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Evaluating Effectiveness and Cost of Time-lapse Triggered Camera Trapping Techniques to Detect Terrestrial Squamate Diversity

Recent advancements in camera trap technology have allowed researchers to explore methodologies that are minimally invasive, and both time and cost efficient (Long et al. 2008; O'Connell et al. 2010; Gregory et al. 2014; Meek et al. 2014; Swinnen et al. 2014; Newey et al. 2015). The use of cameras for understanding the distribution and ecology of mammals is advanced; however, their utility for surveying other vertebrate fauna is mostly unknown (Ariefiandy et al. 2013; Welbourne 2013; Bennetts and Clements 2014; Welbourne et al. 2015). Triggering systems using active-infrared (AIR) or passive-infrared (PIR) sensors have shown some success in reptile research, but most implementations are species-specific (e.g., Bennett and Clements 2014). Camera traps using such trigger systems to gather information across poikilothermic taxa can be limited or inaccurate under different environmental conditions (Swann et al. 2010; Rovero et al. 2013). Many of the camera traps available today can be programmed to trigger over a scheduled time interval, without relying on the use of an infra-red trigger system. Here we present the results of a time-lapse triggered camera trapping technique used to detect diurnal and terrestrial squamate species in a long-leaf pine savannah ecosystem. To determine the feasibility, effectiveness, and cost of this technique, we also compare these data with traditional box trapping data collected from these same trapping locations the year before.

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Methods

Two localities in the area known as Foxhunter's Hill in the Sabine National Forest in eastern Texas, USA, were chosen for the purpose of testing time-lapse triggered camera traps as a means to detect terrestrial squamate diversity. These localities were previously part of a long-term trapping effort by the USDA Forest Service (Rudolph et al. 2006) in which box traps with drift fences were used to capture snakes in long-leaf pine savannahs in east Texas. The original design consisted of a 121.9 × 121.9 cm plywood/hardware cloth box trap equipped with 4 funnels, positioned in the center of the array. The drift fences were constructed of 6.4 mm mesh hardware cloth, approximately 15 m in length and 61 cm in height (Burgdorf et al. 2005; Rudolph et al. 2006). Four drift fences per array were installed perpendicular to each side of the box trap, and buried 10 cm in depth (Burgdorf et al. 2005; Rudolph et al. 2006). For the purpose of this study, two box trap arrays from Rudolph et al. (2006) were opened from 27 August to 17 October 2014. The box traps were checked every 3 days during this 51-day period and all squamates were identified.

In 2015, the box traps were removed and our cameras were installed at the estimated center of each array. A RECONYX PC800™ was mounted onto a 3 m (~10 ft) piece of metal conduit buried 2 m in the ground (Fig. 1). A flexible Gorillapod™ camera tripod was used to position the camera face-down. The camera was tested and adjusted to ensure the images would contain the entire area previously covered by the box trap. The area was also raked clean of debris, both at the beginning of our testing and on visits when SD cards and batteries were replaced. Each camera used 12 Energizer Lithium Ion batteries, as suggested by the manufacturer, and was equipped with Verbatim Premium 32 gigabyte SD cards. The cameras were programmed to take an image every 30 seconds, with the assumption that a squamate

Fig. 1. An example of our camera trap design deployed in longleaf pine habitat.

Fig. 2. An example of a Coachwhip photographed in the above trap.

exhibiting normal behavior would likely move slowly across the target area. The cameras were armed from 0700 to 2100 h, for 56 days from 27 August to 22 October 2015. The SD cards and batteries of both cameras were changed once, three weeks after deployment, and then armed for five additional weeks to test how long the batteries and memory storage would last. Species, time of detection, and number of images in which an observation occurred were recorded from retrieved SD cards by examining each image taken. The time spent analyzing images was logged in hours to determine time and cost efficiency.

