POPULATION DENSITY ESTIMATES OF NIGHT MONKEYS (*Aotus azarae boliviensis*) IN TAMBOPATA, PERU

A Thesis

by

MACKENZIE ROSE PRYOR

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Chair of Committee,	Sharon Gursky
Committee Members,	Michael Alvard
	Jeffery Winking
Head of Department,	Darryl de Ruiter

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ABSTRACT

Habitat loss is a major problem for many forest dwelling species worldwide. This habitat loss is often due to activities associated to population growth, and nonhuman primates are among the most affected by these forest changes in tropical regions. Azara's night monkey (*Aotus azarae boliviensis*) is experiencing threats such as commercial gold mining, infrastructure development, deforestation for agriculture, and subsistent hunting and trade in the northernmost distribution of their range in Tambopata, Peru. Whereas the IUCN Red List currently classifies this species as "Least Concern", continued high rates of habitat loss suggests that additional data may be needed to reevaluate this subspecies' conservation status. This paper provides population density estimates of *A. a. boliviensis* at three distinct forest sites experiencing varying degrees of disturbance (i.e. new secondary, old secondary, primary). This was done by walking transects along the existing trail systems at each site in order to detect and count population numbers of *A. a. boliviensis*. Vegetation was also sampled at each site using vegetation plots. For each plot, relevant forest characteristics were recorded. Over the course of 120.54 kilometers and 78 hours of surveying, I detected 24 monkeys at the new secondary forest site, 22 monkeys at the old secondary forest site, and 11 monkeys at the primary forest site, for a total of 57 monkeys across all sites. We calculated population densities of 25.1 monkeys/km^2 at the new secondary forest site, 30.5 monkeys/km^2 at the old secondary forest site, and 15.0 monkeys/km^2 at the primary forest site, though there was not a significant difference between these values at each

site. There was also no significant difference between the forest measurements at each site, which could be attributed to the sites' uses for ecotourism. Based on these results, it may be true that *A. a. boliviensis* prefers slightly disturbed secondary forest sites. Population densities in this study are lower than most other estimates, especially of the same species in a similar area. Consequently, the IUCN red list classification for this species should incorporate the extensive variation in density and behavior when re-evaluating this species conservation status.

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All other work conducted for this thesis was completed by the student independently.

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CHAPTER I

INTRODUCTION

Habitat loss is a major problem for many forest dwelling species worldwide. It is estimated that over the past three centuries, the global area of forest has decreased by 50%, and currently, tropical forests have been disappearing at a rate of up to 130,000 km^2 per year (Laurance 2010). Approximately 80% of forests in West Africa have been converted to an agriculture-forest mosaic, resulting in a significant loss of forest species (Norris et al. 2010). Likewise, between the years 2000 and 2012, it is estimated that Indonesia lost 6.02 million hectares of primary forest, and this forest loss increased at a rate of approximately 47,600 hectares per year (Margono et al. 2014). Analyses of Landsat images of Madagascar show that between the years 1953 and 2000, forest cover decreased by about 40%. Habitat loss is also prevalent in South America. In the Madre de Dios Department, the annual rate of forest loss due to gold mining increased from ~2,166 hectares/year between 1999-2007 to ~6,145 hectares/year between 2008-2012 (Asner et al. 2013). This rampant forest destruction in the tropics poses major threats to forest-dwelling species (Strier 2007).

The loss of forest is due to activities associated with population growth and capitalism, such as agriculture, logging, livestock farming, road construction, and mining (Estrada et al. 2017). As human populations continue to grow, more forests are destroyed and the plant and animal communities that rely on these habitats are decreasing. Non-human primates are among the most affected by these forest changes in

