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Matthew E. Symmank

Christopher E. Comer

James C. Kroll

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Author(s): Matthew E. Symmank, Christopher E. Comer and James C. Kroll
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Using Infrared-Triggered Cameras to Monitor Activity of Forest Carnivores

Matthew E. Symmank[1,2,*], Christopher E. Comer[1], and James C. Kroll[1]

Abstract - The activity patterns of 4 forest predator species were monitored, using infrared-triggered cameras, within a 1318-ha study area in East Texas. We recorded 161 photographic capture events in 1925 trap-nights over 17 weeks. Photographic capture events included 18 *Lynx rufus* (Bobcat), 109 *Procyon lotor* (Raccoon), 21 *Didelphis virginiana* (Virginia Opossum), and 13 *Canis latrans* (Coyote). We developed an easily replicated method of measuring time on a percent scale to compare activity data over several months, accounting for changes in sunrise and sunset times. Bobcat activity was 38.9% crepuscular and 22.1% diurnal. The activity of the other 3 species was mostly nocturnal: Raccoon 94.5%, Virginia Opossum 100%, and Coyote 77%. Moon phase based on percentage of visible light did not affect either Raccoon or Virginia Opossum nocturnal activity level.

Introduction

A wide variety of predator species inhabit the forested areas of North America. Several species of medium-sized forest predators including *Procyon lotor* (L.) (Raccoon), *Didelphis virginiana* Kerr (Virginia Opossum), *Mephitis mephitis* (Schreber) (Striped Skunk), *Urocyon cinereoargenteus* (Schreber) (Gray Fox), *Canis latrans* Say (Coyote) and *Lynx rufus* (Schreber) (Bobcat) are often found in co-occurring populations th,roughout the southeastern United States (Chamberlain and Leopold 2005), including East Texas. These species are similar in size and exhibit dietary overlap (Chamberlain and Leopold 1999, Gardner and Sunquist 2003), yet are sympatric over a wide range (Anderson and Lovallo 2003, Kaufmann 1982). In particular, Coyotes and Bobcats exhibit both interference and exploitative competition in some ecosystems (Anderson and Lovallo 2003), and Raccoons and Virginia Opossums exhibit a high degree of apparent ecological overlap (Shirer and Fitch 1970). Furthermore, Bobcats and Coyotes both can be important predators of Raccoons and Virginia Opossums (Gardner and Sundquist 2003, Gehrt 2003). Dietary overlap and coexistence have been studied in some combinations of these species (e.g., Azevedo et al. 2006, Dijak and Thompson 2000); however, no consensus on the mechanisms that enable these species to coexist has been reached.

Temporal activity partitioning is one of several potential mechanisms enabling these competing species to coexist. Findings by Neale and Sacks (2001) suggest temporal partitioning between Bobcats and Coyotes, in which Coyote activity is largely nocturnal and Bobcat activity is predominantly diurnal. The extent to

[1]Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, SFASU Box 6109, Nacogdoches, TX 75962. [2]Currentent address - Texas Parks and Wildlife Department, Richland Creek Wildlife Management Area, Streetman, TX 75859. [*]Corresponding author - matt.symmank@tpwd.texas.gov.

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which temporal partitioning occurs among additional predator species such as Virginia Opossum and Raccoon is currently not well documented. Although extensive overlap in spatial partitioning of Bobcats, Coyotes, and Gray Fox has been documented (Chamberlain and Leopold 2005), research to determine the extent of temporal partitioning is lacking, due at least in part due to the difficulties associated with obtaining large quantities of reliable information using traditional techniques, and the complications of temporal data analysis over a long period of time. A better understanding of the temporal partitioning of forest carnivores is necessary to fully understand the ecology of co-occurring predators. Such understanding is fundamental to successful management of these species.

