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Chapter 16

CALLICEBUS ORNATUS, AN ENDEMIC COLOMBIAN SPECIES: DEMOGRAPHY, BEHAVIOR AND CONSERVATION

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ABSTRACT

Habitat loss and fragmentation are two of the main threats to primate species worldwide. Studies of species of *Callicebus* in forest fragments have highlighted the species´ ecological plasticity and adaptability of this genus. The aim of this chapter is to evaluate ecological and demographic aspects of dusky titi monkeys in fragmented areas and to elucidate possible features that make them tolerant to habitat loss and fragmentation. Using census data collected from two databases: 1) from a large fragment (1080 ha, from 2008-2013) and 2) from 46 fragments (range: 4.87-1080 ha, from 2013-2014), we found that *Callicebus ornatus* use of forest edge is significantly different from random ($p < 0.05$) for the largest fragment. All the other observations of *C. ornatus* groups made in this study were in forest fragment edges. These data support our hypothesis that this species prefers forest fragment edges to the interior of a forest. Vegetation analysis showed that forest near the edge of a large fragment was 1.4 times more diverse ($D = 0.953$) than forest 300-400 m from the forest edge ($D = 0.92$). We also found that group sizes and density indices are not significantly affected by fragment size ($p > 0.05$), although average group size and the average density indices for fragments of 1-50 ha present higher values compared to the other fragment size categories. Therefore, we did not find support for our hypothesis of fragment size as a determinant of group size and density for *C. ornatus*. A more detailed exploration of landscape, forest structure and resource availability variables is needed to understand how habitat loss and fragmentation is affecting this species. The findings in this chapter supports the ecological adaptability and plasticity of *Callicebus ornatus* through its ability to use the edge of forest fragments.

Keywords: *Callicebus ornatus,* habitat loss, fragmentation, use of edges, birth season

INTRODUCTION

Habitat loss and fragmentation are two of the main threats to primate species worldwide (Rylands et al., 2008; Marsh et al., 2013). These two processes occur at the landscape scale, affecting the amount of habitat available and how separate the fragments are in the landscape (Forman and Godron, 1986; Fahrig, 2003) and producing changes in species demography, behaviour and ecology (Boyle et al., 2009; Chapman et al., 2010; Gonzalez-Zamora et al., 2011; Boyle et al., 2012; Carretero-Pinzon, 2013a). Primate studies in fragments have been done mainly at the patch scale, evaluating the effect of fragment size and isolation on the primate species presence or absence and their densities (Harcourt and Doherty 2005; Arroyo-Rodriguez et al., 2013; Arroyo-Rodriguez and Fahrig 2014; Benchimol and Peres 2013). Primate responses to habitat loss and fragmentation have been found to be consistent across species, with increases of density, feeding behavior and parasitic prevalence and diversity, while genetic diversity and individual species´ presence decrease (Carretero-Pinzón et al., 2015). In Colombia, the main drivers of deforestation are population growth and migration, infrastructure projects, palm oil plantations, agriculture and cattle ranching (Etter et al., 2006; Fedepalma, 2014; Ecopetrol, 2015). These drivers are also some of the main factors affecting the loss of habitat for the dusky titi monkey (Carretero-Pinzon, 2013b).

Studies with species of *Callicebus* in forest fragments have highlighted the ecological plasticity and adaptability of the species of this genus (Pyritz et al., 2010). Occupancy data for species such as *C. moloch* have not found evidence of fragment size effects (Michalski and Peres 2005). However, for species living in caatinga forest (*C. coimbrai* and *C. barbarabrownae*) fragment size and groundwater seem to be important for their presence (Ferrari et al., 2013). Densities reported for *C. ornatus* in fragments are higher than those reported for the species in continuous areas (Polanco-Ochoa and Cadena 1993; Wagner et al., 2009; Carretero-Pinzon, 2013a). However, these two cited studies have small sample sizes for fragments and a larger sample is needed to understand if fragment size is affecting density and if so, in what way it is affecting it.

The dusky titi monkey (*Callicebus ornatus*) is a small Neotropical primate that lives only in Colombia. Studies of this species have been limited to undergraduate theses of short duration (6 months or less) focused on the ecology of this species in a continuous area (Polanco-Ochoa and Cadena, 1993) and ecology, behavior and densities in fragments of different sizes (Sanchez, 1998; Ospina, 2006; Wagner et al., 2009). Although dusky titi monkeys inhabit secondary forests and seem to adapt well to this habitat (Defler, 2010), we still don't know how much habitat loss and fragmentation are affecting their demography, ecology and behavior. Additionally, it seems this species prefers areas near fragment edges which can give them some advantages in fragmented landscapes where small and degraded fragments are available in which edge effects predominate. Studies of the effects of edge variables on forest dynamics in Amazonia have found that edge variables can affect forest dynamics up to 300 m from the edge (Laurence et al., 1998). Such forest dynamics affect forest-dependant animal populations such as primates. Primate studies have found that some species can be tolerant to edge effects and this tolerance can provide advantages for survival in forest fragments (Lehman et al., 2006; Quemere et al., 2010).

