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Basking Ecology of the Yellow-Blotched Sawback (*Graptemys flavimaculata*), an Imperiled Turtle Species of the Pascagoula River System, Mississippi, United States

Will Selman[1,2] and Carl P. Qualls[1]

[1]*Department of Biological Sciences, The University of Southern Mississippi, 118 College Drive #5018, Hattiesburg, Mississippi 39406 USA [carl.qualls@usm.edu];*
[2]*Rockefeller Wildlife Refuge, Louisiana Department of Wildlife and Fisheries, 5476 Grand Chenier Highway, Grand Chenier, Louisiana 70643 USA [wselman@wlf.louisiana.gov]*

Abstract. – Basking is an understudied aspect of turtle biology, especially considering how frequent and observable it is in some species. Researchers have suggested many physiological roles that basking likely fulfills in turtles. We documented seasonal basking behavior of the yellow-blotched sawback (*Graptemys flavimaculata*) on the Leaf River, a tributary of the Pascagoula River in southeastern Mississippi. We used binoculars and a spotting scope to determine *G. flavimaculata* individual- and population-level basking patterns throughout the main active months (April–October) and across the daily activity period; we also describe a new method to determine population basking percentage that may be useful for future aquatic turtle surveys. We found distinct differences in individual- and population-level basking behavior across months, sexes, and the daily activity period. We also documented differences in basking structures used between the sexes but found little correlation between population-level basking and several environmental temperature variables.

Key Words. – Reptilia; Testudines; Emydidae; turtle; *Graptemys flavimaculata*; basking behavior; thermal ecology; deadwood; conservation; Pascagoula River system; Mississippi; United States

Basking activity is one of the most conspicuous daily behaviors exhibited by aquatic emydid turtles. Early studies suggested that the primary physiological role of basking in turtles was to regulate body temperatures, as well as condition the skin and shell (Cagle 1950; Boyer 1965; Auth 1975; Shealy 1976). Others also hypothesized that basking increases metabolic and digestion rates (Moll and Legler 1971; Parmenter 1980; Hammond et al. 1988; Avery et al. 1993), aids in vitamin K synthesis (Pritchard and Greenhood 1968), increases follicular and egg production in female turtles during the nesting season (Vogt 1980; Krawchuk and Brooks 1998; Carrière et al. 2008), allows turtles to rest (Boyer 1965; Waters 1974), fights infection by ''behavioral fever'' (Monagas and Gatten 1983), and rids turtles of ectoparasites (Cagle 1950; Neill and Allen 1954; Shealy 1976; Vogt 1979). Moll and Legler (1971) stated that basking is likely initiated by a single impulse, which is either triggered by an external factor or internal physiological need, while other secondary benefits are thereafter gained.

Members of the genus *Graptemys* (Family Emydidae) are highly aquatic freshwater turtles, with almost all species occurring in single river drainages of the southeastern United States (Ernst and Lovich 2009). Turtles within this genus often occur in large basking aggregations, usually on emergent deadwood snags (i.e., fallen trees from river banks). Sometimes turtles stack upon one another, and they may bask up to several meters above the water surface (Boyer 1965; Floyd 1973; Vogt 1980); both of these behaviors likely function to enhance the detection of predators (Boyer 1965). Even though *Graptemys* are habitual baskers (Boyer 1965; Lindeman 1999a), there are relatively few recent, season-specific studies of this habit within this genus (*G. pseudogeographica*/*G. ouachitensis*, Coleman and Gutberlet 2008; *G. geographica*, Bulté and Blouin-Demers 2009).

The yellow-blotched sawback (*Graptemys flavimaculata*) is an imperiled species, endemic to the Pascagoula River system of southeastern Mississippi, United States (Ernst and Lovich 2009; Selman and Jones, in press). *Graptemys flavimaculata* was listed as Federally Threatened by the US Fish and Wildlife Service (1991) due to population declines in the 1980s. Following Federal listing, several studies were initiated to determine the population status (Jones 1994), home range and seasonal movements (Jones 1996), habitat associations (Lindeman 1998, 1999a), reproduction and nesting ecology (Horne et al. 2003), seasonal hormone cycles (Shelby et al. 2000; Shelby and Mendonça 2001), and the impacts of recreation on basking and nesting behavior (Moore 2003; Moore and Seigel 2006). Most of these studies were conducted in the lower Pascagoula River (Jackson County, Mississippi), which harbors the most robust population of *G. flavimaculata* (Selman and Qualls 2009a). However, little is known about the natural history of this species outside of this population.

Studies by Moore and Seigel (2006) found that many *G. flavimaculata* in the lower Pascagoula River were disturbed from their basking locations by human recreational activity, with females more likely to be disturbed than males. Fewer turtles were observed basking during midday hours, which also coincided with the highest level of recreational activity. However, due to the high levels of recreational activity observed during their study, it is unlikely that this population exhibited basking patterns similar to other populations in upstream, minimally disturbed areas. Also, outside of the lower Pascagoula River population, little is known of the behavioral ecology of *G. flavimaculata* from smaller river reaches, away from large amounts of human activity.

We examined the species' basking ecology by studying individual- and population-level basking behaviors at a minimally disturbed site. Specifically, we studied the role that sex, age class, and season had on individual basking duration, while also quantifying population-level basking behavior across seasons. Further, we examined sex-based preference for basking structure type, documented the impact of human and natural disturbances on basking turtles, and analyzed the effect of environmental temperatures on population-level basking frequency.