Several methods to record temporal data and compare animal activity-patterns over long time periods are available to researchers. Recording activity patterns using traditional techniques, such as direct observations and radiotelemetry, have been successful in providing valuable and accurate data on animal activity (Greenwood 1982, Grinder and Krausman 1999, Kitchings and Story 1978, Sharp and Sharp 1956), but recording more detailed activity patterns with these methods is labor intensive and costly. Infrared-triggered cameras have been used successfully to document activity patterns for *Puma concolor* (L.) (Mountain Lion) (Pierce et al. 1998), co-occurring populations of *Odocoileus virginianus* (Zimmerman) (White-tailed Deer) and *Tayassu tajacu* (L.) (Collared Peccary) (Koerth et al. 1997), and sympatric populations of Virginia Opossums and Raccoons (Carver et al. 2011). Cameras provide a useful survey system to evaluate wildlife activity-patterns over long time periods because they can be operated continuously in a cost-effective manner. Infrared-triggered cameras are also well suited for the collection of data on activity patterns because human influence on animal activity is reduced compared with human impacts in studies that use direct observation or radiotelemetry.

Analyzing temporal data over long periods of time is complicated because researchers must account for the changes in sunrise and sunset times that occur over the course of their studies. Ladine (1997) used timers on live traps to accurately record activity time; image capture-times were then standardized as a percent scale between 0 (sunset) and 1 (sunrise). However, the author did not provide details on if or how data were standardized during the full 24-hr period, making it impossible for others to replicate the study. Recently, Carver and coworkers (2011) standardized time to a 12-hr day-length to present time-activity data collected on circular plots. Perhaps because of the lack of an accepted system to compile long-term activity data, few researchers have evaluated diel activity patterns of multiple species within a forest population (but see Carver et al. 2011).

The effects of moon phase have not been found to have a significant effect on terrestrial mammal activity (Bender et al. 1996, Roseberry and Woolf 1986, Springer 1982), yet many charts and tables that predict periods of greatest animal activity based on lunar cycles are available to hunters who wish to increase their success (e.g., Solunar Tables®; solunarforecast.com). A clear and scientific understanding of moon phase effects on animal behavior would refute or verify the utility of these tables to predict the activity levels of terrestrial mammals, and inform the public.

Our objectives were to (1) use infrared-triggered cameras to obtain data on predator temporal activity patterns, (2) develop a system to accurately analyze data to account for changes in sunrise and sunset, and (3) evaluate the effects of moon phase on predator activity. To accomplish our objectives, we used a system of infrared-triggered cameras to record the activity of several species of forest predators in eastern Texas. We also developed a procedure similar to Ladine (1995) to analyze temporal data by standardizing day- and night-length, and measuring time using a 24-hr percent scale. This system allows temporal data collected over long periods of time to be accurately compared in relation to sunrise and sunset times.

Field-Site Description

The study was conducted on a 1318-ha privately owned tract located approximately 16 km west of Nacogdoches, TX (Nacogdoches County). The study site was a mixture of upland *Pinus taeda* L. (Loblolly Pine) plantations of various ages (including numerous clearcuts where trees were <5 years old), hardwood lowlands, and mixed pine-hardwood forests. The property had an extensive network of gravel roads, and numerous warm- and cool-season food-plots were planted to provide supplemental forage for White-tailed Deer. The study area was surrounded by a deer-proof fence. The property was primarily used for timber, oil, and gas production and is leased for White-tailed Deer hunting. Predators are not actively harvested on the property but are opportunistically taken by lease members.

The study area is located in the Pineywoods ecoregion of East Texas, which is characterized by managed and natural pine forests on upland sites. Dominant overstory species include Loblolly Pine, *Pinus echinata* Mill. (Shortleaf Pine), and *Pinus palustris* Mill. (Longleaf Pine). Upland pine forests are interspersed with hardwoods in low-lying areas, mixed pine-hardwood forests, and upland hardwood stands (Diggs et al. 2006). Regional climate is humid and subtropical with an annual average rainfall of approximately 128 cm; average mean temperature during January is 9 °C, and average mean temperature during July is 27 °C (Stephen F. Austin State University/National Weather Service weather station, Nacogdoches, TX).

