
LIFE HISTORY AND ECOLOGY OF THE PASCAGOULA MAP TURTLE (*GRAPTEMYS GIBBONSI*)

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Abstract.—*Graptemys gibbonsi* Lovich and McCoy (Pascagoula Map Turtle) is one of the most poorly understood turtle species in North America. Following the description of the species in 1992, little formal research has been conducted on the species other than population survey work. From 2005 to 2008, we conducted ecological studies on *G. gibbonsi* throughout the Pascagoula River system of southeastern Mississippi, USA. We captured turtles at four sites to determine population structure, growth, movements, and some aspects of reproduction and nesting. We studied a single population to examine basking ecology and diet. We used visual surveys at four sites to document population density and relative abundance. Body size varied significantly across sites and population-level sexual size dimorphism also varied. Growth was relatively rapid in small adults, with growth being slower in larger adults. Mean minimum linear active areas were small based on recapture location points (males, 0.37 river km; females, 0.69 river km). Basking durations were greater in the spring and fall relative to summer, while also being longer during morning and evening periods; females generally basked on larger, more robust logs versus smaller branches chosen by males. *Graptemys gibbonsi* basked at lower percentages (12% less) across seasons and throughout the day relative to the sympatric *G. flavimaculata*. Population densities and relative abundances of *G. gibbonsi* were greater at middle and upstream localities compared to downstream sections of the Pascagoula River system. Diet of males (n = 8) consisted primarily of caddisfly larvae and insect fragments, while females (n = 4) consumed mostly Asian clams (*Corbicula* spp.). Reproduction extended from April to July for females > 15.4 cm plastron length, with nests (n = 3) encountered on both sandbars and cutbanks.

Key Words.— population structure; sexual dimorphism; population density; diet; basking; Leaf River; Chickasawhay River

INTRODUCTION

The Pascagoula Map Turtle, *Graptemys gibbonsi*, was formally described after Lovich and McCoy (1992) determined that *G. pulchra* Baur 1893 (Alabama Map Turtle) was a composite species consisting of three distinct, allopatric taxa: *G. ernsti* (Escambia Map Turtle), *G. pulchra* (Alabama Map Turtle), and *G. gibbonsi* (Pascagoula Map Turtle). In 2010, *G. gibbonsi* was further divided into two separate taxa, with *G. pearlensis* (Pearl Map Turtle) being described from the Pearl River system, where it is allopatric to *G. gibbonsi sensu stricto* of the Pascagoula River system (Ennen et al. 2010). The four species once considered to comprise *G. pulchra*, together with *G. barbouri* (Barbour's Map Turtle, endemic to the Apalachicola and Choctawhatchee drainages), comprise the *pulchra* clade (Lovich and McCoy 1992; Lamb et al. 1994; Stephens and Wiens 2003).

Prior to 1992, relatively little was known about *Graptemys gibbonsi sensu stricto* other than distribution and abundance information from surveys (Tinkle 1958; Cliburn 1971; Earl McCoy and Richard Vogt, unpubl. report). Even though described in 1992, a lack of

information still exists relating to basic life-history attributes of *G. gibbonsi*. *Graptemys gibbonsi sensu lato* ranked 46th of 58 North American turtle species and 11th of 12 *Graptemys* species in overall literature citations (Lovich and Ennen 2013). However, many of the citations Lovich and Ennen (2013) consulted concerned only *G. pearlensis* and thus, the knowledge of *G. gibbonsi* is even less than they reported.

The only recent publications on *G. gibbonsi sensu stricto* document sexual size dimorphism and seasonal variation of reproductive hormones (Graham et al. 2015) and four brief notes on natural history, three of which concern basking (Selman and Qualls 2008a, 2008b; Selman et al. 2008) and the fourth concerned the diet of a single female (Ennen et al. 2007). *Graptemys flavimaculata* (Yellow-blotched Sawback), a federally threatened turtle species (U.S. Fish and Wildlife Service 1991), is sympatric with *G. gibbonsi* in the Pascagoula River system. Presumably, *G. gibbonsi* has been overlooked because of this conservation designation, as much conservation attention and research has been devoted to *G. flavimaculata* (for review see Selman and Jones 2011), while *G. gibbonsi* received little attention except for distribution and abundance work coincident

with *G. flavimaculata* surveys. Survey work during the mid-1990s indicated that *G. gibbonsi* occurred at lower abundance than *G. flavimaculata* within the Pascagoula River system (Lindeman 1998, 1999). Later surveys in 2006 and 2008 (Selman and Qualls 2009) corroborated Lindeman's findings that *G. gibbonsi* occurred in lower numbers than *G. flavimaculata*.

The distribution and abundance of *G. gibbonsi* throughout the Pascagoula River system is the best well understood aspect of the species. The first significant surveys of *G. gibbonsi* were completed by Cliburn (1971) and later surveys by Lindeman (1998, 1999) were done in the mid-1990s. Cliburn (1971) found *G. gibbonsi* in many of the major rivers and tributaries of the Pascagoula River system, while Mount (1975) did not list *G. gibbonsi* from the Escatawpa River in southwestern Alabama. Lindeman (1998, 1999) found *G. gibbonsi* in several new and smaller drainages, but in lower densities and relative abundance compared to *G. flavimaculata*; consequently, Lindeman (1998, 1999) recommended that *G. gibbonsi* should be considered as a candidate for threatened status under the Endangered Species Act.

Later, Selman and Qualls (2009) found *G. gibbonsi* throughout the Pascagoula River system of southeastern Mississippi, with populations in small, headwater creeks (about 5 m wide) to larger rivers (>100 m wide; Fig. 1). *Graptemyis gibbonsi* was found in all previous localities (as described by Cliburn 1971; Lindeman 1998, 1999; Jack McCoy and Richard Vogt, unpubl. report), as well as eight new river or creek systems (Selman and Qualls 2009), including within the Escatawpa River of southeastern Mississippi; only a single male was observed and later captured. Similar to Lindeman's surveys, *G. gibbonsi* was found in lower densities relative to *G. flavimaculata*, with areas of localized abundance (Selman and Qualls 2009). The highest basking densities of *G. gibbonsi* were found within the upper Pascagoula, lower Leaf, and Chickasawhay rivers (10.5–44.5 individuals per river km [rkm]). *Graptemyis gibbonsi* was the second most abundant basking species in small rivers and medium creeks (behind *Pseudemys concinna*, River Cooter), while ranking third in abundance in larger rivers (behind *P. concinna* and *G. flavimaculata*) and smaller creeks (behind *P. concinna* and *Trachemys scripta*, Slider Turtle). Population estimates for a site on the Leaf River ranged between 34 and 44 individuals per rkm (Selman and Qualls 2009). Selman and Qualls (2009) concurred that *G. gibbonsi* should be federally listed as threatened and uplisted by the International Union for the Conservation of Nature (IUCN) to endangered. Peter Floyd and Hilton Floyd (unpubl. report) found increasing densities of *G. gibbonsi* within the Pascagoula River as they moved further upstream (4.6–6.6 per rkm) compared to

downstream reaches (2.5 per rkm), with none observed in the Escatawpa River.

Outside of these population surveys and anecdotal reports, nothing else is known about the life history and ecology of *Graptemyis gibbonsi*. In addition, the species is currently listed as a species of greatest conservation need in Mississippi (Mississippi Museum of Natural Science 2005) and was recently listed as Endangered by the International Union for the Conservation of Nature (van Dijk 2011). We combine information from related studies (capture-recapture, basking ecology, basking densities, and diet) to gain a better understanding of the life history of this Pascagoula drainage endemic. While not a complete ecological treatment of *G. gibbonsi*, it provides a better understanding of the species. Data acquired for this study were generated simultaneous to research on *G. flavimaculata* (Selman and Qualls 2009, 2011; Selman 2012).

METHODS

Population structure.—From April through October of 2005 and 2006, we sampled *G. gibbonsi* via trapping at sites on the Leaf (LR, Forrest County; 4.0 rkm), Pascagoula (PR, Jackson County; 5.9 rkm), and lower Chickasawhay (LCR, Greene County; 7.6 rkm) rivers, Mississippi, USA, once per month for three to five days each month (Fig. 1). We similarly trapped the LR and PR sites during the 2007 and 2008 field seasons, while we trapped a fourth site on the upper Chickasawhay River (UCR, Clarke County; 5.3 rkm) four days in 2008 and 2009. The habitat characteristics for the first three sites are detailed in Selman (2012). The fourth site was a small to medium-sized headwater river, with alternating gravel and sandbar sections and steep cutbanks on outer river bends; daily flow from April 2005 to November 2009 ranged between 1.6 and 411 m³/sec, with considerably lower daily flow rates relative to the other three sites (Selman 2012). At all sites, we captured turtles by attaching open-topped basking traps (made of 3/4" PVC coated crawfish wire; The Fish Net Company, Jonesville, Louisiana, USA) to known turtle basking structures as described by Selman et al. (2012). We used a maximum of 17 traps in a single trap day, but we moved some traps throughout the day, especially if turtles avoided the trap log or due to constantly changing water river levels. We placed traps on different structure types (e.g., logs, branches, tree crowns, tangles) to sample structures preferred by different size classes and sexes of turtles. We also captured individuals opportunistically by hand or by dip net at all sites.

After capture, we determined the sex of individuals when possible based on the presumption that males were smaller and had thicker and longer tails, with the cloaca posterior to the carapace rim (Lovich et al. 2009). We took several morphometric measurements including

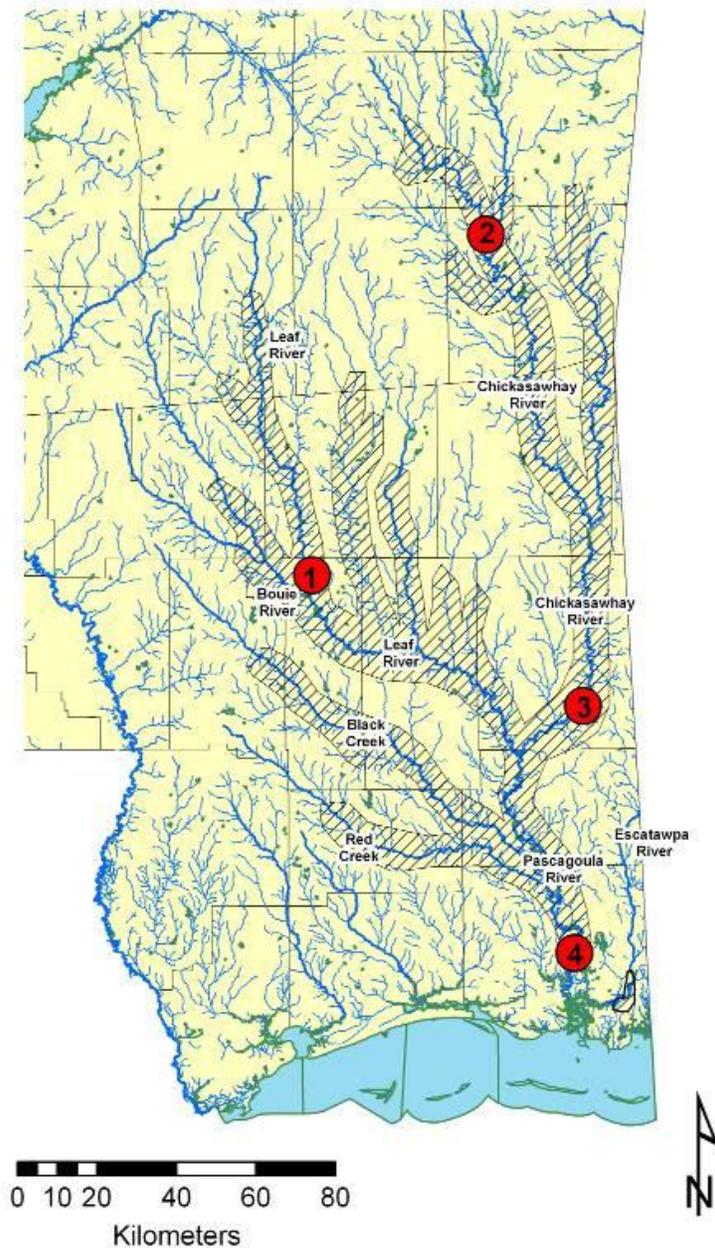


FIGURE 1. Range of *Graptemys gibbonsi* throughout the Pascagoula River system (black cross hatching; as described by Selman and Qualls 2009) and sample sites. Sample sites are: 1) Leaf River, 2) upper Chickasawhay River, 3) lower Chickasawhay River, and 4) Pascagoula River.

midline plastron length (PL) and male claw length (CLAW; longest foreclaw on either forelimb) to the nearest 1 mm with tree calipers. In 2008, we recorded female head width (FHW) at LR, PR, and UCR using a plastic ruler to measure the distance (in mm) between the lower jaw insertion points. We also visually inspected turtles for external parasites, scute abnormalities, and injuries. We permanently marked the marginal scutes with holes from an electric drill according to the method of Cagle (1939); we did not include recaptured

individuals in the morphometric analyses. We recorded capture locations using a handheld GPS system. Following marking and measuring of turtles, we released all individuals at their points of capture.

