North American Journal of Fisheries Management 29:869–875, 2009
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DOI: 10.1577/M08-184.1

[Article]

Assessment of the Flathead Catfish Population in a Lightly Exploited Fishery in Lake Wilson, Alabama

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Abstract.—Population metrics and the fishery for flathead catfish *Pylodictis olivaris* were examined in Lake Wilson, an impoundment of the Tennessee River in Alabama. We described the recreational and commercial exploitation, angler size selectivity, and population demographics and used modeling to assess the impact of exploitation and minimum length limits on the abundance of memorable (860-mm) and trophy (1,020-mm) fish. A total of 1,113 flathead catfish were collected, and 646 of these fish ($\geq$300 mm) were tagged and released to estimate exploitation. The length distribution indicated that there was a high proportion of larger fish in the population, the relative stock densities of preferred-, memorable-, and trophy-length fish being 21, 8, and 2%, respectively. Ages were estimated from otoliths ($N = 198$), and it was found that fish were slow growing (von Bertalanffy growth coefficient, 0.066) and long-lived (maximum age, 34 years) and expressed a high annual survival rate (83%) and low instantaneous natural mortality (range, 0.099–0.159). From a liberal tag loss rate (2.617%/month) and range of angler nonreporting (20–70%), estimates of exploitation ranged from 5% to 13%. Commercial angling accounted for 26% of the harvest. However, comparison of the observed and simulated length distributions and the difference between catch-curve survival and natural mortality strongly suggested that exploitation was about 5%. Anglers preferred to harvest larger fish, the highest selection being for fish 600–800 mm long. A reduction in harvest rates would have a larger impact on the maintenance of memorable- and trophy-length fish in the population than 356-, 508-, or 610-mm minimum length limits. At exploitation rates greater than 12%, very few trophy-size flathead catfish would remain in the population even if a high minimum length limit (610 mm) were imposed. Currently, flathead catfish are lightly exploited in this section of the Tennessee River and regulations to maintain the quality size of the population are not necessary at this time. However, this population is slow growing and long-lived with low natural mortality and would be sensitive to overfishing. If exploitation should increase and exceed natural mortality, the abundance of memorable- and trophy-size fish would be greatly reduced.

Greater interest in the population assessment and management of catfish (Ictaluridae) fisheries in North America has been expressed (Arterburn et al. 2002). Until recently, assessments to further understanding of the population dynamics and management of flathead catfish *Pylodictis olivaris* have been rare (Kwak et al. 2006; Sakaris et al. 2006; Makinster and Paukert 2008). In Alabama, about 36% of anglers fish for catfishes, and 28% of the total freshwater angler effort in the USA is directed toward these fish (USFWS and Bureau of the Census 2007). Arterburn et al. (2002) reported that fishery biologists recognize that flathead catfish and blue catfish *Ictalurus furcatus* are important to anglers as trophy fish and that 75% of catfish anglers are in favor of developing trophy fisheries. In addition, 65% of catfish anglers would support harvest regulations (Arterburn et al. 2002). Exploitation rates have not been estimated for flathead catfish fisheries in Alabama. Alabama currently does not regulate recreational or commercial fishing for any catfish species with gear, creel, or length limits. The only exception is that only one catfish (of any species) over 864 mm may be harvested per day.

Using otoliths to age catfish (Nash and Irwin 1999; Buckmeier et al. 2002; Kwak et al. 2006; Maceina and Sammons 2006) indicated that they live longer, grow more slowly, and probably have lower natural mortality rates than previously reported when ages were estimated from pectoral spines. Thus, these fish may be more vulnerable to overfishing than previously thought. In 1990, nearly 100,000 kg of catfish were harvested in the Wheeler Dam tailwater of Lake Wilson, Alabama (Janssen and Bain 1996). Blue catfish and channel catfish *I. punctatus* represented 97% and flathead catfish 3% of the total catfish harvest (Janssen and Bain 1996). From the results of a creel survey conducted on Lake Wilson in 2006, most commercial and recreational anglers harvested small blue and channel catfish, and directed fishing effort to catch flathead catfish was low (Holley et al. 2009). In addition, during our sample collections of blue catfish

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Received August 19, 2008; accepted January 29, 2009
Published online July 27, 2009

and channel catfish (Holley et al. 2009), a high proportion of memorable-length (860-mm) and larger flathead catfish was observed. From these observations and a previous creel survey (Janssen and Bain 1996), we speculated that flathead catfish exploitation was low. The objectives of this paper were to describe the population attributes (including growth and natural and fishing mortality) of flathead catfish in Lake Wilson. We also describe the characteristics of the commercial and recreational fishery. Finally, simulation modeling was used to explore the impacts of exploitation on the flathead catfish population.

