Fisheries Report 17- 08

INVESTIGATION OF CHANNEL CATFISH AND BLUE CATFISH POPULATION DYNAMICS IN THREE TENNESSEE RESERVOIRS

A Final Report Submitted to

Frank C. Fiss, Chief
Fisheries Division
Tennessee Wildlife Resources Agency
Nashville, Tennessee

By

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FOREWORD

This final report is based on a thesis prepared in partial fulfillment of the Master of Science degree at Tennessee Technological University.

Two abbreviations that appear throughout the text are *i.e.* (from the Latin "*id est*"), meaning "that is", and *e.g.* (from the Latin *exempli gratia*) meaning "for example". All units of measurement are metric, unless otherwise indicated.

- To convert Celsius (^{o}C) to Fahrenheit (^{o}F), multiply ^{o}C by 1.8 and add 32.
- One hectare equals 2.47 acres, and one km equals 0.621 miles.
- Divide by 25.4 to convert lengths in mm to lengths in inches
- One kilogram (kg) = 2.2 pounds

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

1. Channel Catfish and Blue Catfish are important components of commercial and recreational fisheries in several Tennessee reservoirs on the Tennessee River. Annual recreational harvest (both species) since 2008 has averaged 244,991 kg in Kentucky Lake and 121,079 kg in Chickamauga Lake. Commercial harvest (both species) in 2014 was nearly 190,000 kg in Kentucky Lake and 40,025 kg in Chickamauga Lake. The recreational and commercial harvests in both reservoirs were dominated by Blue Catfish. In stark contrast, the recreational fishery in Ft. Loudoun Lake in the headwaters of the Tennessee River, where a consumption advisory exists, averages only 4,400 kg per year and commercial fishing is banned.

2. The objectives of this study were to evaluate catfish sampling protocols in Kentucky Lake, Chickamauga Lake, and Ft. Loudoun Lake, estimate growth and longevity, mathematically model yields and the potential for growth overfishing of Channel Catfish, and mathematically model the abundance of trophy Blue Catfish under different maximum size limits. A variety of gears were deployed seasonally in 2015 and subsamples of each species were aged using lapilli otoliths. Ages were assigned to unaged fish using an age-length key.

3. Tandem hoop nets collected more than 3,600 Channel Catfish during spring, summer, and fall sampling in 2015 in those three Tennessee reservoirs. Catch per unit effort was consistently high (27.5-38.6 fish/series) in all reservoirs during spring sampling.

4. Channel Catfish grew faster in Kentucky Lake and Chickamauga Lake; whereas, fish in Ft. Loudoun Lake grew slower but lived much longer (age 21 versus ages 12-15). Annual mortality (A) ranged from 61.1% in Kentucky Lake to 26.9% in Chickamauga Lake and 17.7% in Ft. Loudoun Lake.

5. Yield modeling showed the potential for growth overfishing in the Kentucky Lake Channel Catfish population but minimum length limits (e.g., 305 mm or 356 mm total length [TL]) could ameliorate that potential. There was little or no evidence of growth overfishing in the Channel Catfish populations in the other two reservoirs, even at high exploitation rates.

6. Low-frequency (15 pps) electrofishing was less effective at capturing Blue Catfish than what has been observed in other reservoirs on the Tennessee River and elsewhere in the country. Because the number of Blue Catfish collected with low-frequency electrofishing was low (n=230), several other gears (trotlines, n = 210; hoop nets, n = 126; gill nets, n = 9; angling, n = 5) were used to increase sample sizes. Blue Catfish populations exhibited trends similar to Channel Catfish in the three reservoirs. They grew faster in Kentucky Lake and Chickamauga Lake but lived much longer (age 37 versus ages 17-18) in Ft. Loudoun Lake.

7. The number of trophy Blue Catfish (> 914 mm total length [TL]) was modeled using a Beverton-Holt dynamic pool model under two management scenarios: (1) the current regulation allowing harvest of one Blue Catfish over 864 mm TL per day; and (2) a regulation allowing for no harvest of Blue Catfish over 914 mm TL. Modeling at three levels of natural mortality and over a range of fishing mortality suggested that changing the current regulation to the “none over 914 mm” regulation would reduce the number of trophy Blue Catfish in those populations under most of the combinations of fishing and natural mortality simulated.

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INTRODUCTION

Channel Catfish *Ictalurus punctatus* and Blue Catfish *I. furcatus* of the family Ictaluridae are popular commercial and recreational species throughout the United States, with Tennessee being no exception. In 2011, catfish were the second most pursued recreational species in the state behind black bass (USDI and USDC 2011). In 2015, commercial catfish harvest in Tennessee totaled nearly 360,000 kg (E. Ganus, Tennessee Wildlife Resources Agency [TWRA], personal communication). Increased interest in catfish over the past twenty years has yielded much recent literature, including two international symposia (Irwin et al. 1999; Michaletz and Travnichek 2011); however, only a few studies of catfish have been conducted in Tennessee (Hale and Timmons 1990; Timmons 1999; Stewart 2009). In addition to the paucity of studies on catfish in Tennessee, there have been relatively few studies nationwide on catfish in large reservoirs. Thus, Tennessee reservoirs provide an ideal stage to study these popular fish.

With continued commercial harvest and increasing attention from recreational anglers, biologists are pressed now more than ever to manage these populations for increased quality and sustainability. However, Brown (2009) reported that 61% of biologists actively managing catfish stocks were concerned about gear efficiency and accuracy. To properly manage catfish and gain an understanding of the dynamics of catfish populations, there is a need to efficiently and accurately sample them. Efficiency is defined as catch per unit effort (CPUE) and accuracy refers to how closely samples represent the true population characteristics. Presently, there are many unknowns about catfish sampling. Several popular techniques are biased or in the infancy of their development. Bodine et al. (2013) summarized what is known about various techniques currently in use; in most cases, gill nets, trotlines, and high-frequency electrofishing lack efficiency and can over-represent large catfish. Bodine et al. (2013) reported that tandem hoop nets were the most efficient and accurate gear to sample Channel Catfish; whereas low-frequency electrofishing appeared to be the most efficient and accurate gear to sample Blue Catfish.

In addition to inherent gear bias, the biology and behavior of these species may play an important role in how effectively managers are able to sample them. Channel Catfish and Blue Catfish are common throughout Tennessee and much of the United States. Both species spawn in cavities during late spring to early summer (Pflieger 1997; Graham 1999). During the pre-spawn period, Channel Catfish and Blue Catfish tend to be highly mobile, although Blue Catfish are the more migratory of the two species (Graham 1999; Hubert 1999). Channel Catfish are well adapted to living in various freshwater systems and prefer littoral habitats associated with structure (Hubert 1999). Compared to Channel Catfish, Blue Catfish have a narrower preference for habitat. Though regarded primarily as riverine fishes, preferring channel or near-channel habitat associated with deep water and swift current (Etnier and Starnes 1993), the generalist nature of Blue Catfish has allowed the species to adapt and thrive in many altered freshwater systems.

Most (77%) of the annual catfish harvest in Tennessee is caught by commercial fishers (Stewart 2009). Commercial fishers use a variety of gears to target Channel Catfish and Blue Catfish. Blue Catfish, which are desirable table fare due to their mild, white flesh, represent the majority of commercial catfish harvest in Tennessee. Most catfish harvested by commercial fishermen are sold to private fish markets; however, there is a growing concern among biologists that large catfish are being transported alive out of state and sold to markets elsewhere. The long-lived, relatively slow-growing nature of catfish, especially Blue Catfish, makes them particularly vulnerable to overfishing if the fishery is targeting large brood stock (Sullivan and Vining 2011).

Catfish anglers represent 35% of all anglers in Tennessee and account for over 4,900,000 days of fishing annually (USDI and USDC 2011). The recreational catfish fishery has long been viewed primarily as a harvest-oriented fishery. A survey by Stewart et al. (2012) showed that 71% of Tennessee catfish anglers fished specifically for catfish to harvest. However, recreational anglers have begun to realize the potential for catfish to provide trophy fisheries. Increased publicity through television shows, magazine articles, near-state record catches, and social media have led to growing awareness of existing trophy catfish fisheries (e.g., Red River, North Dakota; Tennessee River, Tennessee-Alabama; James River, Virginia; Santee Cooper Lakes, North and South

Carolina; Lake Texoma, Texas-Oklahoma). Subsequently, a shift toward managing these species as sportfish has occurred. Most (58%) Tennessee anglers favored managing catfish as sportfish in a recent survey (Stewart et al. 2012). As a result, catfish were classified by the TWRA as sportfish in 2007, thus allowing the use of federal sportfish restoration funds for management.

Currently, there are no regulations in Tennessee on the commercial or recreational harvest of catfish shorter than 864 mm (34") total length (TL). Commercial and recreational anglers are restricted to harvesting no more than one "trophy" catfish longer than 864 mm TL per day and there is a possession limit of two trophy catfish. Although these regulations were enacted with little opposition, they lacked a solid scientific basis. Used in combination with accurate sampling protocols, mathematical modeling can inform management decisions and potentially improve current regulations (Slipke et al. 2002; Holley et al. 2009).

The objectives of this study were to: (1) assemble a statewide database on commercial and recreational harvest of catfish and examine historical trends in terms of yield; (2) develop unbiased catfish sampling protocols for the use of trotlines, low-frequency electrofishing, tandem hoop nets, or a combination of these three approaches; (3) mathematically model the yield and potential for growth overfishing for Channel Catfish in response to different minimum size limits; and (4) mathematically model the abundance of trophy Blue Catfish under different maximum size limits

STUDY AREAS

Kentucky Lake

Kentucky Lake (Figure 1), the lowermost impoundment on the Tennessee River, is a 64,800 ha mainstem reservoir located in western Tennessee's Stewart, Henry, Houston, Benton, Humphreys, Decatur, Perry, Wayne, and Hardin counties. Kentucky Dam was completed in 1944 for the purposes of flood control, hydropower, and navigation at Tennessee River kilometer 35 (TRkm, measured from its confluence with the Ohio River). A canal located near TRkm 41 connects Kentucky Lake to Lake Barkley and the Cumberland River system, allowing for passage of barge traffic with no need for a lock. Kentucky Lake is the most eutrophic mainstem reservoir on the Tennessee River (based on a Trophic State Index [TSI] value of 56.2; Scholten et al. 2008) with a mean depth of 5.4 m and water levels fluctuate approximately 1.5 m between winter and summer pools. Kentucky Lake has nearly 3,321 km of shoreline and its upstream boundary is Pickwick Dam (TRkm 332). Downstream of TRkm 186, Kentucky Lake is lacustrine with many coves and embayments. Upstream of TRkm 186, Kentucky Lake is more riverine. Kentucky Lake supports the largest commercial and recreational catfish fisheries in the state.

Chickamauga Lake

Chickamauga Lake (Figure 1) is a 14,665 ha mainstem reservoir located on the Tennessee River in eastern Tennessee's Hamilton, Rhea, Meigs, McMinn, and Bradley counties. Chickamauga Dam, about 11 km upstream of Chattanooga (TRkm 758), was completed in 1940 and is operated for flood control, hydropower, navigation, and recreation. Chickamauga Lake is less eutrophic than Kentucky Lake (TSI = 50.8; Scholten et al. 2008) with a mean depth of 5.5 m and an annual fluctuation of about 2.3 m between winter and summer pool. Chickamauga Lake has 1,261 km of shoreline and its upstream boundary is Watts Bar Dam (TRkm 853). The Hiwassee River, a major tributary to this reservoir, enters Chickamauga Lake at Hiwassee Island (TRkm 804.5). Upstream of this point Chickamauga Lake exhibits more riverine characteristics, whereas downstream of Hiwassee Island the reservoir is more lacustrine. Chickamauga Lake supports the second largest commercial and recreational catfish fisheries in the state.

