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Tools and Technology

Identifying Performance Differences Among Trail Cameras Used to Monitor Forest Mammals

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ABSTRACT As a result of the increasing popularity of remotely triggered (trail) cameras among hunters, amateur naturalists, and field biologists, a large variety of equipment and technologies have become available. Among various models of cameras, such features as the size of detection zone, trigger speed, and sensitivity of infrared-motion detector can influence performance, including animal detection rates. Variation in detection (or photographic) rates among cameras may be problematic in studies where several models of cameras are used, especially when performance differences are not incorporated in the study design. To evaluate this potential source of sampling bias, we conducted head-to-head field trials with 2 cameras (Cuddeback™ Capture IR and Reconyx™ HC 600 Hyperfire) that had substantially different attributes that can affect sampling efficiency. Among initial comparisons, we found that Reconyx cameras (large detection zone and high-sensitivity motion detector) recorded approximately twice as many independent photographs as did the paired Cuddeback cameras. In subsequent trials, we reduced the sensitivity of the motion detector on the Reconyx cameras and positioned a wooden stake with bait in the center of the immediate detection zone of both cameras. These adjustments reduced performance differences between the 2 cameras. We recommend that biologists involved with research, inventory, or monitoring programs that rely on more than one model of trail camera consider a testing phase where they can evaluate and possibly adjust differences among cameras.

KEY WORDS forest mammals, remotely triggered camera, sampling bias, trail camera.

The fast pace of performance advances among remotely triggered (trail) cameras has prompted widespread application of this technology to address a variety of natural history questions and conservation concerns (O'Connell et al. 2011, Ancrenaz et al. 2012, Meek et al. 2012). Trail cameras can provide a cost-effective, non-invasive approach for determining the distribution or activity of target species, often when alternative methods may be far less practical (reviews by Cutler and Swann 1999). Trail cameras may be especially useful for investigating species that are solitary, extremely mobile, and occur at low densities (Balme et al. 2009). In addition to documenting presence (e.g., Cain et al. 2003), trail-camera photographs have been used with conventional capture–recapture models to estimate density (e.g., Heilbrun et al. 2006) and identify habitat associations of specific species (Di Bitetti et al. 2006, Kelly and Holub 2008). Trail cameras are also an effective tool to monitor responses to management actions (Bengsen et al. 2011) and potential consequences of climate change, land-use activities, or encroachment by invasive organisms (Kays et al. 2009).

As with any sampling device, variation in efficiency among cameras (photographic-detection rate) may introduce an unintended source of error. Using 6 different camera models and simulated animal bodies, Swann et al. (2004) found that detection rates among different cameras ranged from 17% to 77% of experimental encounters. Several parameters can affect detection rates, including camera position, trigger speed (time between an animal walking into the detection zone and a picture being recorded), and sensitivity of infrared-motion detector (Swann et al. 2004). Variation in detection may be problematic if photographs are used to index population size (e.g., Bengsen et al. 2011) or species richness (e.g., Li et al. 2012). In these situations, using one model of camera may limit the variation associated with camera performance (but see Damm et al. 2010). However, in large-scale inventories or monitoring projects where more than one model of camera is deployed (e.g., Erb et al. 2012), unexplored variation in camera performances may yield an inaccurate representation of the population or community being studied.

To further examine the potential problems associated with variation in camera detection rates and explore possible solutions, we compared 2 camera models with substantially different features that can affect performance. First, we evaluated how detection rates of forest mammals varied by different camera models. We then modified our deployment

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protocol in an effort to reduce performance differences between the cameras and compared results.

STUDY AREAS

Camera-sampling stations were distributed in portions of Cheshire County in the southwestern and Strafford County in the southeastern portion of New Hampshire, USA. Dominant overstory species in both areas included eastern white pine (*Pinus strobus*), eastern hemlock (*Tsuga canadensis*), red maple (*Acer rubrum*), American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), and sugar maple (*A. saccharum*). Topography was moderately rugged with elevation reaching 965 m above sea level in the southwest and rolling hills to coastal plain in southeastern New Hampshire. Average annual temperatures were $-6°C$ in the winter and $15°C$ in the summer (NOAA 2011). We expected to detect a variety of mammals, including eastern chipmunks (*Tamias striatus*), red squirrels (*Tamiasciurus hudsonicus*), eastern gray squirrels (*Sciurus carolinensis*), weasels (*Mustela* spp.), snowshoe hares (*Lepus americanus*), beavers (*Castor canadensis*), striped skunks (*Mephitis mephitis*), feral house cats (*Felis catus*), opossums (*Didelphis virginiana*), raccoons (*Procyon lotor*), fishers (*Martes pennanti*), gray foxes (*Urocyon cinereoargenteus*), red foxes (*Vulpes vulpes*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), black bears (*Ursus americanus*), white-tailed deer (*Odocoileus virginianus*), and moose (*Alces alces*).

