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Tools And Technology

Set AHDriFT: Applying Game Cameras to Drift Fences for Surveying Herpetofauna and Small Mammals

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ABSTRACT The use of game cameras by wildlife biologists and managers to survey wildlife, particularly medium- and large-bodied mammals, has increased dramatically. Previous attempts to survey small mammals and ectotherms have had limited detection success or were focused solely on a single species. We describe the Adapted-Hunt Drift Fence Technique (AHDriFT), which combines commercially available game cameras and traditional drift fences to survey reptiles, amphibians, and small mammals. Across 4,502 trap-nights at the Merritt Island National Wildlife Refuge, Florida, USA (Jun 2014 to Jun 2015), we recorded images for 2,523 unique vertebrate detections (2% unidentifiable) averaging 0.56 unique triggers/night. Using AHDriFT enables long-duration surveys with high detectability while minimizing observer time. Guide-boards increased terrestrial vertebrate image capture at minimal cost. During 1 year of usage, no mortality was documented using this camera-trap system and field time was reduced by 95%, requiring only monthly visits of approximately 3 hr for 9 fence arrays to download images from the camera systems, compared with pitfall or funnel traps that require at least daily monitoring. © 2017 The Wildlife Society.

KEY WORDS amphibians, community survey, drift fence, Florida, game camera, reptiles, small mammals.

The use of game cameras by wildlife biologists has rapidly expanded, especially as declining equipment costs and improved capabilities of commercial cameras have made them more attractive tools for researchers to reduce wildlife mortality risks and investigator time commitment (Cutler and Swann 1999, Swann et al. 2004, O'Connell et al. 2010). However, the use of game cameras is limited by inaccurate camera triggering, difficulty in distinguishing among species, cost, and size of focal organism (McCleery et al. 2014). Game cameras use a variety of trigger systems that can be divided into 2 main groups: active and passive. Active triggers include systems such as infrared beams that activate the camera system when obstructed (Cutler and Swann 1999) and pressure plates that signal the camera when compressed (Lerone et al. 2015). These triggers are prone to mechanical degradation over time, leading to replacement by passive systems (Cutler and Swann 1999). Passive triggers measure infrared radiation to detect rapid changes in temperature relative to the ambient environment and are commonly used in ecological studies (Swann et al. 2011). Passive trigger sensors work best for medium to large endothermic animals; however, they have difficulty in detecting small or ectothermic animals with body temperature indistinguishable from the surrounding environment (Cutler and Swann 1999).

Game cameras have not been widely used to survey herpetofauna owing to limitations of both active and passive systems for detecting reptiles and amphibians (Cutler and Swann 1999). Most studies that have used these techniques for herpetofauna target a single species during nesting or breeding, or use active triggers for larger species (reviewed in Welbourne 2014). To broaden the use of game cameras for herpetofauna community surveys, Welbourne (2013) described a system referred to as the "Camera Overhead Augmented Temperature" or "COAT" method, which used

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cork bark tile in gaps along a drift fence to funnel reptiles into a camera's field-of-view. However, this design has limited applicability during certain hours of the day owing to a reliance on high ambient temperature, difficulty in detecting small species, and use of only 1 trap station/fence (Welbourne 2013, 2014).

Studies using game cameras to survey small mammals also are rare owing to problems associated with identifying species. The baited Hunt trap attracts mammals to a close-focus camera survey station inside an overturned bucket to improve photo quality and allow for easier identification (McCleery et al. 2014). The camera is attached with L-brackets to a transparent pane elevated above an inverted bucket and viewing downward into the bucket (McCleery et al. 2014). This method is effective in capturing photographs of small mammals, but it omits species not attracted to the bait and often results in thousands of photos of the same individual (McCleery et al. 2014).

Both previously described methods survey wildlife communities by funneling animals into a confined space, and use a floor to create a flat background temperature to maximize detection of temperature changes. Both methods employ the same camera model without specifying camera selection criteria or clearly testing alternatives, and several modifications can be made to maximize camera sensitivity and capture rate while reducing overall costs. Here, by combining the Hunt trap design (McCleery et al. 2014) and COAT design (Welbourne 2013) with traditional drift fence methods, we address limitations of reduced image-capture windows, sensitivity to smaller species, high cost for individual cameras, and use of only 1 camera/survey station. We captured images of a variety of organisms including small mammals, reptiles, amphibians, and even invertebrates. Our Adapted-Hunt Drift Fence Technique (AHDriFT) funnels wildlife along drift fences into buckets that house game cameras. Our surveys operated for long time periods without trap mortality, while minimizing the time required for field visits to retrieve and process images.

