FINAL PERFORMANCE REPORT

Federal Aid Grant No. F21AF00118 (T-119-R-1)

Evaluating the Spatial and Temporal Distribution and Ecology of Bighead and Silver Carp and Native Fishes of the Lower Red River Basin

Oklahoma Department of Wildlife Conservation

November 1, 2020 through June 30, 2022

FINAL PERFORMACE REPORT

State: Oklahoma **Grant Number:** F21AF00118 (T-119-R-1)

Grant Program: State Wildlife Grants

Grant Title: Evaluating the Spatial and Temporal Distribution and Ecology of Bighead and Silver Carp and Native Fishes of the Lower Red River Basin.

Grant Period: November 1, 2020 – June 30, 2022

Project Leader: Dr. Shannon K. Brewer, Auburn Cooperative Fish and Wildlife Research Unit, Auburn University, Auburn, AL 36832; 334-750-5632; skb0064@auburn.edu

Executive Summary

We began a fisheries assessment investigating the current population status of Bighead Carp and Silver Carp in the lower Red River basin, while compiling information on native fishes within the basin. Our study objectives were to: 1) conduct an invasive carp population assessment, and 2) conduct a native species assemblage assessment. To most effectively target both juvenile and adult carp and native fishes, we separated sites (i.e., a sample reach that will be visited multiple times) and associated gears according to the targeted fish size (i.e., juvenile sites and adult sites). We sampled 119 sites (65 juvenile sites and 54 adult sites), and completed 319 surveys (i.e., repeat visits at a site, 149 juvenile surveys and 170 adult surveys). We captured most smaller-bodied fishes using mini-fyke nets and seine hauls, whereas most of the larger-bodied fishes including carp were collected using gillnets and electrofishing sampling. Hoop nets captured fewer fishes when compared to other gear types. We sampled 129,302 fishes in 2021 and 2022, comprising 74 species and 44 genera. We collected 287 carp (58 Bighead Carp and 229 Silver Carp). All carp collected were adults. Ages of Bighead Carp ranged from 3 to 15 years, whereas Silver Carp were between 3 and 13 years of age. Silver Carp total length (mm) ranged from 616 to 1091-mm and Bighead Carp ranged from 949 to 1350-mm. Although Bighead Carp were larger than Silver Carp, the Silver Carp had a higher average egg estimate (713,587) compared to sampled Bighead Carp (486,897). Both male and female carp species were collected, however, none of the ovaries appeared to have empty follicles or were spent. The most abundant species sampled was Red Shiner (66,040), followed by Bullhead Minnow (13,689), Mississippi Silverside (7,707), and Western Mosquitofish (7,406). Of the 74 riverine

species sampled, four were non-native including Bighead Carp, Silver Carp, Common Carp, and Grass Carp. Species scientific names are provided in Appendix A.

I. OBJECTIVES:

Objective 1 (TRACS Strategy – Research, Survey, Data Collection and Analysis)
Conduct 1 investigation by June 30, 2022.

- Activity Tag 1: Fish and wildlife species data acquisition and analysis
    - Target Species Types: *Identify target species: Paddlefish, Alligator Gar, Chub Shiner, Silverband Shiner, Plains Minnow, Blue Sucker, Black Buffalo, all fish SGCN that occur in the lower Red River are likely to be captured during native fish surveys*

SUB-RECIPIENT NARRATIVE OBJECTIVES:

1) Determine the spatial and temporal extent of Bighead Carp and Silver Carp in the Red River basin of Oklahoma;

2) Determine habitat associations of large river fish assemblages, and

3) Summarize the age structure of bighead carp sampled through fall 2021.

II. SUMMARY OF PROGRESS

INTRODUCTION

Freshwater ecosystems are among the most biodiverse systems on earth; however, they may also be the most endangered (Reid et al. 2019). Despite covering only 2.3% of the Earth's surface, freshwater ecosystems account for 9.5% (126,000 species) of described animal species (Balian et al. 2008). Dudgeon et al. (2006) lists over-exploitation, flow modification, water pollution, habitat-degradation, and invasive species as the five major threats to biodiversity. Invasive species, or introduced non-native species that are able to survive to recruitment, reproduce across a variety of habitats, and expand their ranges to locations outside of where they were first introduced are of particular concern (Blackburn et al. 2011). Invasive species are of concern because they alter food web interactions, compete with other species for space and resources, and can ultimately change native species assemblage structure (Carey and Wahl 2010). As such, there is a need to understand population demographics of invasive species and the spatial and temporal extent to which they occur.

Two species emblematic of the concerns caused by invasive species are Bighead Carp *Hypopthalmichthys nobilis* and Silver Carp *Hypopthalmichthys nobilis* (hereafter carp). In areas where they have been introduced, carp cause ecological (Schrank et al. 2003; Irons et al. 2007; Sampson et al. 2009), economic (Lovell et al. 2006), and safety (Vetter et al. 2015) concerns. Since their detection in the 1970's (Freeze and Henderson 1982; Kelly et al. 2011), carp have proliferated and been reported in 23 states (Kolar et al. 2005). One of the reasons carp have been so successful is because they are filter feeders (Williamson and Garvey 2005), and both species have been linked to declines in phytoplankton and zooplankton abundances (Irons et al. 2011; Sass et al. 2014; Cooke 2016). Carp affect fish populations through interspecific competition and depletion of resources (Schrank et al. 2003; Sampson et al. 2009). As a result, carp are often linked to declines in native fish diversity and densities (Kolar et al. 2007) including the recruitment of native juvenile fishes (Chick et al. 2020b). In addition to their ecological effects, carp also cause economic declines. For example, the carp invasion in Lake Michigan is projected to result in a 7 billion dollar loss via commercial fisheries revenue (Buck et al. 2010). Lastly, carp pose threats to human safety due their penchant to launch themselves out of the water often causing serious injuries to boaters (Spacapan et al. 2016).

