cerro Las Garzas	Santa María Mixtequilla	95°17′	16°29′	ISDLF–ISELF[a]	10.30	1	Fecal	–
2	N Cerro Negro	Santiago Laollaga	95°17′	16°34′	ISDLF–ISELF[a]	10.40	2	Vocal, direct	0.10
3	N Cerro Negro	Santiago Laollaga	95°16′	16°34′	ISDLF–ISELF[a]				
4	S Cerro Negro	Santiago Laollaga	95°18′	16°31′	ISDLF–ISELF[a]	14.98	1	Direct	0.07
5	E Cerro Las Garzas	Magdalena Tlacotepec	95°13′	16°28′	ISDLF–ISELF[a]	5.79	1	Carcass	–
6	Cerro Chango	Santiago Jocotepec	95°56′	17°43′	HELF	12.18	3	Direct	0.25
7	Cerro Chango	Santiago Jocotepec	95°57′	17°42′	HELF				
8	Cerro Chango	Santiago Jocotepec	95°55′	17°42′	HELF				
9	Cerro Naranjos	El Barrio de la Soledad	95°02′	16°42′	ISDLF–ISELF[a]	11.67	1	Vocal	–
10	Cerro Monte Negro	Santiago Ixcuintepec	95°33′	16°55′	ISELF–POF	7.94	1	Vocal	–
11	Cerro La Pedrera	Asunción Ixtaltepec	94°56′	16°39′	LDLF–ISDLF	5.17	1	Direct	0.19
12	Río Escondido	Santa María Chimalapa	94°46′	17°07′	HELF	1.76	1	Direct	0.57
13	Río Grande	San Miguel Chimalapa	94°37′	16°43′	ISELF–POF	7.11	1	Direct	0.14
14	NO de Escolapa	Santa María Chimalapa	94°49′	16°54′	HELF	8.44	1	Direct	0.12
15	Cerro Salomón	San Miguel Chimalapa	94°12′	16°44′	MMF	6.85	1	Direct	0.15
16	Cordón El Retén	San Miguel Chimalapa	94°16′	16°42′	MMF	13.00	2	Direct	0.15
17	Cordón El Retén	San Miguel Chimalapa	94°16′	16°42′	MMF				
18	Cerro La Calhidra	Asunción Ixtaltepec	94°57′	16°39′	LDLF–ISDLF	3.64	1	Direct	0.27
19	San Juan Teponaxtla	San Juan Tepeuxila	96°42′	17°43′	MMF	4.99	None	–	–
20	Las Maravillas	Capulalpam de Méndez	96°19′	17°17′	MMF–POF	3.68	None	–	–
21	N Tonaguia	San Juan Comaltepec	96°02′	17°21′	MMF	8.30	None	–	–
22	Paso La Mica	Juchitán de Zaragoza	94°52′	16°37′	LDLF–ISDLF	11.39	None	–	–
23	E Santa Maria Chimalapa	Santa María Chimalapa	94°37′	16°54′	HELF	2.68	None	–	–
24	Río Hamaca	Santa María Chimalapa	94°42′	17°01′	HELF	4.29	None	–	–
25	El Tronador	Matías Romero	94°52′	17°05′	HELF	3.32	None	–	–
26	Vista Hermosa	Santiago Comaltepec	96°20′	17°38′	MMF–HELF	4.22	None	–	–
27	Chayotepec	Santa María Guienagati	95°29′	16°44′	MMF–POF	7.17	None	–	–
28	Espinazo del Diablo	Santa María Chimalapa	94°05′	17°07′	HELF	5.03	None	–	–
29	Arroyo Cuchara	Santa María Chimalapa	94°47′	16°51′	HELF	6.19	None	–	–
30	Génova	Santa María Chilchota	96°43′	18°15′	HELF	4.40	None	–	–
31	Cerro Panorama	Santa María Chilchota/San José Independencia	96°41′	18°16′	HELF	3.78	None	–	–

POF, pine–oak forest; *MMF*, moist montane forest; *HELF*, high evergreen lowland forest; *ISELF*, intermediate semi-evergreen lowland forest; *ISDLF*, intermediate subdeciduous lowland forest; *LDLF*, low deciduous lowland forest

