Population Characteristics of Flathead Catfish in the Lower Tennessee-Tombigbee Waterway

Tyler Stubbs, *Mississippi Department of Wildlife, Fisheries, and Parks, 272 CR 995, Tupelo, MS 38804*

Jason Olive,[1] *Mississippi Department of Wildlife, Fisheries, and Parks, 272 CR 995, Tupelo, MS 38804*

Nathan Martin, *Mississippi Department of Wildlife, Fisheries, and Parks, 272 CR 995, Tupelo, MS 38804*

Charles Watts, *Mississippi Department of Wildlife, Fisheries, and Parks, 272 CR 995, Tupelo, MS 38804*

Abstract: Flathead catfish (*Pylodictus olivaris*) populations were sampled in three northeastern Mississippi reservoirs (Aberdeen, Columbus, and Aliceville) along the Tennessee-Tombigbee Waterway to evaluate stock characteristics. Specifically, data were collected on relative abundance, growth, mortality, recruitment, and size structure. These samples were part of a statewide effort to document current population status in reservoirs and to develop management goals. Sampling was conducted in late summer (July–August) during 2011–2013 using low-frequency electrofishing. All fish 250 mm total length and greater were aged using pectoral spine sections. Relative abundance (fish km^{-1}) was higher in Aliceville Lake (12.56 fish km^{-1}) than in Aberdeen Lake (7.54 fish km^{-1}) or Columbus Lake (7.37 fish km^{-1}), but length-frequency distributions, growth and annual mortality rates, and recruitment variation of flathead catfish were similar among reservoirs. This is in contrast to downstream gradients of fish population metrics typically observed in river ecosystems, which could be due to habitat homogenization resulting from navigation-related anthropogenic activities.

Key words: age, recruitment, growth, electrofishing, pectoral spine

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Recent nationwide surveys indicated catfish (family: Ictaluridae) were targeted more than any other species in Mississippi and ranked third nationally behind panfish and black bass (U.S. Department Interior, U.S. Fish and Wildlife Service, U.S. Department of Commerce, and U.S. Census Bureau 2011). For this reason, state and federal agencies have started to make management of catfish populations a priority (Kwak et al. 2011). Many states lack baseline information on catfish populations, particularly for flathead catfish (*Pylodictus olivaris*), due to costs, lack of man-power, and inefficient sampling techniques (Michaletz and Dillard 1999, Reitz and Travnichek 2006, Ford et al. 2011, McCain et al. 2011, Bodine et al. 2013). Flathead catfish are targeted by both recreational and commercial anglers in Mississippi. Recreationally, they are targeted by rod-and-reel and passive gear anglers as well as hand fishers. Information such as growth, mortality, and relative abundance are important when guiding management plans for any species, especially a top predator such as flathead catfish that is targeted by multiple user groups and has the potential to impact other fish populations due to their piscivorous nature (Jackson 1999, Grussing et al. 1999). The majority of flathead catfish research has been conducted in rivers (Michaletz and Dillard 1999, Pugh and Schramm 1999, Kwak et al. 2006, Jolley and Irwin 2011, Porter et al. 2011). Although recent studies have been completed on larger impounded river systems such as the Tennessee and Upper Mississippi rivers (Holley 2006, Marshall et al. 2009, McCain et al. 2011, Steuck and Schnitzler 2011, Bodine et al. 2013), information on reservoir flathead catfish populations is still lacking. Compilations of growth rate data for this species across its native range have shown that growth is highly variable within age groups, populations, and among waterbodies and shows no latitudinal effects (Jackson 1999, Kwak et al. 2006). Estimates of mortality, exploitation, and recruitment patterns of flathead catfish are rare in the published literature (Kwak et al. 2006). Factors affecting these rate functions are even less understood.

