Exploitation of Largemouth Bass in Wheeler Reservoir, Alabama and Simulated Effects of Minimum Length Limit Regulations

Jeffrey W. Slipke, *Department of Fisheries, 203 Swingle Hall, Auburn University, AL 36849-5419*

Michael P. Holley, *Department of Fisheries, 203 Swingle Hall, Auburn University, AL 36849-5419*

Michael J. Maceina*, Department of Fisheries, 203 Swingle Hall, Auburn University, AL 36849-5419*

Abstract: Between the early and late 1990s, a nearly 10-fold decline in angler catch rates of large (≥2.27 kg) largemouth bass *(Micropterus salmoides)* was observed in Wheeler Reservoir, Alabama. The objective of our study was to estimate the exploitation rate of largemouth bass and compare predicted population responses from simulated minimum length limit (MLL) regulations in an attempt to explain this reduction. Exploitation was seasonal, with most of the harvest occurring during spring. Spring and early summer exploitation estimates adjusted for tag loss and angler non-reporting ranged from 10% to 15% in 2001, 9% to 14% in 2002, and 6% to 10% in 2003. No fish were reported as harvested in the first four months following tagging in October 2002. Simulation modeling predicted that a 406-mm MLL could potentially increase by 56% the proportion of a cohort that would recruit to 508-mm (approximately 2.27 kg), compared to a 305-mm MLL. Thus, current exploitation rates and an angler enforced 305-mm MLL did not account for the dramatic decline of largemouth bass ≥2.27 kg in Wheeler Reservoir. Additionally, nearly half as many fish were predicted to recruit to the more restrictive 406-mm MLL, compared to a 305-mm MLL. Our results have implications for largemouth bass management in reservoirs that have a substantial contingency of tournament anglers. Restrictive length limits have the potential to increase the abundance of trophy length fish in a population but at the cost of restricting the number of fish available for anglers to catch and weigh-in at a tournament.

Key words: largemouth bass, exploitation, simulation modeling, length limits

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Largemouth bass *(Micropterus salmoides)* is the most highly-sought freshwater fish species in the United States and Alabama (USFWS 2001). Largemouth bass fishing also accounts for the majority of the effort expended by anglers who fish Wheeler Reservoir, Alabama (Floyd and Greene 2001). Although no specific studies have investigated the economic impact of the Wheeler Reservoir largemouth bass fishery, anecdotal data suggests that recreational and competitive fishing for largemouth bass provides a substantial economic input for the surrounding communities (Bryan 1995).

Alabama does not have a minimum length limit (MLL) on largemouth bass in Wheeler Reservoir, but a creel limit of 10 fish per day exists.

Wheeler Reservoir is a mainstem impoundment of the Tennessee River in northern Alabama. The reservoir was impounded in 1936, covers 27,166 surface ha at full pool, and has approximately 1,711 km of shoreline. Wheeler Reservoir has a mean growing season chlorophyll-a concentration of 13 mg/m^3 (Clayton and Maceina 2002) which classifies it as eutrophic (Forsberg and Ryding 1980).

During the late 1990s, biologists with the Alabama Division of Wildlife and Freshwater Fisheries (ADWFF) began receiving complaints from anglers that catch rates of large (≥2.27 kg) largemouth bass had substantially declined in Wheeler Reservoir (Floyd and Greene 2001). Data from largemouth bass tournaments compiled for the ADWFF Bass Angler Information Team (BAIT) program verified this anecdotal information and showed that the amount of effort to catch a fish ≥2.27 kg in Wheeler Reservoir had increased from an average of 166 angler hours between 1990 and 1994 to an average of 2,585 angler hours between 1998 and 2001. Electrofishing data confirmed this trend, as the relative stock density of memorable-length fish (Anderson and Neumann 1996) declined from 3.1 in 1994 to 0.3 in 2000 concurrent with a decline in largemouth bass growth rates (M. J. Maceina, Auburn University, unpub. data; D. R. Lowery, Tennessee Valley Authority, unpub. data).