STUDY AREA

Sampling occurred along the coastal dunes at the John F. Kennedy Space Center and Merritt Island National Wildlife Refuge, Florida, USA, from June 2015 through June 2016. We chose to survey coastal dunes to test the camera systems in high heat (32° C summer average), high humidity, and corrosive conditions. Access to the refuge was restricted, limiting potential disturbances to equipment. Since the 1970s, 69 species of nonmarine reptiles and amphibians have been recorded on the site, along with a variety of mammalian and invertebrate species (Seigel et al. 2002). Merritt Island National Wildlife Refuge supported several federally protected species, such as southeastern beach mice (*Peromyscus polionotus niveiventris*), gopher tortoises (*Gopherus polyphemus*), and eastern indigo snakes (*Drymarchon couperi*) that could be at risk for trap-related mortality associated with traditional survey methods such as capture boxes or pitfall traps.

METHODS

Camera Traps

Owing to the high cost of the Reconyx® (Holmen, WI, USA) camera line (>US$600/camera) used by McCleery et al. (2014) and Welbourne (2013), we tested 4 different cameras to select a single model for our study (Table 1). We obtained one of each camera model new from the manufacturer. We performed preliminary tests to ensure proper function and select a single standardized camera type for field surveys. We tested only 1 camera/model; thus, our methods, selection criteria, and results are provided as a guide for camera model selection. We evaluated cameras by allowing an individual garter snake (*Thamnophis sirtalis*; snout-to-vent length 30 cm) and a juvenile northern water snake (*Nerodia sipedon*; snout-to-vent length 12 cm) to make 3 passes through each camera trap. Each camera unit was set to the highest sensitivity, lowest flash setting, and fastest night shutter speed, capturing 3 burst photos/trigger event. We evaluated camera performance by determining whether the camera captured quality photographs of both snakes in all trials. If >1 camera met all the criteria, then we selected the lower cost model.

We modified AHDriFT traps and camera housings from the Hunt trap by using 18.9-L gray buckets (US Plastic Corp. Lima, OH, USA; Table 2; Fig. 1a). The L-bracket attachments allowed airflow and easy access to download data and change batteries. We attached 2 wooden boards to the outside and inside of the bucket to guide wildlife toward the cameras; the interior boards formed an unconnected "V" funnel pointing toward the center of the bucket. We provided a standardized width of wood as a reference scale for identifying wildlife. We positioned each camera in the bucket so the black infrared (IR) sensor was closer to the entrance than the lens, causing wildlife to cross the camera's IR detection band shortly after entering the bucket and before passing under the camera lens (Welbourne 2014). Cameras were all set to the highest sensitivity, lowest flash setting, fastest night shutter speed, and 3 burst photos/trigger for the duration of the study. This study was conducted under U.S. Fish and Wildlife Service permit

Table 1. Cameras compared for survey deployment using the Adapted-Hunt Drift Fence Technique (AHDriFT) camera system method at the John F. Kennedy Space Center and Merritt Island National Wildlife Refuge, Florida, USA, from June 2015 through June 2016.

Manufacturer	Location	Camera	Model	Fixed focus; Attachments	Cost (US$)
Bushnell® Corp.	Overland Park, KS	NatureView HD Max	119439	Yes; 25 cm/45cm	$249.99
Bushnell® Corp.	Overland Park, KS	8 MP Trophy Cam HD	119676C	No	$249.99
Moultrie® Feeders	Birmingham, AL	Moultrie 880i	MCG 12633	No	$149.99
Reconyx®	Holmen, WI	HC600 Hyperfire High Performance Camera	HC600	No	$549.99
Wingscapes®	Calera, AL	Wingscapes BirdCam Pro	WCB-00116	Yes; Adjustable	$199.95

Table 2. Instructions for constructing the Adapted-Hunt Drift Fence Technique (AHDriFT) camera housing used at the John F. Kennedy Space Center and Merritt Island National Wildlife Refuge, Florida, USA, from June 2015 through June 2016. Steps are displayed in Figure 1.