We used one-factor ANOVAs to compare plastron length for females (all sites) and for males (excluding PR turtles due to low sample size); all juvenile individuals were excluded from the analyses. When ANOVAs were significant, we used a Tukey-Kramer *post hoc* comparison to define differences among sites. We

included gravid females, as determined via palpation ($n = 8$; 5 LR and 3 LCR), in the analysis due to the overall small sample size of female captures at all sites. We used a Chi-squared test to determine if populations deviated from a 1:1 sex ratio at each sample site. We used linear regressions to determine the relationship between body mass and plastron length for both males and females (using a log mass and log PL transformation).

To examine differences in sexual size dimorphism (SSD) among three sites with adequate sample sizes of adults (excluding the PR), we calculated the sexual dimorphism index (SDI; Lovich and Gibbons 1992) for each site; a value of zero represents no difference in body sizes across sexes, while positive values indicate female-biased SSD and negative values indicate male-biased SSD (Gibbons and Lovich 1990). This was completed by dividing the mean PL of mature females (≥ 15.4 cm PL; present study) by the mean PL of presumed mature males (≥ 7.0 cm PL; Shealy 1976) and then subtracting one. To determine the relationship of secondary sex characteristics to individual body size, we used a linear regression for the two measured secondary sex traits (FHW, all 2008 sites; CLAW, all four sites 2005–2008) with PL as the covariate.

Growth.—Assessing body size of known-aged individuals was not possible due to the lack of known-aged juveniles that were recaptured and the presence of false growth annuli (Shealy 1976), which made determining age unreliable. Therefore, we only discuss the size of hatchlings and the growth of marked and recaptured subadult and adult individuals.

Movements.—We inferred the movements of *G. gibbonsi* from recapturing marked individuals. For capture and recapture points, we plotted the GPS coordinates within GoogleEarth (v. 6.1; Google Inc., Mountain View, California, USA) and then minimum rkm moved were then measured between these points along the mid-river channel (Kornilev et al. 2010). To estimate activity area, we used the distance between the two most distant capture points (Sexton 1959; Kornilev et al. 2010), while also calculating the number of days between captures. We used a linear regression to determine if the number of recaptures (1–4) or number of days between first and last capture (1–1,254 d) influenced the activity area length. We acknowledge that more points are needed accurately measure home ranges for riverine *Graptemys* species (Jones 1996); our calculations are minimum activity areas and are likely underestimates.

Basking ecology observation methods.—We studied basking ecology at the LR (Forrest County; Site 1 in Fig. 1), with habitat characteristics described in Selman and

Qualls (2011) and Selman (2012). Observation methods of turtle basking behavior were similar to those described by Selman and Qualls (2011), with daily observations ($n = 43$) lasting 4–10 consecutive hours (mean = 4.85 h). We observed individual and population-level basking with a 60 mm, 15–45 \times zoom spotting scope with tripod from June to October 2007 and April to May 2008. The observer was located in concealed, fixed positions on sandbars opposite of cutbank sections where turtle basking structures (i.e., emergent deadwood) were abundant. We attempted observations each month on at least one weekend day and one weekday, with some observations shortened by severe weather.

When a *G. gibbonsi* was observed emerging onto a basking structure, we documented the time of emergence, basking structure type, and the sex of the individual using secondary sex characteristics (i.e., males were smaller with larger tails); we could not visually determine the sex of smaller turtles and they are hereafter referred to as juveniles. When the individual reentered the water, we documented the time of submergence and total basking time. We categorized basking structure types as logs, floating logs, branches, crowns, tangles (modified from Lindeman 1999, following Selman and Qualls 2011). At the population level, we counted the number of basking *G. gibbonsi* within a measured, predetermined stretch of river at the beginning of each hour from our fixed position (hereafter, basking frequency counts). When possible, we determined the sex of individuals. To document accurate river distance surveyed, we used a laser range-finder (Nikon Laser 800, Melville, New York, USA).

We measured three environmental temperatures at the study site using HOBO Water Temp Pro v2 and Pro v2 Temperature/External temperature data loggers (Onset Computer Corporation, Bourne, Massachusetts, USA): ambient air temperature at a shaded site (AT), water temperature (WT), and the temperature of a sunny basking log (LT). Data loggers collected temperatures every 5 min. We retrieved the temperature data with a HOBO Waterproof Shuttle and then directly associated an hourly temperature reading (e.g., 35 °C) with each hourly basking frequency count (e.g., 1100).

Data for individual basking durations had a non-normal distribution, thus we log-transformed the data to meet parametric assumptions. We used a two-factor ANOVA to determine the effects of gender and month (April to October) on basking duration, with a gender \times month interaction. Likewise, we used a two-factor ANOVA to determine the effects of gender and time of emergence (0900–1700 categorized by one-hour intervals) on turtle basking duration, with a gender \times time of emergence interaction. We excluded juveniles from these analyses due to low sample size. For all ANOVA tests significant at $\alpha = 0.05$, we used Tukey-

Kramer *post hoc* tests to define differences. To determine if sexes used basking structure types equally (including juveniles), we used a Chi-squared test.

To quantify population-level basking, we used an analysis similar to that of Selman and Qualls (2011). Briefly, we calculated the percentage of the population basking for each hourly basking frequency count by using a population size estimate (34 per river km; Selman and Qualls 2009) to determine how many turtles should be in a particular river distance. For each hourly count, we then divided the total number of *G. gibbonsi* observed basking by the estimated number of turtles in the observed stretch of river. We used one-factor ANOVAs to determine if percentage basking was equal across months (April to October) and by hour of day (0700–2000). In addition to basking percentage, we also used raw basking count data observed to determine yearly and seasonal basking patterns for each sex and age category. To determine the relationship of basking incidence with temperature, we used second-order polynomial regressions to relate raw basking frequency counts to WT, AT, and LT, with male and female data separately analyzed. We used JMP 9 (SAS Institute Inc., Cary, North Carolina, USA) for all statistical analyses and accepted significance of tests at $\alpha = 0.05$.

Population density and relative abundance.—At LR and PR, we conducted 3–7 replicate counts by boat per year to determine *G. gibbonsi* population basking density as well as the relative abundance from 2006 to 2008; only a single count was conducted at UCR and LCR in 2008. During surveys, we located basking turtles with binoculars from a boat or by walking sandbars when they were present (from the upstream end to the downstream end) and using a spotting scope with tripod. We calculated the mid river distance of each site using the GoogleEarth path measuring tool (v. 6.1; Google Inc., Mountain View, California, USA). Total *G. gibbonsi* we observed per survey was then divided by the survey distance (in river km) to get a basking density estimate. Further, we calculated relative abundance by dividing the total *G. gibbonsi* observed per survey by the total number of all basking turtles observed.

Diet.—In 2007 and 2008, we captured *G. gibbonsi* at the LR, and we retained individuals in 18.9-L buckets with a small amount of water in the bucket (about 5 cm deep); the water kept fecal contents moist and the shallow depth kept turtles from swimming continuously. We brought individuals back to the lab overnight, and we collected fecal contents the following morning by straining the contents in a 1-mm sieve; we retained contents in jars with 70% ethanol. We recorded turtle sex, date of collection, and identification number and thereafter, we released individuals at their capture sites the following day even if no fecal contents were

collected. Because *Graptemys* stomach flushing has been shown to be unreliable (i.e., shell fragments not regurgitated; Lindeman 2006), we elected to analyze fecal contents to determine diet and acknowledge that some diet items may be unrecognizable in fecal contents (i.e., soft-bodied organisms).

We later sorted prey remains under a dissection microscope, and we determined the volume of each prey item category via volumetric displacement of water to the nearest 0.1 ml. We estimated categorical samples that displaced < 0.1 ml to constitute either 0.05 or 0.01 ml. We used an Index of Relative Importance (IRI; Hyslop 1980, as modified by Bjorndal et al. 1997) in separate analyses of the diets of males and females. For each prey category *i*, we used data on mean percent total volume (%V_{*i*}) and percent frequency of occurrence (%F_{*i*}) to calculate the index:

$$IRI_i = 100V_iF_i / \sum (V_iF_i).$$

Within each sex, IRI_{*i*} values sum to 100 over all prey categories.

Reproduction and nesting.—During trapping efforts, we palpated captured female *G. gibbonsi* to determine the presence of shelled eggs. Palpation is an effective method in determining the presence of shelled eggs in freshwater turtles (Zuffi et al. 1999); however, it often underestimates the number of gravid females in earlier egg stages with less calcification (Keller 1998). We report the percentage of females gravid by month and for the overall nesting period. However, it is likely that some gravid females were not detected or some females without eggs may have been between clutches. Therefore, our estimates are likely a lower frequency compared to radiographic (Keller 1998) or ultrasound methods (Kuchling 1989). We also opportunistically encountered nesting females while we were trapping, walking to and from basking observation sites, and conducting distribution and abundance surveys on the river (Selman and Qualls 2009). We never observed a complete nesting event, but we describe partial nesting observations.

RESULTS AND DISCUSSION

Population structure.—In four years, we captured 11 *G. gibbonsi* (2 ♂, 7 ♀, 2 juveniles) at the PR and 76 (28 ♂, 44 ♀, 4 juveniles) were captured at the LR. In two years, we captured 68 individuals (50 ♂, 9 ♀, 9 juveniles) at the LCR and 30 individuals (15 ♂, 12 ♀, 3 juveniles) at the UCR. Pooled captures from all sample sites indicate a lack of juvenile captures, with only 20 juveniles captured at all sites (10.6% of captures). There was also a large PL range of females (6.0–22.0 cm PL size classes; Fig. 2). Sex ratios at two of the three sites

TABLE 1. Comparisons of male and female plastron lengths (PL, cm), body mass (BM, g), female head width (FHW, cm), and male claw length (CLAW, cm) among four sample sites for *Graptemys gibbonsi*. Significant differences among sampling sites for males and females are indicated by different letters. Site names are abbreviated as described in text: LR = Leaf River, UCR = Upper Chickasawhay River, LCR = Lower Chickasawhay River, and PR = Pascagoula River. Asterisk (*) means the sample size was too small to include in the analysis of male PL.

