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THE IMPACTS OF HURRICANE KATRINA ON A POPULATION OF YELLOW-BLOTCHED SAWBACKS (*GRAPTEMYS FLAVIMACULATA*) IN THE LOWER PASCAGOULA RIVER

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***Abstract*.—The Yellow-blotched Sawback (*Graptemys flavimaculata*) is a riverine turtle that is endemic to the Pascagoula River system of southern Mississippi, USA. Population declines led to Federal listing as a threatened species in 1991, with the most robust population inhabiting the Lower Pascagoula River near Vancleave, MS (approx. 24 river km from the Pascagoula River mouth). We conducted a mark-resight survey of this population during the spring and summer of 2005-2006. On 29 August 2005, Hurricane Katrina entered the Mississippi Gulf Coast, the location of our study site. On 13 October 2005, we conducted a one-hour preliminary visual survey by boat through the study area and we identified eight individuals that we marked prior to Katrina's landfall. This demonstrated that at least some of the 49 previously-marked individuals remained in the study area. Later, we conducted more extensive mark-resight surveys within the same 3.5 km section of river in October of 2005-2006. The population estimate for 2006 was significantly lower than the 2005 population estimate for the same stretch of river, suggesting that numbers substantially decreased during the year following the hurricane. Of the plausible explanations for this pattern, the available evidence most strongly supports a real decline in population, presumably due to the long-term impact of Hurricane Katrina. Possible reasons for such a long term effect include hurricane induced saltwater intrusion and low levels of dissolved oxygen with direct impacts on individuals or indirect impacts on the prey populations (e.g., gastropods and other aquatic macroinvertebrates). Follow-up surveys are planned to investigate further these influences on the long-term population trends of *G. flavimaculata*.**

Key Words.—conservation; *Graptemys flavimaculata*; Hurricane Katrina; Pascagoula River; turtle; Yellow-blotched Sawback

FIGURE 1. Male Yellow-blotched Sawback (*Graptemys flavimaculata*) from the Lower Pascagoula River, Mississippi, USA. The species is characterized as having a narrow head with yellow stripes, a yellow blotch on each pleural scute, and a pronounced vertebral keel in males and a less pronounced ridge in females. (Photographed by Mary Perez)

INTRODUCTION

The Yellow-blotched Sawback (*Graptemys flavimaculata*) is a freshwater aquatic turtle that is endemic to the Pascagoula River system of southern Mississippi, USA (Fig. 1). It occurs only in the Pascagoula River and its tributaries, including the Leaf, Chickasawhay, and Escatawpa Rivers (Cliburn 1971; U.S. Fish and Wildlife Service 1993; Ernst et al 1994; Selman, W. and C. Qualls. 2006. Steroid hormone levels and current population status of the yellow-blotched sawback turtle [*Graptemys flavimaculata*]. Report to the Mississippi Department of Wildlife, Fisheries, and Parks. Jackson, MS. 58 pp). *Graptemys flavimaculata* also inhabit portions of the Bouie River, Okatoma Creek, Bluff Creek, Tallahala Creek, and Bogue Homa Creek (Selman and Qualls *ibid*, unpubl. data). Population declines led to its federal listing as a threatened species in 1991 (US Fish and Wildlife Service 1991), and as an endangered species by the State of Mississippi (Mississippi Natural Heritage Program 2003). *Graptemys flavimaculata* are obligate freshwater turtles that predominantly occur in main river