To address potential effects of exploitation on the size structure of the largemouth bass population in Wheeler Reservoir, we initiated a study in spring 2001 to determine the rate of largemouth bass exploitation and to investigate the potential impact of imposing a minimum length limit on largemouth bass. The specific objectives of our study were to estimate seasonal and annual rates of exploitation using mark-recovery data and to compare predicted population responses from simulated minimum length limit regulations.

Methods

Exploitation

Largemouth bass ≥305 mm TL were collected by electrofishing from four regions of Wheeler reservoir during each of three seasonal time periods: spring 2001 (March–April), spring 2002 (March–April), and fall 2002 (October). Tournament anglers enforce a 305-mm MLL, and we assumed that most anglers who routinely harvested fish would release fish <305 mm anyway. Fish were measured (TL; mm), tagged with individually numbered Floy t-bar anchor tags (Model FD-68BC) in the pterygiophore musculature of the dorsal fin, and immediately released. Tags were labeled to alert anglers that a "reward" was available in exchange for the returned tag and with an identification number, address, and telephone number to claim the reward. Rewards were randomly assigned a value ranging from US$5 to $50. The exploitation study was promoted with information posters at boat ramps and local tackle shops, and pre-paid business reply envelopes were available at local businesses. Ten percent of the fish were double tagged to estimate tag shedding rate. We assumed that tag loss was related to time; therefore, we used logistic regression to estimate the probability of shedding a tag (i.e., coded as 1 for no tag loss or 0 for a single tag lost) with an equation of the form

$$P_t = 1 - \frac{e^{(b_1 \times \log_e d + b_0)}}{1 + e^{(b_1 \times \log_e d + b_0)}}$$

where P_t = probability of tag loss, b_1 = parameter estimate, b_0 = y-intercept, and d = number of days between tagging and recapture (Miranda et al. 2002). The number of days between tagging and recapture was $\log_e$ transformed to provide for a more normal distribution and reduce the coefficient of variation (SD/mean). Tag loss rates were computed at 30-day intervals and used to compute monthly exploitation estimates. Anglers who returned tags were asked when and where the fish was caught and whether the fish was harvested or released. The exploitation rate μ of tagged fish was calculated as:

$$\mu = \frac{(N_h)}{[(N_t) \times (1 - P_t) \times (1 - P_{nr})]}$$

where N_h = number of tagged fish reported as harvested, N_t = number of tagged fish at large in the reservoir, and P_{nr} = angler non-reporting rate. Exploitation was estimated monthly for the first four months following tagging for fish tagged in spring 2001 and 2002. For fish tagged in fall 2002, exploitation was estimated monthly for the eight-month period following tagging. The number of tagged fish at large was adjusted each month by subtracting the number of tags returned in previous months from the number initially tagged. Angler non-reporting was not directly estimated during this study, but we assumed that this rate ranged between 20% and 50% based on previous studies (Larson et al. 1991, Zale and Bain 1994, Maceina et al. 1998, Schultz and Robinson 2002). The length-frequency distributions of released, harvested, and tagged fish were compared with Kolmogorov-Smirnov (KS) two-sample tests to determine if fish were caught or harvested in proportion to the tagged population.

Simulation Modeling

The largemouth bass population in Wheeler Reservoir was simulated with the FAST simulation software program (Slipke and Maceina 2000) to explore the potential response of imposing a 356- or 406-mm MLL on increasing the abundance of fish >508 mm (memorable length). Model parameters were derived from a large sample of largemouth bass collected in spring 2000 (M. J. Maceina, Auburn University, unpub. data) and from the exploitation estimates obtained in the present study (Table 1). Total annual mortality was estimated at 40% based on catch curve analysis (M. J. Maceina, Auburn University, unpub. data); therefore, we conducted simulations over a range of conditional natural mortality (20%–30%). Based on the von Bertalanffy growth parameters we computed for this population, it took fish 10 years on average to reach 508 mm TL. Each simulated cohort began with 100 recruits to

Table 1. Life history parameters used to simulate the largemouth bass population of Wheeler Reservoir, Alabama, 2000.

