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DISTRIBUTION AND ABUNDANCE OF TWO IMPERILED *GRAPTEMYS* SPECIES OF THE PASCAGOULA RIVER SYSTEM

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Abstract*.—Species distribution and abundance is often difficult to delineate due to species factors (e.g., crypsis, low abundance) or to researcher sampling techniques. Species of the genus *Graptemys* are primarily riverine turtles and have historically been subject to declines because of anthropogenic changes to river systems. Therefore, to better inform conservation efforts, we thoroughly studied the distribution and abundance of two imperiled *Graptemys* species within the Pascagoula River System, Mississippi, USA: the Yellow-blotched Sawback (*Graptemys flavimaculata*) and the Pascagoula Map Turtle (*Graptemys gibbonsi*). Turtle populations were studied in 17 counties in southeastern Mississippi using four methods: mark-resight population surveys (three populations), bridge surveys (160 bridge crossings), basking density surveys without marked individuals (23 localities), and trapping (three populations). *Graptemys flavimaculata* was found to be present throughout its historical range, as well as in new drainage localities; abundance in historically surveyed areas was generally higher than previous surveys had reported. *Graptemys gibbonsi* was also found in many new localities and occurred in most of the drainages of the Pascagoula River system. However, abundance was much lower for *G. gibbonsi* than for *G. flavimaculata* throughout the Pascagoula River system and individuals were not found in several historical localities, suggesting localized extirpations. We recommend that *G. gibbonsi* should be listed as state Endangered in Mississippi and Louisiana, U.S. federally listed as Threatened, and upgraded to Endangered (EN) under IUCN listing guidelines. Future conservation measures should extend to protect additional riparian habitat throughout the Pascagoula River system and future surveys of other *Graptemys* species are warranted due to the imperiled status of this genus.

Key Words.—abundance; basking; distribution; *Graptemys flavimaculata*; *Graptemys gibbonsi*; river turtle; mark-resight estimate; Pascagoula River.

INTRODUCTION

The ability to determine the distribution and abundance of imperiled herpetofaunal species is often complicated by cryptic behaviors, low population densities, challenging habitats, and difficulty in capturing individuals for potential mark-recapture studies. Therefore, distribution records for these species are often 'patchy' and incomplete, which poses difficulties for making conservation decisions. Accurate distributional information is increasingly important since many management decisions are now being made at a landscape level. Of particular concern are decisions that involve watersheds that are impacted due to anthropogenic modifications (e.g., impoundments, channel alteration, poor riparian zone management) and the potential negative effects they may have on aquatic communities.

The Pascagoula River Basin is the least impacted major river system in the lower 48 United States (Dynesius and Nilsson 1994). It is also home to several endangered and imperiled aquatic species including several fish (Gulf Sturgeon [*Acipenser oxyrinchus desotoi*], Pearl Darter [*Percina aurora*], Freckled Darter [*Percina lenticula*], Crystal Darter [*Crystallaria asprella*], Alabama Shad [*Alosa alabamae*]; Ross 2001) and two imperiled *Graptemys* species, the Yellow-blotched Sawback (*Graptemys flavimaculata*) and the Pascagoula Map Turtle (*Graptemys gibbonsi*). Members of the genus *Graptemys* are highly aquatic turtles that often inhabit rivers with moderate flow rates, high density of deadwood snags (Lindeman 1998, 1999), and width enough to provide an open canopy to allow ample opportunities for aerial basking. Many of the 12 species in the genus are endemic to single or adjacent southeastern river drainages (Ernst et al. 1994) and seven Gulf Coastal *Graptemys* species are state-listed as threatened or endangered due to river alterations that include impoundments, dredging, channelization, and de-snagging (i.e., manual removal of deadwood snags from a river; Buhlmann and Gibbons 1997).

Graptemys flavimaculata is a federally Threatened species that is endemic to the Pascagoula River system (USFWS 1991); whereas, *G. gibbonsi* occurs within the Pearl and Pascagoula River systems and has no current state or federal protection. Additionally, both species are considered among the top five endangered turtles in North America (IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. 2007. Turtles in Trouble: North America's Most Endangered Tortoises and Freshwater Turtles. Available from http://www.iucn-tftsg.org/trouble [accessed 7 November 2008]). The last

surveys for these two turtle species were conducted in the late 1970's and mid-1990's (McCoy, C.J., and Vogt, R.C. 1979. 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; Lindeman 1998, 1999); the results of these studies suggested that populations of both species were declining.

Since the 1970's, there has been a movement to preserve the Pascagoula River system, primarily through riparian land acquisition (e.g., The Nature Conservancy), and focus on research and conservation of protected aquatic species. However, recent events seem to be antagonistic towards these efforts, including a Federal Strategic Petroleum Reserve project, refineries requesting freshwater withdrawal, proposed impoundments for recreation, and de-snagging projects, all of which have the potential to alter the natural flow regime of this unique system and its aquatic communities. Because of the imperiled nature of these two *Graptemys* species, and the looming threats to the Pascagoula River system, we determined that it was critical to obtain current detailed information on the distribution and abundance of these species to document long-term changes in population distribution and population densities.

MATERIALS AND METHODS

Population distribution and relative abundance.—We used two methods to determine the population distribution of *Graptemys flavimaculata* and *Graptemys gibbonsi*: surveys of rivers and creeks crossed by roads (hereafter referred to as bridge surveys) and basking density surveys by boat or canoe. We conducted bridge surveys from August to October in 2006 and 2008, at 160 bridge crossings in 17 counties throughout the Pascagoula River basin (Fig. 1). At each bridge survey locality, we located and identified turtles with a 60 mm, 15–45× spotting scope (Leupold, Beaverton, Oregon, USA). From these observations, we determined presence/absence of these two basking species along with other basking turtles such as Softshell Turtles (*Apalone* spp), River Cooters (*Pseudemys concinna*), Razorback Musk Turtles (*Sternotherus carinatus*), and Red-eared Sliders (*Trachemys scripta elegans*). We also recorded the sex of basking *Graptemys* at each bridge crossing when possible; as well as, the number of each species basking to determine a relative density at each bridge survey locality. We conducted basking density surveys by boat or canoe on selected river and creek stretches within the basin to determine more accurately the species presence/absence, as well as their relative abundance (Fig. 1). During these surveys, we located basking turtles by binoculars from a canoe. When sandbars were present, we walked along them from the upstream end to the downstream end and used a spotting scope with tripod to locate basking turtles. Turtles were located more effectively by this method compared to locating turtles while floating downstream (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.) due to the wariness of basking turtles, particularly in creeks and rivers. We determined the presence or absence of turtles on these river stretches by these methods because of the high frequency of basking exhibited by turtles of the genus *Graptemys* (Boyer 1965; Ernst et al. 1994). Later, we calculated relative abundances of species as the number of basking turtles observed per river kilometer. Additionally, we recorded notable locations of turtles during boat/canoe surveys (i.e., new drainage localities or new upstream distributions) using a hand-held GPS (Garmin GPS 72).