The aim of this chapter is to evaluate ecological and demographic aspects of dusky titi monkeys in fragmented areas, in order to elucidate possible features that make them tolerant to habitat loss and fragmentation. We hypothesized that the dusky titi monkeys is a species that prefers forest fragment edges to forest interior and this is one of the main features that allows them to survive in fragmented areas. Additionally, we hypothesized that forest edges might have a superior offering of foods compared to the interior in a large forest fragment. We also hypothesized that group size and density of this species is determined by fragment size. In order to test these hypotheses we ask the following questions: 1) Are dusky titi monkeys more common in fragment forest edges compared with fragment forest interior in a large fragment where edge and interior can be defined (1080 ha)? 2) Is the offering of foods somehow superior near the edge of large fragments? 3) Is there an effect of fragment size on dusky titi monkey group size and density? In addition, in this chapter we present data defining a birth season for *Callicebus ornatus* in fragmented areas and a list of plant species consumed by this species in the area.

MATERIALS AND METHODS

Study Area

This study was conducted near the town of San Martín de Los Llanos and neighboring towns (3°45’05.67”N 73°44’23.09”W to 3°25’10.57”N 73°26’20.00”W), Department of Meta, in the Colombian Llanos. This area has fragments of different sizes (range 4.61-1080 ha, Figure 1) surrounded by pastures, natural savannas, palm oil plantations and small scale agriculture. The presence of small forest fragments (less than 1 ha), isolated trees and live fences is common in some parts of the study area (Figure 2). Elevation varies from 300-400 meters. Five Neotropical primates are found in this area: *Sapajus apella fatuellus*, *Alouatta seniculus*, *Saimiri cassiquiarensis albigena*, *Callicebus ornatus*, and *Aotus brumbacki* (Carretero-Pinzón, 2013a). The weather in this area is characterized by a wet season (April-November, average 1777 mm) and a dry season (December-March, average 357 mm), with an annual average temperature of 26°C (Carretero-Pinzón, 2008). The vegetation of these fragments shared species richness with differences in the importance of plant species in each fragment (Stevenson and Aldana, 2008; Carretero-Pinzón, unpublished data). Fragmentation is an ongoing process in this region due to livestock practices, palm oil plantations and petrol exploitation (Wagner et al., 2009; Carretero-Pinzón 2013b; Carretero-Pinzón and Defler, in press).

Primate Surveys

The data presented in this chapter come from two databases. One database is of the largest fragment in the area (1080 ha) in which census surveys have been done from 2008 to

2013, every two to four months. These surveys were done in transects of 400-2600 m, in which edge effects were considered to penetrate the fragment up to 300 m from the edge (sensu Laurence et al., 1998, 2011). The other database includes survey data from 46 fragments conducted during 2013-2014. Surveys from both data sets were conducted from 0530 to 1100 and again from 1330 to 1630. Transects were walked at approximately 1.5 km/h. When a primate group was observed, a minimum of 15 minutes was taken to count the group members and to determine group composition (number of males, females, juveniles and infants). The coordinates of each group observation were registered using a GPS. Surveys were not conducted during heavy rain. *Ad libitum* observations of group composition and independent infants of the same groups in the largest (1080 ha) forest and three groups of a small fragment (23 ha) were taken. Plant species consumed during the census and during *ad libitum* observations were also recorded (data 2008-2014).

Data Analysis

Data surveys from the largest fragment were pooled and we used χ^2 tests (Zar, 1996) to test whether the frequency of observation of *Callicebus ornatus* groups in the fragment interior and fragment edge were significantly different from random. Also, we used a linear regression (Zar, 1996) to test if fragment size had an effect on group size and density index of *Callicebus ornatus*. Density indices were calculated as the total of individuals observed in a fragment divided by the number of surveys conducted in that fragment. For the statistical analysis we used R software (www.r-project.org).

Vegetation Analysis

A system of measured trails was developed outlining two hectares of forest. The first hectare was measured in a grid of four squares 50 m X 50 m (oriented linearly) under the home ranges of two *Callicebus ornatus* close to the forest edge (10-20 m). The second hectare was located in a large square (100 m X 100 m), divided into four parts (50 m X 50 m) by trails and located 300-400 m from the forest edge. All trees with DBH of 10 cm and above were marked in each hectare square with flagging tape and each individual tree was assigned a number. All DBH and tree heights were registered. Species determinations were made with the collaboration of Francisco Castro, a local botanic who is an expert on the local llanos vegetation. A Simpson Diversity Index was carried out for each 1 ha plot (Simpson, 1949).

