Chapter 12
An Eight-Year Life History of a Primate Community in the Colombian Llanos

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Abstract Forest areas in Colombian Llanos are highly degraded due to the expansion of palm oil crops, petrol extraction, and other human interferences, making primate species in Colombia more susceptible to population reduction and local extinction. An eight-year study of primate density monitoring was conducted in five forest fragments of different sizes in San Martín, Colombian Llanos. *Alouatta seniculus*, *Sapajus apella*, *Callicebus ornatus*, *Saimiri sciureus albigena*, and *Aotus brumbacki* were present in the fragments. Direct visual contacts were made in small (1–10 ha) and medium (10–100 ha) fragments. Primate density in an extra-large fragment (1,050 ha) was calculated using line transect method. Results showed that population density for *A. seniculus* ranged from 0.81 to 78.57 ind/km^2, *S. apella*, 0.95–52.98 ind/km^2, *C. ornatus*, 1.07–54.76 ind/km^2, *S. s. albigena*, 3.85–170.24 ind/km^2, and *A. brumbacki,* 3.26–13.10 ind/km^2. Most species reported in small and medium fragments have a higher population density than those reported in other studies, except for *A. seniculus,* which fell in a normal range. Densities in the extra-large fragment for *Alouatta*, *Callicebus,* and *Sapajus* are similar to that reported in continuous forest, while densities for *Saimiri* was lower than that reported for continuous forest. Variations that affected population density among fragments are due to differences in-group composition per species, vegetation, and size of the fragment. All primate species present in this region use fencerows as part of the landscape matrix to cross among fragments. Increasing the connectivity between fragments is necessary in this region to improve sustainability of this primate community.

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Introduction

Colombian Llanos or the Orinoco is an area composed of different ecosystems including flooded and unflooded savannas, tropical rainforest, and gallery forest. This study is focused on the western Orinoco basin in Meta, Colombia which has been colonized since the sixteenth century. However, Stevenson and Aldana (2008) suggest that several factors provide evidence that this area was a continuous tropical forest before human disturbance: (1) Abandoned pastures in this area rapidly convert into forest succession suggesting that ecological conditions are favorable to support continuous forests, (2) Climate and geographical position close to the Andes is similar to that found at Tinigua National Park which is a continuous tropical forest (>2,500 mm with a 2–3 month dry period) as defined by Holdridge (1967), (3) Soils correspond to depositional zones that are relatively rich in nutrients and can sustain continuous forest in flooded and terra firme soils, and (4) Cultivated oil palms in San Martin have a biomass similar to that of a humid forest.

San Martin has historically been a livestock town due to its natural savannas. These natural savannas have been converted to pastures over the years leaving fragments of different sizes, especially around watercourses. In recent years, palm oil plantations and extractive activities, such as petrol extraction, have increased the fragmentation process. This is especially true of palm oil crops since the Meta Department is the main producer of palm oil in Colombia (Fedepalma 2010).

Fragmentation produces changes in environmental conditions, composition, and abundance of animals and plant species (Saunders et al. 1991; Stevenson and Aldana 2008) including habitat reduction, isolation, distance between fragments, fragment size, changes in quantity and quality of food, and forest structure all affects primate species densities (Hobbs and Yates 2003; Marsh 2003; Saunders et al. 1991; Stevenson and Aldana 2008). Fragmentation and habitat loss are the main threats to Colombian primates (Defler 2004). Therefore, persistence in small fragments of some species of primates depends on their skill to use the matrix surrounding forest fragments.

Primate density has been studied in tropical rainforest throughout the world (Carvalho 2003; Chapman et al. 2004; Crockett 1996; Crockett and Eisenberg 1987; Defler 1981; Dvoskin et al. 2004; Estrada and Coates-Estrada 1996; Freese 1976; Mbora and Meikle 2004; Plumptre and Reynolds 1994; Romanini et al. 2003), but there are only a few studies of primate population density in the Colombian Llanos. These reports mainly focus on howler monkeys (*Alouatta seniculus*), tufted capuchins (*Cebus* nee *Sapajus* (sensu Lynch-Alfaro et al. 2012) *apella*), white-fronted capuchins (*Cebus albifrons*), and dusky titi monkeys (*Callicebus ornatus*) (Carretero-Pinzón 2005; Defler 1981; Defler and Pintor 1985; Wagner et al. 2009). Data reported here is from eight-years of primate density surveys conducted at five forest fragments. Some possible explanations for species permanence in different sizes of fragments are explored.

Study Zones

This study was conducted near the town of San Martín de los Llanos, Department of Meta, in the Colombian Llanos, at two Zones: Santa Rosa-Arrayanes and Las Pampas (elevation 350 m; Fig. 12.1). These Zones have different sizes of forest fragments surrounded by pastures used for livestock. Some pastures are surrounded by fencerows to connect forest fragments. Five Neotropical primates: *Sapajus apella*, *Alouatta seniculus*, *Saimiri sciureus albigena*, *Callicebus ornatus*, and *Aotus brumbacki* live sympatrically in the area (Carretero-Pinzón 2005). This region was characterized by wet season (April–November) and dry season (December–March) with an annual average temperature of 26 °C (Carretero-Pinzón 2008). Plant

