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River Turtles and One Dam Lake: Two Imperiled *Graptemys* Species in the Pearl River and Potential Impacts of the Proposed One Lake Project

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Abstract. – The impacts of human modifications of rivers and associated riverine fauna are well documented, especially following the construction of impoundments. In the Pearl River system of Mississippi and Louisiana, 2 endemic *Graptemys* species are found (*G. oculifera*; *G. pearlensis*), but little is known of their densities in urban segments near Jackson, Mississippi, even though both are species of conservation concern. I used spotting scopes and binoculars to complete replicated basking surveys for both *Graptemys* species during the summers of 2017 and 2018 in 5 equidistant segments of the Pearl River and nearby oxbow lakes. Basking densities for both species were generally higher in river segments upstream and downstream of Jackson compared to middle segments. *Graptemys oculifera* were found in greater densities than *G. pearlensis* in all segments (14–69-times higher). *Graptemys oculifera* was found in 4 of the 6 oxbow lakes surveyed, but mean densities decreased 10-fold compared with river segments; *G. pearlensis* was absent from all oxbow lakes. Densities for a generalist turtle species, *Trachemys scripta*, increased 35 times in oxbow vs. river habitats. The middle 3 survey segments (~ 15.9 river kilometers) are inclusive of a proposed river impoundment project—the One Lake Project—for flood control and economic development. Estimates of direct and indirect impacts of this project are sizeable for *G. oculifera* (direct impact: 1684; indirect: 2129) while estimates for *G. pearlensis* are lower (direct: 88; indirect: 219). The One Lake Project would surely alter existing riverine processes and will favor generalist turtles such as *T. scripta* that prefer nonflowing lake settings at the expense of riverine *Graptemys* species. The One Lake Project would be a major setback to both *Graptemys* species in and around the project area and would negatively impact the recovery potential of both species.

Key Words. – basking density surveys; channelization; chelonians; *Graptemys oculifera*; *Graptemys pearlensis*; imperiled; Jackson, Mississippi; Ross Barnett Reservoir; river turtle; urban river

The southeastern United States contains one of the most diverse turtle faunas worldwide, harboring over 10% of the world's turtle species (Buhlmann et al. 2009), but over 60% of southeastern United States turtle species are considered imperiled and at risk for declines (Buhlmann and Gibbons 1997). Along with direct threats to turtles, such as collection for the pet trade, threats to riverine habitat are also widespread and include channelization, desnagging (i.e., removal of trees and deadwood from the river channel), pollution, excess sedimentation, and impoundments (Moll and Moll 2004). For the latter, reservoirs alter riverine hydrology (for review, see Bunn and Arthington 2002) and are a leading contributor to species endangerment in the United States, particularly in the southeastern United States (Czech et al. 2000).

One such river system with historical modifications is the Pearl River system of central Mississippi and southeastern Louisiana. The Pearl River is a biologically diverse river drainage, but multiple modifications around Jackson, Mississippi were made before and following the historic Easter Flood of 1979 (i.e., the flood of record for the region). In the 1960s, the Pearl River was channelized to improve floodwater conveyance through a historically sinuous segment of the river, and levees were constructed to reduce flooding in the city of Jackson. In 1963, the river system was further altered by the construction of the Ross Barnett Reservoir upstream of Jackson, which regulates downstream flows via a dam and spillway system. Lastly, along with these modifications, this entire segment of the Pearl River has also been historically subjected to degraded water quality via industrial, municipal, and residential sources (McCoy and Vogt 1979). Degraded water quality persists into the present due to large amounts of litter (W.S., *pers. obs.*) and untreated sewage that has been discharged into the Pearl River and tributaries in the Jackson area (Mississippi Department of Environmental Quality, https://www.mdeq.ms.gov/mdeq-issues-water-contact-advisory-for-pearl-river-and-other-streams-in-the-jackson-area/; accessed 28 May 2019).

Since the Easter Flood of 1979, several flood-control options have been proposed for flood protection of Jackson (e.g., Shoccoe Dry Dam, Two Lakes Plan, LeFleur Lakes Plan), and most of these have also touted recreational and waterfront development potential. Currently, another proposed flood control plan, the One Lake Project, is slated to impound ~ 16 river kilometers (rkm) of the Pearl River while also widening and deepening portions of the river channel. However, this project would alter riverine processes and, subsequently, these altered processes would impact the associated aquatic fauna, including riverine turtles, which are dependent upon natural river flows (Graf 2006).

Two endemic riverine turtle species occur sympatrically in the Pearl River system of central Mississippi: *Graptemys oculifera* (ringed sawback; Baur 1890) and *Graptemys pearlensis* (Pearl map turtle; Ennen et al. 2010). Even though information has been collected for both species throughout the river system (e.g., Jones and Hartfield 1995; Lindeman 1998, 1999; Shively 1999; Selman and Jones 2017; Lindeman et al. 2020), there is relatively little population data for either species throughout the segment of the Pearl River that flows through downtown Jackson, including the section slated for the One Lake Project. The objective of this study was to determine the abundance of each *Graptemys* species via basking density surveys in this urbanized segment of the Pearl River while also determining densities in local oxbow lakes in the Jackson area (Hinds/Rankin counties) for comparison. Additionally, 3 of the Pearl River segments I surveyed are inclusive of the proposed One Lake Project; thus these data may also serve as preconstruction data for postconstruction comparisons if the project is completed.

