

## **Hobbseus yalobushensis, a Crayfish of Intermittent Streams: Biotic and Habitat Associations, Life History Characteristics, and New Localities**

Author(s): Susan B. Adams, Blake A. Davis, and Darren A. Miller

Source: The American Midland Naturalist, 179(1):126-149.

Published By: University of Notre Dame

<https://doi.org/10.1674/0003-0031-179.1.126>

URL: <http://www.bioone.org/doi/full/10.1674/0003-0031-179.1.126>

---

BioOne ([www.bioone.org](http://www.bioone.org)) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at [www.bioone.org/page/terms\\_of\\_use](http://www.bioone.org/page/terms_of_use).

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

# Hobbseus yalobushensis, a Crayfish of Intermittent Streams: Biotic and Habitat Associations, Life History Characteristics, and New Localities

SUSAN B. ADAMS<sup>1</sup>

USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research, 1000 Front St.,  
Oxford, Mississippi 38655

BLAKE A. DAVIS<sup>2</sup> AND DARREN A. MILLER

Weyerhaeuser Company, P.O. Box 2288, Columbus, Mississippi 39704

**ABSTRACT.**—*Hobbseus yalobushensis*, the Yalobusha rivulet crayfish, is a species of conservation concern because it is known from only six localities in parts of three central Mississippi counties. No studies have focused on the species since its description in 1989. Our objectives were to: (1) identify additional *H. yalobushensis* localities within a landscape managed intensively for loblolly pine (*Pinus taeda*) production, (2) relate stream size, water quality variables, and flow permanence to species presence or density, (3) characterize the aquatic community in relation to *H. yalobushensis*, (4) better define elements of the species' life history, and (5) compile unpublished *H. yalobushensis* localities from post-1989 collection records. During February and March 2011–2013, we made 56 samples in 24 reaches of 16 streams in Calhoun County, Mississippi. We documented captured crayfishes, fishes, and amphibians and measured habitat and water quality variables. Catch-per-unit-effort (CPUE, number per 100 s electrofished) of *H. yalobushensis* was significantly higher in intermittent than perennial stream reaches. Predatory fishes were the best indicator of *H. yalobushensis* absence, and the CPUE of all fishes had the strongest negative correlations with *H. yalobushensis* CPUE. *Hobbseus yalobushensis* CPUE was also negatively correlated with that of three other crayfishes. At least three age classes were evident based on length-frequency charts. *Hobbseus yalobushensis* has persisted in a landscape of intensively managed loblolly pine where streamside management zones were maintained according to Mississippi forestry best management practices. Future research needs include: evaluating the species' persistence under other land management practices (*e.g.*, row crop agriculture); examining whether predatory fishes and other crayfishes influence the species' distribution; extending sampling to additional intermittent streams to clarify the species' range and distribution; and monitoring long-term population trends.

## INTRODUCTION

Defining a species' conservation status and applying effective and efficient conservation efforts requires information about distribution, abundance trends, habitat needs, autecology, and life history. A recent global assessment of crayfish conservation status categorized 21% of species as “data deficient” (Richman *et al.*, 2015). Most “data deficient” assessments resulted from lack of basic information about species' distributions, abundances, or threats. The percentage of “data deficient” species equaled the combined percentages of species categorized as extinct, critically endangered, and endangered. The highest number of data deficient species globally was from the southeastern U.S.A. (Richman *et al.*, 2015). Indeed, little or nothing is published about the ecology and life history of many crayfish species in Mississippi.

<sup>1</sup> Corresponding author: Telephone: (662) 234-2744 ext.267; e-mail: sadams01@fs.fed.us

<sup>2</sup> Present address: 920 Zinn Chapel Road, Reedsville, West Virginia 26547

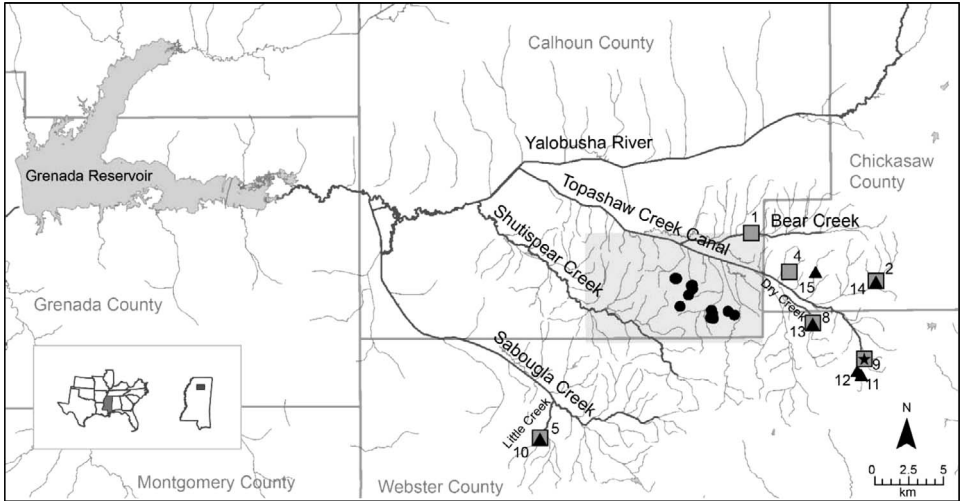


FIG. 1.—New and previously-known but unpublished localities for *Hobbseus yalobushensis*. Grey squares labeled 1-9 align with collection numbers from Fitzpatrick and Busack (1989). Black triangles labeled 10-15 indicate localities from 2009 collections by the US Forest Service and Mississippi Museum of Natural Science (data in Table 2). Black circles indicate localities from this study (see Fig. 2 for detail). Star indicates the type locality. Grey-shaded rectangle delineates area detailed in Figure 2

The crayfish genus *Hobbseus* is nearly endemic to Mississippi, with the ranges of six of the seven species restricted to the state, and the seventh extending into Alabama. *Hobbseus* species are small and relatively short-lived crayfishes, often occurring in temporary waters. Beyond the species descriptions, no further publications have focused on any *Hobbseus* species. In the latest International Union for the Conservation of Nature (IUCN) Red List review (IUCN 2013), three *Hobbseus* species were ranked “data deficient,” three “endangered,” and one “least concern.” Population trends were unknown for all seven species.

*Hobbseus yalobushensis* is the only *Hobbseus* species in the Mississippi River basin, where it is known from only six localities in southern headwater tributaries of the Yalobusha River drainage in three counties (Fitzpatrick and Busack, 1989; Fitzpatrick, 1996) (Fig. 1). Fitzpatrick (2002) also reported the species from Attala and Choctaw counties, Mississippi but gave no localities and referenced no collection records or voucher specimens to corroborate his report. The species is ranked “Endangered” by the IUCN Red List due to a fragmented range  $<5000 \text{ km}^2$  and observed, inferred, or projected continuing decline in the area, extent and/or quality of habitat (IUCN 2013). The species is also ranked “Endangered” by the American Fisheries Society (Taylor *et al.*, 2007), “G2 Imperiled” by NatureServe (2013), and “Tier 1” (in need of immediate conservation action and/or research) by Mississippi (MDWFP, 2005).

*Hobbseus yalobushensis* life history is poorly documented. Individuals used streams from January to June (Fitzpatrick and Busack, 1989), suggesting the species is a secondary burrower. Form I males were collected in March, April, and June, and immature individuals were collected from January through March. The largest individual reported was a female with a carapace length (CL) of 21.8 mm. Form I males ranged from 14.8 to 18.0 mm CL.

During a study on another rare crayfish, *Procambarus lylei*, we found a new *H. yalobushensis* locality in central Mississippi. We expanded our study to learn more about *H. yalobushensis* distribution, habitat associations, ecology, and life history. Our objectives were to: (1) identify additional *H. yalobushensis* localities in a landscape managed intensively for loblolly pine (*Pinus taeda*) production, (2) relate stream size, water quality variables, and flow permanence to species presence or density, (3) characterize the aquatic community in relation to *H. yalobushensis* density, (4) better define elements of the species' life history, and (5) compile unpublished *H. yalobushensis* localities from post-1989 collection records.

#### METHODS

##### STUDY AREA

*Hobbsius yalobushensis* occurs entirely within the Southern Hilly Gulf Coastal Plain ecoregion (65d), characterized by dissected irregular plains, rounded hills with gently to strongly sloping side slopes, and some wide floodplains with broad terraces (Chapman *et al.*, 2004). Streams are low to moderate gradient with sand or clay substrates. Forests are mixed hardwood and pine (*Pinus* spp.), and land uses include primarily mixed forest, pine plantations, pasture, hayfields, and croplands with some cattle production (Chapman *et al.*, 2004).

The study area in southern Calhoun County, Mississippi straddled the divide between Topashaw and Shutispear creeks, southern tributaries of the Yalobusha River in the Yazoo River system (Table 1, Figs. 1, 2). Study reaches were on Weyerhaeuser-owned land in a matrix of intensively-managed loblolly pine plantations. Streamside management zones, maintained according to forestry best management practices for water quality protection (MFC, 2008), were dominated by mature hardwood trees along many reaches and by loblolly pines along several others. Widths of streamside management zones varied based on stream type (perennial, intermittent, ephemeral) and slope (MFC, 2008). Pasture or forest lands belonging to other private landowners bordered several reaches. Nearly all stream channels, except for some extreme headwaters, were incised due to pervasive channel headcutting (Simon, 1989; Hartfield, 1993). Study reaches varied from ephemeral to perennial.

##### EXISTING COLLECTION RECORDS

We requested *H. yalobushensis* records from museums holding Mississippi crayfish collections and from several individuals who collected crayfishes in the state during the past 10 y. We compiled the records along with USDA Forest Service collection records. If necessary the records were georeferenced using Delorme TopoUSA versions 6.0 and 7.0 and hardcopy maps of Mississippi counties from various years. To the extent data were available, we noted other crayfishes, fishes, and amphibians collected with *H. yalobushensis*.

##### FAUNAL SAMPLING

We sampled during February and March, 2011–2013. The goals guiding selection of new study reaches differed between 2011 and 2012. In 2011 we selected stream reaches to test effects of loblolly pine stand management treatments on *P. lylei*, whereas in 2012, we selected additional reaches to improve understanding of *H. yalobushensis* distribution. In 2012 we selected reaches in small streams with defined channels in the extreme headwaters of Topashaw Creek tributaries and slightly larger reaches downstream. Where possible without leaving Weyerhaeuser land ownership, downstream reaches were selected in perennial

TABLE 1.—Locations of study reaches in Calhoun County, Mississippi. Latitude and longitude are in decimal degrees and from the NAD83 map datum. Bold indicates reaches where *Hobbsseus yalobushensis* was captured. Flow class indicates intermittent (I), perennial (P), or ephemeral (E); capital letters indicate flow class known from direct observations or measurements, and lower case indicates flow class inferred from fish community and indicator species analysis or, for reach T-8, by channel conditions. Abbreviations: tributary (trib.), creek (cr.)