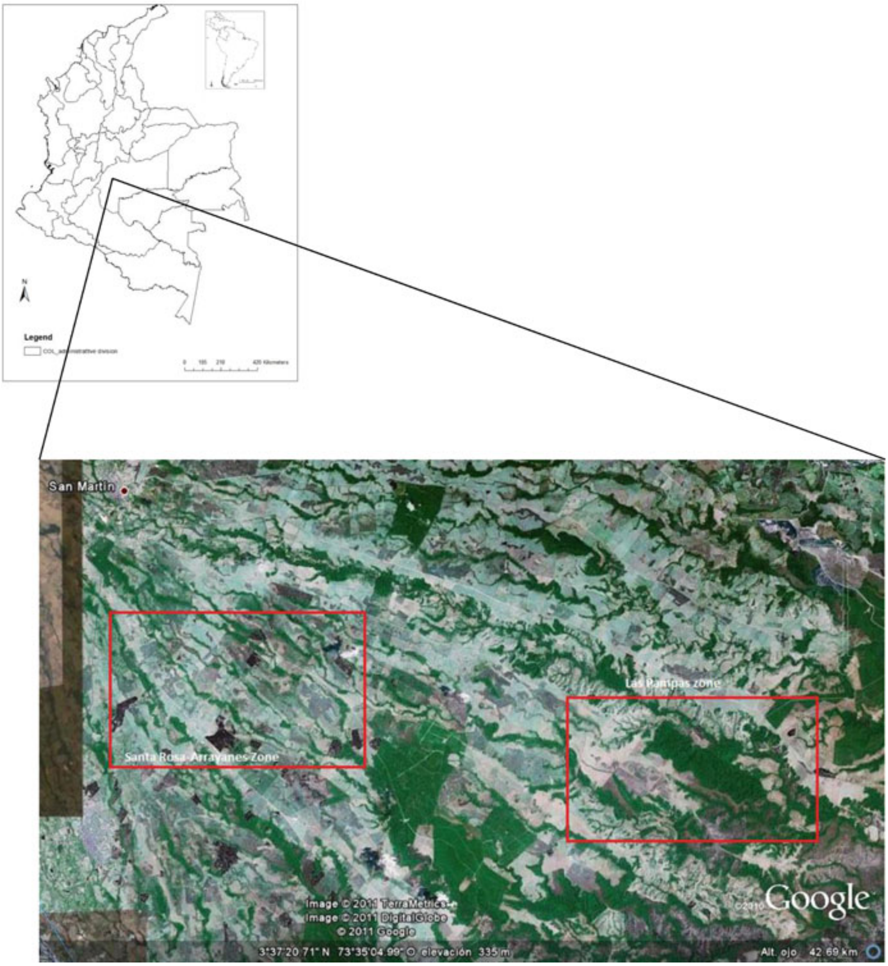

Fig. 12.1 General location of Santa Rosa-Arrayanes Zone and Las Pampas Zone (Google Earth image accessed on 15 June 2012)

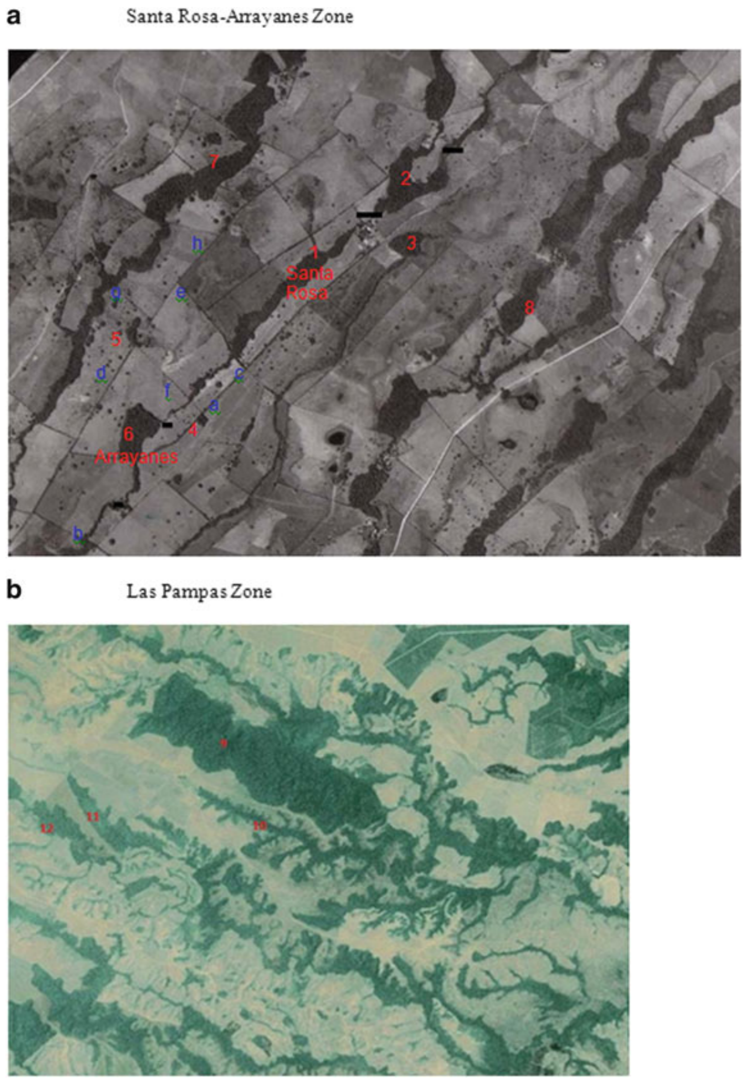

Fig. 12.2 (**a**) Aerial Photograph from Santa Rosa-Arrayanes Zone (in 1997; scale 1:46,000, IGAC, Colombia): *Black lines* correspond to sites in which forest is fragmented now. *Red numbers* correspond to fragments connected by fencerows (Fragment 1: 21 ha; Fragment 2: 46.5 ha; Fragment 3: 11 ha; Fragment 4: 0.5 ha; Fragment 5: 2 ha; Fragment 6: 16 ha; Fragment 7: 120 ha; Fragment 8: 130 ha). *Blue words* correspond to fencerows where primates were observed. (**b**) Satellite image of Las Pampas Zone (Google Earth image): *Red numbers* correspond to fragments where primate species have been observed (Fragment 9: 1,050 ha; Fragment 10: 186 ha; Fragment 11: 155 ha; and Fragment 12: 222 ha)

species richness is different between fragments with some species shared (Stevenson and Aldana 2008).

Santa Rosa-Arrayanes Zone (*SRAZ*). Located at 3°3′30″N 73°35′40″ W. This Zone has small (1–10 ha), medium (10–100 ha), and large fragments (100–1,000 ha), most of them connected by fencerows and surrounded by pastures (Fig. 12.2).

Table 12.1 Plant species found at forest Fragments 1, 2, 3, and 6 at Santa Rosa-Arrayanes Zone

