TECHNIQUES

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Camera-trap Basking Arrays Detect Western Chicken Turtles (*Deirochelys reticularia miaria*) in Dynamic Ephemeral Wetland Mosaics

Landscapes dominated by ephemeral wetlands vary in both space and time as temperature and precipitation vary regionally, seasonally, and annually (Niemuth et al. 2010). Regionally, the size, density, and spatial configuration of ephemeral wetland complexes are determined by where rain falls and is diverted, creating large wetland complexes following flood events or smaller complexes following wandering seasonal storms (Niemuth et al. 2010; Vanderhoof et al. 2016). Locally, individual ephemeral wetlands exhibit an array of sizes and shapes and vary in permanence with temperature and precipitation (Euliss et al. 2014), creating drying gradients across the landscape among wetlands, but also within them, from highly ephemeral edges to more permanent wetland centers (Gabrielsen et al. 2016). For species dependent on ephemeral wetland complexes, these spatial and temporal dynamics continually alter the location, size, density, and spatial configuration of suitable habitat (Herfindal et al. 2012; Gabrielsen et al. 2022). For biologists studying species dependent on ephemeral wetland complexes, these spatial and temporal dynamics continually alter the location, number, type, density, and spatial configuration of sites needed to sample suitable habitat for the target species, which can be unmanageable to track when sampling methods involve intensive trapping.

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Semiaquatic freshwater turtles, in particular, often inhabit ephemeral wetland complexes and can be difficult to study, because individuals frequently make far-ranging terrestrial movements among many wetlands for mating, foraging, basking, aestivating, and overwintering purposes (Bennett et al. 1970; Buhlmann and Gibbons 2001). These ecological attributes make semiaquatic freshwater turtles vulnerable at multiple scales, from individual road mortality to large-scale habitat loss (Buhlmann and Gibbons 2001; Gibbs and Shriver 2002), consequently resulting in the need for population monitoring at multiple scales for management, conservation, or restoration goals (e.g., Ryberg et al. 2017). Population monitoring of semiaquatic freshwater turtles traditionally involves invasive trapping with baited or unbaited hoop nets (Brown et al. 2011), deployment of basking traps (Gamble 2006), or less invasive visual encounter surveys using spotting scopes and binoculars (Lindeman 1999). Sampling turtles across large, dynamic, ephemeral wetland complexes with these traditional monitoring methods can be time-consuming and expensive, but camera traps have recently become a cheap, efficient, non-invasive, automated alternative to studying turtle movements and basking (Mali et al. 2016; Unger and Santana 2019), nesting and aestivation (Geller 2012; Bowers et al. 2021b), and detection/survival (Bluett and Schauber 2014). Herein, we assess the efficacy of a relatively inexpensive camera-trap basking array designed to move up and down with the changing water levels of ephemeral wetlands occupied by Western Chicken Turtles (*Deirochelys reticularia miaria*; Fig. 1A, B), a subspecies under review for protection under the U.S. Endangered Species Act (USFWS 2011).

Methods

The range of *D. r. miaria* extends west of the Mississippi River in Louisiana, Texas, Arkansas, Oklahoma, and Missouri (Schwartz 1956). At long-term *D. r. miaria* study sites in the western portion of its range, we deployed one camera-trap basking array at four different wetlands, including one wetland in Waller County and three wetlands in Harris County, Texas, USA (Fig. 1), all known to have chicken turtles present at the time of the study. We designed the array to provide basking surfaces that would move up and down in the water column as ephemeral wetlands dried and refilled. To construct each of the four arrays, we first drilled 2.5-cm diameter holes in the ends of two wooden, treated pine fence

