A Population Assessment and Minimum Length Limit Evaluation for White Bass in the Arkansas River, Arkansas

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Abstract: White bass (*Morone chrysops*) are a popular sport fish throughout most of their zoogeographic distribution. We conducted a population assessment of white bass in Pool 4 of the Arkansas River. Using population metrics calculated from the assessment, responses of the white bass fishery to a 254-mm or 305-mm minimum length limit (MLL) were simulated using the Fishery Analysis and Modeling Simulator (FAMS) model. White bass ages ranged from 1–7, but 88% of white bass were less than age 5. Conditional natural mortality averaged 0.43, and total annual mortality was 54%, so exploitation was estimated to be 0.15. Implementation of a 254-mm MLL would reduce the number of fish harvested by 18%–32%, but increase the average weight of harvested fish by 21%–43%. Yield was predicted to increase or decrease by 10% depending upon natural mortality and exploitation. The portion of the cohort reaching preferred size (300 mm TL) ranged from 5% to 26%. Implementation of a 305-mm MLL was predicted to decrease the number of fish harvested by anglers by 37%–60% but increase average weight of harvested fish by 47%–101%. Change in yield ranged from –30% to 12%, but the percent of preferred-sized white bass in the populations was predicted to increase 14%–86%. The Arkansas River white bass population was characterized by low exploitation, moderately high natural mortality, and moderate growth rates. Yield is unlikely to change much under a minimum length limit, but size structure could be improved.

Key words: modeling simulation, yield, mortality, growth

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White bass (*Morone chrysops*) are an important target species for anglers in many locales; however, research on white bass is less common than on other, more popular sport fish. Some characterizations of white bass population dynamics and ecology are available in peer-reviewed literature (e.g., Colvin 2002, Lovell and Maceina 2002). Much of this knowledge was synthesized in a 2000 poster symposium on white bass during the 130th annual meeting of the American Fisheries Society. Willis et al. (2002) believed the increased research attention was a response to the growing interest from anglers targeting white bass in a variety of aquatic systems. In addition, fishery professionals were changing their management focus from populations to community assessments, and including white bass in their management plans.

Considerations of the effects of minimum length limits on white bass fisheries have indicated mixed results. Lovell and Maceina (2002) simulated a minimum length limit (MLL) on white bass in Alabama reservoirs and concluded that the MLL could increase yield when the population expressed fast growth, high relative weight, conditional natural mortality (*cm*) ≤30%, and exploitation >30%. After implementation of a 254-mm MLL and creel limit in Texas, the size structure of the white bass population in Lake Whitney improved while fish harvested decreased, which were the goals of the regulation (Muoneke 1994). However, most states do not manage their white bass populations with a regulation. The few states that do have harvest restrictions usually use liberal creel limits, a length limit, or a special regulation combining creel and length limit. No state has imposed a closed season on white bass fisheries.

Imposition of a minimum length limit depends upon the likelihood of achieving stated management goals. Specific management goals for the Arkansas River white bass fishery are unclear. Most white bass fisheries are harvest oriented, but some anglers might be interested in the capture of trophy white bass. A minimum length limit could improve a fishery by increasing yield or improving size structure when growth is fast, exploitation is moderate, and natural morality is low (Allen and Miranda 1995). However, imposing MLL regulations on populations that are short-lived, slow-growing, and experiencing high natural morality can negatively affect the number of harvestable fish (Allen and Miranda 1995, Lovell and Maceina 2002). Under the latter conditions, the protection of fish for future harvest is unlikely, and MLL regulations are ineffective (Colvin 2002, Schultz and Robinson 2002).

Like most freshwater fishes, white bass growth and natural morality vary along a latitudinal gradient. Southern populations have faster growth that is accompanied by higher natural mortality. As latitude increases, white bass growth and natural mortality decrease. Managing white bass with a MLL may be appropriate somewhere along this latitudinal gradient. Arkansas white bass may have the population dynamics necessary for a MLL to improve yield, given the latitudinal position of the state within the white bass zoogeographic distribution. White bass in Arkansas have fast growth rates, similar to those populations farther south, but a fair proportion of fish live beyond age 4. The objectives of our study were to characterize the population of white bass in the Arkansas River, Arkansas, and evaluate the effects of a MLL on the Arkansas River white bass fishery. The response of the population to a 254-mm and 305-mm MLL were compared to a fishery that had no MLL. Different scenarios were examined by varying natural mortality and exploitation.

