

Trapping Turtles or Trapping Errors? A case study in Alligator Snapping Turtles

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Abstract: When surveying for a species with a potentially fragmented distribution of variably sized populations, such as the Alligator Snapping Turtle, it is important to use effective sampling methods. While numerous surveys have been conducted to assess the current distribution of Alligator Snapping Turtles, detection probability and risk of falsely concluding absence from limited trapping efforts are seldom addressed. We conducted surveys at four sites in Oklahoma where previous surveys had failed to detect the species. We then used permutation analysis on real and theoretical trapping data to assess the robustness of previous surveys and to determine a baseline level of effort needed to detect populations with different relative abundances. We detected Alligator Snapping Turtles at two of our four sample sites where the species was not detected in previous lower-effort surveys, highlighting the importance of increased sampling effort and multiple sampling bouts through time. Our findings suggest that some surveys conducted near the periphery of the species' geographic range may have been insufficient to detect low-density populations. Based on our permutation analyses, we provided guidelines for minimum sampling effort necessary to effectively detect populations above a predetermined density threshold.

Introduction

Effective species conservation relies on accurate assessments of the distribution, abundance, and demographic structure of populations, often requiring considerable effort to evaluate even small portions of a species' range. With finite resources and time, researchers must balance the breadth of site coverage with the intensity of effort at each site. While surveying more locations may seem efficient, doing so with minimal effort risks falsely concluding absence—espe-

cially for rare or elusive species. A priori planning that aligns survey goals with realistic detection probabilities is critical for optimizing efforts that are invariably limited by time and funding.

The secretive Alligator Snapping Turtle (*Macrochelys temminckii*) exemplifies the challenge of detecting low-density populations. Historically widespread across Gulf of Mexico drainages, this species has declined due to habitat loss and overharvesting, leading to range contractions, particularly at the northern periphery (US-

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FWS 2021). Numerous surveys have attempted to document the species' current distribution after a petition to list the Alligator Snapping Turtle under the Endangered Species Act was denied in 1983 due to insufficient information regarding the species' status (Heck 1998). Yet many surveys failed to account for detection probability in their survey design, increasing the risk of erroneous conclusions regarding extirpation.

Detection of turtles varies with environmental conditions, trapping methods, population density, and effort (Buchanan et al. 2019, Rosenbaum et al. 2023). Previous studies suggest that small populations may go undetected without adequate sampling intensity (Tyre et al. 2003). Here, we highlight the importance of sufficient sampling effort by re-examining sites in Oklahoma where past surveys failed to detect Alligator Snapping Turtles (Riedle et al. 2001). Using permutation analyses, we assessed the adequacy of previous survey efforts throughout the species range, offering recommendations for future sampling protocols to ensure accurate population assessments.

Methods

Turtle surveys. We conducted surveys in June–July 2018 at four sites in eastern Oklahoma where Alligator Snapping Turtles historically occurred and past studies reported absence (Riedle 2001). All survey sites were located within the Arkansas River drainage and were upstream of reservoirs or were tributaries of dammed rivers. Sites were navigable by motorboat and typified by high turbidity, muddy stream beds, and tall banks (Voves 2020). We selected these sites because Alligator Snapping Turtles were presumed to be absent, yet habitat appeared to meet the species' life history requirements, making these sites promising candidates for future reintroduction efforts.

We surveyed each site for seven consecutive days, with a minimum of 15 baited hoop nets deployed daily, totaling 100–120 net nights (NN) per site. We used single-throat 0.9-m diameter and double-throat 1.2-m diameter hoop nets

with 2.5-cm mesh and baited with fresh or frozen fish. We positioned nets in optimal habitat—near submerged cover such as downed trees and undercut banks. We divided each survey reach into an upper portion and lower portion, and we moved rebaited traps from one section to the other each night (Hollender et al. 2022). In the case of one site, the seven-day trapping effort was split between a small tributary (Chouteau Creek) serving as the upper portion and the main-stem Neosho River as the lower portion. These rivers were not spatially independent, but their habitat differed in such a way that detection could be affected—Chouteau Creek was characterized by greater abundance of submerged structure and canopy cover and less current than the main-stem Neosho River (Voves et al. 2023). Thus, we report the effort separately for this site. We set traps such that a portion remained partially above water with a floatation device placed inside to safeguard against potential rising water. We measured, sexed, and notched captured turtles of all species with a common scute notch to identify recaptures. Alligator Snapping Turtles received Passive Integrated Transponder (PIT) tags in the right rear leg for permanent marking.

