ASSESSMENT OF ELECTROFISHING BIAS, ANGLER EXPLOITATION, AND A CREEL SURVEY, AND FLATHEAD CATFISH POPULATION ASSESSMENT IN LAKE WILSON, ALABAMA

Except where reference is made to work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee. This thesis does not include proprietary or classified information.

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Matthew David Marshall

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Science

Auburn, Alabama
August 9, 2008

ASSESSMENT OF ELECTROFISHING BIAS, ANGLER EXPLOITATION, AND A CREEL SURVEY, AND FLATHEAD CATFISH POPULATION ASSESSMENT IN LAKE WILSON, ALABAMA

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VITA

Matthew David Marshall, son of William Cantey and Margaret Joyce Marshall, was born on February 8, 1982 in Montgomery, Alabama. He graduated from Macon East Montgomery Academy in 2000. He attended Auburn University and graduated *cum laude* with a Bachelors of Science degree in Fisheries Management in May, 2004 and began working as a Research Assistant II in the Department of Fisheries, Auburn University in August 2004. In January, 2007, he entered Graduate School, Auburn University.

THESIS ABSTRACT

ASSESSMENT OF ELECTROFISHING BIAS, ANGLER EXPLOITATION, AND A CREEL SURVEY, AND FLATHEAD CATFISH POPULATION ASSESSMENT IN LAKE WILSON, ALABAMA

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Master of Science August 9, 2008
(B.S., Auburn University, 2004)

86 Typed Pages

Directed by Michael J. Maceina

A popular recreational and commercial catfish fishery for blue catfish *Ictalurus furcatus,* channel catfish *I. punctatus,* and to a lesser extent, flathead catfish *Pylodictus olivaris* exists on Lake Wilson, Alabama. Catfish were collected using low-frequency (15 pulses/s), and temporal and size bias associated with electrofishing recapture was determined for blue catfish and flathead catfish. A roving creel survey was conducted from April to October 2006 to evaluate catfish angling effort, catch, and harvest. Fish greater than 300 mm total length (TL) were tagged with Carlin dangler tags to estimate electrofishing recapture rates and exploitation from angler tag returns. For flathead catfish, simulation modeling was conducted to explore the impacts of three minimum

length limits and exploitation on yield, number of fish harvested by anglers, and memorable-size and trophy-size fish abundance.

Immediate (24 h) recapture rates were low for blue catfish (2%) and flathead catfish (1%) from an enclosed cove, and longer recovery periods may be required before these fish again become susceptible to electrofishing gear. Similarly, overall recapture rates of tagged blue catfish and flathead catfish were low (0 to 4%) during routine electrofishing surveys despite an increase in the number of tagged catfish at large and indicated low capture probabilities and/or high abundance of catfish. The recapture of tagged channel catfish was not observed possibly due to inefficiency of low-frequency electrofishing for this species.

A roving creel survey was conducted from April to October 2006 and about 73,000 h of angler effort were directed at catfish and anglers harvested 49,015 kg (8 kg/ha). Angler catch was predominantly blue catfish and channel catfish and the catch of flathead catfish was not observed.. Despite high angler effort and harvest, catch and harvest rates were high and averaged 1.5 and 1.2 catfish/hour, respectively. Harvest was 72% higher in 1990 than 2006, and this decrease was possibly attributed the a decline in commercial anglers and differences in creel survey design. Catfish anglers supported a regulation beneficial to trophy-size blue catfish, but were concerned about bag limits as most anglers describe larger blue catfish (≥ 9 kg) as poor quality for consumption.

The majority of blue catfish and channel catfish harvested were between 300 and 550 mm and fish greater than 700 mm were rarely harvested. For all catfish species, the probability of harvest was highest at 600-700 mm and declined for larger catfish (≥ 800 mm) indicating preference for angler-quality and angler-preferred sized catfish. Most

angler tag returns occurred from April to October and were located in the vicinity of the Wheeler Dam tailrace. Estimates of exploitation from tag returns ranged from 6 to 19% for blue catfish, 4 to 13% for channel catfish, and 4 to 15% for flathead catfish at varying levels of angler non-reporting. Based on results of my simulation modeling, flathead catfish predicted exploitation rates (≈ 6%) were similar to estimates computed from angler tag returns (5.4%). Thus, exploitation did not exceed natural mortality estimates (17%) and growth overfishing was very unlikely even if exploitation rates increased about three fold in the current fishery. A minimum length limit of 610 mm would be beneficial for maintaining the flathead catfish population, but the number of fish available for anglers to harvest would be reduced by about 50% compared a 356 and 508 mm minimum length limit. Although the flathead catfish fishery is lightly exploited, growth is slow and fish are extremely long lived, and a potential increase in exploitation caused by the popularity of the Lake Wilson catfish fishery may become a concern for future management of the fishery.

ACKNOWLEDGMENTS

This projected was accomplished with the support of many people. I would like to thank my advisor, Dr. Mike Maceina, for his assistance and guidance, and providing his statistical and fishery biology expertise. I would like to thank my committee members, Dr. Dennis DeVries and Dr. Rusty Wright, for their insight and suggestions. Thanks to Michael Holley, Ryan Hunter, Ben Ricks, Dr. Steve Sammons, Michael Sheperd, and David Stormer for their assistance in the field and analytical advice. Finally, I would also like to thank my family members for their support. Funding for this project was provided by the Alabama Division of Wildlife and Freshwater Fisheries through Federal Aid in Sport Fish Restoration funds (F-40).

Style manual or journal used North American Journal of Fisheries Management

Computer software used WordPerfect 12.0, SAS 9.1, FAST 2.1, Microsoft Excel 2003, SigmaPlot 9.0

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INTRODUCTION

Recreational angling for blue catfish *Ictalurus furcatus*, channel catfish *Ictalurus punctatus,* and flathead catfish *Pylodictus olivaris* has increased in popularity throughout the USA. In Alabama, 31% of all anglers target catfish and 27% of freshwater anglers in the USA directed effort toward these fish (USFWS 2001). Currently, recreational and commercial fishing for catfish are not regulated in Alabama.

For effective management of a fishery, determination of gear bias and angler exploitation and preferences for a particular species, fish size, location, or season is essential (Nelson and Little 1986; Bayley and Austen 1990, 2002; Peterson et al. 2004). Lack of information or sampling error can lead to misinterpretations of data and inappropriate management decisions (Ricker 1975; Rachels and Ashley 2002). The use of multiple gear types may increase sample accuracy, but time and costs can limit the use of multiple gears (Nelson and Little 1986). Electrofishing is relatively efficient and less labor intensive than other sampling methods, thus, reducing time and costs (Willis and Murphy 1996; Reynolds 1996).

The capture efficiency of electrofishing is affected by species, size, physiological, and morphological characteristics of fish (Arias-Arias 1979; Bohlin and Coxw 1990; Breteler et al. 1990; Anderson and Neumann 1996; Dolan and Miranda 2003; Peterson et al. 2004). For most fish species, electrofishing tends to be biased toward the capture of larger individuals and exhibits species selectivity (Breteler et al. 1990; Anderson and Neuman 1996; Reynolds 1996; Dolan and Miranda 2003). Thus, evaluations on the capture efficiency of catfish using electrofishing are needed before accepting a sample as a representative of the population (Jacobs and Swink 1982; Libosvarsky 1990; Reynolds 1996). Sampling blue catfish and flathead catfish with boat mounted low-frequency electrofishing is a relatively new technique (Justus 1996; Rachels and Ashley 2002) and little documentation of any sampling bias has been conducted (Vokoun and Rabeni 1999). Typically, channel catfish are collected more effectively and efficiently using gill nets and hoop nets than electrofishing (Gale et al. 1999; Michaletz and Sullivan 2002; Robinson 1999; Vokoun and Rabeni 1999).

Typically, fishery biologists sample catfish with a Smith-Root 7.5 GPP system, with settings from 500 to 1000 V, 15 to 60 Hz and 1 – 4 amps (Justus 1996). Prior to the Smith-Root 7.5 unit, telephone generators, monkey rigs, and modified Smith-Root electrofishers were used to collect catfish (Corcoran 1979; Gilliland 1988). The characteristics of the telephone generator led Corcoran (1979) to modify a Smith-Root Type V battery powered generator to output a low-frequency pulsed (20 - 40Hz) direct current. The modified electrofisher was successful at collecting blue catfish, which were rarely found in previous electrofishing samples using higher frequencies. Pugh and Schramm (1998) determined electrofishing collected greater numbers and wider length ranges of blue catfish with fewer samples than hoop nets; however, they were unable to determine which gear obtained the better representative sample because the length distributions of the population were unknown. Rachels and Ashley (2002) found electrofishing was effective at collecting smaller blue catfish and channel catfish (< 381 mm), but ineffective at collecting larger individuals (> 381 mm). Similarly, Stauffer and Koenen (1999) observed greater capture efficiency (number of fish sampled/ crew-hour) of flathead catfish using low-frequency DC electrofishing than other sampling methods, but few fish greater than 600 mm were collected. Quinn (1988) and Justus (1996) suggested that low-frequency electrofishing can obtain a representative length distribution for flathead catfish; however, water temperatures below 20°C may limit capture effectiveness. In contrast, Stauffer and Koenen (1999) stated low-frequency electrofishing does not encompass the entire age and length distributions of flathead catfish populations. Justus (1996) reported all size ranges of channel catfish were collected at high-frequencies and low-frequencies of electrofishing were optimal for blue catfish and flathead catfish.

In conjunction with an evaluation of electrofishing size selective capture for catfish, angler size-selectivity, effort, harvest, and exploitation were evaluated on Lake Wilson for the catfish fishery. Angling effort directed toward catfish can be higher in the tailwaters of dams (Jackson and Dillard 1993; Graham and DeiSanti 1999) and high angler effort was observed in the Wheeler Dam tailrace (Janssen and Bain 1996). Creel surveys are often used to determine effort, catch, and harvest and to evaluate management regulations (Malvestuto 1996). Also, angler catch rates have been used to index fish abundance with the assumption that more fish are caught by anglers when these fish are abundant than when fish are scarce (Hoenig et al. 1997). Roving creel surveys allow for instantaneous counts of anglers to determine effort, but angler interviews are recorded from incomplete fishing trips and assumes stationary harvest rates over time (Hayne 1991). In contrast, access point creel surveys provide more accurate estimates of harvest from completed fishing trips, but fishing effort can be biased. In 1990, an access point creel survey conducted by Janssen and Bain (1996) in the Wheeler Dam tailrace on Lake Wilson found 43% of the total fishing effort was directed toward catfish and total annual harvest was nearly 100,000 kg, and blue catfish and channel catfish accounted for 63% and 34% of the harvest, respectively. The harvest of flathead catfish was negligible, representing 3% of the total catfish harvest in the Wheeler dam tailrace (Janssen and Bain 1996). In Lake Wilson, Grussing et al. (2001) found flathead catfish was more abundant than blue catfish and channel catfish using electrofishing and gill nets possibly indicating angler preference for blue catfish and channel catfish in this fishery.

Exploitation rates of catfish in Alabama have not been estimated. A review of nine studies by Hubert (1999) found exploitation of channel catfish ranged from 1% to 30%. In Kentucky Lake, estimated exploitation of blue catfish was 17% (Timmons 1999). Graham and Deisanti (1999) reported exploitation rates for blue catfish and channel catfish were 8% to 15% and 6% to 15%, respectively, in the Harry S Truman Dam tailrace, Missouri. In the Kansas River, Makinster and Paukert (2008) determined exploitation of flathead catfish was less than 10% even after accounting for an estimated angler nonreporting rate of 80%.

Anglers select for a particular size fish because of preference, seasonality, and fishing gear. Size selective angling was observed for larger yellow perch (> 200 mm), when a wide distribution of sizes was available to anglers (Isermann et al. 2005). In Mississippi, size selective exploitation of crappie occurred (Miranda and Dorr 2000) with the highest exploitation rates directed at 26-32 cm fish. Catfish anglers in the Flint River, Georgia selected for larger size flathead catfish (610 to 709 mm) in proportion to fish collected using electrofishing (Quinn 1993). Size selective exploitation may act as an embedded length limit and therefore can change the age and length structure if exploitation is high and size of fish harvested by anglers is small.

In a recent survey, catfish anglers indicated that fisheries biologists should direct more attention towards the management of catfish fisheries with emphasis on trophy catfish (Arterburn el al. 2002). Until recently, few studies have examined minimum length limits to determine potential impacts on yield, catch, and trophy catfish production (Holley 2006; Sakaris et al. 2006; Makinster and Paulkert 2008). In Lake Wilson, the blue catfish fishery would not have benefitted from a minimum length ranging from 305 to 457 mm due to low fishing mortality and high abundance of blue catfish (Holley 2006). For native flathead catfish populations, Sakaris et al. (2006) and Makinster and Paulkert (2008) recommended higher minimum length limits to protect against growth overfishing caused by high exploitation rates.

The objectives of this study were to estimate exploitation, angler harvest, effort and selectivity of blue catfish, channel catfish and flathead catfish in Lake Wilson, Alabama. In addition, I examined potential electrofishing bias of blue catfish and flathead catfish. Specifically, I 1) quantified capture probabilities of blue catfish and flathead catfish; 2) performed a roving creel survey to estimated angler effort and harvest of catfish; 3) estimated exploitation and predicted angler harvest size selectivity; 4) assessed the effects of minimum length limits on the flathead catfish population.

STUDY AREA

This study was conducted on Lake Wilson, Alabama, a 6,400 ha impoundment of the Tennessee River (Figure 1). The reservoir was constructed in 1924 by the Tennessee Valley Authority (TVA) to provide hydroelectric power and navigation. Lake Wilson is approximately 24 km in length and contains 269 km of shoreline. Lake Wilson supports a popular recreational and commercial fishery for catfishes, especially the tailrace below Wheeler Dam. Sampling locations consisted primarily of the tailwaters below Wheeler Dam to approximately 5 km downstream, but also included other locations that offered suitable habitat throughout the reservoir.