Fragment 1		Fragment 2		Fragment 3		Fragment 6	
Species	Family	Species	Family	Species	Family	Species	Family
27		30		11		24	
Schefflera morototoni	Araliaceae	*Schefflera morototoni*	Araliaceae	*Himatanthus articulatus*	Apocynaceae	*Annona sp.*	Annonaceae
						Duguetia sp.	Annonaceae
Guatteria ferruinea	Annonaceae	*Guatteria ferruginea*	Annonaceae	*Oenocarpus bataua*	Arecaceae	*Guatteria ferruinea*	Annonaceae
Xylopia polyantha	Annonaceae	*Xylopia aromatica*	Annonaceae				
		Xylopia polyantha	Annonaceae	*Unonopsis sp.*	Annonaceae	*Himatanthus articulatus*	Apocynaceae
Himatanthus articulatus	Apocynaceae						
		Himatanthus articulatus	Apocynaceae	*Arrabidaea sp2.*	Bignoniaceae	*Bombacopsis sp.*	Bombacaceae
Arrabidaea sp2.	Bignoniaceae						
		Arrabidaea sp2.	Bignoniaceae	*Protium sp.*	Burseraceae	*Protium sp.*	Burseraceae
Protium sp.	Burseraceae			*Trattinnickia cf. aspera*	Burseraceae	*Trattinnickia cf. aspera*	Burseraceae
Protium glabrescens	Burseraceae	*Bombacopsis sp.*	Bombacaceae				
Trattinnickia cf. aspera	Burseraceae			*Cecropia membranacea*	Cecropiaceae	*Cecropia membranacea*	Cecropiaceae
		Protium sp.	Burseraceae			*Pouroma bicolor*	Cecropiaceae
Clusia cf. palmicida	Clusiaceae	*Trattinnickia cf. aspera*	Burseraceae	*Pera arborea*	Euphorbiaceae		
Garcinia madruno	Clusiaceae					*Pera arborea*	Euphorbiaceae
		Cecropia membranacea	Cecropiaceae	*Ocotea oblonga*	Lauraceae		

(continued)

Table 12.1 (continued)

Fragment 1		Fragment 2		Fragment 3		Fragment 6	
Species	Family	Species	Family	Species	Family	Species	Family
27		30		11		24	
Combretum laxum	Combretaceae	*Cecropia sciadophylla*	Cecropiaceae			*Diospyros c.f pseudoxylopia*	Flacourtiaceae
				Byrsonima sp.	Malpighiaceae		
Pera arborea	Euphorbiaceae	*Clusia cf. palmicida*	Clusiaceae			*Ocotea oblonga*	Lauraceae
		Garcinia madruno	Clusiaceae	*Ficus americana*	Moraceae		
Diospyros c.f pseudoxylopia	Flacourtiaceae					*Bellucia pentamera*	Melastomataceae
Ryania speciosa	Flacourtiaceae	*Combretum laxum*	Combretaceae			*Bellucia grossularioides*	Melastomataceae
						Henriettella cf. goudotiana	Melastomataceae
Ocotea oblonga	Lauraceae	*Erythroxylon sp.*	Erythroxylaceae			*Miconia trinervia*	Melastomataceae
Bellucia pentamera	Melastomataceae	*Pera arborea*	Euphorbiaceae			*Enterolobium cyclocarpum*	Mimosaceae
Bellucia grossularioides	Melastomataceae						
Henriettella cf. goudotiana	Melastomataceae	*Ryania speciosa*	Flacourtiaceae			*Siparuna guianensis*	Moniminiaceae

Miconia sp3	Melastomataceae				
Miconia trinervia	Melastomataceae	*Ocotea oblonga*	Lauraceae	*Pseudolmedia laevis*	Moraceae
Siparuna guianensis	Moniminiaceae	*Bellucia pentamera*	Melastomataceae	*Iryanthera laevis*	Myristicaceae
		Bellucia grossularioides	Melastomataceae	*Virola sp1.*	Myristicaceae
Ficus americana	Moraceae	*Henriettella cf. goudotiana*	Melastomataceae	*Virola sp2.*	Myristicaceae
		Miconia elata	Melastomataceae		
Virola sp1.	Myristicaceae	*Miconia trinervia*	Melastomataceae	*Duroia hirsuta*	Rubiaceae
Virola sp2.	Myristicaceae	*Miconia sp3*	Melastomataceae		
Iryanthera laevis	Myristicaceae			*Vochysia lehmannii*	Vochysiaceae
		Enterolobium cyclocarpum	Mimosaceae		
Duroia hirsuta	Rubiaceae				
		Ficus americana	Moraceae		
Vochysia lehmannii	Vochysiaceae				
		Virola sp1.	Myristicaceae		
		Virola sp2.	Myristicaceae		
		Iryanthera laevis	Myristicaceae		
		Vochysia lehmannii	Vochysiaceae		

Plant species present in the study fragments ranged from 11 to 30 species (Table 12.1). Primate species were identified in eight fragments at SRAZ (Table 12.3). Census surveys focused on Fragments 1 (21 ha), 2 (46 ha), 3 (13 ha) and 6 (16 ha) at SRAZ (from 2004 to 2011). Fragments 4 (0.5 ha) and 5 (2 ha) have primates, but the sites are used only as dormitories or as fruit sources; groups using these fragments have their home range in other fragments (1 and 6). Fragments 7 (130 ha) and 8 (120 ha) at SRAZ have primate species, but census data hasn't been collected there due to logistical problems.

Las Pampas Zone (*LPZ*). Located at 3°34′51.93″N 73°27′02.56″W. This Zone has large (100–1,000 ha) and extra-large fragments (more than 1,000 ha) surrounded by pastures (Fig. 12.2). This Zone is a natural private reserve called Las Unamas Reserve surrounded by two other natural reserves, Rey Zamuro and Matarredonda (www.lasunamas.com). There were 197 plant species found in the study fragment (Table 12.2). Four fragments at LPZ have primates (Table 12.3), but Fragment 9 (1,050 ha) was the only one studied (from 2008 to 2011).

Population Information

Densities of primate species were estimated differently depending on fragment size defined by Marsh (2003). In small (1–10 ha) and medium (10–100 ha) fragments, population densities were calculated based on direct visual counts of individuals or groups between March 2004 and December 2011. For the larger categories, only Fragment 9 (1,050 ha) densities were calculated based on five line-transects of at least 1,000 m each. The other fragments at LPZ have insufficient data for density analysis. Surveys in all forest fragments were taken between 6:30 and 17:00 h to search for primate groups. These were conducted several times per month. At SRAZ, groups in each fragment were monitored and individuals identified. Group identification was facilitated by other behavioral studies conducted concurrently at this Zone (Beltrán 2005; Carretero-Pinzón 2008; Escudero 2004; Fajardo 2007; Ospina 2006; Ramos 2008; Torres 2005).

Population density at SRAZ was calculated based on the formula of ecological density: the number of individuals divided by the available or sampled area (Soini 1992). Population density at LPZ was calculated with Distance 6.0 (Thomas et al. 2002). At SRAZ, *Aotus* sleeping sites were searched according to literature, local references, and personal observations (Defler 2004). Data for *Aotus* at LPZ was insufficient for comment in this chapter. Group composition, census numbers (reproductive males and females), male to female ratio (number of adult males divided by number of adult females), and female to immatures ratio (number of adult females divided by number of juveniles and infants) were calculated based on 2011 sampling results for SRAZ and LPZ (Brito and Grelle 2006).

