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Camera Trap Observations of Nonhabituated Critically Endangered Wild Blonde Capuchins, *Sapajus flavius* (Formerly *Cebus flavius*)

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Abstract Habituation presents major challenges for the study of wild primates, particularly in areas where threats such as hunting pressure and increasing forest fragmentation exist. This study describes the use of ground camera trapping to investigate nonhabituated blonde capuchins. Capuchins are arboreal animals, but often use the ground when foraging. Thus, we hypothesized that a ground-baited camera trapping station would be an efficient method to document the presence of capuchins, and to collect information about aspects of their social behavior and ecology. We conducted 92 systematic trapping days over 15 months (from December 2010 to February 2011 and from August 2011 to July 2012). The capuchins visited the trapping stations 43 times. All visits occurred between 05:13h and 17:32h, and lasted 3 min-2:03 h. Sixty-five percent of the photographs included our target species. Groups contained up to 46 individuals and were multimale-multifemale. We recorded no monkeys at the trapping stations during August and November (2011) and January (2012). Infants were more likely to be carried than not. Infants were carried by both sexes; however, 96% of

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photographs showed females as carriers. Adult males always arrived first at the camera trapping stations, suggesting that males led the group's movements. The ground-baited camera trapping stations proved effective for confirming the presence of the blonde capuchins in the study site and for documenting aspects of their social behavior. The technique could potentially be used to provide comparative data among populations of this and other primate species in areas where habituation is difficult or risky to the primates.

Keywords habituation · noninvasive technique · primate surveys

Introduction

Researchers use a range of methods to survey animals, e.g., line transects, total counts, cue counts, and lure strip transects (Buckland *et al*. 2010; Pruetz and Leasor 2002), and to study their behavioural ecology, e.g., focal animal and scan sampling methods (Altmann 1974). Habituation is usually the first step in research on wild primates as it allows researchers to observe individuals at close range, permitting the collection of data that would otherwise be difficult to obtain (Ando *et al*. 2008; Crofoot *et al*. 2010; Tutin 1999; Williamson and Feistner 2003). However, habituation may involve risk to the primates, particularly in areas where hunting pressure and increasing deforestation pose considerable threats (Doran-Sheehy *et al*. 2007). In these cases, habituation to humans reduces the flight response, making the wild primates more susceptible to poaching (Crofoot *et al*. 2010; Williamson and Feistner 2003). Studies involving habituation of wild primates also usually require substantial investments of researcher time and resources (Ross and Reeve 2003).

Camera traps can potentially provide noninvasive and time-efficient observational snapshots of mammal behavior (Kierulff *et al*. 2004; Mccallum 2012; Melovski *et al*. 2008; Silveira *et al*. 2003; Silver *et al*. 2004; Srbek-Araujo and Chiarello 1999; Tan *et al*. 2013; Trolle and Kéry 2005). Camera trapping has proved successful for collecting diverse types of information from arboreal mammals with relatively little human effort in the field (Cerbo and Biancardi 2013). However, this technique has only recently been applied to investigate the activities of arboreal primates (Kierulff *et al*. 2004; Olson *et al*. 2012; Tan *et al*. 2013; see this special issue of the *International Journal of Primatology*).

We describe the use of ground camera trapping to document aspects of the behavior and ecology of the Critically Endangered blonde capuchin, *Sapajus flavius* (formerly *Cebus flavius*), in a highly fragmented area in the northeast of Brazil. Blonde capuchins are endemic to northeast Brazil and their habitat, the Atlantic forest, has experienced substantial fragmentation and deforestation for >500 yr (Saatchi *et al*. 2001). The species was believed to be extinct until 2006, when populations were officially rediscovered in fragments of Atlantic rain forests in northeast Brazil (Oliveira and Langguth 2006; Pontes *et al*. 2006). Studies of this charismatic species in fragments of Atlantic rain forest may help in preserving this biodiversity hotspot and will be valuable for obtaining information to promote the conservation of this Critically Endangered species (Conservation International 2013; Veríssimo *et al*. 2011). The species is now one of the five primate species targeted by the Brazilian government as a priority for conservation in the northeast of the country (PAN-PRINE 2012). An efficient

monitoring technique would therefore be beneficial for the development of conservation and management programs (Cerbo and Biancardi 2013).