METHODS

Collection, processing, and age assignment

Blue catfish, channel catfish, and flathead catfish were collected from various locations, including the tailrace below Wheeler Dam and the main reservoir, using a Smith-Root (7.5 GPP) boat electrofisher with low-frequency (15 mHz) direct current (100 - 1000 V). Due to the distance from the electrofishing boat that catfish can surface, a chase boat was used to assist in netting surfacing fish (Daugherty and Sutton 2005). Pedal time (s), depth (m), temperature (°C), and the GPS location were recorded for each station. Electrofishing surveys were conducted during October 2004 and 2005, May-June 2005, 2006, and 2007, July 2007 and August 2005 and 2007.

All catfish were placed in to a 400 L live well for processing. Total length was measured to the nearest mm, and for fish less than 5.0 kg, weight was recorded to the nearest 1 g. Catfish larger than 5.0 kg were weighed to the nearest 10 g. For catfish greater than 300 mm total length (TL), Carlin Dangler tags were attached with stainless steel wire posterior to the first dorsal spine and between the pterygiophores. Each tag had an individual number and indicated the name, address, and phone number of the Fisheries Department at Auburn University. The adipose fin of all tagged catfish was clipped to identify tag loss.

Ages were determined from 198 flathead catfish by sectioning sagittal otoliths following the methods of Buckmeir et al. (2002). Growth was described using the von Bertalanffy (1938) growth equation and the theoretical maximum length (L_∞) was constrained to the largest flathead catfish (1,145 mm) collected during the study.

<u>Electrofishing recapture efficiency</u>

A 1.4 ha cove was enclosed with a 91 m long and 9 m deep block net. Scuba divers checked deployment of the net to ensure the net was secured to the bottom. Blue catfish and flathead catfish were collected with electrofishing in the Wheeler Dam tailrace. Catfish less than 300 mm received an upper caudal fin clip for recapture identification and all fish exceeding 300 mm were tagged with a Carlin Dangler tag. After marking and tagging, all catfish were transported and placed into the cove. Catfish were allowed to recover for 24 h in an attempt to reduce bias due to behavior changes caused by electrofishing and handling during tagging (Peterson et al. 2004). After recovery, the cove was sampled with two electrofishing passes (i.e. one h between passes); 1) 15 pulses/s and 2) 30 pulses/s. All recaptured tagged catfish were recorded to calculate capture efficiencies of all catfish. The length and weights of untagged catfish were recorded as well. Recapturablity (q) for a given fish species and size was calculated as:

$$q = \frac{c}{v}$$

where c = the number of individuals recaptured by electrofishing and v = the number of tagged individuals in the enclosed area.

Using the number of blue catfish and flathead catfish tagged and recaptured by electrofishing I estimated recapture rates. I assumed the number of recaptures would increase with the number of tagged catfish at-large and adjusted the number-at-large over time using a tag loss rate of 31.4%/year (Kevin Sullivan; Missouri Department of Conservation; personal communication). Also, angler harvested fish were subtracted from the total number of fish-at-large. The cumulative number of blue catfish and flathead catfish tagged and recaptured was plotted over time (months) and analysis of covariance (ANCOVA) was used to test for differences in the slopes of the cumulative number of fish tagged and recaptured.

Creel survey

A roving creel survey was conducted in 2006 on Wilson Lake to collect angler data on effort, catch, harvest, and opinions related to potential regulation related to the catfish fishery. Non-uniform probabilities (P) were assigned to three river sections for conducting the survey (Figure 1); A) TVA-RM 270 to Wheeler Dam tailrace (P = 0.50), B) TVA-RM 265 to TVA-RM 270 (P = 0.25), and C) Wilson Dam to TVA River Mile (TVA-RM) 265 (P = 0.25). Higher sampling effort was directed from TVA-RM 270 to the Wheeler Dam tailrace as I observed a higher proportion of anglers fished this section of the reservoir compared to other sections. After data were tabulated, section probabilities to compute angler effort were adjusted to reflect my estimates of variable effort among the three reservoir sections. The roving creel initiated on 15 April and ended on October 31, 2006 as catfish harvest mainly occurred from May through September in the Wheeler Dam tailrace (Janssen and Bain 1996). The fishing season was divided into three time blocks consisting of 8 weekdays and 8 weekend days; 1) 15 April to 31 May, 2) 15 June to 31 July, 3) 15 September to 31 October. Sampling units within each day were four randomly chosen 5-h periods (0800-1300, 1000-1500, 1300-1800, or 1400-1900 hours).

The study period elapsed 214 d, of which 48 days (24 weekdays and 24 weekend days) were surveyed. Creel survey statistics were summarized for weekdays and weekends, then adjusted for the number of weekdays and weekends during the 214 d period. Anglers were interviewed on the water and questions concerning catch, and representative lengths of catfish harvested were obtained from catfish anglers. Trip details including length of trip, species sought, and location of residence were asked. Anglers from the three counties (Colbert, Lauderdale, and Lawrence) adjacent to the study area were considered "local." If anglers were targeting catfish, they were asked if they were aware of the exploitation study on catfish and if they would be willing to return a tag from a catfish for a small reward.

Catfish anglers were also asked for their opinion of a regulation that would be beneficial toward maintaining or enhancing trophy size blue catfish in the population. Finally, catfish anglers were asked if they had answered the above questions in a previous interview, and if so, these data were not included in the analysis to avoid duplicate responses. Estimates of total fishing effort, catch, catch-per-effort, and harvest-per-effort and associated relative standard errors were calculated using equations from Malvestuto et al (1978). Total weight harvested was computed by multiplying the average weight of catfish harvest times the number harvested. Data related to tagging awareness and returns, and opinions were calculated by percent of responses. Differences in responses to a regulation were tested for homogeneity between Alabama residents and nonresidents using χ^2 analysis.

Exploitation and angler size selectivity

Exploitation of tagged catfish fish was calculated from:

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

where, N_h = number of tagged fish reported as harvested, N_t = number of tagged fish at large, P_{nr} = angler nonreporting rate, and P_t = tag loss rate (31.4% / year). Although I did not estimate angler non-reporting, I assumed this rate ranged between 20% and 70% based on previous studies (Zale and Bain 1994; Maceina et al. 1998). Carlin Dangler tag loss was 15.7% over a six-month period for blue catfish (Kevin Sullivan; Missouri Department of Conservation; personal communication) and I used this rate to adjust for exploitation estimates. Thus, the wide range of non-reporting rates and high tag loss rate likely provided an accurate range of exploitation rates. However, Graham and DeiSanti (1999) reported that all Carlin Dangler tags were retained from 30 large blue catfish (4.5-19.0 kg) held in a 0.20 ha pond and Travnichek (2004) held 38 flathead catfish in a hatchery pond for one year with no tag loss.

To facilitate angler tag returns, rewards were randomly assigned values of US$5, $10, $20 and $50. Offering rewards for returned tags increases angler compliance, however nonreporting rates must still be included in exploitation estimates (Zale and Bain 1994; Maceina et al. 1998; Miranda et al. 2002). Postage paid envelopes were available at local businesses, which included an survey card for anglers to complete to obtain information on their name, address, date and location the fish was caught, gear used, commercial or recreational angler, and weather 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. Locations of angler tag returns were partitioned into the three sections previously stated in the creel survey. The length-frequency distributions of harvested and tagged fish were compared with Kolmogorov-Smirnov (KS) two-sample tests to determine if 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). All tags returned by anglers when the fish was harvested (October 2004-October 2007) were used to determine angler size selectivity. Blue catfish, channel catfish, and flathead catfish grow slowly (Holley 2006), thus length was not corrected for the time between angler capture and tagging.

Flathead catfish simulation modeling

The effects of two potential length limits (356 and 508 mm) on the flathead catfish fishery and population were explored using the Fishery Analysis and Simulation Tools (FAST) software program (Slipke and Maceina 2006). I assumed that the minimum size of flathead catfish harvested was 356 mm from angler tag returns on Lake Wilson. Currently, the state of Oklahoma imposes a 508 mm minimum length limit for flathead catfish. Proportional size distribution indices (Guy et al. 2007) were calculated using the length categories found in Anderson and Neumann (1996) and compared to simulated models. The weight-length relationship was from flathead catfish sampled. Instantaneous natural mortality rates (M) were estimated from the equations presented in FAST (Slipke and Maceina 2006) and these were averaged, and fishing mortality was adjusted from the range of potential angler exploitation rates. Overall annual mortality (AM) and instantaneous annual mortality (Z) were estimated using weighted catch-curve regression (Maceina 1997) with ages assigned to all unaged fish using a length:age key (Slipke and Maceina 2006). For catch curve analysis, I assumed that age-4 flathead catfish and older were fully recruited to the fishery and the sampling gear. Instantaneous fishing mortality (F) was derived by subtracting the average M from Z. Exploitation (μ) was also estimated from estimates of AM, F, and Z from:

$$\mu = \frac{F*AM}{Z}$$

Population metrics of flathead catfish were incorporated into FAST and the abundance at memorable length (≥ 860 mm TL) and trophy length (≥ 1,020 m TL) and yield were modeled over a range of exploitation and the two potential minimum length limits.

RESULTS

Collection

A total of 4,765 catfish was collected from October 2004 to August 2007 using electrofishing, of which 2,905 were blue catfish, 699 were channel catfish, and 1,113 were flathead catfish. Of the blue catfish and channel catfish collected, 1,855 and 321 were tagged and released, respectively. For flathead catfish, 646 were tagged and released, and 198 fish were sacrificed for age determination. In addition, 40 blue catfish and 2 channel catfish were collected, tagged, and released during tournaments held in March 2005 and March 2006. Lengths of blue catfish ranged from 98 to 1,291 mm, channel catfish ranged from 65 to 646 mm, and flathead catfish ranged from 77 to 1,145 mm (Figure 2).

Electrofishing recapture efficiency

On May 8, 2007, a total of 144 blue catfish were placed into the enclosed cove and total lengths ranged from 285 to 1,130 mm (Figure 3). Three tagged and one unmarked blue catfish were captured by electrofishing the following day, corresponding to a recapture rate of 2%. On June 19, 2007, a total of 94 flathead catfish were placed into the enclosed cove and total lengths ranged from 124 to 1,031 mm (Figure 3). One tagged and three unmarked flathead catfish were recaptured by electrofishing the following day, and the recapture rate was 1%. For blue catfish and flathead catfish, several tagged catfish were observed near the water surface during electrofishing; however, these fish were not fully immobilized and subsequently escaped capture.

From October 2004 through August 2007, 16 blue catfish (mean TL = 471; SD = 210) and 16 flathead catfish (mean TL = 578; SD = 216) that were previously tagged were recaptured using electrofishing and recapture rates for sample events ranged from 0.0 to 0.8% for blue catfish and ranged from 0.3 to 4.0% for flathead catfish (Tables 1 and 2). The recapture of a tagged channel catfish was not observed during the study period. The length of time between electrofishing capture and recapture of blue catfish and flathead catfish ranged from 29 to 462 d and 2 to 972 d, respectively. Despite the increase in tagged at-large catfish over time, a corresponding increase in recapture rates did not occur (Figure 4). Analysis of covariance indicated the slopes between cumulative number of fish tagged and recaptured varied over time for blue catfish ($F = 12.75$; $P < 0.01$) and flathead catfish ($F = 7.15$; $P < 0.01$). Three blue catfish and 5 flathead catfish had clipped adipose fins without tags, thus tag loss occurred during the study. However, because of the low recapture rate of tagged fish and low observation of fin clips, I did not estimate a tag loss rate.

Creel survey

I collected creel information from 1,102 anglers and 50% of these anglers were targeting catfish. Similarly, about 50% of the total fishing effort on Wilson Lake (144,700 hours) was directed toward catfish (Table 3). Catfish anglers caught a total of 109,500 catfish and about 80% of these fish were harvested. Total harvest was 49,200 kg

(7.81 kg/ha), with blue catfish and channel catfish representing 63% and 37% of the total catfish harvest during the creel survey. Catch rates of blue catfish and channel catfish were high (1.50 fish/hr) and catch of flathead catfish was not observed. Lengths of blue catfish harvested by catfish anglers that I measured ranged from 242 to 711 mm TL (N = 102 fish, mean = 379 mm) and channel catfish ranged from 290 to 515 mm TL (N = 60 fish, mean = 386 mm). The average weight of a catfish harvested by anglers was 565 g.

Local residents from three counties surrounding Lake Wilson contributed 22% of the catfish anglers, while 49% of the catfish anglers were from out-of-state (primarily Tennessee; Table 3). Among catfish anglers, 53% were aware of the tagging study that was being conducted and all anglers responded that they would return a tag for a reward. Most catfish anglers (71%; Table 3) would support management decisions to increase abundance of trophy blue catfish; however, some anglers stated they release large blue catfish and raised concerns about imposing bag limits on smaller size catfish. Responses toward a trophy blue catfish regulation were similar between residents and nonresidents of Alabama (χ^2 = 1.35; P = 0.71; Figure 5).

Exploitation and angler size selectively

A total of 2,822 catfish were tagged from October 2004 to August 2007. Most angler tag returns occurred between April to October and 88, 67, and 90% of blue catfish, channel catfish, and flathead catfish tag returns, respectively, occurred during these months (Figure 6). A total of 106 anglers returned 186 tags, of which, recreational anglers returned 74% of the tags and five commercial fisherman returned 26% of the tags. The mean time between tagging and tag return by anglers was 248 d (SD = 209) and ranged from 3 to 878 d. Anglers returned 89 and 129 tags within 6 months and 1 year of tagging, respectively, and 57 tags were returned greater than one year after tagging (Figure 7). Of anglers responding (*N* = 174), 73, 2, and 3% of tags returned were caught in sections A, B, and C, respectively (Figure 1), and 20% of anglers responded capture occurred in Lake Wilson without specifying a section. Four angler tag reterns were caught outside of Lake Wilson with three captures in Lake Pickwick, Alabama and one capture in the Mississippi River near West Memphis, Arkansas.

For blue catfish, anglers returned 137 tags of which 128 were harvested. Total lengths of blue catfish harvested ranged from 304 to 924 mm (Table 4). Estimates of the average annual exploitation between November 2005 to October 2007 of blue catfish from angler tag returns of harvested fish ranged from 5.6% to 18.6% and included tag loss and three rates of angler non-reporting (Table 5). Anglers harvested larger blue catfish out of proportion to fish that were tagged (KSa = 2.77; $P < 0.0001$; Figure 8). The mean total lengths of harvested and tagged blue catfish were 456 mm and 418 mm, respectively (Table 4).