Methods

Camera survey of predator activity patterns

We collected data during two sampling periods from 29 June–2 August and 6 September–28 November 2005. For the first sampling period, we established 21 camera stations on 7 transects located throughout the 1318-ha research site. We placed 3 camera stations along transects at intervals of 200 m. We randomly assigned coordinates for the first station per transect and the transect azimuth using ArcGIS (Environmental Systems Research Institute Inc., Redlands, CA). This configuration yielded a mean coverage of ≈1 camera/188.3 ha. For the second sampling period, we overlaid the 1318-ha research site with a 65-ha block grid and systematically established a camera station within each block for a total of 20 camera stations (Fig. 1). We set up cameras near game trails, roads, or other suitable locations (Jacobson et al. 1997) within 200 m of the center of each grid block. This configuration yielded a mean coverage of ≈1 camera/65.9 ha. We recorded the GPS coordinates of each camera station using a Trimble® Pro XRS GPS receiver (Trimble Navigation Limited, Sunnyvale, CA).

During both sampling periods, camera stations were comprised of a Trailmaster® 1500 transmitter and model TM1500 Active Infrared Unit receiver (Goodson and

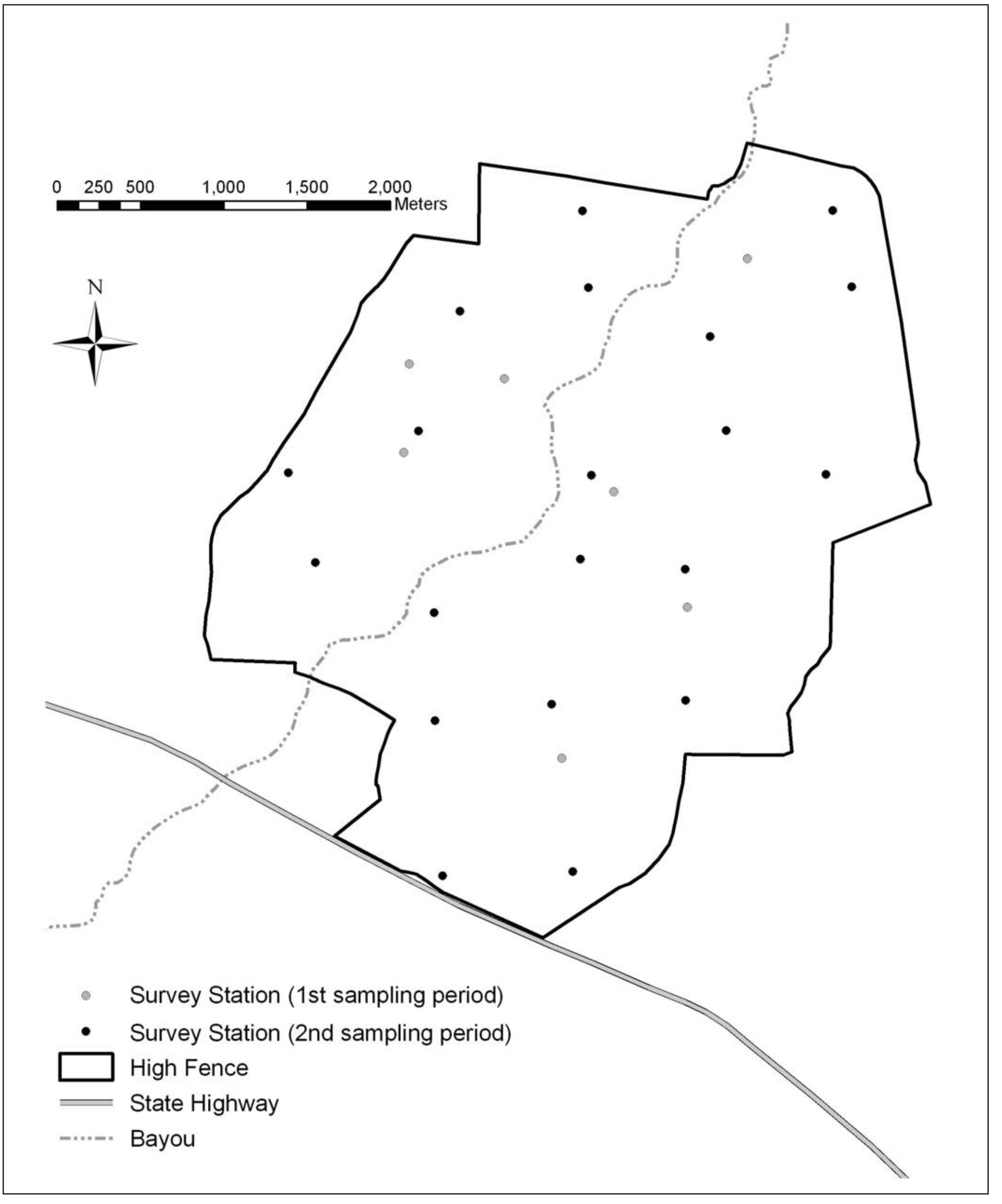

Figure 1. Locations of infrared-triggered camera stations for assessment of time-activity patterns of forest carnivores, Nacogdoches County, TX, from 29 June–2 August and 6 September–28 November 2005.

Associates, Inc., Lenexa, KS). We placed the transmitter and receiver portion of the camera stations 3–4 m apart, 30 cm above the ground. We oriented the stations in a north–south direction only if necessary to reduce the number of false events created by direct sunlight shining on the receiver window (Hernandez et al. 1997). We programmed camera stations for 24-hr-per-day activity, with a 6-sec delay between photographs and a pulse delay setting of 5, so that the infrared beam had to be broken for 0.25 sec before a photograph was taken. At each station, we wrapped a clean, unused rag around a 20-cm wooden post, fastened the rag with twine, put a chemical attractant (Bobcat urine) on the rag, and placed the post