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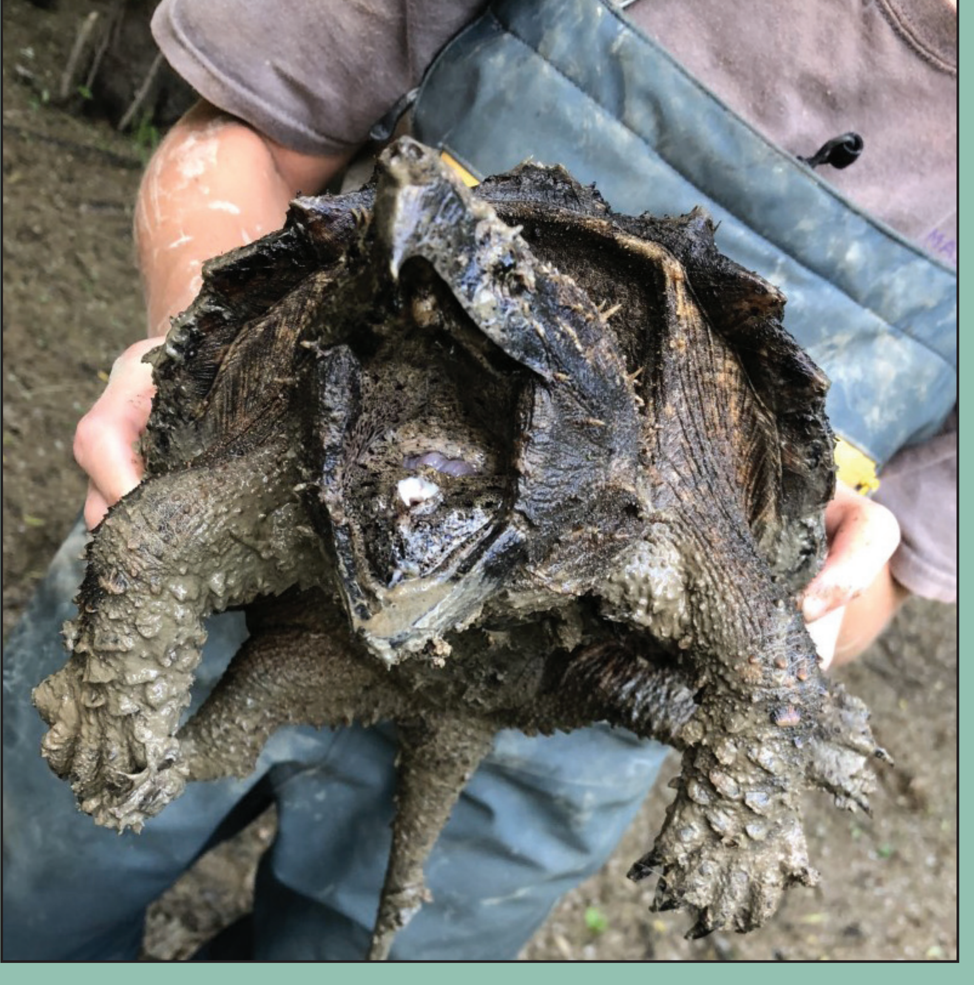

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Cover Photograph: Juvenile Alligator Snapping Turtle (***Macrochelys temminckii***) captured in Daisy Pond, Lefleur's Bluff State Park. Photograph © Gracie Bellnap.

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A Diverse Aquatic Turtle Assemblage in an Urban Mississippi Oasis

Gracie Bellnap[1] and Will Selman[1*]

Abstract - The loss of natural habitats associated with urbanization is increasing, and natural areas may serve as refuges for wildlife in urban areas. In central Mississippi, one such area is LeFleur's Bluff State Park (LBSP, ~120 ha), located primarily in the floodplain of the Pearl River but also surrounded by highly developed areas of Jackson, Mississippi. We investigated a diverse aquatic turtle assemblage in 3 LBSP cypress ponds during the summers of 2017 and 2018 using 3 different capture methods. *Trachemys scripta* (Slider Turtle), a cosmopolitan generalist, was the most commonly-encountered species, but aquatic turtle richness was high and richness/diversity varied across study ponds; the assemblage included *Macrochelys temminckii* (Alligator Snapping Turtle), a species currently proposed for listing under the US Endangered Species Act. Collectively, we captured 9 turtle species typically associated with both pond and riverine habitats, and this finding is suggestive of connectivity between our study ponds and the nearby Pearl River. Fyke nets caught the highest number of species and had the highest trapping efficiency of all methods tested. Our data serve as baseline information on this diverse urban turtle assemblage, and we also provide methodological recommendations for researchers working in similar aquatic environments.