A total of 12 tagged channel catfish were harvested (range = 350 to 627 mm TL) and the average estimated annual exploitation ranged from 4.0% to 13.2% (Table 6). The mean total lengths of harvested channel catfish were slightly larger than fish tagged (Table 4). However, due to low numbers of harvested channel catfish, the difference in total lengths between tagged and returned fish was not significant (KSa = 1.26; $P = 0.08$).

For flathead catfish, anglers returned 33 tags, 29 were harvested, and the average estimated annual exploitation ranged from 4.3% to 14.5% (Table 7). Total lengths of harvested flathead catfish ranged from 358 to 994 mm. Anglers harvested larger flathead catfish out of proportion to fish that were tagged (*KSa* = 1.89; $P < 0.002$; Figure 8) and the mean total lengths of harvested and tagged fish were 589 mm and 504 mm, respectively (Table 4).

For blue catfish, logistic regression predicted a low probability (0.03) of angler harvest of fish that were about 300 mm TL, with peak harvest selectivity (0.16) at about 650 mm, and the relationship between probability of harvest and length was parabolic (Wald $\chi^2 = 34.66$; $P < 0.0001$; concordance = 0.65; Figure 9). The equation that predicted angler length preference for blue catfish was:

$$p = \frac{e^{0.0188(TL) - 0.00001(TL2) - 7.8256}}{1 - e^{0.0188(TL) - 0.00001(TL2) - 7.8256}}$$

For channel catfish, logistic regression predicted a low probability (0.01) of angler harvest of fish about 300 mm, with peak harvest selectivity (0.20) at about 630 mm or the largest fish that was tagged (Figure 9). The relationship between probability of harvest and length (Wald $\chi^2 = 5.99$; $P = 0.01$; concordance = 0.66; Figure 9) was curvilinear. The equation that predicted angler length preference fo channel catfish was:

$$p = \frac{e^{0.0102(TL) - 7.8999}}{1 - e^{0.0102(TL) - 7.8999}}$$

The probability of harvest was low (0.01) for flathead catfish about 300 mm, with peak harvest selectivity (0.09) at about 700 mm, and the relationship was parabolic

(Wald χ^2 = 10.91; P = 0.004; concordance = 0.68; Figure 9). The equation that predicted angler length preference fo flathead catfish was:

$$p = \frac{e^{0.0204(TL) - 0.00001(TL2) - 9.6739}}{1 - e^{0.0204(TL) - 0.00001(TL2) - 9.6739}}$$

Flathead catfish simulation modeling

Flathead catfish growth was slow and the von Bertalanffy growth equation (Table 9) predicted the time to reach stock (350 mm), quality (510 mm), preferred (710 mm), memorable (860 mm), and trophy (1,020 mm) lengths were 4.2, 7.6, 13.3, 19.7, and 32.2 years, respectively (Figure 10). Weighted catch-curve analysis for flathead catfish age 4 to 34 years old estimated annual mortality was 17% (Z = -0.186; r^2 = 0.78; P < 0.01; Figure 11). Five estimates of instantaneous natural mortality ranged from 0.099 to 0.159, and averaged 0.127 (Table 8). The difference between Z and M was 0.059 (F) and suggested that exploitation was about 5.4%.

At my estimated minimum exploitation rate of 5.4% (20% non-reporting) for flathead catfish that were harvested from 356 to 1,000 mm (i.e. exploitation occurred for fish 4.3 to 29 years old), simulation modeling predicted proportional size distribution indices similar or slightly lower to my observed values (see Figure 2). The predicted PSD_Q, PSD_P, PSD_M, and PSD_T values were 44, 14, 4, and 1, respectively, compared to observed values of 43 14, 7, and 1, respectively.. At an exploitation rate of 8.7% (50% non-reporting), the predicted PSD_Q, PSD_P, PSD_M, and PSD_T values were 39, 10, 2, and 1, respectively, and the proportion of preferred and memorable size were much less than observed in the population. Thus, based on empirical and predicted proportional size distributions of flathead catfish, exploitation was likely about or slightly less than 6%.

Based on the life history parameters for this flathead catfish population (Table 9), growth overfishing was predicted when exploitation exceeded 12% and 19% at a 356 and 508 mm minimum length limit, respectively (Figure 12). With a 610 mm minimum length limit, growth overfishing was not apparent and maximum yield would occur at exploitation rates of 20% or higher (Figure 12 and 13). However, a 610 mm minimum length limit would reduce the number of flathead catfish harvested by about 50% compared to a 356 mm minimum length limit at a exploitation rate of about 6% (Figure 14). At a maximum yield and an exploitation rate of 20%, the number recruiting to memorable and trophy size would increase by about three fold under a 610 mm minimum length limit compared to a 356 mm minimum length limit (Figure 15). With a minimum length limit of 508 mm and exploitation rates of 5% to 10%, a small increase in yield (2% to 13%) would occur and the number of fish harvested would decrease by about 34% compared to a 356 mm minimum length limit (Figures 13 and 14). Also, at a 5% to 10% exploitation rate, I predicted that about 18% to 45% more fish would recruit to memorable size and trophy size under a 508 mm minimum length limit, compared to a 356 mm minimum length limit; however, the percent of a cohort that would recruit to memorable and trophy size under three simulated minimum length limits would less than 4% and less than 0.5%, respectively (Figure 15).

DISCUSSION

Electrofishing recapture efficiency

Low-frequency DC electrofishing collected greater numbers of blue catfish and flathead catfish, and appeared less effective at sampling channel catfish as this species represented 37% of the catfish harvested in the creel survey, but only 15% of these fish were collected with electrofishing. Typically, higher frequencies (≥ 30 pulses/s) of DC electrofishing are more effective for sampling channel catfish (Justus 1996) and at times, gill nets and hoop-nets are the preferred sampling method for this species (Robinson 1999; Michaletz and Sullivan 2002). Although a chase boat was used during sampling, I observed more blue catfish and flathead surfaced than were collected with fish immobilized up to 30 m from the electrofishing boat.

Little information is known about electrofishing recapture rates and size selectivity of blue catfish (Buckmeier 2007) and flathead catfish. The immediate (≤ 24 h) recapture rate was low for blue catfish (2%) and flathead catfish (1%). My initial electrofishing capture probability was unknown; however, extremely low recaptures of blue catfish and flathead catfish indicated longer recovery periods may be required before catfish again become susceptible to electrofishing gear. I was unable to determine whether low recapturablity was due to fish size or a stress-induced reaction caused by the initial electrofishing capture. During electrofishing, I observed electrotaxis, or the induced swimming caused by an electric current, of several tagged blue catfish and flathead catfish on the waters surface, but these fish were not immobilized and subsequently were not recaptured. Despite ensuring the block net was secured to the bottom, possibly some escapement of catfish occurred. However, if I assumed a 50% escapement rate my estimates of recapture rates would still be low. Libosvarsky (1990) stated that repeated exposure of fish to electric currents lowers the power threshold (i.e. electricity transferred from the water to fish) for immobilization resulting in narcosis at greater distances. Fish immobilized at greater distances reduces the chance of encounter by the electrofishing crew, thus decreasing the catchablity of second and subsequent electrofishings.

I observed low recapture rates of tagged catfish during electrofishing surveys similar to observed recapture rates in the enclosed cove indicating low capture rates and/or high abundance of blue catfish and flathead catfish in Lake Wilson. Despite the increase in the number of at-large blue catfish and flathead catfish, a higher recapture rate of these tagged fish did not occur. Some tag loss did occur, but was only observed for 8 of the 40 fish recaptured over a three-year period and likely did not influence recapture rates of tagged fish. High variability in size of catfish recaptured by electrofishing possibly indicated no size bias and electrofishing may provide a less biased representation of upper sizes of large-bodied fish species (Dolan and Miranda 2003). In Lake Livingston, Texas, Buckmeier (2007) tagged over 30,000 blue catfish and reported that recapture rates were low (0 to 4%) with no increasing or decreasing pattern across months and habitats and size-biased electrofishing was not evident. The physiological responses of catfish to electrical current are not well understood and additional research into these responses is needed.

Creel Survey

Fishing effort was high for blue catfish and channel catfish in Lake Wilson and comprised 50% of the total fishing effort. In 1990, Janssen and Bain (1996) found catfish were the most sought after group of fish in the Wheeler Dam tailrace. In the Truman Dam tailrace, Missouri, Graham and Deisanti (1999) reported 47% of all anglers targeted catfish. Similar to my study, Janssen and Bain (1996) found catch and harvest was dominated by blue catfish and channel catfish, with negligible catch and harvest of flathead catfish. Total harvest and harvest rate of catfish was high (7.81 kg/ha) in Wilson Lake compared to other reservoirs (mean = 2.8 kg/ha) in the USA (Miranda 1999). Despite high fishing pressure and harvest (kg) of catfish, harvest rates (1.19 fish/h) were high and greater than those reported in the Truman Dam tailrace (0.14 and 0.29 fish/h; Graham and Deisanti 1999) and the Missouri River after a commercial fishing ban ($\leq$ 0.23 fish/h; Stanovick 1999)

Catfish harvest (April-October) was 72% higher in 1990 than in 2006 (84,706 and 49,200 kg respectively; Janssen and Bain 1996). The decrease in catfish harvest was attributed to two factors: 1) a decrease in commercial anglers and 2) differences in creel survey types. Freshwater commercial anglers accounted for 26% of all catfish tag returns during my study, but were rarely encountered in the creel survey. If a commercial anglers workday was primarily during the early morning hours then my creel survey design possible decreased the chance of encounter due to the 0800 h and 1000 h start times. From 2000 to 2006, the number of freshwater commercial fishing licences purchased in Alabama and the three counties (Colbert, Lauderdale, and Lawrence) surrounding Lake Wilson have decreased by about 30 and 50%, respectively (Alabama Department of Wildlife and Freshwater Fisheries, unpublished data), and the average number of licenses sold in these counties from 2000 to 2006 (mean = 15) has drastically decline from 1976 to 1982 (mean = 290). The extreme decline in commercial anglers in Lake Wilson possibly reallocated more catfish effort and harvest to recreational anglers. Commercial fishing can contribute a large portion the catfish harvest leading to overexploitation that could warrant changes in harvest regulations to maintain the fishery (Pitlo 1997; Slipke et al. 2002). However, the decrease in commercial fisherman in Alabama and the counties surrounding Lake Wilson likely reduced the possibility of overexploitation and possibly was related to high catch and harvest rates by recreational anglers. Stanovick (1999) reported that harvest and catch rates of catfish by recreational anglers increased after a commercial fishing ban in the Missouri River, Missouri.

Roving creel surveys obtain harvest information from incomplete fishing trips and instantaneous counts of angler effort, while access point creel surveys compute harvest information from completed fishing trips and effort is derived from the number of boats at the access point. Roving creel surveys rely on anglers reporting fish harvested and for fish species with higher bag limits, harvest tend to be underestimated (Mallison and Cichra 2004). In Orange Lake, FL, Mallison and Cichra (2004) observed that anglers targeting sunfish underestimated harvest by 19% compared to counted harvest. I observed high numbers of catfish caught and harvested by anglers and if the reported harvest by anglers was underestimated by about 20%, then my estimates of harvest for Lake Wilson would have also been underestimated by about 10,000 kg. The roving creel survey used in my study encompassed all of Lake Wilson and was stratified into three sections. In contrast, the access point creel survey used by Janssen and Bain (1996) was located at two boat ramps near the Wheeler Dam tailrace increasing bias towards anglers seeking catfish. Of catfish anglers, I observed 79, 8, and 13 % in sections A, B, and C, respectively, on Lake Wilson.

Anglers are becoming more interested in catching, releasing, and protecting larger trophy size catfish (Arterburn et al. 2002) and several catfish tournaments where anglers target larger catfish occur annually on Lake Wilson and other reservoirs on the Tennessee River (www.kingkatusa.com; www.southerncats.com). The majority of catfish anglers would support a regulation that enhanced a trophy blue catfish fishery, but did not consider large blue catfish (≥ 9 kg) of harvest value due to poor taste and quality of flesh. I observed most anglers harvested fish 250 to 550 mm and several anglers harvested more than 50 fish per trip. Anglers on Lake Wilson were more concerned about obtaining fish for consumption and were against a bag limit. In general, catfish anglers on Lake Wilson targeted smaller sized catfish for consumption; however, htye enjoyed the potential of catching larger trophy size catfish. In a survey of anglers across the USA, Arterburn et al. (2002) reported that 68% of catfish anglers surveyed did not considered themselves a trophy angler, but 71% planned on pursuing trophy catfish the next year. In Texas, obtaining catfish for consumption was also an important motive for catfish anglers and catching a trophy catfish was of low importance, but catching a trophy catfish was more important for anglers targeting blue catfish and flathead catfish than channel catfish (Wilde and Ditton 1999).

Exploitation and Size Selectivity

Exploitation of blue catfish, channel catfish, and flathead catfish was highly seasonal and varied spatially, with most fish harvested between April and October and most tag returns occurring near the Wheeler Dam tailrace (i.e., section A). A disproportionally high number of tags (26%) were harvested by five commercial anglers compared to recreational anglers. A survey of the Missouri River stated commercial anglers accounted for 38% of catfish harvest, but comprised 11% of anglers (Stanovick 1999). Timmons (1999) reported over 65% of blue catfish and channel catfish tag returns were by commercial anglers in Kentucky Lake, Kentucky. In the upper Mississippi River, commercial anglers caused a decline in channel catfish yield due to growth and recruitment overfishing (Pitlo 1997; Slipke et al. 2002) and resulted in a minimum size increase. Commercial fishing can impact catfish fisheries (Pitlo 1997), but commercial fishing for catfish appears to be declining in Alabama.