Population estimates and trapping ratios.—During 2005–2008, we trapped *Graptemys* at three sites within the Pascagoula River system (Fig. 1): the Lower Pascagoula River (site number 1), Leaf River (site number 5), and Chickasawhay River (site number 8; trapped only in 2005 and 2006). We trapped turtles by attaching open-topped basking traps (made of 3/4" PVC coated crawfish wire; The Fish Net Company, Jonesville, Louisiana, USA) to turtle basking structures and left them slightly submerged; traps varied in size from 56 × 46 × 31 cm to 122 × 61 × 25 cm. We used nails and cotton twine to fasten traps to logs or branches known to be *Graptemys* spp. basking sites. We used a maximum of 17 traps during a trap-day and checked each trap approximately every hour. We occasionally moved traps if turtles were noted to avoid the trap log. We also captured turtles by hand and with a dip net.

Following capture, we marked individuals on the carapace (second and third vertebral scutes) with waterproof, tree-marking spray paint (Aervoe® Lead-Free Fluorescent Glo Spray Paint, Aeryoe Industries, Inc. Gardenerville, Nevada, USA) for subsequent mark-resight surveys. These marks allowed visual identification of marked turtles while basking, but did not allow determination of individual identity. We also determined and recorded the species and sex on all captured individuals. We released all paint-marked turtles at their point of capture after the paint mark on their shell had dried.

We made three mark-resight surveys during selected months from 2005–2008 at three locations within the Pascagoula River system (Leaf, Chickasawhay, and Lower Pascagoula Rivers). Before initiating visual count surveys, we paint-marked at least 10 turtles to

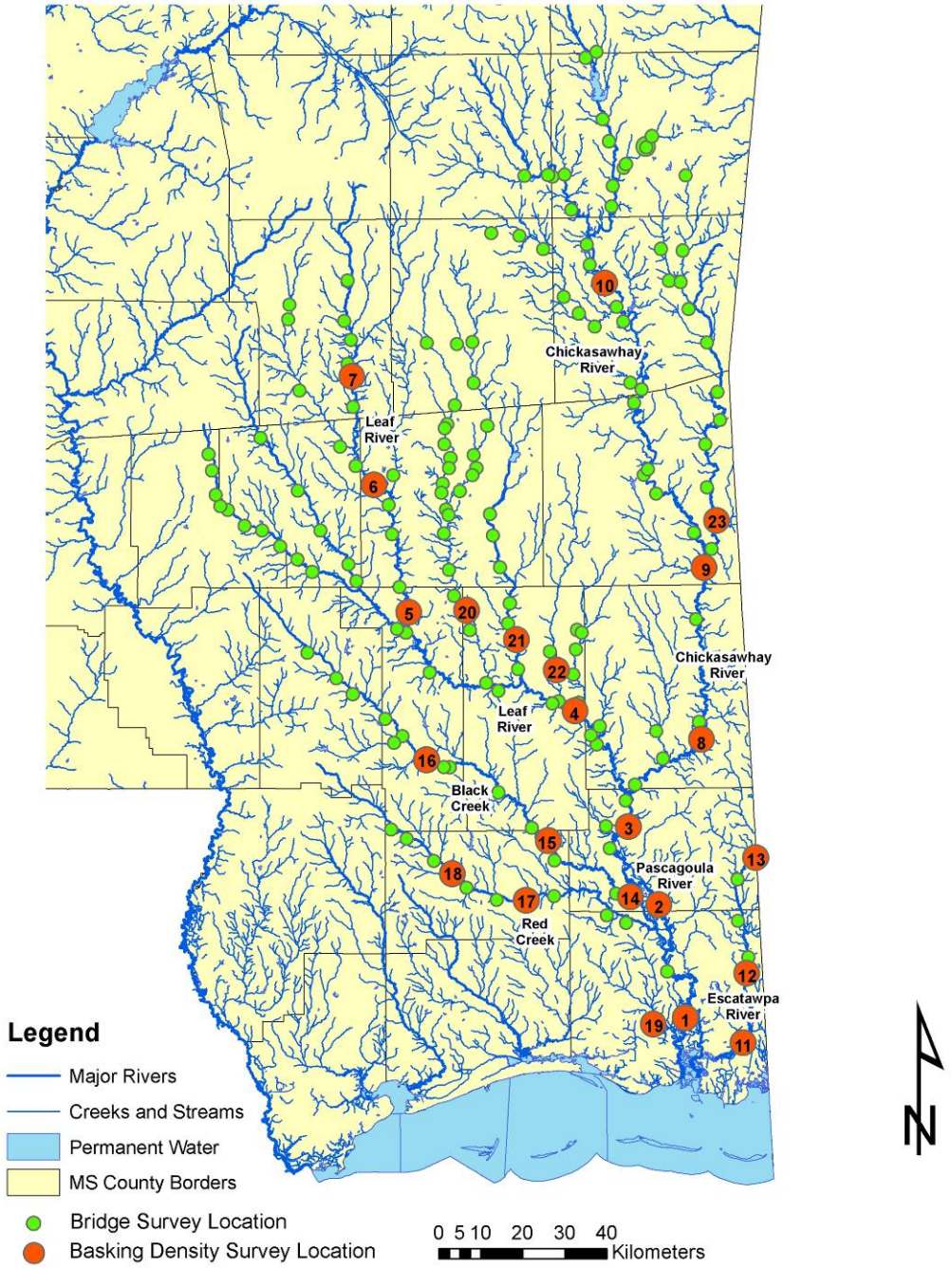

FIGURE 1. Locations of bridge and basking density surveys of *Graptemys flavimaculata* and *G. gibbonsi* conducted in 2006 and 2008 within the Pascagoula River system, Mississippi, USA. Numbers on basking density localities correspond with site numbers in Table 2.

ensure that a sufficient number of marked turtles were available in the population. We conducted mark-resight surveys during optimal basking times (1000–1500 h) under mostly sunny to sunny conditions during April, October, or early November. Each survey was completed within 3–4 h. We performed all surveys by walking along the banks or sandbars and located, identified, and counted marked and unmarked turtles using a 60 mm, 10–45× spotting scope (with tripod). Survey lengths were 2.4 river km (rkm) for the Chickasawhay River site, 3.2 and 3.75 rkm for the Leaf River site, and 2.0 rkm for the Lower Pascagoula River site. Also, we made surveys within two weeks of the initial capture to assure that no paint marks were lost. We used the program NOREMARK (White 1996) to estimate population sizes because it did not require that

TABLE 1.—Results of bridge surveys for *Graptemys flavimaculata* and *G. gibbonsi* by drainage (sorted by drainage size). See Fig. 1 for survey locations.

