Estimating Bobcat Abundance in East Texas Using Infrared-triggered Cameras

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Abstract: Reliable population estimation techniques for cryptic forest predators generally are lacking. Development of an efficient and reliable technique to estimate predator abundance directly would be a valuable tool for wildlife managers concerned with predator management. We evaluated the potential for camera survey techniques to provide abundance estimates for bobcats (*Lynx rufus*) in southeastern forest habitats. We also determined our ability to capture other forest carnivores photographically using these techniques. We used TrailMaster 1500 active infrared-triggered cameras to estimate abundance on a 1318-ha private land holding in eastern Texas. Camera stations were located along roads and wildlife travel corridors using a 65-ha block grid overlaying the property. We established 20 camera stations yielding a mean coverage of approximately 1 camera/65.9 ha. All camera stations were baited with bobcat urine and a visual attractant and monitored for 12 weeks. We recorded 15 bobcat photographic events of seven separate individuals that were identified using spot pattern and other distinctive markings. These data were used to derive a population abundance estimate of seven bobcats during the 12-week study period using the computer program CAPTURE. This corresponded to a density of 0.29–0.58 bobcats/km^2, which compared favorably with other studies conducted in similar habitats. In addition to providing a monitoring technique for bobcats, photographic survey techniques could be adapted for monitoring other cryptic carnivores.

Key words: abundance, bobcat, camera, density, east Texas, individual identification, infrared-triggered camera, *Lynx rufus*, TrailMaster

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The estimation of bobcat (*Lynx rufus*) population density in the southeastern United States is important for researchers and wildlife managers. Although bobcat population ecology has been well-studied in some parts of its range, reliable methods to estimate abundance in southeastern forested habitats generally are lacking. Current forest management practices in the Southeast are thought to promote bobcat population increases through maintenance of early successional habitats (Conner et al. 2000). However, insufficient information regarding bobcat populations in east Texas, combined with large areas of suitable habitat, make the development of an effective predator monitoring system a significant need.

Accurate estimation of population abundance and density would be valuable to wildlife managers for several reasons. For example, predator populations may be important in the promotion of species of economic or conservation concern such as Northern bobwhite (*Colinus virginianus*) and wild turkey (*Meleagris gallopavo*). Although the importance of bobcat predation has not been quantified, bobcats have been photographed predating simulated wild turkey and northern bobwhite nests in south Texas (Hernandez et al. 1997). Furthermore, loss of carnivores such as bobcats and coyotes (*Canis latrans*) from habitat fragments has been associated with decreases in songbird diversity through release of mesopredators such as raccoons (*Procyon lotor*) and opossums (*Didelphis virginiana*; Crooks and Soule 1999). Thus, the presence and abundance of these predators can have important implications for a variety of other species.

Infrared-triggered cameras have been used successfully in wildlife applications, including assessment of population parameters (Mace et al. 1994, Karanth 1995, Jacobson et al. 1997, Koerth et al. 1997), and may provide a quick and cost-effective technique for monitoring and evaluating bobcat populations. These systems have been used to estimate abundance and occupancy in a variety of forest cats, including ocelots (*Leopardus pardalis*, Trolle and Kery 2003), tigers (*Panthera tigris*, Karanth and Nichols 1998) and jaguars (*Panthera onca*, Silver et al. 2004). Many cat species have distinctive coloration or spot patterns that facilitate individual identification in photographic captures. Heilbrun et al. (2003,

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2006) were successful in identifying individuals and obtaining abundance estimates of bobcats in south Texas, and Larrucea et al. (2007b) successfully identified individual bobcats from photographs in California.

Estimation of bobcat and other predator population demographics using photographic mark-recapture monitoring has not been thoroughly tested and evaluated. We analyzed the use and feasibility of infrared-triggered cameras for monitoring bobcat populations in east Texas. Our objectives in this study were to (1) determine the feasibility of using a camera monitoring system to estimate bobcat abundance and density in southeastern forested habitat and (2) evaluate the ability of a camera monitoring system to obtain photographic captures of other forest carnivores.

Study Area

The study was conducted on a 1318-ha tract located approximately 16 km west of Nacogdoches, Texas (Nacogdoches County). The study area was part of a private land holding owned by the Hayter Trust. The Hayter Trust property contains a mixture of upland loblolly pine (*Pinus taeda*) plantations of various ages (including numerous recent clearcuts <5 years of age), hardwood lowlands and mixed pine/hardwood forests. The regional climate is humid and subtropical, with an annual average rainfall of approximately 119 cm. Mean temperature during January is 9 C, whereas average mean temperature during July is 28 C.

