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From the Field

Camera Trap Feasibility for Ecological Studies of Elusive Forest Deer

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ABSTRACT The difficulty in observing and capturing elusive species in the wild is one of the main reasons for the limited number of studies on such species. This knowledge gap affects the development of conservation and management plans. Hence, testing the feasibility of research tools is essential for the future use and reliability of such tools. Camera traps increasingly are used as an alternative to capturing animals for wildlife research, and to generate important data for the management and conservation of many species. We identified individual free-ranging gray brocket deer (*Mazama gouazoubira*) from the Brazilian Pantanal by their natural markings. From October 2011 through September 2012, we investigated the feasibility of using camera traps for home range, habitat use, and activity period studies based on individuals with natural marks compared with the concurrent data collected from Global Positioning System (GPS) collars. Home range studies based on camera traps have limitations related to the quantity of individuals with natural marks and need for population premonitoring to detect them. The irregular performance of camera traps and lower detection probability in open habitats restricted its application in the habitat use study, especially among highly heterogeneous habitats. However, the positive correlation ($r = 0.98$, $P < 0.001$) between the frequency of photographic records and distances travelled by deer with GPS locations indicated reliable use of camera traps for research into activity periods. Camera traps can be used as an alternative to telemetry, potentially expanding the perspective and scope of noninvasive ecological studies for elusive and cryptic species.

KEY WORDS activity periods, Brazil, brocket deer, Cervidae, elusive species, GPS collar, habitat use, home range, *Mazama gouazoubira*, Pantanal.

Studies involving cryptic animals in the wild are logistically challenging (Vogliotti 2003, Barea-Azcón et al. 2007, Rahman et al. 2016). Many species, particularly nocturnal ones with elusive behaviors or from habitats with restricted access, are rarely spotted and captured, making behavioral and ecological studies of such free-ranging animals challenging. Such challenges result in a lack of basic knowledge about such species' ecology, and many are classified as "Deficient Data" by the International Union for Conservation of Nature. Such gaps in ecological knowledge can negatively affect development of management plans and conservation programs (Taber et al. 2016). Thus, use of alternative tools that allow studies of elusive species in the wild are needed to inform effective conservation actions.

Among the tools that have emerged to overcome those difficulties, camera traps can enable noninvasive acquisition of location information of free-ranging animals (Rovero and Marshall 2009, O'Connell et al. 2011). Camera traps have been useful in various ecological studies, including species inventories and studies of population density, home range, activity period, and habitat use (Silver et al. 2004, Azlan and Sharma 2006, Di Bitetti et al. 2006, Dillon and Kelly 2008, Tobler et al. 2008). One of the advantages of wildlife camera-trap studies compared with other sampling methods is that they provide data without the animal being captured

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(Swann et al. 2011). Thus, being a noninvasive tool, camera traps do not require physical or chemical animal restraint, avoiding capture stress or myopathy, which can occur in deer (Vogliotti 2003, Catão-Dias and Camargo 2010).

The brocket deer (*Mazama* spp.) comprises a group of small to medium-sized deer in the tropical and subtropical Americas (Eisenberg and Redford 1999, Duarte and González 2010). Hunting and habitat loss have reduced the abundance of species of this group (Tiepolo and Tomas 2006). Their selection of closed-forest environments, solitary habits, and elusive behavior are the main causes for the paucity of information about these species in the wild (Vogliotti 2003). In the Atlantic Forest, Brazil, for example, the search for brocket deer lasted 4 years and only 3 animals were captured; none of the 11 types of capture traps tested, such as drop nets, clover, and snare traps, were considered successful (Vogliotti 2003). Capturing individuals for systematic telemetry monitoring is logistically unfeasible in these forests because of their remoteness, and efficient methodology is not available for such conditions (Vogliotti 2003, Duarte et al. 2010).

The gray brocket deer (*Mazama gouazoubira*) in the Brazilian wetland Pantanal is not as elusive as are other brocket deer. The peculiar mosaic landscape formed by different phytophysiognomic units of this biome (Rodela et al. 2007) offers unique capturing opportunities, unlike for other species and in other regions. The gray brocket deer feeds in open habitats near edges of lakes during twilight periods where it can be approached slowly until it is close enough to be chemically immobilized using a dart-gun (Antunes 2012). Gray brocket deer captured in Pantanal enable the comparison of data from Global Positioning System (GPS) collars and camera traps to describe the space use by this species of deer in and around forests.

