Attachment and deployment of remote video/audio recording devices (Crittercam) on wild American alligators (Alligator mississippiensis, Daudin 1801)

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Attachment and Deployment of Remote Video/Audio Recording Devices (Crittercams) on wild American Alligators

(Alligator mississippiensis)

Historically, researchers have used direct observation, often with the assistance of specialized equipment (e.g., binoculars, telescopes, remote video/audio recorders), to document animal behavior and ecology (Altman 1974). However, these observer-based techniques typically cause disturbance to animals via presence of observers or equipment, are limited in the data that can be collected (e.g., field of view, magnification), and often occur over short temporal scales, all of which restrict the inferences that can be gleaned from the data (Marsh and Hanlon 2004; Samuel et al. 1987). Documenting the behavior of aquatic species, such as crocodilians, presents additional complications because the majority of their interactions occur below the water’s surface where direct observation can be even more challenging (Dickens et al. 2011). To overcome these limitations and increase the quality and quantity of observational data, researchers have utilized technological advances to develop devices that can be attached to animals and are capable of collecting video and audio data from the animal’s point-of-view. Collectively known as “animal-borne imagery,” this field has flourished in the past 20 years, in part due to the success of the National Geographic Remote Imaging (NGRI) Crittercam program (Marshall 1998). To date, their animal-borne imaging systems have been used to study the behavior of over 60 species spanning a wide range including aquatic vertebrates and invertebrates, such as large sharks, sea turtles, and Humboldt squids, as well as terrestrial species such as lions, bears, and various species of birds (Marshall, unpubl. data). Crittercam, in addition to other animal-borne imaging systems, has revolutionized the field of animal behavior and ecology by permitting the observation of novel natural history characteristics, such as cryptic foraging behaviors or subtle species interactions, and by expanding the range of response variables available for ecological studies, such as diving, foraging, and prey capture success rates (Moll et al. 2007).

To facilitate use of animal-borne imaging to study crocodilians, initial experiments were conducted with Crittercam units on crocodilians in 1988 and later in 2004. Variations on a neoprene-and-nylon webbing style harness were used to attach a video recorder to capture Alligator mississippiensis (American Alligator) and in 2001 test fittings were done with Gavialis gangeticus (Indian Gharial), although planned wild deployments were not carried out. Attempting to design an attachment apparatus that could securely hold the Crittercam during deployment but also incorporated a reliable, automatically-activated releasing mechanism led to development of fairly complex harnesses that were difficult to make and deploy. Here we present a much simpler method for attaching and detaching Crittercam units on crocodilians that has proven successful and we summarize the results from our first deployments on wild adult A. mississippiensis in two Florida estuaries.

Methods and Materials— From 22 April to 6 May 2010 and 27 April to 8 May 2011, adult (> 2 m total length, TL) A. mississippiensis were captured using standard crocodilian capture techniques (e.g., snatch hooks and rope snares) as part of ongoing research and monitoring programs. Once secured, individuals were subject to standard morphometric measurements (head length, head width, snout-to-vent length, total length, and tail girth), blood sampling, scute tissue biopsies, and urine collection. Individual alligators were held for 20–30 minutes during sampling and Crittercam unit attachment and then immediately released at their sites of capture. The location of individual alligators outfitted with a Crittercam unit was monitored via an onboard VHF radio transmitter throughout the duration of each deployment.

Crittercam units were loaned by NGRI for two weeks during each sampling period. Each cylindrical Crittercam unit (5.7 cm height × 27 cm length, 770 g) was secured using two worm gear hose clamps (10 cm max. diameter) to a composite base (32 × 10 × 3 cm, 350 g), hereafter known as the cradle, constructed out of a thin (3 mm thickness) carbon-fiber base-plate and buoyant polyurethane foam body, formed to accommodate the Crittercam unit (Fig. 1A). Once mounted to the cradle, the Crittercam footprint measured 32 × 10 × 7.5 cm and weighed 1 kg (Fig. 1B). Additionally, to reduce vibration, adjust the field of view, and add stability, we fixed a single piece of 5-cm-thick heavy-duty urethane foam cut to dimensions of the cradle (0.78 g/cm², Airtex Industries Inc., Houston, Texas) to the bottom of the cradle using hot glue.