Methods

Lake Wilson is 6,400-ha main-stem impoundment of the Tennessee River located in northwestern Alabama. Flathead catfish are native to this river. They were collected using a Smith-Root (7.5 GPP) electrofisher with low pulse frequency (15 pulses/s) and direct current (100–1,000 V) during daylight. A chase boat was used to assist in netting surfacing fish. Electrofishing surveys were conducted during October 2004 and 2005, May–June 2005, 2006, and 2007, July 2007, and August 2005 and 2007.

All flathead catfish were placed in a 400-L live well for processing. Total length (TL) was measured to the nearest millimeter; fish weighing less than 5.0 kg were weighed to the nearest gram, those weighing more than 5.0 kg to the nearest 10 g. In fish longer than 300 mm, Carlin dangler tags were attached with stainless steel wire posterior to the first dorsal spine and between the pterygiophores. Each tag had a unique number and indicated the name, address, and phone number of the Fisheries Department at Auburn University. Ages were determined from a subsample of 198 flathead catfish (93–1,110 mm) by sectioning sagittal otoliths following the methods of Buckmeier et al. (2002).

Exploitation and angler size selectivity.—During the 48-month tagging study, the exploitation (μ) of tagged flathead catfish was calculated each month according to the equation

$$\mu = N_h/[(N_t)\cdot(1-P_{\text{nr}})(1-P_t)],$$

where N_h is the number of tagged fish reported as harvested, N_t is the number of tagged fish at large, P_{nr} is the angler nonreporting rate, and P_t is the tag loss rate (2.617%/month). Although we did not estimate the angler nonreporting rate, we assumed that it lay between 20% and 70% based on previous studies (Zale and Bain 1994; Maceina et al. 1998). Elsewhere, the loss rate of Carlin dangler tags was reported to be 15.7% over a 6-month period for blue catfish (Kevin Sullivan, Missouri Department of Conservation, personal communication), and we used this rate to adjust our exploitation estimates each month. Thus, the wide range of nonreporting rates and high tag loss rate probably provided an accurate range of exploitation rates.

To facilitate angler tag returns, rewards were randomly assigned values of US$5, $10, $20, and $50. Although offering rewards for returned tags increases angler compliance, nonreporting rates should still be included in exploitation estimates (Zale and Bain 1994; Maceina et al. 1998; Miranda et al. 2002). Survey cards and postage-paid envelopes were available at local businesses; anglers were asked to give their name and address, the date and location at which the fish was caught, the gear used, whether the respondent was a commercial or recreational angler, and whether the fish was released. Each month, the number of fish at large was computed by removing the number harvested and the number of tags lost from the total number tagged, as fish were being tagged throughout the study. Exploitation was averaged over the 48-month period and estimated as an average annual (12-month) rate. The length-frequency distributions of harvested and tagged fish were compared by means of Kolmogorov–Smirnov two-sample tests (KSa) to determine whether fish were harvested in proportion to the tagged population.

The effect of fish length on the probability of angler harvest was analyzed with logistic regression (Miranda and Dorr 2000). Only tags returned by anglers when the fish was harvested (October 2004–July 2008) were used to determine angler size selectivity. Because flathead catfish grow slowly (this study), length was not corrected for the time between angler capture and tagging.

Simulation modeling.—The effects of three potential length limits (356, 508, and 610 mm) on the flathead catfish fishery and population were explored using the Fishery Analysis and Simulation Tools (FAST) software program (Slipke and Maceina 2006). We assumed from angler tag returns at Lake Wilson that the minimum size of flathead catfish harvested was 356 mm. Relative stock density (RSD; the percentage of stock-length fish that were also quality, preferred, memorable, or trophy fish) indices were calculated using the length categories in Anderson and Neumann (1996) and compared with the RSD values predicted by the simulation models. The von Bertalanffy (1938) growth equation was computed from mean length-at-age data (Table 1). The weight–length relationship was derived from the flathead catfish sampled (Table 1). Instantaneous natural mortality rates (M) were estimated from five published equations that use life history demographic data (Table 2) and then averaged. Mean conditional natural mortality was computed as $1 - e^{-M}$ using the average value for M. Fishing mortality was

TABLE 1.—Life history parameters used to model the flathead catfish population in Lake Wilson with the yield-per-recruit model in FAST (Slipke and Maceina 2006).