METHODS

Study Site. — This was a relatively undisturbed locality on the Leaf River (Forrest County, Mississippi, United States), selected because it was free of excessive human recreational activity that could alter turtle basking behavior and because previous studies documented sufficient numbers of *G. flavimaculata* in this area (Selman and Qualls 2009a). Although 2 boat ramps were nearby, one 3.8 river kilometers (rkm) downstream and a second 12.7 rkm upstream of the site, low water levels during most of the year limited access by motorized boats. This river stretch was characteristic of a medium-sized (approximately 30 m wide), Gulf Coastal Plain river, with alternating sandbar and cutbank sections, abundant submergent and emergent deadwood snags, and a sand and gravel substrate.

Basking Observation Methods. — Observations of turtle basking behavior were conducted during the months of June–October 2007 and April–May 2008. We did not study basking behavior during the winter (November–March) since previous studies had documented minimal basking for *Graptemys* during this time period (Moore 2003; Moore and Seigel 2006; Coleman and Gutberlet 2008). Basking behavior was studied by an observer located in a concealed position on a sandbar opposite of a cutbank section where emergent deadwood snags were abundant. Observations were conducted with binoculars or a 60-mm, ×15–×45 zoom spotting scope with tripod. Observations were attempted each month on one weekend and one weekday, with observations sometimes shortened by impending severe weather. Daily observations (n = 43) lasted 4–10 consecutive hours in a single day (mean = 4.85 hours), with multiple turtles often being monitored simultaneously (range 0–10 individuals). During observations, basking behavior was documented using 2 methods: 1) individual turtle observations to document basking duration, and 2) hourly counts to determine population-level basking frequency.

In the first method, when an individual *G. flavimaculata* was spotted emerging onto a basking structure, the time of emergence and basking structure type were recorded. We also noted the sex of the individual using secondary sex characteristics when possible (undetermined sex and hatchlings; hereafter referred to as juveniles). Males are smaller, have longer foreclaws, longer tails, and taller carapacial spines relative to females (Selman and Jones, in press). When the individual terminated basking, the time of submergence and total basking time were recorded. When turtles were startled into the water prematurely, the apparent reason for submergence (natural or human) was also noted. Basking structure types used by turtles were categorized similar to Lindeman (1999a), with structures visually determined as logs, branches, tree crowns, or tangles based on their size and structural complexity. Stumps were categorized as branches or logs depending on their size. Since we did not individually mark turtles to confirm the identity of turtles when basking, we could not determine the amount of time during the day that a single turtle basked.

The second method, hourly basking frequency counts, was completed by counting the number of basking *G. flavimaculata* within a measured, predetermined stretch of viewable river at the beginning of each hour. The sex was recorded when possible, as well as the number of other turtle species observed basking (*Apalone mutica*, smooth softshell; *Graptemys gibbonsi,* Pascagoula map turtle; *Pseudemys concinna*, river cooter; *Sternotherus carinatus*, razorback musk turtle; and *Trachemys scripta scripta*, red-eared slider). We determined the river distance surveyed using a laser range-finder (Nikon Laser 800).

Three environmental temperatures were measured at the study site using HOBO® Water Temp Pro v2 and Pro v2 Temperature/External temperature data loggers (Onset Computer Corp). We measured ambient air temperature (AT) at a shaded terrestrial site, water temperature (WT), and the log temperature (LT) of a sunlit basking log. Temperature data were collected every 5 minutes at the site, with WT and LT loggers being attached to basking logs with nails and string. We collected the temperature data with a HOBO® Waterproof Shuttle (Onset Computer Corp) and thereafter associated these temperature readings with each hourly basking frequency count. Temperature data were not collected during June 2007, and LT could not be collected in April and May 2008 because loggers were lost during high water levels. We used LT data from another site (Pascagoula River, Jackson County; approximately 115 km southeast) for April and May 2008, with the presumption that there was little difference in LT across the 2 sites for that time period and based on comparative data for other months that were similar. Additionally, since WT loggers had to be attached to a log below the water surface and because there were naturally fluctuating river levels, WT could not be collected at the same depth for every reading.

Statistical Analysis. — Data for individual basking durations had a nonnormal, Poisson distribution. Therefore, we log-transformed our individual basking data to meet parametric assumptions. We used 2-factor ANOVAs to determine 1) the effects of class (male, female, juvenile) and month (April–October) on basking duration and also to determine 2) the effects of sex and time of emergence (0900–1700 hours categorized by 1-hour intervals) on basking duration. For all ANOVAs, if significant differences were found ($p < 0.05$), we used a Tukey-Kramer post hoc test to delineate differences. Lastly, we used a chi-square contingency table analysis to determine if the sexes used different basking structures equally.

To estimate population-level basking, we calculated the estimated percentage of the population that was basking during each hourly basking frequency count by taking the distance of the river stretch observed and estimating the number of turtles that should be in that stretch using a known population-size estimate (96/rkm; Selman and Qualls 2009a). For each hourly count, we divided the total number of *G. flavimaculata* observed basking by the estimated number of turtles in the observed stretch of river. We used 1-factor ANOVAs to determine if 1) the estimated percentage basking was equal across observed months (April–October) and 2) if the estimated percentage basking was equal throughout the day (0700–2000 hours). Lastly, we plotted raw basking counts of males, females, and juveniles observed to determine yearly and seasonal (Spring [April, May], Summer [June, July, August], Fall [September, October]) basking trends.