Capuchin monkeys are largely arboreal (Fragaszy *et al*. 2004; Freese and Oppenheimer 1981), but often forage on the ground (Milano and Monteiro-Filho 2009; Ottoni 2011; Ottoni and Izar 2008). Thus, we hypothesised that ground-baited camera traps would be an efficient method for documenting the presence of blonde capuchins in the wild and useful for the collection of information about their social behavior. Our camera traps could be triggered at any time of the day or night so we could assess whether the blonde capuchins conformed to the diurnal pattern of behavior observed in most capuchins studied previously (Fragaszy *et al*. 2004; Freese and Oppenheimer 1981). Furthermore, as capuchins show strong maternal care (Fragaszy *et al*. 2004; Freese and Oppenheimer 1981), adults are likely to carry the infants when on the ground. We therefore predicted that female capuchins would carry infants more than males do, as reported for other capuchin monkey species (Fragaszy 1989).

Methods

Study Site

We conducted fieldwork at a privately owned forest fragment locally known as Mata dos Macacos in Igarassu, Pernambuco, Brazil (07º46.411″ S, 035º00.238″ W). The fragment consists of *ca.* 340 ha of primary and secondary Atlantic forest, surrounded by sugar cane fields (Fig. 1). The area has a rainy season between April and August and a dry period between November and December (CPRH 2003). The reported mean total annual precipitation and monthly temperature are 1687 mm and 25°C, respectively (Schessl *et al*. 2008).

The blonde capuchins at the study site were not habituated. During our initial attempts to survey the area, the capuchins produced alarm calls and fled in response to our presence.

Camera Trap Monitoring

Our study consisted of a pilot period (October–November 2010) and a systematic sampling period (December 2010–July 2012). During the pilot study, we collected 10 days of camera trap data. We calculated the number of trap days as the time between camera placement and collection. We used two to four cameras at each site. During this period, we tested using the cameras with and without provisioning, and experimented with different foods as attractants. We tested fruits, e.g., ripe bananas, watermelon, mango, jackfruit, and mixed fruits, but these decomposed quickly (usually within 48 h, depending on the fruit) and failed to attract the blonde capuchins to the stations. Finally, we tested 2 kg of dried corn, which attracted the capuchins successfully. We also tested different locations in the forest fragments and different heights for the camera traps (each location/height for at least a week) to determine the most productive site. We placed cameras on roadsides (between sugar cane fields and the forest, as there is some evidence that the blonde capuchins raid sugar cane plantations [Oliveira and Langguth 2006], and we detected some monkey footprints on the ground); in the forest (*ca*. 2 m