The goal of this study was to use the gray brocket deer in the Brazilian wetland Pantanal as a study case for evaluating the feasibility of using camera traps in ecological studies with elusive species in the wild. Our objectives were to 1) evaluate the possibility of individual recognition by natural markings; and 2) compare the results of home range, habitat use, and activity studies from GPS collars with those from camera traps.

STUDY AREA

The study was conducted at Nhumirim Farm, a research property of the Brazilian Agricultural Research Corporation (18°59′17″S; 56°37′09″W), located in Corumbá city, Mato Grosso do Sul county, Brazil, situated in the region known as Nhecolândia. The region had a tropical climate with average annual temperature and precipitation of 26.4° C and 115.2 cm, respectively (Rodela and Queiroz Neto 2007). The vegetation distribution in this region was unique, dispersed as mosaics, especially in the lower terrain, with a great diversity of forage plant species (Fig. 1; Rodela et al. 2007). *Vernonia scabra, Forsteronia pubescens, Sebastiana hispida*, and *Tocoyena formosa* were some of the plant species that comprise the gray brocket deer diet in the Nhecolândia Pantanal (Antunes 2012). The highest elevation areas in the region were mainly semideciduous seasonal forests, whereas the lower elevation areas were mainly open savanna (Ratter et al. 1988).

Land cover types included the following: 1) forest, formed by semideciduous seasonal forests composed of trees up to 18 m in height and often surrounded by caraguatá (*Bromelia balansae*); 2) Cerrado, a type of savanna with shrubs and small trees about 4–6 m in height with an apparent graminoid layer; 3) savanna, grasslands with scattered shrubs, situated at the transition between the Cerrado and grasslands; 4) grassland; and 5) lake, low depth ponds that in the dry season were colonized by pioneer vegetation (Rodela 2006).

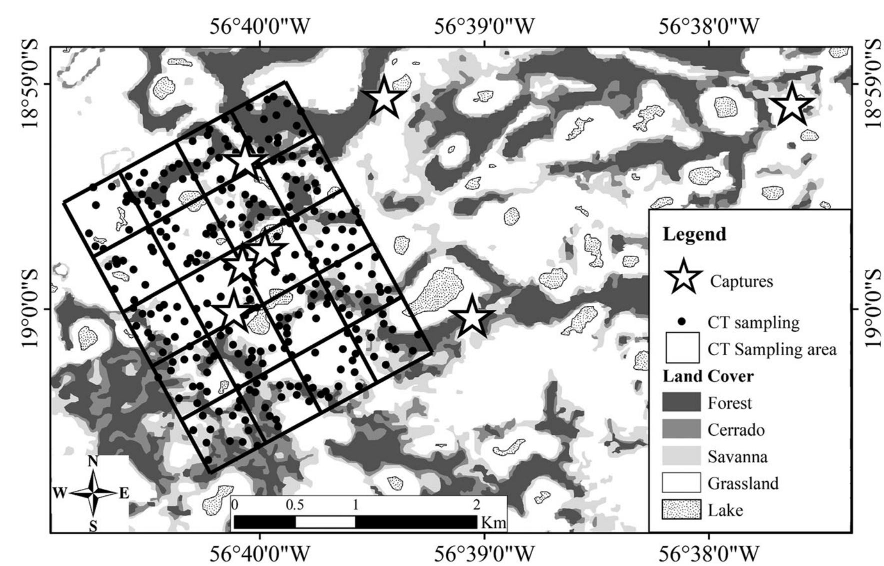

Figure 1. Study location showing the sampling area of the camera traps (CT sampling area). The area was designed based on the closest proximity ($n = 4$) of the Global Positioning System (GPS) monitored gray brocket deer to the capture sites ($n = 7$) in the different land cover types of the Brazilian Pantanal during 2011–2012. Each CT sampling site represents approximately 30 days of camera-trap monitoring.