Reach code	Location	Latitude	Longitude	Flow class
S1	Trib. to reach S3 stream	33.7545	-89.3013	I
S2	Trib. to reach S3 stream	33.7582	-89.3003	I
S3_down	Trib. to Shutispear Cr.	33.7544	-89.3030	P
S3_up	Trib. to Shutispear Cr.	33.7575	-89.3022	P
S4	Trib. to reach S5 stream	33.7484	-89.2949	I
S5	Trib. to Shutispear Cr.	33.7490	-89.2957	P
T1_down	Trib. in Topashaw Cr. drainage	33.7350	-89.234	P
<b>T1_mid</b>	Trib. in Topashaw Cr. drainage—down- and upstream of weir	33.7350	-89.2326	i?
<b>T1_up</b>	Trib. in Topashaw Cr. drainage—upstream of Weyerhaeuser road crossing.	33.7344	-89.2304	I
<b>T2</b>	Trib. to reach T3 stream	33.7561	-89.2474	I
<b>T3_down</b>	Trib. to Topashaw Cr.	33.7563	-89.2467	i
<b>T3_up</b>	Trib. to Topashaw Cr.	33.7538	-89.2465	I
<b>T4_down</b>	Trib. to Buck Cr.	33.7366	-89.2138	i
<b>T4_up</b>	Trib. to Buck Cr.; down- and upstream of culvert	33.7391	-89.2189	i
<b>T5_down</b>	Trib. in Topashaw Cr. drainage; downstream end at Weyerhaeuser property boundary.	33.7398	-89.2318	i
<b>T5_up</b>	Trib. in Topashaw Cr. drainage; down- and upstream of road.	33.7378	-89.2310	i
T6_down	Trib. in Topashaw Cr. drainage	33.7443	-89.2547	p
<b>T6_up</b>	Trib. in Topashaw Cr. drainage	33.7425	-89.2564	i
<b>T7_down</b>	Trib. to reach T3 stream	33.7607	-89.2589	i
<b>T7_up</b>	Trib. to reach T3 stream	33.7608	-89.2603	i
<b>T8</b>	Headwaters of trib. to reach T6 stream	33.7499	-89.2497	e
T9	Headwaters of trib. to reach T3 stream	33.7537	-89.2551	E-I
T10	Trib. to reach T11 stream.	33.7643	-89.2732	i
T11	Trib. to Topashaw Cr.	33.7685	-89.2725	p

stream segments. Reaches sampled in 2011 were also sampled in 2012 and 2013, and most reaches sampled 2012 were resampled in 2013 (Appendix 1). In total we made 56 samples in 24 reaches of 16 streams.

During each sampling visit, our team quantified crayfishes, fishes, and amphibians. Study reaches were typically 50 to 100 m long, with the longest being 219 m. We initially calculated reach lengths as 40 times the average stream width with a minimum of 160 m and a maximum of 220 m; however, in the very small intermittent streams, the longest segments between substantial changes in channel features (*e.g.*, tributaries, nick points) were often 50–100 m, in which case we sampled the entire distance. In reaches longer than 70 m, we usually divided the sampling into two subreaches and enumerated animals by subreach. We sampled in an upstream direction using a backpack electrofisher (Smith-Root model 12A programmable output wave, battery-powered electrofisher set at 60 Hz, 6-ms pulse width,

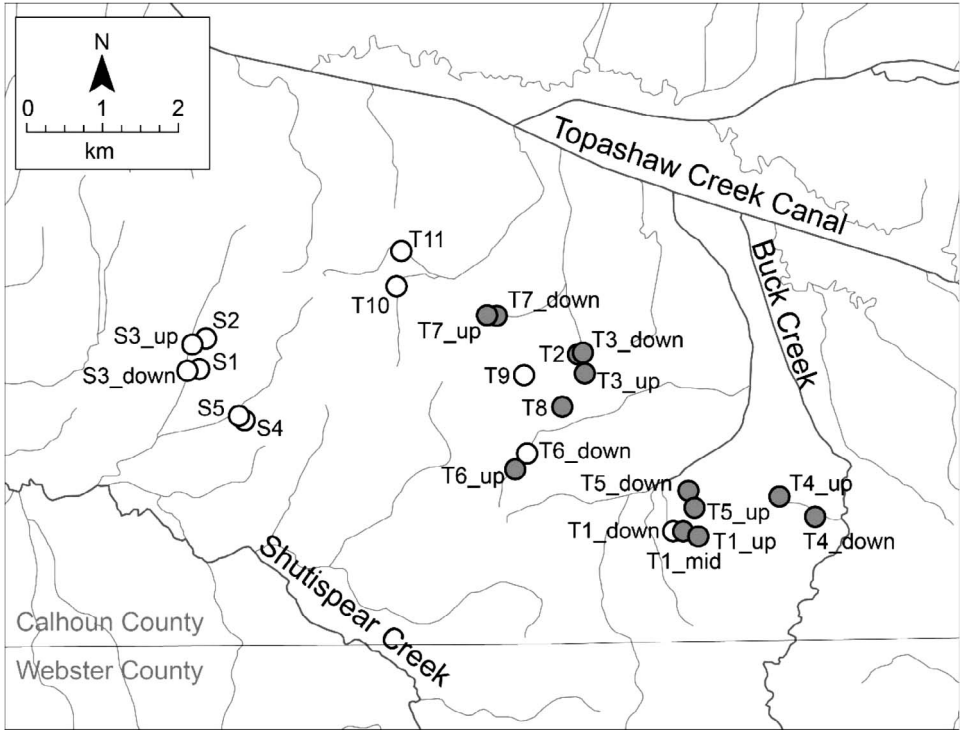


FIG. 2.—Reaches sampled in Calhoun County, Mississippi, during the present study. Map area is indicated by grey rectangle in Figure 1. Grey circles indicate reaches with and white circles those without *Hobbseus yalobushensis*. Reach labels align with reach codes in Table 1

and 400–500 V; Vancouver, Washington) without block nets and two people dipnetting. We attempted to sample all habitat types in a reach uniformly, striving for a minimum electrofishing time of 240 s per reach. Actual electrofishing times were recorded and ranged from 227 to 1570 s per reach (5–13 s/m; mean 6.8 s/m  $\pm$  1.8 SD). One small ephemeral reach lacked a defined channel and was sampled only by dipnetting; therefore, we excluded the reach from quantitative analyses.

We processed most crayfishes, fishes, and amphibians on-site and released them into the subreach where captured. We vouchered specimens of each crayfish species, each fish species seldom-encountered in our broader regional sampling, and individuals of questionable identity (including many age 0 crayfishes). Specimens are to be deposited at the Mississippi Museum of Natural Science (Jackson, Mississippi). We identified nearly all crayfishes to species. For all adults and most juveniles, we recorded sex, male reproductive form, molt condition, and number of chelae. We measured post-orbital carapace length (POCL) to the nearest 0.1 mm using dial calipers and wet weight to the nearest 0.1 g using Ohaus Explorer scales (Parsippany, New Jersey). When large numbers of age 0 crayfish were captured, a subset were processed as above, and the remainder were counted then weighed as a group. In 2012 and 2013, fish were identified to species and measured on a measuring

board to the nearest 5 mm (total length [TL]). We identified amphibians in the field when possible and otherwise photographed them.

#### HABITAT SAMPLING

During each sampling visit, we measured stream size and water quality variables. We measured wetted stream width (m) at four locations spaced equally throughout each subreach. In 2011 we measured thalweg (location of the greatest discharge along a stream cross-section) depth (m) at each width location. In 2012 and 2013, we measured thalweg depth approximately every 3 m throughout each reach. We measured stream temperature (C), dissolved oxygen (DO, percent saturation and mg/l), conductivity (mS/cm), pH, and, in 2013, turbidity (NTU) at one location in each reach using a Hydrolab Quanta Multi-Probe Meter (Hach Company, Loveland, Colorado) calibrated daily for DO and weekly for other measurements.

Where possible, we estimated stream discharge ( $\text{m}^3/\text{s}$ ) in reaches. Five reaches had flumes instrumented to calculate discharge year-round. In several reaches immediately downstream of road crossings, we used a bucket and timer to measure discharge from a perched culvert. In reaches that were deep enough, we estimated discharge using the velocity-area method (Harrelson *et al.*, 1994) with a Marsh–McBirney Flowmate 2000 and topsetting rod (Marsh–McBirney, Frederick, Maryland).

Determining intermittent versus perennial streamflow status of reaches also required several approaches. We visited some reaches during several dry seasons to look for surface water. For reaches with flumes, even when flumes were dry, stream pools sometimes retained water, and in parts of the reaches, surface flow may have persisted. However, our observations indicated prolonged periods of dry flumes indicated drying throughout the reaches. Therefore, we considered a reach intermittent if its flume was dry for >10 consecutive days. For the remaining reaches, we inferred stream permanence based on fish communities (see below). Ephemeral reaches were those that flowed intermittently and lacked a well-defined stream channel.

#### ANALYSES

To compare *H. yalobushensis* sizes in our study (measured as POCL) to those in previous studies (measured as CL or body length [BL]), we made all three measurements on a subset of individuals we collected since 2008 and used linear regression to estimate CL and BL from POCL of the individuals ( $N = 42$ ;  $\text{POCL} > 9$  mm). We analyzed both sexes together. Unless otherwise noted all analyses were conducted in SPSS 22 (IBM Analytics, Armonk, New York). Rather than correcting P-values for multiple tests, we looked for patterns of significance, especially between years (Moran, 2003).

To calculate *H. yalobushensis* length–weight relationships, we regressed log weight on log POCL for all individuals retaining both chelae and weighing > 0.05 g. We tested whether slopes of regression lines for the adult forms (male form I [M1], male form II [M2], and female [F]) were parallel using a general linear model (GLM). Because they were not parallel ( $P < 0.001$  for interaction term in GLM), we regressed each form separately. We determined if sex ratios of adults and juveniles differed significantly from 1:1 using chi-square tests.

We used fish community data to infer intermittent versus perennial flow status in 12 stream reaches. To identify fishes associated with either perennial or intermittent flow, we used indicator species analysis (PC-Ord 6.0, MjM Software, Glenden Beach, Oregon;



McCune and Grace, 2002; McCune and Mefford, 2011) on fish catch-per-unit-effort (CPUE, number per 100 s electrofished) data from reaches with known flow status. We analyzed 2012 and 2013 data separately. Indicator species analysis assesses proportional frequencies and proportional abundances of species between sample groups (e.g., perennial versus intermittent). Indicator values for each species can range from 0 (no value as a group indicator) to 100 (a perfect indicator). A species that is a perfect indicator of a group always occurs in that group and never occurs in the other groups analyzed. To determine the significance level of each species' highest indicator value, we generated P-values from Monte Carlo tests with 5000 randomizations. We used the significant indicators in evaluating fish data from reaches with unknown flow status to infer whether the reaches were intermittent or perennial.

