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## OBSERVATIONS OF DIURNAL ACTIVITY IN A 'STRICTLY' NOCTURNAL PRIMATE, THE PERUVIAN NIGHT MONKEY (*AOTUS MICONAX*), YAMBRASBAMBA, PERU

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### Introduction

Cathemerality, defined as “sporadically active throughout a 24-hour day” (Fleagle 1988, p.52), or as “when significant amounts of activity, particularly feeding and/or traveling, occur within both the light and dark portions of that cycle” (Tattersall 1987, p. 201), is widespread across many mammal species, in all major biomes (Curtis and Rasmussen 2006). As with nocturnality, cathemerality must confer an evolutionary advantage. This advantage may be in the form of decreased interspecific competition, coping with deficits in ambient light and temperature, and/or predator avoidance or prey capture (Curtis and Rasmussen 2006).

It is probable that modern primates are descended from nocturnal basal taxa (Ross et al. 2007; Santini et al. 2015). In the extant primates, nocturnal behavior is well established in the lorises and galagos, as well as several genera of lemur (Colquhoun 2011), and cathemerality is known in two genera of lemurs, *Eulemur* and *Hapalemur* (Colquhoun 2011). There are also several published records of nocturnal behavior in other diurnal primate species including *Cebus capucinus*, *Lemur catta*, *Macaca fuscata yakui*, *Pan troglodytes*, and *Rhinopithecus brelichi* (Nishikawa and Mochida 2010; Parga 2011; Perry 2012; Donati et al. 2013; Tan et al. 2013; Krief et al. 2014).

Night monkeys (*Aotus* spp.) are the only nocturnal haplorhine, and subsequently the only nocturnal platyrrhines (Fernandez-Duque 2011). Most *Aotus* are considered ‘strictly’ nocturnal, with only two species (*A. azarae* and *A. nigriceps*), in the southernmost, most seasonal, part of the genus distribution, showing cathemerality (Mann 1956;

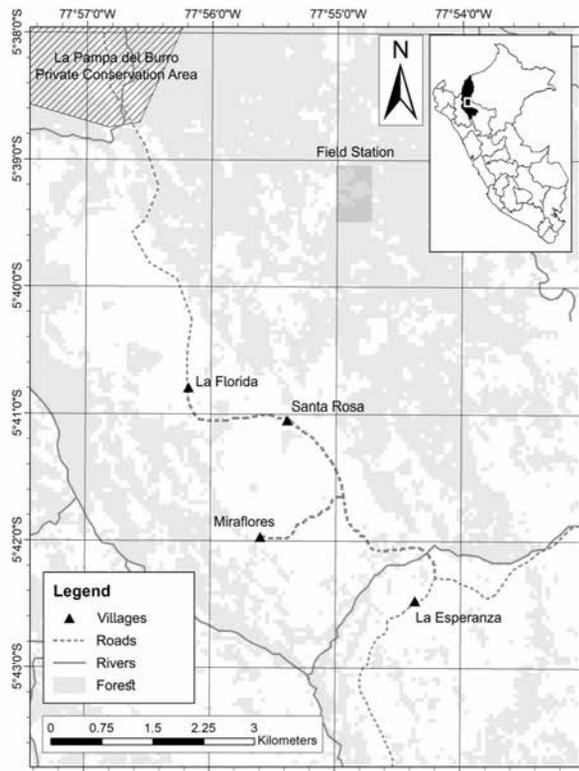
Wright 1989; Donati and Borgognini-Tarli 2006; Fernandez-Duque and Erkert 2006; Erkert et al. 2012; Khimji and Donati 2014). Nocturnal and diurnal activity in *Aotus* spp. is influenced by moon luminosity and ambient temperature (Fernandez-Duque 2003; Fernandez-Duque and Erkert 2006). The paucity of field studies on most *Aotus* species means that many aspects of their behavioral ecology are still unknown, and diurnal activity may be more common than thought.

