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Growth And Population Assessment Of Spotted Bass (Micropterus Punctulatus) In Beaver, Table Rock, And Bull Shoals Lakes, Northern Arkansas-Southern Missouri

Jeremy Troy Risley
Missouri State University

GROWTH AND POPULATION ASSESSMENT OF SPOTTED BASS (*MICROPTERUS PUNCTULATUS*) IN BEAVER, TABLE ROCK, AND BULL SHOALS LAKES, NORTHERN ARKANSAS-SOUTHERN MISSOURI

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Jeremy Troy Risley

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ABSTRACT

Little research has been conducted on spotted bass, *Micropterus punctulatus*, even though it is a popular recreational fish. Most previous research was on young-of-the-year fish and interactions among other species in reservoirs, with little research on adult spotted bass in the Ozarks region or other regions of the United States. The objective of this study was to compare the growth and population characteristics of spotted bass within and among Beaver, Bull Shoals and Table Rock Lakes. Growth, abundance, and conditions within and among reservoirs were similar. However, spotted bass in Beaver Lake did not reach as great lengths as those in the other reservoirs and the condition of the larger spotted bass was lower than all other sizes of spotted bass. Competition and overcrowding could be causing the slower growth of the older spotted bass in Beaver Lake. The current regulations for spotted bass for the three reservoirs appear to be working; however Table Rock Lake length limit could be reduced and Bull Shoals Lake length limit could be increased to 13 inches (330 mm) or 14 inches (356 mm).

KEYWORDS: spotted bass, *Micropterus punctulatus*, otolith, fish age, growth, population dynamics, Beaver Lake, Table Rock Lake, Bull Shoals Lake

This abstract is approved as to form and content

Dr. Daniel Beckman
Chairperson, Advisory Committee
Missouri State University

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Dr. Daniel Beckman

Dr. Chris Barnhart

Dr. John Havel

Dr. Frank Einhellig, Graduate College Dean

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INTRODUCTION

Why are growth and population structure of fishes important in reservoir fisheries science? These measures allow for quick and effective assessment of fish health and population production as well as effects of environmental, chemical and endogenous conditions affecting fish populations (Devrives and Frie 1995). Factors that regulate growth and population structure of fishes in reservoirs include prey availability, suitable habitat, water quality, water level fluctuations, population densities, interspecific competition, angler exploitation and management practices (Jenkins 1975; Devrives and Frie 1995). By understanding the factors affecting growth and population structures, fisheries managers can determine regulatory strategies to effectively manage or modify a fish population.

Sunfish make up the family Centrarchidae, consisting of eight genera with twenty-seven species. Native to North America, this family includes some of the most widely recognized species in the world, some of which are commonly used in physiological and ecological experiments (Robison and Buchanan 1988). Sunfish inhabit many types of water bodies, from lakes to streams to ponds and drainage ditches, and have been introduced to many areas of North America and other parts of the world for ecological, recreation and economic purposes (Robison and Buchanan 1988).

The spotted bass, *Micropterus punctulatus,* is one of the centrarchids targeted by recreational fishermen. It is congeneric with largemouth and smallmouth bass and a few less common species. Spotted bass are characterized as large, slender, elongate olive-green colored bass with the upper jaw reaching to or slightly behind the rear margin of the eye (Robison and Buchanan 1988). Their native range extends farther south than

smallmouth bass but not as far north as either smallmouth or largemouth bass (Vogele 1975). Spotted, largemouth and smallmouth bass can occur together in a water body (Fisher et al. 2000, Long and Fisher 2005). Spotted bass are able to hybridize with smallmouth bass (hybrids are often referred to as "mean mouth") when one is introduced into the native range of the other (Pierce and Van Den Avyle 1997). Reservoirs and streams in the Arkansas, Ohio, Tennessee, and White River are the only systems where the native ranges of spotted, largemouth and smallmouth bass overlap (Janssen 1992).

Spotted bass are primarily found in moderate or larger streams and rivers, but also have adapted to reservoirs (Vogele 1975, McMahon et al. 1984, Robison and Buchanan 1988, Janssen 1992). Spotted bass have a high degree of ecological and habitat segregation from largemouth bass and smallmouth bass due to different habitat preferences, thus limiting competition among species (Robison and Buchanan 1988, Buynak et al. 1989, Janssen 1992, Scott and Angermeier 1998, Long and Fisher 2005). Spotted bass typically favor habitats intermediate to those favored by smallmouth and largemouth bass. However, habitat is not as important to spotted bass as for the other bass species (McMahon et al. 1984, Buynak et al. 1989, Janssen 1992, Scott and Angermeier 1998, Long and Fisher 2005).

In streams, spotted bass are found in areas of clear to turbid waters with permanent, moderate flow, unvegetated, deep pools and rocky substrate (Howland 1931, Janssen 1992). In reservoirs, the factors determining suitable habitat for spotted bass are substrate type, turbidity, fertility, and water depth (McMahon et al. 1984). Spotted bass prefer areas of rocky substrates, steeply sloping shorelines, or main channel areas and tend to avoid areas of emergent vegetation and mud bottoms (Vogele 1975, Scott and

Angermeier 1998). Spotted bass can inhabit deep, open water areas and are more pelagic than largemouth bass in reservoirs (Webb and Reeves 1975). In reservoirs containing riverine and impounded sections, spotted bass are typically more abundant in the impounded section. In the riverine section of the reservoir, spotted bass will inhabit areas near the shoreline which feature fine substrate containing woody debris or overhanging vegetation (Scott and Angermeir 1998). Sammons and Bettoli (1999) suggested spotted bass might be less sedentary than largemouth or smallmouth bass.

Spotted bass appear to be more selective feeders than the other black bass species and their diets are highly variable from year to year, among strata of the lake, and throughout the year (Aggus 1973, Novinger 1988). Young spotted bass (0-51 mm) feed on zooplankton (cladocerans) and aquatic insects (Applegate et al. 1967, Janssen 1992). Juvenile spotted bass (51 -201 mm) feed on terrestrial and aquatic insects, crayfish, and fish such as young-of-the-year largemouth bass, shad and bluegill (Applegate et al. 1967, Mullan and Applegate 1967, Novinger 1988, Matthews et al. 1992, Long and Fisher 2000). As adults (> 201 mm), spotted bass predominantly feed on crayfish and fish such as shad (*Dorosoma* spp.) (Aggus 1973, Janssen 1992, Long and Fisher 2000).

Spotted bass tend to grow slower than largemouth bass and slower than or similar to smallmouth bass (Vogele 1975, DiCenzo et al. 1995). The maximum age for northern spotted bass has been reported at 7 years, but can vary among locations (Vogele 1975, Carlander 1977). Dicenzo et al. (1995) found the Alabama subspecies of spotted bass can live up to 11 year old. The world record spotted bass, caught in California, was ten pounds, four ounces (4.65 kg). Spotted bass become mature after one or two years and spawn at two or three years of age. Typically, growth is greater in large reservoirs than in

small impoundments and streams (Vogele 1975, Robison and Buchanan 1988); however, Tillma and Guy (1998) found no significant difference in spotted bass growth between Kansas streams and reservoirs. Spotted bass were not reported to exhibit gender specific growth differences by Olmsted and Kilambi (1978), unlike other black bass species such as largemouth bass or Suwannee Bass (Schramm and Smith 1988, Bonvechio et al. 2005). DiCenzo et al. (1995) found the Alabama subspecies of spotted bass grew larger and older then the northern subspecies. They reported catching spotted bass over 500 mm length. Growth of spotted bass are correlated with mean depth, drainage area, age of reservoir, total dissolved solids, high alkalinity, conductivity and chlorophyll-a, low Secchi-depth and elevation, and stable water condition (Jenkins 1975, DiCenzo et al. 1995). Relative weights of spotted bass are positively correlated with drainage area, chlorophyll-a, alkalinity, and conductivity and a negatively correlated with secchi-depth (DiCenzo et al. 1995).

Spotted bass abundance and growth are related to the trophic state of the reservoir (DiCenzo et al. 1995). Spotted bass are more abundant and have better growth in oligotrophic or mesotrophic conditions; largemouth bass populations are more abundant in eutrophic conditions and smallmouth bass are more abundant in oligotrophic conditions (McMahon et al. 1984, Bowman 1993, Buynak 1996); however, Buynak (1996) could not find any increase in abundance of spotted bass and nutrient levels. Maceina et al. (1996) found spotted bass grew faster and had better body condition in eutrophic reservoirs (chlorophyll-a ≥ 8 mg/m^3) than in oligo-mesotrophic reservoirs (chlorophyll-a ≤ 7 mg/m^3); however, they could not infer relationship between increasing algae biomass and spotted bass growth and condition due to small sample size.

Recruitment of spotted bass has been widely studied, but it is still difficult to predict strong year classes. Studies conducted to correlate spotted bass recruitment with variables such as reservoir hydrology, timing of the spawning season, predator abundance or water levels have had little to no success (Novinger 1988, Sammons et al 1999, Sammons and Bettoli 2000). Ploskey et al. (1996) and Reinert et al. (1997) found the biomass of age-0 spotted bass was correlated with increase in reservoir surface area during spring and summer. Sammons and Bettoli (2000) stated that the finding of Ploskey et al. (1996) makes it difficult to determine effects of hydrology on the recruitment of spotted bass.

Oligotrophication (reduction in nutrients load) could be beneficial to spotted bass by increasing spotted bass recruitment and decreasing largemouth bass recruitment, resulting in a shift in species dominance from largemouth to spotted bass in some reservoirs (Buynak et. al. 1989, Greene and Maceina 2000, Maceina and Bayne 2001). Greene and Maceina (2000) found age-0 spotted bass were more abundant and grew faster than largemouth bass in the oligo-mesotrphic parts of the reservoirs showing that behavioral adaptations to clear water and rocky substrate could be the reason spotted bass were more successful in the less productive areas then largemouth bass.

Annual ring deposition in otoliths has been verified for largemouth bass (Taubert and Tranquilli 1982, Long and Fisher 2001, Buckmeier and Howells 2003) and smallmouth bass (Heidinger and Clodfelter 1987, Long and Fisher 2001) but no validation has been performed for spotted bass except for daily ring deposition in age-0 fish (DiCenzo and Bettoli 1995). Annual ring formation in spotted bass scales has been

verified up to age three through increment analysis (Olmsted and Kilambi 1978, Long and Fisher 2001).

Study Site

Beaver, Table Rock, and Bull Shoals Lake are U.S. Army Corp of Engineers reservoirs impounded for multipurpose uses such as flood control, water supply, and hydropower (Haggard and Green 2002, Galloway and Green 2003, Green et. al. 2003). These dendritic, highland reservoirs are located in the upper White River system (Figure 1).

Beaver Lake is a 80 km long reservoir impounded in 1963 (Haggard and Green 2002) (Table 1). The upper end of the lake is eutrophic, the middle part is mesotrophic and the lower end of the lake is oligotrophic (Bowman 1993). Water visibility can vary from 0-3 m in the tributary arms to 3-6 m near the dam. The official lake record spotted bass is five pounds five ounces (2.4 kg).

Table Rock Lake is a 96 km long reservoir impounded in 1958 (Green et. al. 2003) (Table 1). The reservoir has four major regions: the James River Arm, the Kings River Arm, the White River, and the Long Creek Arm. The James River arm is eutrophic to mesotrophic. Multiple sources of nutrient loading results in high productivity in the James River Arm; however successful efforts have been made to reduce the amount of nutrient loading, especially phosphorus, entering the James River (LMVP 2005). The Kings River Arm has high productivity due to nutrient loading from the nearby poultry farms. The Kings River is eutrophic (LMVP 2002, LMVP 2005). These arms can have strong year classes of bass when other areas have poor year classes (personal

communication, Bill Anderson, Missouri Department of Conservation, 2003). The rest of the lake is mesotrophic. The Long Creek arm is heavily forested and does not contain any major human population centers (Michaletz 1998). Water visibility varies from 0.5-2.5 m in the Kings River and James River Arms to 2.5-5.5 m in the White River and Long Creek Arms (LMVP 2002, LMVP 2005). Table Rock Lake produced the Missouri state record spotted bass of seven pounds eight ounces (3.4 kg).

Lake Taneycomo is located between Table Rock Lake and Bull Shoals Lake. This small riverine impoundment is 32 km long and was constructed in 1913 (Mullan and Applegate 1966, Weiland and Hayward 1997). Since this coldwater impoundment is managed as a tailwater trout fishery for much of its length and has a limited spotted bass population, it was not included in this study.

Bull Shoals Lake is a 130 km long reservoir impounded in 1951 (Galloway and Green 2003) (Table 1). Bull Shoals Lake has three major creek arms: White River, Big Creek Arm and Little North Fork Arm (Theodosia Arm). The upper White River and Big Creek Arm are mesotrophic (Havel and Pattinson 2004, LMVP 2005). The Theodosia Arm ranges from eutrophic to mesotrophic (LMVP 2005). The mid to lower end of the lake is oligotrophic (Havel and Pattinson 2004). Bull Shoals Lake receives most of its nutrients from upstream reservoirs. Water visibility can vary from 1.5->12 m during the year (Havel and Patterson 2004). Due to the high fluctuation of water levels (as much as 9 m in a year), Bull Shoals' fish populations experience "boom or bust" year-class production (Ploskey et. al. 1985) (Figure 2). The current Arkansas state record spotted bass was taken from Bull Shoals Lake and weighed seven pounds fifteen ounces (3.60 kg).

The minimum length limit on spotted bass is 12 inches (305 mm) in Beaver and Bull Shoals Lake and 15 inches (381 mm) in Table Rock Lake. There is a 6 fish daily possession limit on spotted bass for these lakes.

Study Objective

Objectives of this study included determining if there are differences in the abundance, growth, size structure, condition, mortality and recruitment of spotted bass within and among Beaver Lake, Bull Shoals Lake and Table Rock Lake, gather and analyze historical data collected on spotted bass by the Arkansas Game and Fish Commission and Missouri Department of Conservation, and model the spotted bass populations to evaluate the current regulations in each reservoir.

METHODS

Spotted Bass Collection

Sampling was carried out from October through November, 2004, using electrofishing. Samples were conducted after the water temperature fell below 70°F (21.1°C) to follow the Arkansas Game and Fish Commission sampling protocol. The lakes were broken into three sections: upper, middle and lower, including major tributaries. There were three samples conducted on Beaver Lake, four samples on Table Rock Lake, and five samples (with one site sampled twice due to low numbers captured during the first night) on Bull Shoals Lake (Figures 3-4). Beaver and Bull Shoals Lakes samples were collected while assisting the Fisheries Biologists during their annual bass population samples. Graduate students, faculty and I conducted the Table Rock Lake samples following the same procedures used by the Arkansas Game and Fish Commission. These sample sites were selected with the advice of the Fisheries Biologist for Table Rock Lake.

The samples were conducted with flat bottom aluminum electrofishing boats using a 220-volt generator and a commercial-made variable voltage pulsator to produce pulsed direct current; two booms were configured as the anodes and the aluminum hull as the cathode. Samples were conducted using either 60 or 120 pulse per second pulsed-DC outputs at 500 volts. The electrical current ranged from 5-6 amps, which was measured by the electrofisher. During each sample night, a minimum of three 30-minute runs was conducted with pedal time recorded in seconds for each run but converted to hours for convenience. Pedal time is the amount of time the electrofishing boat is actually shocking.

Catch Per Effort Analysis

Catch per unit of effort (CPUE) is used in fisheries for surveying and monitoring fish populations over time. CPUE was quantified as the number of spotted bass caught / hours of electrofishing pedal time. CPUE was calculated for each section as an index of abundance for use in comparisons among sections. CPUE and coefficient of variation (CV=100*Standard deviation/mean) was determined for each section and sample lake.

CPUE was $\log_{10}$-transformed ($\log_{10} n + 1$) and compared among sections for each lake and among sample lakes using a one-way analysis of variance (ANOVA; Procedure GLM; SAS Institute 2004, Bonvechio et al 2005, Long and Fisher 2005). If significance was determined least squares means LSMEANS was used to test for differences among sample sites (SAS Institute 2004, Bonvechio et al 2005, Long and Fisher 2005). Test for differences in CPUE of spotted bass ≤ 180 mm, ≥ 180 mm, ≥ 280 mm, and ≥ 350 mm were conducted among sections and sample lakes. The same analysis was conducted to assess differences in historical CPUE among sections, lakes and years (Long and Fisher 2005).

For tests conducted in this study, I considered $\alpha = 0.05$ to be significant.

Historical Electrofishing Data

Electrofishing data was collected from the Arkansas Game and Fish Commission (AGFC) and Missouri Department of Conservation (MDC) during annual electrofishing sampling from 1987-2003. Data on individual fish were used for the Beaver and Bull Shoals Lake and length frequency distribution data from annual reports were used for Table Rock Lake. Since the historical electrofishing data were collected in the spring, no

statistical test was conducted on differences between my data and the historical data. Since a small portion of Bull Shoals Lake is in Missouri, the sections are different then the areas I collected in. The AGFC upper sample area will be considered in the middle section of the lake for this project. In the test for differences in CPUE among sections, I left it the same as the AGFC and also combined the areas to compare to my data (the AGFC considers West Sugarloaf, the upper area and I consider it the middle section for my project).

Processing of Fish

A random sample of spotted bass was collected for each section. Spotted bass were also collected from a fishing tournament conducted during the sampling period on Bull Shoals Lake to obtain larger fish, than captured in the electrofishing samples. Only total length, to the nearest millimeter (± 1 mm), was recorded due to time restraints. The fish were placed into coolers and transported to the lab for processing. The next day, the weight, to the nearest gram (± 1 g), and the sex of the fish were recorded for each bass. The sex of the fish was recorded as male, female, or immature (if the reproductive organs were not fully developed).

Processing of Otoliths

All fish captured were aged using otoliths. The methods for preparation otoliths were described fully by Thompson and Beckman (1995). Sagittal otoliths were dissected from the inner ear chamber by cutting through the isthmus. Once the bulla potion of the prootic bone was located, all the tissue and skin was removed and the bulla was scored

using wire cutters. Bending the head backwards cracked the bulla, which exposed the otoliths (Secor et. al 1991).

A small amount of EmBed-812 polymer (Electron Microscopy Sciences) was placed into clear silicone rubber embedding molds and baked in a Cole-Parmer oven at 60°C for 24 hours in preparation for embedding. The otoliths were placed sulcus down (to reduce trapped air bubbles) into the half-filled clear silicone rubber embedding molds, and EmBed-812 polymer was added to fill the molds. The otoliths were allowed to remain in the polymer for five to ten minutes at room temperature to allow all the air bubbles to rise to the top of the mold for removal; then the molds were baked for 24 hours. Embedded otoliths were removed from the oven, allowed to cool down, and were sliced into sections using a Struers Minitom diamond-tipped low-speed saw.

The sectioned otoliths were placed into a pool of glycerol on a dissecting microscope and examined at 20-40X magnification. A light beam was reflected through the sectioned otolith at different angle until the annuli appeared. The opaque rings were counted and recorded for each fish.

Some otoliths were not embedded and sectioned, but instead were broken at the core using tweezers. Once broken, the otolith was placed on a putty mound and a drop of glycerol was placed on the otolith. A light beam was reflected through the otolith and the opaque rings were counted.

Growth Analysis

Growth is one of the major factors affecting a fish population and is used to set length limits and other regulations. For this study, I assume spotted bass form annuli on

an annual basis and all fish were considered to have an annulus at the edge of the otolith starting January 1 (Olmsted and Kilambi 1978, Long and Fisher 2001). Because spotted bass were collected in the fall, 0.5 was added to the age of each fish to account for 6 months of growth (Example: the mean total length at age 3++ would be entered as 3.5 to account for the 6 months of growth before captured) (Fiss et al. 2001). An experienced reader examined a random sub-sample of aged otoliths to verify accuracy of age estimates.

Growth rates of spotted bass were modeled using the von Bertalanffy growth equation. The von Bertalanffy growth model can be used to predict the length of a fish as a function of its age (von Bertalanffy 1938, Haddon 2001). The equation used is: $L_t=L_\infty [1-e^{-k(t-to)}]$ where L_t is length at age t in years, L_∞ is the asymptotic length, k is a growth coefficient of catabolism, and t_0 is the age at which the length would theoretically be zero (Olmsted and Kilambi 1978). Von Bertalanffy growth curves were constructed for each section, lake, and gender using mean length-at-age. Von Bertalanffy growth models were constructed using Marquardt Method (Procedure NLIN; SAS Institute 2004).

Differences in growth rates among sections, lakes, and genders were determined using two methods. The first method was using analysis of covariance (ANCOVA), to relate total length to log_{10}-transformed age (Lovell and Maceina 2002, SAS Institute 2004). Only age was log_{10}-transformed, because the relationship between length and age exhibited a non-linear shape. Differences in slope indicated growth differences and differences in elevation indicate growth differences were maintained to the oldest ages tested (Lovell and Maceina 2002). If differences between either the slope or y-intercept of the growth equations were significant, student t-tests were used to determine

differences in length at age using all individuals. Because pairwise length at age comparisons lacks independence, alpha levels were adjusted using Bonferroni correction (Lovell and Maceina 2002). This method only tests for differences in growth rates but does not test for differences in von Bertalanffy growth curves. Because the von Bertalanffy growth curve is non-linear, analysis of residual sum of squares was used to determine differences in growth curves among sections, lakes, and genders (Beckman et. al 1991, Haddon 2001). This method compares a full model in which two sample sections, lakes or genders were modeled separately to a reduced model in which the sections, lakes or genders were grouped together (Procedure NLIN; Beckman et. al 1991, SAS Institute 2004). If significant differences were detected, a test for differences in the von Bertalanffy parameters (L_{∞}, k, t_0) was conducted (Procedure NLMIXED; SAS Institute 2004, Isely and Grabowski in press).

Using the von Bertalanffy growth parameters, the predicted times to reach 12 inches (304.8 mm), 13 inches (330.2 mm), 14 inches (355.6 mm) and 15 inches (381 mm) were calculated to determine the amount of time to reach the current minimum length regulations and possible other length regulations found in either state.

Age frequency distributions were constructed for each lake. Kolmogorov-Smirnov test (KS) non-parametric two-sample test was used to test for differences in age-frequency distributions among lakes even though all assumptions are not met for this test (Procedure NPAR1WAY; SAS Institute 2004, Neumann and Allen in press).

Size Structure Analysis

Size structure of spotted bass from each lake was described by constructing relative frequency distributions and calculating stock density indices.

Relative frequency distribution is the percentage of catch occupied by a certain length group in a sample and is useful when comparing samples that have different sample sizes due to different sampling effort (Neumann and Allen in press). Relative length frequencies were constructed for each lake and compared among lakes using Chi-square and KS non-parametric tests (Procedure NPAR1WAY; SAS Institute 2004, Neumann and Allan in press). For these tests, there are two assumptions: all samples are random and they are independent (Neumann and Allan in press). Neumann and Allan (in press) explain that, for practical purposes, these two assumptions are hardly met, but that the test can still be used for this type of study. In this study, independence is met due to different lakes, but randomness most likely isn't met due to sampling gear (Neumann and Allan in press). Tests for differences were only conducted on samples collected in this study and not compared to past data, due to the difference in sampling season and seasonal change in size structure.

Using the historical electrofishing data, length frequencies were constructed and compared among lakes using KS test (Procedure NPAR1WAY; SAS Institute 2004, Neumann and Allan in press).

Proportional stock density (PSD) and relative stock density (RSD) are quantitative descriptors of length frequency analysis to assess balance within a fish population (Anderson and Neumann 1996, Devries and Frie 1996, Slipke and Maceina 2001). PSD for spotted bass is the number of bass $\geq$ quality length/ number of bass $\geq$ stock length

*100 (Anderson and Neumann 1996, Devries and Frie 1996). The desirable PSD range for spotted bass is from 30-60 (Ney 1999). RSD for spotted bass, is the number of bass ≥ preferred length/ number of bass ≥ stock length *100 (Anderson and Neumann 1996, Devries and Frie 1996). The desirable RSD range for spotted bass is 0-10. (Ney 1999). PSD and RSD were computed for each section and lake and were compared among lakes. Confidence intervals (95%) were calculated for each section using methods described by Gustafson (1988). Stock, quality, preferred, and memorable lengths for spotted bass are defined as fish ≥ 180, 280, 350 and 430 mm TL, respectively (Table 2) (Anderson and Neumann 1996).

Incremental RSD is the percentage of individuals between the minimum lengths for a specified size group larger than stock size. Incremental RSD is calculated by the number of spotted bass in between two given length classes / number of bass ≥ stock length. RSD stock-quality (S-Q), RSD quality-preferred (Q-P), RSD preferred-memorable (P-M) and RSD memorable-trophy (M-T) were computed for each section and lake and were compared among lakes (Anderson and Neumann 1996). For example, the RSD Q-P incremental stock density is number of fish from 280-349.9 mm / number of fish ≥ 180 mm (Anderson and Neumann 1996). Chi-square test was used to determine differences among stock density indices (Procedure FREQ; SAS Institute 2004, Neumann and Allan in press).

Condition Analysis

Length-weight regression models were produced by using the transformed equation: log (weight) = a + b * log (length), where a is the y-intercept and b is the slope

of the equation (Anderson and Nuemann 1996). Length-weight regressions can be used to predicted yield or weight of harvested fish and are often linearized to simplify interpretation (Slipke and Maceina 2001). The assumptions of the regression are linearity, homoscedasticity, normality, and independence (Pope and Kruse in press). ANCOVA was used to determine differences in length-weight regressions, slope and intercept of the length-weight regressions among lakes (SAS Institute 2004, Pope and Kruse in press).

Physiological conditions of the spotted bass population for each lake were determined using relative weights (index of condition). Relative weight (W_r) was defined as: $W_r = W/ W_s *100$, where W is the observed weight (grams) and W_s (standard weight) is the length-specific standard weight (Anderson and Neumann 1996). The W_s equation for spotted bass is: $\log_{10}W_s = -5.392 + 3.215 \log_{10}TL$ (Wiens et al. 1996). No fish under 100 mm was used in the relative weight analysis (Wiens et al. 1996). The mean relative weight was calculated for five size categories: Sub stock (Sub s), stock-quality (S-Q), quality-preferred (Q-P), preferred-memorable (P-M), and memorable-trophy (M-T). Differences in condition were tested among sections and lakes to determine if relative weight changed with length and if there are significant differences in relative weight among size categories (Procedure GLM; SAS Institute 2004, Pope and Kruse in press). If significance was determined, Tukey's test was used to determine which sections were significantly different (SAS Institute 2004).

Mortality

Mortality describes the removal of individuals from a population or the number of individuals removed during a time period (Slipke and Maceina 2000). In fisheries,

mortality is broken up into natural and fishing mortality. Linearized catch curves (unweighted and weighted) are used to determine annual mortality (A) and have three assumptions: constant recruitment, constant mortality and same catchability for all ages (Slipke and Maceina 2000). Only weighted catch curves were used for this study. Weighted catch curves deflate the older, less numerous age classes and reduce their influence on the outcome (Slipke and Maceina 2000). Weighted catch curves were constructed by taking the $\log_e$ of the number of fish captured from each age class fully vulnerable to the sampling method (Slipke and Maceina 2000). For all analysis, age-1 and older were considered fully vulnerable to electrofishing. Weighted catch curves were constructed using Fishery Analyses and Simulation Tools (FAST) software (Slipke and Maceina 2000). Catch curves for each lake were compared using ANCOVA (SAS Institute 2004). Fishing and natural mortality were estimated from literature review for modeling purposes.

Historical annual mortality rate were determined for lakes where age and growth was conducted during the 1987-2003 period. Weighted catch curves were used to determine annual mortality rates.

Recruitment

Recruitment is the movement of fish into a catchable, harvestable or adult size (Slipke and Maceina 2000). Recruitment is used to assess length limits and is one of the major factors affecting a fish population (Slipke and Maceina 2000). Recruitment was assessed using the recruitment variability index (RVI) (Guy and Willis 1995, Isermann et al. 2002), recruitment coefficient of determination (RCD) (Maciena 1997, Isermann et al.

2002), and using residuals from catch curves. The RVI was defined as: RVI= $[CRF/(N_m+N_p)]-N_m/N_p$, where CRF is the cumulative relative frequency of number at age, N_m is the number of years fish were not collected, N_p is the number of age classes, and $N_p > N_m$ (Guy and Willis 1995). The RCD was the coefficient of determination (r^2) from the weighted catch curve. Coefficient of variation (CV) was calculated for age-0 and age-1 for each lake. High CV suggests large fluctuations in recruitment over time (Maceina 1997, Slipke and Maceina 2000). Age class strength was determined by analyzing the residuals from catch curves for each lake (Maceina 1997, Slipke et al. 1998, Splike and Maceina 2000). Residuals found above the least-square regression line would indicate strong age classes and residuals below would indicate weak age classes (Maceina 1997).

Population Modeling

The spotted bass populations were modeled incorporating growth, mortality and recruitment using the Jones Modification to the Beverton-Holt Model in FAST software (Slipke and Maceina 2001). This model was used to determine the effects different mortality rates, exploitation rates, and minimum length limits have on a fish population. Variables put into this model included von Bertalanffy growth parameters, length – weight regression variables, and estimates of conditional fishing and natural mortality (Slipke and Maceina 2001) (Table 2).

RESULTS

Catch Per Unit Effort

A total of 203 spotted bass were collected from Beaver Lake. The overall pedal time (time electrofishing) for Beaver Lake was 3.47 hours with a mean spotted bass CPUE of 58.8 fish/hour. The mean CPUE values of spotted bass ranged from 52.4 fish/hour at ≥ 180 mm to 2.4 fish/hour at ≥ 350 (Table 3). There was a significant difference in CPUE of all fish and in the ≥ 180 mm, ≥ 280 mm and ≥ 350 mm length groups among sections. For all comparisons, CPUE decreased from upper to middle to lower sections (Table 4 and Figure 5).

A total of 232 spotted bass were collected from Table Rock Lake. The overall pedal time for Table Rock Lake was 6.88 hours with a mean CPUE of 34.2 fish/hour. The mean CPUE values ranged from 22.34 fish/hour at ≥ 180 mm to 5.7 fish/hour at ≥ 350 mm (Table 3). There was a significant difference in CPUE of all fish, and three length groups among sections. Overall, CPUE decreased from upper, James River, lower, to middle section. The order varied among length groups (Table 4 and Figure 6).

A total of 275 spotted bass were collected from Bull Shoals Lake. The overall pedal time was 7.84 hours with a mean CPUE of 32.6 fish/hour. The mean CPUE values ranged from 20.64 fish/hour at ≥ 180 mm to 2.17 fish/hour at ≥ 350 (Table 3). Overall, CPUE decreased from Theodosia arm, to upper, middle and lower sections. The order varied among length groups (Table 4 and Figure 7).

CPUE differed among lakes for all fish, and among all three length groups. For all comparisons, except the ≥ 350 length group, CPUE decreased from Beaver to Table

Rock to Bull Shoals Lake. For fish ≥ 350, CPUE decreased from Table Rock to Beaver to Bull Shoals Lake (Table 4 and Figure 8).

Historical electrofishing data was collected from the three sample lakes from 1987-2003. (Table 5-7)

For Beaver Lake, there was a significant difference in the CPUE among sections for all fish and section/years interaction for ≥ 180 mm and ≥ 280 mm length groups. The CPUE decreased, from middle, lower, and upper section for all length groups except ≥ 350 mm, which decreased from lower, middle, and upper section (Table 8 and Figure 9-12).

For Table Rock Lake, there was a significant difference in the CPUE among sections for all fish and all length groups except < 180 mm. The CPUE decreased from James River, to Kings River, to Long Creek, to the middle section for all length groups except for ≥ 350 mm, which decreased from James River, to Kings River, to the middle section, to Long Creek (Table 8 and Figure 13-16).

For Bull Shoals Lake, there was a significant difference in the CPUE among sections and section/years interaction for all length groups except for all fish and < 180 mm length group. The CPUE decreased, in descending order, from lower, middle, and upper section using AGFC strata description and the CPUE decreased, in descending order, from lower, Theodosia, upper, to middle using my section description. There was a significant difference in the CPUE for < 180 mm and ≥ 280 mm length groups among years (Table 8 and Figure 17-20).

Comparing historical data, CPUE differed among lakes. There was a significant difference in the CPUE among lakes for all length groups except < 180 mm, years for <

180 mm and ≥ 350 mm length groups, and lake/years interaction for < 180 mm, ≥ 280 mm and ≥ 350 mm length groups. The CPUE of all fish and ≥ 180 mm length group decreased from Table Rock, Beaver, and Bull Shoals Lake and ≥ 280 mm and ≥ 350 mm length groups decreased from Table Rock to Bull Shoals to Beaver Lake (Table 9 and Figure 21-24).

Growth

A total of 176 spotted bass were aged from Beaver Lake samples. Ages ranged from 0.5 to 6.5 years, with age-1.5 fish dominating the sample with 40 % of the catch (Figure 25). Four fish were removed before the von Bertalanffy growth curves were constructed due to low number of individuals in the age class, or evidence of disease or abnormal growth. The four fish were 74, 77, 82 (all aged 0.5 years old), 315 (4.5 years old), 351 (5.5 years old), and 352 mm (6.5years old). The von Bertalanffy growth equation was L_t=401.5 [1-e $^{-0.3768(t-(-0.4838))}$] with R^2 of 99.9% (Table 10 and Figure 26).

There was a significant difference among growth curves and in t_0 between lower and middle sections (Table 11 and Figure 27). There was no difference in mean lengths for ages 0.5-4.5 except for age-2.5 (t-value = -4.18, df =12, Bonferroni correction, P<0.0125). The middle section had a higher mean length for age-2.5.

There was a significant difference in the elevation coefficients between the lower and upper sections. The upper section had a higher elevation coefficient. There was a significant difference in growth curves and in. k and t_0 (Table 11 and Figure 27). There was no difference in mean lengths for ages 0.5-4.5 except for age-1.5 (t-value = -3.26,

df=16, Bonferroni correction, $P<0.01$) and age-2.5 (t-value = -4.86, df=15, Bonferroni correction, $P<0.01$). For both ages, the upper section had the higher mean length.

There was no significant difference in growth between middle and upper sections and genders (Table 11-12 and Figure 27-28)

A total of 232 spotted bass were aged from Table Rock Lake. Ages ranged from 0.5 to 11.5 years, with age-1.5 fish representing 56% of the catch (Figure 25). Only fish ranging from 0.5 to 8.5 years old were used for computing the growth curve and four fish were removed before computing the von Bertalanffy growth curves due to age, evidence of diseases or abnormally slow growth. The four fish removed were: 350, 300 (each age 3.5 and diseased), 330, 320, 401 mm (each 9.5 years old), and 444 mm (11.5 years old). The von Bertalanffy growth equation was $L_t=451.5\,[1\text{-}e^{-0.3030(t-(-0.3673))}]$ with R^2 of 98.1% (Table 10 and Figure 26).

