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Population Density of *Aotus* cf. *lemurinus* (Primates: Aotidae) in a Subandean Forest Patch on the Eastern Slopes of the Western Andes, Region of Dapa, Yumbo, Valle del Cauca, Colombia

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Abstract: Little is known of the demography of night monkeys, *Aotus*. The few studies that have been conducted in specific sites of the Amazon region do not allow for landscape-level inferences, and many of them fail in terms of the basic principles of statistical inference or are inadequate regarding assumptions of the methods used (replication and randomness). Night monkeys in the Colombian Andes inhabit generally fragmented landscapes of differing structure and composition (size, shape, isolation and vegetation types). However, there has been no quantitative diagnosis of their status or any effective monitoring of their populations. We estimated the population density of *Aotus* cf. *lemurinus* in a forest of about 900 ha on the eastern slopes of the Western Cordillera in the department of Valle del Cauca, Colombia, between 1,600 and 2,178 m above sea level. We used the Distance sampling method, with 30 linear transects with a total transect length of 9 km and a survey effort of 98.4 km. Surveys were conducted between 18:00 and 22:00 and between 03:00 and 06:00. The population density was estimated to be 113 individuals/km^2, one of the highest reported for the genus. This density could be a crowding effect related to the isolation process or a density compensation because of the reduced abundance of other species that may compete with night monkeys in some niche dimensions. A monitoring programme is needed to determine the trend of this population.

Introduction

Habitat loss is one of the most pervasive threats to biodiversity worldwide (Laurence *et al.* 2000). Forest loss causes the extirpation of forest-dependent species, but the viability of populations remaining in forest fragments is often uncertain and highly variable between species and populations (Laurence *et al.* 2002). An understanding of ecological parameters and a species' responses to environmental change is necessary to achieve effective conservation. Population biology theory and conservation management explicitly require accurate estimates of abundance to calculate the minimum sizes of viable populations (Begon *et al.* 2006). These data can be obtained through the estimation of population densities, understood as the number of individuals of a species in an area or habitat (Barrows 2001). Population density varies over time, and it is important that inferences about population trends should not be made based on assessments with limited geographic and temporal variation (Rudran and Duque 2003). It is also necessary to evaluate aspects such as group size and composition, as they are important elements in the dynamics that influence population density as a demographic parameter (Crockett and Eisenberg 1987). Data on density and age and sex composition of a population is important to understand tolerance to the loss or transformation of a species' habitat (Estrada *et al.* 1994, 1996; Cuarón 2000).

The original extent of occurrence of *Aotus lemurinus*, assuming an elevational range of 1,000 m to 3,000 m asl, was about 137,000 km^2 (Hernández-Camacho and Cooper 1976; Morales-Jiménez and de la Torre 2008, modified by the authors, taking altitude into account). We estimate that between 2007 and 2012, forests in the species' range were reduced by almost 3,000 km^2 (2.2% in five years), and more than 300 forest patches were lost. Forests in 28% of its range (38,700 km^2) are highly fragmented—more than 4,700 fragments that vary greatly in size (mean = 523 ha, median = 92 ha, SD = 5,390). More than 72,000 km^2 of its range are now largely a matrix of crops and cattle pasture (unpubl. data).

The Dapa region in the department of Valle del Cauca, Colombia, has a total area of 2,409 ha, and in 2007 there was