METHODS

Animal Capture, Marking, and Identification of Individuals

We captured gray brocket deer in July 2011 using a technique similar to that described for the pampas deer (*Ozotoceros bezoarticus*; Piovezan et al. 2006). We slowly approached deer using circular movements to get within approximately 15 m to sedate them with an anesthetic dart from a gas-pressurized dart-gun (DANINJECT®, Børkop, Dinamarca). We prepared darts with 30 mg of xylazine hydrochloride (Rompun®, Bayer S.A., São Paulo, Brazil) and 100 mg of ketamine hydrochloride (Vetaset®, Fort Dodge Animal Health, Fort Dodge, IA, USA). We equipped the darts with a very-high-frequency (VHF) transmitter to enable the animals to be found after being darted. We estimated age of captured animals by dental wear of the individual. All animal care and use procedures were approved by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (permit# SISBIO/10636-1).

We marked the captured deer with ovine ear tags in one ear and radiotransmitter collars with VHF and GPS (LOTEK Wireless® 6000SL, ON, Canada). We marked each collar individually with red tape in different arrangements to enable us to recognize individuals in the photographic records when numbered ear tags were not visible (Fig. 2). Capture procedures lasted 30–50 minutes from initial anesthetic administration, after which we delivered 0.05 mg/kg of intra-muscular midazolam for anesthetic recovery. To track the survival status of deer after capture and during the study period, we monitored the VHF transmitters monthly with homing method by ground using a receiver (TR2 - TELONICS®, Inc., Mesa, AZ, USA).

Data Collection: GPS Collars

For home range and habitat use studies we programmed the GPS collars to collect sequentially geographic point location every 13 hours for 1 year, from October 2011 through September 2012, for collection of locations at different times of the day. For the activity period study, we programmed collars to collect location data sequentially every 15 minutes for 72 hours on 2 occasions: 15–17 September 2011 and 24–26 March 2012. In November 2012, we recovered the collars from the field via their VHF signals after they dropped from the deer automatically.

Camera Traps

To compare results from camera-trap data with those obtained by biotelemetry, we distributed 20 camera traps (models 6.2D and 4.0C, Tigrinus Research Equipment, Timbó, Brazil) in an area of 500 ha, where we intended to cover the home range of 4 animals. Three of the deer remained in the interior of the camera-trap area, and one remained closer to the sampling area boundary (Fig. 1). We divided the sampling area into 20, 25-ha plots and placed one camera trap in each plot. We placed camera traps approximately 500 m apart in animal paths at a height of 50 cm above ground, without bait. To increase photographic opportunities and the number of sampling locations within each land cover type, we changed camera-trap monitoring points within plots about every 30 days when we monitored the functioning of camera traps and exchanged batteries. We deployed all camera traps from October 2011 through September 2012, and programmed cameras to take one photo with 30 seconds of delay between photos; cameras recorded the time, date, and location of all photographs taken.

Individual recognition was necessary for the home-range studies using camera traps, so we noted natural markings of deer without collars to identify individuals. We used natural markings such as cuts, scars, or other signs for animal recognition to evaluate the possibility of using camera traps in home range studies.

Data Analysis

Home range.—We used geographic locations and photographic records to estimate the home ranges of GPS-collared deer. We estimated home ranges using a minimum convex polygon with 95% of the locations, removing 5% of the relocations farthest away from the centroid of the home range, which is one of the most frequently used methods and recommended contours for home range estimation (Laver and Kelly 2008, Calenge 2015). We used the ratio of camera-trap: GPS and collar home-range estimates to compare the 2 techniques. We estimated the home range using adehabitatHR package in Program R version 3.4.2 (Calenge 2006, R Core Team 2017).