In assessing relationships of *H. yalobushensis* to habitat and biotic associates, we used only data from reaches sampled quantitatively in the Topashaw Creek drainage. Because we did not know why *H. yalobushensis* was evidently absent from the Shutispear Creek drainage, we could not assume that reach-level factors were responsible for its absence there. We also excluded data from 2011 when few reaches in the Topashaw Creek drainage were sampled. Because the remaining sample size was insufficient for ordination approaches to associating habitat variables and crayfish, we conducted univariate analyses. We first compared *H. yalobushensis* CPUE and habitat variables between perennial and intermittent reaches in 2012 using Mann-Whitney U-tests; because only two perennial reaches were sampled in 2013, we did not repeat the analysis for that year. We then examined relationships between *H. yalobushensis* CPUE and the continuous habitat variables (DO, conductivity, pH, width, depth, width:depth ratio, and in 2013, turbidity) using Spearman's rank correlation, analyzing 2012 and 2013 data separately; we tested correlations first using all quantitatively sampled reaches in the Topashaw Creek drainage and then excluding reaches containing predatory fishes.

To determine whether other species were associated with presence or absence of *H. yalobushensis*, we conducted an indicator species analysis including CPUE of the following: each crayfish (excluding *H. yalobushensis*) and fish species; creek chub *Semotilus atromaculatus* >100 mm TL; and combined CPUE of all sunfishes (*Lepomis* spp.), all predatory fishes, all fishes, and both salamander species (*Eurycea cirrigea* and *Eurycea longicauda guttolineata*). We tested 2012 and 2013 data separately. We also tested for rank correlations (Spearman's) between CPUE of *H. yalobushensis* and other crayfish species and fish groups.

## RESULTS

In 2009 *H. yalobushensis* was found at three new localities and was confirmed at, or very near, three localities reported in Fitzpatrick and Busack (1989) (Table 2; Fig. 1). During our study we found the species in eight additional streams (13 reaches; Table 1, Figs. 1, 2), bringing the total number of streams and ditches from which the species is documented to 17. We captured 2225 *H. yalobushensis*, with 81% of those being juveniles captured in 2012 and 2013 (Table 3, Appendix 1). *Hobbseus yalobushensis* CPUE was remarkably similar among years in all except two reaches (T4\_down and T6\_up; Fig. 3, Appendix 2).

## HABITAT

Stream reaches sampled from 2011–2013 varied from ephemeral to small perennial (Table 1). Four reaches were considered intermittent because their flumes had no flow for a maximum of 18 to 63 consecutive days per year. Four reaches without flumes were dry



during at least one visit and were considered intermittent, and four others that were visited several times during dry seasons and always had flow were considered perennial.

We identified significant fish indicators of perennial but not intermittent flow. The blackspotted topminnow *Fundulus olivaceus* and bluntnose minnow *Pimephales notatus* were significant indicators of perennial flow in both 2012 and 2013 (Table 4). Although we did not collect *P. notatus* in Topashaw Creek tributaries during the study, it occurred in the drainage in 2009 (Table 2). Five additional fishes indicated perennial flow in 2013 (Table 4). The only species that had its highest indicator value in intermittent streams both years was the goldstripe darter, *Etheostoma parvipinne*. Both *E. parvipinne* and *S. atromaculatus* were common in intermittent streams, but they also occurred in perennial streams, rendering them poor (and nonsignificant) indicators of flow status.

Based on fish assemblages, we assigned flow status to 11 Topashaw Creek drainage reaches, classifying two as perennial and nine as intermittent; an additional reach could not be classified (*see below*). Of the intermittent reaches, five had no fish in 2012 and 2013 and four had some combination of no fish, *E. parvipinne* alone, or *E. parvipinne* and *S. atromaculatus* in the two years (reach T10 was sampled only in 2012). Of the perennial reaches, one (T11) contained *F. olivaceus* and eight other fish species and the other (T6\_down) contained six fish species in 2012 and two in 2013, although it did not contain *F. olivaceus*. One reach with a flume (T1\_mid) was not classified definitively; the flume did not dry completely, but at least some sections of the reach dried, and although in 2013 the only fish we caught was *E. parvipinne*, in 2012 we also caught *S. atromaculatus*, one *Lepomis cyanellus*, and one *Noturus phaeus*. Because we could not definitively categorize the reach, we excluded it from analyses of perennial versus intermittent reaches.

Although channel size and shape varied among reaches (Appendix 1), all except the ephemeral reaches had incised channels. Channel width : depth ratios ranged from 4.4–12.5 ( $6.7 \pm 1.42$  SD). Substrate consisted of some combination of soft clay, hard clay, and sand in all reaches. Leaf packs and woody debris were scattered about most reaches in varying amounts but were not quantified, and aquatic vegetation was absent, or nearly so, in all reaches.

Reaches containing *H. yalobushensis* during sampling in 2012–2013 had the following characteristics. Wetted widths ranged from 0.4–1.6 m ( $0.92 \pm 0.29$ , mean  $\pm$  SD) and thalweg depths from 8–38 cm ( $13.9 \pm 4.27$ ). Instantaneous stream discharges on the day of sampling ranged from  $2.90 \times 10^{-4}$ – $4.41 \times 10^{-3}$  m<sup>3</sup>/s ( $2.08 \times 10^{-3} \pm 1.35 \times 10^{-3}$ ) in the 27% of *H. yalobushensis* reaches where we were able to measure it. Water temperatures varied from 5.8–17.6 C ( $10.8 \pm 2.94$ , mean  $\pm$  1 SD), DO saturation usually exceeded 65% but ranged from 35–95% ( $77.0 \pm 17.74$ ; DO mg/l: 4.3–11.6;  $8.8 \pm 2.19$ ). The streams had low specific conductivity, 0.03–0.18 mS/cm ( $0.07 \pm 0.42$ ), typical of headwater streams in the ecoregion, and pH ranged from 5.63–7.00 ( $6.19 \pm 0.354$ ). Turbidity in 2013 was highly variable (10.5–87.4 NTU,  $31.6 \pm 21.85$ ). Reach T6\_up was unique in that the trees in the stream management zone consisted almost entirely of loblolly pines rather than hardwoods; therefore, pine needles replaced leaf packs in the reach. Compared to all reaches with *H. yalobushensis*, T6\_up had near-average CPUE of *H. yalobushensis* in 2012 and the highest CPUE in 2013 (Fig. 3).

*Hobbseus yalobushensis* CPUE was higher in intermittent (median = 5.2, N = 14) than perennial stream reaches (median = 0.0, N = 3; Mann-Whitney U-test,  $P < 0.02$ ) in the Topashaw Creek drainage in 2012; we did not find the species in the three perennial reaches sampled in the drainage. Perennial reaches were deeper (median = 20 cm) than intermittent reaches (median = 13 cm; Mann-Whitney U-test,  $P < 0.01$ ), but no other

TABLE 2.—Unpublished localities for *Hobbseus yalobushensis* known prior to this study and previously published localities resampled in 2009. All localities are in Mississippi. Coordinates are in decimal degrees using map datum NAD83. Number and forms of *H. yalobushensis* are indicated (abbreviations as in Table 3), as are other crayfish and fish species from the same collection, if known. Under Nearby Localities, “F&B” indicates Fitzpatrick and Busack (1989), and numbers of nearby sites from that paper are noted

Map label	Waterbody	Location	County	Latitude	Longitude	Date collected
10	Little Creek trib. floodplain	On E side of MS Hwy. 404 just N of jct. with CR 18; N of trib. in woodland pools. T21N R9E NW4 Section 28.	Webster	33.657	-89.367	3/11/2009
11	East Fork Topashaw Creek trib.	At unnamed gravel road diverging to S from CR 165 (W Griffin Rd.). 7.6 Km NNE of Clarkson, 6.7 Km SW of Mantee.	Webster	33.697	-89.115	4/23/2009
12	West Fork Topashaw Creek trib.	At unnamed gravel road diverging to S from CR 165 (W Griffin Rd.). 7.8 Km NNE of Clarkson, 6.8 Km SW of Mantee.	Webster	33.700	-89.118	4/23/2009
13	Dry Creek	Upstream of CR 266 (aka Pepper Road)	Webster	33.732	-89.152	4/23/2009
14	Topashaw Creek	Upstream of MS Hwy. 340.	Chickasaw	33.759	-89.104	4/23/2009
15	Topashaw Creek Canal trib.	Upstream of CR 407; 1.71 km W of jct. with MS Hwy. 341	Chickasaw	33.765	-89.15	4/23/2009

environmental variables differed significantly between the categories (P-values for all tests > 0.05).

We did not find strong evidence of correlation between *H. yalobushensis* CPUE and the continuous habitat variables we measured. In 2012 CPUE was significantly correlated with conductivity when all Topashaw sites were included (Spearman's rho = 0.55,  $P < 0.03$ ,  $n = 17$ ) but not when only predator-absent reaches were included (Spearman's rho = 0.36,  $P < 0.29$ ,  $n = 11$ ). Conductivities in predator-present reaches (0.035–0.042 mS/cm) were in the low end of the range of conductivities in predator-absent reaches (0.032–0.131). No other correlations were significant in 2012. In 2013 no correlations were significant with all reaches included, but when only predator-absent reaches were included, CPUE was negatively correlated with turbidity (Spearman's rho = -0.67,  $P < 0.04$ ,  $n = 10$ ).

TABLE 2.—Extended

Nearby localities	Collectors	Catalog #	# forms captured	Other crayfishes	Comments
F&B: 5-7	Jones, Peyton, Murray, Copley	MMNS 2291	5-M1, 2-M2, 6-F, 1-J	<i>Cambarus striatus</i> , <i>Procambarus acutissimus</i> , <i>P. lylei</i>	
New	JG McWhirter, AM Carson, MR Bland	USFS 4791	3-M2, 8-F	<i>C. striatus</i> , <i>Faxonius etnieri</i>	Riparian hardwood trees. Big meanders. No fish caught. Salamanders.
New	JG McWhirter, AM Carson, MR Bland	USFS 4894	3-M2, 1-F	<i>C. striatus</i> , <i>P. hayi</i>	Riparian hardwood and conifer trees. Fish: <i>Semotilus atromaculatus</i> . Salamanders.
F&B: 8	JG McWhirter, AM Carson, MR Bland	USFS 4893	2-M2, 3-F, 3-JF	<i>C. striatus</i> , <i>F. etnieri</i> , <i>P. hayi</i>	Fishes: <i>Luxilus chrysocephalus</i> , <i>S. atromaculatus</i> , <i>Lepomis macrochirus</i> , <i>Erimyzon claviformis</i> , <i>Etheostoma nigrum</i> , <i>Fundulus olivaceus</i> , <i>Pimephales notatus</i> . Frogs.
F&B: 2	JG McWhirter, AM Carson, MR Bland	USFS 4793	12-M2, 5-F	<i>C. striatus</i> , <i>P. hybus</i>	No fish caught. Tadpoles.
New	JG McWhirter, AM Carson, MR Bland	USFS 4797	1-F	<i>C. striatus</i> , <i>F. etnieri</i> , <i>P. hayi</i>	Fishes: <i>F. olivaceus</i> , <i>S. atromaculatus</i> , <i>Lepomis cyanelus</i> , <i>L. macrochirus</i> .