There was no significant difference in growth or mean lengths for ages 0.5-8.5 among sections or genders, except for age-1.5 between lower and James River (t-value = -3.26, df=16, Bonferroni correction, $P<0.01$) and middle and James River (t-value = 4.32, df=12, Bonferroni correction, $P<0.01$). For both test, the James River had a higher mean length for age-1.5 (Table 12-13 and Figure 27-28).

A total of 286 spotted bass were aged from Bull Shoals Lake. Ages ranged from 0.5 to 10.5 years, with age-1.5 fish representing 64% of the catch (Figure 25). Only fish ranging from 0.5 to 8.5 years old were used for computing the growth curve and one fish was removed before computing the von Bertalanffy growth curves due to age, evidence of diseases or abnormal slow growth. The one fish removed was 395 mm (10.5 years

old). The von Bertalanffy growth equation was L_t=451.1 [1-e $^{-0.3041(t-(-0.3959))}$] with R^2 of 98.7% (Table 10 and Figure 26)

There was no significant difference in growth or mean lengths for ages 0.5-8.5 among sections or genders except for age-1.5 between upper section and the other sections (t-value = -3.75 - -4.15, df= 15 - 23, Bonferroni correction, P<0.0166). The upper section had a higher mean length at age-1.5. There was significant difference in L_∞ and k between lower and upper section, middle and upper section, and middle and Theodosia Arm and in t_0 between middle and upper section (Table 12, 14 and Figure 27-28).

A total of 47 spotted bass were aged For Bull Shoals Lake tournament fish. Ages ranged from 2.5 to 9.5 years, with age-3.5 fish representing 53% of the catch (Figure 25). Due to the low number of tournament fish sampled, the tournament age data were combined with the other Bull Shoals Lake data to construct a von Bertalanffy growth curve. Only fish ranging from 0.5 to 8.5 years old were used for computing the growth curve and three fish were removed before computing the von Bertalanffy growth curves due to age, evidence of diseases or abnormal slow growth. Fish removed were 340, 374 (9.5 years olds), and 395 (10.5 years old). The von Bertalanffy growth equation was L_t=461.5 [1-e $^{-0.3374(t-(-0.2439))}$] with R^2 of 98.3% (Table 10 and Figure 29).

There was no significant difference in growth or mean lengths for ages 0.5-7.5 (ages 0.5-4.5 when Beaver Lake was include in the test) among lakes except for age-1.5 between Beaver Lake and the other lakes (t-value = 7.77 - 9.10, df=201 - 235, Bonferroni correction, P<0.01) and age-3.5 between Bull Shoals Lake with tournament fish and the other lakes (t-value = -3.37 - -3.53, df=69 - 77, Bonferroni correction, P<0.007 to 0.01).

Beaver Lake had a higher mean length at age-1.5 and Bull Shoals Lake with tournament fish had a higher mean length at age-3.5 (Table 15 and Figure 30).

There was a significant difference between the Table Rock Lake and Bull Shoals Lake age distributions (KS =1.31, P= 0.011) and no significant difference among the other age distributions comparisons (KS = 0.50 - 1.61, P=0.07 - 0.96).

Size Structure

The size range for the 203 spotted bass collected from Beaver Lake was from 74 - 393 mm total length (Figure 31). The 190-229 mm length groups of fish represented 38 % of the catch (Figure 32). The mean size was 240 mm and the median was 227 mm total length. Weight ranged from 4 - 745.9g with the mean weight of 213g and the median weight of 152.9 g (Figure 33). The sex ratio for spotted bass aged in Beaver Lake was 76 females and 68 males; 34 immatures were also aged. The total PSD for Beaver Lake was 34.4 and the RSD_{14} was 4.44 (Table 16).

The size range for the 232 spotted bass collected from Table Rock Lake was 96 - 444 mm total length with a mean length of 232 mm and a median length of 210 mm (Figure 31). No length group of fish dominated the catch (Figure 32). Weight ranged from 9.6 - 1330.9 g with a mean of 254 g and a median of 116.3g (Figure 33). The sex ratio was 71 females and 68 males; 93 immatures were also aged. The total PSD for Table Rock Lake was 49.02 and the RSD_{14} was 22.88 (Table 16).

The size range for the 275 spotted bass collected from Bull Shoals Lake was 70 - 435 mm total length with a mean length of 217 mm and a median length of 200 mm (Figure 31). The 150-169 mm length groups of fish represented 17 % of the catch (Figure

32). The mean size was 217 mm and the median was 200 mm total length. Weight range was from 9 - 1162.8 g with the mean weight of 188g and the median weight of 101.5 g (Figure 33). The sex ratio for spotted bass aged in Bull Shoals Lake was 76 females and 91 males; 108 immatures were also aged. The total PSD for Bull Shoals Lake was 30.66 and the RSD_{14} was 11.56 (Table 16). Eight spotted bass/smallmouth bass hybrids were collected (TL= 166 - 224 mm).

The size range for the 47 spotted bass collected from Bull Shoals Lake tournament was 310 - 480 mm total length with a mean length of 376 mm and a median length of 374mm (Figure 31). The 360 mm length groups of fish represented 15 % of the catch (Figure 32). Weight range was from 384.5 - 1816 g with the mean weight of 840g and the median weight of 784.6 g (Figure 33). The sex ratio for spotted bass aged in Bull Shoals Lake was 23 females and 24 males.

There were significant differences in size distributions for all pairwise comparisons among lakes sampled except the Table Rock-Bull Shoals comparison and in the proportion of fish in each length category. Significance of other comparisons between length categories varied, see Table 17.

Relative-length frequency distributions were constructed for Beaver, Table Rock, and Bull Shoals Lake using the fish captured by the Arkansas Game and Fish Commission and the Missouri Department of Conservation from 1987-2003 except for Table Rock Lake where fish from 1988-2003 were used (Figure 34). In the Table Rock Lake data, the James River 1988 sample was excluded and the middle section was only sampled from 1995 to 2003. For Beaver Lake, there were 4,925 spotted bass collected ranging from 55 - 444 mm (median = 272 mm). For Table Rock Lake, there were 16,500

spotted bass collected ranging from 64 - 495 mm in length. For Bull Shoals Lake, there were 11,612 spotted bass collected ranging from 68 - 528 mm (median = 270 mm). Refer to Table 18 and Figure 35-37 for data on fish captured within each section of the sample lakes. There was a highly significant difference in the length frequency among sections for each lake (Table 19).

Condition

The length-weight regression for Beaver Lake was log (weight) = -5.035 +3.057 * log (length) with a R^2 of 98.66 % (Figure 38). A negative relation exists between W_r and TL (t-value = -6.92, df =1, P<0.001) (Figure 39). The slope of the length-weight regression line was less then the slope of the W_s regression line (-0.071). The mean W_r (± SE) values are given in Table 20. There was a significant difference in W_r among the length groups ($F_{3, 195}$ =19.02, P<0.001). There was significant difference in the W_r of stock- to quality-length fish among sections (Table 21). The relative weight decreases from the upper section to the lower section.

The length-weight regression for Table Rock Lake was log (weight) = -5.395 +3.211 * log (length) with a R^2 of 99.3 % (Figure 38). No relation exists between W_r and TL (t-value = 0.02, df =1, P=0.9858) (Figure 39). The slope of the length-weight regression line was more then the slope of the W_s regression line (0.0001). The mean W_r (± SE) values are given in Table 20. There was a no significant difference in W_r among the length groups ($F_{4, 225}$ =1.21, P=0.3094). There was a significant difference in the W_r of sub-stock fish and stock- to quality-length fish among sections (Table 21). For the sub-stock, the James River and lower section were significantly different from the upper

section ($P<0.01$). For the stock- to quality-length fish, there was a significant difference between James River and upper section and the lower and upper sections ($P<0.01$).

The length-weight regression for Bull Shoals Lake was log (weight) = -5.445 +3.234 * log (length) with a R^2 of 99.0 % (Figure 38). No relation exists between W_r and TL (t-value = 0.76, df =1, P=0.4501) (Figure 39). The slope of the length-weight regression line was more then the slope of the W_s regression line (0.0066). The mean W_r (± SE) values are given in Table 20. There was a no significant difference in W_r among the length groups ($F_{4, 263}$ =1.47, P=0.2112). There was a significant difference in the W_r in the stock- to quality-length fish among sections (Table 21).

The length-weight regression for Bull Shoals Lake tournament fish was log (weight) = -6.097 +3.496 * log (length) with a R^2 of 91.9 % (Figure 38). No relation exists between W_r and TL (t-value = 1.70, df =1, P=0.0966) (Figure 39). The slope of the length-weight regression line was greater then the slope of the W_s regression line (0.070). The mean W_r (± SE) values are given in Table 22. There was a no significant difference in W_r among the length groups ($F_{2, 44}$ =1.57, P=0.2194).

When the tournament fish are added to the Bull Shoals Lake samples the length-weight regression was log (weight) = -5.513 +3.265 * log (length) with a R^2 of 99.2 % (Figure 40). There was a highly positive relation exists between W_r and TL (t-value = 3.20, df =1, P=0.0015) (Figure 40). The slope of the length-weight regression line was greater than the slope of the W_s regression line (0.021). The mean W_r (± SE) values for are given in Table 22. There was a no significant difference in W_r among the length groups ($F_{4, 321}$=2.97, P=0.0196). A combination of differences must have attributed to the significant difference since no two length categories were significantly different. There

were no significant differences between the quality- to preferred-length ($F_{4, 38}$=0.70, P=0.5962) and preferred- to memorable-length ($F_{3, 16}$=0.42, P=0.7398), when the tournament fish were compared to the other strata in Bull Shoals Lake.

Pairwise comparisons detected significant differences among various length-weight, slope, intercept and relative weight comparisons. The significance of other comparisons varied (See Table 23). The most significant differences were observed for relative weights of quality- to preferred-length fish among sample lakes.

Mortality

For Beaver Lake mortality calculations, a length-age key was used to include the fish sampled but not aged (N=25). Only ages 1.5-4.5 were used for the weighted catch curve; the annual mortality rate ($\pm CI_{0.95}$) calculated was 45 ± 17% with an R^2 of 97 % (Table 24 and Figure 41).

For Table Rock Lake, ages 1.5-9.5 were used in the analysis; the annual mortality rate ($\pm CI_{0.95}$) was 41 ± 12% with a R^2 of 86 % (Table 24 and Figure 41).

For Bull Shoals Lake, ages 1.5-8.5 were used in the analysis; the annual mortality rate ($\pm CI_{0.95}$) was 55 ± 15% with a R^2 of 80% (Table 24 and Figure 41).

There was no significant difference in weighted catch curves between the Beaver Lake and Table Rock Lake ($F_{1, 9}$=0.64, P=0.4426), Beaver Lake and Bull Shoals Lake ($F_{1, 10}$=0.08, P=0.7787), or Table Rock Lake and Bull Shoals Lake ($F_{1, 15}$=0.08, P=0.7872). Since the majority of the fish collected in each lake were in age 1.5-4.5, catch curve were constructed and compared among the samples lake. The mortality for Beaver, Table Rock, and Bull Shoals Lake for age 1.5-4.5 using weighted catch curves was 45%,

54% and 54%, respectfully. There was no significant difference in the weighted catch curves between Beaver and Table Rock Lake ($F_{1,4}$=0.18, P=0.6904), Beaver and Bull Shoals Lake ($F_{1,4}$=0.13, P=0.7381), or Table Rock and Bull Shoals Lake ($F_{1,4}$=0.01, P=0.9201).

A total of twenty-seven age and growth samples (9 per sample site) were conducted in the King River, James River, and Long Creek Arms from 1987- 2003. Three other samples were conducted in the middle section of the lake. The mean overall annual mortality rate was 34% and the range was 18 % to 56% and varied among sections (Table 25).

A total of 5 age and growth samples were conducted in the upper end and Theodosia arm of Bull Shoals Lake from 1987- 2003. The mean overall annual mortality rate was 46% and the range was 19% to 57% (Table 25).

Recruitment

The coefficient of variation (CV) for age-0.5 fish collected in Beaver Lake was 19.6% and for age-1.5 was 10.3%. The variables used in the recruitment variability index (RVI) were: CRF = 5.17, N_m =0 and N_p= 6. The RVI index for Beaver Lake was 0.86. The recruitment coefficient of determination (RCD) was 0.96. Using the residuals from the weighted catch curve, 2003 had the strongest year class strength, 2001 had moderately strong year class strength, and 2002 had the weakest year class strength.

The CV for age-0.5 fish collected in Table Rock Lake was 25.6% and for age-1.5 was 22.4%. The variables used RVI were: CRF = 7.85, N_m =0 and N_p= 9. The RVI index for Table Rock Lake was 0.87 and the RCD was 0.86. Using the residuals from the

weighted catch curve, 2003 had the strongest year class strength, 2001, 1999 and 1995 had moderately strong year class strengths, 2002 had the weakest year class strength, and 2000 had moderately weak year class strength.

The CV was 16.5% for age-0.5 fish and 19.0% for age-1.5 fish captured in Bull Shoals Lake. The variables used in the RVI were: CRF = 7.34, N_m =2 and N_p= 8. The RVI index for Bull Shoals Lake was 0.68 and the RCD was 0.80. Using the residuals from the weighted catch curve, 1997 had the strongest year class strength, 2003, 2000 and 1996 had moderately strong year class strengths, 1999 had the weakest year class strength, and 1998 had moderately weak year class strength. Data from tournament caught fish suggested that 2001 and 1995 could have been years with strong year class strengths.

Population Modeling

For Beaver Lake, population models indicated that with a conditional natural mortality (M) of 10% and exploitation (E) of less than 30%, a 12- or 13-inch (in.) minimum length limit (MLL) would result in the greatest yield. With E of 30-50%, a 13-in. MLL would yield the most spotted bass. Growth overfishing (the growth potential of a population is reduced and maximum yield cannot be reached due to high harvest rate and early age recruitment to a fishery (Slipke and Maceina 2001)), occurred for the 10- and 11-in. MLLs at an E greater than 40%. With M of 15% and E of less than 30%, an 11-, 12- or 13-in. MLL would result in the greatest yield. With E of 30-50%, a 12- or 13-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10-in. MLL at an E greater than 40%. With M of 20% and E of, less than 30%, a 10- or 11-in.

MLL would result in the greatest yield. With an E of 30-50%, 11- or 12-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10-in. MLL at an E greater than 50% (Figure 42).

For Table Rock Lake, population models indicated with a conditional natural mortality (M) of 10% and exploitation rate (E) of less than 30%, a 13- or 14-in. MLL would result in the greatest yield. With E of 30-50%, 14-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10- and 11-in. MLLs at an E greater than 30% and 12-in. MLL at an E greater than 40%. With M of 15% and E of less than 30%, a 12- or 13-in. MLL would result in the greatest yield. With E of 30-50%, a 13- or 14-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10- and 11-in. MLLs at an E greater than 40%. With M of 20% and E of less than 30%, an 11-, 12-, or 13-in. MLL would result in the greatest yield. With E of 30-50%, a 13-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10-in. MLL at E greater than 40% (Figure 42).

For Bull Shoals Lake with no tournament fish, population models indicated with a conditional natural mortality (M) of 10% and exploitation rate (E) of less than 30%, a 13- or 14-in. MLL would allow the greatest yield. With E of 30-50%, a 14-in. MLL would result in the greatest yield. Growth overfishing occurred for the 10- and 11-in. MLLs at E greater than 30% and 12-in. MLL at an E greater than 40%. With M of 15% and E of less than 30%, a 12- or 13-in. MLL would result in the greatest yield. With E of 30-50%, a 13- or 14-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10- and 11-in. MLLs at an E greater than 40%. With M of 20% and E of less than 30%, an 11-, 12-, or 13-in. MLL would result in the greatest yield. With E of 30-50%,

13-in. MLL would result in the greatest yield. Growth overfishing occurred for the 10-in. MLL at an E greater than 40% (Figure 43).

For Bull Shoals Lake including tournament fish, population models indicated with M of 10% and E of less than 30%, a 13- or 14-in. MLL would result in the greatest yield. With E of 30-50%, a 15-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10-, 11- and 12-in. MLLs at E greater than 30% and 13- in. MLL at E greater than 40%. With M of 15% and E of less than 30%, a 13-in. MLL would result in the greatest yield. With E of 30-50%, a 14-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10- and 11-in. MLLs at E greater than 40%. With M of 20% and E of less than 30%, a 12- or 13-in. MLL would result in the greatest yield. With E of 30-50%, a 13-in. MLL would yield the most spotted bass. Growth overfishing occurred for the 10-in. MLL at E greater than 40% (Figure 43).

DISCUSSION

The information gathered from this study can assist fisheries managers in determining regulatory strategies to effectively manage or modify the spotted bass population in these reservoirs and other reservoirs. It will provide more information about the life history, age, growth and ecology of spotted bass, which is limited.

The objectives of this study were to determine if there are differences in the abundance, growth, size structure, condition, mortality and recruitment of spotted bass among Beaver Lake, Bull Shoals Lake and Table Rock Lake, gather and analyze historical data collected on spotted bass, and model the spotted bass populations to evaluate the current regulations in each reservoir.

Sampling

When studying spotted bass, it can be difficult to obtain a representative sample of the population because spotted bass, especially the larger fish, inhabit deeper water than can be effectively sampled using electrofishing except for during the spawn. Without having larger fish in the samples, it makes it difficult to determine overall growth rates for the population. For example, the largest spotted bass sampled in historical data were 444, 495, and 521 mm for Beaver, Table Rock and Bull Shoals Lake, respectively. A survey was taken of local fishing guides to determine the average size of the largest spotted bass caught in the three sample lakes. The result of the survey was 457, 521 and 521 mm for Beaver, Table Rock and Bull Shoals Lake, respectively, showing the difficulties of sampling larger spotted bass in these reservoirs. Also, results can be highly variable within or among reservoirs. These reasons are why many

researchers are reluctant to study spotted bass in reservoirs even though this species is popular among recreational fishermen.

Originally, this study was to be conducted in the spring when the largest size range of fish could be sampled. This would leave open the possibility of a fall sampling period to collect more fish for analysis. However, due to the high water in the spring of 2004, only the fall was sampled. Differences in catch rates and mean length for spotted bass between spring and fall samples were documented by Sammons and Bettoli (1996). They found spotted bass catch rates were lower and mean lengths were shorter in fall than spring samples. They stated the same trends exist for largemouth bass but not for smallmouth bass.

Two situations were identified while sampling in the fall for spotted bass in these reservoirs. First, spotted bass were consistently collected in areas that were close to deeper water such as main lakes areas, bluffs and points, which could be different from sampling in the spring. Second, the age-0 and age-1 spotted bass were highly abundant near the shoreline. Sampling in the fall would allow a fisheries manager to determine recruitment and age class strength.

Aging

There have been several age and growth studies conducted on spotted bass; however, most of the early studies used scales to age spotted bass. Long and Fisher (2001) considered sectioned otoliths to be the most precise when aging spotted bass. The maximum age for northern spotted bass has been reported at seven years (Vogele 1975, Carlander 1977). DiCenzo et al (1995) observed an 11 year old Alabama spotted bass

using otoliths and Webb and Reeves (1975) documented, through personal communication with a Missouri Department of Conservation biologist, an age 11 northern spotted bass in Lake Taneycomo. In this study, an 11.5 year old spotted bass was collected in Table Rock Lake.

Sample Lakes

Beaver, Table Rock, and Bull Shoals Lakes are known among recreational and tournament fishermen for having healthy, abundant spotted bass populations.

The CPUE, PSD, and RSD results from this study and past sampling indicate the spotted bass population is stable in Beaver Lake and has been over the years except for a two fairly large year classes moving through the population in the 1990s. Spotted bass are found throughout Beaver Lake but were more numerous in the upper section during this study. However, over the years, spotted were more numerous in the lower and middle sections. Rainwater and Houser (1975) and Bowman (1993) found the spotted bass distribution to be fairly uniform throughout the reservoir; However, Bowman (1993) found spotted bass numbers decreased from upper section to the lower section. Looking at the historical electrofishing data, there has been a shift in the spotted bass collected between the lower and middle sections. During the earlier years of sampling, the lower section had the highest numbers and the larger spotted bass. In the mid 1990's the middle section began to hold the highest number of spotted bass from all size groups. This shift could be due to the reintroduction of smallmouth bass into Beaver Lake in 1981 (Bowman 1993). However, the smallmouth bass population didn't become established till the early 1990's when reproduction was discovered in Beaver Lake (Bowman 1993).

Studies have shown when spotted bass and smallmouth bass are found in the same reservoir, they tend to segregate longitudinally among habitats and trophic state (Bowman 1983, Buynak et al. 1989, Janssen 1992, Scott and Angermeier 1998, Long and Fisher 2005). Spotted bass tend to occupy the middle section and smallmouth bass tend to occupy the lower section of the reservoir. Over the years, the upper section of Beaver Lake has never had as dense population of spotted bass compared to the other sections of the reservoir likely due to healthy largemouth bass population (Rainwater and Houser 1975, Rainwater and Houser 1982, Bowman 1993). This was not demonstrated in the results from this study. One explanation for the differences in CPUE during this study and past samples is sample season. This study was conducted in the fall, whereas all the other samples have been conducted in the spring. A portion of the spotted bass population in highland reservoirs move into the creek arms and upper ends of the reservoir to feed on the shad population which is abundant in theses areas during the fall.

The historical data show a fairly constant spotted bass population in Table Rock Lake since 1987 with a high PSD and RSD. These high values indicate abundant larger size fish likely due to the larger length limit. The size structure of spotted bass was highly variable among sections. In this study, the upper end of the reservoir and the James River Arm were the sites that had the highest number of overall fish, and fish up to 350 mm sampled. These results were similar to the results from Beaver Lake; however, the historical data suggest there has always been a larger population of spotted bass in the James River Arm than in the lower or middle sections of the reservoir. This is likely due the high productivity and forage base found in the James River Arm. The middle section

had the highest number of fish over 350 mm. The historical data support the results from this study.

The results from this study and historical data show spotted bass are numerous throughout the Bull Shoals Lake. In this study, the Theodosia Arm had the highest number and the largest sized spotted bass captured. There was a large variation in CPUE within sections. The historical data show CPUE as well as PSD and RSD values are variable throughout time. Overall, the lower section has had the largest and greatest number of spotted bass. However, there has been more effort to collect fish in the upper, Theodosia Arm and the lower section compared to the middle section. CPUE of all size groups has been more variable compared to the other lakes, showing that recruitment is variable within this population. Even though the larger fish have been more numerous in the lower section of the lake, the two largest fish recorded in any of the historical data for these sample lakes (508 and 521 mm) were recorded in the upper end of Bull Shoals Lake. Rainwater and Houser (1975) found spotted bass to be more abundant in the upper section than in the lower section of Bull Shoals Lake.

Among the reservoirs, Beaver Lake had the highest CPUE; however, the larger fish were sampled in Table Rock Lake. Spotted bass distribution for these three reservoirs did not follow the longitudinal distribution demonstrated in other studies. (Buynak et al 1989, Janssen 1992, Scott and Angermeier 1998, Sammons and Bettoli 1999, Long and Fisher 2005). In these studies, spotted bass were more abundant in the middle section were as the largemouth bass were more abundant in the upper section and smallmouth bass were more abundant in the lower section.

Spotted bass grow quickly up to 305 mm (12 inches) in Beaver Lake, but once they reach this length growth begins to slow. There were no fish collected over 6 years old in this reservoir even though older fish could exist. The growth of spotted bass is somewhat constant throughout the reservoir even though a significant difference in the growth between sections was detected. Due to the difference in the sample size and number of large and older spotted bass aged, no pronounced difference among sections can be inferred. The fast growth and high relative weights of smaller fish (< 280 mm) suggest there is abundant forage for these fish.

There is good, fairly constant growth of spotted bass throughout Table Rock Lake due to the similarities in trophic state, except in the James and Kings River arms. The growth data collected in this study are consistent with other data collected for the James River Arm, Long Creek and middle section of the lake (Figure 44).

There were no significant differences in growth among sections in Bull Shoals Lake even though there were significant differences in L_∞ among a few sections. These differences are likely due to differences in sample size and the amount of larger fish sampled among sections. Although there was no significant difference detected among sections for this study, age and growth data from the Missouri Department of Conservation show the growth rates from this study for older spotted bass in the upper section and Theodosia Arm might be underestimated (Figure 45).

There were no significant differences detected in growth of spotted bass from ages 0.5 to 4.5 among the three reservoirs; however, there were no fish collected over 400 mm in Beaver Lake even though spotted bass over 400 mm are caught by anglers in Beaver Lake. There was a significant difference in the size structures among the

reservoirs. Median length was highest in Table Rock Lake followed by Bull Shoals and Beaver Lake.

Even though the relative weights in Beaver Lake were in the healthy range for all size groups, the relative weights decreased as fish size increased. This reduction in growth and weight of larger spotted bass could be due to 1) intra-species competition among spotted bass, 2) inter-species competition with other species such as walleye, largemouth bass, smallmouth bass, white bass, or striped bass for forage, especially in open water areas or 3) overcrowding as a result of limited harvest of spotted bass. With catch and release of black bass being very popular among recreational and tournament fishermen the reduction in growth and weight as size increases is likely due to the limited harvest of spotted bass causing overcrowding and increasing the competition among larger spotted bass for forage. The forage base can be highly variable among years in this reservoir especially the gizzard and threadfin shad populations, which experience "boom or bust" years.

The spotted bass were in good condition throughout Table Rock Lake and in the different size groups even though there were significant differences in the condition among sections of the reservoir. Due to the high productivity of the James River Arm, there is a large shad base for the spotted bass to forage, allowing these fish to be in better condition than in other areas of the reservoir. The good condition of spotted bass in the lower section could be due to the large amount of shad forage found in the sample site during sampling efforts. The shad were so numerous that at times it made it difficult to sample. The spotted bass in the upper section had lower mean relative weights among sections. Differences in conditions among sections is Table Rock Lake could possibility

be due the differences in forage and/or habitat abundance; however, this is only speculation since prey and habitat abundance was not measured in this study. There have been efforts to reduce the amount of nutrients coming into James River from area communities. If the nutrient load is reduced, there could be an increase in the number of spotted bass in James River Arm, however, the growth and condition of these fish could decrease. With oligotrophication, there could be a shift of dominance in the James River from largemouth to spotted bass (Maceina and Bayne 2001, Greene and Maceina 2000)

The spotted bass are in good condition throughout Bull Shoals Lake and in the different length groups.

There was significant difference in condition of spotted bass among reservoirs. The spotted bass in Table Rock and Bull Shoals were in better condition then in Beaver Lake. Differences in condition could be due to spotted bass abundance, competition, amount of preferred physical and chemical habitats, and\or food availability.

The mortality rate of spotted bass in Beaver and Table Rock Lake was lower than Bull Shoals Lake. This could be because no age-5 or 6 fish were collected in Bull Shoals Lake. It is likely natural mortality makes up a large part of the mortality rate due to slower growth rates and short life span of the spotted bass and the practice of catch and release by the anglers (Novinger 1987). This is especially true for Table Rock Lake due to the higher length limit regulation.

Recruitment is fairly stable in Beaver and Table Rock Lake and is variable in Bull Shoals Lake. This could be due to the amount of water level fluctuation. Typically, Beaver and Table Rock lake water levels stay fairly constant except for high water events. Bull Shoals Lake water level fluctuates more often and to a greater degree. When

Bull Shoals Lake was created, more shoreline was purchased to allow for higher amount of water storage. With the high degree of fluctuation, the spotted bass recruitment is more variable in Bull Shoals Lake.

When the sampling was almost completed, the opportunity became available to collect tournament caught fish to make up for the larger fish that were not being sampled in the regular sampling. The fish gathered were slightly faster growing than most of the fish captured electrofishing, possibly due to their aggressive nature. The tournament-captured fish were in better condition than most of the other fish captured. By including the tournament fish, an entire age class, which was not captured during electrofishing was included in the analysis. By incorporating tournament-caught spotted bass into the study, it allowed for analysis of fish that were unable to be capture by electrofishing due to their tendencies to inhabit deep water. Including tournament-caught or hook and line sampled spotted bass in reservoir population studies should be considered when available.

Management Practice

Since age and growth was a major part of this study and there were two different regulations on the sample lakes, length limits were examined to determine which would be most beneficial to the populations. Since this was only a one-year study, it is difficult to make a definitive statement as to which length limit would be most beneficial. These data can be incorporated with future data to determine the most beneficial length limit for each lake. When considering a management option for a particular organism, the manager must consider the three components: organisms, habitat and people (Nielson 1999). In the management process, managers must consider the ecological, economic, sociocultural,

and political components (Krueger and Decker 1999). Each of the three sample lakes are very important to the economics of the surrounding communities, thus issues concerning these lakes are often highly political.

Beaver Lake's current minimum length limit (MLL) is 12 in. My results indicate that maintaining the current management regulations would be most beneficial option for this fishery. Models indicate spotted bass are reaching 12 and 13 in. in approximately 3.3 years and 4.1 years, respectively (Table 26). Yield would be increased with a 13-in. MLL; however, it could increase crowding and competition within the population leading to a decrease in growth rates.

Table Rock Lake's current MLL is 15 in. and has been in places since 1976 (Novinger 1987). Table Rock Lake is the most likely to encounter angler resistance to regulation changes among the three sample lakes. The fisheries biologist for Table Rock Lake has recommended the current MLL be reduced to 12 in. MLL in annual reports since the late 1980's. Novinger (1987) stated the length limit should be reduced to a 13-in. MLL. Due to the high opposition from the numerous local stakeholders and the perceived difficulties of anglers to accurately distinguish between spotted bass and largemouth bass, the regulation has remained at 15 in. MLL (which is the same as largemouth bass). My results indicate a 13- or 14-in. MLL would increase the yield. Models indicate that spotted bass are reaching 13, 14 and 15 in. in approximately 4, 4.7 and 5.8 years, respectively (Table 26). By lowering the length limit, it would possibly encourage more harvest, allowing the remaining fish to have better growth rates. However, Table Rock Lake has a reputation for having a healthy population of large

spotted bass. Lowering the MLL could result in more fish being harvested, but few large fish may be available.

Bull Shoals Lake's current MLL is 12 in. My results indicate a 13- or 14-in. MLL would increase the yield. Models indicate that spotted bass are reaching 12, 13 and 14 in. in approximately 3.3, 4 and 4.7 years, respectively (Table 26). By increasing the MLL, it would protect fish for at least one more year and could help to stabilize recruitment in this reservoir. Because the annual mortality rate is the highest in Bull Shoals Lake compared to the other study lakes, increasing the MLL would restrict some of the harvest, increasing the yield of spotted bass and allowing for larger fish to be caught.

With spotted bass being difficult to sample, it is difficult to determine the correct management practices and if changes in regulations are beneficial. Several studies have been conducted concerning harvest regulation for spotted bass throughout the Southeastern United States. Buynak (1983) and Buynak et al. (1991) found lowering the minimum length limit in Cave Run Lake, Kentucky would increased the angler exploitation of the abundant, slow-growing spotted bass with no effect on growth. Kornman (1990) recommended no size limit for spotted bass to allow for more harvest and increase the growth rates of largemouth bass. Even though spotted bass live sympatrically with largemouth bass and anglers have difficulties distinguishing between the two species, different management practices are needed and have been successfully implemented in reservoirs for each species because of the differences in growth and mortality (Novinger 1987, Buynak et al. 1991, DiCenzo et al. 1995, Fisher et al. 2000). When these species are managed under one minimum length limit, spotted bass tend to "stockpile" under the minimum length limit (Fisher et al. 2000). Spotted bass can account

for a large percentage (10-60%) of the black bass harvested even when largemouth bass is the dominant species (Novinger 1988, Sammons et al. 1999).

Finally, spotted bass can contribute significantly to the sport fishery in reservoirs but information on their life history, age, growth and ecology is limited compared to largemouth and smallmouth bass research (Olmsted and Kilambi 1978, Sammons and Bettoli 2000, Long and Fisher 2001). Spotted bass will be important in the future with the aging of reservoirs and movement for cleaner water. With many reservoirs becoming oligotrophic and many rivers losing valuable backwater habitat for largemouth bass, spotted bass populations will continue to increase and require more specific management research and actions.

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Table 1: Physical characteristics for the three reservoirs.

		Sample Lakes		
		Beaver Lake[1]	Table Rock Lake[2]	Bull Shoals Lake[3]
Conservation Pool	Surface Area (hectares)	11,420	17,442	18,388
	Shoreline Length (km)	723	1,198	1,191
	Pool Elevation (meters above MSL)	341.50	278.89	199.24
Flood pool	Surface Area (hectares)	12,829	21,165	28,830
	Shoreline Length (km)	777	1,379	1,690
	Pool Elevation (meters above MSL)	344.42	283.77	211.84
	Watershed (km^2)[4]	3,087	10,411	15,672
	Average Depth (m)	18	19	20
	Maximum Depth (m)	61	61	65
	Shoreline Development[5]	19.10	25.0	24.80
	Average hydraulic retention time (years)[6]	1.5	0.8	0.75

1: (COE 1991), 2: (Novinger 1987), 3: (COE 1998)
4: (http://water.usgs.gov/pubs/wdr/WDR-AR-03/WDR-AR-03-1.pdf), 5: Unpublished data from Mike Bivin (Arkansas Game and Fish Commission Fisheries Data Analyst)
6: (Haggard and Green 2002, Green et. al. 2003, Galloway and Green 2003)

Table 2: Parameters used in the F.A.S.T. software to model the populations. Regression coefficients a and b were estimated from the length-weight regression {$\log_{10}$ (Weight, g) = **a** + **b**[$\log_{10}$ (Length, mm)]}.

Parameters	Sample Lakes			
	Beaver	Table Rock	Bull Shoals	Bull Shoals with tournament fish
Initial Number	1000	1000	1000	1000
b	3.058	3.207	3.235	3.265
a	-5.035	-5.387	-5.446	-5.513
Max Age (y)	9	10	10	10
L_∞	401.5	451.6	451.1	461.5
k	0.3768	0.3030	0.3041	0.3374
t_0	-0.4838	-0.3673	-0.3959	-0.2439
w_∞	845.42	1339.05	1382.21	1532.92
Conditional fishing mortality	0.10-0.60 by 0.10 increments			
Conditional natural mortality	0.10-0.20 by 0.05 increments			
Length limits considered	10-15 inches by 1 in. increments			

Table 3: Mean catch-per-hour of electrofishing (CPUE) for sections within sample lakes. Pedal time is the amount of time, in hours, when electricity was applied to the water. Numbers given are means with coefficient of variation (CV) in parentheses.

