USING CAMERA-TRAP TECHNOLOGY TO IMPROVE UNDERGRADUATE EDUCATION AND CITIZEN-SCIENCE CONTRIBUTIONS IN WILDLIFE RESEARCH

MELISSA KARLIN,* AND GABRIELLE DE LA PAZ

Department of Physics and Environmental Sciences, St. Mary's University, One Camino Santa Maria, San Antonio, TX 78228
** Correspondent: mkarlin@stmarytx.edu*

ABSTRACT—We performed a pilot study to determine whether camera traps were an effective means for establishing a baseline of species richness, distribution, and abundance at a state natural area in San Antonio, Texas, that has never undergone a full wildlife census. We measured 1,714 trap events and 18 wildlife species. We calculated low species diversity and evenness; and white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), and gray fox (*Urocyon cinereoargenteus*) were the most abundant species. However, the invasive exotic feral pig (*Sus scrofa*) was also recorded in high densities. The results of this camera study illustrate the ease with which camera traps can be used to collect baseline data, by undergraduate students in the case of this study, which can provide vital field-based research experiences for students and produce much needed wildlife occurrence data for federal or state agencies in designing management plans for species of concern, such as the feral pig, or for threatened or endangered species.

RESUMEN—Hicimos un estudio piloto para determinar si las trampas de cámaras serían un método efectivo para establecer una base de la riqueza de especies, su distribución y abundancia en una área natural estatal en San Antonio, Texas, que previamente no fue censada completamente para su fauna. Capturamos 1,714 eventos en las trampas y 18 especies de fauna. Calculamos una diversidad de especies baja y pareja. Las especies más abundantes fueron el venado de cola blanca (*Odocoileus virginianus*), el coyote (*Canis latrans*) y el zorro gris (*Urocyon cinereoargenteus*). También se registró en alta densidad la especie exótica invasiva del cerdo salvaje (*Sus scrofa*). Los resultados de este estudio camarógrafo demuestran lo fácil que es usar trampas de cámaras para recolectar información de base, en este estudio por estudiantes universitarios, que puede proveer experiencias vitales de investigación de campo para estudiantes y que produce información muy necesitada de datos de ocurrencia de fauna silvestre para agencias federales y estatales a fines de diseñar planes de manejo para especies que den preocupación, como el cerdo salvaje, o para especies amenazadas o en peligro de extinción.

Assessing species presence and abundance is often the first step in designing conservation priorities for a given area because it provides a baseline survey from which to design management plans. Traditional approaches to estimating presence and abundance include animal tracking, direct observations conducted along line transects, or counts of identifying features such as nests or dung (Eberhardt and Van Etten, 1956; Bider, 1968; Fashing and Cords, 2000; Barnes, 2001). These traditional approaches are often very time-consuming and subject to observation error and sampling bias. Since the mid-2000s, remotely triggered photographic camera units, called trail cameras or camera traps, have been increasingly used in the field by researchers to record species richness, abundance, animal behavior, and to identify individual animals of interest based on markings, for medium to large-sized animals (Silveira et al., 2003; McCallum, 2012). This approach is preferable to more conventional tracking techniques because cameras can be left in the field for extended periods (up to 12 months), which reduces human disturbance of the area; can withstand a wide range of weather conditions; can store thousands of images at a given time; and are less invasive than traditional techniques such as radiotelemetry or capture–mark–recapture, which require capturing and handling the animal (Cutler and Swann, 1999; McCallum, 2012). Camera traps are also particularly effective for surveying nocturnal or elusive species such as coyotes (*Canis latrans*), bobcats (*Lynx rufus*), or feral pigs (*Sus scrofa;* Heilbrun et al., 2003), or for surveying solitary species such as mountain lions (*Puma concolor*). Because camera traps also record day and time, animal behavior patterns and characteristics can also be determined using this technology (Bridges et al., 2004); otherwise these would require frequent spatial and temporal data collection using Global Positioning System (GPS) or radiotelemetry, which is very costly.

Camera traps have also become widely used in citizen science projects surveying medium to large-sized animals, in which citizens are trained to use the cameras, operate GPS units, and download pictures collected by the cameras; the unpaid, volunteer citizen scientists give researchers much-needed field assistance when budgets are tight, and the extra field assistance can allow the scope of the study to greatly expand in geographic area (Cohn, 2008; Forrester et al., 2013). While researchers benefit from the extra field assistance, these citizen scientists are also being exposed to the natural world and becoming involved in the scientific process (Cohn, 2008). The National Audubon Society's annual Christmas bird count may be the oldest example of citizen science, but presently citizen scientists are used by many federal and state agencies, nonprofits, and universities for a variety of projects: the United States Geological Survey employs citizen scientists to monitor frog populations; the National Park System to monitor coastal water birds; and the North Carolina Museum of Natural Sciences and the Smithsonian Institute to document mammals throughout the mid-Atlantic region using camera traps (i.e., the eMammal project; Cohn, 2008; Forrester et al., 2013).

Undergraduate students majoring in a natural science, much like citizen-scientists, also benefit from hands-on research projects that expose them to the scientific process. Studies have shown that when undergraduate students were given the opportunity to work with faculty on their research, students became more confident in their abilities to do research, became more interested in the discipline, improved their critical thinking skills, and felt that they were a part of the scientific community (Elsen et al., 2009). A study on the Undergraduate Research Opportunity Program founded in 1989 at the University of Michigan, which targets first- and second-year students, found that these students that were in an intellectual relationship with a faculty member had lower attrition rates than nonparticipants in the Undergraduate Research Opportunity Program (Nagda et al., 1998). Finally, a survey of undergraduate research experience specifically at four liberal-arts colleges revealed that students involved in faculty research experienced positive results, such as increased confidence to do research, in contributing to science, and in "feeling like a scientist" (Seymour et al., 2004:508).

