Population Dynamics of Blue Catfish and Flathead Catfish in the Neosho River, Oklahoma

Oklahoma Department of Wildlife Conservation, Streams Program

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Executive Summary:

Five catfish surveys on the Neosho River were conducted in 2025 to evaluate contemporary catfish population dynamics between May 13th, 2025 and May 22th, 2025. Low frequency electrofishing (3 sites with 2 supplemental sites done prior to regular sampling) was conducted for Blue Catfish *Ictalurus furcatus* and Flathead Catfish *Pylodictis olivaris*. The electrofishing dataset includes 241 Blue Catfish and 43 Flathead Catfish. The numbers of Blue Catfish and Flathead Catfish ≥ stock length were 219 and 32 respectively. Blue Catfish relative abundance (CPUE; fish per hour electrofishing) was 155, which is above the statewide average of 42. Blue Catfish size structure appears skewed with proportional size distribution (PSD) indices estimated at PSD-Q = 35.2, PSD-P = 1.8, and PSD-M = 0, and PSD-T = 0. Estimated von Bertalanffy (VB) growth parameters for Blue Catfish were $L_\infty = 690$, $k = 0.087$, $t_0 = -1.54$. Compared to the current statewide standard growth rate, Blue Catfish exhibit slightly above average growth for most of their life span in the Neosho River. Blue Catfish annual mortality was estimated at 11.77%, which is lower than average range for lotic populations in Oklahoma of 20.8%. Flathead Catfish CPUE was 24, which is well above the statewide average of 14. Flathead Catfish PSD indices were PSD-Q = 81.2, PSD-P = 37.5, PSD-M = 3.1, and PSD-T = 0. However, size structure indices should be interpreted with caution because of the low number of Flathead Catfish ≥ stock length. Estimated VB growth parameters for Flathead Catfish were $L_\infty = 763$, $k = 0.151$, and $t_0 = 0.079$. Relative to the current statewide standard growth rate, Flathead Catfish RGI values are below average for lotic populations in Oklahoma except for ages three through thirteen. Flathead Catfish annual mortality was estimated at 1.9%, which is below the average for lotic populations in Oklahoma, though mortality for Neosho River should be used in great caution because of the lack of adequate represented age classes. Continued collection of catfish population data will assist in the development of specific management goals and determine if current lotic catfishing regulations are meeting the priorities of anglers.

Introduction

Stream fishing represents an important fisheries resource for freshwater anglers, and in Oklahoma, it is estimated that between 24-31% of anglers fish in rivers or streams every year (Fisher et al. 1998; Fisher et al. 2002; U.S. Department of the Interior et al. 2011). Catfish provide popular fisheries throughout their range (U.S. Department of the Interior et al. 2011); however, most state agencies do not intensively manage catfish populations (Michaletz and Dillard 1999; Arterburn 2002). Surveys of Oklahoma angler preferences have revealed that catfish are the most sought-after species by anglers in rivers and streams (York 2019). Therefore, catfish represent an important natural stream resource warranting management in Oklahoma. Despite their popularity in Oklahoma, catfish population management has received very little attention in lotic systems. Consequently, lotic catfish population dynamics data are almost non-existent (but see Lemmons and Schnell 1994; Kuklinski and Patterson 2013).

Beginning in 2016, the Oklahoma Department of Wildlife Conservation (ODWC) Streams Program instituted a catfish monitoring effort for Blue Catfish *Ictalurus furcatus* and Flathead Catfish *Pylodictis olivaris*. To date, nine rivers across the state have been surveyed. Data collected within the catfish monitoring program will document contemporary catfish population dynamics and serve as the baseline for a long-term dataset that evaluates population dynamic trends over time. Additionally, data from this program will be used to generate statewide standards that will be useful for comparing populations among rivers and/or regions to help determine specific management goals. In conjunction, data will be used to evaluate lotic catfish harvest regulations under an adaptive management framework to align catfish populations with the priorities of Oklahoma catfish anglers. Past research regarding attitudes of catfish anglers reflected the importance of harvest opportunities, but catfish anglers also value the opportunity to catch trophy-sized individuals (Arterburn 2002; Kuklinski and Boxrucker 2008). Thus, gaining insight into current population dynamic rates is imperative for assisting management decisions aimed at maximizing lotic catfish angling opportunities.

Methods

The Neosho River was sampled to evaluate current Blue Catfish and Flathead Catfish population dynamics. A total of three boat electrofishing surveys were conducted with the addition of two preliminary supplemental surveys for additional specimens. Surveys were completed during the period of May 13th to May 22nd, 2025. Daily discharge data was obtained from USGS gauge stations located along the Neosho River and analyzed with the R Data Retrieval Package.

Study area. —The headwaters of the Neosho River originate Northeast of Council Grove Lake in Morris County, Kansas. The watershed has a drainage area of around 32,789 square kilometers. The Neosho River flows 740 kilometers (km) though Kansas and Oklahoma where it terminates into the Arkansas River near Fort Gibson, Oklahoma. Previous community surveys done by ODWC found 54 species in the mainstem Neosho River consisting of 14 species of greatest conservation need and 14 recreationally important species which included Blue Catfish and Flathead Catfish (Starks et al. 2019).

There are approximately 143 river kilometers (rkm) found within Oklahoma separated by three reservoirs: Grand Lake O' the Cherokees, Hudson Lake, and Fort Gibson Lake. Sites were selected within the more riverine habitat above or between the lakes. The Neosho River wetted channel widths fell between 118 m and 210 m. The river channel substrate shifts as you head further downstream. In the Southeast Kansas portion of the river, there are more gravel substrates of varying sizes. In the Oklahoma portion of the Neosho River there is a shift of less gravel within the channel and more soft sediments with large boulders. The study area is found within the Central Irregular Plains (Cherokee Plains and Osage Cuestas), Ozark Highlands (Springfield Plateau and Dissected Springfield Plateau-Elk River Hills), and Boston Mountains (Lower Boston Mountains) ecoregions.

Field Methods. —Catfish were sampled using low-frequency (7.5-15 Hz) electrofishing (LFE). Low-frequency electrofishing is the most common sampling method for both Blue Catfish and Flathead Catfish (Brown 2007), and LFE is a recommended technique for generating age and growth, size structure, and relative abundance estimates for both species (Vokoun and Rabeni 1999; Bodine et al. 2013). Electrofishing was conducted with pulsed direct current (DC) using a boat equipped with a Midwest Lake Management Infinity Control Box and bow-mounted booms with two, six-dropper anode arrays. The shock boat maintained a fixed position for a minimum of two minutes while shocking to allow time for catfish to surface (Justus 1994). A chase boat was used to increase capture efficiency of both species (Daugherty and Sutton 2005b; Bodine et al. 2013) and was responsible for collecting surfacing catfish around the shock boat. Blue Catfish commonly occurs in open water habitat (Graham 1999; Bodine and Shoup 2010;

Bodine et al. 2013), and Flathead Catfish have an affinity for large woody debris and rock habitats (Jackson 1999), so each habitat type was sampled within each site. Shocking was conducted in a downstream direction. There is evidence that trotlines and hoop nets may be more effective at targeting larger catfish (Gale et al. 1999; Stauffer and Koenen 1999; Chapman 2002; Ford et al. 2011); but the labor-intensive nature of these methods combined with generally low catch rates precludes their use in current ODWC Stream Program standardized sampling (Ford et al. 2011; McCain et al 2011).

Laboratory Methods. —Catfish were returned to the laboratory on ice and identified to species. Total length (TL, mm) and weight (g) were recorded for each individual. Both lapilli otoliths were extracted from all specimens (Long and Stewart 2010). Otoliths provide the most accurate and precise age estimates for catfish, especially for older individuals (Nash and Irwin 1999; Barada et al. 2011). Otolith preparation and age estimation followed the methods outlined in Homer and Jennings (2011). Annuli were counted independently by two experienced readers. In instances where age estimates varied between the two readers, a third reader verified the age estimate. If a consensus on age was not reached, the age estimate for that individual was removed from the age dataset. All otoliths were photographed using a PrimeCam 12Pro S camera mounted on a Nikon SMZ25 to facilitate ease of reading and long-term storage of data.

Analyses. —Length-frequency and age-frequency histograms were used to visually assess the frequency of fish from each length group and age class in the sample. Proportional size distribution (PSD) indices were calculated to assess the proportion of individuals within the population that are larger than a specified length value. Gabelhouse (1984) developed a fish quality index that defines standard length categories for stock, quality, preferred, memorable, and trophy size classes of Blue Catfish and Flathead Catfish for calculating PSD's (Table 1). Proportional size distribution indices were calculated for the various size metrics using the following formula:

$$PSD - X = \frac{\#\, fish\ \geq specified\ length}{\#\, fish\ \geq minimum\ stock\ length} \times 100$$

where *X* indicates the length category (e.g., quality, preferred, memorable, or trophy) of interest. Size distribution indices were calculated in the FSA package version 0.9.3 (Ogle et al. 2022) in R version 4.2.1 (R Core Team 2022) and OFAT (Oklahoma Fisheries Analysis Tools).

Estimation of growth rates was accomplished by fitting a von Bertalanffy (VB) equation to paired age-length data from each population. The VB growth equation formula is as follows:

$$L_t = L_\infty\left[1 - e^{-k(t-t_0)}\right]$$

where t is time units, which represent the age of the fish in years, L_t is the length of the fish at age t, L_∞ is the theoretical average maximum length, k is the growth coefficient (i.e., how quickly the function approaches L_∞), and t_0 is the "x-intercept" needed for model fitting. Mean length at age estimates were used to populate the VB growth function to remove any concern for biasing parameter estimates stemming from non-independent measures of growth (Quist et al. 2012). Upper and lower 95% confidence intervals (CI) were calculated using 10,000 iteration bootstrapping. Growth parameters were estimated using the nls function in FSA package version 0.9.3 (Ogle et al. 2022) in R version 4.2.1 (R Core Team 2022) and OFAT for comparisons.

To facilitate comparisons of catfish growth rates across Oklahoma, we calculated relative growth index (RGI) values using the following equation:

$$RGI = (L_t/L_s)\ x\ 100$$

where L_t is predicted length at age t from an individual river and L_s estimates of predicted length at age were calculated from a VB growth model for each species using pooled statewide data collected since 2016 (i.e., statewide standard growth models). Relative growth index values of 100 indicate average growth, while values above or below 100 indicate above-average and below-average growth, respectively (Casselman and Crossman 1986; Quist et al. 2003).

Mortality rates were calculated using weighted linearized catch-curves. Age classes on the ascending limb of catch curve plots were removed as they are underrepresented in the sample and heavily influence mortality rate estimation. The descending limb of the catch-curve is linear when the natural logarithm of catch is plotted against age, and the negative slope of the linear regression model fit to the data is an estimate of instantaneous mortality (Z) (Ogle 2016). Weighted regression methods were used because old age classes are typically represented by few individuals, which may bias estimates of total annual mortality (A) (Maceina and Bettoli 1998). Upper and lower 95% CI were estimated for both Z and A. Catch-curve mortality rates are based on assumptions not commonly met in fisheries including constant recruitment, constant survival among year classes, constant survival among years, and a representative age sample from the population (Ogle 2016). However, despite these limitations, catch-curves are commonly used in scientific literature to compare mortality rates among populations. Thus, catch-curves were utilized in place of more intensive mortality estimation techniques derived from tagging studies. Mortality rates were estimated in FSA package version 0.9.3 (Ogle et al. 2022) in R version 4.2.1 (R Core Team 2022) and OFAT.

