ACTIVITY BUDGET AND RANGING OF A GROUP OF MADIDI TITIS (*PLECTUROCEBUS AUREIPALATII)* IN RESERVA ECÓLOGICA TARICAYA, WITH PRELIMINARY NOTES ON DIET COMPOSITION, HABITAT USAGE AND ADDITIONAL SIGHTINGS

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Abstract

This study aims to provide the first data on activity budget and ranging of one group of *Plecturocebus aureipalatii* and give preliminary notes on habitat usage and diet composition. Additionally, censuses were carried out to determine the presence of other groups in the area. The study site was strongly impacted by human actions (i.e. selective logging, small scale agriculture and hunting), it contained secondary, mixed- and less disturbed forest. The study group consisted of three habituated adult animals, living around an eco-tourist lodge. Using the scan-sampling method, the group was investigated over the course of four months to collect data on activity budget, ranging and habitat usage. Diet composition was only investigated for a limited period, using focal animal sampling. The activity budget showed a high percentage of stationary behaviour compared to other species, while the percentage of time spent on feeding/foraging behaviour was lower. This may have been caused by the presence of plantations and therefore easily accessible fruits. Analyses of habitat usage showed a strong preference for secondary forest. Ranging and diet composition did not seem to differ from expectations based on other titi monkey species. A long-term study of more groups is recommended to get a better understanding of this species and its requirements.

Key Words: *Plecturocebus*, habitat usage, titi monkey, activity budget, homerange.

Resumen

Este estudio tiene como objetivo proporcionar los primeros datos sobre el presupuesto de la actividad y movimientos de un grupo de *Plectrocebus aureipalatii* y dar notas preliminares sobre el uso del hábitat y la composición de la dieta. Además, se realizaron censos para determinar la presencia de otros grupos en la zona. El sitio del estudio fue fuertemente afectado por las acciones humanas (i. e., la tala selectiva, la agricultura a pequeña escala y la caza), contenía bosque secundario, mixto y menos perturbado. El grupo de estudio estaba conformado por tres animales adultos habituados, que vivían alrededor de un alojamiento eco-turístico. Utilizando el método de muestreo de exploración, el grupo fue estudiado durante cuatro meses para recopilar datos sobre el presupuesto de la actividad, sus recorridos y el uso del hábitat. La composición de la dieta sólo se investigó durante un período limitado, utilizando el método de muestreo de animal focal. El presupuesto de actividades mostró un alto porcentaje de comportamiento estacionario comparado con otras especies, mientras que el porcentaje de tiempo dedicado a la alimentación/ comportamiento de forrajeo fue menor. Esto pudo haber sido causado por la presencia de plantaciones y por lo tanto de frutas fácilmente accesibles. Los análisis del uso del hábitat mostraron una fuerte preferencia por los bosques secundarios. Los movimientos y la composición de la dieta no parecen diferir de lo esperado basados en otras especies de monos titi. Se recomienda un estudio a largo plazo de más grupos para obtener un mejor conocimiento de esta especie y sus requisitos.

Palabras clave: *Plecturocebus*, uso de hábitat, mono lucachi, presupuesto de actividades, rango de hogar.

Introduction

The huge biodiversity in the Neotropics is continuously threatened by anthropogenic actions; predominantly forest fragmentation and deforestation (Costa and Foley, 2000; Negri *et al.*, 2004). Protection of tropical forests is important because of the ecosystem functions they provide, such as climate regulation, soil protection and the supply of goods (Foley *et al.*, 2007). Different primate species respond differently to forest fragmentation depending on their specific habitat requirements (Bernstein *et al.*, 1976; Schwarzkopf and Rylands, 1989). To create helpful conservation plans it is, therefore, important to understand the habitat usage and activities of individual species. Titi monkeys are a diverse group of diurnal Neotropical primates that range in body mass from 0.8 to 1.4 kg (Smith and Jungers, 1997). Currently 33 species in three genera (*Cheracebus*, *Callicebus* and *Plecturocebus*) are recognized