Drainage	No. Bridges Surveyed	No. of *G. flavimaculata*	No. of *G. gibbonsi*	Mean Basking Turtles per Bridge (all species)
Bouie River	2	9	1	24.0
Chickasawhay River	13	34	57	10.2
Leaf River	16	180	108	26.8
Pascagoula River	3	66	13	28.3
Total: Large and Medium Rivers	**34**	**289**	**179**	**21.2**
% of Basking Turtles Observed (721)		**40.1**	**24.8**	
Black Creek	12	-	6	2.8
Bogue Homa	6	1	10	3.3
Bouie Creek	10	1	-	1.8
Bucatunna Creek	13	-	9	2.8
Chunky Creek	4	-	7	10.3
Escatawpa River	3	-	-	0
Gaines Creek	3	2	1	0.7
Okatoma Creek	5	2	-	2.6
Red Creek	7	-	6	1.9
Tallahalla Creek	15	2	18	4.1
Tallahoma Creek	11	-	9	1.9
Thompson Creek	2	-	2	3.5
Total: Small Rivers and Large Creeks	**91**	**8**	**68**	**2.2**
% of Basking Turtles Observed (260)		**3.1**	**26.2**	
Atkisson Creek	1	-	-	0
Big Creek (Chickasawhay Drainage)	2	-	-	0.5
Big Creek (Leaf Drainage)	1	-	-	0
Chickasawhay Creek	1	-	-	0
Hurricane Creek	1	-	-	0
Little Black Creek	1	-	-	0
Long Creek	2	-	1	0.6
Nuakfuppa Creek	1	-	-	0.3
Oakohay Creek	5	-	1	1.4
Okatibbee Creek	5	-	4	1.2
Piney Woods Creek	1	-	-	0
Sandhill Creek	1	-	-	0
Souinlovey Creek	6	-	4	2.8
Sowashee Creek	5	-	-	1.9
Tallahata Creek	1	-	-	2.0
West Tallahala Creek	1	-	-	8.0
Total: Medium and Small Creeks	**35**	**0**	**10**	**1.7**
% of Basking Turtles Observed (60)		**0.00**	**16.7**	
Number of Bridges with Species Present (%)		31 (19)	66 (42)	
Mean observed per bridge when Species Present		9.83300	4.38000	
Total	**160**	**297**	**257**	**1041**
Percentage of Total		**0.28530**	**0.24688**	

we uniquely mark turtles and it also accounted for additional marked individuals being added to the population between survey intervals.

We also analyzed trapping data from 2005–2008 to determine species ratios at the three trapping localities. Presumably, trapping for *Graptemys* would be unbiased due to similar use of the basking snags by the two species. However, juveniles were likely underestimated because they were observed during the study to bask on smaller objects closer to the bank and in shallower water, in contrast to adults that usually bask on snags away from the bank and in deeper water (Jones 1996).

RESULTS

Graptemys flavimaculata *distribution and relative abundance.*—We found *Graptemys flavimaculata* to be present at all historical drainage localities to the distributional limits originally described by previous surveys (Cliburn 1971; McCoy and Vogt. 1979. *op. cit*.; USFWS 1991; Lindeman 1998), including within the Pascagoula River, Leaf River, Chickasawhay River, Bouie River, Escatawpa River, Lower Black Creek, and Lower Red Creek. New drainage localities were documented by bridge survey including Bogue Homa (Perry County), Bouie (Covington and Jefferson Davis

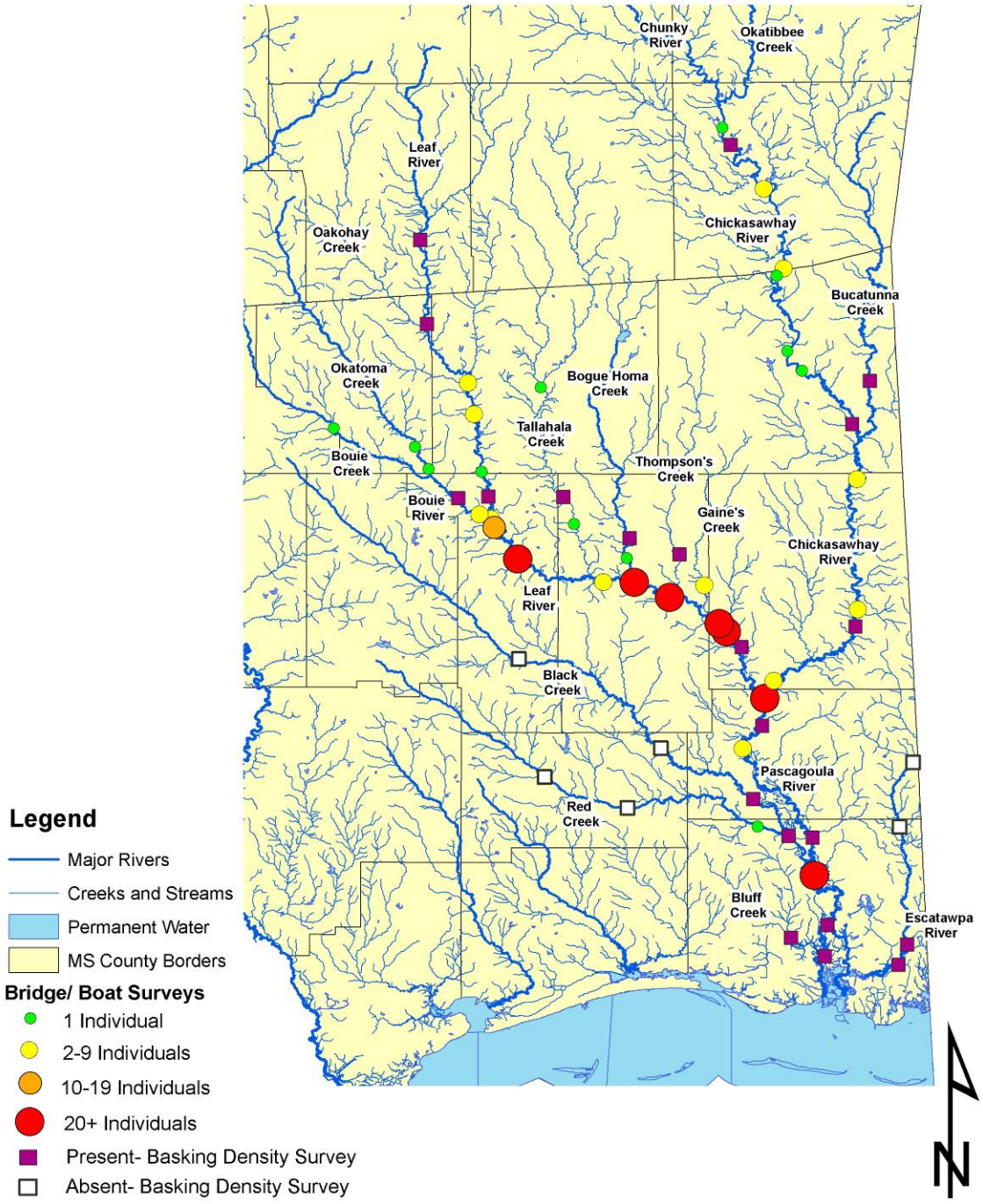

FIGURE 2. Bridge and basking density survey results for *Graptemys flavimaculata* within the Pascagoula River system, Mississippi, USA, 2006–2008. For specific basking density survey results by locality, see Table 2; for presence/absence data for individual bridge crossing results.

counties), Gaines (Perry County), and Okatoma creeks (Forrest County; Fig. 2). Additionally, we documented new drainage localities by boat/canoe survey including within Bluff (Jackson County), Bucatunna (Wayne County), and Thompson creeks (Perry County). The populations within Bluff Creek and the Escatawpa River appear to be geographically disjunct from the primary population within the Lower Pascagoula River due to brackish marsh between these freshwater habitats. The upstream limits for *G. flavimaculata* in the

TABLE 2. Basking density surveys of *Graptemys* within the Pascagoula River system, Mississippi, USA, including major and minor tributaries. nt = data not taken on sex of individuals observed. * = indicates site within range of *G. flavimaculata* recovery plan. † = indicates site that meets requirements suggested by *G. flavimaculata* Recovery Plan. See Fig. 1 for locations of numbered survey sites.