The high percentage of Carlin dangler tags returned beyond six months after tagging (52%) and tags returned beyond thirty months possibly indicated high tag retention by catfish. Although I was unable to estimate tag loss, rates high as 31.4% were observed in Missouri, but tag loss rates of 0% have also been reported (Graham 1999; Travnichek 2004), and these wide ranges of tag loss warrant future investigation. If the tag loss rate was less than 31.4%, then my range of exploitation estimates were high and if I assumed no tag loss then my estimates of exploitation would decrease by about 20%. Angler non-reporting ranging from 20% to 70% likely accurately encompassed the range of non-reporting. About 50% of catfish anglers were unaware of the catfish tagging program in the creel survey and I speculated tag returns from uniformed angler was unlikely. A non-reporting rate of 50% was within estimates reported in previous studies (Zale and Bain 1994; Maceina et al. 1998).

Estimates of exploitation for blue catfish were highly variable and averaged 9% to 19% over a range of angler non-reporting rates. This range of exploitation was similar to estimates reported in Lake Kentucky (17%; Timmons 1999) and in the Truman Dam tailrace, Missouri (8% to 15%; Graham and Diesanti 1999). Based on angler tag returns, the exploitation rates of channel catfish and flathead were similar and ranged from 4% to 13% and 4% to 15%, respectively. Exploitation of channel catfish was similar to the Truman Dam tailrace in Missouri (6% to 15%; Graham and Deisanti 1999) and Lake Kentucky (11%; Timmons 1999). Shrader et al.(2003) estimated exploitation of channel catfish exploitation in Brownlee Reservoir and the Snake River in Oregon, corrected for tag loss and angler non-reporting, at 2% to 30% from 1995 to 1997. Channel catfish were harvested by anglers in the creel survey on Lake Wilson, but tag returns were low. Due to the inefficiency of electrofishing for channel catfish, low sample size of channel catfish tagged possibly lowering my estimates of exploitation. Based on results of my simulation model, the exploitation rate of flathead catfish was low in Lake Wilson ($\approx$ 6%) similar to the findings of Makinster and Paulkert (2008). Few anglers targeted flathead catfish and I assumed tag returns were incidental catches by anglers targeting other species. In addition, 53% of flathead catfish anglers considered themselves to be trophy anglers (Arterburn et al. 2002) and do not pursue the harvest of smaller flathead.

Catfish anglers harvested larger blue catfish, channel catfish, and flathead catfish than for fish tagged by electrofishing. Angler size selectivity of all three catfish species occurred in the fishery, with fish from about 600 to 700 mm TL experiencing the highest exploitation. Most blue catfish tagged or harvested ranged from 300 to 550 mm with few fish over 550 mm harvested and no blue catfish or flathead catfish over 1,000 mm TL were harvested. Quinn (1993) reported greater size selectivity of flathead catfish by anglers from 600 to 700 mm TL compared to electrofishing samples. Blue catfish over 800 mm TL were rare in electrofishing samples from Lake Wilson, but some harvest was reported with the potential to alter the population structure with high exploitation.

Size-selective exploitation may be caused by selective fishing gear, seasonal exploitation, and angler preference altering the population structure (Miranda and Dorr 2000). I observed small jugs and typical bass fishing gear as the common gears used by anglers, and I suspect these gears may be inadequate at for capturing larger catfish (≥ 9 kg).

Flathead Catfish Simulation Modeling

Modeling simulations of the flathead catfish population suggested the implementation of a minimum length limit was not warranted in Lake Wilson at this time. My estimates of exploitation (≈ 6%) from catch-curve analysis were similar to estimates from tag returns (5.4%) when angler non-reporting was 20%. Thus, exploitation did not exceed natural mortality estimates (17%) and growth overfishing was very unlikely even if exploitation rates increased about three fold in the current fishery. However, a minimum length limit of 610 mm would maximize yield, but reduce the number of fish available for harvest by 50% compared a 356 mm minimum length limit. In Kansas, Makinster and Paulkert (2008) suggested growth was sufficient to maintain the flathead catfish fishery at low exploitations rates (about 10%) and a minium length limit would protect against increases in exploitation. In addition, Makinster and Paulkert (2008) aged flathead catfish with spines and may have underestimated ages and overestimated growth of catfish older than 5 years (Nash and Irwin 1999; Buckmeier et al. 2002) lowering the sensitivity of the fishery to exploitation. Sakaris (2006) suggested higher minimum length limits (508 mm) should be implemented to protect native flathead catfish populations from higher exploitation. Although the Lake Wilson flathead catfish fishery is lightly exploited, growth is slow and fish are long lived, and a potential increase in exploitation caused by the popularity of the Lake Wilson catfish fishery may become a concern for future management of the fishery.

CONCLUSION

Low-frequency electrofishing consistently collected blue catfish and flathead catfish greater than 300 mm and channel catfish appeared to have low vulnerability to the gear despite frequently appearing in angler harvests. Knowledge of gear bias toward catfish will help data interpretation by managers to use while making management decisions. High catch and low exploitation rates and low recapture rates of catfish suggest these species were highly abundant in Lake Wilson and the high catch and harvest of catfish of recreational anglers may be attributed to the decline in commercial anglers in the lake. Current exploitation rates of flathead catfish were low and do not appear to impact the population or size structure and the implementation of a minimum length limit is not needed at this time.

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TABLES

Table 1. Recaptures of blue catfish from electrofishing during collection months. The number at large was corrected for tag loss and the number removed by anglers at the end of the previous month before collection occurred.

Year	Month	Number tagged	Number recaptured	Number at-large	Percent recaptured
2004	October	7		7	
2004	November	0		6.8	
2004	December	0		6.6	
2005	January	0		5.5	
2005	February	0		4.3	
2005	March	28	0	4.2	0
2005	April	0		31.4	
2005	May	69	0	30.5	0
2005	June	173	0	96.9	0
2005	July	0		255.9	
2005	August	356	2	246.2	0.8
2005	September	0		583.4	
2005	October	158	2	566.2	0.4
2005	November	0		703.2	
2005	December	0		683.8	
2006	January	0		664.9	
2006	February	0		645.5	
2006	March	12	0	627.6	0
2006	April	0		618.9	
2006	May	385	2	599.7	0.3
2006	June	264	4	943.9	

Table 1. Continued

Year	Month	Number tagged	Number recaptured	Number at-large	Percent recaptured
2006	July	0		1,161.3	
2006	August	0		1,017.9	
2006	September	0		1,079.7	
2006	October	0		1,049.39	
2006	November	0		1,020.9	
2006	December	0		994.2	
2007	January	0		968.2	
2007	February	0		938.9	
2007	March	0		913.3	
2007	April	7	0	886.4	0
2007	May	144	3	860	0.3
2007	June	55	0	966.73	0
2007	July	135	1	988	0.1
2007	August	61	2	1,090.6	0.2
2007	September	0		1,120.5	
2007	October	0		1,089.1	

Table 2. Recaptures of flathead catfish from electrofishing during collection months. The number at large was corrected for tag loss and the number removed by anglers at the end of the previous month before collection occurred.

Year	Month	Number tagged	Number recaptured	Number at-large	Percent recaptured
2004	October	62		62	
2004	November			59.4	
2004	December			57.8	
2005	January			56.3	
2005	February			53.8	
2005	March			52.4	
2005	April			51.1	
2005	May	97	2	49.7	4
2005	June	11	1	142.9	0.7
2005	July			149.9	
2005	August	28	1	143.9	0.7
2005	September			164.4	
2005	October	237	4	159.1	2.5
2005	November			384.4	
2005	December			374.7	
2006	January			364.9	
2006	February			355.3	
2006	March			346	
2006	April			336	
2006	May			326.2	
2006	June	64	1	316.7	0.3

Table 2. Continued

Year	Month	Number Tagged	Number recaptured	Number at-large	Percent recaptured
2006	July			370.7	
2006	August			356	
2006	September			344.7	
2006	October			335.7	
2006	November			326.9	
2006	December			318.3	
2007	January			310	
2007	February			301.9	
2007	March			294	
2007	April			285.3	
2007	May			274.8	
2007	June	67	3	266.6	1.1
2007	July	81	4	323.9	1.2
2007	August			394.3	
2007	September			384	
2007	October			369.9	

Table 3. Fishery statistics (relative standard errors in parentheses) for anglers targeting catfish in the Wheeler Dam tailrace. Estimates were for 1 April to 31 October 2006. Anglers from Colbert, Lawrence, and Lauderdale counties in Alabama were considered local anglers.

Fishery statistic	2006
Fishing effort (h)	72,900 (13,705)
Fishing pressure (h/ha)	11.57
Catfish catch (*N*)	109,500 (21,353)
Catch per area (*N*/ha)	17.38
Catch rate (*N*/h)	1.5
Total catfish harvest (*N*)	87,100 (18,030)
Weight of catfish harvest (kg)	49200
Harvest per area (*N*/ha)	13.83
Weight of catfish harvest per area (kg/ha)	7.81
Harvest rate (*N*/h)	1.19
Mean total length of catfish harvested (mm)	381
Mean weight of catfish harvested (g)	565
Local anglers (%)	22
Alabama anglers (%)	51

Table 4. Summary of catfish tagged, returned, harvested for three species of catfish. The lengths of returned and harvested fish are lengths measured when tagged. Standard errors are in parentheses.

	Number of catfish		Mean total length (mm)	
Species	Tagged	Harvested	Tagged	Harvest
Blue catfish	1,854	128	418 (9)	456 (11)
Channel catfish	321	12	418 (4)	472 (28)
Flathead catfish	646	29	504 (6)	589 (29)

Table 5. Monthly exploitation from angler tag returns over a three-year period for blue catfish in Lake Wilson. The number-at-large was adjusted for the number removed and the percentage of tags lost each month.

Year	Month	Number tagged	Number harvested.	Number at-large	Exploitation corrected for tag loss
2004	October	7	0	7.0	0
2004	November	0	0	6.8	0
2004	December	0	0	6.6	0
2005	January	0	1	6.5	15.5
2005	February	0	1	5.3	18.8
2005	March	28	0	31.5	0
2005	April	0	0	30.7	0
2005	May	69	0	97.0	0
2005	June	173	0	263.0	0
2005	July	0	7	256.1	2.7
2005	August	356	3	589.3	0.5
2005	September	0	3	570.9	0.5
2005	October	158	2	706.9	0.3
2005	November	0	2	686.5	0.3
2005	December	0	1	666.6	0.2
2006	January	0	1	648.1	0.2
2006	February	0	2	630.2	0.3
2006	March	12	1	623.5	0.2
2006	April	0	4	606.2	0.7
2006	May	385	3	961.3	0.3
2006	June	264	15	1,190.3	1.3

Table 5. Continued.

Year	Month	Number tagged	Number harvested.	Number at-large	Exploitation corrected for tag loss
2006	July	0	15	1,144.6	1.3
2006	August	0	13	1,100.0	1.2
2006	September	0	9	1,058.6	0.9
2006	October	0	2	1,022.1	0.2
2006	November	0	1	993.4	0.1
2006	December	0	0	966.4	0
2007	January	0	0	941.1	0
2007	February	0	4	916.5	0.4
2007	March	0	1	888.6	0.1
2007	April	7	3	871.2	0.3
2007	May	144	10	985.7	1.0
2007	June	55	11	1,003.8	1.1
2007	July	135	7	1,098.2	0.6
2007	August	61	3	1,122.1	0.3
2007	September	0	1	1,089.8	0.1
2007	October	0	2	1,060.3	0.2
Average annual exploitation for a one year period (Nov. 2005 - Oct. 2007)					**5.6**
Average annual exploitation corrected for 20% non-reporting					**7.0**
Average annual exploitation corrected for 50% non-reporting					**11.1**
Average annual exploitation corrected for 70% non-reporting					**18.6**

Table 6. Monthly exploitation from angler tag returns over a three-year period for channel catfish in Lake Wilson. The number-at-large was adjusted for the number removed and the percentage of tags lost each month.

Year	Month	Number tagged	Number harvested.	Number at-large	Exploitation corrected for tag loss
2004	October	59	0	59.0	0.0
2004	November	0	1	57.5	1.7
2004	December	0	0	55.0	0.0
2005	January	0	1	53.5	1.9
2005	February	0	0	51.2	0.0
2005	March	2	2	51.8	3.9
2005	April	0	0	48.5	0.0
2005	May	101	2	145.6	1.4
2005	June	6	1	145.6	0.7
2005	July	0	0	140.9	0.0
2005	August	1	0	138.1	0.0
2005	September	0	0	134.5	0.0
2005	October	75	1	204.0	0.5
2005	November	0	0	197.7	0.0
2005	December	0	0	192.6	0.0
2006	January	0	0	187.5	0.0
2006	February	0	0	182.6	0.0
2006	March	0	0	177.8	0.0
2006	April	0	0	173.2	0.0
2006	May	24	0	192.0	0.0
2006	June	32	0	218.2	0.0

Table 6. Continued.

Year	Month	Number tagged	Number harvested.	Number at-large	Exploitation corrected for tag loss
2006	July	0	0	212.4	0.0
2006	August	0	1	206.9	0.5
2006	September	0	0	200.5	0.0
2006	October	0	1	195.3	0.5
2006	November	0	0	189.2	0.0
2006	December	0	0	184.2	0.0
2007	January	0	0	179.4	0.0
2007	February	0	0	174.7	0.0
2007	March	0	0	170.1	0.0
2007	April	0	0	165.7	0.0
2007	May	0	0	161.3	0.0
2007	June	6	1	163.0	0.6
2007	July	15	0	172.3	0.0
2007	August	0	0	167.8	0.0
2007	September	0	0	163.4	0.0
2007	October	0	1	159.2	0.6
Average annual exploitation for a one year period (Nov. 2004 -Oct. 2007)					**4.0**
Average annual exploitation corrected for 20% non-reporting					**5.1**
Average annual exploitation corrected for 50% non-reporting					**8.2**
Average annual exploitation corrected for 70% non-reporting					**13.2**

Table 7. Monthly exploitation from angler tag returns over a three-year period for flathead catfish in Lake Wilson. The number-at-large was adjusted for the number removed and the percentage of tags lost each month.