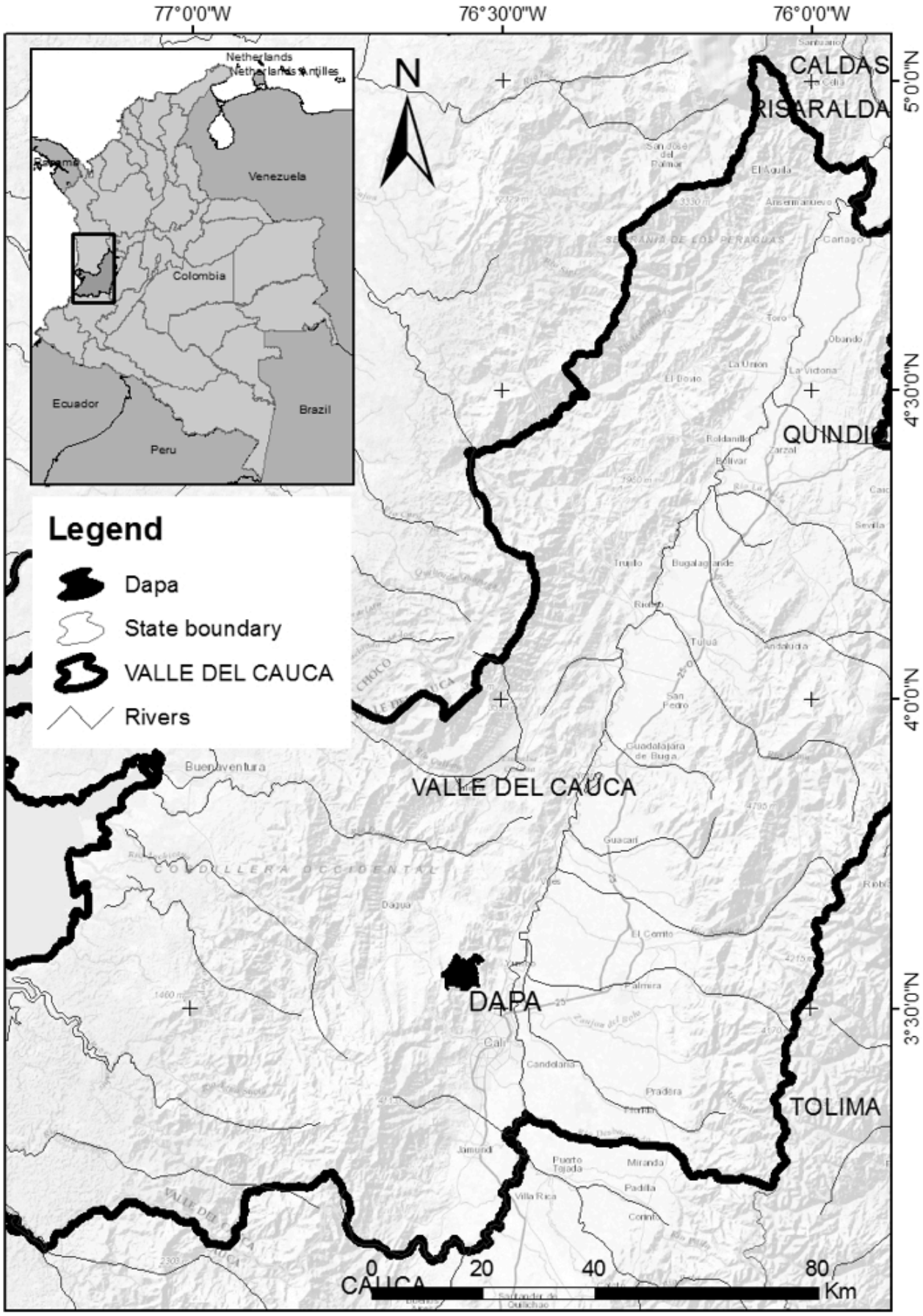

Figure 1. Study site.

at least one patch of dense forest of 262 ha, and a further 162 ha of successional vegetation (17% of the total area, although 512 ha of the aerial photograph analyzed was under cloud). By 2012, there was no dense forest remaining. The vegetation was transformed into 454 ha of fragmented forests and 612 ha of successional vegetation (44%). While it is possible that no forest had been lost, the increased degradation and fragmentation were evident.

Aotus lemurinus is classified as Vulnerable on the IUCN Red List of Threatened Species (Morales-Jiménez and de la Torre, 2008; Rojas-Diaz *et al.* 2012), and data on its habitat requirements and population numbers are needed for the formulation and implementation of conservation measures (Defler 2003). Here we estimate the population density of *Aotus* cf. *lemurinus* in Dapa, for comparison with density estimates from other regions (Heltne 1977; Green 1978; Rathbun and Gache 1980; Wright 1985; Zunino *et al.* 1985; Aquino and Encarnación 1986a, 1986b, 1988; García and Braza 1989; Stallings *et al.* 1989; Arditi and Placci 1990; Brown and Zunino 1994; Fernandez-Duque *et al.* 2001; Colombia, FIDIC 2007; Hernández and Diaz 2010; Maldonado 2011; Roncancio *et al*. 2012).

