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Activity patterns of the culpeo fox (*Lycalopex culpaeus magellanica*) in a non-hunting area of northwestern Patagonia, Argentina

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Abstract. The culpeo fox is the largest native canid in Patagonia. The majority of past studies on culpeo foxes have focused on trophic ecology, population dynamics, natural history, competitive interactions, management, and habitat use. Little work has been done on determining activity patterns of the fox and thus, conclusions regarding culpeo fox activity patterns have been based on limited data. The objective of our study was to determine culpeo fox activity patterns in a protected area (Lanín National Park, Argentina) using "camera-traps" to test the hypothesis that the culpeo fox is still nocturnal in non-hunting areas. Data were collected from October 2008 through May 2009 at 29 infrared triggered camera stations. We obtained 1,261 culpeo fox photos of which 234 were used for analyses. Diet was studied from 34 culpeo fox scats. Culpeo foxes were most active during nighttime (>70% of the records) confirming the general patterns obtained in other studies. Additionally, examination of culpeo fox scats revealed that they mostly preyed on nocturnal small mammals. The present study offers evidence against the widespread assumption that nocturnal activity of this species is a behavioral response to human harassment, as it was conducted in a protected area where culpeo foxes are not hunted. Instead, their nocturnal behavior may be related to prey activity patterns.

Key words: camera trapping, carnivore behavior, feeding ecology, prey activity patterns, South American Andean forest.

The culpeo fox (Mammalia, Carnivora, Canidae) is the largest native canid in Patagonia and the second largest canid in South America after the Aguará guazú or maned wolf (*Chrysocyon brachyurus*) (Ginsberg and MacDonald 1990; Parera 2002). It is a medium-sized (6–13 kg) opportunistic predator that inhabits western and southern South America from southern Colombia to Tierra del Fuego province in Argentina and Chile (Redford and Eisenberg 1992; Novaro 1997). It feeds on small mammals, reptiles, birds, introduced lagomorphs (European hare *Lepus europaeus* and European rabbit *Oryctolagus cuniculus*), arthropods, sheep (*Ovis aries*), and goats (*Capra hircus*) (Novaro 1997; Novaro et al. 2000; Pia et al. 2003; Silva et al. 2005). Culpeo foxes are habitat-generalists, occupying steppes, shrublands and forests up to 4,500 m asl. (Redford and Eisenberg 1992; Novaro 1997; Jiménez et al. 2001; Acosta-Jamett and Simonetti 2004). It is one of the main species in the carnivore assemblage of the Valdivian Temperate forests of the Southern Andes of Argentina and Chile (Redford and Eisenberg 1992; Funes et al. 2006), an exceptional eco-region of the world in terms of biodiversity (Biodiversity Hotspots 2010) and among the 25 places of highest conservation value worldwide (Myers et al. 2000).

Previous studies on the culpeo fox have focused on its natural history, trophic ecology, population dynamics, competitive and social interactions, management (including hunting), habitat use and selection (Diuk-Wasser 1995; Novaro 1997; Salvatori et al. 1999; Novaro et al. 2000; Acosta-Jamett and Simonetti 2004; Correa and Roa 2005; Novaro et al. 2005). However, conclusions regarding the activity patterns of the culpeo fox have been determined using a limited amount of data.

The few studies of daily activity patterns (Johnson and

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Franklin 1994; Salvatori et al. 1999; Lucherini et al. 2009; Olarte et al. 2009) that have been conducted determined that culpeo foxes were primarily nocturnal. Some authors interpreted this nocturnal preference as a behavioral response of the foxes to avoid hunting by humans (Jiménez et al. 2001; Olarte et al. 2009).

The use of remote cameras as "traps" is a common technique in carnivore research and they are mainly used to collect information on secretive nocturnal species (Kucera and Barrett 1993; Karanth et al. 2004; Lucherini et al. 2009). Most remote camera systems record the date and time at which photos are taken, making it an easy, non-invasive technique to study activity patterns (Lucherini et al. 2009). The use of infrared-triggered digital cameras as "camera traps" allow for the remote recording of wildlife activity on a continual basis without the presence of a fieldworker. They can also be used to survey large areas with a minimum of effort (Silveira et al. 2003).