Methods

Research focused on Pool 4 of the lower Arkansas River, which is located near Pine Bluff, Arkansas. This area encompasses 32 km of river channel between dams 4 and 5, and has a surface area of 2,300 ha (Schramm et al. 2008). Pool 4 has numerous tributaries and backwaters connected to the main river channel. Primary substrates consist of a heterogeneous mixture of silt, clay, sand, and gravel. Additionally, submersed macrophytes and woody debris are present in littoral zones along tributaries and backwaters (Schramm et al. 2008).

White bass sampling occurred over two years in 10 tributaries identified using aerial photographs in conjunction with field observations. Sampling was conducted generally from the last week of February until fish left the tributaries, usually near the end of April or into early May. All fish were collected using a boom-mounted electrofishing boat. Electrofishing settings were standardized depending on water temperature and conductivity to achieve a power output of approximately 3,000 W, which equated to approximately 7–10 A of current (Burkhardt and Gutreuter 1995). Sampling consisted of three 600-sec transects per tributary. The first transect began at the tributary mouth and proceeded down the Arkansas River along the shoreline. The second transect began at the tributary mouth and proceeded upstream into the tributary. The third transect began at the tributary mouth and proceeded up the Arkansas River along the shoreline. Tributaries were sampled three–five times each year. All sampling was conducted during daylight hours.

In the laboratory, white bass were measured (total length; TL) to the nearest mm and weighed to the nearest g. Fish that were ≤100 mm TL were removed from the data set prior to calculating mean relative weight (Brown and Murphy 1991). Length frequencies were constructed to examine the size structure of the population, and a weight-length (W-L) equation was fit to all the data, pooled across years. Sagittal otoliths were removed for aging, and whole and cross-sectioned otoliths were viewed under a dissecting microscope and double-blind read by two independent readers. If the readers disagreed on the annulus count, a third reader examined the otolith or the second otolith was cross-sectioned and re-examined. Once ages were assigned, we plotted the age structure of the population. Growth of white bass was estimated using a von Bertalanffy (1938) growth equation (Proc NLIN, SAS Institute 2004). Total annual mortality and total instantaneous mortality (Z) of age 2–7 white bass were calculated using weighted catch-curve (Maceina 1997). Instantaneous natural mortality (M) and conditional natural mortality (*cm*) were estimated using equations found in the Fishery Analysis and Modeling Simulator (FAMS) developed by Slipke (2010). Estimates for M and *cm* were computed by averaging five of the *cm* model options (e.g. Hoenig 1983, Peterson and Wroblewski 1984, Chen and Watanabe 1989, Jensen 1996, Quinn and Deriso 1999) in FAMS. We calculated instantaneous fishing mortality (F) and exploitation (u) assuming a Type II fishery, where natural and fishing mortality occur simultaneously (Ricker 1975).

Using the FAMS model, the Arkansas River white bass population was simulated under 254-mm and 305-mm MLL regulations and no MLL (assuming fish are susceptible to harvest at 203 mm). Modeling followed methods similar to Lovell and Maceina (2002). Yield-Per-Recruit models were simulated to evaluate the effects of the length limit on mean weight of fish in the creel (g), number of fish harvested, yield (kg), and proportion of the cohort reaching a preferred size for white bass (300 mm TL). Models were run over three levels of conditional natural mortality (*cm*), 0.3, 0.4, and 0.5, and conditional fishing mortality (*cf*) ranged from 0.05–0.40, stepped at 0.05 increments. All modeling scenarios assumed steady-state equilibrium conditions, with initial number of recruitments fixed at 1,000 age-0 fish. Maximum age was set to 7 years, which corresponded to the oldest individuals collected.

Results

A total of 693 white bass were collected during the two years of sampling. Length frequency distributions for the two sample years varied (Figure 1). The 2010 length frequency distribution showed a strong 2009 year class that comprised the peak between 180 and 240 mm. A weak 2010 year class was clear from the 2011 frequency distribution, but the peak between 240 and 280 mm again illustrated the strength of the 2009 year class (Figure 1). Prescence of this strong year class in the length frequencies was supported by the age frequencies as well (Figure 2). Mean (SD) age was 2.5 (0.1) years, and the oldest fish each year was age 7.