Ft. Loudoun Lake

Ft. Loudoun Lake (Figure 1) is the uppermost reservoir on the Tennessee River. The 5,908 ha mainstem reservoir begins at Ft. Loudoun Dam (TRkm 969) and extends into parts of Loudoun, Knox, and Blount counties. Ft. Loudoun Dam was completed in 1943 for the purposes of hydropower, flood control, and navigation. Ft. Loudoun Lake is connected to Tellico Lake and the Little Tennessee River by a canal constructed for barge traffic. The reservoir is situated along the southern edge of the city of Knoxville in eastern Tennessee and extends 88 km from the Ft. Loudoun Dam to its headwaters at the confluence of the Holston and French Broad rivers. Ft. Loudoun Lake is eutrophic (TSI = 54.7; Scholten et al. 2008) with approximately 579 km of shoreline and the annual fluctuation between winter and summer pools is about 1.8 m. A consumption advisory exists and the reservoir is closed to commercial harvest of catfish due to high levels of polychlorinated biphenyls (PCBs) and mercury.

METHODS

Historical Trends in Harvest

Commercial harvest data were obtained from the TWRA. Three categories (Channel Catfish, Blue Catfish, and Channel or Blue Catfish) of commercial data were received for 2014-2016. Before 2013, commercial fishers were only required to report harvest in terms of "Any Catfish" rather than reporting on a species-specific basis. Harvest information was used to calculate combined average yield (kg/ha) of Channel Catfish and Blue Catfish from 2014-2016.

Recreational harvest information was described using creel survey data obtained from the TWRA. Data from 2008-2015 were provided for Kentucky Lake and Chickamauga Lake (2013 data were not collected for Chickamauga Lake). Three years of data (2009, 2012, and 2015) were available for Ft. Loudoun Lake. Average recreational yield (kg/ha) was calculated for both species separately and both species combined.

Channel Catfish

Data Collection

Channel Catfish were sampled during the summer of 2014 and the spring, summer, and fall of 2015 with tandem hoop nets. Kentucky Lake was partitioned into three sections (riverine, transition, and lacustrine), whereas Chickamauga Lake and Ft. Loudoun Lake were each partitioned into two sections (riverine and lacustrine). Nets were set in 1-6 m of water. Steep slopes were avoided, and nets were oriented parallel to shore or structure. Eight series of tandem hoop nets were set in every section of each reservoir during each season, with two exceptions: the riverine section of Kentucky Lake could not be sampled in spring 2015 and only seven series were set in the riverine section of Ft. Loudoun Lake during summer 2015.

Each tandem hoop net consisted of three single hoop nets tied in a series. Single hoop nets were 3.4 m in length and contained seven fiberglass hoops that diminished in size from the largest hoop at the front (~0.8 m diameter) to the smallest hoop at the cod end. Nets were made of 25-mm square mesh, which has been shown to improve catch rates over other mesh sizes (Gale et al. 1999; Michaletz and Sullivan 2002; Flammang and Schultz 2007) and improve the accuracy of size-related metrics for fish longer than 250 mm TL (Michaletz and Sullivan 2002; Buckmeier and Schlechte 2009). Each net had two fingered, crowfoot-style throats, attached to the second and fourth hoops. To reduce escapement, the second throat (attached to the fourth hoop) was further constricted with plastic zip ties about 15 cm from the cod end of the throat on each net (Sullivan and Gale 1999; Porath et al. 2011). Hoop nets were rigged with a 91-cm bridle on the front hoop similar to Flammang and Schultz (2007). The series was formed by attaching the cod end of the first net to the bridle of the second net, and the cod end of the second net to the bridle of the third net. An anchor was attached to the cod end of the third net, and additional weights were attached to the bridle of the first net and the bridle between the first and second net. A bait bag containing ~1.5 kg of waste cheese bait and a small float was placed in the rear chamber of each net in the series. Soak duration for tandem hoop nets was 72 h.

Total length (TL) of all Channel Catfish was recorded. A subsample from spring 2015 was weighed and lapilli otoliths were removed. Otoliths were processed according to the methods of Buckmeier et al. (2002). Once processed, otoliths were viewed under a dissecting microscope using a fiber optic filament for side illumination. One reader assigned ages in two independent readings. When discrepancies between the first and second readings occurred, a third reading always agreed with one of the previous readings and the agreed-upon age was assigned. Age estimates were obtained for ten fish per 25 mm length bin. In Ft. Loudoun Lake, data from 28 fish were used from the summer 2015 sample to supplement low sample sizes in five length bins. Age-length keys were used to assign ages to all unaged fish in the spring 2015 samples. One fish (174 mm) was unable to be assigned an age, so it was removed from further analyses.

Previous research by Sullivan and Gale (1999), Michaletz and Sullivan (2002), and Wallace et al. (2011) suggested that Channel Catfish experienced very little mortality in tandem hoop nets and tandem hoop nets had low bycatch rates and bycatch mortality of non-target fishes. All bycatch was quantified by species.

Data Analysis

Two-way analysis of variance (ANOVA) with an interaction term was used to test for differences in mean catch per unit effort between reservoirs and seasons. Tukey's Honest Significant Difference (HSD) was used as a post-hoc test to describe all pairwise comparisons. Length-frequency distributions were compared among reservoirs using pairwise Kolmogorov-Smirnov tests. Proportional size distribution (PSD) was calculated and further broken down into categories describing the stock structure of preferred (PSD-P), memorable (PSD-M), and trophy (PSD-T) length fish for each population in the spring 2015 sample. Channel Catfish size distribution categories consist of stock ($TL \geq$ 280 mm), quality ($TL \geq 410$ mm), preferred ($TL \geq 610$ mm), memorable ($TL \geq 710$ mm), and trophy ($TL \geq 910$ mm) (Gablehouse 1984). Log_{10}-weight: log_{10}-length relationships were calculated for fish in spring 2015 and differences in robustness among reservoirs were tested using multiple linear regression with a dummy variable. Additionally, relative weight (Wr; Wege and Anderson 1978) was calculated for each population in the spring 2015 sample.

Growth was described using the von Bertalanffy model:

$$L_t = L_\infty \left(1 - e^{-K [t - t_o]}\right),$$

where L_t = length at time t, L_∞ = theoretical maximum length, K = Brody growth coefficient, and t_o = theoretical age at length zero. An AIC model selection approach was used to determine parameter estimates (R Core Team 2015; Ogle 2016).

Catch-curve analysis was used to estimate the instantaneous mortality rate (*Z*) assuming equal catchability and constant recruitment and mortality over time (Ricker 1975). Weighted linear regression of the $\log_e$-transformed data was limited to the descending right-hand portion of the catch-curve to ensure that only year classes fully recruited to the gear were included (Miranda and Bettoli 2007). The slope of that regression line was *Z* and variance of that slope was used as a measure of precision (Neter et al. 1990).

Yields in each reservoir were mathematically modeled using the yield-per-recruit (YPR) option in Fisheries Analysis and Modeling Simulator (FAMS; Slipke and Maceina 2010). The YPR option uses the Jones (1957) modification of the Beverton-Holt (1957) equilibrium yield model. Parameters required for modeling yields included von Bertalanffy growth coefficients, slope and intercept values from weight-length relationships, natural and fishing mortality estimates, and initial population size (1,000 recruits). For each population, the conditional rate of natural mortality (*cm*) was estimated by averaging the eight estimators in FAMS. The predicted response of each population to 254 mm (10 inch; assumed to represent "no limit"), 305 mm (12 inch), and 356 mm (14 inch) minimum length limits at varying levels of exploitation was modeled. Populations were considered to be experiencing growth overfishing when yield decreased with increasing exploitation.

Blue Catfish

Data Collection

Blue Catfish were targeted with boat-mounted low-frequency pulsed DC electrofishing from May-August of 2015 when water temperatures were greater than 18°C (Bodine and Shoup 2010) and April of 2016. Electrofishing lasted for 300 s at each site. The electrofishing boat was equipped with a Midwest Lake Electrofishing Systems (MLES; Polo, Missouri) Infinity Box powered by a Honda EG5000X generator. Two MLES Hexagon Plate Anode Arrays (each with 6 droppers) were attached to booms extending from the bow, with the hull functioning as the cathode. A pulse setting of 15 pulses per second (pps) was used (Cailteux and Strickland 2009). The electrofishing crew consisted of a driver and two dip-netters. At sites where current was negligible, electrofishing was relatively stationary, using enough movement in a localized area to collect surfacing fish. In areas of noticeable current, electrofishing took place in a zig-zag pattern in a downstream direction.

Several other gears were used to supplement electrofishing samples. Blue Catfish were collected from commercial gill nets and trotlines during spring 2015 and spring 2016 in Kentucky Lake, trotlines and hoop nets during fall 2015 in Chickamauga Lake, and trotlines and hoop nets during fall 2015 in Ft. Loudoun Lake. Total length and weight was recorded, and lapilli otoliths were removed and processed to estimate age. Otoliths were processed according to the methods of Buckmeier et al. (2002) and as described above for Channel Catfish otoliths.

Data Analysis

Mean CPUE was calculated for samples collected during May-July 2015 and April 2016 in Kentucky Lake and May-June 2015 in Chickamauga Lake. Electrofishing was not conducted until fall 2015 in Ft. Loudoun Lake, and no fish were captured, so that reservoir was removed from CPUE analysis. Length and age-frequency distributions were produced for each reservoir. Additionally, length-frequency data were pooled and visually inspected to describe the sizes of Blue Catfish collected in each gear. Robustness was described among reservoirs per the methods above used for Channel Catfish. Blue Catfish growth was also described using von Bertalanffy growth models. Prior to fitting growth models, an age correction of 0.8 was added to all fish collected during the fall (towards the end of the growing season).

The Dynamic Pool option in FAMS was used to model Blue Catfish population response to two maximum length limit scenarios designed to protect trophy size catfish: the current Tennessee regulation (1 fish > 864 mm [34 inches] per day), and a proposed maximum size limit regulation (no harvest > 914 mm [36 inches]). Of specific interest was the number of Blue Catfish in the population that were greater than 914 mm under the two regulations. Parameters required for modeling (Table 1) included von

Bertalanffy growth coefficients, slope and intercept values from weight-length relationships, natural and fishing mortality estimates, and an initial population size (100,000 recruits). Low catches of Blue Catfish precluded fitting catch-curves to estimate mortality. Rather, the two limits were modeled under varying levels of natural and fishing mortality estimated by Holley et al (2009). Conditional fishing mortality (*cf*) was set at 0.24 for fish shorter than the two maximum size limits, which approximated the highest exploitation rate (u = 20%) reported by Holley et al. (2009). No data exists to describe how often anglers are forced to release fish longer than the current 864 mm maximum size limit; therefore, the number of large ($\geq$ 914 mm [36 inches]) Blue Catfish was simulated under three scenarios: fishing mortality of fish longer than the current 864 mm maximum limit (*cf* = 0.24) was reduced slightly (*cf* = 0.18), moderately (*cf* = 0.12), and severely (*cf* = 0.06) with a "one-over" provision. These three hypothetical reduced fishing mortality rates equated to scenarios whereby anglers rarely, occasionally, or often caught more than one fish over the current 864 mm maximum size limit and were forced to return any fish in excess of one. Mortality rates in the Dynamic Pool model are age-specific; therefore, using the von Bertalanffy growth model, it was estimated that an 864 mm long and 914 mm long Blue Catfish was ~age 13 and ~age 15 in Kentucky Lake, respectively, and ~age 16 and ~age 18 in Chickamauga Lake, respectively. Once the numbers of large Blue Catfish under the current regulation with three different reductions in *cf* was estimated, the number of large Blue Catfish that would be in the population if *cf* stayed at *cf* = 0.24 for age 13-14 fish in Kentucky Lake and age 16-17 fish in Chickamauga Lake, but dropped to zero for age 15 and older fish in Kentucky Lake and age 18 and older fish in Chickamauga Lake, was estimated. The simulations were performed at the low, average, and high estimates of natural mortality reported by Holley et al. (2009) (i.e., *cm* = 0.115, 0.146, and 0.168, respectively).