To determine the relationship between turtle basking (using raw data on males and females from basking frequency counts) with WT, AT, and LT, we used a second-order polynomial regression. We used JMP 7.0.2 (SAS Institute Inc, Cary, NC) for all statistical analyses.

RESULTS

During the 7-month study (June–October 2007; April–May 2008), 186.1 hours of basking observation were logged at the Leaf River site. During these observations, 1124 independent basking occurrences for *G. flavimaculata* individuals (478 females, 595 males, 51 juveniles) were documented and 157 hourly basking frequency counts were made.

Individual Basking Behavior. — Mean basking duration (all sexes throughout the year) was 38.4 minutes ($n = 1124$; SD, $\pm$ 49.9 minutes). Mean male basking duration was 36.2 minutes ($n = 595$; SD, $\pm$ 49.9 minutes; range, $<$ 1–464 minutes), mean female basking duration was 42.8 minutes ($n = 478$; SD, $\pm$ 51.0 minutes; range, $<$ 1–336 minutes), and mean juvenile basking duration was 23.5 minutes ($n = 51$; SD, $\pm$ 31.1 minutes; range,

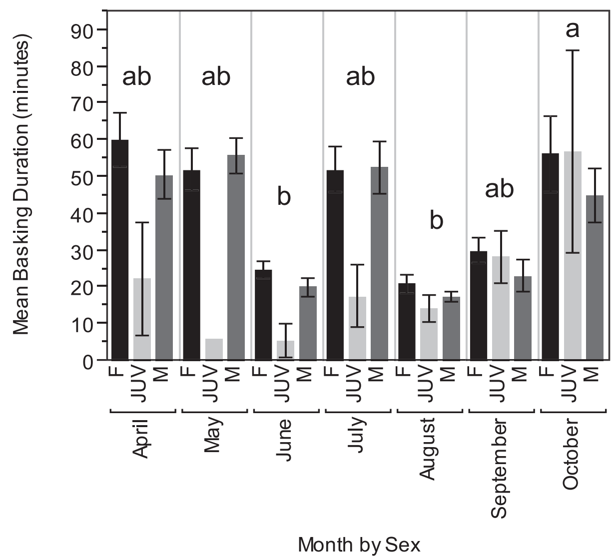

Figure 1. *Graptemys flavimaculata* basking duration (in minutes) by sex (females, black bars; males, dark gray bars; juveniles, light gray bars) and month. Different letters above bars denote significant differences as determined by post hoc comparisons.

$<$ 1–149 minutes). We documented 120 individuals (10.7%) with basking durations longer than 100 minutes, 17 individuals (1.5%) over 200 minutes, and 5 individuals (0.4%) over 300 minutes. The maximum basking duration observed was 464 minutes (1004–1748 hours) by a male *G. flavimaculata* on 15 April 2008 when log temperatures (27.3°C [1004 hours] to 33.2°C [1748 hours]) were considerably warmer than air (13.0°C–17.6°C) or water (16.4°C–20.0°C) temperatures.

There was a significant difference in individual basking duration among months ($F_{6,1117} = 3.4$, $p = 0.003$), with significantly longer basking periods observed in October relative to June and August. October basking was similar to April, May, July, and September basking, while April, May, July, and September basking periods did not differ from June and August values (Fig. 1). There were also significant differences among the 3 classes of turtles ($F_{2,\ 1117} = 5.75$, $p = 0.003$); females basked longer than juveniles, and there was no difference between males and juveniles. The interaction of month with class was not significant ($F_{12,1117} = 1.09$, $p = 0.36$). We also found a significant difference in individual basking duration by time of emergence ($F_{10,1096} = 3.51$, $p = 0.0001$), with longer basking durations observed in the morning (0700–1100 hours) and afternoon hours (1600–1800 hours) relative to midday hours (1200–1500 hours; Fig. 2). There was a similar significant difference among the sexes ($F_{2,1096} = 5.22$, $p = 0.006$), with females basking significantly longer than males and juveniles and males basking significantly longer than juveniles; the interaction of hour and class was not significant ($F_{20,1096} = 1.07$, $p = 0.37$).

We found a significant difference among the sexes in basking structure type used ($\chi^2 = 174.12$; $p < 0.0001$).