Results

In 2015, a total of 152 detections of six squamate species were documented on camera traps (Table 1, Figs. 1–2). An additional six detections of juvenile lizards and a single observation of a toad (Family Bufonidae) could not be identified to species, and thus were left out of the dataset. Of detected fauna, roughly 96% were lizards, with six snake observations comprising the remainder (Table 1). For comparison, box traps from the same locations opened over a similar time period in 2014 yielded a total of seven captures of three squamate species. Only snakes were captured in the box traps (Table 1). On average, all species of squamates were detected with camera traps between approximately1030 and 1400 h, although the range of detections for all species was from 0700 to 1921 h. The temporal detection window for snakes was slightly narrower than for lizards, but there was considerable overlap in the detection window across species of both lizards and snakes (Table 1). Two lizard species had a single individual that was detected in consecutive pictures, but no snakes were detected in consecutive pictures.

Both cameras operated without error, despite multiple rain events and numerous days with windy conditions. All three site visits were completed in 2 h, with the majority of time contributed to deployment. After three weeks of trapping, both cameras still had SD cards with available memory and battery power. After five weeks of trapping, the SD card memory of camera 2 was full; however, the batteries on both cameras still had sufficient life. Labor was heavily weighted towards analyzing the images. Total time analyzing the 166,840 images captured during the entire experiment was roughly 25 h. An average of 1.5 person hours was needed per 10,000 images.

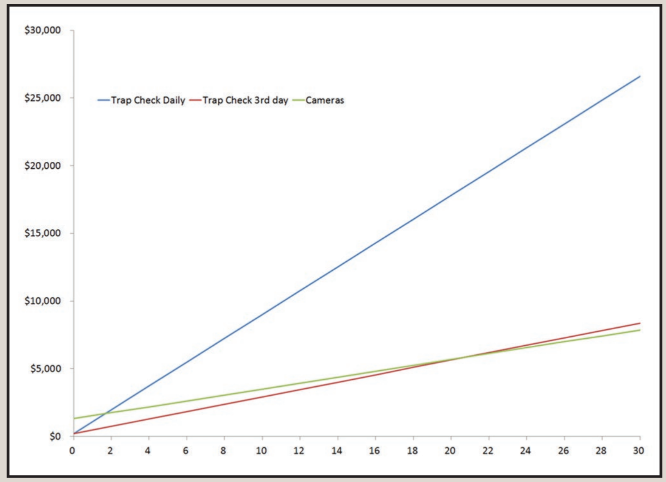

Fig. 3. Cost comparison between traditional box trapping with daily trap checking (blue), trap checking every 3rd day (red), and time-lapse triggered camera trapping methods (green) over a 30-month study timeline. The cost of camera trapping methods over time (slope) is less than traditional box trapping methods with daily and 3-day trap checking.

This battery, digital storage, and labor information was used to calculate a cost comparison between traditional box trapping and time-lapse triggered camera trapping methods over an equal time period of 56 days (Table 2). For the camera trapping calculations, a four-week (28-day) trapping cycle was assumed to be optimal, because the data suggested a three-week cycle was too short and a five-week cycle too long under the current time-lapse trigger schedule. Equipment and supply costs represent the actual costs for each method; however, the cost of equipment that would be required for both trapping methods (e.g., drift fences and stakes) was not included. For the purpose of comparison, personnel wages were assumed to be equivalent for both methods, and a standard government travel rate was used.

The start-up and maintenance costs of equipment and supplies were much larger for camera trapping than box trapping (US $1310 vs. $200, respectively). Personnel costs varied for the box trapping method depending on whether traps needed to be checked daily (US $870) or every three days (US $285). Time needed for data entry was assumed to be equal for both trap checking schedules. Personnel costs for the camera trapping method (US $405) fell in between costs of daily and every third day box trap checking schedules. Travel costs also varied for the box trapping method depending on whether traps needed to be checked daily (US $891) or every 3 days (US $259), and both of these costs were greater than the travel costs of camera trapping (US $32). The total cost of camera trapping ($1,747) was less than the total cost of box trapping on a daily schedule (US $1,961), but that relationship reversed when box traps were checked every third day (US $744).