since the first appraisal of taxonomy based on molecular evidence (Byrne *et al.*, 2016). The genus *Callicebus* only occurs in the Atlantic forests of Brazil and has the smallest distribution range of the three genera (Van Roosmalen *et al.*, 2002; Byrne *et al.*, 2016), whereas the genus *Plecturocebus* is distributed throughout central Brazil, the dry forests of Paraguay and Bolivia, and the Peruvian, Colombian and Ecuadorian Amazon (Van Roosmalen *et al.*, 2002; Byrne *et al.*, 2016). The genus *Cheracebus* only occurs in Northern Brazil, Colombia, Venezuela, Peru and Ecuador (Van Roosmalen *et al.*, 2002; Byrne *et al.*, 2016). River barriers are a big factor in speciation, since titi monkeys are unable to swim (Ayres and Clutton-Brock, 1992; Van Roosmalen, 2002). This partly explains the distribution of the three separate genera.

Titi monkeys are monogamous and parental care is mainly carried out by males (Spence-Aizenberg *et al.*, 2016). Group size generally varies from two to six individuals (Ferrari *et al.*, 2000; Wagner *et al.*, 2009; Kulp and Heymann, 2015). Habitat usage and requirements vary with different species of titi monkeys; the majority seems to be flexible and tolerate both natural and anthropogenic habitat disturbances (van Roosmalen *et al.*, 2002; Bicca-Marques and Heymann, 2013). Only a few species (e.g. *Cheracebus torquatus*) are considered to be habitat specialists (Kinzey and Gentry, 1979; Aquino *et al.*, 2008). Several species persist, and in some cases, thrive within secondary forest and forest fragments. (Ferrari *et al.*, 2000; Heiduck, 2002; van Roosmalen *et al.*, 2002). Diet consists mostly of fruits, seeds, leaves and invertebrates (Kinzey, 1992; Norconk, 2007; Heymann and Nadjafzadeh, 2013), although they are mainly frugivorous (Hershkovitz, 1990). Threats on titi monkey species, in addition to the general threats of forest fragmentation, include occasional hunting by indigenous and local people (Martinez and Wallace, 2007).

Plecturocebus aureipalatii Wallace *et al.* 2006, was first described in Madidi national park in Western Bolivia and is currently categorized as an IUCN species of Least Concern due to its broad distribution within protected areas in Bolivia and Peru (Wallace *et al.*, 2008). "This species is distinguished by a golden crown, caused by golden tipped hairs with dark longer base, dark forehead with slightly less golden coloration; deep orange throat and ventral area; deep orange burgundy limbs from elbow and knees to hands and feet; dark tail with clear paler whitish tip" (Wallace *et al.*, 2006). Since the reinstatement of *P. toppini* however, the validity of *P. aureipalatii* is unclear, as it might be a junior synonym of *P. toppini* (Vermeer and Tello-Alvarado, 2015). Molecular genetic research is necessary to provide clarity. Both *P. aureipalatii* and *P. toppini* belong to the monophyletic *P. moloch* group as proposed after the first molecular genetic taxonomy analysis of titi monkeys (Byrne *et al.*, 2016).

As a result of holotype collections and sightings, in addition to the river barriers, it is hypothesized that *P. aureipalatii* only occurs in de Madre de Dios region of Peru and in Western Bolivia, between Rio Tambopata, Rio Beni and Rio Madre de Dios (Ayres and Clutton-Brock, 1992; Vermeer and Tello-Alvarado, 2015). Geographical barriers supposedly separating *P. aureipalatii* and *P. toppini* are Rio Madre de Dios and Rio Tambopata (Vermeer and Tello-Alvarado, 2015). Therefore, at this time it is assumed that individuals observed south of Rio Madre de Dios were *P. aureipalatii*.

Since the first study describing *P. aureipalatii*, only a few field studies directed at this species have been published, mainly regarding distribution and abundance (Martinez, 2010; Crespo, 2013; Vermeer and Tello-Alvarado, 2015). The first preliminary notes on the abundance of *P. aureipalatii* showed an overall density of 6.2 animals/km2, with an average group size of three (Wallace *et al.*, 2006). However, a more recent census carried out in Madidi National Park revealed an estimated density of 22.2 animals/km2 but a correlation between density and habitat did not seem to exist (Crespo, 2013). Not many studies have been published regarding the activity budget or activity patterns of either *Cheracebus spp.*, *Callicebus spp.* or *Plecturocebus* spp. A recent study on two groups of *P. cupreus* (Kulp and Heymann, 2015), also a member of the monophyletic *P. moloch* group (Byrne *et al.*, 2016), showed a high percentage (>50%) of resting, followed by locomotion (19%) and feeding and foraging (16% to 20%) in less disturbed- and secondary forest.