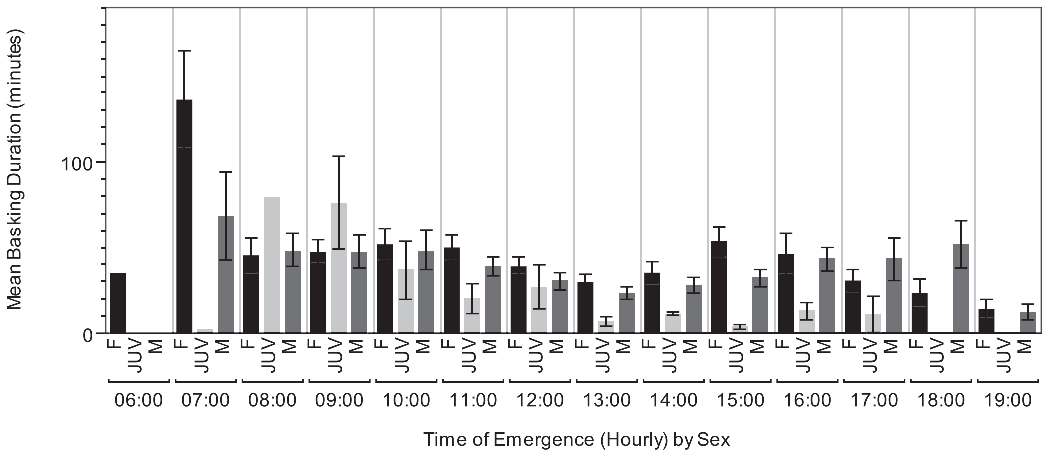

Figure 2. *Graptemys flavimaculata* basking durations (in minutes) by sex (females, black bars; males, dark gray bars; juveniles, light gray bars) and daily time period. Each individual that emerged to bask within a specific hour (e.g., 0800–0859 hours) was considered only to emerge at the beginning of that time (0800 hours).

Females used logs and floating logs more frequently as basking platforms (81.5%) than branches (14.7%). Males used logs and floating logs (46.5%) and branches (39.8%) almost equally; males also used crowns (9.3%) and tangles (4.1%) more often than females (3.3% and 0.4%, respectively). One female was observed basking on a river bank, likely due to high river levels that submerged many deadwood structures. The basking structures utilized by adults were usually in deeper portions of the river, while having open water between the basking structure and the river bank. Juveniles were most often observed using branches (64.7%) and logs (27.5%) with a smaller proportion using crowns (7.9%). The preferred basking locations of juveniles were usually within a few meters of the bank and among overhanging vegetation.

Population Level Basking Behavior. — We found a significant difference in the estimated percentage basking across months ($F_{6,156} = 7.10$, $p < 0.001$; Fig. 3), with significantly higher percentages observed during May and July relative to other months. We also found a significant difference in the estimated percentage basking by time of day ($F_{13,155} = 1.89$, $p = 0.036$; Fig. 4), with higher percentages basking from 1200 to 1400 hours and again from 1600 to 1800 hours relative to morning (0800–1100 hours) and evening (1900–2000 hours).

For both males and females, basking frequency (i.e., raw basking data) showed a clear bimodal pattern with peaks around 1200–1300 hours and 1600–1800 hours across all seasons (Fig. 5A), but there were differences among the 3 seasons. During the spring (Fig. 5B), basking frequency was unimodal and peaked for both sexes during the midday hours (1200–1400 hours); female to male basking ratio was highest during the spring. During the summer (Fig. 5C), basking frequency was bimodal for both sexes with a morning peak around 0900 hours and a late afternoon peak at 1600–1900 hours. During the summer, basking occasionally continued until 2000 hours (past sunset) and male basking counts were higher than female counts during all hours. During the fall (Fig. 5D), basking frequencies were less distinct for males and females with peaks at both 1200 and 1600 hours. Female

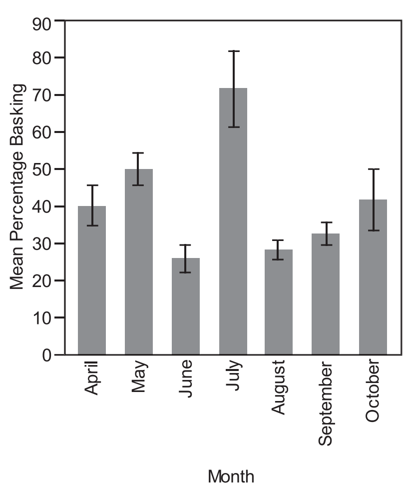

Figure 3. Estimated percentage of the Leaf River *Graptemys flavimaculata* population basking across observed months.

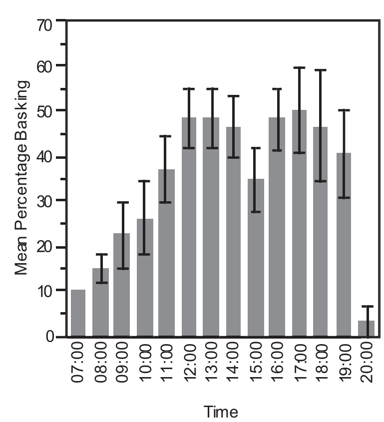

Figure 4. Estimated percentage of the *Graptemys flavimaculata* population basking at the Leaf River site across the daily activity period.

