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Short Communication

Activity pattern of Geoffroy's cats (*Leopardus geoffroyi*) during a period of food shortage

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ABSTRACT

The activity pattern of mammalian carnivores is influenced by several factors, including environmental conditions, interference from competitors, and behavioral thermoregulation. Facing extreme environmental conditions the activity rhythm of animals may change. The activity patterns of Geoffroy's cats (*Leopardus geoffroyi*) were studied during a period of prey scarcity in a scrubland area of central Argentina, based on five individuals radio-collared and monitored by radio-telemetry. Activity readings were recorded every 15 min during 6- to 24-h observation periods, and a total of 3121 fixes totaling 780.3 h of monitoring were gathered for these cats. Geoffroy's cats were significantly more active during daytime (58.1 ± 9.4% of active fixes) than during the night (33.6 ± 2.9%). Although they were active at any time of the day, an activity peak was recorded from 12.00 to 17.00 h. This pattern is opposite to those observed in other areas or even to that recorded for this species in the same area during a period of higher prey abundance. This apparent shift toward diurnal activity could be a response to a combination of ecological (prey availability, predators or competition avoidance) and physiological (energy saving) factors. Geoffroy's cats are behaviorally flexible, but this ability may not be enough to maintain survival (and population size) under harsh environmental conditions.

The activity pattern of mammalian carnivores is influenced by a number of factors, including environmental conditions, social behavior, interference from competitors, and behavioral thermoregulation (Beltran and Delibes, 1994; Carothers and Jacksic, 1984; Gittleman, 1986; Schmidt-Nielsen, 1983). Facing extreme climates, severe droughts, catastrophic events or human exploitation, the activity rate and rhythm of animals may change (i.e., Kitchen et al., 2000; Price, 1971; Van Dyke et al., 1986). However, the circadian cycles of availability and vulnerability of prey could be considered as one of the main influences on predator's activity (Ferguson et al., 1988; Lodé, 1995; Zielinski, 1988).

Geoffroy's cat (*Leopardus geoffroyi*) is a small wild cat classified as "near threatened" (Nowell, 2002), that occurs in a wide variety of habitat types from Bolivia and Brazil to southern Argentina and Chile (Nowell and Jackson, 1996). Nocturnal small rodents usually constitute the main prey for this felid throughout its distribution, although the introduced brown hare (*Lepus europaeus*) or waterbirds were found to be important prey items for Geoffroy's cat in particular localities (Bisceglia et al., 2008; Canepuccia et al., 2007; Johnson and Franklin, 1991; Manfredi et al., 2004; Novaro et al., 2000; Sousa and Bager, 2008; Vuillermoz, 2001). According to studies conducted in Argentina (Castillo et al., 2008; Pereira et al., in press), Chile (Johnson and Franklin, 1991) and Bolivia (Cuéllar et al., 2006), Geoffroy's cats are mostly active during crepuscular and nocturnal hours than during the day in both undisturbed and rural areas. These findings have been supported by reports of its hunting behavior (Branch, 1995; Yanosky and Mercolli, 1994) and studies of its behavior in captivity (Foreman, 1997).

As part of a long-term study on the ecology of Geoffroy's cat in central Argentina (see Pereira et al., 2006), 10 individuals (8 adult females, 1 adult male, and 1 subadult female) were radio-collared and monitored by radio-telemetry during the autumn and winter of 2003 (May–July). The monitoring period coincided with a severe drought and a strong decline in the abundance of the Geoffroy's cat's main prey. Small-rodent biomass in autumn 2003 (134.5 g/ha) was the lowest recorded for the area in a six-year period, relative abundance of brown hares (*L. europaeus*) declined 88% between predrought and drought periods, and alternative prey (i.e., small birds, tinamous, armadillos) was also scarce (see Pereira et al., 2006 for details). Likely due to this prey decline, one of the adult females and the male equipped with radio-collars dispersed from the study

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area shortly after collared, whereas the remaining seven females were found dead within a 54-day period after been collared. Necropsies were conducted on five cats and their deaths were attributed to starvation (M. Uhart and D. McAloose, Wildlife Conservation Society, unpublished data). An additional collared female Geoffroy's cat was killed by another predator, but also showed a pronounced loss of body mass. The purpose of this paper is to describe the activity pattern of five of these Geoffroy's cats during a period of extreme food shortage. Detailed information on spatial ecology and density of this population during the prey decline is provided by Pereira et al. (2006).