Previous surveys occurred May through August 1997–1999 using very similar methods (Riedle 2001, Riedle et al. 2009). In short, they set 1.05-m diameter hoop nets with 2.5-cm mesh baited with fresh fish upstream from submerged structures. They set 3–18 nets each afternoon and checked them the following morning, typically for fewer than three consecutive nights (Riedle 2001). In this past effort, they marked only Alligator Snapping Turtles with drilled holes in a unique sequence along the marginal scutes. Effort per site was reported in Riedle (2001), but specific site coordinates were not attainable. To the best of our knowledge, with correspondence from D. Riedle, past trapping effort included 25 total NN in Big Cabin Creek May 1997 and 1999 (Craig Co.), 10 NN in the Neosho River July 1998 (Mayes Co.), 20 NN each in two stretches of the Deep Fork River July 1997 (Okmulgee Co), and 57 total NN among at least three stretches of the Poteau River August 1998 (LeFlore Co.) with effort ranging from 10–22 nets per site. Riedle (2001) did not trap in the Chouteau Creek. We

recognize the possibility that we did not sample the precise locations and turtle populations as sampled previously (Riedle 2001).

Permutation analyses. To estimate false negative probabilities, we resampled our trapping data from sites with confirmed captures across 10,000 iterations for varying effort levels, calculating the proportion of iterations that resulted in zero captures—leading to a conclusion of false absence. We used these probability curves to evaluate the likelihood that the absences of Alligator Snapping Turtles reported from previous survey efforts (Shipman et al. 1995; Riedle et al. 2009; Bluett et al. 2011; Baxley et al. 2014) were false negatives, assuming surveyed sites supported populations that were comparable to those we surveyed in Oklahoma.

We also generated theoretical catch-per-unit-effort (CPUE) scenarios to determine the minimum NN required to detect populations at different abundance levels with 95% confidence. When Alligator Snapping Turtles occur in greater abundance, more individuals are expected to be captured assuming trapping effort remains constant, resulting in a higher CPUE, defined as the number of captures divided by the total number of traps set. We simulated trapping results for 51 theoretical surveys of 200 NN each, each defined

by a different CPUE. For each trap, we assigned a value of 1 if an Alligator Snapping Turtle was detected and 0 otherwise. The simulated CPUEs ranged from 0.005 (1 detection in 200 NN) to 0.500 (100 detections), increasing by 0.010 (2 detections) with each new simulation. For each CPUE level, we conducted permutation analyses across varying effort levels to determine the minimum effort required to reduce the probability of a false negative to below 5%. All analyses were implemented in R version 3.5.0 “Joy in Playing” (R Core Team 2022).

Results

Turtle surveys. We sampled turtles at four sites in Oklahoma over 475 NN and captured 20 individual Alligator Snapping Turtles at two locations—Big Cabin Creek and the Poteau River (Table 1). The capture rate was much higher in the Poteau River (0.130 CPUE) than in Big Cabin Creek (0.024 CPUE). In the Poteau River, we captured 17 turtles (14 juveniles, 2 females, and 1 male) in 127 NN. In Big Cabin Creek, we captured 3 turtles (2 juveniles and 1 female) in 124 NN. All turtles combined, juveniles measured 164–331 mm in carapace length, while adults measured 411–457 mm.

Table 1. Survey sites, counties, length of river surveyed, dates surveyed, net nights (NN), and number of Alligator Snapping Turtles captured in Oklahoma in 2018 (with recaptures in parentheses). Also included are dates and effort (NN) of previous sampling efforts at these locations that occurred in 1997–99 (Riedle 2001). Note that no *M. temminckii* were detected at any of these locations in 1997–99.