Lake		Overall	Lower	Middle	Upper
Beaver Lake	Total Pedal Time	3.47	1.17	1.16	1.13
	# of fish sampled	203	36	62	105
	Mean CPUE	58.84 (46.24)	30.92 (10.63)	53.08 (5.21)	92.54 (4.80)
	CPUE fish ≥180 mm	52.37 (52.42)	25.47 (16.41)	45.27 (15.60)	86.39 (8.17)
	CPUE fish ≥280 mm	17.82 (62.51)	8.10 (88.90)	15.39 (14.84)	29.97 (27.32)
	CPUE fish ≥350 mm	2.36 (144.62)	0	1.74 (86.67)	5.32 (87.78)

Lake		Overall	Lower	Middle	Upper	James River Arm
Table Rock Lake	Total Pedal Time	6.88	2.28	1.96	1.19	1.43
	# of fish sampled	232	54	30	81	67
	Mean CPUE	34.24 (62.65)	23.88 (65.52)	17.24 (52.30)	67.87 (11.28)	45.83 (37.91)
	CPUE fish ≥180 mm	22.34 (82.36)	7.93 (65.52)	13.21 (47.59)	44.05 (20.17)	39.09 (49.14)
	CPUE fish ≥280 mm	11.23 (72.46)	2.94 (99.19)	12.26 (51.01)	16.82 (30.82)	18.20 (41.06)
	CPUE fish ≥350 mm	5.7 (98.99)	1.67 (120.78)	8.70 (86.22)	5.90 (63.27)	7.85 (75.91)

Lake		Overall	Lower	Middle	Upper	Theodosia Arm
Bull Shoals Lake	Total Pedal Time	7.84	2.68	3.83	1.32	1.19
	# of fish sampled	275	62	125	32	56
	Mean CPUE	32.65 (73.14)	25.53 (60.41)	36.70 (87.33)	23.80 (43.90)	46.58 (45.59)
	CPUE fish ≥180 mm	20.64 (81.99)	15.14 (94.67)	20.76 (102.07)	18.46 (55.08)	34.16 (37.93)
	CPUE fish ≥280 mm	6.15 (86.16)	4.69 (110.82)	4.08 (76.68)	6.89 (23.57)	14.29 (53.27)
	CPUE fish ≥350 mm	2.17 (137.88)	2.48 (102.07)	1.32 (155.09)	0.75 (200)	5.97 (89.03)

Table 4: Comparison of CPUE among sections for each sample lake and among lakes. Asterisks denote significant differences (ANOVA; $P \leq 0.05$).

Lake	Parameter	df	F	P
Beaver Lake	All Fish	2,6	171.74	<0.0001*
	Fish ≥ 180 mm	2,6	56.64	0.001*
	Fish ≥ 280 mm	2,6	6.62	0.03*
	Fish ≥ 350 mm	2,6	6.29	0.03*
Table Rock Lake	All Fish	3,14	8.71	0.002*
	Fish ≥ 180 mm	3,14	10.88	<0.0001*
	Fish ≥ 280 mm	3,14	9.51	0.001*
	Fish ≥ 350 mm	3,14	3.79	0.035
Bull Shoals Lake	All Fish	3,18	0.66	0.586
	Fish ≥ 180 mm	3,18	1.06	0.391
	Fish ≥ 280 mm	3,18	2.44	0.097
	Fish ≥ 350 mm	3,18	1.44	0.264
Among Lakes	All Fish	3,46	4.04	0.024*
	Fish ≥ 180 mm	3,46	6.24	0.004*
	Fish ≥ 280 mm	3,46	4.79	0.013*
	Fish ≥ 350 mm	3,46	4.19	0.021*

Table 5: Population characteristics of spotted bass for Beaver Lake from 1987 to 2003 from annual electrofishing samples (Data from Arkansas Game and Fish Commission (AGFC)).* denotes high water sampling. PSD stands for proportional stock density and RSD stands for relative stock density. The preferred range for PSD is 30-60 and for RSD is 0-10.

Year	Number of fish sampled	Catch/hr. (< 180 mm)	Catch/hr. (≥ 180 mm)	Total Catch per hour (CPUE)	PSD	RSD_{14}
1987	466	3.57	46.94	50.51	45.7	6.7
1988	371	7.31	55.78	63.09	48.5	8.8
1989	378	2.77	42.76	45.53	47.3	9.0
1990	396	3.81	43.37	47.18	50.8	6.0
1991	290	2.53	46.45	48.98	45.1	5.1
1992	249	5.00	60.59	65.59	50.4	4.3
1993	276	6.38	52.31	58.69	58.9	8.9
1994	245	2.84	46.87	49.71	55.7	7.1
1995	306	2.88	49.08	51.96	48.1	9.3
1996	216	0.91	48.16	49.07	55.2	19.8
1997	272	2.08	38.30	40.38	54.3	10.9
1998	265	4.42	40.65	45.07	60.3	8.4
1999	288	4.44	53.69	58.13	54.5	16.9
2000	310	3.00	74.62	77.62	47.3	6.4
2001	148	3.02	41.65	44.67	52.2	8.7
2002*	151	15.19	24.35	39.54	33.3	8.6
2003	298	8.23	61.90	70.13	33.5	7.2
This Study (2004)	203	6.4	52.1	58.50	34.4	4.4

Table 6: Population characteristics of Spotted Bass for Table Rock Lake from 1987 to 2003 from annual electrofishing samples (Data from Missouri Department of Conservation (MDC)). PSD stands for proportional stock density and RSD stands for relative stock density. The preferred range for PSD is 30-60 and for RSD is 0-10.

Year	Number of fish sampled	Catch/hr. (< 180 mm)	Catch/hr. (≥ 180 mm)	Total Catch per hour (CPUE)	PSD	RSD_{14}
1987	1175	4.93	34.23	39.17	57.6	14.2
1988	442	1.72	20.71	22.44	79.7	24.3
1989	679	4.75	37.63	42.38	58.8	13.8
1990	859	4.15	44.77	48.92	70.4	19.7
1991	1041	7.91	52.62	60.52	52.9	18.1
1992	1020	6.16	67.75	73.91	58.3	15.9
1993	1181	5.44	70.32	75.71	80.9	35.0
1994	896	2.75	50.89	53.65	73.9	29.4
1995	1059	2.26	47.69	49.95	68.4	23.9
1996	1221	1.72	45.98	47.70	81.2	43.2
1997	1219	2.08	43.27	45.32	74.6	27.8
1998	1141	3.10	54.87	57.97	79.5	31.4
1999	1177	2.97	50.73	53.70	73.8	33.1
2000	1704	7.96	79.56	87.52	63.1	24.1
2001	895	5.54	42.58	48.12	75.4	30.7
2002	1601	3.07	59.22	62.30	72.3	43.0
2003	698	1.40	37.84	39.25	73.6	44.7
This Study (2004)	232	11.49	22.24	33.73	49.0	22.9

Figure 7: Population characteristics of spotted bass for Bull Shoals Lake from 1987 to 2003 from annual electrofishing samples (Data from AGFC and MDC). * denotes no samples were collected, 1 denotes years were only Theodosia arm was sampled, and 2 denotes high water years. PSD stands for proportional stock density and RSD stands for relative stock density. The preferred range for PSD is 30-60 and for RSD is 0-10.

	Year	Number of fish sampled	Catch/hr. (< 180 mm)	Catch/hr. (≥ 180 mm)	Total Catch/ hr. (CPUE)	PSD	RSD_{14}
Arkansas Game and Fish Commission	1987	296	1.93	31.80	33.73	49.5	4.7
	1988[2]	247	11.58	36.96	48.55	48.9	9.0
	1989	211	6.45	43.93	50.37	52.7	21.7
	1990	280	34.28	21.85	56.13	31.2	15.6
	1991	188	4.92	56.76	61.68	56.1	23.1
	1992	87	7.11	23.82	30.93	70.1	28.4
	1993	237	2.13	48.43	50.57	69.2	29.5
	1994[2]	90	2.37	28.05	30.42	42.2	8.4
	1995[2]	149	16.47	90.25	106.73	65.1	28.6
	1996	262	0.77	99.53	100.30	65.4	14.6
	1997	118	2.26	27.37	29.63	70.6	18.3
	1998[2]	134	0.64	28.07	28.71	78.6	38.9
	1999	120	0.83	32.48	33.31	70.9	21.4
	2000	142	2.86	34.10	36.97	41.2	7.6
	2001	114	5.78	30.85	36.63	71.9	34.4
	2002[*2]	-	-	-	-	-	-
	2003	98	2.55	25.20	27.75	56.2	18.0
Missouri Department of Conservation	1987	422	2.19	30.78	32.97	44.9	3.3
	1988[12]	466	5.00	38.96	43.96	57.9	16.9
	1989	1,695	4.98	56.21	61.19	42.1	9.3
	1990	589	4.61	34.14	38.75	44.3	8.1
	1991	948	5.32	80.10	85.41	44.1	12.6
	1992	430	6.56	39.68	46.24	43.1	5.4
	1993	469	2.45	55.09	57.55	45.9	7.3
	1994[*2]	-	-	-	-	-	-
	1995[12]	93	2.80	15.8	18.60	50.6	12.7
	1996	265	5.80	47.2	53.00	55.5	7.6
	1997	395	3.09	37.63	40.72	52.1	10.9
	1998[2]	293	0.91	52.36	53.27	51.4	8.0
	1999	592	4.34	51.51	55.85	60.8	10.4
	2000	821	6.14	92.77	98.92	46.0	4.8
	2001	635	5.32	52.94	58.26	49.4	7.8
	2002[2]	269	2.78	24.95	27.73	48.4	12.4
	2003	457	2.64	40.47	43.11	31.0	7.9
	This Study (2004)	275	13.01	22.07	35.08	33.7	11.6

Table 8: Comparison of CPUE among sections for each sample lake using historical data. There was no test for sections/years interaction in Table Rock Lake. Asterisks denote significant differences (ANOVA; $P \leq 0.05$).

Lake	Parameter	Comparison	df	F	P
Beaver	All Fish	Sections	2,194	6.24	0.002*
		Years	16,194	0.85	0.625
		Sections/Years	30,194	1.93	0.004*
	< 180 mm	Sections	2,194	1.26	0.287
		Years	16,194	2.93	0.0002*
		Sections/Years	30,194	1.29	0.158
	≥ 180 mm	Sections	2,194	7.52	0.0007*
		Years	16,194	1.11	0.344
		Sections/Years	30,194	1.86	0.007*
	≥ 280 mm	Sections	2,194	14.29	<0.0001*
		Years	16,194	1.50	0.104
		Sections/Years	30,194	1.61	0.031*
	≥ 350 mm	Sections	2,194	25.77	<0.0001*
		Years	16,194	1.48	0.111
		Sections/Years	30,194	1.32	0.138
Table Rock	All Fish	Sections	3,47	6.30	0.001*
		Years	13,37	1.17	0.335
	< 180 mm	Sections	3,47	2.11	0.111
		Years	13,37	1.60	0.130
	≥ 180 mm	Sections	3,47	7.38	0.0004*
		Years	13,37	1.23	0.298
	≥ 280 mm	Sections	3,47	6.37	0.001*
		Years	13,37	1.05	0.428
	≥ 350 mm	Sections	3,47	3.15	<0.0001*
		Years	13,37	1.97	0.053
Bull Shoals	All Fish	Sections	3,160	13.30	<0.0001*
		Years	16,160	1.21	0.262
		Sections/Years	40,160	1.47	0.051
	< 180 mm	Sections	3,160	1.13	0.337
		Years	16,160	1.94	0.021*
		Sections/Years	40,160	0.83	0.757
	≥ 180 mm	Sections	3,160	18.79	<0.0001*
		Years	16,160	1.28	0.217
		Sections/Years	40,160	1.59	0.024*
	≥ 280 mm	Sections	3,160	31.81	<0.0001*
		Years	16,160	2.60	0.001*
		Sections/Years	40,160	1.55	0.030*
	≥ 350 mm	Sections	3,160	13.40	<0.0001*
		Years	16,160	1.34	0.180
		Sections/Years	40,160	0.72	0.884

Table 9: Comparison of CPUE among length categories for all sample lake using historical data. Asterisks denote significant differences (ANOVA; $P \leq 0.05$).

Lake	Parameter	Comparison	df	F	P
All Lakes	All Fish	Lake	2,366	4.95	0.020*
		Years	13,366	0.82	0.641
		Lake/Years	26,366	1.20	0.231
	< 180 mm	Lake	2,365	1.74	0.178
		Years	13,365	2.43	0.004*
		Lake/Years	26,365	2.97	<0.0001*
	≥ 180 mm	Lake	2,366	4.93	0.008*
		Years	13,366	1.19	0.284
		Lake/Years	26,366	1.29	0.159
	≥ 280 mm	Lake	2,366	13.31	<0.0001*
		Years	13,366	1.53	0.103
		Lake/Years	26,366	1.82	0.009*
	≥ 350 mm	Lake	2,366	42.77	<0.0001*
		Years	13,366	2.12	0.013*
		Lake/Years	26,366	2.34	0.0003*

Table 10: Length (mm) von Bertalanffy parameters for sections in each lake. L_∞ is the asymptotic length, k is a growth coefficient of catabolism and t_0 is the age at which the length would theoretically be zero. T. stands for tournament fish. CI refers to confidence intervals.

Lake	Sections	Number Aged	L_∞	± 95% CI	k	± 95% CI	t_0	± 95% CI
Beaver Lake	Overall	176	401.5	49.7	0.3768	0.13	-0.4838	0.28
	Lower	35	450.6	149.8	0.2262	0.16	-0.9751	0.60
	Middle	62	452.4	178.1	0.2993	0.28	-0.6017	0.73
	Upper	79	440.4	23.5	0.3509	0.05	-0.3979	0.10
Table Rock Lake	Overall	232	451.6	64.6	0.3030	0.15	-0.3673	0.60
	Lower	54	424.3	105.4	0.3104	0.26	-0.4145	1.03
	Middle	30	459.2	74.4	0.3499	0.20	-0.0455	0.60
	Upper	81	447.2	189.7	0.2557	0.29	-0.7689	1.30
	James River	67	463.7	135.2	0.3072	0.27	-0.3645	0.92
Bull Shoals Lake	Overall	286	451.1	68.3	0.3041	0.15	-0.3959	0.64
	Overall W/T. Fish	341	461.5	53.3	0.3374	0.14	-0.2439	0.49
	Lower	62	458.5	98.8	0.2907	0.17	-0.4099	0.65
	Middle	126	490.6	76.7	0.2434	0.10	-0.5566	0.52
	Upper	32	372.5	108.4	0.5451	0.55	-0.1493	0.68
	Theodosia Arm	67	407.5	96.8	0.4057	0.32	-0.2011	0.78

Table 11: Comparison of growth parameters among sections for Beaver Lake. Asterisks denote significant differences (ANCOVA or t-test; $P \leq 0.05$).

Sections	Parameter	Test	df	F or t value	P
Lower-Middle	Slope	ANCOVA	1,6	1.71	0.239
	Elevation	ANCOVA	1,7	4.79	0.065
	Growth Curve	ANOVA	3,4	21.24	0.006*
	L_∞	t-test	10	-0.05	0.965
	k	t-test	10	-1.46	0.175
	t_0	t-test	10	-2.26	0.048*
Lower-Upper	Slope	ANCOVA	1,6	4.26	0.085
	Elevation	ANCOVA	1,7	5.69	0.049*
	Growth Curve	ANOVA	3,4	148.71	<0.0001*
	L_∞	t-test	10	0.56	0.589
	k	t-test	10	-5.42	0.003*
	t_0	t-test	10	-7.90	<0.0001*
Middle-Upper	Slope	ANCOVA	1,6	0.42	0.541
	Elevation	ANCOVA	1,7	0.17	0.690
	Growth Curve	ANOVA	3,4	1.90	0.271
	L_∞	t-test	10	0.51	0.621
	k	t-test	10	-1.25	0.239
	t_0	t-test	10	-2.09	0.064

Table 12: Comparison of growth parameters for genders within sample lakes. Asterisks denote significant differences (ANCOVA or t-test; $P \leq 0.05$).

Lake	Parameter	Test	df	F or t value	P
Beaver	Slope	ANCOVA	1,4	2.95	0.161
	Elevation	ANCOVA	1.4	5.49	0.066
	Growth Curve	ANOVA	3, 133	0.69	0.560
	L_∞	t-test	139	0.11	0.909
	k	t-test	139	0.12	0.908
	t_0	t-test	139	0.29	0.771
Table Rock	Slope	ANCOVA	1,10	0.03	0.861
	Elevation	ANCOVA	1.11	0.02	0.894
	Growth Curve	ANOVA	3, 9	0.08	0.969
	L_∞	t-test	15	0.55	0.587
	k	t-test	15	-0.44	0.665
	t_0	t-test	15	-0.32	0.754
Bull Shoals	Slope	ANCOVA	1,6	1.08	0.339
	Elevation	ANCOVA	1,7	0.12	0.737
	Growth Curve	ANOVA	3,5	0.01	0.997
	L_∞	t-test	11	-0.16	0.878
	k	t-test	11	-0.18	0.861
	t_0	t-test	11	-0.23	0.821

Table 13: Comparison of growth parameters among sections for Table Rock Lake. James stands for James River. Asterisks denote significant differences (ANCOVA or t-test; P ≤ 0.05).

Sections	Parameter	Test	df	F or t value	P
Lower-Middle	Slope	ANCOVA	1,10	1.43	0.259
	Elevation	ANCOVA	1,11	0.92	0.358
	Growth Curve	ANOVA	3,10	1.97	0.183
	L_∞	t-test	16	-0.91	0.374
	k	t-test	16	-0.41	0.691
	t_0	t-test	16	-1.04	0.314
Lower-Upper	Slope	ANCOVA	1,8	0.22	0.654
	Elevation	ANCOVA	1,9	0.02	0.895
	Growth Curve	ANOVA	3,8	0.17	0.914
	L_∞	t-test	14	-0.39	0.704
	k	t-test	14	0.53	0.607
	t_0	t-test	14	0.79	0.443
Lower-James	Slope	ANCOVA	1,6	0.01	0.914
	Elevation	ANCOVA	1,7	0.03	0.582
	Growth Curve	ANOVA	3,8	1.25	0.354
	L_∞	t-test	14	-0.87	0.401
	k	t-test	14	0.03	0.980
	t_0	t-test	14	-0.14	0.891
Middle-Upper	Slope	ANCOVA	1,10	2.42	0.151
	Elevation	ANCOVA	1,11	0.69	0.423
	Growth Curve	ANOVA	3,10	2.36	0.133
	L_∞	t-test	16	-0.18	0.861
	k	t-test	16	-0.82	0.423
	t_0	t-test	16	-1.50	0.152
Middle-James	Slope	ANCOVA	1,10	0.54	0.480
	Elevation	ANCOVA	1,11	0.00	0.994
	Growth Curve	ANOVA	3,10	0.29	0.832
	L_∞	t-test	16	0.10	0.923
	k	t-test	16	-0.44	0.662
	t_0	t-test	16	-0.99	0.339
Upper-James	Slope	ANCOVA	1,8	0.65	0.444
	Elevation	ANCOVA	1,9	0.59	0.463
	Growth Curve	ANOVA	3,8	1.43	0.304
	L_∞	t-test	14	0.26	0.795
	k	t-test	14	0.50	0.625
	t_0	t-test	14	0.94	0.364

Table 14: Comparison of growth parameters among sections for Bull Shoals Lake. Theod. stands for Theodosia Arm. Asterisks denote significant differences (ANCOVA or t-test; $P \leq 0.05$).

Sections	Parameter	Test	df	F or t value	P
Lower-Middle	Slope	ANCOVA	1,6	0.03	0.875
	Elevation	ANCOVA	1,7	0.01	0.920
	Growth Curve	ANOVA	3,6	0.23	0.876
	L_∞	t-test	12	-1.13	0.282
	k	t-test	12	1.08	0.302
	t_0	t-test	12	0.76	0.461
Lower-Upper	Slope	ANCOVA	1,6	0.02	0.90
	Elevation	ANCOVA	1,7	0.92	0.369
	Growth Curve	ANOVA	3,5	1.77	0.268
	L_∞	t-test	11	3.16	0.009*
	k	t-test	11	-2.48	0.031*
	t_0	t-test	11	-1.47	0.171
Lower-Theod.	Slope	ANCOVA	1,8	0.08	0.783
	Elevation	ANCOVA	1,9	0.01	0.931
	Growth Curve	ANOVA	3,6	0.46	0.718
	L_∞	t-test	12	1.51	0.158
	k	t-test	12	-1.45	0.173
	t_0	t-test	12	-0.83	0.420
Middle-Upper	Slope	ANCOVA	1,6	0.08	0.793
	Elevation	ANCOVA	1,7	0.93	0.367
	Growth Curve	ANOVA	3,5	3.31	0.115
	L_∞	t-test	11	4.93	0.004*
	k	t-test	11	-3.55	0.005*
	t_0	t-test	11	-2.57	0.026*
Middle-Theod.	Slope	ANCOVA	1,6	0.11	0.728
	Elevation	ANCOVA	1,7	0.12	0.737
	Growth Curve	ANOVA	3,6	1.23	0.367
	L_∞	t-test	12	2.49	0.028*
	k	t-test	12	-2.37	0.035*
	t_0	t-test	12	-1.45	0.174
Upper-Theod.	Slope	ANCOVA	1,6	0.16	0.703
	Elevation	ANCOVA	1,7	0.39	0.553
	Growth Curve	ANOVA	3,6	0.39	0.768
	L_∞	t-test	11	-1.09	0.298
	k	t-test	11	0.95	0.365
	t_0	t-test	11	0.24	0.812

Table 15: Comparison of growth parameters among sample lakes. Asterisks denote significant differences (ANCOVA or t-test; $P \leq 0.05$).

Lakes	Parameter	Test	df	F or t value	P
Beaver-Table Rock	Slope	ANCOVA	1,6	0.58	0.475
	Elevation	ANCOVA	1,7	0.08	0.779
	Growth Curve	ANOVA	3,8	0.65	0.604
	L_∞	t-test	14	-1.00	0.336
	k	t-test	14	0.57	0.579
	t_0	t-test	14	-0.38	0.711
Beaver-Bull Shoals	Slope	ANCOVA	1,6	0.66	0.446
	Elevation	ANCOVA	1,7	0.15	0.714
	Growth Curve	ANOVA	3,6	0.69	0.592
	L_∞	t-test	12	-1.22	0.244
	k	t-test	12	0.70	0.499
	t_0	t-test	12	-0.35	0.732
Table Rock-Bull Shoals	Slope	ANCOVA	1,10	0.05	0.821
	Elevation	ANCOVA	1,11	0.01	0.911
	Growth Curve	ANOVA	3,10	0.01	0.998
	L_∞	t-test	16	0.02	0.987
	k	t-test	16	-0.02	0.987
	t_0	t-test	16	0.11	0.917
Beaver-Bull Shoals T.	Slope	ANCOVA	1,6	1.52	0.263
	Elevation	ANCOVA	1,7	0.14	0.722
	Growth Curve	ANOVA	3,8	1.60	0.265
	L_∞	t-test	14	-1.24	0.234
	k	t-test	14	0.31	0.760
	t_0	t-test	14	-0.83	0.420
Table Rock-Bull Shoals T.	Slope	ANCOVA	1,14	0.28	0.631
	Elevation	ANCOVA	1,15	1.94	0.184
	Growth Curve	ANOVA	3,12	1.38	0.296
	L_∞	t-test	18	-0.37	0.718
	k	t-test	18	-0.52	0.607
	t_0	t-test	18	0.49	0.631

Table 16: Proportional stock density (PSD), relative stock density (RSD_{14}) with 95 % confidence intervals and incremental relative stock density (RSD) for sample lakes. Incremental refers the percentage of fish in between two length categories. S = Stock, Q = Quality, P= Preferred, M= Memorable, and T= Trophy. The preferred range for PSD is 30-60 and for RSD is 0-10.

Lake	Stock Indices	Overall	Lower	Middle	Upper	
Beaver	PSD	34.44 (±6.89)	36.67 (±17.25)	33.96 (±12.75)	34.69 (±9.45)	
	RSD_{14}	4.44 (±3.01)	0 (± 0)	3.77 (±5.13)	6.12 (±4.74)	
		Overall	Lower	Middle	Upper	James R.
Table Rock	PSD	49.02 (±7.92)	38.89 (±22.52)	87.50 (±13.23)	37.74 (±13.05)	46.55 (±12.84)
	RSD_{14}	22.88 (±6.66)	22.20 (±19.18)	54.17 (±19.94)	13.21 (±9.12)	18.97 (±10.09)
		Overall	Lower	Middle	Upper	Theodosia A.
Bull Shoals	PSD	30.66 (±7.44)	32.43 (±15.08)	20 (±9.37)	36 (±12.82)	41.46 (±15.08)
	RSD_{14}	11.56 (±4.76)	16.22 (±11.88)	8.57 (±6.56)	4.00 (±7.68)	17.07 (±11.51)
		Overall	Lower	Middle	Upper	
Beaver	RSD S-Q	65.56	63.33	66.04	65.31	
	RSD Q-P	30.00	36.67	30.19	28.57	
	RSD P-M	4.44	0	3.77	6.12	
	RSD M-T	0	0	0	0	
		Overall	Lower	Middle	Upper	James R.
Table Rock	RSD S-Q	50.98	61.11	12.50	62.26	53.45
	RSD Q-P	26.14	16.70	33.33	24.53	27.59
	RSD P-M	21.57	22.20	45.83	13.21	18.97
	RSD M-T	1.31	0	8.33	0	0
		Overall	Lower	Middle	Upper	Theodosia A.
Bull Shoals	RSD S-Q	69.94	67.57	80.00	64.00	58.54
	RSD Q-P	18.50	16.22	11.43	32.00	24.39
	RSD P-M	10.98	16.22	7.14	4.00	17.07
	RSD M-T	0.58	0	1.43	0	0

Table 17: Comparison of size structure data among sample lakes. KS indicates Kolmogorov-Smirnov test. Asterisks denote significant differences (KS or Chi-square; P ≤ 0.05).

Lakes	Comparison	Test (df)	Test statistics	P
Beaver-Table Rock	Size Structure	KS	2.69	<0.0001*
	Proportion in Length groups	Chi-Square (3)	57.97	<0.0001*
	Stock-to-Quality	Chi-Square (1)	6.90	0.001*
	Quality-to-Preferred	Chi-Square (1)	25.18	<0.0001*
	Preferred-to-Memorable	Chi-Square (1)	2.38	0.123
Beaver-Bull Shoals	Size Structure	KS	3.18	<0.0001*
	Proportion in Length groups	Chi-Square (3)	52.81	<0.0001*
	Stock-to-Quality	Chi-Square (1)	0.91	0.340
	Quality-to-Preferred	Chi-Square (1)	1.05	0.306
	Preferred-to-Memorable	Chi-Square (1)	6.19	0.013*
Table Rock-Bull Shoals	Size Structure	KS	1.51	0.022*
	Proportion in Length groups	Chi-Square (3)	13.13	0.004*
	Stock-to-Quality	Chi-Square (1)	12.28	0.001*
	Quality-to-Preferred	Chi-Square (1)	7.41	0.007*
	Preferred-to-Memorable	Chi-Square (1)	0.47	0.491

Table 18: Historical CPUE data collected within each sample lake. AGFC stands for Arkansas Game and Fish Commission. MDC stands for Missouri Department of Conservation. Theod stands for Theodosia Arm.

Lake	Sections	Total #	Hrs	≥ 180 mm	≥ 280 mm	≥ 350 mm	≥ 430 mm
Beaver	Overall	4925	94.4	4518	2240	409	8
	Lower	1257	24.1	1167	668	149	3
	Middle	2410	41.7	2249	1122	221	4
	Upper	1258	28.5	1102	450	39	1
Table Rock	Overall	16500	304.8	15360	10957	4607	50
	James R.	5451	77.9	5119	3678	1495	15
	Kings R.	4082	74.1	3811	2645	907	6
	Long Cr.	3856	84	3459	2418	966	11
	Middle Strata	3111	68.3	2971	2216	1239	18
Bull Shoals	Overall	11612	199.1	10492	5145	1178	21
	AFGC	2773	63.3	2369	1385	449	11
	MDC	8839	135.8	8123	3760	537	10
	Lower	1711	17.4	1527	981	336	5
	Middle	1062	45.9	842	404	50	6
	Upper	4371	50.5	4042	1637	61	3
	Theod.	4468	85.3	4081	2123	473	7

Table 19. Comparison of length frequency among sections for each sample lake and among sample lakes using historical data. KS indicates Kolmogorov-Smirnov test. Asterisks denote significant differences (KS; $P \leq 0.05$).

	Comparisons	KS	P
Beaver Lake	Lower-Middle	1.99	0.0007*
	Lower-Upper	4.38	<0.0001*
	Middle-Upper	4.20	<0.0001*
Table Rock Lake	Kings-James	2.52	<0.0001*
	Kings-Middle	7.39	<0.0001*
	Kings-Long Cr.	1.86	<0.0001*
	James-Middle	5.51	<0.0001*
	James-Long Cr.	2.29	<0.0001*
	Middle-Long Cr.	6.12	<0.0001*
Bull Shoals Lake	Lower-Middle	4.99	<0.0001*
	Lower-Upper	4.89	<0.0001*
	Lower-Theodosia	4.68	<0.0001*
	Middle-Upper	4.13	<0.0001*
	Middle-Theodosia	4.45	<0.0001*
	Upper-Theodosia	4.98	<0.0001*
Among Lakes	Beaver-Table Rock	16.85	<0.0001*
	Beaver-Bull Shoals	1.59	0.012*
	Table Rock-Bull Shoals	21.77	<0.0001*

Table 20: Mean relative weights (W_r) (±SE) for sample lakes.
Relative weight is an index of condition with 100 being considered healthy.
S = Stock, Q = Quality, P= Preferred, M= Memorable, and T= Trophy.

Lake		Overall	Lower	Middle	Upper	
Beaver Lake	Sub-stock	98.21 (±2.27)	96.08 (±5.83)	99.67 (±3.66)	97.48 (±2.60)	
	S-Q	100.23 (±0.83)	94.69 (±2.48)	100.52 (±1.17)	101.72 (±1.11)	
	Q-P	90.56 (±0.95)	93.10 (±1.74)	86.74 (±3.97)	90.00 (±1.30)	
	P-M	87.60 (±3.26)	0	91.31 (±12.99)	86.37 (±2.71)	
	M-T	0	0	0	0	
	Total	96.91 (±0.69)	94.43 (±1.67)	96.36 (±1.56)	97.43 (±0.98)	
		Overall	**Lower**	**Middle**	**Upper**	**James R.**
Table Rock Lake	Sub-stock	96.40 (±1.03)	97.43 (±1.50)	100.31 (±1.25)	91.82 (±1.81)	103.53 (±0.79)
	S-Q	99.24 (±0.98)	104.92 (±2.89)	93.60 (±2.50)	93.57 (±1.23)	103.81 (±1.11)
	Q-P	96.09 (±1.78)	96.92 (±1.10)	102.00 (±5.75)	90.10 (±3.23)	97.84 (±1.71)
	P-M	97.29 (±2.11)	101.30 (±7.88)	99.24 (±2.96)	87.27 (±6.05)	100.34 (±2.24)
	M-T	102.84 (±4.35)	0	102.84 (±4.36)	0	0
	Total	97.49 (±0.65)	99.23 (± 1.33)	99.87 (± 1.89)	91.86 (± 1.08)	101.78 (± 0.81)
		Overall	**Lower**	**Middle**	**Upper**	**Theodosia A.**
Bull Shoals Lake	Sub-stock	97.35 (±1.20)	96.85 (±2.06)	96.44 (±2.01)	105.97 (±7.05)	105.71 (±3.51)
	S-Q	99.51 (±0.77)	96.36 (±1.20)	98.75 (±1.15)	104.25 (±1.91)	101.37 (±1.64)
	Q-P	101.66 (±1.91)	105.21 (±2.76)	97.71 (±1.91)	98.80 (±3.20)	104.98 (±4.97)
	P-M	97.28 (±1.70)	95.39 (±4.45)	97.74 (±2.73)	92.39 (±0)	99.28 (±2.02)
	M-T	94.35 (±0)	0	94.35 (±0)	0	0
	Total	98.82 (±0.61)	97.32 (±1.19)	97.59 (±1.04)	102.69 (± 1.78)	102.92 (±1.48)

Table 21: Comparison of relative weights (W_r) (index of condition) for size groups among sections within each sample lake. Asterisks denote significant differences (GLM; $P \leq 0.05$).

Lake	Parameter	df	F	P
Beaver Lake	Sub-Stock	2,16	0.21	0.814
	Stock-Quality	2,115	4.82	0.010*
	Quality-Preferred	2,52	0.80	0.456
	Preferred-Memorable	1,6	0.39	0.554
Table Rock Lake	Sub-Stock	3,73	5.53	0.002*
	Stock-Quality	3,74	14.32	<0.0001*
	Quality-Preferred	3,36	2.29	0.095
	Preferred-Memorable	3,29	2.30	0.098
Bull Shoals Lake	Sub-Stock	3,96	2.39	0.073
	Stock-Quality	3,117	3.53	0.017*
	Quality-Preferred	3,28	1.09	0.371
	Preferred-Memorable	3,16	0.42	0.740

Table 22: Mean relative weights (W_r) (±SE) for tournament spotted bass from Bull Shoals Lake and Bull Shoals Lake including tournament fish. Relative weight is an index of condition with 100 being considered healthy. S = Stock, Q = Quality, P= Preferred, M= Memorable, and T= Trophy.

	Tournament Fish	Overall with tournament fish
Sub-stock		97.35 (±1.20)
S-Q		99.51 (±0.77)
Q-P	99.99 (±4.45)	101.46 (±1.59)
P-M	106.39 (±1.57)	102.64 (±1.26)
M-T	104.79 (±2.76)	102.70 (±2.99)
Total	104.76 (±1.53)	99.74 (±0.56)

Table 23: Comparison of condition data among sample lakes. Bull Shoals T. stands for tournament fish included in the Bull Shoals sample. Asterisks denote significant differences (ANCOVA or GLM; $P \leq 0.05$).

Lakes	Comparison	df	F	P
Beaver-Table Rock	Length-Weight	1,426	0.04	0.851
	Slope	1,425	22.7	<0.0001*
	Intercept	1,425	22.5	<0.0001*
	Sub-Stock	1,94	0.59	0.445
	Stock-Quality	1,194	0.59	0.445
	Quality-Preferred	1,92	8.54	0.004*
	Preferred-Memorable	1,39	4.45	0.041*
Beaver-Bull Shoals	Length-Weight	1,464	2.49	0.115
	Slope	1,463	29.4	<0.0001*
	Intercept	1,463	28.4	<0.0001*
	Sub-Stock	1,112	0.09	0.763
	Stock-Quality	1,237	0.41	0.520
	Quality-Preferred	1,84	33.5	<0.0001*
	Preferred-Memorable	1,25	8.33	0.008*
Table Rock-Bull Shoals	Length-Weight	1,495	2.37	0.124
	Slope	1,494	0.82	0.365
	Intercept	1,494	0.65	0.421
	Sub-Stock	1,170	0.34	0.562
	Stock-Quality	1,197	0.04	0.834
	Quality-Preferred	1,70	4.49	0.038*
	Preferred-Memorable	1,50	0.00	0.999
	Memorable-Trophy	1,1	1.26	0.463
Beaver-Bull Shoals T	Length-Weight	1,522	10.1	0.0002*
	Slope	1,521	46.0	<0.0001*
	Intercept	1,521	43.6	<0.0001*
	Quality-Preferred	1,101	35.9	<0.0001*
	Preferred-Memorable	1,61	18.1	<0.0001*
Table Rock-Bull Shoals T	Length-Weight	1,553	5.91	0.015*
	Slope	1,552	5.27	0.022*
	Intercept	1,552	4.51	0.034*
	Quality-Preferred	1,87	5.03	0.027*
	Preferred-Memorable	1,86	5.40	0.023*
	Memorable-Trophy	1,5	0.00	0.981
Bull Shoals-Bull Shoals T	Length-Weight	1,312	5.18	0.024*
	Slope	1,311	2.93	0.088
	Intercept	1,311	2.76	0.098

Table 24: Number at age of spotted bass captured from each sample lake. For Beaver Lake, an age length- key was used to for fish that were not aged. * Denotes the ages used for the catch curve analysis.