Step	Generalized instructions
1.	Remove 2 13 × 10-cm^2 sections of the bucket top opposite each other; ensure a large enough opening for the largest target species
2.	Reattach lid and place bucket on lid
3.	Remove bottom of bucket
4.	Attach 3 L-brackets to the bottom of the bucket to support the camera pane
5.	Attach 2 203 × 76 × 25-mm^3 wooden guide boards to the exterior of bucket
6.	Attach 2 76 × 50 × 13-mm^3 wooden boards to the inside of the bucket
7.	Attach game camera to plexiglass pane large enough to sit on the previously attached L-brackets; if the camera does not have a screw-hole, cut spaces for the camera attachment strap to secure it
8.	Place camera pane on L-brackets, using additional bolts to secure the system
9.	Tape down the camera strap to prevent slippage, and cover with aluminum tape to reduce heat
10.	Cover entire bucket with shade cloth to minimize heat exposure
11(a).	To minimize camera flash, place black tape over the flash unit with several slits or holes cut through it. Local site experimentation will be needed to ensure consistent images
11(b).	An alternative to tape, commercially available gel filter paper can be layered over the camera flash unit to provide more uniform light reduction

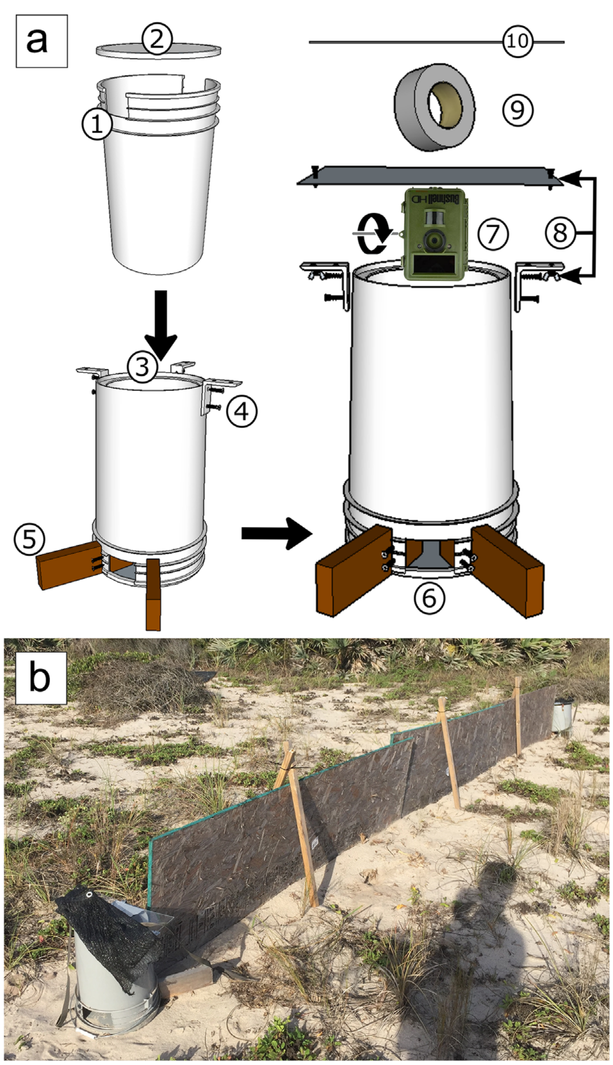

Figure 1. Adapted Hunt Drift Fence Technique (AHDriFT) camera system developed and tested at the John F. Kennedy Space Center and Merritt Island National Wildlife Refuge, Florida, USA, from June 2015 through June 2016. (a) Camera housing assembly instructions. Numbers refer to instructions provided in Table 2. (b) The drift fence was made of wooden oriented strand boards screwed together with the camera housings on opposite ends of the fence to direct wildlife movement.

#LSSC-13-00023, and approved by the Towson Institutional Animal Care and Use Committee #03312014RS-01.