Results

Environmental conditions. —In May 2025, daily discharge for the Neosho Rover near Commerce, Oklahoma ranged from 1.4 ft^3/s to 41200 ft^3/s with an average of 2626 ft^3/s. Site lengths were all approximately two rkm. During electrofishing efforts, water temperatures ranged from 21 ˚C to 22 ˚C. Conductivity and water clarity averaged 349 µS/cm and 14.7 cm, respectively. Shocking efforts were recorded in seconds (s) for three surveys, not including the two supplemental surveys, ranged from 1,200 s to 2,400 s per site with an average of 2,000 s.

Blue Catfish. —Surveys in the Neosho River yielded a total of 242 Blue Catfish. Catch per unit effort (CPUE) was 155 ± 78.75 fish per hour (Table 2). Blue Catfish sizes ranged from 200-880 mm (7.9-34.6 in), and ages ranged from 1-19 years. A few younger age classes were not well represented; there was a very strong representation from age class 14 (Figure 6). The number of individuals ≥ stock length (300 mm; 12 in) was 219. The number of individuals ≥ quality size (510 mm; 20 in) was 77. The number of individuals ≥ preferred size (760 mm; 30 in) was 4. No memorable (890 mm; 35 in) or trophy (1140 mm; 45 in) individuals were collected (Table 3). Blue Catfish growth parameters estimated from the VB growth function were $L\infty$ = 691*,* k = 0.087*,* and t_0 = -0.05 (Table 4, Figure 7). Predicted mean length at age is reported out to the maximum age (19 years) collected in the survey (Table 6). Compared to the current statewide standard growth rate, Neosho River Blue Catfish RGI values suggest above average growth at all ages except 1-5 collected in this sample. RGI values from ages 6-19 were at or above the statewide average of 100 (Figure 8). Blue Catfish annual mortality in the Neosho River was estimated at 11.7% (Table 7).

Flathead Catfish. —Surveys in the Neosho River yielded 43 Flathead Catfish. Catch per unit effort (CPUE) was 24 ± 3.77 fish per hour (Table 2). Flathead Catfish sizes ranged from 155-890 mm (6.1-35in), and ages ranged from 2-30 years. There was no adequate representation of ages among individuals above the age of 20 (Figure 9). The number of individuals ≥ stock length (350 mm; 14 in) was 32. The number of individuals ≥ quality size (510 mm; 20 in) was 26, Flathead Catfish PSD-Q was 81.2. The number of individuals ≥ preferred size (710 mm; 28 in) was 12, PSD-P was 37.5. One individual was ≥ memorable size (860 mm; 34 in) and PSD-M was 3.1. No individuals over trophy size (1,020 mm; 40 in) were collected in these samples (Table 3). Flathead Catfish growth parameters estimated from the VB growth function were $L\infty = 762$, $k = 0.151$, and $t_0 = 0.079$ (Table 4, Figure 10). Predicted mean length at age is reported out to the maximum age (30 years) represented in the survey (Table 8). Relative to the current statewide standard growth equation, RGI values are above or at average through ages 3-13, with the remaining reported ages being below the statewide average. (Figure 8). Flathead Catfish annual mortality in the Neosho River was estimated at 1.89% (Table 7).

Discussion

Environmental Conditions. —Discharge, turbidity, and water temperature can influence the efficiency of LFE (Justus 1994; Bodine and Shoup 2010). The Neosho River is separated by multiple reservoirs, affecting the natural riverine habitat. Flooding conditions were experienced, near time of sampling. In general, increased discharge may negatively bias capture efficiency as catfish rising to the surface may remain in sight for a shorter period or never make it to the surface. However, the authors are not aware of any studies that have explicitly studied how varying discharge values affect LFE efficiency in lotic systems. Discharge's relationship to capture efficiency is also complicated by channel morphology (i.e., width/depth ratio and sinuosity), so comparisons among rivers are difficult. Water clarity also potentially biased capture rates in the Neosho River, more so at Site 1 Located above Grand Lake near Miami Park. The average water clarity measurement during LFE was low (14.7 cm), and turbid systems increase the difficulty of spotting catfish; thus, individuals floating just under the surface of the water may have gone unseen. The Stream Program's standardized sampling protocol mandates water temperatures to be greater than 18°C when conducting LFE catfish surveys. Bodine and Shoup (2010) and Grussing et al. (1999) noted capture efficiencies of catfish increased when temperatures were greater than 18°C, and Quinn (1986) described increased capture efficiencies for Flathead Catfish in water temperatures greater than 20°C during LFE surveys. Furthermore, Justus (1994) noted LFE catfish capture efficiencies in the Mississippi River improved with increasing water temperatures from 22°C to 27°C. Water temperatures during our LFE surveys ranged from 21 ˚C to 22 ˚C. Therefore, water temperatures were above the threshold for all sampling events and should not have negatively biased capture efficiencies. In summary, certain environmental biases (discharge and turbidity) may have negatively affected CPUE's.

Blue Catfish. —Sample size of Blue Catfish from the Neosho River surveys in 2025 (n = 242) falls as the third highest of the Blue Catfish sample sizes in lotic systems sampled by the streams program throughout Oklahoma (Rodger et al. 2016; Rodger et al. 2017a, 2017b; Rodger et al. 2018a, 2018b; Rodger and Starks 2019; Rodger and Starks 2020; Rodger and Starks 2021, Wallace et al. 2023, Cox et al. 2024). Blue Catfish CPUE (155± 78.75) was higher than the statewide average of 42 ± 13 fish per hour (Table 2). Blue Catfish CPUE was significantly lower than values reported from Oklahoma reservoirs (Mauk and Boxrucker 2004; Boxrucker and Kuklinski 2006; Kuklinski and Patterson 2011). Furthermore, there have been no studies in Oklahoma aimed at understanding how relative abundance estimates from reservoirs and rivers in the same system compare. However, preliminary evidence based on historical reservoir relative abundance estimates and contemporary lotic estimates within the same system suggest Blue Catfish may have much higher relative abundances in lentic systems. For example, Lake Texoma, Oolagah Reservoir, Eufaula Reservoir, and Hugo Reservoirs had CPUE's of 225, 848, 390, and 634 fish per hour, respectively (Kuklinski and Patterson 2011). The Red River, Washita River, Verdigris River, Deep Fork, and Kiamichi River flow into these reservoirs, respectively (with the Red and Washita rivers both flowing into Lake Texoma), and boast CPUE's of 33, 16, 114, 67, and 46 fish per hour, respectively (Rodger et al. 2017a, 2017b; Rodger et al. 2018a, 2018b; Rodger and Starks 2020). It's worth noting that lotic Blue Catfish catch rates may have been affected by environmental conditions (as discussed above), and in general, sampling catfish in lotic systems poses additional challenges compared to lentic environments. Reservoir surveys also operate two chase boats (Boxrucker and Kuklinski 2006), while lotic surveys utilized one. Thus, it is difficult to directly compare CPUE from the two habitats. However, this pattern will continue to be evaluated as additional rivers are sampled, and more data becomes available for comparison. Moreover, biologists will continue to gain greater insight into average statewide relative abundance estimates in Oklahoma lotic systems as more rivers are surveyed and precise estimates of relative abundance are obtained.

Blue Catfish size structure in the Neosho River appears to be relatively similar to statewide averages. Blue Catfish PSD-Q and PSD-P estimates in the Neosho River were only slightly higher and lower respectively than statewide estimates while PSD-M and PSD-T could not be determined (Table 3). In general, proportions of preferred size and above Blue Catfish surveyed by LFE are generally low in rivers statewide. We could not find any reported size structure indices from lotic populations outside of Oklahoma for comparison, and there are no published standards for balanced catfish populations. Miranda (2007) provided a minimum sample size recommendation of 75 individuals ≥ stock length to adequately describe size structure. After incorporating 2025 data, all the contemporary surveys have met this sample size threshold for Blue Catfish. As data from other rivers continues to be collected and certain sample sizes are augmented as needed, biologists will gain greater insight into the variability of Blue Catfish size structure indices in Oklahoma rivers.

Growth rates of Blue Catfish have been reported to generally be slow in Oklahoma (Kuklinski and Patterson 2011). In Oklahoma tailwaters, growth estimates from Kuklinski and Patterson (2013) suggest it takes Blue Catfish 11, 10, 9, 7 and 7 years to reach quality size (510 mm; 20 in) in Robert S. Kerr, Kaw, Hugo, Texoma, and Keystone tailwaters, respectively. Mauk and Boxrucker (2004) reported approximately 9 years were required to reach quality size in Lake Texoma. Growth rates of Blue Catfish in other Oklahoma reservoirs are highly variable. For example, reported mean length at age estimates suggest Blue Catfish reach quality size in as fast as 6 years in Keystone and Oologah reservoirs but estimates from Fort Gibson and Sardis reservoirs never exceeded quality size, even for fish up to 17 years old (Kuklinski and Patterson 2011). Limited data is available to compare other native lotic populations of Blue Catfish aged using otoliths, but Stewart et al. (2009) report growth rates that suggest it only takes 6 years for Blue Catfish to reach quality size in the Mississippi River. Growth rates of introduced Blue Catfish populations in Georgia and Virginia suggest quality size can be reached in 4-8 years (Bonvechio et al 2011b; Greenlee and Lim 2011). This study estimates that on average it takes Blue Catfish 8.5 years to reach quality size.

A meta-analysis of catfish growth in North America provided some key insights regarding Blue Catfish growth. In general, Blue Catfish growth rates tend to be faster in locations that are sunny, wind-driven, and exhibit high rates of evapotranspiration. Thus, Blue Catfish tend to grow faster at southern latitudes. Additionally, Blue Catfish growth rates were faster in lotic systems compared to lentic systems (Rypel 2011). The Neosho River is situated in central to Eastern Oklahoma; thus, it is likely that it's latitude and climate have a potential positive effect on growth rates, not as severe of an effect as some more southern systems though. In terms of diets, Blue Catfish are considered opportunistic omnivores that feed on fish, invertebrates, mussels, algae, and plant matter (Brown and Dendy 1961; Graham 1999; Grist 2002; Bonvechio et al. 2011b; Kuklinski and Patterson 2013; Schmit et al. 2019). In general, there is a shift towards fish prey around 300 mm TL (Brown and Dendy 1961; Graham 1999), but ontogenetic shifts have been reported to occur at greater lengths (500-900 mm TL) (Schmitt et al. 2019). Summer diet collections from tailwaters in Oklahoma have shown dominant prey items may vary among systems (Kuklinski and Patterson 2013). A potential hypothesis for the above average growth of certain age classes in Neosho River Blue Catfish may be the use of more energetically valuable fish prey resources (e.g., shad *Dorosoma* spp.) in their diets with the availability of nearby lentic systems. Gizzard Shad *Dorosoma cepedianum* and Threadfin Shad *Dorosoma petense* are thought to be key diet items for southern populations of Blue Catfish (Graham 1999). If fish prey resources make up larger proportions of Blue Catfish diets in the Neosho River, then faster growth rates would be expected. However, the extent to which density-dependent factors interact with density-independent factors (e.g., habitat quality, hydrologic flow regime, system fertility) to regulate growth in Oklahoma rivers is unknown. In summary, lotic Blue Catfish growth may be slower in Oklahoma relative to other states (Stewart et al. 2009; Kuklinski and Patterson 2011, Bonvechio et al 2011b; Greenlee and Lim 2011), but relative to other Oklahoma river systems, our data suggests Cimarron River growth rates may be above average.