	Sample Lakes		
Age	Beaver Lake	Table Rock Lake	Bull Shoals Lake
0.5	15	6	10
1.5	99*	130*	183*
2.5	42*	24*	45*
3.5	30*	35*	21*
4.5	15*	9*	21*
5.5	1	14*	0*
6.5	1	5*	0*
7.5	0	3*	4*
8.5	0	2*	1*
9.5	0	3*	0
10.5	0	0	1
11.5	0	1	0

[1] Twenty –five fish were added to Beaver Lake sample. Two fish were add to age 0.5, 15 fish added to age 1.5, 6 fish added to age 2.5, 2 fish added to age 3.5, and 2 fish added to age 4.5.

Table 25. Annual mortality rates (%) for sections in Table Rock and Bull Shoals Lake using historical data.

Lake	Section	Mean	Range
Table Rock	Kings R.	37	22 – 55
	James R.	32	18 – 46
	Long Cr.	36	22 – 56
	Middle	26	24 – 28
Bull Shoals	Upper-Theodosia	46	19 – 57

Table 26: Predicted age for given lengths using von Bertalanffy parameters. The current length limit for Beaver and Bull Shoals Lake is 12 inches (304.8 mm). The current length limit for Table Rock Lake is 15 inches (381 mm).

Lake	12 in. (304.8 mm)	13 in. (330.2 mm)	14 in. (355.6 mm)	15 in. (381 mm)
Beaver	3.29	4.10	5.27	7.41
Table Rock	3.34	3.97	4.74	5.76
Bull Shoals	3.31	3.93	4.71	5.73
Bull Shoals With Tournament Fish	2.96	3.48	4.12	4.93

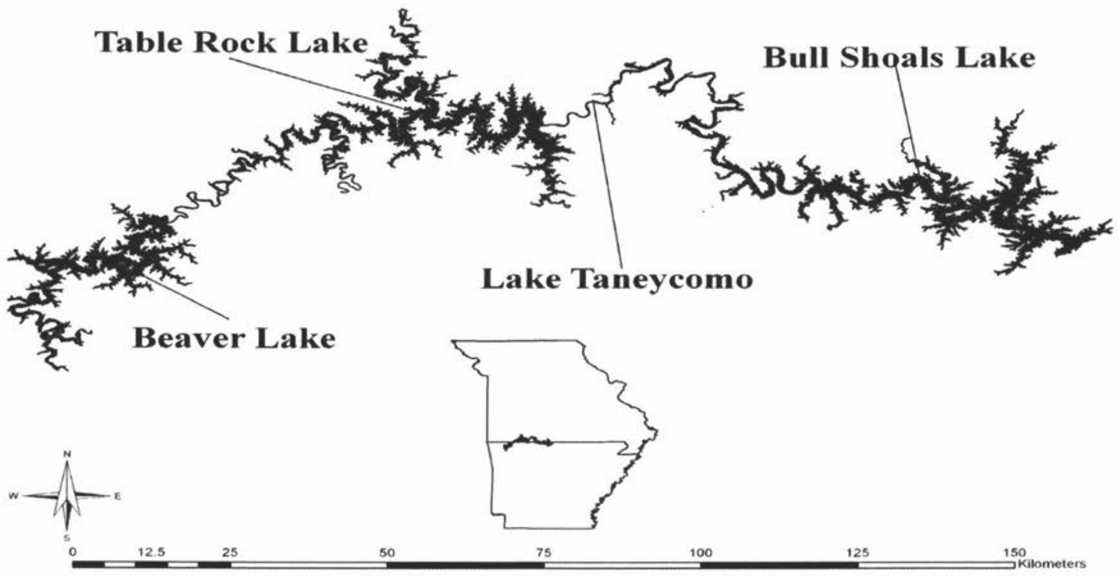


Figure 1: Upper White River Basin. Data retrieved August 2005 from http://nhdgeo.usgs.gov/viewer.htm.

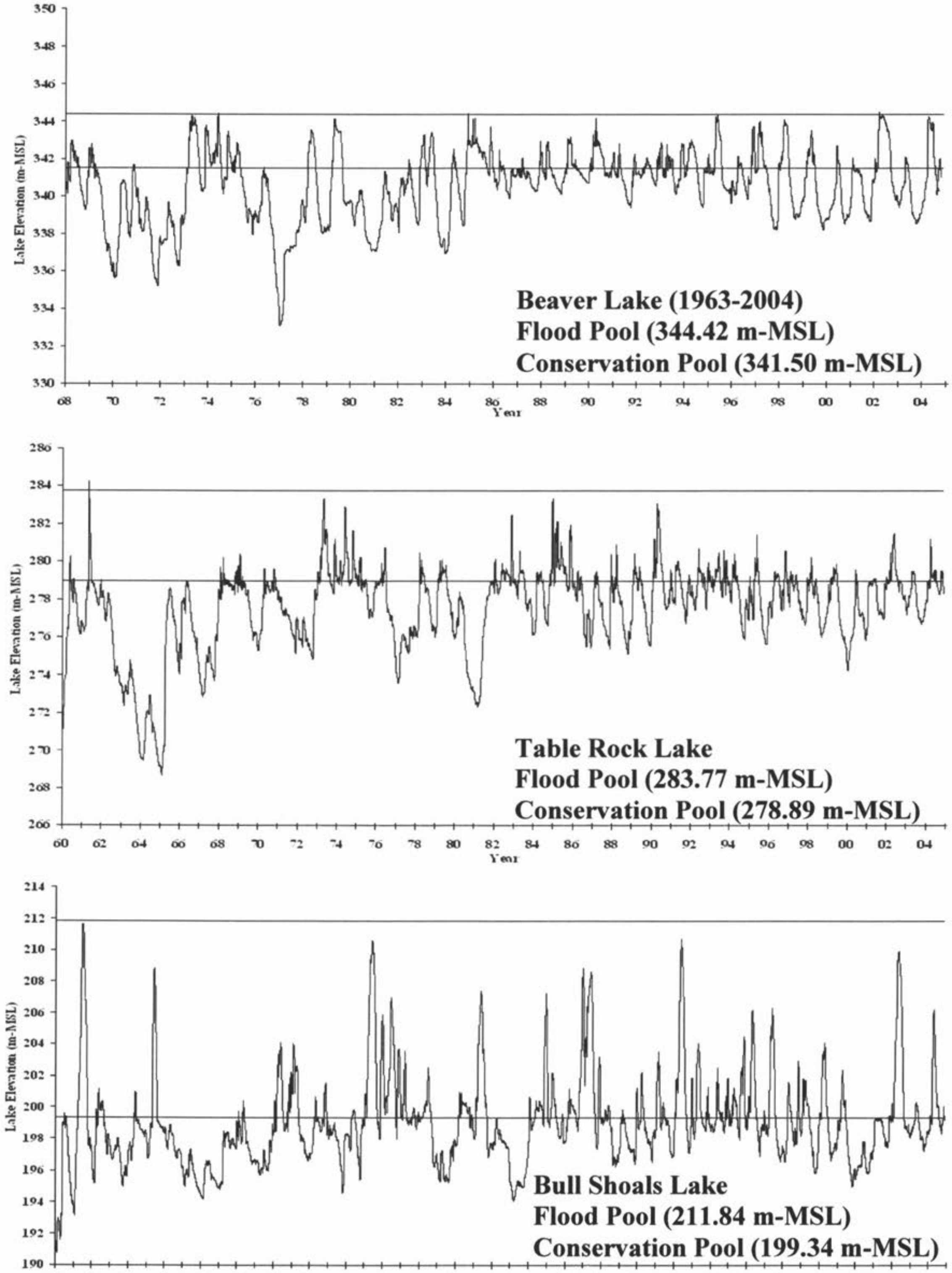


Figure 2: Daily Lake Elevation for sample lakes. Horizontal lines represent Flood Pool and Conservation Pool. m-MSL stands for meters above mean sea level. Water levels are from time reservoirs filled till December 2004. Data collected from the U.S. Corp of Engineers, Little Rock District.

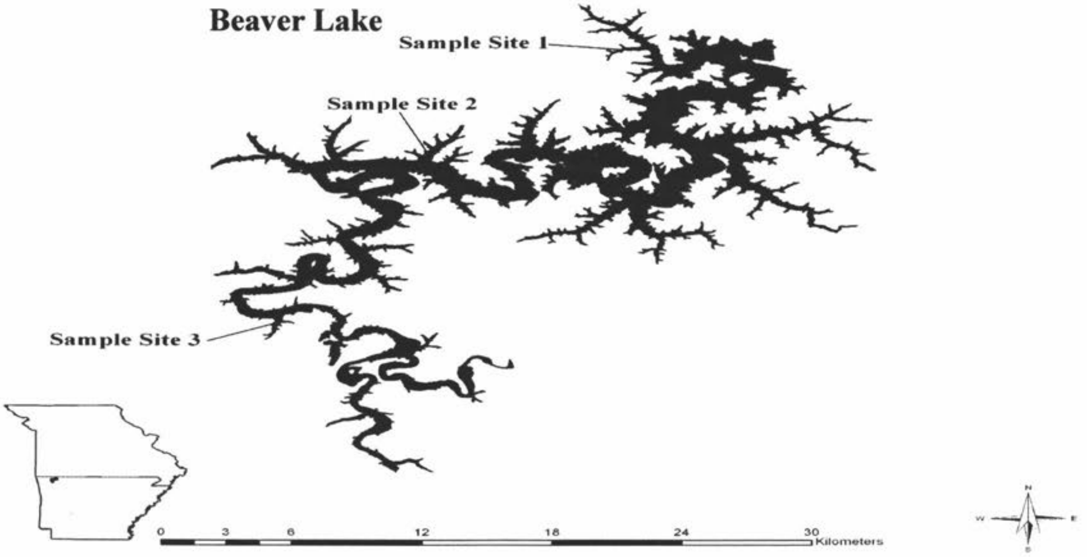


Figure 3: Beaver Lake Sample Sites. Beaver Lake Sample Site 1: Indian Creek, Sample Site 2: Ventris Hollow, and Sample Site 3: Nelson Hollow. Sample site 1 was considered lower section, site 2 was considered middle section, and site 3 was considered upper section. Data retrieved August 2005 from http://nhdgeo.usgs.gov/viewer.htm.

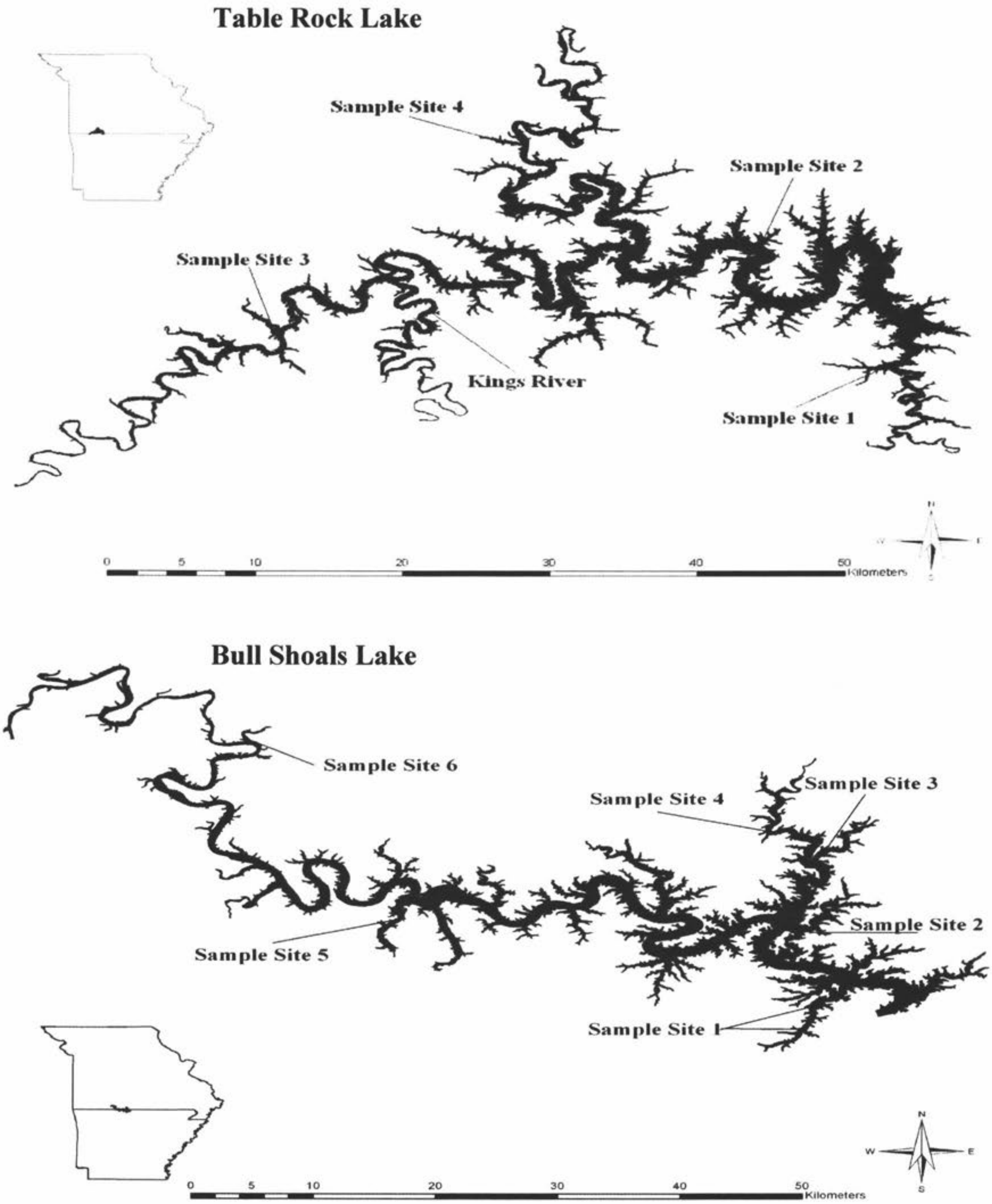


Figure 4: Table Rock and Bull Shoals Lake Sample Sites. Table Rock Lake Sample Sites 1: Brushy Creek, Sample Site 2: Whites Branch, Sample Site 3: Rock Creek, and Sample Site 4: Woolly Creek-James River. Sample site 1 was considered lower section, site 2 was considered middle section, site 3 was considered upper section, and site 4 was considered James River section. Bull Shoals Lake Sample Site 1: Jimmy's Creek, Sample Site 2: Mountain Creek, Sample Site 3: Spring Creek-Theodosia Arm, Sample Site 4: Theodosia Arm, Sample Site 5: West Sugarloaf and Sample Site 6: Beaver Creek. Sample site 1 was considered lower section, site 2, 3, and 5 was considered middle section, site 6 was considered upper section, and site 4 was considered Theodosia Arm section. Data retrieved August 2005 from http://nhdgeo.usgs.gov/viewer.htm.

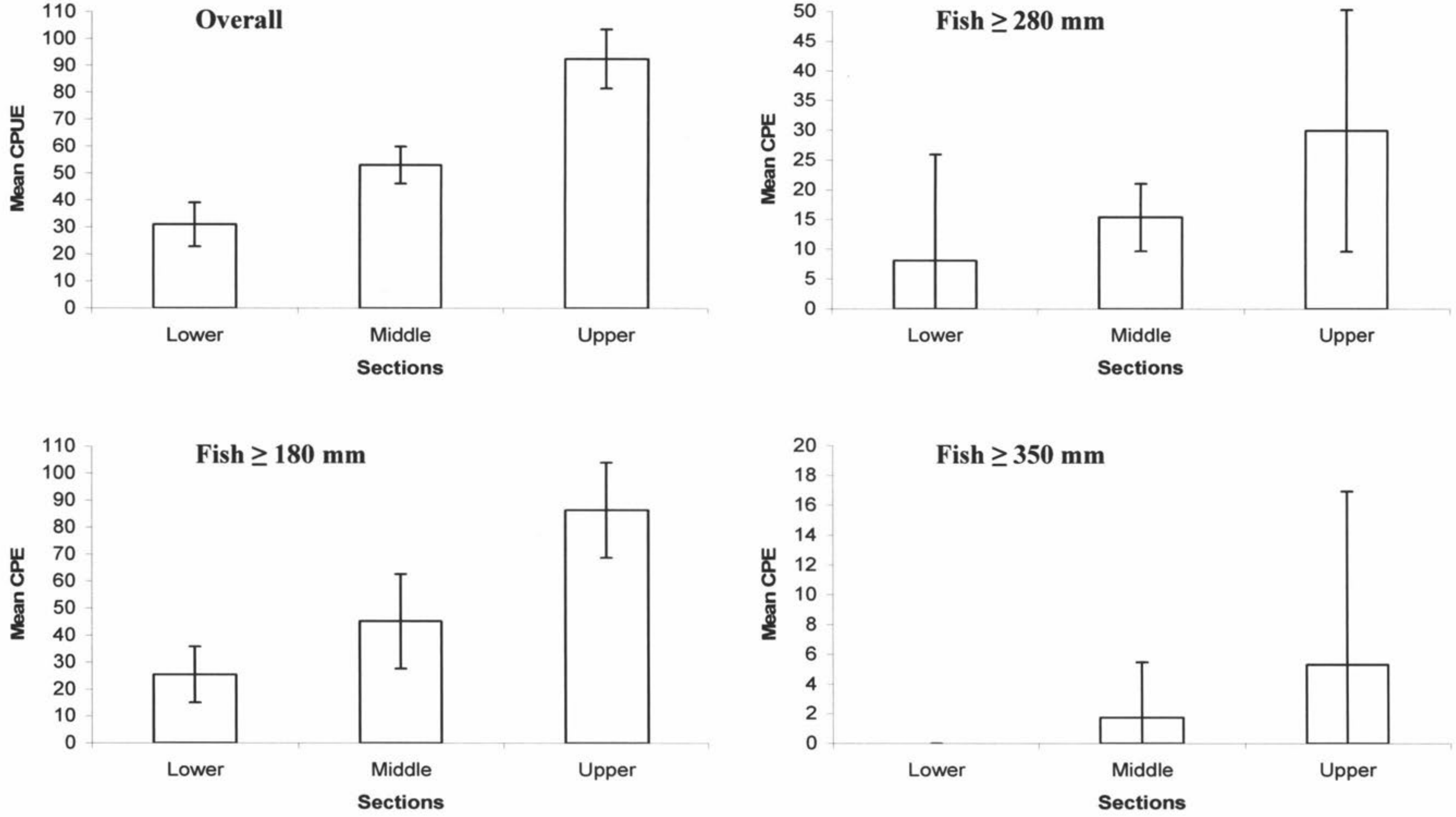


Figure 5: CPUE of spotted bass for sections within Beaver Lake. Mean ± 95 % confidence intervals.

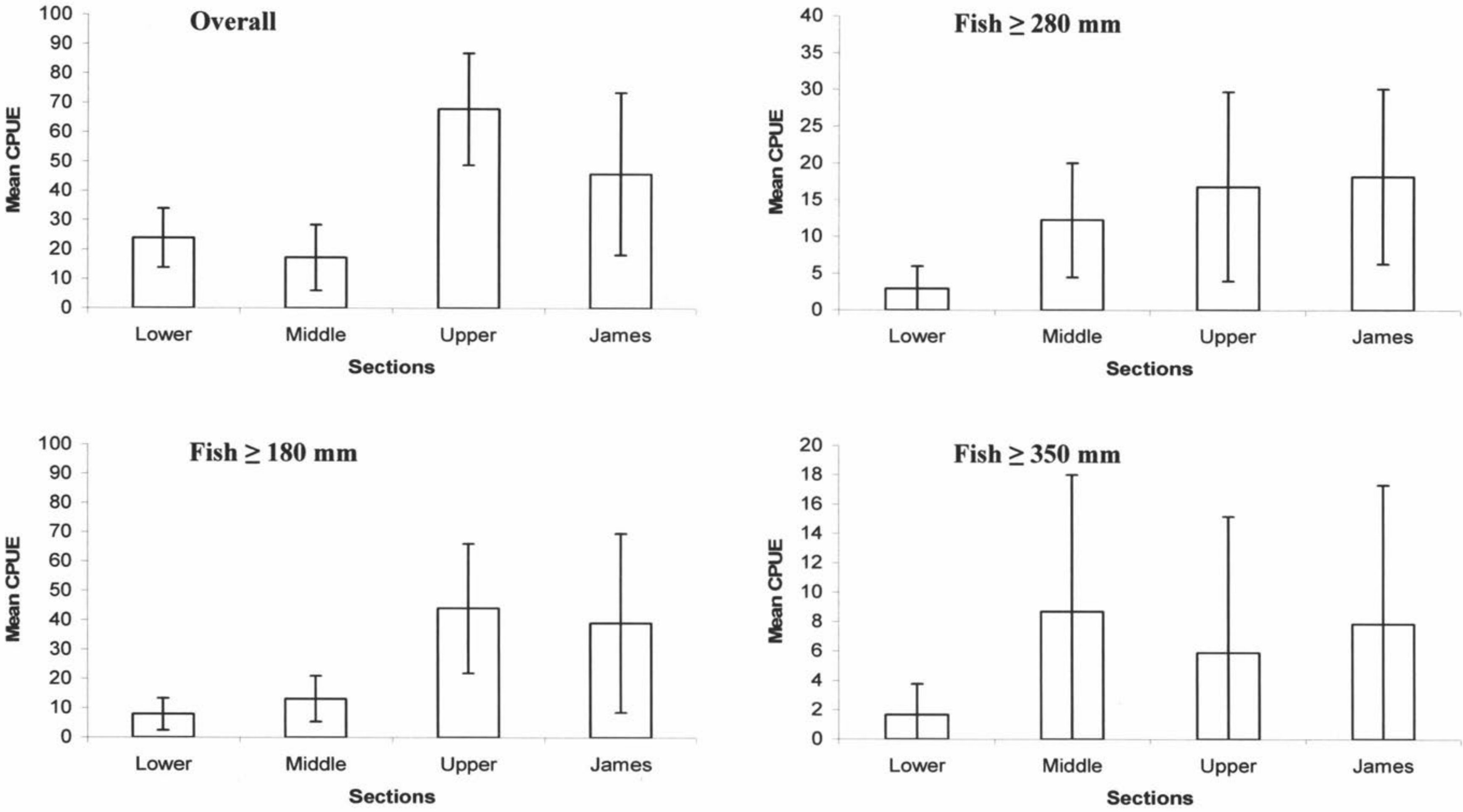


Figure 6: CPUE of spotted bass for sections within Table Rock Lake. Mean ± 95 % confidence intervals.

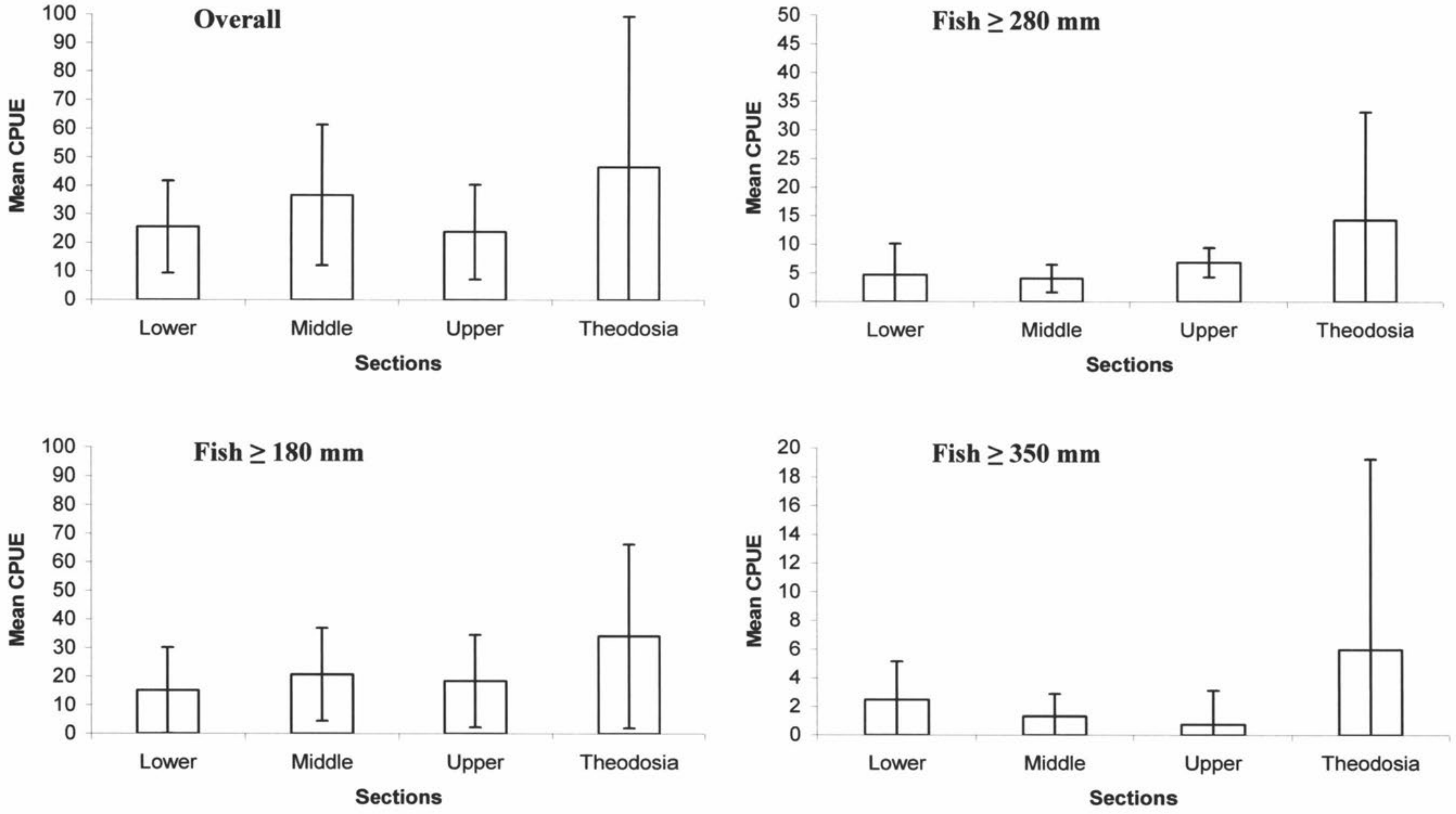


Figure 7: CPUE of spotted bass for sections within Bull Shoals Lake. Mean ± 95 % confidence intervals.

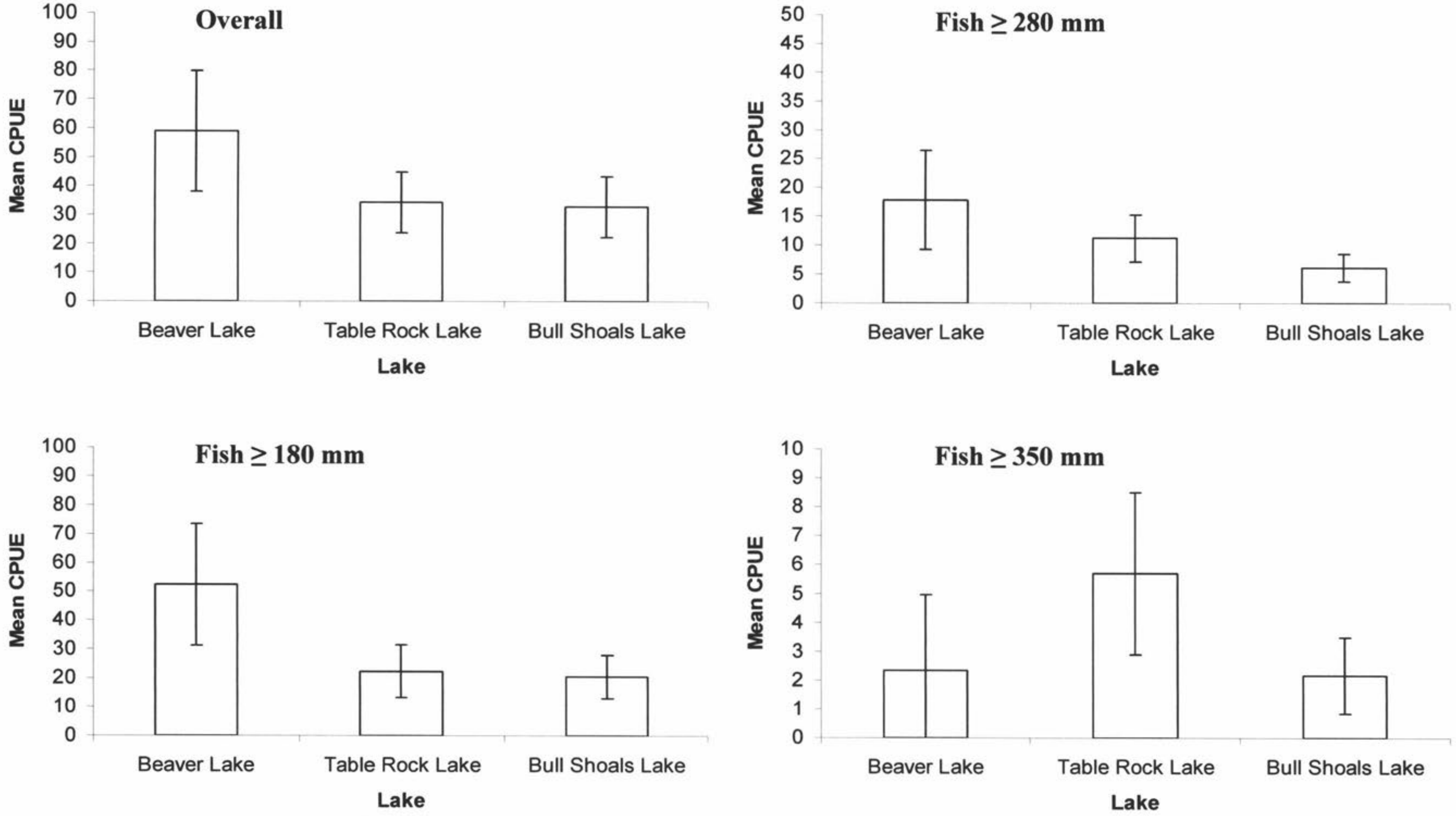


Figure 8: CPUE of spotted bass among sample lakes. Mean ± 95 % confidence intervals.

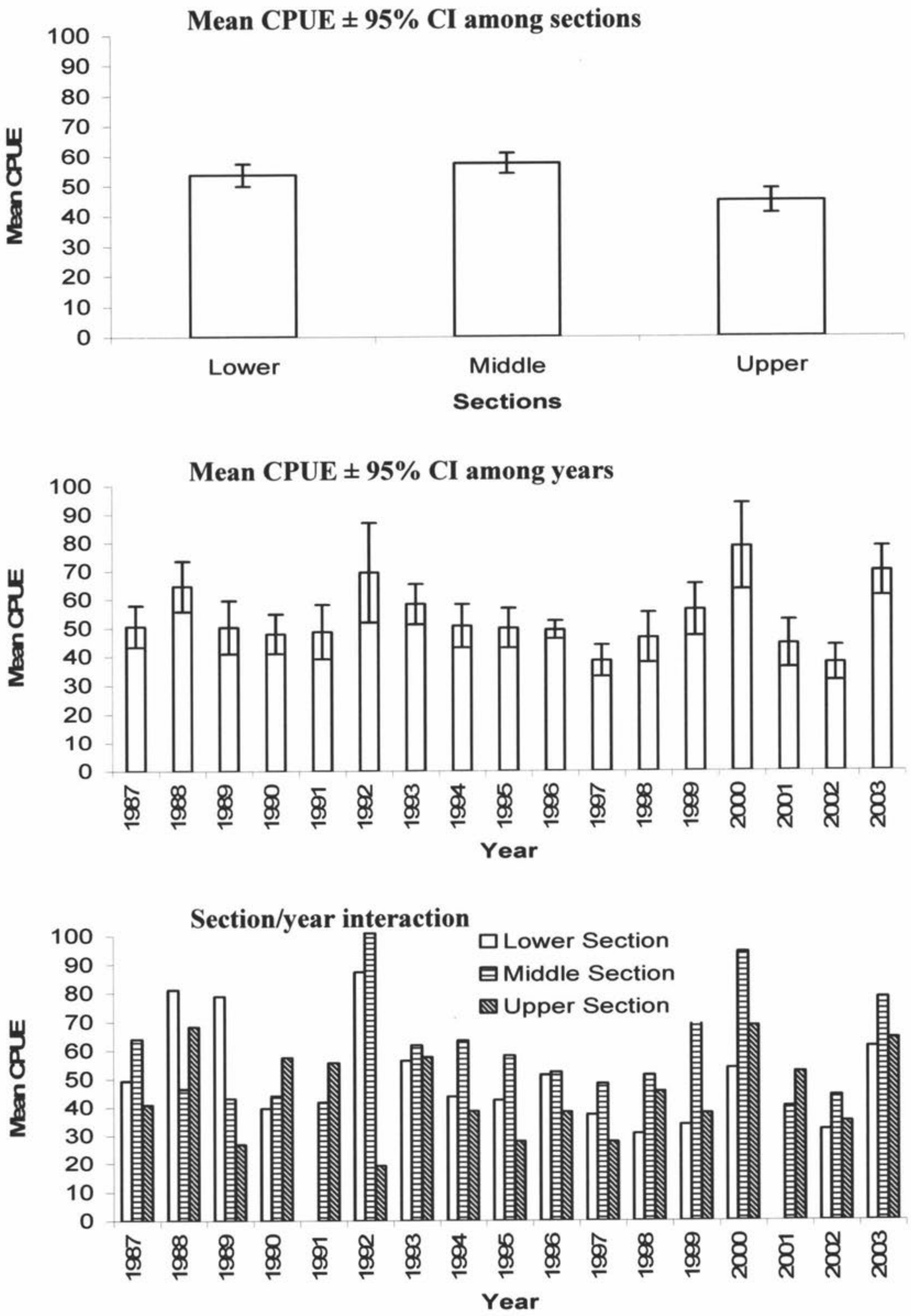


Figure 9: Historical electrofishing data for fish captured from 1987 to 2003 in Beaver Lake. The mean CPUE for middle section in 1992 was 119. CPUE refers to catch per unit effort and CI refers to confidence intervals.

