Effectiveness of Slot-length Limits to Maintain an Arkansas Trophy Largemouth Bass Fishery Characterized by High Voluntary Release Rates by Anglers

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Abstract: Lake Monticello in southeastern Arkansas is a renowned destination for trophy-sized (≥3.63 kg) largemouth bass (*Micropterus salmoides*; LMB). However, little analysis has been conducted on population characteristics of this population and the anglers fishing for them. Therefore, the size structure and potential harvest of the bass population was evaluated in the context of an existing 406–533 mm slot-length limit (SLL) and other potential SLLs. A total of 1023 LMB was collected using electrofishing during springs 2006–2007. Differences in growth were detected among gender with only one male aged above the slot. Modeling results suggested that alternative SLLs (457–559 mm or 483–559 mm) marginally increased the number of harvestable fish and number reaching trophy size while reducing the number dying within the slot. A 12-mo creel survey ($n = 820$ parties) revealed that 72% of anglers targeted bass, with most bass harvested (76%) below the slot. Voluntary release rates averaged 87% for bass and non-bass anglers. A mail-in survey of 249 anglers revealed most (77%) agreed or strongly agreed with catch and release fishing for LMB. These results suggested that education of anglers is needed about the importance of selective harvest to achieve fisheries management goals for improving trophy bass fishing. Given the obvious impact on the local economy, efforts needs to be taken to ensure that Lake Monticello remains a trophy LMB fishery in the future, as 89% of LMB anglers indicated they were fishing for trophy LMB.

Key words: size structure, harvest, creel survey, population modeling

Journal of the Southeastern Association of Fish and Wildlife Agencies 3:112–120

Development of trophy lakes by fisheries agencies for largemouth bass (LMB; *Micropterus salmoides*) has become increasingly common by fisheries management agencies across the United States. Reasons for the development of trophy lakes include angler demand (Wilson and Dicenzo 2002, Beardmore et al. 2011) and the impact of tourism on the local economies (Wilson and Dicenzo 2002, Chen et al. 2003). The culture of bass fishing has largely changed from catching a dinner to catching a trophy bass (Wilson and Dicenzo 2002, Bonds et al. 2008, Dotson et al. 2013). As fisheries managers are accountable to and supported by their constituencies, management decisions should have a positive economic effect (Weithman 1999, Driscoll and Myers 2013).

Length limits have been used to enhance size structure of LMB populations with varying degrees of success (e.g., Wilde 1997, Parks and Seidensticker 1998, Myers and Allen 2005, Paukert et al. 2007). Nonetheless, it is generally agreed that length-limit regulations can impact the size structure of LMB populations (Myers and Allen 2005, Carlson and Isermann 2010, Dotson et al. 2013). Minimum-length limits seem to be less effective in increasing size structure as compared to maximum-length limits and large protective slot-length limits (Wilde 1997, Myers and Allen 2005). Recently, Dotson et al. (2013) demonstrated that length-limit regulations in Florida were successful in creating trophy Florida LMB (FLMB; *M. s. floridanus*) populations, even in lakes having low angler harvest. Although catch and release proved to be the best option to produce trophy FLMB, large protective slot limits were also shown to be effective as an alternative management strategy, similar to what Carlson and Isermann (2010) identified for Minnesota LMB populations.

However, length-limit regulations must be implemented in the context of national trends in angler attitudes and actions towards their fisheries. Allen et al. (2008) found that mean exploitation of LMB nationally had declined from 35% during 1976–1989 to 18% during 1990–2003. Much of the research focus has been on anglers targeting LMB; lesser studied are the differences in attitudes and harvest of anglers whose primary target species is not LMB (Fisher 1997, Anderson et al. 2007). Anglers considered "harvest oriented" typically differ in their harvest attitudes as compared to 'sport' fishermen (Sutton 2003). Largemouth bass fisheries have been shown to be composed of many groups of anglers differing in attitudes, motivations, and behaviors (Ditton 1996), and success of any harvest regulation depends on engaging the varying user groups during the process.