RESULTS

Forest Fragment Edge Versus Interior Use by Groups of *Callicebus ornatus*

We conducted a total of 641 census hours (634.4 km) in the largest fragment (1080 ha), in which 92 vocal (66%) and visual (34%) contacts with *Callicebus ornatus* groups were registered. The proportion of observations of *C. ornatus* groups at the forest edge was significantly different from observations in the forest interior for both types of observations (Figure 3, $p > 0.05$).

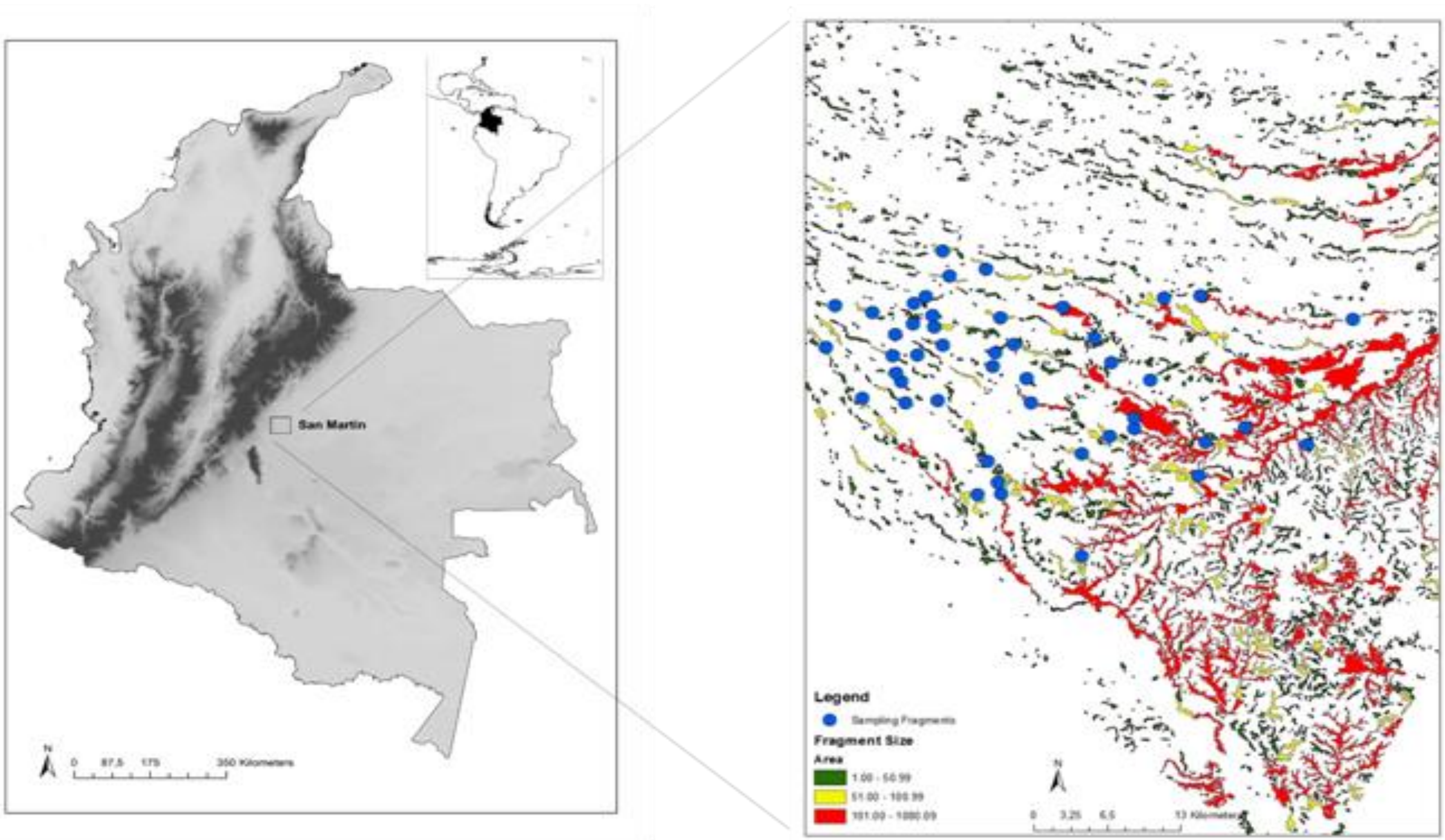

Figure 1. Locations of fragments sampled in the San Martin area, Colombia (total area of 1932 km^2).

Figure 2. Detail of the study area showing living fences and isolated trees (detailed area: 114 km^2).