Table 12.2 Plant species found at forest Fragment 9 at Las Pampas Zone (http://www.lasunamas.com)

Fragment 9			
Specie	Family	Specie	Family
197			
Aphelandra sp	Acanthaceae	*Enterolobium schomburgkii*	Fabaceae
		Inga alba	Fabaceae
Tapirira guianensis	Anacardiaceae	*Inga brachyrhachis*	Fabaceae
		Inga cylindrica	Fabaceae
Annona sp1	Annonaceae	*Inga nobilis*	Fabaceae
Annona sp2	Annonaceae	*Inga thibaudiana*	Fabaceae
Duguetia cf. macrophylla	Annonaceae	*Inga villosissima*	Fabaceae
Guatteria cf. liesneri	Annonaceae	*Inga punctata*	Fabaceae
Guatteria recurvisepala	Annonaceae	*Inga velutina*	Fabaceae
Rollinia edulis	Annonaceae	*Andira surinamensis*	Fabaceae
Xylopia aromática	Annonaceae	*Clitoria cf. javitensis*	Fabaceae
Xylopia cf. sericophylla	Annonaceae	*Dioclea guianensis*	Fabaceae
		Derris pterocarpus	Fabaceae
Aspidosperma sp	Apocynaceae	*Machaerium quinata*	Fabaceae
Couma macrocarpa	Apocynaceae		
Fosteronia affinis	Apocynaceae	*Casearia javitensis*	Flacourtiaceae
Fosteronia graciloides	Apocynaceae	*Lindackeria paludosa*	Flacourtiaceae
Himatanthus articulata	Apocynaceae	*Ryania sp*	Flacourtiaceae
Lacmellea edulis	Apocynaceae		
Tabernaemontana sananho	Apocynaceae	*Heliconia hirsuta*	Heliconiaceae
Anthurium clavigerum	Araceae	*Vismia baccifera*	Hypericaceae
Monstera dilacerata	Araceae	*Vimia cayennensis*	Hypericaceae
Monstera gracilis	Araceae	*Vismia guianensis*	Hypericaceae
Spatiphyllum canaeifolium	Araceae	*Vismia macrophylla*	Hypericaceae
Dendropanax arboreus	Araliaceae	*Lacistema aggregatum*	Lacistemataceae
Dendropanax cf. caucanus	Araliaceae		
Schefflera morototoni	Araliaceae	*Aniba panurensis*	Lauraceae
		Nectandra membranacea	Lauraceae
Attalea insignis	Arecaceae	*Ocotea floribunda*	Lauraceae
Attalea maripa	Arecaceae	*Ocotea oblonga*	Lauraceae
Euterpe precatoria	Arecaceae	*Ocotea cf. oblonga*	Lauraceae
Mauritia flexuosa	Arecaceae		
Oenocarpus bataua	Arecaceae	*Eschweilera sp*	Lecythidaceae
Oenocarpus mapora	Arecaceae		
Socratea exorrhiza	Arecaceae	*Byrsonima crassifolia*	Malpighiaceae
Syagrus orinocensis	Arecaceae	*Byrsonima cf. stipulacea*	Malpighiaceae
		Mascagnia macrodisca	Malpighiaceae
Pollalesta discolor	Asteraceae		
Vernonia cf. Brasiliensis	Asteraceae	*Ischnosiphon arouma*	Marantaceae
		Maranta cf. friedrichsthaliana	Marantaceae
Anemopaema oligoneuron	Bignoniaceae	*Monotagma laxum*	Marantaceae

(continued)

Table 12.2 (continued)

Fragment 9			
Specie	Family	Specie	Family
197			
Arrabaideae cf. candicans	Bignoniaceae		
Arrabaidea sp	Bignoniaceae	*Norantea guianensis*	Marcgraviaceae
Jacaranda obtusifolia	Bignoniaceae		
Jacaranda copaia	Bignoniaceae	*Bellucia grossularioides*	Melastomataceae
Pleonotoma tretragonocaulis	Bignoniaceae	*Loreya strigosa*	Melastomataceae
		Miconia affinis	Melastomataceae
Eriotheca macrophylla	Bombacaceae	*Miconia dolichorrhyncha*	Melastomataceae
		Miconia elata	Melastomataceae
Cordia bicolor	Boraginaceae	*Miconia holosericea*	Melastomataceae
Cordia nodosa	Boraginaceae	*Miconia matthaei*	Melastomataceae
		Miconia tomentosa	Melastomataceae
Crepidospermum rhoifolium	Burseraceae	*Toccoca guianensis*	Melastomataceae
Protium aracouchini	Burseraceae		
Proptium glabrescens	Burseraceae	*Mendoncia lindavii*	Mendodonciaceae
Protium guianense	Burseraceae		
Protium cf. guianense	Burseraceae	*Abuta grandifolia*	Menispermaceae
Protium heptaphyllum	Burseraceae		
Protium cf. heptaphyllum	Burseraceae	*Siparuna guianensis*	Monimiaceae
Protium llanorum	Burseraceae		
Protium sagotianum	Burseraceae	*Brosimum cf. lactescens*	Moraceae
Trattinickia rhoifolia	Burseraceae	*Brosimum lactescens*	Moraceae
		Clarisia racemosa	Moraceae
Cecropia ficifolia	Cecropiaceae	*Ficus trigona*	Moraceae
Cecropia sciadophylla	Cecropiaceae	*Maquira cf. calophylla*	Moraceae
Coussapoa villosa	Cecropiaceae	*Perebea mollis*	Moraceae
Pouroma bicolor	Cecropiaceae	*Perebea xanthochyma*	Moraceae
Pouroma minor	Cecropiaceae	*Pseudolmedia laevis*	Moraceae
		Pseudolmedia cf. laviegata	Moraceae
Hirtella americana	Chrysobalanaceae	*Pseudolmedia oblicua*	Moraceae
Hirtella elongata	Chrysobalanaceae		
Licania cf. kunthiana	Chrysobalanaceae	*Iryanthera laevis*	Myristicaceae
Licania cf. subarachnophylla	Chrysobalanaceae	*Virola elongata*	Myristicaceae
		Virola sebifera	Myristicaceae
Calophyllum brasiliense	Clusiaceae	*Virola surinamensis*	Myristicaceae
Clusia sp	Clusiaceae		
Garcinia madruno	Clusiaceae	*Stylogyne cf. turbacensis*	Myrsinceae
Marila cespedeziana	Clusiaceae	*Myrsine guianensis*	Myrsinceae
Tovomita sp1	Clusiaceae		
		Myrcia sp	Myrtaceae
Cochlospermum orinocense	Cochlopemaceae		
Cochlospermum vitifolium	Cochlopemaceae	*Ouratea sp*	Ochnaceae