METHODS

River Study Sites. — The Pearl River is a moderately-sized Gulf Coastal Plain river (basin size, 22,348 km^2) that drains much of central Mississippi and southeastern Louisiana. Mississippi's capital and largest city, Jackson, is located near the midpoint of the drainage in central Mississippi, downstream of the Ross Barnett Reservoir. Five equidistant and consecutive river segments (5.3 rkm each; total 26.5 rkm) of the Pearl River were selected for river turtle surveys in Jackson (Hinds and Rankin counties; Fig. 1). Two segments (S1, S2) occur upstream of a lowhead dam on the Pearl River that pools water for municipal water intake and the other 3 survey segments occur downstream of the lowhead dam (S3–S5). Segments 1 and 5 are similar because they are more natural and have alternating sandbar and cutbank sections with high levels of submergent and emergent deadwood. They also have an intact riparian forest buffer (i.e., forest up to the river's edge) in which the primary tree species include water oak (*Quercus nigra*), bald cypress (*Taxodium distichum*), overcup oak (*Quercus lyrata*), and black willow (*Salix nigra*). Segment 2 is a relatively straight portion of the Pearl River with fewer sandbar and cutbank sections, but similar to S1 and S5, S2 maintains moderate–high amounts of deadwood and a mostly intact riparian forest buffer. In the S2 reach, a large, 4-lane state highway crosses the Pearl River. Segments 3 and 4 encompass the channelized portion of the Pearl River, with additional human modifications including mowing within the riparian buffer, herbicide application to vegetation, and desnagging of riverine deadwood. The river lacks a riparian forest buffer along most of S3 and S4 and, instead, is bordered by a grassy/shrubby margin. In-stream differences include few deadwood snags and a shallow, sandy bottom with few deep sections. Within S3 and S4, 2 major interstate highways, 1 US highway, a local road, and 2 railroad bridges cross the Pearl River. Of the 5 segments surveyed, 3 occur within the planned zone of the One Lake Project (S2–S4), while 2 segments occur upstream (S1) and downstream (S5) of the proposed One Lake Project.

Oxbow Lake Study Sites. — In 2018, I also surveyed 6 local oxbow lakes of the Pearl River located in Hinds and Rankin counties. Four different oxbow lakes at LeFleur's Bluff State Park, collectively known as Mayes Lakes, were surveyed from 7 different observation sites (Fig. 2). The 4 lakes included Wing Lake (1 site; 3.0 ha; 0.35 km surveyed), Cypress Lake (1 site; 2.8 ha; 0.36 km surveyed), East Mayes Lake (3 sites; 8.7 ha; 1.02 km combined), and West Mayes Lake (2 sites; 6 ha; 1.07 km combined). All of these sites contain wetland vegetation characteristic of floodplain oxbow ponds including bald cypress, swamp tupelo (*Nyssa aquatica*), red maple (*Acer rubrum*), and the invasive Chinese tallow tree (*Triadica sebifera*). However, a primary difference was that Wing Lake was shallower than the other 3 lakes and had considerable pond surface coverage of white water lily (*Nymphaea odorata*).

A fifth oxbow lake, YMCA Lake (1 site; 1.6 ha; 0.43 km), was surveyed. It is located ~ 3 km south-southwest of the Mayes Lakes. This oxbow lake is a historic channel of the Pearl River, but it was isolated from the river following channelization and levee construction in the 1960s. The YMCA Lake is surrounded by commercial development and trees line ~ 50% of the shoreline; shoreline trees are primarily silver maple (*Acer saccharinum*), American sycamore (*Platanus occidentalis*), and Chinese tallow tree.

The sixth oxbow lake I surveyed was Crystal Lake (4 sites; 0.95 km combined), ~ 1.5 km south-southeast of the YMCA Lake. It is considerably larger than the other oxbow lakes at ~ 55 ha. Similar to the YMCA Lake, Crystal Lake is a historical channel of the Pearl River that was cut off following channelization, and it is the largest segment of the historic Pearl River that was isolated following levee construction. The margins of the lake are primarily vegetated with water oak, black willow, red maple, and Chinese tallow tree. The lake is eutrophic with considerable amounts of duckweed (*Lemna* sp.), alligatorweed (*Alternanthera philoxeroides*), and water hyacinth (*Eichhornia crassipes*). The margins of the lake are lined with dense stands of cattails (*Typha* sp.) and giant cutgrass