We use camera traps to study seasonal and daily activity patterns of the culpeo fox in the Andean forests of northwestern Patagonia, where it had not been previously studied. To explore the effect of hunting on the culpeo fox activity, we tested the hypothesis that the culpeo fox is still nocturnal in areas where humans do not hunt it. Additionally, we compared our results with those obtained from other locations, and we examined the culpeo fox diet to elucidate the possible cause of their nocturnal activity.

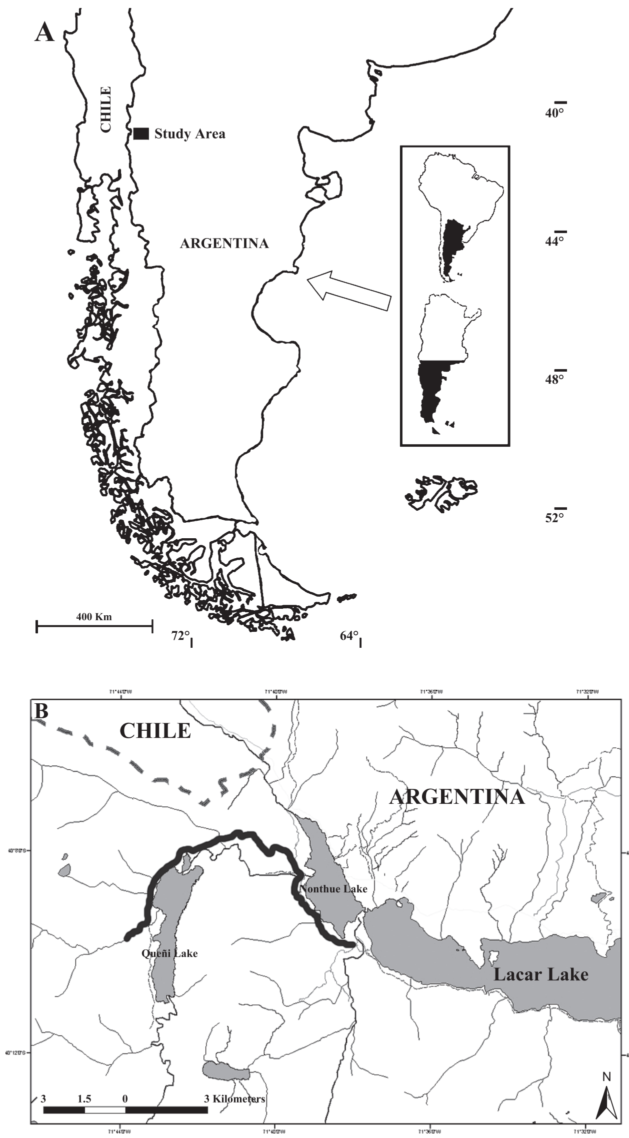


Fig. 1. A) Location of the study area (black rectangle) in Neuquén province, Argentinean Patagonia with a reference map of the location in South America, and B) Map of the main trail (black continuous line) where the camera trap stations were set within the study area.

Methods

The present study was conducted in Lanín National Park (Neuquén province, Argentina, 40º08'14.8"S, 71º42'43.5"W, 650 m asl., Figs. 1A, B), a 412,000 ha protected area that includes Valdivian Temperate forests. The study site is a pristine area in Hua Hum Basin within the Subantarctic Forest Ecoregion with a landscape composed of hillsides and glacier valleys, dominated by raulí (*Nothofagus nervosa*) and coihue (*Nothofagus dombeyi*) as the main arboreal species, with a thick understory of bamboo (*Chusquea culeou*) and michay (*Berberis* sp.). Average daily temperature at the study site varies seasonally from 4.1ºC (winter) up to 21.1ºC (summer). Precipitation occurs mainly during the winter months with an annual average around 2,500 mm (Funes et al. 2006).

In the present study area there are approximately 30 permanent human inhabitants. The nearest main city is San Martin de los Andes (40º09'18.2"S, 71º21'15.2"W, 45 km far to the east) which has a population of 25,000. Culpeo fox hunting is prohibited in the Park since its creation in 1937 and poaching in the park is rare since the small number of local inhabitants do not consider foxes to be harmful (Park ranger G. D`Oliveira, pers. comm.). Neuquén province hunting regulations (outside National Parks Administration jurisdiction), allow for the legal hunt of foxes with guns or foothold traps under three different modalities: "*sport hunting*" (hunting season: 01 May–31 July, 10 foxes per season per hunter), "*commercial hunting*" (hunting season: 01 May–15 August, 50 foxes per season per hunter), and "*problem-*

wildlife hunting" (hunting season: year round, no limit of foxes). This latter modality of hunting is used to minimize culpeo fox predation on sheep and goats. However, the nearest private ranch where foxes are hunted is about 60 km to the east from our study site.