halfway between the camera transmitter and receiver. We displayed a visual attractant (an aluminum pie plate for the first sampling period or 3 large feathers tied together for the second sampling period) approximately 2–3 m from the ground in close proximity to the infrared-triggered camera and chemical attractant. We checked all cameras twice-weekly to replace film, batteries, and lure as necessary.

We categorized all photographs by the species that triggered the camera system, and considered multiple photographs of the same species or group of the same species taken within 30 minutes as one capture event. No capture events recorded multiple species.

Data analysis

Because day/night length varied nearly 4 hours throughout the 17 weeks of sampling, it was necessary to standardize time data for comparisons of time activity. We converted all time measurements into hourly decimal format and set sunrise and sunset as zero values. We then calculated all night photographic capture times as:

$$\frac{\text{(time since sunset)}}{\text{night length}} \text{ X } 10$$

and calculated day photographic capture times as:

$$\frac{-\text{(time since sunrise)}}{\text{day length}} \text{ X } 10$$

We collected activity information on 4 species of forest predators (Bobcat, Raccoon, Coyote, and Virginia Opossum) and analyzed the data using our system of standardizing time based on sunrise and sunset. We classified activity as crepuscular, nocturnal, or diurnal, and defined crepuscular periods as 5% of time before and after sunset plus 5% of time before and after sunrise. We defined nocturnal and diurnal periods as all day and night periods exclusive of crepuscular times.

We used chi-square goodness-of-fit tests to determine if the temporal distribution (crepuscular or day/night) of activity of forest predators as captured in our photographic data differed from what would be expected of a random pattern of activity at the camera stations. We also compared the activity patterns among the species using pairwise chi-squared tests. In cases where the expected values of some cells were <5, we also calculated Fisher's exact tests for those pairs. All statistical analyses were performed in SAS 9.2 (SAS Institute 2003) using $\alpha = 0.05$.