Introduction

Urbanization is often cited as the primary cause of species loss, as natural habitats are destroyed or degraded by human infrastructure (Alford and Richards 1999, Czech et al. 2000, Edmondson 1991, Gibbons et al. 2000, McKinney 2008). Some regions of the United States (US) retain less than 20% of the wild acreage they once had (Gibbons et al. 2000), and existing natural areas (e.g., parks, refuges, and wildlife management areas) may be inadequate to preserve biodiversity. Nonetheless, within urban centers, the establishment of natural areas may mitigate local wildlife losses (Savard et al. 2000). Without natural areas embedded in urbanized landscapes, some species may become extirpated (Nielsen et al. 2014). Therefore, studies of biodiversity in urban settings are of increasing interest, particularly those quantifying natural area biodiversity and how biodiversity may persist in human-modified settings.

The southeastern US is one of the most diverse aquatic regions in the world, and it was recently designated a global biodiversity hotspot (Noss et al. 2015). The Gulf Coastal Plain in the southeastern US is considered a chelonian biodiversity hotspot (Buhlmann et al. 2009, Mittermeier et al. 2015), but some of its turtles are species of conservation concern. Turtles face numerous threats in the region, including habitat destruction and fragmentation, fisheries by-catch, and collection for the international pet, food, and traditional medicine trades (Rhodin et al. 2018). These factors have collectively contributed to declines in freshwater turtle populations. Because turtles make up most of the vertebrate biomass in wetland communities, reduced numbers of turtles may significantly change the ecological function and integrity of aquatic ecosystems (Lovich et al. 2018). For example, turtles act as both consumers of plants and animals and as prey to larger animals, with the latter typically as-

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sociated with the egg and juvenile stages (Glorioso et al. 2010). Thus, the natural balance of ecosystems can be disturbed by the decline of turtle populations. Urban parks may serve as important refuges for local turtle populations because they usually include natural and/or semi-natural aquatic and terrestrial habitats. If the parks are large enough and offer the requisite resources for turtles, these parks may support turtle populations that might otherwise not exist in urban and suburban environments (Dupuis-Désormeaux et al. 2019).

We studied the turtle assemblage of 3 small (all ≤1.1 ha) cypress ponds at LeFleur's Bluff State Park (LBSP; ~123 ha), a small urban park in Jackson, Mississippi. At the time of this study, the population of Jackson and surrounding suburban areas (tri-county area: Hinds, Madison, Rankin counties) was 493,918 (US Census Bureau 2021). Our goal was to document the aquatic turtle assemblage at these locations in the Pearl River floodplain. While investigating the turtle assemblage, we also tested the efficacy of a variety of trapping methodologies for floodplain turtle assemblages, and we provide a cost–benefit analysis for each method.

Materials and Methods

Study Sites

LeFleur's Bluff State Park is located in Jackson, Mississippi (Hinds County). Most of the park occurs within the floodplain of the Pearl River. We studied the turtle assemblage in 3 cypress ponds (Hammock, Armadillo, and Daisy) in the southern portion of LBSP (Fig. 1).