Discussion

Our study showed that time-lapse triggered camera trapping in conjunction with drift fences can be an effective technique for detecting diurnal, terrestrial squamate diversity. On a 30-sec trigger schedule from 0700 to 2100 h, the time-lapse camera traps detected twice as many squamate species (N = 6) as the

Table 1. Total detections by species from 166,840 images taken using time-lapse triggered RECONYX PC800TM camera traps deployed in Foxhunter's Hill (Sabine National Forest) from 27 August to 22 October 2015. To compare sampling methods, box trap captures at the same sites are also reported from the year before, 27 August to 17 October 2014.

			Camera trap detections per species (2015)			Consecutive detections	
Common name	Scientific name	Box trap captures (2014)	N	Mean Time	Time Range	Once	Twice
Green Anole	*Anolis carolinensis*	0	28	1056	0820–1634	27	1
Prairie Lizard	*Sceloporus consobrinus*	0	96	1337	0700–1921	95	1
Six-lined Racerunner	*Aspidoscelis sexlineata*	0	21	1405	0943–1724	21	0
Coal Skink	*Plestiodon anthracinus*	0	1	1147	1147	1	0
All Lizards		0	146	1236	0700–1921	144	2
Coachwhip	*Coluber flagellum*	5	5	1351	1159–1608	5	0
Cottonmouth	*Agkistrodon piscivorus*	0	1	1041	1041	1	0
Copperhead	*Agkistrodon contortrix*	1	0	-	-	-	-
Corn Snake	*Pantherophis guttatus*	1	0	-	-	-	-
All Snakes		7	6	1216	1041–1608	6	0
All Species		7	152	1230	0700–1921	150	2

Table 2. Cost comparison between traditional box trapping and time-lapse triggered camera trapping methods over an equal time period of 56 days. The cost of equipment that would be required for both trapping methods (e.g., drift fences and stakes) was not included. Prices shown in US dollars.

	Box Trapping	Cost ($)	Camera Trapping	Cost ($)
Equipment and Supplies	2 Hardware Cloth Box Traps	180	2 ReconyxTM PC800 Camera Traps	1100
	2 Refuges/Water Dishes	20	4 Premium SD cards (32G)	60
			2 Metal conduit poles (3m)	5
			2 GorrillapodTM Camera Tripods	70
			48 AA Lithium Ion Batteries	75
Personnel				
($15 per hour)	Trap check daily or every 3 days		Trap check every 28 days	
	55 or 16 one-hour trips	825 or 240	2 one-hour trips	30
	3 hours of data entry	45	25 hours of data processing	375
Travel				
($0.54/mile)	55 or 16 thirty-mile trips	891 or 259	2 thirty-mile trips	32
	Total	$1,961 or $744	Total	$1,747

traditional box traps (N = 3) over a similar time period. This difference in species richness between methods was driven by a lack of lizard detections in the box traps, most likely due to escape. Alternatively, with regard to snake species, the two methods yielded similar results with the box traps detecting just one more species than the camera traps (N = 3 vs 2, respectively). Two species, the Copperhead (*Agkistrodon contortrix*) and Corn Snake (*Pantherophis guttatus*), were only detected in the box trap, and one species, the Cottonmouth (*Agkistrodon piscivorus*), was only detected in the camera trap. This small difference in snake species richness and species identity between the two methods could be explained by hours of operation. The box traps were open during both day and night hours, whereas the cameras were operational during day-light hours. As such, it is not surprising that diurnal snakes like Coachwhips (*Coluber flagellum*) were detected in equal numbers by both methods and more snakes that tend to be nocturnally active were detected in the box traps.

While this study demonstrated that the time-lapse triggered camera trapping technique can be effective at detecting diurnal, terrestrial squamate diversity, it also illustrated some limitations of this technique. Start-up equipment and supply costs were much higher than for traditional box trapping, as specialized game cameras were not cheap (Table 2, Kays and Slauson 2008). This presents another potential problem as these cameras can be subject to a higher likelihood of theft, especially given the current demand of this technology for a variety of other applications. The loss of data due to theft could be detrimental to the outcome of a project. However, according to our cost comparison between the two methods, the high start-up cost of camera trapping was offset by the large personnel and travel costs associated with checking box traps on a daily schedule. Indeed, trapping arrays that are spread out geographically in other studies or that are located far from housing will increase travel and personnel costs for box trap checking and therefore favor the camera trapping technique, which requires fewer trap checking trips overall. The cost comparison also indicated that travel and personnel costs for box trap checking can be minimized if box traps are checked less frequently, but fewer trap checks would also yield less precise data (e.g., capture date), and could result in higher trap mortality rates for both target and non-target species and higher escape rates (Burgdorf et al. 2005). In addition, the financial gain from offsetting high labor and travel costs with reduced box trap checking erodes over longer study timelines. For example, if the costs of these different trapping methods are calculated over a 24-month study timeline, which is probably typical for most herpetological surveys, then the camera trapping technique becomes the least expensive overall (Fig. 3).