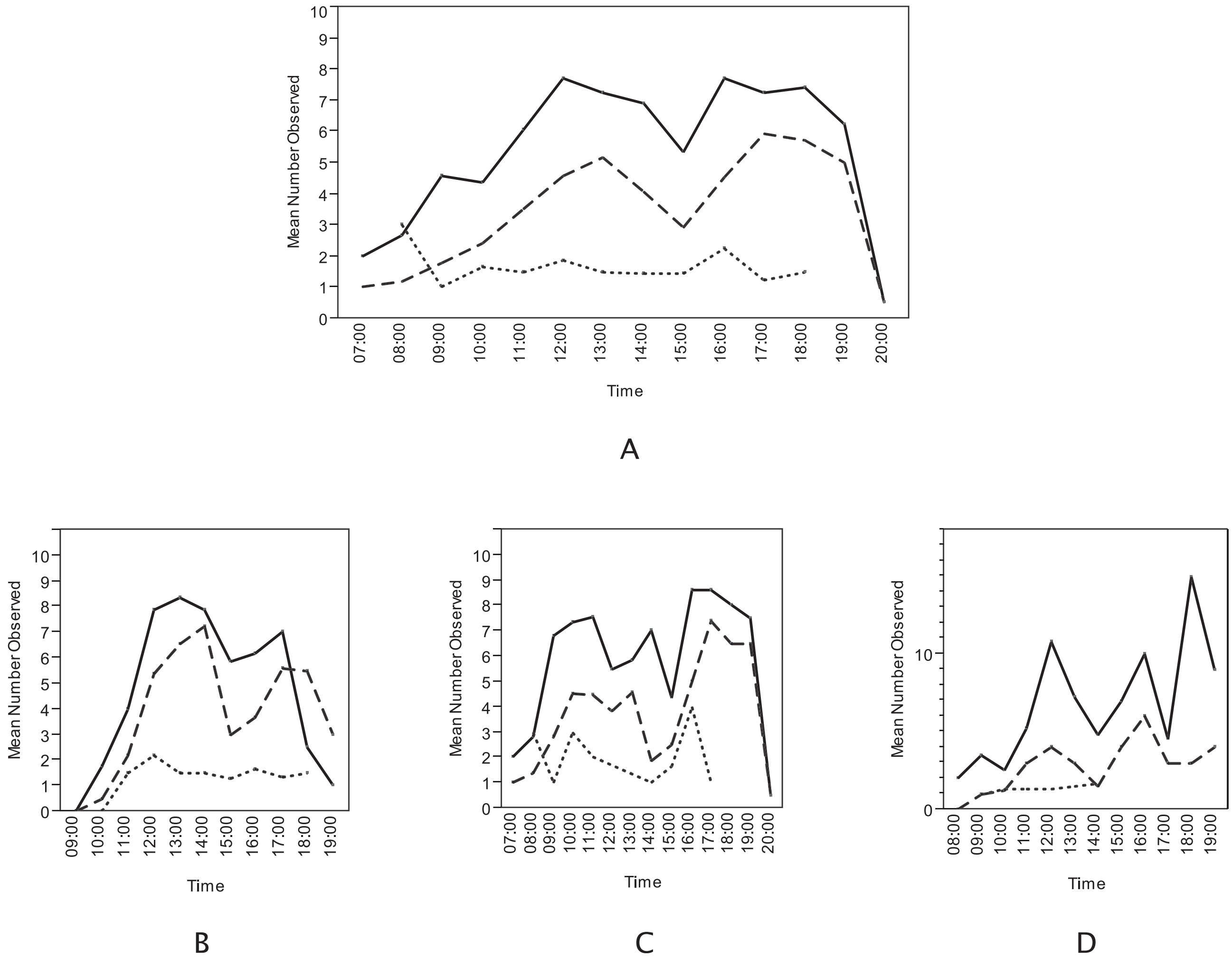

Figure 5. Leaf River *Graptemys flavimaculata* basking frequencies of males (solid line), females (dashed), and juveniles (dotted) throughout day during the entire year (A, April–October), spring (B, April and May), summer (C, June–August), and fall (D, September and October).

to male basking ratios were lower during the fall relative to other seasons. Juveniles basked at much lower levels throughout all seasons, with no clear pattern to preferred basking times.

Population Basking and Environmental Conditions. — We observed basking *G. flavimaculata* across all months and almost all environmental temperatures recorded from April to October (WT, 15°C–34.7°C; AT, 10.9°C–39.8°C; LT, 10.6°C–42.5 °C). Since basking was observed under extremely variable environmental conditions, we wanted to determine which environmental variable or variables were responsible for most of the variation in population level basking. Using a second-order polynomial regression, there was a weak but significant relationship between basking male counts and LT ($R^2 = 0.053$, $p = 0.024$), but no relationship with AT ($R^2 = 0.011$, $p = 0.45$) or WT ($R^2 = 0.009$, $p = 0.51$). Female basking counts showed weak but significant relationships with all 3 variables, (LT, $R^2 = 0.13$, $p < 0.0001$; WT, $R^2 = 0.065$, $p = 0.009$; AT, $R^2 = 0.064$, $p = 0.010$). Peak basking in both males and females was observed at WT of 16°C–31°C, LT of 23°C–40°C, and AT of 15°C–35°C.

Graptemys flavimaculata were also seen basking during many ''unconventional'' conditions, including heavy cloud cover, rain, impending thunderstorms, and even into the late evening after sunset. Late evening basking times were notable since turtles were observed during the summer to bask until after 1900 hours, with one individual basking until 2002 hours. During these periods, AT and LT were usually cooler than WT.