Because they are noninvasive, easily operated, and do not require extensive training, camera traps represent an excellent tool for incorporating both citizen science and undergraduate students in research opportunities in which the data collected will actually be used for scientific research and analysis. For undergraduate students seeking opportunities in wildlife research, camera traps are able to expose students to wildlife ecology and behavior without the need for them to receive training on how to safely trap and handle species, how to operate and deploy very-high-frequency telemetry or GPS collars, and how to chemically immobilize species. These students can also be left in the field unsupervised, which reduces time commitments by the faculty researcher that would otherwise be required if a student was involved in trapping wildlife. After using camera traps to survey species' presence or absence, the data collected can be used by state or federal agencies to target management of species of concern, such as threatened or endangered wildlife or invasive exotic species. For example, the feral pig is an invasive exotic pest species; feral pigs are a significant threat to native flora and fauna in all areas where they occur(currently $\geq$40 of the 50 states; Friebel and Jodice, 2009). Because of the damage they inflict on the natural resources, by rooting and digging for food, creating wallows, and destroying vegetation, natural resource managers in areas where feral pigs occur often must develop management or control programs for this species. They also compete for food resources directly with native animals, including white-tailed deer (*Odocoileus virginianus*). Management programs to control feral pigs, however, are often expensive, time-consuming, difficult to implement, and are generally met with limited success (Dziecioowski et al., 1992; Waithman et al., 1999; Hone, 2002).

The purpose of this research was to perform a pilot study to determine whether camera traps were an effective means for establishing a baseline of species richness, distribution, and abundance at a state natural area in San Antonio, Texas, that has never undergone a full wildlife census. As a part of this project, undergraduate environmental-science students were enlisted to assist in the deployment and retrieval of cameras and analysis of photographic data, to illustrate how the use of trail camera data can be incorporated into course curriculum and student research projects. If successful in establishing a baseline wildlife census, this research will be expanded and the results used to guide management activities, conservation priorities, and most critically at this point in time, target feral pig management to areas of highest feral pig presence and activity.

METHODS AND MATERIALS—Government Canyon State Natural Area (Government Canyon SNA) is an approximately 47.04-km^2 area outside of San Antonio in northwestern Bexar County, Texas (Fig. 1). Dominant vegetation includes Ashe juniper (*Juniperus ashei*) and a mixed deciduous component of Texas oak (*Quercus buckleyi*), live oak (*Quercus fusiformis*), shin oak (*Quercus durandii* var. *breviloba*), cedar elm (*Ulmus crassifolia*), Texas ash (*Fraxinus texensis*), and escarpment black cherry (*Prunus serotina;* Watson et al., 2008).

The southern half of the Government Canyon SNA property was divided into 20, 1-km^2 grids and one camera was placed in every grid for a minimum of 6 weeks each,