The study site is at the limits of the presumed ranges of *A. zonalis* and *A. lemurinus* (Defler 2010). The Andean or lemurine night monkey *A. lemurinus* occurs at higher elevations, above 1,000–1,500 m, whereas the Chocoan night monkey *A. zonalis* occurs in the lowlands to the west. These taxa are sibling species, and we refer to the night monkey in the Dapa region as *Aotus* cf. *lemurinus* pending confirmation of its identity using molecular genetic data.

Methods

Study site

The Dapa region is on the eastern slopes of the western cordillera near the city of Cali in the Cauca River Valley (3°33'46"N, 76°33'04"W), in the municipality of Yumbo, department of Valle del Cauca. Elevation in this region ranges from 1,000 to 2,200 m asl. The survey was carried out in an area of 2,409 ha. The native vegetation is Tropical Montane Cloud Forest (TMCF). The study was conducted in the forested area of Dapa (Fig. 1). Of a possible study site of about 993 ha, we selected three zones of about 300 ha, each covered largely by cloud forest. Members of the local community had confirmed that night monkeys occurred there, and also informed us that the type of forest was their natural habitat.

Data Collection

We carried out line transect surveys between March and July 2015. We used the Distance sampling method, counting night monkeys (single individuals or groups), and measuring the perpendicular distance from the path with a tape measure between the individual seen or the approximate center of the group and the transect (Buckland *et al*. 2001). We always tried to count the entire group, but usually that is not possible and there is a significant negative relationship between group size and perpendicular distance, and if we use the group mean to estimate the density, this could be an underestimate. To avoid this bias, we use the estimated group size using the regression with respect to group size and perpendicular distances. The distribution of detection distances was then used to build a detection function (detection probability as a function of distance from the transect) (Buckland *et al*. 2001). Transects were surveyed repeatedly to increase sample size for calculating encounter rate. A coefficient of variation (CV) was calculated from encounter rates, detection probabilities and group sizes. The CV was used to calculate a confidence interval.

We set up 30 transects in three blocks (10 in each block) throughout the study area. The total sampling effort was 98.4 km (180 surveys along 30 transects, with an average of six surveys of each transect). Surveys were conducted between 18:00 and 22:00 and between 3:00 and 6:00 based on the active periods of the night monkeys and as such to increase the detection probability. Surveys were carried out for 20 consecutive nights in each area, in each block of 10 transects. Each transect was walked as quietly as possible at an average speed of 0.6 km/h. To keep detectability constant along the transect we tried to walk at a constant speed, and when a group was located, the observers stayed with the group for a maximum of 15 minutes (Peres, 1999). For the majority of the records, however, it was, around three minutes. The night monkeys were located by the red light reflection of the eyes, by the typical click vocalization, and by the noise of them moving in the canopy, and only recorded when clearly identified as night monkeys (Fig. 2) rather other arboreal mammals such as *Potos* or *Bassarycion*.

Figure 2. Photograph of *Aotus* cf. *lemurinus* in Dapa. Photo by Armin Hirche, 2015.