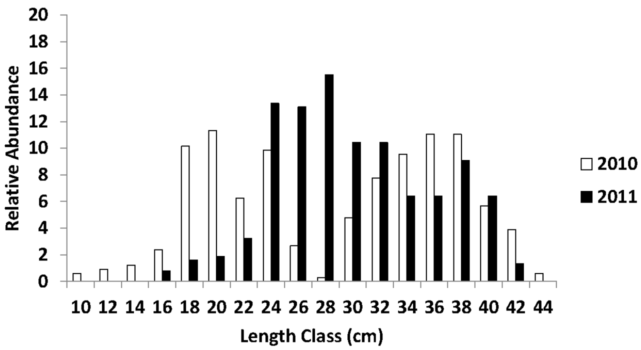

Figure 1. Length frequency distributions for white bass sampled in Pool 4 of the Arkansas River during 2010 (white) and 2011 (black). The 2009 year-class dominated our catches in both years. In 2010, all of the fish between 100–260 mm TL were age 1. In 2011, the age-2 fish ranged from 210–340 mm TL.

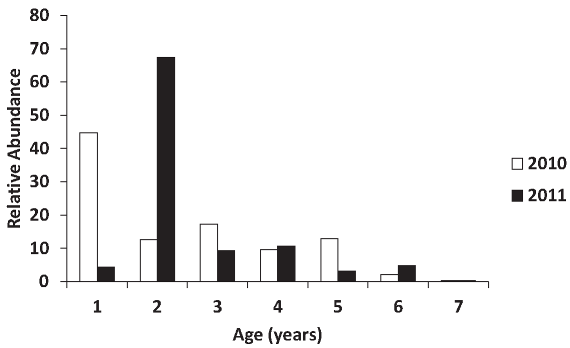

Figure 2. Age frequency distribution for white bass sampled in Pool 4 of the Arkansas River during 2010 (white) and 2011 (black).

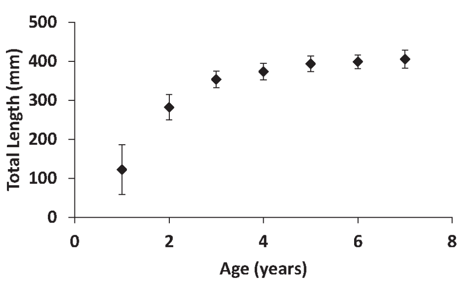

Figure 3. Mean size at age for white bass sampled in Pool 4 of the Arkansas River. Error bars represent one standard deviation.

Mean length at age 1 was 122 (63) mm and most fish reached preferred size by age-2 (Figure 3). Average length at age 3 was 353 (21) mm, and fish continued to grow about 20 mm/year thereafter. Overall, growth was relatively fast, with $K = 0.45$ (Table 1). Mean relative weight during the study was 98 (1). The slope and intercept of the linearized W-L equation were 3.20 and –5.38, respectively (Table 1). The weighted estimation of A was 54%. The five *cm* estimates from FAMS ranged from 0.28 to 0.49, and mean *cm* was

Table 1. Model parameters used to conduct simulations of the Pool 4 Arkansas River white bass fishery.

Equation	Term
von Bertalanffy growth coefficients	$L_\infty = 433$ mm $K = 0.450$ $t_0 = -0.46$
[a]Weight-length coefficients	Slope (b) = 3.20 Intercept (a) = –5.38
Conditional natural mortality (cm)	0.3–0.5 by 0.1
Conditional fishing mortality (cf)	0.10–0.40 by 0.05
Maximum age	7 years
Minimum length limits modeled	No limit (harvest begins at 203 mm) 254 mm 305 mm

a. Both variables were $\log_{10}$ transformed.