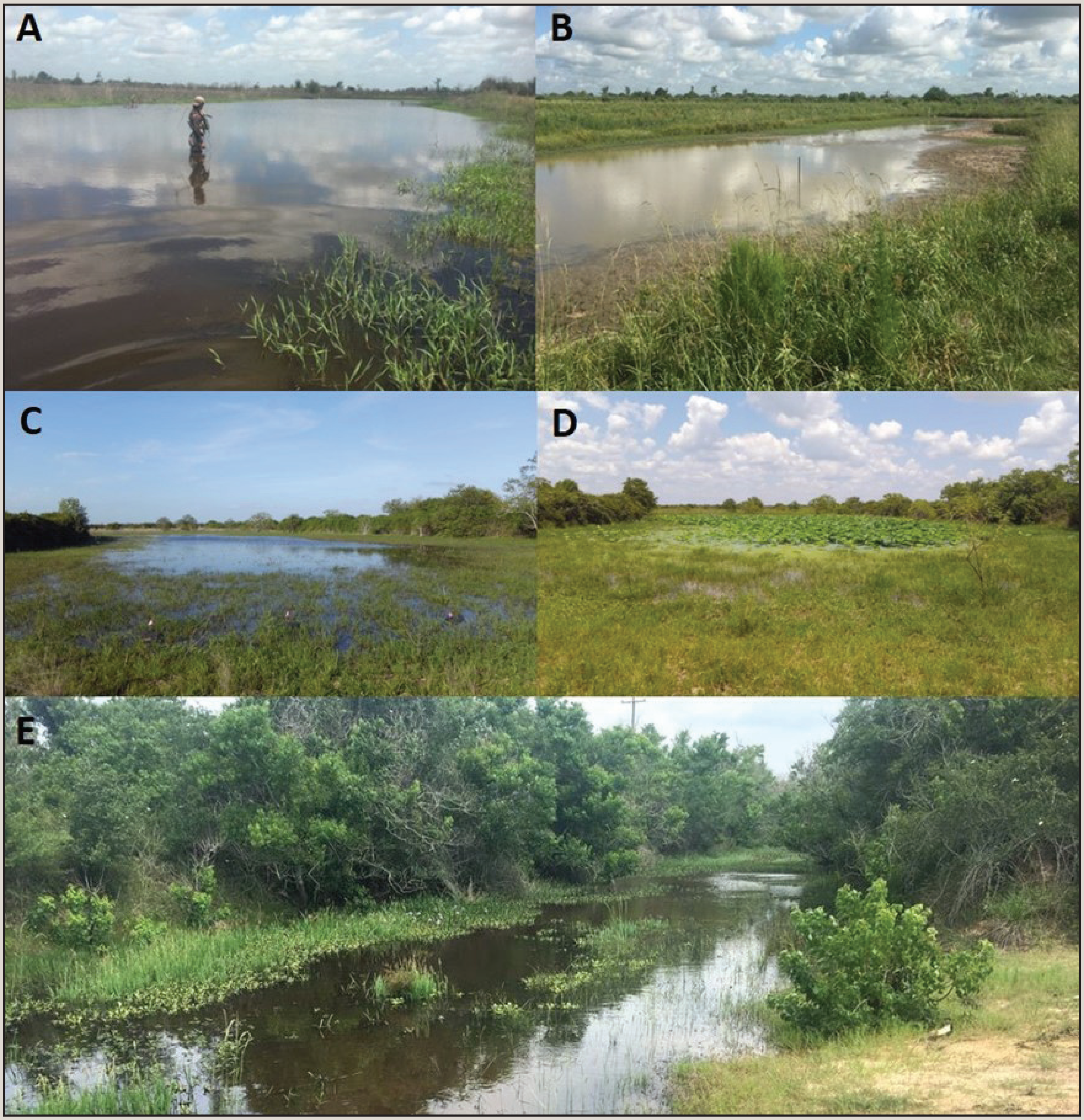

Fig. 1. Wetland B, an ephemeral prairie pothole in Waller County, Texas, USA, is shown full (A) and drying (B). Each year of the study nearly all wetlands occupied by Western Chicken Turtles (*Deirochelys reticularia miaria*) dried down, requiring basking camera structures that moved up and down with changing water levels. Wetland M, a natural prairie pothole depression in March 2018 (C) and May 2018 (D) after significant American Lotus (*Nelumbo lutea*) growth in Harris County, Texas. (E) Wetland O located in Harris County, Texas is comprised of old irrigation ditches that have eroded over time and is functionally similar to isolated ephemeral wetlands.

posts 1.2 m long and 15 cm in diameter (Figs. 2, 3). We tied one end of each post to a metal toilet flange with a 1.5-m cord. We placed the toilet flange over a 1.8-m tall t-post protected by PVC pipe to prevent friction between the post and the toilet flange. By attaching a float made from an empty gallon milk jug to the toilet flange, the cords were able to move up and down with the wooden posts and changing water levels. With the two wooden posts stretched almost taut from the t-post and about 1.2 m apart from one another, we slid two 1.8-m lengths of electrical conduit pipe through the untethered holes and hammered them into the ground to keep the wooden posts from drifting out of camera view. It was important to set them tight enough that the wooden posts would not slide around, but not so tight that they would not be able to slide up and down as water levels changed. To mount the camera, we installed a u-post between the two cords and as close as possible to the t-post assembly, with the

Table 1. Monthly camera observations of Western Chicken Turtle (*Deirochelys reticularia miaria*) basking events recorded in three wetlands in two Texas, USA, counties in 2019. Blank entries indicate that the camera-trap basking array was not yet deployed or that the wetland dried to a point where the wooden posts were on the ground.

