Age and Growth Comparison of White Bass Among Three Southeastern U.S. River-Reservoir Systems

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Abstract: White bass (*Morone chrysops*) are a popular sport fish native to the Mississippi River basin and widely introduced elsewhere. We examined population characteristics of this species in three systems (Kentucky Lake, Tennessee; Tennessee-Tombigbee Waterway, Mississippi; and Grenada Lake, Mississippi) with different habitats and fishery characteristics to evaluate whether population dynamics varied sufficiently to require system-specific management. Using white bass collected from these three systems in 2019–2020, we tested two aging techniques and found sectioning of otoliths provided more precise age estimates compared to using whole otoliths. We collected white bass up to 9 years of age, representing the oldest maximum age reported for southern populations. However, populations were composed of mostly younger fish, with 84% four years old or younger. All fish reached preferred size (300 mm TL) by age 3 across study areas. We found differences in length-at-age among populations, but we do not believe that these differences were large enough to justify system-specific management regulations.

Key words: otolith, regulations, annulus, longevity, length-at-age

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White bass (*Morone chrysops*) are a species in the temperate bass family native to the Mississippi River drainage. The species has been widely introduced outside its native range to create sport fishing opportunities, with both positive effects in providing new opportunities and negative effects on other species documented (e.g., Dill and Cordone 1997, Powers and Ceas 2000, Rohde et al. 2009). Among anglers, white bass are popular within their current range, especially during spring spawning migrations when they concentrate in smaller tributaries and below dams (Muoneke 1994). Many white bass fisheries are primarily harvest-oriented (Ganus et al. 2015); for example, up to 63% of white bass caught in Tennessee reservoirs annually are harvested (Black 2014).

Despite this popularity, research on white bass is lacking for many waterbodies where fisheries occur. Range-wide indices, including minimum length categories and standard weight equations have been developed for this species (Neumann et al. 2012), but regional and waterbody population characteristics are rarely reported in the peer-reviewed literature. It is difficult to achieve consistent management of individual fisheries without robust data on population dynamics. These dynamics can vary considerably over a small geographic area, particularly among waterbodies that are different in form and function (e.g., Sissenwine 1984, Stubbs et al. 2014). Yet, white bass in many states are primarily managed using generic statewide regulations that vary among states. For example, there is no bag limit on white bass in Mississippi, but Tennessee has a limit of 15 fish per day.

Growth, recruitment, and mortality are key population rate functions that regulate most fisheries (Ricker 1975, Quist et al. 2012) as well as influence resiliency of fish populations to angling and harvest. Age and growth data can provide valuable insight into these processes and are important components of informed management regulations. Unfortunately, time and financial limitations of agency personnel often preclude targeted sampling for white bass, as management priorities are usually focused on other species of greater interest to the angling public (Hunt et al. 2008).

In this study, we compared age and growth estimates of white bass from three different systems in Mississippi and Tennessee: a mainstem river/reservoir system, a heavily modified navigational canal/river system, and a flood-control reservoir. Our objectives were to 1) determine appropriate aging protocols for white bass; 2) provide an overall regional assessment of white bass age and growth, and 3) compare white bass age and growth among systems.

Methods

Impounded in 1944, Kentucky Lake is a 64,800-ha mainstem impoundment of the Tennessee River in western Tennessee and Kentucky that serves as a large flood-control reservoir and provides navigation and hydroelectric production. The reservoir supports over 1.3 million angler-h of fishing effort annually, with about 31,000 angler-h directed at white bass (Ganus et al. 2015). The Tennessee-Tombigbee Waterway in Mississippi and Alabama was completed in 1984 and is a smaller, shallower system with less

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stable hydrology, greater turbidity and sedimentation (McClure 1985), and limited angling effort compared to Kentucky Lake. It includes a series of small mainstem impoundments along the Tombigbee River connected to the Tennessee River by a navigational canal. Grenada Lake is a 14,163-ha shallow flood-control reservoir constructed in 1954 on the Yalobusha River in western Mississippi containing a popular white crappie (*Pomoxis annularis*) fishery that by far receives the most fishing pressure (Hunt et al. 2008). This reservoir follows a water-level rule curve that varies about 4 m annually in normal precipitation years, although greater fluctuations are common. Grenada Lake is managed solely by the state of Mississippi, whereas the Tennessee-Tombigbee Waterway is managed by Mississippi and Alabama, and Kentucky Lake is managed by Tennessee and Kentucky.