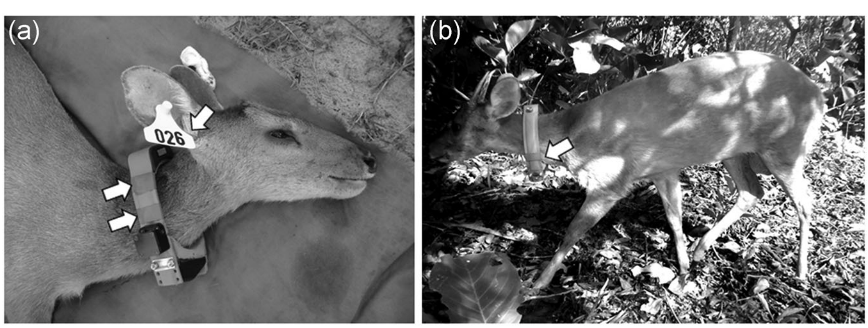

Figure 2. Example of a gray brocket deer marked with bovine ear tags and Global Positioning System collars and monitored in Pantanal, Brazil, during 2011–2012. Each collar was individually marked (a, b) to enable the recognition of individuals in photographic records.

Habitat use.—We used 4 land cover types for the habitat use analysis: forest, Cerrado, savanna, and grassland. We determined habitat use for all GPS-monitored deer using the number of point locations in each land cover type. We did not place camera traps in direct proportion to available land cover types, so we adjusted our estimates of habitat use according to variable sampling effort among land cover types. To correct for the difference in sampling effort among land cover types, we considered the number of records of deer with and without collars in each land cover type per 100 camera-trap days. We considered independent photographic records when they were taken ≥1 hour apart at the same camera-trap-sampled station, except when it was possible to identify distinct adult individuals.

Activity period.—We assumed the frequency of appearance in photographs and minimum distance travelled estimated by GPS fixes as directly correlated with activity of individual deer. We estimated the circadian rhythm according to camera-trap data based on frequency of independent records of all deer with or without a collar for the 12-month monitoring period using each photograph as an activity record of the species. For GPS monitoring data, we estimated activity by movements of each animal recorded every 15 minutes over the 6-day data collection period. We compared activity periods between camera traps and GPS collars with a circular correlational test using Oriana software version 4.02 with $\alpha = 0.05$ (Jammalamadaka and SenGupta 2001, Kovach 2011).

RESULTS

We captured 7 deer in July 2011: 5 males, designated as M1, M2, M3, M4, and M5, and 2 females, designated as F1 and F2. Captured deer ranged in mass from 16 to 22 kg and in age from 8 through 72 months. We sampled 4,361 camera-trap days that resulted in 665 photographs of gray brocket deer, of which we discarded 163 because they did not meet the independence criteria. Of the 502 independent records, 106 were from the 4 marked and monitored individuals inside the sampling area and recorded at 52 different camera-trap sampling points (Table 1). The GPS monitoring resulted in 3,302 points for home range and habitat use analysis and 3,339 points for activity period evaluation. We could not find the collar from male M5; therefore, we measured ecological characteristics of only 6 individuals using GPS collar methodology. In April 2012, we found M2 dead with no clear cause of death, so we monitored this deer for 6 months.

Home Range

Individual home range area estimates by location data from GPS collars ($n = 6$) and camera traps ($n = 5$) varied from 33.9 ha to 98.0 ha and from 8.4 ha to 59.9 ha, respectively (Table 1, Fig. 3). Comparison of estimated home range area for the 2 individuals monitored over 12 months within the camera-trap sampling area (F1 and M1) indicated that the estimates made using camera-trap data were approximately 80% of the estimates using the GPS data (Table 1, Fig. 3). We found a major underestimation of home range using camera traps (80%) for individual M2, possibly due to the low number of photographic records during the 6-month monitoring period.

We identified 4 individuals by natural markings in 21 records. This result represented 5.3% of the total records for nonmonitored deer without collars. Identifiable markings were mainly ear cut marks or deformities. The estimated home range area for the individual with natural markings that had the largest number of photographic records ($n = 13$) in different locations ($n = 8$) was 7 ha (Table 1).

Habitat Use

Gray brocket deer used all 5 land cover categories, but in different proportions (Fig. 4). The GPS samplings showed that grassland was most used by the deer (43.6%), followed by savanna (20%), forest (19%), Cerrado (13.5%), and lake (3.6%). These results for GPS-based land-cover use were different from those estimated by camera traps, which showed that Cerrado had more records per 100 camera traps per day (15.4) and was the most used land cover, followed by forest (11.6), savanna (11), and grassland (10.6).