The Peruvian night monkey (*Aotus miconax*) is one of the least studied of all Neotropical primates. This species is endemic to northern Peru (Shanee et al. 2015) and restricted to montane and pre-montane forests between ~1,200 and 3,100 m a.s.l. (Shanee et al. 2015). This species is considered Endangered by the IUCN (2019). *Aotus miconax* is considered a ‘strictly’ nocturnal night monkey (Fernandez-Duque 2011) and previously had only been observed leaving and arriving at its nest sites between sunset and sunrise (Shanee et al. 2013). The diet of *A. miconax* is highly omnivorous, composed of large amounts of ripe fruits, leaves and insects, and smaller amounts of buds and flowers (Shanee et al. 2013). Two studies have suggested the possibility of diurnal activity in *A. miconax* (Shanee et al. 2013; Campbell et al. 2019), but these studies did not document diurnal activities first hand.

Here we present *ad libitum* observations of diurnal behavior in *Aotus miconax* gathered in 2012 and 2018. The first observations, from 2012, were made whilst surveying forest fragments in preparation for presence/absence surveys of *A. miconax*, and the 2018 observations, during behavioral studies of *Lagothrix flavicauda*, in continuous forest. As cathemerality in *A. azarae* and *A. nigriceps* is influenced by light and temperature, we tested whether moon illumination, moon phase, or ambient temperature had an effect on instances of diurnal behavior in *A. miconax*.

### Study site and Methods

Observations were made at the El Toro field site, in Amazonas region, Peru (05°39'46" S, 77°54'32" W) (Fig. 1), an area of made up of ca. 700 ha of disturbed primary forest and regenerating secondary forest, interspersed with pasture, that is part of continuous forest leading to the Amazonian lowlands. Terrain in the area is very rugged, with high ridges and deep valleys between 1,800 and 2,400 m a.s.l. Annual rainfall is ca. 1,700 mm, with a drier season from August to December. The primary premontane and montane forests of the area have been selectively logged over the past ~ 30 years and have a thick mid- and understory with an average canopy height of 15–25 m. The land is titled to the *Campesino Community* of Yambrasbamba, with a single land title of 80,545 ha. People in the community are predominantly subsistence farmers (tubers, corn and beans), with some small-scale commercial production (cattle, coffee and ‘rocoto’).



**Figure 1.** Map showing location of field site and surrounding villages.

Field trips for behavioral data collection on *Lagothrix flavicauda* were carried out continuously from 2008 to 2019. Trips were made every two weeks and lasted five days. Researchers left the field station at ~06:00h each day and returned at ~19:00h each day during field trips. Additional nocturnal surveys of *Aotus miconax* were made between March and June 2018 (Doolan 2018). All data collection was made by at least one researcher accompanied by experienced local field guides. Researchers carried standard field equipment; handheld GPS units were used to georeference primate sightings and observations were aided by the use of binoculars and cameras with telephoto lenses. Observations of *Aotus* diurnal activity were made during 2012 and 2018.

We used moon illumination and phase data given in our handheld GPS units. We used ambient temperature data for 2018 gathered on site (Lacrosse ws1600). As we only collected weather data during our standard fieldwork we did not have a complete set for the entire period (March – June 2018). When data were missing we used records from the *Servicio Nacional de Meteorología e Hidrología del Perú* weather station at Chachapoyas (<https://senamhi.gob.pe/?&p=estaciones>). This station is the closest to the field site (~60 km south), that is at a similar elevation (2,400 m a.s.l.). No temperature data were available for 2012, so these observations were not included in hypothesis testing. We also recorded instances of diurnal behavior reported to us by local informants and field guides. These reports consisted of information volunteered during normal

conversation, generally people sought us out as they knew of our interest in local primates. These reports occurred sporadically during the entire period (2012-2018); we did not note the specific date of each report.

## Results

We observed diurnal activity in *Aotus miconax* on 13 occasions during field work in 2012 (three observations) and 2018 (10 observations). All records were of *ad libitum* encounters either during behavioral follows of *Lagothrix flavicauda* in continuous forest, during preparatory field work or during surveys of forest patches. Moon illumination on the nights preceding observations varied considerably (Table 1), between 10% and 99% (mean 43.09,  $\pm$  34.91), and showed no discernible trend (One sample Kolmogorov-Smirnov Test, 0.096). Average temperatures during the months of March to June 2018 were 19.6°C during the day, and 11.5°C at night. There was no significant difference across the study period between diurnal and nocturnal temperatures when diurnal behaviour was and was not observed (T-Test,  $t=0.472$ ,  $df=242$ ,  $p=0.637$ ). There was no significant difference from average daytime temperatures on days when we observed *A. miconax* active during daylight hours (T-Test,  $t=0.168$ ,  $df=120$ ,  $p=0.867$ ). There was no significant difference from average nighttime temperatures on nights immediately preceding days when we observed *A. miconax* active during daylight hours (T-Test,  $t=1.276$ ,  $df=120$ ,  $p=0.204$ ).