RESULTS

Historical Trends in Harvest

Commercial yields of Channel Catfish and Blue Catfish combined were comparable in the two reservoirs on a per-hectare basis. Average commercial yields from Kentucky Lake and Chickamauga Lake were 3.97 kg/ha and 3.24 kg/ha, respectively. However, because Kentucky Lake is much larger than Chickamauga Lake, the magnitude of commercial harvest (total kg) from Kentucky Lake was much greater (4-7X higher). Since the implementation of a species-specific reporting requirement, the total reported commercial harvest of “Blue or Channel Catfish” between 2014 and 2016 decreased from 31.0% of the total harvest to 4.7% in Kentucky Lake. In Chickamauga Lake, the commercial harvest of “Blue or Channel Catfish” declined from 64.7% to 36.3% of the total reported commercial harvest. Commercial harvest totals in both reservoirs tended to consist of Blue Catfish more than Channel Catfish, though this is speculative because of the uncertainty caused by the catch-all “Blue or Channel Catfish” category.

The recreational catfish fisheries in Kentucky Lake and Chickamauga Lake were dominated by Blue Catfish, which represented on average 69% and 75% of the total weight of catfish harvested between 2008 and 2015, respectively (Table 2). On a per-hectare basis, Channel Catfish and Blue Catfish yields in the recreational fishery in Kentucky Lake were 1.19 kg/ha and 2.59 kg/ha, respectively. In Chickamauga Lake, Channel Catfish and Blue Catfish recreational yields were 2.03 kg/ha and 6.23 kg/ha, respectively. Thus, average combined recreational harvest of Channel Catfish and Blue Catfish from Chickamauga Lake (8.26 kg/ha) was more than double that of Kentucky Lake (3.78 kg/ha) on a per-hectare basis. Individual Channel Catfish and Blue Catfish harvested from Chickamauga Lake were, on average, 50% and 59% heavier, respectively, than those harvested from Kentucky Lake. In Ft. Loudoun Lake, mean recreational yield was 0.17 kg/ha for Channel Catfish and 0.58 kg/ha for Blue Catfish, or 0.75 kg/ha combined.

Channel Catfish

Tandem hoop nets captured large numbers (n=3,743) of Channel Catfish. Significant differences in catch were observed among seasons ($F=9.068$; df=2, 147; $P<0.001$) and reservoirs ($F=5.699$; df=2, 147; $P=0.004$). Additionally, there was a significant interaction ($F=5.554$; df=4, 147; $P<0.001$). Mean catch per unit effort was highest during spring in Kentucky Lake (36.9 fish/series $\pm$ 7.44) and Chickamauga Lake (38.6 fish/series $\pm$ 5.47), whereas CPUE was highest during summer in Ft. Loudoun Lake (45.9 fish/series $\pm$ 12.09) (Figure 2). Channel Catfish represented 26.6% of the total catch of fishes in hoop nets. Most (62.0%) of the catch in hoop nets consisted of Bluegill *Lepomis macrochirus* and Redear Sunfish *L. megalotis*. Other species commonly of interest to managers were present only in low numbers (Spotted Bass *Micropterus punctulatus*, n=338; Largemouth Bass *M. salmoides*, n=2; Smallmouth Bass *M. dolomieu*, n=4; Black Crappie *Pomoxis nigromaculatus*, n=331; White Crappie *P. annularis*, n=93; Blue Catfish, n=306; Flathead Catfish *Pylodictis olivaris*, n=66; Walleye *Sander vitreus*, n=3). Mortality was low for Channel Catfish removed from hoop nets (<1%) and other fish species caught as bycatch (3.4%). Mortality of turtles in the bycatch (n=306) was 82.5%.

Channel Catfish lengths varied from 214 to 655 mm TL in Kentucky Lake, 227 to 673 mm TL in Chickamauga Lake, and 174 to 652 mm TL in Ft. Loudoun Lake (Figure 3). All length-frequency distributions were significantly different from one another (K-S test; $P<0.0001$). A greater proportion of quality and preferred size fish were sampled in Chickamauga Lake, whereas the Ft. Loudoun Lake population consisted primarily of stock-size individuals. Proportional size distribution (PSD) and PSD-P values were 52.7% and 0.8% for Kentucky Lake, 80.0% and 1.6% for Chickamauga Lake, and 43.1% and 0.3% for Ft. Loudoun Lake. No memorable or trophy sized Channel Catfish were sampled in any reservoir.

Multiple linear regression on the $\log_{10}$-weight: $\log_{10}$-length data produced the following relationship:

$$\text{Log}_{10}(\text{WT}) = -5.92 + 3.32\ \text{Log}_{10}(\text{TL}) + (\text{dummyKY})(0.03) + (\text{dummyFL})(-0.01)\ (r^2=0.9858),$$

where dummyKY = {0, when not Kentucky Lake

{1, when Kentucky Lake

dummyFL = {0, when not Ft. Loudoun Lake

{1, when Ft. Loudoun Lake

Slopes of $\log_{10}$-weight: $\log_{10}$-length relationships in each reservoir were similar (F=1.8237; df=2, 813; P=0.162) and all intercepts (elevations) differed from one another (F=18,890; df=3, 815; P<0.001). Biologically, this means that Channel Catfish in Kentucky Lake were 7.2% heavier on average than fish of a similar length in Chickamauga Lake, and 9.6% heavier on average than fish in Ft. Loudoun Lake. Additionally, variation in relative weights of Channel Catfish in each population mirrored the findings of linear regression modeling: fish were most robust in Kentucky Lake (mean Wr = 95.7), followed by Chickamauga Lake (91.0), and Ft. Loudoun Lake (87.5).

The range of ages of Channel Catfish were fairly similar in Kentucky Lake (2-12) and Chickamauga Lake (3-15); however, Channel Catfish were much older (3-21) in the commercially-unexploited Ft. Loudoun Lake population (Figure 4). The best von Bertalanffy growth model according to AIC model selection (Table 3) included unique L_∞ and K values for each lake, but a common t_o. Final von Bertalanffy models were as follows:

Kentucky Lake: $L_t = 759\ (1 - e^{-0.135\ [t - (-0.622)]})$

Chickamauga Lake: $L_t = 544\ (1 - e^{-0.227\ [t - (-0.622)]})$

Ft. Loudoun Lake: $L_t = 514\ (1 - e^{-0.163\ [t - (-0.622)]})$

Channel Catfish in Kentucky Lake and Chickamauga Lake achieved greater lengths and grew faster than Channel Catfish in Ft. Loudoun Lake, which grew slower but lived longer (Figure 5).

Channel Catfish experienced the highest mortality rate in Kentucky Lake and the lowest in Ft. Loudoun Lake. The youngest ages considered in the catch-curve analysis were age 5 in Kentucky Lake and Ft. Loudoun Lake and age 6 in Chickamauga Lake. Instantaneous mortality (Z) estimates from catch-curve analysis were 0.944 (Kentucky Lake), 0.313 (Chickamauga Lake), and 0.195 (Ft. Loudoun Lake) (Figure 6). Those estimates equated to interval annual mortality estimates of 61% for Kentucky Lake, 27% for Chickamauga Lake, and 18% for Ft. Loudoun Lake.

Information from the weight-length relationships and von Bertalanffy growth functions were used to model yield over three minimum length limits at varying levels of exploitation (Table 4). Conditional natural mortality (*cm*) estimates from FAMS estimators were 0.24, 0.29, and 0.24, for Kentucky Lake, Chickamauga Lake, and Ft. Loudoun Lake, respectively. In Kentucky Lake, with minimum length limits of 254 mm, 305 mm, and 356 mm, growth overfishing occurred when exploitation exceeded 26%, 35%, and 44%, respectively (Figure 7). At an exploitation rate of 35%, the 305 mm size limit boosted yields ~15% and the 356 mm size limit boosted yields ~25%. There was much less evidence of growth overfishing in Chickamauga Lake, where exploitation rates had to exceed 43% - 61% before yields declined with the 254 mm and 305 mm size limits. There was no evidence of growth overfishing with the 356 mm size limit and yields at the two highest size limits increased only marginally at intermediate levels of exploitation. There was even less evidence of growth overfishing in the Ft. Loudoun Lake population. Yields declined only when exploitation exceeded 44% under the “no size limit (254 mm)” regulation. For the two largest size limits, yields continued to increase with increasing exploitation.

Blue Catfish

Five hundred and eighty Blue Catfish were collected: 235 in Kentucky Lake, 108 in Chickamauga Lake, and 237 in Ft. Loudoun Lake. Total length varied from 123 to 1,122 mm in Kentucky Lake, 257 to 887 mm in Chickamauga Lake, and 206 to 1,008 mm in Ft. Loudoun Lake (Figure 8). Most Blue Catfish were captured using low-frequency electrofishing and trotlines (Figure 9). Mean CPUE for five-minute low-frequency electrofishing samples was 2.42 fish ($\pm$ 0.62) in Kentucky Lake and 2.20 fish ($\pm$ 0.63) in Chickamauga Lake. Ft. Loudoun Lake was not sampled until fall 2015 and no Blue Catfish were collected.

The slopes of $\log_{10}$-weight: $\log_{10}$-length relationships differed among populations (F=7.5355; df=2, 544; P < 0.001). Data were truncated to remove the smallest (<200 mm) and largest (>775 mm) individuals and slopes were tested again. After truncating the data, the slopes were similar ($F=1.9659$; $df=2, 484$; $P=0.141$) and all intercepts (elevations) differed from one another ($F=14,220$; $df=3, 486$; $P<0.001$). Multiple linear regression on the truncated $\log_{10}$-weight: $\log_{10}$-length data produced the following relationship:

$$\text{Log}_{10}(\text{WT}) = -6.16 + 3.41\ \text{Log}_{10}(\text{TL}) + (\text{dummyKY})(0.05) + (\text{dummyFL})(-0.04)$$

($r^2=0.9887$),

where dummyKY = {0, when not Kentucky Lake
{1, when Kentucky Lake

dummyFL = {0, when not Ft. Loudoun Lake
{1, when Ft. Loudoun Lake

Mirroring the trends for Channel Catfish, Blue Catfish in Kentucky Lake were 12.3% heavier on average than fish of a similar length in Chickamauga Lake, and 23.2% heavier on average than fish in Ft. Loudoun Lake.

Blue Catfish ages were similar in Kentucky Lake (1-17) and Chickamauga Lake (2-18), but they lived much longer in Ft. Loudoun Lake (range: 3 – 37) (Figure 10). The data used for von Bertalanffy growth modeling for Kentucky Lake produced an unreasonable value of L_∞. Instead, I solved for K and t_o while holding L_∞ constant at the value estimated by Holley et al. (2009; L_∞=1,303) in Wilson Lake on the Tennessee River in Alabama. The von Bertalanffy growth functions were as follows:

Kentucky Lake: $L_t = 1,303\ (1 - e^{-0.079\ [t - (-0.387)]})$

Chickamauga Lake: $L_t = 1,452\ (1 - e^{-0.051\ [t - (-1.405)]})$

Ft. Loudoun Lake: $L_t = 1,245\ (1 - e^{-0.034\ [t - (-2.191)]})$

Blue Catfish in Kentucky Lake and Chickamauga Lake grew much faster than in Ft. Loudoun Lake, although the latter population achieved much older ages (Figure 11).