We used Moultrie M40 Digital Trail Cameras with 12v solar power panels (Trigger and Reel 2010) to gather data on the activity of the culpeo fox following guidelines established for forest carnivore surveys in western U.S.A. (Zielinski et al. 1983; Jones and Raphael 1993). We installed 29 camera stations (approximately 0.5–1 km apart, approximately 100 m to both sides of the main trail (13.6 km). Each camera station was baited with a piece of meat which was hung from a tree branch unavailable to the fox and commercial lures (Fur Country Lures, Minnesota Trapline, and Big Sky Lures). In addition, we hung an aluminum plate above the station as a visual attractant, and applied a catnip spray to the vegetation toward which the camera was aimed. Cameras were continuously active between October 2008 and May 2009, and were checked approximately every 15 days to replace both bait and memory cards. Cameras were set to take 3 consecutive pictures (with 10 sec. of delay) each time they were activated by an animal and to record date and time on each photo.

We divided each day into 12 equal time intervals. As the sunsets were 22:12–23:37 (this means the earliest and the latest sunset) and the sunrises were 09:45–11:25 (this means the earliest and the latest sunrise) in this area during the study, we defined nighttime as the time intervals between 22:00 and 10:00 (US Naval Observatory 2010). We define "*record*" as a unique time interval culpeo fox use event. Since many culpeo fox photos within the same time interval of the same day at the same camera station were of the same individual, they were counted only once when determining the total number of culpeo fox records in that particular time interval and these were the records we used in our analysis.

We calculated seasonal average time interval records (ATIR) defined as the average number of records obtained per time interval within a season (spring: 01st October to 21st December, summer: 22nd December to 21st March, fall: 22nd March to 19th May). We considered "most active periods" as those time intervals with more records than the ATIR for each season. We performed Chi-Square goodness of fit analyses to test the statistical null hypotheses that fox records were equally distributed within 12 time intervals for each season. If fox records are inequitably distributed within those 12 time intervals, we consequently conducted non parametric Binomial analyses to test the statistical null hypotheses of equal number of records during daytime and nighttime (no deviations from 0.5) for each season. We considered values of $P < 0.05$ statistically significant in all analyses (Zar 1996).

During this study period, we collected 34 culpeo fox scats near the "camera traps". The culpeo fox is the only wild canid in the Park, and its scats are easily distinguishable by size and shape. Thus, we are confident that all scats collected were culpeo fox scats. Collected scats were analyzed following the methods of Reynolds and Aebischer (1991). Mammalian prey items were identified by comparing teeth and skulls to specimens from the Centro de Ecología Aplicada de Neuquén collection or with the use of small mammal keys (Pearson 1995). Hair found in the scats was identified to species using hair keys (Chehebar and Martin 1989). The results are presented as the percentage occurrence (number of occurrence of the prey item divided by the total number of occurrences of all prey items in all scats).

Results

A total of 1,261 culpeo fox photos were taken in 3,514 active trap-days. The overall camera-trap success for culpeo foxes was 35.9 photos per 100 active trap-days. The culpeo fox was the most frequently photographed wild mammal species comprising more than 90% of photos taken during the course of the study. Other wild species that were also photographed included numerous mammals: huiña cat *Leopardus guigna* (n = 1), long haired mouse *Abrothrix longipilis* (n = 7), long tailed mouse *Oligoryzomys longicaudatus* (n = 8), black rat *Rattus rattus* (n = 6), Valdivian opossum *Dromiciops gliroides* (n = 10), European hare (n = 19), and wild boar *Sus scrofa* (n = 5), and avian scavengers: crested caracara *Caracara plancus* (n = 36), chimango caracara *Milvago chimango* (n = 23), and black vulture *Coragyps atratus* (n = 25).