Blue Catfish are known to be a long-lived species with individuals capable of living past 20 years of age (Stewart et al. 2009; Greenlee and Lim 2011; Kuklinski and Patterson 2011; Kuklinski and Patterson 2013; Rodger et al. 2017b; Rodger et al. 2018a). The oldest individual the authors found reported in the literature was a 32-year-old from Robert S. Kerr Reservoir in Oklahoma (Kuklinski and Patterson 2011). Maximum ages from contemporary surveys have ranged from 14 to 23 years (Rodger et al. 2016; Rodger et al. 2017a, 2017b; Rodger et al. 2018a, 2018b; Rodger and Starks 2019; Rodger and Starks 2020; Rodger and Starks 2021). The oldest individual sampled from the Neosho River was 19 years old. Annual mortality for Neosho River Blue Catfish was estimated at 11.77%, which is within the observed range for lotic Blue Catfish populations in Oklahoma and lower than the statewide average of 20.8% (Table 7). Compared to other populations in North America, mortality in the Neosho River is less than estimates from lotic systems in Alabama, Missouri, Georgia, and Virginia (Kelley 1968; Graham and DeiSanti 1999; Bonvechio et al. 2011b; Greenlee and Lim 2011; Jolley and Irwin 2011). Therefore, lower than average mortality rates ensure at least a small proportion of individuals in the population reach larger size classes.

Flathead Catfish. —Total sample size of Flathead Catfish captured with LEF from the Neosho River surveys in 2025 (n =43) is fourth smallest among contemporary surveys (Rodger et al. 2016; Rodger et al. 2017a, 2017b; Rodger et al. 2018a, 2018b; Rodger and Starks 2019; Rodger and Starks 2020; Rodger and Starks 2021, Wallace et al. 2023, Cox et al. 2024). Flathead Catfish CPUE for LEF surveys was greater (24 ± 3.8) than the statewide average of 14 ± 3 fish per hour and is currently the second highest relative abundance recorded in contemporary surveys (Table 2). However, Neosho River Flathead Catfish relative abundance is much lower than estimates from large rivers across the United States that utilized LFE for sampling. For example, Flathead Catfish CPUE's are reported to be greater than 100 fish per hour in the Missouri and Mississippi rivers (Robinson 1997; Ford et al. 2011; Porter et al. 2011). Conversely, CPUE from smaller systems averaged 28 fish per hour (Stauffer and Koenen 1999; Chapman 2002; Jolly and Irwin 2011; Moody-Carpenter 2013). The average CPUE representing smaller rivers in those studies is also significantly different than our estimate from the Neosho River. As discussed above, Flathead Catfish CPUE may have been negatively affected by environmental conditions (i.e., discharge, conductivity, turbidity).

Despite a high CPUE, reliable estimate of Flathead Catfish size structure was still difficult to obtain because of the low number of individuals ≥ stock length (n = 32) captured in our surveys. As previously mentioned, Miranda (2007) provided a minimum sample size recommendation of 75 individuals ≥ stock length to adequately describe size structure. This threshold has proven difficult to meet for lotic Flathead Catfish populations in Oklahoma as all the rivers surveyed so far have failed to meet this benchmark. Therefore, size structure indices and comparisons should be interpreted with caution until additional surveys bolster sample sizes of individuals ≥ stock length. Based on current estimates, PSD-Q and PSD-P in the Neosho River are near the higher end of the range reported in Oklahoma rivers. PSD-M are lower than statewide estimates. PSD-T in the Neosho River could not be calculated.

Unlike Blue Catfish, growth data for lotic populations of Flathead Catfish is widely available in the literature. However, most of these studies utilized pectoral spines for aging. For example, McCoy (1953) estimated growth rates from the newly formed Wister Reservoir on the Poteau River from collections in 1949 using pectoral spines, and the data suggests quality size was reached in 4 years. Similar growth rates are also reported for the Illinois River, Lake Texoma, and Boomer Reservoir in Oklahoma (McCoy 1953). In a review of native, lotic Flathead Catfish populations aged using spines, Kwak et al. (2006) noted the time required to reach quality size ranged from 3-9 years, and the time needed to attain memorable size ranged from 8-22 years. However, Nash and Irwin (1999) demonstrated the potential biases associated with pectoral spines as an aging structure and subsequently a shift to otoliths took place in the 2000's (Grabowski et al. 2004; Kwak et al. 2006; Kaeser et al. 2011; Steuck and Schnitzler 2011). Olive et al. (2011) still suggest pectoral spines may provide reliable estimates for Flathead Catfish up to age 9, but age estimates may vary depending on preparation technique (Nash and Irwin 1999; Koch et al. 2011). Thus, growth comparisons made with historical studies using pectoral spines should be limited to younger age classes and be interpreted with caution.

Flathead Catfish growth is known to be highly variable, and population growth rates may be affected by density-dependent factors such as intraspecific competition or by density-independent factors like prey type, climate, stream order, system productivity, hydrologic flow regime, or exploitation (Kwak et al. 2006; Jones and Noltie 2007; Rypel 2011; Massie et al. 2018). In large-scale reviews of Flathead Catfish growth, studies have reported no significant differences in Flathead Catfish growth rates between lotic and lentic systems (Rypel 2011; Massie et al. 2018). Massie et al. (2018) determined growth rates were significantly affected by climate as maximum length estimates were greater at southern latitudes for Flathead Catfish populations within their native range. Although, current research seems to agree that Flathead Catfish growth is generally more affected by finer-scale processes than mechanisms operating at larger scales (Rypel 2011; Massie et al. 2018). Thus, future research aimed at elucidating mechanisms responsible for variable Flathead Catfish growth in Oklahoma rivers may provide insight into the most important factors driving differences in population growth rates.

Annual mortality for Neosho River Flathead Catfish was estimated at 1.9%. This represents the lowest estimate from contemporary Oklahoma lotic studies; this percentage should be used with caution due to the lack of adequately represented age classes. The statewide estimate from pooling all Flathead Catfish data is currently 18.6% (Table 7). Published estimates of Flathead Catfish annual mortality from rivers across the United States range from 12% to 62% with an average of 35% (Robinson 1997; Daugherty and Sutton 2005a; Kwak et al. 2006; Makinster 2006; Sakaris et al. 2006; Bonvechio et al. 2011a; Jolly and Irwin 2011; Kaesar et al. 2011; Moody-Carpenter 2013; Hilling et al. 2019; Hamel et al. 2020; Schall and Lucchesi 2020). Therefore, Flathead Catfish populations in Oklahoma may have lower than average annual mortality rates when compared to populations across the country. The oldest Flathead Catfish sampled in our survey was 30 years old. Maximum age reported from contemporary studies has ranged from 12 years in the Washita River to 27 years in the Deep Fork (Rodger et al. 2016; Rodger et al. 2017a, 2017b; Rodger et al. 2018a, 2018b; Rodger and Starks 2019; Rodger and Starks 2020; Rodger and Starks 2021). Flathead Catfish are considered a long-lived species as individuals in other populations in North America demonstrate their potential to reach 20 years old (Chapman 2002; Makinster 2006; Sakaris et al. 2006; Jolly and Irwin 2011; Kaeser et al. 2011). In fact, the oldest individual we found reported in the literature was a 30 year old from the upper Mississippi River (Steuck and Schnitzler 2011). Conversely, Kwak et al. (2006) reference 19 native lotic Flathead Catfish populations, and only one population produced an individual greater than 20 years of age. However, the oldest individual we as a department have sampled is a Flathead Catfish reported as 38 years old from Pine Creek Resevoir.

Management Recommendations. —We recommend the continued inclusion of the Neosho River in the Streams Program catfish monitoring rotation and the continued building of a robust statewide dataset to evaluate existing catfish regulations. However, there are rivers on the current monitoring rotation that have yet to be sampled and, as was the case for the Neosho, some rivers only sampled in one year are in greater need of augmented sample sizes. Despite a total of three LEF surveys and two supplemental surveys done in concurrence with Invasive Carp sampling, population dynamics estimates in the Neosho River would still benefit from an increased sample size of Flathead Catfish and Blue Catfish ≥ stock size to improve size structure indices. Improving accuracy and precision of statewide standards will be useful for comparing populations among rivers and/or regions to help determine specific management goals for the Neosho River. The timing of sampling (pre-spawn) provides biologists with an opportunity to collect additional data, such as size-specific fecundity estimates and size-at-maturity estimates for Blue Catfish and Flathead Catfish, which began in 2017. The collection of this data will permit the use of additional quantitative techniques (e.g., yield-per recruit models, age/stage structured matrix population models, spawning potential ratios) to further examine the contemporary status of Oklahoma's lotic catfish populations and assess the likelihood of growth and/or recruitment overfishing. Additionally, collecting human dimensions data that provides insight into Oklahoma catfish anglers' current opinions, desires, motivations, and harvest tendencies would provide critical information for biologists to better manage catfish fisheries in lotic systems. Currently, more data is necessary to inform any potential future lotic catfishing regulations.

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Tables

Table 1.—Size (mm/in) of stock, quality, prefered, memorable, and trophy Blue Catfish, Flathead Catfish and Chann. Adapted from Gabelhouse (1984).

Species	Stock	Quality	Preferred	Memorable	Trophy
Blue Catfish	300 / 12	510 / 20	760 / 30	890 / 35	1140 / 45
Flathead Catfish	350 / 14	510 / 20	710 / 28	860 / 34	1020 / 40
Channel Catfish	280 / 11	410 / 16	610 / 24	710 / 28	910 / 36

Table 2.—Catch per unit effort (# fish per hour electrofishing) for Neosho River catfish with comparisons to pooled statewide data and individual results from Poteau, Red, Spring, Deep Fork, Washita, Kiamichi, Cimarron, and Verdigris rivers. Numbers in parentheses are 95% confidence intervals, and relative standard error (RSE) is reported for comparison.