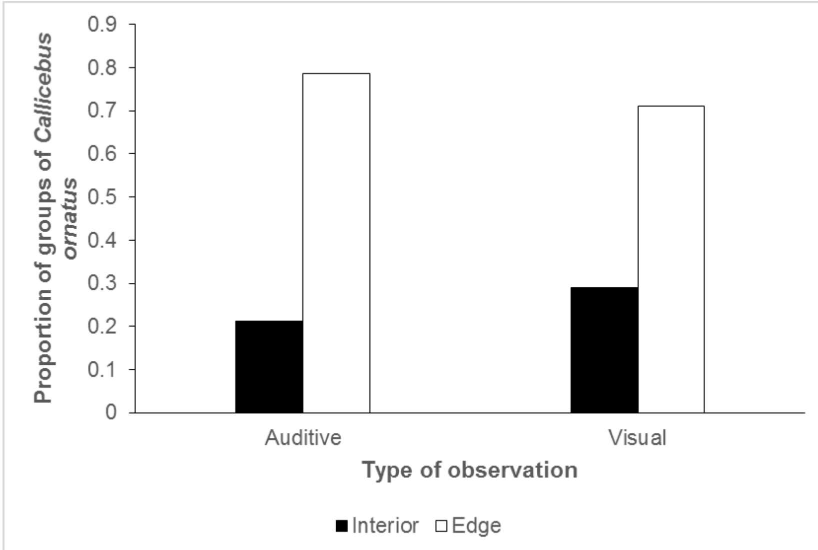

Figure 3. Proportion of *Callicebus ornatus* groups observed at the forest fragment edge versus the forest fragment interior, for auditive and visual types of observations.

Fragment Size Effects on Group Size and Density Index

We observed a total of 351 groups; this includes all groups observed and differentiated from the largest fragment and all groups observed in the other 46 fragments during 2013-2014. Although fragment size did not explain the variation in group size of *C. ornatus*, a tendency to reduce the group size, especially in fragments over 100 ha was observed (Figure 4; $R^2 = 0.001435$, df = 149, p = 0.6442).

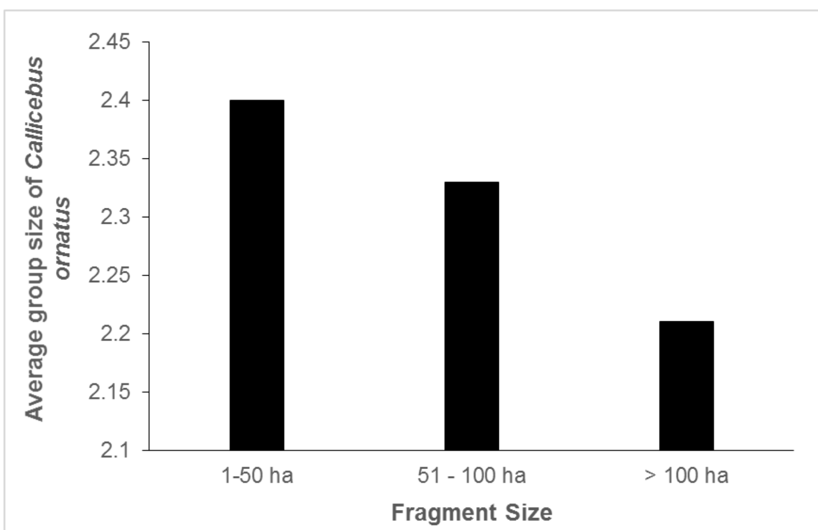

Figure 4. Variation of the average group size of *Callicebus ornatus* with fragment size.

Similarly, fragment size did not explain the density index found in the study area (Figure 5, $R^2 = 0.001435$, df = 149, p = 0.6442), however a tendency to reduce the density index in fragments over 50 ha was observed.

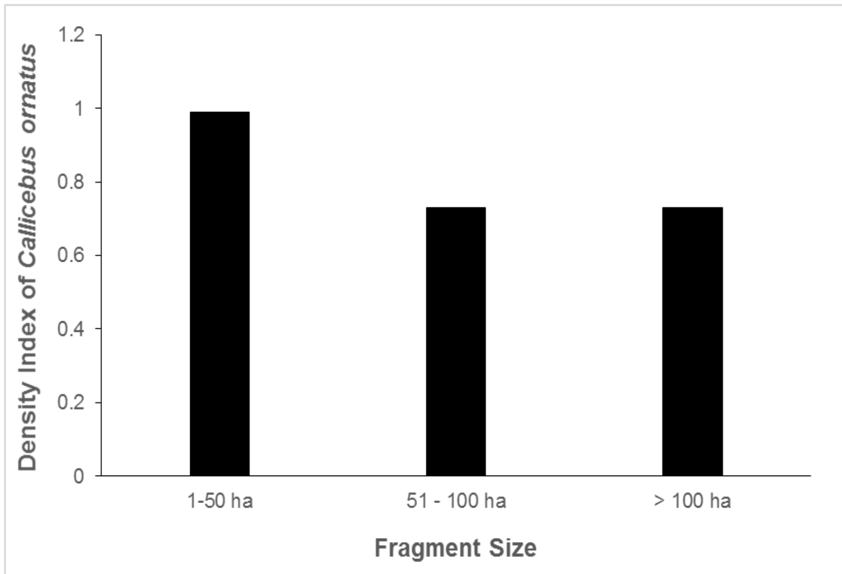

Figure 5. Density index of *Callicebus ornatus* in fragments of different size.