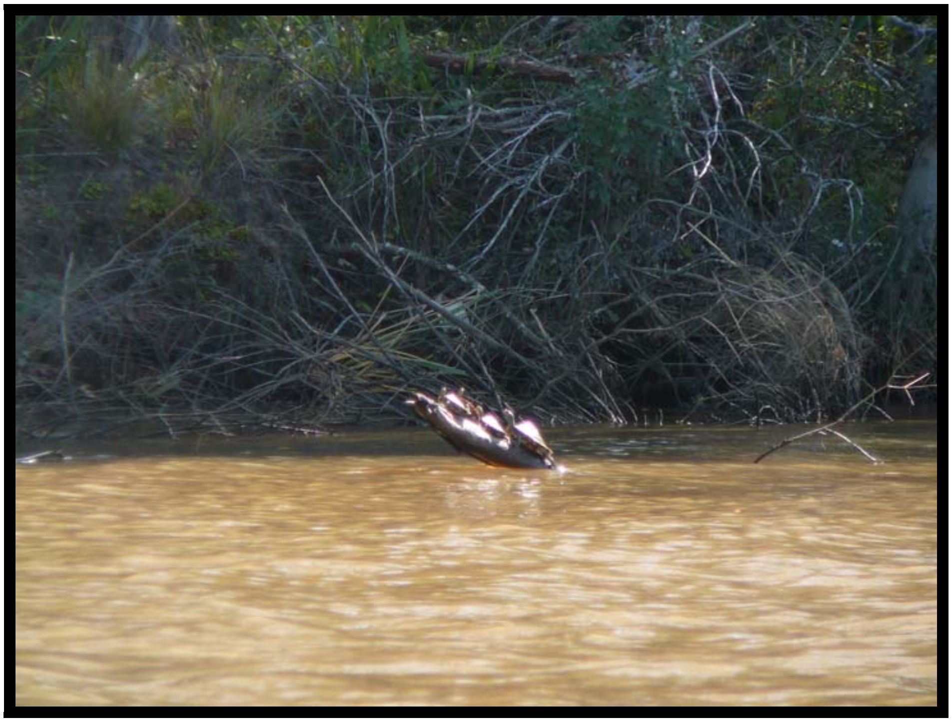

FIGURE 2. One female (bottom) and three male Yellow-blotched Sawbacks (*Graptemys flavimaculata*) basking on a snag in the Lower Pascagoula River, Mississippi, USA. This is a common sight in the Lower Pascagoula River where densities are the highest within the range of *G. flavimaculata*. The habitat in this section of the Pascagoula River is characterized as a large, moderate to high flow river with ample sunlight and many snags available for basking (Photographed by Mary Perez).

channels and larger tributaries. However, Jones (1996) noted that some female *G. flavimaculata* moved overland to nearby cypress ponds, while males occurred in nearby oxbow lakes and flooded timber following overbank flooding. Except for such anecdotal observations, we know very little about the behavioral response of these and other riverine turtles to natural flooding events, especially the massive flooding associated with storm surge and heavy rains from a major hurricane.

The most robust population of *G. flavimaculata* exists in the Lower Pascagoula River (Fig. 2) in the vicinity of Vancleave, MS, about 24 river km from the Pascagoula River mouth (McCoy, C.J., and R.C. Vogt. 1980. Distribution and population status of the ringed sawback turtle (*Graptemys oculifera*), blotched sawback (*Graptemys flavimaculata*), and black-knobbed sawback (*Graptemys nigrinoda*) in Alabama and Mississippi. 30 pp. USFWS Contract No. 14-16-0004-79-038., unpubl. data; Stewart 1989; unpubl. data). During the spring and summer of 2005 and 2006, we focused a trapping and mark-resight study on this population using visual surveys during October to estimate population size in the study area.

On 29 August 2005, Hurricane Katrina entered the Gulf Coast of Mississippi, including our study site. The study area experienced high winds of > 190 km/h, and a 3.7 to at least 4.6 m storm surge. In addition to the surge, the river reached 5.0 gauge m and remained at > 3.0 m for 13 days (Fig. 3), with normal river levels between 0.9 to 1.2 m and flood stage occurring at 4.6 gauge m (Michael Runner, pers. comm.). The only available river stage data is from Graham's Ferry gauging station, which is 26 river km upstream from our study site. This was the only station online throughout Hurricane Katrina. Because of the northern location of this station makes these numbers likely underestimates for flooding at our study site. Thus, Hurricane Katrina offered the opportunity to study the response of *G. flavimaculata* to one of the most severe natural disasters occurring in this drainage during recorded history.