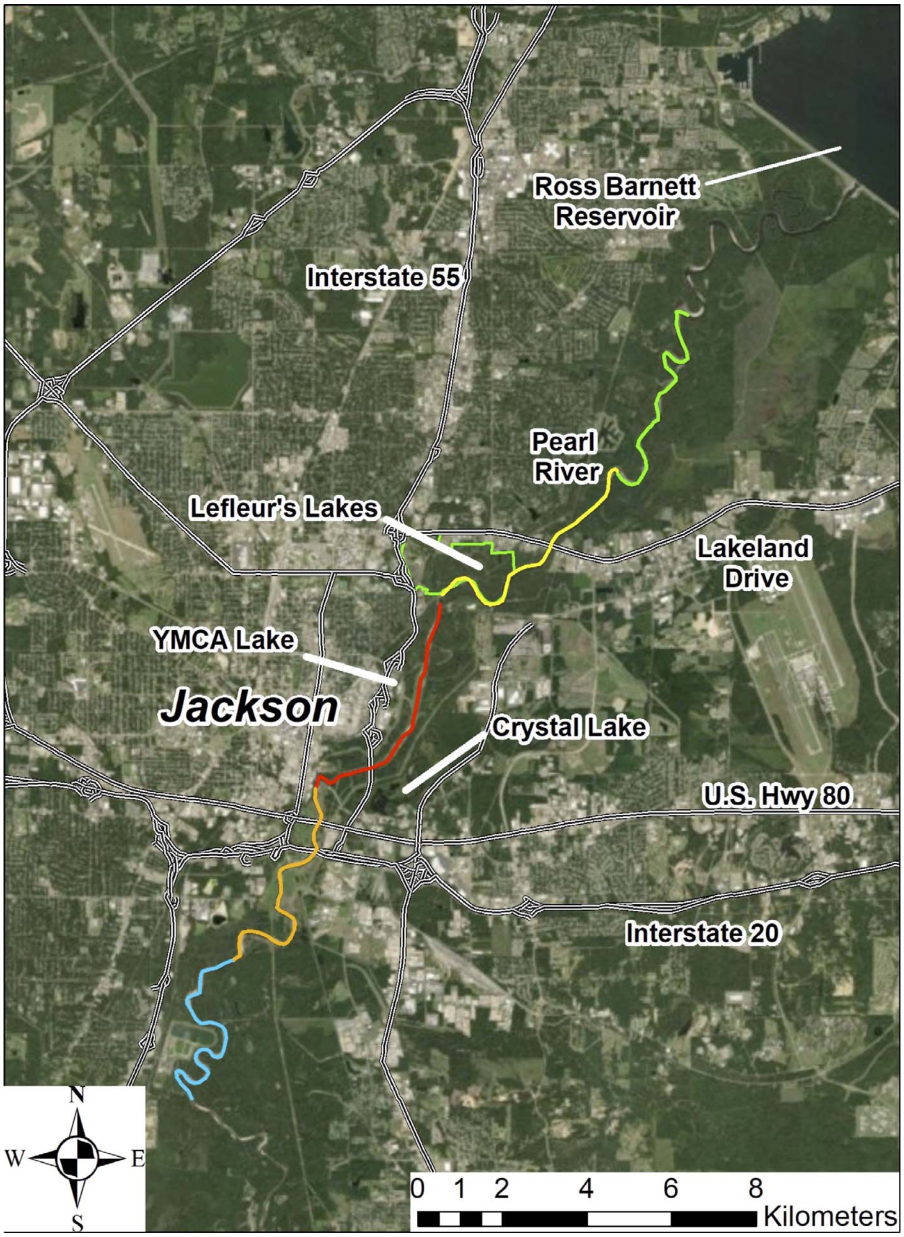

Figure 1. River turtle survey segments along the Pearl River and oxbow lakes surveyed near Jackson, Mississippi (Hinds and Rankin counties). Different river segments are in different colors (green = S1, yellow = S2, red = S3, orange = S4, turquoise = S5) and major highways/interstates are outlined in white. General locations for oxbow lakes surveyed are also depicted here; LeFleur's Lakes details depicted in Fig. 2. (Color version is available online.)

(*Zizaniopsis miliacea*). Based on historical imagery, large portions of this lake have transitioned from open water to freshwater marsh over the last 20 yrs.

Methods for Field Observations. — All river survey segments were floated by boat during the months of June and July 2017 and 2018. I completed 6 replicate surveys for S1 and 5 replicate surveys for S2–S5 (total of $\sim$ 137.8 rkm surveyed). For the latter, flooding during June 2017 prevented us from completing a sixth round of surveys for S2–S5. When sandbars were present, the boat was moored on the upstream end of the sandbar, and I identified and counted basking turtles using a spotting scope ($\times$20–60) while walking down the sandbar (similar to Selman and Qualls 2009). I identified the sex and life history class (adult/juvenile) of *G. oculifera* and *G. pearlensis* when possible based on descriptions by Jones and Selman (2009) and Lovich et al. (2009), respectively. In the absence of sandbars, visual surveys consisted of floating downstream ($<$ 5 km/hr) in an outboard motorboat with 2 observers who were equipped with binoculars ($\times$15). Each observer counted opposite banks of the river and another person served as data recorder. I also used a Nikon CoolPix p900 digital camera with $\times$83 optical zoom to take photographs of large basking aggregations of turtles that were difficult to identify from a distance with binoculars. All surveys were completed between the

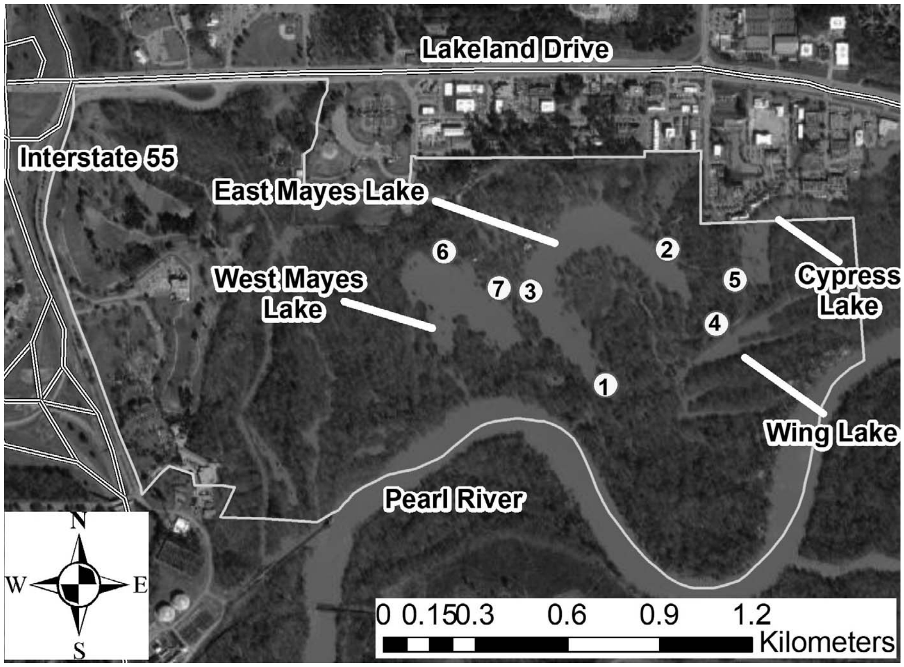

Figure 2. LeFleur's Bluff State Park lake survey site vantage points located at East Mayes Lake (1–3), Wing Lake (4), Cypress Lake (5), and West Mayes Lake (6–7).

midmorning to midafternoon hours (~ 0900–1530 hrs) when environmental conditions were conducive to basking. I avoided surveying on days when large amounts of rain or thunderstorms occurred in order to minimize the variance of conditions during our observations and for safety reasons, respectively.

For the lake study sites, I completed 4 replicated spotting scope surveys for basking turtles during June and July 2018. Surveys were made from fixed locations along the bank of the oxbow lakes using a spotting scope (×20–60) with tripod. Survey distances along both the river and banks were estimated using the measuring tool in GoogleEarth Pro (v. 7.1.5.1557; Google Inc., Mountain View, CA).