Lake Monticello in southeastern Arkansas is a renowned destination for trophy-sized largemouth bass, which in Arkansas is considered to be a fish 3.63 kg and larger (AGFC 2002). Although Lake Monticello is most noted for trophy-sized LMB, less than 1% ($n = 13$) of LMB sampled ($n = 1431$) during routine annual

spring electrofishing results from 2000–2005 were trophy-size (unpublished data). Lake Monticello has been stocked annually since impoundment by the Arkansas Game and Fish Commission (AGFC), primarily with FLMB, at a rate of 165 fish ha^{-1}. This ongoing stocking has resulted in most bass (+19192446173 67%) being intergrades between FLMB and native northern LMB (Allen et al. 2009). Lake Monticello is a small reservoir with a limited watershed, and primary productivity is low (chlorophyll-*a*, 3.3 mg m^{-3}). Further, alkalinity is low in the reservoir (18 mg L^{-1}). Therefore, the lake is fertilized annually to increase productivity, and threadfin shad (*Dorosoma petenense*) are also stocked annually at a rate of 165 fish ha^{-1} to improve the available forage base for LMB. However, little analysis has been conducted on population characteristics of the LMB in Lake Monticello and the anglers that fish for them. The purpose of this study was to collect LMB growth and angler harvest data to develop regulations for Lake Monticello to sustain the trophy potential of LMB fishery while decreasing the numbers of LMB within the slot. Thus the objectives of this study were to 1) estimate growth of LMB in Lake Monticello, 2) identify LMB harvest and angler attitudes towards their harvest in Lake Monticello, 3) compare the harvest of anglers targeting or not targeting LMB as their primary species, and 4) evaluate the potential effects of potential slot-length limit (SLL) changes on LMB size structure.

Methods

Study Area

Lake Monticello, a 607-ha reservoir impounded in 1993, is popular among anglers targeting LMB, crappie (*Pomoxis* sp.), channel catfish (*Ictalurus punctatus*), and varying sunfishes. When opened to fishing in 1997, LMB were strictly catch and release. Beginning in 1999, a 406-to 533-mm SLL regulation went into effect with a four-fish limit, only one of which could be over the slot. By spring 1999, largely due to concerns by local anglers and publicity by the media, the upper end of the SLL was increased from 533 mm to 610 mm with no change in creel limits. In 2003, the SLL was changed back to 406- to 533-mm SLL to be consistent with trophy bass management criteria of other reservoirs in Arkansas (AGFC 2002). No tournaments were or are presently allowed on Lake Monticello.

Fish Collections

The LMB population was sampled using nighttime boat-mounted electrofishing conducted during March–April 2006 and March 2007. Samples consisted of 1800-sec electrofishing transects conducted at various fixed shoreline locations around the reservoir. All LMB were measured for total length (TL, mm). A subsample of fish was returned to the laboratory for processing. In the laboratory, LMB were measured for TL (mm), weighed (g), and sagittal otoliths were extracted. All otoliths were sectioned and fish ages were estimated using the method of Buckmeier and Howells (2003). An age-length key, using all aged fish from 2006 and 2007, was used to assign ages to un-aged fish sampled based on length.

Population Metrics

In all cases, LMB sampled in spring of 2006 and 2007 were combined for analysis. Proportional size distribution (PSD) indices for quality-sized (PSD), preferred-sized (PSD-P), memorable-sized (PSD-M), and trophy-sized (PSD-T) fish were used to estimate size structure (Neumann et al. 2012).

Von Bertalanffy (1938) growth curves were fitted for the whole population and by gender using Fishery Analysis and Modeling Simulator (FAMS 1.0; Slipke and Maceina 2010). An analysis of covariance (ANCOVA) using $\log_{10}$-transformed ages for aged fish only was used to examine growth differences between gender (Lovell and Maceina 2002). Total annual mortality (A) and total instantaneous mortality (Z) were calculated using aged and age-assigned fish using a weighted catch curve (Maciena 1997); fish were fully recruited to the electrofishing gear by age 2, and catch curves were run for age-2 to age-13 fish. Natural and fishing mortality rates of LMB were unknown for Lake Monticello; therefore instantaneous natural mortality (M) and conditional natural mortality (*cm*) were estimated by averaging the results from four natural mortality equations in FAMS (e.g., Hoenig 1983, Chen and Watanabe 1989, Jensen 1996, Quinn and Deriso 1999). Conditional fishing mortality estimates were derived from a study of navigation pools in the nearby lower Arkansas River (Fontaine et. al 2009).