[a] Patches of intermediate subdeciduous and semi-evergreen forest located in a landscape dominated by low deciduous lowland forest

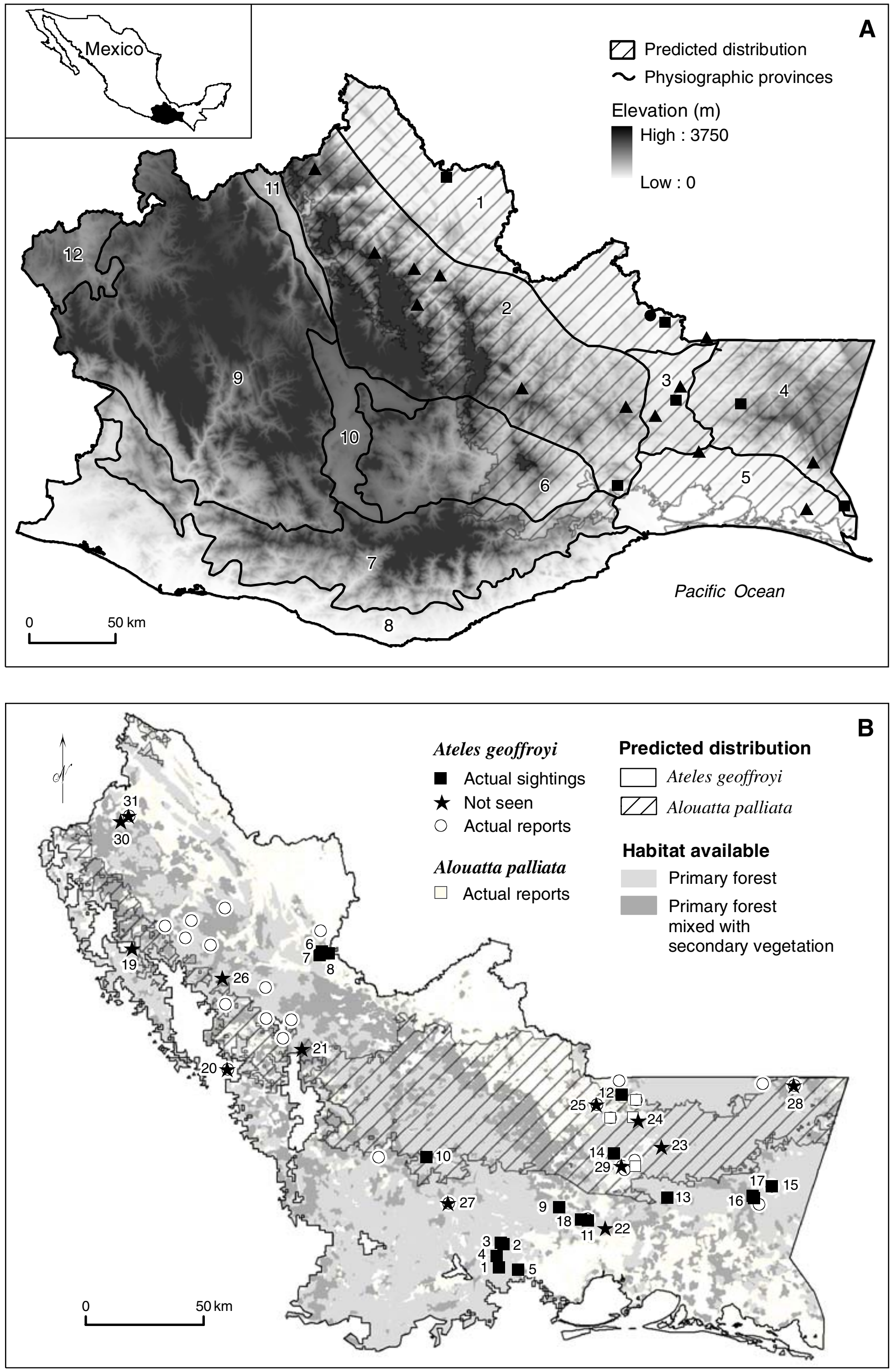

Fig. 1 **a** Map of the joint predicted distribution for *Ateles geoffroyi* and *Alouatta palliata* using the following types of historical records: *circle* collection records for *Alouatta palliata*; *squares* collection records for *Ateles geoffroyi*; *triangles* reports from interviews for *Ateles geoffroyi*. The physiographic provinces of the state of Oaxaca (drawn from Ortiz-Pérez et al. 2004) are: *1*, Gulf Coastal Plain; *2*, Sierra Madre of Oaxaca; *3*, Tehuantepec Isthmic Depression; *4*, Chimalapas region; *5*, Tehuantepec Coastal Plain; *6*, Central Mountains and Valleys; *7*, Sierra Madre del Sur; *8*, Pacific Coastal Plain; *9*, Western Oaxacan Mountains and Valleys; *10*, Central Valleys of Oaxaca; *11*, Tehuacan Depression; *12*, Balsas Depression. **b** Magnification of **a**, with predicted geographic distributions for *Ateles geoffroyi* and *Alouatta palliata*. *Shadowed areas* show current areas with primary forest and forest mixed with secondary vegetation. *Numbers* indicate surveyed sites; the presence of spider monkeys was verified for sites 1–18, while monkeys were not seen at sites 19–31 (see Table 1)

Distribution patterns of spider and howler monkeys

Data from the modeled distribution, surveys, and recent reports of the presence of *A. geoffroyi* suggest that the distribution of this species is mostly restricted to northeastern Oaxaca. We found no published or unpublished reports to support the extrapolated range for *Ateles* given in Hall (1981), which runs along the Pacific coast between the reported sightings for Oaxaca (Goodwin 1969), and the isolated record for Jalisco (Villa 1957). Although howler monkeys were not detected in our surveyed sites, reports from interviews and other evidence (i.e., pictures taken of this primate by local people) suggest their presence in the Chimalapas region.