Data Analysis. — Because *G. oculifera* basking density data was nonnormally distributed, I used a nonparametric Kruskal-Wallis test to determine if *G. oculifera* densities (i.e., number observed per kilometer) were equal across the 5 segments surveyed. If differences were observed, I used a Wilcoxon nonparametric multiple comparisons post hoc analysis to determine differences among segments. Because *G. oculifera* juvenile densities were nonnormally distributed, I used a nonparametric Wilcoxon Rank Sums test to determine if the number of *G. oculifera* juveniles was equal among the segments surveyed and then used a Wilcoxon nonparametric multiple comparisons analysis to determine differences among segments. Similarly, *G. pearlensis* densities were nonnormally distributed, so I used a nonparametric Wilcoxon Rank Sums test to determine if *G. pearlensis* densities were equal among the sites and Wilcoxon nonparametric multiple comparisons to determine differences among segments. Because lake and river densities were nonnormally distributed, I used 2 Wilcoxon rank sums tests to determine if lake and river densities of both *G. oculifera* and *Trachemys scripta* (red-eared slider) were equal.

Because the One Lake Project would impact S2–S4, it seemed essential to estimate the number of turtles that would be directly impacted (i.e., the US Fish and Wildlife Service [USFWS] definition of "harm" that actually injures or kills wildlife; National Oceanic and Atmospheric Administration 1999) by this project in those segments, while also considering potential indirect effects upstream or downstream. During basking density surveys, I detected only a fraction of the overall population because many individuals remain underwater. Thus, it is important to consider the basking frequency (i.e., the percentage of the population that may be basking at any one time) in order to estimate total population size. There are currently no basking frequency data for either *G. oculifera* or *G. pearlensis*, but monthly basking frequency information is available for 2 ecologically equivalent species from the Pascagoula River, *G. flavimaculata* (Selman and Qualls 2011) and *Graptemys gibbonsi* (Selman and Lindeman 2015), respectively. Based on the study by Selman and Qualls (2011) and the time of year, I estimated that only 20%–30% of the *G. oculifera* population was observed during June/July basking surveys. Similarly, I estimated that only 10%–15% of the *G. pearlensis* population was observed during June/July basking surveys based on the study by Selman and Lindeman (2015). These percentages were used as correction factors (3.3 times and 5 times for *G. oculifera*, 6.6 times and 10 times for *G. pearlensis*) to calculate estimated population sizes within the One Lake Project area for both species by multiplying the high and

Table 1. Mean basking densities of *Graptemys oculifera* within the Pearl River near Jackson, Mississippi, for 5 river segments and per river kilometer (rkm). Below each mean in parentheses are range and standard deviation. For mean *G. oculifera*/rkm comparisons, values with different superscript letters indicate significant different densities among river segments.

Segment	Males	Females	Juveniles	Total	Total/rkm
1	163.7 (82–242; 65.94)	83.8 (53–112; 26.71)	23.5^{A} (7–40; 13.29)	279.5 (173–389; 97.89)	52.5^{A} (33–73; 18.40)
2	130.6 (97–166; 30.24)	45.6 (32–56; 11.67)	36.8^{A} (11–60; 20.46)	220.6 (149–295; 62.80)	41.5^{A} (28–55; 11.81)
3	30.2 (22–44; 8.38)	28.2 (12–50; 13.68)	2.6^{B} (0–4; 1.67)	62.6 (42–77; 14.77)	11.7^{B} (8–15; 2.78)
4	69.0 (31–113; 34.09)	29.8 (19–43; 11.48)	5.8^{B} (1–17; 6.61)	109.6 (59–177; 48.55)	20.6^{B} (11–33; 9.12)
5	161.2 (121–223; 39.06)	66.2 (34–106; 31.32)	6.0^{B} (2–12; 4.00)	240.4 (166–291; 46.58)	45.2^{A} (31–55; 8.75)
Total	113.0 (66)	52.0 (59.6)	15.3 (17.0)	186.3 (102)	35.0 (19.2)

low correction factor by 1) the minimum count I observed for each segment, 2) the mean of all counts for that segment, and 3) the maximum count I observed for each segment (e.g., 6 calculations; 3 different counts, and 2 percentage correction factors). I made calculations for segments directly impacted (S2–S4) and also for segments that might be indirectly impacted (S1, S5). Indirect impacts may include siltation/contaminants flowing downstream or the movement of turtles from the impacted area into neighboring stream reaches that may alter the population dynamics (i.e., crowding). The mean and range of these 6 estimates are reported.

RESULTS

Summary of Pearl River Surveys. — In all river surveys during 2017 and 2018, I observed 5643 turtles in 137.8 total rkm surveyed. I observed 8 species basking during these surveys including (in order of rank abundance) *Graptemy oculifera* (4843 individuals; 35.1/rkm; 86%), *Graptemys pearlensis* (188; 1.4/rkm; 3%), *Pseudemys concinna* (134; 1.0/rkm; 2%), *Trachemys scripta* (64; 0.46/rkm; 1%), *Sternotherus carinatus* (49; 0.36/rkm; < 1%), *Graptemys pseudogeographica* (31; 0.22/rkm; < 1%), *Apalone mutica* (9; 0.07/rkm; < 1%), and *Apalone spinifera* (3; 0.02/rkm; < 1%). The remaining turtles were either unidentified *Graptemy*s sp. (80; 1%), unidentified *Apalone* sp. (43; < 1%), unidentified emydids (129; 2.2%), and unidentified turtle species (70; 1%).

Status of Graptemys oculifera. — The mean number of *G. oculifera* observed per survey for all segments surveyed was 186 turtles (113 males, 52 females, 15 juveniles, 6 unknown sex) and densities for all segments averaged 35.0/rkm. Adults of both sexes and juveniles were observed within all segments surveyed. However, there was considerable variability in densities among the segments (Table 1). *Graptemys oculifera* densities were statistically different among the 5 river segments ($\chi^2 = 17.2$, df = 4, $p = 0.002$; Fig. 3). Wilcoxon nonparametric multiple comparisons post hoc analyses indicated that S1 (52.5/rkm), S2 (41.5/rkm), and S5 (45.2/rkm) had higher densities than did S3 (11.7/rkm) and S4 (20.6/rkm); there were no differences among S1, S2, and S5 or between S3 or S4 (Table 1). *Graptemys oculifera* were observed in higher densities than *G. pearlensis* during all surveys at all sites (Fig. 3). For all surveys combined, *G. oculifera* was observed at 25 times higher densities in comparison to *G. pearlensis*, while within-site comparisons of both species ranged from a low of 14 times higher in S5 to a high of 69 times higher in S2.

