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Diversity, Abundance and Habitats of the Primates in the Río Curaray Basin, Peruvian Amazonia

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Abstract: Western Amazonia is one of the regions of the world with the highest terrestrial biodiversity. We conducted transect censuses between November and December 2012 in order to determine the diversity and the densities of primate populations, and their group sizes and habitat use in the Río Curaray region. During 610 km of transect surveys, we encountered 304 groups of 13 primate species. Woolly monkeys, *Lagothrix poeppigii*, were the most frequently observed (n = 49 sightings) and pygmy marmosets, *Cebuella pygmaea*, the least (n = 8). Population density was lowest for howler monkeys, *Alouatta seniculus* (9.8 individuals km^{-2}) and saki monkeys, *Pithecia aequatorialis* (11.8 individuals km^{-2}) and highest for squirrel monkeys, *Saimiri macrodon* (65.0 individuals km^{-2}) and woolly monkeys (65.3 individuals km^{-2}). Primate groups were most frequently encountered in "palmales de altura" (97 encounters of 12 species). In conclusion, the Río Curaray region harbors a very high diversity of primates, matching other sites in Amazonia and worldwide, and populations there are evidently healthy and well conserved. We recommend the creation of a protected area contiguous with the Yasuní National Park in Ecuador.

Key Words: Western Amazonia, primate diversity, population density, habitat

Introduction

Amazonia, particularly its western part, is one of the most species-rich regions of the world (for example, Gentry 1988; Voss and Emmons 1996; Myers *et al.* 2000). The Río Napo, a major tributary of the upper Río Amazonas, has been identified as a center of species richness for four major taxa—vascular plants, amphibians, birds, and mammals (Bass *et al.* 2010)—indicating the importance of this region for global, regional and local conservation efforts. However, the forests there are coming under increasing threat, particularly due to oil and gas exploration and drilling (Finer *et al.* 2008; Soto *et al.* 2010). Like other areas in Peru, the Río Napo region is part of the country-wide concessions for oil drilling (Perú Petro 2007); a continuously growing threat to habitats and species. Primates, particularly the larger species of the family Atelidae, are sensitive to habitat disturbance and fragmentation (Cowlishaw and Dunbar 2000). Even small-scale disturbance such as seismic explorations preceding actual oil drilling may affect their populations (Kolowski and Alonso 2012). Furthermore, bushmeat hunting, which often increases when remote areas become more accessible due to commercial, large-scale exploitation of oil, gas and timber, is also a major threat to primate populations in Amazonia (Peres 1990).

With this background, we conducted a survey of primate populations along the upper Río Curaray, a southern tributary of the Río Napo. This is a relatively remote area (300 km from the city of Iquitos) but may become a focus of oil exploitation. Although a few general or taxon-specific primate surveys have been conducted in the Río Curaray basin (Aquino *et al.* 2005, 2013; Heymann 2000; Heymann *et al.* 2002; Kolowski and Alonso 2012), the status of the primate fauna of this area is little known.

Here we present the results of a survey conducted in November and December 2012 on both banks of the upper Río Curaray. We were interested in evaluating the diversity and abundance of primate populations and their relationship to habitat type, and examining whether this river is a species boundary in its upper reaches, as suggested by previous studies on *Saguinus* and *Pithecia* (Heymann *et al.* 2002; Aquino *et al.* 2009a).

Methods

Study area

The Río Curaray is in the extreme northwest of Peruvian Amazonia, towards the border with Ecuador, and is included in Lote 39 of the oil drilling concession to Repsol Exploración Perú (Perú Petro 2007). So far, forests along both sides of the Curaray show only slight disturbance, mainly due to sporadic logging and subsistence hunting. They will, however, be exposed to the threats emerging from petroleum prospecting and the infrastructure and personnel that accompany it.

Climate data from the nearest meteorological station (Arica, 1°36'01"S, 75°12'01"W, at the confluence of the ríos Nashiño and Curaray; Fig. 1) are available only for the period between December 1976 and July 1982 (SENAMHI 2008). Mean annual rainfall exceeds 2200 mm per year, with January receiving <150 mm per month.

