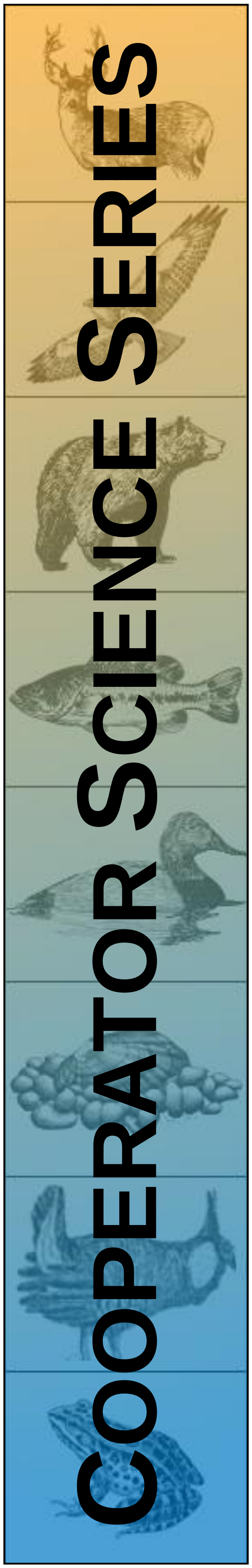

U.S. Fish and Wildlife Service

Spatial And Temporal Variation in Recruitment And Growth of Channel Catfish, Alabama Bass and Tallapoosa Bass in the Tallapoosa River and Associated Tributaries

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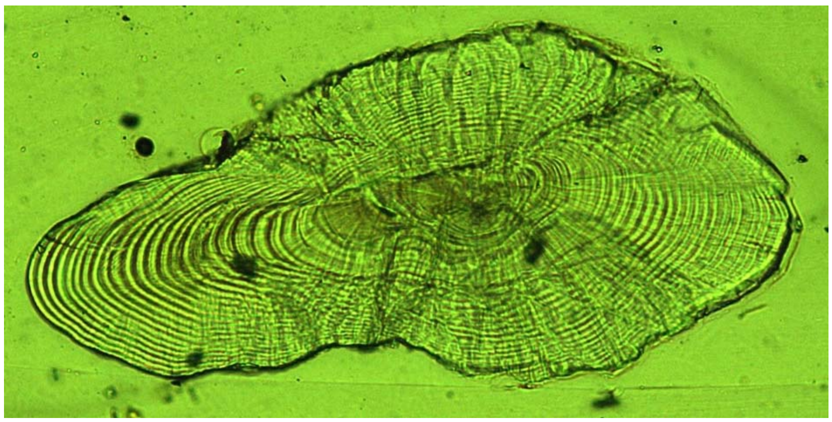
SPATIAL AND TEMPORAL VARIATION IN RECRUITMENT AND GROWTH OF CHANNEL CATFISH ALABAMA BASS AND TALLAPOOSA BASS IN THE TALLAPOOSA RIVER AND ASSOCIATED TRIBUTARIES



Sport Fish Restoration Project F-40, Study Number 66
Final Report to the Alabama Department of Conservation and Natural Resources
Division of Wildlife and Freshwater Fisheries

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Abstract- Effects of hydrology on growth and hatching success of age-0 black basses and Channel Catfish were examined in regulated and unregulated reaches of the Tallapoosa River, Alabama. Species of the family Centrarchidae, *Ictalurus punctatus* Channel Catfish and *Pylodictis olivaris* Flathead Catfish were also collected from multiple tributaries in the basin. Fish were collected from 2010-2014 and were assigned daily ages using otoliths. Hatch dates of individuals of three species (*Micropterus henshalli* Alabama Bass, *M. tallapoosae* Tallapoosa Bass and Channel Catfish) were back calculated, and growth histories were estimated every 5 d post hatch from otolith sections using incremental growth analysis. Hatch dates and incremental growth were related to hydrologic and temperature metrics from environmental data collected during the same time periods. Hatch dates at the regulated sites were related to and typically occurred during periods with low and stable flow conditions; however no clear relations between hatch and thermal or flow metrics were evident for the unregulated sites. Some fish hatched during unsuitable thermal conditions at the regulated site suggesting that some fish may recruit from unregulated tributaries. Ages and growth rates of age-0 black basses ranged from 105 to 131 d and 0.53 to 1.33 mm/day at the regulated sites and 44 to 128 d and 0.44 to 0.96 mm/d at the unregulated sites. In general, growth was highest among age-0 fish from the regulated sites, consistent with findings of other studies. Mortality of age-0 to age-1 fish was also variable among years and between sites and with the exception of one year, was lower at regulated sites. Multiple and single regression models of incremental growth versus age, discharge, and temperature metrics were evaluated with Akaike's Information Criterion (AIC_c) to assess models that best described growth parameters. Of the models evaluated, the best overall models predicted that daily incremental growth was positively related to low flow parameters and negatively related to the number of times the hydrograph changed direction (e.g., reversals). These results suggest that specific flow and temperature criteria provided from the dam could potentially enhance growth and hatch success of these important sport fish species.

Introduction

The Tallapoosa River is regulated by four dams owned by the Alabama Power Company. R. L. Harris Dam is the newest and upper most facility (operating since 1983) and flows from the dam have been managed adaptively for multiple stakeholder objectives since 2005 (see Irwin and Kennedy 2009). One of the stakeholder's primary objectives is to provide quality sport fisheries in the Tallapoosa River in the managed area below the dam. Flow management (termed the Green Plan) has been occurring since March 2005; however, sport fish populations as measured by recruitment of age-0 sport fishes (black basses and catfishes) relative to recruitment at unregulated sites has not responded adequately to specific flows at the dam. Two main types of flow manipulation has occurred: 1) provision of higher volumes in the mainstem (during non-generation periods) through pulsing flows through the dam and 2) provision of spawning windows of opportunity below the dam in the spring and summer months. Spawning windows (minimum of 7 days without 2-unit generation flows or < 8,000 cfs) have been provided in most years since adaptive management began but depressed recruitment has occurred in the mainstem in most years indicating that these management periods may not be adequate for early growth and survival, and ultimate recruitment to the fisheries.

Humphries and Lake (2000) differentiated between reproduction and recruitment where river regulation regimes may be conducive for spawning activities but may not be appropriate for larval development and growth to juvenile and older stages. They suggested that identification of factors that affect recruitment were critical for prescription of flow regimes to rehabilitate rivers. In addition, recruitment to the fishery (age-1+ fish) has not been assessed relative to flow prescriptions. Studies of Channel Catfish recruitment from age 0 to age 1 are limited (Patton and Hubert 1998) and similar studies of black basses appear limited to Largemouth Bass in lentic systems (e.g.; Maceina and Isely 1986; Ozen and Noble 2005; Rogers and Allen 2009). It is likely that the paucity of information regarding age-0 to age-1 mortality is related to gear selectivity because traditional electrofishing boats do not sample age-0 black basses well (ERI, unpublished data). However, it has been demonstrated in a reservoir system that age-0 black bass abundance collected with electrofishing gear in near-shore, shallow water was predictive of age-1 recruitment as measured by abundance metrics from boat electrofishing [90% linear model relating age-1 catch-per-unit-effort (CPUE) to age-0 CPUE; Ozen and Noble 2005]. Although this relation in riverine systems is unknown, studies that estimate population metrics (e.g., density, capture probability) with multiple gears indicate that capture probability can be accounted for and reliable estimates obtained for different year classes. Another mitigating factor for both growth and recruitment of fishes is temperature regime which is influenced by Harris Dam management and has been shown to influence early life history processes of fishes (Andress 2000; Rogers and Allen 2009;

Goar and Irwin, unpublished data) as well as growth of age-1+ fish (Patton and Hubert 1998).