Graptemys oculifera juveniles were found in all segments surveyed, indicating that females nest successfully in all segments. However, juvenile basking densities were different among the segments surveyed ($\chi^2 = 17.1$, df = 4, $p = 0.002$; Table 1). Wilcoxon nonparametric multiple comparisons post hoc analyses indicated that S2 (mean, 36.8/survey) and S1 (23.5/survey) had higher juvenile counts than did S3, S4, and S5 (2.6, 5.8, and 6.0, respectively); there were no differences between S2 and S1 or among S3, S4, and S5 (Table 1).

Status of Graptemys pearlensis. — The mean number of *G. pearlensis* observed for all segments surveyed was 7.2 turtles (4.1 males, 1.9 females, 0.7 juveniles, 0.5 unknown sex) per survey with densities of all segments averaging 1.4 turtles/rkm. Adults of both sexes were observed in all segments, but juveniles were not observed in S3 during any 2017/2018 survey. Contrary to *G. oculifera*, *G. pearlensis* densities were low in all river segments surveyed (range, 0.4–3.2/rkm; Table 2), but densities were statistically different across sites ($\chi^2 = 20.3$, df = 4, $p = 0.004$; Fig. 3). Wilcoxon nonparametric multiple comparisons post hoc analyses showed that S5 had higher densities than S1–S4. Segment 1 had greater densities than S2 and S3, but not S4, and there were no differences among S4, S2, and S3. Too few juveniles of *G. pearlensis* were observed to make comparisons among segments (Table 2).

Oxbow Lake Turtle Community and Densities. — During oxbow lake surveys, I observed 226 turtles along 16.7 km of shoreline at the 6 lakes. I observed 7 species basking during these surveys, including *Trachemys scripta* (80; 4.8/km; 35.4%), *Pseudemys concinna* (72; 4.4/rkm; 31.9%), *Graptemys oculifera* (48; 2.9/km; 21.2%), *Graptemys pseudogeographica* (3; 0.18/km; 1.3%), *Ap-*

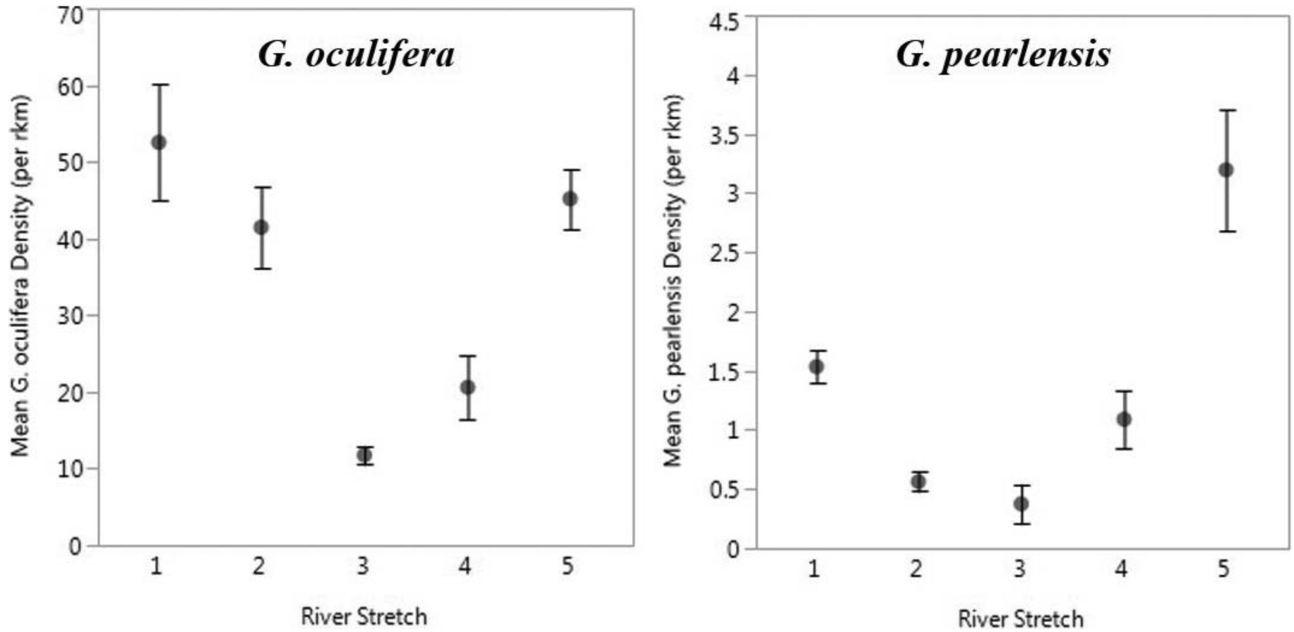

Figure 3. Variability in *Graptemys oculifera* (left) and *Graptemys pearlensis* (right) basking densities among 5 survey segments of the Pearl River. Note the difference in scale on the *y* axis for each species. Error bars represent ± 1 SE.

alone spinifera (3; 0.18/km; 1.3%), *Sternotherus carinatus* (2; 0.12/km; < 1%), and *Chrysemys dorsalis* (1; 0.06/km; < 1%; Table 3). The remaining individuals were unidentified emydids (14; 6%) and unknown turtles (3; 1.3%). *Graptemys pearlensis* was absent from all lake locations.

Graptemys oculifera was observed in 4 of 6 oxbow lakes surveyed including East Mayes, West Mayes, Cypress, and Crystal lakes; they were not observed in Wing Lake or YMCA Lake (Table 3). *Graptemys oculifera* densities combined in all lake locations averaged 3.4/km, which was 10 times less than in all river segments surveyed (35.0/rkm for all river segments). Further, *G. oculifera* populations were strongly male-biased in lakes (38 males, 7 females, 1 unknown sex). A single *G. oculifera* juvenile was observed twice at only a single location and it seems likely that it was the same individual (location 2, East Mayes Lake). When considered collectively, *G. oculifera* densities in lake sites were significantly lower than those observed at river sites ($\chi^2 = 44.5$, df = 1, $p < 0.0001$; Fig. 3).