	Males				Females			
	LR	UCR	LCR	PR	LR	UCR	LCR	PR
PL								
n	51	15	52	2	51	12	9	8
Mean	9.7 ^a	8.6 ^b	9.3 ^a	7.1*	16.3 ^a	14.5 ^{a,b}	16.6 ^a	9.2 ^b
Min	7.6	7.4	6.9	6.6	8.2	9.2	6.9	7.0
Max	11.6	9.4	11.8	7.6	20.6	21.6	22.7	12.8
SE	0.11	0.16	0.14	0.50	0.53	1.38	1.80	0.72
BM								
n	50	15	51	2	51	12	9	7
Mean	199.4	134.3	169.0	82.5	1,247.3	945.4	1,413.3	224.3
Min	95	80	75	70	115	145	70	100
Max	340	180	325	95	3700	2700	3150	800
SE	6.99	7.90	7.89	12.5	114.9	273.3	386.3	256.0
FHW								
n					7	6	-	2
Mean					3.74	4.11	-	1.95
CLAW								
n	51	15	51	-				
Mean	0.93	0.89	0.86	-				

(excluding the PR due to inadequate sample sizes) deviated from equality, with significant female dominance at LR ($\chi^2 = 4.00$, $df = 1$, $P = 0.046$) and male dominance at LCR ($\chi^2 = 39.5$, $df = 1$, $P < 0.001$). The sex ratio at UCR did not deviate from equality ($\chi^2 = 0.14$, $df = 1$, $P = 0.710$). Sex ratio biases via trapping at the LR and LCR were also observed by WS during basking density surveys (both the LR and LCR) and basking ecology surveys (LR), thus supporting that

trapping sex ratios were not due to sampling methodology. Similarly, Graham et al. (2015) found a deviation from equal sex ratios at the LCR, but no deviation from equal sex ratios at a site downstream of the LR site where we found a female bias. Male bias at the LCR may be driven by high sedimentation rates (Will Selman, pers. obs.) that may limit availability of molluscan prey, while female bias at the LR may be driven by high female prey availability, with abundant *Corbicula* and native mussels observed at this site. More detailed studies are needed to determine prey availability at these sites and comparative diet studies.

Mean PL was different across sites for males ($F_{2, 93} = 4.84$, $P = 0.010$) and females ($F_{3, 73} = 4.93$, $P = 0.004$; Table 1). Males at LR and LCR were significantly larger than UCR males, with no difference between LR and LCR males. Females at LR and LCR were significantly larger than PR females, but similar in size to UCR females; there was no difference between UCR and PR females. The largest female at PR was 12.8 cm, which is considerably smaller than the maximum PL at the other three sites (LR = 20.6 cm, LCR = 22.7 cm, UCR = 21.6 cm) and for museum specimens (max = 23.5 cm; Jeffrey Lovich, pers. comm.). Mean female PL across sites was 14.9 cm (6.9–22.7 cm) and mean male PL across the sites was 9.2 cm (6.6–11.8 cm; Table 1). Body mass was significantly related to PL for both males ($r^2 = 0.94$, $F_{1,118} = 1760.8$, $P < 0.001$) and females ($r^2 = 0.97$, $F_{1,79} = 2690.7$, $P < 0.001$; Fig. 3). Using carapace length (CL) for comparison to Graham et al. (2015), both

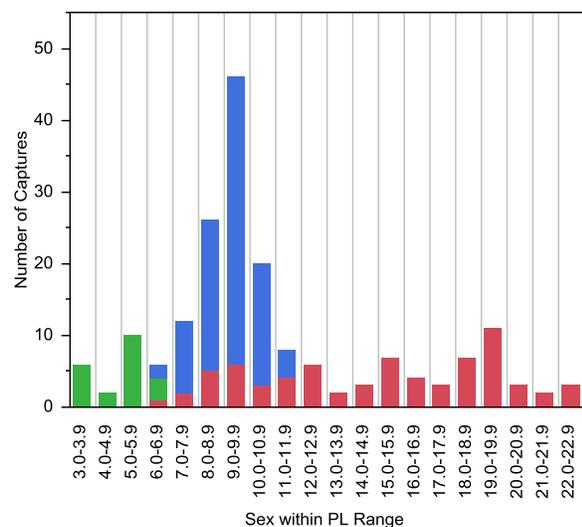


FIGURE 2. Plastron lengths (cm) of all *Graptemys gibbonsi* captured during the study at all four sites: unsexed juveniles (green), males (blue), and females (red).

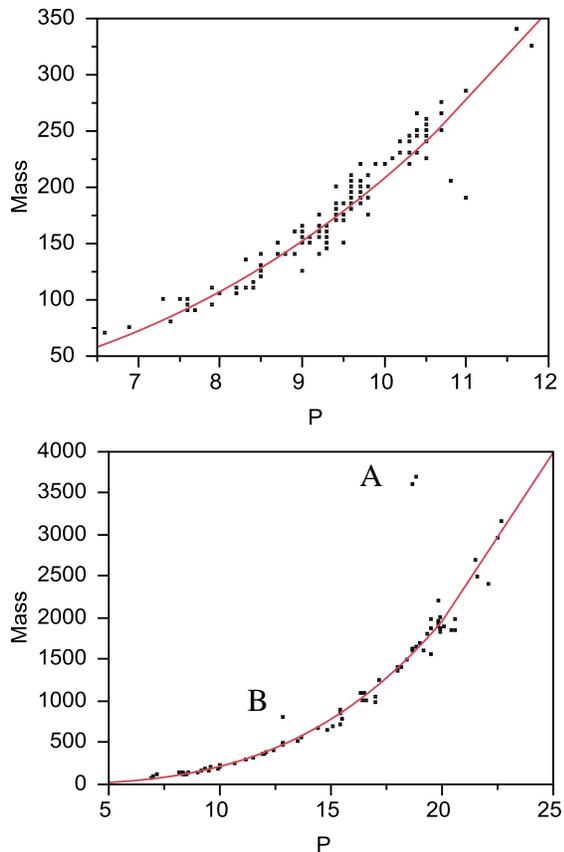


FIGURE 3. *Graptemys gibbonsi* body mass (g) by plastron length (cm) comparisons at all sample localities for males (top; Formula: $\text{Log}[\text{Mass}] = -1.479962 + 2.9610758 * \text{Log}[\text{PL}]$) and females (bottom; Formula: $\text{Log}[\text{Mass}] = -1.952179 + 3.1823077 * \text{Log}[\text{PL}]$). For females, the two large outliers (A) are both relatively short and heavy Leaf River females (one was gravid), while the smaller outlier (B) was a relatively short and heavy Pascagoula River female (12.8 cm PL, 800 g) that had a malformed, circular shell as described in the text.

LR males (this study mean CL: 11.3 cm, max CL: 14.1 cm; Graham et al. mean CL: 10.4 cm, max CL: 13.0 cm) and females (this study mean CL: 18.8 cm, max CL: 25.3 cm; Graham et al. mean CL: 16.7 cm, max CL: 22.7 cm) were larger from this study. LCR males (this study mean CL: 10.7 cm, max CL: 13.8 cm; Graham et al. mean CL: 11.3 cm, max CL: 13.5 cm) and females (this study mean CL: 19.4 cm, max CL: 27.3 cm; Graham et al. mean CL: 22.7 cm, max CL: 26.7 cm) were relatively similar in size across studies.

Interpopulational differences in body size were also observed for *G. flavimaculata* in the Pascagoula River system (Selman 2012), with the largest observed PLs for both male and female *G. flavimaculata* observed in at the PR site. Lindeman (2013) observed that narrow-headed *Graptemys* increase in body size near their downstream range limits close to the coast, while Jones and Hartfield (1995) did not observe this pattern in *G.*

oculifera. This observed pattern is converse to the smaller sizes of *G. gibbonsi* observed at the PR site in this study, with few large individuals observed in the population. It appears that these small individuals were growth-stunted adults rather than juveniles (discussed further below in Growth sub-section). A proximate explanation for this difference may be due to changes in *G. gibbonsi* prey species presence and/or abundance in the brackish-influenced lower Pascagoula River, while suitable prey species and/or prey abundance are available for *G. flavimaculata*. Basking observations and trapping results also seem to confirm this (discussed further in Population Densities and Relative Abundance section) with basking densities extremely low in the area and fewer captures (i.e., small sample sizes), respectively.

Sexual size dimorphism was pronounced for *G. gibbonsi*, with females attaining greater mean plastron lengths than males at all sites (SDI = 0.92 for LR, 1.24 for UCR, and 1.18 for LCR). We could not calculate SDI for the PR because maturity was difficult to identify in growth of stunted adults. Compared to *G. flavimaculata* (Selman 2012), CLAW for *G. gibbonsi* was relatively short ($n = 117$, mean = 0.89 cm, range = 0.5–1.4), but there was a positive relationship between CLAW and PL ($F_{1,117} = 63.3$, $r^2 = 0.36$, $P < 0.001$; Table 1). There was large variability in female body sizes, with considerable variability also in FHW ($n = 15$, mean = 3.7 cm, range = 1.7–5.1 cm). There was a significant positive relationship of FHW with PL ($F_{1,15} = 347.6$, $r^2 = 0.96$, $P < 0.001$).

Growth.—Ten hatchlings (i.e., turtles captured in the fall or spring lacking any prominent growth annuli) had a mean size of 3.7 cm PL (3.3–4.2 cm) and a mean mass of 11.7 g (10–15 g). We observed hatchlings in both the fall ($n = 1$; 9 October 2008) and spring ($n = 9$). We captured the three smallest individuals (PL: 3.3, 3.4, 3.6 cm) in April and May, with body lengths the same or smaller than the lone individual captured in October (PL: 3.6 cm); this indicates that partial delayed emergence may be possible in this species. Delayed emergence in wild *Graptemys* populations has only been observed in species from northern latitudes (see Gibbons 2013), with no delayed emergence observed in a related broad-headed *Graptemys* species in the southeastern US (*G. ernsti*; Shealy 1976). We recaptured only seven females (six LR, one PR) and 15 males (12 LR, two LCR, one PR) during the study to document growth. Larger females (initially captured with $\text{PL} \geq 19.3$ cm) and males (≥ 9.5 cm PL) recaptured across years exhibited zero or negligible growth, while smaller females grew rapidly and smaller males grew slowly (Table 2).

We did not capture or observe basking any large females in the PR population, as noted above. Even though annuli were difficult to assess in this species, the

TABLE 2. Growth table of recaptured *Graptemys gibbonsi*, sorted by sex (females top, males bottom) and by plastron length (smaller individuals first). Individuals with negative values for growth likely represent zero or negligible growth with researcher measurement error.