Growth

Multiple research projects have reported on spatial variation in growth of catfishes and black basses in the middle Tallapoosa River below R.L Harris dam and in several associated tributaries. Nash (1999) compared growth of (age 1-10+) flathead catfish and channel catfish and found that fish grew slower at regulated sites versus unregulated tributaries; however, young fish (< age-3) were larger at age at the highly regulated site versus the other sites. Similarly, age-0 channel catfish grew faster up to day 100 at regulated sites versus unregulated sites in the Tallapoosa River (Sakaris 2006). Earley (2012) reported faster growth for age-1+ Alabama Bass in the regulated section of the Tallapoosa River and Irwin et al. (1997) observed the same trend for age-0 Alabama bass, although they also reported "stress" marks on a high percentage of age-0 otoliths and suggested that flow regulation or altered temperature caused the marks. Each of these authors indicated that these findings (fast growth at regulated sites) were counter intuitive and suggested various reasons for their findings including from compensatory mechanisms because of density dependence and shifts in life history strategies such as "bet-hedging" to actual stress responses causing early maturity and other behavioral changes. However, Sakaris (2006) and Earley (2012) both indicated that growth for these species was related to specific hydrologic features, specifically growth was impacted when flow reversals or "peaks" exceeded a threshold and flow features that affected growth varied spatially and temporally. Further, Goar and Irwin (unpublished data) reported that growth and mortality of channel catfish were impacted by various flow and temperature regimes in a laboratory study. Whereas, growth and mortality were impacted by high flow or pulsed flow combined with low temperature treatments versus high flow and base flow combined with ambient temperature treatments. In fact, mortality was near 100% for fish in the high flow/low temperature treatments. These findings indicate that flow management can influence growth (and recruitment); therefore, relations between growth and specific management scenarios should be quantified.

Age-0 Recruitment

In 1951 (pre-regulation), the fish community in the middle Tallapoosa River was dominated by catfishes and minnows; small catfishes (< 101mm) numerically dominated (n = 890) a rotenone survey conducted at Horseshoe Bend on the middle Tallapoosa River (Swingle 1953). In 1996 a similar rotenone survey was conducted and very few (< 70) small catfish were collected indicating that potential lack of recruitment. Research conducted over almost the last two decades has indicated two strong trends related to recruitment of fishes below Harris Dam. These trends are: 1) a longitudinal recovery gradient where age-0 fish are more abundant in lower river reaches (further from dam; Travnichek and Maceina 1994; Costley 1998; Irwin et al., unpublished data) and 2) increased recruitment during years where periods of flow stability (no 2-unit peaks) either occurred naturally or were provided by the Green Plan in the form of a "spawning window" (Andress 2000; Freeman et al. 2001; Martin 2009; Earley and Sammons, unpublished data; Irwin et al., unpublished data). Even after implementation of flow management, recruitment still seems to be limited for these species especially closer to the dam.

Relatively higher recruitment events were observed during the drought years of 2007 and 2008 potentially indicative of some feature of flow in the river limiting recruitment of these species during non-drought years. This finding fits well with the low flow recruitment hypothesis (LFRH) proposed by Humphries et al. (1999) to explain recruitment success of some species in regulated rivers. This phenomenon was also described for the Tallapoosa River by Freeman et al. (2001) where several species of fish recruited during periods of non-generation due to late summer low flows into Lake Harris and consequent decreased flows from Harris Dam. This concept and empirical data form the underpinnings for managing "spawning windows" but successful recruitment may depend on provision of "growing windows" for larval fish because flow periods that are conducive to spawning may not result in survival of larvae. Goar and Irwin (unpublished data) estimated that in all combinations of treatments (from high flow and low temperature to low flow and warm temperature) mortality of channel catfish alevins varied by treatment but was greatly reduced in all treatments after day 11. Finally, Sakaris (2006) reported a protracted spawning season for channel catfish where hatch dates occurred into the fall months below Harris Dam. Provision of flows conducive to spawning and rearing could potentially enhance natural recruitment; however, definition of these windows in terms of "when" and "how long" is critical. In addition, temperature regime must be included in the window definition process because it is known that Harris Dam affects thermal regimes downstream of the dam. Temperature regimes in turn will influence the length and timing of spawning and rearing windows.

This project quantified spatial and temporal differences in growth and recruitment of basses and catfishes among regulated (mainstem) and unregulated sites (mainstem and tributary sites) in the Piedmont section of the Tallapoosa River. Specific objectives were to: 1) determine timing of hatching and growth of Channel Catfish, Alabama Bass and Tallapoosa Bass through analysis of daily age at multiple sites; 2) compare differences in growth, recruitment, and mortality (to age-1) among site type (regulated and unregulated) and between years for age-0 fish; 3) use these data to refine length and timing of spawning and rearing windows of opportunity and to evaluate early recruitment for continued evaluation in the adaptive management framework.

Methods

Young-of-year (YOY) basses and catfishes were collected using pre-positioned area electrofishers (PAEs; Irwin et al. 2011) in spring/summer and fall 2010-2014 at five sites within the Tallapoosa River Basin (Figure 1). Additionally, backpack electrofishing techniques were employed at 21 tributary sites in the basin in 2013-2014; species of the family Centrarchidae, *Ictalurus punctatus* and *Pylodictis olivaris* were targeted (Table 1; Figure 2). All backpack electrofishing was conducted after sunset to account for diel movement of juvenile basses and catfishes (Irwin et al. 1999; Irwin and Noble 2000); whereas, PAE sampling was conducted during daylight hours for safety reasons. Sites were classified as regulated (Horseshoe Bend, Wadley and Malone, Alabama) or unregulated (Heflin, Alabama and Hillabee Creek, Alexander City, Alabama) depending on influence of R.L Harris Dam (hydropeaking) on the Tallapoosa River. All the tributary sites were not regulated by large dams, although low-head structures may have been in place upstream in some cases. Long-term monitoring with PAEs was conducted as follows. PAEs were constructed of two 6-cm long electrodes, separated by 1.5 m, and remotely powered with alternating current by a 3500 W generator and GPP unit (Smith-Root 305 GP; Smith-Root, Vancouver, Washington, USA). Each of the four sites consisted of five randomly selected (and then fixed) shoal habitats; 10 PAE samples were taken at each site per season. After fish were stunned with electrical current, they were collected in nets, euthanized in MS-222 (140 mg/l), placed on ice and returned to the laboratory.

Laboratory Methods

All fish were measured to the nearest 0.1 mm TL and weighed to the nearest 0.01 g. Sagittal otoliths were extracted from fish using a dissecting microscope with forceps and stored in centrifuge tubes prior to preparation. Daily ages and hatch dates of fish were calculated following the techniques of Taubert and Coble (1977), Santucci and Wahl (2003), and Roberts et al. (2004). Catfish otoliths were prepared by the methods described by Sakaris et al. (2008). Otoliths were embedded in crystal bond resin on glass slides and were ground to the core with fine sandpaper (400 grit) until a thin transverse section was obtained. Daily otolith rings were counted from the core to the outer edge at 400X magnification. Otolith radii were measured from the center of the core to the outer edge using an image analysis system to the nearest μm (Image-Pro® Plus, Media Cybernetics, Inc., Silver Spring, Maryland). Radii were also measured from the core towards the edge of each otolith at 5 d increments to estimate daily incremental growth (i.e., 0-5, 5-10, 10-15, and so on, until 100 days post hatch, Image-Pro® Plus). Temperature was measured throughout the study at sites using Onset temperature loggers and hydrologic data were downloaded from http://waterdata.usgs.gov/nwis/rt for all mainstem sites.