During 2019 and 2020, white bass were collected in March through November in the Tenneesee-Tombigbee Waterway; in June, July, and August in Kentucky Lake; and in July and August in Grenada Lake. White bass were collected from the three systems by angling. Sampling in the Tennessee-Tombigbee Waterway also included electrofishing using a boat-mounted 7.5 GPP unit (Smith-Root, Inc., Vancouver, Washington) operated for a target output power of 3000–4000 W, with 30 of 40 fish from this system collected during electrofishing. All white bass were retained and placed on ice for processing later at Mississippi State University. We determined TL (mm), weight (g), and sex of each fish by gonadal examination. We extracted both sagittal otoliths and dry-stored them in labeled vials. We were not able to successfully remove otoliths from two of the 179 fish collected, so these two fish were removed from analyses.

We selected either the right or left otolith based on cleanness and condition (i.e. cracks, blood stained, etc) for age determination. For whole-otolith aging, otoliths were placed under water and digitally imaged under 40X magnification using a Leica S8A-PO dissecting microscope with attached Leica DFC290HD camera (Leica Camera AG, Wetzlar, Germany). For sectioned-otolith aging, each otolith was mounted on a labeled microscope slide using epoxy resin, and then a transverse 1-mm section including the nucleus was cut for analysis using a low speed Buehler isomet saw (Buehler Ltd, Lake Bluff, Illinois) with diamond wafering blades operating at 145 rpm. Sections were remounted and sanded to reveal annuli and then digitally imaged under 40X magnification. For each technique, age of each otolith was estimated by two independent readers by viewing the images. If age estimates for an otolith differed between the two readers for either technique, the otoloith was examined and discussed by both readers until a consensus was reached (Quist et al. 2012). We assumed a 1 January birthdate.

Agreement between aging techniques was compared by fitting linear regression to the age estimates from whole and sectioned otoliths (for each otolith, x = sectioned-otolith estimate, y = whole-otolith estimate) with PROC GLM (SAS Institute 2012) and assessing whether the 95% confidence interval of the slope estimate included 1, which would indicate agreement (Wahl et al. 2011). Based on comparative patterns observed, subsequent analyses proceeded using the age estimates from sectioned otliths. Mean total length-at-age was compared between male and female white bass using ANCOVA (PROC GLM) on $\log_{10}$-transformed length and age data, holding sex as a class variable. Similarly, we compared length-at-age between systems using ANCOVA on $\log_{10}$-transformed length and age data holding waterbody as a class variable (Isely and Gabrowski 2007). Significance level for all tests was set at $P \leq 0.05$.

Results

We collected 179 white bass by angling and electrofishing from the three systems combined, including 78 from Grenada Lake, 61 from Kentucky Lake, and 40 from three pools of the Tennessee-Tombigbee Waterway (Table 1). Sex was determined for all but six immature fish, with 57.2% females and 42.8% males comprising the overall sample.

Table 1. White bass population characteristics derived from samples collected during 2019 and 2020 in three river-reservoir systems in Mississippi and Tennessee. Tenn-Tom is the Tennessee-Tombigbee Waterway. Age data are from sectioned otoliths.