The property contained an extensive network of gravel roads, and numerous warm and cool season food plots for white-tailed deer (*Odocoileus virginianus*). The study area within the Hayter Trust was surrounded by a deer-proof fence; however, we did not believe this fence limited bobcat movements in the area. Deer hunters and other users did not harvest bobcats on the property during the study.

Methods

Camera Survey

We used a systematic, grid-based arrangement of camera stations to estimate abundance of bobcats in the study area. We overlaid the study area with a 65-ha block grid and established a camera station within each block (Figure 1). Cameras were located near the center of each grid block, but subjectively placed within a 200-m diameter circle to allow placement near bobcat sign, game trails, roads, or other suitable locations (Jacobson et al. 1997). This configuration yielded 20 camera stations and a mean coverage of approximately 1 camera/65.9 ha, considerably less than reported average annual home ranges of bobcats in Louisiana (97 for females and 494 ha for males; Hall and Newsome 1976) and Mississippi (863 ha for females and 1719 ha for males; Chamberlain et al. 2003). We assigned GPS coordinates to all camera stations using a Trimble Pro XRS GPS receiver (Trimble Navigation Limited, Sunnyvale, California).

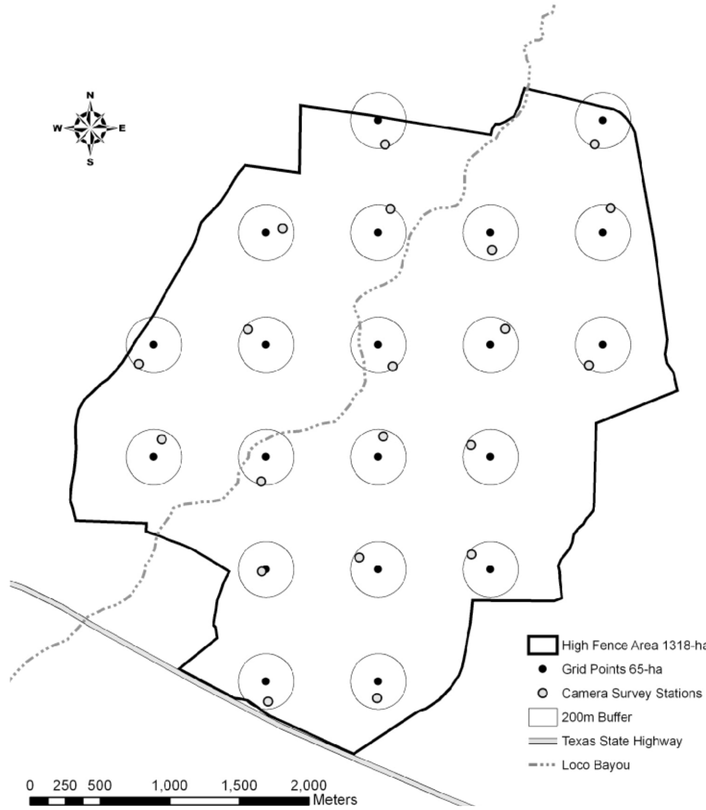

Figure 1. Locations of infrared-triggered camera stations for bobcat population survey, the Hayter Trust, Nacogdoches County, Texas, from 6 September to 28 November 2005.

Camera stations consisted of TrailMaster 1500 Active Infrared Units with the transmitter and receiver portion of the camera stations placed 3–4 m apart, 30 cm above the ground and in a north to south direction to reduce the number of false events due to direct sunlight on the receiver unit (Hernandez et al. 1997; Figure 2). A hair snare also was included in the camera setup in order to obtain genetic samples for individual identification as part of a separate study. Camera stations were active 24-h per day, with a 6 sec delay between photographs, and a setting of 5 on pulse delay, meaning the infrared beam was broken for 0.25 sec before a photograph was taken. A short delay between photographs aided in obtaining multiple photographs of the same individual during a single capture event, defined as one or multiple photographs taken within a 24-h period.