Parameter	Value
Von Bertalanffy growth coefficients[a]	
L_{inf} (mm)	1,145
k	0.066
t_0	−1.341
Maximum age	34
Mean conditional natural mortality	0.113
Exploitation rate (%)	0–20
Log_{10} weight–length regression coefficients	
Intercept	−5.732
Slope	3.287
Minimum length limits (mm)	356, 508, and 610
Initial population	1,000

[a] L_{inf} is the theoretical maximum length, k the growth coefficient, and t_0 the time at which length would theoretically be zero.

adjusted for the range of potential angler exploitation rates. Instantaneous annual mortality (Z) and survival ($S = e^{-Z}$) were estimated from a weighted catch-curve regression (Maceina 1997) in which ages were assigned to all unaged fish on the basis of a length–age key (Slipke and Maceina 2006). Annual mortality (AM) was equal to $1 - S$. The catch-curve analysis included age-5 and older flathead catfish (about 356 mm) that were fully recruited to the fishery. Instantaneous fishing mortality (F) was derived by subtracting the average value of M from Z. Exploitation (μ) was also estimated as $\mu = F \cdot \text{AM}/Z$.

Population metrics of flathead catfish were incorporated into FAST. The abundance at memorable length (≥860 mm) and trophy length (≥1,020 m) and yield were modeled over a range of exploitation rates and the three potential minimum length limits assuming a constant 1,000 age-0 recruits in each simulation.

Results

A total of 1,113 flathead catfish were collected, of which 646 fish (≥300 mm) were tagged and released. The length of all of the fish collected ranged from 77 to 1,145 mm, and the RSDs of preferred- (710-mm), memorable-, and trophy-length fish were high (Figure 1). Anglers returned 39 tags, 34 fish were harvested, and the average estimated annual exploitation rate ranged from 5% to 13% after accounting for tag loss and angler nonreporting rates of 20–70%. Commercial anglers accounted for 26% of the fish harvested. The total length of harvested fish ranged from 358 to 994 mm. Anglers harvested larger flathead catfish in proportion to fish that were tagged ($KSa = 2.10$; $P < 0.001$; Figure 1); the mean total lengths of harvested and tagged fish were 584 and 504 mm, respectively. The probability of harvest was low (0.01) for flathead catfish about 300 mm, with peak harvest selectivity (0.09) at about 700 mm; the relationship was parabolic (Wald $\chi^2 = 12.8$, $P = 0.0017$; concordance = 0.69; Figure 1). For the 39 tags returned, 38 fishers reported the gear type used. For commercial anglers (9 responses), 78, 11, and 11% of the fish were caught by trotline, gill net, and angling, respectively; for recreational fishers (29 responses), 59, 14, 14, 7, and 7% of the fish were caught by angling, gill net, other gear, jug, and trotline, respectively.

Flathead catfish growth was slow and the von Bertalanffy growth equation (Table 1; Figure 2) predicted that the time required to reach stock (350 mm), quality (510 mm), preferred, memorable, and trophy lengths would be 4.2, 7.6, 13.3, 19.7, and 32.2 years, respectively. The weighted catch-curve regression for flathead catfish 5–34 years old estimated annual mortality at 17% ($Z = -0.186$, $r^2 = 0.79$, $P < 0.01$; Figure 2). We suspect that the formation of weak and strong year-classes caused variation about the slope of the regression, but a plot of the catch-curve residuals against age showed a homoscedastic pattern and the catch-curve regression was linear (Maceina 1997). After age 25, 7 of 9 year-classes were missing, which may have influenced our estimate of annual mortality. However, the catch-curve regression computed for fish 5–25 years old provided an estimate of mortality ($Z = -0.189$) similar to that for fish 5–34 years old. The five estimates of instantaneous natural

TABLE 2.—Sources, equations, and estimates of instantaneous natural mortality rates (M) based on the population demographics of flathead catfish from Lake Wilson.