MATERIALS AND METHODS

Camera Deployment

We selected 2 cameras that differed in major component features that would likely affect photographic rates (Table 1), specifically Cuddeback™ Capture IR (Non Typical, Inc., Park Falls, WI) and Reconyx™ HC 600 Hyperfire (Reconyx, Inc., Holmen, WI). Cameras were examined in the field to verify that they were in working condition, but we did not evaluate performance differences between cameras of the same model. To conduct head-to-head comparisons, we strapped one of each model of camera to a wooden frame to ensure that both cameras were at the same height, pointed in the same direction, and pointed at the same angle (Fig. 1). We selected sampling sites that were near existing forest openings or game trails to ensure a clear detection zone. Frames were secured to the base of a tree (approx. 30 cm above the ground) using a ratchet strap.

Initial protocol.—Our initial sampling bouts were intended to reveal the extent of detection differences between models of cameras. Once a pair of cameras was secured to a tree, coyote urine was used as an attractant and liberally sprayed in the estimated detection zone of both cameras. No additional baits or scents were used. Sensitivity of the passive infrared detectors (PIR) was set at "high" on all Reconyx cameras and no adjustment was possible among Cuddeback cameras. Using this protocol, 6 pairs of cameras were deployed for 7–9-day trials in October and November 2010.

Modified protocol.—Subsequent camera deployments included several modifications. First, we positioned a wooden stake approximately 3 m directly in front of both cameras. Once the stake was driven into the ground, we attached a domestic chicken leg to it using a plastic zip tie. Our intent was to have animals spend time in the detection zone of both cameras, thus increasing probability of detection. We then distributed a commercial gland lure (e.g., Caven's Gusto Lure; Cumberland's Northwest Trappers Supply, Inc., Owatonna, MN) and commercial canned cat food or oil-soaked sardines in the immediate area. During these trials, we also varied sensitivity of the PIR among Reconyx cameras by using "high," "medium–high," "medium," and "low" settings. Cameras were deployed for 7–9-night sampling bouts in October–December 2011 and February–April 2013. We conducted all field procedures in accordance with University of New Hampshire Institutional Animal Care and Use Committee (Protocol 110903).

Data Analysis

For individual cameras, photographic detections of a species were considered independent if they were separated by ≥ 30 min from subsequent photographs of the same species, indicated by a date and time stamp on each photograph (Silver et al. 2004, Kelly and Holub 2008). For specific trials, independent photographs were tallied for each camera model and detection rates (no. of independent photographs) between camera models were compared using a Chi-square goodness-of-fit test (Zar 1999). The expected number of photographs was based on sampling effort of each camera model during the trial, similar to the approach used to evaluate efficiencies of different small-mammal traps and baits (e.g., Sealander and James 1958, Woodman et al. 1996). We only used detections when both cameras in a pair functioned during the entire sampling bout. To further evaluate detection differences between cameras and field configurations, we grouped mammals by body-size classes.

Table 1. Attributes of trail cameras used in head-to-head field trials to document presence of forest mammals in southern New Hampshire (USA) during 2010–2013.

Attributes[a]	Cuddeback Capture IR™	Reconyx HC 600 Hyperfire™
Horizontal detection angle (degrees)	14	40
Detection range (m)	11.0	30.5
Detection area (m^2)	14.7	324.3
Trigger speed (s)	0.55	0.19
Sensitivity of passive infrared detector	Fixed	Variable: low, medium–low, medium, medium–high, high settings

[a] Camera attributes supplied by manufacturer or www.trailcampro.com (accessed 5 Apr 2011).

Figure 1. Paired cameras mounted on a wooden frame to facilitate comparison of camera detection rates of forest mammals in southern New Hampshire (USA) during 2010–2013.

Finally, we standardized rates by reporting detections per 100 camera-nights.

RESULTS

Initial Protocol

Using only coyote urine as an attractant and a high PIR detector setting on the Reconyx, we recorded 10 species of mammals during 342 camera-nights (171 nights/camera model) with 99 independent pictures taken by the Reconyx cameras and 51 recorded by Cuddeback cameras ($\chi^2 = 15.36$, $P < 0.001$). Reconyx cameras detected 9 species (red and gray squirrels, snowshoe hares, beavers, gray foxes, raccoons, bobcats, coyotes, and white-tailed deer). Cuddeback cameras detected 7 species, failing to detect a snowshoe hare, beavers, and a bobcat but detecting a fisher that the Reconyx cameras missed. When partitioned by size classes, Reconyx recorded more small ($\chi^2 = 19.27$, $P < 0.001$) and medium-sized mammals ($\chi^2 = 5.14$, $P = 0.02$) than did Cuddeback cameras (Fig. 2a).