Insaurralde (1992) found that flathead catfish abundance in rivers is directly correlated to mature riparian areas and the resulting in-stream large woody debris. Riparian areas are typically used by flathead catfish during flooding; however, impoundments on the Tennessee-Tombigbee Waterway (TTW) are heavily regulated and experience relatively stable water conditions when compared to other river systems due to channelization for navigation and the construction of levees. Although the impoundments on the TTW are heavily regulated and altered, short time periods of flooding may occur in the tributaries similar to the flood pulse concept (Junk et al. 1989). However, the brief and irregular frequencies of flooding within these reservoirs may limit fish production when compared to rivers and reservoirs that experience regular inundation of the flood plain for an extended period of time. Factors

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1. Present address: Arkansas Game and Fish Commission, 500 Ben Lane, Camden, AR 71701

such as depth, flow, drainage area, and land use as well as the geographical section of a river suggests that spatial assessments within a river system are important to observe differences in fish populations (Vannote et al. 1980, Skains and Jackson 1993, Paukert and Makinster 2009, Jolley and Irwin 2011). Miranda et al. (2008) and Chick et al. (2006) demonstrated that a downstream gradient in fish community structure and fish population metrics is present in impounded river ecosystems as well. The objectives of this study were to evaluate the stock structure of flathead catfish populations in three lock-and-dam (LAD) impoundments on the TTW in Mississippi and to evaluate how stock characteristics change longitudinally in this reservoir cascade.

Study Area

Completed in 1985, the TTW is a 377-km man-made navigation project connecting the Tennessee (Ohio River Basin) and Tombigbee (Mobile River Basin) rivers in northeast Mississippi and west-central Alabama (Figure 1). The TTW was constructed to provide a shortcut for barges from the Tennessee and Ohio rivers to the Gulf of Mexico. This project included canals, levees, river channelization and straightening, and construction of 10 locks and dams. The northernmost section of the TTW, the Divide Section, consists of a 47-km canal between the Yellow Creek embayment of Pickwick Lake on the Tennessee River and Bay Springs Reservoir. The middle section, the Canal Section, includes five impoundments with a levee extending along the entire western shoreline. The lower section of the TTW, known as the River Section because the Tombigbee River joins the man-made canal here, is impounded by four LADs, and the system follows the historical path of the river from this point downstream to its confluence with the Alabama River, thus forming the Mobile River. Unlike many LAD impoundments along larger rivers, the impoundments on the TTW tend to be smaller (<5,000 ha), with less variable water fluctuations (<3 m yr^{-1}) as water levels are maintained at specific levels for navigation by the U.S. Army Corps of Engineers. This study was conducted on the three uppermost River Section impoundments: Aberdeen, Columbus (John C. Stennis LAD) and Aliceville (Tom Bevill LAD) lakes (Table 1, Figure 1). Only the 1214 ha of Aliceville Lake in Mississippi were sampled.

Table 1. Location of dam relative to the mouth of the Mobile River at Mobile Bay, surface area, drainage area, and description of sampling effort and flathead catfish catch for Aberdeen, Columbus, and Aliceville lakes on the Tennessee-Tombigbee Waterway during 2011–2013.

Impoundment	Location (km from mouth)	Surface area (ha)	Drainage area (km^2)	Year sampled	Samples taken	Distance sampled (km)	Total catch
Aberdeen	576	1668	5302	2011	13	15.2	112
Columbus	539	3606	11,500	2012	13	19.6	140
Aliceville	494	3359	14,892	2013	9	11.7	134