The number of culpeo fox records were not evenly distributed among the daily 12 time intervals for each season (spring: $\chi^2 = 53.05$, $df = 11$, $P < 0.0001$; summer: $\chi^2 = 57.75$, $df = 11$, $P < 0.0001$; fall: $\chi^2 = 32.93$, $df = 11$, $P = 0.0001$). The percentage of culpeo fox records was higher during the night in all seasons (spring: 72.3%, Z = 4.0613, P < 0.0001; summer: 72.9%, Z = 4.4907, P < 0.0001; fall: 70.9%, Z = 3.1013, P = 0.0010; Table 1), indicating that they were more active during the night in

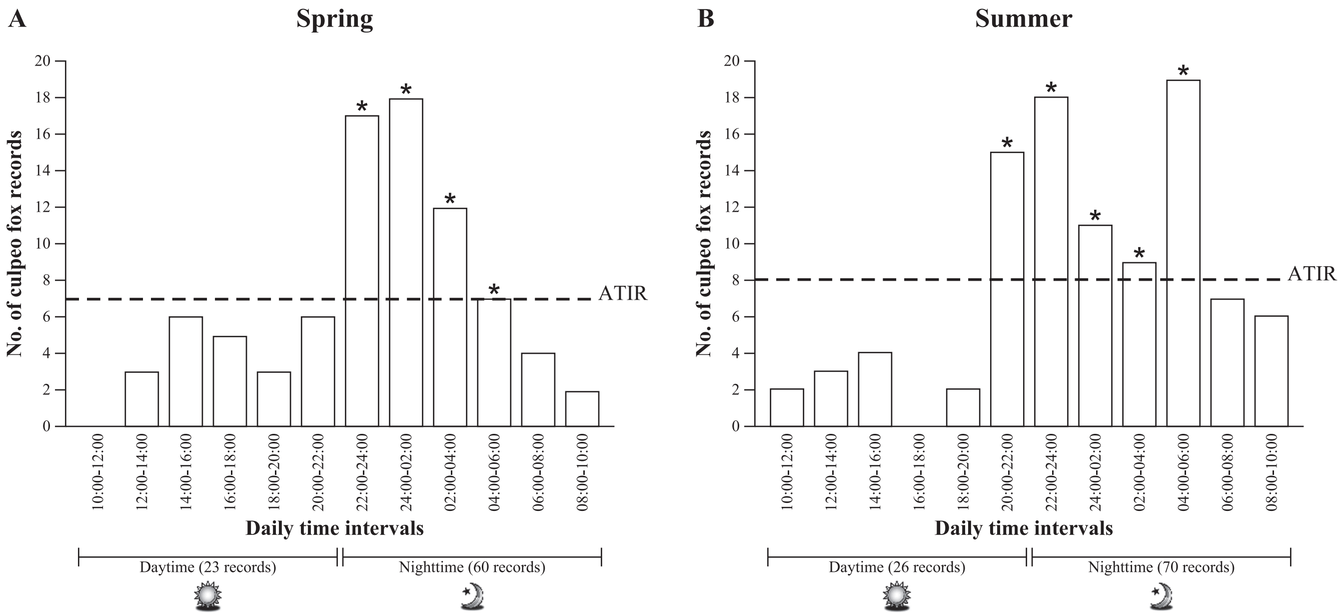
Table 1. Summary of the data obtained from the camera trap stations during spring, summer, and fall in Hua Hum Basin (Lanín National Park, Argentina) between October 2008 and May 2009

	Spring	Summer	Fall	Total
Camera active trap-days	1,102	1,452	960	3,514
No. of photos	445	522	294	1,261
No. of records	83	96	55	234
ATIR ± *SE* (min; max)	7 ± 5.1 (0; 18)	8 ± 1.9 (0; 19)	5 ± 1.1 (1; 10)	20 ± 4.1 (6; 45)
% of records in nighttime	72.3	72.9	70.9	72.2
No. of records in MAP	47	57	38	172

ATIR, Average time interval records; MAP, Most active period.

this area. More specifically, they were most active between 22:00–04:00 during the spring, between 20:00–06:00 during the summer, and between 20:00–08:00 during the fall (Figs. 2A–C). Although there is a gradual monthly increase of culpeo fox records (activity) from October to April with an exceptional peak in December (weighted by active trap days), culpeo fox activity varies seasonally being more active during spring, followed by summer and fall (Fig. 3).