In FAMS, a Beverton-Holt equilibrium yield model with female growth rates was used to simulate the effects of different SLLs at various exploitation rates. Female growth rates were used due to their faster growth and greater trophy potential (Schramm and Smith 1987). Three SLLs were modeled: the current 406–533 mm, 457–559 mm, and 483–559 mm (Table 1). The two proposed SLLs were chosen as a compromise between biologists' and anglers' recommendations. With Lake Monticello managed for trophy LMB, the metrics of interest were: number harvested, number dying within the slot, mean TL (mm) and weight (g) above the slot, and number reaching trophy size. Based upon the weight-length relationship, LMB in Lake Monticello reached trophy weight (3.63 kg) at approximately 589 mm TL; thus this length was used for trophy length in modeling exercises. Three different levels of conditional natural mortatiltiy (0.30, 0.35, and 0.40) were used as parameters for modeling. Three different levels of conditional fishing mortality (0.10, 0.15, and 0.20) were used, which encompasses the exploitation rate of 13.8% from the nearby lower Arkansas River (Fontaine

Table 1. Parameters used for FAMS modeling. Growth coefficients were calculated from aged female LMB only from 2006–2007 data. Weight-length regression derived from unpublished fall 2006 data from Lake Monticello. Conditional natural mortatiltiy rates were estimated from four equations found in FAMS. Conditional fishing mortality rate was estimated from literature.

Parameters	Terms
von Bertalanffy growth coefficient	$L_\infty = 590$ mm
	$K = 0.3662$
	$t_0 = -0.2170$
Weight-length coefficient	Slope (b) = 3.412
	Intercept (a) = –5.897
Conditional natural mortality	0.30, 0.35 and 0.35
Conditional fishing mortality	0.10, 0.15, and 0.20
Maximum age	14 years
Slot limits modeled	406–533 mm
	457–559 mm
	483–599 mm
Recruitment length	254 mm
Conditional natural mortality estimates: Chen and Watanabe (1989) – 0.450 Hoenig (1983) – 0.260 Jensen (1996) – 0.550 Quinn and Deriso (1999) – 0.190	Mean = 0.363

et al. 2009). All modeling had initial number of recruitments set at 1000 age-0 fish. Maximum age was set to 14, which corresponded to one year older than the oldest individual collected.

Creel and Mail Surveys

A 12-mo creel survey was conducted to determine angling effort, catch and harvest of LMB from 1 March 2008 to 28 February 2009 utilizing an access-point design at two public launch sites (Pollock et al. 1994). The access-point design incorporated a two-stage stratified random sampling component. Days (weekends and weekdays) were the primary sampling units and shifts (morning and afternoon) were the secondary sampling units. Sixteen creel shifts (8 week days and 8 weekend days) were conducted monthly. From May to August, 4-h shifts were conducted, while 5-h shifts were conducted during the other months. All sampling units were sampled with equal probabilities (Pollock et al. 1994, Fontaine et al. 2009).

Additionally, at a randomly selected hour during each shift, the creel clerk conducted an instantaneous and cumulative angling pressure count, which were made by counting all fishing boat trailers at each access and were used to estimate total fishing effort (Lambou 1961, Malvestuto 1996). During each shift, a creel clerk interviewed all angling parties when they returned to the access area or while bank fishing. The creel clerk asked one angler in the party a series of standard questions and measured each fish harvested (TL, mm). Angler pressure (h ha^{-1}), catch rates, and harvest rates were calculated for anglers that did or did not primarily target LMB, following Pollock et al. (1994). Voluntary release rates (VRR) of LMB were calculated for both bass and non-bass anglers and compared for bass caught above and below the slot.

If anglers indicated they were fishing for LMB during the creel survey, they were asked if they would participate in a mail survey. Each willing participant was assigned a unique number for identification purposes. An introductory letter, a seven-page mail survey with 15 questions, and a pre-paid envelope were sent to each angler. The letter also contained information pertaining to a drawing for cash and prizes for those who returned the survey. If anglers did not respond to the first letter, they were sent up to two more follow-up letters, surveys, and pre-paid envelopes. The survey (similar to Bonds et al 2008) consisted of one open-ended and 14 close-ended questions (partial list of questions in Table 2). Five of the closed-ended questions used the Likert scale. Anglers were asked questions regarding harvesting/releasing of largemouth bass, slot limit regulations, changing of regulations, demographics and when, why and how often they fish Lake Monticello. These data provided insight as to how successful potential SLL changes would be in altering angler harvest. At the end of the creel survey, a drawing was conducted for 12 US$25 and four $50 prizes. A letter of thanks, a notification to drawing winners and a copy of the results from the mail survey were then sent to participants.

