Articles

SYMPATRIC *ALOUATTA SENICULUS* AND *CEBUS CAPUCINUS* IN AN ANDEAN FOREST FRAGMENT IN COLOMBIA: A SURVEY OF POPULATION DENSITY

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Abstract

Due to human activities, the Colombian Andean forests have lost about 85% of their original cover and very few species of primates persist in these fragmented landscapes. In the Western Cordillera, we evaluated the population density of *Alouatta seniculus* and *Cebus capucinus* by line transect census methodology, in a pre-montane isolated forest fragment of 559 ha, between 1200 to 1700 m of altitude. This is one of the few localities where the two species coexist naturally and the first study of their abundance in this cordillera. As we expected according to their diet and strategies, howlers had a higher density, 169 indv/km2 and an abundance of ~943 individuals. By contrast, the capuchins had a lower density, 13.5 ind/km^2 with a population of ~76 individuals. Despite contrasting abundance, both species' conservation in this isolated fragment will depend on landscape-level management to decrease isolation and increase habitat availability in the long term.

Key Words: red howler, white-faced capuchin, premontane forest fragment, abundance, line transect surveys

Resumen

Debido a actividades humanas, los bosques Andinos de Colombia han perdido cerca del 85 % de la cobertura boscosa original y muy pocas especies de primates subsisten en estos paisajes fragmentados. En la cordillera Occidental, evaluamos la densidad de *Alouatta seniculus* y *Cebus capucinus* por medio de muestreo por censos por transectos lineales, en un fragmento aislado de bosque premontano de 559 ha, entre 1200 y 1700 m de altitud. Esta es una de las pocas localidades donde las dos especies coexisten naturalmente y el primer estudio sobre su abundancia en dicha cordillera. Tal como era esperado de acuerdo a su dieta y estrategias, los aulladores presentaron una alta densidad (169 ind./km^2) y una abundancia de ~943 individuos. Por el contrario los capuchinos presentaron una densidad menor, de 13,5 ind./km^2 con una población de ~76 individuos. A pesar de presentar abundancias contrastantes la conservación de estas especies en dicho fragmento dependerá de un manejo de paisaje que disminuya el aislamiento y provea más hábitat disponible en el largo plazo.

Palabras clave: Mono aullador rojo, mono cariblanco, fragmento de bosque premontano, abundancia, transectos lineales.

Introduction

Due to historical, geographical and ecological reasons, most of Colombia's human population is concentrated in the Andean region and in the Caribbean plateau. The ridges and valleys between 1000 and 2500 m have been highly transformed and fragmented and some regions are virtually deforested (Kattan and Alvarez-Lopez, 1996). In some forest remnants a few primates have been able to survive, including *Alouatta seniculus,* the red howler monkey, and *Cebus capucinus,* the white-faced capuchin monkey. These two species are not considered threatened; but the rapid conversion of the forests to isolated fragments in the Colombian mountains may carry a risk to primates and other wildlife found there (Defler, 2004).

Alouatta seniculus occurs from the north Colombian Andes to southern Bolivia. In Colombia, this herbivorous primate is found from 0 to 3200 m of altitude, in different forest types, including isolated remnants and secondary growth forest (Defler, 2004). *C. capucinus* is distributed from Central America to Colombia and northwestern Ecuador, between the Pacific Ocean and the Western Andes Mountains, reaching 1800 to 2000 m altitude. This omnivorous species prefers primary forest or advanced secondary forest, but is also found in degraded forest remnants (Hernández-Camacho and Cooper, 1976; Defler, 2004). In Colombia, the capuchins were found in the valley of the upper Cauca River, between Central and Western mountain ranges (where the Western cordillera is not high), but most of those population are locally extinct and the current

distribution is not well documented (Hernández-Camacho and Cooper, 1976; Defler, 2004).

In the eastern slope of the Western Cordillera of Colombia, *A. seniculus* and *C. capucinus* coexist in an isolated premontane forest fragment (Yotoco), and this is one of the few known localities where these species are sympatric. We estimated the population density of these two species in the fragment. For howlers, this is the first density survey in the Western cordillera and in the premontane forest life zone. For white-faced capuchins, this is one of the first population density reports for South America and this fragment is one of the last remnants in Colombia where the species survives other than the Pacific coast.