Parameter	Value
von Bertalanffy growth coefficients	L_{inf} = 550 mm
	K = 0.228
	t_o = –1.274 years
Maximum age	13 years
Conditional natural mortality	20% to 30%
Conditional fishing mortality	13% to 28%
Log_{10} weight:log_{10} length coefficients	intercept = –5.830
	slope = 3.388
Minimum length limits (total length)	305 mm
	356 mm
	406 mm

examine changes in the percentage of a cohort that would recruit to various lengths under different management scenarios. Based on the weight-to-length relation we computed for this population, fish weigh about 2.27 kg at a length of 508 mm. Therefore, we compared the proportion of a cohort that would recruit to 508 mm under each simulated minimum length limit. We also compared the number of fish that would recruit to the legal fishery for each of the simulated minimum length limits. Although there was no minimum length limit at Wheeler reservoir, we used 305 mm as the baseline minimum length limit for our simulations because the smallest fish we tagged to estimate exploitation was 305 mm.

Results

Exploitation

A total of 2,348 largemouth bass were tagged in spring 2001, 1,568 in spring 2002, and 1,932 in fall 2002 (Table 2). The logistic regression model used to estimate tag loss from the number of days at large indicated there was a significant effect of time on tag loss ($P < 0.02$). The parameters $b_0 = 1.872$ and $b_1 = -0.424$ in the model suggested that 39.5% of the tags were shed within the first 30 days after initial tagging and over 61% of the tags were shed after 240 days (Table 2). The number of tags returned from each tagging batch was 512 (22%) from those tagged in spring 2001, 251 (16%) from spring 2002, and 218 (11%) from fall 2002. Most fish were reported as caught and/or harvested during the spring and early summer. The number of tagged largemouth bass that were reported as harvested during the four-month period after being tagged was 94 in spring 2001, 55 in spring 2002, and zero in fall 2002. Spring and early summer exploitation estimates accounting for tag loss, but not accounting for angler non-reporting, were 8% in spring 2001, 7% in spring 2002, and 5% in fall 2002. These estimates represent minimum exploitation rates since they were based on tag returns from only the spring and early summer, and non-reporting

Table 2. Monthly tag return results and exploitation estimates for largemouth bass tagged in Wheeler Reservoir, Alabama, 2001–2002. Exploitation rates were adjusted for tag loss rate and a hypothetical non-reporting rate ranging from 0.20 to 0.50.

Season	Mo	*N* tagged at large	Released	Harvested	Tag loss (%)	Exploitation (%)
Spring 2001	March/April	2348	280	55	39.5	4.8–7.7
	May	2013	109	34	46.7	4.0–6.3
	June	1870	26	3	50.9	0.4–0.7
	July	1841	3	2	54.0	0.3–0.5
	Total		418	94		9.5–15.2
Spring 2002	March/April	1568	113	23	39.5	3.0–4.9
	May	1432	44	18	46.7	2.9–4.7
	June	1370	30	11	50.9	2.1–3.3
	July	1329	9	3	54.0	0.6–1.0
	Total		196	55		8.6–13.9
Fall 2002	Oct–Feb	1932	45	0	N/A	0.00
	March	1887	44	8	56.3	1.2–1.9
	April	1836	40	12	58.2	2.0–3.1
	May	1784	36	12	59.8	2.1–3.4
	June	1736	17	5	61.2	0.9–1.5
	Total		182	37		6.2–9.9

rates were not considered. Adjusted exploitation estimates ranged from 6% to 15%, assuming non-reporting rates of 20% to 50% (Table 2).

Anglers generally caught-and-released or harvested largemouth bass in proportion to the length-frequency distribution of tagged fish (Fig. 1). All pair-wise KS comparisons between populations of tagged fish, released fish, and harvested fish indicated no significant differences ($P > 0.05$) in length-frequency distributions except for the comparisons between tagged and released fish in spring 2002 and 2003. The mean length of fish tagged was 360 mm in spring 2001, 354 mm in spring 2002, and 356 mm in fall 2002. The mean length of tagged fish that were caught and released was 355 mm in spring 2001, 345 mm in spring 2002, and 345 mm in fall 2002/spring 2003. The mean length of tagged fish that were reported harvested was 354 mm in spring 2001, 344 mm in spring 2002, and 342 mm in spring 2003. Of fish harvested, 49 (52%) were ≤356 mm and 86 (91%) were ≤406 mm in spring 2001, 40 (73%) were ≤356 mm and 48 (87%) were ≤406 mm in spring 2002, and 28 (76%) were ≤356 mm and 34 (92%) were ≤406 mm in spring 2003.