(continued)

Table 12.2 (continued)

Fragment 9			
Specie	Family	Specie	Family
197			
Buchenavia capitata	Combretaceae	*Peperomia cf. macrostachya*	Piperaceae
Combretum laxum	Combretaceae	*Piper obliquum*	Piperaceae
Terminalia amazonia	Combretaceae		
		Olyra latifolia	Poaceae
Connarus sp	Connaraceae	*Pariana sp*	Poaceae
Rourea cf. glabra	Connaraceae		
		Coccoloba sp.	Polygonaceae
Cayaponia granatensis	Cucurbitaceae		
Gurania eriantha	Cucurbitaceae	*Alibertia sp*	Rubiaceae
		Capirona decorticans	Rubiaceae
Asplundia moritziana	Cyclanthaceae	*Durota hirsuta*	Rubiaceae
		Duroia sp	Rubiaceae
Dichapetalum spruceanum	Dichapethalaceae	*Malanea sp*	Rubiaceae
		Geophila repens	Rubiaceae
Curatella americana	Dilleniaceae	*Psychotria casiquiaria*	Rubiaceae
Davila nítida	Dilleniaceae	*Psychotria muscosa*	Rubiaceae
Doliocarpus multiflorus	Dilleniaceae	*Psychotria poeppigiana*	Rubiaceae
		Posoqueria longiflora	Rubiaceae
Diospyros pseudoxylopia	Ebenaceae		
		Cupania scrobiculata	Sapindaceae
Sloanea aff guianensis	Eleocarpaceae	*Cupania sp*	Sapindaceae
		Matayba sp1	Sapindaceae
Erythroxylum macrophyllum	Erythroxylaceae	*Paullinia cf. faginea*	Sapindaceae
		Paullinia sp	Sapindaceae
Alchornea discolor	Euphorbiaceae	*Talisia intermedia*	Sapindaceae
Alchornea triplinervia	Euphorbiaceae	*Pouteria sp1*	Sapotaceae
Alchorneopsis floribunda	Euphorbiaceae	*Pouteria sp2*	Sapotaceae
Hyeronima alchorneoides	Euphorbiaceae	*Pouteria sp3*	Sapotaceae
Maprounea guianensis	Euphorbiaceae	*Sarcaulus brasiliensis*	Sapotaceae
Pera arborea	Euphorbiaceae		
Sapium laurifolium	Euphorbiaceae	*Simaba cedron*	Simarubaceae
Bauhinia guianensis	Fabaceae	*Solanum cyathophorum*	Solanaceae
Dialium guianense	Fabaceae	*Cyphomandra sp*	Solanaceae
Brownea ariza	Fabaceae		
Senna silvestris	Fabaceae	*Herrania nitida*	Sterculiaceae
Abarema jupunba	Fabaceae	*Sterculia guapayensis*	Sterculiaceae
		Teobroma glaucum	Sterculiaceae
		Vitex compressa	Verbenaceae
		Vochysia ferruginea	Vochysiaceae
		Vochysia lehmannii	Vochysiaceae

Table 12.3 Primate species present at forest fragments in Santa Rosa-Arrayanes and Las Pampas Zones

Fragment size (Ha)	*A. seniculus*	*S. apella*	*S. s. albigena*	*C. ornatus*	*A. brumbacki*
Santa Rosa-Arrayanes Zone (*SRAZ*)					
0.5	X	X	X	0	0
2	X	X	X	0	0
13	X	X	X	0	X
16	X	X	X	X	X
21	X	X	X	X	X
46	X	X	X	X	X
120	X	X	0	X	X
130	X	X	X	X	0
Las Pampas Zone (*LPZ*)					
155	X	X	X	0	0
186	X	X	X	X	X
222	X	X	X	?	?
1,050	X	X	X	X	X

Table 12.4 Primate densities of each fragment studied (average densities and annual densities for fragments at Santa Rosa-Arrayanes Zone and combined density for Fragment 9 at Las Pampas Zone)

	Alouatta (ind/km^2)	Sapajus (ind/km^2)	Saimiri (ind/km^2)	Callicebus (ind/km^2)	Aotus (ind/km^2)
Fragment 1: 21 ha					
2004	76.19	47.62	152.38	61.90	19.05
2005	76.19	52.38	152.38	61.90	19.05
2006	90.48	61.90	190.48	61.90	19.05
2007	85.71	52.38	190.48	61.90	19.05
2008	80.95	52.38	152.38	47.62	0.0
2009	76.19	52.38	147.62	52.38	0.0
2010	66.67	52.38	171.43	42.86	9.52
2011	76.19	52.38	204.76	47.62	19.05
Average	78.57	52.98	170.24	54.76	13.10
SD	7.2	3.97	22.30	8.05	8.73
Fragment 2: 46.5 ha					
2004	8.70	21.74	32.61	8.70	4.35
2005	30.43	39.13	0.0	8.70	4.35
2006	30.43	39.13	0.0	6.52	4.35
2007	23.91	21.74	0.0	6.52	4.35
2008	23.91	26.09	0.0	4.35	0.0
2009	23.91	30.43	0.0	8.70	0.0
2010	19.57	30.43	65.22	8.70	4.35
2011	23.91	30.43	65.22	10.87	4.35
Average	23.91	29.89	20.38	7.88	3.26
SD	6.87	6.75	29.87	1.99	2.01
Fragment 3: 13 ha					
2004	30.77	0.0	7.69	0.0	0.0

(continued)

Table 12.4 (continued)