				Turtle Basking Density (turtles observed per km)					
				G. flavimaculata			*G. gibbonsi*		
Drainage	**Site Number**	**Date Surveyed**	**Distance Surveyed (km)**	Females	Males	Total	Females	Males	Total
Pascagoula River Site*†	1	10/31/07	2.0	32.5	31.5	67	-	1.0	1.0
Pascagoula River*†	2	7/15/08	3.2	45.9	85.3	139.2	4.0	8.9	13.7
Pascagoula River*†	3	7/15/08	4.5	14.0	39.2	57.3	6.4	10.5	20.4
Total Pascagoula			**9.7**	**30.8**	**52**	**87.8**	**3.5**	**6.8**	**11.7**
Leaf River*†	4	7/31/08	4.2	16.1	36.5	60.0	17.3	22.9	44.5
Leaf River Site*†	5	10/15/07	3.8	8.3	14.7	23.7	3.5	4.0	7.7
Leaf River*	6	7/9/08	22.2	2.0	1.7	3.8	4.2	1.5	5.9
Leaf River*	7	7/10/07	22.9	0.1	0.2	0.3	2.5	0.6	3.3
Total Leaf			**53.1**	**6.6**	**13.3**	**22**	**6.9**	**7.3**	**15.3**
Chickasawhay River*†	8	9/24/08	3.2	5.6	16.9	24.9	10.5	12.9	27.3
Chickasawhay River*	9	7/29/08	8.0	1.6	4.5	6.4	7.1	3.9	14.9
Chickasawhay River*	10	6/16/08	5.2	1.0	2.0	3.0	4.0	5.0	10.5
Total Chickasawhay			**16.4**	**2.7**	**7.8**	**11.4**	**7.2**	**7.3**	**17.6**
Escatawpa River	11	6/28/06	9.7	nt	nt	4.2	-	-	-
Escatawpa River	12	10/20/08	4.0	-	-	-	-	-	-
Escatawpa River	13	10/2/08	10.6	-	-	-	-	-	-
Total Escatawpa			**24.3**	**nt**	**nt**	**1.4**	**-**	**-**	**-**
Black Creek	14	7/7/08	8.0	1.3	2.3	4.2	1.3	1.6	5.2
Black Creek	15	6/6/08	15.9	-	-	-	2.3	0.7	3.7
Black Creek	16	7/11/07	8.1	-	-	-	0.6	1.0	3.4
Red Creek	17	6/23/08	22.4	-	-	-	1.5	0.5	2.5
Red Creek	18	8/7/07	15.7	-	-	-	0.3	0.3	0.9
Bluff Creek	19	9/16/06	6.5	0.9	0.2	1.1	-	-	-
Tallahala Creek	20	9/23/08	16.9	1.7	2.6	4.3	2.9	2.6	7.5
Bogue Homa	21	6/6/07	17.1	0.3	1.1	1.7	4.1	0.5	4.9
Thompson Creek	22	9/25/08	10.1	0.8	0.6	1.4	1.3	1.0	2.9
Bucatunna Creek	23	7/13/07	15.3	-	0.2	0.2	1.9	1.4	5.3
Total Creeks			**136**	**0.5**	**0.7**	**1.3**	**1.6**	**1.0**	**3.6**
Total			**239.5**	**8.1**	**14.8**	**24.8**	**3.8**	**4.5**	**9.6**

Chickasawhay River were confirmed near Stonewall (Clarke County, Mississippi) by boat and bridge survey, as previously described by Cliburn (1971). However, we found by canoe survey that *G. flavimaculata* extend farther north in the Leaf River, to north of Taylorsville (Smith County, MS), approximately 25.65 rkm north of the previously known locality for *G. flavimaculata* near U.S. Hwy 84 at Hot Coffee, Mississippi (Covington County; Cliburn 1971). We also documented range expansions within Tallahala Creek (north 46.25 rkm; Cliburn 1971) to the vicinity of Ellisville, Mississippi (Jones County). Downstream limits for *G. flavimaculata* were observed within 13.5 rkm north of the mouth of the Pascagoula River; individuals have been captured at the mouth of the Pascagoula River, near U.S. Hwy 90 (Tom Mann, pers. comm.), but these likely represent vagrant individuals.

We found that only 31 (19%) of 160 bridge crossings that were surveyed had *G. flavimaculata* present (Table 1). However, when *G. flavimaculata* were present at bridge crossings, multiple individuals were usually observed basking (mean of 9.83 individuals). *Graptemys flavimaculata* was the second most abundant basking turtle observed within the Pascagoula River system (29% of 1,041 basking turtles observed), while *P. concinna* was the most abundant (39%). Within the Pascagoula and its larger tributaries, *G. flavimaculata* was the most abundant basking *Graptemys* (40%; Table 1), particularly within the Pascagoula (84% of basking turtles) and the Leaf (63% of basking turtles) rivers. *Graptemys flavimaculata* was the fifth most abundant basking species within smaller rivers and large creeks (3%; behind *P. concinna*, *G. gibbonsi*, *Apalone sp.*, and *Trachemys scripta elegans*) and was absent from medium/small creeks (Table 1). The highest relative densities of *G. flavimaculata* were in the Pascagoula and Lower Leaf rivers, between Vancleave and Hattiesburg, as McCoy and Vogt (1979. *op. cit.*) suggested (Fig 2). Lower densities were found in regions of the Upper Leaf River, Chickasawhay River, and several medium-sized creeks (Fig.2; Table 1 and 2). Basking density surveys by boat or canoe aligned well with bridge survey results