County	Wetland	J	F	M	A	M	J	J	A	S	O	N	D	Total
Waller	B	–	–	82	149	878	127	214	3	0	0	0	0	1453
Harris	M	–	–	–	1	38	6	0	20	–	–	–	–	65
Harris	O	–	–	–	–	56	66	58	0	0	0	0	0	180

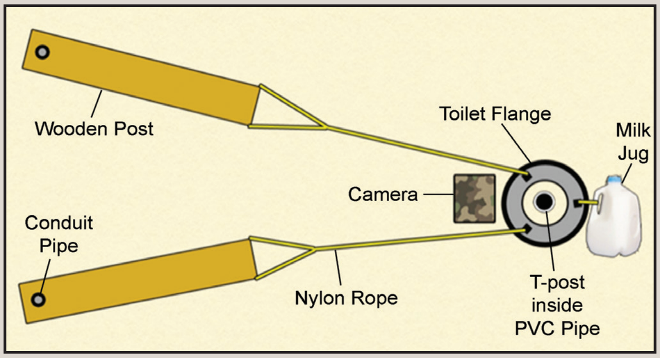

Fig. 2. Diagram (viewed from above) of a camera-trap basking array designed to detect the presence of Western Chicken Turtles (*Deirochelys reticularia miaria*). Components include two wooden fence posts, some nylon rope, a toilet flange, two lengths of metal electrical conduit pipe, a milk jug, a t-post, and a game camera.

camera aimed at the two wooden posts. If some items were not available in a particular region, the components of this design could be replaced with surrogate alternatives. For example, the u-post could be replaced with another t-post, the wooden posts could be replaced with a different floating material wrapped in hardware cloth, or the toilet flange could be replaced with any stainless metal ring of adequate diameter. We used Hyperfire 1 (Reconyx, Holman, Wisconsin, USA) cameras and set them to capture images every minute from 0700 to 2000 h. We replaced batteries every 50 d.

We installed the arrays with cameras facing north, so that at least one side of each post would have sunlight at all times during sunny days. If deployed in the southern hemisphere, this design should be deployed with the camera facing south. We selected positions within each wetland that had heavy *D. r. miaria* traffic during a parallel telemetry study on spatial ecology and were deep enough to remain floating for most of the activity season (Bowers et al. 2021a). Water was about 65 cm deep when deployed at each position. We deployed arrays in late February 2019 in Waller County and late April 2019 in Harris County. To process images, we logged a new observation each time a new *D. r. miaria* individual climbed onto a post to begin basking and took notes on visibility and water depth for each array.

Results

Cameras remained active until the wetlands dried and the wooden posts were on dry ground. The cameras captured 5460 images per wetland during each week of deployment and five researchers with expertise on the identification of turtle species in the region worked opportunistically to process images during breaks from other projects. During periods when no turtles were basking, the software included with the cameras displayed a sequence of 1000 images per minute, but processing images of basking events could take considerably more time. During 2019, we logged a total of 1698 observations of *D. r. miaria*, including 1453 in Waller County and 245 in Harris County (Table 1; Fig. 4). Detection success varied among wetlands. At the wetland in Waller County (Wetland B) where the most detections occurred (N = 1453), the array was in open water directly adjacent to a heavily vegetated area (Fig. 1A, B). Wetland M in Harris County was a shallower pothole wetland with few open water areas and had the least detections (N = 65). This result could have been because of either visibility issues with American Lotus (*Nelumbo lutea*) growing fast enough to block portions of the camera during some periods or availability of ample natural basking sites if *D. r. miaria* basks on American Lotus (Fig. 1C, D). Wetland O in Harris County was a former irrigation canal that had eroded into a linear ephemeral wetland via cattle activity and the high banks had become infested with the invasive Chinese Tallow Tree (*Triadica sebifera*). This array had nearly three times as many detections (N = 180) as the array at Wetland M, but far fewer than at Wetland B, possibly because the wooden posts were shaded for more hours by the tree-lined banks of Wetland O (Fig. 1E). We detected no *D. r. miaria* basking events at an additional, larger wetland in Harris County with heavy wave activity during windy days that caused the wooden posts to bounce up and down throughout the day.