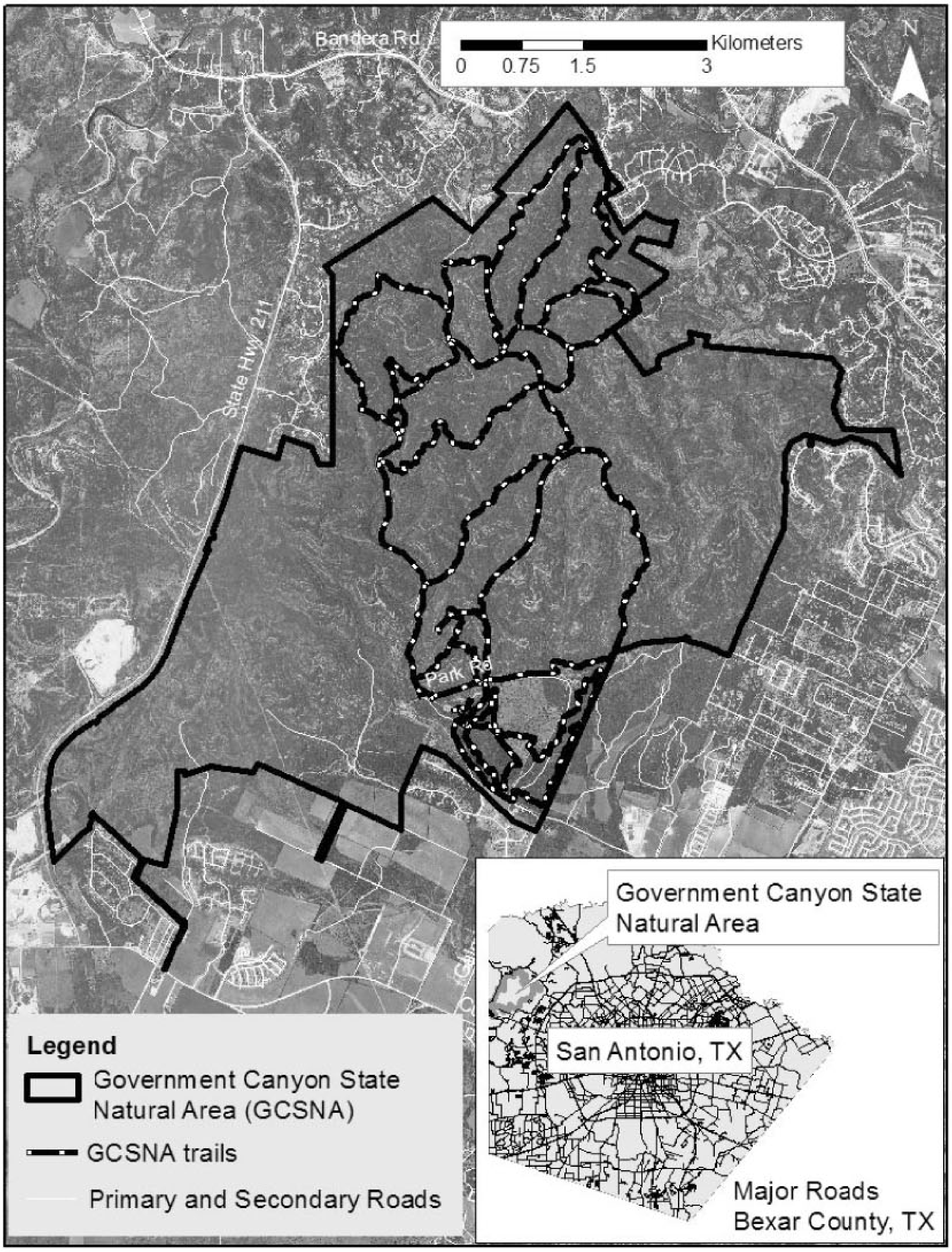

FIG. 1—Study site at Government Canyon State Natural Area (GCSNA), San Antonio, Texas, for camera study conducted from September 2013 to December 2013.

beginning in September 2013 (Fig. 2). The 30–60-day sampling time period is generally used to assume a closed population on sampled animals (Karanth et al., 2011). The grid size was selected because it underestimates the area covered by potential species in this area, such as bobcats, which were sampled at approximately 1.29-km^2 intervals (Heilbrun et al., 2003); and based on average home range size of feral pigs, which may be as small as 2.02 km^2 but are generally much greater (Friebel and Jodice, 2009). Dr. Karlin trained three undergraduate students on the operation of trail cameras and GPS units by taking them in the field to within 250 m of the center of each grid. Students were instructed to find the nearest game trail and tree that could support the camera fastened at 12–16 inches (approx. 30–41 cm) off the ground (Heilbrun et al., 2003). Camera stations were not baited in order to prevent heterogeneous capture probability (Jacobson et al., 1997; Heilbrun et al., 2003).

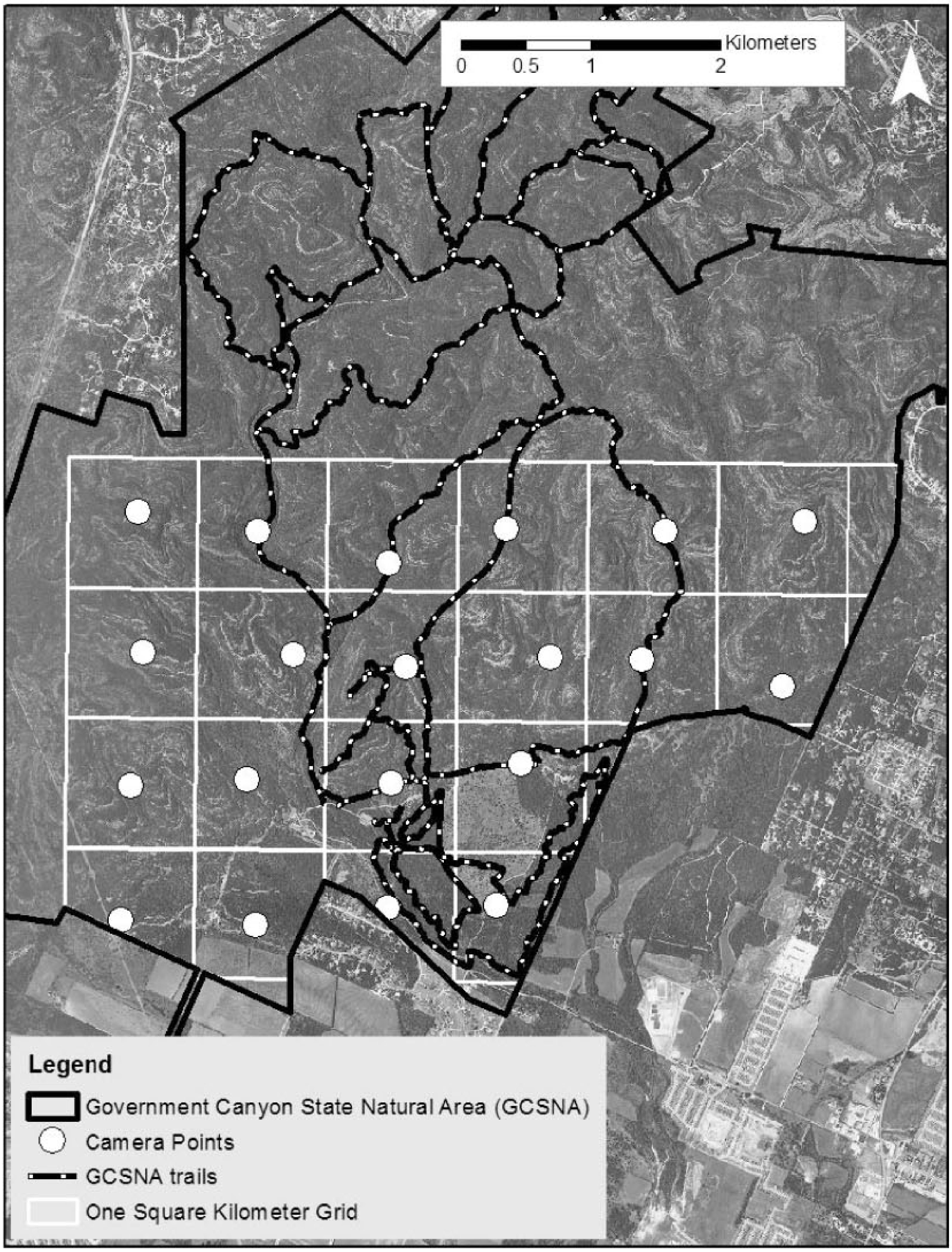

Fig. 2—Sampling grid scheme for camera study conducted at Government Canyon State Natural Area, San Antonio, Texas, from September 2013 to December 2013.