We expected to find a high density and abundance of howlers, due to their herbivorous diet, reduced space requirements, energy-saving strategy, and recognized ability to persist in fragmented environments (Crockett and Eisenberg, 1987; Crockett, 1998; Terborgh *et al.*, 2001; Bicca-Marques, 2003; Arroyo-Rodriguez and Dias, 2010). By contrast, for capuchins, we expected to find a low density in this isolated fragment, due to their high space requirements, high activity levels, and omnivorous diet (Oppenheimer, 1990; Fragaszy *et al.*, 2004). In past decades, capuchins and howlers were confiscated and released in Yotoco by the local environmental authority (Corporación Regional del Valle del Cauca, CVC), but no records were maintained. Therefore, the origin of the individuals in this fragment is unknown. It is possible that the current populations are a mixture of native and introduced individuals.

Methods

Study area

The Bosque de Yotoco Natural Reserve is an isolated forest fragment of 559 ha located in the eastern slope of the Western Cordillera of Colombia (3° 50' N, 76° 20' W) (Fig. 1), between 1200 and 1700 m of altitude. Yotoco has an average temperature of 20 °C and an average rainfall of 1500 mm per year (Escobar, 2001). The reserve is in transition between wet and dry pre-montane life form, according to Holdridge (Orejuela *et al.*, 1979). Yotoco was designated as a reserve in 1959 by local institutions for watershed protection. Most of the reserve is covered by mature forest and secondary vegetation in different stages of succession, due to the strong human disturbance that happened prior to its establishment as a protected area (logging, burning, and hunting, among others). Three species of primates inhabited this fragment: howlers, capuchins and owl monkeys (*Aotus* cf. *lemurinus*). Yotoco is immersed in a matrix of pastures for livestock. In these privately owned farms it is possible to find small forest remnants (< 10 ha), which are under pressure from hunting and logging. Despite the close proximity of these small remnants, the whole region is isolated from other primate populations (> 30 km).

Data collection

We conducted a line transect survey to estimate the density of primates from February to June 2004 (Peres, 1999). We established ten transects across the reserve (with an average length of 1.19 km). Each transect was walked 21.2 times on average, at a speed of approximately 0.5 km / hour on average. We carried out each census at 8:00 am (the presence of fog in the mountain forests prevents census earlier) with a return census walk at 14:00. We estimated the primate population density using DISTANCE 6.0 (Thomas *et al.*, 2009). This software calculates the probability of detection, modeled as a function of observed distances from the transect (using perpendicular distances), and then uses this probability to estimate the proportion of primate groups that were not detected in the sample (Thomas *et al.*, 2002). We compared six theoretical models on the distribution of observed distances: 1) half-normal with cosine expansion, 2) half-normal with hermite polynomial, 3) uniform with cosine, 4) uniform with simple polynomial, 5) hazard-rate with cosine, and 6) hazard-rate with simple polynomial. As recommended by Buckland *et al.* (2001) we chose for each species the model with the lowest Akaike Information Criterion (AIC) value.

Due to the short time interval to observe the groups during the census, we followed several groups of howlers out of the census routine for longer periods of time. This enabled

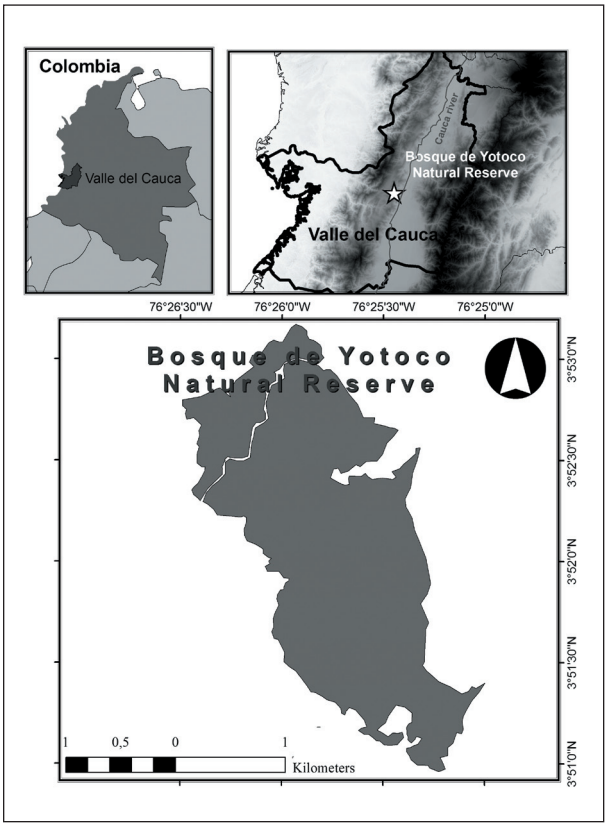

Figure 1. The Bosque de Yotoco Natural Reserve is an isolated forest fragment of 559 ha located in the eastern slope of the Western Cordillera of Colombia, between 1200 and 1700 m of altitude.