Summary Statistics and Analysis

Catch-per-unit-effort (#fish/minute) was calculated for sites that were sampled with the backpack electrofishing unit. Density of fish collected in PAEs (#fish/100 PAE) during monitoring for adaptive management was calculated as an index of recruitment for comparison among sites. In addition, decomposition (Z=mortality) rates were estimated for target species by averaging the decrease in density between age-0 and age-1 for two consecutive pairs of years for 2009-2014.

Growth and hatch date estimates

Linear models were used to assess and estimate relations between growth rate (mm/day) and site type (regulated versus unregulated). Hatch dates were estimated using the following formula:

$$1) Hatch\ date = collection\ date - age\ (d) - 5\ d$$

where collection date was the calendar day of capture, age was the mean number of growth rings counted per fish, and estimates were less 5 d to account for the period of time between hatch and when fish began to lay down daily growth rings. Logistic regression models (1 = hatch occurred on a date; 0 = hatch did not occur on a date) were used to determine if hatch date was related to flow and temperature metrics at regulated and unregulated sites for all years.

Influence of hydrologic and temperature variation on growth and hatch

Single and multiple regression models were constructed to assess relations between daily incremental fish growth, hydrology and temperature at regulated and unregulated sections of the Tallapoosa River, Alabama. Sub-hourly river discharge data (~30 min) were obtained from US Geological Survey (USGS) gaging stations that were located in close proximity to three sampling locations: 1) USGS 02412000, Upper Tallapoosa River near Heflin, Alabama, 2) USGS 02414500, Middle Tallapoosa River at Wadley, Alabama (for Malone-Wadley and Peter's Island sites), and 3) USGS 02415000, Hillabee Creek near Hackneyville, Alabama (http://waterdata.usgs.gov/nwis/rt). Hydrologic and temperature variables were calculated to describe the flow regime and flow characteristics and were used as independent variables in multiple regression models (Table 2). Using 30 min data from USGS gages, reversals were calculated to evaluate the rate of flow change. Flow metrics were defined as: HIGH = sum of number of hours/5 d discharge > 5,000 cfs (high pulse frequencies); MID = sum number of hours/10 d discharge was between 2,500-5,000 cfs (mid-range pulse frequencies; PULSE = sum number of hours/5 d discharge was between 250-2,500 cfs (pulse flow frequencies); LOW = SUM number of hours/10 d discharge was between 0-250 cfs (low flow frequencies). Temperature metrics were defined as: DELTA_T = average difference between maximum and minimum temperatures in a 5 d. period and TEMP_DD was calculated by estimating the number of cumulative degree-days/10 d (°F). The use of degree-days was based on previous work by Andress (2002) and Martin (2008). Multiple regression models were developed similar to the model presented in Maceina (1992), with age (AGE) as the main, independent factor explaining variability in growth and hydrologic and temperature variables (ENV) explaining the remaining variation:

1) $Daily\ Incremental\ Growth =$
$$\beta_0 + \beta_1(\mathrm{AGE}) \pm \beta_2(\mathrm{ENV}_{\mathrm{flow}}) \pm \beta_3(\mathrm{ENV}_{\mathrm{temp}}),$$

where β_0, β_1, and β_3 were the regression coefficients for the intercept and slope (Maceina 1992). Five-day incremental growth data from otoliths were used as estimates of fish growth, and age was defined as the beginning of each growth interval (e.g., 0 – 5 d post hatch, age = 0 d). Single and multiple variable models with only age, hydrologic, or temperature variables as independent variables were also considered in the event hydrologic and temperature variables explained more of the variation than did age. Multicollinearity diagnostics (variance inflation factors, VIF's) were conducted to determine if independent variables co-varied in multiple regression models. Variables that significantly collinear were not included in the same models. Significance was set at α = 0.05, and all statistics were conducted using Program R (R Core Team 2013).

AIC model selection-Single and multiple regression models from combinations of non-collinear predictor variables were constructed and ranked using Akaike's Information Criterion (AIC) corrected for small sample size (Burnham and Anderson, 1998). We compared fit among models using a model selection approach. AIC balances the minimization of residual error (RSS) with problems associated with over-parameterization and can be used to identify the most parsimonious models with the least amount of bias from a set of candidate models (Burnham and Anderson 1998). Top-ranked models (i.e., models receiving substantial support) were those models having ΔAIC_c values within 2 of the "best" model (i.e., $\Delta AIC_c < 2$; Burnham and Anderson 1998). Akaike weights indicate the probability or weight of evidence, relative to the best-fitting model, of the tested models (Burnham and Anderson 1998). Adjusted r^2 was also calculated for each model.

<u>*Results*</u>

Tributary sites-Sixteen sites in the Tallapoosa Basin were sampled between 23 September and 6 November 2013 (Table 1) after high spring and summer flow regimes precluded sampling earlier in the year. In 2014, 17 sites were sampled between 5 June and 30 July. In 2013, 283 age-0 individuals of target species (including *Lepomis* spp.) were captured (Table 1; Figure 2). Of those, 13 were *Micropterus* spp. and only one Flathead Catfish was captured (Cane Creek). In 2014, 62 total individuals were captured; 15 *Micropterus* spp. and no catfishes were captured (Table 1; Figure 2). These results indicated an 8.3 fold increase in catch-per-unit-effort (CPUE = #fish/second) of *Micropterus* spp. between 2013 (0.11 fish/min) and 2014 (0.91 fish/min).

Recruitment and mortality rates in regulated versus unregulated sites-During spring and fall of 2010-2014, 136 individuals (total length < 100 mm) of *Micropterus* spp. were collected in PAEs from three regulated and two unregulated reaches in the basin (Figure 1). We calculated #fish/PAE x100 as an index of recruitment for comparison among sites (Figure 3). Recruitment varied between species and site type (regulated versus unregulated) and among years (Figure 3). *M. henshalli* recruitment was lower at the regulated sites versus the unregulated sites for all years except 2012. *M. tallapoosae* recruitment was more variable when site type was compared but was always lower than *M. henshalli* recruitment. Channel Catfish recruitment indices were in a range similar to *M. tallapoosae*; however, there were no clear patterns attributable to site type alone (Figure 4). Mortality estimates (Z from fall to spring the following year) for *M. henshalli* were highly variable and ranged from -1.11 to -12.73 at the regulated sites and from -0.07 to -9.17 at the unregulated sites (Figure 5). For *M. tallapoosae* mortality estimates ranged from –0.91 to -1.31 at the regulated sites and from –0.74 to -2.78 at the unregulated sites (Figure 6). Average mortality estimates were higher at the unregulated versus regulated site for both species; -5.5 versus -4.2 for *M. henshalli* and -1.1 versus -0.41 for *M. tallapoosae* (Figure 7; not tested statistically). Mortality estimates for Channel Catfish were not reliable based on sample size variation among years.

Hatch dates and growth rates.-We aged 82 *Micropterus* spp. and 16 Channel Catfish. Hatch dates of *Micropterus* spp. varied by site type and year (Table 3. With one exception (2013), initial hatches at the regulated sites were later than hatches at the unregulated sites. In general, hatches occurred over a longer period of time in the unregulated sites (including tributary sites; Table 3. Channel Catfish hatch dates were also variable by year and site type (Table 4). Ages and growth rates of age-0 black basses ranged from 105 to 131 d and 0.53 to 1.33 mm/day at the regulated sites and 44 to 128 d and 0.44 to 0.96 mm/d at the unregulated sites.