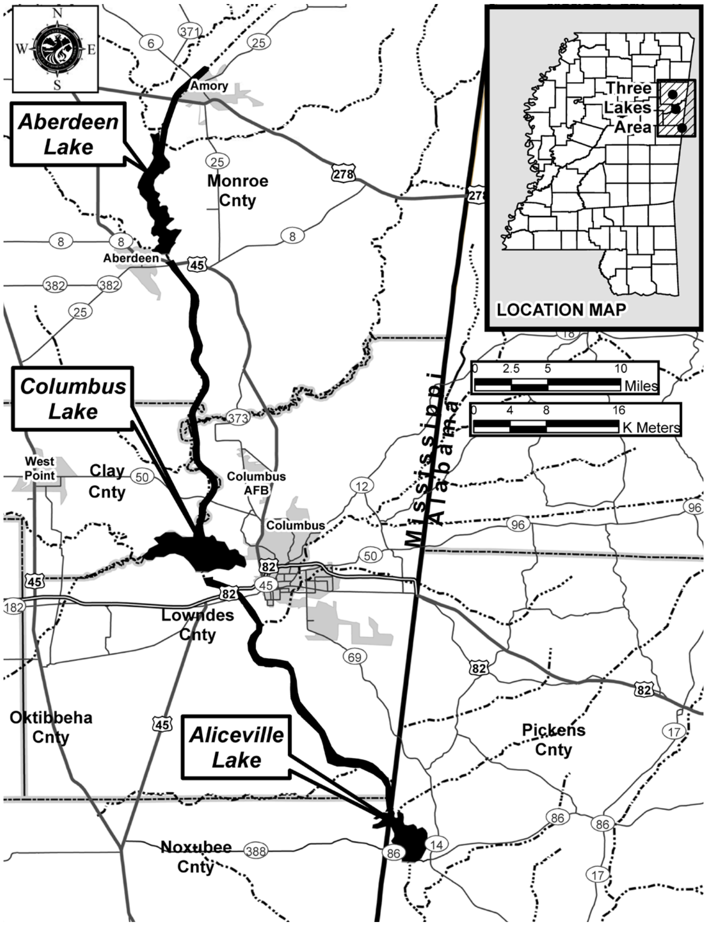

Figure 1. Map of the Tennessee-Tombigbee Waterway in Mississippi, including Aberdeen, Columbus, and Aliceville lakes.

Methods

During summer months (July–August) from 2011 through 2013, subjectively selected sites within various accessible habitats (main channel, secondary channel, backwater, tributaries) ranging from 1–2 km in length were sampled for flathead catfish (Vokoun and Rabeni 1999; Table 1). Sampling was conducted with a Smith-Root boat-mounted electrofisher with pulsed DC operated in low range (170–340 volts) at 15 pulses sec-1, and percent of range was manually adjusted to achieve 1–2 amp output (Porter et al. 2011, Bodine et al. 2013). A chase boat was used to capture fish that surfaced away from the electrofishing boat (Gilliland 1987, Bodine et al. 2013). Total distance traveled by the electrofishing boat during each sample was recorded as a measure of effort.

Flathead catfish were measured for total length (TL, mm) and weight (g). The left pectoral spine of each fish was removed for age and growth analysis and fish were released. Spines were dried in the lab for two weeks, cleaned, and sectioned through the articulating process using a low-speed isomet saw (Turner 1980, Buckmeier et al. 2002, Olive et al. 2011). Spines were read by two independent readers; if an age was not agreed upon, a third independent reader was employed to help determine the correct age through consensus.

Electrofishing catch per unit effort (CPUE; total number of flathead catfish per km) was calculated for each impoundment as an index of abundance (Miranda 2005). Length- frequency distributions were constructed by pooling flathead catfish into 10-mm-TL groups for each impoundment. Differences in length-frequency distribution among impoundments were examined using Kolmogorov-Smirnov tests in the PAST software package (Hammer et al. 2001). Mean lengths at each age were calculated for each impoundment and were used to model growth rates and determine predicted lengths at age using the von Bertalanffy growth function in Fisheries Analysis and Simulation Tools (FAST; Slipke and Maceina 2000). Difference in growth rates (using predicted mean lengths at age) among impoundments was tested using an analysis of covariance (ANCOVA) to examine slopes of the total length to age regressions using PAST (Hammer et al. 2001). Age frequencies were generated for each impoundment, and instantaneous annual mortality (Z) was estimated using a weighted catch curve in FAST (Slipke and Maceina 2000); total annual mortality (A) was estimated using $1\text{-}e^{-z}$. Total annual mortality was also estimated using two length-based methods for comparison, the Robson-Chapman and Heinke methods (Miranda and Bettoli 2007). For the Robson-Chapman method, A is estimated using $1 - (T / N + T - 1)$, where $T = \sum$ (coded age group $*$ catch) and $N = \sum$ catch. Heinke's method estimates A as n_o / N, where n_o = the number of fish in the youngest age considered and $N = \sum$ catch. Both methods assume constant recruitment, constant mortality, and equal vulnerability.