Drift Fence Construction and Camera Deployment

We used wooden, oriented strand board for the drift fences; this material was sufficiently rigid to withstand strong winds and did not rapidly corrode or conduct heat unlike metal. We constructed each fence in the field with 3 2.4-m × 0.6-m × 0.63-cm boards screwed together along the top and bottom edges of each board to form a single 7-m × 0.6-m × 0.63-m fence. The joined boards were held upright between 2 1-m gardening stakes hammered at 60° angles toward the fence and secured with cable ties (Fig. 1b). These boards were not attached to the stakes; therefore, the stakes would not impede wildlife travelling along the fence. This design also allowed for quick removal of the whole fence in the event of a major storm. We placed one bucket at each end of the fence, and cut a groove through the acrylic glass pane to create a tight fit from the bottom of the bucket to the fence itself. We deployed 9 drift fences (4 in natural dunes and 5 in dunes constructed since 2012) each measuring 7 m long and separated by 0.1–1.5 km in the coastal dunes at John F. Kennedy Space Center, and placed 18 NatureView® (Bushnell Corp., Overland Park, KS, USA) cameras in pairs at the fence ends. Each camera was powered by 12 high-capacity Ni-MH rechargeable batteries (Model #HR-3UTHA-AMZN, AmazonBasics®; Amazon.com Inc., Seattle, WA, USA), and equipped with a single 32-GB secure digital card. We replaced camera batteries in 4–8-week intervals, and downloaded photos monthly.

Data Management

We organized images manually by species, and removed all duplicate images with the "camtrapR" package in Program R (version 3.3.1; Niedballa et al. 2016). We treated images as nonindependent, and retained a single image when the same species was captured within 60 min at paired cameras.

RESULTS

In the preliminary tests for camera selection, only the fixed-focal distance cameras (NatureView® and Wingscapes® [Calera, AL, USA]) successfully photographed both snakes.

The Wingscapes camera failed to reliably photograph the northern water snake in repeat trials, so we selected the NatureView camera with the 25-cm lens attachment for extended field trials because it met all 3 criteria list above. The NatureView® camera is also available outside of the continental United States, making it a potential choice as standardized equipment in future studies.

Among the 4,502 trap-nights, 16 cameras were triggered in 2,523 distinct capture events by reptiles (21 species), amphibians (3 species), mammals (8 species), and birds (1 species [Fig. 2; Table 3]). We had no trapping mortality, and several protected species triggered the cameras (Table 3). Filter-gel windows (Table 2 [11b]) improved identification of some small mammal species by increasing uniformity of night-time images across all cameras, while detection of invertebrates indicates detection sensitivity of our system. There were 51 (2% of all captures) unidentified triggers; no data were retrieved from 2 cameras that malfunctioned upon deployment. Time required to download photos from each fence averaged 20 min/fence, or 3 person-hours/monthly visit. Cameras functioned properly for 84% of the total deployment time (4,502 out of 5,347 trap-nights).

DISCUSSION

Detectability is a concern when using game cameras for surveys (Rovero et al. 2008); however, our system detected numerous invertebrates and herpetofauna throughout a 24-hour period, indicating the system was sensitive to ectotherms, in addition to small mammals often overlooked by other systems. Although we did not evaluate trigger reliability of all cameras, we randomly selected one camera in July 2015 to automatically trigger every 5 min for 1 week, while still set to also photograph from the IR trigger. Time-lapse photographs taken during this time had identical captures when compared with the IR trigger. Based on the agreement between the time-lapse images and IR triggers, these cameras are reliably triggering for vertebrate wildlife. Although we photographed large invertebrates (≥2.5 mm, Table 3), smaller invertebrates (including antlions; Myrmeleontidae) entering the traps did not trigger the cameras. We also captured by-catch: green sea turtle hatchlings (*Chelonia mydas*) carrion carried through the traps by ghost crabs (*Ocypode quadrata*) were captured on images (Fig. 2).