Activity Period

Analysis of the graphic profiles of both data collection methods (GPS collar and camera traps) presented a similar

Table 1. Home range area (ha) for gray brocket deer monitored with Global Positioning System (GPS) collars and camera traps in the Brazilian Pantanal, during 2011–2012, and their respective number of geographic points, independent photographic records, and locations of records. Home ranges were estimated using a minimum convex polygon method, considering 95% of the locations. Two-dashes mean that the individuals were out of camera-trap sampling area or not monitored by GPS collar, except M5, whose collar was not found.

	GPS collars (GPS)		Camera traps (CT)			CT/GPS
Animal	Points	Home range	Records	Places of records	Home range	CT underestimation
F1	581	75.9	16	13	59.9	0.2
M1	604	66.7	50	20	52.6	0.2
M2[a]	280	45.9	12	7	8.4	0.8
F2	554	52.7	–	–	–	–
M3	687	98.0	–	–	–	–
M4	596	33.9	–	–	–	–
M5[b]	–	–	28	12	37.6	–
NM[c]	–	–	13	8	7.0	–

[a] Monitored during 6 months.
[b] GPS collar not found.
[c] Naturally marked female deer.

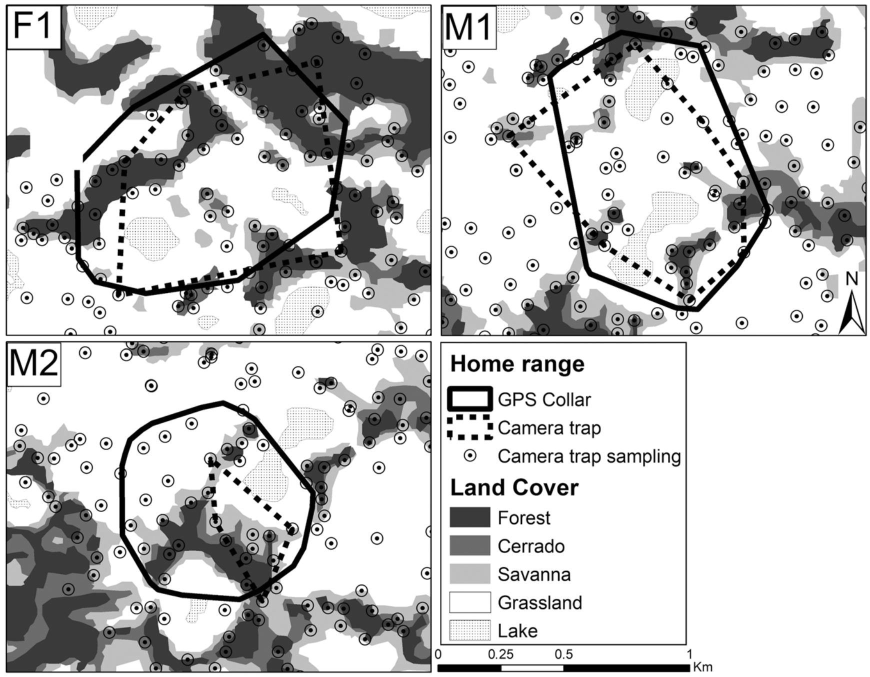

Figure 3. Home ranges of 3 individual (F1, M1, and M2) gray brocket deer monitored in Pantanal, Brazil, during 2011–2012. Home ranges were based on the Global Positioning System collar locations (continuous line polygons) and on the camera-trap records (dotted line polygons) using a minimum convex polygon with 95% of locations.

bimodal activity pattern (Fig. 5). Furthermore, the circular correlational test indicated that the activities measured by both tools were similar, and circadian profiles were highly correlated (Fig. 6; $r = 0.98$, $P < 0.001$).