	Alouatta (ind/km²)	Sapajus (ind/km²)	Saimiri (ind/km²)	Callicebus (ind/km²)	Aotus (ind/km²)
2005	38.46	0.0	7.69	0.0	0.0
2006	38.46	0.0	7.69	0.0	0.0
2007	30.77	0.0	7.69	0.0	0.0
2008	30.77	0.0	0.0	0.0	0.0
2009	30.77	0.0	0.0	0.0	0.0
2010	30.77	0.0	0.0	0.0	0.0
2011	30.77	0.0	0.0	0.0	0.0
Average	30.77	0.0	3.85	0.0	0.0
SD	3.56	0.0	4.11	0.0	0.0
Fragment 6: 16 ha					
2004	0.0	0.0	0.0	0.0	0.0
2005	68.75	31.25	0.0	18.75	12.5
2006	75	43.75	0.0	25	6.25
2007	68.75	43.75	0.0	25	18.75
2008	62.5	31.25	0.0	12.5	6.25
2009	56.25	31.25	0.0	12.5	6.25
2010	50	31.25	0.0	18.75	12.5
2011	37.5	31.25	0.0	18.75	12.5
Average	52.34	30.47	0.0	16.41	9.38
SD	24.31	13.54	0.0	8.14	5.79
Fragment 9: 1,050 ha					
2008–2011	0.81	0.95	30.33	1,073	n.a

n.a: not applicable

Demographics

Average densities of primate species in the study area are shown in Table 12.4, for both Zones. SRAZ Fragment 1 (21 ha) was found to have the highest average density of all five primate species as compared to the largest fragment at LPZ (1,050 ha). All five species were found together in Fragments 1, 2 and 6 at SRAZ and at Fragment 9 and 10 from LPZ. However, a *Saimiri* group used both Fragment 1 and 6, thus a density of this species in Fragment 6 was not estimated to avoid double counting. For the duration of the study, Fragment 3 (13 ha) had only one group of *A. seniculus*. One individual of *S. s. albigena* was last recorded there in 2008. These densities varied only slightly between years for each fragment. Densities in Fragment 9 are the lowest for all fragments reported here.

Three types of group composition can be found: one male–one female (*Callicebus ornatus* and *Aotus brumbacki*), one male–two females (*Alouatta seniculus* and *Sapajus apella*), and multimale–multifemale (*Saimiri sciureus albigena*, Table 12.5). All groups contain several juveniles and infants. These types of group compositions were found in all fragments with variations in the number of juveniles and infants.

Table 12.5 Group size, composition and male: female and female: immature ratios for each primate species group differentiated in this study at both Zones (Data based on 2011 samplings)

		Adults			Subadults		Juveniles			Infants						
Primate Species	Group ID	Males	Females	Unknown	Males	Females	Males	Females	Unknown	Males	Females	Unknown	Total	Males: Females	Females: Immatures	Census number
Fragment 1																
Alouatta seniculus	1	1	2	0	1	0	0	0	0	0	0	1	5	0.5	1	3
Alouatta seniculus	2	2	2	0	0	0	0	0	1	0	0	1	6	1	1	4
Alouatta seniculus	3	1	1	0	0	0	0	0	2	0	0	1	5	1	0.33	2
Sapajus apella	1	1	1	0	0	0	0	0	3	0	0	0	5	1	0.33	2
Callicebus ornatus	1	1	1	0	0	0	0	0	1	0	0	1	4	1	0.5	2
Callicebus ornatus	2	1	1	0	0	0	0	0	1	0	0	0	3	1	1	2
Callicebus ornatus	3	1	1	0	0	0	0	0	1	0	0	1	4	1	0.5	2
Saimiri sciureus albigena	1	5	8	0	0	0	0	0	20	3	3	3	42	0.625	0.28	13
Aotus brumbacki	1	1	1	0	0	0	0	0	0	0	0	0	2	1		2
Aotus brumbacki	2	1	1	0	0	0	0	0	0	0	0	0	2	1		2
Fragment 2																
Alouatta seniculus	1	1	2	0	0	0	0	0	0	0	0	1	4	0.5	2	3
Alouatta seniculus	2	1	2	0	1	0	1	0	0	1	0	0	6	0.5	0.67	3
Sapajus apella	1	1	2	0	0	0	0	0	3	0	0	2	8	0.5	0.4	3
Sapajus apella	2	1	2	0	0	0	0	0	1	0	0	0	4	0.5	2	3
Callicebus ornatus	1	1	1	0	0	0	0	0	1	0	0	1	4	1	0.5	2
Saimiri sciureus albigena	1	3	5	0	0	0	0	0	7	0	0	0	15	0.6	0.71	8
Aotus brumbacki	1	1	1	0	0	0	0	0	0	0	0	0	2	1		2
Fragment 3																
Alouatta seniculus	1	1	2	0	0	0	1	0	0	0	0	0	4	0.5	2	3
Fragment 6																
Alouatta seniculus	1	1	2	0	0	0	0	0	1	0	0	0	4	0.5	2	3

Sapajus apella	1	1	1	0	1	0	0	0	2	0	0	0	5	1	0.33	2
Aotus brumbacki	1	1	1	0	0	0	0	0	1	0	0	0	3	1	1	2
Fragment 9																
Alouatta seniculus	1	1	2	0	0	0	0	1	0	1	0	0	5	0.5	1	3
Alouatta seniculus	2	1	2	0	0	0	0	1	0	0	0	1	5	0.5	1	3
Alouatta seniculus	3	1	2	0	0	0	0	0	2	0	0	0	5	0.5	1	3
Alouatta seniculus	4	1	2	0	0	0	0	0	0	0	0	0	3	0.5		3
Alouatta seniculus	5	2	3	0	0	0	0	1	0	0	0	0	6	0.67	3	5
Alouatta seniculus	6	1	2	0	0	0	0	1	0	0	0	0	4	0.5	2	3
Alouatta seniculus	7	1	2	0	0	0	0	0	0	0	0	0	3	0.5		3
Alouatta seniculus	8	1	2	0	2	0	1	1	0	0	0	0	7	0.5	0.5	3
Alouatta seniculus	9	1	2	0	0	0	0	0	0	0	0	1	4	0.5	2	3
Alouatta seniculus	10	2	2	0	0	0	0	0	2	0	0	0	6	1	1	4
Alouatta seniculus	11	1	2	0	0	0	0	1	0	0	0	0	1	0.5	2	3
Alouatta seniculus	12	2	2	0	0	0	0	0	0	0	0	0	4	1		4
Sapajus apella	1	1	2	0	1	0	0	0	3	0	0	1	7	0.5	0.4	3
Sapajus apella	2	1	1	0	0	0	0	0	2	0	0	0	4	1	0.5	2
Sapajus apella	3	1	2	0	1	0	0	0	2	0	0	0	6	0.5	0.67	3
Sapajus apella	4	2	2	0	1	0	0	0	2	0	0	2	9	1	0.4	4
Sapajus apella	5	2	3	0	0	0	0	0	3	0	0	2	10	0.67	0.6	5
Sapajus apella	6	1	2	0	1	0	0	0	2	0	0	2	7	0.5	0.4	3
Sapajus apella	7	1	2	0	0	0	0	0	2	0	0	2	7	0.5	0.5	3
Sapajus apella	8	1	2	0	1	0	0	0	2	0	0	2	8	0.5	0.4	3
Sapajus apella	9	2	2	0	0	0	0	0	3	0	0	1	8	1	0.5	4
Sapajus apella	10	1	2	0	0	0	0	0	2	0	0	1	6	0.5	0.67	3
Callicebus ornatus	1	1	1	0	0	0	0	0	1	0	0	0	3	1	1	2
Callicebus ornatus	2	1	1	0	0	0	0	0	1	0	0	0	3	1	1	2
Callicebus ornatus	3	1	1	0	0	0	0	0	1	0	0	0	3	1	1	2
Callicebus ornatus	4	1	1	0	0	0	0	0	0	0	0	0	2	1		2