Modeling the response of Blue Catfish to a change from the current regulation (one fish > 864 mm TL) to a new trophy regulation (no fish > 914 mm TL) resulted in primarily negative outcomes for both the Kentucky Lake and Chickamauga Lake populations. These outcomes were consistent across the three levels of natural mortality; therefore, the results presented herein are based on an average conditional natural mortality rate (*cm*) of 0.146 (Holley et al. 2009). In Kentucky Lake, if the current regulation only slightly reduces fishing mortality above the maximum size (i.e., anglers rarely catch a trophy fish), the number of fish longer than 914 mm (15+ years old) would increase only slightly (~1%) under the proposed new regulation. However, if the reduction in fishing mortality for fish longer than 864 mm TL is moderate, the number of fish in the population longer than 914 mm would be reduced approximately 17%. If the current regulation greatly reduces fishing mortality for trophy fish (i.e., anglers regularly catch more than one trophy fish per day), the number of large individuals in the population would be reduced by over 30% if the regulation was changed to a maximum (no-fish-over) size limit of 914 mm TL. In this latter scenario, subjecting fish between 864 and 914 mm TL to increased exploitation removes more fish from the population than the no-fish-over 914 mm TL regulation protects. In Chickamauga Lake, the number of individuals greater than 914 mm (~ 18+ years old) would be reduced in each scenario modeled. If the current regulation is slightly, moderately, or greatly effective at reducing fishing mortality of trophy fish, the proposed regulation would reduce the number of those fish in the population by approximately 14%, 25%, or 35%, respectively.

DISCUSSION

Historical Trends in Harvest

With an annual harvest of several hundred thousand kg, commercial harvest is an important component of Tennessee's catfish fisheries. Commercial fishing data can inform fisheries managers on aspects relating to the health of a fishery. Collecting consistent, species-specific long-term data on a fishery of such magnitude can provide valuable insight into population trends, and should be a priority if catfish fisheries are to remain a valued renewable resource. A decrease in recent years in the overall percentage of harvest reported as "Blue or Channel Catfish" suggests commercial anglers may be doing a better job of reporting catches on a species-specific basis; however, improving identification skills and ensuring proper reporting is important to collecting actionable data. Currently, the magnitude of "Blue or Channel Catfish" reportedly harvested could substantially alter the species-specific harvest conclusions.

Recreational catfish anglers have long been perceived as harvest-oriented. Recreational catfish harvest was similar to commercial harvest on a per-hectare basis in Kentucky Lake, but more than double the commercial harvest in Chickamauga Lake. On average, Channel Catfish and Blue Catfish harvested recreationally from Chickamauga Lake were larger than those harvested recreationally from Kentucky Lake. Harvest in both recreational fisheries was dominated by Blue Catfish. In Ft. Loudoun Lake, recreational harvest was relatively low. In recent years it has been shown that recreational catfish anglers likely favor the concept of managing for trophy fisheries (Arterburn et al. 2002; Stewart et al. 2012).

Channel Catfish

Recommendations regarding the best season for sampling with tandem hoop nets have varied in the literature. Based on studies from small impoundments in Missouri, Michaletz and Sullivan (2002) suggested sampling May-June for several reasons (e.g.., avoid stressing captured fish at high temperature and low D.O.; assess the fishery for the upcoming season) though no seasonal differences in CPUE were observed. Flammang and Schultz (2007) suggested summer sampling (July-August) based on a study of small impoundments in Iowa, listing greater precision of CPUE estimates and logistical concerns associated with staff availability as their primary reasoning. In the current study, Channel Catfish were effectively sampled using tandem hoop nets during all sampling seasons, though differences in CPUE were evident among reservoirs and seasons. Tandem hoop nets had the greatest utility (i.e., highest catches) during spring in Kentucky Lake and Chickamauga Lake, but caught the most fish during summer in Ft. Loudoun Lake.

Advantages of tandem hoop net sampling that have been highlighted in other studies are the low bycatch and low sampling-induced mortality (Sullivan and Gale 1999; Michaletz and Sullivan 2002; Flammang and Schultz 2007). Higher levels of bycatch were experienced in this study; however, sampling-induced mortality of catfishes was consistent with previous studies. Additionally, those previous studies found turtle mortality to be high, but of little concern when nets were set to avoid prime turtle habitat.

Previous studies suggested tandem hoop nets obtain representative samples for Channel Catfish above 250 mm (Michaletz and Sullivan 2002; Buckmeier and Schlechte 2009), but in those studies, there were no large fish collected when "known" populations were being sampled. In the present study, length-frequency distributions differed among systems. The Chickamauga Lake population consisted primarily of quality and preferred size fish, whereas the Ft. Loudoun Lake population consisted primarily of stock-size fish. The Kentucky Lake Channel Catfish population size structure was intermediate to what was observed in the other two reservoirs. A noteworthy observation is that no memorable or trophy size Channel Catfish were collected in any reservoir. It is unclear if the lack of memorable and trophy size fish was representative of the population or a product of gear bias.

Weight-length relationships provide valuable information about the health of a fishery. Across systems, Channel Catfish put on weight at a similar rate as they increased in length (i.e., weight-length relationships exhibited similar slopes). However, robustness at similar lengths differed in each system. Channel Catfish in Kentucky Lake were heaviest at a given length, while fish in Ft. Loudoun Lake were the lightest. Mean relative weight values provided further support for Channel Catfish being most robust in Kentucky Lake and least robust in Ft. Loudoun Lake. Differences in growth can be attributed to various biotic and abiotic factors or combinations thereof such as density-dependence, prey availability, trophic state, and temperature. Identifying the mechanisms leading to differences in robustness among the three populations was beyond the scope of this study; however, Kentucky Lake is the most eutrophic of the three reservoirs and being the lowermost reservoir in the Tennessee River system, it is likely the warmest.

Similar to what was observed for Blue Catfish by Stewart (2009), differences in Channel Catfish growth were observed among the three reservoirs in this study. Channel Catfish grew faster and reached greater lengths in Kentucky Lake and Chickamauga Lake, whereas fish in Ft. Loudoun Lake grew slower but lived longer. One objective of this study was to determine if growth differences were present, which they were, but the underlying mechanisms are not known. Such differences highlight the advantage of using site-specific regulations. However, simplicity of regulations often wins the favor of anglers. This study did not take into account potential differences in growth between riverine and lacustrine habitats or differentiate between sexes, though Marshall et al. (2009) found no sex-specific differences in age and growth structure in Lake Wilson, AL.

Channel Catfish experienced the highest level of instantaneous mortality in Kentucky Lake, which was triple the mortality in Chickamauga Lake and nearly five times the mortality in Ft. Loudoun Lake. Given the ban on commercial fishing in Ft. Loudoun Lake and the relatively small recreational fishery there, it is likely that total mortality in Ft. Loudoun Lake consists almost entirely of natural mortality.

Simulation modeling has been used extensively to determine the potential for growth overfishing and the capacity of regulations to ameliorate growth overfishing (e.g., Isermann et al. 2002; Slipke et al. 2002; Colvin et al. 2013; Eder et al. 2016; Stewart et al. 2016). Evidence of growth overfishing in Channel Catfish was apparent at moderate to high levels of exploitation in Kentucky Lake, whereas little evidence of growth overfishing existed for the Chickamauga Lake or Ft. Loudoun Lake populations. The yield plots suggested that minimum length limits could increase Channel Catfish yield and reduce the likelihood of growth overfishing in Kentucky Lake. Stewart et al. (2016) modeled 15 Channel Catfish populations and suggested that minimum length limits can effectively improve yield and reduce growth overfishing, and Pitlo (1997) reported a positive response to an increased minimum length limit in the upper Mississippi River.

Blue Catfish

Low-frequency electrofishing was far less effective than expected at capturing Blue Catfish. Environmental factors such as conductivity, temperature, substrate, depth, and flow contribute to the efficacy of low-frequency electrofishing. Previous studies have suggested that low-frequency electrofishing is most effective when temperature exceeds 18°C (Bodine and Shoup 2010). This method has been used effectively at much greater depths than high-frequency electrofishing. Because catfish do not elicit a typical response to electrofishing as seen with other fishes, an additional boat deemed a chase boat is often used in this type of sampling. Previous research on Flathead Catfish by

Cunningham (2004) and Daugherty and Sutton (2005) suggests the use of a chase boat has no significant impact on low-frequency electrofishing catch rates in low (0-0.3 m/s) or high (>0.6 m/s) water velocities. This observation, as well as the added expense and logistics associated with having an additional crew, justified not using a chase boat in the present study. Based on anecdotal evidence from my own field observations, a chase boat would not have improved the overall capture of Blue Catfish in this study. Sampling efficiency was low overall but there were occasions when this gear was quite effective; however, there were many more instances when this gear was ineffective. Blue Catfish were only captured in reasonable numbers from mid-April through mid-June. Furthermore, minimum sample sizes are important for accuracy and precision of size structure indices, but they assume that the sample is random and representative of the population (Anderson and Neumann 1996; Vokoun et al. 2001; Miranda 2007). Blue Catfish school in similar size-classes and cannot be sampled in a random and representative manner by a single or a few samples (Bodine et al. 2011). Rather, Bodine et al. (2011) suggested that sampling sites should be the primary sampling unit (instead of individual Blue Catfish) and they recommended sampling 10-20 sites with the capture of at least one fish per site. Because of low catch rates in the present study, additional fish for age-growth and robustness analyses had to be obtained from other gears. Additional study and further development of our knowledge regarding low-frequency electrofishing is necessary to determine its future utility for Blue Catfish sampling on large Tennessee River reservoirs.

Similar trends in weight-length relationship were exhibited among reservoirs by Blue Catfish (between 200 and 775 mm TL) and Channel Catfish (i.e., slopes were similar, but elevations differed). Blue Catfish in Kentucky Lake were the most robust whereas those in Ft. Loudoun Lake were the least robust. As with Channel Catfish, many factors or combinations of factors could potentially lead to the differences in weight-length relationship that was observed.

As with other population metrics discussed above, the Blue Catfish growth rates presented in this study showed patterns similar to those of Stewart's (2009). Blue Catfish grew faster and reached greater lengths in Kentucky Lake and Chickamauga Lake, whereas fish grew slower but lived much longer in Ft. Loudoun Lake. Stewart (2009) reported Blue Catfish as old as age 14 in Kentucky Lake and age 34 in Ft. Loudoun Lake. I observed Blue Catfish as old as age 17 in Kentucky Lake, age 18 in Chickamauga Lake, and age 37 in Ft. Loudoun Lake. Holley et al. (2009) reported a maximum age of 25 in Lake Wilson, Alabama.