DISCUSSION

Camera traps and biotelemetry are 2 important tools for ecological data collection of free-ranging animals. In some cases, both tools are jointly used to generate complementary data or for comparison of methods (Maffei et al. 2004, Soisalo and Cavalcanti 2006, Dillon and Kelly 2008). Researchers have used camera traps to conduct home-range estimates for wild species when recognition of individual animals is possible based on the distinctive pelage patterns or antler configuration (e.g., jaguars [*Panthera onca*] and ocelots [*Leopardus pardalis*], spotted pacas [*Cuniculus paca*], and marsh deer [*Blastocerus dichotomus*]; Tomas and Miranda 2003, Maffei et al. 2004, Goulart et al. 2009, Peres et al. 2017). Brocket deer do not have such patterns, but natural markings present in some individuals (such as cuts, scars, and other marks) could be used instead with limited success.

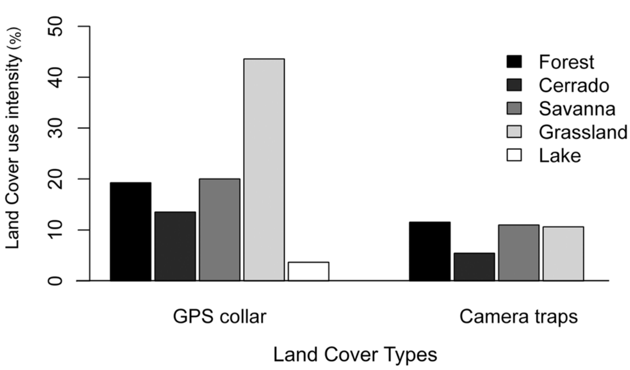

Figure 4. Land cover use (%) of gray brocket deer estimated by Global Positioning System collars and camera traps (photographic records from 100 camera traps/day) in 5 land cover categories, in Pantanal wetland, Brazil, during October 2011–September 2012. The Lake land cover was not sampled by camera traps.

We registered 21 photographic records of animals with natural markings, which represented just over 5% of all deer records and enabled recognition of 4 individuals. Despite our expectation that few individuals with natural marking in the wild could be identified and monitored by camera traps, most of the home-range studies using telemetry involving *Mazama* spp. have been based on fewer individuals than the number with natural markings found in this study (Leeuwenberg et al. 1999, Barrientos and Maffei 2000, Vogliotti 2003, Antunes 2012).

We recorded the gray brocket deer in all the monitored land-cover categories, but with different intensities. It is common for wildlife researchers to place camera traps on trails in closed land-cover types, in order to maximize records (Karanth et al. 2011). Specific habitat use might be related to different behaviors performed by the species, such as rest, traveling, and foraging, which might vary in intensity or be exclusive to a habitat type (Grotta-Neto et al. 2019). These behavioral variations will likely overrepresent use of habitat types that the animals typically use to travel and underrepresent other habitat types used for feeding or resting.

Another factor that might explain differences in land-cover use estimates between the 2 techniques may be related

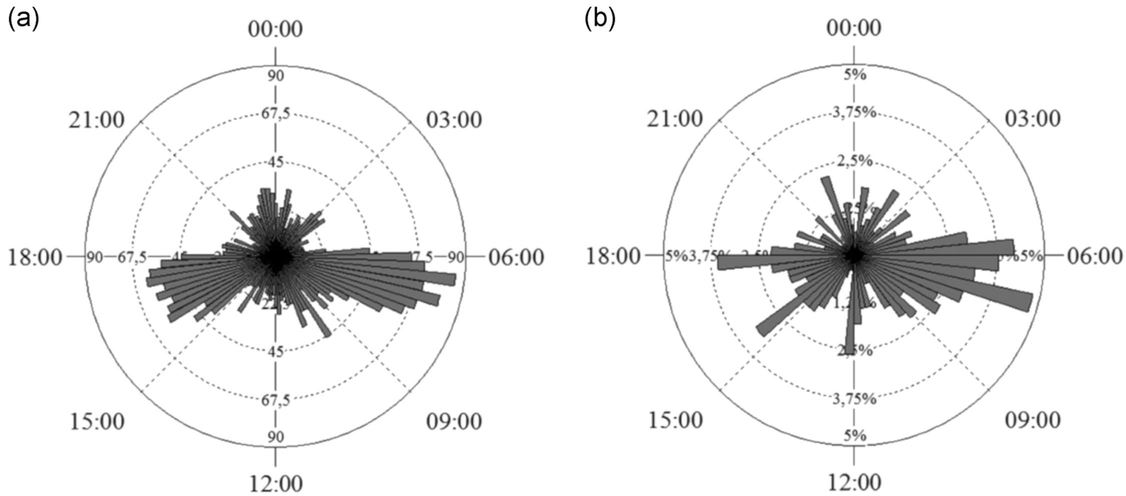

Figure 5. Activity periods of gray brocket deer in the Brazilian Pantanal wetland during 2011–2012, based on the (a) average minimum distance travelled (in meters) every 15 minutes between geographic points recorded by Global Positioning System collars and (b) percentage of records from camera traps.