For our censuses, we identified four different areas, two on each bank of the Curaray (Fig. 1; for geographic coordinates and habitat types see Table 1). We distinguished the following habitat types:

High forest (*monte alto*): vegetation composed almost entirely of trees of generally 20–25 m height, with some emergents above 30 m; open understorey, compact soils. Common tree species: *Macrolobium angustifolium* (Fabaceae; common name: "pashaco"), *Eschweilera* spp. (Lecythidaceae; "machimango"), *Couma macrocarpa* (Apocynaceae; "leche huayo"), *Chrysophyllum* spp. (Sapotaceae; "caimitillo"), *Cedrelinga cateniformis* (Fabaceae, "tornillo"), *Parahancornia* sp. (Apocynaceae; "naranjo podrido"), *Pouteria* spp. (Sapotaceae; "caimitillo"), *Hymenaea courbaril* (Fabaceae; "azúcar huayo") and *Vantanea* spp. (Humiriaceae; "añuje rumo"). The few palms (Arecaceae) are mainly *Astrocaryum murumuru* ("huicungo") and *Iriartea* sp. ("pona"). This vegetation type is common on low hills and high terraces.

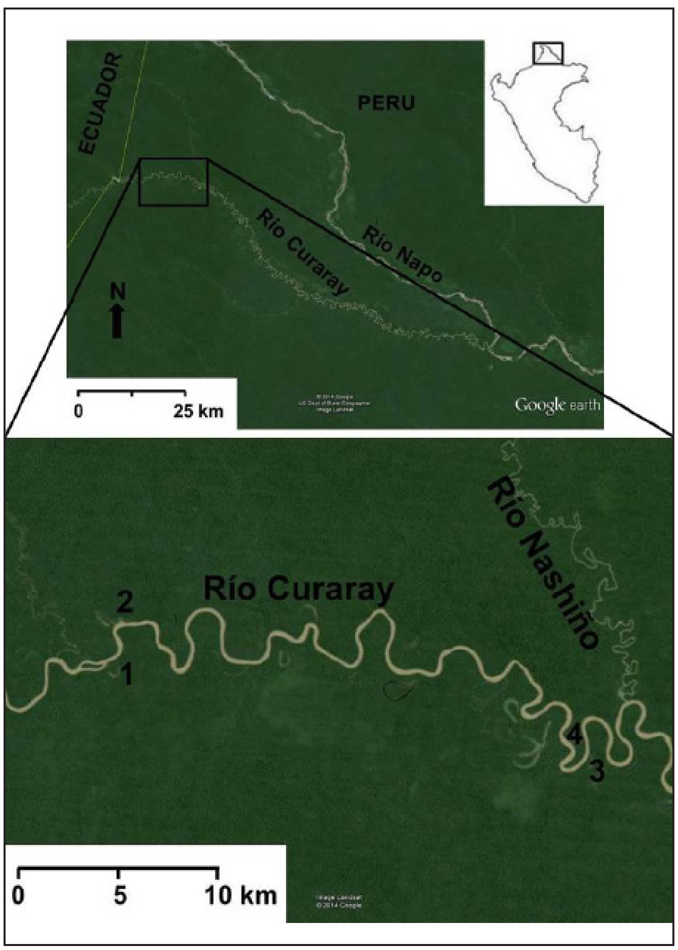

Figure 1. Location of survey sites on the Río Curaray. Numbers correspond to the list in Table 1.