Site	Sex	ID	1st Capture	PL	Subsequent Captures	PL	Growth
Pascagoula	F	L11	8/28/2008	8.4	10/30/2008	8.3	- 0.1
Leaf	F	R2-L8	4/5/2006	16.6	5/7/2007	18.0	1.4
Leaf	F	R9-L12	5/13/2008	18.7	9/10/2008	18.8	0.1
Leaf	F	R8	5/5/2005	19.3	4/3/2006	19.3	0
Leaf	F	R2-L11	5/3/2006	19.8	6/6/2006	19.8	0
					4/11/2004	19.9	0.1
Leaf	F	R1	5/4/2005	20.4	5/5/2005	20.4	0
Leaf	F	R2-L10	5/3/2006	20.6	4/6/2007	20.6	0
Pascagoula	M	R8	4/21/2007	6.8	7/19/2007	7.6	0.8
Chickasawhay	M	L12	6/16/2005	8.2	11/3/2005	8.4	0.2
Leaf	M	R12	5/6/2005	9.1	5/3/2006	9.2	0.1
					9/5/2006	9.4	0.2
Leaf	M	R3-L9	6/2/2006	9.3	6/3/2008	9.5	0.2
Leaf	M	R8-L2	4/11/2007	9.3	10/10/2008	9.4	0.1
Leaf	M	R3	5/5/2005	9.4	9/11/2007	9.6	0.2
					5/13/2008	9.6	0
Leaf	M	R1-L12	9/27/2005	9.5	4/11/2007	9.6	0.1
Leaf	M	R3-L12	4/5/2007	9.5	10/13/2007	9.5	0
Leaf	M	R8-L12	5/8/2007	9.7	6/1/2007	9.7	0
					9/9/2008	9.8	0.1
					10/8/2008	9.7	- 0.1
Leaf	M	R9-L11	5/12/2007	9.7	10/9/2008	9.7	0
Chickasawhay	M	R2-L2	10/30/2005	9.8	11/10/2005	9.8	0
Leaf	M	R10-L8	10/13/2007	10.3	4/17/2008	10.3	0
Leaf	M	R10-L1	6/3/2008	10.4	10/10/2008	10.4	0
Leaf	M	R1-L3	9/26/2005	10.5	9/29/2005	10.5	0
					10/13/2007	10.5	0
					10/10/2008	10.5	0
Leaf	M	R3-L8	6/2/2006	10.7	9/5/2006	10.7	0
					4/5/2007	10.7	0
					7/2/2008	10.7	0
					10/9/2008	10.7	0

spacing of annuli for PR turtles in most individuals was qualitatively observed to be smaller than in other populations (e.g., one small female was found with 15–20 narrow growth rings). For females, the PR habitat may be marginal and not conducive to the rapid growth observed in upstream, freshwater habitats where freshwater mollusks are more abundant. However, male growth may not be as inhibited due to greater prey availability (primarily aquatic insects; see diet section below).

Movements and linear activity area.—Of the 22 individuals we recaptured in the study (see above in Growth section), 15 were recaptured once, seven were recaptured twice, four were recaptured three times, and a single LR male was recaptured four times. The mean distance moved between recapture locations was 0.60 ± 0.50 rkm (range 0.01–1.24 rkm) for females and 0.41 ± 0.47 rkm (0.01–1.81 rkm) for males. The mean time

between recaptures was 181 ± 141 d (1–397 d) for females and 298 ± 216 d (11–732) for males. The maximum single movement observed for a female was 1.7 rkm (LR female, 19.8 cm PL) between 3 June 2006 and 11 April 2007 (Fig. 4). The longest maximum male movement was 0.8 rkm (LR male, 9.1 cm PL) between 5 September 2006 and 11 October 2008. Conversely, three males were recaptured either on the same log (LR male, 9.7 cm PL) or within the GPS accuracy (LCR male, 8.2 cm PL; LR male, 10.4 cm PL), with this occurring over 129, 140, and 150 d, respectively. Similarly, a LR female (16.6–18.0 cm PL) was captured on the same basking log with over one year (397 d) between captures.

The mean minimum linear activity area was 0.69 ± 0.60 rkm (0.01–1.69 rkm) for females and 0.37 ± 0.34 rkm (0.01–0.94 rkm) for males. The longest male minimum linear activity area was 0.95 rkm (PR male

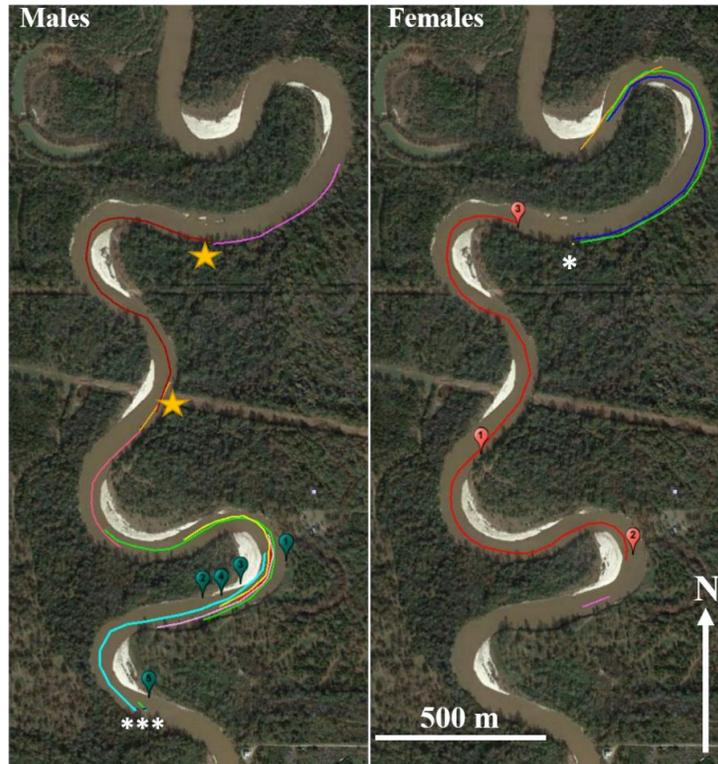


FIGURE 4. Linear activity area of recaptured male ($n = 12$) and female ($n = 6$) *Graptemys gibbonsi* at the Leaf River site, Mississippi, USA, with different color lines representing unique individuals. For both maps, the individual with the most captures has each capture locality labeled by a marker with the capture number inside (male, R3-L8; female, R2-L11). The longest male home range (R1-L3, crimson red) is denoted by yellow stars, while the longest female movement was R2-L11 (red). Three males and one female had small linear activity areas due to the recapture location being from the same log or within GPS accuracy of the initial capture (~ 9 m); these individuals are indicated by white asterisks. (Base imagery is from a 2013 Google Earth image).

recaptured once, 7.6 cm PL), while a LR female (recaptured twice, 19.8 cm PL) had the longest linear activity area of 1.69 rkm. A single LR male (10.7 cm PL) was recaptured four times, with a relatively small activity area within two river bends (0.73 rkm; Fig. 4). There was no significant relationship between the minimum activity area length and number of captures ($F_{1,22} = 2.24$, $P = 0.150$) or the days between first and last capture ($F_{1,22} = 1.20$, $P = 0.290$). Very little information on activity area or home range lengths is available in the literature for *Graptemys* species, but our minimum activity areas are generally shorter, likely due to our methodology. Jones (1996) found that *G. flavimaculata* had home range lengths from < 200 m to 5.9 km (males, range: 0.18–5.90 rkm, mean = 1.86 rkm; females, range: 0.23–2.85 rkm, mean = 1.55 rkm), while Bennett et al. (2010) found that female *G. geographica* had mean home ranges between 1.81 and 8.51 rkm. Because our values are for minimum linear activity areas based on capture points, they are likely underestimates and may be due to basking site fidelity exhibited by some individuals. A more detailed radiotelemetry study

is likely to find larger home range lengths for *G. gibbonsi* than those reported here.

Basking ecology.—Throughout the 7-mo basking study (June to October 2007; April to May 2008), we logged 186.1 total hours of basking observation at LR. During these observations, we recorded 388 independent basking occurrences for *G. gibbonsi* individuals (257 F, 112 M, 19 J). Additionally, we made 157 hourly basking frequency counts at LR. Mean basking duration for all *G. gibbonsi* was 43.4 min ($n = 388$, $SD = \pm 52.4$ min). Mean male basking duration was 43.3 min ($n = 112$, $SD = \pm 54.6$ min, range = < 1 –322 min), mean female basking duration was 44.2 min ($n = 257$, $SD = \pm 52.6$ min, range = < 1 –437 min), and mean juvenile basking duration was 31.9 min ($n = 19$, $SD = \pm 34.4$ min, range = < 1 –127 min). For a similar study conducted concurrently at the LR site, Selman and Qualls (2011) found *G. flavimaculata* basked for shorter durations across all sexes (males: 36.2 min, females: 42.8 min,

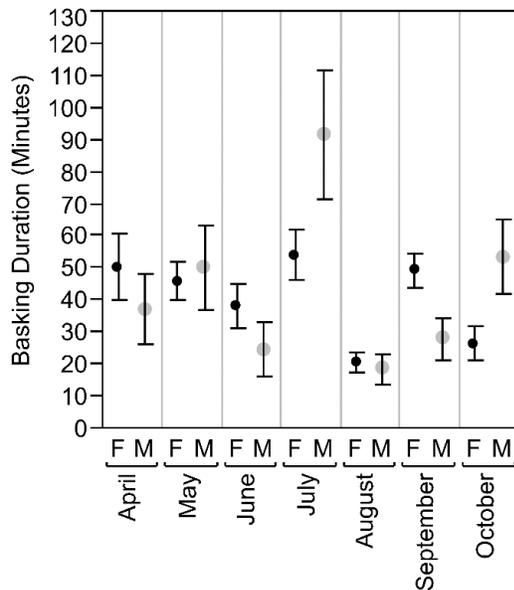


FIGURE 5. *Graptemys gibbonsi* basking duration (in minutes) by sex (females, black bars; males, gray bars) and month. Error bars represent one standard error.

juveniles: 23.5 min). Presumably the longer durations observed for *G. gibbonsi* are related to the increased time to reach their thermal optima due to their larger size and maybe different shape (i.e., higher domed) relative to *G. flavimaculata* (Boyer 1965). For basking longevity, 42 *G. gibbonsi* individuals (10.9%) had basking durations ≥ 100 min, five individuals (1.3%) > 200 min, and three individuals (0.8%) > 300 min. The maximum basking duration observed was 437 min (1055–1812) by a female on 15 April 2008 when LT (29.8° C at 1055 to 32.0° C at 1812) was warmer than AT (14.8–17.7° C) or WT (16.7–20.0° C).

There was a significant month \times sex interaction for individual basking duration ($F_{6,368} = 2.241, P = 0.039$). Longer basking periods for males were observed in July and October, while longer basking periods for females were observed in July and September; shorter basking periods were observed in August. July had longer basking periods during an unseasonably cool period with higher water levels than normal (Selman and Qualls 2011). Basking duration was longer for males than females during the months of July and October, but females basked longer than males during June and September; similar basking durations were observed in April, May, and August (Fig. 5). We also found a significant difference in individual basking duration by time of emergence ($F_{11,365} = 3.500, P = 0.001$), with longer basking durations observed in the morning (0700–1000) and mid-afternoon hours (1500–1700) relative to midday/late afternoon hours (1100–1400, 1800–1900; Fig. 6). There was no difference between

the sexes ($F_{1,365} = 0.91, P = 0.340$) and the interaction of gender \times time of day was also not significant ($F_{11,365} = 0.82, P = 0.620$). For *G. ernsti*, Shealy (1976) found a sharp increase in basking that coincided with higher water levels similar to what we found in July 2007. Similar to Selman and Qualls (2011), basking durations were longer in spring and fall months and correlated to cooler environmental temperatures, while also likely tied to reproductive cycles in both males and females during these times.

There were differences in the basking structure type used by males and females ($\chi^2 = 83.2; df = 7, P < 0.001$). Females basked on large logs or floating logs more frequently (79%) than branches (12%), whereas males used smaller branches (43%) and logs or floating logs (48%) almost equally. Females and males used tree crowns almost equally (5% and 7%, respectively), but tangles were used little (0% and 0.4%, respectively). Basking juveniles ($n = 19$) used branches (44%) and tangles (28%), with fewer observations on logs (22%) or crowns (6%). Many of these values for *G. gibbonsi* mirror those of male and female *G. flavimaculata*, with the only large difference being the higher use of tangles (22% vs. 0%) and lower use of branches (44% vs. 64.7%) by *G. gibbonsi* juveniles relative to *G. flavimaculata* juveniles (Selman and Qualls 2011). Six females and one male were observed basking on sand/dirt banks during high river levels that submerged many deadwood structures. The preferred basking locations of adult turtles of both sexes within the river channel had water between the basking structure and river bank, while juveniles were often located closer to the bank, similar to behaviors observed in *G. flavimaculata* (Selman and Qualls 2011).