		Total length (mm)			Weight (g)				Age (year)		
Population	***n***	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Mean Wr**	**Min**	**Max**	**Mean**
Overall	179	173	422	311.7	73	1140	430.6	94.6	1	9	3.0
Undetermined	6	175	250	208.5	73	158	104.5	88.0	1	2	1.4
Male	74	173	414	303.9	74	863	384.2	93.6	1	9	2.9
Female	99	188	422	323.7	89	1140	485	95.8	1	9	3.2
Grenada Lake	78	173	422	317.8	73	946	475.8	98.4	1	9	2.9
Kentucky Lake	61	229	393	322.1	115	1,004	436.3	89.7	1	6	3.6
Tenn-Tom	40	186	422	283.6	74	1140	333.8	94.9	1	4	2.3

We observed discrepancies between initial ages assigned using whole otoliths and sectioned otoliths in 37 of 179 fish (20.7%; Figure 1). Although known-age fish were not available to validate age designations, improved clarity and readability of the sectioned otoliths suggested that they were more likely than whole otoliths to represent the true age of the fish. Under the assumption that estimates from sectioned otoliths were closer to true ages, estimates from whole otoliths underestimated fish ages compared to otolith sections 20% of the time, most commonly by one year but occasionally by as much as four years ($F = 1019.7$; df = 1, 174; $P < 0.001$; 95% confidence interval for regression slope: 0.68–0.78). Ages were rarely (1%) overestimated with whole otoliths. Further, reader discrepancies were two-fold greater for whole than for sectioned otoliths, requiring more discussion to reach consensus. Regardless of aging method, the age-1 annulus was difficult to locate and required special attention to detect with consistency for all fish in our sample (Figure 2).

Based on estimates from sectioned otoliths, fish ranged in age from 1 to 9 years old across all three populations, but 84% were less than 4 years old and 72% of fish sampled were between 2 and 4 years old. No age-0 fish were collected. Length-at-age suggested that about one-third of fish reached preferred size (300 mm) by age 2 and all exceed preferred size by age 3 (Table 2). Females grew faster than males ($F = 140.2$, df = 3, 168, $P < 0.001$), and growth appeared to slow considerably after age 4.

Mean total length-at-age was also different among systems across all ages ($F = 97.63$, df = 5, 170, 168, $P < 0.001$). Because only ages 2–4 were collected in all three systems, we also demonstrated length-at-age to be statistically different for this age range ($F = 42.9$, df = 5, 119, $P < 0.001$). Both overall and within the 2-to 4-year-old range, Grenada Lake white bass were the largest and Kentucky Lake fish were the smallest.

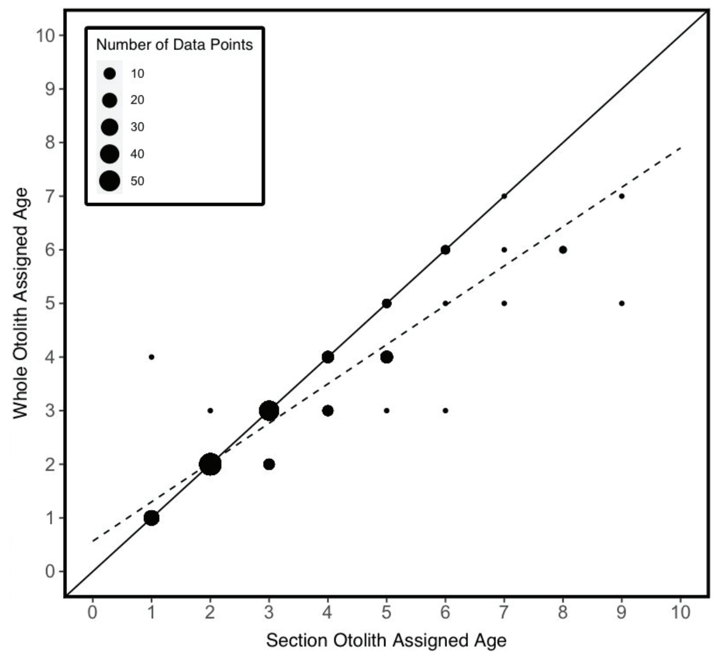

Figure 1. Comparison of whole otolith versus sectioned otolith age assignments for white bass collected from Grenada Lake, Kentucky Lake, and Tennessee-Tombigbee Waterway in 2019 and 2020. Solid line represents a 1:1 relationship and the dotted line is the observed relationship.