The goal of this study was to collect the first data on habitat usage and activity budget and ranging of *P. aureipalatii.* One group of *P. aureipalatii* in an area strongly disturbed by humans was observed over the course of four months to determine their home range, activity budget, diet composition and habitat usage. Habitat usage was studied by determining the group's presence in different habitat types, analysing vertical forest usage and sleeping sites. The activity budget was analysed hourly in order to discover activity patterns at different times of day, while location data was taken to determine the home range. Additionally, censuses were carried out to discover other groups in the surrounding area.

Methods

Study area

The study was carried out in and around Reserva Ecólogica Taricaya (12º31.5'S, 68º59'W), on the south bank of the Rio Madre de Dios in southeastern Peru, approximately 25 km north-east of Puerto Maldonado (12°36'S, 69°11'W). This region has a hot and humid, tropical climate. Records from the nearest meteorological station in Puerto Maldonado show an annual mean precipitation of over 2,000 mm between 1961 and 1990. In the same period, a monthly average temperature of 16ºC to 32ºC was recorded. During the investigation, sunrise occurred between 0539 h and 0558 h, while sunset occurred between 1722 h and 1758 h. In and around the study site there is a regular presence of scientists, maintenance workers and tourist guides. Two lodges with several bungalows, and three farms were present in the study area.

Subjects

A habituated group of *P. aureipalatii* was investigated. In the beginning of the observations, the group consisted of one adult male, two adult females and one juvenile male. The juvenile male died on March 30, 2016 from pulmonary haemorrhage, as a necropsy showed. As a result the first 73 scans included four individuals, while the remaining observations included three.

Observational methods

The study was carried out from March 21, 2016 to July 14, 2016. Observations took place between 0600 h and 1700 h. The group was observed during 127 hours over a total of 39 non-consecutive days with observation lengths ranging from 1 to 11 hours. A total of 2,365 valid individual subject observations took place, representing 764 scan samples. This resulted in nine full statistical days, with 67 observations per full day, based on the sampling time with the lowest number of observations. The time between visual detection of the group until the start of behavioural recording was usually between two and five minutes as the subjects were already habituated and did not respond to the presence of the observers. During observations, a distance of at least five meters between the observer and subject was maintained to avoid flight behaviour. Vocalization playback was occasionally used to locate the group. Activity data (defined in Table 1) and the vertical position (Table 2) of all individuals simultaneously, was recorded every 10 minutes using scan sampling (Altmann, 1974). When an individual was out of sight, no records were taken. Feeding data was recorded using focal animal sampling (Altmann, 1974); animals that were feeding were continuously observed until feeding behaviour stopped. During sixteen observation days between March 22 and May 30, 632 minutes of feeding behaviour was recorded. The duration of feeding was recorded together with the type of food. Distinctions were made between fruits, flowers, leaves and arthropods. Trees used as sleeping sites were recorded when the group was observed being stationary and positioned on the same branch next to each other, in the late afternoon (after 1620 h). The heights of these trees were estimated using a Tangent Height Gauge. The diameter was calculated using measurements of the circumference at breast height.

A Garmin GPSmap 62st GPS receiver was used to record the group's location (with an accuracy of 10 meters), in addition to the location of feeding plants and the location of trees used as sleeping sites.

Table 1. Definition of activity categories.

Activity	Definition
Foraging and Feeding	Looking for food, holding and manipulating food, grabbing prey, ingestion
Locomotion	Moving a distance of ≥ 1 m
Stationary	Being stationary; making passive body contact with another individual
Social	Social playing, fighting, vocalising, allogrooming
Other	Activities not fitting into any of the other categories, eg., defecating, urinating

Table 2. Definition of vertical positions.