Species	River	CPUE	95% CI	RSE
Blue Catfish	Statewide	42	(29 – 55)	16
	Kiamichi	46	(29 – 63)	14
	Poteau	13	(9 – 18)	14
	Red	33	(5 – 61)	34
	Spring	2	(-17 – 21)	71
	Deep Fork	67	(34 – 100)	11
	Washita	16	(-1 – 33)	41
	Cimarron	28	(17 - 39)	18
	Neosho	155	(76 – 234)	50
	Verdigris	114	(79 – 149)	11
Flathead Catfish	Statewide	14	(12 – 17)	10
	Kiamichi	26	(21 – 31)	9
	Poteau	14	(11 – 18)	10
	Red	12	(6 – 18)	20
	Spring	15	(-104 – 134)	26
	Deep Fork	9	(4 – 14)	15
	Washita	4	(1 – 7)	33
	Neosho	24	(20 – 27)	2

	Cimarron	3	(1 - 5)	28
	Verdigris	20	(-2 – 42)	39

Table 3.—Proportional size distributions for Neosho River catfish with comparisons to pooled statewide data and individual results from Poteau, Red, Spring, Deep Fork, Washita, Spring, Kiamichi, Cimarron, and Verdigris rivers. Rivers marked by asterics indicate sample size of stock size individuals ≥ 75, which is the published minimum sample size to adequately describe size structure. Numbers in parentheses are 95% confidence intervals. Q=quality, P=prefered, M=memorable, T=trophy. Sizes based on Gablehouse (1984).

Species	River	N ≥ Stock TL	PSD-Q	PSD-P	PSD-M	PSD-T
Blue Catfish	Statewide*	1041	34 (31 – 37)	2 (1 – 3)	1 (1 – 2)	0 (0 – 1)
	Kiamichi*	193	39 (32 – 46)	3 (1 – 6)	1 (0 – 3)	0
	Poteau*	101	30 (22 – 39)	0	0	0
	Red*	107	40 (31 – 50)	4 (2 – 9)	4 (2 – 9)	0
	Deep Fork*	167	47 (40 – 55)	0	0	0
	Washita*	113	52 (43 – 61)	4 (2 – 10)	3 (1 – 8)	1 (0 – 5)
	Spring*	113	36 (28-46)	0	0	0
	Cimarron*	98	35 (26-44	3 (1-8)	0	0
	Neosho*	219	35.2 (29-42)	1.8 (1-5)	0	0
	Verdigris*	360	19 (15 – 23)	2 (1 – 4)	1 (0 – 2)	0
Flathead Catfish	Statewide*	224	59 (53 – 66)	25 (20 – 31)	9 (6 – 13)	1 (1 – 4)
	Kiamichi	67	49 (38 – 61)	24 (15 – 35)	6 (2 – 14)	3 (1 – 10)
	Poteau	45	67 (52 – 79)	31 (20 – 46)	4 (1 – 15)	0
	Red	30	43 (27 – 61)	3 (1 – 17)	0	0
	Spring	19	84 (62 – 95)	26 (12 – 49)	11 (3 – 31)	0
	Deep Fork	7	57 (25 – 84)	43 (16 – 75)	43 (16 – 75)	0
	Cimarron	10	70 (40-89)	20 (6-51)	10 (2-40)	0
	Washita	11	46 (21 – 72)	27 (10 – 57)	18 (5 – 48)	0

Verdigris	45	71 (57 – 82)	31 (20 – 46)	13 (6 – 26)	2 (0 – 12)
Neosho	32	81 (65-91)	38 (23-55)	3 (1-16)	0

Table 4.—Parameter estimates and 95% confidence intervals from the von Bertalanffy growth model for Cimarron River catfish with comparisons to pooled statewide data and individual results from Poteau, Red, Spring, Deep Fork, Kiamichi, Washita, and Verdigris rivers.

Species	**River**	**L∞**	***k***	***t_0***
Blue Catfish	Statewide	1077 (976 – 1222)	0.057 (0.047 – 0.068)	-1.67 (-2.00 – -1.38)
	Kiamichi	1020 (882 – 1281)	0.073 (0.049 – 0.096)	-1.07 (-1.79 – -0.55)
	Poteau	758 (676 – 896)	0.108 (0.078 – 0.141)	-0.70 (-1.21 – -0.30)
	Red	1203 (920 – 2419)	0.058 (0.022 – 0.095)	-2.00 (-3.37 – -1.11)
	Spring	643(598-713)	0.144(0.110–0.179)	-0.02(-0.58–-0.38)
	Deep Fork	590 (568-619)	0.201 (0.168-0.236)	-0.10 (-0.52-0.22)
	Washita	1384 (1031–1384)	0.044 (0.041–0.071)	-1.78 (-2.40 – -0.95)
	Verdigris	1384 (1126-1384)	0.036 (0.035-0.048)	-2.19 (-2.39 – -1.79)
	Neosho	691 (599 - 1030)	0.087 (0.036 - 0.141)	-1.54 (-6.935- -1.542)
	Cimarron	960 (818-1322)	0.08 (0.04-0.120)	-1.37 (-2.99 - 0.28)
Flathead Catfish	Statewide	1215 (1034 – 1545)	0.061 (0.042 – 0.080)	-0.96 (-1.42 – -0.57)
	Kiamichi	1279 (1088 – 1483)	0.056 (0.045 – 0.070)	-0.37 (-0.81 – 0.03)
	Poteau	1032 (897 – 1276)	0.081 (0.056 – 0.106)	-0.43 (-0.88 – -0.06)
	Red	671 (609 – 738)	0.423 (0.310 – 0.586)	0.10 (-0.19 – 0.34)
	Spring	910 (686 – 2756)	0.096 (0.017 – 0.248)	-1.13 (-4.61 – 0.50)
	Deep Fork	963 (826 – 1213)	0.123 (0.074 – 0.179)	0.53 (-0.63 – 1.15)

Washita	1059 (903 – 1315)	0.181 (0.115 – 0.253)	0.61 (0.19 – 0.91)
Verdigris	860 (729 – 1123)	0.135 (0.077 – 0.204)	-0.07 (-1.01 – 0.54)
Neosho	762 (670-951)	0.151 (0.071-0.256)	0.079 (-2.79- -1.337)
Cimarron	879 (715-1085)	0.24 (0.14-0.35)	0.14 (-1.01 – 0.54)

Table 6.—Neosho River Blue Catfish predicted mean lengths at age (mm) from Von Bertallanfy growth curve and associated 95% CI with comparisons to Poteau, Red, Deep Fork, Washita, Spring, Kiamichi, Verdigris and Cimarron rivers.

Age	Kiamichi	Poteau	Red	Deep Fork	Washita	Verdigris	Spring	Cimarron	Neosho
1	142 (119 - 166)	128 (111 - 144)	192 (164 - 221)	117 (93 – 142)	159 (129 – 184)	150 (142 – 156)		169 (117-216)	220 (174-264)
2	204 (188 - 221)	192 (182 - 204)	249 (229 - 270)	203 (188 – 219)	211 (189 – 233)	194 (188 – 199)	162 (147-179)	231 (197-265)	259 (227-292)
3	261 (249 - 274)	250 (241 - 260)	303 (287 - 320)	273 (260 – 287)	262 (245 – 281)	236 (231 – 241)	226 (216-238)	289 (267-311)	295 (273-320)
4	314 (303 - 326)	303 (292 - 314)	353 (338 - 370)	331 (318 – 345)	311 (296 – 327)	277 (273 – 281)	282 (272-293)	341 (327-356)	328 (310-348)
5	363 (353 - 375)	349 (338 - 361)	401 (385 - 419)	378 (365 – 392)	357 (344 – 373)	316 (313 – 321)	330 (319-343)	390 (379-402)	358 (343-376)
6	409 (399 - 421)	391 (380 - 403)	446 (430 - 465)	417 (404 – 430)	401 (390 – 416)	354 (351 – 359)	372 (360-385)	435 (424-447)	386 (371-403)
7	452 (441 - 464)	429 (417 - 441)	489 (472 - 508)	448 (437 – 460)	443 (433 – 459)	390 (387 – 395)	408 (396-421)	476 (464-489)	411 (397-428)
8	492 (481 - 503)	463 (451 - 474)	529 (512 - 548)	474 (464 – 485)	484 (473 – 499)	425 (422 – 431)	440 (428-451)	514 (501-558)	435 (420-451)
9	529 (518 - 540)	493 (482 - 504)	567 (549 - 587)	495 (486 – 505)	522 (511 – 538)	459 (455 – 465)	467 (456-477)	549 (535-563)	456 (442-471)
10	563 (552 - 574)	520 (509 - 532)	603 (584 - 623)	513 (504 – 521)	559 (547 – 574)	492 (487 – 498)	490 (480-500)	582 (567-596)	475 (462-489)
11	595 (584 - 607)	545 (531 - 558)	637 (616 - 659)	527 (518 – 536)	595 (581 – 610)	524 (518 – 529)	511 (501-520)	611 (597-626)	493 (481-505)
12	625 (613 - 638)	567 (551 - 582)	669 (646 - 694)	538 (529 – 548)	629 (613 – 644)	554 (547 – 560)	528 (518-539)	639 (623-655)	509 (498-521)
13	652 (638 - 668)	586 (568 - 605)	699 (671 - 729)	548 (537 – 558)	661 (643 – 677)	584 (575 – 590)	544 (532-556)	664 (646-683)	524 (513-536)
14	678 (661 - 697)	604 (582 - 627)	727 (695 - 764)	556 (544 – 567)	692 (671 – 709)	612 (602 – 618)	557 (543-572)	687 (667-709)	538 (525-551)
15	702 (682 - 724)	620 (595 - 647)	754 (715 - 798)	562 (549 – 575)	722 (697 – 740)	639 (627 – 646)	568 (552-586)	709 (685-735)	551 (536-566)
16	724 (701 - 750)	634 (605 - 665)	779 (735 - 833)	567 (553 – 582)	751 (720 – 769)	666 (651 – 673)	578 (560-599)	729 (700-761)	562 (544-581)
17	745		803	571	778	691	587	747	573

	(718 - 776)		(751 - 867)	(556 – 588)	(742 – 797)	(674 – 698)	(567-610)	(714-785)	(551-597)
18	764 (733 - 800)		826 (767 - 900)	575 (558 – 593)	804 (762 – 823)	716 (695 – 723)	594 (571-621)	764 (726-808)	582 (557-611)
19			847 (780 - 932)	578 (560 – 597)	829 (781 – 849)	739 (716 – 747)	601 (576-631)	779 (736-830)	591 (652-626)
20				580 (562 – 600)	853 (798 – 873)		607 (580-639)		
21					876 (814 – 896)		611 (583-647)		
22					897 (830 – 918)				
23					918 (844 – 939)				

Table 7.—Total annual (A) and total instantaneous mortality (Z) for Cimarron River catfish with comparisons to pooled statewide data and individual results from Poteau, Red, Spring, Deep Fork, Washita, Kiamichi, and Verdigris rivers. Numbers in parentheses are 95% confidence intervals. Ages represents the descending limb of the catch curve used to estimate the mortality rate.