The main prey items found in culpeo fox scats were cricetine rodents (Percentage occurrence = 56), primarily Southern pericote (*Loxodontomys micropus*), followed



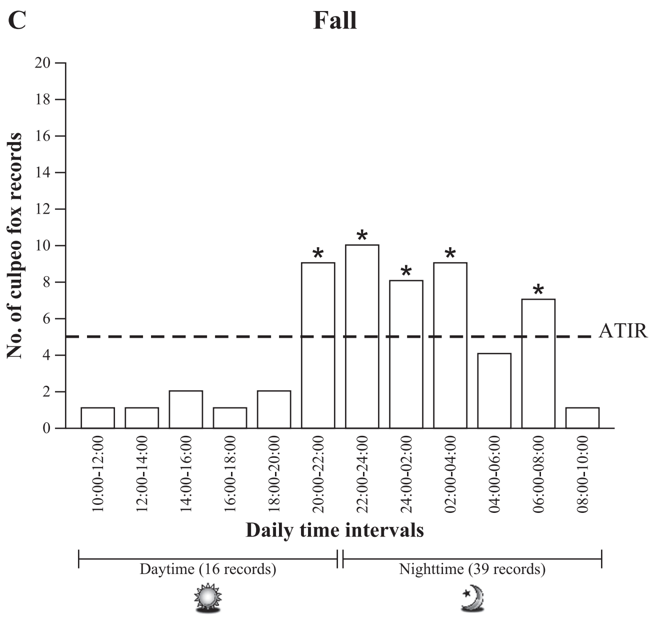


Fig. 2. Daily activity patterns (No. of records) of culpeo fox in A) spring, B) summer, and C) fall in Hua Hum Basin (Lanín National Park, Argentina) between October 2008 and May 2009. Daytime and nighttime are indicated as well as the total number of records for both periods. Dashed lines indicate the average time interval records (ATIR). Bars with a * on top constitute the most active period (MAP).

by European hares and fossorial Tuco-tucos (*Ctenomys* sp.) (Table 2). The percentage occurrence of nocturnal prey was at least 88% and included cricetine rodents as most species are nocturnal (Pearson 1995; Spotorno et al. 2000).

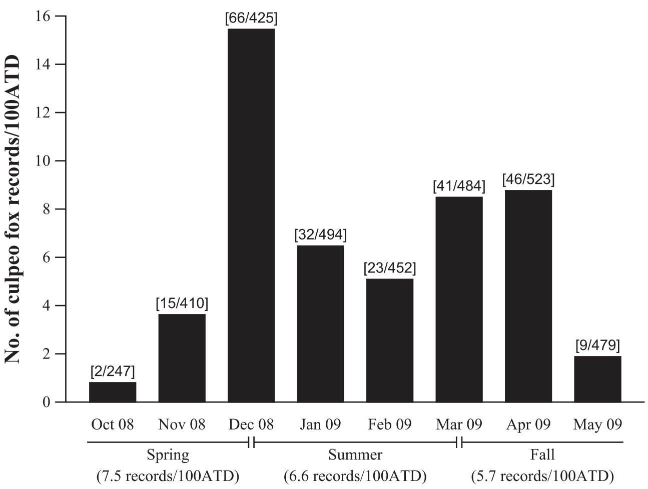


Fig. 3. Monthly activity patterns (No. of records per 100*active trap-days (100ATD)) of culpeo fox during spring, summer, and fall in Hua Hum Basin (Lanín National Park, Argentina) between October 2008 and May 2009. The No. of records/active trap-days is indicated above each bar, and the No. of records/100ATD is also detailed for each season.

Table 2. Percentage occurrence of prey items in culpeo fox scats collected in Hua Hum Basin (Lanín National Park, Argentina) between October 2008 and May 2009

Prey item	Percentage occurrence
Mammals	
Order Rodentia	
Loxodontomys micropus (☾)	26
Phyllotis xanthopygus (☾)	6
Oligoryzomys longicaudatus (☾)	2
Abrothrix olivaceus (☾/☼)	2
Unidentified cricetines (☾ or ☾/☼)	20
Ctenomys sp. (☾/☼)	14
Rattus sp. (☾)	2
Order Lagomorpha	
Lepus europaeus (☾)	16
Arthropods	6
Birds	4
Carrion	2
Number of scats	34

☾, nocturnal; ☾/☼, nocturnal/diurnal.