Our findings, consistent with the historical records, suggest that in northeastern Oaxaca *A. geoffroyi* has a wider distribution than *A. palliata* in terms of both altitude and geographic range. The contrast between these current distribution patterns may be related to historical factors that have limited primate movements, rather than differences in response to habitat fragmentation. In Oaxaca, compared to other states in southern Mexico, large areas of habitat remain available for these primates. Mexico in general, and Oaxaca in particular, possess high orographic complexity, resulting in a very heterogeneous landscape. Although both primates are found in a diversity of habitats (Van Roosmalen and Klein 1988; Rowe 1996; Serio-Silva et al. 2006; this study), *Ateles* shows a better ability than *Alouatta* to move across mountainous landscapes (Ford 2006). It has been suggested that this difference in movement ability has allowed spider monkeys to disperse farther north than howler monkeys and to move to the Pacific side of Mexico (Ford 2006), where they are currently found (Hernández-Yañez 1993; Ortiz-Martínez and Rico-Gray 2007).

Recent and historical data indicate that the distribution of spider monkeys in the Sierra Madre of Oaxaca is restricted to the Atlantic slope, except at their southernmost limit (Fig. 1). It is likely that these higher mountains and the adjacent mountains to the north of them (Sierra Madre Oriental) could represent a barrier to the dispersal of monkeys in the southwest. This could explain, to a certain extent, the historical distribution patterns of these monkeys along the Atlantic slope as far up as the state of Tamaulipas.

The factors limiting primate dispersion along the Coastal Plain of Tehuantepec to the forest of the western Pacific coast remain unknown. In their southernmost distribution, spider monkeys occupy the edge of the Sierra Madre of Oaxaca at its border with the Sierra Madre del Sur and the Tehuantepec Coastal Plain (Fig. 1). Temperature and precipitation maps for the state of Oaxaca (García 1997a, 1997b) show that the lowlands between the two mountains occur where there is a climatic transition to higher temperature and lower precipitation. This is the limit between dry forest and dry thorn forest (Rzedowski 1978). For an arboreal primate the size of a spider monkey, the tree cover of dry thorn forest offers less support and shelter from the sun and predators than dry forest does and could represent an ecological barrier.