The literature is replete with studies on the predicted effects of minimum size limits (e.g., Isermann et al. 2002; Slipke et al. 2002; Holley et al. 2009), harvest slot limits (e.g., Scarnecchia et al. 1989; Gwinn et al. 2015), and protected slot limits (Paukert et al. 2001; Eder et al. 2016) on fish population structure and yields. Although maximum size limits have been applied to some freshwater fisheries (e.g., Largemouth Bass; Carlson and Isermann 2010) studies of their efficacy are rare (Isermann and Paukert 2010). Even rarer still are reports on the response of fish populations to maximum size limits that allow anglers to harvest one or two fish over the maximum size, despite the fact that at least eight states in the U.S. manage some of their catfish fisheries with a "*one [or two] over the maximum size limit*" regulation. These regulations are basically an unevaluated compromise that are enacted to allow anglers to harvest a trophy fish. Some marine fisheries are also managed with a "*one-over-maximum size limit*" regulation (e.g., spotted seatrout *Cynoscion nebulosus*; Murphy et al. 2011) but as with the aforementioned catfish regulations, the reduction in fishing mortality for large fish managed with those "*one or two over*" regulations is unknown. Properly evaluating such regulations would require an extensive tagging study with an emphasis on differentiating between trophy and non-trophy fish exploitation, with all of the difficulties inherent in any reward tagging study, especially the problem of non-reporting (Denson et al. 2002; Pine et al. 2003). Additionally, a more thorough evaluation of Blue Catfish growth, with particular emphasis on sampling trophy size fish, would provide useful information. Nonetheless, modeling results presented herein suggest that changing the current trophy regulation (1 fish > 864 mm TL per day) to the proposed regulation (no fish > 914 mm TL) could substantially reduce the number of large (> 914 mm TL) Blue Catfish in the population under several scenarios. Stewart et al. (2016) suggested that length-based trophy regulations would not be effective in increasing the biomass of trophy catfish unless the length limit was drastically reduced.

MANAGEMENT IMPLICATIONS

Tandem hoop nets and low-frequency electrofishing have been reported as the best available methods for sampling Channel Catfish and Blue Catfish, respectively. Until now, however, these methods had not been evaluated in large reservoirs in Tennessee. The results of this study suggest that tandem hoop nets are an effective method for capturing large numbers of Channel Catfish with relatively little effort, and low sampling-induced mortality to target species or bycatch. Managers should consider tandem hoop nets a viable (or even preferred) method when monitoring Channel Catfish populations or conducting research on Channel Catfish in Tennessee reservoirs. On the other hand, low-frequency electrofishing was not nearly as effective as reported in other studies. On some sampling occasions, low-frequency electrofishing was highly effective; however, this method caught few (if any) fish on most occasions. This study suggests low-frequency electrofishing has potential to be an effective sampling tool, but that it's utility may be limited to a brief window of time between mid-April and mid-June. Without further research to explore alternative settings (e.g., pulse frequencies) or determine what environmental drivers influence utility of low-frequency electrofishing in Tennessee reservoirs, managers will likely need to consider alternate methods for sampling Blue Catfish.

The results presented herein clearly show the effects of commercial and recreational fishing on the age structure, mortality rate, and longevity of both catfish species in Tennessee reservoirs. Specifically, the age structures of both species were truncated in the two reservoirs open to commercial and recreational fishing (Kentucky Lake and Chickamauga Lake) relative to the commercially unfished (and lightly recreationally-fished) populations in Ft. Loudoun Lake. Faster growth in the two heavily-exploited Channel Catfish populations compensated for higher mortality and younger maximum ages, resulting in size structures that were reasonably comparable among reservoirs. Faster growth in the two heavily-exploited Channel Catfish populations also reduced or completely eliminated the likelihood of growth overfishing over a range of exploitation rates that might be encountered. Faster growth by Blue Catfish in the two heavily-exploited populations also resulted in size-distributions that were more similar among the three reservoirs than the age-distributions. In the absence of definitive information on exploitation rates of Channel Catfish, there is no compelling reason at the present time to implement any size limit regulations on those populations.

Much was unknown and many assumptions had to be made to simulate how trophy Blue Catfish abundance might change if the one-over-864 mm TL (34") daily size limit regulation was changed to none-over-914 mm (36"). Specifically, no information exists to describe how often commercial and recreational fishers encounter more than one trophy Blue Catfish during each day of fishing. This same uncertainty is faced by biologists managing catfish and other species elsewhere with similar *"one-or-two-over a maximum size limit*" regulations. What is known with certainty is the fact that changing the current regulation for Blue Catfish in Tennessee reservoirs to "*none-over-914 mm TL*" will subject Blue Catfish between 864 mm and 914 mm to unrestricted harvest for an additional ~ two years (i.e., the amount of time it will take a Blue Catfish to grow through that size interval). In simulations from this study, subjecting fish in that size (and age) interval to the full force of fishing mortality was not offset by prohibiting harvest of all fish longer than 914 mm TL and abundance of trophy fish declined under nearly all of the scenarios modeled. At the present time, and in the absence of any information that stocks of large Blue Catfish are declining statewide, changing the current regulation to "*none over 914 mm TL*" would appear to be counterproductive if the objective was to increase trophy fish abundance.

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Table 1. Blue Catfish parameters used for Dynamic Pool model.

Model Parameters	Kentucky Lake	Chickamauga Lake
Von Bertalanffy coefficients (L_∞; K; t_o)	1,303; 0.079; -0.387	1,452; 0.051; -1.405
Log_{10} weight:log_{10} length slope (b)	3.41	3.41
Log_{10} weight:log_{10} length intercept (a)	-6.11	-6.16
Maximum age	17	18
Average *cm*	0.146	0.146
cf	0.0-0.24	0.0-0.24

Table 2. Recreational harvest of Channel Catfish and Blue Catfish from 2008-2015.

Reservoir	Species	2008	2009	2010	2011	2012	2013	2014	2015	Mean kg	Mean kg/ha
Kentucky	Channel	62,802	61,752	34,512	142,613	106,202	87,787	65,492	57,379	77,317	1.19
	Blue	103,263	190,986	91,207	182,030	245,693	245,645	101,377	181,196	167,674	2.59
Chickamauga	Channel	44,315	28,643	42,353	5,727	17,052	.	15,878	54,353	29,760	2.03
	Blue	110,320	118,493	122,249	84,028	89,962	.	40,509	73,672	91,319	6.23
Ft. Loudoun	Channel	.	1,711	.	.	605	.	.	635	984	0.17
	Blue	.	7,161	.	.	3,060	.	.	22	3,414	0.58

Table 3. AIC model selection for Channel Catfish growth from spring 2015. Model names represent which von Bertalanffy parameters use unique values for each lake ([Omega] represents the use of common values across lakes; whereas, [L_∞, K, t_o] represents unique values of each parameter in each lake).

Model	k	AIC	Delta AIC
L_∞, K	8	17011.11	0
L_∞, K, t_o	10	17011.01	0.10
L_∞, t_o	8	17017.06	6.05
K, t_o	8	17038.07	27.06
L_∞	6	17058.67	47.66
K	6	17104.51	93.50
t_o	6	17367.05	356.04
Omega	4	17799.56	788.55

Table 4. Parameters used for Channel Catfish Yield per Recruit models in three Tennessee reservoirs.

Parameters	Kentucky	Chickamauga	Ft. Loudoun
Von Bert coefficients (L_∞; K; t_o)	759; 0.135; -0.622	544; 0.227; -0.622	514; 0.163; -0.622
Log_{10} weight:log_{10} length slope (b)	3.32095	3.32095	3.32095
Log_{10} weight:log_{10} length intercept (a)	-5.890203	-5.915501	-5.929588
Maximum age	12	15	21
cm	0.24	0.29	0.24
cf	0.1-0.8	0.1-0.8	0.1-0.8

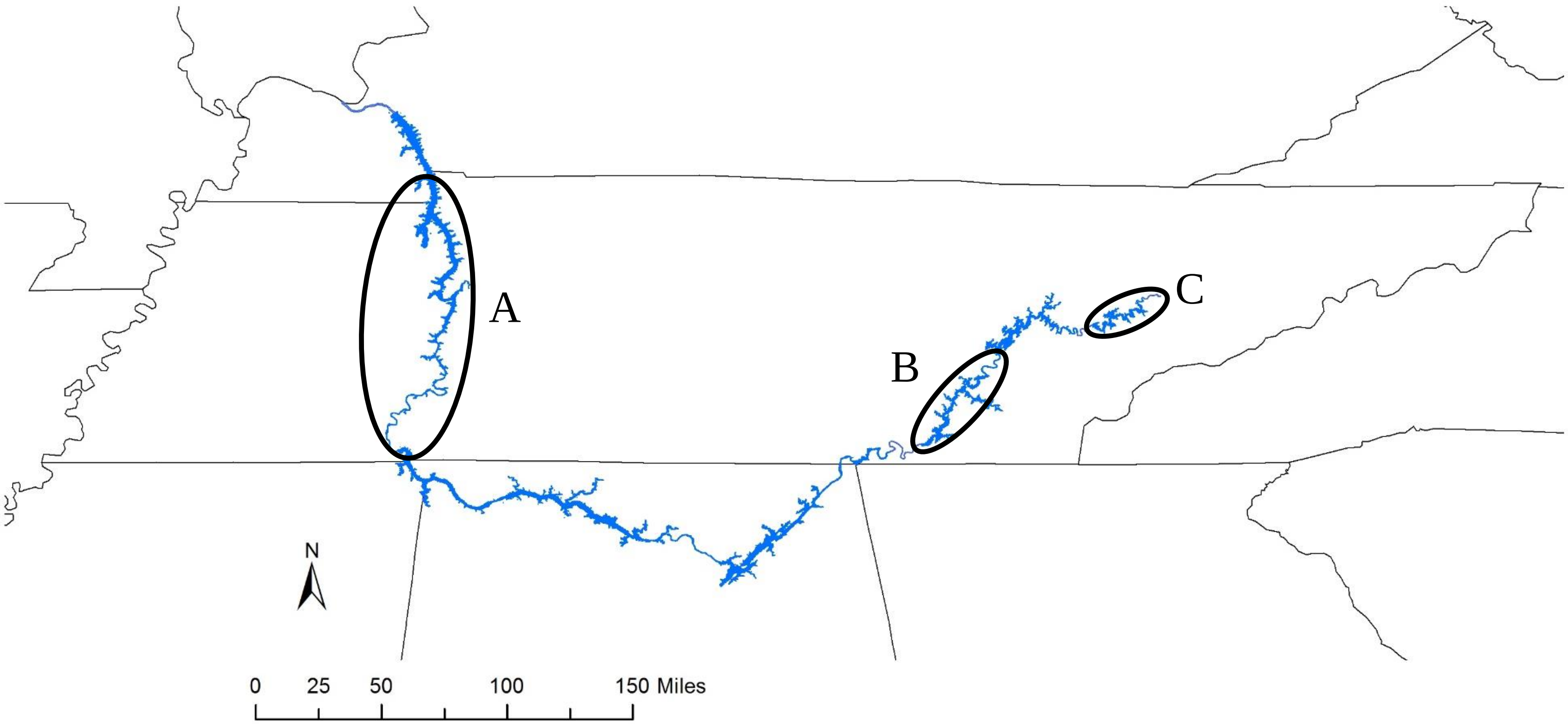

Figure 1. Map of the Tennessee River including three study reservoirs; Kentucky Lake (A), Chickamauga Lake (B), and Ft. Loudoun Lake (C)

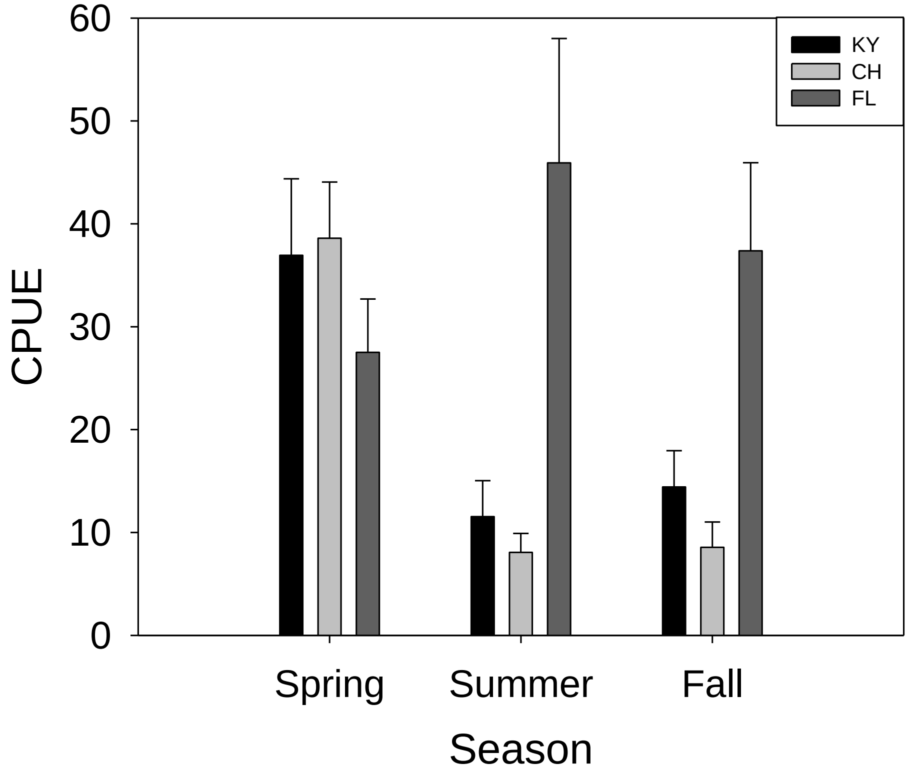

Figure 2. Seasonal catch per unit effort (number of fish/tandem series) of Channel Catfish using tandem hoop nets in Kentucky Lake (KY), Chickamauga Lake (CH), and Ft. Loudoun Lake (FL). Error bars represent one SE.