Source	Equation[a]	M
Quinn and Deriso (1999)	$-\log_e(\text{Ps})/\text{Max}_{age}$	0.135
Hoenig (1983)	$1.46 - 1.01 \cdot \log_e(\text{Max}_{age})$	0.122
Jensen (1996)	$1.50 \cdot k$	0.099
Peterson and Wroblewski (1984)	$1.92 \cdot \text{Max}_{wt}^{0.25}$	0.159
Chen and Watanabe (1989)	$(1/t_f - t_i) \cdot \log_e(e^{k \cdot t_f} - e^{k \cdot t_0})/(e^{k \cdot t_i} - e^{k \cdot t_0})$	0.122

[a] Ps = the proportion of fish surviving to the maximum age (set at 0.01); Max_{age} = the maximum age; Max_{wt} = the maximum weight of fish computed from the weight–length regression in Table 1 with L_{inf} from the von Bertalanffy growth equation; t_f = the final age, which was assumed to be the maximum age; and t_i = the initial age, which was assumed to be 1 year. See Table 1 for other symbols.

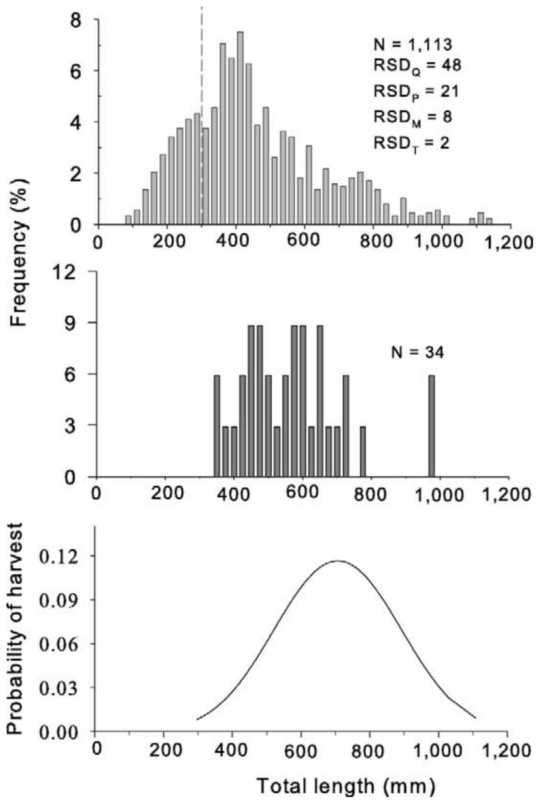

FIGURE 1.—The upper panel shows the length distribution and relative stock density (RSD) values for all flathead catfish collected by electrofishing at Lake Wilson (Q = quality, P = preferred, M = memorable, and T = trophy). Only fish 300 mm and longer (i.e., to the right of the dashed line) were tagged. The middle panel shows the length distribution of flathead catfish harvested by anglers and the lower panel angler size selection for flathead catfish. The equation used to predict angler selection was $P = 1 - \exp(0.0233 \cdot \mathrm{TL} - 0.00002 \cdot \mathrm{TL}^2 - 10.2472)$.

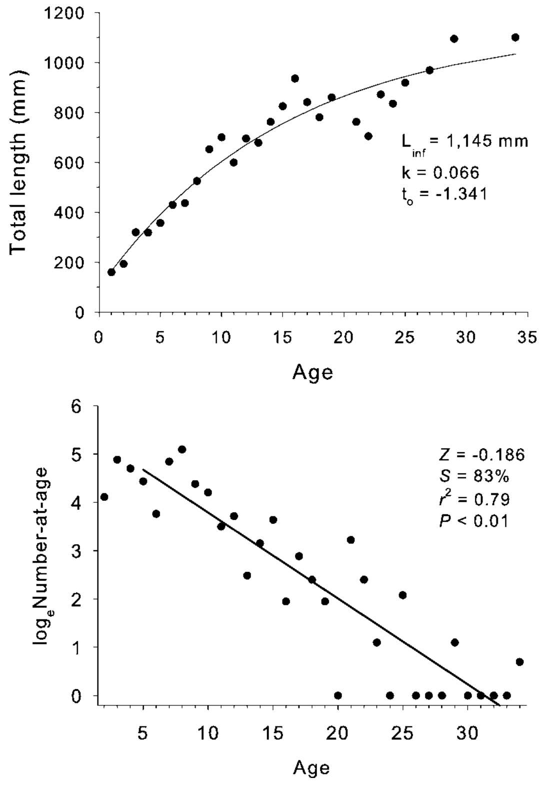

FIGURE 2.—The upper panel shows the mean lengths at age of flathead catfish and the growth predicted by the von Bertalanffy growth equation (L_{inf} is the theoretical maximum length, k the growth coefficient, and t_0 the time at which length would theoretically be zero). The lower panel shows the number at age and the weighted catch-curve regression used to estimate instantaneous annual mortality (Z) and survival (S). The catch curve was fitted to fish 5–34 years old; the number-at-age data are for fish 2–4 years old.

mortality ranged from 0.099 to 0.159 and averaged 0.127 (Table 2). The difference between Z and M was 0.059, implying that exploitation was about 5.4%.