We used bobcat urine as a chemical attractant on a clean rag attached with twine to a 20-cm high, 4 x 2 cm wooden post. We placed the chemical attractant halfway between the camera transmitter and receiver. A visual attractant of three large feathers tied together was displayed approximately 2–3 m from the ground in

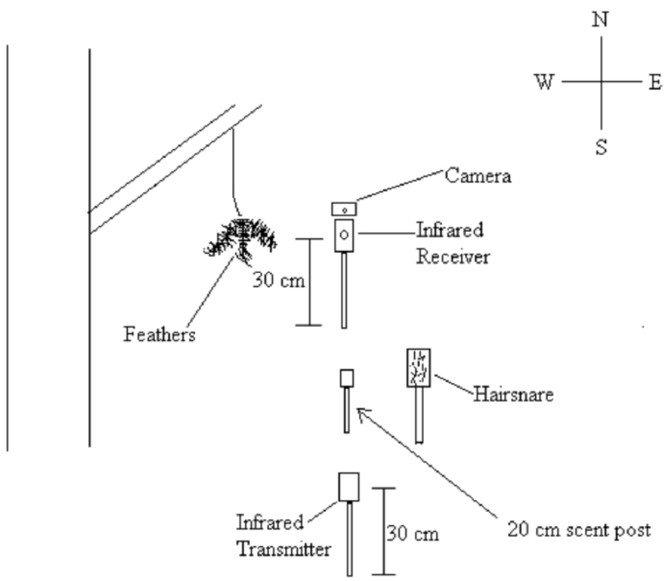

Figure 2. Camera and hair snare monitoring station setup for bobcat population survey, the Hayter Trust, Nacogdoches County, Texas, from 6 September to 28 November 2005.

close proximity to the infrared-triggered camera and chemical attractant.

Cameras were placed and monitored at each location for 12 weeks from 6 September to 28 November 2005. They were checked twice per week to replace film and batteries as necessary and to replenish chemical attractant. We used a study period of 12 weeks to minimize the chance of violating the assumption of a closed population (Karanth and Nichols 1998). A time period of 12 weeks or less has been used consistently in camera surveys of other forest cat species (Karanth and Nichols 1998, Trolle and Kery 2003, Silver et al. 2004, Haines et al. 2006). We also conducted the study outside the primary birthing season for bobcats (April-June; Anderson and Lovallo 2003, Fritts and Sealander 1978).

Abundance/Density Analysis

We used the computer Program CAPTURE (Otis et al. 1978) to estimate bobcat population size. We divided the 12-week study period into six two-week trapping occasions for analysis and recorded photographic capture data. All models and assumptions of Program CAPTURE are described in detail by Otis et al. (1978) and Karanth (1995). The model selection algorithm of program CAPTURE selects the most appropriate model from among seven available to use in estimating population abundance (Otis et al. 1978). We also performed a goodness of fit test and closure test in the program CAPTURE to examine our assumption of population closure during the survey period.

Using the bobcat abundance estimate from CAPTURE, we determined a population density estimate using the known area of camera coverage. Camera coverage area consisted of the study area plus a buffer of specific width around the coverage area. The buffer width was based on observed movements of animals photographed at multiple camera stations using the formula:

$$W_d = (\Sigma\, d/m/2)$$

where W_d is buffer width (meters), d is the maximum distance (meters) traveled between two camera trapping locations documenting the same individual, and m is the number of individuals recorded at two or more camera stations (Karanth and Nichols 1998). Using ArcGIS (Environmental Systems Research Institute, Inc. Redlands, California), total area used by identified bobcats was determined and density of bobcats calculated using the formula:

$$D = N/(A+W_a)$$

where D is density, N is the number of animals estimated from the program CAPTURE, A is the area (ha) comprised by the 100% minimum convex polygon of camera stations and W_a is the buffer area (ha) beyond the camera station area (Otis et al. 1978).

Bobcat Identification

We individually identified bobcats by spot pattern and other distinctive markings (Heilbrun et al. 2003; Figure 3). Photographs were processed in digital format and enlarged to facilitate positive identification. We assigned each bobcat a unique identification number and recorded bobcat identification number, date, time,

