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BODY SIZE AND AERIAL BASKING DYNAMICS OF THE SPINY SOFTSHELL (*APALONE SPINIFERA*) IN A HUMAN-MODIFIED LANDSCAPE IN TENNESSEE, USA

CHRISTOPHER J. O'BRYAN[1,2,*], M. KEVIN HAMED[3], THOMAS F. LAUGHLIN[4], AND J. WALLACE COFFEY[5,†]

[1]School of Earth and Environmental Sciences, The University of Queensland, Brisbane QLD 4072, Australia
[2]Centre for Biodiversity and Conservation Science, The University of Queensland, Brisbane, QLD 4072, Australia
[3]Department of Fish and Wildlife Conservation, Virginia Tech, Blacksburg, VA, 24061, USA
[4]Department of Biological Sciences, East Tennessee State University, Johnson City, TN, 37614, USA
[5]100 Bellebrook Road, Bristol, TN, 37620, USA

**Corresponding author: c.obryan@uqconnect.edu.au*
†Deceased September 27th, 2016.

ABSTRACT: Spiny Softshells (*Apalone spinifera*) are found in aquatic environments throughout much of the central-eastern USA. Although this species is widespread throughout much of Tennessee, little is known about Spiny Softshells in the state's northeastern counties. Further, little work has investigated the role of Spiny Softshell body size on resource use, and the morphometrics of the species in a human-modified ecosystem. Here we present results of a four-month capture and basking observation study conducted in 2004. We investigated whether larger body size was positively associated with presence at limited aerial basking resources that are potentially important for thermoregulation. We found that hoop trap captures positioned next to basking sites, a proxy for aerial basking resource use, were not associated with sex or body size measurements. Opportunistic basking observations revealed most individuals basked in the afternoon. Our study, while short in duration and of low sample size, builds understanding on the body size and intraspecific effects of resource use by Spiny Softshells in a human-modified ecosystem.

Key Words: exploitative competition; thermoregulation; conservation; chelonian; human pressure; reptile; habitat use; morphometrics; ontogenetic shift; ontogeny

INTRODUCTION

The Spiny Softshell (*Apalone spinifera*; Figure 1) is a wide-ranging semi-aquatic turtle found throughout much of the central-eastern USA (Powell et al. 2016). In Tennessee, Spiny Softshells are found in freshwater streams, rivers, and ponds, and are thought to occur statewide; however, verified records are sparse for much of the state's northeastern counties (Scott and Redmond 2008, O'Bryan et al. 2015), with little published information on their natural history and morphometrics from the region (Rowell 1970, Jackson 1971).

Spiny Softshells are sexually dimorphic, with females being significantly larger than males (Webb 1962, Graham 1991), and they exhibit a wide range of body sizes that may result in larger individuals having a high demand for or competitive advantage over resources. Because of their larger size, females may exhibit social dominance and outcompete smaller individuals for food and aerial basking sites through direct and indirect competitive interactions (Lindeman 2000). Although exploitative competition has been observed interspecifically in other turtle species such as between the invasive Pond Slider (*Trachemys scripta*) and native turtles (Cadi and Joly 2003), little is known about the effects of body size on resource use within Spiny Softshell populations (see Lindeman 2000). Furthermore, while they are found in most aquatic ecosystem types across their range, Spiny Softshells may be susceptible to human-mediated environmental disturbances (e.g., Brown et al. 2012) such as surface water runoff and chemical pollution because of their ability to exchange respiratory gases cutaneously (Marchand 1942, Dunson 1960, Stone et al. 1992, Ultsch 2006). In light of this, an improved understanding of their presence and population dynamics in human-modi-