Low forest (*monte bajo*): trees with heights of 15 to 20 m, the majority covered by epiphytes and lianas. Dense understorey characterized by the presence of herbaceous plants such as *Calathea* sp. (Marantaceae; "bijao"), *Bactris* sp. (Arecaceae; "ñejilla") and *Costus* sp. (Costaceae; "cañagria"); includes riparian vegetation. Common tree and liana species are *Couroupita guianensis* (Lecythidaceae; "ayahuma"), *Inga* spp. (Mimosaceae; "shimbillo"), *Cecropia* spp. (Cecropiaceae "cético"), *Rheedia* sp. (Clusiaceae; "charichuelo"), *Annona* sp. (Annonaceae; "anona") and *Passiflora* sp. (Passifloraceae; "granadilla"). This habitat type is common on low and medium terraces, and is subject to inundation on the lower terraces.

Palmal de altura: dominated by palms of 20–25 m height, intermingled with emergent trees of >30 m height such as *M. angustifolium* and *Eschweilera* spp. The most common palms are *Oenocarpus bataua* ("ungurahui"), *Socratea* sp. ("huacrapona"), *Iriartea* sp., *Astrocaryum chambira* ("chambira"), *A. murumuru*, *Phytelephas macrocarpa* ("yarina"), *Scheelea cephalotes* ("shapaja") and *Scheelea* sp. ("shebón"). The understorey is generally open and sometimes abundant in small *Lepidocaryum tenue* ("irapay") palms or perennial herbs. This habitat type is found mainly on low hills and high terraces.

Palmal de planicie: dominated (>70% of individuals) by *Mauritia flexuosa* (Arecaceae; "aguaje"), associated with *Mauritiella* sp. (Arecaceae; "aguajillo"), *Euterpe* sp. (Arecaceae; "chonta") and some fig trees *Ficus* (Moraceae; "renaco"). Common in medium and low terrace forests. Abundance of stilt roots and frequent flooding with black water

Table 1. Census areas and their predominant forest types at the Río Curaray.

Area	River bank	Coordinates	Name	Predominant forest types
1	Right	452622/9829407	Paujil	Medium and low terrace forest
2	Left	474749/9821868	Shuyal	High and low terrace forest
3	Right	452080/9826841	Colpa	High and low terrace forest
4	Left	475731/9821084	Ponal	Low hill forest, high and medium terrace forest

can make access difficult. Subject to inundation on the low terraces.

Varillal: dense vegetation with trees and small trees between 10 and 25 m and few emergents above 30 m. Trees bolt upright with sclerophyllic leaves, similar to typical white-sand forests of the Peruvian Amazon. The soils differ from typical white-sand forest, however, by being sandy-clayey and rarely entirely sandy. Emergent trees represented mainly by *Parkia* spp., *Manilkara* spp. and *Eschweilera* spp. Uniquely present south of the Curaray in so-called *manchales*, located between peaks of the low hills, and on high terraces.

Tree swamp (*pantano arbóreo*): composed of trees of 20–25 m with an open understorey and ground covered by standing water and abundant stilt roots. The vegetation is dominated by *Ficus* spp. ("renaco"), intermingled with *Tachigali* sp. (Mimosaceae; "tangarana"), *Guarea* sp. (Meliaceae; "requia"), and few palms, mainly *Euterpe* sp. This habitat type is common on low terraces where it is subject to inundation.

Transect censuses

In November and December 2012, we opened four transects of 3–5 km length at each of the four survey areas. We carried out diurnal censuses between 0630 h and 1300 h, and nocturnal censuses between 1830 h and 2200 h. Two teams of two observers each moved simultaneously along two different transects with an average speed of 1 km/h. Each transect was walked three to four times. Each time a primate group was detected the following information was recorded: group size; perpendicular distance from the transect of the first individual seen; height and activity at the moment of detection; presence of neonates and young infants; interspecific association with other primate species; and the vegetation type where the group was seen. Censuses were conducted on the transects both going out and returning. In all, we walked 610 km of transects (430 km diurnal, 180 nocturnal).

Data analyses

Due to the small number of sightings (<30) for most species, we used the formula suggested by Burnham *et al.* (1980) for calculation of densities: D = N/2dL, where D = the density (groups/km²), N = the number of sightings, L = the accumulated transect length, and d = the mean perpendicular distance from the transect. The population density was then obtained by multiplying D by mean group size. We also calculated the number of sightings per 10 km of walked transect. We excluded *Cebuella pygmaea* from the analyses, as this species is restricted to river-edge forest, and is thus not easily recorded along transects extending away from the river.