Crittercam units were attached to alligators using a harness constructed from a single (1–2 m) length (size varied depending on girth of individual) of 2.52 cm wide 100% cotton webbing (National Webbing Products Co., Plainview, New York; Fig. 2). To allow for full mobility of the head and neck we positioned the Crittercam unit foam side down on the dorsum of the alligator so that the anterior edge of the cradle rested above the anterior edge of the shoulder girdle. The middle of the length of cotton webbing was laid through a channel at the anterior edge of the shoulder girdle. Two protruding bolts (1 cm in height) at the leading edge of the harness were used to mount the Crittercam unit. A thin (3 mm thickness) carbon-fiber base-plate and buoyant polyurethane foam body, formed to accommodate the Crittercam unit (Fig. 1A). Once mounted to the cradle, the Crittercam footprint measured 32 × 10 × 7.5 cm and weighed 1 kg (Fig. 1B). Additionally, to reduce vibration, adjust the field of view, and add stability, we fixed a single piece of 5-cm-thick heavy-duty urethane foam cut to dimensions of the cradle (0.78 g/cm², Airtex Industries Inc., Houston, Texas) to the bottom of the cradle using hot glue.

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the alligator at the shoulder girdle and opposing ends secured to a single plastic zip-tie (22.6 kg test) via two 2.5-cm steel quick-links at the posterior of the base-plate of the cradle (Fig. 2). We adjusted each harness to accommodate body size variation by looping the terminal end of the cotton webbing through a 2.5-cm flat metal slide. This loop also served to secure the quick-links in place (Fig. 2A). To allow for programmed detachment, the plastic zip-tie holding the terminal ends of the harness was fed through a portal (0.5 cm diameter) in the base-plate of the cradle then through a circular tube drilled into a rectangular polyoxymethylene (Delrin; DuPont, Washington D.C.) housing (5.4 × 1.9 × 1.2 cm) attached to the base-plate (Fig. 2B). Prior to attachment, within the plastic housing a flattened brass bolt was screwed in a perpendicular tube so the flattened end was flush with the anterior edge of the tube containing the plastic zip-tie to act as a backstop. Following the placement of the zip-tie, a 1-cm-long steel blade (flat on one side and roughly sharpened on the other) was inserted into a portal at the posterior end of the perpendicular tube, held in place by a rubber padded screw, and followed by a small pyrotechnic piston actuator (Chemring Energetic Devices, Downers Grove, Illinois) screwed into a threaded portion of the same portal (Fig. 2B). The actuator was then connected to a power port on the Crittercam unit and grounded to the rear faceplate of the unit using a small bolt. At the programmed time of detachment, an electrical impulse sent to the actuator via the power cord ignited a small amount of gunpowder housed in the actuator. The force from the ignited gunpowder then ejected a small piston from the anterior end of the actuator propelling the small cutting blade into the zip-tie, breaking the zip-tie as it contacted the brass backstop. Once the harness was detached, the Crittercam unit was free to float to the surface or fall on the ground depending on the habitat.

As a fail-safe, a Galvanic Timed Releases (GTR; Neptune Marine Products Inc. Port Townsend, Washington) was inserted between each quick-link and the zip-tie loop of the harness system (Fig. 2). Comprised of two dissimilar metals, GTRs corrode and separate at predictable rates dependent on their size and the salinity and temperature of the water in which they are used. We used two types of GTRs with predicted decay rates of either 24 or 48 h depending on the desired duration of each deployment. All portions of the harness system left in the environment (i.e., cotton webbing, quick links, metal strap slides, and GTRs) were biodegradable and in most cases, the harness was recovered with the Crittercam unit.

Crittercam units, depending on the camera type (standard or high-definition video), had the potential to record 6–8 h of audio and video data, constrained either by the capacity of the onboard batteries or the video data storage, depending on the sampling protocols used. The Crittercams can be programmed to sample the video according to a variety of time and environmental conditions, determined by the user. To maximize the coverage of the 24-h timeframe, we used a combination of 30- and 60-minute
Results.—We outfitted 15 adult alligators (4 females and 11 males, TL range 221–307 cm, mean ± SD: 262 ± 25 cm) with Crittercam units (N = 9, at Merritt Island National Wildlife Reserve, 28.529543°N, 80.606585°W, in 2010 and N = 6, at Guana Tolomato Matanzas National Estuarine Research Reserve, 30.024833°N, 81.329628°W, in 2011; Fig. 3). Crittercam units were on average 1.9% of the total mass of an individual alligator (mean = 52 kg). A total of 102 hours of audio and video data was recorded during deployments, 79.5 h (~78%) of which was usable footage for behavioral analyses (i.e., clear view of surrounding habitat and the alligator’s snout; Fig. 4). Four deployments ended early due either to units detaching prior to scheduled detachment (e.g., snagging on vegetation) or camera lenses becoming obstructed by vegetation and/or substrate. Only one individual displayed signs of discomfort or stress during deployments. That individual, a large male (224 cm TL), was missing a large portion (~40 cm) of its tail from a previous injury and seemed to be disoriented for a portion of the Crittercam deployment. We hypothesize this was due to the added weight and movement of the Crittercam unit in heavy wave conditions in deep water, combined with the loss of stabilization from the missing portion of the tail. In two instances alligators were located using VHF radio signals and the Crittercam unit was manually removed due to the detachment apparatus malfunctioning. Because in our study systems salinities were moderate to high (14–34 ppt) and ambient water temperatures were high (21–25°C), in addition to the fact that units were not fully submerged throughout deployments, GTRs corroded more slowly than anticipated: in 48 and 96 h for predicted 24- and 48-h models, respectively.