Position	Definition
Ground level	Making contact with the ground without holding on to branches or leaves
Under-story	Being positioned in a plant or tree between 0 m and 12 m
Canopy Layer	Being positioned in a plant or tree between 12 m and 25 m
Emergent Layer	Being positioned in a plant or tree higher than 25 m

Habitat analysis

The vegetation of the area was categorised (defined in Table 3) to determine habitat preferences of the Madidi titis. The height and circumference of trees (DBH > 5 cm) in two quadrants of 10 m by 10 m were measured to determine the characteristics of the forest. The locations of the quadrants were chosen based on the frequent presence of the subjects and the representability of the quadrants towards the surrounding forest.

Presence of other groups

A total of nine censuses were carried out between July 4, 2016 and July 14, 2016. Approximately 7.6 km of trails were covered multiple times on foot during a total of over 15 hours, resulting in 22.6 km of surveyed distance. The locations were chosen based on the knowledge of local scientists and tourist guides. The surveys took place between 0545 h and 1000 h in the morning with two complementary surveys in the west of the reserve between 1530 h and 1730 h in the afternoon. Vocalisation playback of *P. aureipalatii* and *P. moloch* was used to promote vocalisation. Once a group was found, group size, age composition and location were recorded. Photographs were taken using a Canon EOS digital camera. Individuals were classified as infants, juveniles or adults. Infants were defined as individuals being carried by their parent, whereas juveniles were noticeably smaller than adults and did not participate in vocalisations. Adults were full grown individuals who participated in vocalisations. The location was recorded using a Garmin GPSmap 62st GPS receiver.

Table 3. Definition of habitats.

Habitat	Definition
Plantations	Gardens, farms and plantations for human purposes
Secondary Forest	Forest containing dense understory vegetation, with a canopy layer not exceeding 30 m
Mixed Forest	Forest containing less understory vegetation, with an emergent layer exceeding 30 m, but with signs of heavy human interventions (eg. logging)
Less Disturbed Forest	Primary forest without a dense understory layer, mainly containing trees exceeding 30 m, up to 55 m

Data analyses

Data explorations and statistical analyses were carried out using IBM SPSS Statistics 21. To determine the correlation between the activity budget and the time of day, the Kruskal–Wallis test was used. The Kruskal-Wallis test was also used to determine the correlation between the time of day and the vertical position and the correlation between the hour of day and habitat presence. The diet composition was determined by the time an individual spent feeding on a particular food type. The home range size was calculated using the 100 % minimum convex polygon (MCP) on the basis of GPS points in Esri ArcGIS 10.3.1. The same software was used to create a map of the study area.

Results

Activity budget

The subjects spent 15% being locomotive throughout the day, while 12% of the time was spent feeding and foraging. The prevailing behaviour over the whole day was stationary (68%), where the least time was spent on social behaviour (5%). Although behaviour not fitting in any of the categories and therefore categorized as 'other' was observed (e. g., urinating or defecating), this behaviour never occurred during the scan sampling moment and is therefore not included in the observations. Overall, the activity budget seemed to depend on the time of day ($p < 0.001$). During the first hour of observation, the subjects were mostly stationary (77.1%), being the least stationary in the late afternoon between 1500 h and 1559 h (51.5%) (Fig. 1). Between 0700 h and 0759 h the animals were most locomotive (23.7%) of all hours, while being the least locomotive (8.8%) between 1000 h and 1059 h. Feeding and foraging behaviour was mostly displayed between 1500 h and 1559 h (23.8%); from 0800 h until 0859 h the least amount of time was spent on feeding (8.2%). Social behaviour was mainly displayed during the middle of the day from 0900 h until 1259 h (ranging from 7.4% to 10.0%). During the rest of the day only between 0% (from 1600 h until 1700 h) to 6.1% (from 1500 h until 1559 h) of social behaviour was observed.