The estimated percentage of the population observed basking differed significantly across months ($F_{6,155} = 6.34, P < 0.001$; Fig. 7). Higher percentages were observed in September and July relative to June and August, but September and July levels were not different compared to April, May, and October levels. There was no difference in the estimated percentage basking by time of day ($F_{13,155} = 0.83, P = 0.624$; Fig. 8). Contrary to Selman and Qualls' (2009) assertion that there were no differences in percentage basking between *G. gibbonsi* and *G. flavimaculata*, we found that *G. gibbonsi* basked at lower percentages across most months (mean: -13.4%; range: -34.9% to +7.3%;) and throughout the day (mean: -11.1%; range: -20.2% to +14.2%) relative to *G. flavimaculata* (Selman and Qualls 2011). It is possible that longer durations for *G. gibbonsi* may offset a lower basking frequency compared to shorter durations and higher frequency of *G. flavimaculata*. Also, *G. gibbonsi* may be more thermally efficient due to their larger size.

For females, yearly basking frequency counts exhibited a bimodal pattern with peaks around 1200–

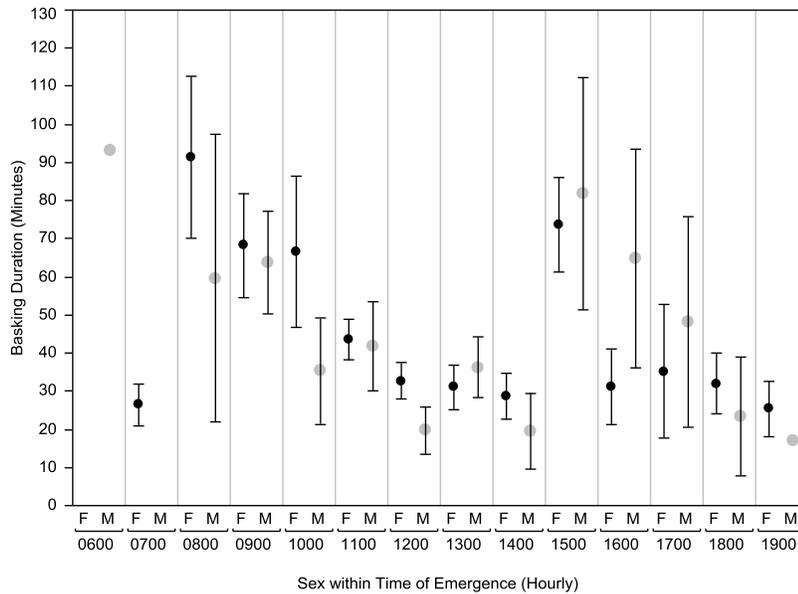


FIGURE 6. *Graptemys gibbonsi* basking durations (in minutes) by sex (females, black; males, gray) and daily time period. Each individual that emerged to bask within a specific hour (ex. 0800–0859) was considered only to emerge at the beginning of that hour (0800). Error bars represent one standard error.

1300 and 1600–1800 across all seasons (Fig. 9A), with males exhibiting much lower basking levels throughout the day with a late afternoon peak (1800–1900). During the spring (Fig. 9B), female basking peaked at midday (1200–1400), whereas males had a smaller midday peak (1400). Female to male basking ratio was highest during the spring and was likely associated with the timing of female ovarian follicle maturation prior to the nesting

season (Shelby et al. 2000, Horne et al. 2003). During the summer (Fig. 9C), female basking was slightly bimodal, with a small morning peak around 0900 and a late afternoon peak at 1600–1900. Males had relatively low basking levels throughout the day until an evening peak (1900), with basking regularly occurring past sunset (latest submergence 2010 h); *G. gibbonsi* males

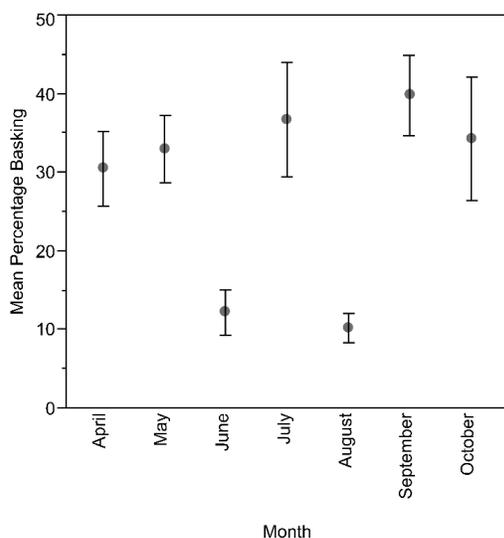


Figure 7. Estimated percentage of the Leaf River *Graptemys gibbonsi* population basking by month. Error bars represent one standard error.

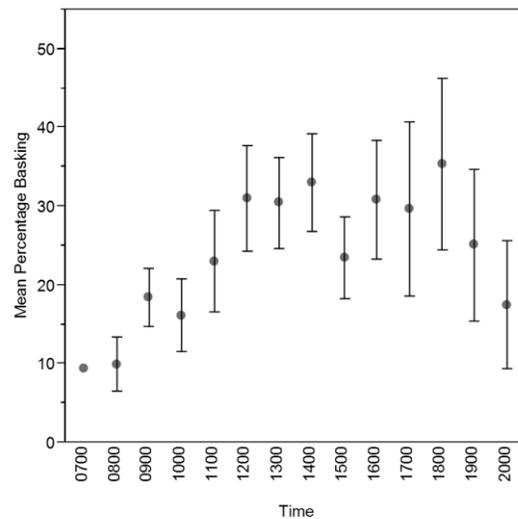


Figure 8. Estimated percentage of the *Graptemys gibbonsi* population basking at the Leaf River site during daily activity period throughout the year. Error bars represent one standard error.

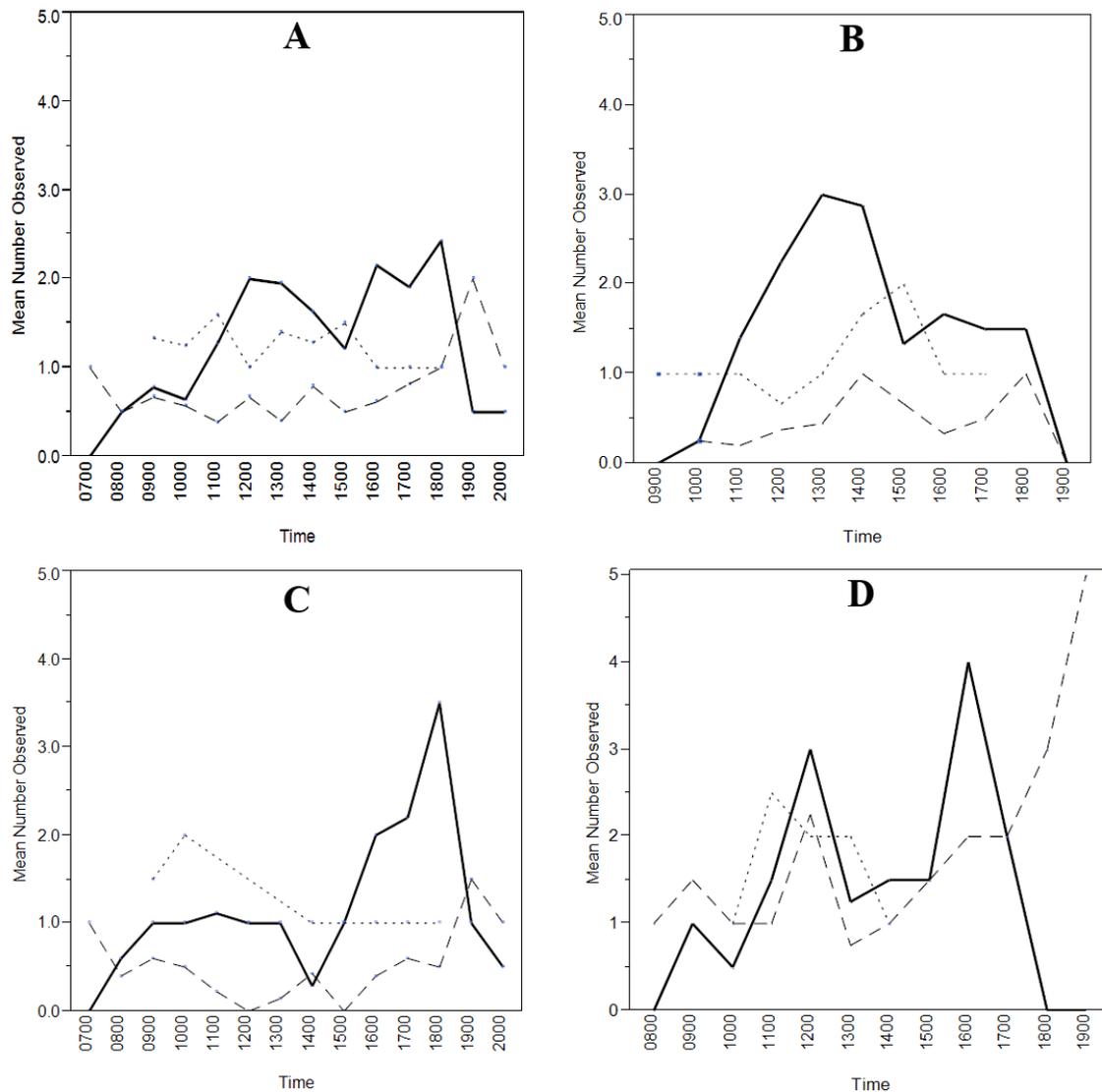


Figure 9. Basking frequencies of *Graptemys gibbonsi* from Leaf River (males, dashed line; females, solid line; juveniles, dotted line) by hour of day. Basking frequencies observed throughout the entire year (April–October) are depicted in chart A. Charts B, C, and D represent spring (April–May), summer (June–August), and fall basking frequencies (September–October), respectively. Note the differences in the times axes for the different seasons.

submergence 2010 h); *G. gibbonsi* males tended to be the last basking turtles observed into the evening hours and were generally observed later than the sympatric *G. flavimaculata* (Selman and Qualls 2011). During the fall (Fig. 9D), females had midday (1200) and afternoon (1600) peaks, while males had a late afternoon peak (1900). Male to female basking ratios were higher during the fall relative to other seasons likely driven by male spermatogenesis during this time (Shelby and Mendonça 2001). Further, *G. gibbonsi* males did not follow the bimodal pattern of *G. gibbonsi* females, which is converse to the similar bimodal patterns

observed for both male and female *G. flavimaculata* (Selman and Qualls 2011). Juveniles basked at much lower levels throughout all seasons similar to juvenile *G. flavimaculata* (Selman and Qualls 2011). However, juveniles were observed more during the spring and fall months, with more observations made across months during midday hours (1000–1500).