Effects of moon phase on predator activity patterns

We compared nocturnal activity levels of two forest predators (Raccoon and Virginia Opossum) among four lunar cycles. We analyzed only Raccoon and Virginia Opossum data because these datasets contained sufficient numbers of photographic captures throughout the moon cycle. The first lunar cycle was from 29 June–27 July 2005. The other three lunar cycles were from 6 September–28 November 2005. We divided the cycles into 5 categories based on the percentage of moon visible (0–20%, 21–40%, 41–60%, 61–80%, and 81–100% moon visibility). We used a chi-squared goodness-of-fit test to compare observed Raccoon and Virginia Opossum activity at different moonlight levels to a random expectation.

Results

Camera survey of predator activity patterns

We recorded 1925 trap-nights during the 2 sampling periods. These efforts resulted in a total of 161 photographs of 4 species of forest predators taken during 17 weeks of camera surveys. We observed asymmetric predator activity patterns for all 4 species of forest carnivores among diurnal, nocturnal, and crepuscular periods of activity (Table 1). One photograph of a 5^{th} forest predator, a Striped Skunk, was also taken during our survey period but was not analyzed.

Eighteen Bobcat photographic capture events were recorded at 11 of 27 camera stations. Bobcats were active periodically throughout the day and night, with 22.1% of all Bobcat activity recorded during daylight periods, however the peak of diurnal activity was immediately prior to sunset (Fig. 2). Crepuscular activity accounted for 38.9% of all Bobcat activity. Bobcat activity did not differ from a random distribution of activity ($\chi^2 = 4.64$, $P = 0.098$).

We recorded 109 Raccoon photographic capture events at 23 of 27 camera stations. Raccoons were found to be almost entirely nocturnal with only 5.5% of photographs recorded during daylight. Raccoon activity began immediately following sunset and continued until immediately preceding sunrise (Fig. 2). Raccoons were significantly more active at night and less active at both crepuscular periods and during the day ($\chi^2 = 85.36$, $P < 0.0001$).

We recorded 13 Coyote photographic capture events at 11 of 27 camera stations. Coyotes were found to be active periodically throughout the day (15.3%) and crepuscular periods (7.7%), with most activity confined to nocturnal periods or early morning (77%) (Fig. 2). Coyotes were significantly more active at night and less active during the day ($\chi^2 = 7.38$, $P = 0.025$).

Table 1. Diel activity patterns of forest carnivores in east Texas, recorded using infrared-triggered cameras. All data from study area, Nacogdoches County, TX, from 29 June–2 August and 6 September–28 November 2005.

	Diurnal	Nocturnal	Crepuscular
Bobcat (*n* = 18)	22.1%	39.0%	38.9%
Raccoon (*n* = 109)	5.5%	82.6%	11.9%
Coyote (*n* = 13)	15.3%	77.0%	7.7%
Virginia Opossum (*n* = 21)	0.0%	95.2%	4.8%

We recorded 21 Virginia Opossum photographic capture events at 7 of 27 camera stations. Virginia Opossums were the only species recorded exclusively during nocturnal periods, with two distinct activity periods during the night. The first activity period began after sunset and slowed at midnight and the second began after midnight and slowed toward sunrise (Fig. 2). Virginia Opossums were significantly more active during the nocturnal period compared to crepuscular or diurnal periods (χ^2 = 26.9, P = < 0.0001).

Bobcat temporal activity patterns differed from both Raccoon (χ^2 = 16.5, P = 0.0003; Fisher's P = 0.0003) and Virginia Opossum (χ^2 = 14.6, P = 0.007; Fisher's P = 0.00025) activity patterns (Fig. 2). The Bobcat pattern was somewhat similar to Coyote activity (χ^2 = 5.02, P = 0.081; Fisher's P = 0.12). All other comparisons (i.e., Coyotes, Raccoons, and Virginia Opossums) showed that temporal activity patterns were not significantly different (χ^2 < 3.65 16.5, P > 0.16; Fisher's P > 0.26). Bobcats differed from the other species primarily in their greater daytime and crepuscular activity.