At our estimated minimum exploitation rate of 5% (20% nonreporting) for harvested flathead catfish from 356 to 1,000 mm (4.3–29 years old), simulation modeling predicted relative stock density indices similar to or slightly lower than our observed values (Figure 1). With a 3% exploitation rate, the predicted RSD values for quality, preferred, memorable, and trophy fish were 49, 18, 6, and 1%, respectively, compared with observed values of 48, 21, 8, and 2. At an exploitation rate of 9% (50% nonreporting), the predicted RSD values were 39, 10, 2, and 0%, respectively. At this higher exploitation rate, the RSDs of preferred-size and larger fish were much less in this simulated population than was observed in our collections. Thus, based on the observed and predicted relative stock densities of flathead catfish, estimates of F from Z and M, and our empirical exploitation estimates, annual exploitation was probably 5% or slightly less.

For this flathead catfish population, the differences in yield among the three minimum length limits were nil at exploitation rates less than 7% (Figure 3). At our estimated exploitation rate (3–5%), growth overfishing was not apparent even with the angler-selected 356-mm minimum length limit. Greater yield could be achieved with the two high minimum length limits at exploitation rates of 10–20% (Figure 3).

Controlling the exploitation rate would have a larger impact on the maintenance of memorable- and particularly trophy-length fish in the population than

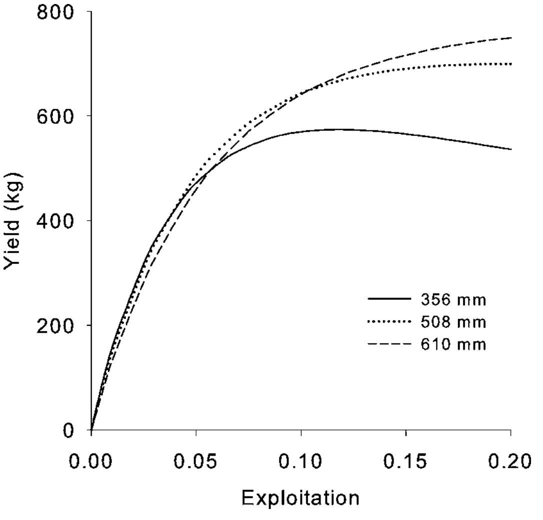

FIGURE 3.—Predicted yields of flathead catfish over a range of exploitation rates and minimum length limits of 356, 508, and 610 mm. The simulations were conducted with an initial population of 1,000 recruits.

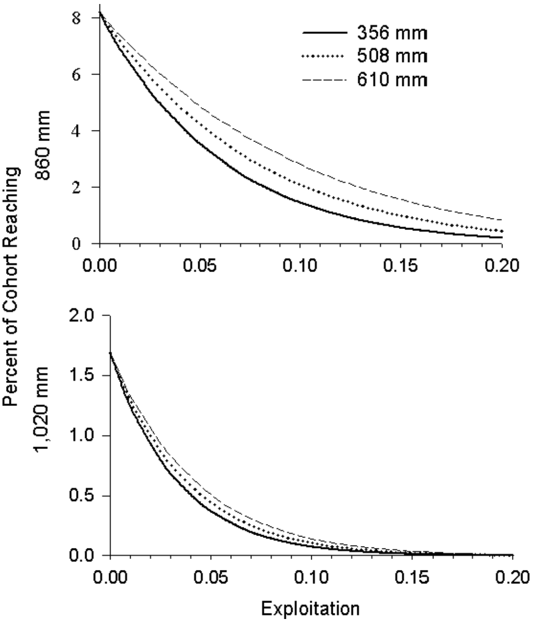

FIGURE 4.—Percentages of a cohort of flathead catfish predicted to reach memorable (860 mm) and trophy size (1,020 mm) over a range of exploitation rates and minimum length limits of 356, 508, and 610 mm.

managing the fishery with three minimum length limits (Figure 4). At an exploitation rate of 5%, 35% more memorable-length fish would be present in the population with a 610-mm minimum length limit than with a 356-mm limit (Figure 4). However, the overall abundance of memorable-length fish would be reduced by about one-half for each 5% increase in exploitation among the range of minimum lengths (Figure 4). Our model predicted a reduction of about 70% in the abundance of trophy-length flathead catfish if exploitation were 5%, and the impact of minimum length limits on fish of this size would be nil. At exploitation rates greater than 12%, very few trophy-length fish would remain in the population (Figure 4).