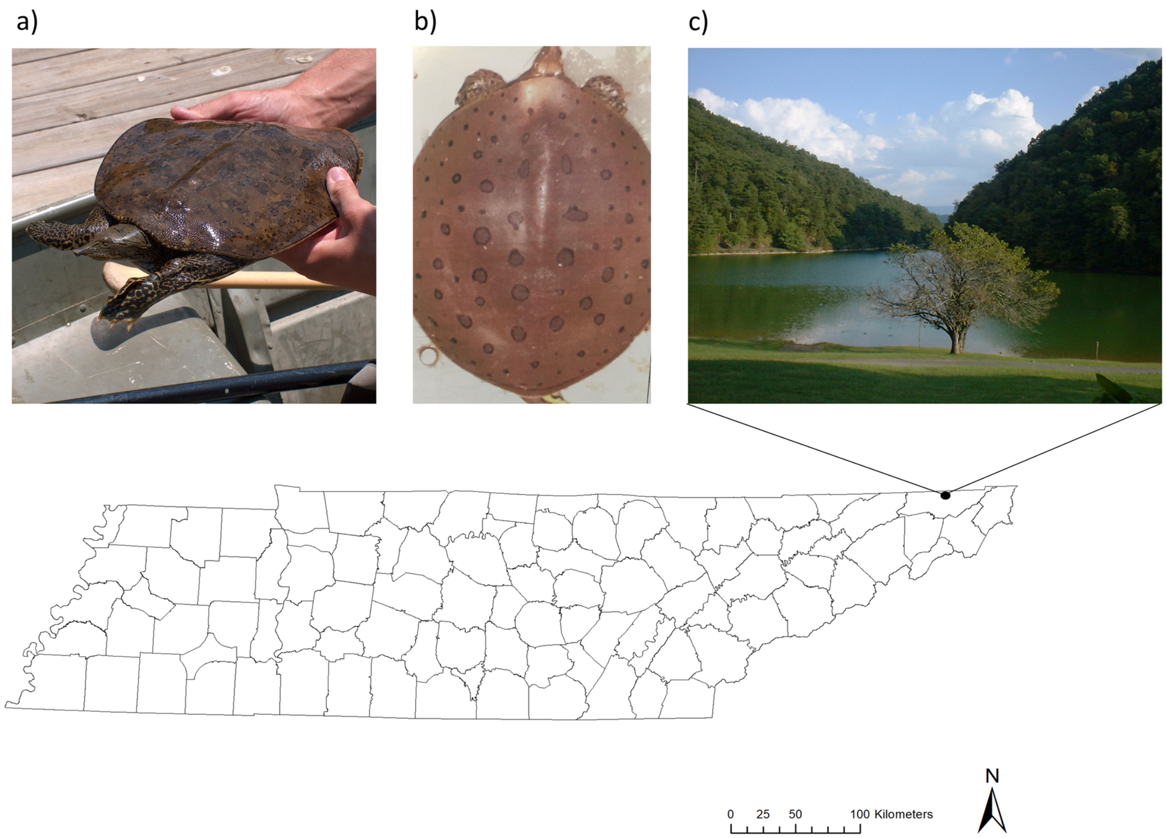

Fig. 1. a) Spiny Softshell (*Apalone spinifera*) female and b) male individuals captured during the project. Photo credit: Corey Brown (2004). c) The study site, Steele Creek Park Lake, City of Bristol, Sullivan County, Tennessee, USA. Photo credit: Christopher O'Bryan (2004).

fied landscapes, as well as the effects of intraspecific dynamics on resource use is a research direction of interest (see Plummer et al. 2008).

Here we provide results from a short-term capture and aerial basking observation study of Spiny Softshells in a reservoir in northeast Tennessee (Figures 1a and 1b). We hypothesized that: (1) Spiny Softshell body size measurements – that is, carapace, plastron, right-hind foot, and body mass estimates – would be considerably larger at trapping sites positioned next to aerial basking resources (i.e., sites that may be important for thermoregulation) than at non-basking sites; and (2) that female Spiny Softshells would be associated with aerial basking sites more than males. In addition to testing our hypotheses, we also provide morphometric and capture data, including metrics for additional turtle species captured during the study. We also provide information on opportunistically observed Spiny Softshell aerial basking events, including time of basking and basking structures used. Our results help build understanding of the body size and basking dynamics of Spiny Softshells in a human-modified landscape in Tennessee.

METHODS

Study site

We conducted the study in Steele Creek Park Lake in Bristol, Tennessee (36.573147, -82.233734; Figure 1c), which is in the Holston River drainage. Opened in 1964 by the City of Bristol, Tennessee, Steele Creek Park is the state's third largest municipal park, containing a 21.9 ha human-made impoundment with a spillway and ~890 ha of undeveloped forest (Rowell 1970, Jackson 1971). While the park has conducted a series of natural history inventories (including turtle surveys in the reservoir; Rowell 1970; Jackson 1971), little is known about the size distribution of Spiny Softshells in the Steele Creek Park Lake, their use of basking structures, and the inter- and intraspecific dynamics of the turtle community.