to monitoring irregularity and apparent low detection probability in open areas for camera traps. Poor equipment performance can be related to the large amount of solar radiation and wind conditions that the traps are exposed to in open habitats (Oliveira-Santos et al. 2010). The camera trap's false-records reduction system, triggered by weather variables such as wind and solar radiation, can momentarily interrupt the operation of the sensor that captures the animal's presence. This can reduce detection probabilities in open land-cover types such as savanna and grassland.

Use of camera traps can be considered an efficient alternative to radiotelemetry techniques for studies of activity period (Tomas and Miranda 2003). The positive correlation between camera traps and biotelemetry data indicated that the frequency of photographic records was linked to distances travelled. Placement of camera traps on trails probably helped to relate the activity pattern to distances travelled. Camera-trap data may have an advantage over telemetry data because those data show a natural unmarked population-wide sample, whereas telemetry-based methodologies infer results from the sampling of a few individuals, which could introduce some random bias when sample sizes are small (Bridges et al. 2004).

Compared with camera traps, telemetry remains a better choice for home range studies for *Mazama*, in spite of capture costs. When activity monitoring is the focus of the study, camera traps are as efficient as telemetry and reliable and cheaper alternative tools. Camera traps can indicate the best time of the day for wildlife researchers and managers to concentrate their efforts to study these species, optimizing captures, observation, and monitoring. Camera traps are not efficient for habitat use studies in highly heterogeneous

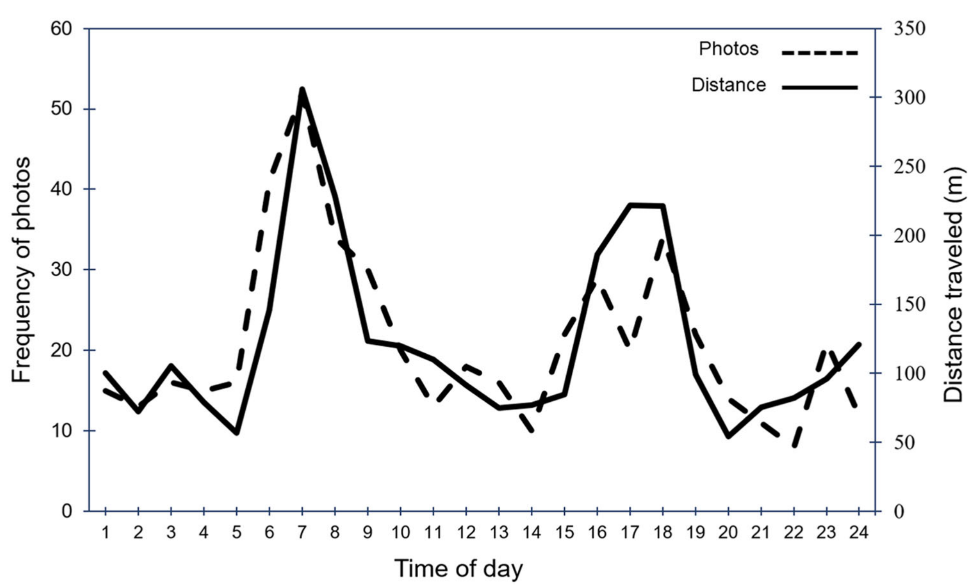

Figure 6. Circadian rhythm of gray brocket deer profiles in the Brazilian Pantanal during 2011–2012, determined based on the frequency of photographic records (dashed line) and the average displacement (m) per hour (continuous line).

environments; therefore, we recommend the use of other tools, such as telemetry or transect sampling, in such habitats.

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