Trachemys scripta was a relatively minor component of the river turtle basking community (0.46/rkm; 1.1%), but it was the most dominant species observed in lake settings (4.8/km, 35.4%). For *T. scripta*, basking densities increased 10-fold in lake settings and their relative abundance increased 32-fold. When considered collectively, *T. scripta* densities in lakes were significantly higher than those observed at river sites ($\chi^2 = 10.2$, df = 1, $p = 0.001$; Fig. 4).

Estimated Population Impacts of the One Lake Project. — Using a 3.3× and 5× visual correction factor for undetected *G. oculifera* individuals, the mean number of turtles impacted in S2–S4 using the 6 calculations would be 1684 individuals (range, 908–2745; Table 4). This is inclusive of males, females, and juveniles that appear to represent a viable and reproducing population along all segments. For *G. oculifera* individuals that might

Table 2. Mean basking densities of *Graptemys pearlensis* within the Pearl River near Jackson, Mississippi, for 5 river segments and per river kilometer (rkm). Below each mean in parentheses are range and standard deviation. For *G. pearlensis*/km density comparisons, values with different superscript letters indicate significant different densities among river segments.

Segment	Males	Females	Juveniles	Total	Total/rkm
1	4.8 (2–9; 2.64)	1.0 (0–2; 0.89)	1.8 (0–3; 1.17)	8.2 (6–11; 1.72)	1.5^{B} (1–2; 0.32)
2	1.6 (0–4; 1.52)	0.8 (0–2; 1.10)	0.4 (0–1; 0.55)	3.0 (2–4; 0.45)	0.6^{C} (0.4–0.8; 0.18)
3	0.8 (0–2; 0.84)	1.0 (0–3; 1.22)	0	2.0 (0–5; 2.00)	0.4^{C} (0–0.9; 0.38)
4	2.6 (0–5; 1.82)	2.4 (1–4; 1.34)	0.4 (0–1; 0.55)	5.8 (1–8; 2.86)	$1.1^{B,C}$ (0.2–1.5; 0.5)
5	10.6 (7–19; 4.83)	4.6 (2–11; 3.78)	0.6 (0–1; 0.55)	17.0 (12–25; 6.08)	3.2^{A} (2.3–4.7; 1.14)
Total	4.1 (4.3)	1.9 (2.3)	0.7 (0.9)	7.2 (6.1)	1.4 (1.1)

Table 3. Diversity and abundance summary of basking turtle observations in 6 oxbow lakes within the Pearl River floodplain in Hinds and Rankin counties, Mississippi. *A.s.* = *Apalone spinifera*; *C.d.* = *Chrysemys dorsalis*; *G.o.* = *Graptemys oculifera*; *G.p.* = *Graptemys pearlensis*; *G.ps.* = *Graptemys pseudogeographica*; *P.c.* = *Pseudemys concinna*; *S.c.* = *Sternotherus carinatus*; *T.s.* = *Trachemys scripta*; Emydid? and Turtle? represent unidentified emydids and turtles of undetermined family, respectively; — = absent.

Lake	Length surveyed (km)	No. of species	*A.s*	*C.d.*	*G.o.*	*G.p.*	*G.ps.*	*P.c.*	*S.c.*	*T.s.*	Emydid?	Turtle?
Crystal	3.8	3	—	—	11	—	—	8	—	12	—	—
Cypress	1.4	4	—	—	9	—	1	40	—	3	—	—
E. Mayes	4.1	5	—	—	24	—	2	12	1	15	4	1
W. Mayes	4.3	5	—	1	4	—	—	4	1	32	8	1
Wing	1.4	2	—	—	—	—	—	3	—	8	—	—
YMCA	1.7	3	3	—	—	—	—	5	—	10	1	—

be indirectly impacted by the One Lake Project and using the similar correction factor approach, the mean number of *G. oculifera* impacted upstream in S1 would be 1164 individuals (range, 571–1945) and the mean number downstream in S5 would be 965 individuals (range, 548–1455; Table 4).

Using a 6.6× and 10× correction factor for undetected *G. pearlensis* individuals, the mean number of turtles impacted would be 88 individuals (range, 27–170; Table 5). Using the similar correction factor approach to account for indirectly impacted individuals, the mean number of turtles impacted upstream in S1 would be 70 individuals (range, 40–110) and the mean number impacted downstream in S5 would be 149 individuals (range, 79–250; Table 5).

DISCUSSION

Status of Graptemys oculifera. — Much research has been conducted on *G. oculifera* since the species was listed as federally threatened in 1986 (USFWS 1986) and after the *G. oculifera* recovery plan suggested studies be undertaken (Stewart 1988). While data existed for S1 (aka, Lakeland site in Jones and Hartfield 1995; Jones 2017), no data on *G. oculifera* densities were available for the river segments in the immediate vicinity of Jackson (S2–S5). My observations indicate that *G. oculifera* persists throughout this highly modified section of the Pearl River and sometimes occurs in relatively high densities. This is surprising, encouraging, and indicative of the recovery potential of the species. Even in the most degraded habitat of S3 and S4, *G. oculifera* still exhibited recruitment; I observed juveniles within these river segments, while numerous turtle nesting crawls, nesting females, and depredated nests were also observed on sandbars (W.S., *pers. obs.*). Because of the removal of riparian vegetation in S3 and S4, other areas are also as open as sandbar habitats and may be suitable for nesting; a high-elevation patch of sandy substrate in the grassy/shrubby margins would likely suffice for many turtles.