(continued)

Table 12.5 (continued)

Primate Species	Group ID	Adults			Subadults		Juveniles			Infants			Total	Males: Females	Females: Immatures	Census number
		Males	Females	Unknown	Males	Females	Males	Females	Unknown	Males	Females	Unknown				
Callicebus ornatus	5	1	1	0	0	0	0	0	2	0	0	0	4	1	0.5	2
Callicebus ornatus	6	1	1	0	0	0	0	0	1	0	0	0	3	1	1	2
Callicebus ornatus	7	1	1	0	0	0	0	0	1	0	0	0	3	1	1	2
Callicebus ornatus	8	1	1	0	0	0	0	0	0	0	0	0	2	1		2
Saimiri sciureus albigena	1	4	9	0	0	0	0	0	17	0	0	0	30	0.44	0.53	13
Saimiri sciureus albigena	2	3	5	0	0	0	0	0	12	0	0	0	20	0.6	0.42	8
Saimiri sciureus albigena	3	4	6	0	0	0	0	0	10	0	0	0	20	0.67	0.6	10
Saimiri sciureus albigena	4	4	8	0	0	0	0	0	18	0	0	0	30	0.5	0.44	12

Solitary individuals were also observed in *A. seniculus*, *S. apella*, *C. ornatus*, and *S. s. albigena* in all fragments at both Zones. *S. s. albigena* also formed small bachelor groups in both Zones, but was not observed in all fragments. *S. s. albigena* group from Fragment 2 disappeared in 2005, was observed again in 2010, but no observations of solitary or bachelor groups were made during that time.

The census number (total reproductive males and females) for all primate species was low for forest fragments studied (Table 12.5). Male to female ratios for all species were high, while female to immature ratios were variable between species and groups (Table 12.5).

Population density reported at SRAZ is higher than that reported in other studies for *S. apella*, *C. ornatus, A. brumbacki*, and *S. s. albigena*. In contrast, *A. seniculus* densities fell between normal ranges reported previously (Table 12.6). At LPZ, population density of Fragment 9 was lower than that reported in continuous forest for *Alouatta*, *Sapajus*, and *Callicebus* probably as a consequence of a low study effort with respect to fragment size as mentioned by Buckland et al. (2010). *Saimiri* density in Fragment 9 was near to that reported for continuous forest (Table 12.6). However, densities reported here for LPZ seem to reflect that this area has populations similar to that of continuous forest compared with densities reported for SRAZ reinforcing the suggestion of Stevenson and Aldana (2008) that this area was a continuous tropical forest before human disturbance. On the other hand, fragmentation seems to have a tendency to increase densities in small and medium fragments with respect to extra-large fragments. A survey with a higher number of fragments of different sizes may be needed to clarify this tendency.

Several deaths were reported in this study, but only anecdotally and only at SRAZ (Table 12.7). Predator attacks were observed for *Sapajus* immatures by domestic dogs and tayras. Two *Alouatta* infant deaths were likely to be infanticide cases (Beltran 2005). One adult male of *Saimiri* was found dead by an unknown cause in 2009, although local people reported domestic dog attacks as the likely reason. An adult female *Aotus* was observed dead with unknown reasons in 2006; this individual was consumed by a *Sapajus* group as an opportunistic behavior (Carretero-Pinzón et al. 2008). Dead individuals of *Callicebus* were not found in this study, but incidents have been reported by local people to the author.

Fencerow Corridors

All species except *Aotus* used fencerows as biological corridors and/or as part of their home ranges. *Alouatta*, *Sapajus,* and *Saimiri* were often observed using fencerows as part of their home ranges and as corridors to travel between fragments during this study. *Sapajus* and *Saimiri* were also observed to use wire fences as corridors. In addition, *Alouatta*, *Sapajus* and *Saimiri* sometimes used pastures and natural savannas around forest fragments to travel between fragments. *Callicebus* were only found to use fencerows two times as part of their home range in 2006. *Aotus* were never found to use fencerows, but local people reported in 2006 an individual of this species using a fencerow apparently to disperse.

Table 12.6 Primate densities reported in this study for both Zones compared with densities reported in other studies

Species	Density reported in this study at Santa Rosa-Arrayanes zone	Density reported in this study at Las Pampas zone	Density reported in other studies	Authors
Alouatta seniculus	23.37–78.57 ind/km^2	0.81 ind/km^2*	35–55 ind/km^2	Gómez-Posada et al. 2007[a], Defler 2004[a,b]
Cebus (= *Sapajus*) *apella*	26.92–52.98 ind/km^2	0.95 ind/km^2**	5.8–6.2 ind/km^2	Carretero-Pinzón 2005[a]
			16–17 ind/km^2	Stevenson et al. 1991[b], Defler and Pintor 1985[a]
			5.8 and 8–10 ind/km^2	Defler 2004[a,b], Soini 1986[b]
Callicebus ornatus	7.61–54.76 ind/km^2	1.07 ind/km^2***	192.2–400 ind/km^2	Mason 1966[a], Wagner et al. 2009[a]
			3–8 ind/km^2	Robinson 1977[a], Polanco 1992[b], Carretero-Pinzón 2005[a]
Saimiri sciureus albigena	3.85–170.24 ind/km^2	30.33 ind/km^2****	50–80 ind/km^2	Klein and Klein 1974[b], Terborgh 1983[b], Soini 1986[b]
			4 ind/km^2	Defler 2004[b]
			1–6 ind/km^2	Carretero-Pinzón 2005[a]
			12.7 ind/km^2	Stevenson 2007[b]
Aotus brumbackii	3.26–13.10 ind/km^2	n.a.	3.3–9.9 ind/km^2	Carretero-Pinzón 2005[a]

n.a. not applicable, *ESW* effective strip width, *AIC* akaike information criterion, *%CV* coefficient of variation percentage