The Recruitment Coefficient of Determination (RCD) (Isermann et al. 2002) was used to examine differences in recruitment variability among impoundments. The RCD is the coefficient of determination (r^2) resulting from a weighted catch curve. In populations exhibiting consistent recruitment, age explains most of the variation in the number of fish at each age (i.e., through mortality) and results in high RCD values. Inconsistent recruitment is expected to result in less predictable trends in number at age and will result in low RCD values (Isermann et al. 2002). Catch-curve residuals were examined as a qualitative method to compare recruitment patterns among impoundments (Maceina 1997). The relationship between mean daily discharge for numerous time periods and time scales (e.g., month of May, annual) collected from the U.S. Geological Survey gauge located at the John C. Stennis LAD and catch-curve residuals from each of the three impoundments was evaluated using simple linear regression in PAST (Hammer et al. 2001). Significance was declared at $P \leq 0.05$ for all analyses.

Results

A total of 388 flathead catfish were collected in 70.4 km of electrofishing effort during this study (Table 1). Catch rates of flathead catfish were higher in Aliceville Lake (12.56 fish km^{-1}, SE = 5.39) than in Columbus Lake (7.37 fish km^{-1}, SE = 1.97) or Aberdeen Lake (7.54 fish km^{-1}, SE = 1.36). Statistical tests were not conducted on catch per effort data due to the use of non-random sampling; however, standard errors for each population overlapped, suggesting no difference. Length-frequency distributions were similar between Aberdeen and Columbus lakes ($D = 0.11$, $P = 0.62$, df = 90), Aberdeen and Aliceville lakes ($D = 0.10$, $P = 0.74$, df = 90), and Columbus and

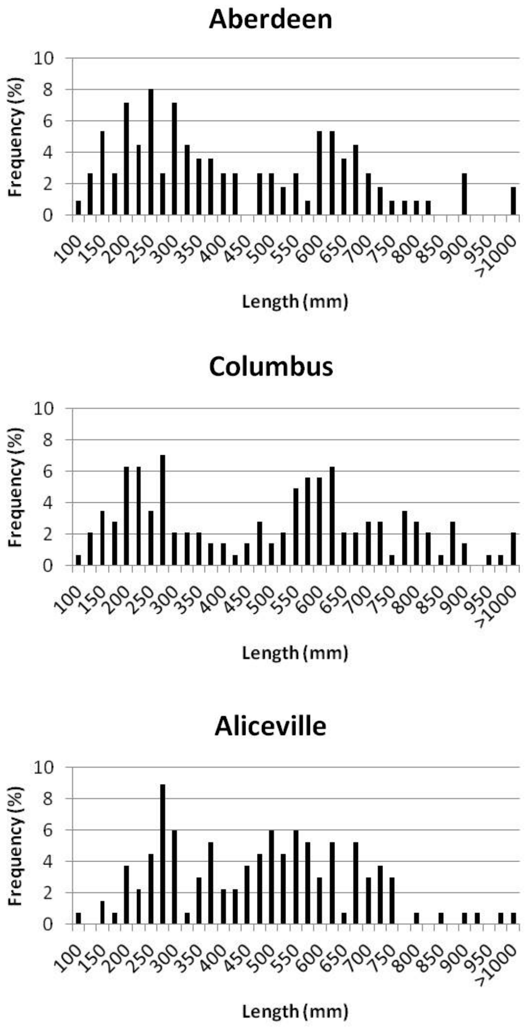

Figure 2. Length-frequency histograms for flathead catfish populations from three impoundments of the Tennessee-Tombigbee Waterway collected during 2011–2013 using low-frequency electrofishing.