Game cameras are commonly being used to replace more invasive and time-intensive survey methods; however, their

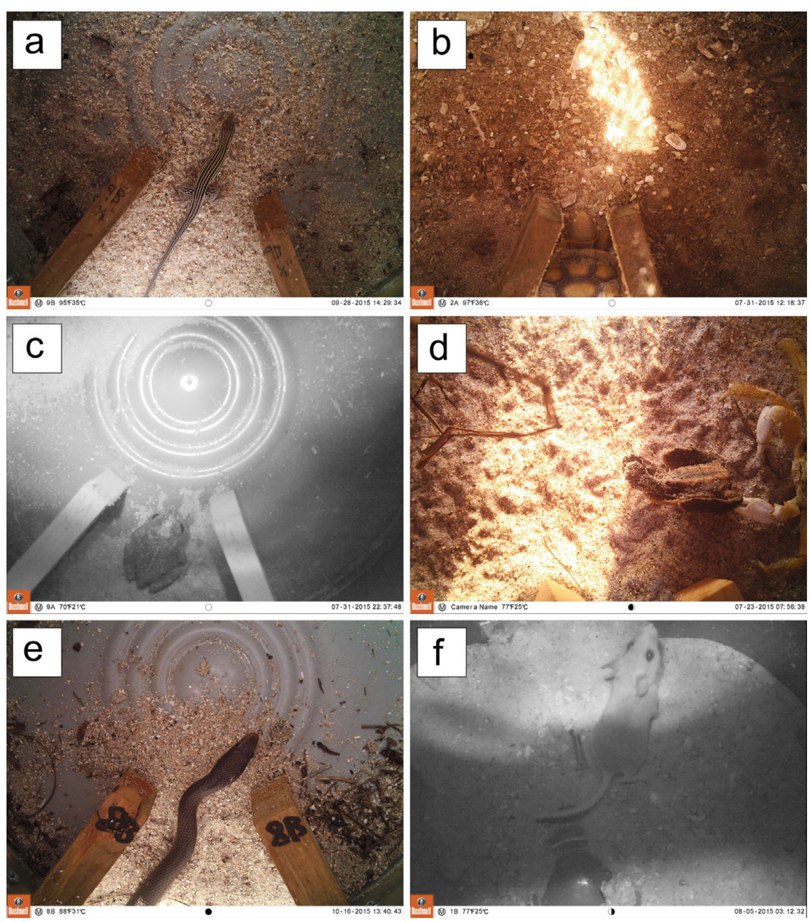

Figure 2. Example images of (a) six-lined racerunner, (b) juvenile gopher tortoise, (c) southern toad, (d) ghost crab with scavenged green sea turtle, (e) black racer, and (f) southeastern beach mouse. All images are from the Merritt Island National Wildlife Refuge, Florida, USA, using the AHDriFT camera system from June 2014 to June 2015.

Table 3. Total number of vertebrate captures and occupied survey sites ($n = 9$ sites) using the Adapted-Hunt Drift Fence Technique (AHDriFT) camera system at the Merritt Island National Wildlife Refuge, Florida, USA, from June 2014 to June 2015, sorted by decreasing frequency of capture.

Species[a]	Common name	No. of sites documented	Total no. of captures
Reptiles			
Aspidoscelis sexlineata	Six-lined racerunner	9	257
Coluber constrictor	Black racer	9	227
Anolis sagrei	Brown anole	9	162
Masticophis flagellum	Coachwhip	9	83
Pantherophis guttatus	Corn snake	9	29
Plestiodon inexpectatus	Southeastern five-lined skink	6	16
Thamnophis sirtalis	Garter snake	5	10
Hemidactylus garnotii	Indo-Pacific house gecko	4	9
Anolis carolinensis	Green anole	5	7
Plestiodon egregius	Mole skink	4	7
Gopherus polyphemus	Gopher tortoise	4	6
Sistrurus miliarius	Pygmy rattlesnake	2	3
Scincella lateralis	Little brown skink	2	2
Terrapene carolina	Florida box turtle	2	2
Crotalus adamanteus	Eastern diamondback rattlesnake	1	1
Drymarchon couperi	Eastern indigo snake	1	1
Hemidactylus turcicus	Mediterranean gecko	1	1
Kinosternon baurii	Striped mud turtle	1	1
Nerodia clarkii	Salt marsh snake	1	1
Opheodrys aestivus	Rough green snake	1	1
Ophisaurus sp.	Glass lizard	1	1
Amphibians			
Gastrophryne carolinensis	Eastern narrowmouth toad	4	12
Anaxyrus terrestris	Southern toad	2	6
Pseudacris ocularis	Little grass frog	1	1
Mammals			
Peromyscus polionotus niveiventris	Southeastern beach mouse	9	728
Spilogale putorius	Eastern spotted skunk	9	627
Sigmodon hispidus	Hispid cotton rat	9	228
Peromyscus gossypinus	Cotton mouse	5	45
Cryptotis parva	North American least shrew	8	40
Sylvilagus palustris	Marsh rabbit	5	7
Canis latrans	Coyote	1	1
Scalopus aquaticus	Eastern mole	1	1
Birds			
Troglodytes aedon	House wren	4	14

