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COMPARISON OF MOTION-ACTIVATED CAMERAS FOR WILDLIFE INVESTIGATIONS

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Motion-triggered cameras are useful in wildlife investigations but quantitative metrics derived from photographs potentially include substantial error. We compared six models of cameras placed side-by-side at a small spring in Mojave National Preserve, California, for 63 days in the spring of 2006, and for 40 days in the fall of 2007. Total number of different species detected varied by camera from 2 to 14 in the first trial and from 1 to 6 in the second. Total number of wildlife photographs taken by each camera ranged from 18 to 348 in the first trial and from 0 to 95 in the second. Photographic rates of a single species, mule deer (*Odocoileus hemionus*), differed by as much as 100% between two units of the same camera model. We did find, however, that the distribution of time intervals between photographs of mule deer was similar for different cameras. These results indicate that photographic rates and number of species detected by motion-triggered cameras can vary significantly even for identical models placed side by side, and have important implications regarding the interpretation of such data across areas.

Key words: camera traps, Mojave Desert, mule deer, *Odocoileus hemionus*, remote photography

INTRODUCTION

Remotely operated or automated cameras (camera traps) have become inexpensive, useful tools for conducting wildlife investigations. Camera traps can be used to provide photographic evidence of species presence (Foresman and Pearson 1998), population estimates (Azlan and Sharma 2003, Maffei et al. 2004, Marshal et al. 2006), information on activity patterns (van Schaik and Griffiths 1996, McCullough et al. 2000), predation (Leimgruber et al. 1994, O'Brien et al. 2003), body condition (Marshal et al. 2006, Marshal et al. 2008), and feeding ecology (Miura et al. 1997; Otani 2001, 2002; Pierce et al. 1998). Still cameras can be set for specified time-lapse photography, triggered mechanically, or triggered by an infrared sensor. Time-lapse photography, where photographs taken are independent of presence of animals, can be used for evaluation of population parameters (e.g., Jaeger et al. 1991) and comparisons of resource utilization (e.g., Bleich et al. 1997). Video systems that record continuously over an interval are capable of capturing images of all animals that come within a field of view (O'Brien et al. 2006). Triggered photographs, however, are not independent of the target animal and resulting variability in detection probability complicates quantitative analysis.

Several authors (Carbone et al. 2001, Carbone et al. 2002, Jennelle et al. 2002, Yasuda 2004) have used photographic rates from animal-triggered camera traps as an index to abundance, density, or diversity. In a review of the use of remote photography for wildlife ecology, Cutler and Swann (1999) cautioned against using photographic rates or numbers of photographs from animal-triggered cameras as indices because of the difficulty in resolving multiple photographs of a single animal, or group of animals, and variation in detectability. Further, Swann et al. (2004) compared 6 models of infrared-triggered cameras using 3 sizes of animal models and reported that the variability between models ranged from 17% to 77% detections per total number of trials.

We began using infrared-triggered cameras in 2004 to detect wildlife at water sources and noticed high variability in the numbers of photographs between different models of cameras. At that time, our objectives were to investigate the species using these water sources (e.g. an index to biodiversity) and how this use varied (i.e., a measure of comparison) among those sources. In an effort to assess the reliability of our camera array for documenting wildlife use of water sources, we conducted two separate tests of several different infrared-triggered camera systems at a small spring. We compared numbers of photographs taken, number of species detected, and the time intervals between photographs of mule deer (*Odocoileus hemionus*) among those cameras when the cameras were run simultaneously. The intent of this side-by-side comparison was to guide the purchase of additional and replacement equipment in order to obtain consistent data from cameras deployed at springs. Although time intervals between photographs appeared to be the better metric, our results can be viewed as a cautionary note to others regarding attempts to quantify results from motion-activated camera systems.