Year	Month	Number tagged	Number harvested.	Number at-large	Exploitation corrected for tag loss
2004	October	7	0	62.0	0.0
2004	November	0	1	60.4	1.7
2004	December	0	0	57.8	0.0
2005	January	0	0	56.3	0.0
2005	February	0	1	54.8	1.8
2005	March	0	0	52.4	0.0
2005	April	0	0	51.1	0.0
2005	May	97	0	144.2	0.0
2005	June	11	0	151.1	0.0
2005	July	0	0	147.2	0.0
2005	August	28	2	170.6	1.2
2005	September	0	3	164.2	1.8
2005	October	237	1	387.7	0.3
2005	November	0	1	376.6	0.3
2005	December	0	0	365.8	0.0
2006	January	0	0	356.2	0.0
2006	February	0	0	346.9	0.0
2006	March	0	0	337.8	0.0
2006	April	0	1	329.0	0.3
2006	May	0	1	319.4	0.3
2006	June	64	1	372.4	0.3

Table 7. Continued.

Year	Month	Number tagged	Number harvested.	Number at-large	Exploitation corrected for tag loss
2006	July	0	0	361.7	0.0
2006	August	0	5	352.2	1.4
2006	September	0	2	338.1	0.6
2006	October	0	0	327.3	0.0
2006	November	0	0	318.8	0.0
2006	December	0	0	310.4	0.0
2007	January	0	0	302.3	0.0
2007	February	0	0	294.4	0.0
2007	March	0	0	286.7	0.0
2007	April	0	1	279.2	0.4
2007	May	0	3	270.9	1.1
2007	June	64	1	323.2	0.3
2007	July	77	1	388.8	0.3
2007	August	0	0	377.6	0.0
2007	September	0	0	367.7	0.0
2007	October	0	4	358.1	1.1
Average annual exploitation for a one year period (Nov. 2004 - Oct. 2007)					**4.3**
Average annual exploitation corrected for 20% non-reporting					**5.4**
Average annual exploitation corrected for 50% non-reporting					**8.7**
Average annual exploitation corrected for 70% non-reporting					**14.5**

Table 8. Estimates of instantaneous natural mortality (M) for flathead catfish from the empirical and theoretical equations presented by authors listed.

Species	Quinn and Deriso[a] (1999)	Hoenig (1983)	Jensen (1996)	Peterson and Wroblewski (1984)	Chen and Watanabe (1989)	**Average**
Blue catfish	0.135	0.122	0.099	0.159	0.122	**0.127**

[a] Proportion set to maximum age was 0.01

Table 9. Life history parameters used to model the flathead catfish population in Lake Wilson, Alabama using the yield-per-recruit model in FAST.

Parameter	Value
von Bertalanffy growth coefficients	L_∞ = 1,145 mm
	K = 0.066
	t_0 = -1.341
Maximum Age	34
Conditional and instantaneous natural mortality (*cm* and *M*)	0.119 and 0.127
Exploitation	0% to 25%
Log10weight:log10 length coefficients	intercept = -5.732
	slope = 3.287
Minimum length limits (total length)	356 mm
	508 mm

FIGURES

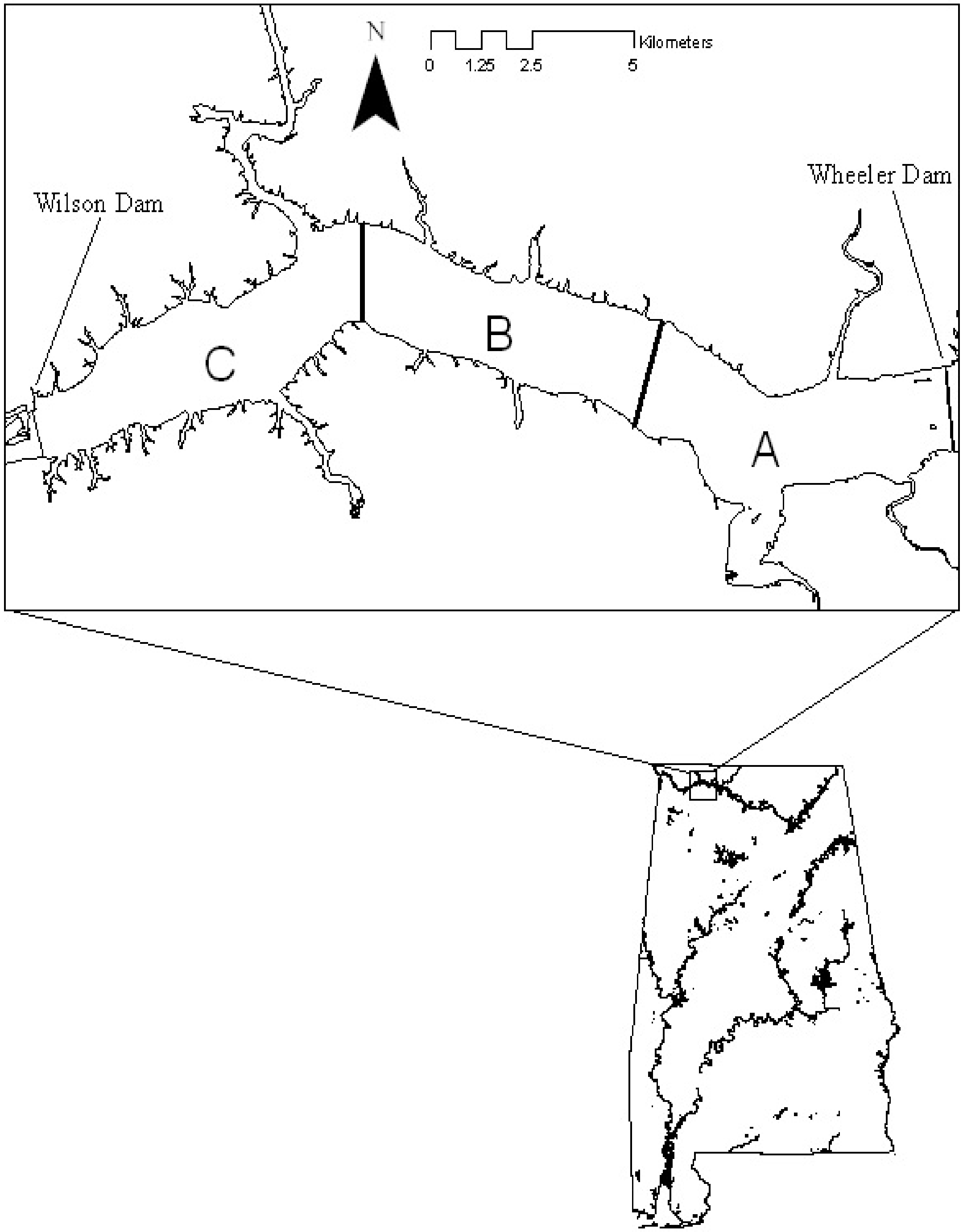

Figure 1. Map of Lake Wilson indicating sections used for the creel survey.

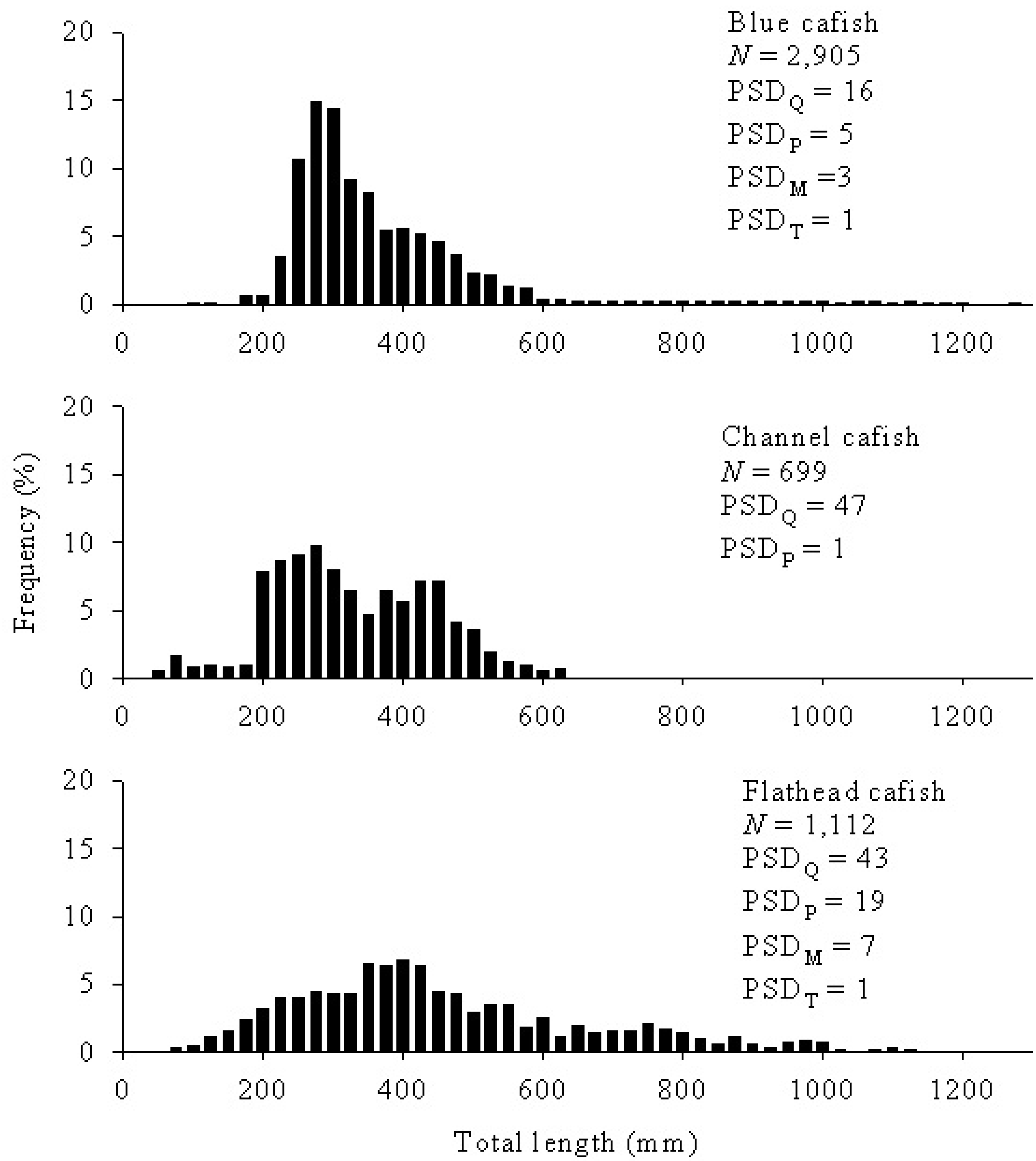

Figure 2. Length frequency histograms for blue catfish, channel catfish, and flathead catfish collected using low-frequency DC electrofishing.

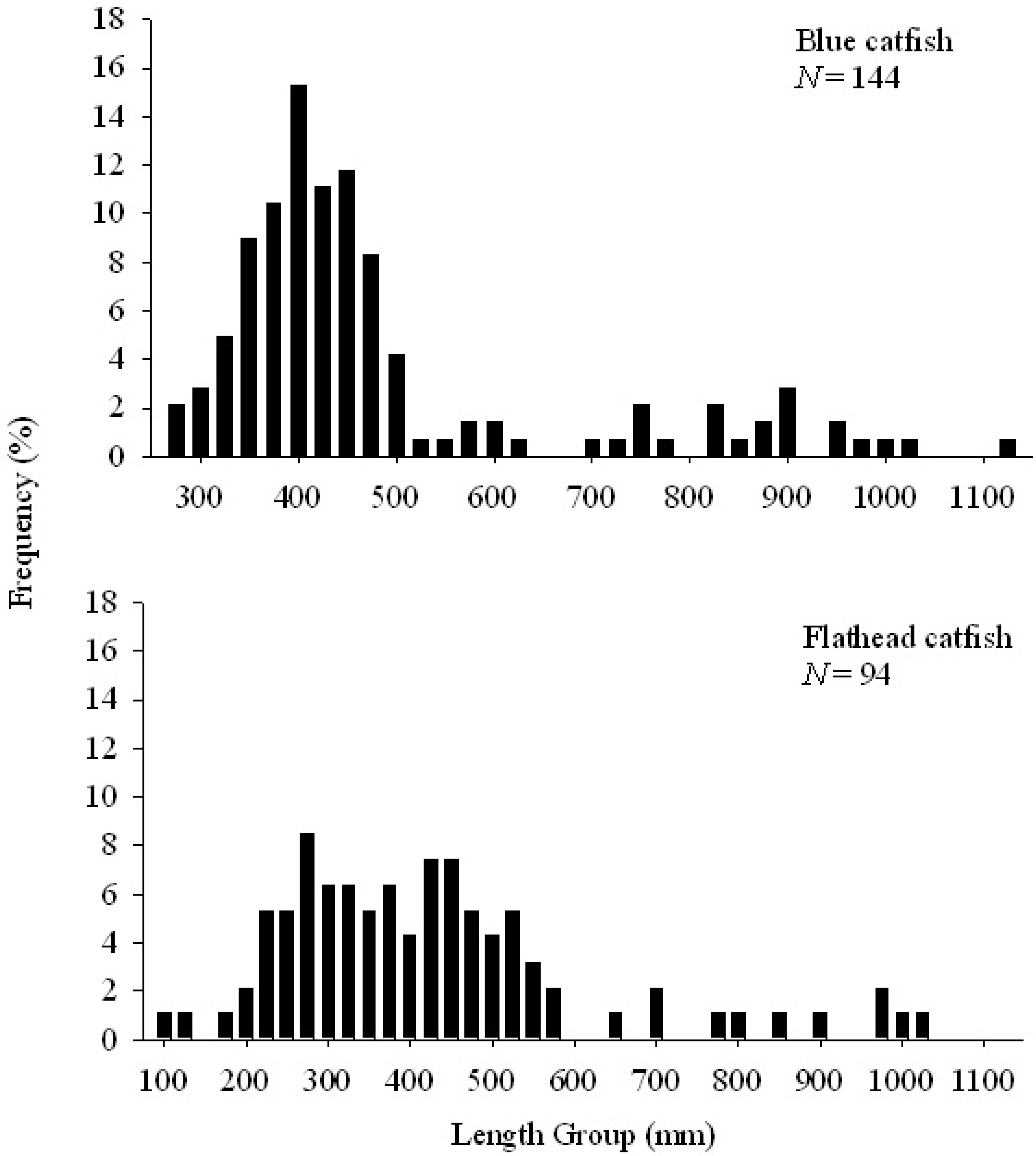

Figure 3. Length frequency histograms for blue catfish and flathead catfish collected using low pulse DC electrofishing and placed into the enclosed cove.