When analyzing the time-activity data, we observed a 74% reduction in activity during the midnight period occurring one-half way between sunrise and sunset from average pre- and post-midnight periods (see Fig. 2). This period of reduced

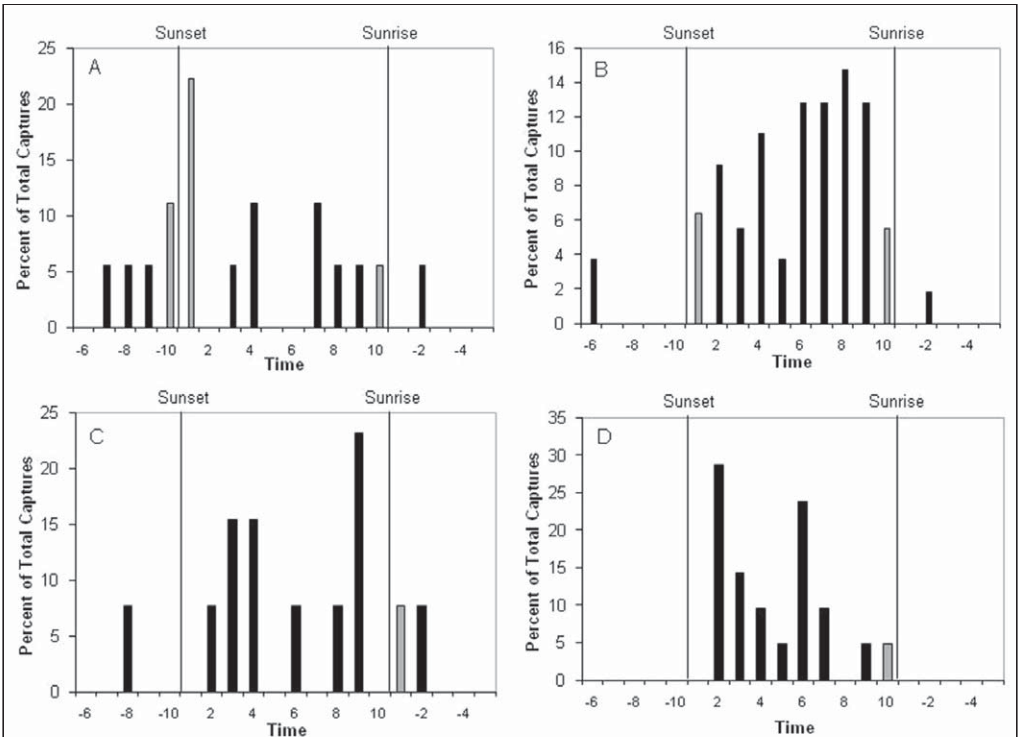

Figure 2.(A) Bobcat n = 18, (B) Raccoon n = 109, (C) Coyote n = 13 and (D) Virginia Opossum n = 21 activity at Bobcat-urine scent stations. Displayed as percent of photographic captures with time measurement recorded as a percent of daylight and dark hours. Crepuscular activity is shown in gray. Data recorded 29 June–2 Aug. and 6 Sept–28 Nov 2005, Nacogdoches County, TX.

activity occurred in all 4 species surveyed, but was most evident in Raccoons and Virginia Opossum.

Effects of lunar cycle on predator activity patterns

We analyzed 98 Raccoon and 21 Virginia Opossum photographic capture-events during 4 moon cycles. For this analysis, we included only nocturnal photographic captures (Fig. 3). The number of observations did not significantly differ from