Disturbances While Basking. — Natural disturbances prematurely startled turtles from their basking structures during the study; these instances disturbed 73 of 1124 (6.6%) monitored *G. flavimaculata*. Most of the natural disturbances were larger turtles pushing smaller ones off of basking structures, both intraspecifically (e.g., larger *G. flavimaculata* females disturbing smaller males) and interspecifically (*Graptemys gibbonsi*, *Pseudemys concinna*). Other natural disturbances include several species of large, predatory birds flying over basking turtles (osprey, *Pandion haliaetus*; great egret, *Ardea alba*; great blue heron, *Ardea herodis*; snowy egret, *Egretta thula*), a swimming beaver (*Castor canadensis*), an unknown fish species splashing near basking turtles, floating logs, and floating river foam. An alligator (*Alligator mississippiensis*) also disturbed a basking *G. flavimaculata* at another site in a related study (W. Selman, *pers. obs.*). Several taxa did not disturb basking turtles including swimming wood ducks (*Aix sponsa*) and water snakes (*Nerodia* sp.). Occasionally, turtles abandoned their basking sites in the absence of any noticeable disturbance, with the whole bale of turtles diving into the water, most likely induced by one individual re-entering naturally when there were large basking aggregations.

In addition to natural disturbances, 119 (10.6%) monitored turtles were disturbed by humans. Many of these instances, however, were because of the researcher (74 disturbed turtles, 6.5%) when approaching thunderstorms prevented watching turtles until natural submergence. If these instances are removed, only 45 (4%) observed turtles were disturbed at the site due to human activities. Only 9 boats were documented passing through the study site during our observation periods. However, every passing boat disturbed at least one basking turtle and almost all monitored basking turtles were disturbed (91%; 30 of 33 monitored individuals). Other human disturbances at the site were associated with neighboring landowners visiting the river to swim or walk the sandbars.

DISCUSSION

Individual Basking Behavior. — The difference in basking duration between adult and juvenile *G. flavimaculata* is not surprising due to the dramatic differences in body size as well as the greater ability of smaller turtles to lose and gain heat (Boyer 1965). Weathers and White (1971) and Auth (1975) also found that larger females take longer to heat and therefore bask for longer durations compared to smaller males. It is puzzling that males in our study did not bask for much shorter periods relative to females (mean 6.6 minutes shorter throughout the year); one would expect considerably shorter durations due to the dramatic sexual size dimorphism in this species, with Leaf River males averaging one-fifth the mass of females (W. Selman, *unpubl. data*). One plausible explanation is that while basking, males appeared better able to change their positions on basking structures compared to females, likely due to their the smaller size and greater agility. Presumably, this allows males to thermoregulate on a finer scale (i.e., can keep body temperatures within a narrower range) than females since they can easily change their body position relative to the sun, thus permitting them to bask slightly longer than expected. We do not have data to support this claim, but this hypothesis was also suggested by Bulté and Blouin-Demers (2009). They proposed that female *G. geographica* do not thermoregulate as accurately as smaller turtles (i.e., males, juvenile females) since their body temperatures were less often within preferred body temperatures. There are also few studies that document maximum basking duration by individual turtles, but during our study, maximum basking duration of individuals (464 minutes for a male, 336 minutes for a female) was comparable to 2 other aquatic emydid species (*P. concinna*, 485 minutes, Selman and Qualls 2009b; *T. scripta scripta*, 430 minutes, Selman and Qualls 2009c).

Daily and Seasonal Basking Behavior. — Daily and seasonal differences in basking duration were expected due to seasonally changing environmental conditions and physiological needs of turtles, as also noted by Moore (2003) for lower Pascagoula River *G. flavimaculata* populations. During the spring, WT is cooler than AT or LT, which makes basking critical for increasing body temperatures and metabolic functions. During the spring, we observed the longest durations and highest basking frequencies of males and females, while observing a daily unimodal basking frequency peaking at midday. The same pattern was observed in *G. nigrinoda* (Waters 1974) and *G. ernsti* (Shealy 1976). While Moore (2003) did not consider basking duration with lower Pascagoula River *G. flavimaculata*, she found higher frequencies of basking females relative to males during the spring and also found a unimodal basking pattern with basking peaking during the midday. Female basking durations are also longer during the spring relative to other months, likely due to a combination of longer basking durations needed to achieve thermal optima (Bulté and Blouin-Demers 2009) and the timing of ovarian follicle maturation prior to the nesting season (Shelby et al. 2000; Horne et al. 2003). Therefore, during the spring, we presume that *G. flavimaculata* basking at the Leaf River site is predominantly utilized to meet physiological needs (i.e., reproductive effort, metabolism, digestion, growth) via thermoregulation.

By summer, WT has increased substantially (maximum 35°C) and basking for thermoregulation appears to be negligible. Basking changes to a bimodal pattern with morning and afternoon peaks, similar to lower Pascagoula River populations of *G. flavimaculata* (Moore 2003). Intense solar radiation during midday hours limits basking durations since turtles could overheat, thus precluding shell drying during these hours. Along with changes in basking duration and frequency during the summer, many turtles were observed shedding carapacial scutes. Auth (1975) also found shorter basking durations of *T. scripta scripta* (yellow-bellied slider) during warmer months than in cooler months. Similarly, Shealy (1976) and Lindeman (in press) found decreased basking in *G. ernsti* and *G. ouachitensis*/*G. pseudogeographica kohnii*, respectively, during the summer when the water was warmer and water levels were lower. Conversely, Sanderson (1974) found that *G. barbouri* basked most frequently during the summer, possibly due to springs entering the Chipola River that cause cooler water temperatures (high of 24°C in June). Further, Craig (1992) found that during the summer, *G. caglei* would often bask when AT was cooler than WT. Since Leaf River *G. flavimaculata* bask for longer durations or higher frequencies during the morning and evening hours (sometimes with AT lower than WT) and we observed many turtles shedding carapacial scutes, we presume that basking during the summer is not primarily for thermoregulation but possibly for shell drying, conditioning, and scute ecdysis.