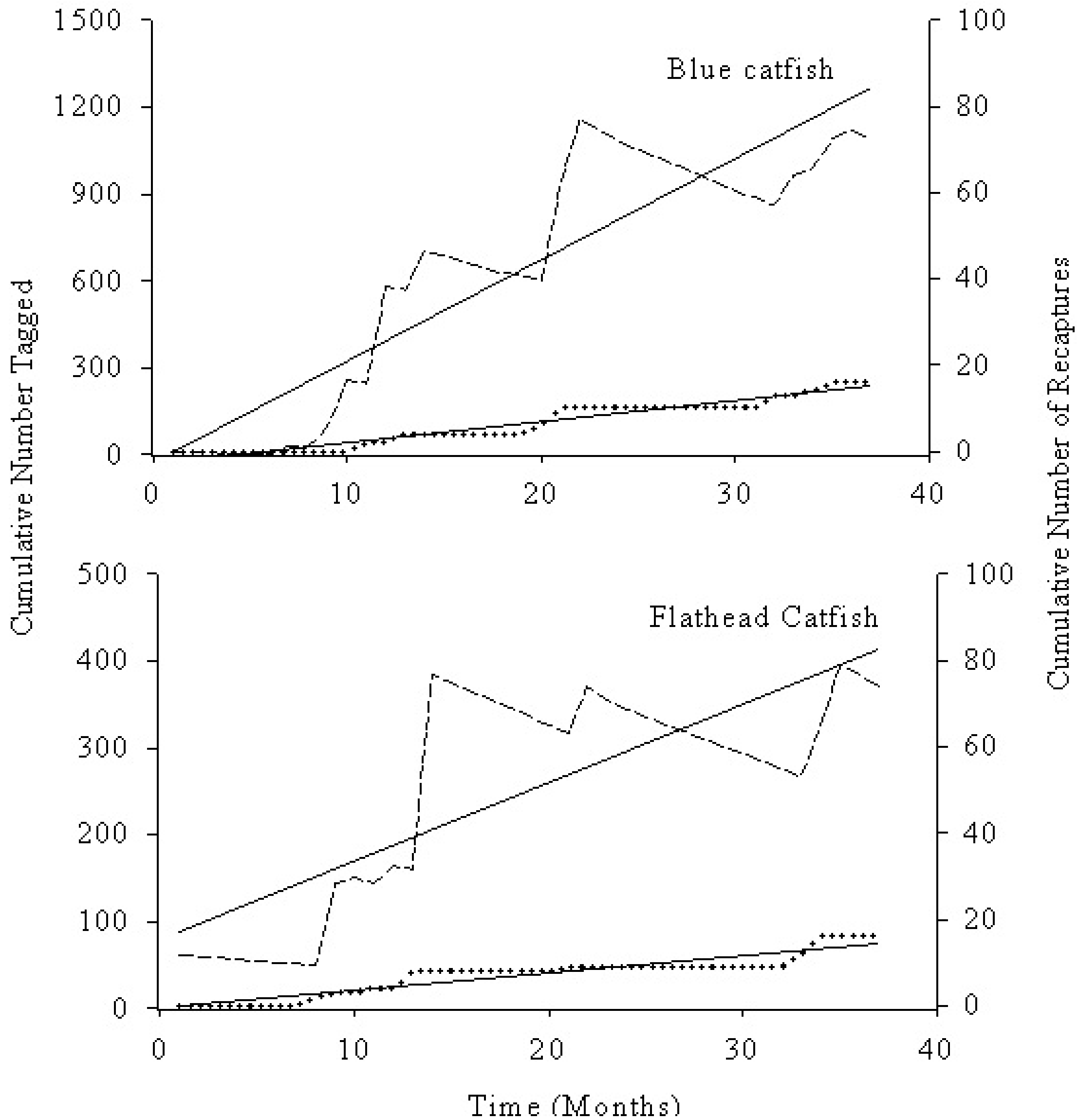

Figure 4. The cumulative number of tagged catfish at large (dashed lines) and the cumulative number of tagged catfish recaptured (dotted lines) from October 2004 to October 2007. The cumulative number of tagged catfish at large is corrected for tag loss and angler harvest of tagged catfish. Solid lines represent predicted values from linear regression.

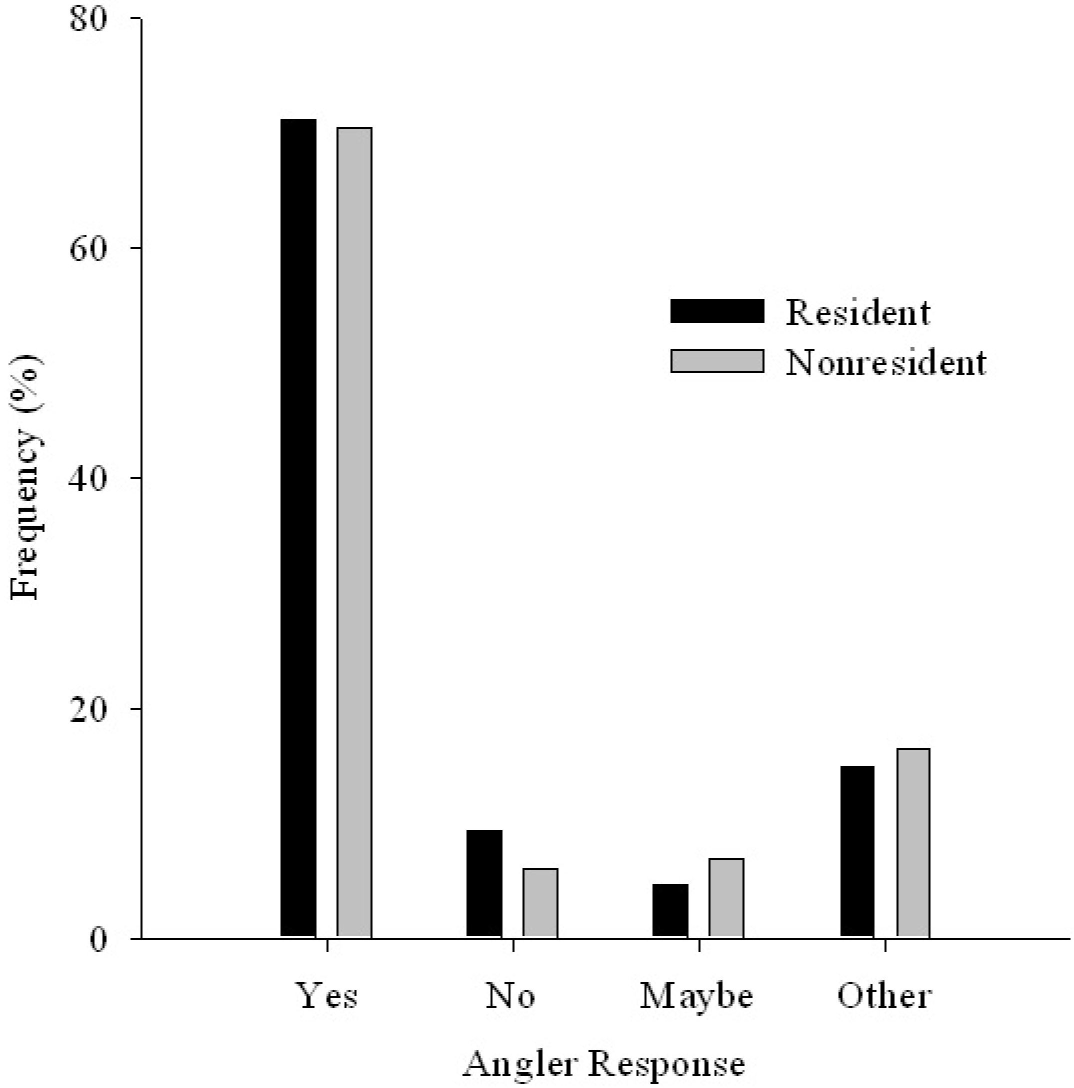

Figure 5. Frequency of angler responses with respect to implementing a trophy blue catfish regulations which were partitioned between Alabama residents (N = 215) and nonresidents (N = 258).

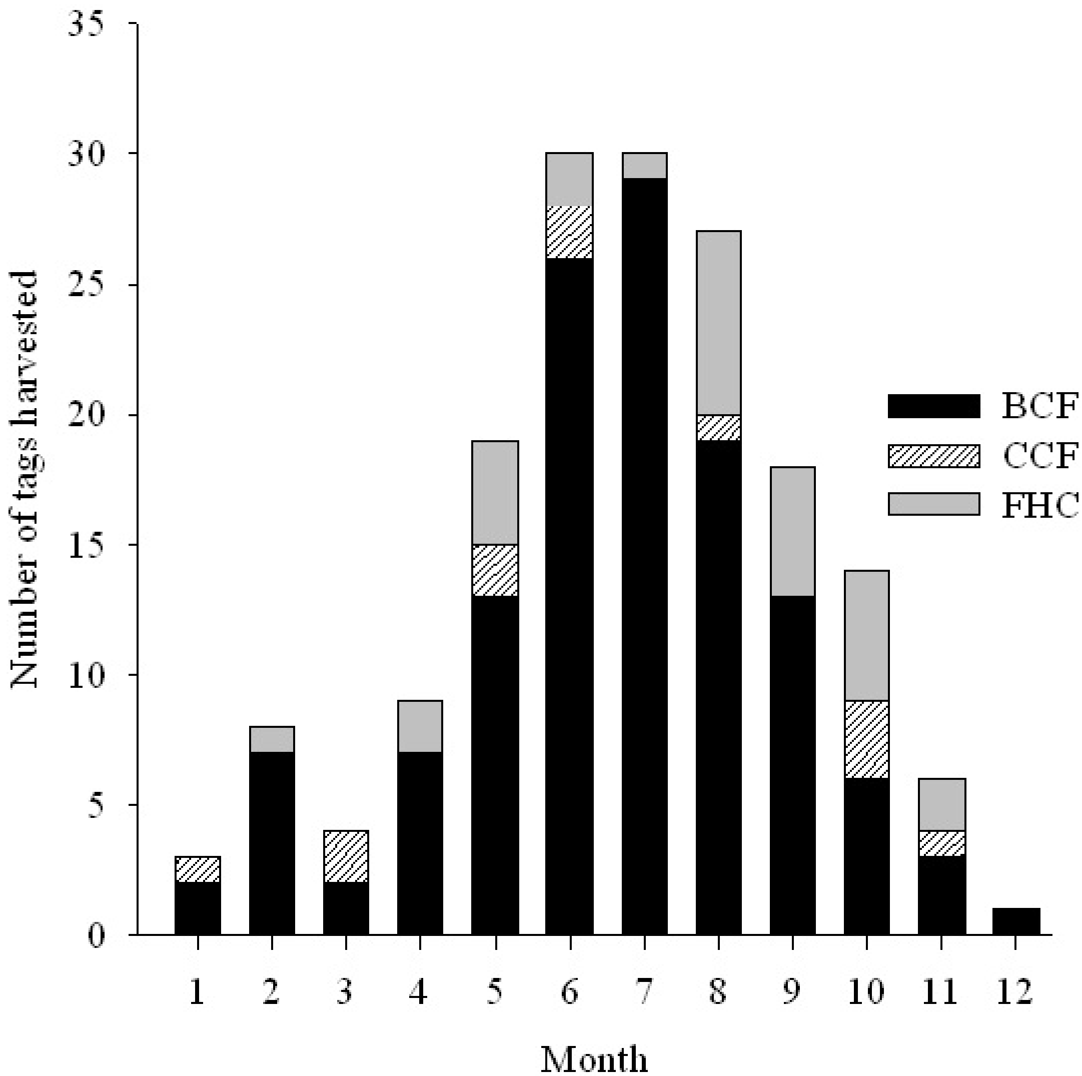

Figure 6. Monthly frequency of harvested tag returns by anglers for blue catfish (BCF), channel catfish (CCF), and flathead catfish (FHC) from October 2004 to October 2007.

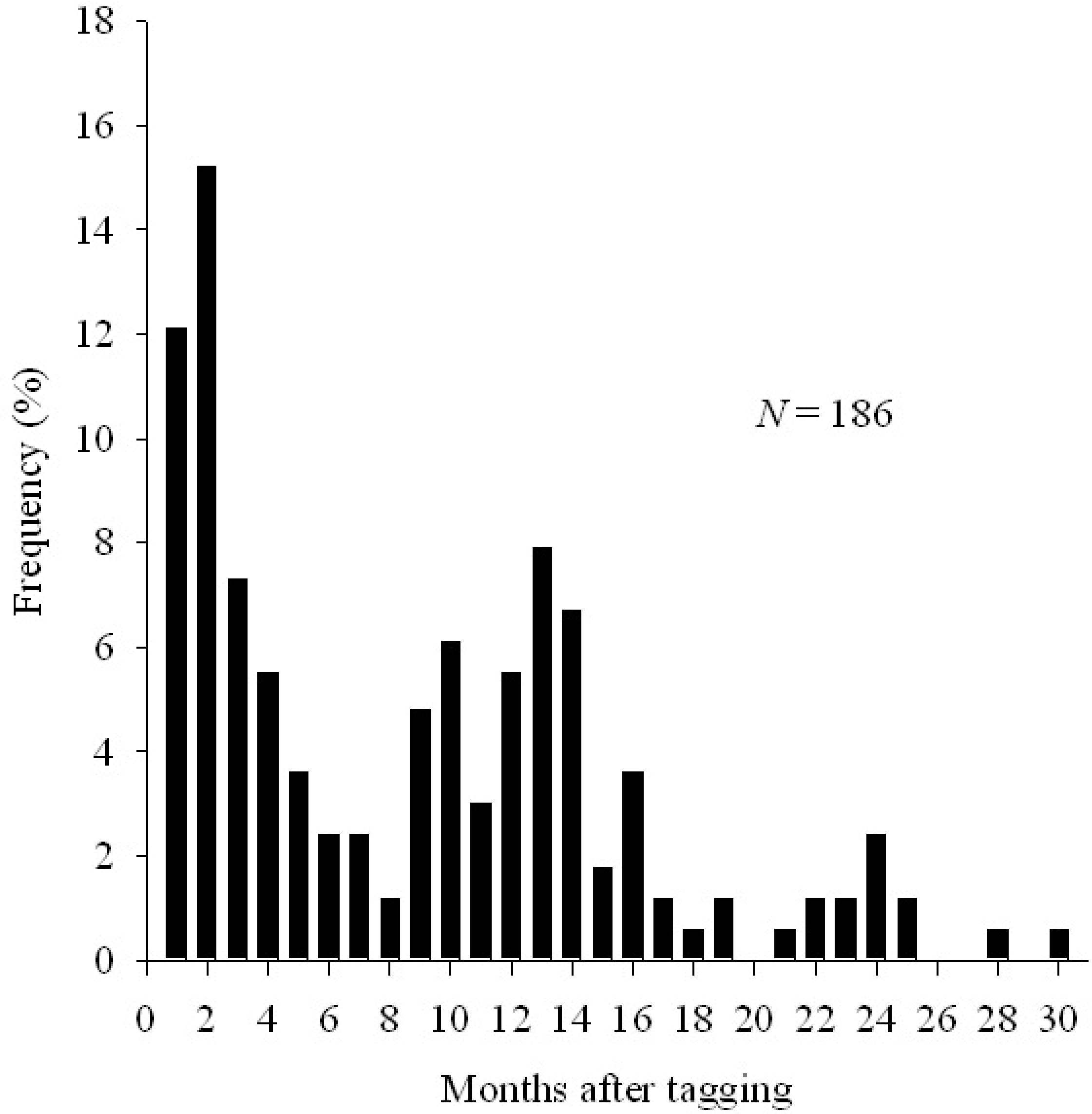

Figure 7. Frequency of time between initial tagging and angler return of tags by month for all catfish species.