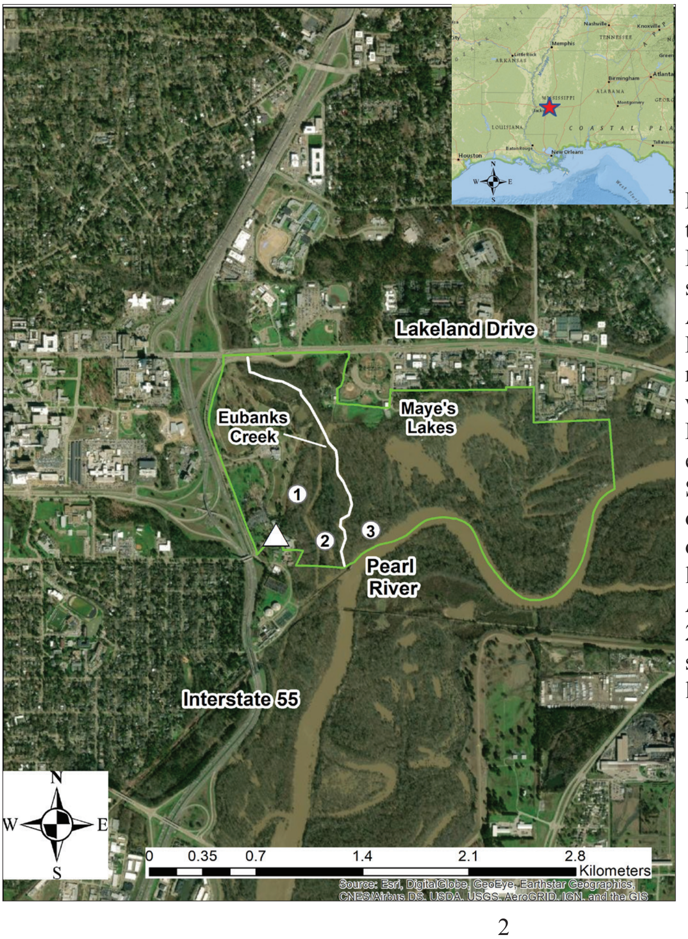

Figure 1. Sampled ponds in the Pearl River floodplain of Lefleur's Bluff State Park, Jackson, MS, USA (Hammock—1, Armadillo—2, Daisy— 3). The Mississippi Museum of Natural Science is located at the white triangle, and the Pearl River extends along the southern border of Lefleur's Bluff State Park. Eubanks Creek is outlined in white. The red star on the inset map indicates the location of Jackson, Mississippi. Aerial photograph was taken in 2017 (Esri, used with permission under Millsaps College site license).

These ponds were characterized by a wide diversity of plant and animal life, muddy and organic substrates, and water levels that seasonally fluctuated with rainfall and river levels. Dominant tree species in the floodplain included *Taxodium distichum* (L.) Rich. (Baldcypress), *Nyssa aquatica* L. (Swamp Tupelo), oak trees (*Quercus lyrata* Walter [Overcup Oak], *Quercus michauxii* Nutt. [Swamp Chesnut Oak], *Quercus nigr*a L. [Water Oak]), and the invasive *Triadica sebifera* (L.) (Chinese Tallowtree).

Hammock Pond was ~1.10 ha in size (32.32677°N, -90.15546°W). Maximum water depths ranged from ~1 to 1.5 m; depths were sometimes slightly deeper than this near the center of the pond depending upon the season. The northern and southern ends of the pond were shallower (<0.5 m deep) and had a thick, organic substrate. Swamp Tupelo and Baldcypress trees were scattered throughout the pond, providing almost complete canopy coverage of the pond's surface. Duckweed L. (*Lemna* sp.) was prevalent and, at times, covered almost the entire surface of the pond. Even though little sunlight penetrated the dense canopy, many turtle basking logs and branches were available. A recreational walking trail with an observation deck bordered the western and southern edges of the pond (trail was ~3–10 m away), and this pond was in closest proximity to the Mississippi Museum of Natural Science (MMNS), ~0.20 km away by trail. Thus, Hammock Pond likely experienced more walking traffic than the other ponds, but walking traffic was still low on the lightly used trail.

Armadillo Pond was ~0.92 ha in size (32.32472°N, -90.15162°W). During normal water conditions, water depths were ≤2 m throughout the pond; the depths were more spatially consistent across the pond compared to Hammock or Daisy ponds (below). Large Swamp Tupelo, Baldcypress, and Chinese Tallowtrees were prevalent along the margins of the pond. The pond had an open canopy, but there were limited basking structures. Baldcypress trees were sparsely scattered throughout the pond, but higher tree densities on the southern end of the pond caused this area to be heavily shaded. Similar to Hammock Pond, the same recreational walking trail and observation deck (~3 m away) occurred along the eastern side of the pond; the pond was mostly obscured from view on the walking trail (>25 m away) because of large amounts of understory vegetation. Recreational walking traffic was rarely observed at Armadillo Pond, ~0.5-km walking distance from MMNS.

Daisy Pond was ~0.82 ha (32.1928° N, -90.0907° W), with several different microhabitats not present in the other study ponds. Pond margins were shallow (<0.5 m, ~10–15 m wide) and heavily shaded by Baldcypress trees; an area of open canopy occurred in the center of the pond. Under normal conditions, this middle section was considerably deeper than the rest of the pond (~1.5–2 m). The substrate was muddy throughout the pond, but sand was also present because of overbank sand deposition after flooding of the Pearl River (~25–30 m from the pond's southern edge). Water level fluctuations in Daisy Pond were greater than in Hammock or Armadillo ponds because of an overflow stream connection to the Pearl River. The walking trail approached the northern edge of Daisy Pond, but walking traffic was minimal because the pond was mostly obscured by thick understory and midstory vegetation (~0.75-km walking distance from the MMNS).