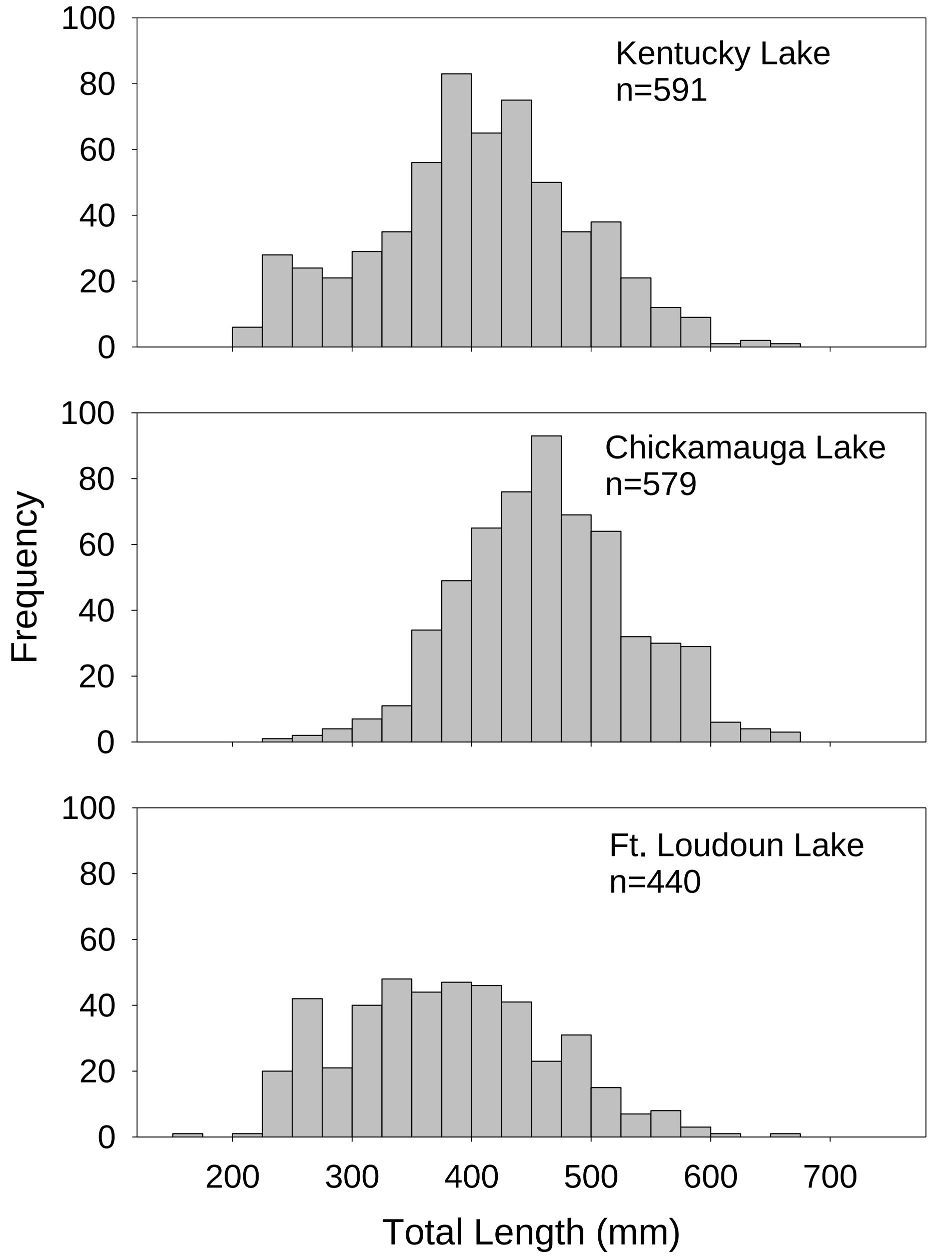

Figure 3. Channel Catfish length-frequency distributions from spring 2015 tandem hoop net sampling in three Tennessee reservoirs.

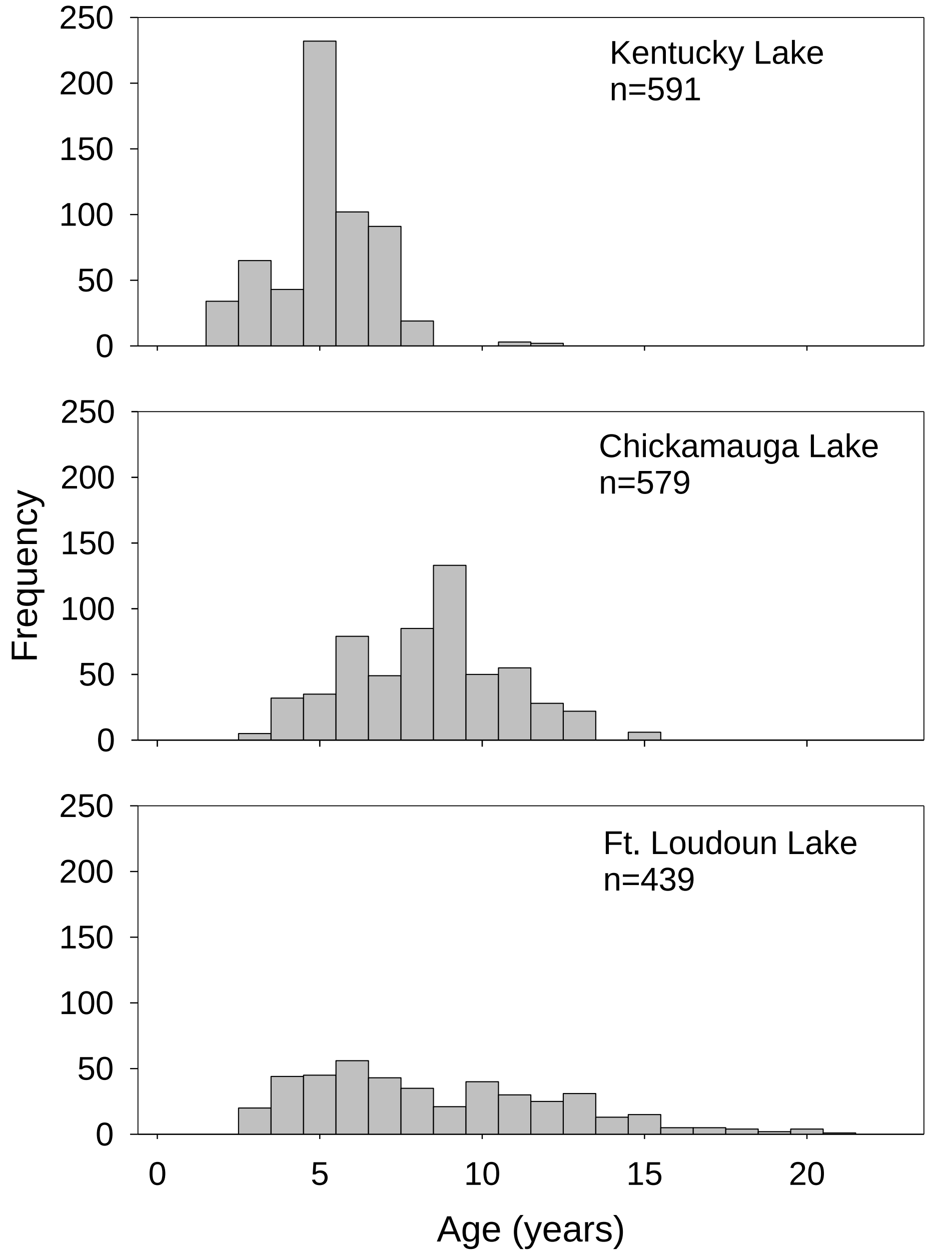

Figure 4. Channel Catfish age-frequency distributions from spring 2015 tandem hoop net sampling in three Tennessee reservoirs.

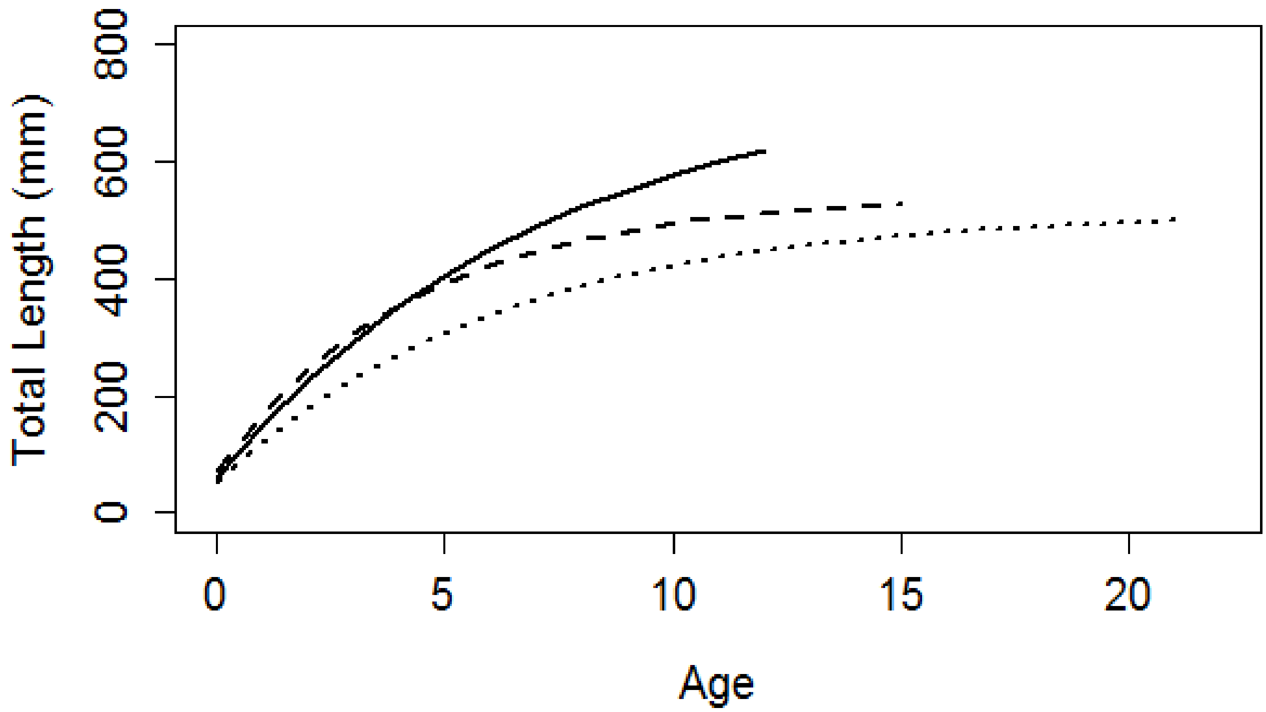

Figure 5. Von Bertalanffy growth curves for Channel Catfish in Kentucky Lake (solid line), Chickamauga Lake (dashed line), and Ft. Loudoun Lake (dotted line).