Captures

All captures were made from 4 May – 27 September, 2004 using finger-throated hoop traps (Memphis Net & Twine Co., Memphis, TN) across 20 trapping locations in Steele Creek Park Lake (four of the 20 sites were randomly selected on the day of trap placement) with total trap time of approximately 938 hours. Ten of the sites were considered 'basking' sites, such that the traps were positioned directly next to a basking structure, and ten were 'non-basking' sites. Basking sites were determined based on known aerial basking locations, which included areas with fallen trees, logs/snags, or gradual embankments. Non-basking sites were comparable in condition to basking sites but did not contain known aerial basking structures. We used an aluminum jon boat for deploying traps, securing each trap with poly-braided rope to tree branches or concrete blocks underneath the surface to hold the entrance in place, and traps were baited with ocean perch and chicken gizzards, or beef liver. For each individual turtle captured, we recorded carapace length, carapace width, plastron length, and straight right hind foot length using calipers or metric tape measurer in addition to mass, using a PESOLA spring scale (PESOLA Präzisionswaagen AG, Schindellegi, Switzerland). We also documented patterns for individual identification. Since Spiny Softshells exhibit sexual dimorphism (Graham 1991) females were identified based on a distinct blotchy pattern on the carapace (see Figure 1a; Graham 1991); however, males retain juvenile morphology (see Figure 1b; Graham 1991). We determined turtles were adult males if the pre-cloacal portion of the tail extended beyond the posterior edge of the carapace (Webb 1962, Robinson and Murphy 1978, Berry and Shine 1980). When other species were captured, we noted the species and sex (if possible), and we measured carapace length and plastron length.

Basking observations

We visually searched for aerial basking Spiny Softshells opportunistically during hoop trap deployment, trap checks, and trap retrieval throughout the project. We used binoculars to scan possible aerial basking structures from the boat, including woody vegetation, lakeside structures such as embankments, and floating vegetation. We scanned the same basking structures during every opportunistic basking survey. These opportunistic surveys were only conducted during weather conditions conducive for aerial basking (e.g., little or no rain). We noted the time, location, and basking material used. We searched between 0900 – 1700 hours, depending on trap checks and deployments.

Analysis

To test our hypothesis of Spiny Softshell sex association with basking site captures, we conducted a Pearson's chi-square test with Yates' continuity correction that tests for dependence in count data. To determine if there was evidence for an association between Spiny Softshell morphometrics and sex, and between morphometrics and basking and non-basking site captures, we conducted a Welch two-sample t-test for comparing differences of the means. For all tests, we used R Statistical Software (R Core Team 2019) and applied a statistical evidence level of $p < 0.05$.

RESULTS

Capture results

We captured 17 unique Spiny Softshells and five recaptures (*n* = 22). All captured turtles were considered adults. Females (*n* = 11) were nearly twice as common as males (*n* = 6). All recaptures were female. We captured 59% of Spiny Softshells at basking sites (*n* = 13), the majority being female (*n = 11*). The remaining 41% of captures were from non-basking sites (*n* = 9), with females also (*n* = 5) outnumbering males (*n* = 4).

We found no evidence that Spiny Softshell sex was associated with capture presence at traps positioned next