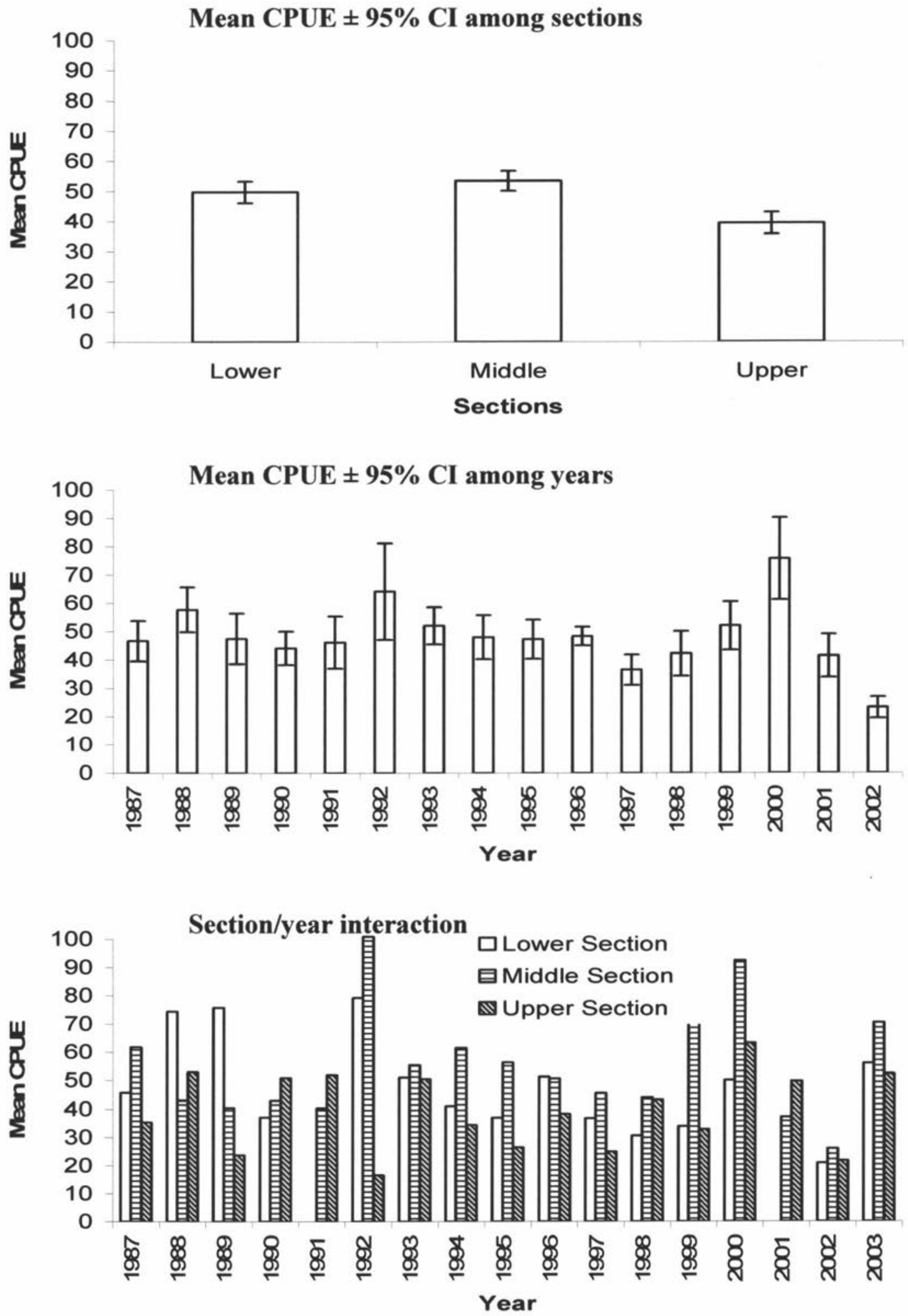


Figure 10: Historical electrofishing data for fish ≥ 180 mm captured from 1987 to 2003 in Beaver Lake. The mean CPUE for middle section in 1992 was 112. CPUE refers to catch per unit effort and CI refers to confidence intervals.

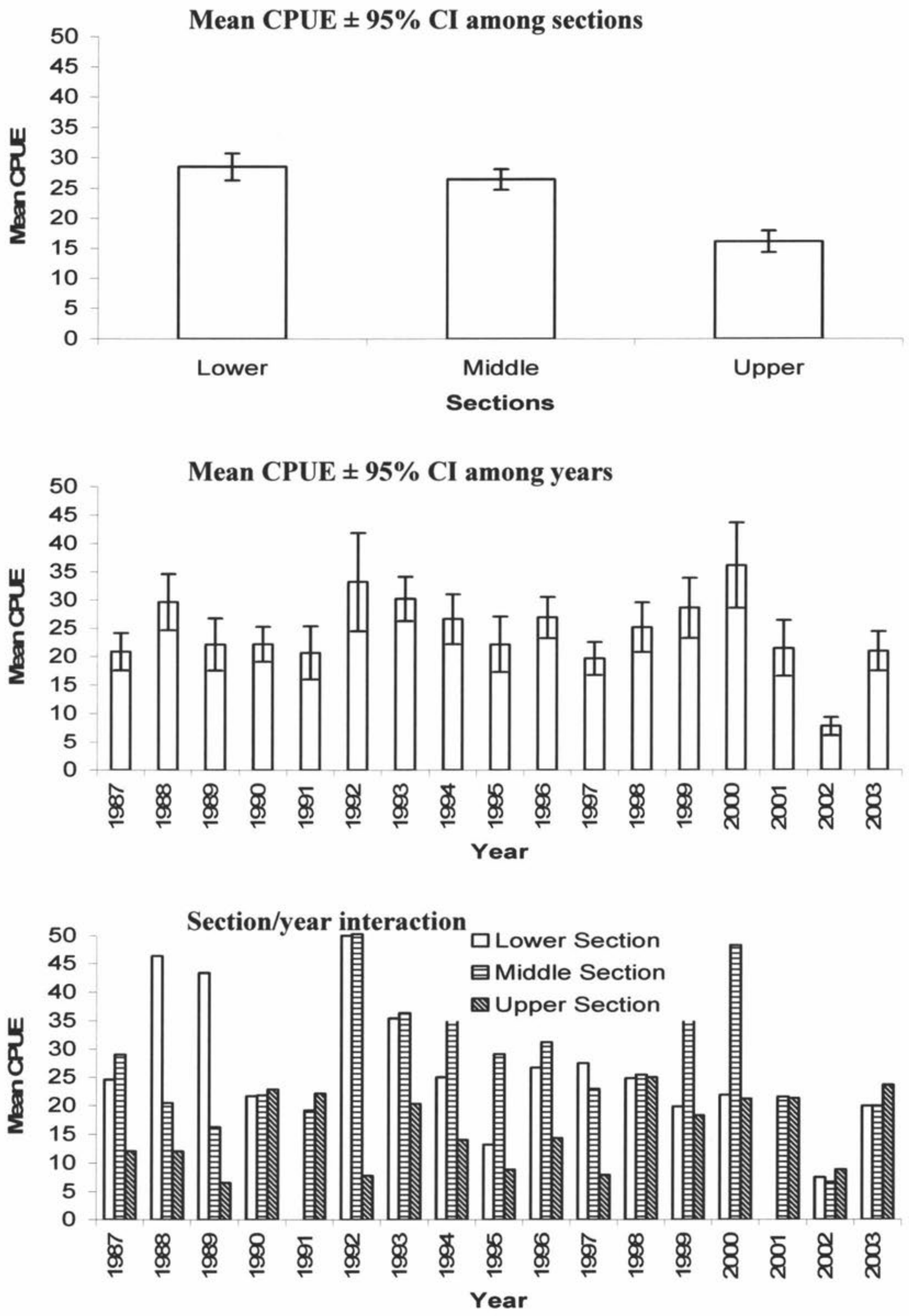


Figure 11: Historical electrofishing data for fish ≥ 280 mm captured from 1987 to 2003 in Beaver Lake. CPUE refers to catch per unit effort and CI refers to confidence intervals.

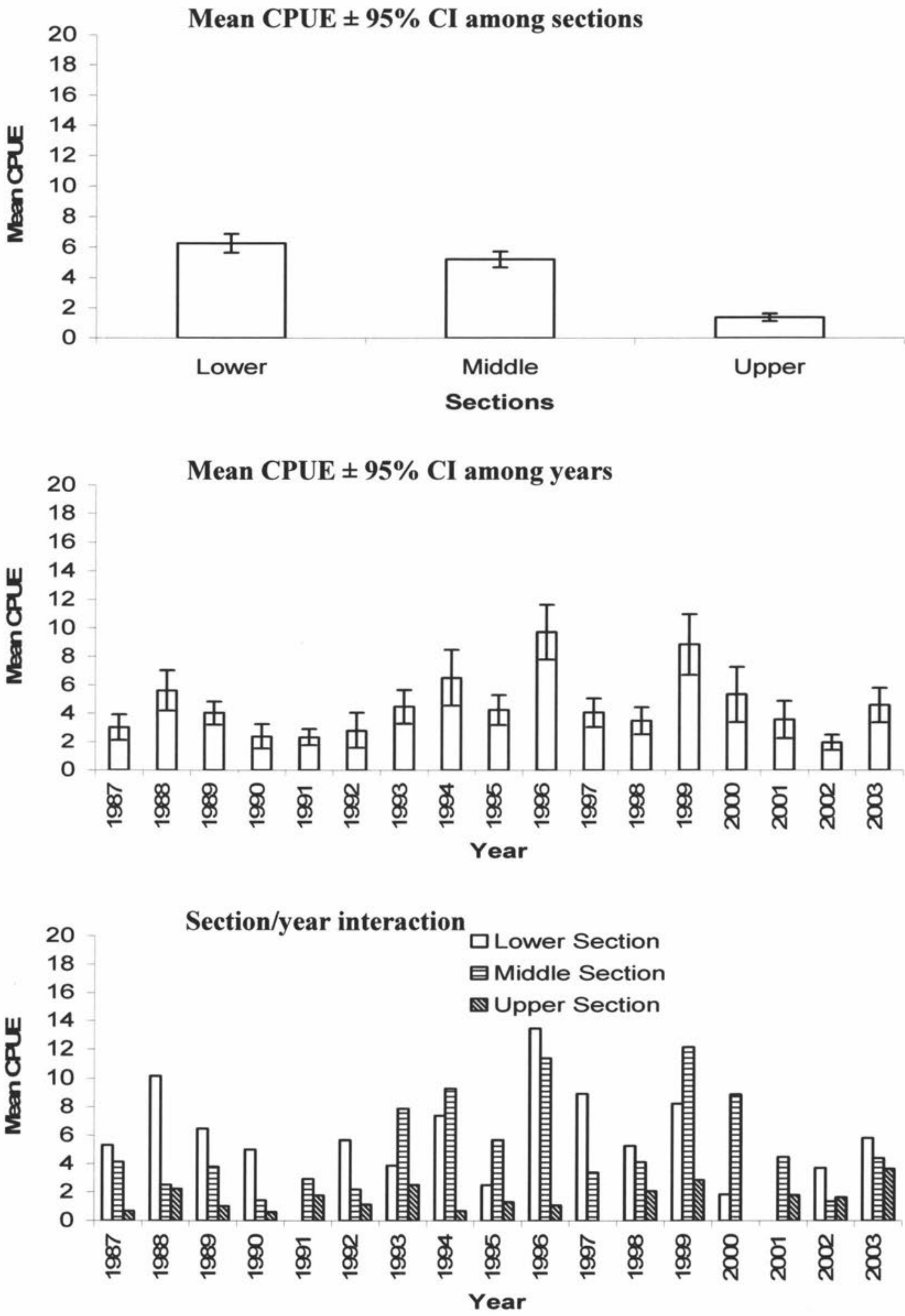


Figure 12: Historical electrofishing data for fish ≥ 350 mm captured from 1987 to 2003 in Beaver Lake. CPUE refers to catch per unit effort and CI refers to confidence intervals.

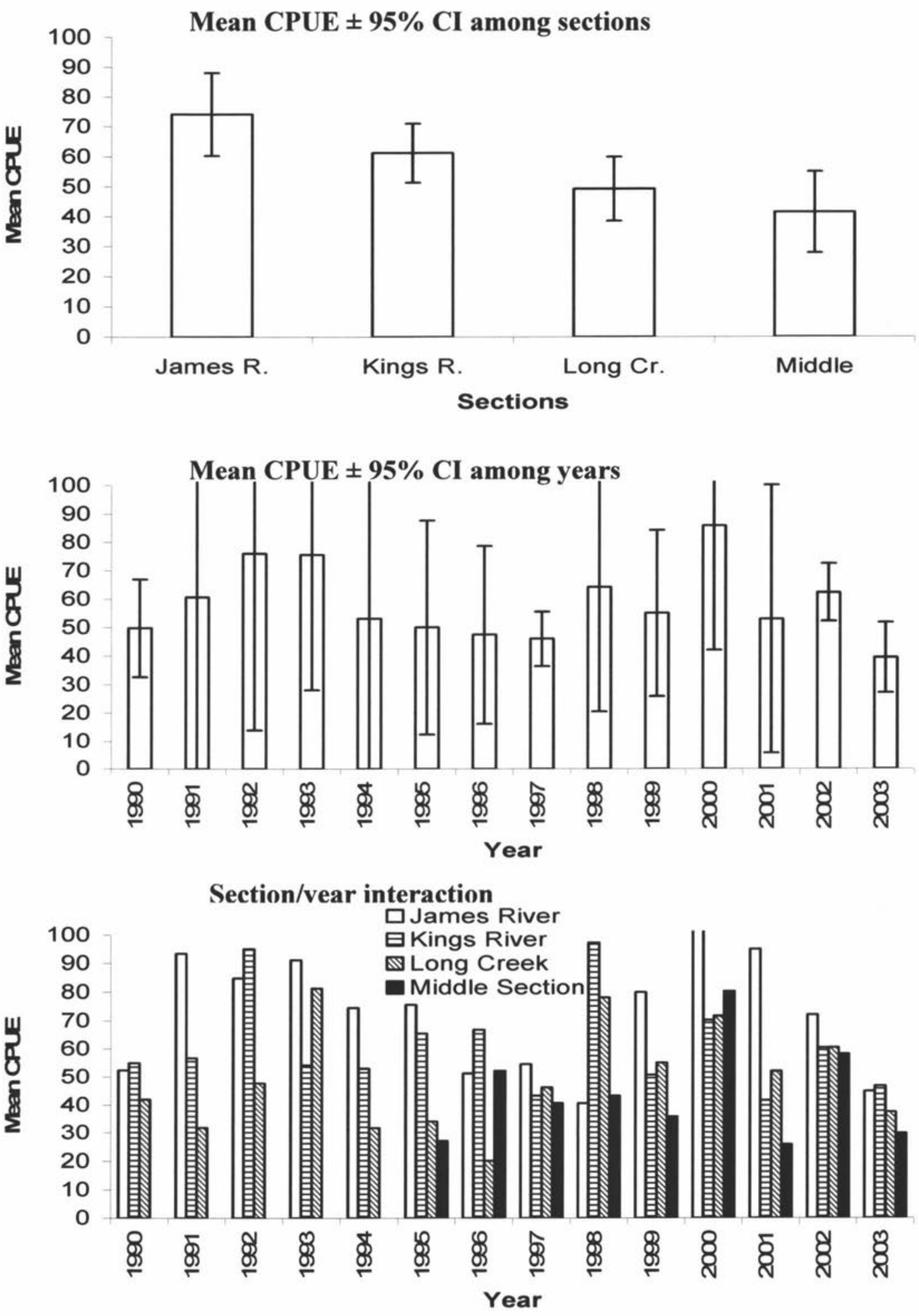


Figure 13: Historical electrofishing data for all fish captured from 1990 to 2003 in Table Rock Lake. The 95% confidence interval for 1991, 1992, 1993, 1994, 1998 and 2000 was ±76.8, 62.0, 47.5, 53.3, 43.8, and 43.8. The Mean CPUE for 2000 James River was 128.4. CPUE refers to catch per unit effort and CI refers to confidence intervals.

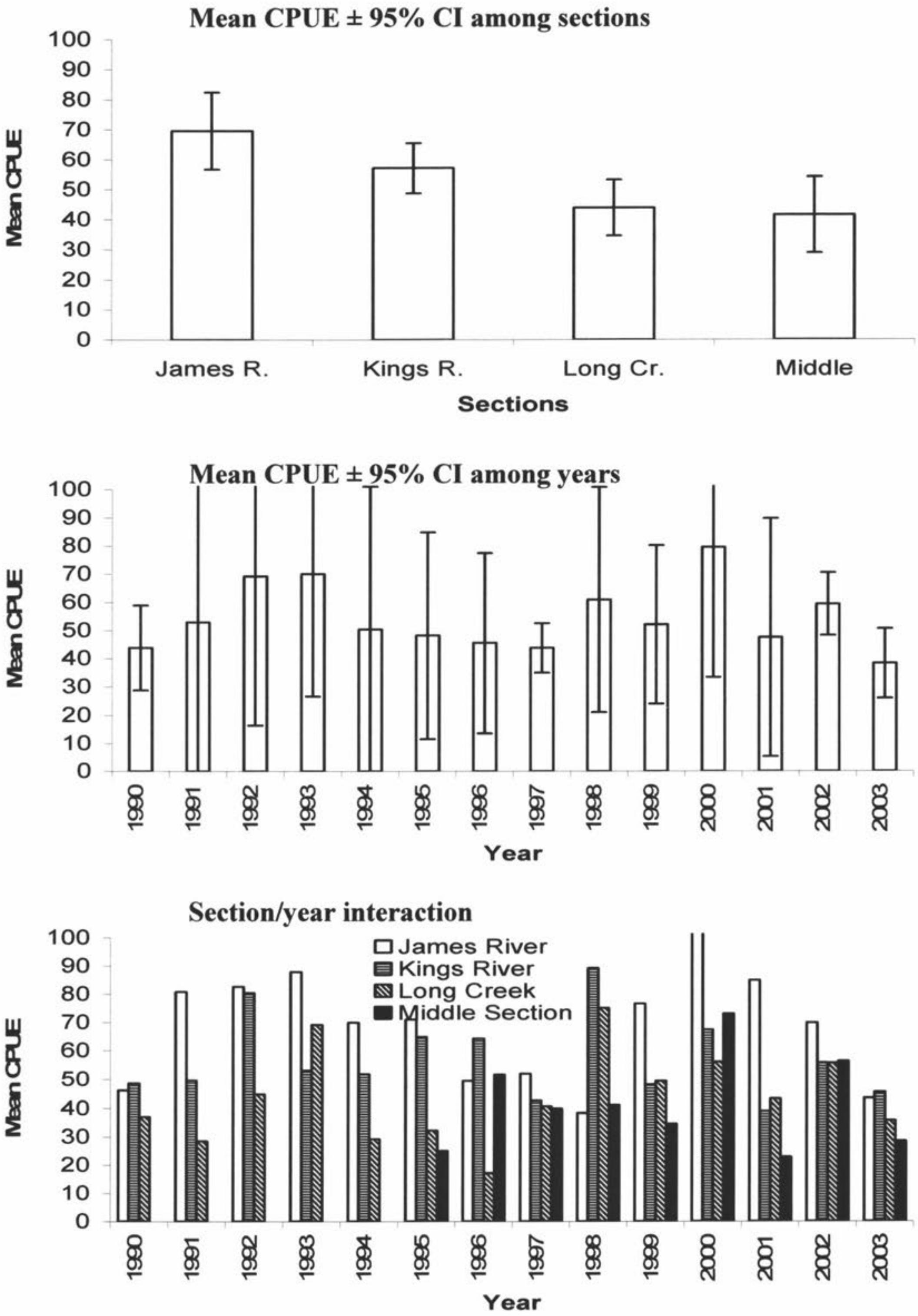


Figure 14: Historical electrofishing data for fish ≥ 180 mm captured from 1990 to 2003 in Table Rock Lake. The 95% confidence interval for 1991, 1992, 1993, and 2000 was ±65.4, 52.8, 43.4, and 46.1. The Mean CPUE for 2000 James River was 121.7. CPUE refers to catch per unit effort and CI refers to confidence intervals.

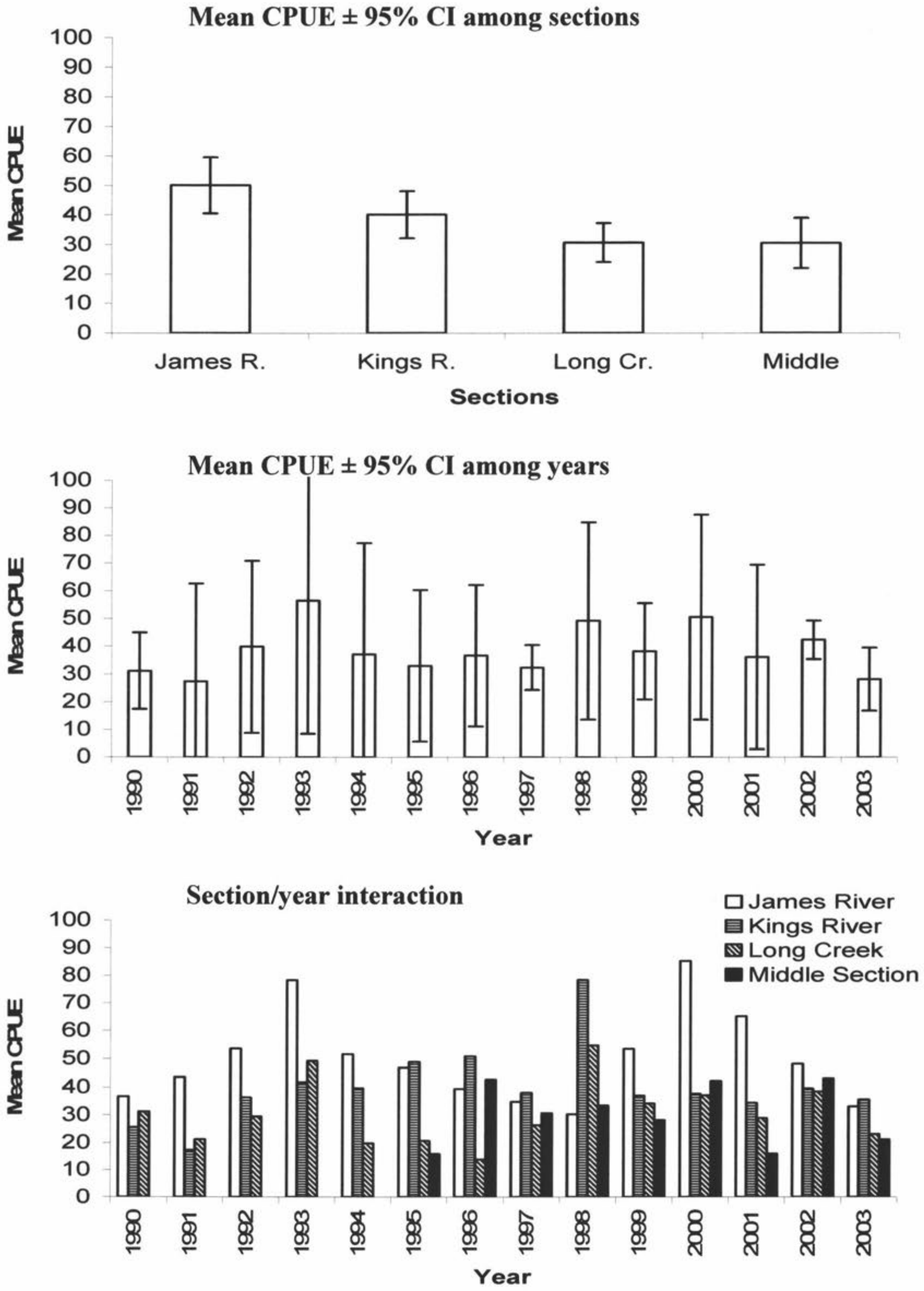


Figure 15: Historical electrofishing data for fish ≥ 280 mm captured from 1990 to 2003 in Table Rock Lake. The 95% confidence interval for 1993 was ±47.9. CPUE refers to catch per unit effort and CI refers to confidence intervals.

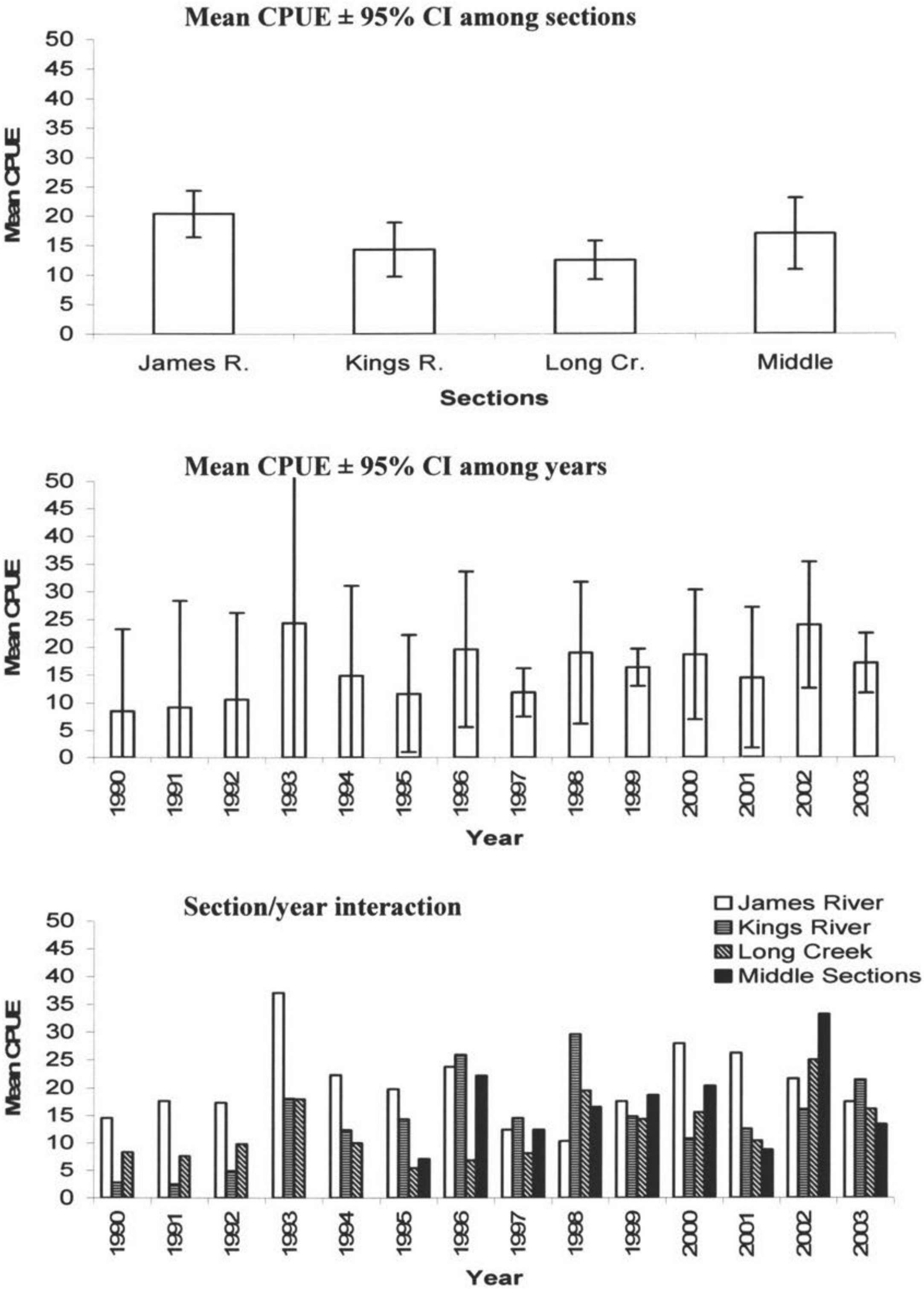


Figure 16: Historical electrofishing data for fish ≥ 350 mm captured from 1990 to 2003 in Table Rock Lake. The 95% confidence interval for 1993 was ±27.3. CPUE refers to catch per unit effort and CI refers to confidence intervals.

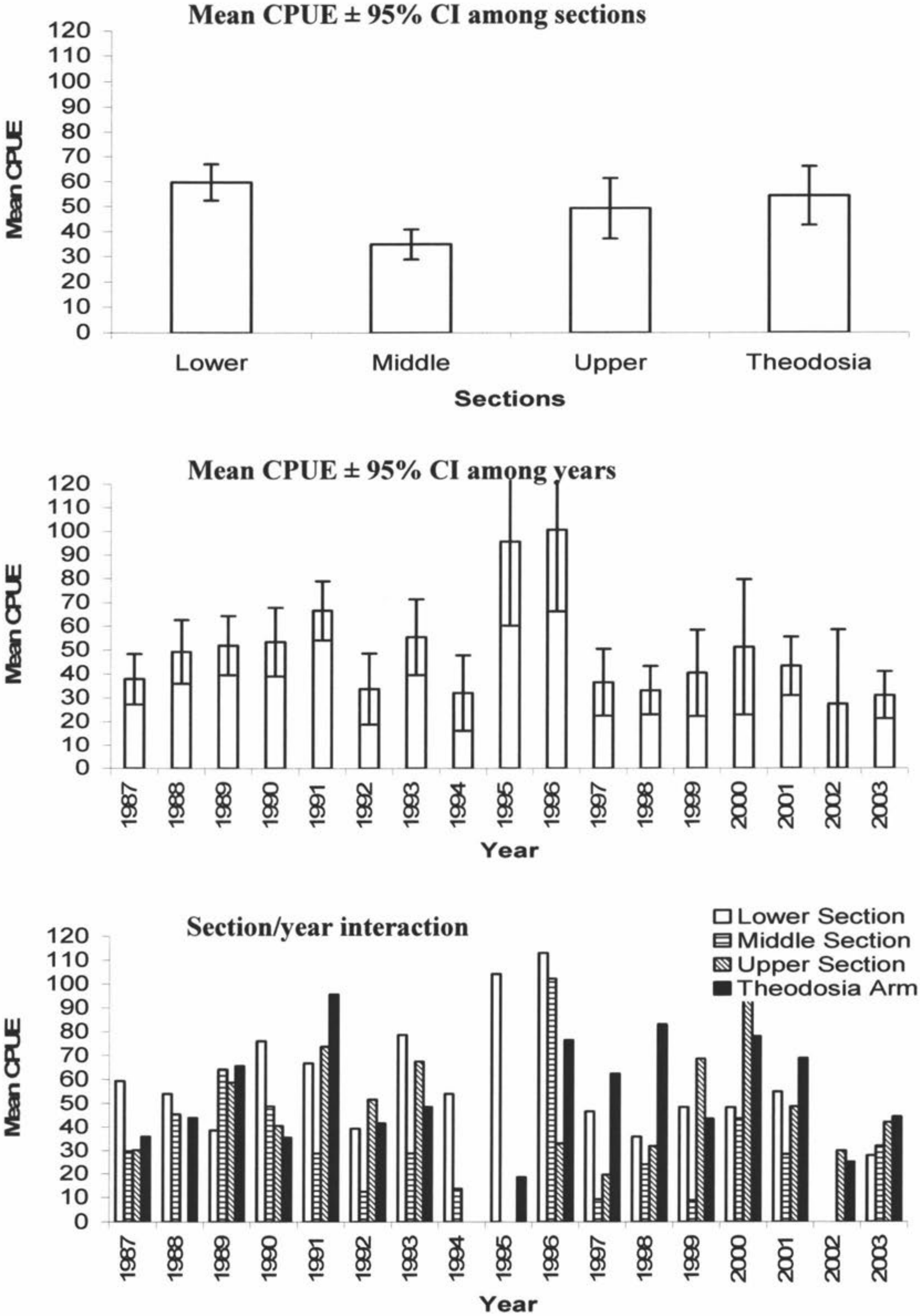


Figure 17: Historical electrofishing data for all fish captured from 1987 to 2003 in Bull Shoals Lake. The 95% confidence intervals for 1995 was ±35.4 and 1996 was ±34.3. CPUE refers to catch per unit effort and CI refers to confidence intervals.

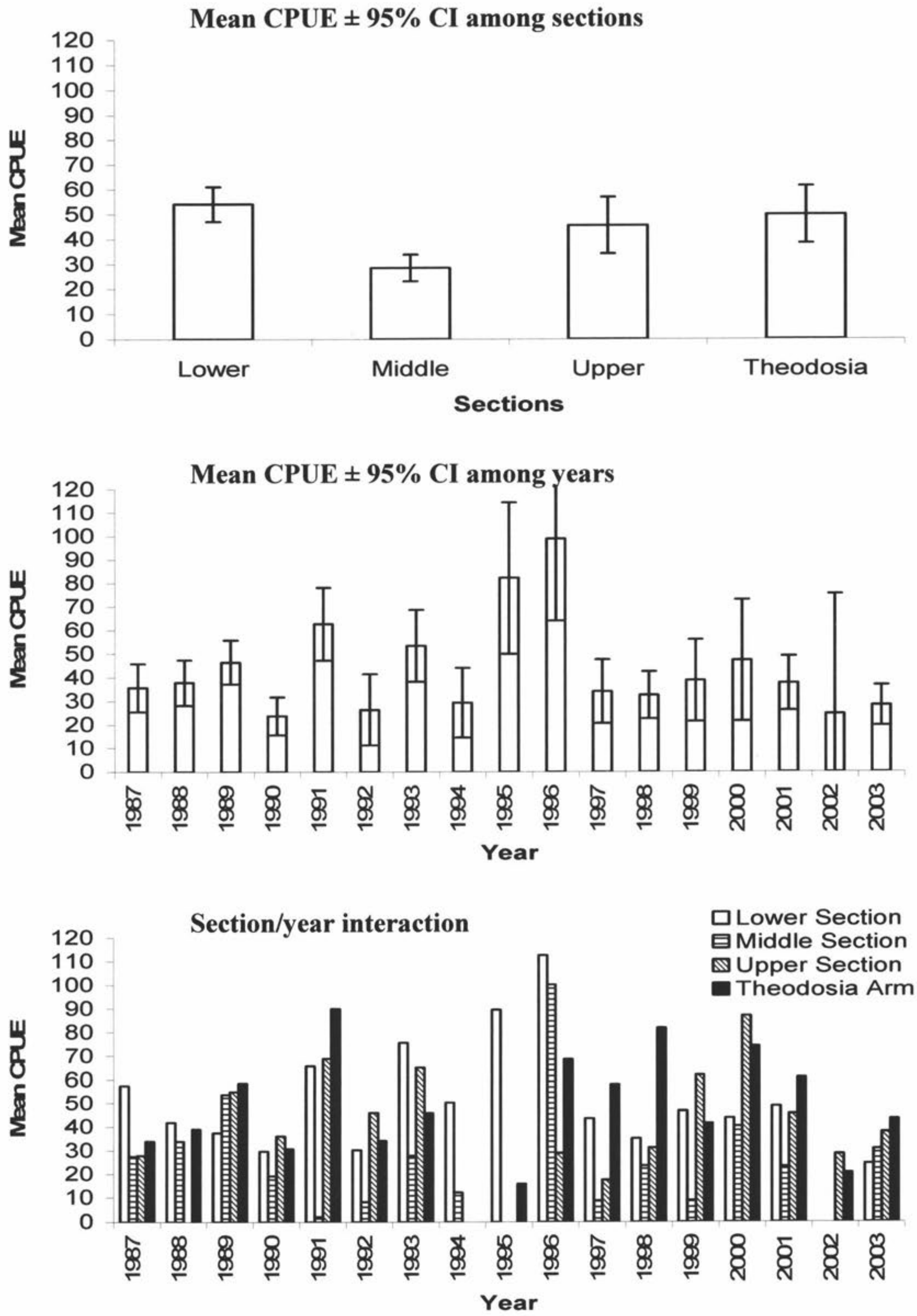


Figure 18: Historical electrofishing data for fish ≥ 180 mm captured from 1987 to 2003 in Bull Shoals Lake. The 95% confidence interval for 1996 was ±34.9. CPUE refers to catch per unit effort and CI refers to confidence intervals.