The cameras used during this study were the DLC Covert Extreme Black 60 (Covert Scouting Cameras, Lewisburg, Kentucky). This camera was a black infrared camera with a 40-ft (12-m) detection range; 12-MP picture resolution; a 1.2-s trigger speed; a variable trigger interval of 1 s–60 min; takes pictures or video; includes 60 infrared black light-emitting diodes; and includes a date, time, temperature, and moon phase stamp on every picture. The infrared technology detects motion, and an animal must move into the detection zone in order to activate the camera (Kelly and Holub, 2008).

After the sampling period had concluded, students independently retrieved the trail cameras we had deployed as a team, again using GPS units to navigate to the site. They were trained to turn off the camera before removing it from the field; and upon returning to campus, they downloaded all pictures to a shared hard drive. Dr. Karlin evaluated the students' abilities to

TABLE 1—Trap success for each species and total combined trap success per 100 trap-nights for camera study conducted at Government Canyon State Natural Area, San Antonio, Texas, from September to December 2013.

Species	Total no. of trap events	Total no. of animal photographs	Trap success per animal
Nine-banded armadillo (*Dasypus novemcinctus*)	12	56	0.94
Axis deer (*Axis axis*)	1	2	0.08
Bobcat (*Lynx rufus*)	16	16	1.26
Coyote (*Canis latrans*)	152	175	11.96
White-tailed deer (*Odocoileus virginianus*)	981	1,419	77.18
Feral Pig (*Sus scrofa*)	101	118	7.95
Gray fox (*Urocyon cinereoargenteus*)	138	146	10.86
Javelina (*Pecari tajacu*)	69	87	5.43
Mountain lion (*Puma concolor*)	1	1	0.08
Porcupine (*Erethizon dorsatus*)	1	1	0.08
Eastern cottontail (*Sylvilagus floridanus*)	41	55	3.23
Raccoon (*Procyon lotor*)	90	110	7.08
Ringtail (*Bassariscus astutus*)	6	6	0.47
Greater roadrunner (*Geococcyx californianus*)	29	32	2.28
Striped skunk (*Mephitis mephitis*)	20	24	1.57
Eastern gray squirrel (*Sciurus carolinensis*)	9	10	0.71
Rio Grande turkey (*Meleagris gallopavo intermedia*)	43	34	3.38
White-winged dove (*Zenaida asiatica*)	4	4	0.31
Total	1,714	2,296	134.85
Total no. of trap-nights	1,271	—	—

recognize common wildlife species, and then allowed them to sort individual species by camera into separate folders. We analyzed photos to determine species type, and we calculated total number of individual species based on Trap Events (Kelly and Holub, 2008), which consisted of a record of an animal within a 30-min period. If the same species was recorded within 30 min, it was assumed to be the same individual and was not counted. We measured trap success for each species by calculating the number of trap events per 100 trap-nights using the formula $TS_i = (N_i/\sum TN) \times 100$, where TS_i is trap success for species *i*, N_i is the number of trap events for species *i*, and $\sum TN$ is the total number of trap-nights (Kelly and Holub, 2008; Bernard et al., 2013).

We also calculated Simpson's Index, which measured species diversity; and we calculated Simpson's Evenness Index, which measured how equitable abundance numbers were across species. We also conducted a rank abundance analysis, which ranked the log of abundance of each species against its rank. Finally, we analyzed activity patterns of species with more than eight trap events, to determine how behavior varied between dawn (0500–0900h), day (0900–1700h), dusk (1700–2100h), and night (2100–0500h; Renaud et al., 1995; Bernard et al., 2013).

To determine sampling saturation for species in Government Canyon SNA, we calculated an observed-species accumulation curve and sampling completeness ratios (observed species number/estimated species number) using three commonly used abundance-based species-richness estimators (i.e., ACE, CHAO1, and JACK1; Bernard et al., 2013) using EstimateS Version 9.1.0 (Colwell, 2013). We calculated the observed-species accumulation curve using the cumulative number of independent photographs, and constructed high and low 95% confidence intervals using EstimateS Version 9.1.0 (Colwell, 2013). The observed-species accumulation curve is typically used to estimate species richness (Ugland et al., 2003); as sampled area increases, the accumulation of new species in the sampled area increases initially, and then in cases where species are easily identified, reaches an asymptote at the saturation point. Some habitat is more difficult to sample and it is unlikely that all species can ever be sampled, and an asymptote may not be reached. Sampling saturation was assumed when the sampling completeness ratio approached one (Bernard et al., 2013), which would suggest that the study area had been sufficiently sampled and the majority of species present had been recorded.

RESULTS—We deployed 20 cameras from September 2013 to December 2013, and recorded 16,105 pictures, of which 2,296 pictures captured a wildlife species, and 1,714 were unique trap events. The 13,809 other pictures that did not include wildlife were either false triggers due to vegetation or shadows, or were pictures of humans. We identified 18 unique wildlife species including 2 different species of deer—the native white-tailed deer and exotic Axis deer (*Axis axis*). We calculated a total combined trap success of 134.85/100 trap-nights (Table 1). White-tailed deer had the highest overall trap success (77.18/100 trap-nights), whereas coyotes had the highest trap success of the predators (11.96/100 trap-nights). Based on the trap events, we calculated that just over 100 individual feral pigs may be found within the natural area, ranging in densities from 1 hog/km^2 to 18 hogs/km^2.