Discussion

The nocturnal activity of culpeo foxes has been interpreted as a response to human persecution (Jiménez et al. 2001; Olarte et al. 2009). The present study presents the first data of culpeo fox activity patterns obtained by using non-invasive "camera traps" in the Andean forest of Argentinean Patagonia. Since this study was conducted in a protected area with little human activity and no hunting, the study supports the idea that culpeo foxes are nocturnal also in the absence of human persecution. We found that overall the most active period of culpeo fox was from 20:00 to 06:00 with peaks between 22:00 and 02:00. Some of the previous studies that examined the activity patterns of culpeo foxes used radio tracking (Salvatori et al. 1999; Olarte et al. 2009) and "camera traps" (Lucherini et al. 2009). Our results are in a general agreement with them.

Although previous studies suggest that culpeo foxes were active primarily at night, the proportion of activity during nighttime has been found to vary geographically (Lucherini et al. 2009). Our study found approximately 70% of culpeo fox records during the night which is similar to the results of Lucherini et al. (2009). On the other hand, Salvatori et al. (1999) reported an average of 47.6 ± 2.8% active locations at night and a smaller but still high percentage (38.7 ± 3.1%) during the day. This dissimilarity may be attributable to differences between field techniques (camera traps and radio tracking), habitat characteristics, prey availability and/or competitive interactions with other carnivores. On the other hand, Di Bitteti et al. (2009) propose that two sympatric foxes (crab-eating fox *Cerdocyon thous* and pampas fox *Lycalopex gymnocercus*) of South America reduce competition with a non-overlapping activity patterns strategy. In the same way, Lucherini et al. (2009) suggest a similar temporal segregation strategy between the Andean cat (*Leopardus jacobita*) and the pampas cat (*Leopardus colocolo*). No other carnivore was recorded during our study, except for one photo of a huiña cat. This suggests that our findings are not due to competitive interactions, such as segregation of temporal or spatial distribution among carnivore species.

Based on our data, we can rule out the persecution hypothesis as an explanation for the nocturnal activity of the culpeo fox. Instead, the nocturnal activity of culpeo foxes could be related to the activity patterns of their main prey. This hypothesis is supported by the fact that the main prey species consumed by culpeo foxes in our study are nocturnal (Pearson 1995; Spotorno et al. 2000). On a seasonal scale, culpeo foxes were less active during fall, when these small mammals reach their highest densities (Piudo et al. 2005). This could be explained by culpeo foxes investing less of their daily time budget in foraging when prey can be more easily found (when they are most abundant and available). Jiménez and Novaro (2004) also found evidence that culpeo foxes adapt their movements to prey availability; their home ranges were negatively correlated with prey abundance. In addition, McCarthy et al. (2005) found a similar predator movement-prey abundance relationship with snow leopards (*Uncia uncia*), and Girard (2001) with kit foxes (*Vulpes macrotis*). However, seasonal patterns may also be explained by reproductive activity. During the breeding season (spring-summer, our most active seasons), culpeo foxes may invest more time in reproduction activities such as searching for mates and dens or parental care. In this regard, our peak of activity during December may be suggesting high reproduction activity, probably due to feeding growing juveniles. These foxes mate mainly between August and October and after a gestation period of around two months, the female gives birth to cubs (Novaro 1997). Of course, these factors are not exclusive, and more than one may influence culpeo fox activity patterns. In addition, Lucherini et al. (2009) concluded that several factors including body mass, predator avoidance, prey acquisition, and competition likely played a role in activity patterns.

In summary, our data shows that culpeo foxes are still nocturnal in a non-hunting area. In addition this behavior may be related to prey activity patterns. In order to support this overall thesis, we believe that future activity patterns researches should be conducted simultaneously in hunting and non-hunting areas, together with feeding ecology studies with larger fecal sample sizes. Culpeo foxes also prey on livestock generating serious conflicts with sheep and goat breeders in other regions of Patagonia (Novaro 1997). Consequently, the knowledge of the possible mechanisms that could be modeling aspects of its behavioral ecology (activity patterns) has great relevance when developing management and conservation strategies for this species.

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