MATERIALS AND METHODS

Study Site.—We conducted our study on the Pascagoula River, Jackson County, Mississippi, USA. We used mark-resight surveys on 3.5 km of the west channel of the Pascagoula River between Poticaw Bayou (31° 30.948 / 088° 37.002), north to the end of the mainstem of the Pascagoula River (30° 30.948 / 088° 36.184). This portion of the Pascagoula has moderate to high flow rates and abundant submerged and emerged

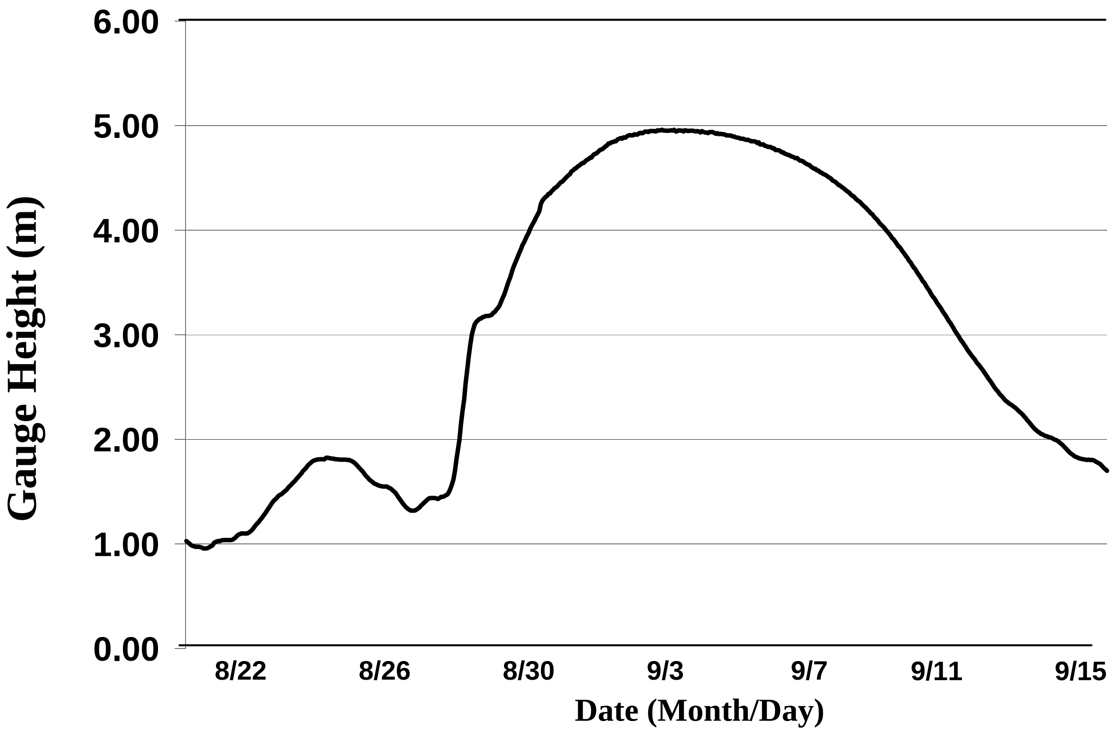

FIGURE 3. Hurricane Katrina stage data from the Graham's Ferry hydrologic station. The location for the gauging station is approximately 26 river km north of the lower Pascagoula River, Mississippi, USA sampling site (data provided by Michael Runner, USGS) and it was the only gauging station to stay online throughout Hurricane Katrina.

deadwood snags. Many bayous, oxbow lakes, and side channels occur within this stretch of river floodplain.

***Sampling Technique*.—**During April through October of 2005 and 2006, we trapped turtles by slightly submerging open topped basking traps made of 3/4" PVC coated crawfish wire (The Fish Net Company, Jonesville, LA) to turtle basking structures. Traps varied in size from 56 x 46 x 31 cm to 122 x 61x 25 cm and we used nails and cotton twine to fasten traps to logs or branches known to be *G. flavimaculata* basking sites. We used a maximum of 15 traps during a trap-day and we checked each trap every hour. We occasionally moved traps if turtles became trap-shy. We also captured turtles by hand or with a dip net.

***Marking and measurements of captured turtles.*—** We marked individuals on the carapace (second and third vertebral scutes) with a nontoxic, nonpermanent, waterproof, tree marking spray paint (Aervoe® Lead-Free Fluorescent Glo Spray Paint) for subsequent mark-resight surveys. These marks allowed visual identification of sighted turtles, but did not allow visual determination of individual identity. Additionally, we obtained straightline carapace and plastron lengths (nearest mm) and body mass (nearest 5 g) for all captured turtles. We released all turtles at their point of capture after the paint mark on their shell had dried.