Species	River	A	Z	Ages
Blue Catfish	Statewide	20.8 (16.03 – 25.3)	0.23 (0.17 – 0.22)	2:23
	Kiamichi	15.2 (6.8 – 22.9)	0.17 (0.07 – 0.26)	2:18
	Poteau	16.8 (11.1 – 22.1)	0.18 (0.12 – 0.25)	2:16
	Red	17.5 (6.3 – 27.3)	0.19 (0.07 – 0.32)	6:19
	Deep Fork	12.2 (3.6 – 20.1)	0.13 (0.04 – 0.22)	5:20
	Washita	20.9 (6.3 – 33.3)	0.23 (0.07 – 0.40)	10:23
	Spring	11.14 (-0.20-21.20)	0.12 (0-0.24	2:17
	Cimarron	11.85 (3.14-19.78)	0.13 (0.03-0.22)	3:19
	Neosho	11.77 (-2.39 – 23.97)	0.12 (-0.02 – 0.27)	7:19
	Verdigris	22.2 (16.9 – 27.2)	0.25 (0.19 – 0.32)	2:19
Flathead Catfish	Statewide	18.6 (15.7 – 21.3)	0.21 (0.17 – 0.24)	2:30
	Kiamichi	24.1 (20.0 – 28.1)	0.28 (0.22 – 0.33)	2:20
	Poteau	13.9 (7.5 – 19.8)	0.15 (0.08 – 0.22)	2:25
	Red	18.3 (4.2 – 30.3)	0.20 (0.04 – 0.36)	1:14
	Spring	1.0 (-6.1 – 7.6)	0.01 (-0.06 – 0.08)	2:20
	Deep Fork	6.2 (-1.3 – 13.2)	0.06 (-0.01 – 0.14)	3:27
	Washita	18.2 (2.1 – 31.6)	0.20 (0.02 – 0.38)	2:12
	Cimarron	7.43 (-2.72-16.57)	0.08 (-0.03-0.18)	1:17

	Neosho	1.89 (-0.85 – 4.56)	0.019 (-0.008–0.047)	2:30
	Verdigris	12.3 (7.3 – 16.9)	0.13 (0.08 – 0.19)	1:20

Table 8.—Neosho River Flathead Catfish predicted mean lengths at age (mm) from Von Bertallanfy growth curve and associated 95% CI with comparisons to Poteau, Red, Spring, Deep Fork, Washita, Kiamichi, Cimarron, and Verdigris rivers.

Age	Kiamichi	Poteau	Red	Spring	Deep Fork	Washita	Verdigris	Cimarron	Neosho
1	93 (72 - 114)	112 (94 – 130)	212 (190 - 231)	168 (69 - 267)	54 (-23 – 135)	73 (21 – 118)	115 (63 – 168)	141 (42-245)	46 (-223-229)
2	158 (142 - 174)	183 (172 – 195)	370 (348 -394)	236 (169 - 317)	160 (113 – 211)	236 (211 – 260)	210 (174 – 248)	307 (242-382)	178 (37-299)
3	219 (206 - 232)	249 (238 - 260)	474 (447 - 499)	298 (241 - 373)	253 (218 – 291)	372 (344 – 400)	292 (260 – 327)	429 (361-506)	285 (204-367)
4	276 (265 - 288)	309 (297 - 323)	542 (515 - 566)	354 (298 - 433)	335 (299 – 374)	486 (449 – 520)	364 (330 – 401)	519 (442-596)	371 (309-440)
5	330 (319 - 342)	365 (350 - 381)	586 (558 -612)	404 (348 - 489)	408 (365 – 454)	581 (539 – 619)	427 (391 – 466)	587 (502-665)	440 (381-508)
6	382 (369 - 395)	417 (400 - 434)	615 (581 - 644)	451 (394 - 536)	472 (422 – 525)	660 (616 – 699)	481 (445 – 520)	637 (543-722)	496 (436-562)
7	430 (415 - 446)	464 (446 - 483)	634 (594 - 669)	492 (437 - 573)	529 (472 – 586)	726 (681 – 767)	529 (492 – 567)	675 (570-768)	540 (479-603)
8	476 (459 - 494)	508 (490 - 527)	647 (600 - 687)	531 (477 - 604)	579 (517 – 639)	781 (731 – 824)	571 (535 – 608)	703 (587-808)	577 (515-634)
9	520 (500 - 539)	549 (530 - 568)	655 (604 -700)	565 (513 - 631)	623 (557 – 686)	827 (771 – 874)	608 (572 – 644)	726 (598-842)	606 (546-658)
10	561 (538 - 583)	586 (567 - 606)	660 (606 - 710)	597 (547 - 655)	663 (593 – 727)	866 (801 – 919)	640 (603 – 676)	742 (604-871)	629 (572-677)
11	599 (574 - 624)	621 (600 - 641)	664 (607 -718)	625 (577 - 678)	697 (627 – 765)	898 (824 – 959)	668 (627 – 707)	755 (608-896)	648 (594-693)
12	636 (608 - 663)	652 (631 - 674)	666 (608 - 723)	651 (603 - 702)	728 (657 – 798)	924 (842 – 996)	692 (647 – 735)	766 (609-918)	663 (612-707)
13	671 (640 - 701)	682 (658 - 706)	668 (609 - 727)	675 (624 - 729)	755 (683 – 828)		713 (663 – 763)	773 (611-937)	675 (626-718)
14	704 (670 - 736)	709 (683 - 735)	669 (609 - 730)	696 (640 - 757)	779 (705 – 855)		732 (676 – 789)	778 (612-953)	685 (636-728)
15	735 (698 - 770)	734 (705 - 764)		716 (652 - 786)	800 (724 – 880)		748 (686 – 813)	783 (612-968)	693 (643-738)
16	764 (724 - 802)	757 (724 - 792)		734 (660 - 817)	819 (741 – 903)		762 (694 – 836)	785 (643-980)	699 (648-746)

17	792 (749 - 832)	778 (742 - 818)		750 (666 - 846)	836 (755 – 925)		775 (701 – 857)	788 (613-990)	704 (651-754)
18	818 (771 - 861)	798 (757 - 843)		764 (671 - 875)	851 (766 – 946)		785 (707 – 877)		708 (653-762)
19	843 (793 - 889)	816 (772 - 866)		778 (674 - 905)	864 (776 – 966)		795 (711 – 895)		711 (655-768)
20	866 (813 - 916)	832 (784 - 888)		790 (677 - 936)	875 (784 – 984)		803 (714 – 912)		715 (656-775)
21		848 (796 - 910)			885 (791-1001)				717 (656-781)
22		862 (806 - 929)			894 (796-1017)				718 (657-786)
23		875 (815 - 948)			902 (801–1032)				720 (657-791)
24		887 (823 - 966)			909 (805–1045)				721 (657-796)
25		898 (830 - 983)			915 (809–1059)				722 (657-804)
26					921 (811–1070)				723 (658-804)
27					926 (814–1082)				723 (658-808)
28									724 (658-811)
29									724 (658-814)
30									724 (658-816)

Figures

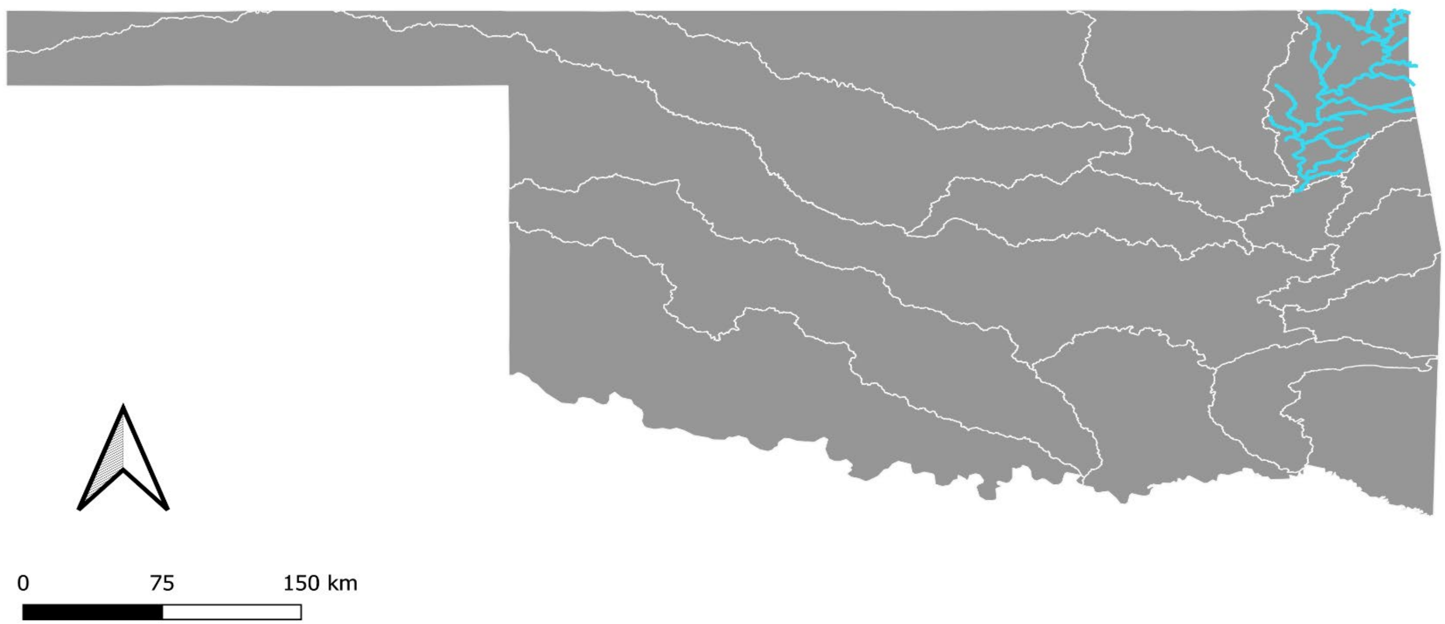

Figure 1. —Map of the Neosho River and tributaries in Oklahoma.