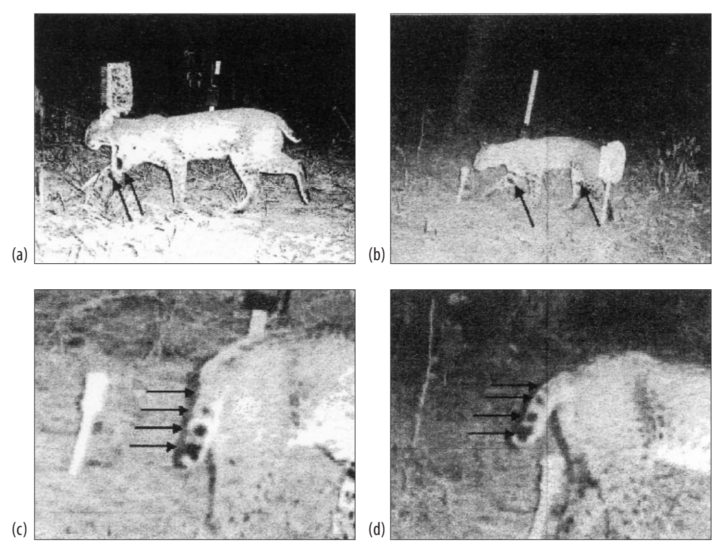

Figure 3. Photographs of different individuals captured during the bobcat population survey at the Hayter Trust study area, Nacogdoches County, Texas, from 6 September to 28 November 2005. (a) Bobcat with two distinctive bands on inside of front right leg and spots on inside of rear right leg; (b) Bobcat with one distinctive band on inside of front right leg and a band on inside of right rear leg; (c) and (d) Two photographs of the same bobcat with four black bands on tail.

camera location, and trapping occasion for each trapping event. We excluded events where bobcats could not be identified reliably due to camera angle or photo quality.

Results

Individual Identification

We recorded 15 bobcat photographic events during the 12-week population survey (1680 trap nights). Eleven events consisted of one photograph, two events consisted of three photographs, one event included four photographs and one event included seven photographs of the same individual. We documented bobcat photographic captures at 9 of 20 camera stations and we did not notice strong spatial clustering of captures (i.e., captures occurred at camera stations throughout the property). One photographic event was excluded due to poor exposure quality. We never recorded more than one individual during any capture event. Using distinguishing features such as tail stripes, leg and body spots, size, and facial markings, we identified seven individual bobcats during the 12-week photographic survey.

Abundance/Density Estimate

Of the seven individual bobcats, four were captured on one occasion, two on three occasions, and one was captured on four occasions (Table 1). The results of the closure test suggested the null hypothesis of closure was not rejected ($z = -0.192$, $P = 0.424$); thus, we considered the population closed in our analysis. The model selection algorithm in the program CAPTURE selected the M_o model as the most appropriate with a model criterion of 1.00. The M_o model assumes that each member of the population is equally at risk to be captured during each trapping occasion with no heterogeneity in capture probability, behavioral response to capture, or variation over time (Otis et al. 1978). In a goodness of fit test, program CAPTURE failed to reject the null model in favor of alternate models including a behavioral response to capture (M_b; $\chi^2 = 0.023$, $P = 0.88$) or time-specific variation in trapping probability (M_t; $\chi^2 = 3.996$, $P = 0.55$). Due to low numbers of photographic captures, our power to reject the null model was relatively low and CAPTURE was unable to test the alternate model including heterogeneity in trapping probabilities (M_h). The program results suggested the most likely population size was seven (SE=1.0346) with a 95% confidence interval of 7–14 individuals.

Based on a minimum convex polygon calculation, the camera survey stations encompassed an area of 8.87 km^2. A buffer width of 1015.3 m was added to this area based on the maximum distances traveled by three individuals (1561 m, 2033 m, and 2498 m) photographed at two stations each during the 12-week study period. Thus, the total survey area was 24.1 km^2. This area yielded an estimated density of bobcats on the study area of 0.29 bobcats/km^2, with a 95% confidence interval for bobcat density of 0.29–0.58 bobcats/km^2.

Other Forest Carnivores

A total of 112 photographs of four other predator species were recorded during the 12-week study including: coyote (12), raccoon (81), Virginia opossum (17) and striped skunk (*Mephitis mephitis;* 2).

Discussion

Our population abundance estimate of seven individuals (0.29 bobcats/km^2) is consistent with estimates of bobcat density for the pineywoods ecoregion made by Bluett and Tewes (1988) and estimates of bobcat density in regions with similar habitat characteristics (Provost et al. 1973, Conner et al. 1983; Table 2). However, ours may be a conservative estimate of true abundance because no kittens were captured during our survey. The age structure of bobcats in Arkansas reported by Fritts and Sealander (1978) sug-

Table 1. Capture histories for bobcat individuals captured at infrared-triggered camera stations over a 12-week period at Hayter Trust, Nacogdoches County, Texas, from 6 September to 28 November 2005.

	Two week trapping occasion					
Bobcat ID	**1**	**2**	**3**	**4**	**5**	**6**
1	0	1	0	1	1	0
2	1	1	0	0	1	1
3	1	0	0	0	0	0
4	0	0	0	1	0	0
5	0	0	0	0	0	1
6	0	1	1	1	0	0
7	0	0	0	1	0	0

Table 2. Selected population density values reported for bobcat populations in the southern United States.