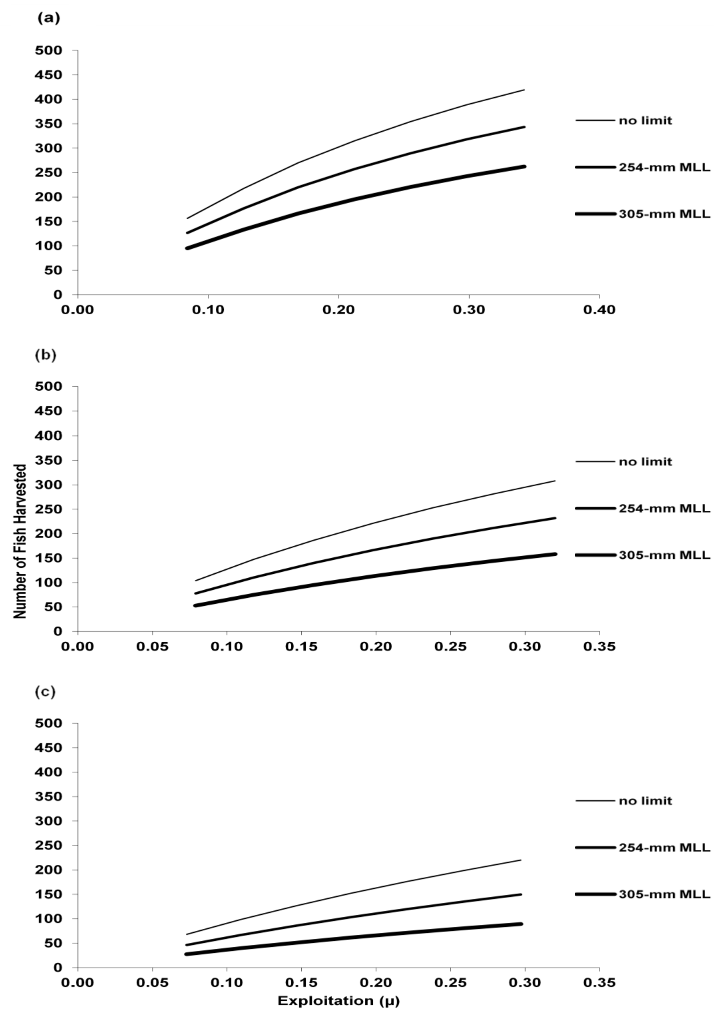

Figure 4. Predicted number of fish harvested at various exploitation rates (*u*) using steady-state equilibrium yield per recruit models where 1,000 age-0 fish enter the population for each simulation. Conditional natural mortalities (*cm*) of (a) 0.3, (b) 0.4, and (c) 0.5 were modeled for no regulation (i.e., harvest begins at 203 mm), a 254-mm minimum length limit, and a 305-mm minimum length limit.

0.43 (0.04). The estimates of *A* and *cm* conferred an estimate of *u* of 0.15.

The FAMS model predicted that implementation of a 254-mm MLL would reduce the number of fish harvested by 18–32% (Figure 4), but would increase the average weight of harvested fish 21%–43% (Figure 5). Change in yield with a 254-mm MLL ranged from a decrease of 10% to a 10% increase (Figure 6). The MLL only improved yield when exploitation was greater than 0.14 and conditional natural mortality was 0.3. The portion of the cohort reaching preferred sized would range from 5% to 26% under a 254-mm MLL (Figure 7).

The FAMS model predicted that implementation of a 305-mm MLL would reduce the number of fish harvested by 37%–60% (Figure 4), while increasing the mean weight of harvested fish by 47%–101% (Figure 5). Change in yield would vary with a 305-mm MLL between –30% and 12% (Figure 6). A 305-mm MLL only improved yield when $u > 0.21$ and $cm = 0.3$. Yield would not increase under a 305-mm MLL at the *cm*, *u*, and growth rate we estimated for the Arkansas River white bass population (see Figure 5b). The Arkansas River white bass population does not appear to be undergoing growth overfishing at the current level of exploitation. Even if the exploitation were twice what we estimated, the increase in yield due to the imposition of a MLL would be about 5%–10%. However, the portion of the cohort reaching preferred sized would range from 14% to 86% under a 305-mm MLL (Figure 7). Considerable improvements in size structure would only occur at moderate to high levels of exploitation and only under the 305-mm MLL.