[a]Fragmented forest

[b]Continuous forest

*ESW 16.7, AIC: 474.93, %CV: 14.17

**ESW 15.31, AIC: 913.92, %CV: 9.28

***ESW 10.52, AIC: 156.25, %CV: 24.69

****ESW 14.9, AIC: 168.55, %CV: 38.25

Table 12.7 Dead individuals found at Santa Rosa-Arraynes Zone

Year	Month	Specie	Sex	Category	Fragment	Cause of death	Observer
2004	August	Alouatta		Infant	1	Unknown	Sandra
2005	April	Alouatta		Infant	1	Twins, possible infanticide	Martha
2006	January	Cebus	Male	Infant	2	Domestic dog attack	Alfredo
2006	February	Aotus	Female	Adult	6	Unknown	Xyomara
2006	November	Cebus	Male	Infant	1	Tayra attack	Xyomara
2008	March	Saimiri		Adult	Wire fence	Domestic dog attack	Pedro
2009	April	Alouatta		Juvenil	1	Unknown	Carolina
2009	April	Alouatta		Juvenil	1	Unknown	Carolina
2009	April	Saimiri	Male	Adult	1	Unknown	Carolina

Discussion

There are no clear distribution patterns of primates in the fragments reported here. SRAZ Fragment 1 showed the highest densities for all species as a result of a higher fruit production compared with other fragments (data of fruit production of Fragment 1 showed higher values than Fragment 6 from September 2005 to January 2007; Carretero-Pinzón 2008), and a high connectivity with other small and medium fragments, which increased access to food resources. However, the population of primate species in this region is lower than that estimated as viable (200–500 breeding individuals; Brito and Grelle 2006).

Alouatta

Adult sex ratios and mother–offspring ratios for *Alouatta* are currently stable. The number of adult males and females in each group found in this study is slightly different with previous literature (Crockett 1996; Defler 2004; Gómez-Posada et al. 2007; Izawa 1997) with a tendency toward more immature males than females in some years. This trend may lead this population to more males than females in the future, even though both males and females were observed to disperse.

Alouatta in SRAZ Fragment 1 frequently used fencerows as part of their home ranges to include small and medium fragments, as well as individual *Ficus* sp. trees within the fencerows themselves or isolated on the pasture matrix. Their use of the *Ficus* sp. fence trees was particularly important during times of seasonal fruit scarcity. Fencerows with trees of greater than 15 m in height assured some cover from predators; however, howlers who crossed open pastures to reach these areas were at high risk of encountering dangerous situations, not unlike howlers in other study sites (Pozo-Montuy and Serio-Silva 2007).

Saimiri

In the case of *Saimiri*, it seems that presence of fencerows increased the likelihood of presence in any fragment of any size, probably as a response to space requirements. In continuous forest, they average a 240 ha home range compared to 100 ha in this study (Carretero-Pinzón 2008; Carretero-Pinzón et al. 2009). This could be one reason why this species was absent from SRAZ Fragment 7, which while large, is isolated from the others. Small and medium fragments (SRAZ Fragments 1, 4, 5, and 6) were connected by fencerows and maintained a stable group of *Saimiri*. *Saimiri* densities reported here may be overestimated precisely because of their mobile nature. Group size and composition are typical of *Samiri* groups (Boinski 1999; Carretero 2000; Defler 2004; Mitchell 1990) in these fragments. For this subspecies solitary males and bachelor groups were observed moving between fragments through fencerows. Bachelor groups have been reported for other species of *Saimiri* (Boinski 1999; Mitchell 1990).

Callicebus

The cryptic behavior of *Callicebus* made it difficult to detect them in the LPZ Fragments 12 and 13. Based on group size of *Callicebus* groups at both Zones, Carretero-Pinzón (in press) showed that there was a tendency toward higher group numbers (4–5 individuals) in smaller and medium fragments compared to large and extra-large fragments (2–4 individuals). Group composition of this species was similar to other sites nearby (Polanco 1992; Wagner et al. 2009). Use of fencerows seemed rare for *Callicebus*, however this may have been underestimated since they were difficult to see on fencerows.

Aotus

Aotus densities reported might be higher due to a greater sampling effort made in this study. Information about this species in general is scarce and previous densities are not available for comparison (Defler 2004). In LPZ Fragment 10, presence of *Aotus* was difficult to determine during the study, but the reserve owner observed this species resting on an *Oenocarpus* palm (E. Enciso pers. comm., January 2012), suggesting their presence as likely. *Aotus* group size and composition was similar to that reported by Solano (1995) at Tinigua National Park. Higher densities in SRAZ Fragment 1 for this species can be explained by a higher number of available nest sites and higher overall fruit production. Solitary individuals observed were probably dispersing animals. *Aotus* weren't observed using fencerows, but more sampling may reveal their use. For instance, an *Aotus* group in SRAZ Fragment 6 has a nest near a fencerow with fruit trees. Additional surveys for *Aotus* must be conducted to further corroborate the apparent increased overall population.

Sapajus

Sapajus group size and composition were typical for this species in the greater Colombian Llanos (Defler 2004), but different from those studied at the Tinigua National Park, which is a more biodiverse site where there was a mean of 16 individuals (Izawa 1980; Stevenson and Aldana 2008; Stevenson et al. 1991). *Sapajus* males in the study area disperse more than females, as all solitary individuals were males.

Sapajus used fencerows regularly for access to small fragments (even less than 1 ha) with dormitory sites and *Ficus* sp., and like *Alouatta* and *Saimiri*, they were observed using wire fences as well as open ground. Their regular, yet seasonal use of fragments means not all sites are used equally. Use of fencerows and small fragments was not without risk particularly for immature individuals, as three predator attacks were observed: Two in a fencerow—one by a domestic dog and the other by a Crested Caracara (*Caracara cheryway*) and the other by a tyra (*Eira barbara*) inside Fragment 1.

Conclusion

In general, the future of *Alouatta*, *Sapajus*, *Callicebus, Saimiri* populations is uncertain, although their current population status appears stable, and *Aotus* appears to be increasing above predicted trends. The higher primate densities observed at Santa Rosa-Arrayanes Zone can be attributed to higher fruit availability as compared to other fragments. But isolation and increased fragmentation could lead to local extinction. Thus, fencerows proved to be invaluable for nearly all species as a means to increase home range, food availability, or sleeping sites. The network of fencerows and fragments is not without risk to the primates in the area, and the need for greater connectivity is apparent due to the lower numbers of the more isolated forest sites and the predation risk to individuals crossing through the matrix. *Saimiri* use fencerows as part of their home range and as biological corridors between fragments, which is an important tool for conservation of this endemic subspecies of squirrel monkeys.

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