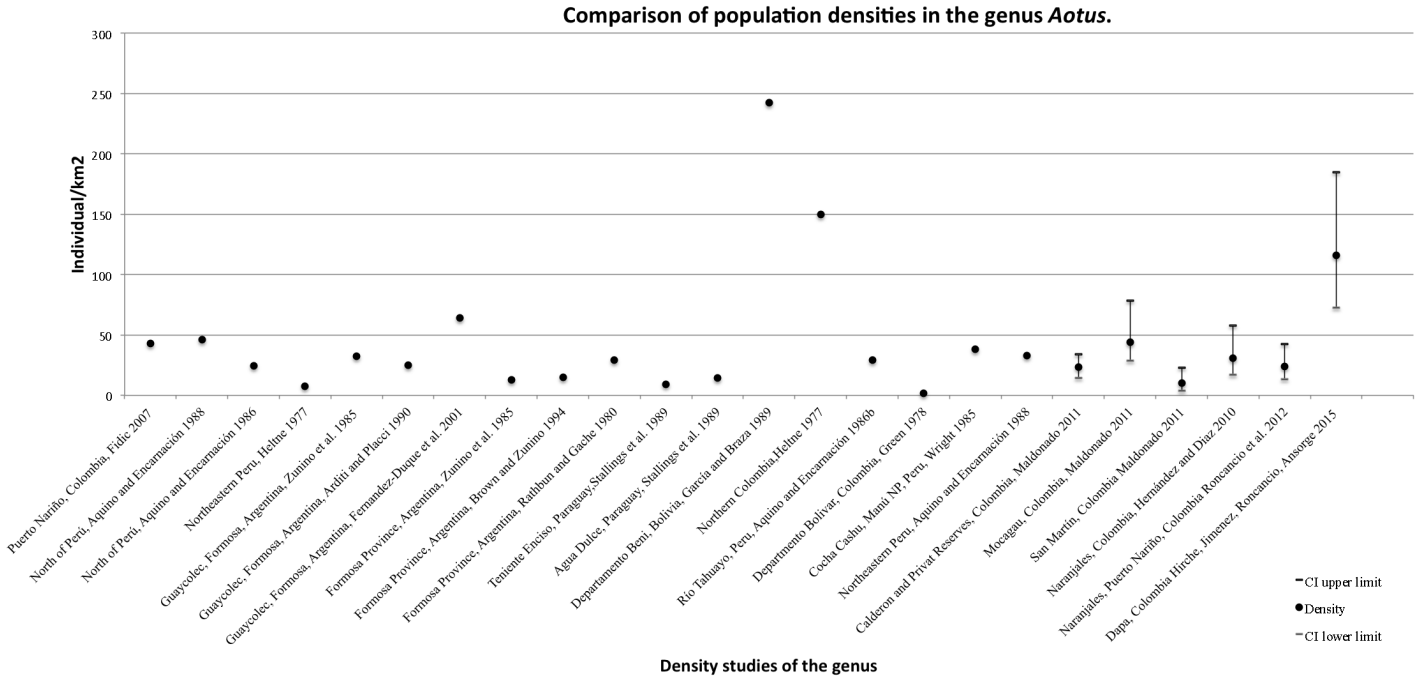

Figure 3. Comparison of population densities in the genus *Aotus.*

Data analyses

We analyzed data with the program Distance 7.0 (Thomas *et al.* 2009). Detection functions were selected according to the fit between the frequency distribution of detection distances and theoretical models (key and adjustment series) provided by the software Distance. The models that we tested were: half-normal (cosine, hermite polynomial), uniform (cosine, simple polynomial) and hazard rate (cosine, simple polynomial). We chose the model providing the best fit according to the Akaike Information Criterion (Buckland *et al*. 2001). The variance of population densities was empirically calculated as the sum of the sampling variances of encounter rates, the estimate of detection probability, and group size (Buckland *et al.* 2001).

We found a relationship between detection probability and group size. The use of mean group size underestimated population density (Buckland *et al.* 2001). Therefore, we used the expected group size estimated from the regression between group size and detection probability.

We used confidence intervals to compare population density estimates among localities. An overlap of >25% between the confidence intervals of two localities was interpreted as no significant difference in population density (Cumming *et al*. 2007).

Results

We obtained 59 records of *Aotus* cf. *lemurinus.* The encounter rate was 0.6 groups/km. Recorded group size ranged from one to five individuals. The frequency distribution of perpendicular distances presented a better fit using the Uniform with Cosine expansion series model. The estimated population density of the night monkeys was 113 ind/km^2 (95% CI = 70.79 to 180.65) and the estimated group density was 52.4 groups/km^2 (95% CI = 33.4 to 82.1), with CV of 23.65 and 22.55, respectively. The average group size was 2.2 individuals (95% CI = 1.9 to 2.5). The most important component of the variance of the density was the encounter rate (74.4%), followed by a probability of detection (16.5%) and by the group size (9%).