Modified Protocol

In our remaining trials, we positioned bait directly in the detection zone of both cameras. The initial trial included maintaining the sensitivity setting on Reconyx PIR on "high." During 16 camera-nights (8 nights/camera model), we continued to obtain a greater number of detections with Reconyx cameras (62) than we did with Cuddeback cameras (21). Because this pattern was similar to our initial effort, we discontinued this trial. In subsequent trails, the PIR setting on Reconyx was reduced to "medium–high" (143 camera-nights/model), "medium" (135 camera-nights/model), and "low" (67 camera-nights/model). Detection rates did not vary by camera model when PIR sensitivity was set at "medium–high" or "medium," but Cuddeback cameras yielded more independent detections when the PIR sensitivity was set at "low" on Reconyx cameras ($\chi^2 = 15.21$, $P < 0.001$; Fig. 3). Comparing detections by size classes of mammals when both camera models had

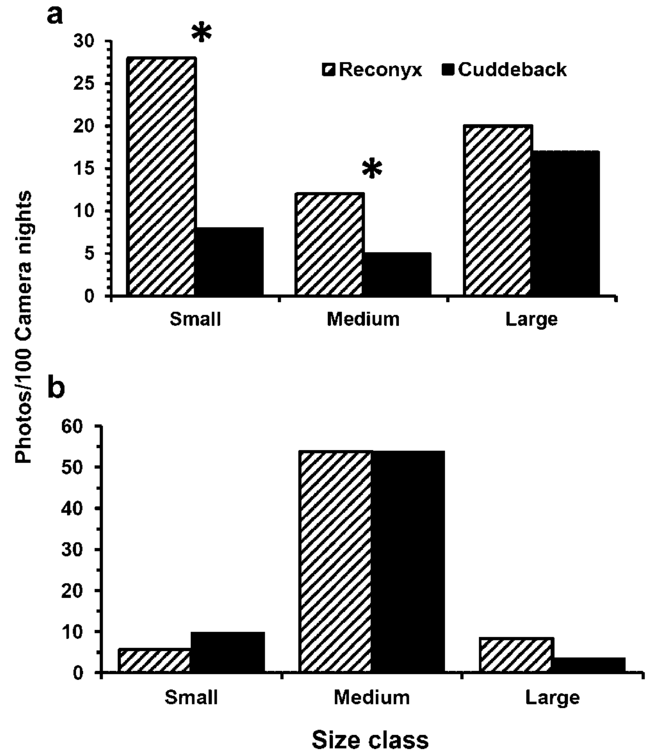

Figure 2. Detection rates of small, medium, and large-body-sized mammals (where small = chipmunks + gray squirrels + red squirrels; medium = snowshoe hares + beavers + striped skunks + house cat + opossums + red foxes + gray foxes + fishers + raccoons + bobcats; and large = coyotes + black bears + white-tailed deer + moose) by paired Reconyx and Cuddeback trail cameras set in southern New Hampshire (USA) during 2010–2013. (a) Passive infrared detectors on Reconyx cameras was set at high and fixed on Cuddeback cameras. (b) Passive infrared detectors on Reconyx cameras was set at medium–high and fixed on Cuddeback cameras. Within a body-size class, an asterisk (*) indicates a difference between camera detection rates ($P < 0.05$).

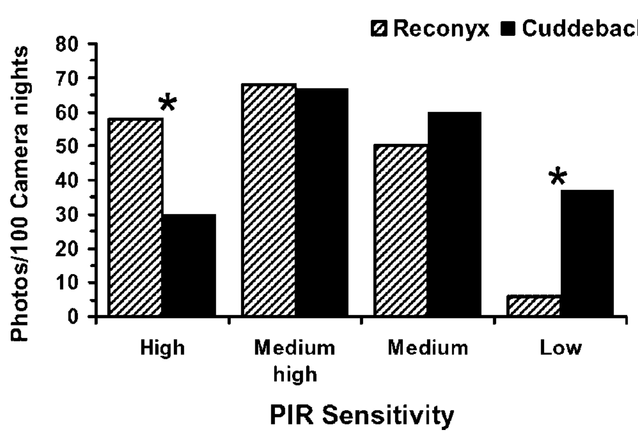

Figure 3. Variation in detection rates of forest mammals by paired Reconyx and Cuddeback trail cameras set in southern New Hampshire (USA) during 2010–2013, where the sensitivity of the passive infrared detector (PIR) on Reconyx cameras varied from low to high. Sensitivity of PIR on Cuddeback cameras was fixed. Within a sensitivity category, an asterisk (*) indicates a difference between camera detection rates ($P < 0.05$).