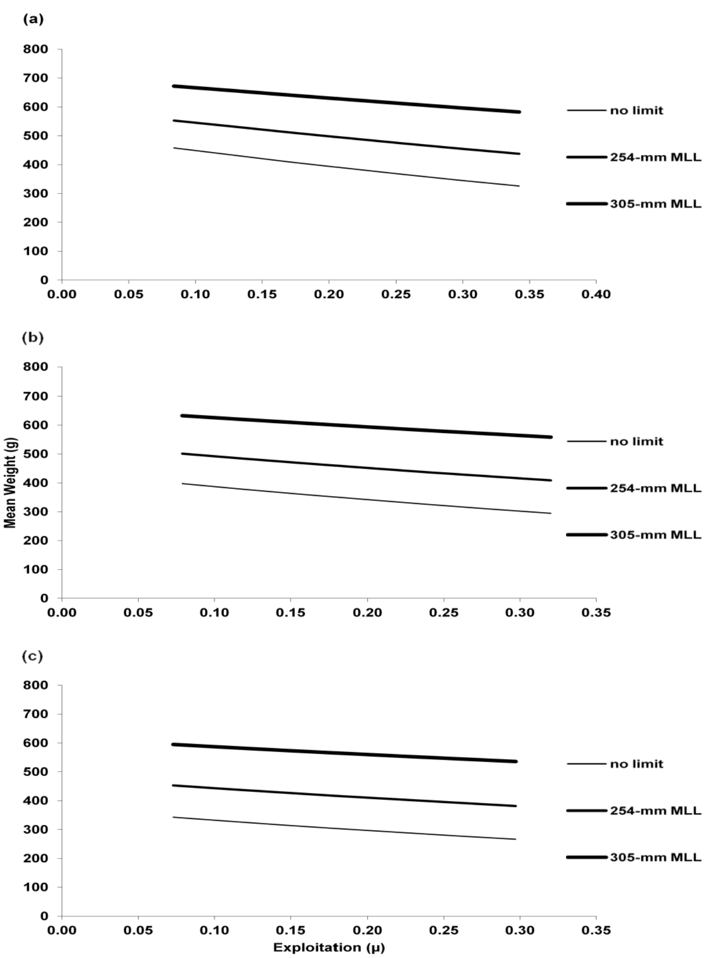

Figure 5. Predicted mean weight of harvested fish at various exploitation rates (*u*) using steady-state equilibrium yield per recruit models where 1,000 age-0 fish enter the population for each simulation. Conditional natural mortalities (*cm*) of (a) 0.3, (b) 0.4, and (c) 0.5 were modeled for no regulation (i.e., harvest begins at 203 mm), a 254-mm minimum length limit, and a 305-mm minimum length limit.