## BIOTIC ASSOCIATES

When fishes were present, CPUE of *H. yalobushensis* was low, and when predatory fishes were present, *H. yalobushensis* was absent (e.g., Fig. 4). The strongest indicator of *H. yalobushensis* absence both years was the CPUE of all fish predators combined; other significant indicators both years were CPUE of *S. atromaculatus* and of all fishes (Table 5). Additional species or groups were significant indicators in 1 y (Table 5). The only taxa that had their highest indicator values in the *H. yalobushensis* present group were the crayfish *Procambarus hybus* in both years and salamanders (*Eurycea* spp.) in 2012, though neither were significant indicators (Table 5). *Procambarus hybus* occurred only in reaches with *H. yalobushensis*, but it was also absent from many *H. yalobushensis* reaches (Appendix 2). Larval and adult salamanders often occurred in reaches with *H. yalobushensis* but were also common in other reaches.

TABLE 3.—Numbers of *Hobbsseus yalobushensis* collected by reach, year, and form. Dashes indicate not sampled. Abbreviations: M1 = form I male, M2 = form II male, F = female, JM = juvenile female, JF = juvenile female, J = juvenile. Significant biases in juvenile sex ratios are indicated by asterisks (chi-square tests; \* = P-value < 0.05, \*\* = P < 0.01; tested only for collections with n > 25 juveniles in which all juveniles were sexed)

Reach	2011					2012						2013					
	M1	M2	F	JM	JF	M1	M2	F	JM	JF	J	M1	M2	F	JM	JF	J
T1_mid	0	0	2	1	0	1	0	0	0	0	0	1	0	0	0	1	0
T1_up	—	—	—	—	—	1	2	0	3	5	0	1	1	1	9	12	0
T2	0	2	3	2	2	0	0	4	12	12	0	0	0	1	1	2	43
T3_down	0	0	4	0	0	1	2	3	0	0	0	0	0	6	2	5	3
T3_up	1	1	4	3	0	0	2	4	1	0	71	0	2	8	20	24	49
T4_down	—	—	—	—	—	23	32	71	115	127	184	1	0	2	39	34	0
T4_up	—	—	—	—	—	3	48	75	48	43	167	2	5	10	78	111*	0
T5_down	—	—	—	—	—	0	0	4	25	8**	0	0	0	0	17	21	0
T5_up	—	—	—	—	—	3	1	8	25	26	1	0	1	5	33	27	0
T6_up	—	—	—	—	—	2	13	14	2	1	64	7	2	8	14	16	217
T7_down	—	—	—	—	—	1	0	0	7	3	0	0	0	1	4	10	0
T7_up	—	—	—	—	—	0	1	1	3	1	0	0	2	1	1	4	0
T8	—	—	—	—	—	0	0	0	3	1	0	2	6	9	23	17	0

*Hobbsseus yalobushensis* CPUE was most strongly negatively correlated with CPUE of all fishes in both years and was negatively correlated with predatory fishes in 2012. In both years the CPUE of *H. yalobushensis* was also negatively correlated with CPUE of three crayfishes: *Cambarus striatus*, *Faxonius etnieri* (formerly, *Orconectes etnieri*, see Crandall and DeGrave, 2017), and *Procambarus hayi* (Table 6).

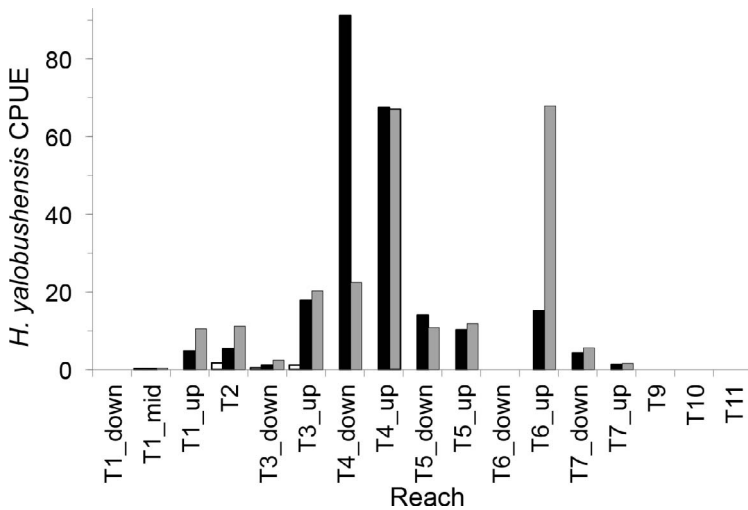


FIG. 3.—Catch-per-unit-effort (number per 100 s electrofished) of *Hobbsseus yalobushensis* by reach and year (2011 – white; 2012 – black; 2013 – grey). Most reaches were not sampled in 2011 (see Table 3)

TABLE 4.—Fish indicators of stream permanence in 2012 and 2013. Observed indicator values (Obs. IV) and P-values for each species and year. P-values indicate the proportion of 5000 randomized trials that had an IV equal to or exceeding the observed IV. “Max group” indicates the group for which each species had its highest IV (0 = intermittent flow; 1 = perennial flow). Species with a single occurrence were excluded. Monte Carlo tests for overall significance of observed IV for fishes were significant both years (2012, P = 0.01; 2013, P = 0.05)

Species	Max group	2012 Obs. IV	P-values	2013 Obs. IV	P-values
<i>Etheostoma chlorosoma</i>	1	—	—	25.0	0.40
<i>E. nigrum</i>	1	50.0	0.11	50.0	0.13
<i>E. parvipinne</i>	0	66.0	0.08	43.2	0.45
<i>E. proeliare</i>	1	45.0	0.19	66.4	0.10
<i>E. zonistium</i>	0	10.0	1.00	—	—
<i>Erimyzon claviformis</i>	1	64.0	0.14	52.3	0.28
<i>Fundulus olivaceus</i>	1	75.0	<b>0.03</b>	75.0	<b>0.03</b>
<i>Lampetra aepyptera</i>	1	25.0	0.37	75.0	<b>0.03</b>
<i>Lepomis cyanellus</i>	1	59.5	0.07	100.0	<b>0.00</b>
<i>L. macrochirus</i>	1	—	—	25.0	0.40
<i>L. marginatus</i>	1	25.0	0.36	—	—
<i>L. megalotus</i>	1	50.0	0.11	75.0	<b>0.03</b>
<i>Luxilus chrysocephalus</i>	1	50.0	0.11	75.0	<b>0.03</b>
<i>Lythrurus umbratilis</i>	1	50.0	0.11	75.0	<b>0.03</b>
<i>Noturus gyrinus</i>	1	25.0	0.37	—	—
<i>N. phaeus</i>	1	50.0	0.11	25.0	0.40
<i>Pimephales notatus</i>	1	75.0	<b>0.03</b>	74.7	<b>0.03</b>
<i>Semotilus atromaculatus</i>	1	42.4	0.77	42.3	0.93

LIFE HISTORY

Across all 3 y, only two form I males were smaller than 11.0 mm POCL (10.2 mm, not weighed; and 10.9 mm, 0.8 g), but form I males constituted 42% and 59% of males in the size ranges 11.0–11.4 mm and 11.5–11.9 mm POCL, respectively (Fig. 5). An apparent age

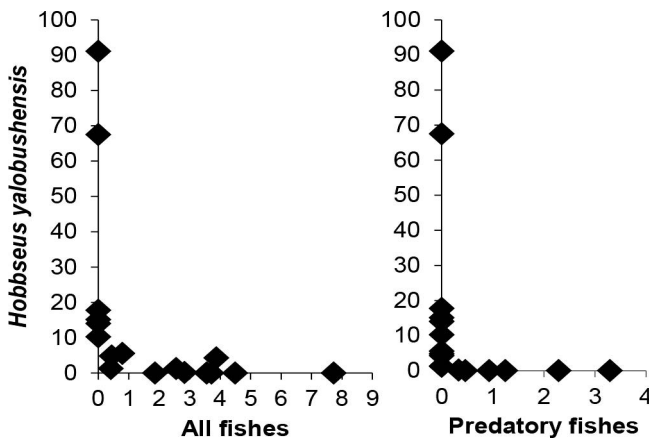


FIG. 4.—Catch-per-unit-effort (number per 100 s electrofished) of *Hobbsseus yalobushensis* versus all fishes and potentially predatory fishes in the Topashaw Creek drainage, Mississippi, in spring 2012

TABLE 5.—Indicator species analysis results showing predictors (species or species groups) of the presence or absence of *Hobbsius yalobushensis*. Sample groups based on presence or absence of *H. yalobushensis* (number of reaches, n). Relative abundance (rel. abundance) indicates percent of the total abundance of a predictor occurring in each sample group. Relative frequency (rel. frequency) indicates the percent of reaches in each group occupied by the predictor. Indicator value (IV) incorporates both metrics. Maximum group (max. group) indicates the group (0 = *H. yalobushensis* absent, 1 = present.) with the highest IV for each predictor. The P-value is the proportion of randomized trials with an IV equal to or exceeding the highest observed IV. *Eurycea* spp. includes *E. cirrigea* and *E. longicauda guttolineata*. *Lepomis* spp. includes all *Lepomis*. Predatory fishes includes all *S. atramaculatus* >100 mm, *L. cyanellus*, *L. gulosus*, and *N. phaenus*