METHODS

We conducted two separate trials operating six different camera models placed side by side and aimed at a small spring in Mojave National Preserve, San Bernardino County, California (35° 17.9' N x 115° 32.0' W). Seepage from a spring box created a zone of green vegetation encompassing an area less than 20 m^2 near the spring, and provided a small amount of surface water restricted to an area of less than 1 m^2. For the first trial we attached 7 cameras of four different models (2 Wildlife Pro [Forestry Suppliers, Inc., Jackson, Mississippi], 2 Leaf River Digital Trail Scan [Leaf River Outdoor Products, Taylorsville, Mississippi], 2 Cuddeback 3.0 Digital [Non Typical, Inc., Green Bay, Wisconsin], and 1 Reconyx Silent Image [RECONYX, Inc., Holmen, Wisconsin]) to a fence equidistant (3 m) from the water source at a height of 1 m. All cameras were aimed directly at the water source. We activated the cameras on 10 February 2006 and operated them continuously until 14 April 2006 for a total of 63 days.

For the second trial, we drove steel posts into the ground in a semi-circle and mounted 10 cameras of six different models (2 Wildlife Pro, 2 Leaf River Digital Trail Scan, 2 Cuddeback 3.0 Digital, 2 Cuddeback Expert 3.0 Digital [Non Typical, Inc., Green Bay, Wisconsin], 1 Reconyx Silent Image, and 1 Stealth Cam [Stealth Cam, LLC, Grand Prairie, Texas]) so that each camera was equidistant (4.5 m) from the water source and aimed directly at the water source. We activated the cameras on 8 November 2007 and operated them continuously until 18 December 2007 for a total of 40 days. All cameras used in both trials were set to photograph detections at a maximum rate of one per minute.

In the first trial we attached cameras to a fence facing the spring towards the southeast. For the second, we installed posts so that the cameras faced the spring towards the northeast so that glare was minimized. We placed cameras of the same model in adjacent pairs; cameras were placed in no particular order, but were not explicitly randomized. Spacing between cameras (1 m) was approximately uniform. We installed fresh batteries at the beginning of the trials, checked them periodically, and replaced batteries when the charge dropped below 50%.

The cameras used in this comparison all implement a passive infrared motion sensor that detected heat radiated from the body of an animal moving across the field of view. A group of radiation sensors coupled through amplifiers and a logic circuit detected changes in ambient infrared radiation and triggered the camera. Although the technical details of most commercially available trail scouting cameras are not provided by the manufacturer, we conducted field tests prior to placing the cameras and noted variability in range, field of view, and sensitivity. As a result, we set models with a jumper setting or internal programmable sensitivity setting, such as the Cuddeback models, on the highest setting. We set those models with detector sensitivity adjustable over a range, such as the Leaf River and Reconyx Silent Image models, at the highest setting that did not produce repeated false detections, as determined by trial and error.

We compared the number of wildlife photographs against the number of blank photographs—those not showing what triggered the camera—both within models and among models using the Chi-square statistic. We estimated the total number of events during the sampling period by subject and time stamp of all photographs, where an event was defined as an animal or group of animals entering the camera detection zone and being recorded by at least one camera. We compared number of species detected by different cameras graphically as a function of time. We compared distributions of time intervals between sequential photographs of mule deer using a Kruskal-Wallis statistic after omitting intervals of less than 30 minutes. Mule deer typically did not remain at the water source longer than 30 minutes, and shorter intervals tended to be repeated photographs of the same animal or group of animals during a single visit.

RESULTS

First Comparison Test

Fourteen species and 402 total events were detected at Kessler Spring during 10 February through 14 April. Most photographs were of cottontail rabbit (*Sylvilagus audubonii*) and mule deer, with fewer photographs of Gambel's quail (*Callipepla gambelii*), coyote (*Canis latrans*), bobcat (*Felis rufus*), and common raven (*Corvus corax*). Several birds, such as mourning dove (*Zenaida macroura*), turkey vulture (*Cathartes aura*) and great-horned owl (*Bubo virginianus*) were also photographed, as were numerous smaller species.