Based on the number of sightings per species, we calculated the Euclidean distance between the primate communities of each habitat type in Ecological Methodology 7.2. To examine the similarity/dissimilarity of the communities, we subjected the resulting distance values to a single-linkage cluster analysis in Statistica 10.0.

Results

We obtained 304 sightings of 13 primate species. Most were of *Lagothrix poeppigii* (N = 49), followed by *Callicebus discolor* (N = 32) and *Ateles belzebuth* (N = 31); the least sightings were logged for *C. pygmaea* (N = 8), and *Pithecia napensis*[1] (N = 16; Table 2). The smallest groups were those of *C. discolor*, *Aotus vociferans* and *Pithecia napensis*, and the largest were of *Saimiri macrodon* (previously *Saimiri sciureus*) and *L. poeppigii* (Table 2). The range of observed group sizes generally matched those recorded in other areas of northeastern Peruvian Amazonia, except for *A. belzebuth* which had larger groups than in other areas (Table 2).

Saguinus tripartitus and *P. napensis* were recorded only north of the Río Curaray, and *Saguinus lagonotus*, *P. aequatorialis* and *Sapajus macrocephalus* (previously *Cebus apella macrocephala*) only south of the Curaray (Fig. 2). The number of sightings was highest for *A. vociferans*, *L. poeppigii* and *S. lagonotus*, and the highest population densities were those of *S. macrodon* and *L. poeppigii* (Table 3).

All primate species combined, the majority of sightings were in *palmal alto* and high forest; 12 of the 13 primate species were encountered in these habitat types (Table 4). Only four and five species, respectively, were sighted in *varillal* and tree swamps (Table 4). Atelids and cebids were most frequently observed in high forest, *palmal de altura* and *palmal de planicie*. *Cebuella pygmaea* was encountered exclusively and *C. discolor* mainly in low forest. Results of the cluster analysis reflect the uneven community composition over habitat types (Fig. 3). Primate communities of *varillales* and tree swamps cluster closely together and, more distantly, with *palmales de planicie*. High forest clusters with *palmales de altura* (Fig. 3). Low forest clearly sticks out, which is due to the lack or scarcity of sightings of large and medium-sized primates (atelids, *Cebus*, and *Sapajus*) there, and the frequent sightings of small primates (callitrichids, pitheciids, and *Saimiri*).

On 30 occasions we saw two species associated with each other. Two-thirds were of squirrel monkeys *Saimiri macrodon* travelling with the capuchin monkeys *S. macrocephalus* (13 cases) or *C. yuracus* (seven cases).

Discussion

The number of primate species encountered during our survey (13) is higher than that reported by Heymann *et al.* (2002), who did not record *A. belzebuth* and *C. pygmaea*. It matches the number of species found in the Manú National Park (Terborgh 1983) and in the Reserva Comunal Tamshiyacu-Tahuayo (now: Area de Conservación Regional Comunal