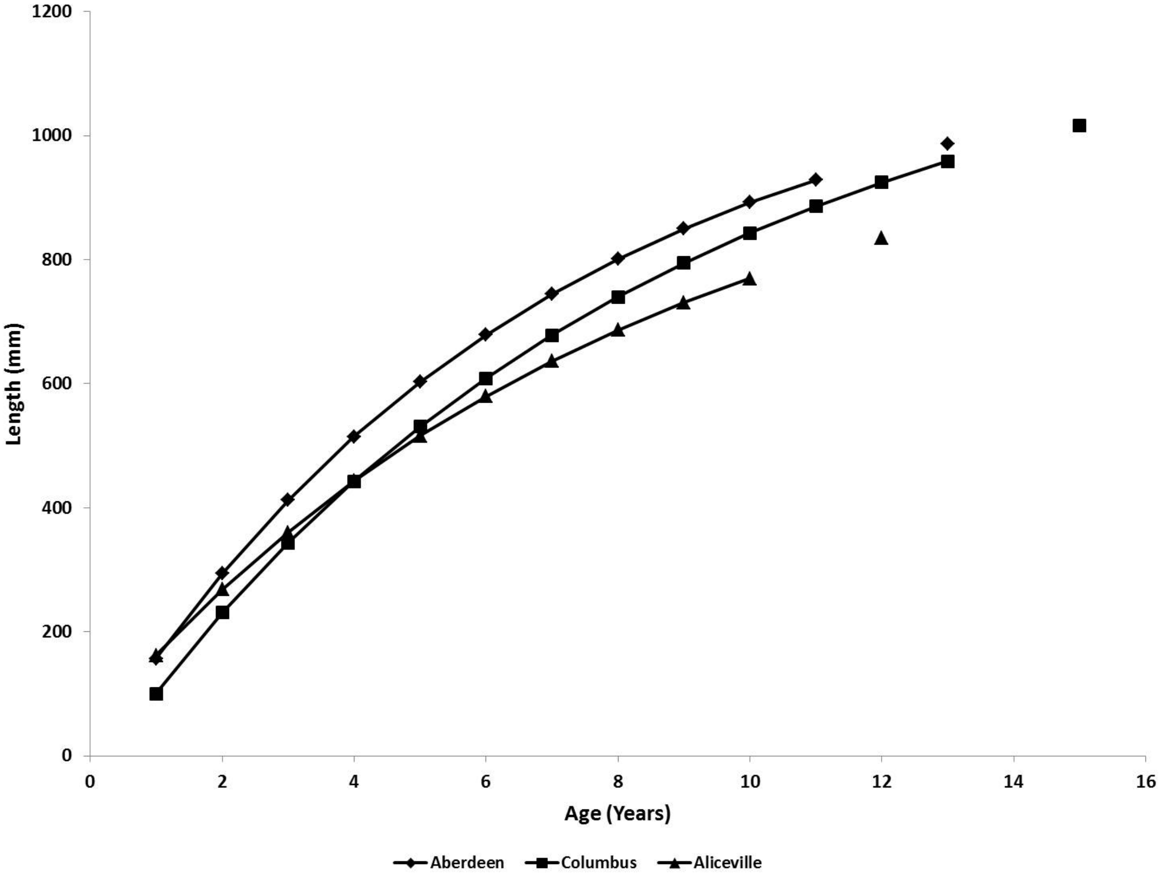

Figure 3. Mean total length (mm) at age predicted for flathead catfish populations using a von Bertalanffy model in three impoundments of the Tennessee-Tombigbee Waterway collected during 2011–2013 using low-frequency electrofishing.

Aliceville lakes ($D = 0.13$, $P = 0.38$, df = 90; Figure 2). Growth rates were similar among the three impoundments (F range 0.29 to 1.18, $P > 0.3$; Figure 3). Estimates of A varied among methods, but were similar among reservoirs, with rates in Aliceville Lake (31%–40%) being slightly higher than those in Aberdeen Lake (28%–35%) or Columbus Lake (27%–33%) (Table 2; Figure 4).

The RCD in all three impoundments indicated that recruitment was moderately consistent, with the lowest value observed in Aliceville Lake (0.77); whereas values were higher in Aberdeen and Columbus lakes (0.89 and 0.93, respectively). Furthermore, examination of catch-curve residuals from all three impoundments indicated that recruitment variation was generally low during 2004–2008. There was no significant relationship between catch-curve residuals for any of the three impoundments and any measure of mean daily discharge that we examined (all $P > 0.3$, $r^2 < 0.3$).

Table 2. Total annual mortality (A) estimates with standard errors in parentheses from three different methods, and ages included in mortality calculations for flathead catfish, in each of the three study impoundments on the Tennessee-Tombigbee Waterway collected during 2011–2013. Note that standard errors could not be calculated for total annual mortality using the Robson-Chapman method due to low sample size.