The observed-species accumulation curve showed that

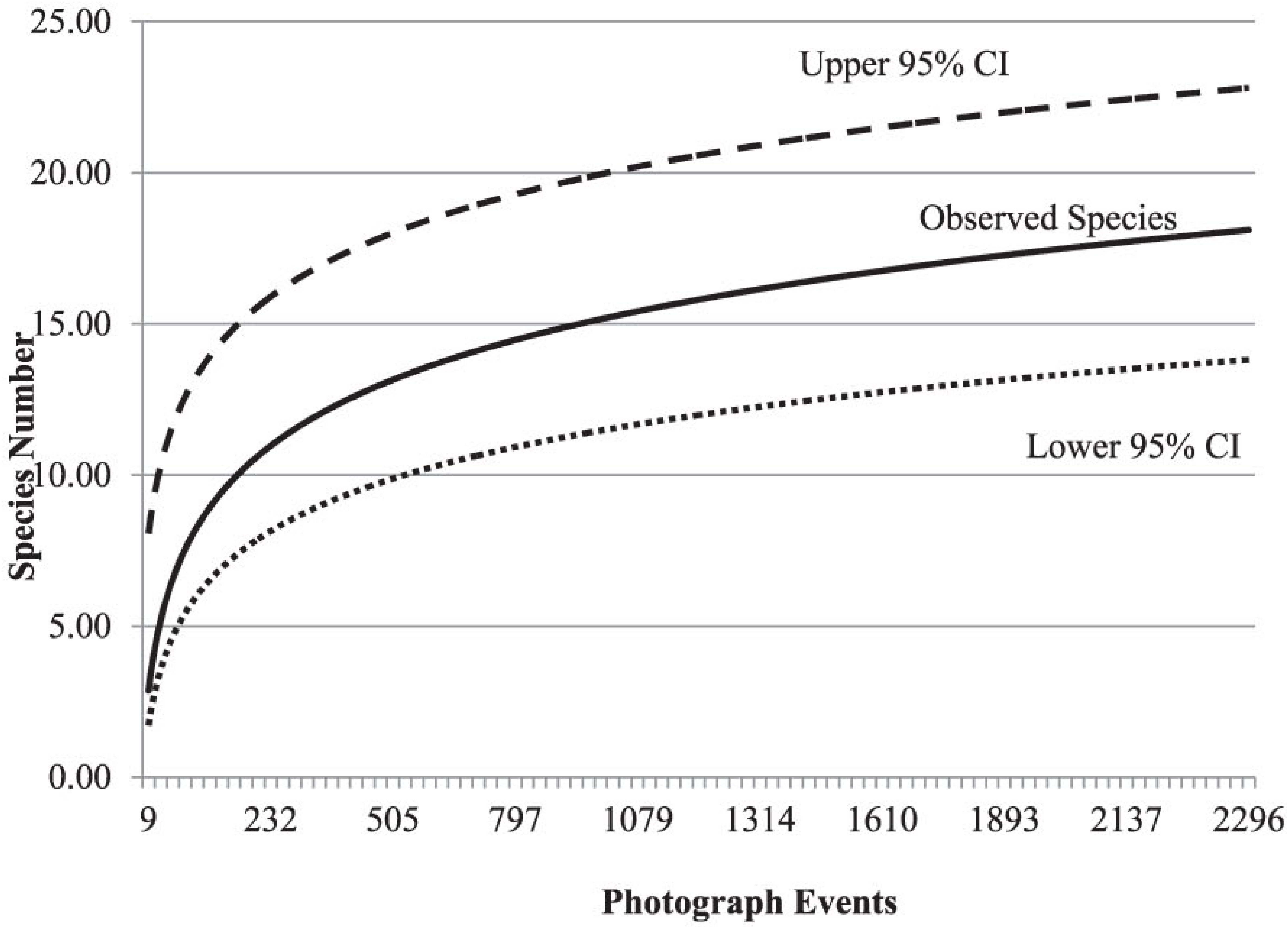

FIG. 3—Species-accumulation curve for camera study conducted at Government Canyon State Natural Area, San Antonio, Texas, from September to December 2013.

the species number began to reach an asymptote between 16 and 18 species, and the estimated upper and lower 95% confidence interval projected between 14 and 25 species for the site (Fig. 3). In addition to the plateau of the species-accumulation curve, we calculated the sampling completeness ratios, which were 0.92 for both the ACE and CHAO1, and 0.94 for the JACK1 ratio; a ratio of 1 indicated complete saturation.

We calculated species richness, Simpson's Index, and Evenness. These indicated that species diversity and evenness at Government Canyon SNA were actually quite low. Potential D ranged from 1 to 18, whereas observed D was only 2.84. E_D was also quite low, with a potential value from 0 to 1 and an actual value of 0.16. These values both indicated that there were a few very dominant species in terms of abundance, and many other species recorded in very low abundance. Based on a rank-abundance analysis, it was clear that white-tailed deer were the most abundant species recorded in Government Canyon SNA; they outnumbered the second most abundant species (coyote) by six times (981 versus 152 trap events).

Finally, we analyzed the activity patterns for species with greater than eight trap events ($n = 13$ species) by percentage of photographs during dawn, day, dusk, and overnight hours (Fig. 4). The striped skunk (*Mephitis mephitis*) and nine-banded armadillo (*Dasypus novemcinctus*) were never active during the day, and the raccoon (*Procyon lotor*) was very seldom active during the day. The bird species were completely diurnal, as was the eastern gray squirrel (*Sciurus carolinensis*). The main mesopredators (bobcat, coyote, and to a lesser extent, gray fox [*Urocyon cinereoargenteus*]), which are typically more active during dawn and dusk, were active at all times of day in this study.