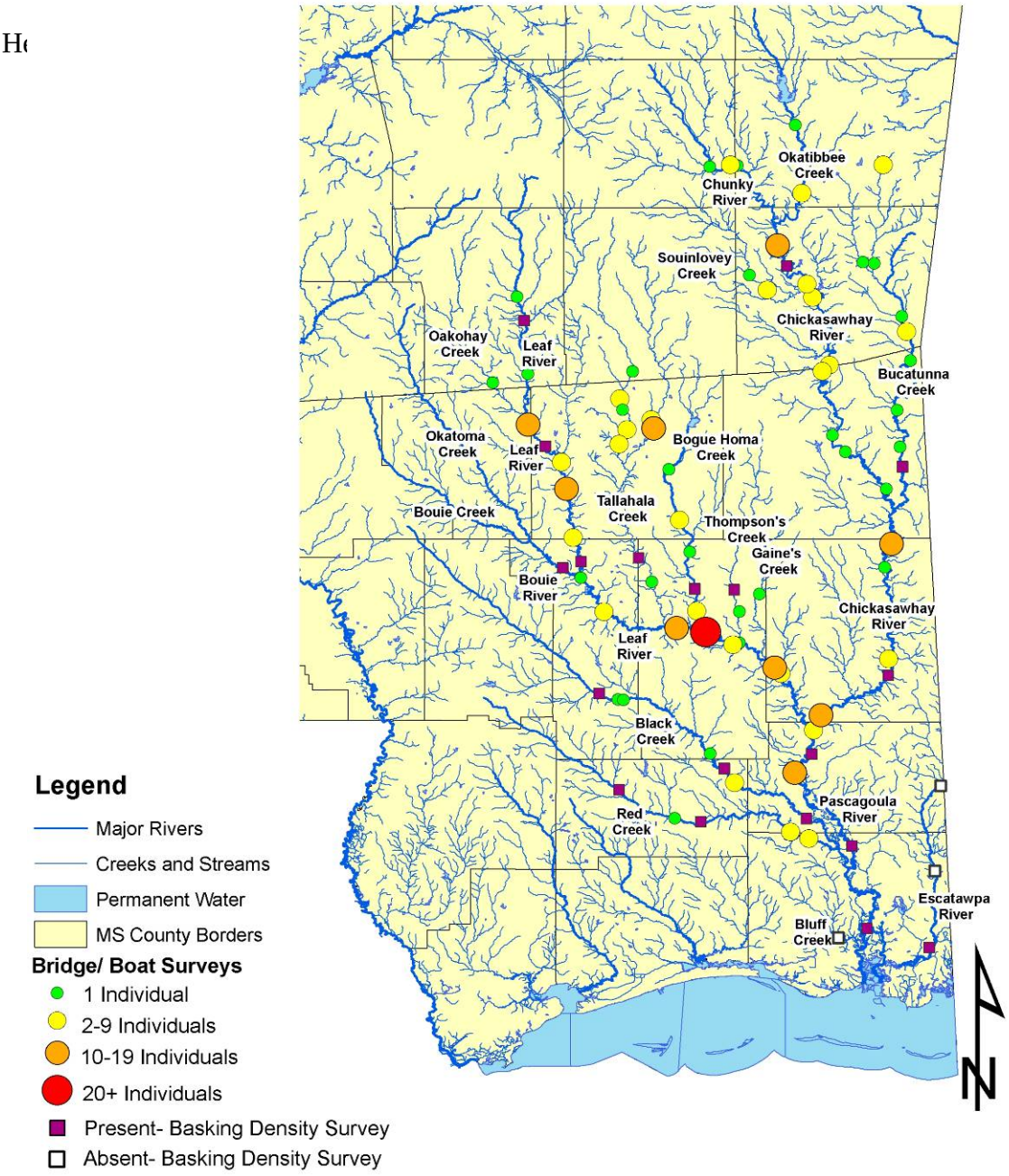

FIGURE 3. Bridge and basking density survey results for *Graptemys gibbonsi* within the Pascagoula River system, Mississippi, USA, 2006–2008. For specific basking density survey results by locality, see Table 2; for presence/absence data for individual bridge crossing results.

that indicated that the largest populations of *G. flavimaculata* exist from the Lower Pascagoula River (vicinity of Wade/Vancleave, Jackson County), upstream in the Leaf River to the confluence of the Bouie River (vicinity of Hattiesburg, Forrest County; Table 2). Basking density surveys also recorded low abundances of *G. flavimaculata* within several medium-sized creeks (< 20 m wide; e.g., Bogue Homa Creek), as was also confirmed by bridge survey.

Graptemys flavimaculata were not found in apparently suitable habitats in the middle portions of Black Creek, Red Creek, and the Escatawpa River. Additionally, we did not observe *G. flavimaculata* within the non-flowing, lake-like sections of the Lower Bouie River that were created by gravel mining operations, but we did see individuals in historical flowing river channels between these lakes. We also documented the absence of *G. flavimaculata* in areas impacted by gravel-mining within Thompson Creek, but found turtles inhabiting intact creek sections upstream and downstream of impacted areas. Also, we noted few individuals in the channelized and de-snagged portion of the Leaf River (3.8 rkm) adjacent to Hattiesburg, Forrest County, Mississippi and downstream of a municipal wastewater input southeast of Hattiesburg.

TABLE 3.—Population estimates for *Graptemys flavimaculata* and *G. gibbonsi* using the program NOREMARK within the Pascagoula River system, Mississippi, USA. * = from Selman and Qualls (2008).

Species	Year	Site	Distance Surveyed (river km)	Population Estimate	95 % CI	Estimated Turtles/km
G. flavimaculata	2005	Chickasawhay	2.4	223	127-419	93
G. flavimaculata	2005	Leaf	3.2	257*	146-482	80
G. flavimaculata	2006	Leaf	3.75	451*	202-1144	120
G. flavimaculata	2007	Leaf	3.75	361	222-726	96
G. flavimaculata	2008	Leaf	3.75	335	245-501	89
G. flavimaculata	2005	Pascagoula	2.0	1203*	732-2339	602
G. flavimaculata	2006	Pascagoula	2.0	641*	433-989	321
G. flavimaculata	2007	Pascagoula	2.0	562	381-946	281
G. flavimaculata	2008	Pascagoula	2.0	583	402-953	292
G. gibbonsi	2007	Leaf	3.75	129	102-179	34
G. gibbonsi	2008	Leaf	3.75	166	109-293	44

Graptemys gibbonsi *distribution and relative abundance.*—We found *G. gibbonsi* inhabiting the Pascagoula, Chickasawhay, and Leaf rivers, as well as the historical localities of Red Creek, Black Creek, Thompson Creek, Tallahala Creek, and the Chunky River (Cliburn 1971; McCoy and Vogt 1979 *op. cit.*; Lindeman 1998). We report previously undocumented drainage localities for *G. gibbonsi* including: Bogue Homa (Perry and Jones counties), Bucatunna (Wayne, Clarke, Lauderdale counties), Long (Clarke County), Gaines (Perry County), Oakohay (Covington, Smith counties), Okatibbee (Lauderdale Counties), Souinlovey (Clarke County), and Tallahoma creeks (Jones, Jasper counties; Fig. 3). We did not observe *Graptemys gibbonsi* during the basking density survey in the Escatawpa River, but we observed four individuals basking in the vicinity of Goode's Mill Lake (Jackson County) after working multiple days in that system. We suspect, like *G. flavimaculata*, that this population is also geographically disjunct from the main Pascagoula River population. We also documented range extensions for *G. gibbonsi* within the Leaf River (north approx 46 rkm; Cliburn 1971), Red Creek (northwest approx 77 rkm; Cliburn 1971), and Tallahala Creek (north approx. 67 rkm; Cliburn 1971). The downstream limits for *G. gibbonsi* appear to be approximately 20 rkm north of the Pascagoula River mouth.

We found *Graptemys gibbonsi* at 66 of 160 surveyed bridge crossings (41%, Table 1). *Graptemys gibbonsi* was less abundant than *G. flavimaculata* at bridge crossings, as there was on average only 4.38 individuals of this species basking per bridge, which is 55% less than the mean number of *G. flavimaculata* present (9.83 individuals). In bridge surveys, *G. gibbonsi* comprised 25% (257 of 1,041 turtles) of the total basking turtles seen, the third most common basking species behind *G. flavimaculata* and *P. concinna*. *Graptemys gibbonsi* was the dominant basking *Graptemys* only within the Chickasawhay River (63%). However, the Chickasawhay River had fewer total basking turtles observed per bridge (10.2) compared to the Pascagoula (28.3) or Leaf rivers (26.8; Table 1). Within the Pascagoula and its larger tributaries, *G. gibbonsi* was the third most abundant basking turtle (25%), behind *G. flavimaculata* and *P. concinna*. *Graptemys gibbonsi* was the second most abundant basking species within smaller rivers and large creeks (26%; behind *P. concinna*) and was the third most abundant basking turtle in medium and small creeks (17%; behind *P. concinna* and *T. scripta elegans*).