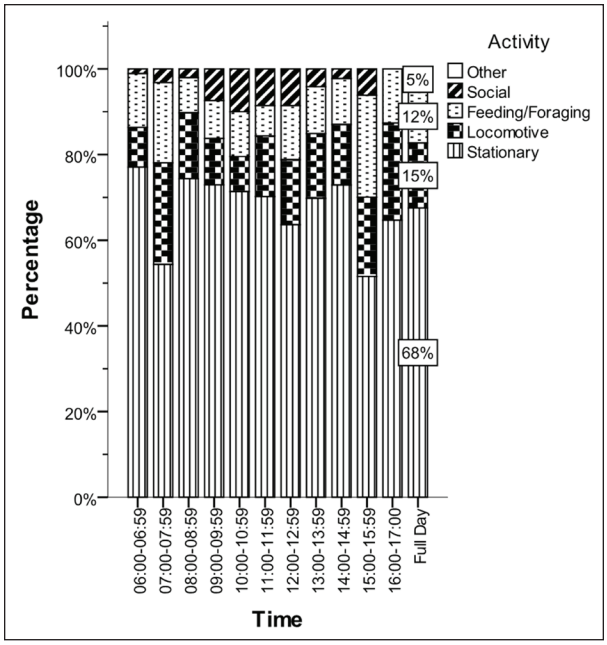

Figure 1. Activity budget of the study group, averaged per hour and over the full day (0600 h – 1700 h).

Diet

The individuals were observed eating fruit for 458 minutes (72%) over 64 occasions. Leaves were fed on for 111 minutes (18%) during 37 observations. Flowers were eaten for 38 minutes (6%, 9 observations), while arthropods were preyed upon during 25 minutes (4%) during 6 observations. Arthropods preyed on included spiders (order *Araneae*) and, on two occasions workers of Army Ants (*Eciton burchellii*).

Habitat usage

Homerange size was 6.9 ha, while the distance between the farthest detection points was 499 m. The study group only spent an average of 2% per day in less disturbed forest, while most time (76%) was spent in secondary forest. Plantations were used for 6% of the observed time, the remaining 15% was spent in mixed forest (Fig. 2). Habitat presence did not significantly depend on the hour of the day ($p = 0.279$). Analysis of a 100 m2 quadrant in the mixed forest showed a basal area of 92 m2/ha. A basal area of 16 m2/ha was found in the 100 m2 quadrant in the secondary forest.

Trees used as sleeping sites had estimated heights ranging from 15 m to 4 9 m ($x^- = 29$, SD = 11) and a DBH (diameter at breast height) ranging from 13 cm to 197 cm ($x^- = 52$, SD = 52). Most nights (86%), the subjects were observed to be sleeping in or above the canopy layer (Table 4). Two nights (14%) were spent sleeping in the understory. Sleeping trees were located at a maximum of 206 m from each other.

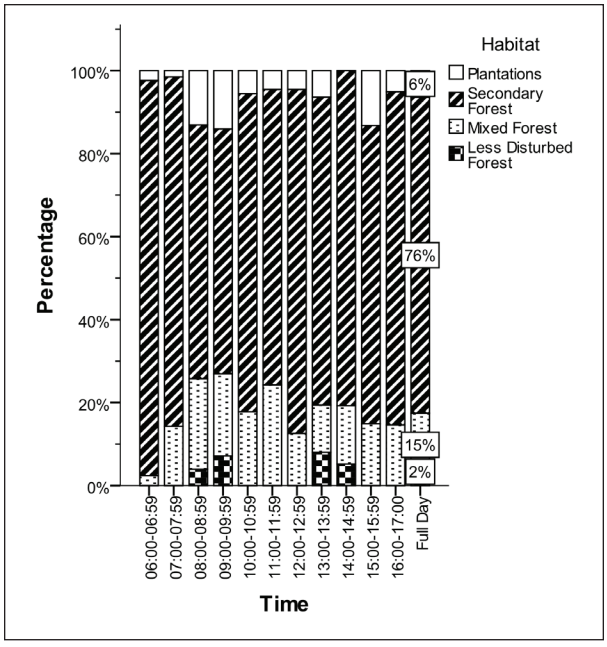

Figure 2. Group presence in different habits, averaged per hour and over the full day (0600 h – 1700 h).