Predictor	2012					2013								
	Rel. abundance		Rel. frequency		Max. group	IV	P	Rel. abundance		Rel. frequency				
	Present (12)	Absent (5)	Present (12)	Absent (5)				Present (12)	Absent (2)	Present (12)	Absent (2)			
<b>Grayfishes</b>														
<i>Cambarus stritatus</i>	40	60	67	100	0	59.7	0.23	23	77	67	100	0	76.8	0.11
<i>Faxonius atrineri</i>	43	57	42	100	0	57.3	0.22	34	66	33	100	0	66.0	0.10
<i>Procamburus hayi</i>	33	67	17	60	0	40.0	0.23	5	95	17	100	0	95.1	<b>0.01</b>
<i>P. lybus</i>	100	0	42	0	1	41.7	0.23	100	0	42	0	1	41.7	0.51
<i>P. lylei</i>	0	100	0	20	0	20.0	0.29	—	—	—	—	—	—	—
<b>Salamanders</b>														
<i>Eurycea</i> spp.	80	20	50	60	1	40.1	0.43	25	75	42	100	0	75.5	0.07
<b>Fishes</b>														
<i>Erimyzon claviformis</i>	0	100	0	40	0	40.0	0.07	0	100	0	50	0	50.0	0.14
<i>Etheostoma artesiaae</i>	0	100	0	20	0	20.0	0.29	—	—	—	—	—	—	—
<i>E. nigrum</i>	0	100	0	20	0	20.0	0.29	—	—	—	—	—	—	—
<i>E. parvipinne</i>	61	39	42	80	0	31.3	0.77	59	41	33	50	0	20.3	1.00
<i>E. prockare</i>	0	100	0	40	0	40.0	0.07	—	—	—	—	—	—	—
<i>E. zonistium</i>	0	100	0	20	0	20.0	0.29	—	—	—	—	—	—	—
<i>Fundulus olivaceus</i>	0	100	0	20	0	20.0	0.29	—	—	—	—	—	—	—
<i>Lepomis cyanellus</i>	1	99	8	60	0	59.3	<b>0.01</b>	0	100	0	50	0	50.0	0.15
<i>L. gulosus</i>	0	100	0	20	0	20.0	0.29	—	—	—	—	—	—	—
<i>L. megalotis</i>	0	100	0	20	0	20.0	0.29	—	—	—	—	—	—	—
<i>Noturus phaeus</i>	7	93	8	60	0	55.9	<b>0.03</b>	—	—	—	—	—	—	—
<i>Semotilus atromaculatus</i>	18	82	17	60	0	49.1	<b>0.05</b>	10	90	25	100	0	90.2	<b>0.03</b>
<i>S. atromaculatus</i> >100 mm	0	100	0	40	0	40.0	0.06	34	66	17	50	0	33.0	0.38

TABLE 5.—Continued

Predictor	2012						2013							
	Rel. abundance			Rel. frequency			Rel. abundance			Rel. frequency				
	Present (12)	Absent (5)	P	Present (12)	Absent (5)	Max. group	Present (12)	Absent (2)	P	Present (12)	Absent (2)	Max. group		
<i>Lepomis</i> spp.	1	99	0	8	60	0	0	100	<b>0.01</b>	0	50	0	14.8	0.15
Predatory fishes	2	98	0	8	100	0	6	94	<b>0.00</b>	17	100	0	93.7	<b>0.03</b>
All fishes	18	82	0	50	100	0	15	85	<b>0.00</b>	42	100	0	85.2	<b>0.03</b>

TABLE 6.—Spearman's rank correlations among CPUE of crayfish species and fish groupings. Results from 2012 (n = 17) are above the diagonal and from 2013 (n = 14) below. Spearman's rho (P-value) given with significant values (P < 0.05) in bold. Predatory fishes as in Table 5

	<i>H. yalobushensis</i>	<i>C. striatus</i>	<i>F. etnieri</i>	<i>P. hayi</i>	<i>P. hybus</i>	Predatory fishes	Total fishes
<i>H. yalobushensis</i>	—	<b>-0.53</b> (0.03)	<b>-0.59</b> (0.01)	<b>-0.52</b> (0.03)	0.41 (0.10)	<b>-0.84</b> (0.00)	<b>-0.86</b> (0.00)
<i>C. striatus</i>	<b>-0.68</b> (0.01)	—	<b>0.64</b> (0.01)	<b>0.52</b> (0.03)	-0.29 (0.26)	0.38 (0.14)	<b>-0.50</b> (0.04)
<i>F. etnieri</i>	<b>-0.62</b> (0.02)	<b>0.63</b> (0.02)	—	0.48 (0.05)	-0.06 (0.83)	0.33 (0.20)	0.48 (0.05)
<i>P. hayi</i>	<b>-0.72</b> (0.00)	<b>0.70</b> (0.00)	<b>0.73</b> (0.00)	—	-0.02 (0.93)	<b>0.54</b> (0.03)	<b>0.68</b> (0.00)
<i>P. hybus</i>	0.14 (0.64)	-0.02 (0.94)	-0.27 (0.35)	-0.20 (0.50)	—	-0.45 (0.07)	-0.17 (0.51)
Predatory fishes	-0.44 (0.12)	0.08 (0.79)	0.35 (0.22)	0.38 (0.18)	-0.12 (0.69)	—	<b>0.74</b> (0.00)
Total fishes	<b>-0.75</b> (0.00)	0.35 (0.22)	0.40 (0.16)	0.47 (0.09)	-0.06 (0.83)	<b>0.70</b> (0.00)	—



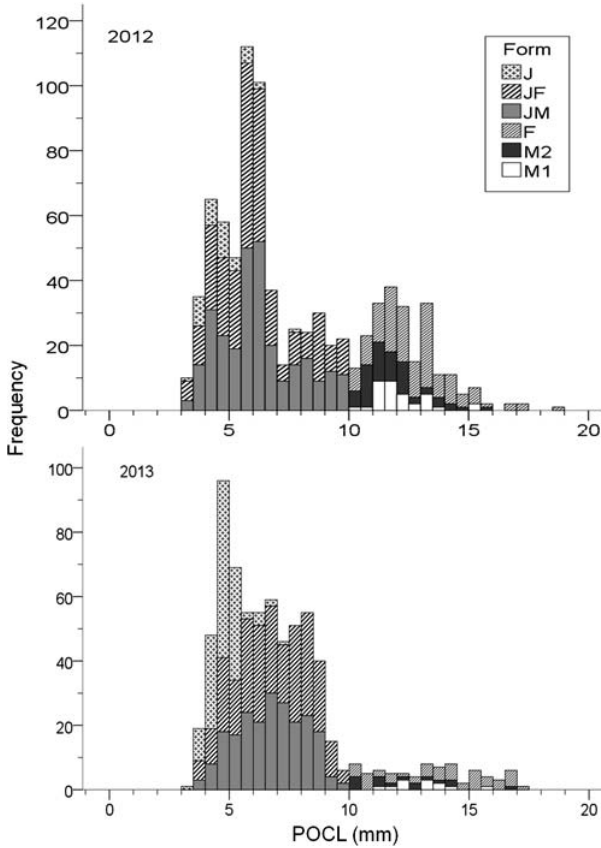


FIG. 5.—Length-frequency histograms of *Hobbseus yalobushensis* from 2012 and 2013 in Calhoun County, Mississippi. Crayfish form abbreviations: M1—form I male, M2—form II male, F—female, JM—juvenile male, JF—juvenile female, J—juvenile

class break near 10 mm POCL was also evident each year (Fig. 5); therefore, we used 10.0 mm as the dividing point between juvenile and adult males. We caught no females with glair glands, eggs, or juveniles attached and had no indication of female size at maturity; therefore, we again relied on the age-class break and designated 10.0 mm as the minimum size of adult females. Visual examination of the length-frequency distributions (Fig. 5) suggested the presence of at least three age classes.

Sex ratios were biased for adults but not juveniles when all samples with appropriate data were combined. For adults the male to female ratio was significantly biased toward females (0.66:1.00,  $\chi^2 = 14.7$ ,  $df = 1$ ,  $P < 0.01$ ,  $n = 343$ ). The juvenile sex ratio was unbiased ( $\chi^2 = 0.0$ ,  $df = 1$ ,  $P < 0.97$ ,  $n = 443$ ) for the combined seven collections in which we captured >25 juveniles and determined the sex of all of them, although the juvenile sex ratio was female-biased in one collection and male-biased in another (Table 3).

TABLE 7.—Weight-length regression results for *Hobbsseus yalobushensis* retaining both chelae and weighing  $\geq 0.05$  g. Sample sizes, regression coefficients (95% confidence intervals), and  $R^2$  for the linear regressions of  $\log_{10}(\text{Weight})$  on  $\log_{10}(\text{POCL})$  for each adult form and for all individuals combined. For every coefficient,  $P = 0.000$

Form	N	Constant (95% CI)	Slope (95% CI)	$R^2$
F	131	-3.251 (-3.368, -3.134)	2.945 (2.840, 3.050)	0.960
M1	33	-3.123 (-3.386, -2.860)	2.877 (2.637, 3.118)	0.951
M2	43	-3.077 (-3.375, -2.779)	2.803 (2.526, 3.080)	0.911
all	521	-3.204 (-3.261, -3.147)	2.907 (2.848, 2.965)	0.948

The relationships between length measurements (POCL versus CL and BL) were linear. The following length conversions applied to individuals  $>9$  mm POCL:

$$\text{CL} = (1.2415) (\text{POCL}) - 0.1466; R^2 = 0.99,$$

$$\text{BL} = (2.4119) (\text{POCL}) + 1.2656; R^2 = 0.97.$$

The weight-length relationship for all individuals combined was

$$W = 0.0006L^{2.907},$$

where  $W$  = weight (g) and  $L$  = length (POCL, mm). Weight-length relationships for the various adult forms of *H. yalobushensis* differed slightly (Table 7). Form I males were often the heaviest individuals of a given length, due primarily to their larger chelae, but females reached the largest sizes overall. The largest individual captured was female (POCL = 18.8 mm; lengths estimated from the regression equations: CL = 23.2 mm; BL = 46.6 mm). Due to a scale malfunction the female was not weighed, but we estimated her weight at 3.2 g (equation for females in Table 7). The heaviest female we weighed was 2.5 g and 17.0 mm POCL. The longest male was form II (POCL = 16.9 mm; weight = 2.0 g, with two regenerated chelae), and the heaviest male was form I (POCL = 15.5 mm; weight = 2.3 g). Form I males ranged from 10.2–15.5 mm POCL (estimated 12.5–19.1 mm CL).

## DISCUSSION

During February and March, *H. yalobushensis* CPUE was highest in intermittent streams with defined channels and wetted widths  $\leq 1$  m. Although *H. yalobushensis* occurs in larger streams, our results confirm Fitzpatrick's (1996) observation that the species "seems to prefer small watercourses with firm" substrates. Fish predation pressure may limit *H. yalobushensis* abundance in perennial streams. Although the hypothesis remains untested, three findings support it: (1) the best indicator of *H. yalobushensis* absence was the CPUE of predatory fishes, (2) in the year we sampled the most perennial streams, *H. yalobushensis* CPUE was negatively correlated with the CPUE of predatory fishes ( $r = -0.84$ ), and (3) no measured habitat variable other than stream permanence was consistently associated with *H. yalobushensis* CPUE. However, these results are correlative, and causality cannot be determined based on our data. Other possible explanations of the distribution include: (1) the presence of fish predators may alter *H. yalobushensis* behavior, rendering them less susceptible to capture, (2) *H. yalobushensis* may move into intermittent reaches to reproduce, moving back into perennial streams as the former dry, or (3) other crayfishes, instead of or in addition to fishes, may restrict *H. yalobushensis* primarily to intermittent streams.