River	County	Length surveyed (km)	Dates Surveyed		Effort		<i>M. temminckii</i> trapped (2018)
			This Survey (2018)	Riedle (2001)	This Survey (2018)	Riedle (2001)	
Big Cabin Creek	Craig	6.83	2–8 June	May 1997, 1999	124	25	3 (0)
Chouteau Creek	Mayes	2.57	14–16 July	--	55	0	0
Neosho River	Mayes	3.58	17–18 July	Jul 1998	49	10	0
Deep Fork River	Okmulgee	11.99	12–18 June	Jul 1997	120	20–40	0
Poteau River	Le Flore	10.96	24 Jun–1 Jul	Aug 1998	127	10–22	17 (1)

Permutation analyses. We used trapping data from the Poteau River (18 captures in 127 NN, including one recapture) and Big Cabin Creek (3 captures in 124 NN) to conduct permutation analyses. The probability of a false negative declined more rapidly in the Poteau River, where 19 NN sufficed to reduce the probability of a false negative below 5%, compared to 78 NN in Big Cabin Creek. Riedle (2001) failed to detect Alligator Snapping Turtles at these sites in 1997. Assuming detection probabilities in those earlier

surveys were comparable to this study, Riedle had a 3–20% chance of falsely concluding absence in the Poteau River (10–22 NN) but a 51% chance in Big Cabin Creek (25 NN). We compared nine additional Oklahoma surveys (Riedle et al. 2009) to our results. Using Big Cabin Creek as a model, one river showed a >50% false negative probability, three rivers exceeded 20%, and two fell below 5% (Fig. 1). Using Poteau River data, only one river exceeded a 5% false negative probability.