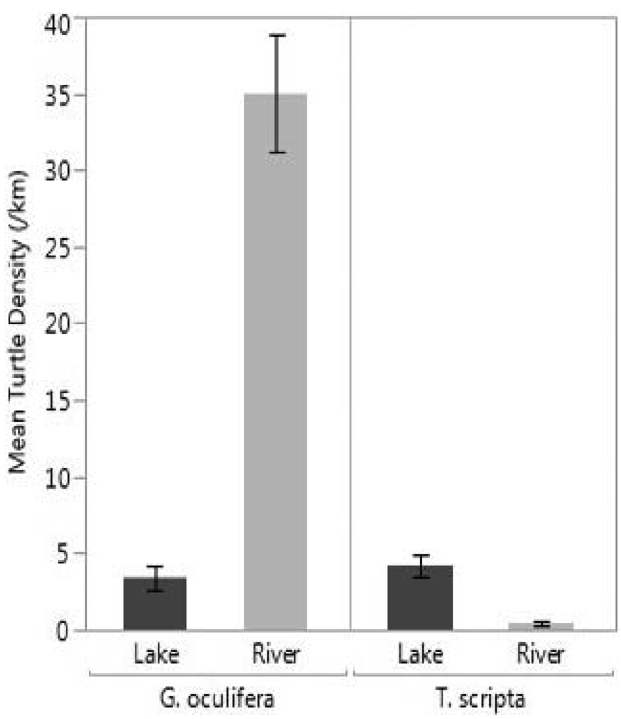

Figure 4. Comparisons of *Graptemys oculifera* and *Trachemys scripta* basking densities in river versus lake settings. Error bars represent ± 1 SE.

Within the channelized portion (S3, S4), there are few deadwood basking structures for turtles compared with upstream (S1, S2) and downstream sections (S5). Along with fewer deadwood basking structures, the river channel has also filled substantially with sand/sediment, and this has left some river sections with a shallow river bottom and few deep refuges preferred by *Graptemys* species. Nonetheless, both *Graptemys* species persist in this setting, albeit at lower densities. Within S3/S4, there were short river sections where moderate to high amounts of deadwood and an intact riparian zone could be found. In these segments, densities of *G. oculifera* were very concentrated, even though few individuals were typically observed upstream and downstream of these locations.

It is not surprising that densities in the most natural sites (S1 upstream and S5 downstream) were highest given the greater prevalence of sandbars, cutbanks, intact riparian buffer, and abundant riverine deadwood for basking. The upstream section (S1) has been the focus of a long-term study by R.L. Jones (site name "Lakeland"), and this population is one of the most stable populations of *G. oculifera* surveyed since the 1980s (Jones 2017; Selman and Jones 2017). Mean densities of *G. oculifera* in S1, S2, and S5 (> 40/rkm) exceeded the densities observed by prior researchers throughout much

Table 4. Visual correction factor calculations (3.3 times and 5 times) for *G. oculifera* within (Segments 2–4), upstream (Segment 1), and downstream (Segment 5) of the One Lake Project area. Min = minimum count observed on that segment, Mean = the mean of all counts for that segment, Max = maximum count on that segment.

	Counts			Min		Mean		Max	
Segment	Min	Mean	Max	× 3.3×	× 5×	× 3.3×	× 5×	× 3.3×	× 5×
2	174	220.6	295	574	870	728	1103	974	1475
3	42	62.6	77	139	210	207	313	254	385
4	59	109.6	177	195	295	362	548	584	885
Estimated in project area				908	1375	1297	1964	1812	2745
1	173	279.5	389	571	865	922	1398	1284	1945
5	166	240.4	291	548	830	793	1202	960	1455
Estimated up- and downstream				1119	1695	1715	2600	2244	3400

of the Pearl River system with the exception of 2 study sites: Ratliff Ferry, Columbia, and Coal Bluff (Selman and Jones 2017; Lindeman et al. 2020). However, in the altered segment of the Pearl River (S3 and S4), mean densities of *G. oculifera* are 2–3-times less than the other river segments surveyed, but these densities are not small and insignificant. Densities in S3 and S4 are similar to densities observed by Shively (1999) in the Bogue Chitto River (4–17/rkm), and they exceed or are similar to densities in the lower Pearl River (0–15.7/rkm, Dickerson and Reine 1996; 20.4/rkm, Lindeman 1998; 22.7/rkm, Lindeman et al. 2020).

Jones (2017) found that *G. oculifera* at the Lakeland site (S1 in this study) have been increasing significantly since 2000; 4 other study populations were in decline during that same time period. Based on our observations of high juvenile counts in S1 and S2, it seems that recruitment in this section is exceptionally high, with juveniles composing 10%–20% of basking *G. oculifera* individuals. The high incidence of juveniles is likely a major contributor to the recent increase in population size, but the reason behind this high recruitment is puzzling. Considering the location of the site within an urban/suburban landscape, one would assume that recruitment would be low because of increased contaminants entering from urban streams and nest mortality associated with subsidized predators (e.g., raccoons). Indeed, I noticed numerous depredated nests on sandbars throughout all river segments (W.S., *pers. obs.*). However, an alternative explanation for the higher recruitment is that S2 mostly lacks discrete sandbars and, therefore, females may select nest sites that are atypical (e.g., small sand banks along the river) rather than larger sandbars that predators can easily target. With nests being more diffuse along these segments and not concentrated on sandbars, predators may not be as successful in raiding nests and nest success may be higher.

Graptemys oculifera in the oxbow lakes of LeFleur's Bluff State Park are able to seasonally reconnect with the main river population during flood events; the river achieved flood stage ~ 5 times between June 2017 and July 2018. For a similar species, Jones (1996) observed radio-marked *G. flavimaculata* (yellow-blotched sawback) that seasonally moved into and out of oxbow lakes in the lower Pascagoula River. However, my observations of few juveniles indicate that oxbow lake populations of *G. oculifera* exhibit nominal recruitment and may be ecological "sinks" that are dependent upon individuals emigrating from the river. Therefore, I suspect that many of the individuals observed in Crystal Lake, a lake separated from the river by levees, are likely older adults that are merely "hanging on" in suboptimal, eutrophic habitats. Because they are disconnected from the Pearl River, emigration out of the system or immigration into the system is likely minimal. Thus, *G. oculifera* at the Crystal Lake site likely does not represent a viable population in the long-term.

Status of Graptemys pearlensis. — *Graptemys pearlensis* was recently petitioned by the Center for

Table 5. Visual correction factor calculations (6.6 times and 10 times) for *G. pearlensis* within (Segments 2–4), upstream (Segment 1), and downstream (Segment 5) of the One Lake Project area. Min = minimum count observed on that segment, Mean = the mean of all counts for that segment, Max = maximum count on that segment.