1 We follow the taxonomic revision of the genus *Pithecia* by Marsh (2014).

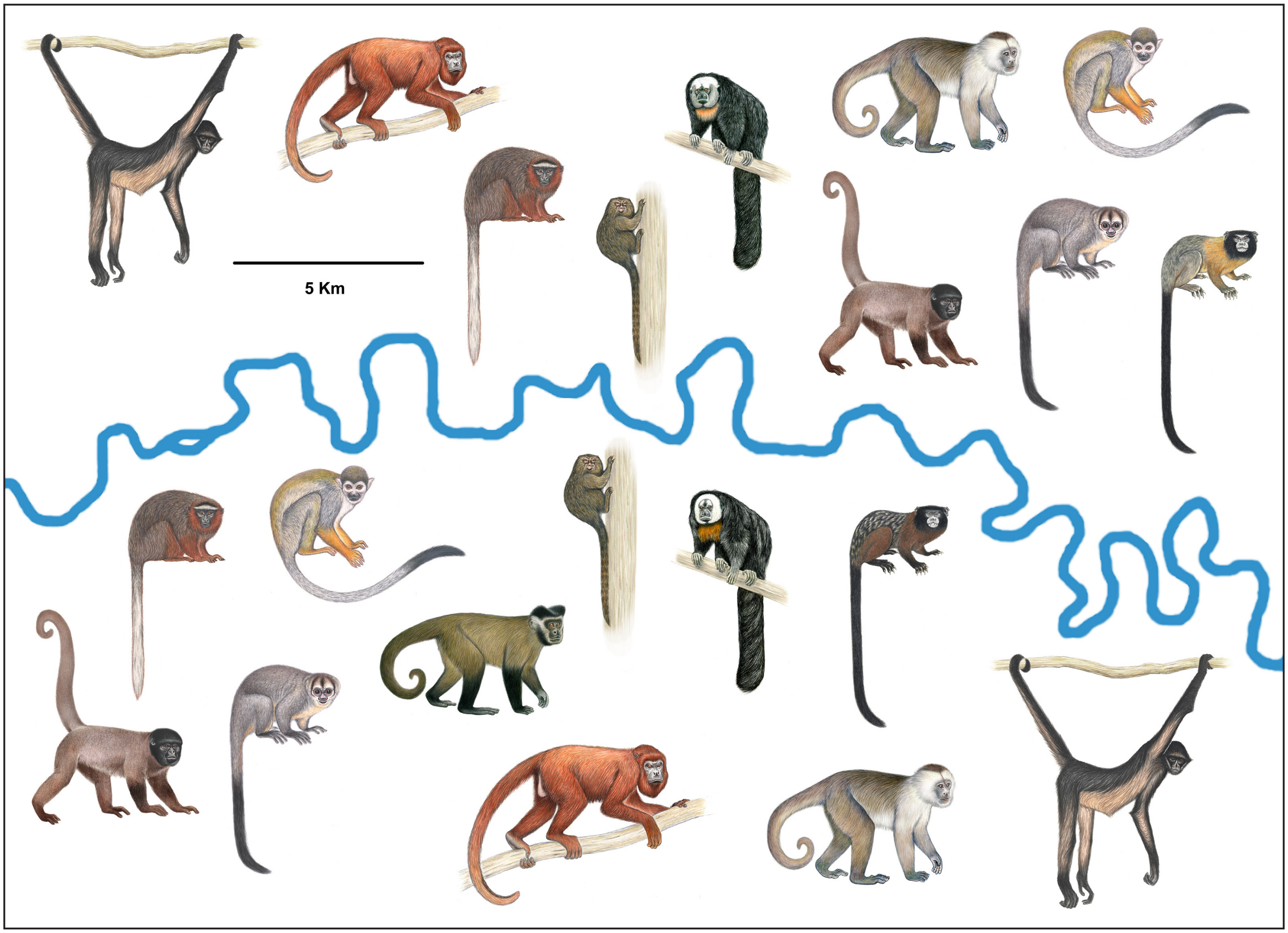

Figure 2. Primate communities north and south of the Rio Curaray at the four localities surveyed (see Table 1, Fig. 1). *Saguinus tripartitus* and *Pithecia napensis* were observed only north of the river (left bank), and *Saguinus lagonotus*, *Sapajus macrocephalus*, and *Pithecia aequatorialis* were observed only south of the river (right bank).