tropical regions (Strier 2007). A recent review on primate extinction threats concluded that approximately 60% of 504 primate species are in danger of extinction with approximately 75% of all primate species experiencing population declines (Estrada et al. 2017). For example, there is a strong decline in orangutan population densities after logging, with an estimated 1,000 Sumatran orangutans being lost each year due to habitat destruction (Wich et al. 2003). However, promising results have shown that if logging is abandoned and forests are given adequate time to regenerate, orangutan populations have been seen to recover as long as there is fruit present (Knop et al. 2004). Alternatively, in other areas, these types of threats can still affect primate communities after they have discontinued. A 28-year study by Chapman et al. (2000) examined how primate communities in Africa recovered after extensive logging. They found that blue monkeys and red-tailed monkeys continued to decline decades after logging stopped. Other species, such as the Ugandan red colobus began to recover, but at a very slow rate of .005 groups/km^2 per year (Chapman et al. 2000). Changes in forest composition can also influence a species ecology. Irwin (2008) found that the diademed sifaka in disturbed forest fragments in Madagascar utilized smaller home ranges, consumed less fruit and engaged in fewer activities such as scent marking, aggression, and play behavior than populations in undisturbed forests. Similarly, a study comparing bearded sakis in fragmented and continuous forests found that the populations in the fragmented forests occupied smaller home ranges, lived in smaller groups, and traveled shorter and repetitive daily distances (Boyle and Smith 2010). These are only a few examples of how primates can be affected by population growth and development.

Numerous primate species within Peru are experiencing many, if not all of these threats to their habitat. One species for which these threats are quite pressing is the Azara's night monkey (*Aotus azarae boliviensis*) in the northernmost distribution of their range within the Tambopata area of Peru (IUCN 2018). Deforestation for agriculture, infrastructure development, and gold mining has resulted in the loss of sleeping and fruiting trees for this genus. From 2001-2011 mining concessions increased in land area by 239% and infrastructure development (i.e. roads) increased by 44%, encroaching into buffer zones surrounding protected areas (Scullion et al. 2014). This genus is also often killed for subsistence hunting as well as captured and traded to the American Health Organization for malaria research (Aquino and Encarnación 1994). It is estimated that over 13,000 night monkeys have been traded since 1975 (Svensson et al. 2016).

While the IUCN Red List currently classifies this subspecies to be of "Least Concern", this subspecies as well as almost all other *Aotus* species are experiencing a decrease in population size (IUCN 2018). Although *A. a. boliviensis* is currently in good standing, the recently reported high rate of habitat loss resulting from agriculture and mining throughout the Tambopata area suggests that additional data may be needed to re-evaluate this subspecies' current conservation status, as extinction risk can change rapidly (Cardillo et al. 2006). Long term studies of a southern subspecies of night monkey, *Aotus azarae azarai*, show high population densities; however, these estimates may not be the best indicator of population sizes in the northern subspecies because of differing behaviors, habitats, and threats between the two subspecies (Fernandez-Duque et al. 2001). It has been suggested that most primate species show high levels of

intraspecific variation and that studying populations in various portions of a species range is important to understand all aspects of the species ecology (Strier 2017).

The primary goal of this paper is to provide population density data on the northernmost range of *A. a. boliviensis* at three distinct forest sites experiencing varying degrees of disturbance (i.e. new secondary, old secondary, primary) within the Tambopata area. Primates that inhabit this area have been experiencing habitat destruction due to deforestation and mining pressures (Estrada et al. 2017). These factors, along with evidence that suggests that *Aotus spp.* inhabit areas with dense canopy cover (which in this case I expect to be the primary forest site), lead to our prediction that the density of monkeys will be highest in the undisturbed site and lowest in the site with the highest degree of disturbance (Aquino and Encarnación 1994).

CHAPTER II

METHODS

Study Species

Night monkeys are small, nocturnal primates that are cryptic in their behavior (Fernandez-Duque et al. 2008a, Wright 1978). Group size ranges from two to six individuals which are made up of a monogamous pair, an infant, and one or two smaller individuals. There is a high degree of paternal investment in offspring survival (Fernandez-Duque et al. 2008b). Family groups sleep in tree hollows and vine clusters called lianas, and a group will switch between three to five different sleeping sites every one to three weeks (García and Braza 1993, Rathbun and Gache 1980, Shanee et al. 2013, Wright 1978). Individual ranges are highly variable, but generally fall between three and six hectares (Fernandez-Duque et al. 2008a, Van der Heide et al. 2012, Wright 1978). The home ranges of different groups will usually overlap slightly, but due to the territorial behavior of owl monkeys, their core areas never overlap. These core areas possess both fruiting and sleeping trees and contain all the resources needed by the monkeys, even during dry seasons (Fernandez-Duque 2016).