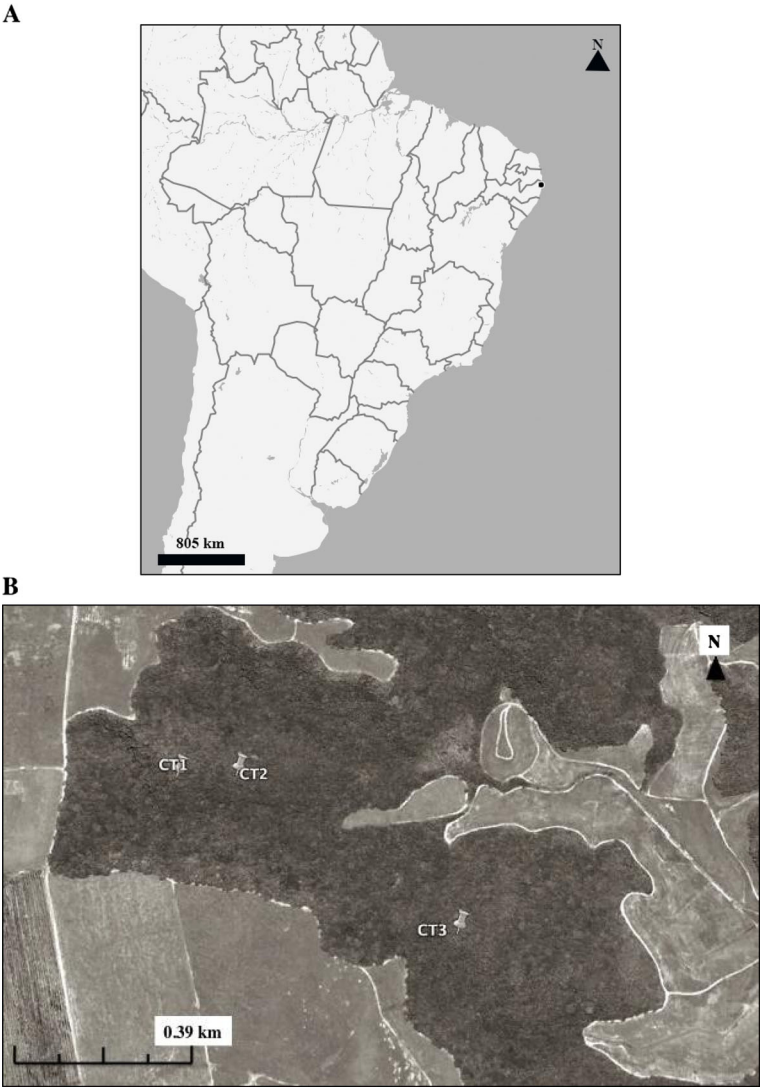

Fig. 1 Map showing study site position (black dot marks the site on A) and camera trap stations (B). CT1 = 07º47.160′ S–035º00.792′ W; CT2 = 07º47.160′ S–035º00.792′ W; CT3 = 07°47.355′ – 035°00.418′ W. Distances between stations, in a straight line, were: C1 to C2 = 136 m, C1 to C3 = 772.5 m, and C2 to C3 = 700 m. Forest fragment image obtained from Google Earth software, Image © 2013—Digital Globe/MapLink.

above the ground pointing at a baiting platform [as in Kierulff *et al*. 2004]); close to the ground, pointing to the tree trunks, lower branches, and canopy (as in Olson *et al*. 2012; Tan *et al*. 2013); and directly on the ground pointing at a custom-made automatic feeder filled with dry corn (also placed on the ground). Only the latter situation captured images of the blonde capuchins so we used this ground trapping station for systematic sampling (Fig. 2). To secure the cameras to the tree base to avoid disturbance from humans and nonhuman primates, we used custom-made metal cages, chains, and padlocks.

We used Camtrakker® Stealthcam STC-l590 cameras. These cameras have passive infrared sensors for heat and motion detection, a flash (incandescent) range of 27.4 m,

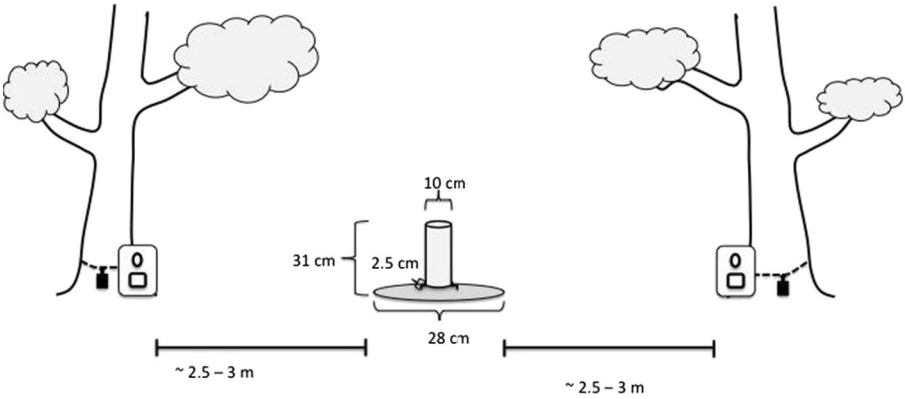

Fig. 2 Ground camera trap station showing relative positions of the cameras to the feeder.

and a 4-s trigger time. We used a single 2 GB SD Card (Kingston, Class 4) to store the images, and eight C Size 5000 mAh NiMH Rechargeable Batteries (Tenergy Premium) to power the cameras. The cameras were set to take pictures at the highest resolution (5 MP) over 24 h each day, with nine images per trigger and a 1-min delay between triggers. Each image recorded the local date and time.