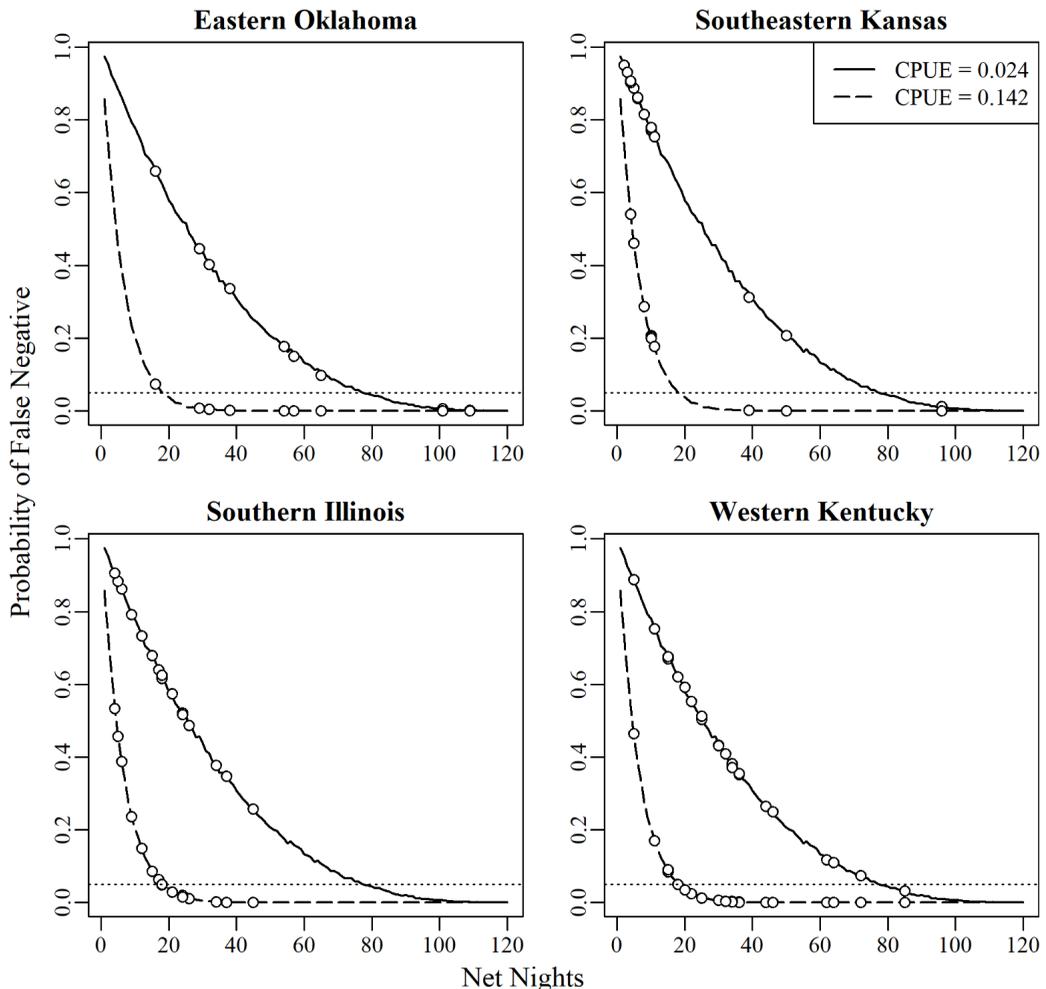


Figure 1. Probabilities of false negatives given reported effort expended at sites during previous surveys where Alligator Snapping Turtles were not detected. Curves are based upon permutations generated from populations in Big Cabin Creek (CPUE = 0.024) and Poteau River (CPUE = 0.142—includes 1 recapture). Each point corresponds to effort invested at one site. The dotted line denotes a probability of 0.05. Data included in the analysis are: Riedle et al. (2009) [Oklahoma], Shipman et al. (1995) [Kansas], Bluett et al. (2011) [Illinois], and Baxley et al. (2014) [Kentucky].

Discussion

When we extended the analysis to surveys outside of Oklahoma, we found that surveys in Kansas (Shipman et al. 1995) had the highest likelihood of producing false absences. If turtle abundance matched that of our low-density site, 84% of 19 sampled sites in Kansas produced false negative probabilities above 0.75. In Illinois (Bluett et al. 2011), 76% of 17 sites exceeded 0.50, and in Kentucky (Baxley et al. 2014), 38% of 24 sites exceeded 0.50. When we modeled higher abundances like those in the Poteau River, the proportion of sites with false negative probabilities above 0.50 dropped to 37% in Kansas, 6% in Illinois, and 0% in Kentucky.

In simulations of theoretical surveys, we found that high turtle abundance ($CPUE \geq 0.26$) required fewer than 10 NN to achieve a false negative probability below 5% (Fig. 2). When CPUE exceeded 0.44, just 5 NN were sufficient for detection. In contrast, populations with very low detection rates ($CPUE \leq 0.05$) required more than 50 NN and detecting turtles at a CPUE of 0.005 required 190 NN.

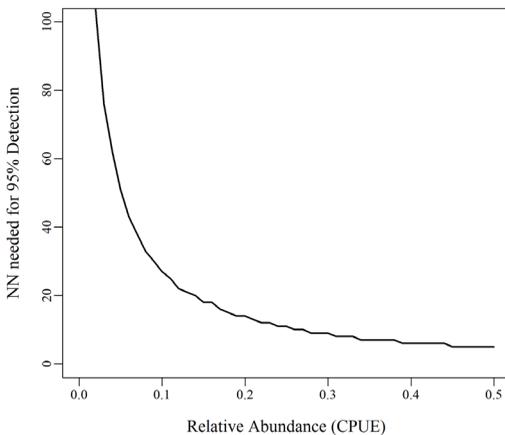


Figure 2. The minimum number of net nights needed with zero captures to conclude absence of *Macrochelys temminckii* with 95% confidence given different relative abundances. Abundance was estimated with increasing catch-per-unit-effort (CPUE) in theoretical capture data consisting of 200 net nights. Permutations were performed under these different CPUE scenarios to estimate minimum effort requirements.