We observed basking *G. gibbonsi* across all months sampled and most environmental conditions (WT: 15–34.7° C; AT: 10.9–39.8° C; LT: 10.6–42.5° C). There were 29 of 141 (21%) basking frequency observations where *G. gibbonsi* were observed basking when water

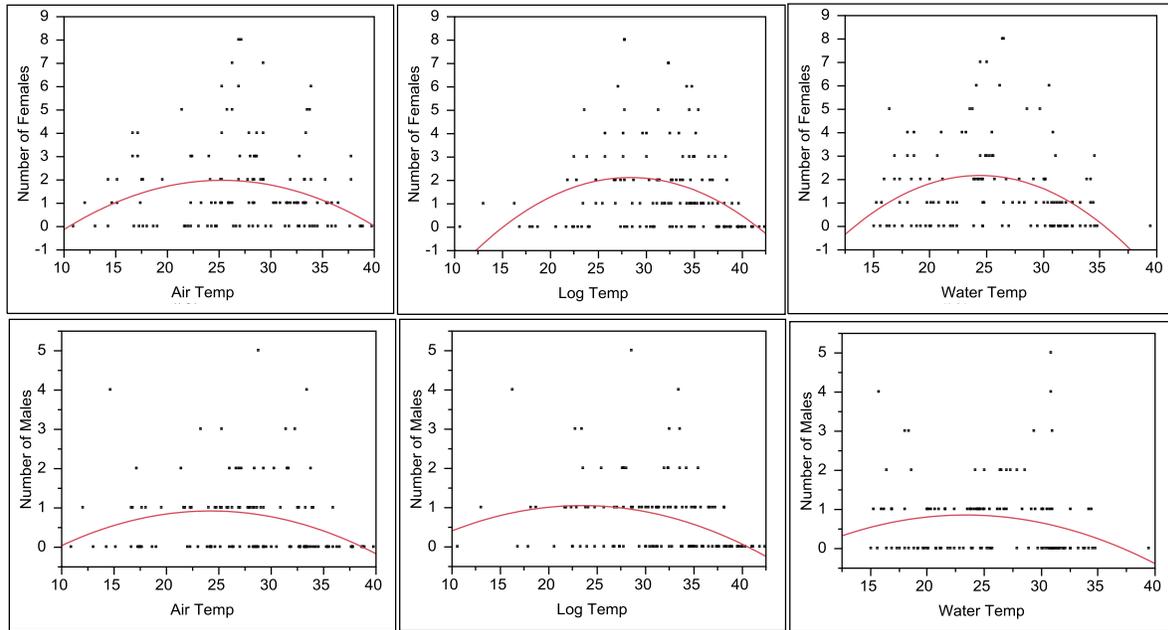


Figure 10. Leaf River *Graptemys gibbonsi* basking for females (top) and males (bottom) for air (left), log (middle), and water temperature (right; measured in °C). All but Water Temperature for males gave significant relationships in second-order polynomial regressions.

temperature was warmer than air temperature. Using a second-order polynomial regression, there was a weak but positive relationship between basking male counts and both LT ($F_{2,141} = 8.52, r^2 = 0.11, P < 0.001$) and AT ($F_{2,141} = 5.08, r^2 = 0.07, P = 0.007$), but no relationship with WT ($F_{2,141} = 2.53, r^2 = 0.03, P = 0.080$; Fig. 10). Male *G. flavimaculata* also exhibited significant relationships with LT, but not with AT (Selman and Qualls 2011), while Coleman and Gutberlet (2008) found significant relationships with AT and WT for both *G. pseudogeographica kohnii* and *G. sabinensis*. *Graptemys gibbonsi* females showed weak positive relationships with all three variables (LT, $F_{2,141} = 9.31, r^2 = 0.12, P < 0.001$; WT, $F_{2,141} = 8.41, r^2 = 0.11, P = 0.004$; AT, $F_{2,141} = 4.91, r^2 = 0.07, P = 0.009$). Female *G. flavimaculata* also exhibited significant relationships with all three variables (Selman and Qualls 2011), while Coleman and Gutberlet (2008) found significant relationships with AT, but not WT for both *G. pseudogeographica kohnii* and *G. sabinensis*. Peak basking in both male and female *G. gibbonsi* was observed at AT of 23–33° C, LT of 24–36° C, and WT of 17–31° C. These peak values were narrower than for *G. flavimaculata* (Selman and Qualls 2011).

Population density and relative abundance.— Population densities varied across the four sample sites, but remained stable at the two sites that were sampled multiple times over four years (Table 3). At these two sites, LR densities were 5–15 times greater than PR densities. We generally found higher densities at the LR

site (0.55–1.45 per 100 m) and two Chickasawhay River sites (0.55–1.55) compared to surveys in the mid-1990s (0.16 on five Leaf River sites, 0.40 on eight Chickasawhay River sites; Lindeman 1998), while lower numbers were observed at the PR (0.1–0.18) compared to those described by Lindeman (1998) for three sites on the Pascagoula River (0.45). Peter Floyd and Hilton Floyd (unpubl. report) found similarly low levels (0.25) in the lower PR compared to the middle (0.46) and upper PR (0.66). Some of these differences are likely due to our surveys being conducted during the fall and spring, while surveys by Lindeman (1998) and Peter Floyd and Hilton Floyd (unpubl. report) were during the summer and summer/fall, respectively. Greater basking densities would be expected during Spring and Fall due to seasonal basking differences previously described. However, Peter Floyd and Hilton Floyd (unpubl. report) suggested that the lack of mussels or lack of sandbar nesting areas in the lower Pascagoula River may limit the downstream distribution of *G. gibbonsi*.

There are noticeable differences for surveys conducted at the LR during the spring and fall months. We observed a two- to three-fold increase in basking density in the spring, with higher female-to-male ratios observed likely due to female energetic needs associated with yolking ovarian follicles (Vogt 1980; Hammond et al. 1988; Krawchuk and Brooks 1998; Carrière et al. 2008). Therefore, future surveys should carefully consider these seasonal differences when deriving conclusions on population densities without marked individuals. At the two sites where a single survey was conducted (UCR,

Selman and Lindeman.—*Graptemys gibbonsi* life history.

TABLE 3. Population density and relative abundance of *Graptemys gibbonsi* at four sites within the Pascagoula River system of southeastern Mississippi. Abbreviations for site names are Leaf River (LR), Pascagoula River (PR), lower Chickasawhay River (LCR), and upper Chickasawhay River (UCR). The distance surveyed is below site name. The number of *Graptemys gibbonsi* observed is denoted as n. Mean values are for multiple surveys in the same month and year.

Site	Year	Date	n	M:F ratio	Mean M:F ratio	Density per 100 m	Mean density for period	Relative abundance	Mean Relative abundance
LR 3.75 rkm	2006	10/4/06	14	0.75:1		0.37		0.12	
	2006	10/5/06	24	1:1		0.64		0.15	
	2006	10/7/06	21	0.31:1	0.63:1	0.56	0.52	0.25	0.17
	2007	4/13/07	64	0.32:1		1.71		0.17	
	2007	4/16/07	52	0.33:1		1.39		0.15	
	2007	4/17/07	45	0.29:1		1.20		0.16	
	2007	4/17/07	71	0.51:1	0.37:1	1.89	1.55	0.18	0.17
	2007	10/15/07	28	1.2:1		0.75		0.15	
	2007	10/16/07	28	1.2:1		0.75		0.13	
	2007	10/19/07	27	1.5:1	1.24:1	0.72	0.74	0.19	0.16
	2008	10/14/08	34	1.13:1		0.91		0.19	
	2008	10/15/08	35	0.52:1		0.93		0.16	
	2008	10/16/08	31	0.94:1	0.82:1	0.83	0.89	0.16	0.17
PR 2.0 rkm	2006	10/30/06	0	-		0.0		0	
	2006	11/1/06	3	All M		0.15		0.01	
	2006	11/8/06	3	All M	-	0.15	0.10	0.01	0.01
	2007	10/31/07	2	All F		0.10		0.01	
	2007	11/1/07	3	0.5:1		0.15		0.02	
	2007	11/1/07	4	3:1	0.8:1	0.20	0.15	0.02	0.02
	2008	11/3/08	4	3:1		0.2		0.02	
	2008	11/5/08	4	All M		0.2		0.02	
2008	11/6/08	3	All M	10:1	0.15	0.18	0.02	0.02	
LCR 2.0 rkm	2008	6/16/08	18	1.25:1		0.55		0.50	
UCR 3.25 rkm	2008	9/24/08	29	0.81:1		1.45		0.45	

LCR), we observed relatively high densities (0.55 and 1.45 per 100 m) similar to Chickasawhay River observations by Selman and Qualls (2009). However, even if a +12% correction factor was used for this difference (see Basking Ecology section above), *G. gibbonsi* would be greatly outnumbered by *G. flavimaculata* in most basking surveys.

Similar to basking densities, relative abundances at the LR and PR remained stable across the four sample years (Table 3). Mean relative abundance of *G. gibbonsi* was 8–17 times greater at the LR than the PR. Even though *G. gibbonsi* basking densities increased at the LR during the spring, relative abundance remained similar between fall and spring. Similar to basking densities, the two surveys on the LCR and UCR had higher relative abundances (0.45 and 0.50) than we observed at the LR or PR. Compared to *G. gibbonsi* relative abundances reported by Lindeman (1998), the levels observed at our two Chickasawhay sites were higher (45–50% vs. 39%), but our LR (17% vs. 28%) and PR (1–2% vs. 11%) abundances were lower. Even though there are some differences, the numbers reported herein are for single

sites while Lindeman (1998) sampled between three and eight sites per river system. Nonetheless, it is clear in the two studies that the Chickasawhay River supports higher relative abundances of *G. gibbonsi* when compared to the Leaf River, while the Pascagoula River supports the lowest levels. Selman and Qualls (2009) reported similar comparisons among these river systems via bridge and basking density surveys, but also found that the Chickasawhay River contained fewer overall basking turtles compared to the other systems (2–3 times less). Therefore, relative abundance values may be misleading and density estimates should also be considered when making comparisons among sites or river systems.

Diet.—We made collections of male feces during April (n = 3), June (2), September (1), and October (2), while collections of female feces were made in April (2), July (1), and August (1). Males sampled for feces ranged from 9.3 to 10.7 cm PL (mean = 9.9 cm PL) and females from 11.5 to 17.2 cm PL (mean = 14.4 cm PL). For male *G. gibbonsi*, three groups predominated in the

TABLE 4. Diet of the Pascagoula Map Turtle (*Graptemys gibbonsi*), with index of relative importance (IRI) calculated based on percent frequency (%F) and mean percent of total volume (%V) for each prey taxon for each group.

Prey taxon	Males (n = 8)			Females (n = 4)		
	%F	%V	IRI	%F	%V	IRI
Asian clams	38	13	8	100	97	99
Caddisfly larvae	63	38	37	25	1	0.3
Insect fragments	88	37	51	25	0.8	0.2
Sponges	13	4	0.8			
Mosses	25	7	3			
Leaf fragments				25	0.1	0.03
Algal stalks	13	1	0.2	25	0.8	0.2

diet: insect fragments (IRI = 51), caddisfly larvae (IRI = 37), and *Corbicula* spp. (Asian Clam; IRI = 8; Table 4). Sponges, moss, algal stalks, and leaf fragments were also present in male fecal contents. Female *G. gibbonsi* diet consisted almost exclusively of *Corbicula* spp. (IRI = 99, mean 97% volume), with lower values for caddisfly larvae, insect fragments, leaf fragments, and algal stalks (each IRI < 0.5; Table 4). Wood fragments were found in male but not in female fecal samples, indicating that females likely forage on river bottom substrate (primarily for *Corbicula*), whereas males likely forage on submerged deadwood structure. Sample sizes were too limited to make any seasonal comparisons.

Ennen et al. (2007) and Peter Floyd and Hilton Floyd (unpubl. report) both found single females to have feces consisting entirely of *Corbicula* spp. in the Leaf River and Black Creek, respectively. Shealy (1976) found that male *G. ernsti*, a similar megacephalic species, were primarily insectivorous, with a smaller part of the diet composed of aquatic snails. Similar to *G. gibbonsi* females, Shealy (1976) found that *Corbicula* spp. was the most important food item in the diet of *G. ernsti* females, while Lindeman (2006) also found similar high levels of *Corbicula* in female *G. versa* (99 IRI). However, we did not find evidence of native mussels in the diet of *G. gibbonsi* females, while Lovich et al. (2011) and Peter Lindeman (unpubl. data) both found native mussels (order Unionoida) in the diets of *G. ernsti* and *G. pulchra*, respectively. Even though native mussels were observed at the LR site (mostly large individuals of *Elliptio crassidens*, *Lampsilis ornata*, *Lampsilis teres*, and *Quadrula verrucosa*), they were not present in the small number of female samples at this site. It is also unknown what proportion of the historical diet of *G. gibbonsi* was composed of native mollusks, but it was likely higher than in modern times due to the decline of aquatic mollusks across the southeastern US (Neves et al. 1997). Several authors have found freshwater turtle diets were more diverse in areas

without *Corbicula* spp. (Atkinson 2013) or before the invasion of *Corbicula* spp. (Lindeman 2006). *Corbicula* spp. may be substituting for the loss of native mussels or *G. gibbonsi* females may preferentially consume *Corbicula* spp. Either way, *Corbicula* spp. is an important dietary component for female *G. gibbonsi* and likely contributes to the persistence of *G. gibbonsi* in the face of massive declines in native freshwater mollusks. Further detailed research is needed to determine if there are seasonal or geographical differences in the diet of *G. gibbonsi*, while also determining the nutritional values of native versus non-native mollusks.