The relative density of *G. gibbonsi* within the Pascagoula River system exhibits no clear pattern (Fig. 3). This species appears to be locally abundant in the upper reaches of the Pascagoula River and sections of the Leaf and Chickasawhay rivers, but between these areas of high abundance, very few individuals were noted. Basking density surveys closely mirrored bridge surveys and indicated that populations of *G. gibbonsi* within the Pascagoula River system were highly variable (Table 2), appearing to be locally abundant within the upper Pascagoula River and lower Leaf River, and in areas of the Chickasawhay River where they were more abundant than *G. flavimaculata*. Bridge surveys did not document *G. gibbonsi* within the middle portion of Tallahala Creek and its presence there was only confirmed during a basking density survey by canoe.

We did not observe individuals during bridge surveys in either Okatoma or Bouie creeks where they had been previously documented. A boat survey of the lower reaches of the Bouie River noted one individual, but this stretch of river has been severely impacted due to gravel mining. Individuals were also conspicuously absent from gravel mining-impacted reaches within Thompson Creek. Furthermore, populations within Tallahala and Tallahoma creeks have higher density above the town of Laurel (Jones County) than downstream in portions of Tallahala Creek, which was historically grossly polluted due to point sources in the vicinity of Laurel (Cagle 1954; Cliburn, pers. comm.; Fig. 3). Lastly, we documented very few *G. gibbonsi* in the lower reaches

TABLE 4.—Trapping results for *Graptemys flavimaculata* (*G.f.*) and *G. gibbonsi* (*G.g.*) for 2005–2008 at three sites within the Pascagoula River system, Mississippi, USA.

Site/River	Year	Species	Total Captured (# of F, M, Juv.)	T Capture Ratio (*G.f.* to *G.g.*)
Leakesville	2005	*G. flavimaculata*	73 (30, 35, 8)	
Chickasawhay		*G. gibbonsi*	45 (4, 31, 10)	1.62 : 1
Leakesville	2006	*G. flavimaculata*	50 (12, 26, 12)	
Chickasawhay		*G. gibbonsi*	25 (3, 19, 3)	2.00 : 1
Hattiesburg	2005	*G. flavimaculata*	65 (18, 42, 5)	
Leaf		*G. gibbonsi*	31 (13, 10, 8)	2.10 : 1
Hattiesburg	2006	*G. flavimaculata*	73 (25, 44, 4)	
Leaf		*G. gibbonsi*	20 (9, 9, 2)	3.65 : 1
Hattiesburg	2007	*G. flavimaculata*	92 (32, 48, 12)	
Leaf		*G. gibbonsi*	27 (9, 13, 5)	3.41 : 1
Hattiesburg	2008	*G. flavimaculata*	96 (24, 51, 21)	
Leaf		*G. gibbonsi*	31 (7, 18, 6)	3.10: 1
Vancleave	2005	*G. flavimaculata*	102 (34, 65, 3)	
Pascagoula		*G. gibbonsi*	1 (0, 0, 1)	102 : 1
Vancleave	2006	*G. flavimaculata*	127 (51, 77, 4)	
Pascagoula		*G. gibbonsi*	2 (1, 0, 1)	63.5 : 1
Vancleave	2007	*G. flavimaculata*	119 (45, 60, 14)	
Pascagoula		*G.gibbonsi*	8 (0, 2, 6)	14.88 : 1
Vancleave	2008	*G. flavimaculata*	131 (55, 48, 27)	
Pascagoula		*G. gibbonsi*	8 (0,0,8)	16.38 : 1

f the Pascagoula River and no individuals were spotted within Bluff Creek, which has no previously documented records for *G. gibbonsi*.

Population estimates and species ratios.—We estimated population sizes for *G. flavimaculata* at 3 sites in 2005 and 2 sites in 2006–2008. In 2005, the Chickasawhay River site (Greene County) had an estimated 232 *G. flavimaculata* (95% CI: 127–419) in 2.4 river km (93 per rkm; Table 3). From 2005–2008, estimates for the Leaf River site (Forrest County) ranged from 257–451 (95%CI: 145–1143) turtles in 3.2-3.75 rkm (80–120 per rkm). The Lower Pascagoula River site (Jackson County) was also surveyed from 2005–2008 and population estimates ranged from 562–1203 (95% CI: 381–2339) turtles in 2.0 rkm (281–602 per r/km).

We could complete only two population estimates for *G. gibbonsi*, both at the Leaf River site. This was primarily due to our inability to catch and paint-mark enough individuals for a reliable population estimate at other sites. The Leaf River site had an estimated 129–166 (95% CI: 102–293) turtles in 3.75 rkm (34–44 per rkm; Table 3). Trapping results also indicated that *G. flavimaculata* outnumbered *G. gibbonsi* at all three sites surveyed (Table 4). The Chickasawhay River site had the lowest *G. flavimaculata* to *G. gibbonsi* ratio (1.75:1), whereas during four years of trapping at the Lower Pascagoula River site, only 19 *G. gibbonsi* were trapped compared to 479 *G. flavimaculata* (25.2:1). The latter site was also juvenile-dominated as 16 of 19 *G. gibbonsi* captured were of juvenile size.

DISCUSSION

Graptemys flavimaculata *status.*— The presence of *G. flavimaculata* in all previously recorded localities, as well as in new ones, suggests that *G. flavimaculata* has not undergone a range contraction as was suggested by Lindeman (1999). Lovich (in Ernst et al. 1994) indicated that *G. flavimaculata* was noticeably absent from reaches below the outflow of effluent from a known paper mill within the Leaf River (New Augusta, Perry County), but our study found this reach to have one of the highest numbers of *G. flavimaculata* and *G. gibbonsi* observed by bridge and by basking density surveys (site number 4). This could be due to improved water quality from cleaner effluent from a paper mill in the intervening years.

Further, our population estimates and basking density surveys at all localities were generally higher than previously reported (USFWS 1991; Lindeman 1998). Recovery requirements for *G. flavimaculata* indicate that populations should meet or exceed 44 turtles per rkm in

the Pascagoula and 22 turtles per rkm in the Leaf and Chickasawhay rivers (USFWS 1993). Population estimates exceeded the USFWS recovery requirements at all three mark-resight localities. The population estimates at the Leaf River site and Chickasawhay River site were considerably higher than what was found during the early 1990's when there were approximately four basking *G. flavimaculata* per river mile in 40 miles of the Leaf River and 20 miles of the Chickasawhay (USFWS 1991). However, USFWS surveys were conducted by moving boats, which have been noted to startle turtles even before they come into the turtle's view (W. Selman, pers. obs.). Therefore, these surveys were likely a very low estimate of population densities for *G. flavimaculata*, especially if weather conditions were not conducive to basking (i.e., cloudiness, summer months). Additionally, basking density surveys met or exceeded recovery requirements at 60% of sites within the Pascagoula River (3 of 3), Leaf River (2 of 4), and Chickasawhay River (1 of 3; Table 2). However, within the Pascagoula River system and the lower 129 rkm of the Leaf and Chickasawhay rivers (specified habitat to be protected in recovery plan), six of six surveys met or exceeded recovery plan objectives (sites 1, 2, 3, 4, 5, 8). The other survey reaches within the upper Leaf and Chicksawhay rivers that did not meet recovery requirements (sites 6, 7, 9, 10) will likely never meet these requirements due to smaller river channels and patchiness of optimal habitat for this species.