[a] Invertebrate families documented on cameras: Acrididae, Apidae, Blattidae, Bombyliidae, Buthidae, Elateridae, Geacarcinidae, Gryllidae, Lycosidae, Mutillidae, Ocypodinae, Salticidae, Scarabaeidae, Sphecidae, Theridiidae, Vespidae.

successful deployment requires balancing cost, battery life, and detection accuracy. Our system was robust to harsh environmental conditions, successfully functioning in a high-humidity, high-temperature (averaging 32°C in the summer) coastal environment. With the addition of reflective aluminum tape on top of the shade cloth, we reduced temperatures that affected camera performance. The AHDriFT cameras triggered throughout a 24-hour period, as opposed to only during specific time frames of the day, demonstrating greater flexibility for capturing both diurnal and nocturnal wildlife (Welbourne 2013). Using AHDriFT eliminates the time of day and weather bias, need for bait, and improves detection sensitivity. The bucket creates a uniform background temperature so that the IR sensor detects throughout the 24-hour capture period while excluding vegetation that otherwise would trigger the camera. The drift fence increases capture frequency by guiding individuals into the trap without bias associated with bait. Additionally, our paired camera stations simulate funnel or box traps place at the ends of typical drift-fence deployment, but greatly reduce the workload required to monitor the fence array. Successful deployment of AHDriFT reduces field time and mortality events, and the system is sensitive to a range of species, offering a tool to conduct preliminary surveys that can inform development of more intensive trapping efforts. Our 7-m fence arrays averaged US $500 for camera-trap and fence materials. If needed, AHDriFT system can be moved among locations and, with high-efficiency rechargeable batteries, the cameras can be deployed for long periods without repeated visits that increase survey costs and potentially create disturbances that affect survey quality.

Game cameras can provide data for evaluating species presence, community assembly, and activity periods. Although our design did not sample tissue from individual animals, the entrance and exit portals could be fitted with hair snares for that purpose. Our design allows for approximation of body size from the photos based on board size; however, the addition of a ruler would increase the accuracy of those estimates (McCleery et al. 2014). Additionally, adding a passive integrative transponder (PIT) tag reader could record recaptures for populationbased analyses. Finally, terrestrial turtles and snakes are difficult to survey with common methods such as visual encounter surveys and drift fences with pitfall traps (Refsnider et al. 2011). Trapping bias is well-documented in herpetofauna, and evaluation of AHDriFT with traditional trapping methods will clarify potential taxonomic bias of this system (Seigel et al. 2002, McKnight et al. 2015).

We evaluated 18 cameras (9 fences) deployed along 63 m of drift fences distributed along 3.5 km of coastline. Total time invested in building the array and retrieving the images was 50 hr. Previously, we surveyed the area with 12 similar-sized drift fences with 2 funnel traps at the ends and a center box trap requiring 4 person-hours for twice-daily trap checks; our AHDriFT method reduced field time by 95%. Additionally, image processing required 1 hr/camera/month and was facilitated by “camtrapR” software, which reduced observer error while sorting data (Niedballa et al. 2016). Compared with conventional trapping methods, AHDriFT has several benefits such as minimizing field time, stress on animals, and mortality risk. However, more studies should be conducted using criteria outlined here for alternative camera models to determine their feasibility. Additional comparisons using other survey systems alongside the AHDriFT system would quantify uncertainty about detectability and potential taxa bias. Despite these limitations, AHDriFT functions well as a survey tool for sites that may be infrequently visited, or for preliminary planning before more intensive trapping efforts are implemented.

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