	Counts			Min		Mean		Max	
Segment	Min	Mean	Max	× 6.6×	× 10×	× 6.6×	× 10×	× 6.6×	× 10×
2	2	3.0	4	13	20	20	30	26	40
3	1	2.0	5	7	10	13	20	33	50
4	1	5.8	8	7	10	38	58	53	80
Estimated in project area				27	40	71	108	112	170
1	6	8.1	11	40	60	54	81	73	110
5	12	17.0	25	79	120	112	170	165	250
Estimated up- and downstream				119	180	166	251	238	360

Biological Diversity to be considered a candidate for federal protection status (vis-à-vis *G. gibbonsi*; USFWS 2011). Surveys throughout the Pearl River system indicate that the species occurs in lower abundance relative to *G. oculifera* (Dickerson and Reine 1996; Lindeman 1998; Selman and Jones 2017; Lindeman et al. 2020). Similarly, my study found that *G. pearlensis* densities were significantly lower during all surveys and in all segments in comparison to *G. oculifera*. Our observed densities fall within most previously reported basking densities for *G. pearlensis* (range, 0–7/rkm), with only a few sites having densities exceeding our observations (range, 10–15/rkm; Pearl River at Columbia, Selman and Jones 2017; portions of the Bogue Chitto River, Shively 1999; a reach of the upper Pearl River in Leake County, Lindeman et al. 2020). Based on *G. pearlensis* capture data from Selman and Jones (2017) for the Lakeland population (i.e., S1, north of Lakeland Drive), this population has undergone a significant population decline since the 1980s. For example, in the 1980s and 1990s, 20–40 individuals were regularly captured per trapping effort, while by 2013, only a single individual was captured with similar effort (Selman and Jones 2017). It is unknown why the population has declined in this segment, but water quality and riverine regulation at the reservoir may have impacted prey item presence and availability (Selman and Jones 2017). Ultimately, the chances of localized extinctions are higher in small populations, such as those of *G. pearlensis*, due to environmental and demographic stochastic events.

I did not find *G. pearlensis* in any of the oxbow lakes surveyed. Similarly, Lindeman (1998) did not find them in Mayes Lakes in the mid-1990s or in multiple surveys of Burnside Lake (Neshoba County, P.V. Lindeman, *pers. comm.*, March 2020). Thus, even though these oxbow lakes may seasonally flood and be connected to the river (with the exception of isolated Crystal and YMCA lakes), *G. pearlensis* appear strictly to use riverine habitat and have a narrower habitat niche than *G. oculifera*.

Estimated Population Impacts of the One Lake Project. — The One Lake Project currently proposes to impound $\sim$ 16 rkm of the Pearl River, encompassing S2–S4. Clearly, the One Lake Project has the potential to impact populations of both *G. oculifera* and *G. pearlensis* along with other riverine turtle species and other aquatic species of conservation concern in the Pearl River (e.g., Gulf sturgeon, *Acipenser oxyrinchus desotoi*). If the One Lake Project is implemented to deepen and widen the river, it will dramatically alter the hydrologic regime of this segment of the Pearl River. It will convert the habitat from a lotic, riverine habitat to a more lentic lake habitat (Bunn and Arthington 2002). With changes to the riverine processes, the habitat of this lake will become vastly different from the existing riverine habitat. For example, one of the major changes that are likely to occur is lower water velocities, and this will limit bank erosion and the additional inputs of deadwood snags along the banks. It also seems likely that food resources and sponge/invertebrate prey communities for *Graptemys* (P. Lindeman, W. Selman, and B. Jones, unpubl. data, 2005–2018) could change dramatically with altered hydrology. Lower river velocities will also not impede the growth of dense stands of emergent vegetation, rendering it similar to the habitat I observed at Crystal Lake. Lower water velocities also minimize the annual scouring of sandbars, without which woody vegetation will encroach on nesting sandbars, likely in the form of Chinese tallow trees. Such a change to the Pearl River should qualify as "habitat alteration," a primary threat to *G. oculifera* as outlined in the USFWS Ringed Sawback Recovery Plan (Stewart 1988).

As a result of the altered habitat, I predict that the One Lake Project would benefit common, generalist turtle species that thrive in these settings at the expense of rarer, specialist riverine turtle species. Indeed, this is exactly what I observed in the oxbow lake surveys: *G. oculifera* densities declined 10-fold compared with in river settings, *G. pearlensis* were absent, and *T. scripta* densities increased 10-fold. Further, *G. oculifera* recruitment appeared to decline dramatically in oxbow lake settings. Therefore, generalist turtles that are better adapted to the nonflowing water will replace specialists such as *G. oculifera* and *G. pearlensis* over time. Following construction, I suspect that turtles will still persist in the One Lake project area, but rare species like the ringed sawback and Pearl map turtle will disappear over time, and the area will be dominated by generalist species such as *T. scripta*.

To conserve and protect both *Graptemys* species around Jackson, a flowing Pearl River is needed to provide proper basking sites, foraging sites, and nesting habitat. Currently, the system provides suitable habitat throughout all of the river segments surveyed, even though some segments had higher turtle densities than others. The upper and lower sections should be targeted for conservation efforts through preservation of existing conditions (i.e., land purchases or conservation easements). The middle segments surveyed support fewer individuals, an apparent consequence of the major human modifications to these segments of the river (e.g., channelization and the lack of deadwood in the river due to riparian forestry practices). To improve these areas to more optimal *Graptemys* conditions, intensive stream restoration is needed to increase river sinuosity and rectify the present straight and channelized condition. Further, management of riparian vegetation through mowing and herbicide applications should be ceased. Lastly, the surrounding levees should be moved further away from the river to permit greater connection to the Pearl River floodplain; this change would also assist with flooding issues to human structures by opening the constricted portion of the floodway. At the moment, none of these seem to be achievable conservation measures given the local flood district's interest in implementing the One Lake Project.

In summary, based on the abundance data presented here, it is anticipated the impacts of the One Lake Project to these *Graptemys* populations will be significant in intensity and long-term in duration. Our survey data indicate *G. oculifera* occurs in greater abundance throughout the One Lake Project area, and recruitment/reproduction are better in this segment than what has been observed in other *G. oculifera* populations. Thus, if completed, the One Lake Project will be a major setback to both *Graptemys* species and negatively impact their recovery potential.

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