Variation in events recorded between camera models was substantial (Table 1). Although the black and white images from the Reconyx Silent Image are of poor quality, that model camera took many more photographs than any of the others, thereby allowing us to identify 14 different species that made use of the spring. At the other extreme, one of the two Wildlife Pro film cameras detected only mule deer or coyote. Another identical model of the Wildlife Pro, however, captured > twice as many images and detected > 4 times as many species. Both of the Cuddeback models detected mule deer, bobcat, coyote, and raven, but no smaller birds. One of the two Cuddeback cameras, however, did photograph a chukar (*Alectoris chukar*) in the same image as a jackrabbit and also photographed a great-horned owl drinking from the spring that was missed by the other cameras. Both of the Leaf River Digital Trail Scan models recorded 4 species, but only two of the four species were the same. The Leaf River cameras recorded the highest percentages (34% and 57%) of photographs with no wildlife, apparently the result of a delay between the trigger mechanism and camera operation.

Table 1. Summary of photographs obtained by 7 remote cameras at Kessler Spring, Mojave National Preserve, San Bernardino County, 10 – 14 February, 2006. SI = Reconyx Silent Image, WP = Wildlife Pro, CB = Cuddeback 3.0 Digital, and LR = Leaf River Digital Trail Scan. Numbers in parentheses indicate different units of the same model.

Camera	Number of photos	People, vehicles	Blank	Wildlife	Number of species	Percent of species	Percent of total events
SI(1)	462	14	100	348	14	100.0	86.6
WP(2)	58	4	4	50	9	64.3	12.4
CB(2)	75	6	12	57	7	50.0	14.2
CB(1)	44	4	7	33	4	28.6	8.0
LR(2)	81	9	46	26	4	28.6	6.5
LR(1)	65	18	22	25	4	28.6	6.0
WP(1)	25	5	2	18	2	14.3	4.5

Comparison of blank photographs to those containing wildlife for each model of camera indicated the most consistency within models for Cuddeback and the least consistency for Leaf River (Wildlife Pro $X^2 = 0.132$, $P = 0.717$, $df = 1$; Leaf River $X^2 = 3.39$, $P = 0.066$, $df = 1$; Cuddeback $X^2 = 0.002$, $P = 0.988$, $df = 1$). For all seven cameras there was no consistency in the number of blank photographs versus wildlife photographs ($X^2 = 84.5$ $P < 0.001$, $df = 6$).

Species detected by each camera as a function of time (Figure 1) tended to level off for different cameras at different numbers of species detected, ranging from 2 to 14. The only species detected by all seven cameras was mule deer, and intervals between photographs of that species were recorded by all cameras in a similar pattern (Figure 2).

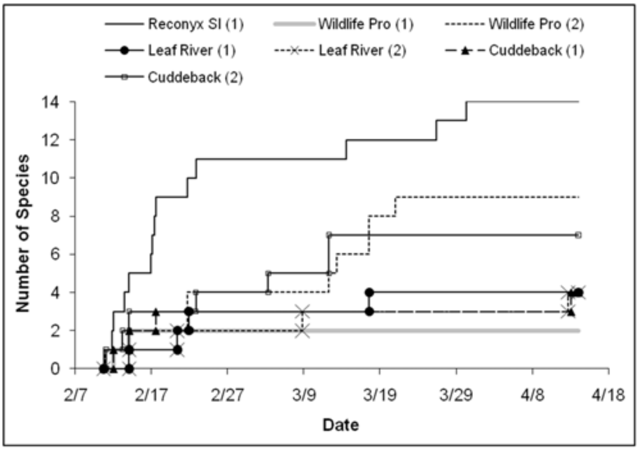

Figure 1. Species were detected at different times by different cameras. Each line representing a camera increased by an increment of 1 at the time that camera recorded a previously undetected species. Cameras appear to be converging on a different total number of species for the sampling period.

Second Comparison Test

During the second trial one of the 2 Cuddeback Expert cameras [CE(2)] photographed numerous small birds of 6 species. Nevertheless, it failed to detect mule deer even though deer visited the spring on at least 5 occasions and were detected by each of the other cameras. The Cuddeback Expert that did photograph the mule deer [CE(1)] failed to detect most of the small birds. Although the Reconxy SI detected most of the small birds, resulting black and white images were of low resolution and did not permit identification of individual species.