Flow and temperature regimes versus hatch date and growth.-Site type specific logistic models of hatch date versus 10-day flow and temperature metrics were evaluated using AICc. Fifteen candidate models were evaluated for combined years for *Micropterus* spp. The regulated site type analysis indicated that hatch was positively related to TEMP_DD (cumulative degree-days) and PULSE flows (250-2500 cfs) and negatively related to LOW flows (<250 cfs). The three top models were weighted similarly (Table 5). Models that included interaction terms between flow metrics and TEMP_DD were included in the model set but were not selected by AICc. The unregulated site type analysis for hatch was not informative; predictive metrics were not defined by any of the models. Five-day incremental growth measurements were evaluated with simple and multiple linear models against flow and temperature metrics and although model fit was poor (large AICc values), models that included flow variables were defined (Table 5). In particular, growth was positively related to low and pulse flows and negatively related to generation flows (MID) and the number of hydrograph reversals at the regulated sites. Growth was positively related to low flows and negatively related to pulse flows at the unregulated sites.

Discussion

The Tallapoosa River below R. L. Harris Dam exhibits great variation in flow and temperature regimes. Quantification of specific flow metrics that influence hatch and growth of important sport fish species has rarely been conducted. Habitat based flow assessments are more common (Freeman et al. 2001); therefore these data add to our knowledge regarding how flow and thermal regimes influence early life history of fishes in regulated rivers. Periods of stable flow in the regulated river positively influence both hatch and daily growth. Quantification of influential patterns explaining growth or hatch were not as strong at the regulated sites likely because conditions suitable for hatching and growth were likely available more often at those sites. A formal evaluation of the thermal differences among sites is underway and may elucidate specific thermal constraints related to spawning, hatching, rearing, and growth conditions.

The overall densities of Channel Catfish (and basses, in most years) in both the regulated and unregulated river may be related to flow and temperature regimes. Initial analysis of cumulative degree days at the sites below the dam indicates that the river is colder than the nearby unregulated sites and thermal requirements for Channel Catfish spawning are not met until late in the year. For the limited Channel Catfish hatch data that we collected during this study, hatches occurred until late in the summer months. Sakaris (2006) reported similar results and noted that a protracted spawning period could be favoring late spawned fish. Another hypothesis is that detection probabilities for fish (and especially Channel Catfish) are low using the gears that we employed in the study.

However, in other systems (lower Alabama River) catch rates of catfishes in PAEs were high (ERI, unpublished data). However, because detection rates are related to abundance and specific habitat use, our actual catch rates may be indicative of very low densities compared to the Alabama River. In addition, habitat availability (and stability) is known to influence recruitment of some fishes in the system (Freeman et al. 2001). Irwin et al. (2011) reported that habitat conditions associated with flow management have improved versus pre-management conditions.

A review of the literature indicated that specific fishery recruitment information related to river regulation is limited. Patton and Hubert (1996) reported that temperature may influence overall growth potential and condition of catchable sized channel catfish and smallmouth bass. Because protracted spawning periods (see Cargnelli and Gross 1996) and variation in overwinter mortality can influence survival to age 1 (see Ludsin and DeVries 1997), recruitment to age 1 should be quantified relative to management of spawning and rearing windows, particularly if timing and duration of management can be initiated to enhance recruitment to the fishery. The mortality rates estimated via decomposition rates of the cohorts through time indicate that mortality in the regulated reach may be lower than rates in the unregulated section. In addition, mortality estimates were variable and appeared independent of initial year-class strength. New studies that have been implemented to follow tagged and stocked cohorts of the species in this study will assist in estimation of mortality of cohorts.

The hatching, survival and growth of young fish that leads to recruitment are complex processes regulated by parental, individual and environmental factors. Hatch date varied considerably between site type and among years, but difference between regulated and unregulated sites were apparent especially related to conditions in a given water year. The high flows of 2013 at all sites likely delayed spawning of these species late into the summer as evidenced by hatch date distribution. However, these late spawns did not appear to result in increased mortality of the cohorts through the winter. This may have been attributed to increased survival of age-1 fish during the drought of 2012 where management flows provided water below Harris Dam. Another main source of uncertainty is the influence of tributaries to recruitment processes. Twenty-eight percent of hatches at the regulated sites occurred during thermal conditions that should not have been conducive to black bass hatching (~60 cumulative degree days needed). Those individuals potentially recruited to the river from warmer tributary habitats.

Repeatedly we have quantified faster growth of age-0 fish in seemingly hostile environments below dams (Irwin et al. 1997, Sakaris 2006, Earley 2012, Goar 2013). This finding is counter-intuitive, yet density-dependent growth rates are a hypothesized mechanism for this phenomenon. Another hypothesis is that collected fish are the genetically disposed fast-growing individuals of a cohort that are ultimately survivors. The new evidence supported by the regression models that relate growth to low stable flows should assist managers in setting flow management prescriptions. Our findings support the ideas put forth by previous studies that hatching success could be improved when spawning periods of 10-15 days in spring and summer are provided (prolonged periods of stable low flow < 5,000 cfs). More analysis of growth parameters related to temperature is warranted including expansion of physiological constraints that temperature imposes on growth (Venturelli et al. 2010).

As part of an adaptive management framework, the utility that operates the dam has provided "spawning windows" during the growing season in every year since flows have been managed (2005). However, specific experiments to assess the length of the provided spawning period as well as specific flow regimes that would favor spawning for these important sport fisheries have not ensued. Because estimation of hatch frequency (along with growth parameters) provides a robust assessment technique, specific temporal and spatial experiments should assist the Alabama Department of Conservation and Natural Resources in defining adequate spawning and rearing conditions. This approach coupled with the current experimental stocking program designed to evaluate potential size-dependent recruitment issues could allow for increased understanding of the mechanisms that allow many fish species to persist in highly managed rivers.

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Table 1.-Total number of individuals of targeted species captured by backpack electrofishing from 21 sites in the Tallapoosa River basin (2013-2014). Total number of seconds sampled is reported for each year.

	2013									2014					
Site	L. auritus	M. tallapoosae	L. cyanellus	L. gulosus	M. henshalli	L. macrochirus	P. olivaris	C. tallapoosae	seconds	L. auritus	M. tallapoosae	L. cyanellus	M. henshalli	M. salmoides	seconds
Cane Creek	9						1	1	17743	2		1			3015
Chatahospee Creek	40								112800				1		1667
Chickanoxee										1	1				3726
Chulafinnee Creek	15					5			14060	2					1354
Cohobadiah Creek	2	1			1				4852		2				1998
Cornhouse Creek	4								4512	4					4020
Crooked Creek "Site3"	14	1			1				18096				1		1560
Dynne Creek	24		9	4	2	6			37665	7					6244
Elkahatchee														1	1160
Emuckfaw										3					3747
High Pine Creek	1								1015	3			2		3000
Hillabee Creek "A"	1								1158						
Hillabee Creek "Co Rd 22 Bridge"	3				2	6			11198						
Horseshoe Bend	9				2	10	1		26576	2	3		3		7526
Hurricane Creek	1							1	2064		1				871
Ketchepedrakee Creek										3	1				3212
Knokes Creek										6					6102
Little Tallapoosa River	8				1				17667						
Pineywood Creek	10					4			10192	7					6321
Tallapoosa River "Randolph Co Rd 88"	74				2				216828						
Wedowee Creek	5					2			8393	5					4135
Total	220	2	9	4	11	33	2	2	504819	45	8	1	7	1	59658

Table 2. Flow and temperature metrics used to model relations between hatch and growth of *M. henshalli, M. tallapoosae* and *I. punctatus*. Metrics were calculated from U.S. Geological Survey gage data for 2010-2014. Temperature metrics were calculated from data collected using Onset temperature loggers.