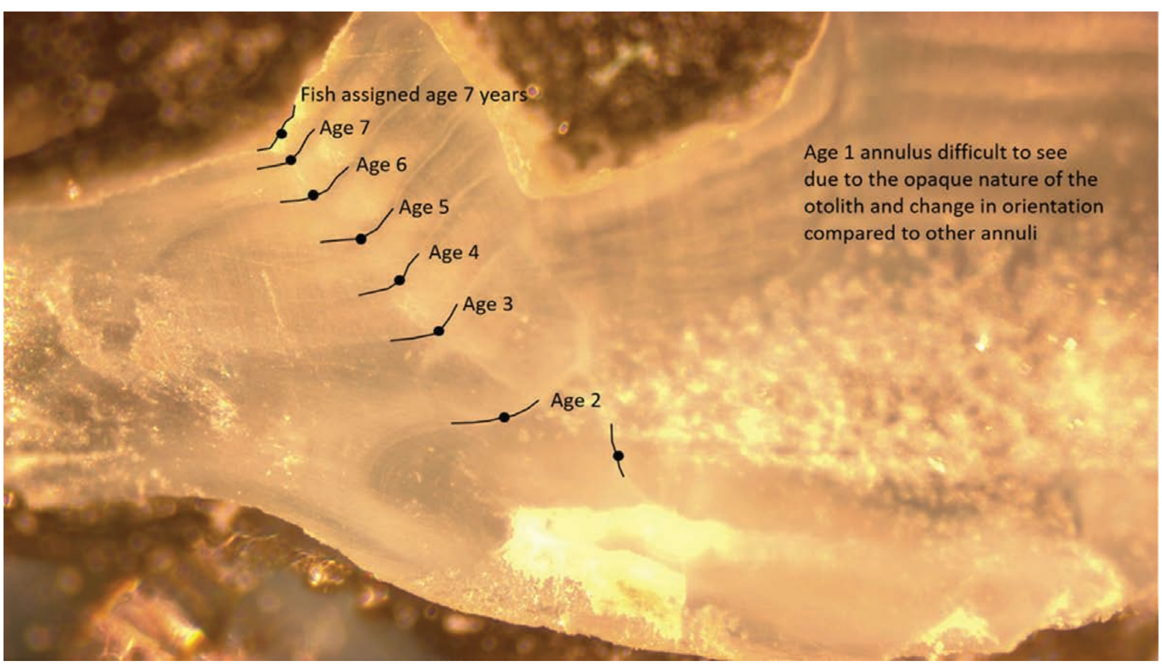

Figure 2. Sectioned white bass otolith displaying assigned ages. Age 1 annuli were difficult to detect and required special attention with this species.

Table 2. Mean and SE of TL (mm) at age, pooled and individually by system, for three white bass populations (Grenada Lake, Kentucky Lake, and Tennessee-Tombigbee Waterway) sampled in 2019 and 2020.

	Overall		Mean TL by System			SE by System		
Age	TL	SE	Grenada	Kentucky	Tenn-Tom	Grenada	Kentucky	Tenn-Tom
1	219.1	5.5	212.5	–	230.6	6.9	–	7.9
2	280.5	4.5	302.9	256.2	261.7	5.5	8.0	5.2
3	329.8	4.5	351.9	313.9	328.1	4.8	1.2	12.8
4	362.7	7.9	362.0	353.9	398.6	13.0	10.0	16.3
5	365.4	2.7	359.0	366.4	–	8.0	2.9	–
6	377.5	5.7	393.3	346.0	–	8.0	27.0	–
7	391.7	10.1	391.7	–	–	10.1	–	–
8	401.5	3.5	405.0	398.0	–		–	–
9	418.0	4.0	418.0	–	–	4.0	–	–