***Population estimates.*—**We conducted a one-hour preliminary visual survey by boat on 13 October 2005, following Hurricane Katrina. We did not include this data in our analysis. Thereafter, we made three mark-resight surveys during October and early November 2005 and 2006, within two weeks of the initial capture and first paint-marked turtle in the population (to assure paint marks were not lost). We paint-marked at least 10 turtles prior to implementing visual count surveys to ensure a sufficient number of marked turtles available in the population. We conducted mark-resight surveys during optimal basking times (1000-1500 hr) under mostly sunny to sunny conditions. We performed all surveys by walking along the banks or sandbars and locating, identifying, and counting marked and unmarked turtles using a 60mm, 10-45x spotting scope with tripod (R.L. Jones, pers. comm.; Shively, S.H. 1999. Survey for the ringed map turtle [*Graptemys oculifera*] in the Bogue Chitto River, Louisiana. Unpublished report to the Louisiana Natural Heritage Program and the Louisiana Department of Wildlife and Fisheries. Baton Rouge, LA. 50 pp.; unpubl. data). Each survey of the 3.5 km stretch took approximately

TABLE 1. NOREMARK population estimates for 2005 and 2006 for *G. flavimaculata* at the lower Pascagoula study site. The number 'marked in population' reflects the number of turtles marked within the study site and the 'marked and observed' refers to the number of marked individuals spotted during the corresponding visual survey.

Site	Survey Date	Marked in Population	Marked & Observed	Total Observed	Pop. Estimate (w/ 95 % CI)
Pascagoula River	**2005**				
	16 Oct	17	3	231	1204
	18 Oct	24	1	244	(786-2077)
	20 Oct	24	9	244	
	2006				
	30 Oct	20	6	236	
	8 Nov	24	10	233	641
	11 Nov	24	7	185	(481-923)

three hours to complete. We used the program NOREMARK (White 1996) to estimate population sizes. We used this program because we did not uniquely mark turtles and it also accounted for additional marked individuals being added to the population between survey intervals.

Body Condition Analyses.—We used morphometric data to assess body condition (mass relative to length) before and after Hurricane Katrina. To examine whether or not body condition (mass relative to length) of *G. flavimaculata* was lower following Hurricane Katrina, we used one-factor ANCOVAs, with before versus after the hurricane as a factor, plastron length the covariate, and body mass as the dependent variable (using a Log Mass transformation for females to provide a better linear fit). Plastron, rather than carapace length tends to be a more accurate measure of overall body length for these turtles, because injury/wear to the marginal scutes introduces error variation to carapace length measurements (Selman and Qualls, unpubl. data). This analysis was done separately for male and female turtles, spanning three monthly trapping samples before (June, July, August 2005) and three following the hurricane (October 2005, April and May 2006). Additionally, given the relatively small size of each monthly sample, lack of samples over the winter months (November through March) following the hurricane, and likely normal variation in body condition over seasons (all of which would limit our statistical power), we also compared body condition of males and females for October 2005 and 2006, immediately after Hurricane Katrina and one year thereafter. A one factor ANCOVA, similar to the previous analysis, was used except year (October 2005 or October 2006) was considered the factor.

RESULTS

Population estimate results.—During our initial boat survey, we identified 16% (8/49) turtles that were marked prior to Hurricane Katrina at the locations where we originally marked them. Thereafter, we conducted three mark-resight surveys on 16, 18, 20 October 2005 using newly marked individuals with a different paint-marking scheme than before the hurricane. This provided a population estimate of 1204 (786-2077, 95% CI) turtles in the 3.5 km stretch of river, or 344 turtles/km (Table 1).

We implemented three more mark-resight surveys on this stretch of river during fall 2006 (30 October; 8, 11 November). Our 2006 population estimate was 641 (481-923, 95% CI) turtles or 183 turtles/km (Table 1). The 2006 estimate was significantly lower than the 2005 population estimate ($Z = 3.489$, $P = 0.0003$; Seber 1982). The *G. flavimaculata* population decreased by 47% (161 turtles/km) between October 2005 and 2006.

Body condition analysis.—These analyses revealed no significant differences in body condition between the three monthly samples before versus after the hurricane for females ($F_{1,33} = 3.52$, $P = 0.07$) or males ($F_{1,54} = 1.87$, $P = 0.18$) and no significant factor by covariate interaction terms for females ($F_{1,38} = 3.89$, $P = 0.06$) or males ($F_{1,54} = 0.29$, $P = 0.59$). The covariate was significant in both analyses ($P < 0.001$), with body mass increasing with plastron length.