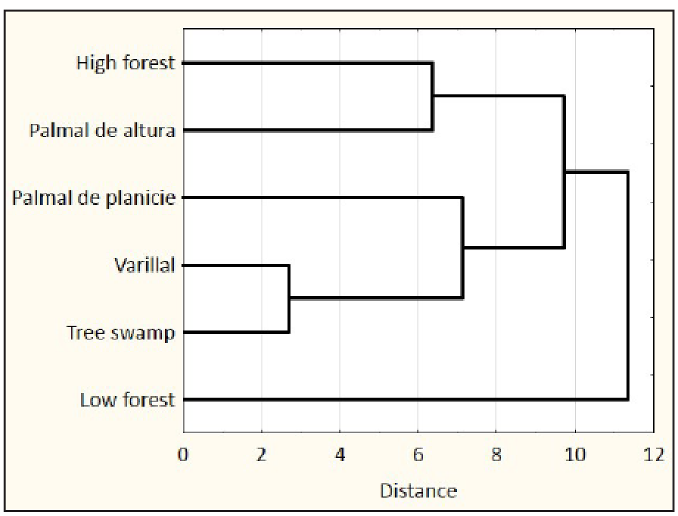

Figure 3. Single-linkage cluster analyses of the similarity of primate communities in the different habitat types.

Tamshiyacu-Tahuayo, ACRCTT) (Puertas and Bodmer 1993)[2]. It is higher than the number of primate species in the Yasuní National Park, Ecuador, where 10 species are found (Bass *et al.* 2010; Marsh 2004). However, not all species occur syntopically, and the maximum number of species at any survey site was 11 (on the south bank of the Curaray). This supports the prediction (Heymann *et al.* 2002) of a maximum of 10–11 species per site, and is in line with the findings of Palminteri and co-workers, who found a maximum of 10 species out of a pool of 13 at all of their survey sites in southeastern Peru (Palminteri 2010). While on a large (continental) scale, forest cover and rainfall are the major predictors of primate species richness (Peres and Janson 1999), habitat type is strongly predictive on the regional/local scale, with *terra firme* forests harboring richer primate communities than flooded forests

2 Puertas and Bodmer (1993) reported 14 species for ACRCTT, but the presence of *Saimiri boliviensis* has not been confirmed and is actually unlikely, as the area is outside its distributional range and northeast of a known hybrid zone with *Saimiri sciureus* on the Río Ucayali (Hershkovitz 1984; Silva *et al.* 1992).

Table 2. Primate species and their group sizes recorded during transect censuses.

Species*	Group size		# of groups		Group size range in other areas
	Mean (SD)	Range	Total	With complete counts	
Ateles belzebuth	12.2 ± 5.5	6–18	31	5	2–11[a]
Lagothrix poeppigii	16.0 ± 5.6	9–23	49	6	5–24[b]
Alouatta seniculus	7.0 ± 2.4	6–11	18	8	2–13[c]
Cebus yuracus	14.0 ± 3.2	9–17	28	5	12–16[b]
Sapajus macrocephalus	12.2 ± 3.3	11–15	18	5	2–13[b]
Pithecia aequatorialis	3.7 ± 1.3	2–6	19	9	2–8[b]
Pithecia napensis	4.5 ± 2.0	2–7	16	6	2–8[c]
Callicebus discolor	3.2 ± 1.2	2–5	32	13	2–6[b]
Saimiri macrodon	43.5[§]	>35	19		2–61[b]
Aotus vociferans	3.6 ± 1.0	2–5	21	8	2–5[d]
Saguinus lagonotus	5.8 ± 1.1	4–7	28	15	2–10[c]
Saguinus tripartitus	5.7 ± 1.3	4–8	17	9	6–9[e]
Cebuella pygmaea	5.6 ± 1.2	5–7	8	3	2–9[c]

* In order of decreasing body mass
[§] Incomplete counts; therefore, mean taken from Aquino *et al.* (2009a)
Sources: [a]Río Samiria: Aquino and Bodmer (2006); [b]Río Itaya: Aquino *et al.* (2009b); [c]Pacaya Samiria: Soini (1986); [d]Río Napo: Aquino *et al.* (1990); [e]Ecuadorian Amazon: Albuja (1994)

Table 3. Sighting rates and population density estimates.