Method	Aberdeen	Columbus	Aliceville
Catch curve	28 (18 – 37)	27 (19 – 35)	31 (3 – 51)
Robson-Chapman	35 (NA)	33 (NA)	37 (NA)
Heinke's	31 (19 – 43)	27 (15 – 39)	40 (26 – 54)
Ages	3 – 13	6 – 15	5 – 12

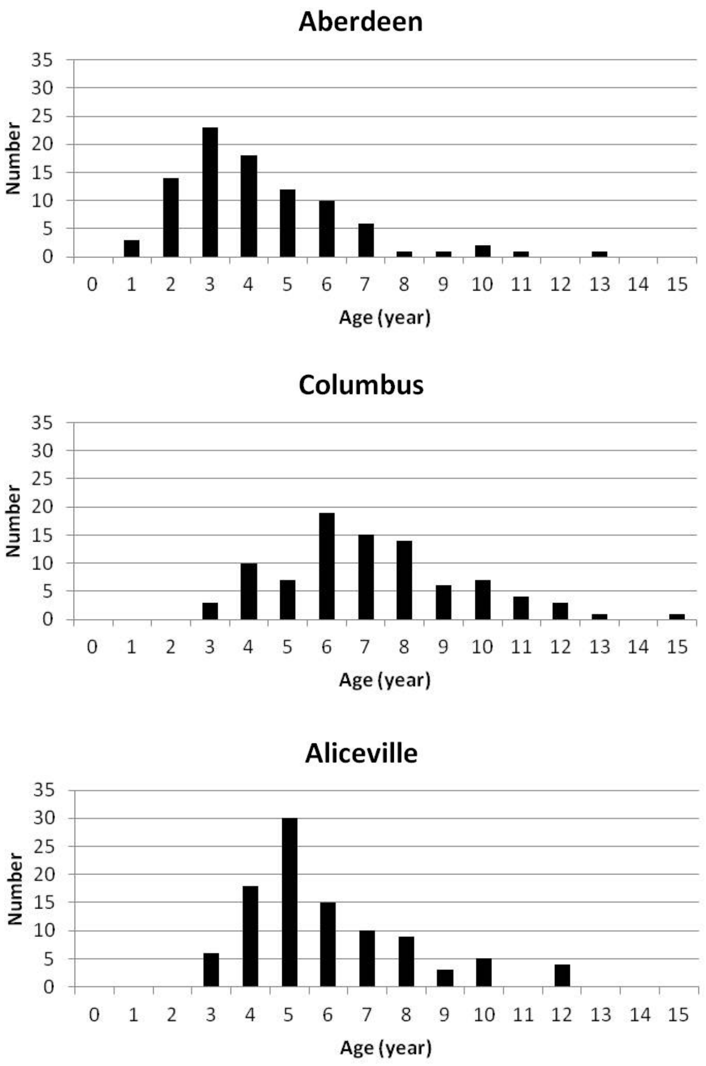

Figure 4. Catch-at-age histograms for flathead catfish in three study impoundments on the Tennessee-Tombigbee Waterway collected during 2011–2013 using low-frequency electrofishing.

Discussion

Our data showed little difference in any flathead catfish population parameters among three successive impoundments of the TTW. However, a limitation to our analyses was the small sample sizes for each impoundment. Vokoun et al. (2001) suggested that 300–400 fish per sample is optimal for representing size structure with minimal bias, and Coggins et al. (2013) showed that sample sizes less than 500–1000 fish could lead to bias in calculation of growth and mortality rates. Sample sizes in our study fell short of these thresholds and therefore some of our results may exhibit some level of bias. One metric that is most likely biased is the weighted catch curve for each lake. A small sample size with a high relative number of the oldest age group can lead to an underestimate of Z (Coggins et al. 2013). This is the primary reason why we included the Robson-Chapman and Heinke methods of estimating mortality, as the latter is thought to be sensitive to low sample sizes of older fish (Miranda and Bettoli 2007).

The lack of difference in recruitment variability is unsurprising. All three impoundments are managed for stable water levels at all times and flood waters are quickly flushed from the system, dampening any flood pulse. Furthermore, all three impoundments are approximately within 100 km of each another, resulting in very similar precipitation and temperature patterns. Flathead catfish recruitment in all three impoundments did not appear to be related to mean daily discharge in any time period. Thus, factors affecting recruitment in these impoundments remain unknown.