Though the genus *Aotus* ranges from Panama to Northern Argentina, the focus species in this study is *Aotus azarae*, which ranges from southern Peru to northern Argentina. The subspecies *A. a. boliviensis* is present in Tambopata National Reserve (IUCN 2018, Wright 1994). The habitats utilized by the monkeys in this study are seasonally flooded lowland forests with various degrees of disturbance. In these types of

forests, trees have thick branches to allow for sleeping hollows as well as growths of clustered vines to be used as sleeping sites (Aquino and Encarnación 1994).

Tambopata represents the northernmost distribution of the range Azara's night monkey, *A. a. boliviensis*. Whereas *Aotus spp*. are almost entirely nocturnal, the other, more commonly studied subspecies of *Aotus azarae* (*A. a. azarai*) is cathemeral. The cause of this difference is uncertain, but it may have an ecological basis (Fernandez-Duque and Erkert 2006). For example, the southern populations of Azara's night monkey occupy gallery forests whereas the northern populations of *Aotus spp*. occupy many different forest habitats due to their vast distribution ranging from Southern Latin America to northern Argentina such as cloud forests, subtropical dry forests, and both primary and secondary tropical forests (Wright 1981, Fernandez-Duque et al. 2001, Fernandez-Duque 2007). Because of these behavioral and ecological differences, it is important to collect additional data on the nocturnal subspecies to see how their population densities compare.

Study Sites

Sampling was conducted from June to July 2019 at three different forest sites within the Tambopata Province in the Madre de Dios Region of Peru. All sites were located on the Tambopata River upstream of the city of Puerto Maldonado. These sites – Posada Amazonas, Refugio Amazonas, and Tambopata Research Center – were chosen due to the varying degrees of disturbance present at each site. These sites are represented in Figure 1. All sites are seasonally flooded lowland forests. Posada Amazonas is a new secondary forest site and the closest site to Puerto Maldonado (~26.7km) and

experiences the highest degree of disturbance. The lodge is jointly run by tourism company, Rainforest Expeditions, and the local indigenous Ese Eja People. Farming, hunting, and fishing are still prevalent in the surrounding area. Refugio Amazonas is an old secondary forest site ~39.6km from Puerto Maldonado and ~13km from Posada Amazonas. Farming and hunting used to be common in this area, but were stopped upon the building of the lodge about two decades ago. It is close to Tambopata Natural Reserve, but is not within the protected area. Tambopata Research Center is a primary forest site located within the Tambopata Natural Reserve (~75.7km from Puerto Maldonado, ~50km from Posada Amazonas, and ~36km from Refugio Amazonas). Peru created the Tambopata Natural Reserve in 1977 as a protected area and has prohibited any type of habitat destruction within it. Due to its protected status, there are no settlements within 40 km of the lodge (Stewart 1988). This area shows the lowest degree of disturbance. All three lodges are active ecotourism sites with researchers, staff, and tourists present throughout the dry season (May to October).