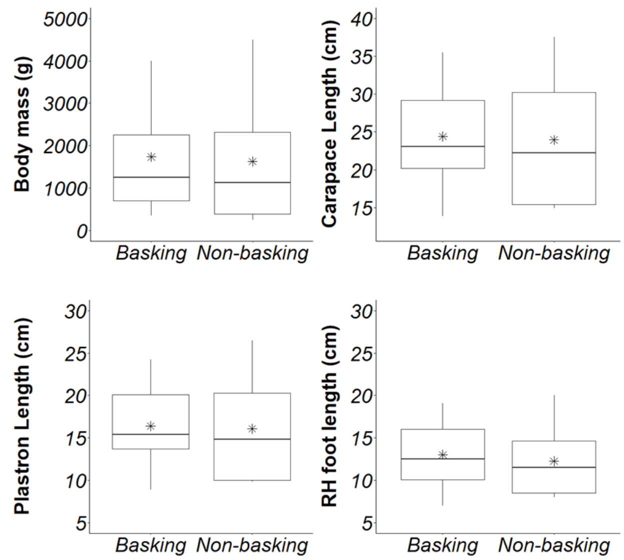

Figure 2. Boxplots of body mass, carapace length, plastron length, and right-hind foot length for basking (*n* = 13) and non-basking (*n* = 9) site captures of Spiny Softshells (*Apalone spinifera*) from May – September 2004 in Steele Creek Park Lake, Bristol, Tennessee, USA. The top and bottom of each boxplot represents the 3rd and 1st quartiles, respectively, the middle line of the boxplot is the median, the stars represent the mean, and the whiskers represent the range (min and max). There was no evidence that these four morphometrics' means were associated with basking or non-basking sites (p > 0.05).

to basking and non-basking sites (χ^2 = 0.47; df = 1; p = 0.492). Further, there was no evidence that Spiny Softshell morphometrics were positively associated with these sites (see Figure 2). For example, mean body mass was not associated with basking site captures (*n* = 13) compared to non-basking site captures (*n* = 9; t = 0.15; df = 14.06; p = 0.883). Similar lack of evidence was found for carapace length (t = 0.11; df = 13.45; p = 0.916), carapace width (t = 0.04; df = 9.01; p = 0.970), plastron length (t = 0.10; df = 13.53; p = 0.92), and right-hind foot length measures (t = 0.36; df = 14.60; p = 0.727).

Captured female Spiny Softshells (*n* = 11) were significantly larger than males (*n* = 6) (Table 1), with female measurements being nearly twice as large as males for most morphometrics (carapace length: 29.09 cm vs 15.23 cm, t = 7.35; df = 10.72; p < 0.001; carapace width: 24.50 cm vs 13.36 cm, t = 6.92; df = 8.94; p < 0.001; plastron length: 19.67 cm vs 9.98 cm, t = 7.19; df = 10.92; p < 0.001; right-hind foot length: 15.04 cm vs 8.30 cm, t = 6.52; df = 11.71; p < 0.001). Furthermore, mean female body mass was over sixfold great-

Table 1. Morphometrics of individual male (*n* = 6) and female (*n* = 11) Spiny Softshells (*Apalone spinifera*) captured from May – September 2004 in Steele Creek Park Lake, Bristol, Tennessee, USA. Asterisks denote a statistically significant difference between males and females (p < 0.5).

Sex	**Carapace length (cm)***	**Carapace width (cm)***	**Plastron length (cm)***	**Right-hind foot length (cm)***	**Body mass (g)***
Females (N = 11)	29.09 (20.20 - 37.50; SD 6.14)	24.50 (17.30 - 31.55; SD 4.69)	19.67 (13.70 - 26.5; SD 4.37)	15.04 (10.06 - 20.00; SD 3.29)	2,386.36 (700 – 4,500; SD 1,305.77)
Males (N = 6)	15.23 (13.90 - 16.50; SD 0.87)	13.36 (11.90 - 14.20; SD 0.86)	9.98 (8.90 - 11.10; SD 0.70)	8.30 (7.00 - 9.00; SD 0.73)	391.67 (250 – 500; SD 96.21)

Table 2. Morphometrics of additional semi-aquatic turtle species captured from May – September 2004 in Steele Creek Park Lake, Bristol, Tennessee, USA.

Species	**Carapace length (cm)**	**Plastron length (cm)**	**Number captured**
Snapping Turtle (*Chelydra serpentina*)	23.28 (range 14.05 - 31.5; SD 8.77)	16.73 (range 11.7 - 20.5; SD 4.53)	3
Pond Slider (*Trachemys scripta*)	14.83 (range 9.1 - 29.2; SD 5.58)	12.54 (range 7.6 - 22.1; SD 4.34)	17
Painted Turtle (*Chrysemys picta*)	10.84 (range 7.5 - 14.2; SD 3.74)	9.15 (range 6.2 - 12.1; SD 4.17)	2

er than males (2,386.36 g vs 391.67 g, t = 5.04; df = 10.20; p <0.001). For morphometrics of additional turtle species captured during the study, see Table 2.