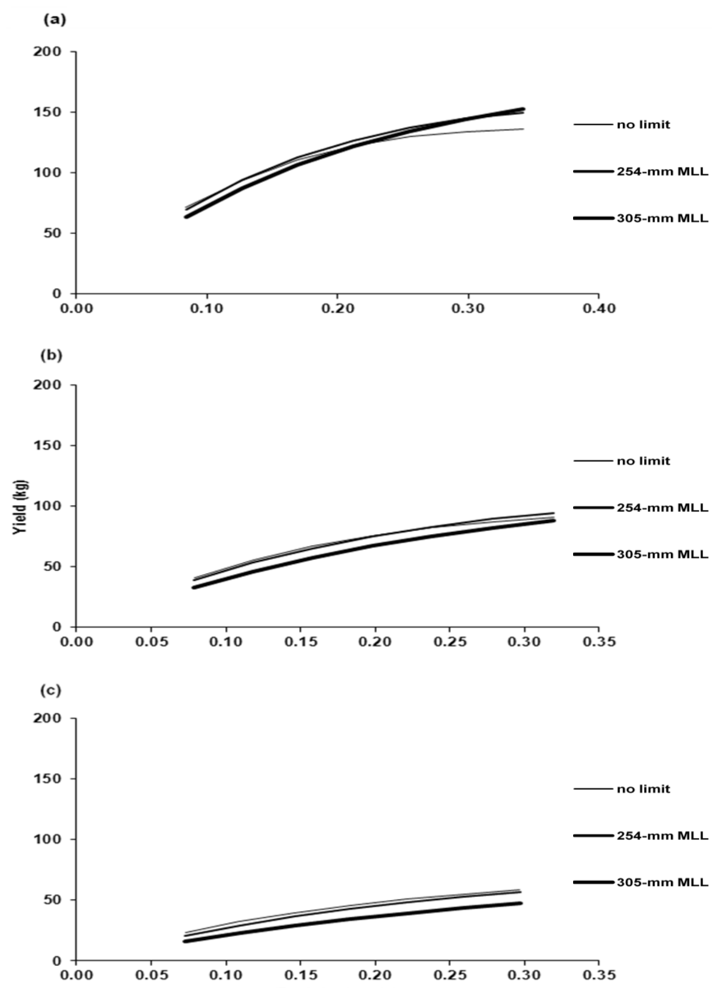

Figure 6. Predicted yield at various exploitation rates (*u*) using steady-state equilibrium yield per recruit models where 1,000 age-0 fish enter the population for each simulation. Conditional natural mortalities (*cm*) of (a) 0.3, (b) 0.4, and (c) 0.5 were modeled for no regulation (i.e., harvest begins at 203 mm), a 254-mm minimum length limit, and a 305-mm minimum length limit.

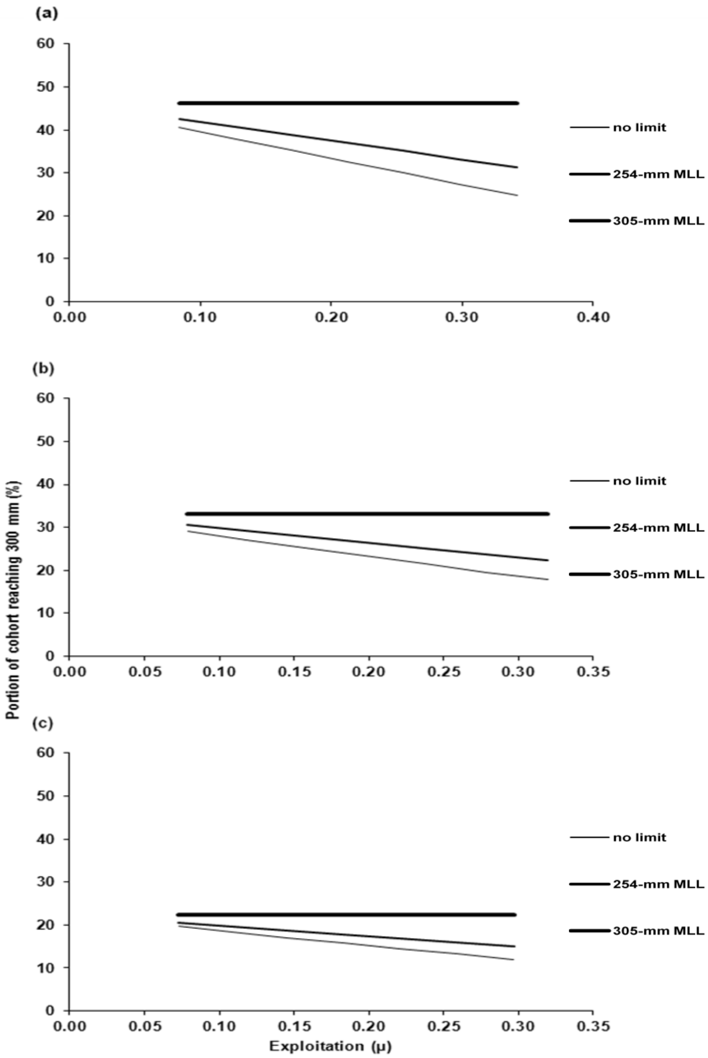

Figure 7. Predicted portion of the cohort reaching the white bass preferred length class (300 mm) at various exploitation rates (*u*) using steady-state equilibrium yield per recruit models where 100 age-0 fish enter the population for each simulation. Conditional natural mortalities (*cm*) of (a) 0.3, (b) 0.4, and (c) 0.5 were modeled for no regulation (i.e., harvest begins at 203 mm), a 254-mm minimum length limit, and a 305-mm minimum length limit.