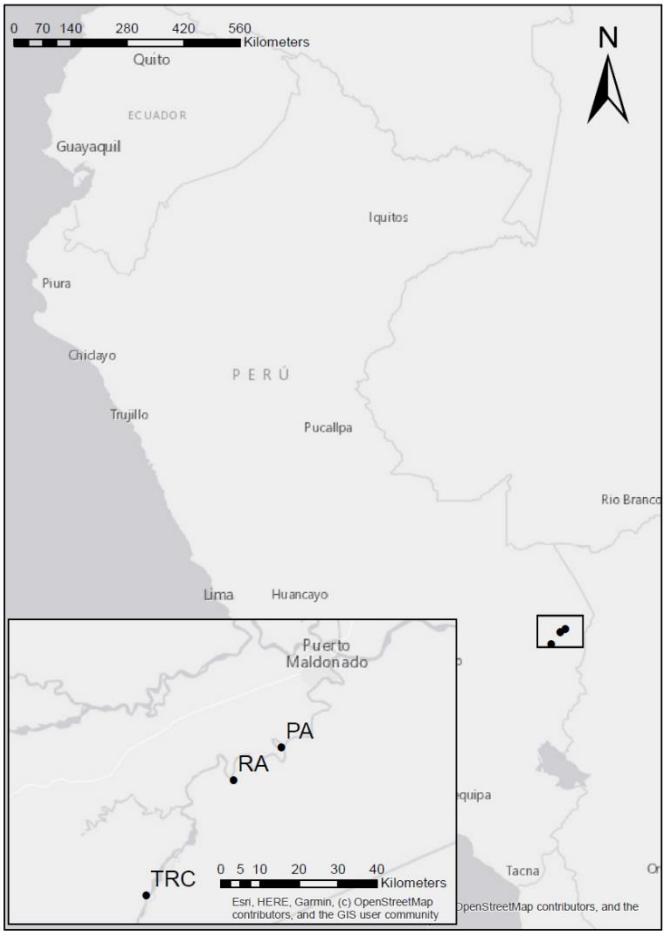

Figure 1. Map of the locations of the three study sites within Peru (PA, Posada Amazonas; RA, Refugio Amazonas, TRC, Tambopata Research Center).

Night Monkey Survey

Data on *A. a. boliviensis* was collected by walking transects along the existing forest trails by the principal investigator and one local Peruvian research assistant. Each site had between 13 and 15 trails and varied in length from 3-5 kilometers. All trails began within 50 meters of the lodge and expanded outward into numerous directions. Maps of the trail system at each site are depicted in Figure 2. Each transect was walked once at a pace ranging from 2-3 km/hr from 17:30 – 19:30 and 4:00 – 6:00. These

observation times were chosen because previous studies have shown that *Aotus spp*. is most active 15 minutes after sunset and before sunrise when they are returning to their sleeping sites (García and Braza 1993). During the transect, we constantly scanned from the base of the trees up to the canopy with flashlights and made periodic stops to listen for calls and movement in the canopy. Upon detecting *A. a. boliviensis*, the time of detection, distance between animal and observer, perpendicular distance between animal and trail, diameter at breast height (DBH) of inhabited tree, group size, altitude and geographic location, and behavior of the animal were recorded. Distances from the animal to the observer were measured using a range finder, and perpendicular distances between the animal and the trail were measured using a measuring tape. These two measurements were used to calculate the height of the animal in the canopy. Altitude and geographic location of the monkey was measured using a GPS (Garmin – GPSMAP 64s 2.6" Handheld GPS).