Limits also exist in the type of data that can be collected with this technique. Using this camera trapping approach, in which animals are never in-hand, means that morphological data, mark/recapture data, and genetic data cannot be taken. Alternatively, there are also types of data that can be collected with the camera trapping approach that cannot be taken with traditional box trapping methods. As described above, this camera trapping technique allowed multiple taxa to be detected compared to traditional trapping methods, which sometimes miss smaller species, due to taxon-specific trap designs (but see below; Kays and Slauson 2008). Additionally, images taken with the camera traps feature date and time stamps as well as moon phase and an ambient temperature reading at the time of detection. Direction of movement of individuals can also be inferred from camera images.

Another limitation of this technique is that species identification or detection from camera imagery is still restricted to larger individuals of lizards and snakes (Meek et al. 2014). For example, juvenile lizards were detected and identified while analyzing the data, but we observed instances in which a positive identification of a juvenile lizard could not be made. Obvious trade-offs occur between having the ability to focus on smaller individuals, while maintaining a large field of view. Although the camera apparatus could be adjusted to easily detect and identify juvenile lizards, these changes could create difficulties in detecting and identifying other squamate species that might pass quickly through or simply miss a smaller field of view. For example, out of the 152 total individuals detected in this study, only two individuals, a Green Anole (*Anolis carolinensis*) and a Prairie Lizard (*Sceloporus consobrinus*), were detected in consecutive images. This indicates that all other individuals, including all the snake species detected, were moving through the camera's field of view in less than 30 seconds. Shrinking the field of view effectively reduces this temporal window of detectability for individuals moving under camera and would therefore decrease the detection probability for most species observed in this study. In a similar way, increasing the time-lapse interval will also decrease the detection probability for most species observed in this study. A doubling of the interval time to one minute will reduce the number of pictures taken by one-half, which probabilistically should also decrease the number of individuals detected by approximately one-half. As this time-lapse camera trapping technique is used more frequently in a variety of studies, it will be important to use the data gathered to develop detectability profiles for each species that describe the field of view and time-lapse intervals necessary to detect certain species based on their size, skin pattern, rate of movement and other behaviors. These detectability profiles will be most beneficial to future studies targeting specific species for long-term monitoring.

In summary, this time-lapse triggered camera trapping technique can provide a less intrusive and cost-effective alternative to traditional trapping methods, especially for research applications requiring species detection only (Long et al. 2008; O'Connell et al. 2010; Meek et al. 2014; Newey et al. 2015). Time-lapse triggered camera trapping is less intrusive than traditional trapping methods, because it minimizes, or prevents, problems associated with traditional trapping methods involving the physical capture of squamate species. These include trapping influenced behavior (trap shyness), unwanted predation events, and trap mortality from unforeseen changes in weather conditions (Fogarty and Jones 2003). In addition, this technique is less intrusive for landowners if surveying on private lands. When using traditional trapping methods to survey private lands, field technicians would be required to check traps every 1–3 days, while the camera trapping technique requires only monthly visits. Thus, this technique minimizes the number of interactions with private landowners and also the time and money required for technicians to be in the field checking and maintaining traps (Kays and Slauson 2008; Long et al. 2008). For research applications that require data collected from animals in-hand (e.g., morphology, mark/recapture, genetics), we suggest that this time-lapse triggered camera trap might be used initially to establish presence and to characterize the target species detectability profile, and then replaced by a traditional box trap for efficient species capture.

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