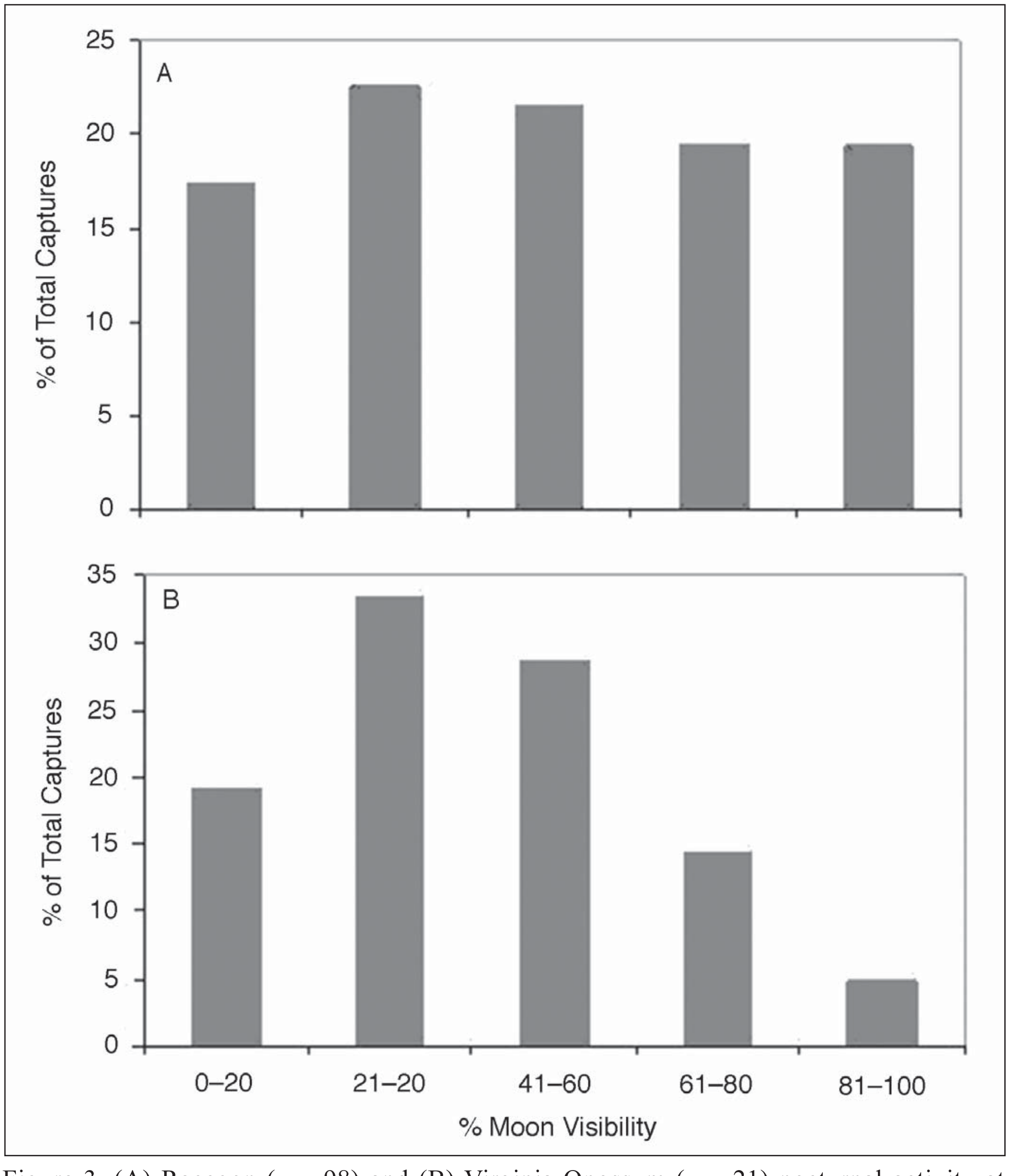

Figure 3. (A) Raccoon (n = 98) and (B) Virginia Opossum (n = 21) nocturnal activity at Bobcat urine scent stations based on percent moon visibility. Displayed as percent of photographic captures. Four moon cycles were recorded: 29 June–27 July and 6 Sept–28 Nov 2005, Nacogdoches County, TX.

a random distribution for either Raccoon ($\chi^2 = 0.7755$, $P = 0.9417$) or Virginia Opossum ($\chi^2 = 5.4286$, $P = 0.2461$). Therefore, we found that moon phase had no effect on either Raccoon or Virginia Opossum activity level. We did not analyze the effects of moon phase for Bobcat or Coyote because of the small number of photographic captures of these species during nocturnal periods.