Turtle Sampling

From May to July 2017, we used 3 different capture methods to capture turtles across 7 weeks. These methods included unbaited fyke nets with leads (Nets and More, Jonesville, LA), baited hoop nets (Nets and More), and baited collapsible crab traps (Promar Collapsible Crab Trap, Austin, TX). We used double-throated, unbaited fyke nets (hereafter, fyke nets) with 0.914-m hoops and 4.8-cm mesh size; the leads of the fyke nets were 7.6 m long and 0.9 m deep (leads with 5.1-cm mesh size). The leads had weights on the bottom line and floats on the top line to ensure the leads were vertical in the water (i.e., functioned as a fence). We used PVC pipes or available structures to position the cod end of the net away from the bank and toward the center of the pond. The lead was fully stretched to the bank and was secured ~1 m away from the water using stakes or available structure. The depth of the water had to be ~45 cm for the throat to be submerged and allow turtles to enter the fyke net. The second method was standard turtle hoop nets with 0.9-m wide hoops with a single throat (5.1-cm mesh size). We set hoop nets with the throat completely in the water (~45-cm depth). The third method we used was collapsible mesh crab traps (61 × 46 × 20 cm; Promar Collapsible Crab Trap). We used wooden stakes or available structure to set both hoop nets and crab traps. Crab traps were set on the edge of the water or in shallow areas to allow a portion of the trap to remain unsubmerged. We baited hoop nets and crab traps with canned sardines. To maximize sardine scent dispersal, we punctured the top of the can several times before setting the trap the first day; each day thereafter, the lid was slightly peeled back (Iverson 1979). If few to no sardines remained in the can after a trap night, the bait was replaced. For all trap types, we placed small sections of pool noodles inside each net, allowing the net to float and ensuring that captured turtles had access to air.

For each sample week in 2017, we set 2 fyke nets, 6 hoop nets, and 8 crab traps. We attempted to equally sample all parts of the pond by spreading the traps across all sections of the pond with sufficient water depth. All 16 traps were set on Monday, and they were thereafter checked for 3 consecutive days. On occasion, inclement weather or rising river levels prevented us from trapping an entire 3-day period. Also, nets had to be occasionally repositioned to accommodate changing water levels, and damaged traps had to be removed for repairs. During the summer of 2017, we sampled each pond twice using all 3 trapping methods, but persistent rain and summer flooding of the Pearl River prevented us from trapping in part of July 2017. Catch per unit effort (CPUE = total number of turtle captures / trap nights) was used as a measure of trap success.

In 2018, we trapped for 8 weeks between May and July. We used 6 fyke nets per week with similar-style leads and similar set methods to 2017. However, we tested the efficiency of 3 different lead lengths (7.62 m, 11.43 m, 15.24 m; 2 nets of each length). We dispersed nets around the pond in order to sample each section equally, and we checked nets for 3 consecutive days each week except in cases of rising water levels or net repairs. No crab traps or hoop nets were used in 2018. In contrast to 2017, the summer of 2018 was characterized by lower water levels because of semi-drought conditions. Thus, we sampled Hammock and Armadillo ponds 3 times each during 2018, while Daisy Pond was sampled once as a result of the pond completely drying during the drought.

For each net/trap, we recorded the number and species of individuals captured per trap each day. We also collected morphometric and sex data from captured individuals for a related study. All newly captured individuals were permanently marked by notching or drilling holes in the marginal scutes using a file or drill, respectively (Cagle 1939). All individuals were released at their point of capture.

Analysis

We used a Shannon Diversity Index (H') to calculate and compare turtle diversity across our 3 study ponds (Shannon and Weaver 1949), with 2017 and 2018 data analyzed separately, and we also calculated evenness of turtles by site (Krebs 1994). Because CPUE was not normally distributed, we used a Kruskal–Wallis rank sum test to determine if CPUE (including all species and all captures/recaptures) was similar across trapping methods (crab trap, hoop net, and fyke) in 2017. We also used a Kruskal–Wallis rank sum test to determine if CPUE was similar across fyke net lead lengths (7.62 m, 11.43 m, 15.24 m) for the 2018 data. Finally, Kruskal–Wallis rank sum tests were used to determine if CPUE (including all species and all captures/recaptures) was equal across ponds for the 2017 and 2018 data. In cases where significant results were found for Kruskal–Wallis rank sum tests, nonparametric Wilcoxon multiple comparison tests were completed to determine differences among tested groups. All analyses were performed in JMP 14 (SAS Corporation, Cary, NC).

Results

Species Richness and Diversity

Across both years of sampling, we captured a total of 341 individuals (79 recaptures) of 9 aquatic turtle species. The 9 species were *Trachemys scripta elegans* (Wied-Neuwied) (Red-eared Slider Turtle), *Pseudemys concinna* (Le Conte) (River Cooter), *Kinosternon subrubrum* (Bonnaterre) (Mud Turtle), *Sternotherus carinatus* (Gray) (Razorback Musk Turtle), *Chelydra serpentina* (L.) (Common Snapping Turtle), *Macrochelys temminckii* (Troost and Harlan) (Alligator Snapping Turtle), *Sternotherus odoratus* (Latreille) (Stinkpot), *Chrysemys dorsalis* Agassiz (Southern Painted Turtle), and *Apalone spinifera* (Le Sueur) (Spiny Softshell) (Table 1). For all captures and all ponds, Slider Turtles dominated the assemblage of turtles in both years (95.3% in 2017; 88.2% in 2018), while the 8 other species represented minor portions of the turtle assemblage in both years (from 0–3% in both years; Table 1).