Lihue Calel National Park (37°57′S, 65°33′W) is composed of flat terrain except for a large, isolated set of bare rock hills. The major habitats are creosote bush (*Larrea* sp.) flats and grasslands with mixed shrub patches. Mean daily temperatures are <8 °C in winter and >25 °C in summer, with hot humid summers and cold dry winters. Annual rainfall (mean ± SD) is 498 ± 141 mm (1986–2002 period), with more than 70% of the water concentrated within spring and summer (October–March). The amount of rain from October 2002 through March 2003, however, was markedly lower (148.7 mm) than the seasonal average (below the lower 95% confidence interval for the mean annual estimate), resulting in a prolonged drought until November 2003 (data from Lihue Calel weather station). Other carnivores in the area include the puma (*Puma concolor*), jaguarundi (*Puma yagouaroundi*), Pampas cat (*Leopardus colocolo*), and Pampas fox (*Lycalopex gymnocercus*).

Geoffroy's cats were trapped during May 2003 with Tomahawk live traps baited with domestic pigeons. Captured individuals were immobilized with ketamine and medetomidine and fitted with a 60-g radiocollar (ATS, Isanti, Minnesota; model M1950) with activity sensor. These radio-collars represented on average 2.2% (range 1.6–3.0%) of the cats' body weights. All individuals appeared to be in average physical condition at the time of capture, although their body weights were slightly lighter (8%) than those of animals captured during years with better environmental conditions (Pereira, 2009). Two additional females were also captured, examined, and released without collaring because of their poor physical condition. Female F04, also captured and radio-collared the year previous to the drought, showed a loss of 500 g in body weight when recaptured in 2003. Radio-collared animals showed no external evidence of parasitism, except for the subadult female.

Geoffroy's cat activity was studied using a hand-held 5-element Yagi antenna or an H-antenna and a portable receiver. I attempted to minimize disturbing the radio-collared cats during monitoring, and the distance between the observer and the target animals was always >180 m. Activity was sampled systematically during 6- to 24-h observation periods, and activity readings were recorded every 15 min. An animal was registered as active when its radio-collar produced an erratic signal (the pulse rate changed during the 1-min monitoring period) and inactive when the signal was constant for at least 1 min. Data were grouped into 12 2-h periods and activity level within each 2-h period was determined by dividing the number of active readings by the total number of readings. Proportions of 2-h activity periods were plotted to identify patterns in activity throughout the day. In order to compare activity levels between diurnal and nocturnal periods, the 15-min activity readings were grouped into 2 blocks (day and night), and comparisons between them were made using a paired *t*-test. Due to variations in the length of the photoperiod throughout the study, day and night were not defined as intervals between fixed times. The 2-h intervals including twilights were assigned to 'day' or 'night' if most of them lasted after dawn or after dusk, respectively. Data from only five adult female Geoffroy's cats were sufficient and balanced over the 24 h period to analyze individual variation in activity rhythms. A total of 3121 fixes for these five cats were gathered, totaling 780.3 h of monitoring (Table 1). Mean number of fixes (±SD) per 2-h period was 260 ± 120 (range = 141–484).

Table 1
Radio-tracking effort and total number of activity readings gathered for 5 adult females Geoffroy's cats radio-marked and monitored in central Argentina during a prey decline in 2003.

Cat number	Body mass at capture (kg)	Total hours tracked	Activity readings
F04	2.3	75.8	303
F07	2.4	156.5	626
F08	3.2	104.0	416
F09	3.0	263.5	1054
F12	3.0	180.5	722

The mean proportion of observations when animals were active was 45.1 ± 5.5% (range = 41.5–54.2). Although monitored individuals were active at any time of the day, they were significantly more active during daytime (58.1 ± 9.4% of active fixes) than during the night (33.6 ± 2.9%; $t = 4.62$; df = 4; $P = 0.0098$). Overall, an activity peak was recorded from 12.00 to 17.00 h, whereas the period of least activity was between 01.00 and 07.00 h (Fig. 1). Female F07 exhibited a slightly different pattern, showing several peaks of activity along the 24-h period; however, its activity was mostly diurnal (Fig. 1).

Predators that hunt at the time of day when the probability of prey capture is highest should enjoy greater prey capture success, and at lower cost, than individuals that forage at random (Belovsky et al., 1989; Curio, 1976; Schoener, 1974; Zielinski, 1986). For this reason, nocturnality in small- and medium-sized felids has been attributed to their specialization in catching nocturnal rodents (Emmons, 1988; Ludlow and Sunquist, 1987). Small nocturnal rodents (Teta et al., 2009) are the major component (up to 94%) of the Geoffroy's cat diet in Lihue Calel (Bisceglia et al., 2008; Pereira, 2009). By being nocturnal, Geoffroy's cats could be active when their main prey is producing visual, auditory, or olfactory cues that betray their location, increasing foraging success. Accordingly, activity of Geoffroy's cat was recorded as predominantly nocturnal in Lihue Calel when prey was not scarce (Branch, 1995; Pereira et al., in press), in agreement with the pattern observed in other areas (Cuéllar et al., 2006; Johnson and Franklin, 1991; Yanosky and Mercolli, 1994). Thus, a shift in the Geoffroy's cat activity pattern toward daylight hours appears to have occurred during the period of prey scarcity.