us to determine a more accurate group size, through direct counts of individuals (Pruetz and Leasor, 2002). Then, we calculated the howlers' density of individuals, introducing in DISTANCE as constants, the average and the standard error of the group size based on direct counts. In the case of capuchins, it was not possible to follow groups outside the census routine, due to time limitations. Therefore, we estimated the group size with data collected during the census (which implies that the population density may be underestimated). From preliminary analysis of the data, we found an inverse relationship between the perpendicular distance from the transect, and the number of individuals counted in a group ($F = 4.9$, $P < 0.05$, $R^2 = 0.19$). For this reason, we worked with the group size estimated from the perpendicular distance at zero meters, according to the regression model. We calculated the capuchins' density of individuals by multiplying the group density and the average group size (Peres, 1999). We calculated empirically the variance of population density for both species, using the sum of the group size, its sample variance of encounter rate and its detection probability (Thomas *et al.*, 2002).

Results

Our survey effort was a cumulative two-way distance of 241.1 km. We recorded 451 independent detections of howlers, from which 128 were solitary adults and subadults. We did not include solitary individuals in the analysis, since it is known that those individuals are usually attempting to join a group and the solitary condition is thus temporary. The mean number of howler groups observed per kilometer in each census was 1.5 (ranging from 0.5 to 2.6). The histogram of detection distances showed some outliers recorded further than 50 m, which affected the trend of this distribution. Then, the detection function was truncated at 50 m by removing 29 records of outliers. The uniform expansion model was used to estimate group density (Table 1), since this model yielded the best fit for distribution of perpendicular distances for howlers. For the howlers' density of individuals calculations, we estimated an average group size of 8.2 individuals (CI 95% = 6.5 - 9.9), which ranged from 4 to 14 (based on direct counts of 17 groups of howlers) (Table 1). Encounter rate for howlers was the variable that contributed the most to the variance of this species density (63%), followed by group size (32.2%) and detection probability (4.8%). The coefficient of variation for the individual and group density was 18.25 and 15.42%, respectively.

For capuchins, we recorded 35 independent detections, with 6 detections of solitary individuals (not included in the analysis, for reasons stated above). The average of capuchins groups registered per km during censuses was 0.15 (ranging from 0 to 0.29). A uniform model with cosine series expansion best fitted the distribution of perpendicular distances. With this model, we calculated the capuchins' density of groups (Table 1). The largest group size observed in capuchins was 9 individuals. From the census, we calculated a group size of 3.6 (CI 95% = 2.8 - 4.6) for this species. This value is lower than the estimated group size at the perpendicular distance at 0 m (according to the regression), which was 4.69 (CI 95% = 3.5 - 6.3). With these data, we calculated the density of individuals (Table 1). The component that contributed to the most variance of the density of this species was the encounter rate (62%), followed by group size (25.5%), and detection probability (12.5%). The coefficient of variation for the density of individuals and groups were 29.9 and 26.25% respectively.

Discussion

The density of howlers in this locality exceeds densities reported for this species in continuous lowland and montane forests, which usually range from 35 to 55 indv/km^2 (Gaulin and Gaulin, 1982; Crockett and Eisenberg, 1987; Chapman and Balcomb, 1998; Gomez-Posada *et al.*, 2007). However, it is consistent with densities found in fragmented landscapes of the Colombian Andes, which tend to exceed 150 indv/km^2 (Gomez-Posada *et al.*, 2009, in press). For the genus *Alouatta*, higher densities have been reported in forest fragments compared to continuous forest, and even some fragments have been reported overcrowded (Estrada and Coates-Estrada, 1996; Terborgh *et al.*, 2001; Cristobal-Azcárate *et al.*, 2005; Van Belle and Estrada, 2005). Forest fragments can act as refuges for species when former distribution ranges are reduced by habitat destruction, thus forcing the populations to be concentrated in protected spaces (Defler, 1981; Pruetz and Leasor, 2002).

The howler population size found in Yotoco is about 1000 individuals. A high population number could maintain the genetic variability in the long term (Robinson and Ramirez, 1982). Although the conditions of total isolation and high-density could cause negative effects in the population, it is known that this genus has the ability to persist in fragmented and disturbed environments (Rylands and Keuroghlian, 1988; Estrada and Coates-Estrada, 1996; Crockett, 1998; Mandujano *et al.*, 2004; Van Belle and

Table 1. Density and abundance of *A. seniculus* and *C. capucinus* in Yotoco Reserve (average / 95% interval of confidence).