Variable	Definition
REV	Number of reversals of the hydrograph/5-10 d
HIGH	Number of hours/5-10 d discharge greater than 5,000 cfs; similar to high pulse frequency (2-unit)
MID	Number of hours/5-10 d discharge between 2,500-5,000 cfs; similar to low pulse frequency (1-unit)
PULSE	Number of hours/5-10 d discharge between 250-2,500 cfs; similar to pulsed frequency (Pulse)
LOW	Number of hours/5-10 d discharge less than 250 cfs; similar to drought conditions
TEMP_DD	Number of Cumulative degree/10 d
DELTA_T	Median change in temperature/10 d

Table 3. Initial and final hatch dates for *M. henshalli* and *M. tallapoosae* (N = 82) collected from multiple sites in the Tallapoosa River basin. No data (x) were available for some years.

	Initial Hatch Date				
Site Type	2010	2011	2012	2013	2014
Tributary	x	x	x	12-Jun	5-Mar
Unregulated	20-Mar	31-Mar	6-Apr	24-Jun	1-Mar
Regulated	18-Jun	9-Apr	12-Apr	12-Jun	27-May
	Final Hatch Date				
Tributary	x	x	x	18-Aug	29-May
Unregulated	23-Apr	29-Jul	2-May	12-Aug	21-Jul
Regulated	18-Jun*	28-Jul	17-Aug	5-Aug	8-Jul

*based on one fish

Table 4. Initial and final hatch dates for *I. punctatus* (N = 16) collected from multiple sites in the Tallapoosa River basin. No data (x) were available for some years.

	Initial Hatch Date				
Site Type	2010	2011	2012	2013	2014
Unregulated	x	x	x	9 Jun	21-Jul
Regulated	8-Jul	x	x	4 Aug	30-Jun
	Final Hatch Date				
Unregulated	x	x	x	12-Aug	28-Jul
Regulated	23-Jul	x	x	5-Aug	17 -Jul

Table 5. AICc table of top models for linear (growth) and logistic models (hatch) that examine the relation to flow and temperature metrics.

Regulated Bass Growth	K	logLik	AICc	delta	weight	R^2
Inc_Growth=Log(Age)-REV+LOW-MID+PULSE	8	-1555.858	3128.2	0	0.54	0.24
Inc_Growth=Log(Age)-REV+LOW+PULSE	6	-1558.731	3129.7	1.56	0.25	0.23
Unregulated Bass Growth						
Inc_Growth=Log(Age)	8	-850.165	1712.8	0	0.29	0.22
Inc_Growth=Log(Age)+LOW	6	-850.324	1713.1	0.32	0.25	0.22
Inc_Growth=Log(Age)-PULSE	7	-851.447	1713.2	0.43	0.23	0.22
Regulated Hatch						
Hatch=TEMP_DD	3	-142.457	290.9	0	0.27	n/a
Hatch=TEMP_DD+PULSE	3	-142.457	290.9	0	0.27	n/a
Hatch=TEMP_DD-LOW	3	-143.25	292.5	1.59	0.12	n/a

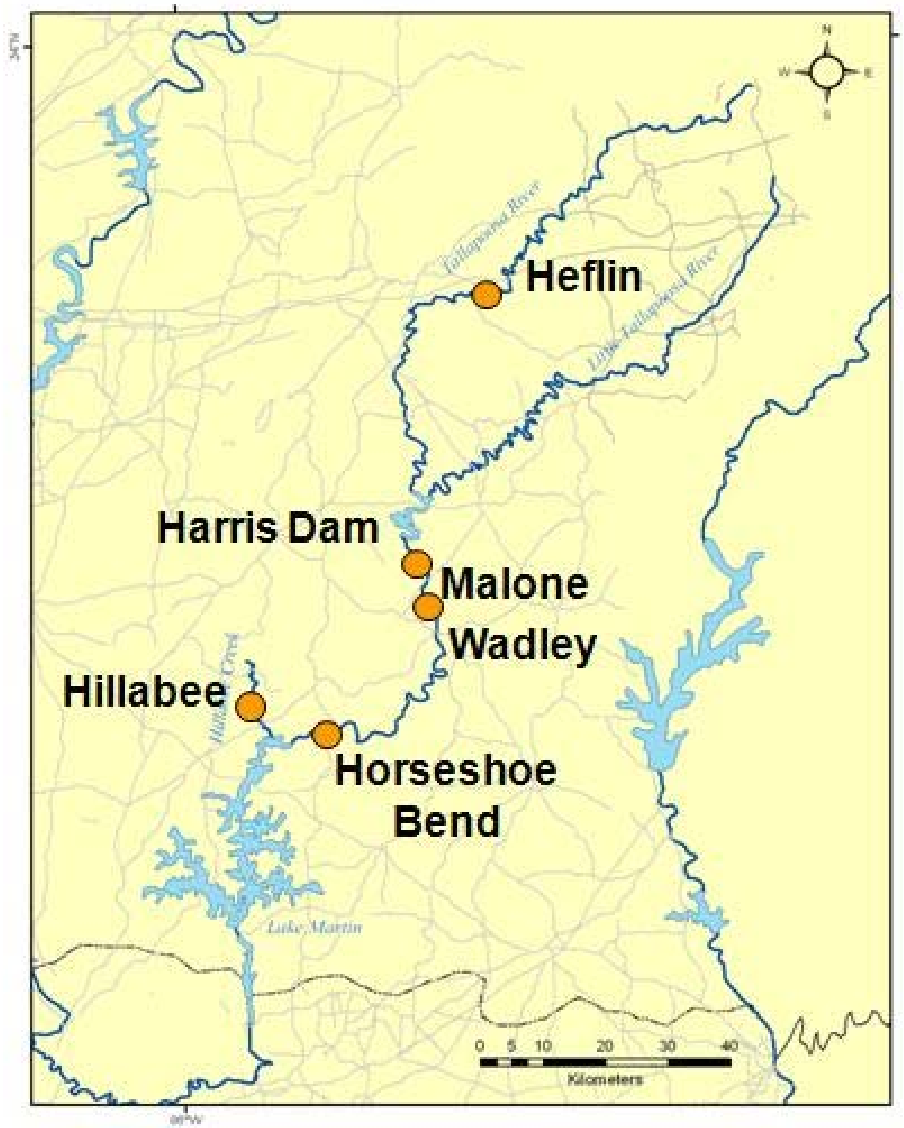


Figure 1. Map of the long-term study sites for collection of target species with pre-positioned area electrofishers. Malone, Wadley and Horseshoe Bend are regulated sites below Harris Dam. Heflin and Hillabee Creek are unregulated sites in the basin.