Comparisons of Turtle Diversity by Pond and Movements

Shannon diversity values were low during both years and for all ponds. However, diversity (H') and evenness (E) values were lower for all ponds in 2017 (Hammock: $H' = 0.29$, $E = 0.21$; Armadillo: $H' = 0.13$, $E = 0.12$; Daisy: $H' = 0.28$, $E = 0.25$) compared to 2018 (Hammock: $H' = 0.61$, $E = 0.38$; Armadillo: $H' = 0.43$, $E = 0.27$; Daisy: $H' = 0.45$, $E = 0.32$). Diversity values were similar among ponds each year, with Hammock Pond having the highest diversity both years.

Of the 355 captures of Slider Turtles in 2017 and 2018, we recaptured 33 individuals. Of these 33 individuals, 28 were recaptured in their original pond (Hammock—12; Armadillo—13; Daisy—3), while 5 were recaptured in a different pond in 2018 than where they were originally captured in 2017. For the latter, 4 individuals (2 females, 2 males) moved from Armadillo to Hammock (~40 m between the ponds, sometimes with a small overflow channel connecting them), while a single male moved from Hammock to Armadillo. Further, only a single male individual was captured in the same year in different ponds (2017—Hammock to Armadillo). No turtles were found emigrating from Daisy Pond to the other 2 study ponds, which were located on the opposite (west) side of Eubanks Creek.

Trapping Methodology

In 2017, CPUE differed among trapping methods ($\chi^2 = 30.57$, $p < 0.0001$). Wilcoxon nonparametric multiple comparisons indicated that fyke nets ($n = 13$ net sets, mean CPUE = 5.33 ± 5.04 SD, range = 0–17.0) captured more turtles than hoop nets ($n = 38$ trap sets, mean CPUE = 0.19 ± 0.39 SD, range = 0–1.7) or crab traps ($n = 46$ trap sets, mean CPUE = 0.267 ± 0.47 SD, range = 0–2.0); there was no statistical difference in CPUE between hoop nets and crab traps. In 2018, there was no difference in CPUE among fyke nets with different lead lengths ($\chi^2 = 0.36$, $p = 0.84$; 7.62-m lead: mean CPUE = 2.11 ± 1.70 SD, range = 0–5.0; 11.43-m lead: mean CPUE = 1.72 ± 1.25 SD, range = 0–4.7; 15.24-m lead: mean CPUE = 1.80 ± 1.44 SD, range = 0–4.3). However, the 15.24-m fyke net captured 6 of the 9 documented species, whereas the 11.43-m fyke nets captured 5 of 9 species, and the 7.62-m captured 4 of 9 species (Table 1).

Catch per unit effort differed among ponds in 2017 ($\chi^2 = 7.95$, $p = 0.02$). Wilcoxon nonparametric multiple comparisons indicated a higher CPUE in Armadillo Pond compared to Daisy or Hammock; CPUE did not differ between Hammock and Daisy ponds. Catch per unit effort did not differ among ponds in 2018 ($\chi^2 = 2.61$, $p = 0.27$). Armadillo Pond (2017 mean CPUE = 1.28; 2018 mean CPUE = 2.18) was the most species rich pond with 6 species, whereas Hammock Pond (2017 mean CPUE = 1.02; 2018 mean CPUE = 2.11) and Daisy Pond (2017 mean CPUE = 0.62; 2018 mean CPUE = 1.49) each had 5 species captured.

Discussion

Urban Aquatic Turtle Richness and Diversity

Our results confirm that ponds within the small natural area of LBSP, a park surrounded by an urbanized landscape, currently support relatively high species richness of aquatic turtles, and the threats to turtles in this area appear to be minimal (i.e., no observed collections, no

Table 1. Total captures of freshwater turtles from 3 different floodplain ponds (Hammock, Armadillo, Daisy) in Lefleur's Bluff State Park, Jackson, MS, in 2017 and 2018. Effort is shown as the number of trap days that a capture method was used at that pond for each year. In 2017, methods included baited crab traps (Crab), baited hoop nets (Hoop), and 7.62-m lead fyke nets (Fyke). In 2018, only fyke nets with different lead lengths (7.62 m, 11.43 m, 15.2 m) were used. Species abbreviations: *A.s.* = *Apalone spinifera*, *C.d.* = *Chrysemys dorsalis*, *C.s.* = *Chelydra serpentina*, *K.s.* = *Kinosternon subrubrum*, *M.t.* = *Macrochelys temminckii*, *P.c.* = *Pseudemys concinna*, *S.c.* = *Sternotherus carinatus*, *S.o.* = *Sternotherus odoratus*, and *T.s.* = *Trachemys scripta*.