During the systematic sampling period, we chose three locations ≥200 m from the forest borders. At location 1 (C1, 07º47.160′ S, 035º00.792′ W), we deployed four cameras (December 2010–February 2011 and August 2011). We set these four cameras at 90° angles and equidistant from one another. As a result of local human activity nearby, we moved the cameras to new locations in September 2011 and deployed two cameras facing in opposite directions at locations 2 (C2, 07º47.160′ S, 035º00.792′ W) and 3 (C3, 127 07°47.355′ S, 035°00.418′ W), from September 2011 to July 2012. The distance between C2 and C3 was 700 m (Fig. 1b). We checked the cameras at least every 48 h. The time that the camera traps were left in the field per month varied according to access (being on privately owned land), but the cameras were operational for a mean of 5 d/mo (range: 3–9).

Data Analysis

Cameras located at the same station were situated in different positions to yield different perspectives. We treated visits with overlapping dates and times as a single visit (Tan *et al*. 2013). We considered an independent visit as when successive images of blonde capuchins were captured ≥1 h apart (Tan *et al*. 2013). The "first" hour of the day was defined based on the sunrise, which varies little at the study site, i.e., *ca*. 05:00 h.

We used the "Magnifier" tool in "Preview" v. 7.0 (Apple Inc.) to inspect images. We recorded: number of animals per image (we marked subjects with a dot when counted to avoid recounting the same individual); group composition (age and sex of the subjects whenever possible); time and duration of visits to the trapping stations; age and sex of the first individual arriving at the station; and visits by other taxa. If multiple individuals appeared in an image, we used their relative body size to distinguish between adult and young individuals. We considered individuals up to three fourths of adult female body size, not including the tail, as juveniles (Oliveira and Langguth 2006). We considered individuals as infants if they were carried by adults, or if they were up to one third of adult female body size. Whenever possible, we identified males

by their prominent testicles, protuberant neck skin, and head shape (Fig. 3). We identified females only when their genitals were visible or the breasts were engorged. We could not sex juveniles and infants.

We used χ^2 tests (including Yates' correction when necessary) to compare 1) arrival times at the camera trapping stations across different hours of the day, 2) the number of times that male and female adults carried infants, and 3) the number of times that infants were carried and not carried.

Results

In the pilot study, we obtained 613 images, of which *ca*. 55% captured at least one blonde capuchin (N = 337, 10 trap days). During systematic sampling we obtained a

Fig. 3 Blonde capuchins of different sex and age. (A) Adult males. The arrows point to the protuberant neck skin and the prominent testicles. (B) Adult females. The arrows show the engorged breasts and the genitals. (C) Juveniles. The arrows point to the juveniles. (D) The arrows point to carried and non-carried infants. Data were gathered from October 2010 to February 2011, and from August 2011 to July 2012, at Igarassu, Brazil.

total of 19,008 still images over 92 trap days and had a capture success rate of *ca*. 65% for our target species (N = 12,351 images including at least one blonde capuchin; Table I). We captured capuchins successfully in 12 of 15 mo of systematic sampling. Months with no images of monkeys were August 2011, November 2011, and January 2012. Approximately 5% of the images captured species other than the blonde capuchins, including bats, rodents, birds (not identified), marsupials (*Didelphis* sp. and *Monodelphis* sp.), coati (*Nasua nasua*), agouti (*Dasyproct* sp.), armadillo (*Tolypeutes* sp.), and a common marmoset (*Callithrix jacchus*). Of the remaining images, 18% of images contained no animal and showed only the background vegetation, 11% captured the researchers during camera checks, and 0.9% were completely black images resulting from equipment failure.

Blonde capuchins visited the trapping stations 43 times, with up to two visits on any one day. The interval between visits was 0–4 days. The number of visits per month varied between 2 and 6 (see Electronic Supplementary Material Fig. S1). On occasions, the corn supplement was exhausted during a single visit. On other occasions, the capuchins ate, left the station, and returned after a period of 1 h to a few days. Visit duration ranged from 3 min to 02:03 h.