Diversity of Hectare Plots

The hectare plot near the edge of the forest (Plot 1) had 1.4 times more tree diversity (D = 0.953) as compared to the forest interior (Plot 2) (D = 0.92). Plot 1 had 452 trees of 10 cm and above, as compared to Plot 2 with 320 trees of 10 cm and above. The trees in Plot 1 were represented by 32 families and 75 species as compared to Plot 2, which had 24 families and 54 species of trees.

Additional Observations

A birth season has been observed in the study area with dependent infants (infants carried solely by the males) from December to March (73 observations): smallest infants have been observed in December and January. Data from repeated observations of the same groups in small fragments have shown independent movements of infants starting after three months of age and total independent movement after six months (repeated *ad libitum* observations of three groups).

A list of plant species consumed by the *C. ornatus* groups observed during the census is shown in Table 1. All the plant species consumed by the groups observed during the censuses were consumed for their fruits and the main plant families were Burseracea, Annonaceae, Fabaceae and Melastomataceae.

Table 1. List of plant species consumed by *Callicebus ornatus* groups observed during census (data from 2008-2013)

Species	Type of item consumed	Species	Type of item consumed	Species	Type of item consumed
Annonaceae		**Fabaceae**		**Moraceae**	
Rollinia cf edulis	Fr	Inga fastuosa	Fr	Pseudolmedia laevis	Fr
Xylopia sp.	Fr	Inga bonplondiana	Fr	Ficus americana	Fr
Xylopia polyantha	Fr	Inga cf. alba	Fr	**Salicaceae**	
Guatteria punctata	Fr	**Malpighiaceae**		Ryania spaciosa	Fr
Arecaceae		Byrsonima crispa	Fr		
Euterpe precatoria	Fr	**Marcgraviaceae**			
Mauritia flexuosa	Fr	Norantea guianensis	Fr		
Burseraceae		**Melastomataceae**			
Protium glabrescens	Fr	Miconia elata	Fr		
Trattinickia aspera	Fr	Bellucia grossularoides	Fr		
Protium cf. robustus	Fr	Miconia trinervia	Fr		
Crepidospermum rhoifolium	Fr	Henriettella cf. goudotiana	Fr		
Protium heptaphyllum	Fr	**Myristicaceae**			
Cecropiaceae		Virola sebifera	Fr		
Pouroma bicolor	Fr	Virola sp1.	Fr		
Clusiaceae		Virola sp2.	Fr		
Garcinia madruno	Fr	Irianthera laevis*	Fr		
Euphorbiaceae		**Myrtaceae**			
Hyeronima alchorneoides	Fr	Psidium guajaba	Fr		

DISCUSSION

The preference for forest fragment edges of *Callicebus ornatus* demonstrates that the species is ecologically adaptable enough to cope with habitat loss and fragmentation. These features make them more tolerant to habitat loss and fragmentation processes. However, this needs to be investigated in more detail as habitat loss and fragmentation are landscape processes. The high frequency of observations (visual and auditory) of *C. ornatus* in forest fragment edges can be explained by several aspects of their ecology. First, *C. ornatus* is a frugivorous species that complements its diet with arthropods (Fruit: 60%, Arthropods: 25.5%, Sanchez, 1998; Ospina, 2006). In addition, the ability of *C. ornatus* to exploit pioneer species such as fruits from *Bellucia* spp., *Miconia* spp., that are common in forest fragment edges (Sanchez, 1993; Ospina, 2006), give them an advantage for its frugivorous diet. Second, analysis of the vegetation diversity in the largest study fragment showed clearly that tree diversity was higher close to the edge and that there were considerably more trees available at a diameter at breast height (DBH) of 10 cm and above. So the fruit offerings were considerably more numerous in this part of the forest, compared to the forest 300-400 m towards the forest interior. Additionally, arthropod consumption could be increased due to an increase of arthropods in forest edges influenced by the amount of light in these areas (Marsh, 2003; Richards and Coley, 2007). Lastly, *C. ornatus* prefers to use habitats in which the proportion of vines is high (Polanco-Ochoa and Cadena, 1993), characteristic of forest fragment edges (Silver and Marsh, 2003).