Individual Camera Observations—We identified white-tailed deer, the most abundant species recorded in this study, at every one of the 20 camera locations (Table 2). The next three most common species—coyote, gray fox, and feral pig—were also found throughout the southern half of Government Canyon SNA at between 80% and 85% of camera locations.

DISCUSSION—The use of camera traps to census the wildlife population at Government Canyon SNA and to establish a baseline census of abundance and distribution was proven quite effective based on the results of this study. The plateau in the observed-species accumulation curve suggested that even if additional trap-nights were allotted, additional species may not be identified and the number of trap-nights in this study was sufficient. The species accumulation curve and sampling completeness ratios suggested that the sampling design and duration were sufficient for documenting the majority of species expected at this site. In light of these numbers, the low

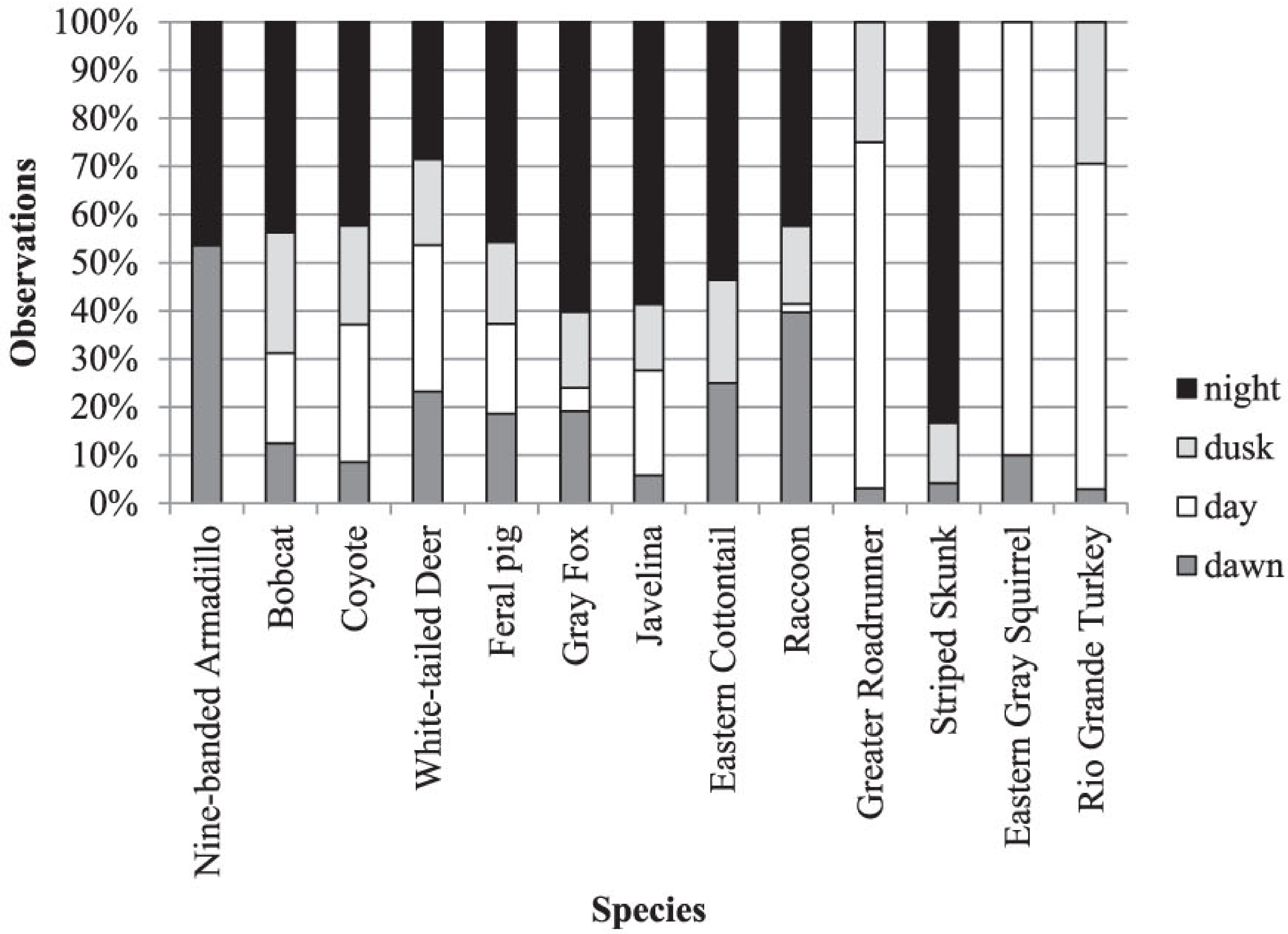

FIG. 4—Activity patterns for 13 species recorded with at least eight trap events in camera study conducted at Government Canyon State Natural Area, San Antonio, Texas, from September to December 2013.

TABLE 2—Percentage of cameras recording species occurrence in a camera-trap study, conducted in Government Canyon State Natural Area, San Antonio, Texas, from September to December 2013.

Species	Percentage of cameras recording species (20 cameras total)
Nine-banded armadillo	25%
Axis deer	5%
Bobcat	35%
Coyote	85%
White-tailed deer	100%
Feral pig	80%
Gray fox	80%
Javelina	50%
Mountain lion	5%
Porcupine	5%
Eastern cottontail	50%
Raccoon	70%
Ringtail	15%
Greater roadrunner	50%
Striped skunk	30%
Eastern gray squirrel	25%
Rio Grande turkey	15%
White-winged dove	10%

species richness, evenness and diversity indices calculated were not a byproduct of insufficient sampling design or duration.