Graptemys flavimaculata was also found in much smaller drainages (15–20 m wide) than previously described for this species. Within these smaller creeks, it is uncertain how much area is occupied by turtles because there are river stretches of apparently suitable habitat (open canopy, snags, moderate flow, sandbars) separated by kilometers of apparent marginal/unsuitable habitat (closed canopy, few snags, high flow with rapids, no sandbars). It was previously uncertain if *G. flavimaculata* used these smaller rivers/creeks for year-round habitat or if they are seasonal refuges. If these smaller rivers/creeks are used only seasonally, one might expect the absence of adult females and hatchlings/juveniles, particularly due to the lack of large nesting sandbars. However, adult females were encountered during both types of surveys across several months in the Upper Leaf River and Bogue Homa, Gaines, Okatoma, and Tallahala creeks. Also, hatchlings/juveniles were found by both survey types across most months within the Upper Leaf River, Bogue Homa, Black, Bucatunna, and Tallahala creeks. We expect that natal beaches are most likely in the vicinity of where we observed hatchlings and juveniles due to the low vagility of these age classes. Additionally, these creeks offer little alternative habitats surrounding them (e.g., oxbow lakes or bayous) for turtles to move to, in contrast to the Lower Pascagoula River habitat that has many associated aquatic habitats (e.g., oxbow lakes, bayous) for turtles to use (Jones 1996). It is also unlikely that these turtles exhibit dramatically different home ranges than those found within the Lower Pascagoula River (male: 1.8 km [range: 0.18 km–5.9 km], female: 1.5 km [range: 0.23–2.85 km]; Jones 1996). Thus, movements of turtles from these smaller drainages (> 10 km from large river habitats) back to main river habitats are unlikely. Therefore, these smaller size drainages (< 25 m wide) appear to offer year-round habitat, including suitable nesting habitat and year-round food resources. We suggest that future studies might target these small drainage populations for comparison to previously studied large river populations, particularly movement patterns.

We do not know why *G. flavimaculata* does not inhabit middle and upper portions of the Escatawpa River, Black Creek, and Red Creek. These areas appear to offer similar or better habitats than other localities where they were observed (i.e., Okatoma and Bucatunna Creeks). The only apparent dispersal barrier between these drainages and the Pascagoula River appears to be when they encounter the Pascagoula River floodplain, where the creeks become narrow with few suitable sandbars and a closed tree canopy over the creek/river. However, individuals were noted above this area within both Black and Red creeks, and therefore, appear to have overcome this barrier. Further, these stretches are considered 'blackwater' habitat (clear, tannin-stained waters), which likely contains fewer nutrients and may historically lack primary prey items; however, this does not explain the presence of *G. gibbonsi* in these portions of Red and Black creeks. The absence of *G. flavimaculata* from middle and upper portions of the Escatawpa River are likely due to the absence of many freshwater mollusks from this drainage (Williams et al. 2008; Robert L. Jones, pers. comm.). Regardless, these areas should be surveyed in the future to determine if expansion is occurring within these creeks, particularly because these stream systems could harbor the exotic Asian Clam (*Corbicula fluminea*) in the future, which is a food item of both *Graptemys* species (Ennen et al. 2007; Selman, unpubl. data).

The decline of the largest population of *G. flavimaculata* in the lower Pascagoula River is disconcerting. This population decreased significantly (by approximately 47%) after 2005, presumably due to the negative impacts from Hurricane Katrina (Selman and Qualls 2008) and did not rebound in the three following years. However, during 2007 and 2008, the percentage of juveniles captured increased dramatically (41 of 250; 16.4%) in comparison to 2005 and 2006 (7 of 229; 3.1%). However, because we did not focus on the nesting of *G. flavimaculata* during this study, we are unsure of the exact mechanism that led to increased juvenile frequency in the Lower Pascagoula River

following Hurricane Katrina. Some possibilities may include: three consecutive dry years following Hurricane Katrina, which might have increased nest/hatching success; (1) lower nest mortality due to flooding (Horne et al. 2003) during these dry years; (2) lower numbers of nest predators due to predator mortality associated with the Hurricane Katrina storm surge and flooding; and (3) better riverine conditions. All of these hypotheses warrant future studies. This population, however, is highly susceptible to declines due to threats that do not exist in upstream populations, many of which many are due to the dramatic human population growth in southeast Mississippi (e.g., excessive recreational boating traffic, likely salinity increases due to municipal and industrial freshwater withdrawals, and human collection).

G. gibbonsi *status.*—*Graptemys gibbonsi*** was found in many localities where it was previously documented, as well as some new drainages and range extensions. Furthermore, previous surveys may have overlooked many of these 'new' drainage localities because of their small sizes, so it is unknown to what extent *G. gibbonsi* historically occurred within these drainages. The presence of *G. gibbonsi* within the Escatawpa River was unexpected considering that Mount (1975) did not record this species in the Alabama portion of the Escatawpa River. Much like *G. flavimaculata*, the absence of *G. gibbonsi* in the upper parts of the Escatawpa River are likely due to the scant mollusk populations of this river system (Williams et al. 2008; R.L. Jones, pers. comm.). This species was found to be in much smaller drainages (i.e., upper Bucatunna and Long creeks) than was *G. flavimaculata*, but these drainages likely contain smaller populations compared to the larger streams that *G. gibbonsi* inhabits. However, throughout the drainage, there appears to be less clarity to the center of abundance for *G. gibbonsi*, which is in contrast to the relatively consistent numbers of *G. flavimaculata* observed in the Leaf and Pascagoula rivers during the same surveys.

The absence of *G. gibbonsi* from Bouie and Okatoma creeks, where it occurred historically, is clear. We suspect that its absence is likely because of periods of historically poor water quality within these drainages. J.William Cliburn (pers. comm.) noted that these creeks were highly polluted during the 1970's and, therefore, this species may have been locally extirpated in these drainages. This would likely be due to the loss of main prey items, which are primarily mollusks for females (Ennen et al. 2007; Lindeman and Sharkey 2001). These drainages currently appear to be suitable habitat for *G. gibbonsi* and both contained *G. flavimaculata*, but we suspect that *G. flavimaculata* may have persisted in these drainages because of a more generalized diet (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 p.). A similar situation was noted within the Pearl River near Columbia, downstream of a pulp mill, where *Graptemys oculifera* (Ringed Sawback) populations remained stable over 17 years, while *G. gibbonsi* declined over the same time period (Will Selman and Robert L. Jones, unpubl. data). *Graptemys gibbonsi*, therefore, could be more prone to declines due to the loss of mollusk populations that have been documented in Mississippi (Jones et al. 2005).

Graptemys gibbonsi population levels could not be determined in the Chickasawhay River or Lower Pascagoula River because of the difficulty in catching enough individuals for a mark-resight survey. Only two population estimates were completed at the Leaf River site and the population was found to be 2–3.5 times lower than population levels of *G. flavimaculata* in the same river stretch. However, if we extrapolate trapping data from our other two sites that lack population estimates and compare them to our Leaf River population estimate, *G. gibbonsi* likely occurs at much lower levels in the Lower Pascagoula River but at similar levels in the Chickasawhay River. In a related study, *G. gibbonsi* did not bask at lower frequencies than *G. flavimaculata*, with respect to population size (Will Selman, unpubl. data), which indicates that basking surveys are a reliable method to census this species and that results can be directly compared to *G. flavimaculata* results.