**Table 1.** Moon phases of the previous night, before diurnal observations.

Date of observation	Moon illumination (% of full moon)	Moon phase
27/1/12	23%	Waxing
15/2/12	49%	Waning
26/2/12	26%	Waxing
2/3/18	99%	Full moon
25/3/18	54%	First quarter
17/4/18	10%	Waxing
17/5/18*	13%	Waxing
30/5/18*	99%	Full moon
12/6/18	11%	New moon
25/6/18	77%	Waxing

\* Two separate observations on the same day

### *Ad libitum* observations from 2012

On the morning of the 28th of January 2012, during field surveys of *Lagothrix flavicauda* in continuous forest, one unknown adult *Aotus miconax* individual, and three individuals (two adults and one juvenile) from a known group of *A. miconax*, were observed locomoting through the forest within the vicinity of the known group's habitual

sleeping site in a vine tangle in the lower crown, approx. 8 meters high, of a *Ficus* sp. tree. The observation took place at approximately 09:00 h.

On the 16th of February 2012, in a small patch of secondary forest, ~1.4 ha (Shanee et al. 2013), just above the village of La Esperanza, two adult *Aotus miconax* individuals were observed feeding on ‘naranjillo’ (*Styloceras laurifolium*) fruits. The observation took place at approximately at 09:00 h.

On the 27th of February 2012, in a small forest patch, < 1 h, just below the village of La Esperanza three *Aotus miconax* individuals (two adults and one juvenile) were observed feeding on fruits in a fig tree (*Ficus* sp.). The observation took place at approximately 16:00 h.

#### *Ad libitum observations from 2018*

On the 3rd of March 2018, we encountered a known group of three *Aotus miconax* (two adults and one juvenile) that live close to the field station, awake and out of their nest. The group then travelled to a nearby tree where they fed on figs (*Ficus* sp.). The observation took place at 13:06 h. On the 26th of March 2018 two members of the same *Aotus miconax* group (one adult and one juvenile) were again seen active during the day, this time traveling through the trees. This observation took place at 12:34 h.

On the 18th of April 2018, again, two members of the same *Aotus miconax* group (one adult and one juvenile) were observed traveling through the trees. This observation took place at 09:46 h.

On the 18th of May 2018, we observed two different groups of *Aotus miconax*, one of four members (three adults and one juvenile) and two members (both adults), traveling through the trees. Both observations took place at approximately 10:4 h but, were recorded by different groups of observers simultaneously at different points of the field site. On the 31st of May 2018, we again observed two instances of different *Aotus miconax* groups travelling during the day time. The two groups (two adults, and two adults and a dependent infant, respectively) were seen at 08:49 h and 16:22 h, by different groups of observers in different areas of the field site. The presence of a group of *Lagothrix flavicauda* passing through the area could have disturbed the *A. miconax* groups on these occasions, but no obvious interactions were observed, and the *A. miconax* groups had still not returned to their nests for over 10 minutes after the *L. flavicauda* group had passed.

On the 13th of June 2018, three *Aotus miconax* individuals (two adults and one juvenile) were seen travelling at 14:23 h. Again, this was possibly due to disturbance by a *Lagothrix flavicauda* group in the area. The group did not return to its nest or enter a new one for the 16 minutes of our observations. On the 26th of June 2018 an unknown group of three *Aotus miconax* was found out of their nest

at 09:25 h during follows of *Lagothrix flavicauda*. The *L. flavicauda* group was causing much disturbance, jumping through the canopy and vocalizing, during this observation and probably disturbed the *A. miconax* group, although no direct interaction between the species was observed.