Year	Pond	Method	Effort	*T.s.*	*C.s.*	*K.s.*	*P.c.*	*C.d.*	*S.c.*	*A.s.*	*M.t.*	*S.o.*	Total
2017	*Hammock*	Crab	40	6	-	1	-	-	-	-	-	-	7
		Hoop	32	4	-	-	-	-	-	-	-	-	4
		Fyke	10	51	1	1	1	-	-	-	-	-	54
	Armadillo	Crab	33	13	-	-	-	-	-	-	-	-	13
		Hoop	33	6	-	-	-	-	-	-	-	-	6
		Fyke	10	59	-	-	1	-	1	-	-	-	61
	Daisy	Crab	41	1	-	-	-	-	-	-	-	-	1
		Hoop	33	1	1	-	-	-	-	-	-	-	2
		Fyke	12	42	-	-	-	-	2	-	-	-	44
	Total			183	2	2	2	-	3	-	-	-	192
2018	*Hammock*	7.62 m	18	24	-	3	1	2	-	-	-	-	30
		11.43 m	18	14	1	1	-	-	-	-	-	-	16
		15.24 m	18	24	3	-	-	-	-	-	-	-	27
	Armadillo	7.62 m	16	30	-	-	-	1	-	-	-	-	31
		11.43 m	16	25	-	-	-	3	-	-	-	-	28
		15.24 m	16	21	-	-	1	-	-	2	-	1	25
	Daisy	7.62 m	6	11	-	-	-	-	-	-	-	-	11
		11.43 m	6	7	1	-	2	-	-	-	-	-	10
		15.24 m	6	16	-	-	-	-	-	-	1	-	17
	Total			172	5	4	4	6	-	2	1	1	195

nearby roads, etc.). Turtle richness is known to be high in Mississippi (n = 31 species; Buhlmann et al. 2008) and the southeast US in general (Buhlmann et al. 2009). One might expect urban areas to maintain lower species richness than natural areas, a pattern primarily associated with the extirpation of rare species in urban areas (McKinney 2008). This absence of rare species was not the case at our study site, as we captured a single juvenile Alligator Snapping Turtle, a species that is currently proposed for listing under the US Endangered Species Act (USFWS 2021). Similarly, Munscher et al. (2020) discovered a thriving population of Alligator Snapping Turtles in the urban center of Houston, Texas. We suspect that the individual in our study was likely associated with a population in the nearby Pearl River that flows through Jackson. However, because we only captured a single individual, further research is needed to document the population status of Alligator Snapping Turtles in the Pearl River near Jackson. Nonetheless, the findings of this study and Munscher et al. (2020) highlight that urban rivers and floodplain pond habitats may maintain rare species of turtles.

Diversity and evenness were relatively low for all ponds in both years, and these low values were associated with capturing few species in each pond and the dominance of Slider Turtles. The Slider Turtle is a ubiquitous aquatic turtle species that is well-adapted for lentic environments like our study site and is a native species to our study area (Ernst and Lovich 2009). However, Slider Turtles have also been widely introduced outside of their native range, and they occur globally in many urban and suburban waterways in high densities (e.g., Snapp et al. 2021), often competing with native turtles for resources (Cadi and Joly 2004). Along with the more commonly encountered Slider Turtle (MMNS Herpetology Collection, catalog #16217), historical records of 5 additional lentic turtle species exist for this region of the Pearl River floodplain (i.e., Hinds and Rankin counties; Southern Painted Turtle, MMNS #4474; Common Snapping Turtle, MMNS #13000; River Cooter, MMNS #10853; Stinkpot, MMNS #10827; Mud Turtle, MMNS #1098). During 2017 and 2018 sampling efforts, we captured each of these species. We also captured species usually associated with lotic environments, including the Spiny Softshell, Alligator Snapping Turtle, and Razorback Musk Turtle. Similarly, all 3 of these species had previously been found near our study site (Spiny Softshell, MMNS #1495; Alligator Snapping Turtle, MMNS #4203; Razorback Musk Turtle, MMNS #4330–4348). However, most of the specimens reported above were collected before the 1970s.