Figure 8. Length frequency histograms of blue catfish and flathead catfish harvested from angler tag returns (top) and tagged (bottom).

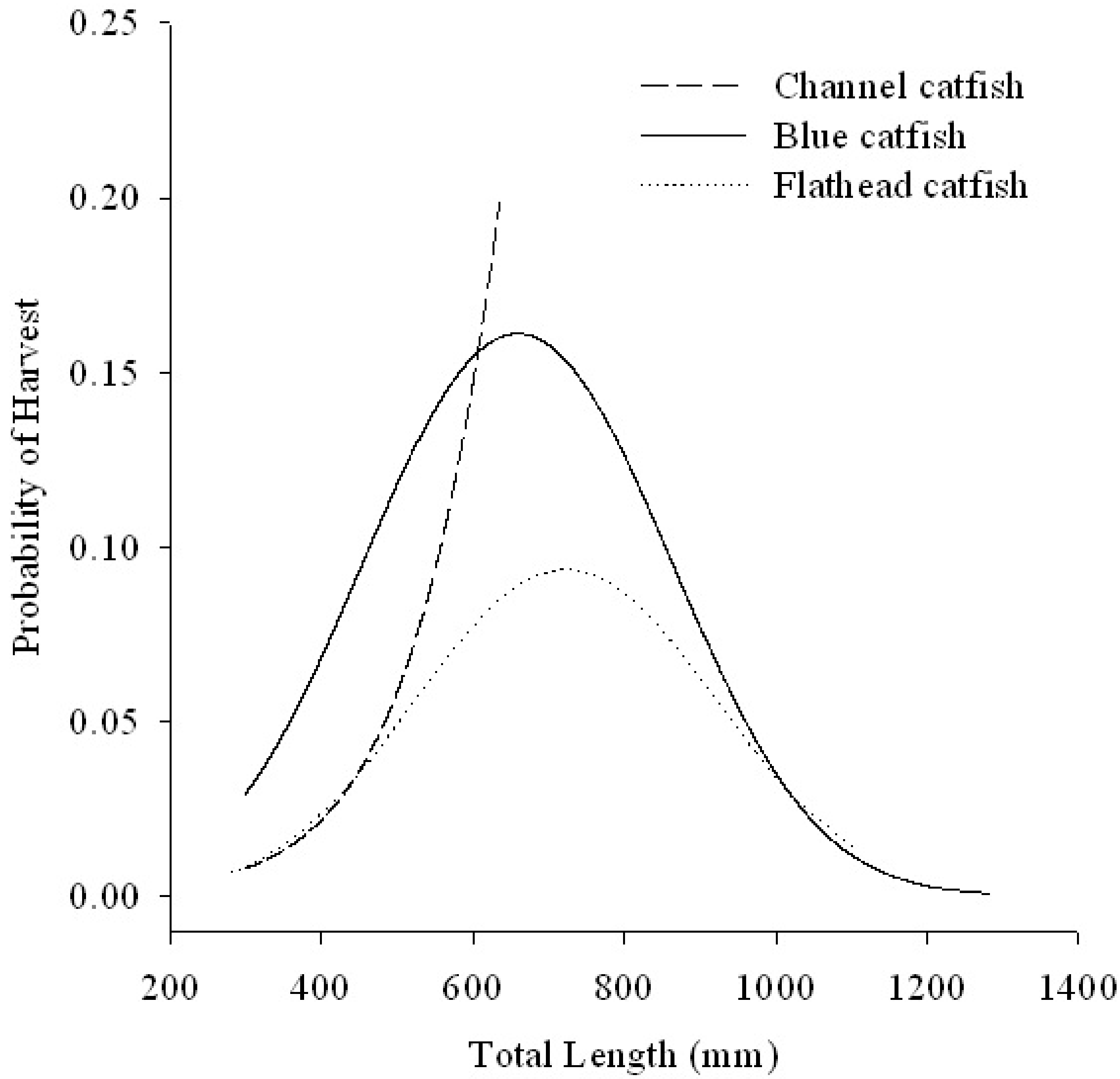

Figure 9. Predicted probability of harvest of blue catfish, channel catfish, and flathead catfish by anglers in relation to total length. Lines were associated with predicted values from logistic regression.

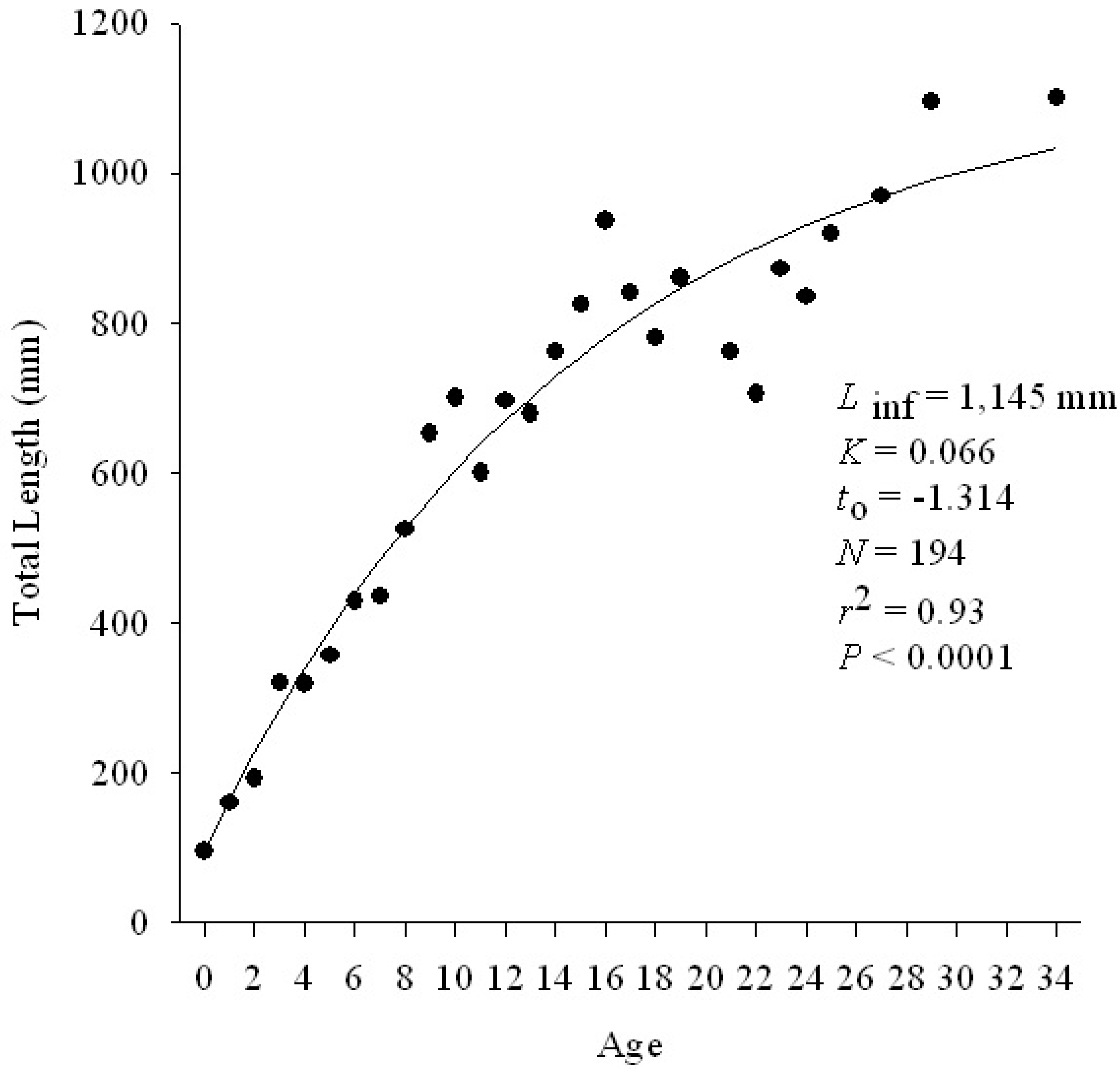

Figure 10. von Bertalanffy growth curve and coefficients for flathead catfish. Data plotted were mean lengths-at-age.

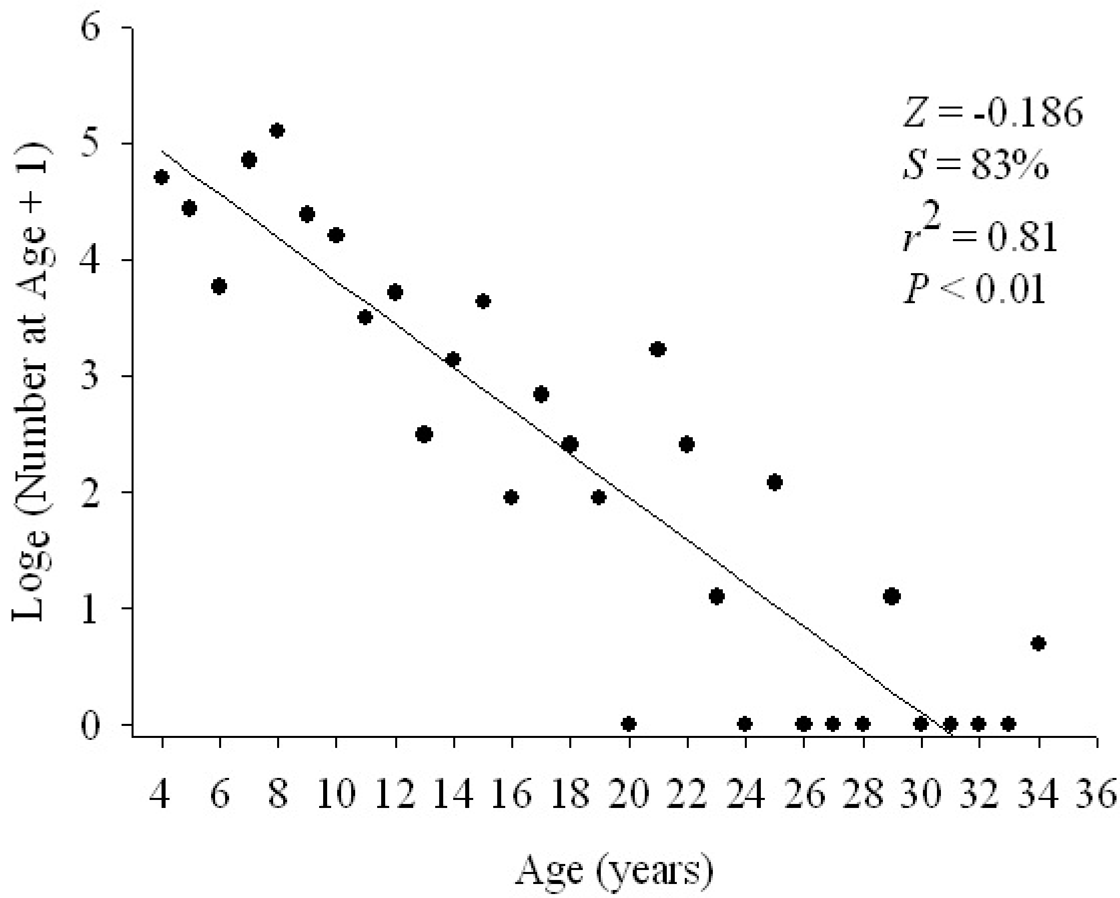

Figure 11. Weighted catch-curve regression and associated statistics computed for flathead catfish.