Our detection of Alligator Snapping turtles in rivers where they were previously believed to be extirpated highlights the importance of sufficient sampling effort when surveying species with fragmented, variably sized populations. Although Riedle (2001) employed methods similar to ours, the high probability they had of falsely concluding absence at Big Cabin Creek suggests that too little effort was invested to reliably detect low-density populations. In contrast, the low probability they had of concluding false absence at the Poteau River implies other factors reduced detectability. Past surveys in the Poteau River were conducted in August, when elevated water temperatures may have suppressed activity (Thompson 2023) or turtles exhibited seasonal movements into deep, cooler water (Riedle et al. 2006), leading to lowered detection probability. Detection probability between the two sampling periods could also have been affected by air temperature, lunar phase, or water flow velocity (Dreslik et al. 2017, Rosenbaum et al. 2023). Alternatively, the population in the Poteau River may have been smaller in 1997, with the juveniles we captured representing recent recruitment. With 20 years separating the two studies, it is difficult to know what additional factors could be at play to affect detection and occupancy of Alligator Snapping Turtles at these sites.

Permutation analysis proved to be a useful tool for evaluating previous efforts to detect Alligator Snapping Turtles. Catch-per-unit-effort is often used as a proxy for abundance because so few surveys have been sufficient to generate robust population estimates. Our results indicate that past surveys in Kansas, Illinois, and Kentucky likely lacked sufficient effort to confidently conclude species absence. Instead, we recommend that surveys resulting in non-detection report a minimum detectable density based on effort. For example, the average effort expended during surveys conducted in Kansas, Illinois, and Kentucky was 24 NN, which, according to our analysis, would only detect a population with a CPUE greater than 0.12 turtles per NN with 95% confidence. Baxley et al. (2014) similarly inferred that survey efforts in Kentucky were only

sufficient to detect relatively abundant populations that would result in a CPUE of 0.06 given an average effort of 34.5 NN—an effort that corresponded to a CPUE of 0.07 in our analysis. We encourage investigators conducting future surveys to interpret non-detections in this context and clearly relate sampling effort to minimum detectable CPUE thresholds.

Surveyors must also carefully report and interpret trapping effort. Some prior studies, such as Riedle et al. (2009), appeared to expend enough cumulative effort to infer absence, but pooling across nearby tributaries obscured local abundances and detection probabilities of sites with potentially variable habitat suitability (Riedle 2001). Future studies must report effort at the site level, not as aggregated totals, to accurately reflect habitat suitability and turtle abundance. Other surveys have faced similar challenges. Some reported trapping effort inconsistently (Folt and Godwin 2013; Huntzinger et al. 2019), pooled sites into large summaries (Wagner et al. 1996; Jensen and Birkhead 2003; Garig et al. 2021; Pearson et al. 2023) or failed to report site-specific effort altogether (Boundy and Kennedy 2006; Shipman and Riedle 2008). If pooling among sites is necessary, it is helpful to report the number of sites included in the summary, as done in Pearson et al. (2023). To facilitate comparison between studies, it may also be advantageous to report inter-trap distances, as trap saturation also affects detection of Alligator Snapping Turtles (Rosenbaum et al. 2023). Thus, we urge future researchers to prioritize transparent, site-specific reporting of trapping effort and results because misinterpreting absences can complicate efforts to synthesize regional distribution patterns.

In light of our findings, we call for more robust survey design standards for Alligator Snapping Turtles. Although detecting relatively dense populations requires modest effort, detecting sparse or fragmented populations demands greater investment. To minimize the risk of falsely declaring a species absence, we recommend a minimum survey effort of 100 NN per site, which corresponds to a 95% probability of detecting a small population with a CPUE of 0.02 turtles per NN or greater. Our recommended minimum

survey effort is greater than the 80 NN recommended by the U.S. Fish and Wildlife Service for rapid assessments of low-density sites (Pearson 2025), which would correspond to detecting a population with a CPUE of 0.025 turtles per NN or greater. These recommended baselines must be viewed as a starting point—not a guarantee. Researchers should adjust effort upward when environmental conditions, such as extreme heat, cold, or flooding, reduce detectability (Rosenbaum et al. 2023). Survey planners should explicitly account for detection probability in study design, report effort and results transparently, and carefully interpret non-detections with respect to sampling intensity. The consequences of inadequate survey design can delay conservation interventions, misinform species assessments, and impair recovery planning. By adopting more rigorous, transparent, and data-driven survey practices, we can ensure that future assessments of Alligator Snapping Turtles—and other elusive species—better reflect biological reality and advance conservation goals.

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