Results

Population Characteristics

A total of 1023 LMB ranging in size from 102 to 655 mm TL were sampled over the two years (2006, $n = 687$; 2007, $n = 336$; Figure 1). Electrofishing catch-per-unit-effort ranged from 22 to 252 fish h^{-1} among years (mean = 80.8 fish h^{-1}; SE = 7.5). Surprisingly few LMB < 300 mm TL were collected during the study, possibly indicating that our gear was selecting for larger fish (Figure 1). Size structure was dominated by fish 400–500 mm TL, with good numbers of larger fish. Four percent of the LMB sampled fit the trophy-size criteria for AGFC (≥ 589 mm; $n = 39$). The largest male LMB collected was 553 mm and 2170 g, whereas the largest female was 655 mm and 4590 g.

Age and Growth

A total of 116 female and 128 male LMB were aged, while an additional 772 LMB had ages assigned with unknown gender. Ages ranged from 1 to 13 years, with a mean age of 6.0 ($n = 1016$; SE = 0.11) years (Table 3). The von Bertalanffy growth equation for the overall sample was $L_t = 497\,[1 - e^{-0.529(t-0.045)}]$, for females was $L_t = 590\,[1 - e^{-0.367(t+0.217)}]$, and for males was $L_t = 481\,[1 - e^{-0.421(t+0.424)}]$

Table 2. Subset of questions asked in the angler mail survey ($n = 234$). Overall, there were 15 questions asked in the mail survey (1 open-ended and 14 close-ended questions). Numbers represent percent of responders selecting that particular answer.

Question 1: Why do you come to Lake Monticello to fish for LMB? (You may circle more than one)	
Opportunity to fish	38%
Opportunity to catch numbers of fish	17%
Opportunity to catch a trophy fish	89%
Opportunity to spend time with family or friends	29%
Opportunity to enjoy nature or the outdoors	37%
Question 2: Lake Monticello is currently closed to bass tournaments. Do you favor or not favor the lake being closed to bass tournaments?	
Favor	73%
Not Favor	18%
Unsure or Undecided	9%

Question 3: Under the Lake Monticello LMB slot limit regulation, fish of a total length within 406 to 533 mm must be released, but fish smaller than 406 mm or larger than 533 mm may be harvested. Please indicate if you agree or disagree with the following statements regarding slot limit regulations.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A
a. Slot 1imits are useful in some situations	59%	35%	3%	1%	1%	1%
b. Slot limits are useful to produce trophy LMB populations	67%	26%	5%	1%	1%	1%
c. Releasing small LMB is always beneficial to LMB populations	12%	23%	17%	31%	11%	6%
d. Slot limits are useful to thin-out small LMB	16%	34%	21%	18%	4%	7%
e. Slot limits are useful to protect quality sized LMB	50%	38%	6%	3%	1%	1%
f. Retaining LMB smaller than the slot can make fishing better	17%	39%	25%	9%	3%	7%

Question 4: Please indicate if you agree or disagree with the following statements concerning harvesting of LMB.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A
a. I practice catch and release fishing for LMB	42%	35%	15%	6%	1%	0%
b. Harvesting LMB smaller than the slot limit goes against my conservation ethic.	9%	13%	24%	38%	14%	1%
c. I release LMB because I do not like the way they taste	3%	2%	10%	24%	60%	1%
d. I release LMB smaller than the slot because they are too small to clean	4%	6%	12%	41%	37%	1%
e. I would harvest LMB smaller than the slot if the minimum slot-length was increased	9%	20%	24%	26%	20%	2%
f. I release LMB below the slot because the daily bag limit is not enough to provide a meal	9%	17%	17%	32%	29%	1%

Question 5: When you catch a LMB in Lake Monticello.

	Always	Often	Sometimes	Rarely	Never
a. Smaller than the slot limit, how often do you harvest it?	3%	10%	19%	25%	45%
b. Larger than the slot limit, how often do you harvest it?	6%	7%	15%	32%	39%

(Figure 2). Female LMB took 3.0 yrs to enter the current SLL and 6.2 yrs to exit it; whereas, males took 4.0 yrs to enter the slot and on average never grew large enough to exit it. Only 1 of 128 males aged during this study were above the slot, further demonstrating that male LMB rarely reached a harvestable size above it. The ANCOVA results also demonstrated that female LMB grew faster than males ($F = 7.15$; $df = 1, 19l$; $P = 0.015$).

Due to the observed sampling bias against smaller, younger fish, the catch curve resulted in an unrealistic estimation of 9% for A ($Z = -0.10$, $r^2 = 0.43$), even when only aged females were used ($A = 15\%$; $Z = -0.168$, $r^2 = 0.57$). Therefore, these mortality estimates were not used in further analysis. The average *cm* estimate for four equations in FAMS was 0.36 ($SE = 0.08$) and ranged from 0.19–0.55 (Table 1).