Species*	Mean detection distance m	Total length of transect walks km	# of sightings/ 10 km of transect walk	Population density		Pucacuro[a]	Itaya[b]	Arabela[c]	Yasuní[d]
				groups/km²	ind./km²	ind./km²	ind./km²	ind./km²	ind./km²
Ateles belzebuth	18	430[†]	0.7	1.9	23.0	0.8	-	13.3	11.5
Lagothrix poeppigii	20	430[†]	1.1	3.1	49.6	10.0	15.4	30.6	31
Alouatta seniculus	15	430[†]	0.4	1.4	9.8	2.1	0.2	n.a.	n.a.
Cebus yuracus	15	430[†]	0.6	2.1	29.4	4.4	6.8	n.a.	n.a.
Sapajus macrocephalus	14	230[‡]	0.8	2.6	31.7	2.8	3.0	n.a.	n.a.
Pithecia aequatorialis	13	230[‡]	0.8	3.1	11.5	2.8	7.8	n.a.	n.a.
Pithecia napensis	10	200[§]	0.8	3.5	15.7	-	-	n.a.	n.a.
Callicebus discolor	9	430[†]	0.7	4.3	13.8	1.1	7.0	n.a.	n.a.
Saimiri macrodon	12	430[†]	0.4	1.4	61.0	5.2	18.2	n.a.	n.a.
Aotus vociferans	8	180[†]	1.1	7.2	26.0	n.a.	n.a.	n.a.	n.a.
Saguinus lagonotus	10	230[‡]	1.2	6.0	34.8	3.0	10.5	14.8	n.a.
Saguinus tripartitus	9	200[§]	0.8	4.7	26.8	-	-	n.a.	n.a.

* In order of decreasing body mass; [†]all transects; [‡]transects south of the Río Curaray (1, 3); [§]transects north of the Río Curaray (2, 4); n.a. = not available
Sources: [a]Aquino *et al.* (2000a); [b] Aquino *et al.* (2009b); [c]Kolowski and Alonso (2012); [d]Dew (2005)

(Palminteri *et al.* 2011; Peres 1997). Our survey corroborates these findings, with fewer primate species in those habitats that are subject to inundation. The lowest number was found in *varillal*, which might be explained by the low floristic diversity (and probably productivity) of white-sand forests (Fine *et al.* 2010; Oñate Calvín 2012).

Our survey confirms previous observations that the Río Curaray forms a distributional limit for two species each of *Saguinus* and *Pithecia* (Aquino and Encarnación 1996; Heymann *et al.* 2002; Rylands *et al.* 2011). In line with Heymann *et al.* (2002), we encountered *S. macrocephalus* only on the south bank of the Río Curaray. However, in contrast to Heymann *et al*. (2002), we encountered *Cebus yuracus* (previously *Cebus albifrons yuracus*) on both banks. The restriction of *S. lagonotus*, *S. macrocephalus* and *P. aequatorialis* to the south bank of the Río Curaray accounts for the higher number of primate species compared to the Yasuní National Park, located north of the Río Curaray (the eastern border of which is only about 25 km from our survey area).

Table 4. Number of sightings of different primate species per habitat type.

Species*	Number of sightings per habitat type						Total
	H.f.	L.f.	P.a.	P.p.	Va	T.s.	
Ateles belzebuth	14	0	8	9	0	0	31
Lagothrix poeppigii	19	0	23	5	2	0	49
Alouatta seniculus	2	0	6	7	0	3	18
Cebus yuracus	4	3	11	9	0	1	28
Sapajus apella	6	2	7	3	0	0	18
Pithecia aequatorialis	8	0	5	2	4	0	19
Pithecia napensis	4	0	12	0	0	0	16
Callicebus discolor	8	19	3	0	0	2	32
Saimiri macrodon	4	5	6	2	1	1	19
Aotus vociferans	3	9	5	4	0	0	21
Saguinus lagonotus	7	9	6	3	3	0	28
Saguinus tripartitus	4	7	5	0	0	1	17
Cebuella pygmaea	0	8	0	0	0	0	8
Total	83	62	97	44	10	8	304
# of species / habitat	12	8	12	9	4	5	