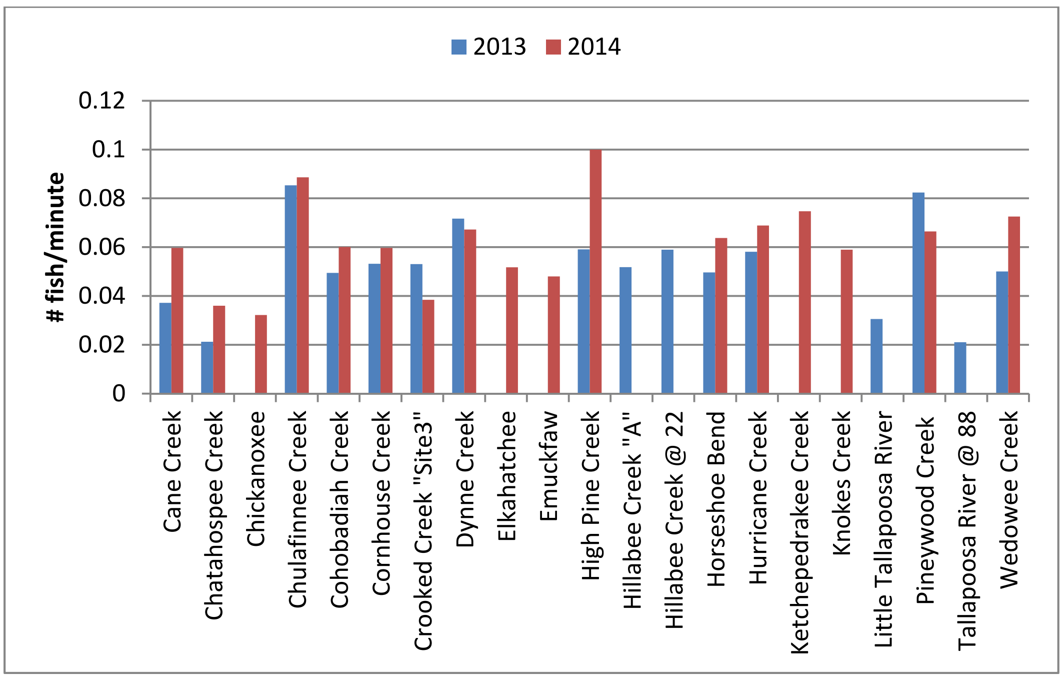
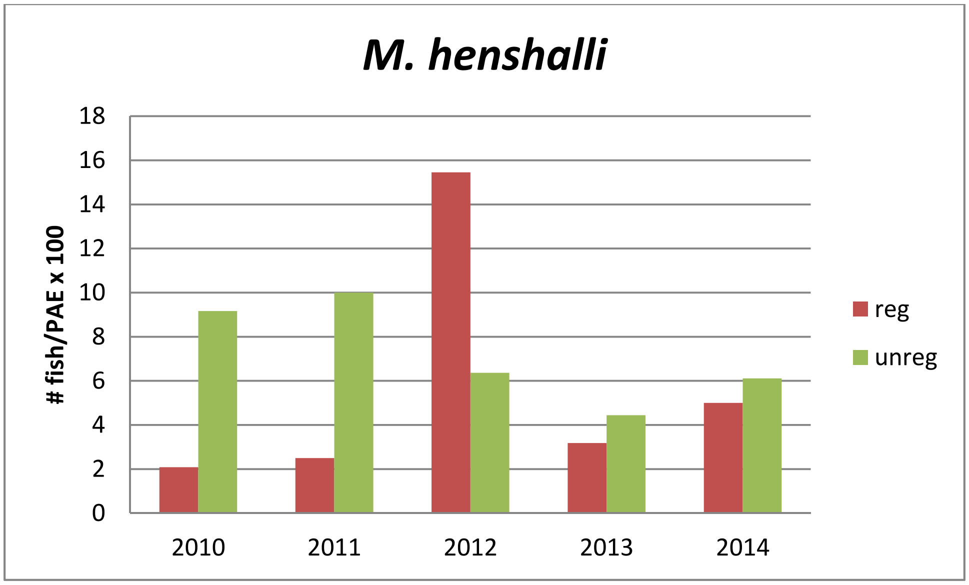


Figure 2. Catch-per-unit-effort (#fish/minute) of target species including *Lepomis* spp. (see Table 1 for species catch data).



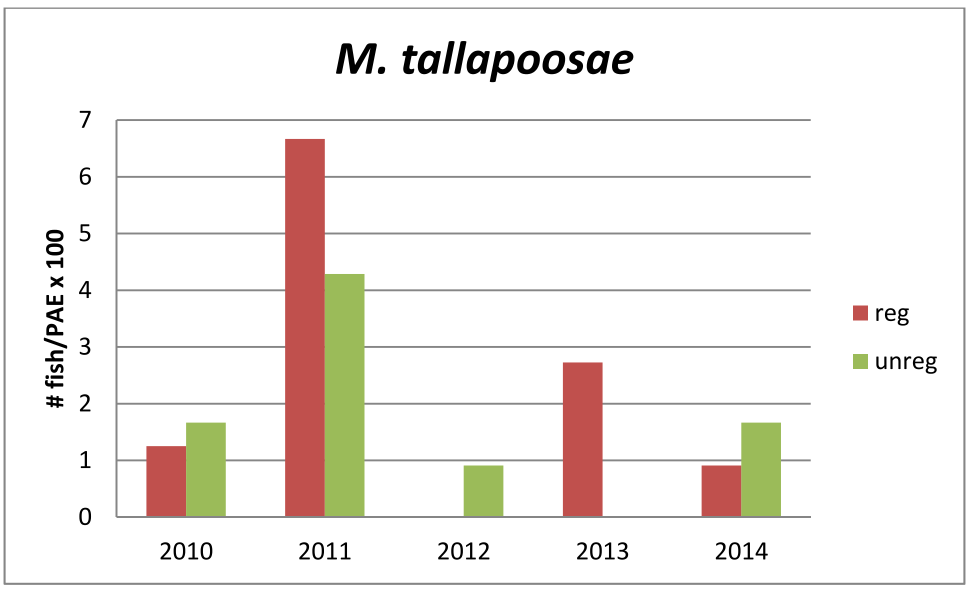


Figure 3. Catch-per-unit-effort (CPUE) of *Micropterus henshalli* and *M. tallapoosae* captured in prepositioned area electrofishers (PAEs; CPUE = #fish/PAE x100). Results can be considered an index of recruitment of the two species. Note that the scale of the bottom graph for *M. tallapoosae* is less than half the scale for the top graph of *M. henshalli.*