Discussion

During our evaluation of forest predator activity patterns, we found infrared-triggered cameras to be well suited to the task of gathering large amounts of activity data over extended time periods, with limited human effort, in a cost effective manner. We experienced some camera malfunctions such as exposure of all film before twice-weekly camera checks and rodents chewing wires; however, these incidents were limited and did not affect data collection significantly. Our system of standardizing time data on a percent scale to eliminate distortion caused by changes in time of sunrise and sunset was also effective in describing activity patterns of 4 forest carnivores. Our tests on the effects of moon phase on activity patterns of Raccoons and Virginia Opossums suggest that moon phase has no effect on activity patterns of these predators.

Bobcat activity was mainly nocturnal with activity peaks occurring at crepuscular periods. These findings for a visual predator like the Bobcat agree with the reported results by Kavanau (1971) during laboratory testing, and Hall and Newsome (1976) in Louisiana. Our Coyote activity data agreed with results reported by Grinder and Krausman (1999) in Arizona and McClennen et al. (2001) in Wyoming, who suggest Coyotes are both diurnal and nocturnal. However, these authors also suggest that Coyotes have activity peaks during crepuscular periods: a finding not supported by our results. Although we had a limited number of Coyote captures, it appears that Coyotes were less active when Bobcats were most active right before and after sunset.

Raccoon activity during the study period was found to be primarily nocturnal, with activity initiated immediately after sunset and ending at sunrise. This pattern of nocturnal activity has long been identified by researchers as the typical pattern of Raccoon activity throughout North America (Carver et al. 2011, Kaufmann 1982). Our study documented Virginia Opossum activity during the 17 weeks of camera surveying as strictly nocturnal, with no photographs taken during diurnal periods. Findings by McManus (1971), in New York and Carver et al. (2011), in Tennessee, are similar to our results with Virginia Opossums, which we classified as nocturnal, with activity peaks during the middle of the night. Activity peaks of both Virginia Opossums and Racoons avoided periods of high Bobcat activity around sunset, suggesting that predation risk may be influencing activity period for these species. Differences between our study location and study locations described in the literature may have effects on activity patterns. Some differences include: habitat type, habitat quality, latitude, altitude, etc.

The reduced activity we observed during the period around midnight was unexpected and most evident in Raccoons and Virginia Opossums. This nocturnal time of inactivity may be a period of rest during long bouts of hunting and/or foraging. To our knowledge a reduction of midnight activity has not been observed before for these four species and should be investigated further.

Limited numbers of photographic captures may have affected our results for Bobcats, Virginia Opossums, and Coyotes; however, sample size appeared adequate in the case of Raccoons. We believe that the sample size of Raccoons (n = 109) was sufficient to determine accurate time activity patterns.

Because it is difficult to uniquely identify individual Coyotes, Raccoons, and Virginia Opossums by unique pelage markings during photographic capture, we are unsure how many animals of these 3 species comprised the total number of photographs. However, during the second sampling period we conducted a Bobcat population survey in which 7 individual Bobcats were photographed a total of 15 times (Symmank et al. 2008). This confirms that multiple individual Bobcats were recorded and activity findings for this species were not based on a sample of just a few individuals.

We believe that our system of recording and analyzing numerous photographic captures of multiple species will aid future research efforts in better analyzing activity patterns and possible temporal partitioning of predator species. Although our data were limited, temporal differences in activity patterns were evident among the 4 species analyzed. Bobcats were active periodically throughout the day and night and Raccoons and Virginia Opossums showed activity peaks between sunset and sunrise. We found that Coyotes were mainly nocturnal but were more diurnal than both Raccoons and Virginia Opossums. It is possible that Raccoons and Virginia Opossums are essentially nocturnal to avoid predation by or competition with larger carnivores such as Bobcats and Coyotes that are active during diurnal and crepuscular periods. Further research into the temporal partitioning will advance our understanding of co-occurring populations of medium-sized predators.

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