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Habitat Characterization and Population Status of the Dusky Titi (*Callicebus ornatus*) in Fragmented Forests, Meta, Colombia

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Introduction

Tropical forests have important ecosystem functions such as soil protection, climate regulation, supply of goods, etc. (Foley *et al.*, 2007). In Colombia, an accelerated process of transformation of natural ecosystems is occurring, which results in habitat reduction and fragmentation. It has been estimated that a third of the country´s forest cover has been eliminated (Alexander von Humboldt Institute *et al.*, 1997), and the principal causes of deforestation are the expansion of the agricultural frontier and colonization. In fact, Colombia is the fourth country with highest levels of deforestation among South American countries (FAO, 2006). In Orinoquia, colonizers have converted forest to savanna ecosystems for agriculture and livestock. Furthermore, recently the African oil palm industry has greatly expanded with government support (Moreno, 2000) and Meta department ranks first in the nation as a producer of African palm (*Phoenix dactylifera*). The land destined to this cropping system covers 47,525 ha, and the production is estimated to be increased by 35,000 ha in the next few years (Gobernación del Meta, 2006), which implies more land conversion and, therefore, further habitat destruction. According to local inhabitants, in the 1940s the study region (San Isidro de Chichimene, Acacías) was an intact forest. Since then, agriculture has greatly expanded in the region with the production of corn, coffee and cassava, and wood extraction and hunting have also increased. In a period of only 30 years colonists have depleted the forests by creating fragments that continue to be intervened through time. Currently, livestock and the expansion of oil palm are the principal causes of deforestation in the region. Earlier deforestation in the region created forest fragments especially fragments along streams in which many species have become isolated. Such is the case of the Vereda San Isidro de Chichimene, a fragmented landscape which still holds rich fauna and flora.

The Colombian endemic primate *Callicebus ornatus* inhabits this region and it has been classified as vulnerable by the IUCN (VU B1ab (iii)) (IUCN, 2008). According to Defler (2004), *Callicebus ornatus* populations are small, and their major threat is colonization; "since *C. ornatus* is endemic to Colombia, its conservation within the country is very important". He recommended censuses to evaluate the species' status in detail and proposed local environmental education campaigns, to insure its survival. Traditionally, primate studies have been conducted in reserve areas. However, the risk of extinction is highest for small populations that are generated when the habitat is fragmented or modified. For this reason, studies outside reserves could help to evaluate the status of such species (Chapman and Peres, 2001), their responses to disturbance, and extinction risk. Furthermore, fragmentation has caused a reduction in plant species diversity and composition in the region (Stevenson and Aldana, 2008). Since fruit production and plant composition may affect primate populations (Stevenson, 2001), we were also interested in the potential effects of vegetation composition on the populations of *C. ornatus*. We were also interested in the potential effects of fragment size (i.e., the area of each fragment) on the population density of the primates, since this factor has demonstrated to have strong effects on primate demographic patterns (Marsh, 2003). In this study, a census of *Callicebus ornatus* and a vegetation sampling were conducted in forest fragments in Vereda San Isidro de Chichimene, to evaluate the status of this species and to determine conservation implications in private lands.

Methods

Study Area

The Vereda San Isidro de Chichimene is located in the Municipality of Acacias in the department of Meta (480 m a.s.l., 73°42'W, 03°55'N). This region corresponds to a very humid tropical forest (Agustín Codazzi Geographic Institute, 1995). Photographic images were taken to register the landscape heterogeneity and the forest cover was described by a LANDSAT image (2000, Figure 1) provided by RedVerde.

The study was carried out in private land. Eight fragments were studied (Figure 2) within 86.24 ha of forest, which corresponded to 8.5% of forest cover remnants in a total of 1010 ha (framed area in Figure 1). The forest remnants consist mainly of riparian secondary forest. These forests tend to be narrow with an average width of 30 m, and show large variations in age and degree of human intervention.