#### *Additional observations*

During presence/absence surveys and habitat characterization of *Aotus miconax* in forest patches and continuous forest in 2018 (Doolan 2018), we inferred diurnal behavior on five occasions when we left groups at a nest site in the morning and did not find them there in the afternoon, or vice versa, when a group did not return to a particular nest in the morning but, was found there before sunset. Other observations during this study included pairs of *A. miconax* seen locomoting at ~10 a.m., but most probably this was due to disturbance by dogs in the area (Doolan, pers. obs). On several other occasions, groups left their nests before sunset or did not return until after sunrise, but these observations occurred within an hour of sunset or sunrise. A number of residents of the villages of La Esperanza, Miraflores, and Santa Rosa (Fig. 1) have recounted observations of *A. miconax* active during daylight hours whilst passing through fragmented habitats to get to their fields. These anecdotal reports cover the entire study period as well as years preceding the start of our investigations.

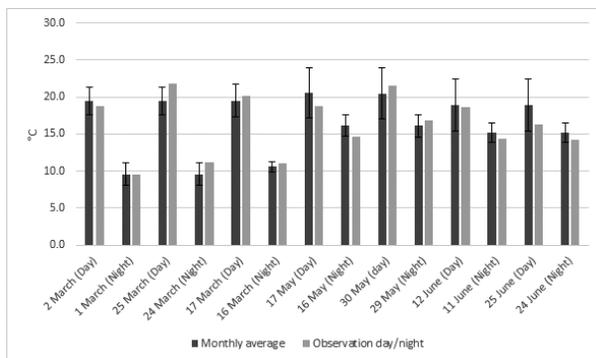
## Discussion

Our observations show that, although classed as a ‘strictly nocturnal’ night monkey species, *Aotus miconax* is also active diurnally on occasion. This activity appears to be sporadic and rare and is likely not enough to class it as cathemeral to the same degree as *A. a. azarai* (Fernandez-Duque 2003; Fernandez-Duque and Erkert 2006). Although field trips occurred during the intervening period, we did not observe any diurnal *A. miconax* behavior during these years. It is possible that diurnal activity in *A. miconax* was less frequent during these years, although local residents still reported instances to us. It is more probable that these behaviors occurred at the same frequency, they were just not noticed by ourselves or other researchers, particularly as we were not carrying out other investigations on *A. miconax* during these periods.

This is not the first report of *Aotus miconax* being active during daylight hours. For example, Campbell et al. (2019) recorded a group leaving their nesting site during daylight hours. Similarly, diurnal activity was inferred by Shanee et al (2013) when leaving groups at nesting sites in the morning, then finding the sites empty prior to starting evening observations later the same day. However, in neither of these studies were the animals observed feeding or traveling during daylight hours. Here we present many direct observations, showing that diurnal behaviors are more common than previously thought.

Nocturnal and diurnal activity in *Aotus* spp. is influenced by moon luminosity (Fernandez-Duque 2003; Fernandez-Duque and Erkert 2006). *A. azarai azarai* in the Argentinian Chaco show marked periodicity in their activity rhythms, being active throughout the night during full moon nights, and displaying much less cathemerality (Fernandez-Duque 2003; Erkert 2004; Fernandez-Duque and Erkert 2006). Our observations did not show any correlation of moon luminosity with diurnal behavior in *A. miconax*, with animals seen active during the day light hours on days preceded by anywhere between 11 and 99% illumination (Table 1).

Temperature also has been linked to changes in nocturnal and diurnal activity in *Aotus* spp. (Erkert 1991; Fernandez-Duque 2003; Fernandez-Duque and Erkert 2006). Temperatures on the nights preceding, and the days when *A. miconax* were active in 2018 were not significantly different to averages across the period (Fig. 2). Seasonal changes in temperature, rainfall, and resource availability have not been found to influence occurrences of diurnal behavior in *A. azarae* (Fernandez-Duque and Erkert 2006; Erkert et al. 2012). At our study site, just 5° south of the equator, temperatures are fairly steady throughout the year. There are seasonal shifts in rainfall and resource production, although our limited data set preclude possibilities of testing the influence of seasonality. Interestingly, sympatric *Lagothrix flavicauda* groups at the study site have been



noted to significantly change their activity budgets and diets between seasons (Fack et al. submitted).

**Figure 2.** Average monthly diurnal and nocturnal temperatures on days and nights, immediately preceding, observations of diurnal activity in *Aotus miconax* in 2018.