Simulation Modeling

At the intermediate conditional natural mortality of 25%, we predicted that the percent of a cohort that would recruit to 508 mm would be quite small under all management scenarios, but would increase with progressively higher minimum length limits (Fig. 2). Additionally, the proportional difference in the change would be

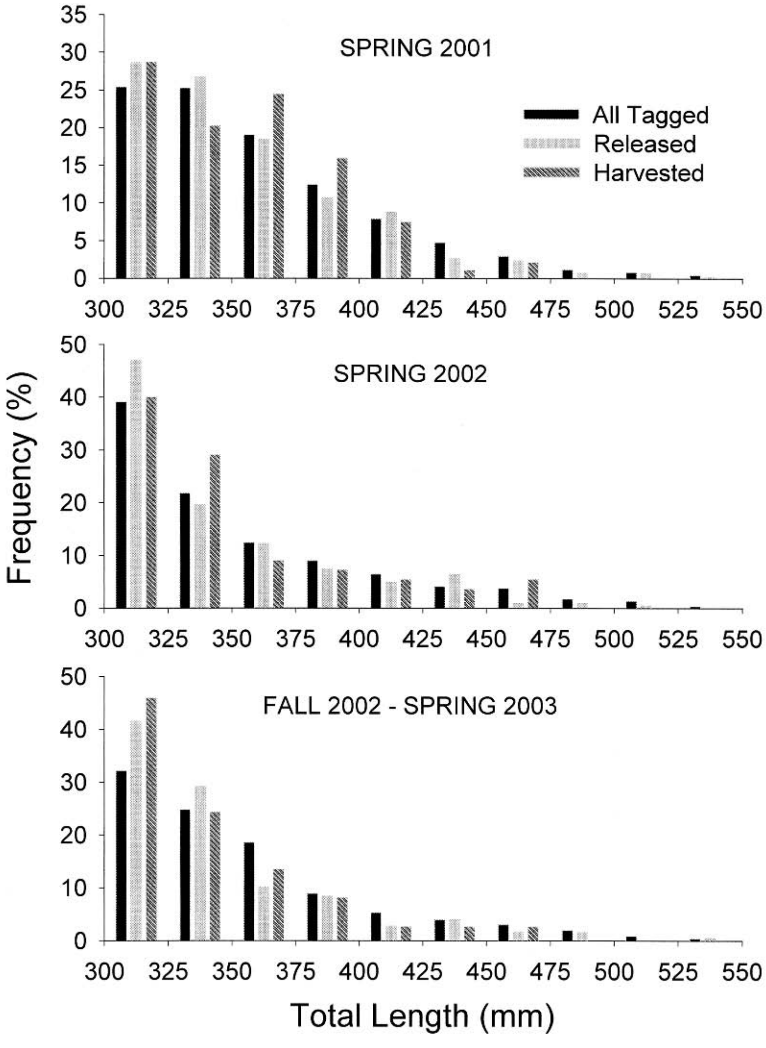

Figure 1. Relation between caught-and-released, harvested, and initially tagged largemouth bass in Wheeler Reservoir, Alabama, during spring 2001 (top), spring 2002 (middle), and fall 2002–spring 2003 (bottom).

greater at higher exploitation rates. If exploitation was on the low end of our estimated range (6%), we predicted that 8% more fish would recruit to 508 mm under a 356-mm MLL and 18% more fish would recruit to 508 mm under a 406-mm MLL, compared to a 305-mm MLL. However, if exploitation was 15%, we predicted that 21% and 56% more fish would recruit to 508 mm under a 356-mm and a 406-mm MLL, respectively, compared to a 305 mm MLL (Fig. 2).