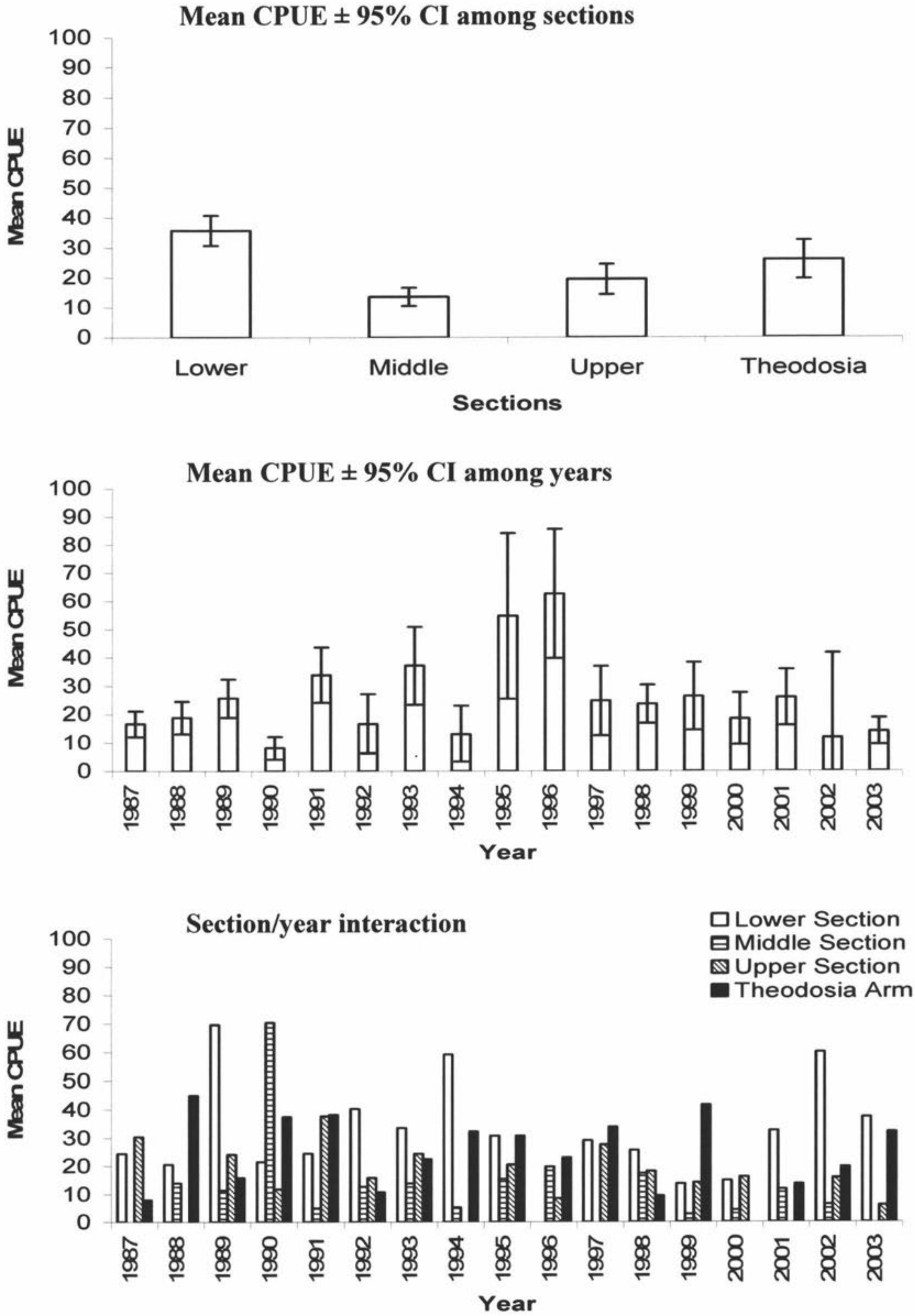


Figure 19: Historical electrofishing data for fish ≥ 280 mm captured from 1987 to 2003 in Bull Shoals Lake. CPUE refers to catch per unit effort and CI refers to confidence intervals.

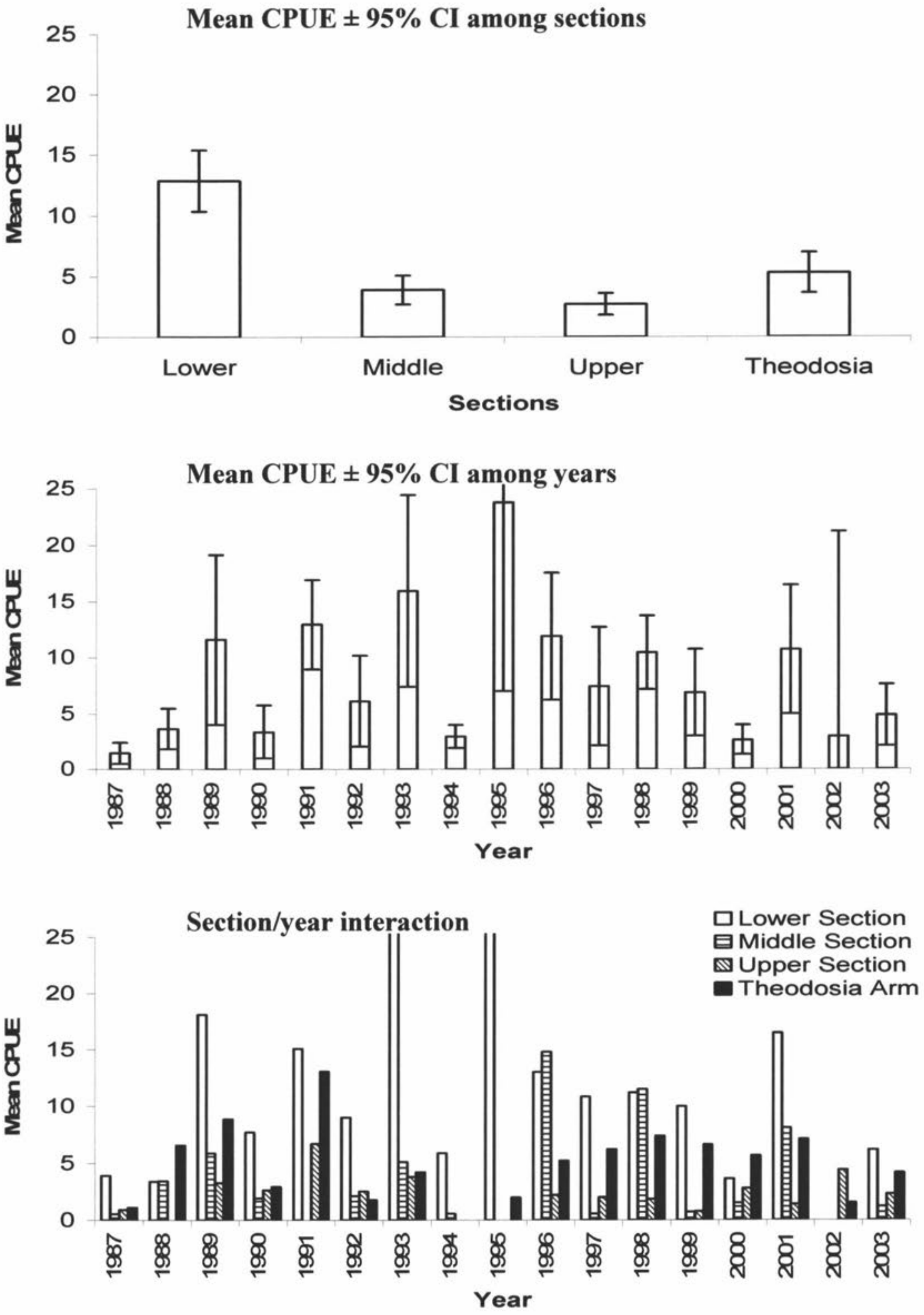
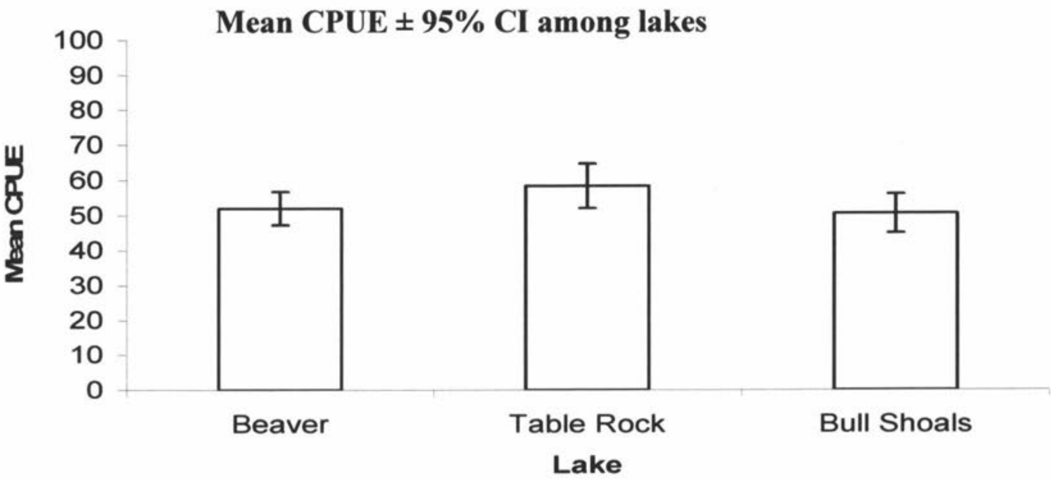
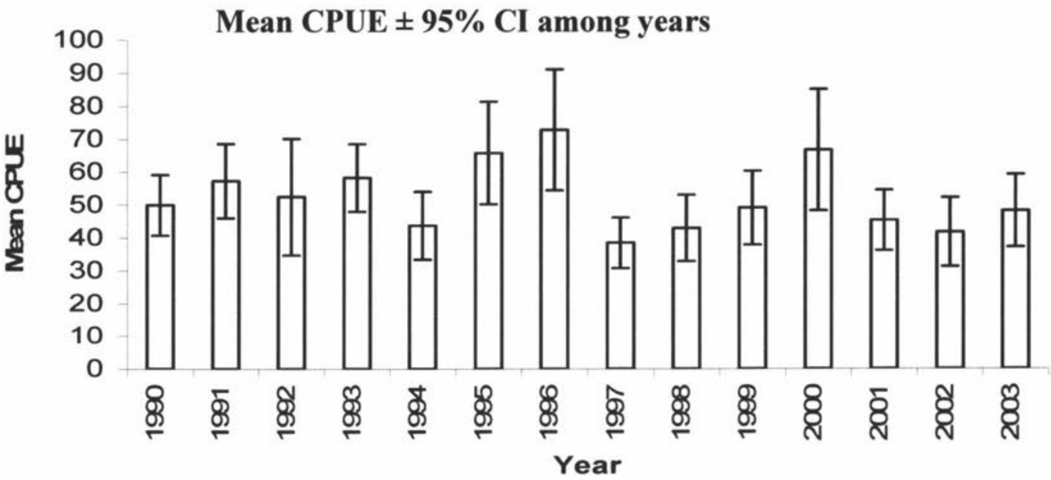


Figure 20: Historical electrofishing data for fish ≥ 350 mm captured from 1987 to 2003 in Bull Shoals Lake. The 95% confidence interval for 1995 was ±24 and the mean CPUE for the lower section in 1993 was 28 and 1995 was 26. CPUE refers to catch per unit effort and CI refers to confidence intervals.





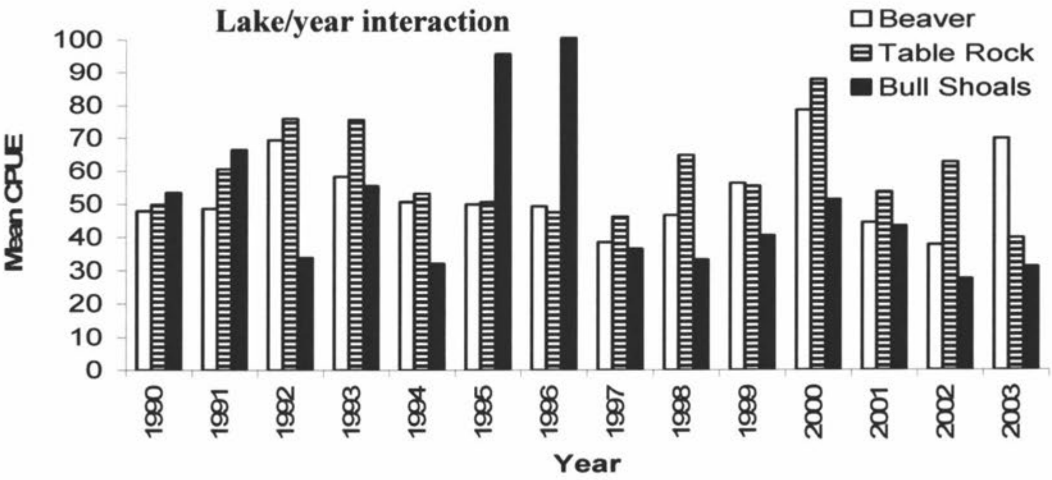


Figure 21: Historical electrofishing data for all fish captured from 1990 to 2003 in sample lakes. CPUE refers to catch per unit effort and CI refers to confidence intervals.

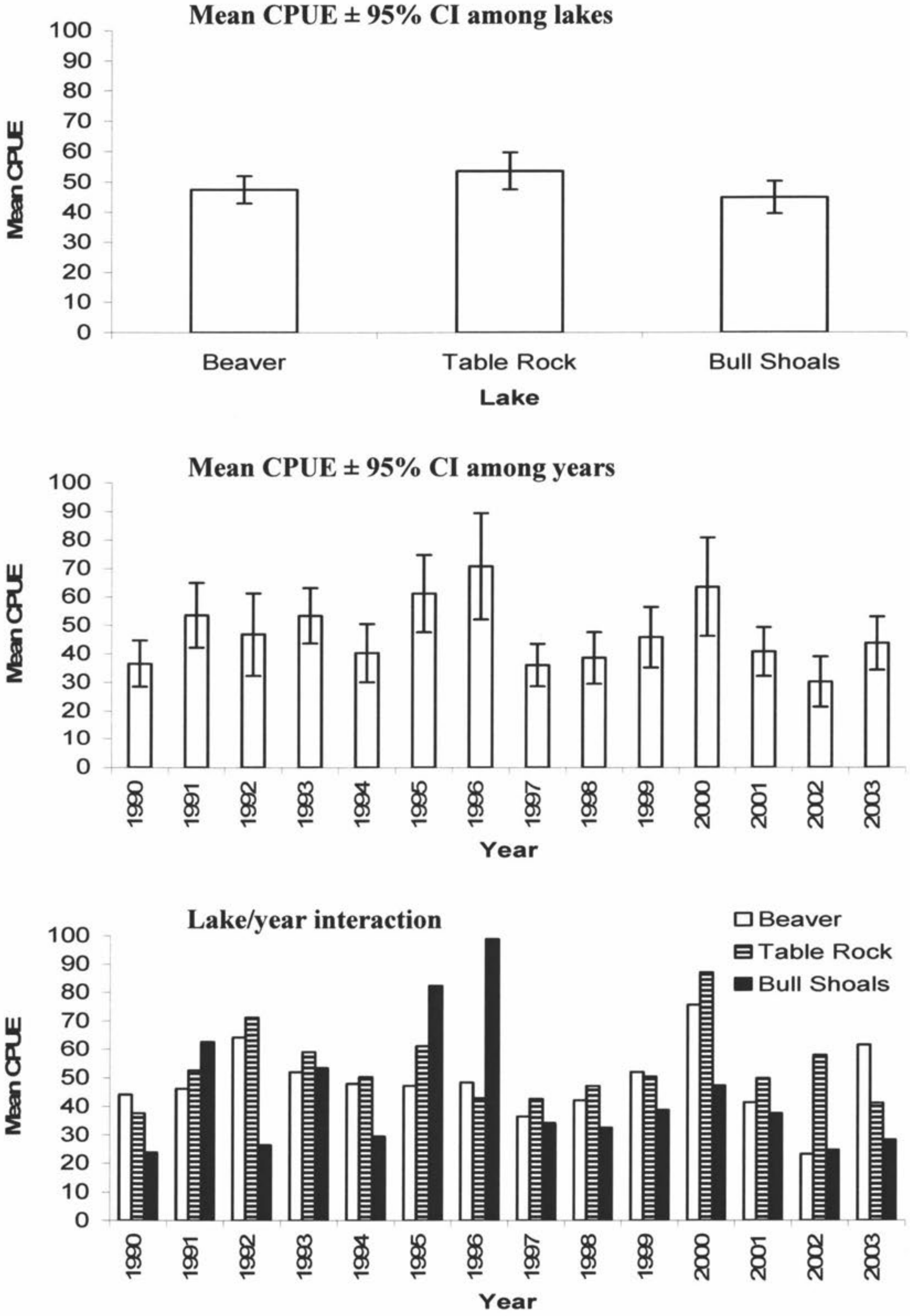


Figure 22: Historical electrofishing data for fish ≥ 180 mm captured from 1990 to 2003 in sample lakes. CPUE refers to catch per unit effort and CI refers to confidence intervals.

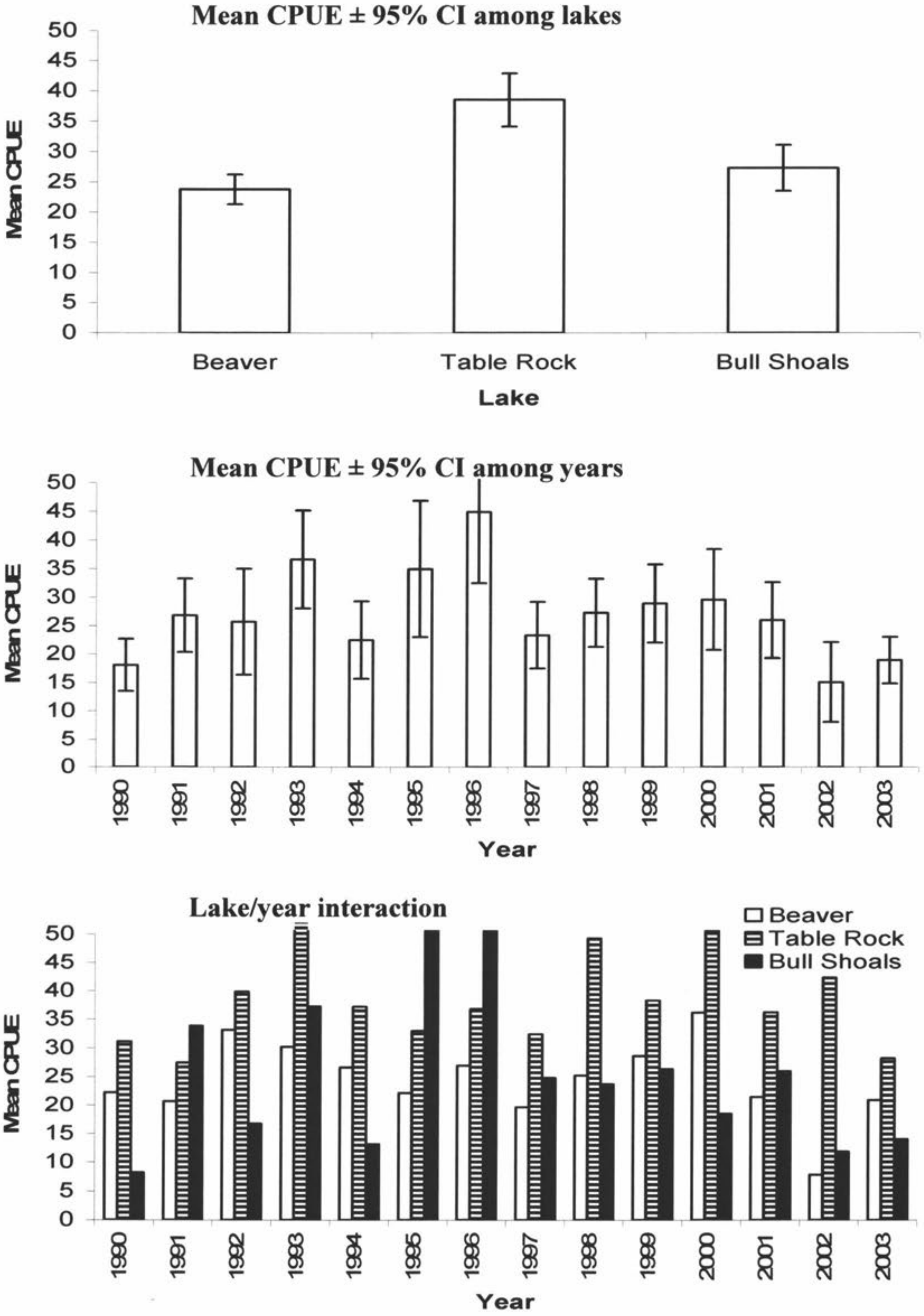


Figure 23: Historical electrofishing data for fish ≥ 280 mm captured from 1990 to 2003 in sample lakes. The 95% confidence interval for 1996 was ±12.4. The Mean CPUE for 1993 Table Rock was 56.5, 1995 bull Shoals was 54.8 and 1996 Bull Shoals was 62.7. CPUE refers to catch per unit effort and CI refers to confidence intervals.

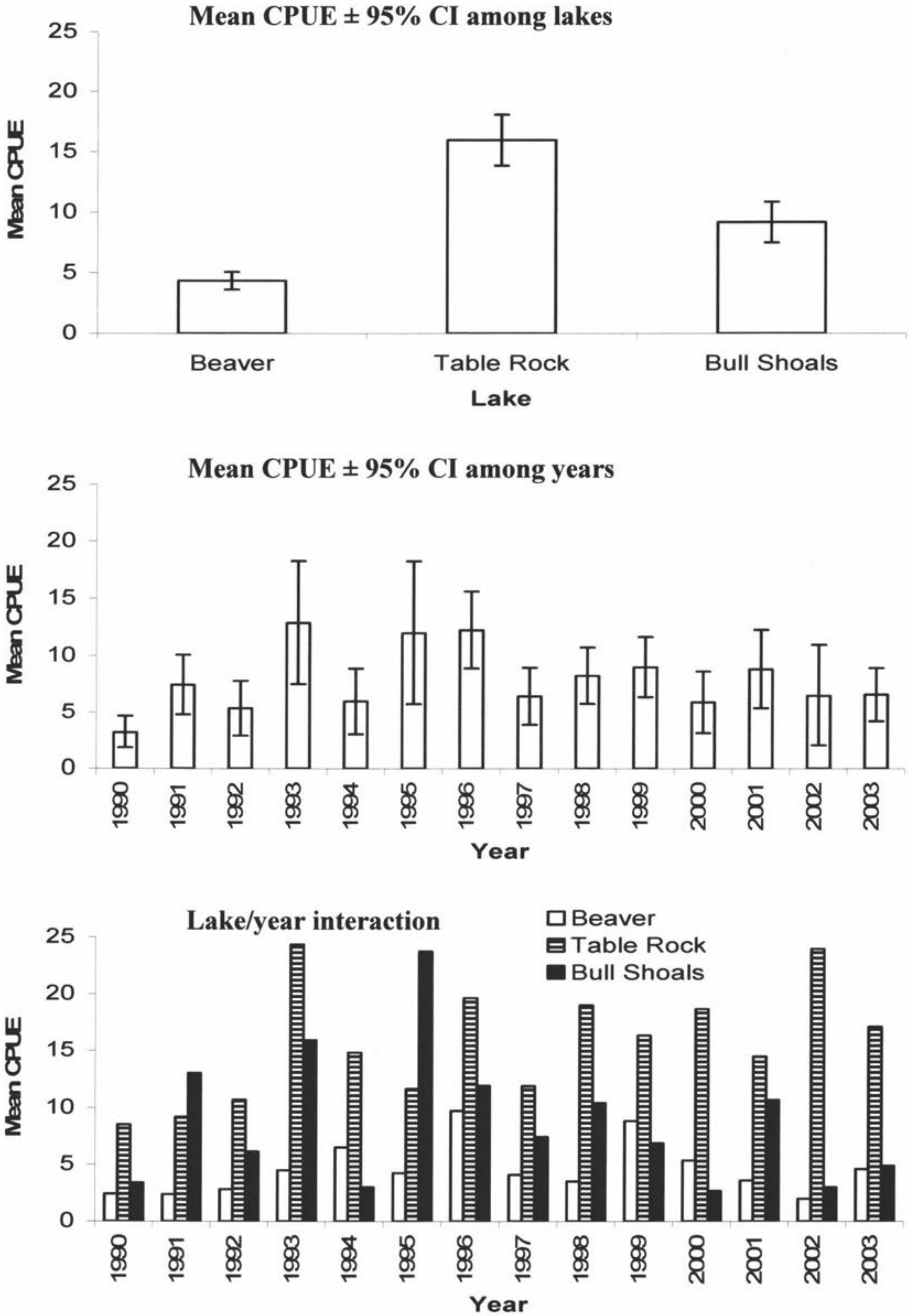


Figure 24: Historical electrofishing data for fish ≥ 350 mm captured from 1990 to 2003 in sample lakes. CPUE refers to catch per unit effort and CI refers to confidence intervals.

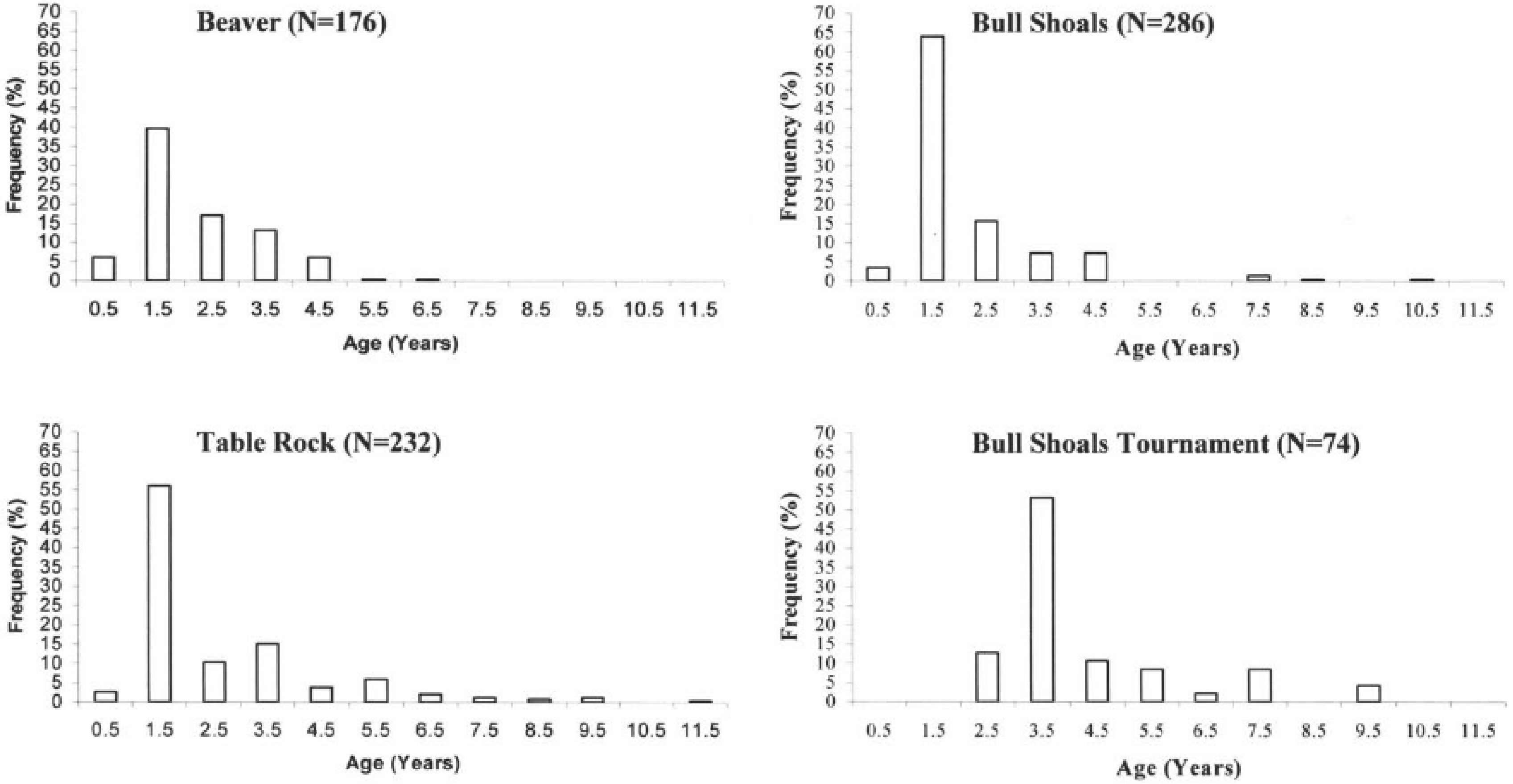


Figure 25: Relative age frequency distribution for the sample lakes. Number of fish sampled is in parentheses.

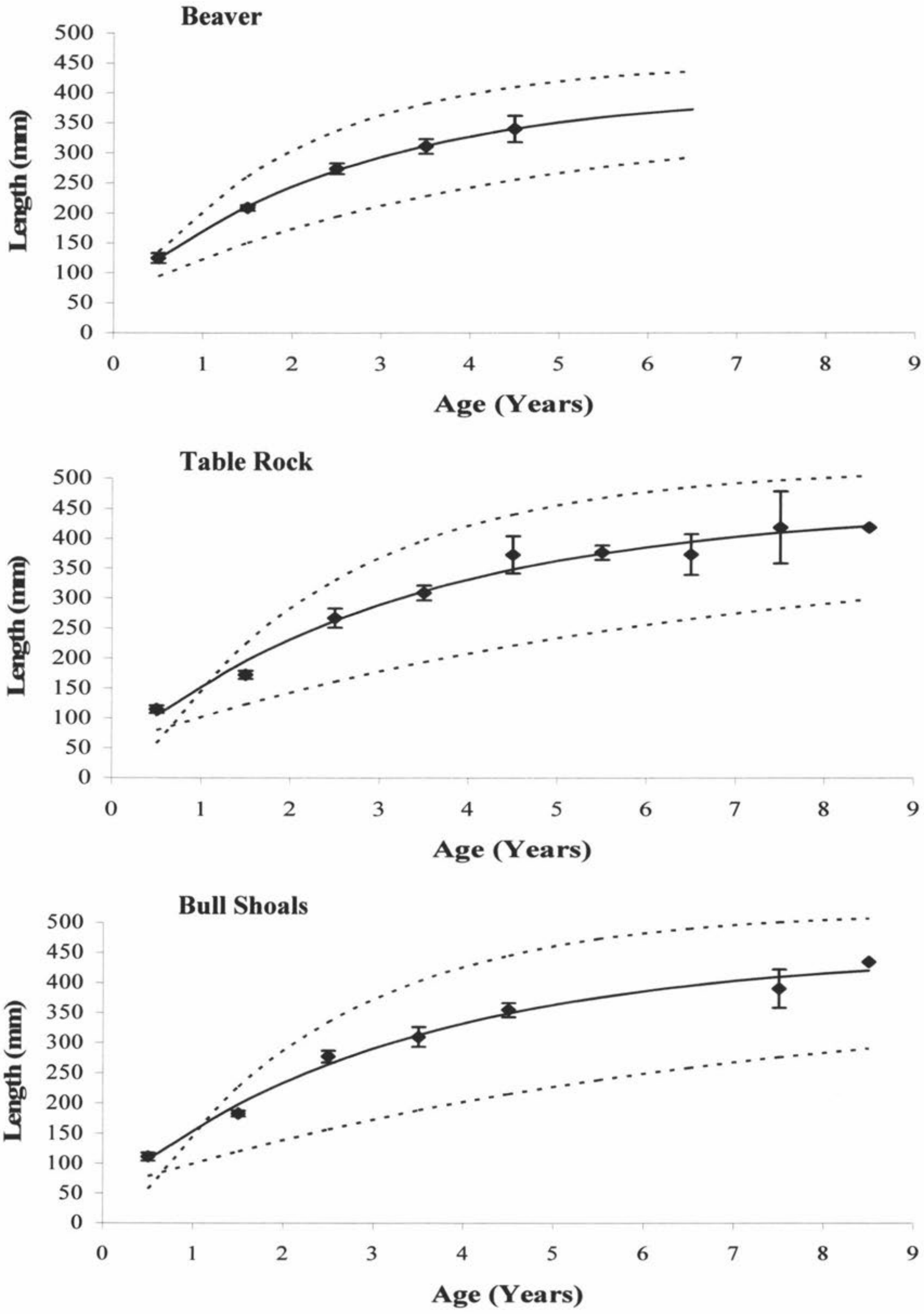


Figure 26: Von Bertalanffy growth curve for each sample lake. Error bars and dotted lines represent 95% confidence intervals for mean length at age and growth curve, respectively. Error bar for age-8.5 in Table Rock Lake was ±222.53.