The most common species we documented was the native white-tailed deer, which is an abundant species in the Edwards Plateau and Hill Country region of Texas. In 2000, a deer management and population trends report indicated that 1,555,000 white-tailed deer were found in the Hill Country, and this figure constituted 40% of the entire Texas deer population (Armstrong and Young, http://www.tpwd.state.tx.us). Government Canyon SNA represents the largest, intact natural area in the San Antonio region, so it may serve as a refuge for many wildlife species in the area, leading to elevated abundance. All native species captured were found within their expected range in Texas, and the two nonnative species—the feral hog and the axis deer—are well-documented in this area of Texas. Only one axis deer was documented, so there does not appear to be any management concern at this point with that exotic species.

The feral hog population, however, was very abundant; it was ranked the fourth most abundant species out of the 18 identified in this study and was documented at 16 of the 20 cameras. Three of the cameras from which it was absent were located in the eastern and western extremes of the natural area, far removed from hiking trails. The fourth location from which it was absent was on a hiking trail, but the trail was located in terrain that was more steep and rocky than many other areas in which the feral pig was present. Other areas where the feral pig was documented, but in low numbers, also corresponded with areas of Government Canyon SNA that were characterized by greater changes in elevation and rocky terrain. Based on observations, the pigs may be using many of the hiking trails for travelling, allowing them to easily spread throughout the natural area. The camera traps were an effective means to document feral pig presence and activity, recording feral pigs at all times of day; recording movement of groups with young; and recording solitary males moving alone. Studies cite feral pig densities within suitable habitat in Texas to range between 2.7 hogs/km^2 to 9.5 hogs/km^2 (Ilse and Hellgren, 1995; Gabor et al., 1999; Harveson et al., 2000). Based on these values, densities within Government Canyon SNA may be higher than many other areas in Texas.

The majority of the mammal species followed the most common activity patterns (Davis and Schmidly, 2004). Species that did not follow the published activity patterns included the bobcat, which should be primarily nocturnal; white-tailed deer, which should be primarily crepuscular; and the raccoon, which should be primarily nocturnal. The bobcat and white-tailed deer were more active during the day than what would have been expected based on published information, which may suggest the level of human disturbance was low enough in Government Canyon SNA to allow these species to be active during the day. The raccoon was active during overnight hours as expected, but it also had a high number of observations during the dawn period. Again, the low levels of human disturbance at Government Canyon SNA may have allowed the raccoon to continue foraging and moving about past the overnight hours, into dawn.

There was no apparent dominant pattern of species presence or absence among the cameras based on location or vegetation type. Cameras were placed on hiking trails, near hiking trails, and far from hiking trails; and along creek beds, in grassy fields, and in closed-canopy Ashe juniper habitats. A few general patterns were noted, however, for some species. The Rio Grande turkey (*Meleagris gallopavo intermedia*) was recorded in the open, flat grassy areas in the southern parts of the study area, and the ringtail cat (*Bassariscus astutus*) was also found in the southern parts of the study area, but in more dense, closed-canopy areas that were also steeper in topography. The javelina (*Pecari tajacu*) was also generally found in areas that were rocky and closed-canopy, but javelinas ranged throughout the study area and were not restricted to any particular region. The bobcat was found throughout the central region of the study area, avoiding the western and eastern extremes of Government Canyon SNA, but using habitat that included flat, open grasses; rocky creek beds; and closed-canopy vegetation.

In this pilot project, we documented the effective use of camera traps to census wildlife species diversity and distribution in a state natural area. The time commitment for deploying and retrieving the cameras was minimal, and three undergraduate students were successfully trained to operate and deploy the cameras and use GPS units to navigate to the predetermined camera locations. The students also successfully sorted the wildlife photos by species, with only minor confusion between some species (e.g., gray fox and coyote). As a result of this project, one undergraduate student had the opportunity to serve as a coauthor on this research project, the project data were incorporated into the course curriculum for a Wildlife Research and Management course, and one additional undergraduate student researcher became interested in learning to use the cameras and has since deployed them at another study site. These students have the satisfaction of knowing they participated in a research project to collect data that contributed to our scientific understanding of the first wildlife abundance and distribution survey for Government Canyon SNA since its founding in 2005. Our results support the use of camera traps as a management tool for providing a complete census of the wildlife population diversity, density, and distribution in managed areas; and support the use of camera traps as a simple teaching tool and research application for incorporating undergraduate students into field-based research. The methodology employed in this project can be easily extended to a citizen-scientist volunteer programs, in which citizens assist in deploying and collecting trail camera data within a broader research project conducted by a state or federal agency, as illustrated by the highly successful eMammal project being conducted by the North Carolina Museum of Natural Sciences and the Smithsonian Institute.

We would like to acknowledge the staff at Government Canyon SNA for their assistance in deploying the cameras and the use of equipment in the field. Also, we would like to thank the St. Mary's University Department of Physics and Environmental Sciences for assistance in acquiring some of the cameras used in this study.

Literature Cited

Barnes, R. 2001. How reliable are dung counts for estimating elephant numbers? African Journal of Ecology 39:1–9.

Bernard, H., A. Hamid Ahmad, J. Brodie, A. Giordano, M. Lakim, R. Amat, S. Koh Pei Hue, L. Shan Khee, A. Tuuga, P. Titol Malim, D. Lim-Hasegawa, Y. Sau Wai, and W. Sinun. 2013. Camera-trapping survey of mammals in and around Imbak Canyon Conservation Area in Sabah, Malaysian Borneo. The Raffles Bulletin of Zoology 61:861–870.