Discussion

White bass are a relatively short-lived species, and although the maximum age is often reported as <9 years (Muoneke 1994, Nordhaus et al. 1998, Baker and Lochmann 2012), the oldest reported individual was age 14 from a South Dakota glacial lake (Willis et al. 2002). Fish are poikilothermic and dependent of environmental temperature for their metabolic function; thus, fish tend to live longer and grow more slowly as latitude increases (Hoenig 1983, Quinn and Deriso 1999). Although the southern populations we studied were primarily composed of fish age 4 or younger, we collected older individuals including seven individuals that exceeded age 7, two of which were 9 years old.

Many factors, including genetics, growth rate, and environment can affect longevity (Das 1994). Six of the seven individuals exceeding age 7 were collected from Grenada Lake, including the oldest fish sampled (9 years old). In Kentucky Lake, the maximum age sampled was age 8, and no fish exceeded age 4 in the Tennessee-Tombigbee Waterway. Genetics is unlikely to mediate longevity differences we observed across these systems, as there is potential migration between the Tennessee River and the Tennessee-Tombigbee Waterway populations through the navigation canal (e.g., Roberts et al. 2013, Hoffman et al. 2017) and Grenada Lake is not very far geographically from these two sites. Thus, longevity differences observed among these systems in our study were likely due either to environmental differences or small sample sizes (Hoenig 2017). Despite our low sample sizes, our findings suggests that white bass have the capacity to live longer than previously reported within their southern range when fishing effort is low. This is supported by the fact that Grenada Lake, which harbors an intense crappie fishery that leads to low targeted angler effort toward white bass, displayed the highest longevity compared to the other two systems where white bass are of greater harvest interest.

We found that sectioning was the preferred technique for white bass ototlith preparation, as use of whole otoliths led to significantly underaging older fish and greater discrepancy between readers. We had some difficulty in detecting the first annulus during initial aging efforts, and it is possible that modifications to section preparation and microscopy protocols would help clarify annuli. This might include additional polishing, oil immersion, or changes in lighting (Quist et al. 2012). However, once we realized that we were missing the annulus, we were able to re-age the otoliths and detect all annuli.

Length-at-age varied among the three systems. Due to small sample sizes, we cannot conclude that these differences are environmentally driven. Regardless, the observed differences among populations were small and likely not biologically significant. Angling pressure and harvest for this species is low compared to other Mississippi species (Hunt et al. 2008, USFWS and USBC 2011), particulary crappie (*Pomoxis* spp.) and largemouth bass (*Micropterus salmoides*). Ganus et al. (2015) reported that white bass were fully mature by age 2 and full recruitment to the fishery (i.e., 254 mm TL) occurred for all fish by age 3. On average, fish reached this size in all three of our study reservoirs by age 2 and exceeded 300 mm TL by age 3. Despite the fast growth exhibited by white bass, associated high natural mortality generally results in minimum-length limits failing to increase yield and harvest potential in most populations (Lovell and Maceina 2002, Schultz and Robinson 2002, Baker and Lochmann 2012, Ganus et al. 2015). This also likely explains few measurable effects of angler harvest on white bass populations being reported, despite these fisheries being primarily harvest-oriented (Muoneke 1994, Schultz and Schneider 1999, Bauer 2002, Betsill and Pitman 2002). In Kentucky Lake, the creel limit was decreased from 30 to 15 fish per day in 2008 (Ganus et al. 2015) for the purpose of remediating variable year-class strength. However, little difference has been observed following this restriction (T. Broadbent, Tennessee Wildlife Resources Agency, personal communication). Thus, we conclude that system-specific regulations for white bass, particularly minimum length limits, are not warranted in general, but may be necessary in systems where fish live longer and exhibit lower natural mortality (e.g., Willis et al. 2002).

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