Reproduction and nesting.—Nine of 81 females captured during the months of April through July were found to be gravid (11%, including recaptures; six of 45 at Leaf River, three of nine at lower Chickasawhay); this is contrary to Graham et al. (2015) finding zero gravid *G. gibbonsi* females during peak nesting season (n = 25). The smallest gravid female was 15.4 cm PL and was captured on 5 April 2007 at LR. Of those females \geq 15.4 cm PL from April to July (n = 32), 28% were gravid. The earliest gravid female was captured on 5 April (2007) and the latest gravid female was captured on 18 July (2005). The relatively long reproductive season suggests that females likely lay more than one clutch per year, although this could not be confirmed due to a lack of recaptured gravid females. Our study found a low percentage of gravid females during the nesting season which likely indicates that inguinal palpation may underestimate the number of gravid females, particularly those without calcified eggshells (Keller 1998). We recommend a more thorough radiographic and/or ultrasound study to more accurately determine reproductive parameters in *G. gibbonsi* females.

We opportunistically observed nesting on three different occasions (once at LR and twice at LCR), with no observations of the full nesting event. We observed both LCR females (13 and 14 June 2006) running down steep sand banks to reenter the river, presumably disturbed by the passing of the researcher's motorized boat. These banks were the outer cutbanks of the river, which are likely lower quality *Graptemys* nesting habitat relative to sandbars deposited on the inside of river bends (Horne et al. 2003). On a third occasion at LR (12 June 2007), we encountered a large female *G. gibbonsi* (approx. 19 cm PL) during the middle of nesting. She was encountered on a cleared forest ATV path, approximately 55 m from the edge of the river and 5.5 m above the water level. The chosen nest site was within the wooded riparian margin of the river, but there was little vegetation within 0.5 m of the nest hole. The site was shaded, with the substrate being a combination of silt and sand. At the time of disturbance, the starter nest hole was approximately 12 cm deep and 3.8 cm in width, with no evidence of the flask-shaped portion of the nest.

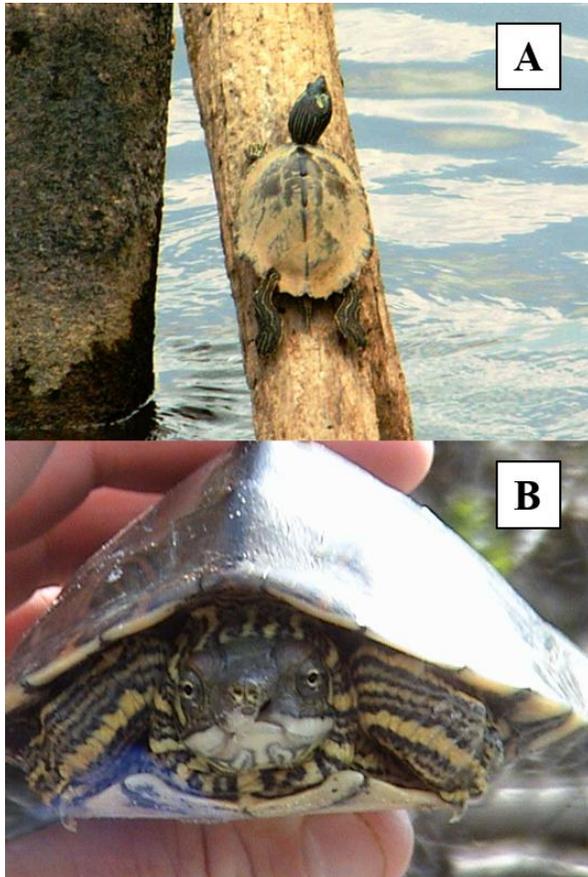


FIGURE 11. Examples of injuries observed in *Graptemys gibbonsi*. Missing, broken, or chipped marginal scutes were relatively common (A), while serious injuries were rarely encountered (healed injury to snout and upper mandible, B).

The female also had sand on her snout, evidence of nuzzling the ground (Morjan and Valenzuela 2001) for appropriate nesting habitat cues as has been reported for other *Graptemys* species (Shealy 1976; Lahanas 1982; Moore 2003).

Predators and parasites.—We found two adult females on sandbars (Perry County and Stone County, Mississippi) that were depredated, presumably while nesting. Both individuals were relatively intact, but small holes had been made through the rear inguinal pockets to access the internal organs or eggs. It is unknown how long the females had been dead, but similar signs with other turtle species appear to be attributable to Raccoons (*Procyon lotor*, Shealy 1976; Robert Jones, pers. comm.) or crows (*Corvus* sp., Cagle 1950; Baxter-Gilbert et al. 2013). Humans are the most common predator and collector of adults; people catch and kill individuals while fishing (Will Selman, pers. obs.), shoot turtles indiscriminately as target practice (Will Selman, pers. obs.), or collect individuals for the

pet trade (Cheung and Dudgeon 2006). Juveniles and hatchlings are likely preyed upon by a number of wading bird species (Genus *Ardea*), large fish (Carr and Messinger 2002), and opportunistically by small mammals. For *G. gibbonsi*, nests are likely the most vulnerable stage, as a number of small and large mammals (e.g., Raccoons, Opossums, feral swine), snakes, and bird species (e.g., crows) are significant nest predators of *Graptemys* species (Lindeman 2013); this would need to be verified in future reproduction and nesting studies.

Individuals occasionally had carapace fouling via mud or attached algae, while seven of the 126 total individuals (5.6%; two males and two juvenile females at LR, three males at LCR) had leeches (Genus *Placobdella*) present on the shell at the time of capture. We found individuals with leeches throughout the sampling year during the months of April (one individual), May (1), June (1), July (2), and August (2). Selman et al. (2008) described the voluntary release of a leech after 50 min of basking from the carapace of a large basking female *G. gibbonsi* in May 2007, with habitual basking likely leading to a lower prevalence of leeches in *Graptemys* species (Lindeman 2013).

Injuries and abnormalities.—Of the 184 individuals captured at all four sites, 45 (24.5%) had minor injuries in the form of missing, chipped, broken, or notched marginal scutes (LR: 25 of 76; PR: one of 10; LCR: 17 of 68; UCR: two of 30; Fig. 11). Males (27.3%) and juveniles (27.8%) had higher rates of marginal scute injuries than females (21.1%). Some major injuries were also observed, including a LR female with a missing but healed hindlimb, a LR female with a mangled forelimb (missing all but one foreclaw), a LCR male with a healed missing hindlimb and a hole in the left side of the snout (i.e., similar to a cleft palate; Fig. 11), and three males (two from LR, one from LCR) with significant breaks in the plastron or carapace. For the latter, two of the injuries were completely healed, while the other was a recent, unhealed wound. Presumably, many of these injuries are the result of natural encounters with mammalian (e.g., River Otter, *Lontra canadensis*; Raccoon) or reptilian (e.g., Alligator Snapping Turtle, *Macrochelys temminckii*) predators; sequential wounds characteristic of boat propeller strikes were not observed. Three individuals (a LR female, LCR and UCR males) had 13 left and right marginal scutes. Further, two LR males and one LCR male had extra pleural scutes, two on the right and the other on the left. One female at PR had a nearly circular carapace (CL 16.6 cm, CW 14.1 cm). We found no cases of kyphosis or lordosis.

Conclusions.—*Graptemys gibbonsi* has been known from the Pascagoula River system since the earliest

formal turtle surveys in the 1950s (Cagle 1954; Tinkle 1958). Even though the species has been present in the 60 y since these studies, relatively little was known about the species prior to this study. Prior researchers had long considered it to be part of a species with a much larger range (*G. pulchra sensu lato* through 1992 and then *G. gibbonsi sensu lato* through 2010) and therefore, less conservation attention was given to the species. With *G. gibbonsi sensu stricto* now considered Endangered by the IUCN (van Dijk 2011), it is imperative to document basic life history and ecology to better conserve and manage the species. We recommend that detailed studies focus on those topics needing additional information, particularly diet (including sampling multiple localities and seasons), movements and habitat use, and reproduction/nesting. Further information on these topics will provide managers and policy makers with the appropriate data in order to better conserve and manage the species and its riverine habitat.

Acknowledgments.—We would like to thank the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) and the U.S. Fish and Wildlife Service (USFWS Grant # 401817G021) for providing funding for this project. Carl Qualls (University of Southern Mississippi [USM]), Brian Kreiser (USM), Bob Jones (Mississippi Museum of Natural Science [MMNS]), Tom Mann (MMNS), and Lynn McCoy (MDWFP) assisted with many logistical aspects of this study. This project could not have been completed without the help of technicians (Dustin Strong, Thomas Boczek, Chris Griffith, Brandon Drescher) and those who assisted during the dry summer of 2006, including Christine Selman, Joe McGee (MMNS), and USM graduate/undergraduate students and faculty. Jimmy Dale Odom permitted us to use his private boat ramp to access the Leaf River site and Pat Spencer granted access to her sandbars on the Leaf River. Josh Ennen and Jeff Lovich provided valuable comments to improve the manuscript. This project was completed in association with Will Selman's dissertation work at USM and was approved by the USFWS, MDWFP, and the USM Institutional Animal Care and Use Committee (IACUC #07032201).

LITERATURE CITED

- Atkinson, C.L. 2013. Razor-backed Musk Turtle (*Sternotherus carinatus*) diet across a gradient of invasion. *Herpetological Conservation and Biology* 8:561–570.
- Baxter-Gilbert, J., J.L. Riley, and J.D. Litzgus. 2013. *Chrysemys picta marginata* (Midland Painted Turtle): avian predation. *Herpetological Review* 44:302–303.
- Bennett, A.M., M. Keevil, and J.D. Litzgus. 2010. Spatial ecology and population genetics of Northern Map Turtles (*Graptemys geographica*) in fragmented and continuous habitats in Canada. *Chelonian Conservation and Biology* 9:185–195.
- Bjorndal, K.A., A.B. Bolten, C.J. Lagueux, and D.R. Jackson. 1997. Dietary overlap in three sympatric congeneric freshwater turtles (*Pseudemys*) in Florida. *Chelonian Conservation and Biology* 2:430–433.
- Boyer, D.R. 1965. Ecology of the basking habit in turtles. *Ecology* 46:99–118.
- Cagle, F.R. 1939. A system of marking turtles for future identification. *Copeia* 1939:170–173.
- Cagle, F.R. 1950. The life history of the Slider Turtle *Pseudemys scripta troosti*. *Ecological Monographs* 20:31–54.
- Cagle, F.R. 1954. Two new species of the genus *Graptemys*. *Tulane Studies in Zoology* 1:167–186.
- Carr, J.L., and M.A. Messinger. 2002. *Graptemys gibbonsi* (Pascagoula Map Turtle). Predation. *Herpetological Review* 33:201–202.
- Carrière, M.-A., N. Rollinson, A.N. Suley, and R.J. Brooks. 2008. Thermoregulation when the growing season is short: sex-biased basking patterns in a northern population of Painted Turtles (*Chrysemys picta*). *Journal of Herpetology* 41:206–209.
- Cheung, S.M., and D. Dudgeon. 2006. Quantifying the Asian turtle crisis: market surveys in southern China, 2000–2003. *Aquatic Conservation: Marine and Freshwater Ecosystems* 16:751–770.
- Cliburn, J.W. 1971. The ranges of four species of *Graptemys* in Mississippi. *Journal of Mississippi Academy of Sciences* 16:16–19.
- Coleman, J.L., and R.L. Guterlet, Jr. 2008. Seasonal variation in basking in two syntopic species of map turtles (Emyidae: *Graptemys*). *Chelonian Conservation and Biology* 7:276–281.
- Ennen, J.R., W. Selman, and B.R. Kreiser. 2007. *Graptemys gibbonsi* (Pascagoula Map Turtle). Diet. *Herpetological Review* 38:200.
- Ennen, J. R., J.E. Lovich, B.R. Kreiser, W. Selman, and C.P. Qualls. 2010. Genetic and morphological variation between populations of the Pascagoula Map Turtle (*Graptemys gibbonsi*) in the Pearl and Pascagoula rivers with description of a new species. *Chelonian Conservation and Biology* 9:98–113.
- Gibbons, J.W. 2013. A long-term perspective of delayed emergence (aka overwintering) in hatchling turtles: some they do and some they don't, and some you just can't tell. *Journal of Herpetology* 47:203–214.
- Gibbons, J.W., and J.E. Lovich. 1990. Sexual dimorphism in turtles with emphasis on the Slider Turtle (*Trachemys scripta*). *Herpetological Monographs* 4:1–29.
- Graham, S.P., C.K. Ward, J.S. Walker, S. Sterrett, and M.T. Mendonça. 2015. Sexual dimorphism and seasonal variation of reproductive hormones in the