The other one-factor ANCOVAs also revealed no significant difference in body condition between October samples in each year for females ($F_{1,11} = 2.04$, $P = 0.18$) or males ($F_{1,38} = 0.25$, $P = 0.62$), and no significant factor by covariate interaction terms for females ($F_{1,11} = 0.09$, $P = 0.76$) or males ($F_{1,38} = 1.56$, $P = 0.12$). The covariate was significant in both of these analyses ($P < 0.001$), with body mass increasing with plastron length.

DISCUSSION

Our observations suggest that this population survived the storm without major losses due to direct mortality. Several reports of massive fish kills following the hurricane noted no evidence of turtle mortality, thus supporting our observations (Buck, E.H. 2005. Hurricanes Katrina and Rita: fishing and aquaculture industries-damage and recovery. CRS report for Congress. 6 pp.; Mississippi Department of Wildlife, Fisheries, and Parks. 2005. Mississippi's comprehensive wildlife conservation strategy. Version 1.1. 11 pp.; Lynn McCoy, pers. comm.). Further, our initial boat survey found previously marked individuals that remained within the same stretch of river we originally marked them, indicating that some individuals maintained or restored their prior home ranges. However, we conducted our preliminary boat survey 45 days after Hurricane Katrina so we could not discern how these turtles remained in the same areas after the hurricane or returned. One possible explanation of this apparent home range fidelity could be that during periods of flooding, the turtles took advantage of the calmer environment that is available in flooded bottomland forest or side channels, in contrast to the main river channel, similar to what has been observed during non-hurricane flooding events (Jones 1996; W. Selman, per obs.). Once river levels began to subside, turtles could then have moved laterally back into the main channel of the river in the same area they had been prior to the high-water event. Alternatively, if the hurricane displaced individuals downstream or upstream, long-range linear movements to return to their home ranges may explain our results. Jones (1996) noted some long-range movements in which individuals covered long distances (>5 km) in less than one week.

The 2006 estimate suggests a substantial decrease (47%) in the number of *G. flavimaculata* in the year following Hurricane Katrina. We have no comparable baseline data (using similar mark-resight methods) prior to Hurricane Katrina to compare population trends before and after the storm, but, our surveys clearly indicate a significant population decline over the subsequent year.

Our estimate one month post-Katrina (344/km) was one of the highest recorded population estimates of *G. flavimaculata* per river kilometer (41.4/km - Stewart 1989, unpubl. data; 370/km, 269/km, 72.8/km, 58/km using multiple methods - Jones, R.L. 1994. Density, population structure, and movements of the yellow-blotched map turtle [*Graptemys flavimaculata*]. Unpublished report U.S. Fish and Wildlife Service and the Mississippi Department of Wildlife, Fisheries, and Parks, Jackson, MS.). This suggests that our population estimate of 2005 may be artificially high due to congregation of turtles from upstream and downstream localities following Hurricane Katrina. The storm surge may have forced turtles northward to our study site and/or the later flooding may have washed upstream turtles downstream to our site. However, this scenario is unlikely for several reasons. First, our 2005 mark-resight survey was 48 days after Hurricane Katrina and presumably, this was enough time for displaced turtles from upstream or downstream localities to return to their respective origins. More importantly, methodologically identical population surveys of two other hurricane affected inland *Graptemys* populations (*G. flavimaculata* in the Leaf River and *G. oculifera* in the Pearl River) showed no evidence of any such displacement of turtles due to flooding and prolonged high river flows during and after Hurricane Katrina (Selman, W. and C. Qualls. 2005. Steroid hormone levels and reproduction in the yellow-blotched sawback turtle (*Graptemys flavimaculata*) and the congeneric ringed sawback turtle (*Graptemys oculifera*). Report to the Mississippi Department of Wildlife, Fisheries, and Parks. Jackson, MS. 33 pp.; 2006 *ibid*). Lastly, similar to the observations by Jones (1996) during smaller floods, Sanderson (1974) observed that Hurricane Agnes had little effect on *Graptemys barbouri* movements and that individuals moved into the flooded margins of the Chipola River to avoid the fast currents of the main river channel. These observations support our contention that the high population estimate from the Lower Pascagoula River site in 2005 was not due to displacement of turtles into our study area.