Fish predation on crayfishes is well-documented in lakes and larger streams (Nyström, 2002), and stream crayfish populations responded positively to loss or reduction of fish populations due to drought (Adams and Warren, 2005) and acidification (Seiler and Turner, 2004). We collected fishes that are known crayfish predators, including *N. phaeus*, *S. atromaculatus* >100 mm, adult (>102 mm) *Lepomis gulosus* and *L. cyanellus* (Ross, 2001), and *Lepomis macrochirus* >50 mm (Boschung and Mayden, 2004). In 2012 we collected one form I male *H. yalobushensis* in a reach (T1\_mid) with a *N. phaeus* (100 mm), but *H. yalobushensis* was absent from all other reaches containing *L. cyanellus*, *L. gulosus*, *N. phaeus*, or *S. atromaculatus* >100 mm. The lack of correlation between *H. yalobushensis* and predatory fishes in 2013 was probably due to low statistical power. We sampled only two perennial streams in the Topashaw Creek drainage that year and collected few predatory fishes.

Behavioral changes in the presence of fish predators could have contributed to the observed *H. yalobushensis* distributions, similar to responses in other systems (Stein and Magnuson, 1976; Collins *et al.*, 1983; Adams, 2007). Burrows provided the only uniformly-available refugia from predation that would have allowed crayfishes to consistently and completely avoid our sampling efforts. However, if fish predators caused crayfishes to retreat to burrows during the day, crayfish growth and population dynamics would have reflected that lack of foraging time, presumably resulting in lower densities in perennial than intermittent streams. While we cannot discount the possibility of seasonal migrations, such migrations may expose *H. yalobushensis* to even greater predation risk.

The possibility that other crayfishes were responsible for the observed distribution is plausible. The CPUE of *H. yalobushensis* was negatively correlated with that of three crayfishes, *C. striatus* and *P. hayi* being the most abundant. In some reaches that were divided into subreaches, the CPUE of *H. yalobushensis* and *C. striatus* were inversely related, and the subreach with higher *H. yalobushensis* CPUE was not always the upstream-most subreach. Both *C. striatus* and *P. hayi* become considerably larger than *H. yalobushensis*, although we collected primarily juveniles. Their larger sizes could be advantageous both in persisting with fish predators (Nyström, 2002; Adams, 2007) and competing with and preying upon *H. yalobushensis*. Both *C. striatus* and *P. hayi* can be abundant in intermittent streams (Adams, pers. obs.); therefore, perhaps the more interesting question is, "Why did *H. yalobushensis* numerically dominate many intermittent reaches?" The answer may lie in subtleties of flow duration, water table depth, and food availability rather than in the simpler assessment of whether or not a stream was intermittent. Although the mechanisms underlying the distributions of these crayfishes are unknown, intermittent streams are clearly of great importance to *H. yalobushensis*.

Incorporating a greater range of stream sizes (including more ephemeral and perennial streams) and better documenting flow duration in future *H. yalobushensis* studies may help discern relationships among species and between flow duration and *H. yalobushensis* density. In one ephemeral reach, the upstream-most *H. yalobushensis* coincided with the beginning of the defined channel; upstream we collected only *P. hybus*. On the downstream end, including more perennial reaches would increase statistical power for detecting relationships of *H. yalobushensis* to flows, fish predators, or other crayfishes. For example the 2009 records indicated *H. yalobushensis* occurring at least occasionally with *F. olivaceus* and *P. notatus*, indicators of perennial flow, although it did not in our study. Also, the species was documented with *Procambarus ouachitae* (Fitzpatrick and Busack, 1989), a crayfish typically restricted to perennial streams.

The stream habitat variables we measured provided little insight into factors influencing the species' distribution. We attributed the large variation in water physicochemical variables

measured during sampling (Appendix 1) primarily to the vicissitudes of spring weather in the region. Given that no habitat variable was correlated with *H. yalobushensis* CPUE in both 2012 and 2013, the significant results may have been due to chance. For example the negative correlation between turbidity and CPUE in 2013 probably reflected sample timing in relation to rainstorms more than a causal relationship. *Hobbsseus yalobushensis* tolerated low DO (down to 4.3 mg/L or 35% saturation) at least for short periods. Indeed, the collection with the lowest DO measurement had the highest *H. yalobushensis* CPUE (due to large numbers of small juveniles). However, high abundance in reaches with poor water quality may reflect predator avoidance strategies rather than habitat preferences (Seiler and Turner, 2004).

Most study reaches were extremely incised, and channel incision influences stream flow in complex ways (Poff *et al.*, 1997). It is unclear how stream flows in the altered channels with reduced connection to the floodplain have influenced *H. yalobushensis* population sizes, and unfortunately, we are unlikely to find study streams within the species' range that are not incised.

We added the following to the list of crayfishes occurring with *H. yalobushensis*: *Procambarus acutissimus*, *P. lylei*, *F. etnieri*, and *P. hybus* (Table 2). One juvenile *Faxonius* could not be identified to species, although it was not *F. etnieri*. We do not know if either of these *Faxonius* taxa are the same as the "undescribed" species from this genus of Fitzpatrick and Busack (1989). *Faxonius etnieri* is a species complex, and we use the specific epithet in the sense of Taylor *et al.*, (2014), acknowledging populations in the Yalobusha River drainage may eventually be described as a new species.

Life history conclusions were based primarily on inferences. Length-frequency histograms indicated that at least 3 y classes were present. The data came from multiple samples and include variation due to differences in hatch timing, growth rates, and sampling dates among samples. However, length-frequency histograms for individual samples that had large numbers of *H. yalobushensis* also indicated at least three age classes, with few individuals surviving to the oldest age class. The smallest *H. yalobushensis* were captured near the start of each sampling season, including 3.1–3.3 mm POCL individuals on 15 February 2012 and a 3.4 mm POCL individual on 22 February 2013. Therefore, eggs probably hatched in late January or early February. Important life-history questions (*e.g.*, timing and location of mating, egg incubation, and fecundity) still remain, because we found no females with glair glands, attached eggs, or attached juveniles. Egg incubation may occur in burrows (McClain, 2010), but mid-winter sampling should be conducted to confirm this.

Crayfish sizes were similar to those previously reported. Using our size conversions, we estimated that the largest individual was 1.4 mm CL larger than the maximum size previously reported and that form I male CLs ranged from 2.3 mm smaller to 1.1 mm larger than those previously reported (Fitzpatrick and Busack, 1989).

Future research should facilitate conservation planning for *H. yalobushensis*. Because stream sampling often focuses on perennial streams, species largely restricted to small, intermittent and ephemeral streams are often overlooked (Lyons, 2006). The distribution of *H. yalobushensis* could be clarified by late-winter to early-spring sampling of intermittent streams with forested riparian areas both within and beyond the known range limits. Long-term population monitoring in several sites would reveal population trends. Monitored sites should represent a range of habitat conditions and include sites with high and low *H. yalobushensis* densities. We showed that *H. yalobushensis* persisted in a landscape of intensively managed pine stands where streamside management zones were maintained. We now recommend evaluating how *H. yalobushensis* densities are influenced by streamside

management zone characteristics and by various land uses, including pasture and row crop. Assessing the importance of roadside ditches and ephemeral ponds to the species may also prove important for conservation. Investigating site-level soil types and historical land uses in relation to the species' density may reveal why *H. yalobushensis* is apparently absent from the Shutispear Creek drainage. Sampling the species in mid-winter and in burrows is expected provide more complete life history information. Finally, better understanding of how fish predation, interactions with other crayfishes, and flow duration relate to the species' density and influence distributions in larger streams will clarify which stream types are essential for the species' persistence.

*Acknowledgments.*—Funding was provided by Weyerhaeuser Company (USFS Collection Agreement # 11-CO-11330127-010) and by the US Forest Service Southern Research Station, Center for Bottomland Hardwoods Research. For assistance with sampling, we thank ZC Barnett, MR Bland, JG McWhirter, VD Reithel, and D Warren (USFS), AC Carson (formerly USFS), and CN Mangum (Weyerhaeuser). JG McWhirter identified most fishes and G Henderson (USFS) created maps. J. Nettles (Weyerhaeuser) provided flume discharge data.

#### LITERATURE CITED

- ADAMS, S. B. 2007. Direct and indirect effects of channel catfish (*Ictalurus punctatus*) on native crayfishes (Cambaridae) in experimental tanks. *Am. Midl. Nat.*, **158**:85–96.
- AND M. L. WARREN, JR. 2005. Recolonization by warmwater fishes and crayfishes after severe drought in upper Coastal Plains streams. *T. Am. Fish. Soc.*, **134**:1173–1192.
- BOSCHUNG, H. T. AND R. L. MAYDEN. 2004. Fishes of Alabama. Smithsonian Books, Washington DC, 736 p.
- CHAPMAN, S. S., G. E. GRIFFITH, J. M. OMERNIK, J. A. COMSTOCK, M. C. BEISER, AND D. JOHNSON. 2004. Ecoregions of Mississippi (color poster with map, descriptive text, summary tables, and photographs; map scale 1:1,000,000). U.S. Geological Survey, Reston, Virginia.
- COLLINS, N. C., H. H. HARVEY, A. J. TIERNEY, AND D. W. DUNHAM. 1983. Influence of predatory fish density on trapability of crayfish in Ontario lakes. *Can. J. Fish. Aquat. Sci.*, **40**:1820–1828.
- CRANDALL K. A. AND S. DE GRAVE. 2017. An updated classification of the freshwater crayfishes (Decapoda: Astacidea) of the world, with a complete species list. *J. Crustacean Biol.*, **37**(5):1–39.
- FITZPATRICK, J. F., JR. 1996. Rare and endangered crayfishes of Mississippi. Mississippi Department of Wildlife, Fisheries, and Parks, Museum Technical Report No. 93, Jackson, 67 p.
- . 2002. The conservation status of Mississippi crawfishes (Crustacea: Decapoda: Cambaridae). *Louisiana Academy of Sciences*, **63**:25–36.
- AND C. A. BUSACK. 1989. *Hobbsseus yalobushensis*, a new crawfish from central Mississippi (Decapoda: Cambaridae). *P. Biol. Soc. Wash.*, **102**:637–643.
- HARRELSON, C. C., C. L. RAWLINS, AND J. P. POTYONDY. 1994. Stream channel reference sites: an illustrated guide to field technique. USFS Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-245, Fort Collins, Colorado, 61 p.
- HARTFIELD, P. 1993. Headcuts and their effects on freshwater mussels p. 131–141. *In*: Cummings, K. S., A. C. Buchanan, and L. M. Kock (eds.). Conservation and management of freshwater mussels. Upper Mississippi River Conservation Committee, Rock Island, Illinois.
- [IUCN] INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE. 2013. IUCN Red List of Threatened Species. Version 2013.2. <[www.iucnredlist.org](http://www.iucnredlist.org)>. Accessed on 13 December 2013.
- LYONS, J. 2006. A fish-based index of biotic integrity to assess intermittent headwater streams in Wisconsin, USA. *Environ. Monit. Assess.*, **122**:239–258.
- MCCLAINE, W. R. 2010. Spawning date and potential contribution to yield from winter-burrowing *Procambarus clarkii* in crawfish aquaculture ponds. *J. Shellfish Res.*, **29**:7–12.
- MCCUNE, B. AND J. B. GRACE. 2002. Analysis of ecological communities. MjM Software Design, Glenden Beach, Oregon. 300 p.
- AND M. J. MEFFORD. 2011. PC-ORD. Multivariate Analysis of Ecological Data, Version 6.15. MjM Software Design, Glenden Beach, Oregon.