Discussion

The population density of *Aotus* in Dapa was significantly higher than estimates of *Aotus* densities in other localities, which mostly range from 30–40 ind/km^2 (Fig. 3). High population densities of primates in forest patches following deforestation have been explained as a crowding effect driven by the reduction and fragmentation of the habitat (Ramos-Fernandez and Wallace 2008). This situation of presumed overpopulation can lead to overexploitation of resources, predation, and reduced survival and birth rates (Milner *et al.* 1999; Begon *et al.* 2006), increased possibility of inbreeding, and possibly a reduction in population size (Estrada and Coates-Estrada 1996; Anzures-Dadda and Manson 2007). This high density could be a temporary situation, depending on the functional connectivity, the population dynamics in isolated conditions, and the viability of the population (Kattan and Álvarez-López 1996; Harcourt and Doherty 2005).

Of the four primates—*Alouatta seniculus*, *Ateles fusciceps* and *Cebus capucinus*, besides *Aotus*—that would have originally occurred in the area (Hernández-Camacho and Cooper 1976), we saw only night monkeys, so the high density of *Aotus* cf. *lemurinus* in this fragment could also result from

density compensation (MacArthur *et al.* 1972). It is probable that the local extinction or depletion of other primates or other species that are less tolerant to the reduction and fragmentation of the forest, or synergistic threats such as hunting (Jonsson *et al.* 2006; Arroyo *et al*. 2007) have reduced the competition in some niche dimensions (Hutchinson 1957), providing for an increase in carrying capacity for the population of *Aotus*. This phenomenon has been found for primates in the Amazon and Guiana Shield in areas that are heavily hunted. In places where the ateline population density has been reduced by hunting, the densities of non-hunted mid-sized primates increase (Peres and Dolman 2000; González-Solis *et al*. 2001). The white-footed tamarin (*Saguinus leucopus*) of the eastern slopes of the central Andean region, in the department Antioquia, show a similar pattern in forest fragments without *Ateles hybridus*, *Alouatta seniculus*, and *Cebus versicolor*, while in fragments with the complete primate assemblage densities were significantly smaller (Roncancio *et al*. 2011, in prep.).

In the study of Castaño *et al.* (2010) in the middle Cauca River basin, night monkeys ate the infructescence's of *Cecropia telealba* (Cecropiaceae), and the fruits (syconia) of *Ficus* cf. *maitin* and *Ficus* cf. *palmicida* (Moraceae) (Castaño and Cardona 2005; Castaño *et al.* 2010). *Cecropia telealba* is dominant in Dapa, which might be a factor promoting the high population density we recorded. The evidently high densities in these forest patches emphasize the importance of these habitats for the conservation of these night monkeys, and we have argued for their protection in regional action plans and besides recommended measures to increase connectivity between the fragments and to minimize the negative impact of their degradation due humans exploiting them for their resources.

To accurately determine the conservation status of a species through the analysis of changes in population density, it is necessary to assess habitat type at each site (successional stage, floristic assemblage, and plant phenology) and such as aspects as disturbance and hunting, and to carry out regular surveys to record any trends in population densities and size. For a monitoring programme to be effective we need to be able to detect change, a feature known as statistical power. The statistical power depends on the precision of the estimates of, in this case, population density. If we have a broad sampling error (e.g., coefficient of variation), a type II error (failure to detect change) is probable, with possibly grave consequences regarding management decisions (March and Trenham 2008). Here, the detectable change to this population based on the coefficient of variance is 16.71% two-tailed, or 5.2% one-tailed, with a statistical power of 0.8, and a significance level of 0.05 (Gerrodette 1987, 1991). To improve the analytic power of the distance sampling method, it is necessary to increase the sampling effort, mainly in the number of transects (sample units) since the component that most contributed to the variance was the encounter rate. Considering the threats faced by *Aotus* cf. *lemurinus*, the environmental NGO DapaViva will conduct surveys every three years to monitor their population density, to contribute to informed measures for their conservation.

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