The camera traps caught images of blonde capuchins between 05:13 and 17:32 h. The times that the monkeys arrived at the image capture stations differed across the hours of the day ($\chi^2 = 28.65$, df = 12, $P < 0.001$). About 24% of the visits started in the first hour of the day (Fig. 4).

The first individuals to be photographed at the ground trapping station were always adult males. We could distinguish nine males and two females easily in the images through natural features, i.e., scars, fur coloration, and skin pigmentation. The cameras trapped up to 46 blonde capuchins per photograph, but 76% of the images had between 2 and 30 individuals (Table I). Group composition during the 43 visits was mostly multimale, multifemale adults with juveniles and infants (Table II).

We observed infants in all months of successful capture (range: one to seven infants), with a maximum in May 2012 (Fig. 5). Only adults carried infants. A total of 2,715 photographs showed infants carried by an adult. Both males and females carried infants, but carriers were female in 96% of the photographs. In 2% of images males carried infants and in 2% of the photographs we could not sex the carrier. Thus, there was an evident female bias in the likelihood of carrying infants ($\chi^2 = 2475.8$, df =

Table I Number and percentage of camera trap images of blonde capuchin monkeys during 92 camera trapping days at Igarassu, Brazil

No. of blonde capuchins per single photograph	No. of photographs	Percentage (%) of photographs
1	1896	15
2–5	4630	37
6–10	2603	21
11–20	2205	18
21–30	835	7
31–40	170	1
>41	12	<1
Total	12,351	100

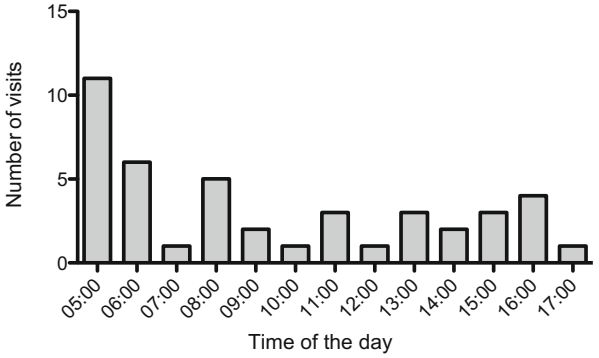

Fig. 4 Arrival times of the blonde capuchin monkeys in the image capture station. Here we consider the full hour, e.g., 5 = 05:00 h to 05:59 h. Total number of visits = 43. Data were gathered from October 2010 to February 2011, and from August 2011 to July 2012, at Igarassu, Brazil.

1, $P < 0.001$). On one occasion we observed a single adult carrying two infants (January 2011). Infants were significantly more likely to be carried than not carried ($\chi^2 = 2451.9$, df = 1, $P < 0.001$). Infants were not carried by an adult group member in 91 photographs, but in each case there was an adult less than *ca.* 10 cm from the infant.

Discussion

Our results suggest that blonde capuchins can be surveyed and studied effectively by ground-baited camera trapping. Despite being considered arboreal, capuchins are often seen on the ground (Aversi-Ferreira *et al.* 2007; Sabbatini *et al.* 2008; Siemers 2000; Wallace and Demes 2008). Behavior while on the ground usually includes use of tools to scavenge on logs and in dirt for food (Milano and Monteiro-Filho 2009; Ottoni 2011; Ottoni and Izar 2008). We also recorded other species of mammals and birds, showing the potential of the ground station for more general surveys of Neotropical mammals.

The cameras photographed up to 46 individuals simultaneously, corroborating observations of fairly large groups in the Family Cebidae (Alfaro 2005, 2007; Di Bitetti 2001; Robinson 1988a,b). This number is also close to the maximum group count we conducted in the area (52 individuals; Bezerra and Bastos *pers. obs.*). We could identify 11 blonde capuchins easily in camera trap images, showing the potential for monitoring individuals in the population. Group composition was multimale–

Table II Group composition during blonde capuchin visits to image capture stations at Igarassu, Brazil

Group structure	No. of visits	Percentage (%) of visits
Multimale multifemale	4	9
Multimale multifemale with juveniles but no infants	2	5
Multimale multifemale with infants but not juveniles	6	14
Multimale multifemale with juveniles and infants	31	72
Total number of visits	43	100