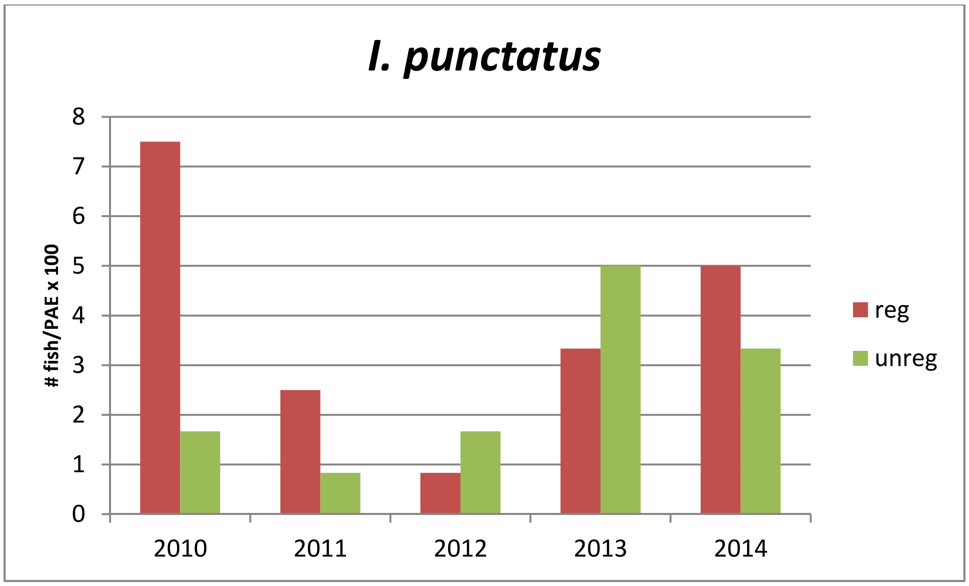
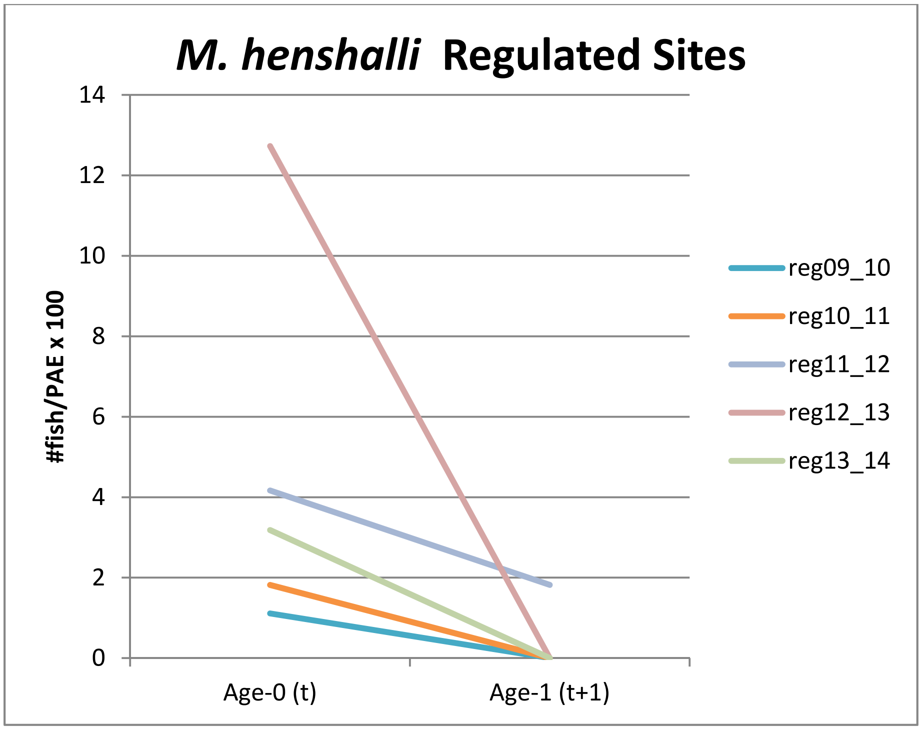


Figure 4. Catch-per-unit-effort (CPUE) of *Ictalurus punctatus* captured in prepositioned area electrofishers (PAEs; CPUE = #fish/PAE x100). Results can be considered an index of recruitment for the species.



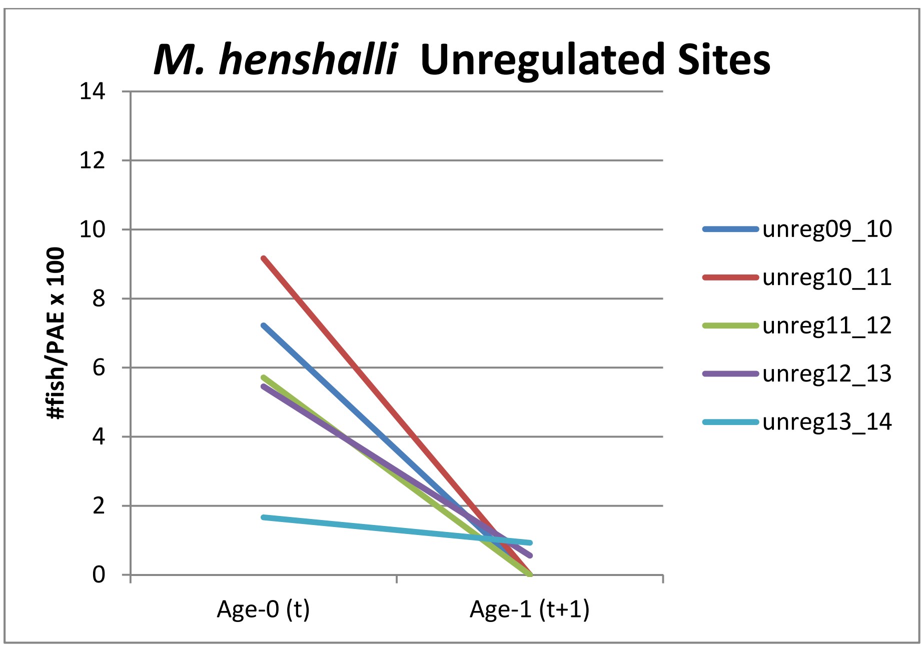


Figure 5. Mortality estimates (Z) from age-0 to age-1 for *M. henshalli* for five consecutive pairs of years at regulated (top panel) and unregulated (bottom panel) sites in the Tallapoosa River basin.