Species	Density group/km^2	Density individuals/km^2	Abundance of groups	Abundance of individuals
Alouatta seniculus	20.6 (14.7-28.9)	169 (116-246)	131 (82.2-165.6)	943 (646-1376)
Cebus capucinus	3.02 (1.7-5.3)	13.5 (7.3-25.1)	16.88 (9.5-29.1)	76 (41-140)

Estrada, 2005). It is important to monitor birth and death rates, and changes in size and abundance of howler groups in the isolated Yotoco fragment over the long term.

Studies of *C. capucinus* in Central America have estimated densities from 5 to 50 individuals/km^2 in continuous forest (Fedigan *et al*., 1985; Robinson and Janson, 1987; Oppenheimer, 1990) and up to 60 individuals/km^2 in fragments (Pruetz and Leasor, 2002; DeGama-Blanchet and Fedigan, 2005). The capuchin density estimated in Yotoco is toward the low end of this range. Unlike howlers, capuchins in Yotoco had low population density and low population size (between 41 to 140 individuals). Low population size is one of the main mechanisms of extinction, as smaller populations have greater probabilities of extinction (Kattan and Alvarez-Lopez, 1996). A small, isolated population, such as the capuchins in Yotoco, could suffer loss of genetic diversity and inbreeding depression, with negative consequences for long term survival (Estrada and Coates -Estrada, 1996; Crockett, 1998; DeGama-Blanchet and Fedigan, 2005).

As expected, population densities of the two species of primates in Yotoco are conspicuously different. These species differ widely in terms of behavior, physiology and morphology. The red howler is a facultative folivore, with an energy saving strategy that allows great flexibility in their diet and behavior and enables low space requirements. For example, a group of howlers in Yotoco has a home range of about 13.5 ha (Palma *et al*. in press), much lower than the space required by a group of capuchins. These characteristics allow howlers to survive in forest fragments (Milton, 1980; Crockett and Eisenberg, 1987; Crockett, 1998; Bicca-Marques, 2003). In contrast, for capuchins, their omnivorous diet and high rates of activity necessitate large space requirements. In Panama, home range was estimated at 164 ha for one group (Oppenheimer, 1990). The capuchins consume mainly fruits and insects and supplementing their diet with flowers, invertebrates and small vertebrates including some eggs. Capuchins' diet should therefore be rich in energy and forces them to be very active in searching for food (Robinson and Janson, 1987; Oppenheimer, 1990; Defler, 2004; Fragaszy *et al*., 2004). These features can cause stress on capuchins inhabiting isolated localities, such as Yotoco.

For both species, rate of encounter was the component that most contributed to variance in the estimation of population density. For future surveys, we suggest using a greater number of transects to decrease the sampling error. The second component that contributed most to the variance was group size. This result reflects the high variation in the social structure of groups of both species. Alternatively, this variation may be an effect of the difficulty of counting the whole groups during the census, due to the inconspicuous behavior of howlers and the evasive actions of capuchins.

Forest protection and human interference largely determine the status of primate populations (Crockett, 1998; Chapman and Balcomb, 1998). In Yotoco after a long period of extractive human activities, bans on wildlife hunting activities and forest protection beginning in 1959 have probably benefited primate populations. For howler and capuchin monkeys, populations have reportedly grown with forest recovery (Crockett and Eisenberg, 1987; Fedigan and Jack, 2001). Unfortunately there are no previous studies in Yotoco, to verify population trends of these species in this fragment. The main threat to primate populations and other species in Yotoco is the high degree of isolation. However, the local environmental authority CVC has already started programs to purchase and protect adjacent lands. For example, on the south side of Yotoco there are several small fragments where capuchins have recently been observed (N. Roncancio, pers. obs). The protection and connection of these forests by corridors (such as live fences, forestry plantations, and shade plantations) may benefit the primates. In the short term, capuchins might benefit from forest regeneration in adjacent areas, as their morphology would allow rapid colonization of areas that are in a recovery process. In the medium term, howlers would use the new forests, where trees are large enough to support their weight and provide canopy connectivity (Fedigan and Jack, 2001; DeGama-Blanchet and Fedigan, 2005). However, the whole region is isolated from other primate populations, so the long-term survival of these two species depends on landscape-level management to reestablish physical and functional connectivity with other primate populations.

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