* in order of decreasing body mass
[#] H.f.: high forest; L.f.: low forest; P.a.: *palmal de altura*; P.p.: *palmal de planicie*; Va: *varillal*, T.s.: tree swamp

That the Río Curaray is a barrier is quite surprising, as it is quite narrow (50–100 m wide) and strongly meandering, resulting in frequent river bend cut-offs of small islands that could transfer species from one bank of the river to the other. However, as meanders of the Río Curaray are extremely constricted (see Google Earth, 1°10'S–2°30'S, 74°05'W–75°35'W), these islands may simply be too small to accommodate a population large enough to persist until merging with a population on the opposite bank of the river (Heymann *et al.* 2002).

Our population density estimates are higher than those obtained for the Río Pucacuro and the upper Río Itaya (Aquino *et al.* 2000a, 2009b). For *L. poeppigii*, *A. belzebuth* and *S. lagonotus* they are also higher than those obtained by Kolowski and Alonso (2012) in the non-hunted forest of the upper reaches of Quebrada Arabela, about 50 km from our area. Since Kolowski and Alonso (2012) used the number of individuals seen upon encounter rather than complete counts to estimate group size for calculating population densities, their estimates are inherently smaller than ours, even if real population densities were actually very similar. More importantly, the fact that both our density estimates and those of Kolowski and Alonso (2012) are consistently higher than those for the Río Pucacuro and the upper Río Itaya supports the notion that human interference affects primate population densities. This effect is particularly strong for the large atelids which are preferred by hunters (Aquino *et al.* 2000b; Peres 1990; Puertas and Bodmer 1993), but may also be pertinent for medium-sized and smaller primates (Endo *et al.* 2010). Being closer to Iquitos (where bushmeat was, and still is, common in the markets Castro *et al.* 1990), and more accessible than the upper Río Curaray, hunting pressure is much stronger at Río Pucacuro and the upper Río Itaya.

For *L. poeppigii* and *A. belzebuth* our estimates are also higher than those for the Yasuní National Park (Dew 2005). Dew obtained his estimates by relating study group size to home-range size, so again results cannot be directly compared. Nevertheless, it is noteworthy that in these two studies and in our study, the density of *L. poeppigii* was always 2–3 times higher than the density of *A. belzebuth*. While it is tempting to speculate that interspecific competition might keep population densities of *A. belzebuth* lower than those of *L. poeppigii* (Dew 2005, Iwanaga and Ferrari 2002), a reverse pattern, i.e. higher population densities for *Ateles*, has been reported from four out of five non-hunted sites in the Manú National Park (Endo *et al.* 2010). Detailed, comparative, long-term, ecological studies and biogeographic analyses are needed to reveal whether populations of *Ateles* and *Lagothrix* affect each other, whether local ecological conditions favor one or the other species, or whether historical events or processes are responsible for current patterns.

Amongst the small species (body mass <1 kg), *C. pygmaea* and *C. discolor* stick out by either having been recorded exclusively or by strongly prevailing, respectively, in a single habitat type. *Cebuella pygmaea* is a highly specialized exudativore that prefers floodplain forest (Soini 1982; de la Torre *et al.* 2000). The only available ecological study of *C. discolor* (by Carillo-Bilbao *et al.* 2005) indicates that this species uses mainly the lower canopy and the understorey, which may facilitate its existence in low forest. However, *S. tripartitus* and *S. lagonotus* also prefer the lower forest strata (Heymann 2000, Heymann *et al.* 2002), but do not prevail in low forest. Additional ecological factors must play a role that we have yet to identify. In conclusion, our survey revealed that the upper Río Curaray harbors a species-rich primate fauna, which adds to the recognition of the Río Napo region as one of the most species-rich areas of the world. To conserve this biodiversity, the creation of a protected area that includes both banks of the upper Río Curaray and that adjoins the Yasuní National Park on the Ecuadorian side would be highly desirable.

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