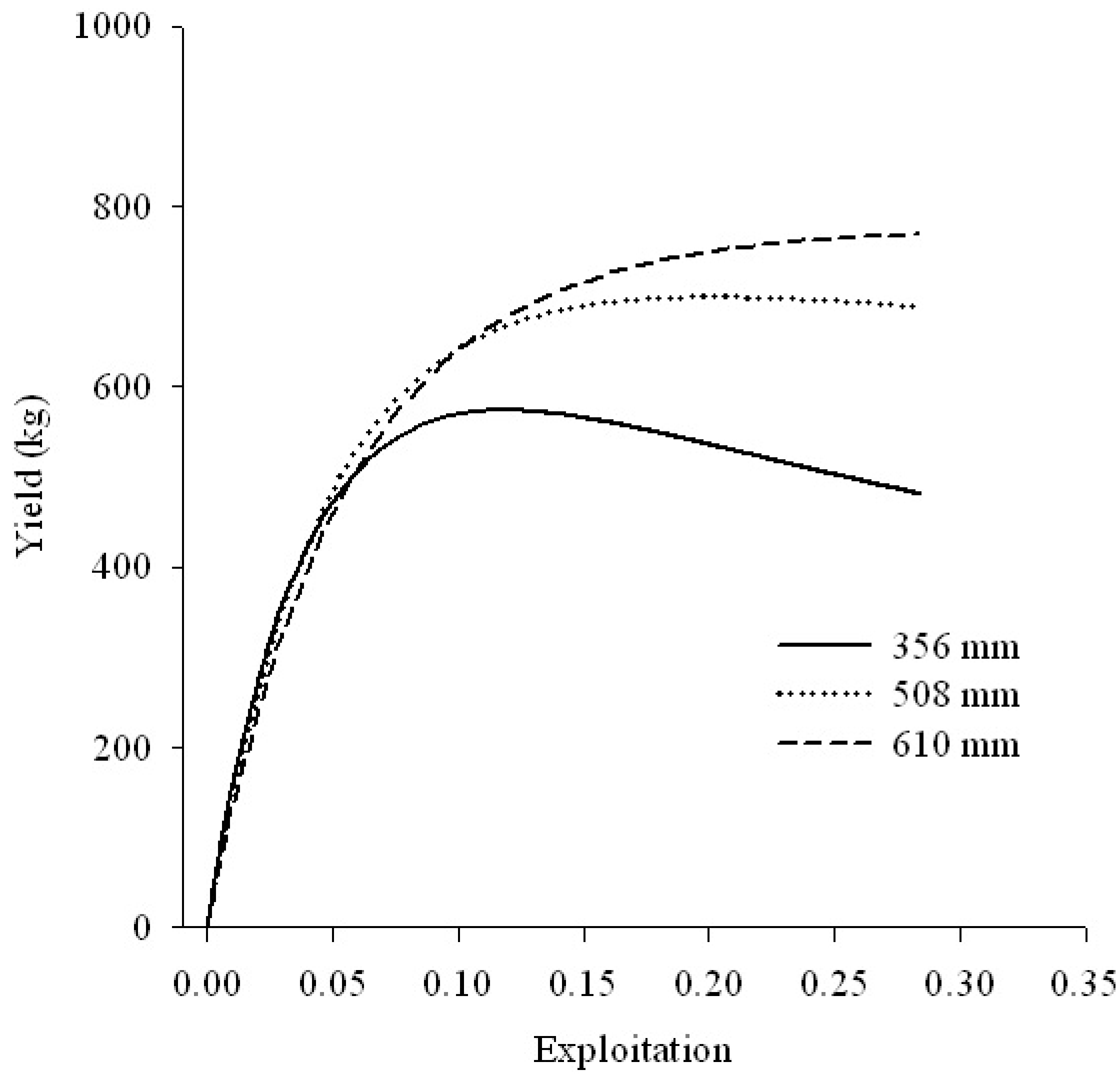

Figure 12. The predicted yield of a cohort of flathead catfish over a range of exploitation for three minimum length limits (356, 508, and 610 mm). The simulation was conducted with an initial population of 1000 recruits.

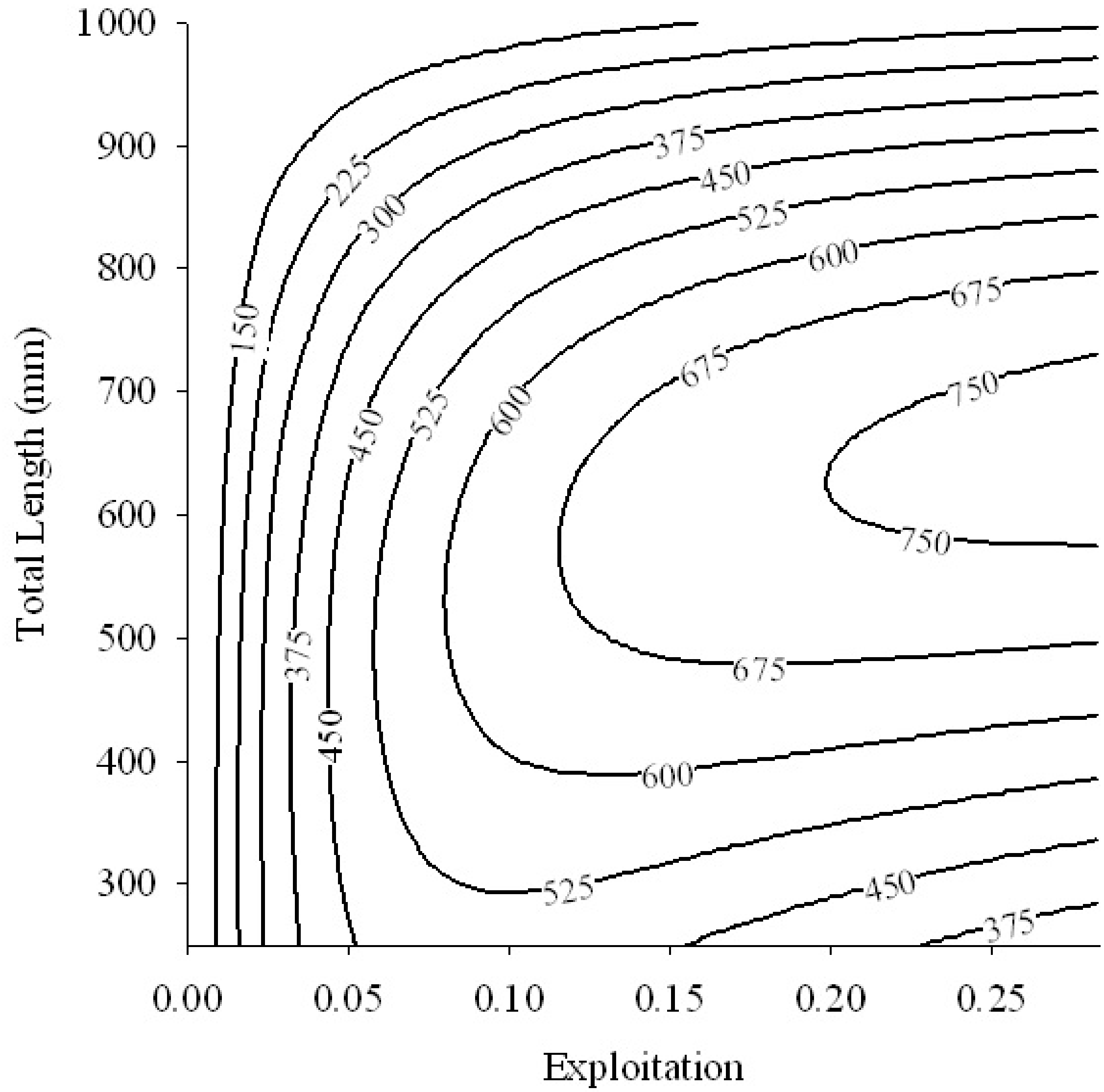

Figure 13. Yield contour plot for flathead in Lake Wilson. The solid lines represent the maximum yield (kg/1,000 recruits).

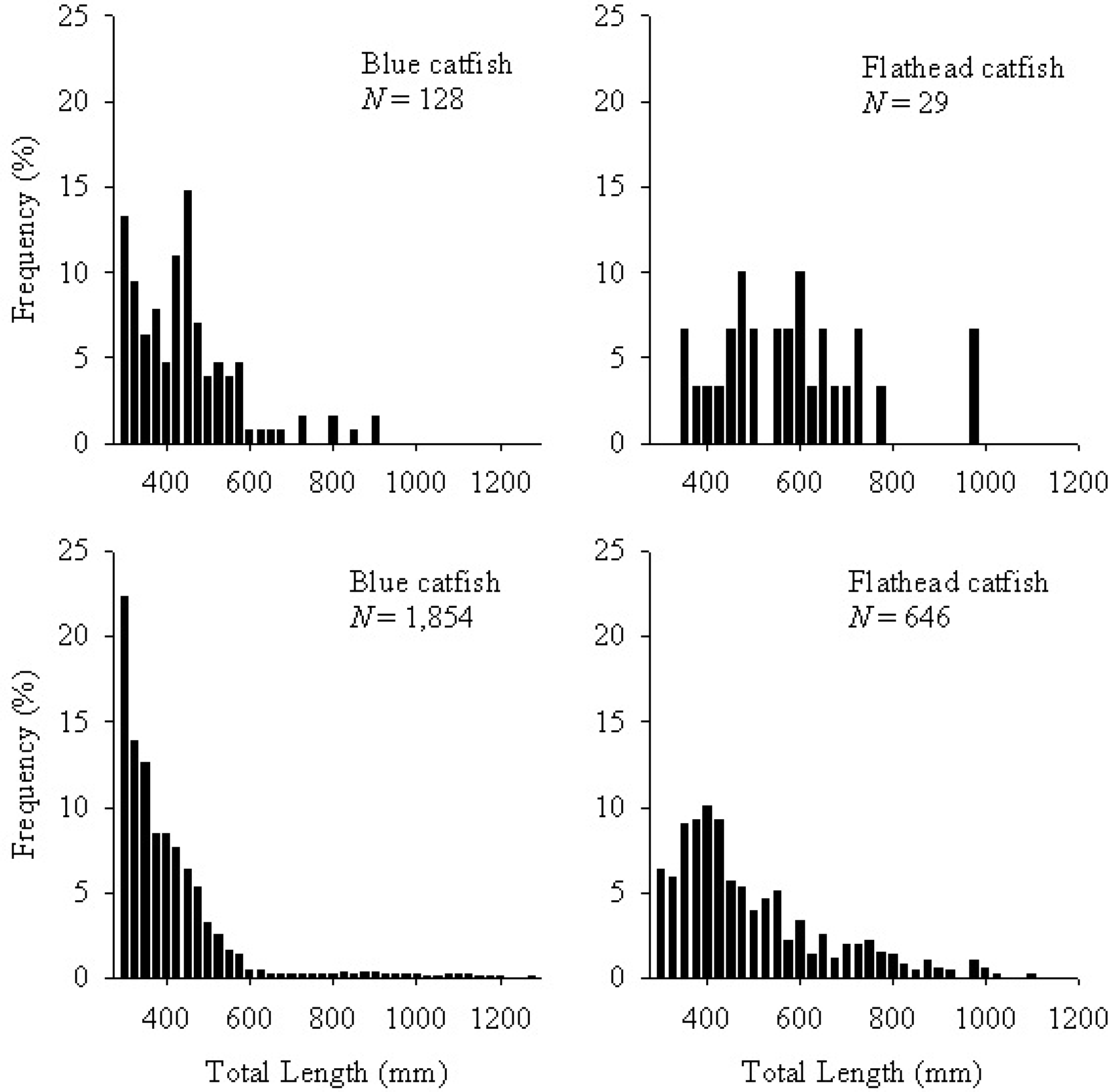

Figure 14. Catch contour plot for flathead catfish in Lake Wilson. The solid line

represent the number of fish harvested per 1,000 recruits.

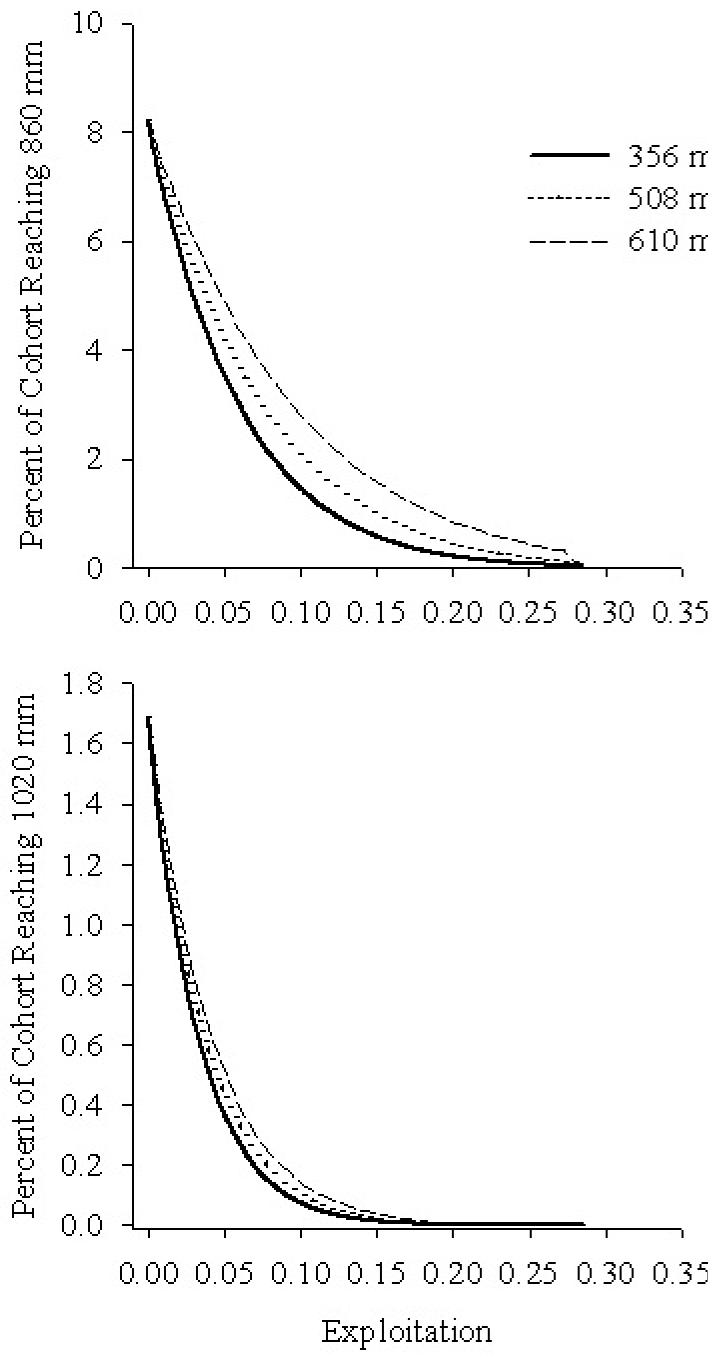

Figure 15. The predicted percent of a cohort of flathead catfish reaching memorable (860 mm) and trophy size (1,020 mm) over a range of exploitation for three minimum length limits (356, 508, and 610 mm).

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