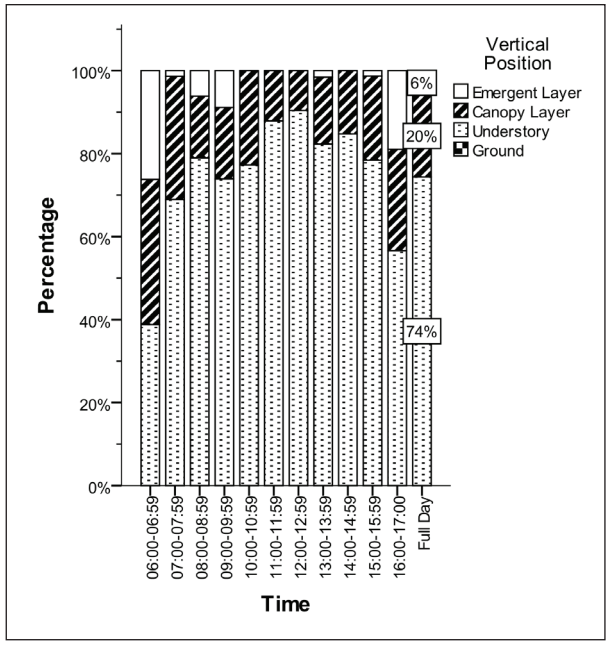

Figure 3. Vertical forest usage (vertical position) of the study group averaged per hour and over the full day (0600 h – 1700 h).

Table 4. Sleeping sites used by the *P. aureipalatii* group.

Tree	Height	DBH (cm)	Vertical Position	Number of nights observed
1	22	23	Understory	1
2	25	45	Canopy Layer	3
3	18	31	Canopy Layer	1
4	49	197	Canopy Layer	1
5	15	13	Understory	1
6	18	24	Canopy Layer	1
7	34	38	Emergent Layer	2
8	34	65	Emergent Layer	2
9	38	40	Emergent Layer	1
10	38	46	Emergent Layer	1

Over the whole day the study group spent the major part of the time in the understory (74%), while the least time was spent in the emergent layer (6%) (Fig. 3). Only during the first observation hour of the day, from 0600 h until 0659 h, did the group spent less than half of their time (39%) being in the understory, while presence there was the highest in the middle of the day (88%) from 1200 h until 1259 h. Presence in the canopy layer was highest between 0600 h and 0759 h (30% to 35%), while least time spent in the canopy layer (10%) occurred between 1200 h and 1259 h. More time spent in the emergent layer seemed to only occur during the first and last observation hours (26% respectively 19%). No subjects were observed in the emergent layer (0%) from 1000 h until 1259 h, and between 1400 h and 1459 h. The vertical position seemed to depend significantly on the time of day ($p < 0.001$). During scan samples, no observations were made of subjects being at ground level. However, a subject was once observed quadrupedal walking on the ground for the duration of fifteen seconds.

Presence of other groups

Four groups, including the study group, were encountered. The groups were only heard vocalizing in the morning, after a vocalization was played through speakers. Group 1 was one time observed while Group 2 was heard vocalizing, proving the presence of two separate groups within a close proximity, instead of one group (Fig. 4). The groups consisted of two to four individuals ($\bar{x}$ = 3, SD = 0.82; Table 5). All groups were found in secondary forest.

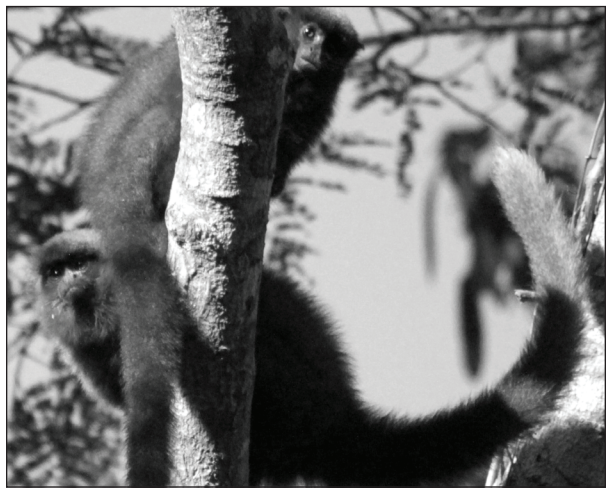

Figure 4. *P. aureipalatii*, two adult members of group 1. Photograph taken by Michael Connor on July 14, 2016.

Table 5. Composition and location of the four encountered groups of *P. aureipalatii*.