Selman and Lindeman.—*Graptemys gibbonsi* life history.

- Pascagoula Map Turtle, *Graptemys gibbonsi*. Copeia 2015:42–50.
- Hammond, K.A., J.R. Spotila, and E.A. Standora. 1988. Basking behavior of the turtle *Pseudemys scripta*: effects of digestive state, acclimation temperature, sex, and season. *Physiological Zoology* 61:69–77.
- Horne, B.D., R.J. Brauman, M.J.C. Moore, and R.A. Seigel. 2003. Reproductive and nesting ecology of the Yellow-blotched Map Turtle, *Graptemys flavimaculata*: implications for conservation and management. *Copeia* 2003:729–738.
- Hyslop, E.J. 1980. Stomach contents analysis - a review of methods and their application. *Journal of Fish Biology* 17:411–429.
- Jones, R.L. 1996. Home range and seasonal movements of the turtle *Graptemys flavimaculata*. *Journal of Herpetology* 30:376–385.
- Jones, R.L., and P.D. Hartfield. 1995. Population size and growth in the turtle *Graptemys oculifera*. *Journal of Herpetology* 29:426–436.
- Keller, C. 1998. Assessment of reproductive state in the turtle *Mauremys leprosa*: a comparison between inguinal palpation and radiography. *Wildlife Research* 25:527–531.
- Kornilev, Y.V., C.K. Dodd, Jr., and G.R. Johnston. 2010. Home range, movement, and spatial distribution of the Suwannee Cooter (*Pseudemys concinna suwanniensis*) in a blackwater river. *Chelonian Conservation and Biology* 9:196–204.
- Krawchuk, M.A., and R.J. Brooks. 1998. Basking behavior as a measure of reproductive cost and energy allocation in the Painted Turtle, *Chrysemys picta*. *Herpetologica* 54:112–121.
- Kuchling, G. 1989. Assessment of ovarian follicles and oviductal eggs by ultra-sound scanning in live freshwater turtles, *Chelodina oblonga*. *Herpetologica* 45:89–94.
- Lahanas, P.N. 1982. Aspects of the life history of the Southern Black-knobbed Sawback, *Graptemys nigrinoda delticola* Folkerts and Mount. M.Sc. Thesis, Auburn University, Auburn, Alabama, USA. 293 pp.
- Lamb, T., C. Lydeard, R.B. Walker, and J.W. Gibbons. 1994. Molecular systematics of map turtles (*Graptemys*): a comparison of mitochondrial DNA restriction site versus sequence data. *Systematic Biology* 43:543–559.
- Lindeman, P.V. 1998. Of deadwood and map turtles (*Graptemys*): an analysis of species status for five species in three river drainages using replicated spotting-scope counts of basking turtles; Linnaeus fund research report. *Chelonian Conservation and Biology* 3:137–141.
- Lindeman, P.V. 1999. Surveys of basking map turtles *Graptemys* spp. in three river drainages and the importance of deadwood abundance. *Biological Conservation* 88:33–42.
- Lindeman, P.V. 2006. Diet of the Texas Map Turtle (*Graptemys versa*): relationship to sexually dimorphic trophic morphology and changes over five decades as influenced by an invasive mollusk. *Chelonian Conservation and Biology* 5:25–31.
- Lindeman, P.V. 2013. The Map Turtle and Sawback Atlas: Ecology, Evolution, Distribution, and Conservation. University of Oklahoma Press, Norman, Oklahoma, USA.
- Lovich, J.E., and J.R. Ennen. 2013. A quantitative analysis of the state of knowledge of turtles of the United States and Canada. *Amphibia-Reptilia* 34:11–23.
- Lovich, J.E., and J.W. Gibbons. 1992. A review of techniques for quantifying sexual size dimorphism. *Growth, Development, and Aging* 56:269–281.
- Lovich, J.E., and C.J. McCoy. 1992. Review of the *Graptemys pulchra* group (Reptilia: Testudines: Emydidae), with descriptions of two new species. *Annals of the Carnegie Museum* 61:293–315.
- Lovich, J.E., W. Selman, and C.J. McCoy. 2009. *Graptemys gibbonsi* Lovich and McCoy 1992 - Pascagoula Map Turtle, Pearl River Map Turtle, Gibbons' Map Turtle. Pp. 029.1–029.8 *In* Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Chelonian Research Monographs No. 5. Rhodin, A.G.J., P.C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhmann, J.B. Iverson, and R.A. Mittermeier (Eds.). doi:10.3854/crm.5.029.gibbonsi.v1.2009, <http://www.iucn-tftsg.org/cbftt/>.
- Lovich, J.E., J.C. Godwin, and C.J. McCoy. 2011. *Graptemys ernsti* Lovich and McCoy 1992 - Escambia Map Turtle. Pp. 051.1–051.6 *In* Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Chelonian Research Monographs No. 5. Rhodin, A.G.J., P.C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhmann, J.B. Iverson, and R.A. Mittermeier (Eds.). doi:10.3854/crm.5.051.ernsti.v1.2011, <http://www.iucn-tftsg.org/cbftt/>.
- Mississippi Museum of Natural Science. 2005. Mississippi's Comprehensive Wildlife Conservation Strategy. Mississippi Department of Wildlife, Fisheries and Parks, Mississippi Museum of Natural Science, Jackson, Mississippi, USA.
- Moore, M.J.C. 2003. Behavioral ecology of the threatened Yellow-blotched Map Turtle (*Graptemys flavimaculata*): implication for conservation and management. M.S. Thesis, Southeastern Louisiana University, Hammond, Louisiana, USA. 72 pp.

- Morjan, C.L., and N. Valenzuela. 2001. Is ground-nuzzling by female turtles associated with soil surface temperature? *Journal of Herpetology* 35:668–672.
- Mount, R.H. 1975. *The Reptiles and Amphibians of Alabama*. Auburn University Agricultural Experiment Station, Auburn, Alabama, USA.
- Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Status of the aquatic mollusks in the southeastern United States: a downward spiral of diversity. Pp. 43–85 *In* *Aquatic Fauna in Peril: the Southeastern Perspective*. Benz, G.W., and D.E. Collins (Eds.). Lenz Design & Communications, Decatur, Georgia, USA.
- Selman, W. 2012. Geographic variation in population structure, shape morphology, and sexual size dimorphism in *Graptemys flavimaculata*. *Herpetological Conservation and Biology* 7:427–436.
- Selman, W., and R.L. Jones. 2011. *Graptemys flavimaculata* Cagle 1954 - Yellow-blotched Sawback, Yellow-blotched Map Turtle. Pp. 52.1–52.11 *In* *Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group*, Chelonian Research Monographs No. 5. Rhodin, A.G.J., P.C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhlmann, J.B. Iverson, and R.A. Mittermeier (Eds.). doi:10.3854/crm.5.052.flavimaculata.v1.2011, <http://www.iucn-tftsg.org/cbftt/>.
- Selman, W., and C. Qualls. 2008a. *Graptemys gibbonsi* (Pascagoula Map Turtle). Interspecific competition for basking sites. *Herpetological Review* 39:216.
- Selman, W., and C. Qualls. 2008b. *Graptemys gibbonsi* (Pascagoula Map Turtle). Interactions with ducks. *Herpetological Review* 39:216–217.
- Selman, W., and C. Qualls. 2009. Distribution and abundance of two imperiled *Graptemys* species of the Pascagoula River system. *Herpetological Conservation and Biology* 4:171–184.
- Selman, W., and C. Qualls. 2011. Basking ecology of the Yellow-blotched Sawback (*Graptemys flavimaculata*), an imperiled turtle species of the Pascagoula River system, Mississippi, USA. *Chelonian Conservation and Biology* 10:188–197.
- Selman, W., J. Jawor, and C. Qualls. 2012. Seasonal variation of corticosterone levels in the Yellow-blotched Sawback (*Graptemys flavimaculata*), an imperiled freshwater turtle. *Copeia* 2012:698–705.
- Selman, W., D. Strong, and C. Qualls. 2008. *Graptemys gibbonsi* (Pascagoula Map Turtle). Basking and parasite removal. *Herpetological Review* 39:216.
- Sexton, O.J. 1959. Spatial and temporal movements of a population of the Painted Turtle, *Chrysemys picta marginata* (Agassiz). *Ecological Monographs* 29:113–140.
- Shealy, R.M. 1976. The natural history of the Alabama Map Turtle, *Graptemys pulchra* Baur, in Alabama. *Bulletin of the Florida State Museum of Biological Sciences* 21:47–111.
- Shelby, J.A., and M.T. Mendonça. 2001. Comparison of reproductive parameters in male Yellow-blotched Map Turtles (*Graptemys flavimaculata*) from a historically contaminated site and a reference site. *Comparative Biochemistry and Physiology C* 129:233–242.
- Shelby, J.A., M.T. Mendonça, B.H. Horne, and R.A. Seigel. 2000. Seasonal variation in reproductive steroids of male and female Yellow-blotched Map Turtles, *Graptemys flavimaculata*. *General and Comparative Endocrinology* 119:43–51.
- Stephens, P.R., and J.J. Wiens. 2003. Ecological diversification and phylogeny of emydid turtles. *Biological Journal of the Linnean Society* 79:577–610.
- Tinkle, D.W. 1958. The systematics and ecology of the *Sternothaerus carinatus* complex (Testudinata, Chelydridae). *Tulane Studies in Zoology* 6:3–56.
- U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants: threatened status for the Yellow-blotched Map Turtle, *Graptemys flavimaculata*. *Federal Register* 56:1459–1463.
- van Dijk, P.P. 2011. *Graptemys gibbonsi*. *In* IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 22 November 2013.
- Vogt, R.C. 1980. Natural history of the map turtles *Graptemys pseudogeographica* and *Graptemys ouachitensis* in Wisconsin. *Tulane Studies in Zoology and Botany* 22:17–48.
- Zuffi, M.A.L., F. Odetti, and P. Meozzi. 1999. Body size and clutch size in the European Pond Turtle (*Emys orbicularis*) from central Italy. *Journal of Zoology* 247:139–143.

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