Some of our observations occurred through disturbance of the night monkeys by other animals. Nocturnal activity in several species of diurnal primate have been observed (Nishikawa and Mochida 2010; Parga 2011; Donati et al. 2013; Tan et al. 2013; Krief et al. 2014), in some cases provoked by the activity of nocturnal species (Nishikawa and Mochida 2010; Krief et al. 2014). During our surveys, *Aotus miconax* were disturbed from their nests by *Lagothrix flavicauda* on a number of occasions. Similarly, a group of four *A. nigriceps* was observed locomoting between 09:30 and 10:00 h at Tambopata National Reserve, in Southern Peru, and another group of *A. nancymaae*, observed

moving through the trees in the Pacaya Samiria National Reserve at approximately 11:00 h. In both cases the groups had disturbed by the activities of other primates, in these cases *Plecturocebus brunneus* and *Sapajus macrocephalus*, respectively (N. Allgas, pers obs). Domestic animals have also been observed to cause diurnal activity in *A. miconax*, where individuals remain in or near human settlements after dawn, drawing the attention of dogs (Shanee and Shanee 2011). It is also possible that at least some of these observations were due to unintentional disturbance by observers, or other human activity in the area. However, this likely was not true in all cases, as on several occasions the animals were already engaged in other activities and away from their nesting sites before our arrival, and there were no other humans in the vicinity.

The forests of Northern Peru suffer massive deforestation for agriculture, cattle ranching and timber extraction (IBC 2016). Deforestation has caused the fragmentation of much of the remaining habitat of *Aotus miconax*, and most remaining habitat is disturbed (Shanee et al. 2015). Species that persist in heavily disturbed forests often develop new ecological strategies to enable them to survive (Shanee and Shanee 2011; Marsh et al. 2013), with those that are successful showing a high degree of behavioral and dietary plasticity (Castano et al. 2010; Shanee and Shanee 2011; Marsh et al. 2013).

Very few observations of diurnal activity have been reported for *Aotus* spp. (Mann 1956; Khimji and Donati 2014) other than *A. a. azarai* (Fernandez-Duque 2003; Fernandez-Duque and Erkert 2006), and this behavior has only previously been inferred for *A. miconax* on a handful of occasions (Shanee et al. 2013; Campbell et al. 2019). As with most species of *Aotus*, detailed studies of all aspects of *A. miconax* behavioral ecology are lacking. It is very possible that further observations of this species will indicate that diurnal activity is more common than thought.

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## RECENT PUBLICATIONS

### BOOKS

*Skeletal Anatomy of the Newborn Primate*, by Smith, T. D., DeLeon, V. B., Vinyard, C. J. and Young, J. W. Cambridge University Press, 328pp. 2020. ISBN: 978-1107152694. This is the first book dedicated to newborn skeletal and dental anatomy and how it varies across primate species. Structured according to anatomical regions, the book includes hundreds of detailed anatomical illustrations, including a color atlas illustrating entire skeletons in representative taxa. Whilst the book is primarily a guide to comparative anatomy, it also highlights the links between development and behavior. *Content:* 1) Introduction; 2) Primate development and growth; 3) Why ontogeny matters; 4) The skull; 5) Dentition; 6) The postcranial axial skeleton; 7) The pectoral girdle and forelimb skeleton; 8) The pelvic girdle and hindlimb skeleton; 9) The newborn primate body form: phylogenetic and life history influences; 10) Ontogeny of feeding; 11) Ontogeny of locomotion.

*Neotropical Ethnoprimatology: Indigenous Peoples' Perceptions of and Interactions with Nonhuman Primates (Ethnobiology)*, edited by Urbani, B. and Lizarralde, M. Springer, 427pp. 2020. ISBN: 978-3030275037. This book reviews the complex interconnections between different indigenous peoples with New World monkeys that sympatrically share their ancestral territories. It includes study cases in a geographic range that covers all of the Neotropics, from southern Mexico through northern Argentina. *Contents:* 1) Perceptions and uses of primates among Popoluca indigenous people in Los Tuxtlas, Mexico - Pinto Marroquin, M., et al.; 2) Mental state attribution to nonhuman primates and other animals by rural inhabitants of the community of Conhuas near the Calakmul Biosphere Reserve in the Yucatan Peninsula Mexico - Urquiza-Haas, E. G., et al.; 3) Local knowledge and cultural significance of primates (*Ateles geoffroyi* and *Alouatta pigra*) among Lacandon Maya from Chiapas,

### ARTICLES

Adams, D. B., Kitchen, D. M. 2020. Model vs. play-back experiments: The impact of sensory mode on