Although we did not find significant effects of fragment size on *C. ornatus* group sizes and densities, a trend towards higher values in average group size and density indices for fragment forests under 50 ha was observed. Small fragment sizes are usually found in highly transformed landscapes (<10% of natural habitat remains, sensu McIntyre and Hobbs, 1999), where the amount of habitat available is lower, the number of fragments present are more isolated and the range of sizes is low (Wilcove et al., 1986; Fahrig, 2003). In this type of forest fragment, previous studies have found higher densities of *C. ornatus* in small fragments (Wagner et al., 2009; Carretero-Pinzón, 2013a), however these studies had small sample sizes. Fragment size has shown a general negative effect for most primate species (Golçalves et al., 2003; Wieczkowski, 2004; Wagner et al., 2009; Carretero-Pinzón, 2013a). However, this pattern can be influenced by resource availability and structural features of the forest fragments that were not considered in the present study. In addition, landscape variables such as patch density and percentage of forest cover can also influence the responses observed. Therefore, a study that includes variables related to resource availability and structural features, as well as landscape variables (a landscape approach), can give us a better understanding of the factors influencing the observed densities (Arroyo-Rodriguez and Fahrig, 2014).

A tendency of larger average groups in fragments under 50 ha suggests possible effects of the fragmentation and habitat loss processes that produce these small fragments (Wilcove et al., 1986; Fahrig, 2003). These high average values in group size also might reflect possible problems for individual dispersion that have been suggested by other authors that could produce these crowded fragments (Wagner et al., 2009; Defler, 2010; Carretero-Pinzon, 2013a). In addition, low individual dispersion and the increase of individuals in groups could cause effects on fitness due to higher stress level that make individuals more prone to parasitic infestation and other health problems (Gillespie and Chapman, 2006; Irwin, 2010; Jaimez et al., 2012).

In conclusion, *C. ornatus* preference for forest fragment edges increases their tolerance to habitat loss and fragmentation effects, however as these are landscape processes, more studies in which landscape variables are evaluated in relation to the presence and abundance *C. ornatus* are necessary. Additionally, although we did not find an effect of fragment size on group size and density index, the tendency observed of higher values in these two parameters in fragments under 50 ha indicates possible effects of habitat loss and fragmentation on demographic aspects of this species that need to be studied in more detail, especially for small fragments (<50 ha). Conservation strategies for *Callicebus ornatus* require more detailed information on the basic ecology of this species in fragmented areas as well as studies evaluating landscape variables that could be affecting its dispersal patterns.

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REFERENCES

Arroyo-Rodriguez, V. and Fahrig, L. (2014). Why is a Landscape perspective important in studies of primates? *American Journal of Primatology*, 76(10), 901-909.

Arroyo-Rodriguez, V. Cuesta-del Moral, E. Mandujano, S. Chapman, C. A. Reyna-Hurtado, R. and Fahrig, L. (2013). *Assessing habitat fragmentation effects on primates: the importance of evaluating questions at the correct scale.* In Marsh, L. K. and Chapman, C. A. (Eds.) Primates in Fragments: Ecology and Conservation, Developments in Primatology: Progress and Prospects. Springer Science + Business Media, New York, pp. 13-28.

Benchimol, M. and Peres, C. A. (2013). Anthropogenic modulators of species-area relationships in Neotropical primates: a continental-scale analysis of fragmented forest landscapes. *Diversity and Distributions*, 19, 1339-1352.

Boyle, S. and Smith, A. (2010). Behavioural modifications in northern bearded saki monkeys (*Chiropotes satanas chiropotes*) in forest fragments of central Amazonia. *Primates* 51: 43-51.

Boyle, S. A. Lourenço, W. C. da Silva, L. R. and Smith, A. T. (2009). Travel and spatial patterns change when *Chiropotes satanas chiropotes* inhabit forest fragments. *International Journal of Primatology* 30, 515-531.

Boyle, S. A. Zartman, C. E. Spironello, W. R. and Smith, A. T. (2012). Implications of habitat fragmentation on the diet of bearded saki monkeys in central Amazonian forest. *Journal of Mammalogy* 93(4), 959-976.

Carretero-Pinzón X. (2008). *Efecto de la disponibilidad de recursos sobre la ecología y comportamiento de Saimiri sciureus albigena en fragmentos de bosque de galería, San Martín (Meta-Colombia)*, Masters thesis, Pontificia Universidad Javeriana, Bogotá, Colombia, p. 132.

Carretero-Pinzón, X. (2013a). *An eight year life history of a primate community in fragments at Colombian Llanos*. In Marsh, L. K. and Chapman, C. A. (Eds.). Primates in Fragments: Complexity and Resilience, Developments in Primatology: Progress and Prospects. (pp. 159-182). Springer Science + Business Media, New York, USA.

Carretero-Pinzón, X. (2013b). *Population density and habitat availability of Callicebus ornatus, a Colombian endemic titi monkey*. In: Especies de Primates Colombianos en Peligro de Extinción. Defler, T. R., Stevenson, P. R., Bueno M. L. and Guzman D. C. Panamericana, Bogota, Colombia, pp. 160-169.

Carretero-Pinzon, X. and Defler, T. R. (in press). *Primates and flooded forest in the Colombian Llanos*. In Barnett A. A., Matsuda I. & Nowak K. (Eds.). Primates in flooded habitats: ecology and conservation. Cambridge. Cambridge University Press.