- [MDWFP] MISSISSIPPI DEPARTMENT OF WILDLIFE, FISHERIES, AND PARKS. 2005. Appendix VIII: Mississippi's species of greatest conservation need by ecoregion p. 375–380. *In*: Mississippi's Comprehensive Wildlife Conservation Strategy 2005-2015, version 1.1, Jackson. (<http://home.mdwfp.com/more.aspx>).
- [MFC] MISSISSIPPI FORESTRY COMMISSION. 2008. Mississippi's BMPs: best management practices for forestry in Mississippi, fourth edition. Jackson. 43 p. Available at [https://www.mdwfp.com/media/156209/forestry\\_bmp\\_2008-7-24.pdf](https://www.mdwfp.com/media/156209/forestry_bmp_2008-7-24.pdf) (accessed 6 December 2016).
- MORAN, M. D. 2003. Arguments for rejecting the sequential Bonferroni in ecological studies. *Oikos*, **100**:403–405.
- NATURESERVE. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available <http://www.natureserve.org/explorer>. (Accessed 2 January 2014).
- NYSTRÖM, P. 2002. Ecology p. 192–235. *In*: Holdich, D. M. (ed.) *Biology of freshwater crayfish*. Blackwell Scientific, Ltd., Ames, Iowa.
- POFF, N. L., J. D. ALLAN, M. B. BAIN, J. R. KARR, K. L. PRESTEGAARD, B. D. RICHTER, R. E. SPARKS, AND J. C. STROMBERG. 1997. The natural flow regime. *Bioscience*, **47**:769–784.
- RICHMAN, N. I., M. BÖHM, S. B. ADAMS, F. ALVAREZ, E. A. BERGEY, J. J. S. BUNN, Q. BURNHAM, J. CORDEIRO, J. COUGHRAN, K. A. CRANDALL, K. L. DAWKINS, R. J. DiSTEFANO, N. E. DORAN, L. EDSMAN, A. G. EVERSEOLE, L. FÜREDER, J. M. FURSE, F. GHERARDI, P. HAMR, D. M. HOLDICH, P. HORWITZ, K. JOHNSTON, C. M. JONES, J. P. G. JONES, R. L. JONES, T. G. JONES, T. KAWAI, S. LAWLER, M. LÓPEZ-MEJÍA, R. M. MILLER, C. PEDRAZA-LARA, J. D. REYNOLDS, A. M. M. RICHARDSON, M. B. SCHULTZ, G. A. SCHUSTER, P. J. SIBLEY, C. SOUTY-GROSSET, C. A. TAYLOR, R. F. THOMA, J. WALLS, T. S. WALSH, AND B. COLLEN. 2015. Multiple drivers of decline in the global status of freshwater crayfish (Decapoda: Astacidea). *Philos. T. R. Soc. B.* **370**:20140060.
- ROSS, S. T. 2001. *The Inland Fishes of Mississippi*. University Press of Mississippi, Jackson. 624 p.
- SEILER, S. M. AND A. M. TURNER. 2004. Growth and population size of crayfish in headwater streams: individual- and higher-level consequences of acidification. *Freshwat. Biol.*, **49**:870–881.
- SIMON, A. 1989. The discharge of sediment in channelized alluvial streams. *J. Am. Water. Resour. As.*, **25**:1177–1188.
- STEIN, R. A. AND J. J. MAGNUSON. 1976. Behavioral response of crayfish to a fish predator. *Ecology*, **57**:751–761.
- TAYLOR, C. A., S. B. ADAMS, AND G. A. SCHUSTER. 2014. Systematics and biogeography of *Orconectes*, subgenus *Trisellescens*, in the southeastern United States, a test of morphology-based classification. *J. Crustacean. Biol.*, **34**:1–14.
- TAYLOR, C. A., G. A. SCHUSTER, J. E. COOPER, R. J. DiSTEFANO, A. G. EVERSEOLE, P. HAMR, H. H. HOBBS, III, H. W. ROBISON, C. E. SKELTON, AND R. F. THOMA. 2007. A reassessment of the conservation status of crayfishes of the United States and Canada after 10+ years of increased awareness. *Fisheries*, **32**:372–389.

APPENDIX 1.—Physicochemical stream reach characteristics at the time of sampling, sampling effort, and date. Bold font indicates collections that included *Hobbsiella yalobushensis*. Abbreviations include: dissolved oxygen (DO), specific conductivity (Spec. cond.), turbidity (Turb., in nephelometric turbidity units-NTU), and stream instantaneous discharge (Q)

Reach	Collection number	Date	Water temp. (C)	DO (mg/l)	DO (%)	Spec. cond. (mS/cm)	pH	Turb. (NTU)	Mean wetted width (m)	Mean thalweg depth (cm)	Width: depth	Q (m <sup>3</sup> /s)	Reach length (m)	Shock time (sec)
S1	SA398	2/14/2011	13.2	8.7	94.1	—	4.90	—	0.87	11.3	7.7	0.00062	165	1136
	SA454	2/14/2012	9.3	9.7	84.7	0.027	6.25	—	0.89	14.0	6.4	0.00134	80	480
	SA493	3/7/2013	11.3	11.5	103.0	0.026	7.02	30.2	0.84	11.0	7.6	0.00227	70	423
	SA400	2/15/2011	7.8	12.0	97.6	0.045	7.10	—	0.85	13.5	6.3	—	219	1041
S2	SA456	2/14/2012	8.8	10.7	91.9	0.030	6.46	—	1.32	17.4	7.6	—	—	480
	SA499	3/13/2013	10.3	6.1	53.4	0.034	6.70	21.5	1.34	15.8	8.5	—	70	453
	SA399	2/14/2011	9.1	11.0	86.2	0.045	7.05	—	2.73	34.4	7.9	—	132	882
	SA455	2/14/2012	7.7	9.1	75.6	0.036	6.28	—	3.11	32.8	9.5	—	500	500
S3_down	SA497	3/13/2013	7.4	9.8	81.7	0.034	7.14	29.7	2.98	23.8	12.5	—	50	309
	SA401	2/15/2011	13.2	11.3	106.0	0.040	6.60	—	3.40	53.3	6.4	0.00015	85	994
	SA457	2/14/2012	9.8	10.8	95.3	0.037	6.13	—	3.76	31.1	12.1	0.00042	100	653
	SA498	3/13/2013	10.4	9.9	87.9	0.034	6.99	24.0	2.97	37.3	8.0	0.00028	100	847
S4	SA407	2/18/2011	13.0	9.2	86.1	0.028	5.97	—	0.80	11.3	7.1	—	100	540
	SA468	2/27/2012	12.5	8.3	77.0	0.026	5.94	—	0.79	10.0	7.9	—	50	378
	SA492	3/7/2013	10.4	8.9	76.8	0.024	6.72	16.0	0.88	10.1	8.6	—	50	281
	SA406	2/18/2011	12.6	9.7	90.1	0.051	5.91	—	2.00	25.8	7.9	—	100	1208
S5	SA467	2/27/2012	12.0	10.4	90.2	0.045	6.03	—	1.73	25.8	6.7	—	100	715
	SA491	3/7/2013	7.7	10.6	86.1	0.041	7.03	27.1	2.09	29.5	7.1	0.00726	100	713
	SA504	2/17/2011	—	—	—	—	—	—	1.05	23.3	—	—	100	737
	SA461	2/21/2012	12.4	9.3	85.6	0.042	6.18	—	1.37	18.9	7.2	—	50	334
T1_mid	SA485	2/28/2013	8.9	9.4	81.0	0.036	6.80	59.8	0.96	17.3	5.6	0.00089	50	283
	SA405	2/17/2011	11.6	9.2	83.4	0.042	5.81	—	1.04	20.0	5.2	—	187	1570
	SA462	2/21/2012	11.9	8.9	81.9	0.036	5.81	—	0.86	13.3	6.5	0.00179	100	600
	SA486	2/28/2013	9.1	10.3	88.5	0.034	6.76	23.3	0.93	14.1	6.6	0.00312	100	662
T1_up	SA463	2/21/2012	11.4	9.9	89.5	0.032	6.31	—	0.44	9.1	4.8	—	—	228
	SA487	2/28/2013	10.1	4.4	35.1	0.033	6.41	21.0	0.63	7.6	8.2	—	50	227
	SA404	2/16/2011	12.2	10.5	99.4	—	5.91	—	0.91	11.0	8.3	0.00066	96	525
	SA459	2/15/2012	9.1	11.0	94.6	0.131	5.68	—	1.07	11.1	9.6	0.00167	506	506
T2	SA480	2/20/2013	5.8	11.6	89.7	0.111	6.36	50.8	0.69	12.3	5.6	0.00111	65	420