Discussion

Natural mortality is often assumed to vary inversely with life expectancy (Hoenig 1983, Quinn and Deriso 1999); thus, because maximum age in a population generally increases with latitude, natural mortality of fishes is likely lower in northern populations than in southern populations (Willis et al. 2002). One study in South Dakota collected a 14-year-old white bass (Willis et al. 2002), but in the southern part of their range, most white bass do not survive beyond age-4 (Muoneke 1994, Nordhaus et al. 1998). Populations in Arkansas appear to have a maximum age near the middle of the two extremes. Houser and Bryant (1970) collected 6-year-old fish in Beaver Reservoir, Arkansas, whereas this study collected two age-7 fish. Given the moderate longevity of white bass observed in this study, the Arkansas River population might experience relatively low natural mortality. Low natural mortality is one requirement for a population to experience increased yield and improved size structure when a MLL is implemented.

White bass in the Arkansas River reached preferred size by age 2, suggesting that the population was relatively fast growing compared to more northern populations. Systems in Alabama and Texas had similar white bass growth rates as the Arkansas River and were likewise similar to that found in our study (Wilde and Muoneke 2001, Lovell and Maceina 2002). However, growth was faster in the Arkansas River than populations in the upper Midwest. In Lake Winnebago, Wisconsin and Spirit Lake, Iowa, mean length at age 3 was 254 mm and 250 mm, respectively (Sigler 1949, Kawatski and Schmulbach 1971). Arkansas River white bass grew slower than populations in Table Rock Lake, Missouri, and Lake Talquin, Florida, where fish grew to 375 mm and 376 mm, respectively, by age 3 (Nordhaus et al. 1998, Colvin 2002). Fast growth is another important trait that is conducive to improvement in yield or size structure with implementation of a MLL.

Similar to what authors have reported for other white bass populations, implementation of a MLL was not predicted to provide large increases in yield in the Arkansas River white bass population (Lovell and Maceina 2002, Schultz et al. 2002). Despite moderately high maximum age and relatively fast growth, Arkansas River white bass would experience reduced yields under most modeled conditions. Like Lovell and Maceina (2002), we found that yield of white bass could be modestly increased with a 254-mm or 305-mm MLL if natural mortality was low ($cm = 0.3$) and exploitation was greater than 0.14. However, we estimated that *cm* for the Arkansas River white bass population was 0.34. Perhaps more importantly, under the exploitation and natural mortality scenarios we modeled, yield was relatively stable. It seems unlikely that large gains in yield would be possible with a MLL under any reasonable exploitation and natural mortality conditions.

Implementation of minimum length limits on the Arkansas River white bass could improve size structure. Based on our estimates of natural mortality and exploitation for the Arkansas River white bass population, approximately 28% more fish would reach a preferred size under a 305-mm MLL. The goal of the current regulation on Arkansas River white bass (25 fish/d creel and no MLL) is unclear. Typically, management regulations are set to achieve goals based on angler desires. In the past, white bass fisheries did not resemble trophy type fisheries (Muoneke 1994). The benefit of catching larger fish under a MLL regulation would need to be evaluated relative to angler preferences.

Our estimate of exploitation for white bass from the Arkansas River was lower than rates from other studies. Schultz and Robinson (2002) reported exploitation rates ranging from 17%–33% in five Kansas reservoirs. In Lake of the Ozarks, Missouri, exploitation ranged from 22%–36% (Colvin 2002). Exploitation on Lake Whitney, Texas, was 47% (Muoneke 1994). These values were measured, not estimated. It is likely our exploitation estimate is low, but it is unclear how low. Our estimate of exploitation depends on the quality of our catch curve. A good catch curve requires that ages are collected in proportion to their actual abundance. Sampling during the spawning season could have introduced bias. Additionally, our age frequency data clearly showed that recruitment was variable from year to year, a result which violates a catch curve assumption. Our exploitation estimate also depends on our natural mortality estimates, which varied as well. We are cautious about putting too much confidence in our low estimate of exploitation; however, a creel survey conducted on Pool 4 in 2007 showed that only 1 of 348 anglers surveyed was specifically targeting white bass (Fontaine 2009). If our exploitation estimate is only slightly low, the 25 fish/d creel limit could be relaxed without negative consequences to the fishery. A tag-reward study could provide concrete justification for a more liberal creel limit, and a creel survey targeting white bass anglers could indicate their preferences regarding size structure.

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