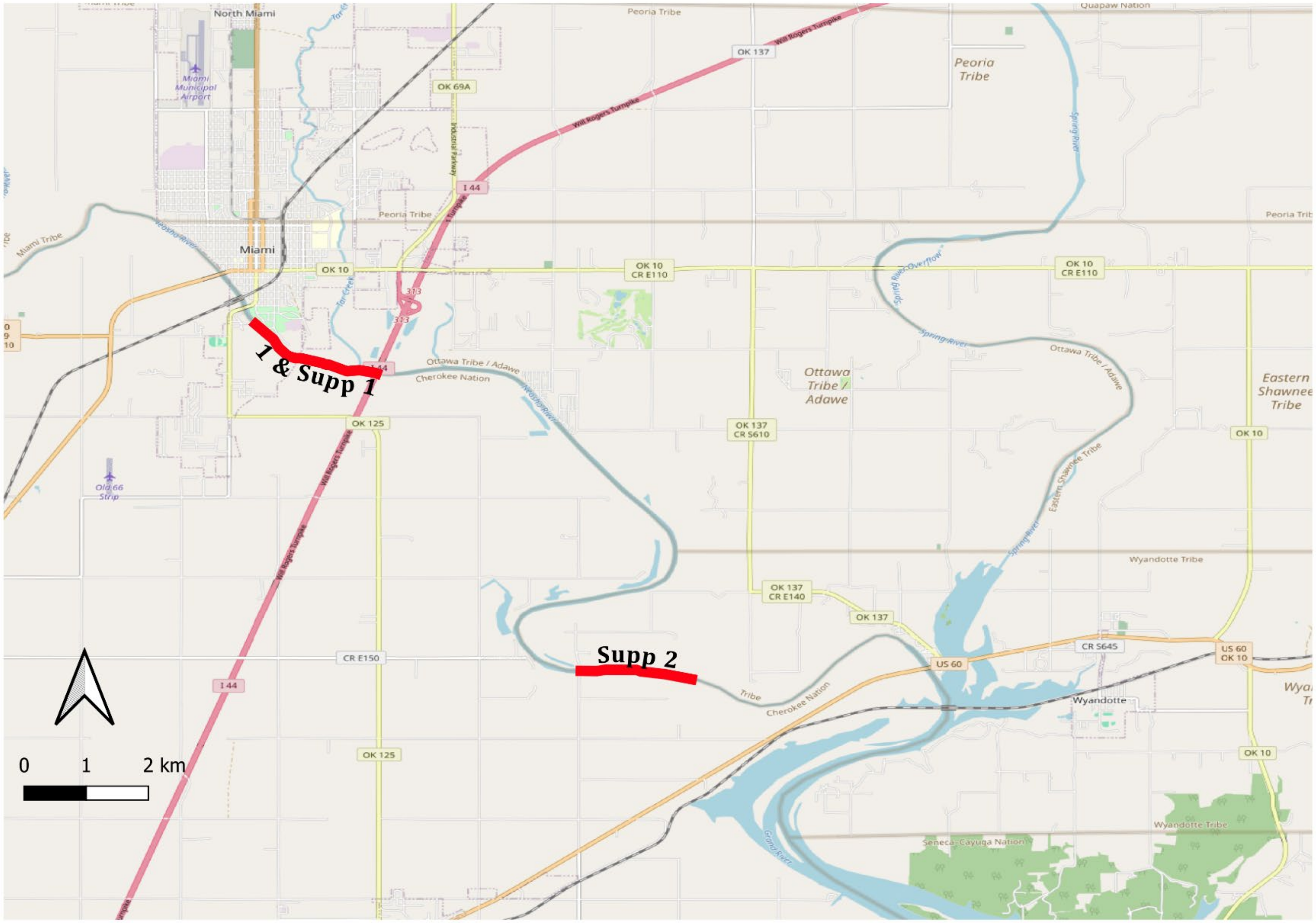

Figure 2. —Map of Electrofishing Sites 1, Supplemental 1, and Supplemental 2.

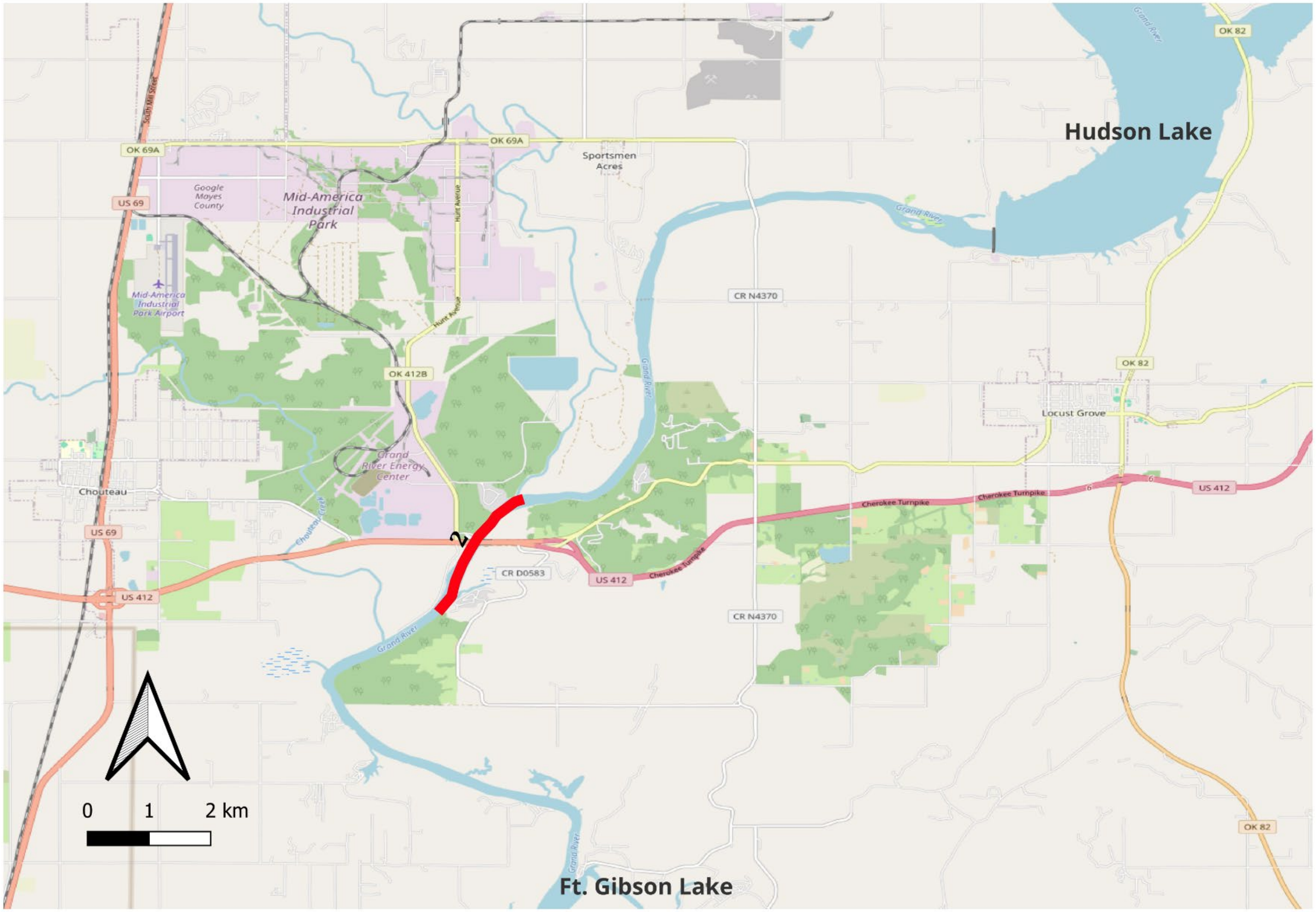

Figure 3. —Map of Electrofishing Site 2.

Figure 4. —Map of Electrofishing Site 3.

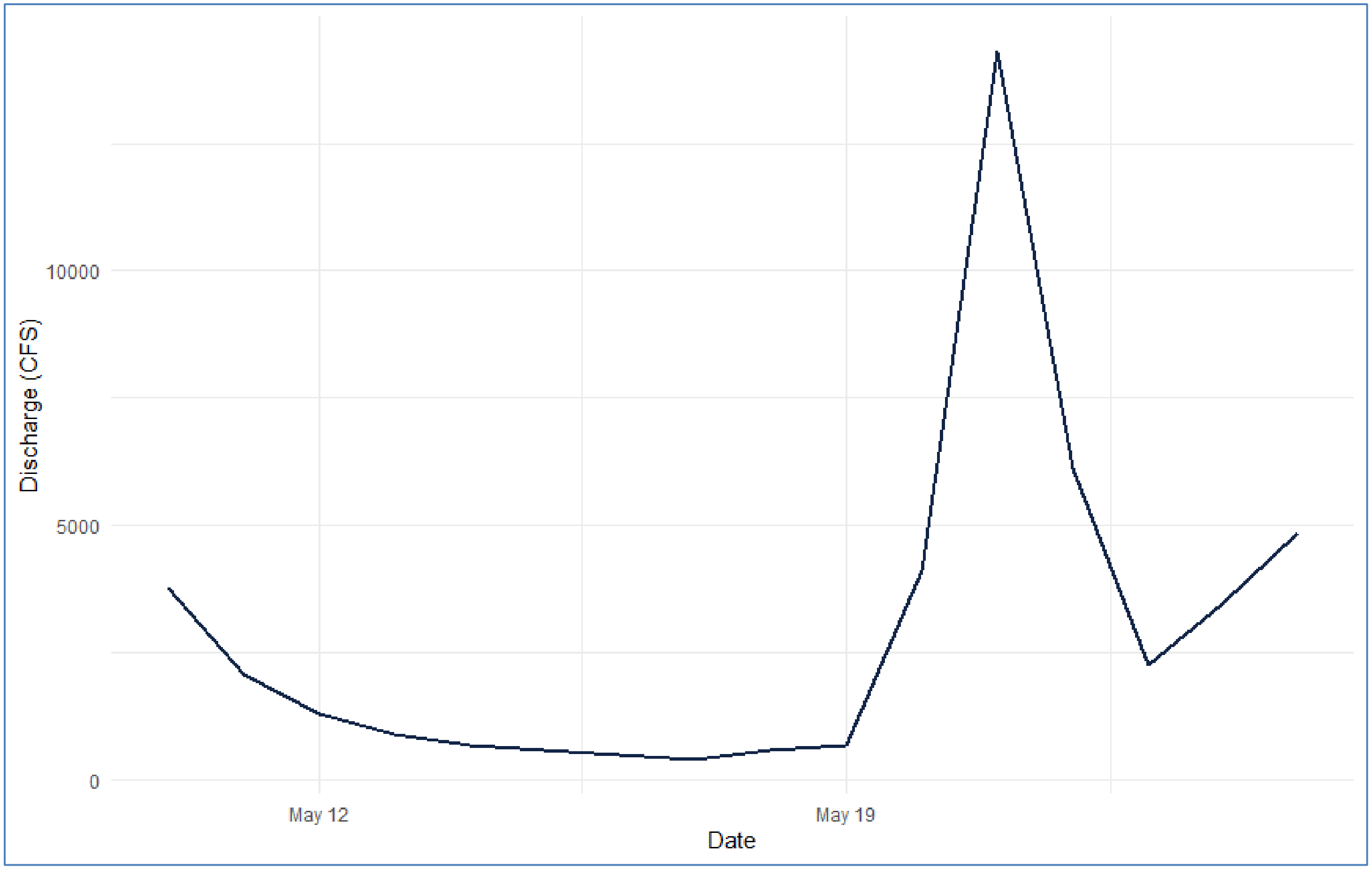

Figure 5. —Daily discharge in cubic feet per second (CFS) for days of electrofishing sampling.