The 79.5 h of unobstructed video and audio data collected during deployments generated clear point-of-view footage in most environmental conditions encountered (Fig. 4). Given the properties of the camera (horizontal field of view: 114 degree for Gen 5.7 SD model and 170 degree for Gen 6.0 HD Crittercam) and its position on the alligator, the field of view encompassed the upper portion of the head, snout, and nostrils as well as the surrounding environment. In three instances the Crittercam and harness was displaced producing a side-angle image of the head and snout. Image clarity and field of view were negatively affected by water turbidity and aquatic vegetation density. In all conditions the movement of the head could be observed. We observed a variety of behaviors and species interactions and were able to record video footage during all times of the day and night, although the depth of view was reduced at night. Behaviors and interactions observed included inter- and intraspecific interactions, prey capture and pursuit, diving behavior, body position, basking patterns, and habitat use (Table 1).

Discussion.—Documenting and studying the behavioral interactions of living organisms, in particular aquatic species, can be difficult due to the constraints of technology, limitations of environmental conditions, and behavioral modifications brought on by the presence of human observers or equipment. To reduce bias and limitations in the study of animal behavior using observational techniques, researchers and technicians have developed animal-borne imagery as an effective means to

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<th>Observable variables</th>
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<th>Direct observation</th>
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*Observations are limited.
collect video and audio data from the perspective of the animal. Here, we demonstrate that animal-borne imagery devices can successfully be used to study the habits of crocodilians with little to no adverse effects on natural behavior. In comparison to direct observation, animal-borne imagery markedly increases both the quality and quantity of certain observational data which can be collected from crocodilians (Table 1). However, animal-borne imagery also has its own limitations in crocodilian studies. While the POV video produced by Crittercam offers an up-close view of animal behavior and interactions, it is restricted by the field of view and position of the camera unit. Additionally, the short duration (~8 h) of video data produced by these units may limit the amount of data available to researchers. Furthermore, when attaching equipment to wild animals there is always the potential to lose or damage the equipment.

From the outcome of deployments performed thus far, we recommend special consideration be given to the size and condition of individual crocodilians receiving Crittercams or similar types of devices. First, individuals smaller than 2 m in total length may be too small to support the added weight and drag of the Crittercam or similar data collection systems. Second, individuals in poor condition (e.g., emaciated, appearing ill or with large injuries) or physically handicapped may not be ideal candidates for camera deployments. With these limitations in mind, animal-borne imagery devices can be useful tools for recording point-of-view video and audio data of crocodilian behavior, ecological interactions, daily activity patterns, and position in the habitat. In addition, when coupled with other data collection devices such as temperature and depth sensors, this data provides an avenue to perform in-depth analyses of the effects environmental conditions have on behavioral and ecological interactions. Although we used a pre-manufactured audio/video recording device (Crittercam), we believe this method of attachment and fail-safe system could be used to deploy a variety of other devices (e.g., small cameras, depth sensors, accelerometers) on any crocodilian species at relatively little cost to researchers.

We suggest the following questions could potentially be addressed using Crittercams or similar equipment while studying crocodilians: What is the diel activity cycle (e.g., basking times, movement rates, den use, and social activities)? What are the rates of submergence? How often do crocodilians attempt to capture prey? What is the rate of success when attempting to capture prey? What foraging techniques are employed while capturing prey? Are certain foraging techniques more successful than others? How do crocodilian species differ in ecological and biological interactions?