APPENDIX 1.—Continued

Reach	Collection number	Date	Water temp. (C)	DO (mg/l)	DO (%)	Spec. cond. (mS/cm)	pH	Turb. (NTU)	Mean wetted width (m)	Mean thalweg depth (cm)	Width: depth	Q (m <sup>3</sup> /s)	Reach length (m)	Shock time (sec)
T3_down	SA403	2/16/2011	13.0	10.7	100.0	—	5.91	—	1.61	35.5	4.5	—	139	848
	SA458	2/15/2012	9.6	10.1	88.9	0.090	6.04	—	1.47	19.7	7.4	—	—	482
	SA479	2/20/2013	6.0	11.3	86.1	0.077	6.34	42.6	1.59	21.3	7.5	—	100	681
T3_up	SA402	2/16/2011	10.7	10.4	90.0	—	6.40	—	0.95	9.5	10.0	0.00074	100	758
	SA460	2/15/2012	9.8	10.4	91.6	0.101	5.95	—	1.34	14.4	9.4	0.00215	—	439
T4_down	SA484	2/22/2013	10.7	9.5	85.3	0.068	6.02	87.4	1.22	17.9	6.8	0.00441	80	509
	SA477	3/21/2012	17.5	4.3	43.0	0.116	5.91	—	0.81	13.4	6.1	—	—	606
T4_up	SA494	3/8/2013	7.2	10.5	85.3	0.116	6.33	10.5	0.98	20.0	4.9	—	50	340
	SA465	2/22/2012	11.3	9.4	84.5	0.130	5.64	—	0.83	14.3	5.8	—	—	569
T5_down	SA495	3/8/2013	8.6	9.6	81.7	0.180	5.63	11.1	0.98	15.2	6.5	0.00029	50	307
	SA478	3/21/2012	17.6	8.0	83.5	0.048	6.40	—	0.69	10.8	6.3	—	—	264
T5_up	SA496	3/8/2013	12.9	9.9	92.0	0.046	7.00	18.7	0.81	10.8	7.5	—	50	354
	SA464	2/21/2012	12.4	9.4	87.4	0.049	6.13	—	0.66	13.4	4.9	—	50	625
T6_down	SA488	2/28/2013	11.3	8.2	73.9	0.044	6.33	21.6	0.74	11.4	6.5	—	100	558
	SA473	3/5/2012	10.6	7.4	65.0	0.035	5.62	—	0.90	20.3	4.4	—	—	646
T6_up	SA489	3/6/2013	8.0	8.8	73.1	0.032	6.42	16.3	0.83	14.3	5.8	—	100	629
	SA474	3/5/2012	11.5	4.5	40.5	0.035	5.76	—	0.71	10.4	6.8	—	—	636
T7_down	SA490	3/6/2013	8.2	7.8	65.1	0.031	6.58	16.0	0.68	12.3	5.5	—	75	389
	SA475	3/5/2012	13.7	7.4	70.3	0.051	6.23	—	1.15	15.2	7.5	—	50	258
T7_up	SA482	2/22/2013	9.5	9.0	77.7	0.035	6.54	36.2	1.23	25.2	4.9	—	50	267
	SA476	3/5/2012	13.2	5.0	46.8	0.044	6.07	—	0.82	8.7	9.5	—	—	469
T8	SA483	2/22/2013	9.8	9.7	85.7	0.033	6.34	40.0	0.68	11.6	5.8	—	98	506
	SA471	2/28/2012	—	—	—	—	—	—	—	—	—	—	—	— <sup>a</sup>
T9	SA481	2/20/2013	—	—	—	—	—	—	—	—	—	—	—	45 m <sup>a</sup>
	SA466	2/22/2012	15.3	7.4	74.0	0.040	5.99	—	1.21	19.8	6.1	—	—	699
T10	SA470	2/28/2012	11.8	8.7	80.2	0.039	5.90	—	0.74	11.3	6.6	—	100	537
T11	SA469	2/27/2012	13.0	9.7	90.6	0.036	6.11	—	1.88	24.8	7.6	—	50	401
Minimum			5.8	4.3	35.1	0.024	4.90	10.5	0.44	7.6	4.4	0.00015	0	227
Maximum			17.6	12.0	103.0	0.180	7.14	87.4	3.76	53.3	12.5	0.00227	219	1570
Mean			10.7	9.2	79.1	0.053	6.27	30.2	1.27	17.8	7.1	—	84	557
SD			2.5	1.8	15.2	0.035	0.47	18.7	0.78	9.1	1.7	—	42	257

<sup>a</sup> not electrofished—sampled only with dipnets

APPENDIX 2.—Catch-per-unit-effort [CPUE, number per 100 s electrofished](counts) of crayfishes by year, reach, and species. Sampling of reach T8 was qualitative, so CPUE is not given. Additional crayfishes found include: in 2012, one *Faxonius* sp. in T1\_up and one *Procambarus* sp. in T7\_down; in 2013, one *Cambarus diogenes* in T8. “ns” = not sampled

Reach	CPUE (counts)						Totals
	<i>C. striatus</i>	<i>H. yalobushensis</i>	<i>F. etnieri</i>	<i>P. hayi</i>	<i>P. hybus</i>	<i>P. lylei</i>	
2011							
S1	1.67 (19)	0.00	0.26 (3)	0.97 (11)	0.00	0.00	2.90 (33)
S2	1.54 (16)	0.00	0.00	0.86 (9)	0.00	0.00	2.40 (25)
S3_down	0.11 (1)	0.00	0.00	0.34 (3)	0.00	1.36 (12)	1.81 (16)
S3_up	0.30 (3)	0.00	0.00	0.80 (8)	0.00	1.21 (12)	2.31 (23)
S4	0.93 (5)	0.00	0.00	2.22 (12)	0.00	0.00	3.15 (17)
S5	0.41 (5)	0.00	0.25 (3)	0.99 (12)	0.00	3.39 (41)	5.05 (61)
T1_down	3.12 (23)	0.00	0.95 (7)	1.63 (12)	0.00	0.00	5.70 (42)
T1_mid	2.80 (44)	0.19 (3)	0.38 (6)	0.76 (12)	0.00	0.00	4.14 (65)
T2	0.38 (2)	1.71 (9)	0.00	0.00	0.19 (1)	0.00	2.29 (12)
T3_down	0.24 (2)	0.47 (4)	0.83 (7)	0.00	0.00	0.00	1.53 (13)
T3_up	0.53 (4)	1.19 (9)	0.00	0.00	0.00	0.00	1.72 (13)
Total counts	(124)	(25)	(26)	(79)	(1)	(65)	(320)
2012							
S1	2.50 (12)	0.00	0.63 (3)	1.67 (8)	0.00	0.00	4.79 (23)
S2	0.83 (4)	0.00	0.00	1.46 (7)	0.00	0.00	2.29 (11)
S3_down	0.00	0.00	0.20 (1)	1.80 (9)	0.00	4.80 (24)	6.80 (34)
S3_up	0.00	0.00	0.15 (1)	0.15 (1)	0.00	5.51 (36)	5.82 (38)
S4	9.52 (36)	0.00	0.00	3.17 (12)	0.00	0.00	12.70 (48)
S5	0.00	0.00	0.00	1.96 (14)	0.00	3.64 (26)	5.59 (40)
T1_down	7.19 (24)	0.00	0.90 (3)	3.89 (13)	0.00	0.00	11.98 (40)
T1_mid	5.17 (31)	0.17 (1)	0.33 (2)	2.67 (16)	0.00	0.00	8.33 (50)
T1_up	0.00	4.82 (11)	0.44 (1)	0.00	0.00	0.00	5.70 (12)
T2	0.40 (2)	5.52 (28)	0.00	0.00	0.59 (3)	0.00	6.92 (33)
T3_down	0.41 (2)	1.24 (6)	1.66 (8)	0.00	0.21 (1)	0.00	3.53 (17)
T3_up	0.00	17.77 (78)	0.00	0.00	0.23 (1)	0.00	18.00 (79)
T4_down	0.00	91.09 (552)	0.00	0.00	2.64 (17)	0.00	93.89 (569)
T4_up	0.00	67.49 (384)	0.00	0.00	0.00	0.00	67.49 (384)
T5_down	1.89 (5)	14.02 (37)	0.00	0.00	0.00	0.00	15.91 (42)
T5_up	9.12 (57)	10.24 (64)	0.96 (6)	0.00	0.00	0.00	20.32 (127)
T6_down	6.35 (41)	0.00	4.02 (26)	0.46 (4)	0.00	0.00	10.99 (71)
T6_up	0.94 (6)	15.09 (96)	0.00	0.00	0.00	0.00	16.04 (102)
T7_down	12.40 (32)	4.26 (11)	7.75 (20)	10.08 (26)	2.33 (6)	0.00	37.21 (95)
T7_up	3.41 (16)	1.28 (6)	0.00	0.00	0.00	0.00	4.69 (22)
T8	(0)	(4)	(0)	(0)	(3)	(0)	(7)
T9	0.86 (6)	0.00	0.14 (1)	6.15 (43)	0.00	0.00	7.15 (50)
T10	5.40 (29)	0.00	0.93 (5)	0.00	0.00	0.00	6.33 (34)
T11	1.00 (4)	0.00	0.25 (1)	0.00	0.00	2.74 (11)	3.99 (16)
Total counts	(307)	(1278)	(78)	(153)	(31)	(97)	(1944)
2013							
S1	4.26 (18)	0.00	0.00	0.71 (3)	0.00	0.00	4.96 (21)
S2	2.43 (11)	0.00	0.00	3.97 (18)	0.00	0.00	6.40 (29)
S3_down	0.00	0.00	0.32 (1)	3.88 (12)	0.00	2.91 (9)	7.12 (22)
S3_up	0.35 (3)	0.00	0.00	0.59 (5)	0.00	2.48 (21)	3.42 (29)
S4	6.05 (17)	0.00	0.00	3.20 (9)	0.00	0.00	9.25 (26)

## APPENDIX 2.—Continued

Reach	CPUE (counts)						Totals
	<i>C. striatus</i>	<i>H. yalobushensis</i>	<i>F. etnieri</i>	<i>P. hayi</i>	<i>P. hybus</i>	<i>P. lylei</i>	
S5	0.14 (1)	0.00	0.28 (2)	0.28 (2)	0.00	4.21 (30)	4.91 (35)
T1_down	3.89 (11)	0.00	0.35 (1)	5.65 (16)	0.00	0.00	9.89 (28)
T1_mid	2.27 (15)	0.30 (2)	0.76 (5)	1.36 (9)	0.00	0.00	4.68 (31)
T1_up	0.00	10.57 (24)	0.00	0.00	0.00	0.00	10.57 (24)
T2	0.95 (4)	11.19 (47)	0.00	0.00	0.24 (1)	0.00	12.38 (52)
T3_down	0.15 (1)	2.35 (16)	1.03 (7)	0.00	0.00	0.00	3.52 (24)
T3_up	0.00	20.24 (103)	0.00	0.00	1.18 (6)	0.00	21.41 (109)
T4_down	0.00	22.35 (76)	0.00	0.00	0.88 (3)	0.00	23.24 (79)
T4_up	0.00	67.10 (206)	0.00	0.00	0.00	0.00	67.10 (206)
T5_down	1.13 (4)	10.73 (38)	0.00	0.00	0.00	0.00	11.86 (42)
T5_up	3.23 (18)	11.83 (66)	0.36 (2)	0.00	0.00	0.00	15.41 (86)
T6_down	7.79 (49)	0.00	1.43 (9)	9.70 (61)	0.00	0.00	18.92 (119)
T6_up	0.26 (1)	67.87 (264)	0.00	0.00	0.00	0.00	68.12 (265)
T7_down	7.49 (20)	5.62 (15)	3.37 (9)	3.37 (9)	0.75 (2)	0.00	20.60 (55)
T7_up	5.73 (29)	1.58 (8)	0.00	0.00	1.19 (6)	0.00	8.50 (43)
T8	(0)	(57)	(0)	(0)	(46)	(0)	(103)
T9	ns	ns	ns	ns	ns	ns	ns
T10	ns	ns	ns	ns	ns	ns	ns
T11	ns	ns	ns	ns	ns	ns	ns
Total counts	(202)	(922)	(36)	(144)	(64)	(60)	(1428)
Grand totals	633	2225	140	376	96	222	3692