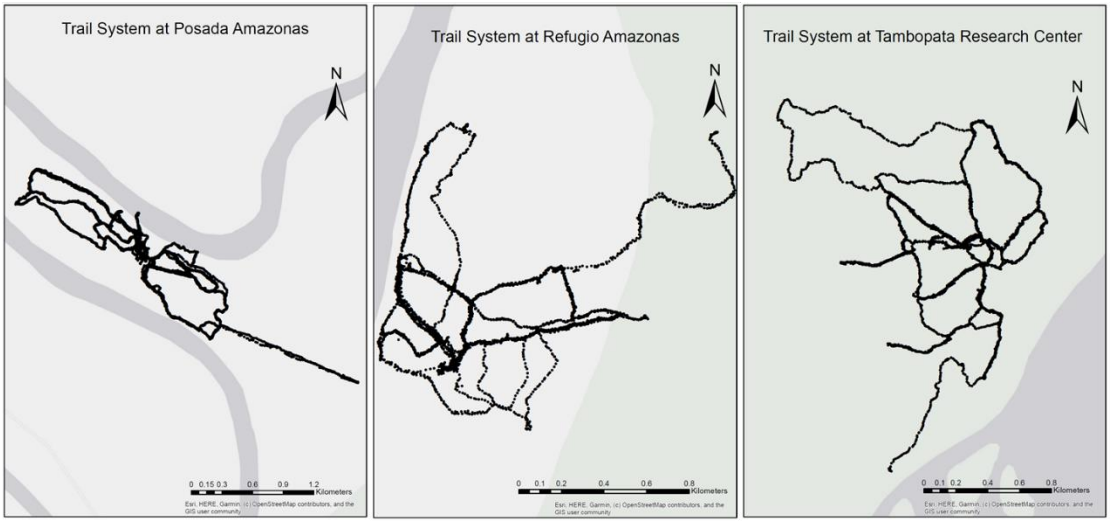

Figure 2. Maps of the trail systems at each site: Posada Amazonas, Refugio Amazonas, and Tambopata Research Center.

Forest Assessment

I sampled vegetation in each area to determine the quantitative ecological differences between each site. The habitat at each site was determined using five vegetation plots (2mx10m). For each plot I recorded the total number of trees, DBH in centimeters of each tree, height of each tree in meters, percent forest cover, altitude, distance from the lodge in kilometers, and qualitative notes about the area. Trees with a DBH of <5cm and/or <1m in height were not counted. DBH was recorded with a diameter tape, height was measured with a clinometer, and forest cover was measured with a densiometer. Altitude and distance from the lodge was recorded with a GPS (Garmin – GPSMAP 64s 2.6" Handheld GPS).

Data Analysis

I used IBM SPSS to calculate descriptive parametric statistics. Due to the non-normality of the data, I used a nonparametric Kruskal-Wallis analysis of variance by

rank to calculate significance for forest characteristics and monkey density. Monkey density was calculated using the formula:

$$D = n/2lw$$

(D = density, n = number of monkeys seen l = transect length, and w = strip half width) (Brockelman and Ali 1987).

CHAPTER III

RESULTS

Over the course of this study, 120.54 kilometers of forest were surveyed at three sites covering a distance of 36-48 km. A range of 12-15 transects were conducted at each site. Over the course of this study, I surveyed for a total of 78 hours and detected 57 monkeys across all sites. These data are detailed below in Table I. At the new secondary site of Posada Amazonas, a total of 24 individuals of *A. a. boliviensis* were observed at altitudes ranging between 153.9 – 200.9 meters. The old secondary site, Refugio Amazonas, had 22 individuals at altitudes ranging between 190.8 – 212.1 meters. At the primary site of Tambopata Research Center, a total of 11 individuals were observed at altitudes ranging between 200.1 – 246.3 meters. Data on monkey detection per transect is depicted in Figure 3.

Population density varied at the three sites ranging from 15.0 – 30.5 monkeys/km^2. The old secondary site of Refugio Amazonas had the highest density of monkeys with 30.5 monkeys/km^2, while the primary forest site of TRC had the lowest density of 15.0. [Despite the appearance, there was no statistical difference in the density of *A. a. boliviensis* calculated per transect between the sites (K-W: n=40, H=41.99, p=.379, df=14).] *A. a. boliviensis* group size ranged from 1-4 individuals and averaged at 2.3 individuals over all sites. Most groups were composed of a breeding pair and there were instances in which a juvenile was observed in a group. No infants were observed during this study, and on two instances only one individual was observed. *A. a.*

boliviensis were observed at an average canopy height of 13.3m in Posada ranging from 3.96 – 25.48m, 16.4m in Refugio ranging from 6.91 – 21.45m, and 13.4m in TRC ranging from 4.9 – 17.29m.

Table I. Summary of data collected during surveys

	Posada	**Refugio**	**TRC**	**Total**
Total Distance (km)	47.80	36.05	36.69	120.54
Total Number of Transects Walked	15	12	13	40
Number of *Aotus*	24	22	11	57
Transect Width (m)	20	20	20	20
Individuals/km^2	25.1[a]	30.5[a]	15.0[a]	23.7
Mean Group Size	2.4	2.4	2.2	2.3
Mean Height in Canopy (m)	13.25	16.41	13.40	14.35