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A Method for Surveying Diurnal Terrestrial Reptiles with Passive Infrared Automatically Triggered Cameras

The use of automatically triggered cameras (hereafter termed cameras) as ecological research tools has expanded considerably in recent decades (Cutler and Swann 1999; Rowcliffe and Carbone 2008). Cameras were once film-based and triggered by mechanical devices such as trip-wires, but now most systems utilize digital technology triggered by active-infrared (AIR) or passive-infrared (PIR) sensors (Swann et al. 2011). Where research questions do not require the physical capture of animals, cameras provide substantial ethical benefits over many traditional survey methods (Putman 1995) and have been shown to be superior to techniques such as live-trapping or hair-tunnels for mammals (De Bondi et al. 2010; Paull et al. 2012). Yet, while the use of cameras for understanding the distribution and ecology of mammals is well advanced, their utility for surveying other vertebrate fauna is mostly unknown. Due to trigger limitations, the use of cameras for reptile research has been restricted to a few species-specific studies. As such, this paper documents a method for use of PIR-triggered cameras to detect multiple species of diurnal terrestrial reptile.

Trigger sensitivity is a key limitation for some cameras. For reliable use, trigger mechanisms need to be sensitive enough to detect the target species, but not so sensitive that excessive false-trigger events (triggering of the camera when an animal is absent) become a hindrance (Swann et al. 2011). Guyer et al. (1997) developed a pressure-plate trigger that was successfully used to study Gopher Tortoises (Gopherus polyphemus) (Boglioli et al. 2003; Johnson et al. 2007), and Maier et al. (2002) developed a subterranean seismic trigger that was successfully used to study turtle nest predation (Marchand et al. 2002). However, as reptile communities include small species (<100 g), these two types of trigger are not practical. Pressure-plates are limited by the mass of the target animal, and so a pressure-plate sensitive enough to detect small reptiles could easily become permanently depressed by displaced vegetation or substrate. Similarly, a seismic trigger sensitive enough to detect small reptiles would be prone to a high level of false-triggers as any vibration in the environment, such as weather events, would trigger the camera.

Active-infrared triggers are analogous to mechanical trip-wires; an infrared beam is transmitted to a receiver and, when broken, signals the camera to capture an image. Trigger sensitivity is generally not a problem with AIR systems but they are limited to where they can be positioned in the landscape (Rice et al. 1995). For example, animals will pass under the beam if it is placed too high, but placing it too low results in high levels of false-triggers from weather events or vegetation disrupting the beam (Rice et al. 1995; Sadighi et al. 1995; Swann et al. 2004). Consequently, AIR triggers would not be suitable for small reptiles. Still, Timber Rattlesnakes (Crotalus horridus), Pig-nosed Turtles (Carettochelys insculpta), and Gopher Tortoises have all been monitored with cameras triggered by AIR sensors (Sadighi et al. 1995; Doody and Georges 2000; Alexy et al. 2003).

Cameras triggered by PIR sensors are currently the dominant type used in ecological research (Swann et al. 2011). Passive-infrared triggers work by measuring the surface temperature, in the form of infrared radiation, emitted by objects in a detection area and trigger the camera when a rapid change in the temperature occurs; for example, when an animal with a higher or lower surface temperature than the background enters the foreground (Swann et al. 2011). Triggering based on temperature in this manner is problematic for reptiles for two reasons. Firstly, while McGrath et al. (2012) successfully detected two Grassland Earless Dragons (Tympanocryptis pinguicollis) with PIR triggered cameras, as reptiles can be similar in temperature to the substrate in the detection zone, they can easily avoid detection (Rovero et al. 2010). Thorbjarnarson et al. (2000) used PIR triggered cameras to study crocodile nesting behavior and found that a crocodile managed to open the nest while only triggering the camera once.

Secondly, because surface temperatures of objects in the environment vary, temperatures within the detection zones are not uniform (Fig. 1a). Given that the camera is triggered by a thermal change in at least one zone of the detection bands, the PIR sensor requires a larger change in temperature to trigger the camera to overcome the thermal variation (Reonxy 2010). Alternatively, consider the reverse; if the temperature in the environment was homogenous, any difference in temperature becomes more pronounced and therefore more easily detected by the PIR sensor (Fig. 1b). These problems can be overcome by implementing the Camera Overhead Augmented Temperature (COAT) protocol described here. By introducing a material to augment the temperature in the detection area, in this case a cork floor tile, thermal variation is removed. Further, as the tile gets considerably

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