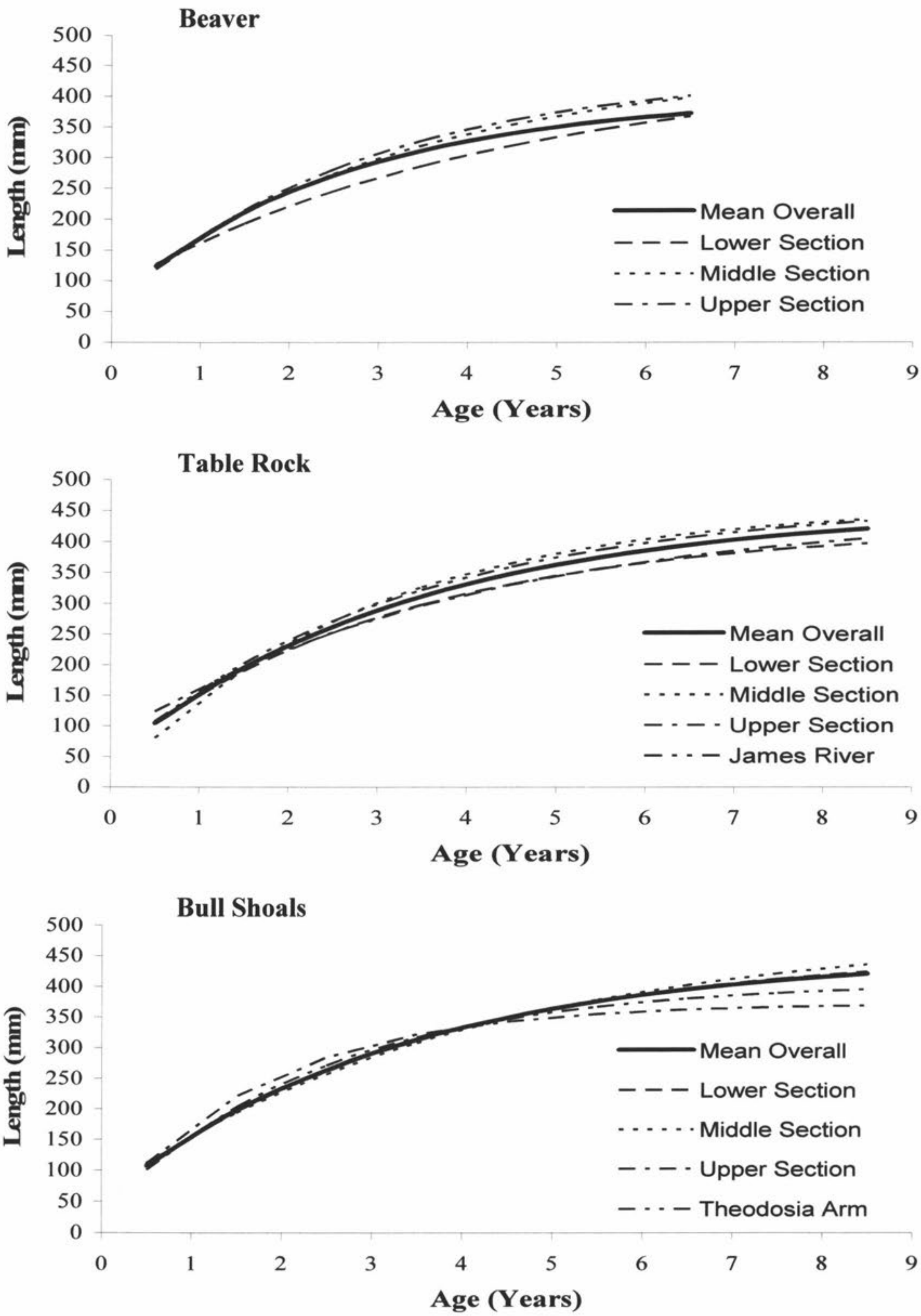


Figure 27: Von Bertalanffy growth curves for sections within each sample lake. Refer to text for explanations of difference among sections.

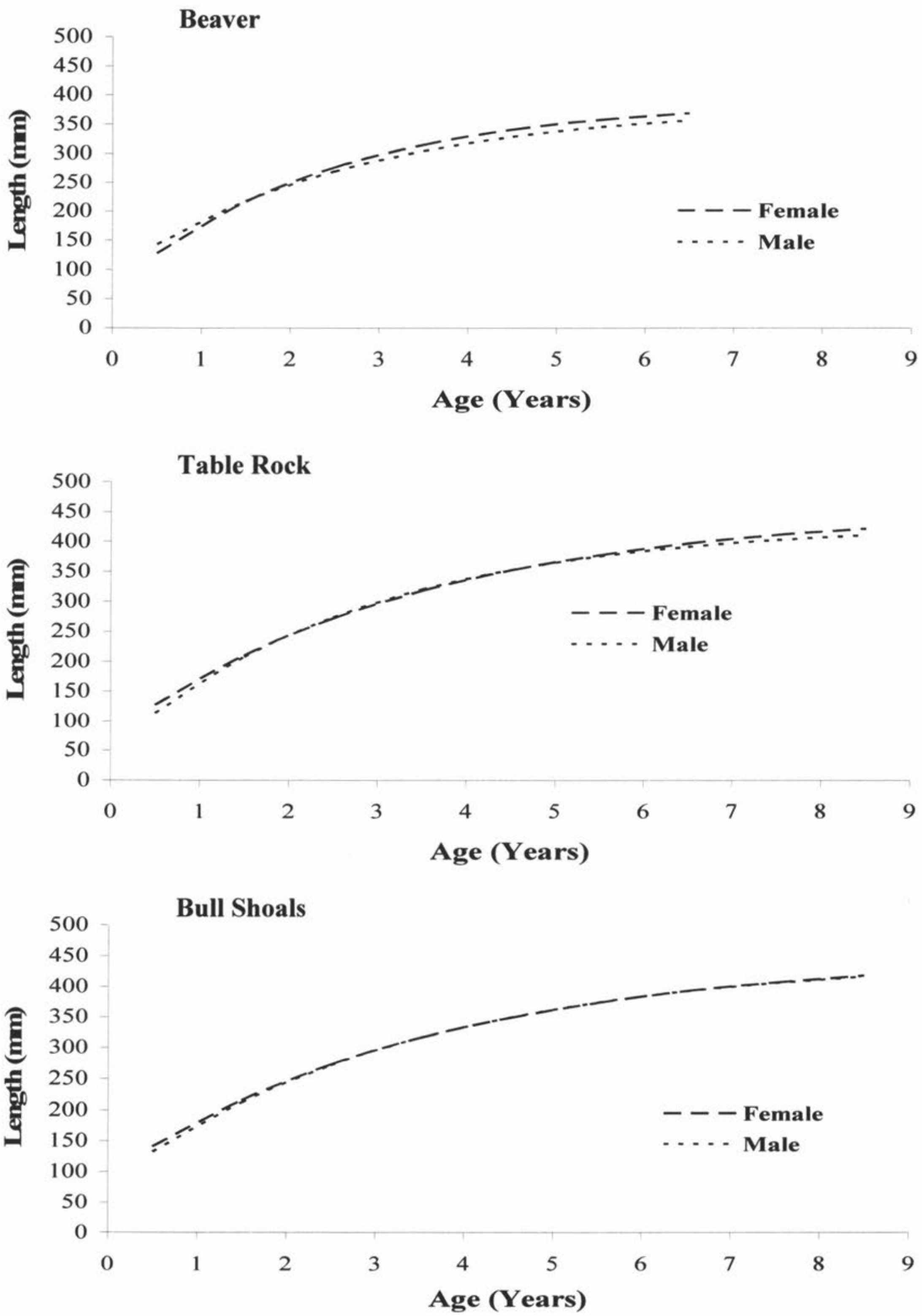


Figure 28: Von Bertalanffy growth curves for each gender in each sample lake.

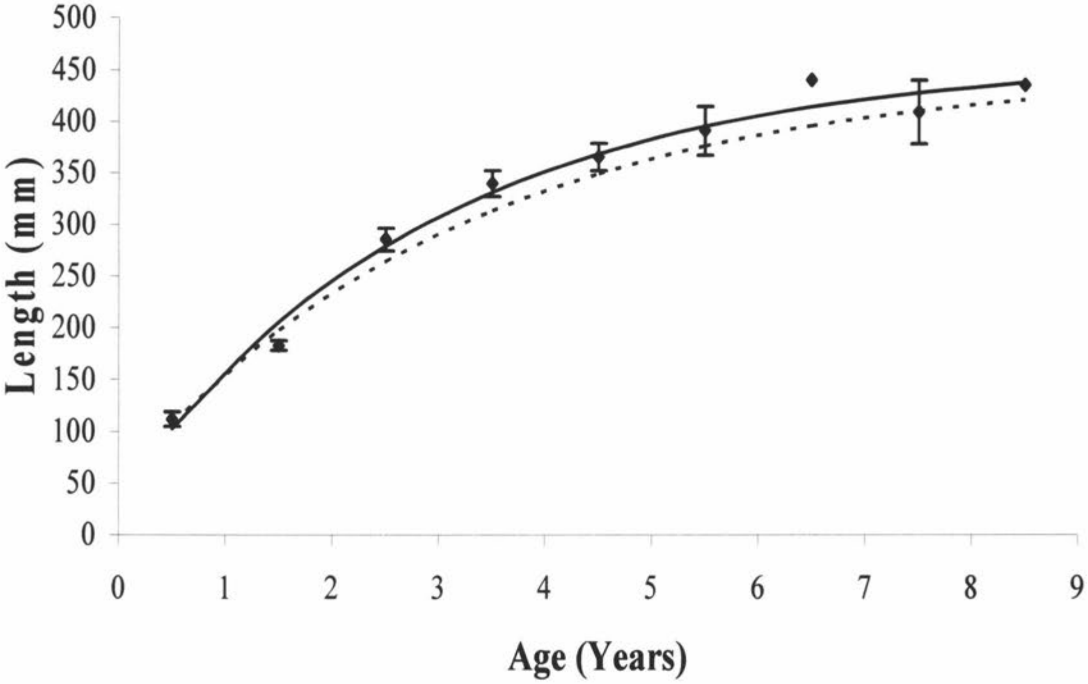


Figure 29: Von Bertalanffy growth curve for Bull Shoals Lake including tournament fish. Error bar represents 95% confidence intervals for mean length at age. Dotted line represents the growth curve without tournament fish.

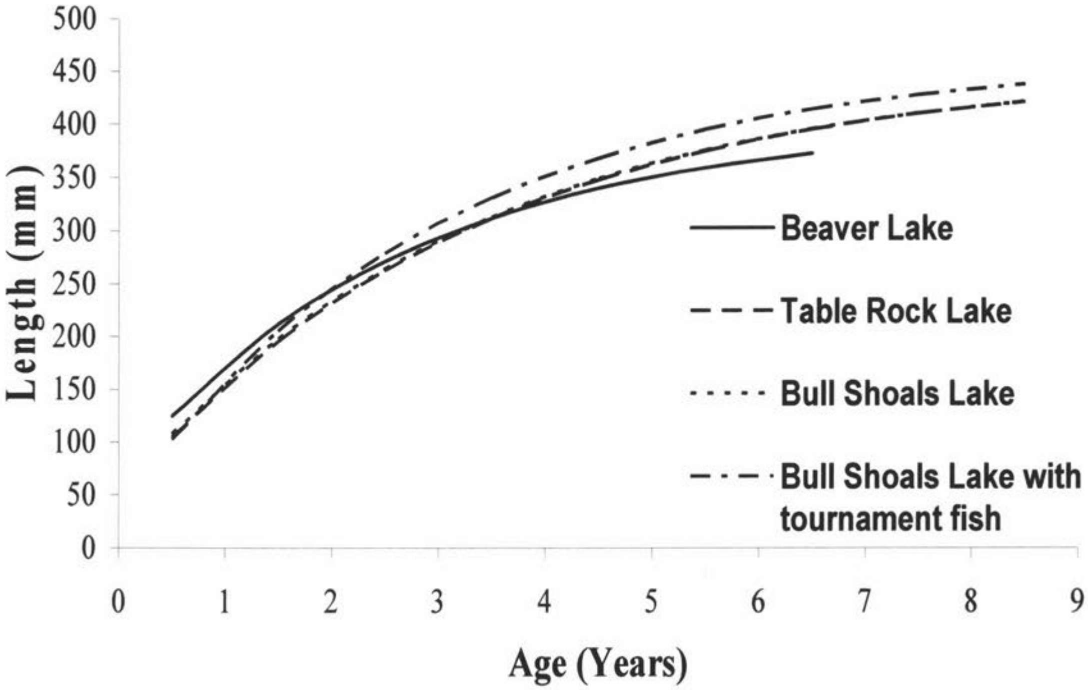


Figure 30: Von Bertalanffy growth curves among sample lakes. The mean at length with Bull Shoals lake T includes tournament caught fish.

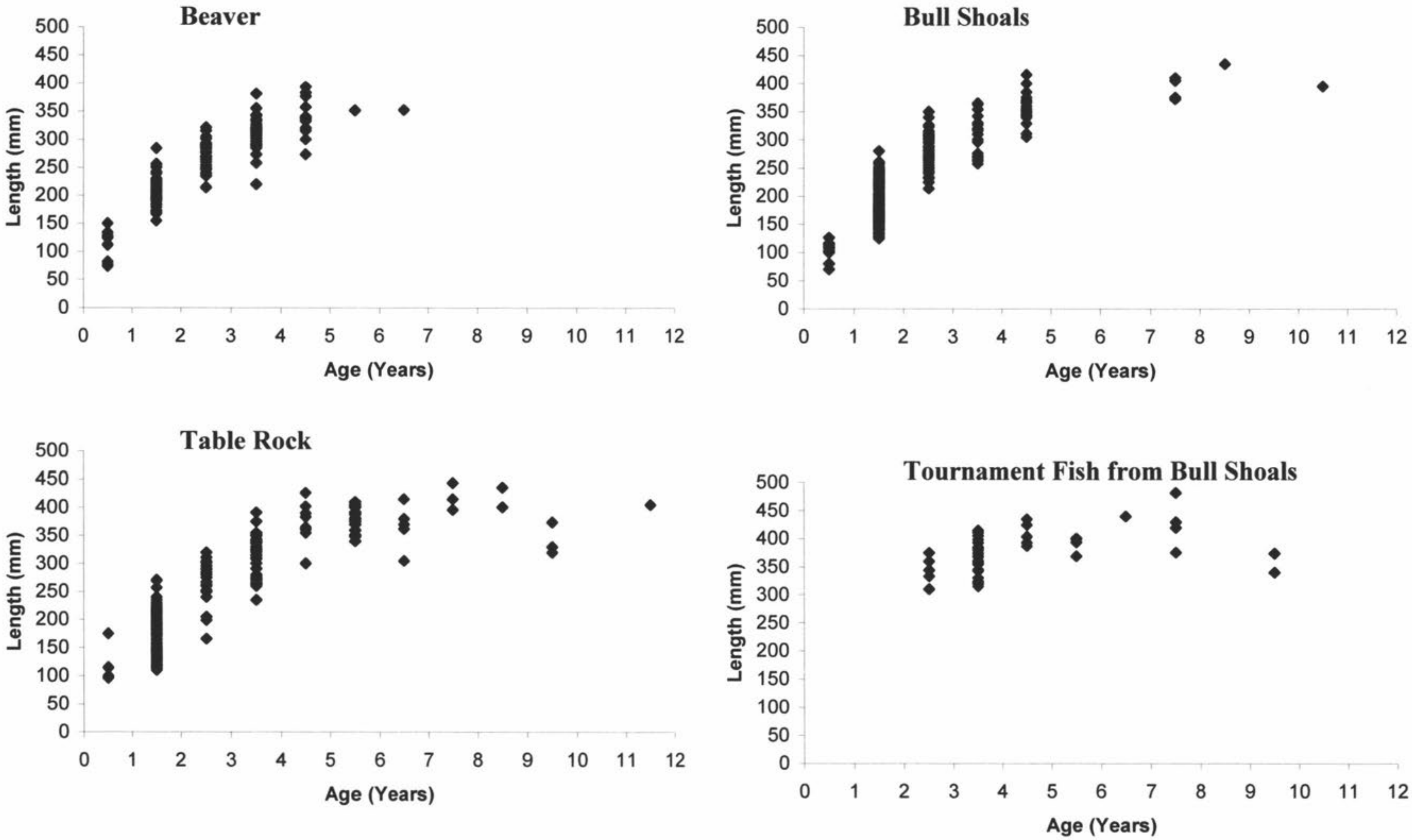


Figure 31: Length at age for individuals captured in each sample lake.

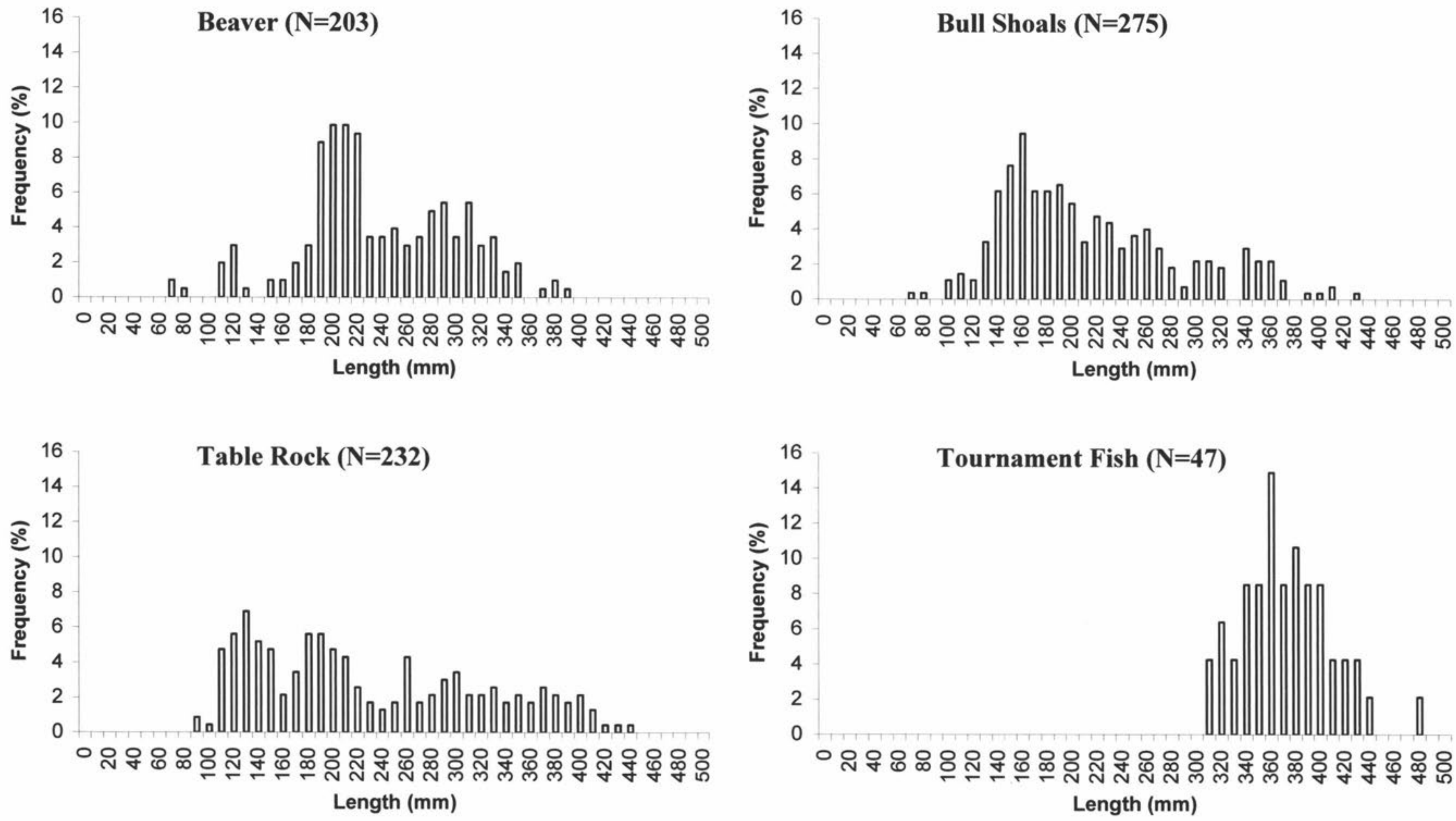


Figure 32: Relative length frequencies for the sample lakes.

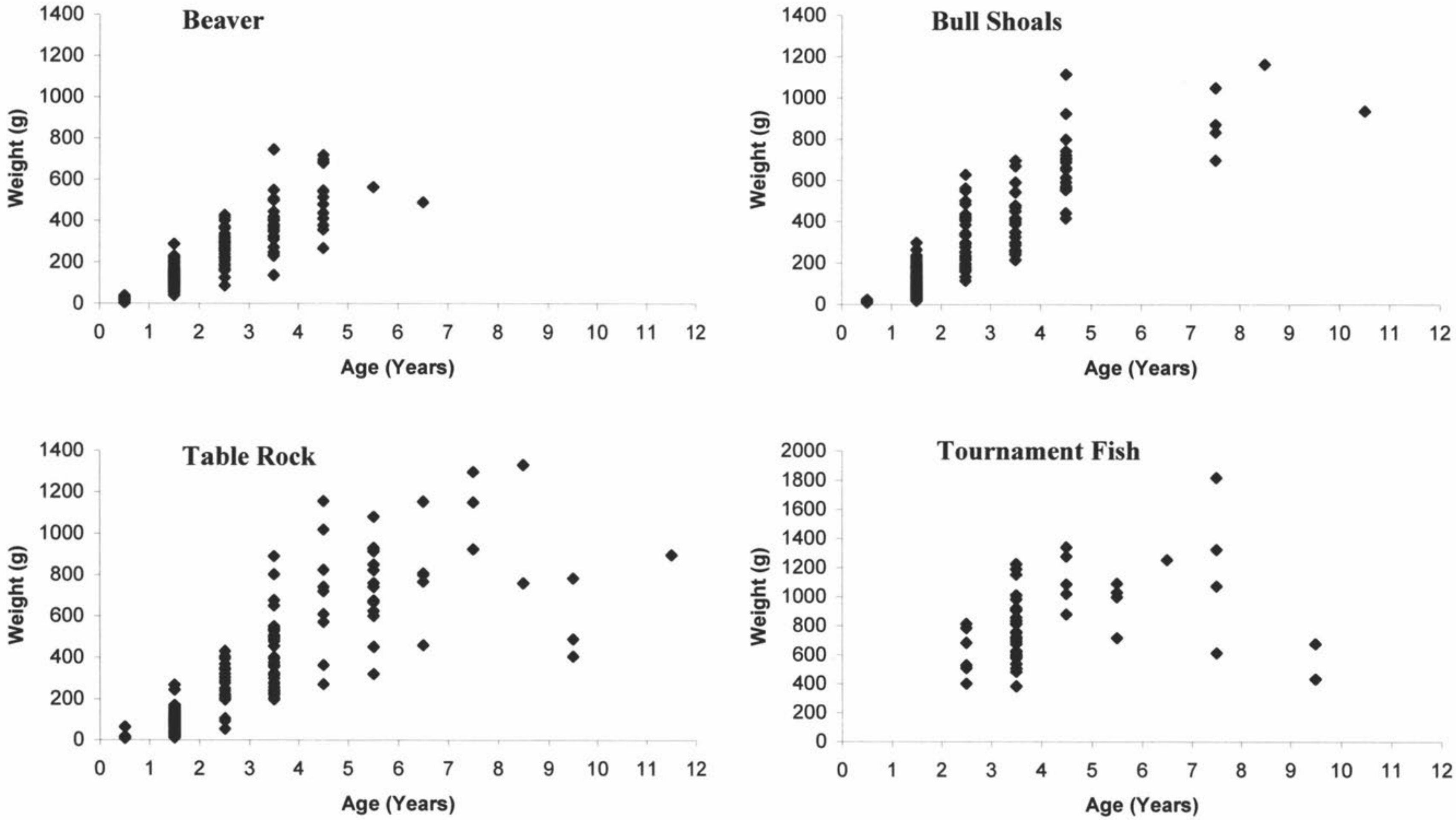


Figure 33: Weight at age for individuals captured in each sample lake.

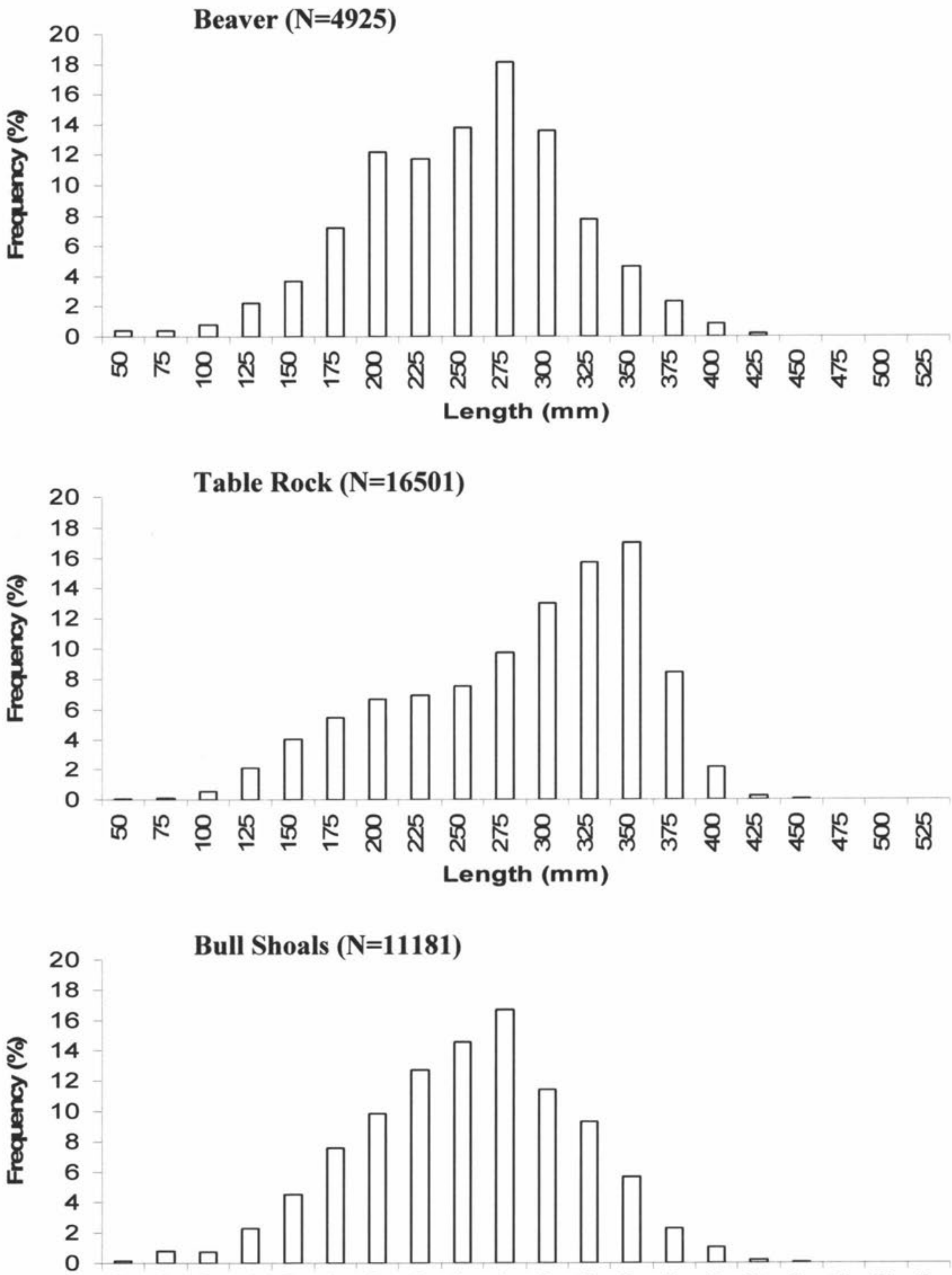


Figure 34: Relative length frequencies of historical electrofishing data from 1987 to 2003 for the sample lakes. Table Rock data are from 1988-2003. Data collected by Arkansas Game and Fish Commission and Missouri Department of Conservation.

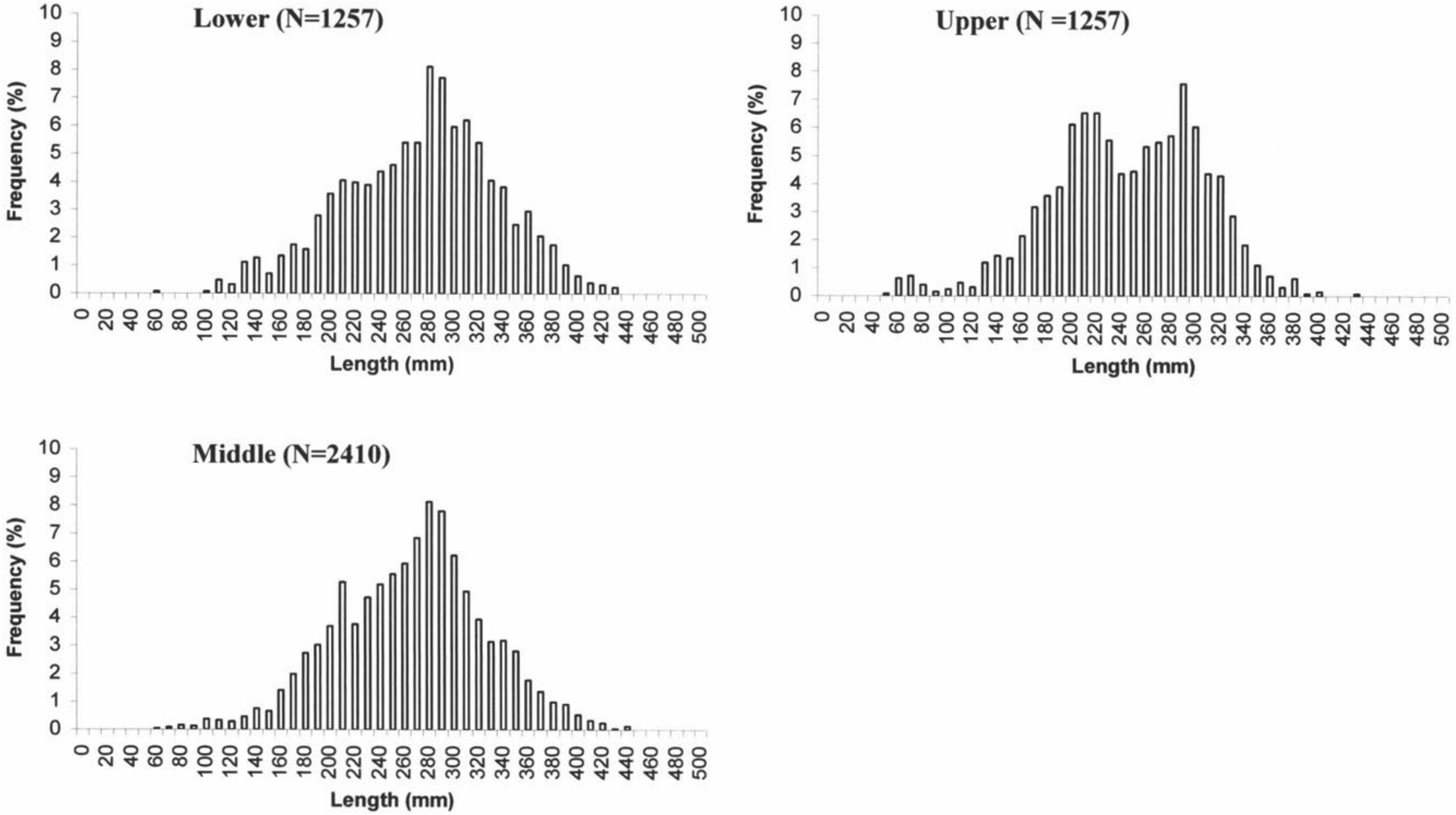


Figure 35: Relative length frequencies of historical electrofishing data from 1987 to 2003 in Beaver Lake.

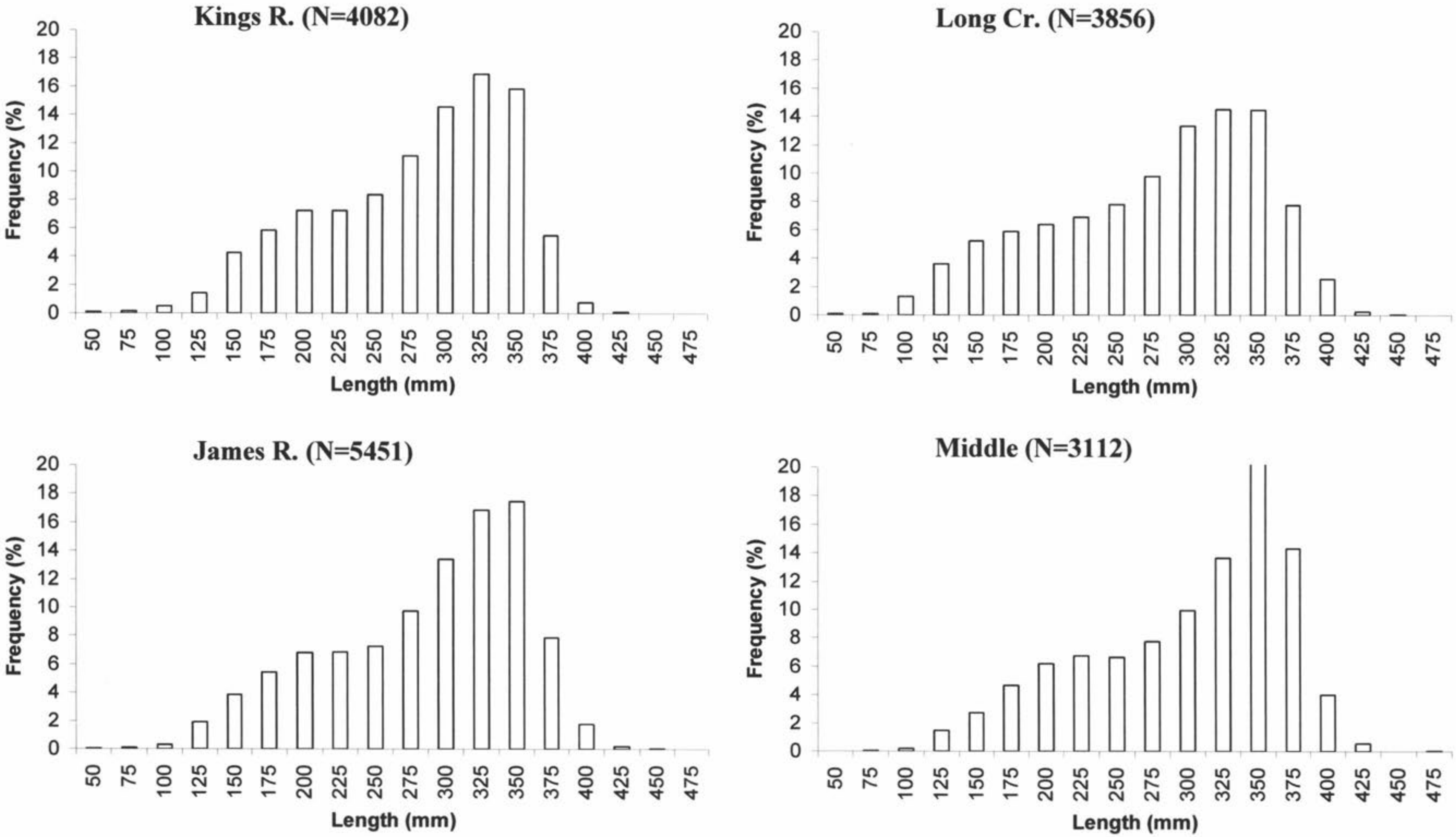


Figure 36: Relative length frequencies of historical electrofishing data from 1988 to 2003 in Table Rock Lake. James River's 1989 number are not included in the length frequency. The relative length frequency for 350 mm length group in middle section was 20.9%.