The lack of difference in size structure and growth rate is surprising given the substantial increase in drainage basin from Aberdeen Lake to the other two pools. The River Continuum Concept (RCC) describes longitudinal gradients in biota due to changes in physical and chemical characteristics of a river (Vannote et al. 1980). Miranda et al. (2008) noted that although the RCC does not apply directly to reservoirs, a similar upstream to downstream gradient may be present in reservoir cascades, as they observed on the Tennessee River system. Miranda et al. (2008) predicted that downstream gradients in impounded river systems would exist for common fishery rate functions such as growth and mortality. Relative to navigation system design, the TTW is similar to the Tennessee River system as well as the Upper Mississippi River, where the fish communities were also found to exhibit a downstream gradient (Chick et al. 2006, Miranda et al. 2008). These systems are LAD impoundments created primarily for navigation, with impounded waters backing up to the next upstream dam. This is different than the systems described by the “serial discontinuity concept” where there is a “reset” of downstream gradients in a river system caused by dams, then the system recovers until it reaches the next dam (Ward and Stanford 1983). In a LAD impounded river navigation system, there is no room for a recovery of river functioning because even the tailwaters are impounded by the next downstream dam. In addition to changes in ecological function in a longitudinal manner, studies have shown significantly faster growth rates for channel catfish in impoundments with larger drainage areas (Mosher 1999, Bouska et al. 2011). Bouska et al. (2011) also reported that size structure of channel catfish populations increased in successive downstream pools of the Missouri River.

We found no significant downstream gradient in any of the population metrics that we examined for flathead catfish, possibly indicating that either the scale we examined was too small to observe significant changes in fish population structure, or the low retention time of these run of the river impoundments prevented the increased nutrient input in the larger, downstream impoundments from having a measurable influence on the flathead catfish population. Thorp et al. (2006) concluded that channelization in river systems (impounded or not) disrupts succession processes that are typical of unaltered riverine ecosystems due to decreasing retention time. Additionally, population characteristics of flathead catfish are highly dependent on in-stream habitat (primarily woody debris), and may reflect the overall health of an aquatic system (Jackson 1999). In an unaltered river ecosystem, fish production increases as you move downstream as autochthonous material replaces allochthonous material as the primary energy source (Vannote et al. 1980). The TTW is a highly altered river system consisting of a series of LADs, reservoirs, and navigation channels. Maintenance of the channels (i.e., dredging and snagging) results in a mostly homogenous mainstream habitat. A limited number of off-channel habitats are available, but they are highly affected by sedimentation due to channel alterations, resulting in reduced habitat heterogeneity (Schramm and Spencer 2006). Our results suggest that the extreme level of habitat modification and homogenization present in the TTW may result in a tempered response by flathead catfish populations to environmental gradients that exist as drainage area increases downstream in an impounded river system.

In comparison to other native flathead catfish populations in the southern and midwestern United States reported by Kwak et al. (2006), growth rates for all three study impoundments were similar to the mean growth rate for reservoir populations. The three TTW impoundments showed more rapid growth rates than flathead catfish populations in two nearby LAD type impoundments (Grussing et al. 1999, Marshall et al. 2009). While total annual mortality rates for the three TTW impoundments were higher than those reported for reservoir and tailwater populations by Marshall et al. (2009), Jolley and Irwin (2011), and Winkelman (2011), they were lower than those reported by Robinson (1997) for the Missouri and Mississippi rivers that were subject to substantial commercial fishing during the study period.

Flathead catfish populations in these impoundments appear to be similar to each other and to other southeastern U.S. reservoir populations. Severe habitat alterations likely inhibit flathead catfish production in this system by mediating potential productivity increases that would typically occur in a downstream direction in an unaltered floodplain river system. In spite of this, consistent recruitment, average growth, and moderate mortality rates should allow this fishery to provide a sustainable harvest for local anglers. A follow-up study using multiple gear types to collect greater numbers of a wider range of fish sizes may provide additional insight into population rate functions. Further, an exploitation study on flathead catfish in these reservoirs would help determine how much of the total annual mortality is from fishing, and which user groups (e.g., commercial, recreational, hand fishers) are responsible for most of the fishing mortality. More studies are needed on flathead catfish populations in reservoirs across their native range to evaluate factors such as gear bias and environmental variables that have the strongest effect on growth, recruitment, and mortality rates. This information will help managers make better decisions regarding harvest regulations and prioritize habitat restoration or enhancement projects.

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