nearly identical overall detection rates (PIR sensitivity on Reconyx = "medium high") revealed that both cameras recorded gray squirrels, feral cats, fishers, gray and red foxes, raccoons, and white-tailed deer. Each model missed one species that the other recorded; Reconyx cameras recorded a red squirrel and Cubbeback cameras recorded a chipmunk. When detections were partitioned by mammal body-size classes, there were no differences (Fig. 2b).

DISCUSSION

Our trials demonstrated clear performance differences by cameras with different component configurations. In particular, small-bodied mammals (e.g., gray squirrels) were detected at a higher rate by Reconyx cameras. This difference may be a consequence of several component differences including a more sensitive PIR (able to detect small-bodied animals), a larger detection zone, and a faster trigger speed among Reconyx cameras in comparison to Cuddeback cameras. Pictures of gray squirrels included a number in "mid-leap," indicating rapid movement through the detection zone and making these animals difficult to detect. On the other hand, we found limited differences between cameras in detecting large-bodied mammals (e.g., white-tailed deer). Therefore, if an investigation or monitoring program is focused on detections of large-bodied mammals, using a mix of camera models would likely be less problematic than it would be for investigations geared toward detecting a wide range of species. Along these lines, Swann et al. (2004) suggested that cameras equipped with a PIR are prone to 2 types of errors: false triggers (taking a photo not triggered by a target animal) and failure to photograph a target animal. False triggers may be caused by wind or rain moving either vegetation or the support to which the camera is attached, radiant heat in a portion of the detection zone (e.g., in a partially shaded area), or by an animal that is within the detection zone but outside the camera's photographic range (Swann et al. 2004). As a result, cameras with a wide detection zone may be prone to frequent false triggers because (small) animals may enter the detection zone before they enter the camera's field of view (Hernandez et al. 1997, Swann et al. 2004). Conversely, camera systems with narrow detection zones may be less likely to produce false triggers but also may fail to photograph some (especially small) target animals (Swann et al. 2004). During our initial trials (Reconyx PIR set at "high" and 171 nights/camera model), we recorded 15 false triggers among Reconyx and only 4 among Cuddeback cameras ($\chi^2 = 6.37$, $P = 0.01$). We did not monitor false triggers during subsequent trials.

By modifying our baiting protocol and the sensitivity of the PIR among Reconyx cameras, we were able to substantially reduce differences in detection rates. Our results suggest that modifying the sensitivity of the PIR may have been more influential in determining detection rates. However, the use of staked baits can provide other benefits, including taking several photographs of individuals as they remain in front of the camera for longer periods. Multiple photographs can facilitate the recognition of individuals (based on unique body marks) that is needed in capture–recapture projects (e.g., Hohnen et al. 2012). Also, incorporating visible marks on the stake would provide an opportunity to place animals into size categories if they are photographed next to the stake, further complimenting an investigator's ability to recognize individuals (Trolle and Kery 2003, Goswami et al. 2012).

Although using bait or other scent attractants may increase the number of animal photographs, there are some additional considerations before adopting this approach. For example, it may not be appropriate to use scent or bait during inventories that incorporate random-encounter models because these methods require that cameras be distributed in a random design without attractants (Rowcliffe et al. 2008). Also, McCoy et al. (2011) reported that the composition of deer detected at baited versus unbaited camera sites were different, where baited sites apparently over-sampled juveniles.

In conclusion, we recommend that biologists consider specific study objectives when selecting cameras. In studies concerned with detections of large-bodied animals, camera differences may be less important but potential biases should still be evaluated. For investigations that are intended to document animals with a wide range of body sizes or studies focusing on small-sized animals, using cameras with a sensitive PIR and large detection zone should yield greater detection rates. Under these circumstances, using a variety of cameras may introduce sampling bias. However, differences in camera efficiencies may be reduced by specific deployment adjustments (e.g., adjusting PIR sensitivities). Incorporating camera differences into the study design should also be considered. For instance, Erb et al. (2012) used camera model as a covariate in a large-scale study of mammal distributions based on occupancy models and found that camera model was a significant contributor to detection rates. Donovan and Alldredge (2007) also indicated that using covariates (including trap type) may be possible in closed-population estimates based on capture–recapture data, but such designs may be challenging to analyze.

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