Length Limit Modeling and Mortality Rates

The models predicted similar results when using 0.10 or 0.15 for conditional fishing mortalities over the range of conditional natural mortality rates simulated. Under the 457- to 559-mm SLL scenario, number of harvestable LMB increased by 12%–15%, and the number of trophy bass increased up to 15% over the current SLL (Table 4). This SLL was also predicted to decrease the number of LMB dying within the slot by 26%–54%. Under the 483- to 559-mm SLL scenario, number of harvestable LMB was predicted to increase 21%–24%, but the number of trophy bass would only increase by 4% over the current SLL (Table 4). The number of LMB dying within the slot was predicted to decrease by 48%–62%. The models predicted that both proposed SLLs increased mean TL of LMB above the slot by an average of 15 mm and the mean weight by an average of 285 g (Table 4).

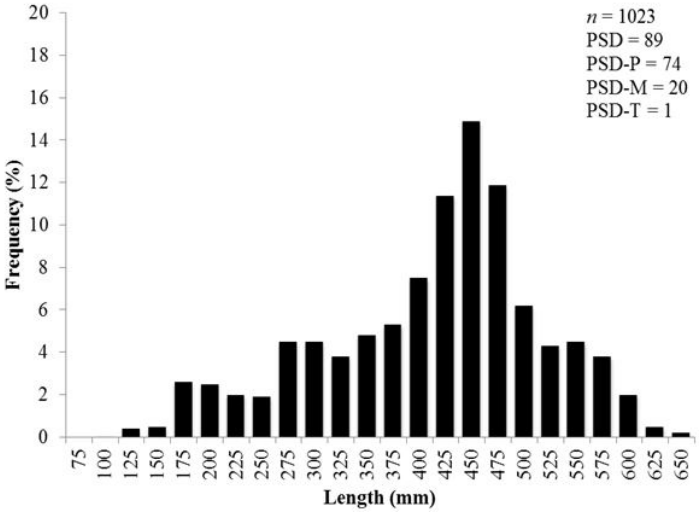

Figure 1. Relative frequency distribution of largemouth bass collected in electrofishing samples from Lake Monticello during the springs of 2006–2007. The proportional size distribution indices are quality-sized (PSD), preferred-sized (PSD-P), memorable-sized (PSD-M), and trophy-sized (PSD-T).

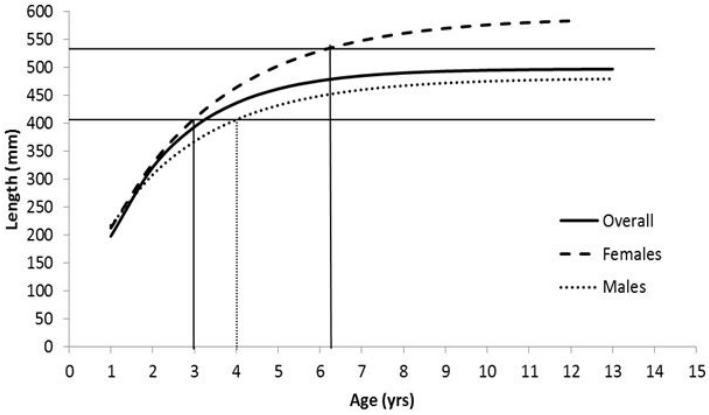

Figure 2. von Bertalanffy growth curve of largemouth bass in Lake Monticello overall and by gender. The overall growth curve includes all aged and age-assigned fish. The female and male growth curves only include aged fish. The black horizontal solid lines represent the 406- to 533-mm slot-length limit. The two vertical solid lines represents the ages when females enter and exit the slot limit. The vertical dash line represents the age when males enter the slot limit.

Table 3. Number of largemouth bass aged (*n*), mean total length (MTL; mm) and standard error (SE) by age for overall sample (includes all aged and assigned age fish), aged females only, and aged males only.