[a]Kruskal-Wallis Test at p>.05: n=40, H=41.99, p=.379, df=14

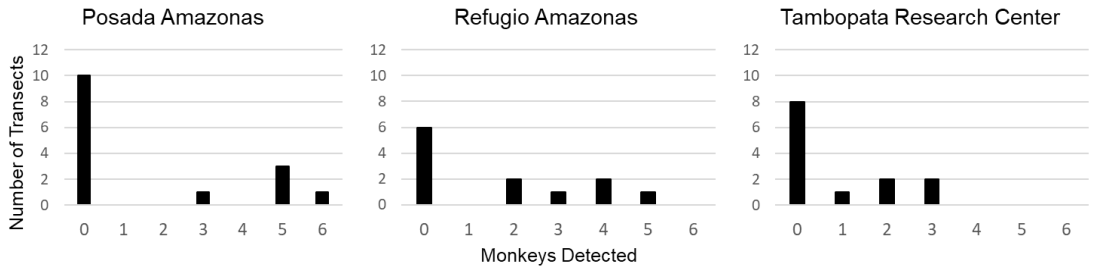

Figure 3. Distributions of the number of night monkeys detected per transect.

The DBH of trees in the vegetation plots across the three sites ranged from 5.0 – 173.7cm. There was no statistical difference in the DBH of trees in the vegetation plots across the three sites (K-W: n=73, H=.294, p=.863, df=2). Tree height for vegetation plots were observed to vary from 3.05 – 67.05m. There was also no significant difference in tree height in the vegetation plots among all sites (K-W: n=73, H=1.853, p=.396, df=2). These values show that despite the different classifications and areas of the forests (i.e. protected areas), the forests do not differ significantly. Canopy cover and altitude were sampled only once per forest plot, so there were not enough datapoints to conduct a Kruskal-Wallis Test. The value means and ranges for all forest characteristics are presented instead in Table II.

Qualitative descriptions of the undergrowth differed between the sites. At Posada Amazonas, the forest was made up of many small trees with a DBH of >5cm, which made them immeasurable for the purpose of this study. There were also a large amount of low-hanging vines that made the forest very difficult to walk through off of the trail systems. It was difficult to get more than two meters off the trails without cutting down undergrowth with a machete. At Refugio Amazonas, the undergrowth was much more

manageable, although there was still a lot of it. It was very dense up to about one meter high, but any undergrowth higher than that was not very common. I was able to go off-trail here without a machete, though it was still difficult. At Tambopata Research Center, undergrowth was not as prevalent as the other sites. While it was still prevalent, there were more small, measurable trees rather than dense undergrowth. This was the easiest location to maneuver off-trail.

Table II. Summary of data on forest characteristics

	Posada	Refugio	TRC
Plots Per Site	5	5	5
Mean DBH (cm)	22.34[a] 6.3 – 125.8	21.17[a] 5.4 – 173.7	22.04[a] 5.0 – 80.5
Mean Tree Height (m)	18.16[b] 3.05 – 67.05	18.02[b] 4.60 – 57.60	21.96[b] 3.36 – 50.32
Mean Canopy Uncovered (%)	14.48 11.44 – 23.92	22.14 9.36 – 32.24	18.34 11.44 – 23.92
Mean Altitude (m)	204.76 190.20 – 217.93	198.39 187.45 – 202.08	229.39 203.30 – 261.21

[a]Kruskal-Wallis Test at p>.05: n=73, H=.294, p=.863, df=2
[b]Kruskal-Wallis Test at p>.05: n=73, H=1.853, p=.396, df=2