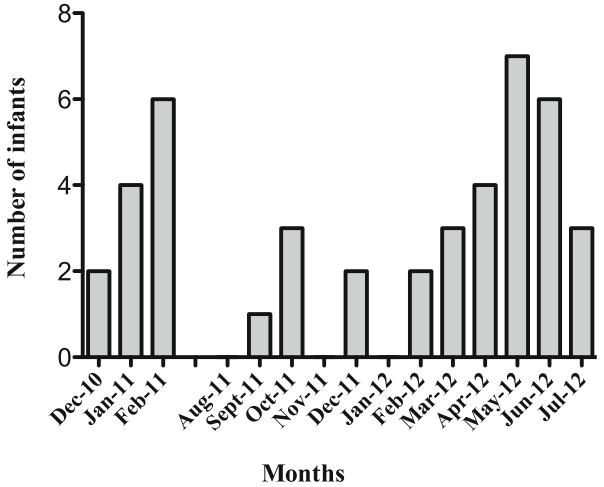

Fig. 5 Maximum number of infant blonde capuchin monkeys in a single photograph during the systematic sampling period at Igarassu, Brazil.

multifemale, as previously observed for other wild capuchins (Alfaro 2007; Di Bitetti 2001). The number of individuals (of different sex and age) in the photographs varied, suggesting that blonde capuchins in the area may adopt a dynamic fission–fusion social system, with the large group dividing into subgroups that later merge, in whole or in part (Alfaro 2007; Amici *et al*. 2008; Bezerra *et al*. 2010; Couzin 2006; Lehmann and Boesch 2004; Quintana-Rizzo 2006; Ramos-Fernández 2005). However, it is also possible that some individuals of all ages stayed high in the canopy and thus were not photographed. In addition, hierarchical relationships within the group and individual variation in motivation to feed may have prevented some individuals from appearing in the images.

On one occasion we observed up to two infants carried by a single individual. This may suggest twinning, although the lack of other observations of two infants also suggests that this may have been evidence of allocare. Capuchins are usually reported as having single offspring, with twinning rare (Defler 2003; Leighty *et al* 2004; Pisinatti *et al* 1999; Rowe 1996). We observed infants in all months where we observed monkeys in images, suggesting the lack of a specific breeding season for the species, in contrast to the seasonal breeding observed in other capuchin species such as *Sapajus nigritus* (Di Bitetti and Janson 2001). Nevertheless, there were months with a considerably higher numbers of infants captured in a single photograph. In May 2012, for example, seven carried infants appeared in a single photograph and in February 2011 and June 2012, six carried infants were caught by the cameras. Infants were more likely to be carried than not and those that were not carried always had an adult in close proximity. This suggests strong parental care and a high level of dependency for blonde capuchin infants.

Blonde capuchins were photographed between 05:13 h and 17:32 h, in accordance with the diurnal habits typical of capuchins (Defler 2003; Fragaszy *et al*. 2004; Freese and Oppenheimer 1981; Rowe 1996). Adult males were always the first to appear in the sequence of photographs on each visit to the camera trapping stations. This may

indicate that males have feeding priority (Crofoot and Wrangham 2010; Gerald 2002; Jack and Fedigan 2006; Muniz *et al*. 2010) or that males protect other group members (Bernstein 1964). Infants, juveniles, and females have a smaller body size than males, and may be more susceptible to predation (Benchimol and Venticinque 2010; Bezerra *et al*. 2008; Ferrari and Beltrão-Mendes 2011). Humans and nonhuman predators have access to the study forest fragment; thus, males could be inspecting the area for safety to avoid predation of females and young individuals.

Through our ground camera trapping stations, we obtained information about blonde capuchins at our study site that would otherwise not be possible owing to the lack of habituation of the animals. A ground image trapping station proved successful for obtaining photographic evidence of the presence of blonde capuchins. It also provided information on several aspects of the life history and behavioral ecology of a nonhabituated population. The technique could potentially be used to survey for and study other populations of this Critically Endangered primate, and other primate species in areas where habituation is difficult or poses a risk to the primates.

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