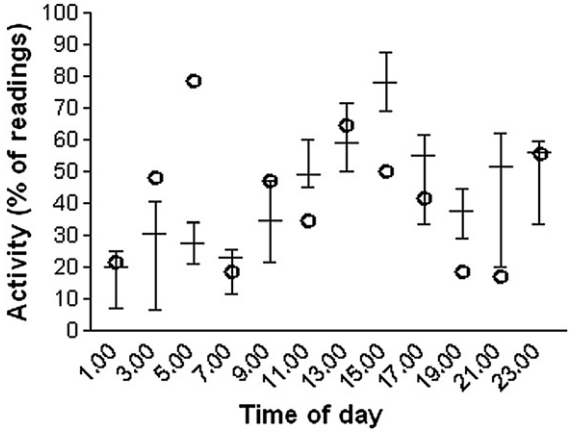

Fig. 1. Activity patterns of 5 female radio-marked Geoffroy's cats monitored in central Argentina during a prey decline in 2003. Data for all females (except F07) were pooled and expressed as the mean value (±SE) for each 2-h period. As the activity of female F07 was slightly different from the rest (see text), the data points for this individual were represented alone (open circles).

Changes in the activity pattern due to prey decline have also been documented in other predators [i.e., culpeo foxes *Lycalopex culpaeus* (Salvatori et al., 1999); mink *Mustela vison* (Zielinski, 1988)]. When food is restricted, individuals can modify their behavior or physiology to maintain their energy balance and body condition (Trites and Donnelly, 2003). Based on the strong prey decline observed in Lihue Calel, the shift in the activity pattern of Geoffroy's cats could constitute an attempt to compensate food intake with alternative diurnal prey. In the same way, the more irregular activity pattern exhibited by female F07 may constitute an expansion of the foraging period, encompassing diurnal and nocturnal hours. However, alternative diurnal prey (e.g., passerine birds, cavies, tinamous) was also scarce in the study area during the drought period (Pereira et al., 2006). As a result, food shortage may have contributed to reduce body condition of Geoffroy's cats (dead animals showed a mean loss in body mass of 38% since captured and collaring) and to a reduction in the survival rate of the local population (Pereira, 2009).

Felids have a high basal metabolic rate, and this implies great energy expenditure for a variety of tasks, such as body maintenance, movement, resource acquisition, and growth (McNab, 1989). Given the high energy demands of nocturnality during colder periods (thermoregulation to face cold stress), reducing activity during the night hours can yield considerable energy savings (Zielinski, 2000). Chappell (1980) found that Arctic mammals could save an average of 30% of thermoregulatory cost if they were diurnal during winter. Because activity increases energy consumption, the energetic cost of nocturnality could be too high when food (energy) availability is highly restricted. Temperature in Lihue Calel during the study period dropped considerably during the night (<-5 °C), and the scarcity of nocturnal prey may have forced Geoffroy's cats to switch their normal activity pattern in order to save energy during this critical period of starvation.

Because behavioral patterns are generally driven by different incentives, other non-physiological factors might be affecting the Geoffroy's cat behavior as well. Interspecific competition among carnivores often leads to intraguild mortality (i.e., Beltran and Delibes, 1994; Donadio and Buskirk, 2006), with the larger competitor preying on the smaller (Palomares and Caro, 1999; Rosenzweig, 1966). The effects of this process on population dynamics are greatest when resources are scarce. During the drought of 2003, one radio-collared and two non-collared Geoffroy's cats were found killed, apparently by pumas or other mammalian carnivores, and the shifts in Geoffroy's cat activity could be a behavioral response to avoid encounters with larger, nocturnal predators. In support of this idea, pumas have been recorded killing and consuming small wild cats in Lihue Calel after a crash in a population of their most common prey item, the plains vizcacha (*Lagostomus maximus*) (Pessino et al., 2001). Also, Zanón-Martínez (2006) recorded several killing events of Geoffroy's cat by pumas in an area close to Lihue Calel during the severe drought of 2003.

An increase in the annual mean temperature and more abundant precipitations in summer are expected to occur in the Monte eco-region under current climate projections (Labraga and Villalba, 2009). However, the distribution of precipitation is substantially influenced by El Niño/Southern Oscillation phenomena, which induce precipitation anomalies both locally and temporarily (Jaksic, 2001). These events have increased in size and duration over the past century, and projections reveal that this trend is likely to increase rapidly in the next 50 years (Walther et al., 2002). The combination of rising temperatures and interannual variability of precipitation can generate occasional droughts of different frequency and severity, leading to variable impacts on prey base of predators (Jaksic, 2001). Although Geoffroy's cats are behaviorally flexible (Manfredi et al., 2004; Pereira, 2009), this ability may not be enough to maintain survival (and population size) under harsh environmental conditions.

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