Since these historical collections of the 9 species were made, there have been substantial hydrologic changes in the region, including the construction of the Ross Barnett Reservoir, an impoundment of the Pearl River, upstream of Jackson in 1963 and the levee protection system around Jackson, which was implemented in the 1960s (Selman 2020). Also, the area surrounding Jackson has been developed significantly over the last 50 years for commercial and residential uses, particularly east of the Pearl River (e.g., the towns of Flowood, Pearl, Brandon). Thus, in spite of these dramatic changes over the last 50 years, our study demonstrates that these 9 species have persisted in the region. However, the outlook for a local riverine turtle species not observed in our study, *Graptemys pearlensis* Ennen, Lovich, Kreiser, Selman, and Qualls (Pearl Map Turtle), is not as positive. This species has declined dramatically in the region over the last 30 years (Selman 2020, Selman and Jones 2017). The future of this diverse turtle assemblage and the greater Pearl River floodplain may be dependent upon the intensity and rate of human development in the region and how it impacts riverine processes. This potential development includes another impoundment that is planned for the Pearl River, the One Lake Project, which will significantly impact the river hydrology, the riverine turtles, and the surrounding floodplain (Selman 2020).

Floodplain Turtle Assemblages and River Connectivity

Captures of species associated with both ponds and flowing streams/rivers suggest that our sampling ponds are regularly connected to the Pearl River. The presence of riverine species points to the importance of river connectivity in these floodplain ponds. In wetlands associated with a river, resources may vary with alternating periods of connectivity and disconnectivity between floodplain ponds and rivers during annual flood and drought cycles (Riedle et al. 2016). Thus, flood pulses are arguably the most important process influencing stream communities because they permit biotic and abiotic exchanges between the river and associated terrestrial floodplain habitats. These interactions lead to shifts in species compositions, nutrient influxes, and changes in chemical processes (Bunn and Arthington 2002, Riedle et al. 2016). During this study in July 2017, flooding connected the Pearl River to all 3 study ponds, possibly contributing to individuals moving among ponds and between the river and the ponds. Indeed, 5 of 33 (15%) interannual recaptures (i.e., those individuals captured in 2017 and recaptured in 2018) exhibited movements between ponds. Further evidence of the connectivity of the Pearl River floodplain is that 2 marked turtles from our project in 2017 were found ~0.75 km north of our sites (i.e., upstream) in Maye's Lake in 2018 (L. Pearson, The University of Southern Mississippi, Hattiesburg, MS, pers. comm.).

Captures of some riverine species in our smaller study ponds also suggest that some of the river turtle species may be better suited to lentic environments than others. For example, 2 riverine specialists—*Graptemys oculifera* (Baur) (Ringed Sawback) and the Pearl Map Turtle—occur within the Pearl River immediately adjacent to the study area (Selman 2020), but they were not captured or observed during our study. Interestingly, Ringed Sawbacks were observed in low densities in larger, deeper oxbow lakes (e.g., 2.8 – 8.7 ha) ~0.6 km northeast of our study site within LBSP, but Pearl Map Turtles were not observed at these locations (Selman 2020). Thus, even though both *Graptemys* species are found immediately adjacent to our study ponds in the Pearl River, and Ringed Sawbacks are found in larger lakes near our study site, it appears *Graptemys* species do not use smaller, lentic environments like our 3 study ponds. In comparison, we found that some lotic species, like the Spiny Softshell, Alligator Snapping Turtle, and Razorback Musk Turtle, may acclimate to smaller bodies of water in urbanized areas, such as the ponds in this study.

The turtle assemblage we observed in this study was different across years, and we captured some species in just 1 of our sampling years. For example, Razorback Musk Turtles were captured in 2017 but not 2018, whereas Southern Painted Turtles were captured in 2018 but not 2017. Turtle species exchanges occur during river flood pulses when floodplain and river habitats are connected (Riedle et al. 2016). Similarly, seasonal droughts may also redistribute individuals occupying these floodplain ponds. We captured a single juvenile Alligator Snapping Turtle in Daisy Pond during our first sampling period of 2018. However, because Daisy Pond dried later in the summer, this individual likely emigrated overland from Daisy Pond to another waterbody (e.g., Pearl River, Eubanks Creek). In summary, we suspect that some turtle species may be transient in these floodplain pond habitats, and consequently, some species may be rare and not be sampled every year. Therefore, multiple years of data are needed to fully explain the nature of these dynamic floodplain turtle assemblages.

Sampling Methodology

When evaluating the best and most appropriate trap type to use, it is important for researchers to account for the cost, time, effort, and expertise required to achieve the research goal(s) (Sterrett et al. 2010). Furthermore, most studies similar to ours also would like to capture a relatively large sample size of turtles for statistical power and a representative sample of the turtle assemblage. Taking these factors into consideration, a variety of methods used together has usually been shown to be most effective (Riedle et al. 2021, Vogt 1980).

In order to effectively sample the entire turtle assemblage, we utilized 3 different methods in 2017 to sample our study ponds. Our results from 2017 indicated that fyke net CPUE was much higher (28×), with ~70% less trap nights, than the CPUE for crab traps or hoop nets, and the fyke nets sampled the turtle assemblage more effectively, catching all 5 species observed in 2017. Hoop nets and crab traps each captured only 2 species. This finding is what led us to further investigate fyke nets during the 2018 field season.