State	Density (bobcat/km^2)	Estimation method	Reference
Oklahoma	0.09 (max)	Radiotelemetry	Rolley 1985
Arkansas	0.10 (min)	Radiotelemetry	Rucker et al. 1989
Arizona	0.26 (min)	Radiotelemetry	Lawhead 1984
E. Texas	0.29–0.58	Photographic survey	This study
E. Texas	0.30–0.60	Average annu. harvest data[a]	Bluett and Tewes 1988
South Texas	0.48	Photographic surveys	Heilbrun et al. 2006
Florida	0.52	Scent station Survey	Conner et al. 1983
South Carolina	0.58	Capture/Radiotelemetry	Provost et al. 1973
Alabama	0.86–1.30	Capture/Radiotelemetry	Miller and Speake 1978

a. Average annual harvest data from Pineywoods ecoregion (1978–1986), divided by the harvest population ratio for South Texas Plains.

gested kittens (age 0–1) represented 17.8% of the population, and Crowe (1974) found kittens represented 36% of the population in Wyoming. In white-tailed deer, Jacobson et al. (1997) suggest adult:fawn ratios may be biased through the use of infrared-triggered camera surveys due to lower mobility and visibility compared to adults.

The utility of the population estimate we derived was somewhat reduced by the relatively large confidence interval obtained. Although this value was comparable to some estimates for other species of dense forests (e.g., Trolle and Kery 2003), it was greater than that recorded for bobcats in more open range habitats (7–14 vs. 13.6–16.7; Heilbrun et al. 2006). The reduced precision of the estimate was primarily a result of a limited number of photographic captures as Heilbrun et al. (2006) reported 49 photo captures in 948 trap-nights (0.052 per trap-night) compared to our 15 in 1,680 trap-nights (0.009 per trap night). Though our density estimates were lower (0.29/km^2 vs. 0.48/km^2, Table 2), the lower number of captures also may reflect reduced visibility and accessibility of camera stations in dense forest habitats or differences between surveys with and without attractants. The use of attractants in noninvasive survey techniques has the potential to attract animals from outside the designated survey area (Kays and Slauson 2008). Alternative techniques such as placement along roads or trails have potential biases as well, and pilot studies suggested use of attractants increased capture rates. In light of our low capture rate overall, we felt that the use of attractants was justified.

Overall, we feel that photographic survey was a useful technique to estimate bobcat abundance in southeastern managed forest habitat. We were able to obtain an abundance estimate during a short 12-week sampling period with limited field effort (approx. 10 h/week). Reduced field effort ultimately makes a camera system more cost-effective compared to other methods of population estimation. Photographic surveys also are less intrusive and safer for both animal and handler when compared to techniques involving live trapping.

Although the bobcat identification procedure was successful, it proved to be a difficult process because of variation in photographic angles. The use of multi-camera TrailMaster setups would aid in photographic identification by obtaining images from multiple angles. Camera stations were checked every three to four days during the survey procedure; however, all 36 exposures occasionally were used prior to our visit, leaving the possibility events were missed. The amount of survey nights lost due to fully advanced film or other malfunctions would be difficult to quantify with reasonable certainty. Time lost could have potentially affected the number of photographic captures but we do not believe this significantly biased the results. Digital camera systems would improve photographic capture of more individuals because of their higher image storage capacity and lower operation noise.

The photographic survey system also was successful in recording photographic captures of non-target east Texas predator species. We were most successful in photographing raccoons and opossums, while less successful with coyotes and skunks. This may be due to a higher abundance of these species and/or behavioral characteristics more conducive to photographic capture. No photographs were taken of gray fox (*Urocyon cinereoargenteus*) despite known presence in east Texas. Also, no black bear (*Ursus americanus*) photographs were taken during this study; however, black bears are rare and transient in east Texas and there have been no recent documented bear sightings in the area. One modification that may improve capture rates for other species is use of different, more species-specific olfactory attractants. Based on these results, we believe the camera survey technique can be adapted to estimate or index populations of these and other predator species. Derivation of mark-recapture abundance estimates for other species is complicated by the lack of unique spot pattern or other pelage characteristics; although some researchers have reported success in identifying individual coyotes by pelage characteristics (Larrucea et al. 2007a). For some species, an initial capture and marking effort may be necessary for mark-recapture studies.

Photographic survey techniques could be expanded on a landscape scale either to estimate population abundance or to index populations of multiple predator species. Cameras can be established along existing survey routes and checked by research or state agency personnel. Utilizing digital camera equipment with higher image storage capacity could decrease necessary visitation to approximately once per week thereby increasing efficiency.

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