Group	Coordinates	Adults	Juveniles	Infants	Total
1	68°59'17"W 12°31'9.6"S	2	2	0	4
2	68°59'27"W 12°31'9.5"S	2	1	0	3
3	68°58'14"W 12°31'23"S	3	0	0	3
4	68°58'9.7"W 12°31'30"S	2	0	0	2

Discussion

This study provides the first data on the activity budgets and habitat usage of *P. aureipalatii* in an area strongly disturbed by human actions. The results on activity budget show a high amount of time spent being stationary throughout the day. This amount of 68% is considerably higher compared to similar primates like *C. personatus* (62%), *P. cupreus* (54.9%), *C. torquatus* (55%), *C. nigrifrons* (29%) and *P. brunneus* (59%) (Clutton-Brock and Harvey, 1977; Kinzey and Becker, 1983; Lawrence, 2007; Caselli and Setz, 2011; Kulp and Heymann, 2015). Furthermore, more time was spent locomotive then was on feeding/foraging. This is surprising as the other studies suggest feeding/foraging behaviour usually prevails over traveling. It is likely that time spent on feeding/foraging was less in this study group compared to other studies because of the presence of plantations and therefore the easy access to fruits. While the study group only spent 6% of its time in plantations, the subjects seemed to only visit the plantations to eat fruits. The amount spent feeding on the different food types, with the major part of the time spent feeding on fruits, did not differ from results from other studies (Hershkovitz, 1990; Kinzey, 1992; Lawrence, 2007; Norconk, 2007; Nadjafzadeh and Heymann, 2008; Heymann and Nadjafzadeh, 2013). However, it is important to take into account that feeding data was only collected during a limited amount of time and, as a result, should only be considered as preliminary data.

The unexpected results regarding the activity budget could be caused by anthropogenic habitat alterations, because titi monkeys may react differently to those disturbances (Ferrari *et al.*, 2000; Heiduck, 2002; van Roosmalen *et al.*, 2002; Bicca-Marques and Heymann, 2013). This suggestion seems to be backed by the habitat preference as 76% of time was spent in secondary forest while only 15% and 2% were spent in mixed and less disturbed forest.

Like some other titi monkeys, *P. aureipalatii* might be able to cope very well with certain habitat alterations (Ferrari *et al.*, 2000; Heiduck, 2002). The vertical forest usage (vertical position) confirms the preference for secondary forest, as 74% of the time is spent in the understory. The preference for secondary forest is also supported by the analysed quadrants in mixed and secondary forest. At forest edges and in young vegetation, insect abundance and leaf quality might be higher than in the interior of less disturbed forest (Fowler *et al.*, 1993; Ganzhorn, 1995). This might explain the habitat preference that was found. The higher presence in the canopy- and emergent layer during the early morning and late afternoon can be explained by the fact that these are the times *P. aureipalatii* is waking up or looking for sleeping sites, which are usually higher than twelve meters as found in this study. The use of sleeping sites below twelve meters, which was observed two times, is unusual, as primates normally sleep higher up to avoid predators (Ferrari and Ferrari, 1990; Anderson, 1998). Because of the low number of observations in sleeping sites, it is difficult to draw conclusions. Additional research is needed to provide more accurate data. The reason for the lower, and seemingly more unsafe sleeping sites is unclear. Home range size seemed to match with other *Plecturocebus spp.* in secondary- and disturbed forest (Brock and Harvey, 1977; Wright, 1986; Johns, 1991; Ferrari *et al.*, 2000; Kulp and Heymann, 2015).

It is important to note that the study regarding distribution was only carried out during a short period with only a few censuses. This means there might be more undiscovered groups present. Because of this, it was not possible to provide accurate abundance estimations of *Plecturocebus aureipalatii* in the area. The average group size of three (two to four individuals) for all four groups found during this study, seems to be normal for titis (Ferrari *et al.*, 2000; Wagner *et al.*, 2009; Kulp and Heymann, 2015).

Concluded is that the study group displays a slightly different activity budget from what can be expected when comparing them to similar primates. The vertical forest usage and habitat usage suggests *P. aureipalatii* is able of adjusting to strongly disturbed forests and human presence. Preliminary data on diet and sleeping sites did not show surprising results, and are comparable to other *Plecturocebus* species. Caution should be taken using the results of this study as species specific for *P. aureipalatii*, as only one group was investigated. It is recommended to study other groups in different habitats and different types and levels of anthropogenic disturbances to determine habitat preferences and their adaptation to human activities.

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