Census of Callicebus ornatus

The census was carried out from January to March 2007 by one, and sometimes two observers, between 5:30 and 12:30 h, during a total of 392 h. Each fragment was visited 12 times. When a primate was detected, the following data were registered: (1) time, (2) group size, (3) group composition, (4) geographical position (GPS, Garmin eTrex, Legend), (5) special traits of individuals, (6) activity of animals when encountered (Williamson and Feistner, 2003). A map of the study area was generated using GPS (Figure 2). Routes through forest fragments and coordinates of group locations were transferred to a PC using MapSource 6.9.1 software. Population densities were based on the number of groups and individuals per group in each fragment (only fragments with more than 3 groups were considered in further analyses: fragments 1, 3, 5 and 8), and forest areas were estimated from the map using GIS tools. Eight fragments were selected in the study area and, since the fragments were not wide (mean 30m. wide), we tried to count all individuals and groups by direct observations from the trails (total length = 57.1 km, estimated from the map). Age categories were determined by size according to Kinzey (1981): Infant, individual depending on locomoting adults; Juvenile I, a second year individual (4–12 months); and Juvenile II a third year individual (12–24 months), sub-adults and adults. Morning calls of *Callicebus* were important cues for detecting them, since they helped to locate the groups. In the afternoon *Callicebus ornatus* is less active than in the morning and vocalizations are not very common, for this reason the census was restricted to morning hours. Whenever possible, photographs were taken with a digital camera to allow differentiation of groups. In the widest fragment (no. 1), walking along trails was not an effective way for detecting all individuals of *Callicebus ornatus*, since low visibility in and cryptic behavior made their detection difficult. For this reason, in fragment no.1, two observers always performed censuses early in the morning, when the vocalizations started. Photographs and the number of group members allowed group differentiation Vocalizations "chirrups" were also used to locate individuals. Juveniles were differentiated by the description of the white head band which develops after the sixth week (Kinzey, 1981). The relationship between *C. ornatus* population densities and the area of the fragment was assessed using simple regression analysis.

Vegetation Sampling

From April to June, 2007 floristic inventories of trees (>10 cm diameter at breast height) were conducted in two plots of 1-hectare (200 m × 50 m) in the fragment 1, divided in 100 m^2 subplots. We considered two contrasting vegetation types found in forest fragments. One plot was built in less disturbed forest and the second one

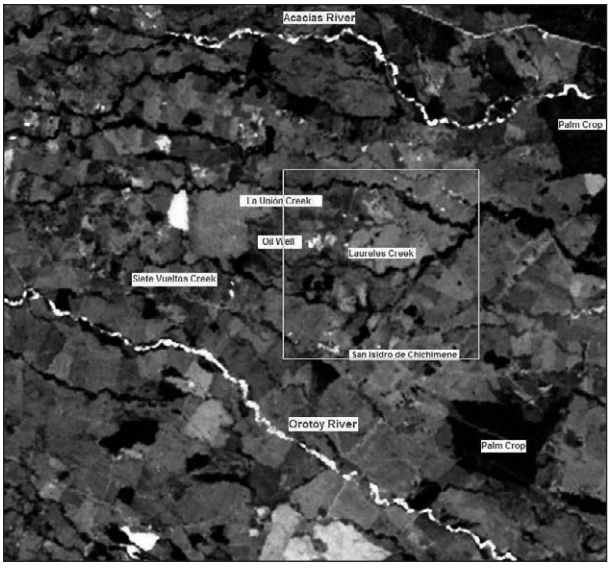

Figure 1. LANDSAT image (RedVerde, 2000). The square indicates the study area, black zones correspond to forests and palm crops.

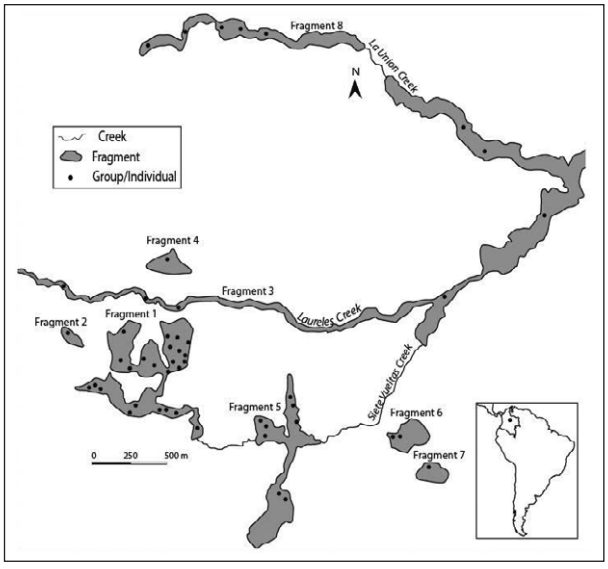

Figure 2. Study site. Fragments where censuses were carried out. Points indicate groups and individuals observed .

is a secondary forest (50 years old). Less disturbed forest refers to a primary forest with some degree of human intervention (i.e. selective logging has occurred in the past). Census methodology was based on two guides of the IAvH (Alexander von Humboldt Institute) (Villareal *et al.*, 2006 and Vallejo-Joyas *et al.*, 2005). Trees in each plot were marked with numbered aluminum tags. Sterile and fertile material were collected and identified by the authors and compared with vouchers in Los Andes University Herbarium and the SINCHI (Institute for Scientific Amazonian Research) herbarium. A species accumulation curve was determined by the program EstimateS, Version 7.5 (Colwell, 2005). Importance indexes were determined by adding the relative frequency, relative density and the relative basal area.