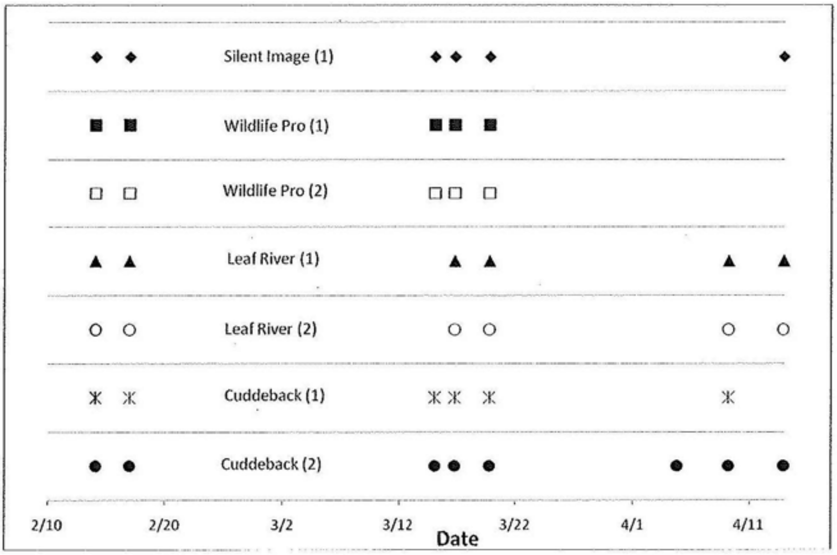

Figure 2. Photographs of mule deer from the first comparison test show generally good agreement on periods of visitation. The first period (14, 16 February) was detected uniformly by all seven cameras. The Leaf River cameras missed the first arrival of the second visitation period (15 March) but recorded the next two visits (16, 19 March) along with the rest of the cameras. The third period of visitation (4, 9, 13 April) was missed by both Wildlife Pro cameras, while results of the remaining five cameras were variable.

Mule deer visited the spring five times according to the combined results of the 8 cameras that detected mule deer; none of the cameras, however, recorded all five events. Only two cameras agreed on the number and days of mule deer visits. One of the cameras [WP(3)] that took only two photographs of wildlife captured one of the mule deer visits, which was missed by all other cameras except two [CE(1) and WP(4)].

Comparison of photographs containing wildlife to photographs with no observable subjects (Table 2) demonstrates little consistency within cameras of the same model (Wildlife Pro $X^2 = 1.56$, $P = 0.212$, $df = 1$; Leaf River $X^2 = 0.041$, $P = 0.949$, $df = 1$; Cuddeback $X^2 = 1.11$, $P = 0.292$, $df = 1$; Cuddeback Expert $X^2 = 0.767$, $P = 0.381$, $df = 1$) and no consistency between models ($X^2 = 56.0$, $P = 0$, $df = 8$). Further, one of the cameras captured no photographs of wildlife. When compared to the results of the first experiment, within-model consistency was reversed.

Table 2. Summary of photographs obtained by 10 remote cameras at Kessler Spring, 8 November – 18 December 2007. CE = Cuddeback Expert 3.0 Digital, SI = Reconyx Silent Image, CB = Cuddeback 3.0 Digital, LR = Leaf River Digital Trail Scan, WP = Wildlife Pro, and SC = Stealth Cam. Numbers in parentheses indicate different units of the same model.

Camera	Number of photos	People, vehicles	Blank	Wildlife	Number of species	Percent of species	Percent of total events
CE(2)	178	7	112	59	6	100	57.8
SI(2)	568	92	381	95	4	66.7	48.9
CE(1)	46	9	27	10	3	50.0	11.1
CB(4)	17	8	1	8	2	33.3	6.7
CB(3)	13	7	2	4	2	33.3	4.4
LR(3)	36	4	27	5	2	33.3	2.2
WP(4)	10	6	0	4	1	16.7	3.3
LR(1)	11	5	5	1	1	16.7	2.2
WP(3)	5	2	1	2	1	16.7	1.1
SC	20	5	15	0	0	0	0