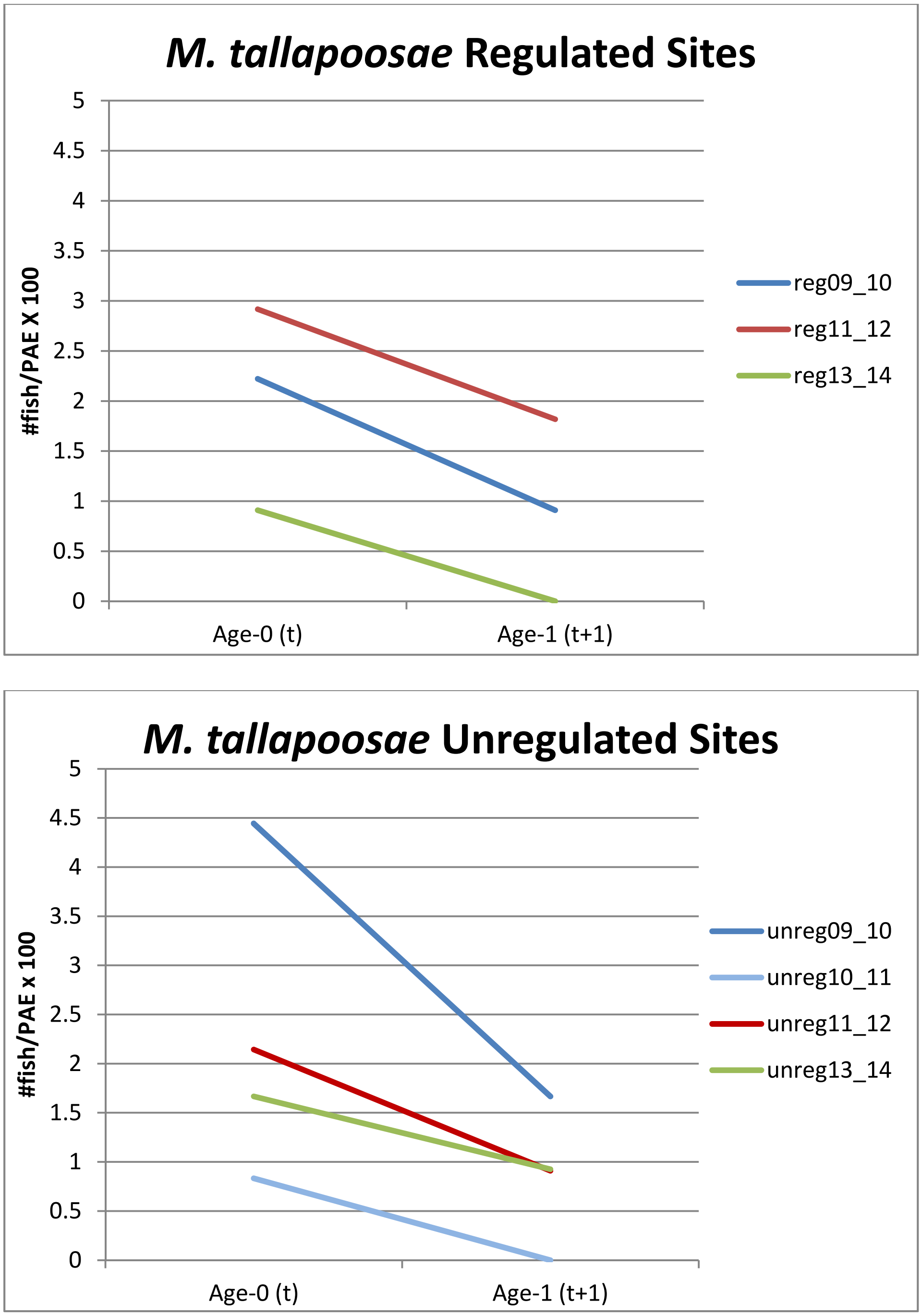


Figure 6. Mortality estimates (Z) from age-0 to age-1 for *M. tallapoosae* for five consecutive pairs of years at regulated (top panel) and unregulated (bottom panel) sites in the Tallapoosa River basin. Note that several years are not represented because of zero catch or unreliable estimates of mortality.

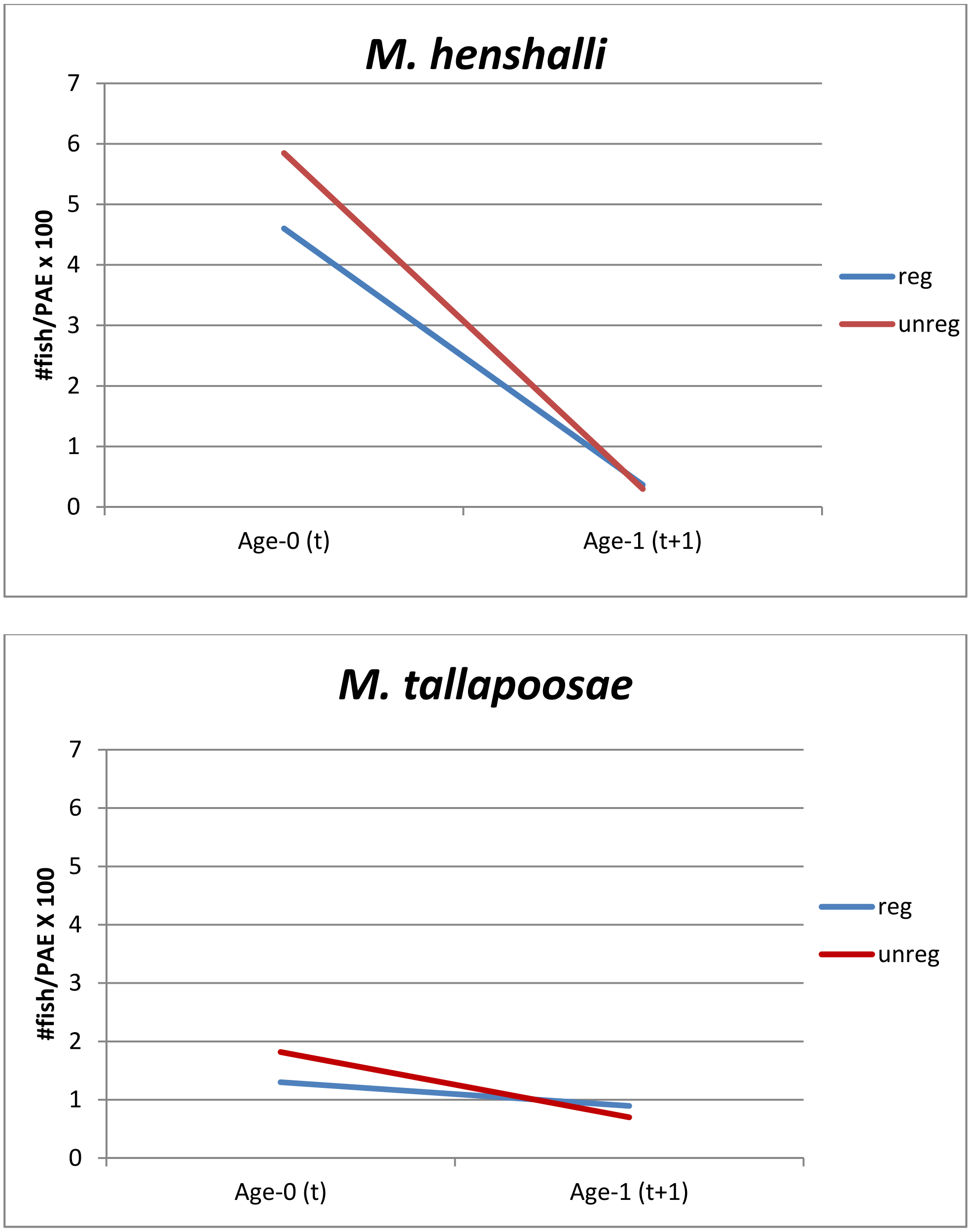


Figure 7. Average mortality estimates (Z) from age-0 to age-1 for *M. henshalli* (top panel) and *M. tallapoosae* (bottom panel) for five consecutive pairs of years at regulated and unregulated sites in the Tallapoosa River basin.

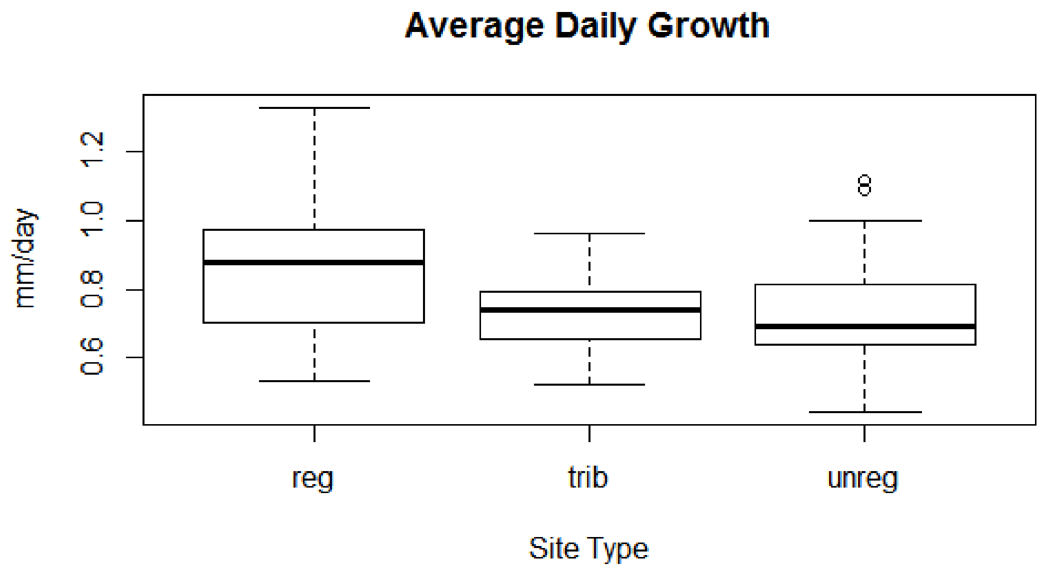


Figure 8. Average daily growth (mm/day) from age-0 *Micropterus* spp. for five regulated (reg) and unregulated (unreg) sites in the Tallapoosa River basin. Tributary (trib) sites were also included in the analysis. Growth of fish from the regulated sites was greater than growth at the other two site types ($p < 0.01$).