Results

Census of Callicebus ornatus

Four primate species inhabit the fragments in the study area: *Saimiri sciureus* (Squirrel monkey), *Cebus apella* (Capuchin), *Aotus brumbacki* (Night monkey) and *C. ornatus* (Titis). Forty three titi groups were detected (Table 1) and its age categories are described in Table 2. The population density was found to be 192.2 individuals/km^2 (Table 3).

There was no relationship between fragment size and population density of C*allicebus ornatus* in the fragments studied ($F = 5.12$, $p = 0.15$).

Vegetation Sampling

A total of 136 tree species (>10cm DBH) were found in 2 ha. The plant species accumulation curves for each plot do not reach an asymptote and show that the less disturbed forest is more diverse than the secondary forest (Figure 3). The density of *Callicebus ornatus* in the secondary forest was 559.1 ind/km^2 and 188.2 ind/km^2 in the less disturbed forest.

A total of 1,070 trees were marked. Tree density was 571 individuals/ha in the less disturbed forest and 499 individuals/ha in the secondary forest. The less disturbed forest plot shares 26.2% of the plant species with the secondary forest. The percentage of species found only in less disturbed forest was higher than the percentage unique to secondary forest (73.8 vs. 55%). In the less disturbed forest *Socratea exorrhiza, Oenocarpus bataua* and *Mabea maynensis,* were the most important species (Table 4). In the secondary forest *Casearia sp, Apuleia leiocarpa* and *Jacaranda copaia* dominated.

Discussion

Census of Callicebus ornatus and considerations for its conservation

Agriculture expansion has caused fragmentation in the study area and the remnants are linear tracts along waterways in a pastureland matrix. Deforestation has caused loss of biodiversity and ecosystem degradation in the region (Stevenson and Aldana 2007). Despite the highly disturbed habitat in the region, some endemic and charismatic species survive (*e.g.*, titi monkeys, night monkeys, otters, and giant anteaters). The population density of species, such as *Callicebus ornatus* is high in the fragments (192.2 individuals/km^2) and even higher than estimates reported for undisturbed forest in the same region (8 individuals/km^2; Polanco, 1992). However, it is important to consider these comparisons with caution because differences in the census methods and a lower visibility in the primary forest could result in an underestimation of *C. ornatus* populations. However, these large differences indeed reflect variation in group density, since group size was similar in fragments and undisturbed forests (Polanco, 1992).

On other grounds we found considerable variations in density estimates between fragments that were not explained by area nor by hunting pressure (currently local people do not hunt primate species in the region), but may be associated with fine grained variations in resources, and other demographic and history processes. *Callicebus ornatus* can survive in secondary forest because pioneer plants are important in their diet (Mason, 1968; Hernández-Camacho and Cooper, 1976; Polanco, 1992; Sánchez, 1998). Other important aspects of their survivorship in degraded forest are their frugivorous-folivorous-insectivorous diet, small size (Fimbel, 1994), and the local extinction of competitors such as large-bodied primate species that have historical records in the area (Stevenson & Aldana, 2008). For instance, fragment 3 showed the lowest population density (60 individuals/km^2). Two reasons could be influencing this result: 1. It is a large tract of forest without fence protection, which means that livestock may transit among the forest preventing plant regeneration. 2. This fragment is connected with the riparian forest of La Unión creek, which was the only fragment with *Cebus apella*. This may

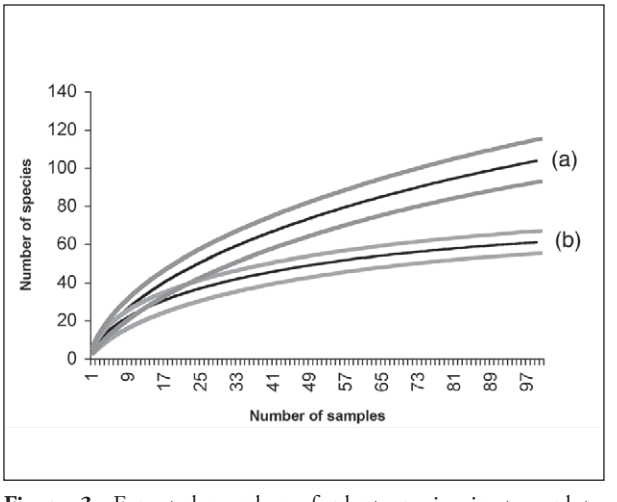

Figure 3. Expected number of plant species in two plots, (**a**) Less disturbed forest, (**b**) secondary forest, where all individuals (DBH>10 cm) were identified to species or morphospecies, near Acacias, Meta, Colombia. The grey lines show 95% confidence intervals.