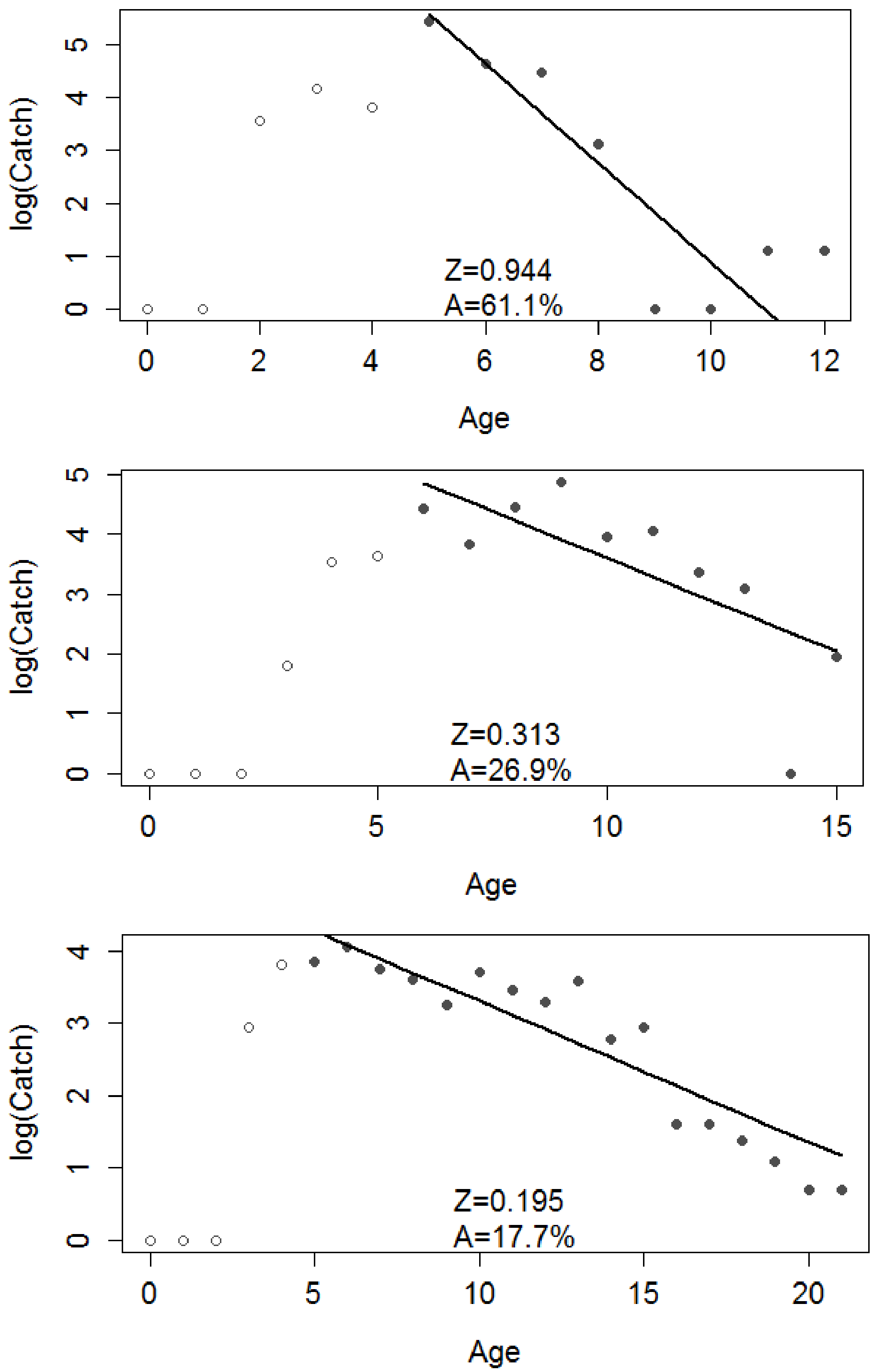

Figure 6. Natural logarithm of catch versus age for Channel Catfish in Kentucky Lake (top), Chickamauga Lake (middle), and Ft Loudoun Lake (bottom). Z is the instantaneous rate of mortality and A is the interval rate of mortality.

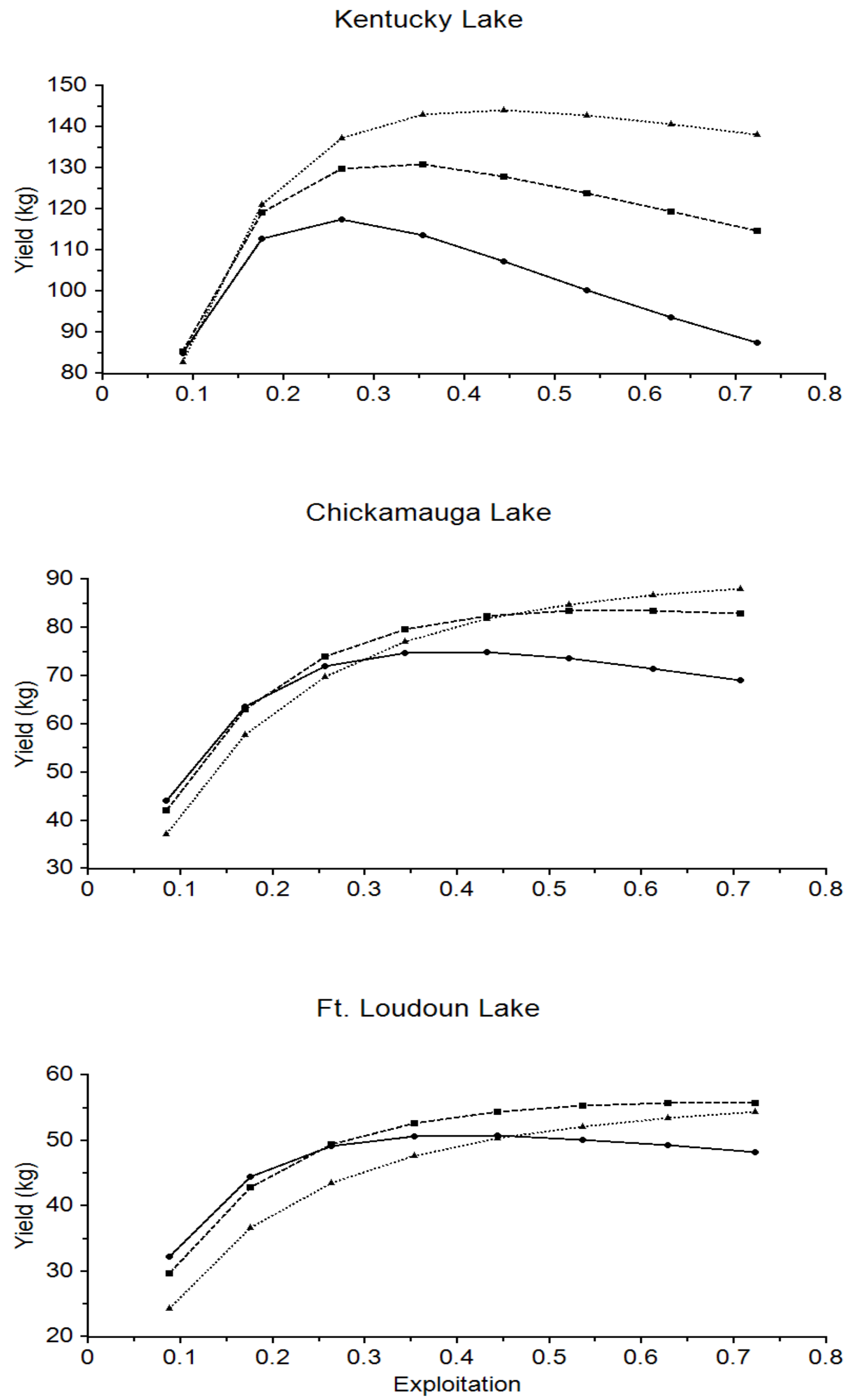

Figure 7. Yield plots for Channel Catfish in three Tennessee reservoirs based on 254 mm (solid line), 305 mm (dashed line), and 356 mm (dotted line) minimum size limits.

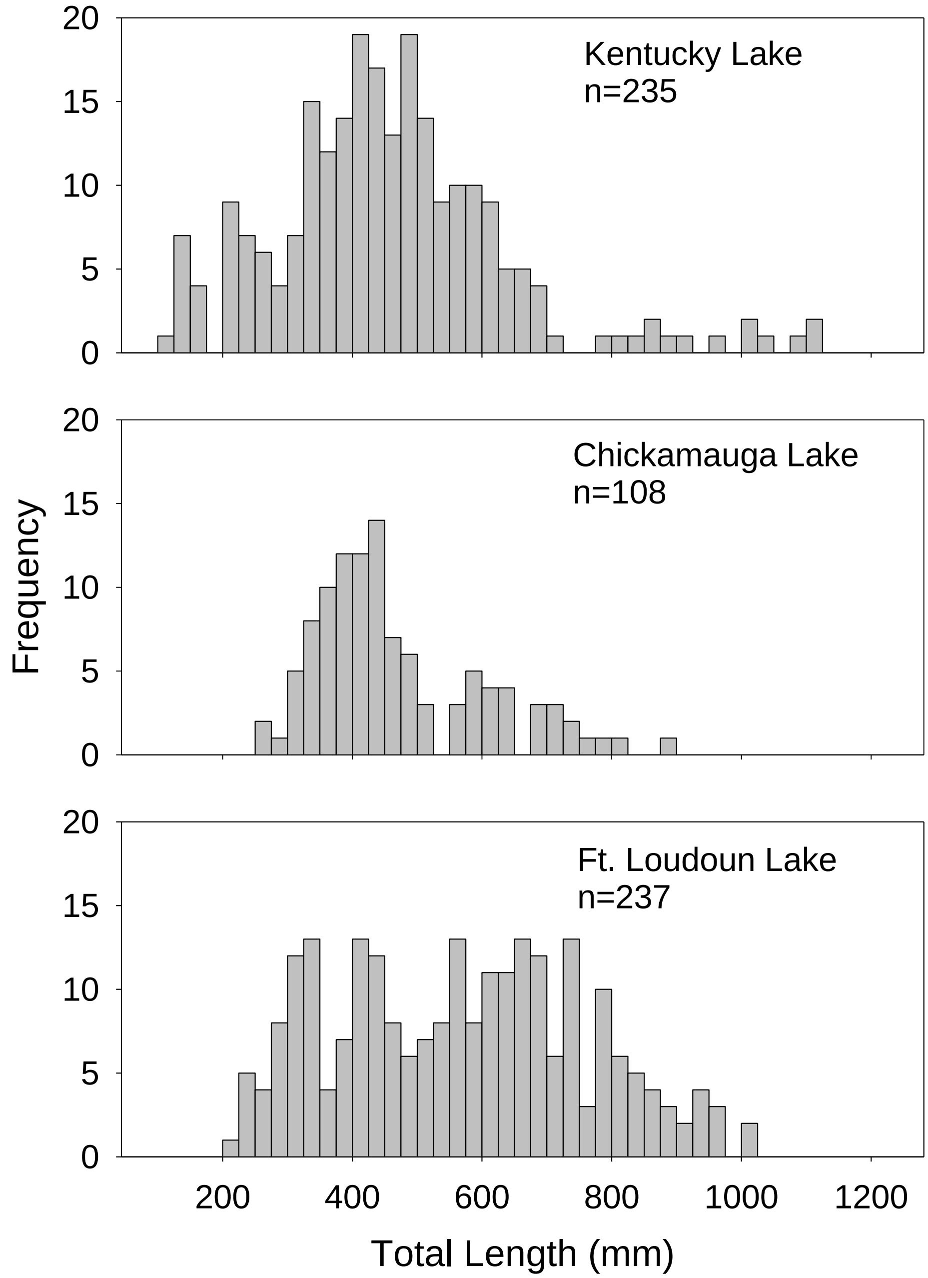

Figure 8. Blue Catfish length-frequency distributions in three Tennessee reservoirs using all gears.