	Overall (*n* = 1016)			Female (*n* = 116)			Male (*n* = 128)		
Age	*n*	MTL (mm)	SE	*n*	MTL (mm)	SE	*n*	MTL (mm)	SE
1	83	203	3.4	11	221	5.7	6	219	8.2
2	165	312	2.8	18	312	9.9	27	302	6.4
3	118	388	2.9	19	401	4.8	12	367	4.6
4	68	437	4.0	7	474	15.5	9	409	6.2
5	66	464	5.4	10	516	7.2	8	432	7
6	65	487	4.6	12	519	6.1	5	456	18.3
7	37	493	10.0	5	557	15.9	4	455	5.3
8	94	498	4.9	8	561	7.3	11	477	8.5
9	145	507	5.1	17	571	5.2	16	460	10.3
10	51	474	6.4	3	554	23.3	8	464	9.9
11	54	501	7.3	4	592	16.2	8	483	11.7
12	37	492	8.1	2	582	26.0	7	479	13.6
13	33	479	3.8				7	483	8.3

Table 4. Results of FAMS modeling of three slot-length limits (SLLs) over various conditional natural mortalities (*cm*) and conditional fishing mortalities (*cf*). Metrics included: total number (*n*) harvested, number (*n*) dying within slot, mean total length (MTL) above the slot limit, mean weight (MWT) above slot, and number of trophy bass (*n* at 589 mm).

SLL (mm)	cm	cf	Total *n* harvested	*n* dying within slot	MTL (mm) above slot	MWT (g) above slot	*n* at 589 mm
406 – 533	0.30	0.10	98	198	558	2980	0.57
457 – 559	0.30	0.10	110	146	572	3244	0.61
483 – 559	0.30	0.10	120	103	572	3244	0.58
406 – 533	0.35	0.10	78	175	556	2946	0.16
457 – 559	0.35	0.10	89	119	571	3226	0.17
483 – 559	0.35	0.10	97	81	571	3226	0.16
406 – 533	0.40	0.10	63	148	555	2914	0.04
457 – 559	0.40	0.10	73	93	570	3209	0.04
483 – 559	0.40	0.10	78	61	570	3209	0.04
406 – 533	0.30	0.15	141	180	557	2953	0.27
457 – 559	0.30	0.15	158	127	572	3230	0.31
483 – 559	0.30	0.15	171	86	572	3230	0.28
406 – 533	0.35	0.15	114	159	555	2923	0.08
457 – 559	0.35	0.15	129	103	571	3214	0.09
483 – 559	0.35	0.15	139	68	571	3214	0.08
406 – 533	0.40	0.15	92	135	553	2894	0.02
457 – 559	0.40	0.15	106	80	570	3199	0.02
483 – 559	0.40	0.15	113	51	570	3199	0.02
406 – 533	0.30	0.20	180	163	555	2928	0.13
457 – 559	0.30	0.20	201	108	571	3217	0.15
483 – 559	0.30	0.20	216	71	571	3217	0.13
406 – 533	0.35	0.20	147	143	554	2900	0.04
457 – 559	0.35	0.20	166	88	570	3202	0.04
483 – 559	0.35	0.20	177	56	570	3202	0.04
406 – 533	0.40	0.20	120	122	552	2874	0.01
457 – 559	0.40	0.20	137	69	569	3188	0.01
483 – 559	0.40	0.20	145	42	569	3188	0.01

If fishing mortality was 0.20, the 457- to 559-mm SLL was predicted to increase number of harvestable LMB by 12%–13% and the number of trophy LMB up to 15% over the current SLL, and decrease the number dying within the slot by 33%–44% (Table 4). Under the 483- to 559-mm SLL scenario, number of harvestable LMB was predicted to increase by 24% over the current limit, but number of trophy bass was predicted to be unaffected. However, the model predicted that number of LMB dying within the slot would decrease by 56%–66% under the 483- to 559-mm SLL compared to the current limit. Under this greater fishing mortality, both SLLs increased the mean TL above the slot by an average of 16 mm and the mean weight by an average of 301 g (Table 4).

Creel and Mail Surveys

The creel surveys interviewed 820 parties composed of 1421 anglers from 14 states. Largemouth bass were targeted by 71% ($n = 582$) of the parties, and those anglers accounted for 76% (74,424 h; 123 h ha^{-1}) of the angling pressure. An extrapolation of creel survey and trailer counts data resulted in an estimated total annual fishing effort of 98,550 h (SE = 8630) or 162 h ha^{-1} on Lake Monticello. The extrapolated total annual LMB catch for all anglers on the lake was 27,757 LMB (0.28 LMB h^{-1}). Fifty-seven percent of the LMB caught were below the 406- to 533-mm SLL, 33% were within, and 10% were above the SLL. Anglers targeting LMB caught 25,055 LMB (0.34 LMB h^{-1}) with 51% caught below, 37% within, and 12% above the SLL.