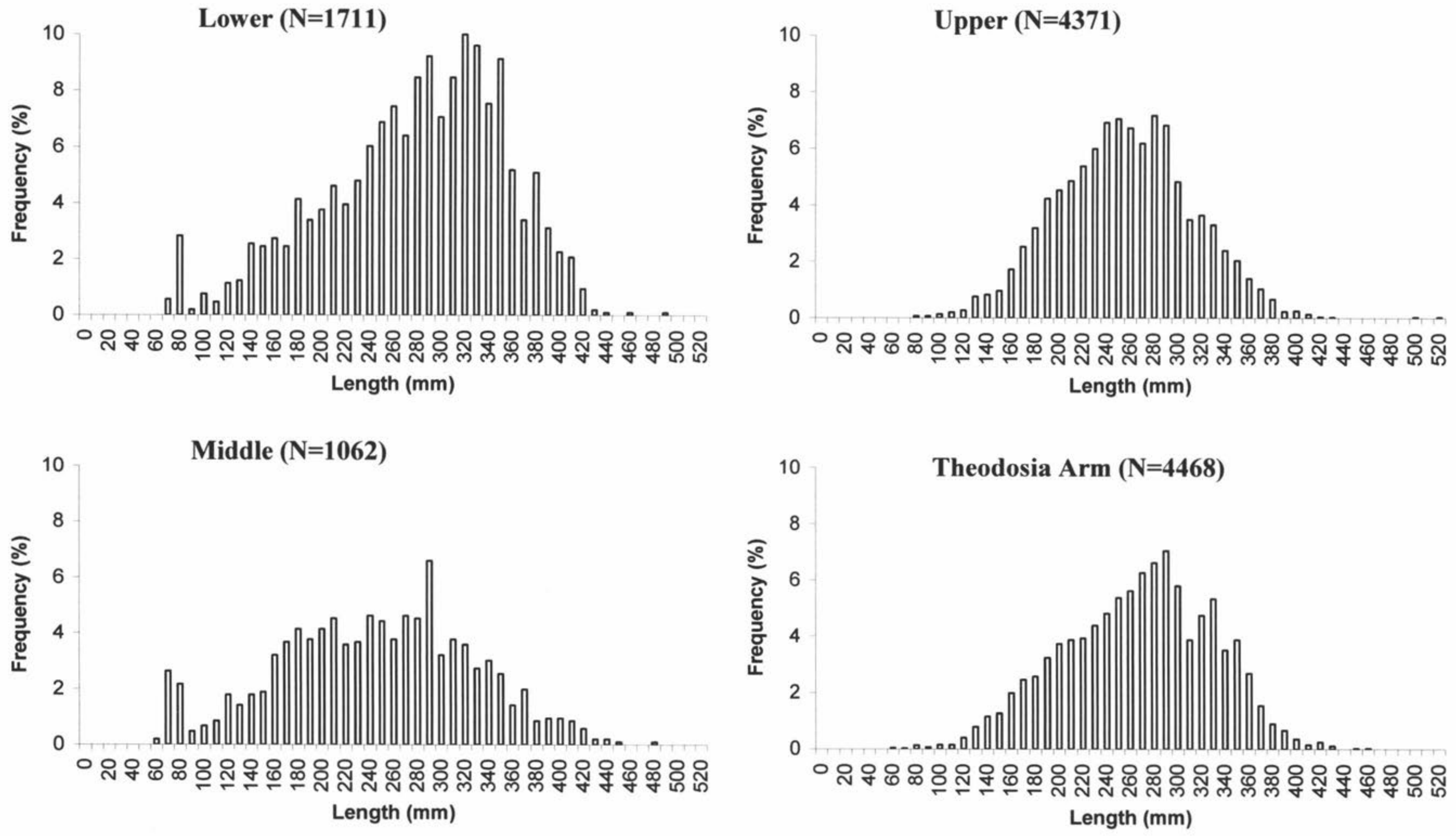


Figure 37: Relative length frequencies of historical electrofishing data from 1987 to 2003 in Bull Shoals Lake.

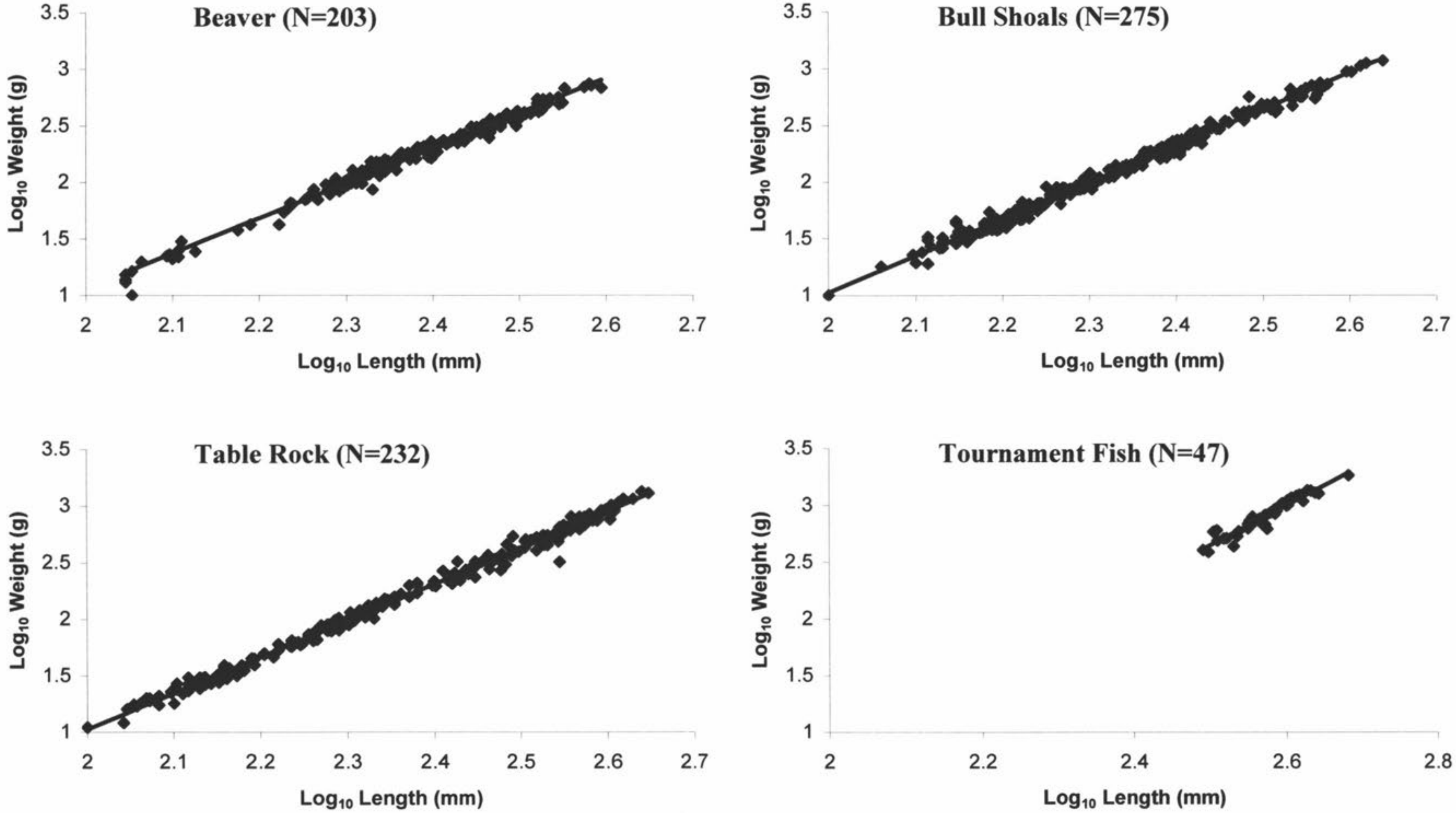


Figure 38: Transformed length-weight regressions for spotted bass from the sample lakes.

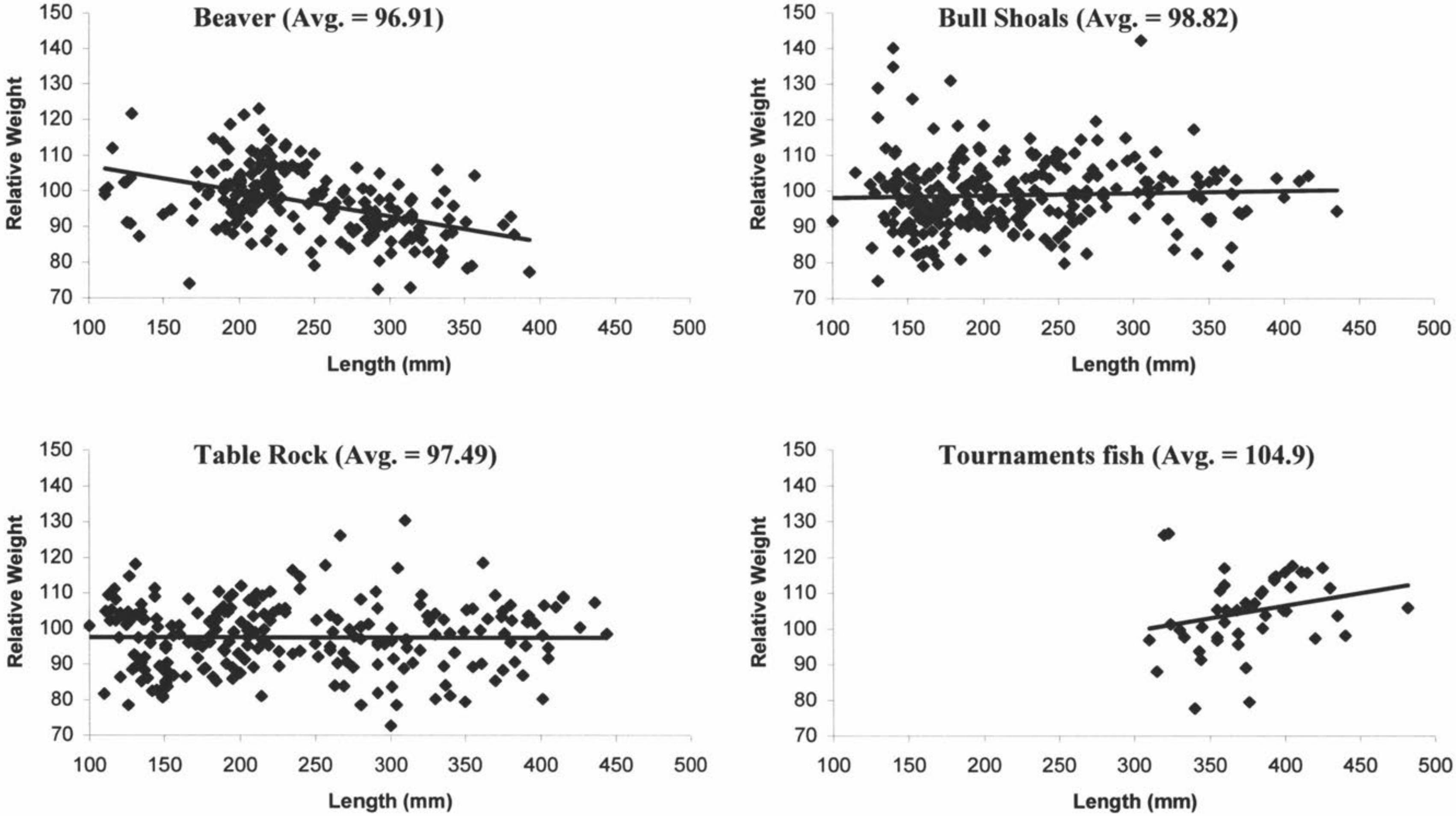


Figure 39: Relative weights for spotted bass from the sample lakes.

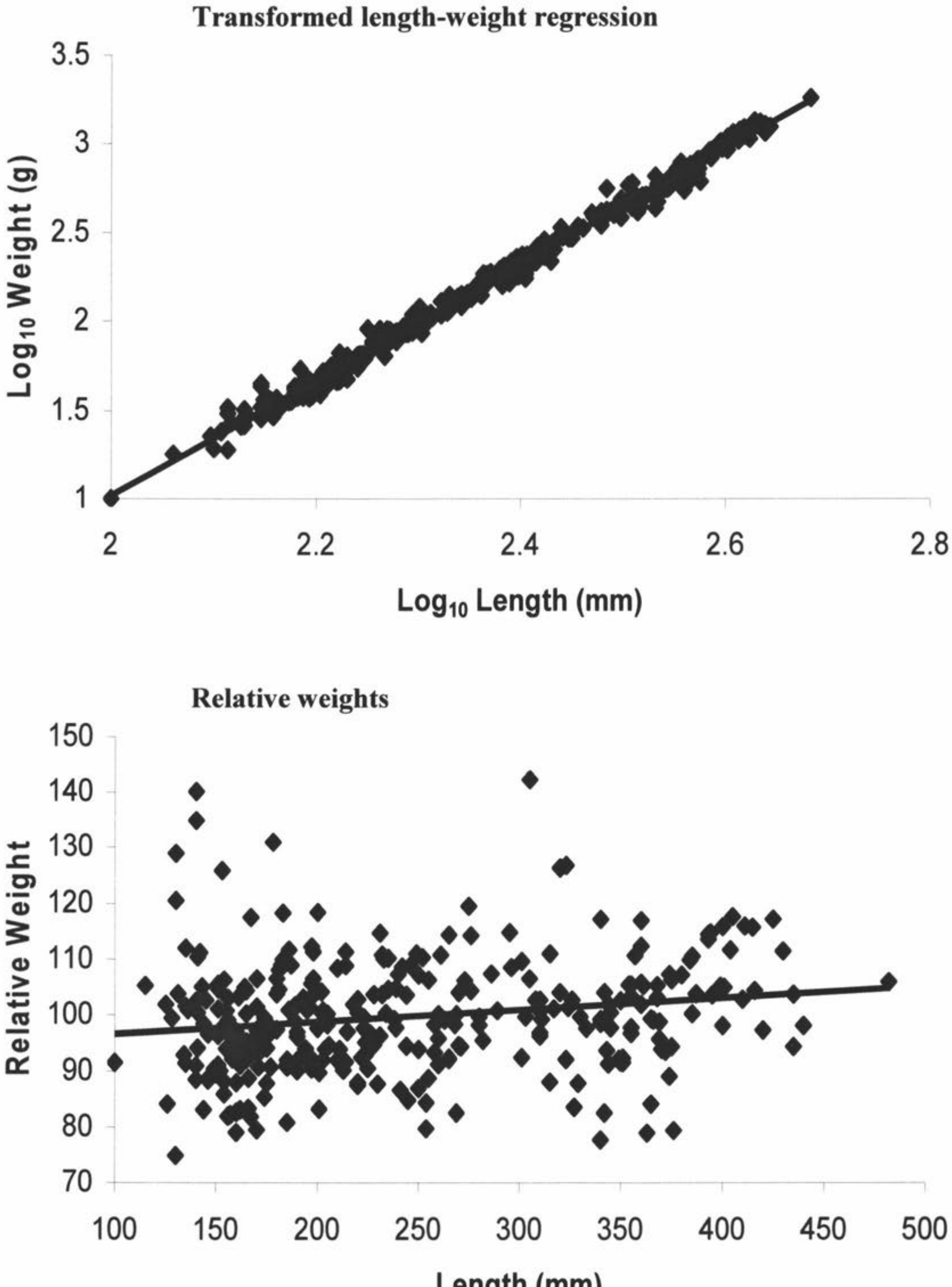


Figure 40: Transformed length-weight regression and relative weights for all spotted bass captured in Bull Shoals Lake.

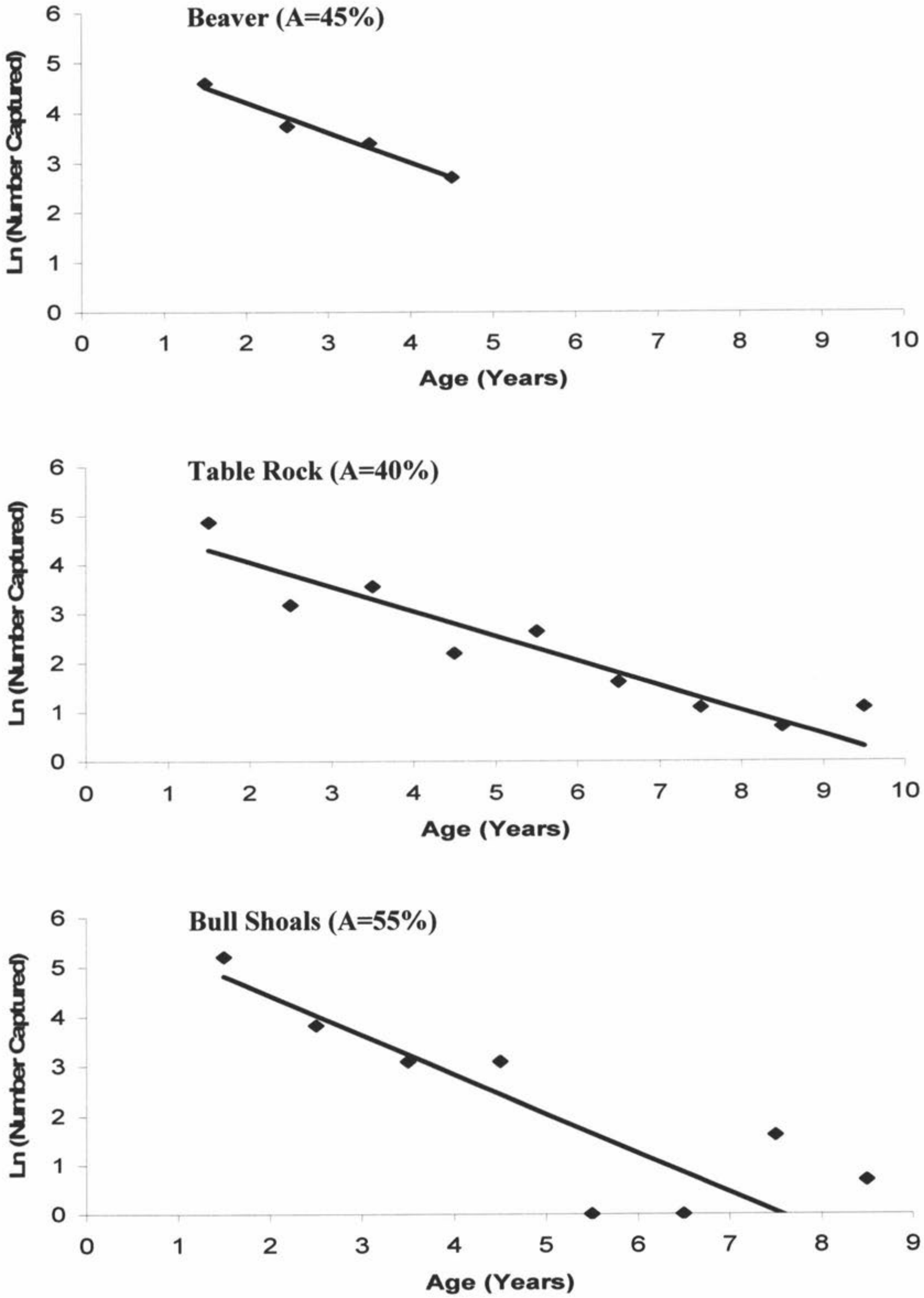


Figure 41: Catch curves for each sample lake. Annual mortality is in parentheses.

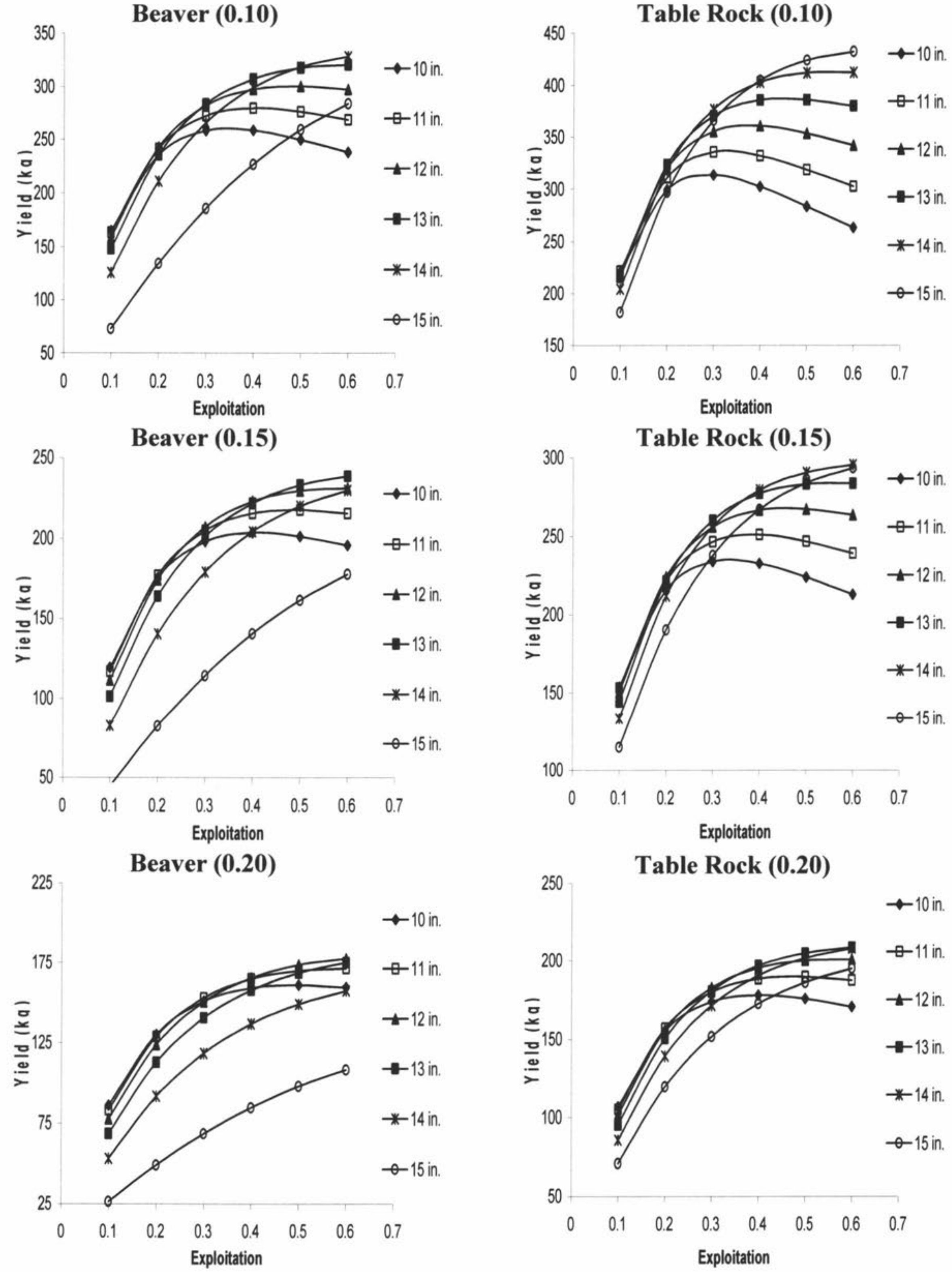


Figure 42: Population modeling results for yield for Beaver and Table Rock Lake at a conditional natural mortality of 0.10, 0.15, and 0.20. Yield is in kilograms (kg).

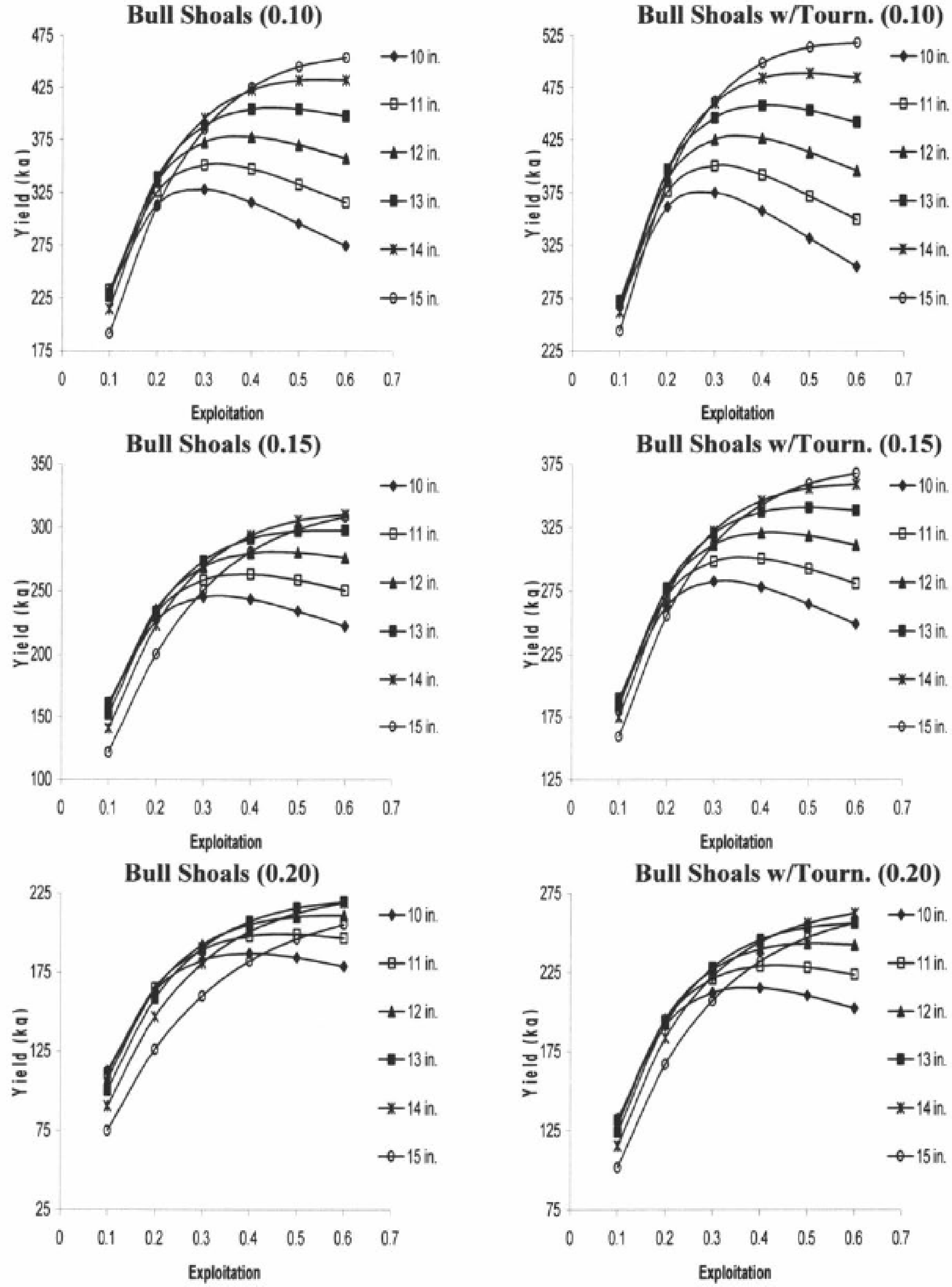


Figure 43: Population modeling results for yield for Bull Shoals Lake and Bull Shoals Lake with tournament fish included, at a conditional natural mortality of 0.10, 0.15, and 0.20. Yield is in kilograms (kg).

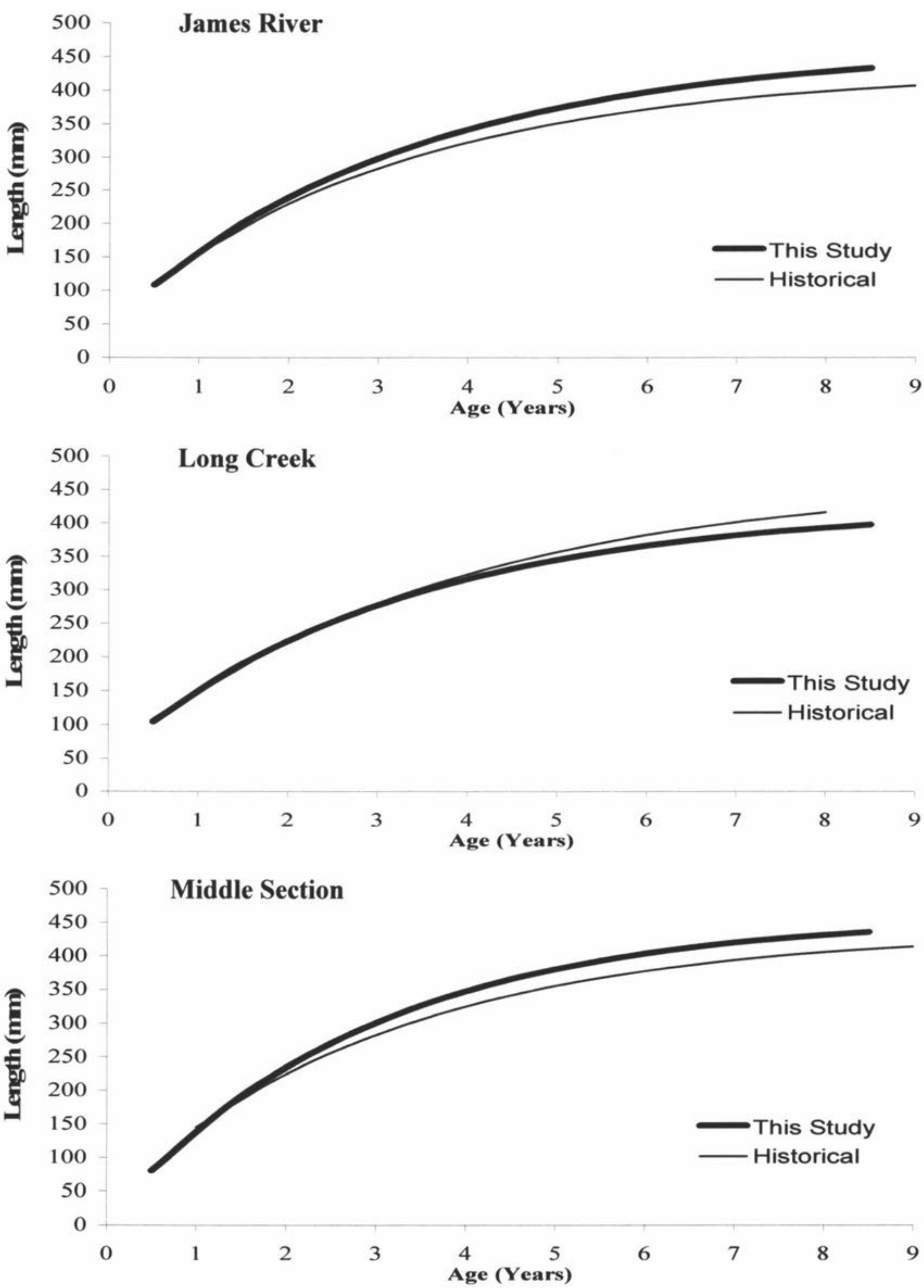


Figure 44: Von Bertalanffy growth curves for Table Rock Lake sample sites comparing data collected in this study to historical aging data. Scales were used to age spotted bass in the historical data. James River age data is from 1987-91, 94, 95, 96, and 2000. Long Creek age data is from 1987-91, 94, 95, 96 and 2001. The middle section is from 1995, 1996 and 1997.

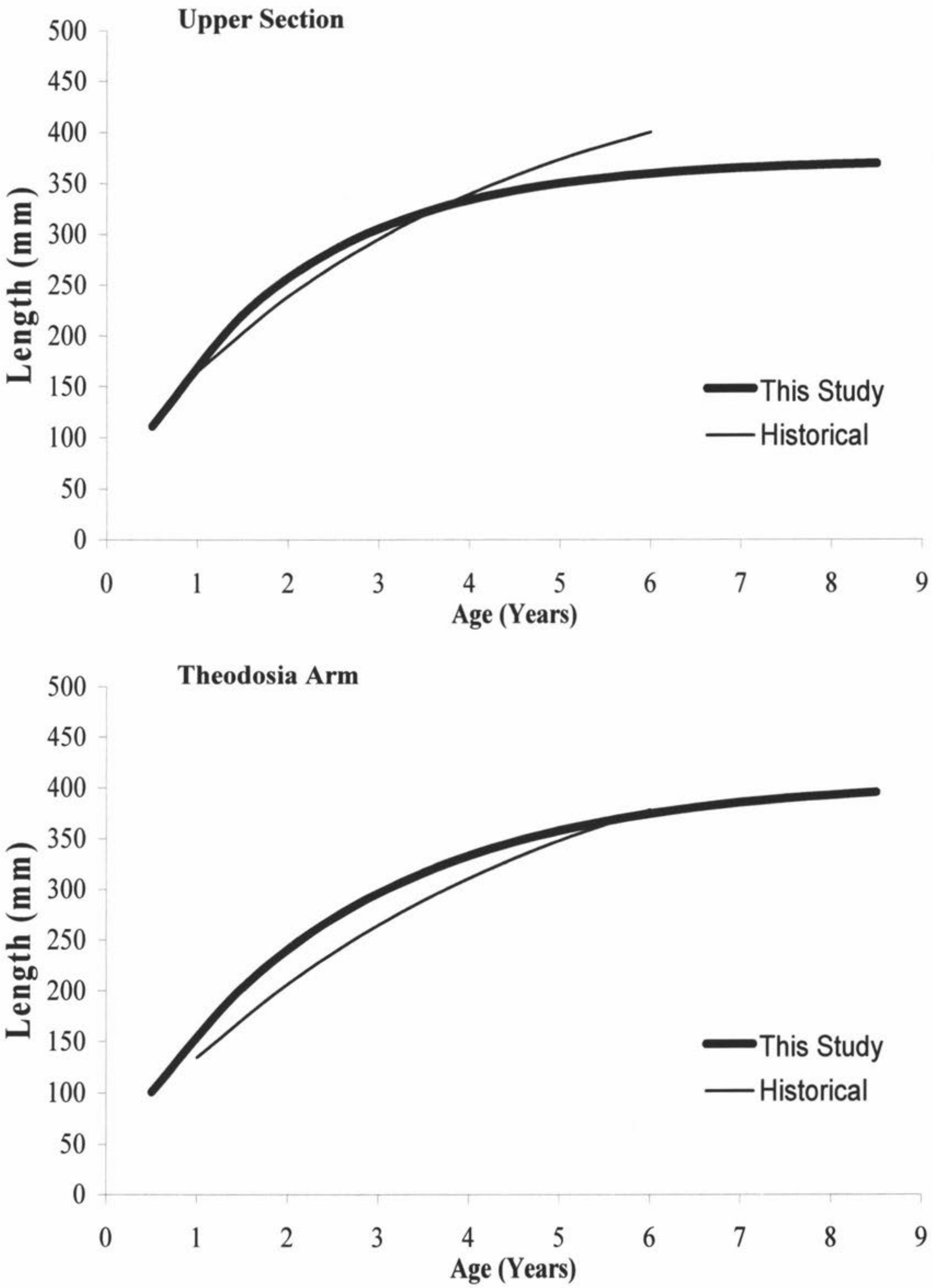


Figure 45: Von Bertalanffy growth curves for Bull Shoals Lake sample sites comparing data collected in this study to historical aging data. Scales were used in the historical data. Upper section age data is from 1991 and 2000. Theodosia age data is from 1987-91, 94, 95, 96 and 2001. The middle section is from 1987, 1989 and 1991.