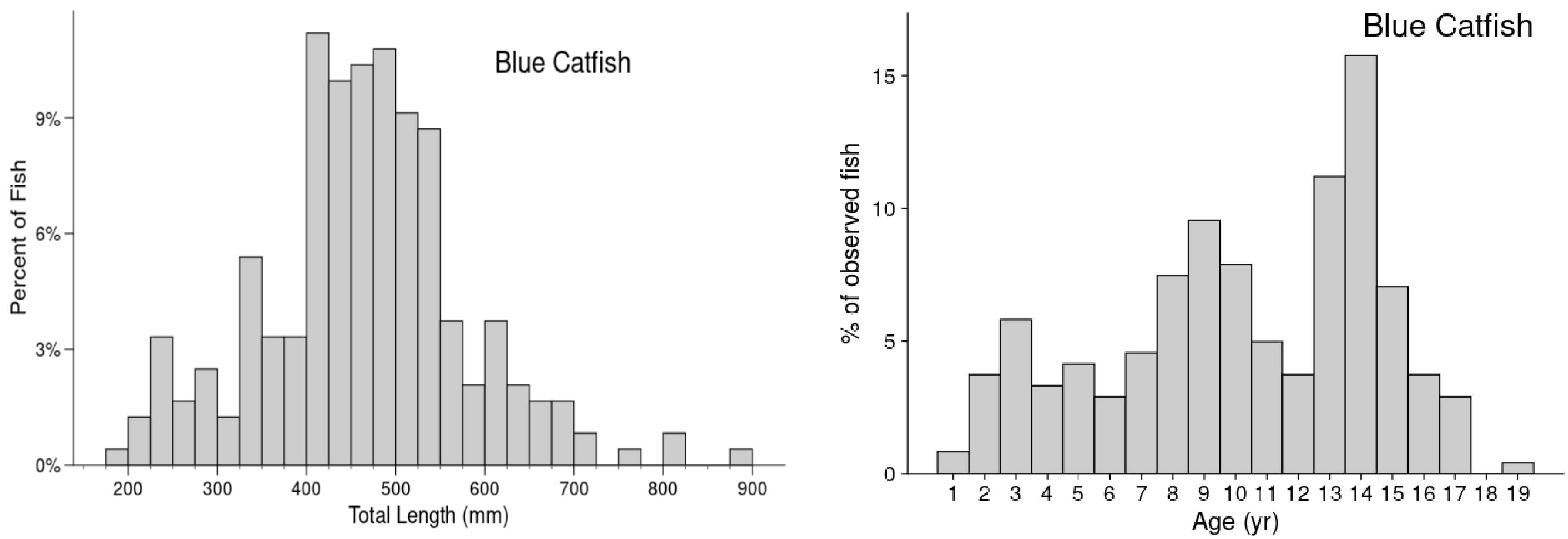

Figure 6. —(Left) Length-frequency histogram for Blue Catfish in the Neosho River. (Right) Age-frequency histogram for Blue Catfish in the Neosho River. Sample size for histograms was 241 and 225, respectively.

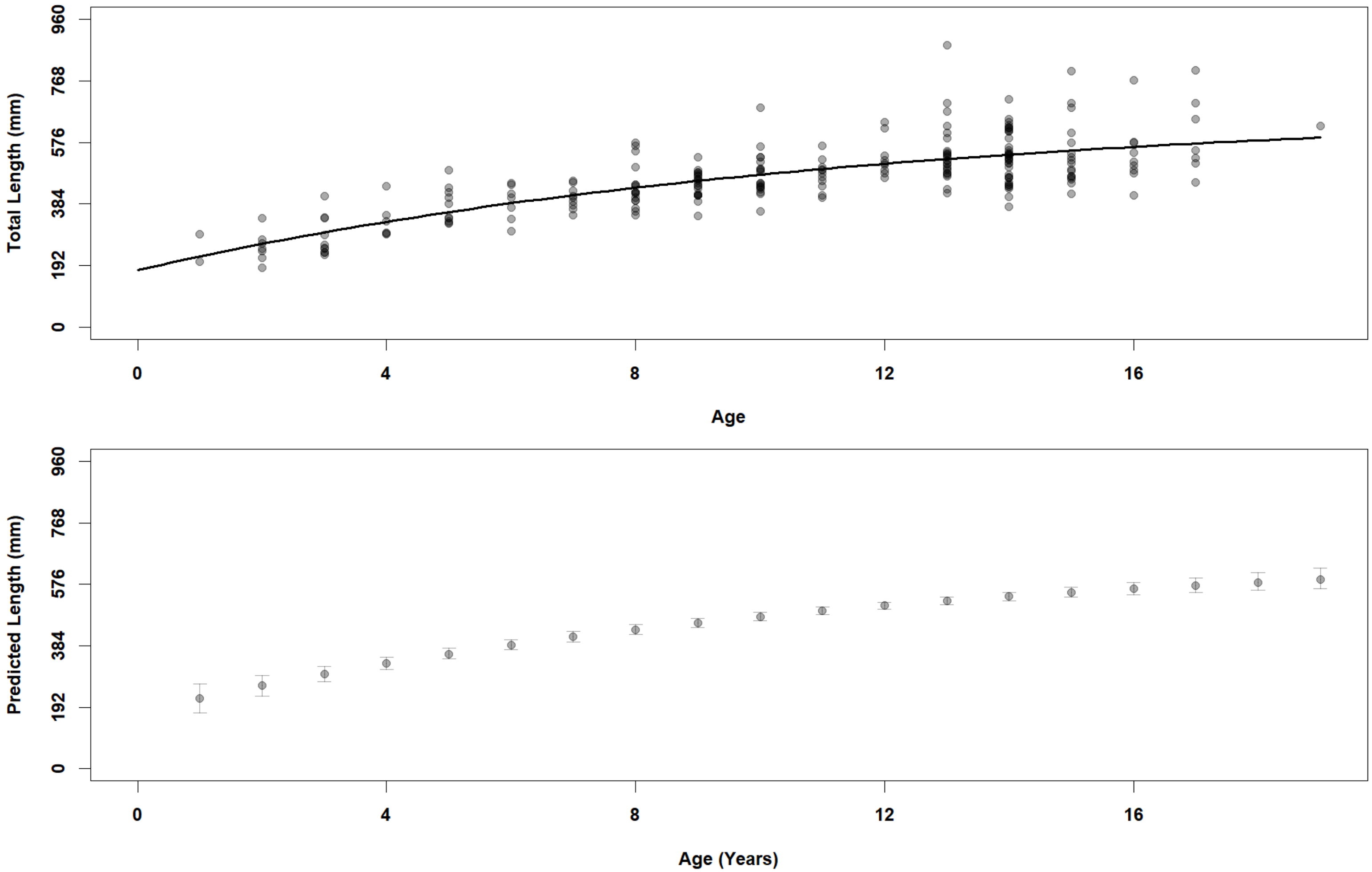

Figure 7. —(Top) Age-length relationship for Neosho River Blue Catfish. Equation is non-linear estimation of the Von Bertallanfy curve. Points represent individual fish. Black line is fitted equation. Estimates of the Von Bertallanfy parameters are $L\infty = 690$, $k = 0.087$, $t_0 = -1.54$. (Bottom) Predicted length at age from Von Bertallanfy growth curve and associated 95% CI.

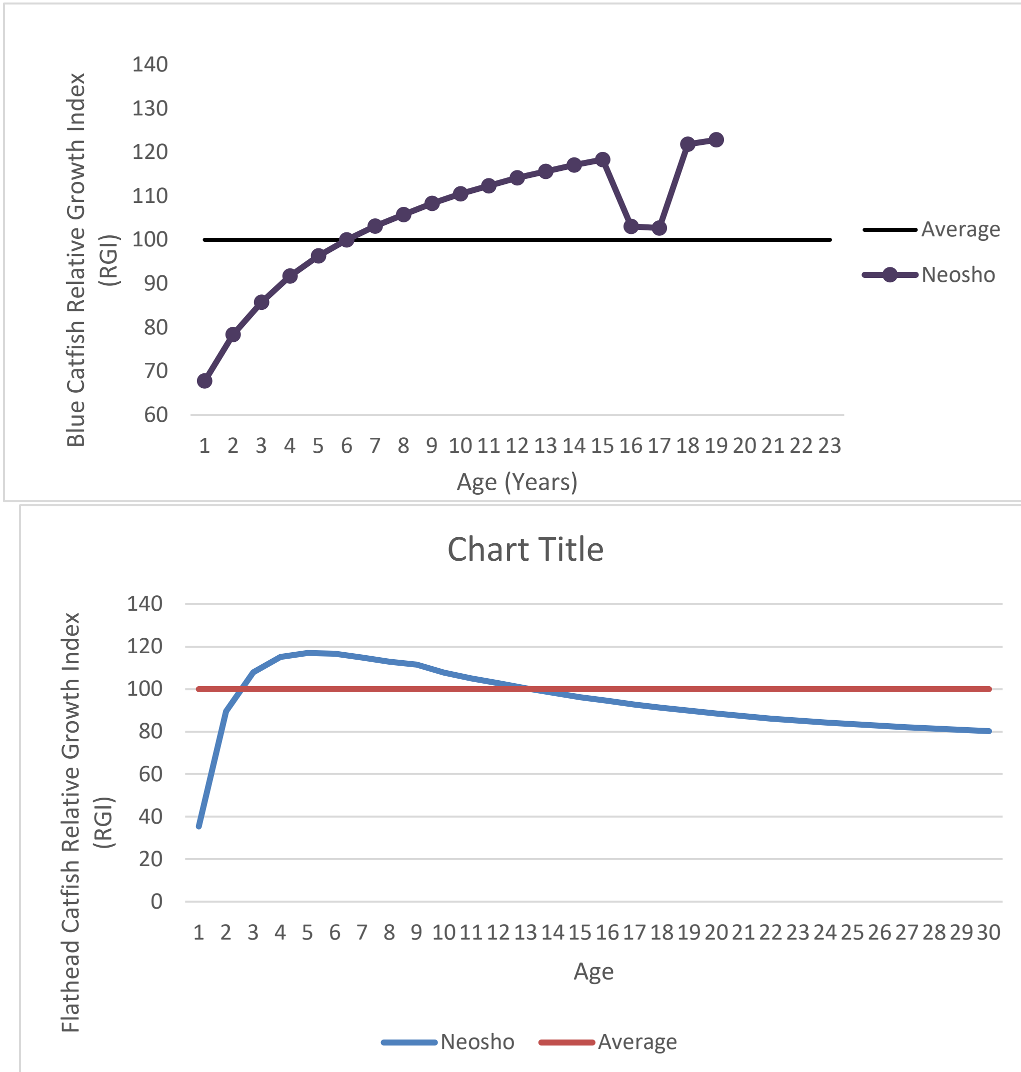

Figure 8. —(Top) Neosho River Blue Catfish relative growth index (RGI) values by age. (Bottom) Neosho River Flathead Catfish RGI values by age. Horizontal dashed line indicates average growth (i.e., RGI = 100) according to the current statewide standard growth equation for each species.