Table 1. Group composition of *Callicebus ornatus* in forest fragments in Acacias, Meta, Colombia.

Fragment	Group	Adults Male	Sub-Adults	Juveniles	Infants	Undetermined	Total
1	1	2		1			**3**
	2	2					**2**
	3	2	1	2	1		**6**
	4	2		1			**3**
	5	2					**2**
	6	2		1			**3**
	7	2					**2**
	8	2		1	1		**4**
	9	2			1		**3**
	10	2			1		**3**
	11	2			1		**3**
	12	2			1		**3**
	13	2		1			**3**
	14	2		1			**3**
	15	2		1	1		**4**
	16	2					**2**
	17	2		1			**3**
	18	2					**2**
	19	2		1	1		**4**
	UNDT					7	**7**
2	20	2		1	1		**4**
3	21	2			1		**3**
	22	2		1	1		**4**
	23	2	1	1			**4**
	35	2		1	1		**4**
	36	2		1	1		**4**
	37	2					**2**
	38	2			1		**3**
4	24	2		1			**3**
5	25	2			1		**3**
	26	2					**2**
	27	2					**2**
	28	2					**2**
	29	2		1			**3**
	30	2		1			**3**
	31	2					**2**
	UNDT					1	**1**
6	33	2					**2**
	34	2		1			**3**
7	32	2					**2**
8	39	2	1	1	1		**5**
	40	2					**2**
	41	2	1	1			**4**
	42	2		1			**3**
	43	2					**2**
Total	**43**	**86**	**4**	**23**	**16**	**8**	**137**

imply a higher level of interspecific competition for space (Sánchez, 1998) or even predation pressure from *Cebus apella*, a species known to hunt and kill small mammals (Galetti, 1990; Izawa, 1990, Sampaio and Ferrari, 2005; Defler, com. pers.).

Fragments of less disturbed forests in which floristic inventories were studied showed an acceptable conservation level and a high density of *Callicebus ornatus* (368.7 ind/km^2). However, the density of *Callicebus ornatus* in the secondary forest was in general higher (mean: 559.1 ind/km^2) than the less disturbed forest (mean: 188.2 ind/km^2), suggesting a preference for secondary forest (Mason, 1968; Hernández-Camacho and Cooper, 1976; Polanco, 1992; Sánchez, 1998). According to Quiñones-Porras (2007), who studied a group in a secondary forest during 4 months (March to June), the most consumed fruits by *C. ornatus* during this period were *Miconia affinis*, *Inga thibaudiana* and *Miconia elata,* as it has been reported in other studies (Polanco, 1992; Sánchez, 1998 & Ospina, 2006). According to Polanco (1992) and Sánchez (1998) during wet season *C. ornatus* still consumes *Miconia* and *Inga* species but lower proportions. Additional observations are required to evaluate fruit feeding preferences in long term studies at the study area.

The density reported for fragment 1 was 368.7 individuals / km^2, a similar estimate as the one found by Mason (1966) of 400 individuals / km^2. This fragment seems to have better conditions than the others, since it is protected from livestock by fences and has a rich plant assemblage. Another potential explanation for these high estimates is the lack of interspecific competition with larger primates (for instance *Alouatta seniculus* was locally exterminated for bushmeat 50 years ago). Yet a third explanation that must be considered is that these high population densities represent refugees from destroyed forests. Thus, these may be hyperdense populations as a result of forest desctruction. This possibility must be evaluated, especially since much forest has been destroyed in the area. High population densities such as the ones found in the fragments could also imply a high probability of epidemics and endogamy. Long term

Table 2. Age structure of the *C. ornatus* population.

	Adults	Sub-Adults	Juveniles	Infants	Total
Counts	86	4	23	16	129
Proportion (%)	66.7	3.1	17.8	12.4	100

Table 3. Population density estimates of *Callicebus ornatus* in the forest fragments near Acacias, Meta, Eastern Colombia.

Fragment	Area (ha)	Groups	Individuals	Groups / ha	Individuals / km^2
1	17.63	19	65	1.08	368.7
3	40	7	24	0.18	60.0
5	10	7	18	0.70	180.0
8	10	5	16	0.50	160.0
Total	77.63	38	123		
Mean				0.61	192.2 ± 128.9

Table 4. Most important plant species in the less disturbed and secondary forests.