Total annual LMB harvest for all anglers surveyed was 1906 LMB, with 75% of the harvested LMB below and 25% above the SLL. This harvest ratio was consistent with the four-fish daily creel limit, where only one harvested bass could be above the SLL. Anglers targeting LMB harvested 1327 LMB, with 67% and 33% below and above the slot, respectively. Thirteen percent of the LMB harvested ($n = 247$) were trophy size or larger, and 229 (97%) of them were harvested by anglers targeting LMB. Ninety-two percent of the LMB angling parties creel-surveyed did not harvest any bass. The voluntary release rate (VRR) of LMB caught under the SLL was 85% for both LMB-anglers and non-LMB-anglers. However, LMB anglers had a higher VRR for bass caught above the SLL (90%) than other anglers (60%).

Of the 582 parties that indicated they were targeting LMB, 300 anglers from 11 states signed up for the mail survey, of which 79% ($n = 237$) responded (Table 2). Bass anglers mainly fished Lake Monticello to catch a trophy fish (89%). Harvest rates from the creel survey corresponded to attitudes expressed by anglers in the survey, as most (77%) strongly agreed or agreed with practicing catch and release fishing for LMB. Seventy percent rarely or never harvested LMB at Lake Monticello, including bass both above and below the SLL. Most anglers recognized the importance of slot limits in producing trophy bass (93%), protecting quality sized bass (88%), and keeping the reservoir closed to fishing tournaments (73%), yet only 50% considered removal of small bass to be important. Some (8%) anglers thought that the creel limit of four fish per day should be increased, which may have contributed to the observed low harvest, even by harvest-oriented anglers.

Discussion

Over the past several decades there has been a transition in focus of LMB anglers towards seeking fisheries providing greater opportunities for catching trophy-size fish (Wilson and Dicenzo 2002, Bonds et al. 2008, Dotson et al. 2013). Almost 90% of anglers fished Lake Monticello because it has a strong reputation for producing trophy bass. This reputation has merit, as our study determined that approximately 17% of the stock-sized LMB in Lake Monticello were memorable. This proportion of memorable bass is much greater than those found in navigation pools of the Arkansas River, another heavily fished water system in Arkansas, where the proportion of memorable bass ranged from 1%–2% (Peacock et al. 2011). Nonetheless, angler catch rates of LMB in Lake Monticello were 30% lower than for other Arkansas reservoirs sampled in a similar time frame and methods (AGFC, unpublished data). These lower catch rates may be in part attributed to Lake Monticello being a small, intensively fished reservoir. For example, Lake Monticello had a seven-fold increase in fishing pressure versus other intensively-fished Arkansas reservoirs sampled, with a surface area less than 5% of those other reservoirs sampled (AGFC, unpublished data).

Management of LMB using length and/or slot limits must consider sexual dimorphic growth rates. Despite the high numbers of trophy bass identified in Lake Monticello in 2006–2007, there was stockpiling of individuals within the SLL, particularly males, which had low potential of reaching trophy size, or more importantly, leaving the SLL. These sexual dimorphic growth rates found in Lake Monticello LMB are normal for this species (Porak et al. 1986, Schramm and Smith 1987, Bonvechio et al. 2013). Females have good growth throughout their life span; whereas, males have lower growth rates that decrease greatly following sexual maturity. Dotson et al. (2013) identified that females were the only individuals to contribute to a trophy bass fishery of Florida, where a trophy bass must be greater than 610 mm TL. Raising the slot limit to those identified should direct angler harvest to the more abundant fish below the slot which could increase the number of male bass harvested.

Environmental impacts on LMB growth in Lake Monticello were not addressed in this study. As a maturing reservoir with an

age of 13 years at the onset of the study, Lake Monticello is likely entering the trophic depression stage of reservoir age (Kimmel and Groeger 1986). Female LMB growth in Lake Monticello was similar to that identified as "medium growth" by Allen et al. (2002), and male LMB growth would be characterized as "fast growth." However, LMB growth and production of trophy bass could decline and stabilize as the reservoir ages. In addition to lake age, environmental factors potentially impacting LMB growth and trophy bass numbers included low alkalinity and oligotrophication (Ney 1996, Crawford et al. 2002).