Drought impacts on this population through October 2006 could also explain the population decline we observed. Most river levels during 2006 were considerably lower than in 2005 and approached 60-year lows (USGS Real-TimeWater Data, http://waterdata.usgs.gov/ms/nwis/rt). However, our comparison estimates for our two upstream sites do not support the drought-effects hypothesis. While both sites suffered from the same drought and low-river levels, we did not observe evidence of population declines during that study (Selman and Qualls 2005 *ibid*, 2006 *ibid*). Occurring in smaller, lower order streams, these northern populations were presumably equally or more subject to drought conditions and associated low river levels than the Lower Pascagoula River (higher order stream) population yet showed no negative effects. Altogether, these observations suggest that the drought had little direct effect on turtle numbers in these *Graptemys* populations.

Thus, neither short-term displacement nor drought effects adequately explain the population decline the Lower Pascagoula River. Rather, it appears that other hurricane impacts on this population of *G. flavimaculata* may explain this decline due to the coastal nature of this site. Mallin et al. (1999) noted that Hurricane Fran adversely affected benthos within the lower Cape Fear River system of North Carolina. They suggested a variety of water-quality issues (e.g., increased sedimentation, presence of contaminants, changes in dissolved oxygen levels, salinity, and an altered flow regime of the river) as possible causes. Hurricane Katrina probably caused similar changes in riverine habitats of the Lower Pascagoula River. Such low levels of dissolved oxygen were documented within the Leaf River, a major tributary of the Pascagoula River (Howell, unpubl. data). Additionally, several reported fish kills in the Lower Pascagoula River indicated severe water quality issues in the system (Buck 2005 *ibid*; MS Department of Wildlife, Fisheries, and Parks 2005; Lynn McCoy, pers. comm.). Schaefer et al. (2006) also documented fish community shifts following Hurricane Katrina within the Lower Pascagoula River and Lower Black Creek. Therefore, changed water quality due to Hurricane Katrina may be implicated in the *G. flavimaculata* population declines observed in the Lower Pascagoula River either by direct mortality (which was not observed) and/or by indirect means, including impacts on prey base (Seigel, R. and R. Brauman. 1994. Food habits of the yellow-blotched map turtle [*Graptemys flavimaculata*]. Report to the Mississippi Department of Wildlife, Fisheries, and Parks. Jackson, MS. 18 pp.).

Our analyses of body condition revealed no significant differences before and after Hurricane Katrina for male or female *G. flavimaculata*. Limited sample sizes and a lack of samples in critical post-hurricane months limited our statistical power and our ability to detect any body condition shifts. Our monthly sample sizes before and after the hurricane never exceeded seven females or 21 males per month. Also, due to the severe problems with municipal/state infrastructure following Hurricane Katrina, we collected no data immediately after the storm during September 2005. We also have no data for the winter months (November 2005 thru March 2006) when turtle trapping was difficult due to the lower basking frequency during cold weather (Moore and Seigel 2006; W. Selman, pers. obs). Further, there is no published work correlating body condition to any environmental and/or seasonal changes in other highly aquatic, freshwater *Emydid* turtles (i.e., *Graptemys* or *Pseudemys*). Therefore, we have no baseline for comparison to evaluate confidently any environmental or seasonal changes in body condition.

The most convincing factor to account for the population decline at the Lower Pascagoula River site was Hurricane Katrina and its potential water quality impacts on the turtles and/or their aquatic macroinvertebrate prey. Because this study of the hurricane's impacts was done opportunistically, we were unable to definitively identify the factors that caused this declines. We will continue monitoring the Lower Pascagoula River population of *G. flavimaculata* through 2008 to evaluate the severity and duration of this decline and the population's potential recovery. Similar survey work is needed on other imperiled *Graptemys* species in Gulf Coast river drainages to determine baseline population estimates in preparation for future opportunities to study these phenomena and for understanding the long-term population status of these turtles (Fitch et al. 2006; Bury 2006).

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CARL QUALLS is an Assistant Professor in Biological Sciences at the University of Southern Mississippi. He teaches Herpetology and Vertebrate Biology, among other courses, and is seen here demonstrating turtle identification characters during a class field trip. Carl's lab conducts ecological and conservation research on several reptile and amphibian species of conservation concern, including *Graptemys flavimaculata*, *G. oculifera*, *Gopherus polyphemus*, *Pituophis melanoleucus lodingi*, and *Rana sevosa*.