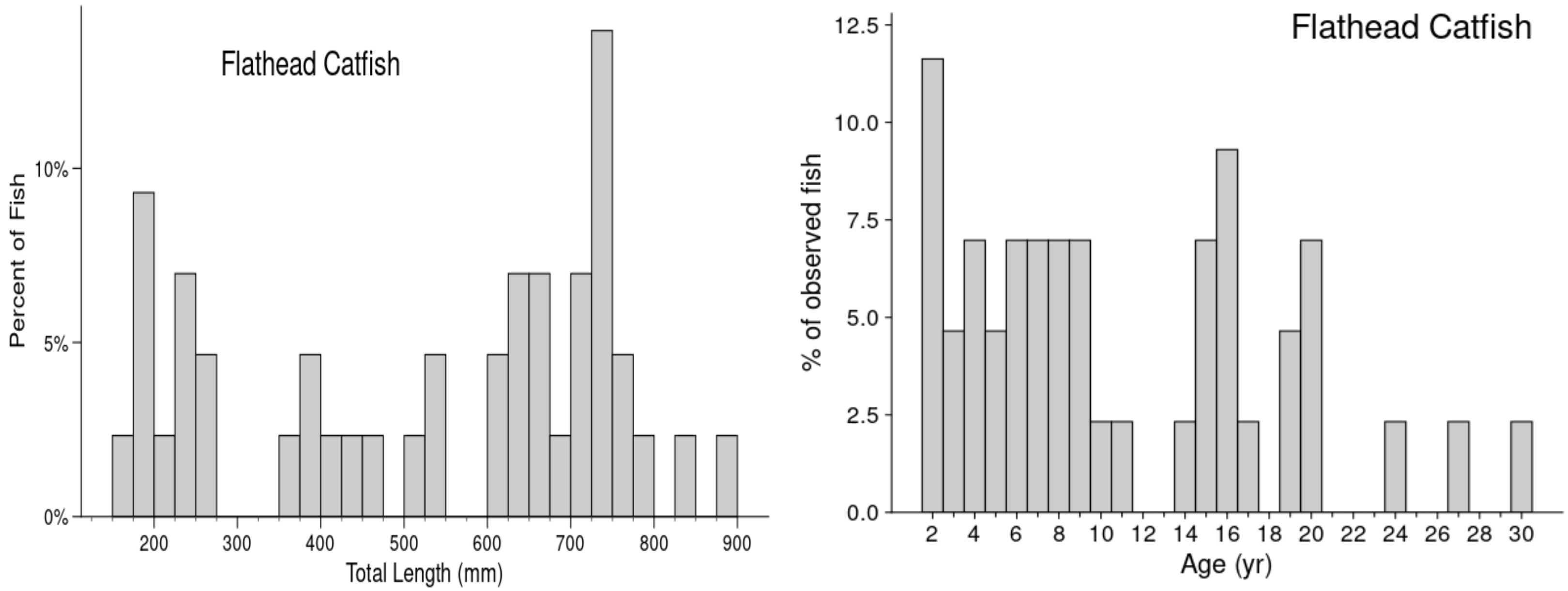

Figure 9. — (Left) Length-frequency histogram for Flathead Catfish in the Neosho River. (Right) Age-frequency histogram for Flathead Catfish in the Neosho River. Sample size for histograms was 43 and 35, respectively.

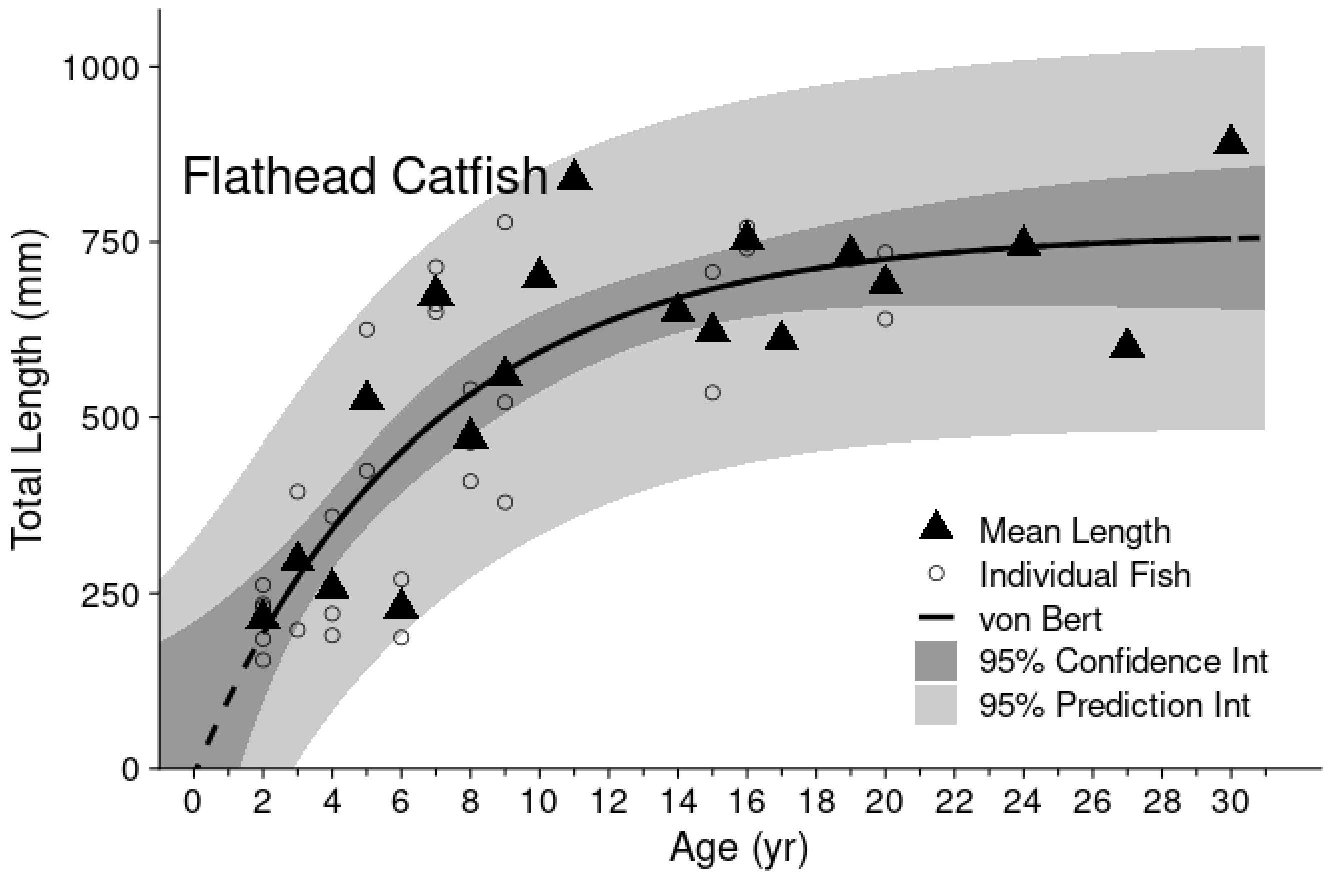

Figure 10. —Age-length relationship for Neosho River Flathead Catfish. Equation is non-linear estimation of the Von Bertallanfy curve using the NLS Method. Points represent individual fish. Dark black line is fitted equation. Light lines depict upper and lower 95% intervals. Estimates of the Von Bertallanfy parameters are $L\infty = 763$, $k = 0.15$, $t_0 = 0.079$

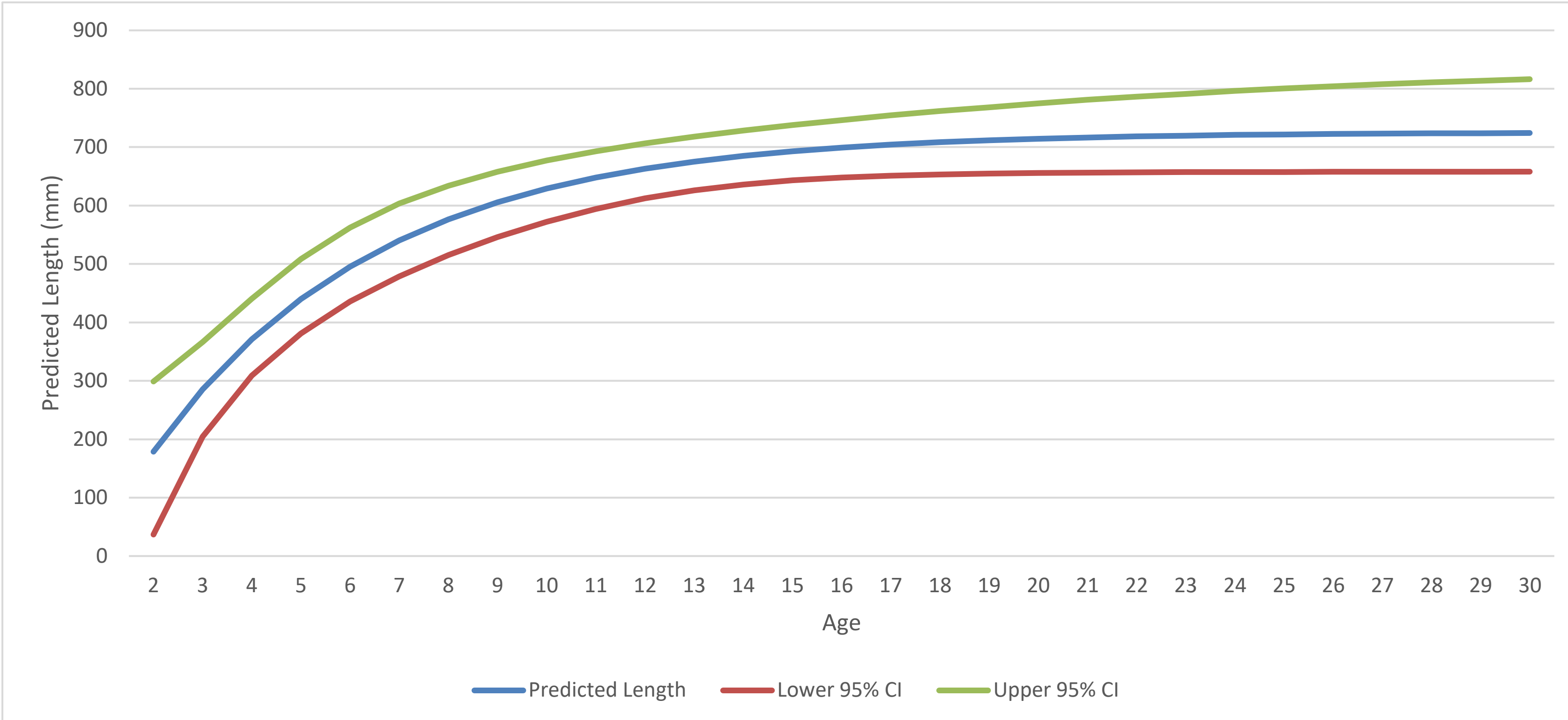

Figure 11. Predicted length at age for Neosho River Flathead Catfish from Von Bertallanfy growth curve and associated 95% CI.