Less disturbed forest					Secondary Forest				
Species	**RF**	**RD**	**RBA**	**IVI**	**Species**	**RF**	**RD**	**RBA**	**IVI**
Socratea exorrhiza	0.108	0.183	0.377	0.668	*Casearia* sp.	0.105	0.067	0.015	0.187
Oenocarpus bataua	0.097	0.121	0.380	0.598	*Apuleia leiocarpa*	0.074	0.044	0.017	0.135
Mabea maynensis	0.068	0.074	0.055	0.197	*Jacaranda copaia*	0.076	0.035	0.005	0.116
Virola sebifera	0.044	0.041	0.028	0.113	*Schefflera morototoni*	0.050	0.035	0.005	0.09
Iriartea deltoidea	0.031	0.043	0.023	0.097	*Alchornea glandulosa*	0.048	0.025	0.002	0.075
Pourouma bicolor	0.033	0.028	0.017	0.078	*Guatteria recurvisepala*	0.048	0.023	0.002	0.073
Caraipa cf. *punctulata*	0.029	0.025	0.016	0.07	*Sapium laurifolium*	0.057	0.001	0.000	0.058
Guatteria recurvisepala	0.029	0.025	0.013	0.067	*Loreya strigosa*	0.040	0.017	0.001	0.058
Senefeldera inclinata	0.031	0.028	0.006	0.065	*Himatanthus articulata*	0.033	0.017	0.001	0.051
Lauraceae sp. 2	0.026	0.023	0.010	0.059	*Trattinnickia aspera*	0.033	0.014	0.000	0.047

* **RF** (Relative frequency), **RD** (Relative density), **RBA** (Relative basal area), **IVI** (Importance Value Index) = RF + RD + RBA (Curtis & McIntosh, 1951).

monitoring of populations and studies of genetic diversity will be necessary to assess the viability of these populations, especially since they may represent refugees. Given that fragments are small, only 8.5% forest cover remains and the permanence of them is uncertain. However, they seem to have a high probability of survival, as long as the destruction of forest remnants stops. In the study area individuals of *C. ornatus* y *S. sciureus* were observed walking on the ground, moving from fragment 1 to 5 (400 m separated). This represents a predation threat for these primates; we witnessed a domestic dog killing the infant of the group 7, when his father tried to gather fruit on the ground. Tree-fences are important structures that help groups to travel between fragments and as food sources (Carretero, 2008). Their use in private lands could be important for primates and other fauna.

Callicebus ornatus is also found in La Macarena and Tinigua National Parks, but these parks have been affected by illicit crops and institutional presence has been jeopardized by lack of personal security. About 4,500 ha of coca crops have been reported in La Macarena park (Acción Social, 2006). The conservation of this endemic primate in private forests is important for its survival. A conservation program for the black lion tamarin from the Brazilian coast on private lands, is showing great success, thanks to a well constructed environmental education program where landowners agreed to participate, increasing protected habitat by about 5,000 ha (Valladares-Pádua *et al.*, 1994; Kleiman and Mallinson, 1998). Conservation programs using private lands seem very important to supplement the efforts of the government, and this effort should be undertaken by all Colombians. It seems important to restore the quality of *Callicebus ornatus* habitat to maintain healthy populations. Political activism is also necessary to take important actions against forest destruction in the region: environmental education and laws must be enforced, forest fragments must be connected and their areas must be increased to avoid the destruction of forest remnants in the piedmont and to protect endemic species in the region.

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Anthropogenic Change and Primate Predation Risk: Crested Caracaras (*Caracara plancus*) Attempt Predation on Mantled Howler Monkeys (*Alouatta palliata*)

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Introduction

Anthropogenic change in primate habitats may be an important factor in predation risk. Predation is often considered a principle selective pressure in primate evolution, and thus an important determining factor for grouping behavior, travel patterns, and choice of sleeping sites (van Schaik, 1983; Isbell, 1994; Treves, 2002; Shultz *et al.*, 2004). Predation events are rarely witnessed in the wild due to their rarity, short duration, and the effects of observer presence. Reports of failed predation attempts or even the absence of predation events (Boinski *et al.*, 2000) will broaden our understanding of this important issue. With our currently limited scope on primate predators and risk factors, we may be missing the impact of human habitat alteration on predation risk and rates. This paper reports a presumed predation attempt by two crested caracaras (*Caracara plancus*) on infant mantled howler monkeys (*Alouatta palliata*) in Costa Rica. Crested caracaras are generally associated with human activity