The percent of a cohort predicted to recruit to the legal fishery was inversely re-

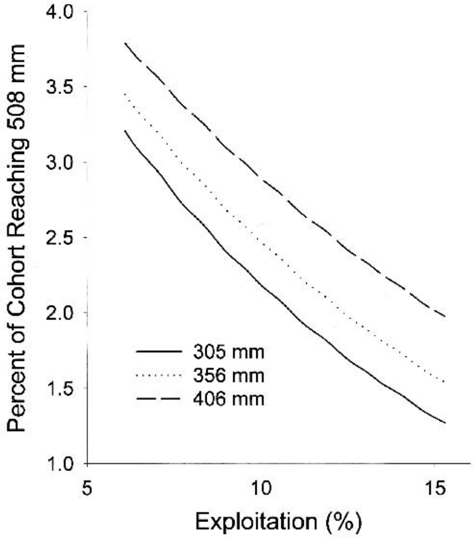

Figure 2. Proportion of a largemouth bass cohort predicted to reach 508 mm under 305-, 356-, and 406-mm minimum length limits and varying rates of exploitation in Wheeler Reservoir, Alabama. Simulations were conducted with a conditional natural mortality rate of 25%.

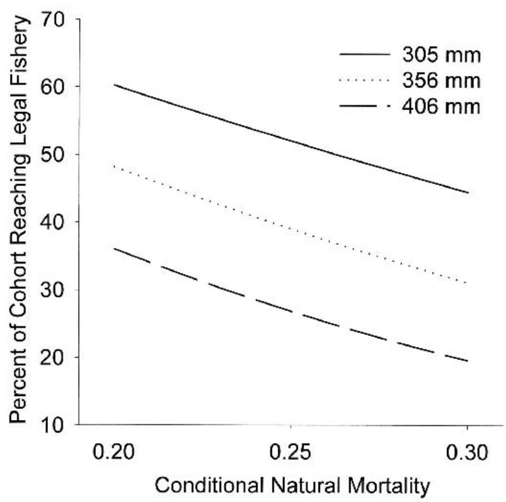

Figure 3. Proportion of a largemouth bass cohort predicted to recruit to the legal fishery under 305-, 356-, and 406-mm minimum length limits in Wheeler Reservoir, Alabama. Simulations were conducted over a range of conditional natural mortality between 20% and 30%.

lated to the natural mortality rate and was highly dependent on the minimum length limit used in the simulations (Fig. 3). At a conditional natural mortality rate of 25%, we predicted that 25% fewer fish would recruit to the legal fishery with a 356-mm MLL and 48% fewer fish would recruit to the legal fishery with a 406-mm MLL, compared to a 305-mm MLL. The differences in the percent of a cohort recruiting to the legal fishery would be slightly smaller if natural mortality was lower and slightly larger if natural mortality was higher (Fig. 3).

Discussion

Exploitation of largemouth bass from Wheeler Reservoir was highly seasonal, with most of the harvest occurring between March and June. The paucity of tag returns, particularly for harvested fish, beyond the four-month period after tagging in the spring of 2001 and 2002 could partially be explained by the relatively high tag loss rate observed during this study. However, of the 1,932 fish tagged in October 2002, no fish had been reported as harvested through February 2003, and only 45 tags had been returned from released fish. Additionally, there were more tags returned in March 2003 than were returned in the previous four months. Therefore, fishing effort and associated harvest for largemouth bass appears to have been negligible during fall and winter months at Wheeler Reservoir. This phenomenon of seasonal harvest was similar to that observed for other species. Schultz and Robinson (2002) reported that 90% of first year tag returns for white bass *(Morone chrysops)* in Kansas reservoirs were caught during spring and summer. Similarly, white bass exploitation was seasonal in two Missouri impoundments, with most of the harvest occurring from April to June (Colvin 2002). Most returns of tagged black crappies *(Pomoxis nigromaculatus)* and white crappies *(P. annularis)* in Mississippi lakes and reservoirs occurred between March and June (Miranda and Dorr 2000).