Carretero-Pinzón, X., Ruíz-García, M., and Defler, T. R. (2010). *Uso de cercas vivas como corredores biológicos por primates en los llanos orientales.* In Pereira, V., Stevenson, P. R., Bueno, M. L., and Nassar-Montoya, F. (Eds.). Libro del Primer Congreso Colombiano de Primatología). (pp. 91-98). Fundación Universitaria San Martin, Bogotá.

Carretero-Pinzon, X. Defler, T. R. McAlpine, C. A. and Rhodes, J. R. (2016). What do we know about the effect of patch size on primate species across life history traits? *Biodiversity and Conservation*, 25 (1), 37-66.

Chapman, C. A. Struhsaker, T. T. Skorupa, J. P. Snaith, T. V. Rothman, J. M. (2010). Understanding long-term primate community dynamics: implications of forest change. *Ecological Applications*, 20(1), 179-191.

Defler, T. R. (2010). *Historia Natural de los Primates Colombianos*. Universidad Nacional de Colombia, Bogotá, Colombia, p. 612, Ecopetrol (2015). http://www.ecopetrol.com.co/especiales/Sustainability-report-2014/espanol/principal/nuestra-cadena-de-valor/produccion. (Accessed October 22nd, 2015).

Etter, A. McAlpine, C. Pullar, D. and Possingham, H. (2006). Modelling the conversion of Colombian lowland ecosystems since 1940: drivers, patterns and rates. *Journal of Environmental Management* 79, 74-87.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology and Systematics* 34, 487-515.

Fedepalma (2014) *Anuario Estadistico 2014: la agroindustria de la palma de aceite enColombia y en el mundo: 2009-2013*. Javegraf, Bogotá**.**

Ferrari, S. F. Santos Jr., E. M. Freitas, E. B. Fontes, I. P. Souza-Alves, J. P. Jerusalinsky, L. Beltrão-Mendes, R. Chagas, R. R. D. Hilário, R. R. Baião, S. A. A. (2013). *Living on the edge: habitat fragmentation at the interference of the semiarid zone in the Brazilian Northeast.* In Marsh, L. K. and Chapman, C. A. (Eds.). Primates in Fragments: Complexity and Resilience, Developments in Primatology: Progress and Prospects. (pp. 121-136) Springer Science + Business Media, New York, USA.

Forman, R. T. T. and Godron, M. (1986). *Landscape Ecology*. John Wiley & Sons, Inc. USA, p. 619.

Gillespie, T. R. and Chapman, C. A. (2006). Prediction of parasite infection dynamics in primate metapopulations based on attributes of forest fragmentation. *Conservation Biology*, 20 (2), 441-448.

Gonçalves, E. C. Ferrari, S. F. Silva, A. Coutinho, P. E. G. Menezes, E. V. Schneider, M. P. C. (2003). *Effects of habitat fragmentation on the genetic variability of silvery marmosets, Mico argentatus*. In Marsh, L. K. (Eds.). Primates in Fragments: Ecology and Conservation. (pp. 17-28). Kluwer Academic/Plenum Publ., New York.

Gonzalez-Zamora, A. Arroyo-Rodriguez, V. Chaves, O. M. Sanchez-Lopez, S. Aureli, F. and Stoner, K. E. (2011). Influence of climatic variables, forest type and condition on activity patterns of Geoffroyi's spider monkeys throughout Mesoamerica. *American Journal of Primatology*, 73, 1189-1198.

Harcourt, A. H. and Doherty, D. A. (2005). Species-Area Relationships of Primates in Tropical Forest Fragments: A Global Analysis. *Journal of Applied Ecology*, 42(4): 630-637.

Irwin, M. T. Junge, R. E. Raharison, J. L. Samonds, K. E. (2010). Variation in physical health of diademed sifakas across intact and fragmented forest at Tsinjoarivo, Eastern Madagascar. *American Journal of Primatology*, 72, 1013-1025.

Jaimez, N. A. Bribiescas, R. G. Aronsen, G. P. Anestis, S. A. and Watts, D. P. (2012). Urinary cortisol levels of gray-cheeked mangabeys are higher in disturbed compared to undisturbed forest areas in Kibale National Park, Uganda. *Animal Conservation*, 15: 242-247.

Laurence, W. F. Ferreira, L. V. Rankin-de Merona, J. M. and Laurence S. G. (1998). Rain forest fragmentation and the dynamics of Amazonian tree communities. *Ecology*, 79(6), 2032-2040.

Laurence, W. F. Camargo, J. L. C. Luizão, R. C. C. Laurence, S. G. Pimm, S. L. Bruna, E. M. Stouffer, P. C. Williamson, G. B. Benitez-Maldivo, J. Vasconcelos, H. L. Van Houtan, K. S. Zartman, C. E. Boyle, S. A. Didham, R. K. Andrade, A. and Lovejoy, T. E. (2011). The fate of Amazonian forest fragments: A 32 year investigation. *Biological Conservation*, 144, 56-67.