Discussion

We estimated that four fish were 27 or 29 years old, and we captured one individual in which 34 annuli were visible. To our knowledge, this presumed 34-year-old fish is the oldest flathead catfish recorded. Otolith annuli formation has not been verified for flathead catfish, but it has for channel catfish (Buckmeier et al. 2002). In the Coosa and Tallapoosa rivers of Alabama, Sakaris et al. (2006) collected flathead catfish as old as 25 and 28 years. Like the flathead catfish in the Tennessee River that we collected, those in the Coosa and Tallapoosa rivers represent native populations, and Sakaris et al. (2006) and Kwak et al. (2006) have noted that introduced flathead catfish grow much faster but do not live as long as populations found within the species' native range.

Although there is an extensive commercial and recreational fishery for blue and channel catfish in Lake Wilson (Holley et al. 2009), the harvest of flathead catfish was low. Most recreational and commercial catfish anglers on Lake Wilson use "dead bait," and hook-and-line anglers fish with light tackle that targets smaller blue and channel catfish (Holley et al. 2009); flathead catfish, by contrast, prefer to consume live fish (Jackson 1999). Thus, the effort directed at catching flathead catfish using live fish as bait was low. Although we computed a maximum annual exploitation rate of 13%, this estimate is probably inflated owing to the inclusion of a high tag loss rate estimate and an upper 70% angler nonreporting rate. Carlin dangling tag loss rates of 0% for catfish have been reported (Graham 1999; Travnichek 2004). If we assumed no tag loss, our estimates of exploitation would decrease by about 20%. Based on catch-curve analysis, the difference between total and instantaneous natural mortality, and calibration of the length distribution using simulation modeling, the exploitation in this population was probably 3–5%. Sakaris et al. (2006) estimated flathead catfish survival as 86% in the Coosa River, which is similar to our estimate of 83%. Kwak et al. (2006) reported that annual mortality was also low (16–20%) in two North Carolina rivers and attributed this to low fishing mortality. Makinster and Paukert (2008) suggested that growth in Kansas was sufficient and natural mortality low enough to maintain flathead catfish fisheries at low exploitation rates (about 10%) in populations in which fish live as long 21 years (based on ages obtained from pectoral spines). Quinn (1993) reported exploitation rates of 14–25% for flathead catfish fisheries in Georgia.

The flathead catfish fishery is lightly exploited at Lake Wilson, so bag and length limits are not necessary at this time. Commercial anglers did not appear to target flathead catfish, and the catch of these fish was incidental to fishing for blue and channel catfish (Holley et al. 2009). In addition, in this region of Alabama the number of licensed commercial catfish anglers has declined nearly 20-fold during the past 30 years and during this study only seven commercial anglers targeting catfish were identified (Holley et al. 2009). In addition, growth was slow, the fish were long-lived, and natural mortality was low. If a moderate increase in exploitation occurs such that the rate is greater than 10%, this will affect the size structure of the population and the abundance of memorable and larger-size fish. Of the tagged catfish caught, 87% were harvested, so most anglers do not practice catch and release. Anglers appeared to select for moderate-size flathead catfish (600–800 mm). Similarly, Quinn (1993) reported that anglers selected for larger flathead catfish (600–700 mm) than were captured with electrofishing. In Lake Wilson, a minimum length of 610 mm would help maintain a greater proportion of larger fish in the population, and this length falls within the angler size selection preference. However, exploitation appears to be a more important factor in regulating length distribution than minimum length limits. If fishing mortality is greater than natural mortality, this will reduce the abundance of memorable- and trophy-length fish in the population.

Acknowledgments

The funding for this research was provided by the Alabama Division of Wildlife and Freshwater Fisheries through Federal Aid in Sport Fish Restoration project F-40. R. Hunter, B. Ricks, S. Sammons, and D. Stormer assisted with field work. D. Devries and R. Wright provided comments to improve this paper.