Our range of estimated exploitation (6% to 15%) was lower than the range reported by Allen et al. (1998) for 34 largemouth bass populations (mean = 36%; range 9% to 72%). However, considering that the exploitation rates reported by Allen et al. (1998) were estimated prior to 1993 and that the practice of catch-and-release for largemouth bass has increased throughout the 1990s (Quinn 1996), our estimates appear reasonable.

Our estimates of exploitation could have been biased low due to a potentially higher level of angler non-reporting. Estimates of angler non-compliance reported in the literature have been variable and wide ranging, depending on the method of assessment and the value of the reward offered for returned tags, and confound the estimation of exploitation through tag returns (Miranda et al. 2002). Maceina et al. (1998) reported that 73% of anglers failed to return postcards used as tag surrogates (Zale and Bain 1994), even though 85% of questioned anglers stated that they would comply by returning tags. Similarly, Miranda et al. (2002) observed a 76% non-compliance rate using surrogate postcards, but only a 38% non-compliance rate from a telephone survey of anglers. Jenkins et al. (2000) reported a significantly higher return rate for tags labeled "reward" compared to tags labeled "no reward," but no difference between those labeled "reward" and those labeled "$50 reward". We publicized our tagging study with a reward value ranging from $5 to $50.

We predicted that at the upper end of our estimated exploitation rate, only a 21% increase in the recruitment of fish to 508 mm would be expected with a 356-mm MLL, but a more than 50% increase in the number recruiting to 508 mm with a 406-mm MLL, compared to the baseline MLL of 305 mm. However, electrofishing and tournament survey data indicated at least a 10-fold decline in fish ≥508 mm during the past 10 years, and a 356-mm or 406-mm MLL would not result in such an increase in memorable length fish. These differences would be more pronounced if exploitation was indeed higher than estimated or if anglers harvested fish <305 mm. Since most of the fish harvested during this study were ≤356 mm, the harvest of fish ≤305 may have occurred. However, we were unable to assess the exploitation of smaller fish because we only tagged fish ≥305 mm.

Our simulations illustrate the trade-off between the potential of restrictive regulations to increase the abundance of trophy fish and allowing anglers to catch and retain smaller, more abundant fish in the population. Although the abundance of largemouth bass ≥508 mm in Wheeler reservoir could potentially be increased through the use of a minimum length limit, the reduction in the proportion of a cohort to recruit to progressively higher minimum length limits would likely be viewed as a negative consequence of a more restrictive management action. Therein lies the paradox of restrictive regulations for tournament fisheries: restrictive regulations have the potential to increase the abundance of trophy fish in a population, but at the cost of restricting the number of fish available for anglers to catch and weigh-in during a tournament.

Most tournaments award prizes for the greatest combined creel weight (Wilde et al. 1998). Hence, tournament fishing for largemouth bass is contingent upon anglers being able to weigh-in a limit of fish each day of an event. However, Wilde et al. (1998) reported that tournament anglers generally preferred to catch one or two big fish than ten smaller fish. Additionally, largemouth bass tournament anglers at Wheeler Reservoir have expressed concern over the lack of large (≥2.27 kg) fish, rather than the inability to weigh-in a limit of fish (Floyd and Greene 2001). Conversely, tournament anglers at West Point reservoir, Georgia preferred a greater abundance of legal-sized largemouth bass compared to more large fish, but fewer fish overall (Peterson and Evans 2003).

Restrictive minimum length limits are ideally suited to fish populations characterized by relatively fast growth, low natural mortality, and moderate to high exploitation rates (Anderson 1980, Novinger 1984). Additionally, harvest restrictions are most appropriate when fishing mortality exceeds natural mortality (Allen and Miranda 1995). If our estimates were biased low, and true exploitation was actually much higher, then fishing mortality could possibly have been equal to or slightly greater than natural mortality. Nevertheless, given the slow growth rate of largemouth bass in Wheeler Reservoir, a restrictive minimum length limit may not be warranted. Considering that it currently takes largemouth bass 10 years on average to reach 508 mm, our simulations indicated that only about 2% to 4% of a cohort would reach this size, even with a 406-mm MLL and if exploitation was on the low end of our estimated range.

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