Bider, J. 1968. Animal activity in uncontrolled terrestrial communities as determined by sand transect technique. Ecological Monographs 38:269–308.

Bridges, A., M. Vaughan, and S. Klenzendorf. 2004. Seasonal variation in American black bear (*Ursus americanus*) activity patterns: quantification by remote photography. Wildlife Biology 10:277–284.

Cohn, J. 2008. Citizen science: can volunteers do real research? BioScience 58:192–197.

Colwell, R. 2013. EstimateS 9.1.0. Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, Mansfield. Available at: http://viceroy.eeb.uconn.edu/estimates/. Accessed 28 June 2014.

Cutler, T., and D. Swann. 1999. Using remote photography in wildlife ecology: a review. Wildlife Society Bulletin 27:571–581.

Davis, W., and D. Schmidly. 2004. The mammals of Texas. Second edition. University of Texas, Austin.

Dzieciowski, R. M., C. M. Clarke, and C. M. Frampton. 1992. Reproduction characteristics of feral pigs in New Zealand. Acta Theriologica 37:259–270.

Eberhardt, L., and R. Van Etten. 1956. Evaluation of the pellet group count as a deer census method. Journal of Wildlife Management 20:70–74.

Elsen, G., G. Visser-Wijnveen, R. van der Rijst, and J. van Driel. 2009. How to strengthen the connection between research and teaching undergraduate university education. Higher Education Quarterly 63:64–85.

Fashing, P., and M. Cords. 2000. Diurnal primate densities and biomass in the Kakamega Forest: an evaluation of census methods and a comparison with other forests. American Journal of Primatology 50:139–152.

Forrester, T., W. McShea, R. Kays, R. Costello, M. Baker, and A. Parsons. 2013. eMammal-citizen science camera trapping as a solution for broad scale monitoring of wildlife populations. Conference proceedings of the 98th ESA Annual Meeting, Minneapolis, Minnesota.

Friebel, B., and P. Jodice. 2009. Home range and habitat use of feral hogs in Congaree National Park, South Carolina. Human–Wildlife Interactions 29:49–63.

Gabor, T. M., E. C. Hellgren, R. A. Van Den Bussche, and N. J. Silvy. 1999. Demography, socio-spatial behavior and genetics of feral pigs (*Sus scrofa*) in a semi-arid environment. Journal of Zoology 247:311–322.

Harveson, L. A., M. E. Tewes, N. J. Silvy, J. D. Hillje, and J. Rutledge. 2000. Prey use by mountain lions in southern Texas. Southwestern Naturalist 45:472–476.

Heilbrun, R., N. Silvy, M. Tewes, and M. Peterson. 2003. Using automatically triggered cameras to individually identify bobcats. Wildlife Society Bulletin 31:748–755.

Hone, J. 2002. Feral pigs in Namadgi National Park, Australia: dynamics, impacts and management. Biological Conservation 105:231–242.

Ilse, L. M., and E. C. Hellgren. 1995. Spatial use and group dynamics of sympatric collared peccaries and feral hogs in Southern Texas. Journal of Mammalogy 76:993–1002.

Jacobson, H., J. Kroll, R. Browning, B. Koerth, and M. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin 25:547–556.

Karanth, K., J. Nichols, and S. Kumar. 2011. Estimating tiger abundance from camera trap data: field surveys and analytical issues. Pages 97–118 in Camera traps in animal ecology (A. F. O'Connell, J. D. Nichols, and K. U. Karanth, editors). Springer, New York.

Kelly, M., and E. Holub. 2008. Camera trapping of carnivores: trap success among camera types and across species, and habitat selection by species, on Salt Pond Mountain, Giles County, Virginia. Northeastern Naturalist 15:249–262.

McCallum, J. 2012. Changing use of camera traps in mammalian field research: habitats, taxa and study types. Mammal Review 43:196–206.

Nagda, B., S. Gregerman, J. Jonides, W. von Hippel, and J. Lerner. 1998. Undergraduate student–faculty research partnerships affect student retention. The Review of Higher Education 22:55–72.

Renaud, M., J. Carpenter, J. Williams, and S. Manzella-Tirpak. 1995. Activities of juvenile green turtles, *Chelonia mydas*, at a jettied pass in south Texas. Fishery Bulletin 93:586–593.

Seymour, E., A. Hunter, S. Laursen, and T. DeAntoni. 2004. Establishing the benefits of research experiences for undergraduates in the sciences: first findings from a three-year study. Science Education 88:493–534.

Silveira, L., A. Jacomo, and J. Diniz-Filho. 2003. Camera trap, line transect census and track surveys: a comparative evaluation. Biological Conservation 114:351–355.

Ugland, K., J. Gray, and K. Ellingsen. 2003. The species-accumulation curve and estimation of species richness. Journal of Animal Ecology 72:888–897.

Waithman, J. D., R. A. Sweitzer, D. Van Vuren, J. D. Drew, A. J. Brinkhaus, I. A. Gardner, and W. M. Boyce. 1999. Range expansion, population sizes, and management of feral pigs in California. Journal of Wildlife Management 63:298–308.

Watson, C. A., F. W. Weckerly, J. S. Hatfield, C. C. Farquhar, and P. S. Williamson. 2008. Presence–nonpresence surveys of golden-cheeked warblers: detection, occupancy and survey effort. Animal Conservation 11:484–492.

Submitted 21 July 2014.

Acceptance recommended by Associate Editor Troy A. Ladine, 31 October 2014.