One anomaly during our study was the month of July 2007, when basking durations (Fig. 1) and basking percentages (Fig. 3) were longer and higher, respectively, than in other summer months. During July 2007, river water levels were high and AT and WT were unseasonably cool as a result of large amounts of rain during the prior week, which was not conducive to turtle basking. Therefore, the long basking durations observed during this month were likely abnormal for this time of year. Waters (1974), Sanderson (1974), and Craig (1992) found that basking activity was more intense following several days of unfavorable basking conditions. Shealy (1976) also concluded that high water levels were positively associated with basking activity. This 1-month anomaly indicates a distinct ability for turtles to adjust their ''normal'' seasonal basking routine due to a dramatic change in environmental conditions. We suspect that if basking behavior was studied across multiple seasons, July would be similar to other summer months, with turtles basking for shorter durations and at lower frequencies.

Daily basking frequencies during the fall appear to shift to a pattern intermediate to spring and summer since WT begins to cool, while AT and LT remain warm. Male turtles are likely undergoing spermatogenesis during this time (Shelby and Mendonça 2001) leading to longer basking durations and higher basking frequencies. Even though females have long basking durations during the fall, they bask in lower frequencies relative to spring months, thus making it unclear whether females begin follicular growth for the upcoming nesting season during the fall (Shelby et al. 2000); Moore (2003) also reported female *G. flavimaculata* from the lower Pascagoula River basking at lower frequencies during the fall. Auth (1975) observed the longest basking durations of *T. scripta scripta* during the fall and early winter (October–December) compared to summer months; however, this study lacked comparative data during the spring to make spring–fall seasonal comparisons.

While no data were collected in our study over the winter months, Jones (1996) and Moore (2003) observed considerably lower numbers of *G. flavimaculata* active during the winter months. Coleman and Gutberlet (2008) also observed lower numbers of basking *G. pseudogeographica kohnii* and *G. ouachitensis sabinensis* during the winter. We opportunistically noted turtle basking while retrieving temperature data from data loggers during the winter, and we also observed lower numbers compared with the spring to fall months. Even though we did not quantify basking during the winter, we presume that when turtles are active, they may bask for long durations, but at substantially lower frequencies. Decreased solar radiation and lower WT would promote long basking periods, as seen by Auth (1975) in *T. scripta scripta*, but the lower thermogenic/physiological demands during the winter would likely reduce population basking frequencies. This scenario would need to be confirmed with future studies.

Juvenile Basking Behavior. — Little is known about the life history of juveniles for most turtle species, with only 3 studies documenting basking behavior in juvenile *Graptemys* (Waters 1974; Shealy 1976; Lindeman 1993). While basking, juveniles face a difficult challenge: basking increases the ability to assimilate food for growth, which is key for this life-history stage, but it also increases the potential for predation. The smaller size and surface area to volume ratio of juveniles would presumably lead to a greater ability to lose or gain heat, thus leading to shorter basking durations than adults. Even though basking for juvenile *G. flavimaculata* has been previously reported (Vogt, *pers. comm.* in Lindeman 1993), no specifics were described. For the 51 juveniles we observed, we found shorter basking durations relative to adults. However, some basking durations were much longer than expected for this age and size class (maximum: 149 minutes). In addition, basking durations and basking frequencies for juveniles were decreased throughout the day, making juvenile basking more unpredictable than that of adults. Waters (1974) also noted erratic basking by juvenile *G. nigrinoda*, with most basking occurring during the morning hours. We also found that juvenile *G. flavimaculata* often chose basking locations closer to the bank and these structures were usually located in or among overhanging vegetation and limbs, similar to the findings of Shealy (1976) with *G. ernsti*. We suspect that juveniles choose locations that are closer to the bank and in shallower water to avoid larger aquatic predators (primarily predatory fish), while also choosing to bask among branches and overhanging vegetation to avoid predatory birds. These areas may also provide dappled sun and shade, allowing juveniles to shuttle between sunny and shady conditions. The poorer swimming ability of juveniles may also confine them to these areas with slower current speeds near the bank relative to the main river channel. Further studies on thermoregulatory behavior and/or habitat use in juvenile turtles are warranted.

Significance of Basking Structures. — The importance of basking structure availability for *Graptemys* species is 3-fold: structures provide a substrate for basking, an attachment site for prey species, and for sleeping and resting (for review, see Lindeman 1999a; Moll and Moll 2004). Due to the channelization and desnagging of many southeastern river systems, understanding the use and importance of basking structures is important for species conservation; for example, Lindeman

(1999a) found a significant correlation between deadwood abundance and basking density for many *Graptemys* species. Within this study, sexes did not use basking structures equally, likely due to dramatic sexual size dimorphism in the species, with females requiring more supportive structures (logs) relative to males or juveniles due to larger body size. Due to the ever changing matrix of deadwood abundance and type across years, seasons, and even days, quantification of these metrics is more appropriate for daily surveys rather than a study of this temporal length. Therefore, we cannot account for the availability and/or the percentage of each type of basking structure used within our river system throughout the entire year, even though we found a large number of females using logs and males using branches. However, surveys conducted by Lindeman (1999a) on snag type and basking turtle found that within the Pascagoula River system the most common type of substrate was branches, followed by logs, tangles, stumps, and tree crowns. Branches were rarely occupied by basking turtles (5%) while logs (12%) and the least encountered substrate type, tree crowns (15%), were occupied most; tree crowns were also highly occupied by turtles within the Pearl (45%) and Tennessee (96%) river drainages. Therefore, if present, turtles may choose tree crowns that offer different basking structure sizes (limbs vs. trunk), different angled structures for differences in daily solar radiation needs, better protection from aerial predators, safety in numbers since many turtles can bask in close proximity to each other, and higher subsurface structure for hiding from aquatic predators.