Mule Deer Intervals

The regularity of visits by mule deer (Figure 2) suggests that the intervals between photographs potentially provide a quantitative comparison of spring visits by mule deer despite variability among cameras. All seven cameras in the first trial captured visits on 14 and 16 February and again on 16 and 19 March. Visits were variably recorded by different cameras 15 March and 4, 9, and 13 April (Figure 2). Many of the intervals between photographs were one to four minutes apart, and a single group of animals tended to trigger the cameras several times. The next shortest intervals ranged from 31 to 35 minutes which, based on qualitative examination of the photographs, is about the maximum length of stay per visit for mule deer at this spring. Four of the cameras recorded 6 intervals between successive photographs that were greater than 30 minutes, 2 recorded 5, and one camera recorded 8 such intervals. After dropping intervals of less than 30 minutes, a Kruskal-Wallis statistic ($H = 2.0$, $P = 0.92$, $df = 6$) indicated no difference in these distributions among the cameras. Despite the small sample size, this result suggests that the distribution of intervals may be less variable than either total number of photographs recorded, or total number of species, and may be a potentially useful metric for assessing water source visitation by mule deer.

DISCUSSION

It was our initial assumption that motion-activated wildlife cameras photograph all medium to large-sized mammals that come within the field of view and range of the camera's motion sensor. One of the more sensitive models, however (as indicated by numerous photographs of small birds) failed to photograph a mule deer that appeared to pass squarely within its field of view. At the same time both of the Wildlife Pro cameras, which overall appeared to be much less sensitive, photographed that animal. One of the Wildlife Pro cameras took only two wildlife photographs during the entire 40-day sampling period, and both were of this mule deer.

Significant variability between different models of cameras was apparent prior to initiating this field test. The Reconyx Silent Image incorporates a passive infrared motion sensor with the greatest sensitivity and widest detection zone. This high sensitivity, however, makes the camera more susceptible to false triggers, and necessitates that trial and error be used to adjust sensitivity. The poor quality images recorded by this model also made identification of small birds difficult. The passive infrared sensor of the Wildlife Pro system was less sensitive than the other models and, even after confirming the setup using the walk-test function, failed to detect the technician while moving within the detection zone.

Small variations in camera orientation appeared to influence results. The two Cuddeback Expert 3.0 Digital cameras would be expected to produce similar results, but one recorded 59 photographs of birds and no mule deer while the other, with the same orientation and focus, took only 6 photographs of birds but captured 4 photographs of mule deer. Comparing the photographic rate of small birds between these identical cameras shows a difference of 90% (calculated as the difference in number of photographs taken by the two cameras, divided by the larger number, multiplied by 100) while the difference in comparing the photographic rate for mule deer was 100%.

We had also assumed that by leaving cameras activated at springs for a long period we would eventually detect all species visiting the spring. Results (Figure 1) suggest, however, that each camera tended to stabilize at a different number of species detected. For example, one Wildlife Pro camera went 59 days without detecting any additional species while, over the same period and at the same location, an identical Wildlife Pro camera recorded 7 additional species. Compared to the number of species detected by the Reconyx Silent Image, the other cameras ranged from 36% to 86% fewer species detected.

Motion-activated cameras have provided much useful information to wildlife biologists, and have been integrated into many field investigations. Whether quantitative comparisons are possible, or if information is limited merely to species detection, date, time, and location, remains in question. Differences between various camera models, and even between different units of identical models, indicate the potential for substantial variability in the number of photographs recorded and number of species detected. The distributions of time intervals between photographs of mule deer may be comparable between camera models given a sufficient number of photographs and an estimate of the time period typically spent at a location, but the potential for significant error exists in quantitative analysis of photographic records using infrared motion-triggered cameras.

Our results showed an even greater disparity between the different systems than reported by Swann et al. (2004), as well as significant differences between units of the same model. Even the cameras that recorded many more wildlife failed to detect animals that were photographed by cameras that recorded many fewer overall detections. Investigators using animal-triggered cameras should be aware of variable detection success inherent in this technology. Additional studies are needed to determine if periodically relocating equipment among sites would reduce this potential bias.

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