Lehman, S. M. Rajaonson, A. and Day, S. (2006). Edge effects and their influence on lemur density and distribution in southeast Madagascar. *American Journal of Physical Anthropology*, 129, 232-241.

Marsh, L. (2003). *The nature of fragmentation*. In Marsh, L. K. (Ed.) Primates in fragments: ecology in conservation, (pp. 1-8). Kluwer Academic/Plenum Publishers, N.Y. USA.

Marsh, L. K. Chapman, C. A. Arroyo-Rodriguez, V. Cobden, A. K. Dunn, J. C. Gabriel, D. Ghai, R. Nijman, V. Reyna-Hurtado, R. Serio-Silva, J. C. and Wasserman, M. D. (2013). *Primates in fragments 10 years later: once and future goals*. In Marsh, L. K. and Chapman, C. A. (Eds). Primates in Fragments: Complexity and resilience, Developments in Primatology: Progress and prospects, (pp. 503-523), Springer Science + Business Media, New York.

McIntyre, S. and Hobbs, R. (1999). A framework for conceptualizing human effects on landscapes and its relevance to management and research models. *Conservation Biology*, 13(6), 1282-1292.

Michalski, F. and Peres, C. A. (2005). Anthropogenic determinants of primate and carnivore local extinctions in a fragmented forest landscape of southern Amazonia. *Biological Conservation*, vol. 124, pp. 383-396.

Ospina, M. J. (2006). *Comparación de los patrones comportamentales de Callicebus cupreus ornatus durante dos épocas estacionales en un fragmento de bosque de galería, en San Martin (Meta).* Undergraduate thesis, Pontificia Universidad Javeriana, Bogota.

Polanco-Ochoa, R. and Cadena, A. (1993). Use of space by *Callicebus cupreus ornatus* (Primates: Cebidae) in La Macarena, Colombia. *Field Studies of New World Monkeys, La Macarena, Colombia,* 8, 19-32.

Pyritz, L. W. Bürntge, A. B. S. Herzog, S. K. and Kessler, M. (2010). Effects of habitat structure and fragmentation on diversity and abundance of primates in tropical deciduous forest in Bolivia. *International Journal of Primatology*, vol. 31, pp. 796-812.

Quemere, E. Crouau-Roy, B. Rabarivola, C. Louis Jr., E. E. and Chikhi, L. (2010). Landscape genetics of an endangered lemur (*Propithecus tattersalli*) within its entire fragmented range. *Molecular Ecology*, 19, 1606-1621.

Richards, L. A and Coley P. D. (2007). Seasonal and habitat differences affect the impact of food and predations on herbivores: a comparison between gaps and understory of tropical forest. *Oikos*, 116, 31-40.

Rylands, A. B. Williamson, E. A. Hoffmann, M. and Mittermeier, R. A. (2008). Primate surveys and conservation assessments. *Oryx*, 42(3), 313-314.

Sanchez, I. M. (1998). *Contribución al conocimiento de la ecología de Callicebus cupreus ornatus Gray 1870 (Primates: Cebidae), en bosques fragmentados del Meta, Colombia*. Undergraduate thesis, Universidad Nacional de Colombia, Bogota.

Silver, S. and Marsh, L. (2003). *Dietary flexibility, behavioral plasticity, and survival in fragments: Lessons from translocated howlers*. In Marsh, L. K. (Ed.). Primates in fragments: Ecology and conservation, (pp. 251-266), New York.

Simpson, E. H. (1949). Measurement of diversity. *Nature* 163: 688.doi:10. 1038/163688a0.

Stevenson, P. R. and Aldana, A. M. (2008). Potential effects of Ateline extinction and forest fragmentation on plant diversity and composition in the western Orinoco Basin, Colombia. *International Journal of Primatology*, 29, 365-377.

Stevenson, P. R. Quiñones, M. J. and Ahumada, J. A. (1994). Ecological strategies of woolly monkeys (*Lagothrix lagothricha*) at Tinigua National Park, Colombia. *American Journal of Primatology*, 32, 123-140.

Wagner, M. Castro, F. Stevenson, P. R. (2009). Habitat characterization and population status of the dusty titi monkey (*Callicebus ornatus*) in fragmented forest, Meta, Colombia. *Neotropical Primates*, 16(1), 18-24.

Wieczkowski, J. (2004) Ecological correlates of abundance in the Tana mangabey (*Cercocebus galeritus*). *American Journal of Primatology*, 63: 125-138.

Wilcove, D. S. McLellan, C. H. and Dobson, A. P. (1986). *Habitat fragmentation in the temperate zone.* In: Conservation Biology Soulé, M.E. (Ed.), Sunderland, MA: Sinauer, pp. 237-256.

Zar, J. H. (1996) *Biostatistical analysis*. Prentice Hall International Editions. Third Edition. Upper Saddle River, New Jersey, 662.

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