References

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447–482 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Arterburn, J. E., D. J. Kirby, and C. R. Berry. 2002. A survey of angler attitudes and biologist opinions regarding trophy catfish and their management. Fisheries 27(5):10–21.

Buckmeier, D. L., E. R. Irwin, R. K. Betsill, and J. A. Prentice. 2002. Validity of otoliths and pectoral spines for estimating ages of channel catfish. North American Journal of Fisheries Management 22:934–942.

Chen, S., and S. Watanabe. 1989. Age dependence and natural mortality coefficient in fish population dynamics. Bulletin of the Japanese Society of Scientific Fisheries 55:205–208.

Graham, K. 1999. A review of the biology and management of blue catfish. Pages 37–49 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. U.S. National Marine Fisheries Service Fishery Bulletin 82:898–903.

Holley, M. P., M. D. Marshall, and M. J. Maceina. 2009. Fishery and population characteristics of blue catfish and channel catfish and potential impacts of minimum length limits on the fishery in Lake Wilson, Alabama. North American Journal of Fisheries Management. 29:1183–1194.

Jackson, D. C. 1999. Flathead catfish: biology, fisheries, and management. Pages 23–36 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Janssen, F. W., and M. B. Bain. 1996. A quantitative comparison of two quality Tennessee River tailrace fisheries. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 48(1994):482–492.

Jensen, A. L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences 53:820–822.

Kwak, T. J., W. E. Pine, III, and D. S. Waters. 2006. Age, growth, and mortality of introduced flathead catfish in Atlantic rivers and a review of other populations. North American Journal of Fisheries Management 26:73–87.

Maceina, M. J. 1997. Simple application of using residuals from catch curve regressions to assess year-class strength in fish. Fisheries Research 32:115–121.

Maceina, M. J., P. W. Bettoli, S. D. Finely, and V. J. Dicenzo. 1998. Analyses of the sauger fishery with simulated effects of a minimum size limit in the Tennessee River of Alabama. North American Journal of Fisheries Management 18:66–75.

Maceina, M. J., and S. M. Sammons. 2006. An evaluation of different aging structures to age freshwater fish from a northeastern U.S. river. Fisheries Management and Ecology 13:237–242.

Makinster, A. S., and C. P. Paukert. 2008. Effects and utility of minimum length limits and mortality caps for flathead catfish in discrete reaches of a large prairie river. North American Journal of Fisheries Management 28:97–108.

Miranda, L. E., R. E. Brock, and B. S. Dorr. 2002. Uncertainty of exploitation estimates made from tag returns. North American Journal of Fisheries Management 22:1358–1363.

Miranda, L. E., and B. S. Dorr. 2000. Size selectivity of crappie angling. North American Journal of Fisheries Management 20:706–710.

Nash, M. K., and E. R. Irwin. 1999. Use of otoliths versus pectoral spines for aging adult flathead catfish. Pages 309–316 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Peterson, I., and J. S. Wroblewski. 1984. Mortality rate of fishes in the pelagic ecosystem. Canadian Journal of Fisheries and Aquatic Sciences 41:1117–1120.

Quinn, S. P. 1993. Description of a multiuse fishery for flathead catfish. North American Journal of Fisheries Management 13:594–599.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, New York.

Sakaris, P. C., E. R. Irwin, J. C. Jolley, and D. Harrison. 2006. Comparison of native and introduced flathead catfish populations in Alabama and Georgia: growth, mortality, and management. North American Journal of Fisheries Management 26:867–874.

Slipke, J. W., and M. J. Maceina. 2006. Fisheries analysis and simulation tools (FAST). Department of Fisheries, Auburn University, Auburn, Alabama.

Travnichek, V. H. 2004. Movement of flathead catfish in the Missouri River: examining opportunities for managing river segments for different fishery goals. Fisheries Management and Ecology 11:89–96.

USFWS (U.S. Fish and Wildlife Service) and Bureau of the Census. 2007. 2006 national survey of fishing, hunting, and wildlife-associated recreation. USFWS and Bureau of the Census, Washington, D.C.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Human Biology 10:181–213.

Zale, A. V., and M. B. Bain. 1994. Estimating tag-reporting rates with postcards as tag surrogates. North American Journal of Fisheries Management 14:208–211.