CHAPTER IV

DISCUSSION AND CONCLUSION

The results of this study found that the density of *A. a. boliviensis* varied from 15.0 to 30.5 monkeys/km^2 depending on forest type. Refugio Amazonas (near secondary) had the highest density of monkeys while TRC (primary) had the lowest density of monkeys. While I predicted that the least disturbed site would show the highest density of *A. a. boliviensis* due to their preference for dense canopy cover (Aquino and Encarnación 1994, Naughton-Treves 2001), no significant difference in density was observed between the sites. The slightly higher density at Refugio Amazonas suggests that the *A. a. boliviensis* may prefer slightly disturbed secondary forest sites to primary forest sites. This could be due to smaller tree branches and more undergrowth than primary forests, increased insect abundance, or a variety of other forest characteristics. On the other hand, this could be an early indicator of how the forests are changing in Tambopata. There may be more monkeys in the secondary forest site because there is overall less primary forest for them to inhabit, forcing them into subpar areas where they must reside at higher densities. It will not be clear if the monkeys prefer the secondary forest sites or if they are simply reacting and moving due to forest disturbance without further surveying. Surveying this area every few years could help answer this question and determine whether it is true that *A. a. boliviensis* prefer secondary forests. Alternatively, it could be true that there is no difference in *A. a. boliviensis* preference between forest types.

The forests where the monkeys were sampled were also not significantly different from one another in neither DBH nor tree height. This similarity between sites could explain the lack of a significant difference between the number of monkeys at each site. The differences in monkey density at each site could be more attributed to what is happening nearby the sites rather than to the sites themselves. The disturbances associated with each site have been kept to the peripheral and have not actually infiltrated the property. This could explain the higher numbers of *A. a. boliviensis* at Posada and Refugio. Similarly, much of the difference between the sites was in the qualitative descriptions of undergrowth, which was too small to measure DBH and height for. Because of this, differences in amount of undergrowth are not represented in the data.

The similarities in DBH and tree height between these three sites could be due to their use for ecotourism. Ecotourist lodges may be more involved in conservation actions because of expectations from guests. When guests go to ecotourist lodges, they expect to see dense forest and diverse wildlife (Kirkby et al. 2011). The sites used during this study are all run by the same ecotourism company, Rainforest Expeditions. Perhaps the reason why the forests at each site are so similar is because the company has actively kept forest disturbance to the surrounding areas and away from the lodges in order to encourage continued tourism.

While the three sites did not differ in monkey density from one another, they are quite different from the *A. azarae* population density in the southernmost part of their range, which have been seen at a density 64 individuals/km^2 (Fernandez-Duque et al.

2001). Because this estimate is over double the largest estimate found in this study, this difference supports the need for measuring densities of species from throughout their range rather than at only one location. This difference in population density could be due to the differing habitats in the south and northernmost parts of *Aotus azarae* distribution. The monkeys in Argentina are found in relatively dry gallery forests compared to Peru where the habitat is wet tropical rainforest (Wright 1994). This differences in density may also be a reflection of the different activity cycles of the monkeys where the population in the south is cathemeral and the population in the north is nocturnal (Fernandez-Duque and Erkert 2006). Researchers are more likely to see all individuals in the day rather than the night when it is dark.

While the results from this study differ from other population density estimates of *A. azarae* in its southernmost range, the results of this study are similar to those of other nocturnal *Aotus* species in their northern distribution. A study of *Aotus zonalis* in Panama detected 19.7 individuals/km^2 in a secondary forest site and no monkeys in a primary forest site (Svensson et al. 2010). Similarly, a study of *Aotus nancymai* detected 25 individuals/km^2 in northern Peru (Aquino and Encarnación 1986).

A study focusing on *Aotus nancymai* and *Aotus vociferans* in tropical lowland forests in northern Peru report higher densities than those found in this study (46.3 individuals/km^2 and 33.0 individuals/km^2 respectively), though they are reported at lower densities at higher elevations (Aquino and Encarnación 1988). This is similar to a study of *Aotus nigriceps* with a density of approximately 40 individuals/km^2 (Wright 1985). Alternatively, a study of *Aotus azarae* in Bolivia estimated a density of 237.9

individuals/km^2 (García and Braza 1989). If this density estimate is accurate, then the number of *Aotus azarae* in the northern region has decreased significantly since the 1989 study was conducted.

In summary, the population densities in this study are lower than most other estimates, especially of the same species in a similar area. Consequently, the IUCN red list classification for this species should incorporate the extensive variation in density and behavior when re-evaluating this species conservation status. Populations in these areas should continue to be monitored to effectively evaluate this species conservation status so that populations do not continue to decrease.

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