In 2018, we found that fyke net lead length was associated with the number of turtle species captured (Table 1). The fyke net with the longest lead (15.24 m) captured the highest number of species (6), including 3 species not detected with other lead lengths (Alligator Snapping Turtle, Spiny Softshell, and Stinkpot), while the 2 shorter length fyke nets captured 4–5 species. The difference in number of species captured by each lead length may be due to random chance or related to the pond depth. For example, the 7.62-m fyke net did not reach the deep, middle portions of the ponds, which could reduce the likelihood of capturing bottom-walkers, such as Razorback Musk Turtles and Mud Turtles. Conversely, the 15.24-m lead reached further into the pond and had the ability to catch both the most mobile turtle species and those that use open, deeper pond microhabitats.

When compared between years, fyke nets demonstrated drastically different mean CPUEs (2017: 5.33; 2018: 1.72–2.11). It is possible that CPUE was higher in 2017 because of early 2018 flooding events that may have changed turtle densities and species distributions among the ponds prior to our 2018 sampling. Alternatively, the employment of 6 fyke nets in 2018 per sampling week (compared to 2 nets per week in 2017) may have led to an oversaturation of traps in the relatively small ponds. In the smaller ponds, individuals can readily move throughout the entire pond; this behavior was observed when individuals were recaptured within the same day at opposite ends of the pond. Thus, with the deployment of 6 fyke nets in 2018, turtles were more likely to encounter a net compared to 2017. Weekly mean CPUEs were similar between 2017, when there were only 2 nets (mean CPUE: 5.33), and 2018, when there were 6 total nets (mean CPUE: 5.63). Further, our 3 most successful net sets from 2017 had much higher trap rates (CPUE: 5.6–9.3) compared to the 3 most successful net sets from 2018 (CPUE: 4.7, occurred 3 times). This finding suggests that 2–4 fyke nets per hectare may be sufficient to adequately sample the turtle assemblage; anything greater may be "overkill" and add additional time, effort, and costs to the study. This ratio of nets/ha may serve as a guide for future studies.

Trapping Considerations for Researchers

Our results indicate that capture method can dramatically influence the perception of turtle assemblage composition. Hoop nets have been the standard trapping method since the 1960s because of their simplicity and low cost (Iverson 1979, Mali et al. 2014, Plummer 1979). However, we found that they recorded a less representative and vastly different turtle assemblage and were not as cost effective as fyke nets (Tables 1, 2). Because fyke nets produced a substantially higher CPUE and higher species richness, we agree with Dreslik et al. (2005) that they provide a better estimation of turtle assemblage dynamics. In general, fyke nets may be overlooked by researchers because they are more expensive and bulkier to transport in the field. However, researchers have consistently reported high capture rates and minimal turtle mortality, and because they are unbaited, they are a less-biased sampling method (Bury 2011, Dreslik et al. 2005, Selman and Baccigalopi 2012, Vogt 1980, Wallace et al. 2007). We acknowledge that, while fyke nets are effective in slow-moving rivers and

Table 2. Comparison of trap type efficiency (total catch per unit effort, CPUE) and a cost–benefit analysis of trapping methods used to capture turtles in cypress ponds at Lefleur's Bluff State Park, Jackson, MS.

Trapping method	Cost (US$)	Added expenses (US$)	Time to set (min)	Weight (kg)	Total species richness	CPUE
Fyke net	233.20–282.69*	4.00 (PVC pipes)	~15 min	4.5–6.8	9	1.7–5.3
Hoop net	93.55	3.00 (2 stakes) ~2.00/week (bait)	~5 min	2.3	2	0.19
Collapsible crab trap	14.99	1.50 (1 stake) ~2.00/week (bait)	2–3 min	0.5	2	0.27

*The cost of fyke nets varies depending on lead net length (i.e., fyke nets with longer leads are more expensive).

ponds, they may be less effective in faster currents because of high flow rates that may dislodge the nets (Sterrett et al. 2010, Vogt 1980).

Based on our results, fyke nets are capable of capturing more turtles and more adequately sampling the turtle assemblage with less effort than other trapping methods in a lentic environment. One remaining question with the study is why the smallest turtle species (e.g., Mud Turtles and Stinkpots) were rarely captured, even by the fyke nets. This finding could be the result of our larger mesh size (i.e., smaller individuals escaping from the net), or it may indicate a habitat with low densities of Kinosternid species. Additional studies on the roles of bait type and mesh size in accurate documentation of turtle assemblages are warranted, along with long-term monitoring of the potential homogenization of turtle assemblages dominated by generalist species like Red-eared Sliders.

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