Opportunistic basking survey results

We opportunistically observed 41 basking Spiny Softshells. Nearly a quarter were observed basking in the morning between 0953 and 1200 (*n* = 9) and the majority were observed in the afternoon between 1201 and 1640 (*n* = 32). Over half of the observed basking individuals were recorded on coarse woody debris (*n* = 24; on downed trees and branches) that were touching the bank (*n* = 21) or floating in open water (*n* = 3). The rest of the recorded basking individuals were observed basking on the banks of the reservoir (*n* = 17) either on rocks (*n* = 14) or on coconut logs used for erosion control (*n* = 3).

DISCUSSION

We provide trap capture, visual observation, and morphometric data of Spiny Softshells from a four-month study in a reservoir in northeast Tennessee. Our results of Spiny Softshell morphometrics are consistent with previous studies in human-modified systems. For instance, Plummer and Mills (2015) studied Spiny Softshell growth and longevity in an urban stream in Arkansas, and their mean plastron lengths for females (22.4 cm) and males (10.5 cm) were similar to our results (females: 19.7 cm; males: 10.0 cm).

We found that females were considerably larger than males across nearly all metrics, but sex was not statistically associated with basking site captures. Similarly, we found no evidence that morphometrics were associated with basking site captures. However, our results should be interpreted with caution because we had low sample sizes, and we were not able to ascertain population size distribution. There is also a possibility that turtles were missed due to sampling biases (Mali et al. 2013, Tesche and Hodges 2015). For instance, we used hoop traps positioned next to aerial basking structures as a proxy for thermoregulatory resource use, and a more thorough investigation that accounts for direct observations of basking events (e.g., camera trap surveys and/or basking traps) may reveal different results. While our results do not provide evidence to suggest that larger individuals were associated with basking site captures, similar studies have found that larger Spiny Softshells use basking sites more than smaller ones (Schneider et al. 2019). The reasons behind these findings are unclear. One plausible explanation is that larger individuals have an intraspecific competitive advantage over smaller individuals for resources such as basking sites and basking times. For example, Lindeman (1999) found that, across four freshwater turtle species, larger individuals caused or resisted displacement from basking locations in 70% of all interactions, and that larger turtles elicited avoidance behaviors from smaller turtles, but not vice-versa, suggesting that larger individuals act as a barrier to basking sites for smaller individuals. Similarly, larger body size of the invasive Red-eared Slider (*Trachemys scripta elegans*) was an important predictor of basking site activity over other species (Polo-Cavia et al. 2010), indicating the prominence of body size for thermoregulatory resource competition within and among freshwater turtles.

Larger individuals may have different thermoregulatory requirements compared to smaller individuals. For example, Bulté and Blouin-Demers (2010) found that large female Northern Map Turtles (*Graptemys geographica*) were not able to thermoregulate as optimally as smaller individuals, and that they had much lower maximum body temperatures and a narrower daily range of body temperatures compared to smaller turtles. Similar findings were discovered for other reptile species, where the large Lutz's Tree Iguanas (*Liolaemus lutzae*) of southeast Brazil selected microhabitats with lower temperatures compared to juveniles, possibly to avoid risk of overheating (Maia-Carneiro and Rocha 2013). Likewise, juvenile Diamond-backed Watersnakes (*Nerodia rhombifer*) showed higher thermal tolerance than adults (Winne and Keck 2005), indicating they may be able to tolerate basking resources during hotter time-periods. Other studies on turtle basking dynamics have shown that the duration of basking times between male and female turtles did not differ significantly, even though the investigators predicted that females would bask longer in order to encourage rapid egg production (Lefevre and Brooks 1995; Millar et al. 2012). We suggest that future research focus on the interface between intraspecific basking resource competition and thermoregulatory requirements of Spiny Softshells.

Although we conducted this study in Tennessee's third largest municipal park, an area with considerable undeveloped land, it is at increasing risk of habitat loss and pollution due to sustained urban development and infrastructure expansion in and around its boundaries. The aquatic herpetofauna in this reservoir may therefore be at heightened risk of decline (Brown et al. 2012, but see Plummer et al. 2008). The human pressures already present within and around the park may be exacerbated by climate change (Gibbons 2013), which can alter turtle habitat selection and hatchling survivability (Butler 2019, Parren et al. 2021). While our study cannot elucidate population health and resilience of the Spiny Softshell in this modified system, future research should incorporate estimates of population growth and survival over time using multiple sampling methods (Tesche and Hodges 2015, Butler 2019). Such investigations will be crucial for a better understanding of the downstream effects of human land-use on aquatic turtles, and their resilience under environmental change.

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