Threats to monkeys

In Oaxaca there are extensive tracts of low-impact tropical and temperate forest (Ricker et al. 2007). The north and eastern regions of the state offer a wide variety of habitats for *A. geoffroyi*. Some of these forests are along the Sierra Madre of Oaxaca and a smaller proportion of them occur in the lowlands of the Gulf of Mexico. Of particular importance is the dry forest on the pacific side, which is considered biologically and structurally different from the dry forest in the Yucatan Peninsula and Central America (Ceballos 1995). Also important is the Chimalapas region which, coupled with the forest of Uxpanapa in the state of Veracruz, and that of the Ocote and La Sepultura in the state of Chiapas, represents one of the largest areas of habitat suitable for the study and conservation of *A. geoffroyi vellerosus* and *A. palliata* in Mexico (Estrada and Coates-Estrada 1988; Estrada and Mandujano 2003). The conservation of forests in Oaxaca is notable if we consider that most of these are not areas protected by the government.

There are only five natural protected areas in Oaxaca, none of which is inhabited by monkeys. A recently implemented alternative for protecting species and ecosystems is to establish a certified area for conservation (ACC), which consists of communal or private land set aside voluntarily by the owners for conservation purposes. Certification is provided by the Mexican Ministry of the Environment (SEMARNAT). Currently at least five ACCs are known to protect primate habitat in Oaxaca.

Despite communal and private initiatives for conservation and the extensive tracts of low-impact forest in Oaxaca, habitat loss and disturbance as well as hunting for pet trading threaten primate conservation. Human population growth and colonization is opening and fragmenting the remaining habitat. In northeastern Oaxaca the most important modifications to forest cover are related to the expansion of crop fields and pasture for raising cattle, the construction of new roads and settlements, the extraction of rock and soil, and human-induced wildfires. As a result, the proportion of the total area of the northeast region that is conserved forest is less than 50%, while forest mixed with secondary vegetation accounts for approximately 23%, according to the latest inventory of Mexican forests (Palacio-Prieto et al. 2000). Where forest has not been cleared, remaining monkey habitat is being degraded by selective logging for construction material (personal observation). Although monkeys are under legal protection in Mexico, we found that very few of the locals are aware of it. Hunting and capture occur and, as documented in other studies, spider monkeys are highly valuable for pet trading (Duarte-Quiroga and Estrada 2003; Cuarón 2005).

Finally, we recommend that the areas inhabited by monkeys should receive greater protection, and that work should be done with local people to develop economical alternatives and improve environmental education. Areas where the presence of monkeys has been reported, as well as the predicted distribution areas for which no data are available, should be assessed to improve our knowledge of spider and howler monkey distributions and statuses.

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Appendix

The records of *A. geoffroyi* and *A. palliata* obtained from scientific collections that were used in the ecological niche modeling are arranged by species. The name of the state in Mexico is followed by the name of the localities. Parentheses enclose the catalog number (when available) and the name of the scientific collection:

Alouatta palliata: Oaxaca: Ubero (212193 American Museum of Natural History). *A. geoffroyi*: Veracruz: Achotal (13896 Field Museum of Natural History), Jesús Carranza (5995 Louisiana State University, Museum of Zoology), San Juan Evangelista (276631 United States National Museum of Natural History); Tabasco: Teapa (7618 Louisiana State University, Museum of Zoology); Campeche: Apazote (108275 United States National Museum of Natural History), Escarcega (92076 University of Kansas, Museum of Natural History), Xpujil (University of Wisconsin–Madison, Zoological Museum); Yucatán: Tizimin (5083 Museum of Zoology; the Mammal Collection of the Alfonso L. Herrera Museo de Zoología); Quintana Roo: Puerto Morelos (108531 United States National Museum of Natural History); Chiapas: Palenque (292203 United States National Museum of Natural History), Montes azules (3 Mammal Collection of the Sureste de México ECOSUR-SC), Lancajá-Lago (38 Mammal Collection of the Sureste de México ECOSUR-SC), Lancajá-Chasayab (1066 Mammal Collection of the Sureste de México ECOSUR-SC); Oaxaca: Tapanatepec (52632 University of Washington, Burke Museum of Natural History), Cerro Mixtequilla (145159 American Museum of Natural History), Sierra Atravesada (145203 American Museum of Natural History); Río Grande (143461 American Museum of Natural History), Río Jaltepec (176648 American Museum of Natural History), Tuxtepec (18920409 United States National Museum of Natural History).

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