Bridge surveys, basking density surveys, and trapping data from the Pascagoula River system indicate that *G. gibbonsi* occurs in much lower abundance throughout the drainage compared to *G. flavimaculata*. In contrast, Tinkle (1958) found these species in nearly similar abundance within the Pascagoula River (21 *G. flavimaculata* to 15 *G. gibbonsi*). In addition, populations of the federally listed as threatened *Graptemys oculifera* were surveyed within the West Pearl River and Bogue Chitto River (Pearl River system) of Louisiana and *G. gibbonsi* populations were in lower numbers in both surveys compared to *G. oculifera* (Dickerson, D.D., and K.J. Reine. 1996. Habitat assessment and relative abundance estimates for the Ringed Sawback Turtle [*Graptemys oculifera*] in dredging sites of the West Pearl River navigation project [Louisiana]. Final Project Report submitted to U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi. 52 p.; Shively, S.H. 1999. *op. cit.*). In addition, over the last 17 years in the Pearl River (vicinity of Columbia, Mississippi), *G. gibbonsi* populations have dropped from 46% of the captured *Graptemys* in 1990 to 17% in 2006; over the same period, *Graptemys oculifera* populations remained stable (Robert L. Jones and William Selman, unpubl. data). In summary, many factors could complicate management decisions for *G. gibbonsi*, including: (1)

smaller population sizes within the Pascagoula and Pearl rivers than either of the threatened species (*G. flavimaculata* and *G. oculifera*); (2) a wider distribution than *G. flavimaculata*; (3) it is a dietary specialist (Ennen et al. 2007; Lindeman and Sharkey 2001); and (4) there are genetic differences among the two major inhabited drainages (Ennen et al., unpubl. data). Therefore, we concur with Lindeman's (1998, 1999) recommendation that *G. gibbonsi* should be federally listed as threatened and be designated as endangered (EN) by the IUCN because both of Lindeman's recommendations were not met, which were larger upstream populations were not found and basking frequency is not lower than *G. flavimaculata* in respect to population size. We also suggest state endangered status for *G. gibbonsi* in Mississippi and Louisiana.

Drainage comparisons.—There appear to be major differences in turtle densities between the two major tributaries of the Pascagoula River system, the Leaf and Chickasawhay rivers. This is supported by our bridge and basking density surveys that found similar densities of both *Graptemys* species in the Pascagoula and Leaf rivers, but much lower densities in the Chickasawhay River. Additionally, our population estimates from the Chickasawhay and Leaf River sites are similar, but the Leaf River site is approximately 121 rkm upstream from the origin of the Pascagoula River, whereas the Chickasawhay River site is only 43.8 rkm. This indicates that good populations of *G. flavimaculata* extend much further up the Leaf River in comparison to the Chickasawhay.

The Leaf River appears to be more similar to the Pascagoula River in that they both have large meander sections with associated nesting sandbars and large amounts of deadwood in cutbank river sections. The Chickasawhay River, on the other hand, is a more north-to-south river and it cuts across rather different geological formations (Bicker 1969) than the Leaf, in particular, rocky strata in the headwaters. In addition, the river level fluctuates quite rapidly in the Chickasawhay in comparison to the Leaf River, likely due to a more restricted channel in the headwaters of the Chickasawhay River. This could lead to swifter river currents, shadier river sections, fewer nesting beaches, and overall lower nutrients within the Chickasawhay River system, which could contribute to the overall lower density of turtles within this river. Support for this conclusion also comes from a study with the Alabama Shad (*Alosa alabamae*), in which was found a lower growth rate and body condition of juvenile shad from the Chickasawhay River in comparison to the Leaf River (Mickle Ph.D. dissertation in prep, University of Southern Mississippi); this fish species feeds partly on aquatic insects, a *Graptemys* prey item.

Conservation recommendations.—We believe that to maintain critical habitat for both species, there should be continued riparian land acquisition along the major tributaries of the Pascagoula (Leaf, Chickasawhay and lower Escatawpa rivers) that harbor *Graptemys* populations. Additionally, continuous efforts should be made to oppose activities that aim to alter the Pascagoula River and its tributaries, including the pending Federal Strategic Petroleum Reserve project. This project plans to withdraw copious amounts (approximately 50 million gallons/day) of water from the Pascagoula River to dissolve a salt cavern for oil storage, as well as carrying (by pipeline) the salt brine by-product to dispose in the Gulf of Mexico. This project has the potential to impact the river system by chronically lowering water levels, by saltwater intrusion in coastal areas due to lower river discharge, through a break in a salt brine-carrying pipeline causing discharge into freshwater systems, or by salt brine influx to the river following brine disposal into the Gulf of Mexico. This project and others like it will likely negatively impact the relatively pristine aquatic communities of this river system.

Appropriate conservation measures for *Graptemys* species within the Pascagoula River system should include protecting and improving habitat suitability of occupied rivers and creeks; discouraging habitat alteration (i.e., de-snagging projects, impoundments, channelization, poorly planned riparian land developments); controlling invasive species; and law enforcement to curtail illegal collection, shooting of turtles, and ATV use on nesting sandbars. We also support any efforts to offer conservation incentive programs to riparian landowners throughout the Pascagoula River system, as well as policies to protect riparian zones. These should decrease the impact of sedimentation on rivers that decreases prey availability and will greatly improve *Graptemys* habitat.

Conclusions and future survey recommendations.—Our data indicate that there has not been an observable range contraction for *G. flavimaculata* since 1970, but possibly a range expansion; it is uncertain if this is a 'real' expansion or an artifact of the more exhaustive survey effort of this study. Additionally, it appears that *G. flavimaculata* populations are more robust than recorded during previous surveys (USFWS 1991; Lindeman 1998, 1999). However, the largest population of *G. flavimaculata* within the Lower Pascagoula River was severely impacted during our study following Hurricane Katrina and many threats continue to exist due to the dramatic human population increase of coastal Mississippi counties. Our data also provide additional support to Lindeman's (1999) recommendation to federally list and upgrade the IUCN status of *G. gibbonsi*. With the little historical information that is available, it is probable that *G. gibbonsi* is declining,

while already having lower range-wide population density than either of the two federally listed *Graptemys* species (*G. flavimaculata* or *G. oculifera*).

Lastly, our study indicates that even though the distribution of a species has been well-studied (i.e., *G. flavimaculata*), additional new populations and/or new drainage localities may exist. Several localities that were deemed too narrow or shallow for *Graptemys* by McCoy and Vogt (1979. *op. cit.*) were found by our surveys to contain *Graptemys* populations. Additionally, four localities for *G. flavimaculata* were thought to not have populations from our bridge survey results (Bucatunna Creek, Thompson Creek, lower Black Creek, and upper Leaf River) and were only later confirmed after basking-density surveys by canoe or boat were completed in the same stretch of river. Even more striking was that *G. gibbonsi* populations were not confirmed by either bridge or basking-density surveys in the Lower Escatawpa, but only after spending multiple days in the area. Therefore, we suggest that rigorous range-wide studies should be initiated for other imperiled southeastern riverine turtle species using multiple methods as in this study to establish baseline distributional and population status data. Surveys should focus on core habitats and existing localities, as well as those areas that have not been surveyed or are believed to be unsuitable habitat. Thereafter, these studies should then be able to provide quality information to individuals making conservation decisions for species or aquatic ecosystems.

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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*. (Photographed by Will Selman)