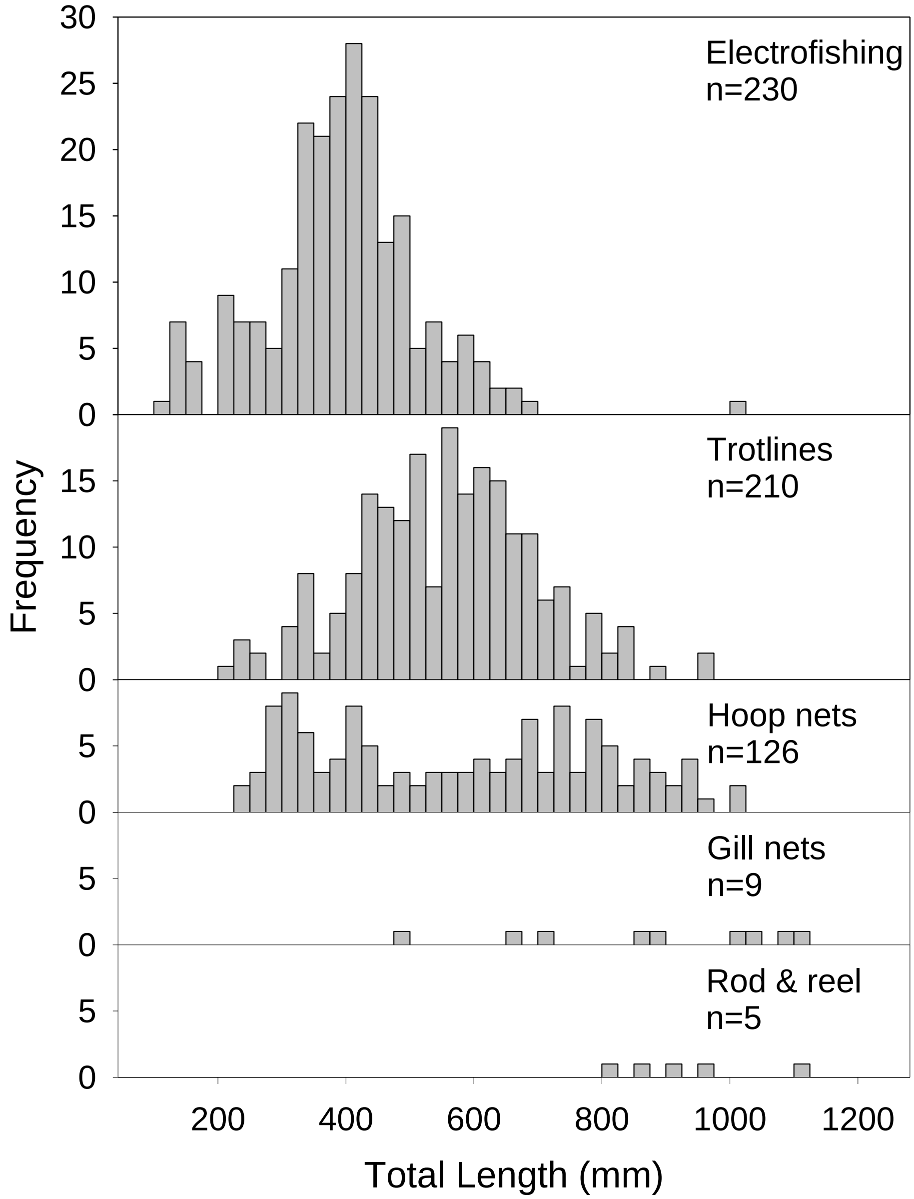

Figure 9. Gear-based Blue Catfish length-frequency distributions pooled over all three study reservoirs.

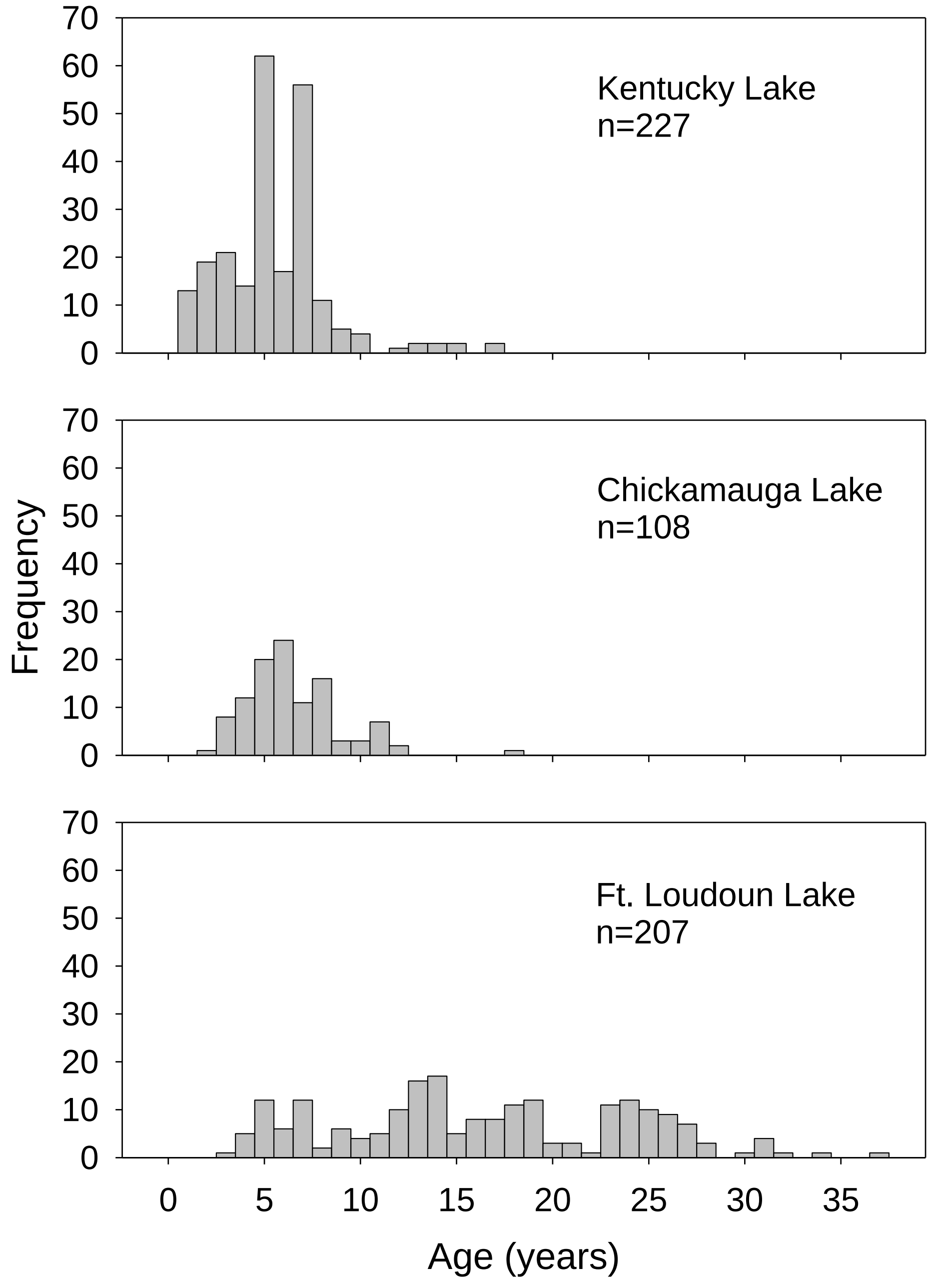

Figure 10. Blue Catfish age-frequency distributions for three Tennessee reservoirs.

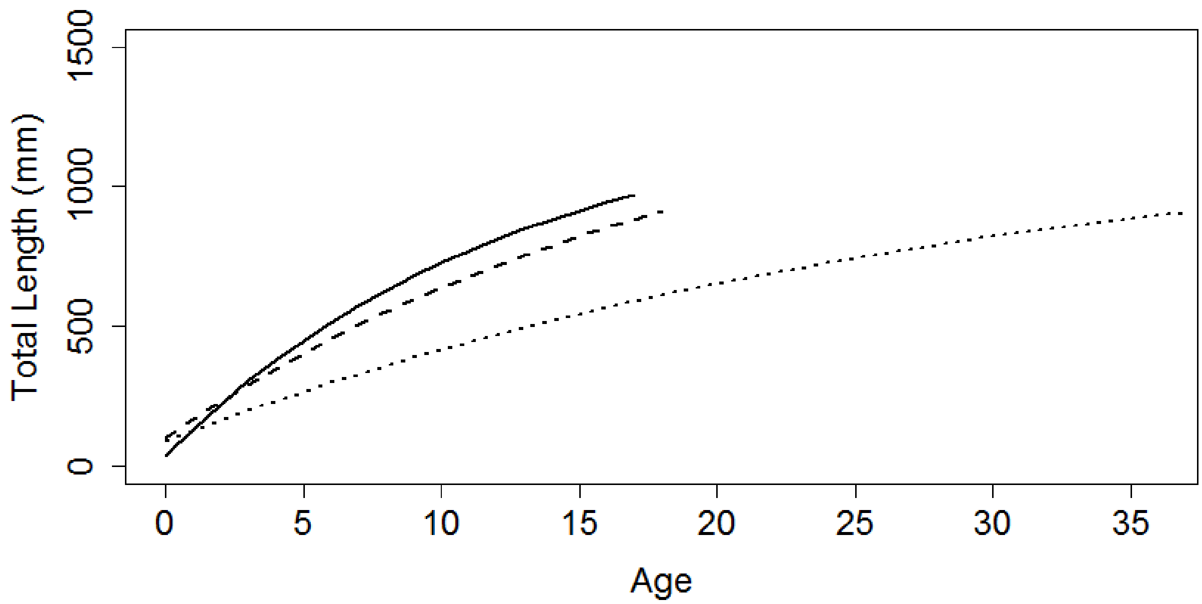

Figure 11. Von Bertalanffy growth curves for Blue Catfish in Kentucky Lake (solid line), Chickamauga Lake (dashed line), and Ft. Loudoun Lake (dotted line).

Cole Harty and Justin Spaulding retrieving a hoop-net in Chickamauga Lake. Photo credit: P.W. Bettoli