Discussion

The camera-trap basking array was effective at detecting *D. r. miaria* during the study, especially at Wetland B, where the species was detected 878 times in May alone. However, there was considerable variation in the number of detections across all four wetlands, including a failure to detect the species at one wetland, even though a concurrent telemetry study confirmed that individuals were active there throughout the study period (Bowers et al. 2021a). The large size and open surroundings of this particular wetland created windy and therefore choppy conditions for the wooden posts that most likely deterred *D. r. miaria* basking activity (Bowers 2020). For this reason, the optimum locations for these camera-trap basking arrays may be in semi-open waters near densely vegetated sections that help prevent waves on windy days. The remaining variation in detections among arrays may reflect actual differences in *D. r. miaria* densities among those wetlands (Bowers 2020), behavioral differences among individuals (e.g., sex or life-history stage-dependent behaviors; McKnight et al. 2015; Bowers et al. 2021a, 2022a, b), or wetland habitat differences that impact turtle behavior (e.g., wetland shading as described for Wetland O and sufficient natural basking sites at Wetland M).

Whether used as a standalone detection method or in support of other sampling methods, the non-invasive, automated data

Fig. 3. Photograph (viewed from the side) of a camera-trap basking array designed to detect the presence of Western Chicken Turtles (*Deirochelys reticularia miaria*).

Fig. 4. Images captured using a camera-trap basking array designed to detect Western Chicken Turtles (*Deirochelys reticularia miaria*) in ephemeral wetlands: A) image of 14 basking Red-eared Sliders (*Trachemys scripta elegans*), one basking *D. r. miaria*, and one *D. r. miaria* in the water hanging on the side of the left log; B) image of four *D. r. miaria*, including three basking individuals and one individual climbing onto the log.

collection provided by the camera-trap basking array created opportunities for studying *D. r. miaria* behavior and population dynamics within ephemeral wetland complexes. For example, the arrays revealed patterns of aquatic activity using frequencies of basking events over time (Table 1). The monthly frequencies of basking events during the study supported the May-June peak aquatic activity patterns documented during telemetry and trapping studies at the same sites (Bowers et al. 2021a, 2022a). With respect to population dynamics, another potential application of this sampling method could lie in capture-recapture or mark-resight studies. During the study, we were able to identify some marked individuals by their individual ID numbers in photographs. Similar research has used basking cameras and artificial rafts to estimate abundance of Red-eared Sliders (*Trachemys scripta elegans*) from mark-resight data (Bluett and Schauber 2014). In future studies, we will evaluate the efficacy of the camera-trap basking array described here for mark-resight applications with *D. r. miaria* and the feasibility of individual pattern recognition in unmarked individuals that visit the structures multiple times.

The simple, durable design and low cost (<$500 USD) of this camera-trap basking array also provides opportunities to scale up research on *D. r. miaria* range-wide. For example, the distribution of *D. r. miaria* within the eastern portion of Texas is widespread (54 counties; Dixon 2013; Hibbitts and Hibbitts 2016), but turtle assemblage studies and herpetological site inventories within the range of *D. r. miaria* in Texas have seldom documented presence of the species (Ryberg et al. 2004; Adams and Saenz 2011; Fitzgerald and Nelson 2011; Riedle 2014; Crump et al. 2016; Ryberg et al. 2017). Given recent studies documenting relatively short survey seasons of about 6 weeks for many individuals and some demographic bias among capture methods (Bowers et al. 2021a; Bowers et al. 2022a), alternative methods of detection like this, which can be deployed year-round at many different locations, might be necessary to understand occupancy and distribution of *D. r. miaria*. The automation of sampling methods using camera traps has already been used to effectively scale up research and monitoring of other reptiles, including rare and secretive snake species (Adams et al. 2017; Anderson et al. 2020; Neuharth et al. 2020; Ryberg et al. 2021; Walkup et al. 2022).

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