While increases in the number of trophy bass in Lake Monticello were detected for both proposed SLLs, most responses were not substantial and likely undetectable by anglers or sampling regimes. Altering the slot limit to 457- to 559-mm or 483- to 559-mm SLL was predicted to result in a modest increase in the number of harvestable LMB, however. More significantly, the mean lengths and weights of bass above the SLLs were predicted to increase by 15 mm and ~300 g, which will be of importance to anglers. Of course, these benefits were predicted under the assumption that anglers harvested fish under the SLL, which in practice can be problematic (Wilde 1997).

Voluntary release rates of bass by Lake Monticello anglers were high, similar to those identified by Myers et al. (2008) and Bonds et al. (2008) from trophy bass fisheries managed using slot limits in Florida and Texas, respectively. Weathers et al. (2000) identified that 92% of anglers fishing Lake Eufaula, Alabama-Georgia, practiced catch and release, similar to our findings. This increase in VRR is a national trend (Quinn 1996, Noble 2002), although there are lakes where VRR is not as extensive (Bonvechio et al. 2013, Isermann et al. 2013). Lower exploitation rates typically lessen the response of the fishery to regulation changes (Novinger 1984, Wilde 1997, Dotson et al. 2013). Bonds et al. (2008) indicated that anglers could potentially practice catch and release to a point where harvest regulations become irrelevant. This seems to be what is occurring in the Lake Monticello LMB fishery. Nonetheless, Dotson et al. (2013) identified through modeling that even with low exploitation the frequency of catching a trophy bass could be improved using length limit changes, and that length limits must be applied in the context of the fishery.

Due to the differing goals for those fishing for recreation and those for food, we expected there to be a difference in harvest between harvest-oriented and sport anglers (Fisher 1997, Sutton 2003, Anderson et al. 2007). Surprisingly this was not supported by the data. High VRR was practiced by both anglers targeting LMB and by anglers where LMB were incidentally caught. If provided a larger creel limit, harvest-oriented anglers may remove more LMB below the SLL, which may increase benefits obtained from any SLL.

Lake Monticello is located in a rural part of southeastern Arkansas in a region having little industry and tourism. Thus, the Lake Monticello fishery has a large impact on the local economy. Anglers were estimated to spend over $647,000 ($1066 ha^{-1}) during the creel survey period (unpublished survey results). While this economic impact was 40% less than that estimated by Chen et al. (2003) at Lake Fork, Texas, it is nonetheless significant to the local economy. With this level of economic impact at Lake Monticello, any action taken that could negatively affect the LMB fisheries should be carefully measured. Therefore, any further management actions for Lake Monticello must ensure the lake remains successful as a trophy bass fishery, as the majority of the anglers fishing indicated they were fishing for trophy bass. State fisheries biologists have met with local angler groups to educate them about the need for harvest of smaller bass in Lake Monticello. Nonetheless, these informational sessions both in groups and individually with local anglers were met with criticism. Despite their understanding of the purpose of a slot limit, anglers were reluctant to remove smaller LMB. Similar outcomes were identified when the Texas Parks and Wildlife attempted to educate angler groups of Lake Fork in Texas (Myers et al. 2008). Sound management practice must be maintained without negatively impacting public perception and usage of this fishery.

As a result of modeling data and surveys, on 1 January 2011 the SLL was increased to 483- to 559-mm and the creel limit was expanded to eight LMB, only one of which could be over the slot. By both increasing the creel limit and increasing the lower end of the slot limit, our goal was to encourage the harvest of smaller LMB (particularly males) to reduce the number of LMB within the slot while sustaining or increasing the frequency of LMB reaching trophy bass size. The size of bass above the slot should increase if the goal of greater angler harvest is achieved. Although sampling following the changes in SLL has not yet been conducted, anecdotal reports by anglers indicate that they have identified minimal increases in catch rates or size of LMB caught following the regulation changes. Ultimately, without angler cooperation the high VRR by anglers of Lake Monticello may negate these changes in both creel limit and SLL.

Acknowledgments

This research was funded by the Arkansas Game and Fish Commission, the Federal Aid to Sport Fish Restoration under Project F-39-R. We thank Diana Andrews, Ben Batten, Colton Dennis, Dr. Mike Eggleton, Brad Fontaine, Sandra Harper, Kevin Hopkins, and Kelly Winningham for assistance with the collection. We thank Diana Andrews, Sandra Harper, Jordon Johnson, Scott Smith, and Angela Schenk for collecting the creel data. We thank Dr. Eggleton, Frank Leone, Jason Olive and Stan Todd for assisting

with database and modeling development. We also thank anonymous reviewers for improving the quality of this manuscript.

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