Basking and Environmental Variation. — Even though some of our environmental temperatures were significantly related to basking abundance, the absence of a strong correlation likely indicates the dramatic differences in seasonal, daily, and individual physiological needs. Coleman and Gutberlet (2008) found significant but weak polynomial relationships, similar to our study, for *G. ouachitensis sabinensis* and *G. pseudogeographica kohnii* basking in comparison to environmental temperatures from the Sabine River in southeast Texas. Coleman and Gutberlet (2008; *G. ouachitensis sabinensis*, *G. pseudogeographica kohnii*) and Waters (1974; *G. nigrinoda*) found turtle basking was greatest when water temperatures were between 15°C and 25°C for both the species examined, while Auth (1975) found that *T. scripta scripta* basking was highest when water temperatures were 31.5°C. For optimal air temperatures, Moore (2003; *G. flavimaculata*) found that more basking turtles were observed between 19°C and 35°C, similar to our findings of the same species (15°C–35°C).

We suspect that some of the variation that cannot be explained by our analyses is due to individuals basking to rest in flowing environments. Very few studies mention the need for turtles to rest by using basking as the means to accomplish this (Boyer 1965; Waters 1974). In nonflowing conditions, turtles may float at the water surface without expending much energy and rest without having to bask aerially. In contrast, turtles in flowing conditions must constantly swim upstream in order to maintain connection to home ranges, while also contending with water currents while feeding (Waters 1974). This would need to be verified in future studies in experimental settings.

Disturbance and Basking. — The impact of natural and anthropogenic disturbances appears to be minimal in this population. Larger aquatic, aerial, and terrestrial predator or ''predator-like'' species appeared to have the biggest impact on whether turtles were disturbed, but these instances were very infrequent. Aggressive interactions between conspecifics and heterospecifics (i.e., basking turtles pushed off logs by other turtles) were observed, similar to studies of other emydids (for review, see Lindeman 1999b). In the encounters we observed, usually larger individuals won aggressive encounters, similar to other studies (Pluto and Bellis 1986; Lindeman 1999b). Newman (1906) and Craig (1992) noted that flying birds disturbed map turtles; often a single turtle reentering the water would often cause ''a chain of plunges extending for several hundred meters along the river'' (Newman 1906).

Because our study population was relatively isolated within a small river system, when a human disturbance occurred it disturbed at least one turtle on every occasion and a high percentage of the basking turtles (91%). In a higher recreational area, Moore and Seigel (2006) found that only 54.6% of human disturbances led to a basking turtle abandoning its structure and others have also noted less wary populations in areas that have high levels of boating or canoeing recreation (P. Lindeman and B. Anders, *pers. comm.*). Further research is needed to determine what role disturbance plays in turtle behavioral responses and habituation to disturbances.

Conclusions. — The behavioral patterns of Leaf River populations of *G. flavimaculata* appear to be quite similar to patterns of lower Pascagoula River populations (Moore 2003), with both populations exhibiting differences in daily and seasonal basking patterns. Moore (2003) also noted a distinct season–gender interaction indicating that the sexes responded differently throughout the season. However, since the 1990s, the number of boats and the size of boats has increased within the lower Pascagoula River (Selman 2010). Currently, we suspect that basking within the lower Pascagoula River population is likely depressed to the patterns found 10 years earlier by Moore (2003) and therefore, not similar to less disturbed populations, like the Leaf River population in this study.

We observed many previously undocumented behaviors of *G. flavimaculata* (Selman and Qualls 2008, 2009d), as well as other turtle species (Selman and Qualls 2009b, 2009c), but we believe that there are many questions still to be answered. Future studies should continue to explore the complexities of this behavior, including the impacts of human disturbance (both behavioral and physiological), juvenile basking behavior, behavioral habituation to disturbance, and the hypothesis of basking as a means of resting. Further, our method of calculating basking percentages based on known population estimates of a measured river stretch may allow future researchers to answer complex questions, especially when trying to compare population-level basking of sympatric turtle species (i.e., *G. flavimaculata* vs. *G. gibbonsi*); this may, however, have some limitations if confidence limits are markedly different between the 2 populations. Further, our findings using this method indicate that *Graptemys* basking percentages can vary markedly across seasons and therefore, future basking survey efforts should take this into account when designing survey protocols.

In summation, the reason and motivation for basking is difficult to explain due to complex daily individual physiological demands across seasons, sexes, and reproductive conditions, as well as environmental conditions that fluctuate dramatically throughout the day and across seasons. However, our study provides an account of *G. flavimaculata* basking ecology across seasons and by sex that will contribute to the further understanding of this threatened species' life history.

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