The climate of the Great Plains ecoregion is relatively extreme, fluctuating between floods and droughts; thus, providing a unique opportunity to study species assemblage structure and population dynamics of both native and invasive fishes. The Red River basin is characterized by extreme floods and droughts (Matthews and Marsh-Matthews 2007), and large conductivity fluctuations (Hargrave and Taylor 2010). Carp occur in the lower Red River basin; however, there has never been extensive sampling targeting carp or many native fishes. Therefore, documenting carp population demographics and distribution along with native fishes is a necessary first step to determining how best to manage the expansion of non-native fishes in the lower basin (i.e., how far have they spread, at what times of year, and what species may be affected).

METHODS

Objective 1. Determine the spatial and temporal extent of Bighead Carp and Silver Carp in the Red River basin of Oklahoma

Juvenile carp sampling

We sampled stream reaches (approximately 300-m in length) in the lower Red River basin for juvenile carp. (Tables 1 and 2). Our sites were distributed across tributaries and within the mainstem Red River (Figure 1). Sites were selected based on river access, proximity to USGS stream gauges, and the likelihood of detection of the target species. Our sites were selected approximately 25-100 km downriver of major dams and confluences because this is the suggested length of river needed to allow carp eggs to develop and hatch while in suspension (Kolar et al. 2007; Garcia et al. 2015). Our sample sites included slackwater habitats such as forewaters, backwaters, side channels, sandbars, and pool complexes. These slackwater habitats are thought to be important nursery areas for a variety of age-0 fish including Bighead Carp and Silver Carp (Jurajda 1999; Love et al. 2017; George et al. 2018). Lastly, discharge and temperature conditions are relatively homogenous across our sites, and the sites are large enough to be considered closed to species immigrations during sampling.

We sampled age-0 carp using three different gear types during daylight hours. Using a combination of gears diminishes some of the sample bias associated with a single gear approach (Clark et al. 2007). For example, passive gears tend to target more active individuals (Fago 1998). At each site, we set mini-fyke nets, sampled using beach seines, and conducted larval tows (see Table 3 for gear descriptions). First, we set 3 mini-fyke nets in <2 m of water at locations adjacent to the shoreline to target small-bodied fishes (Eggleton et al. 2010). Mini-fyke nets are commonly used to sample age-0 carp (Wanner and Klumb 2009; Gibson-Reinemer et al. 2017; Williams 2020) and sometimes capture high numbers compared to other gears (Collins et al. 2017). Next, a beach seine was used to sample wadeable habitat across the site using a modified version of the encirclement technique (Bayley and Herendeen 2000). Transects were established throughout wadeable habitat at each site and seine hauls were completed across each transect. Seine hauls were limited to 25-m to maintain the efficiency of the gear because longer hauls are less efficient (Lombardi et al. 2014). We quantified total seine distance, seine width, and maximum depth for each haul to calculate the area sampled. We completed a sub-surface larval tow at representative location of deeper water (i.e., where we could not seine or place fyke nets). Each tow was executed for 10 min and the volume of water sampled was quantified using a flow meter (General Oceanics Mechanical Flowmeter Model 2030R) attached to the mouth of the net. We standardized larval tows based on the volume of water filtered by the net. Any samples that could not be identified in the field were preserved in 70% ethanol and brought back to the lab for processing.

Juvenile carp habitat

We quantified the physicochemical factors that may be related to carp or native fish distributions across multiple spatial scales (i.e., reach, segment, and catchment). The physicochemical factors are divided into detection (Table 4) and occupancy (Table 5) covariates and identified as those quantified in the field (Tables 4 and 5) or via existing geospatial data (Table 6). Stream habitat use by fishes is hierarchical where finer levels of organization are nested within coarser landscape constraints (Frissell et al. 1986; Imhof et al. 1996). Coarse scale (e.g., segment and catchment) habitat factors are applied to multiple reaches that occur within the same stream segment or catchment (i.e., nested). For example, finer-scale channel unit conditions (i.e., pH and substrate) used by fish are often influenced by coarse factors (i.e., drainage area and geology) of the surrounding watershed (Mollenhauer et al. 2019). Including coarse-scale habitat factors helps explain fish distributions and account for pseudoreplication caused by sampling multiple sites in the same stream segment or river system (i.e., nested).

We measured several factors across each sample site that described the general water-quality conditions. First, we collected temperature and dissolved oxygen samples at 0.5 m below the water's surface for each site using a multi-parameter water-quality meter (YSI ProDSS). We collected salinity from a well-mixed location of each site approximately 0.5m below the surface. We also measured water clarity using a secchi disk, because turbidity can influence resource use, foraging success, and even provide shelter from predators (Zamor and Grossman 2007; Reichert et al. 2010). To characterize the general conditions of each site, we measured all water-quality parameters three times in each site and averaged these values.

We also quantified the proportion of select channel unit features in each site. Because forewater and backwater habitat are often important nursery habitat for many large river fishes (Galat et al. 2004), we quantified the area of each using a meter tape or rangefinder (Simmons Volt 600 Laser Rangefinder) to measure length and average width. Other slackwater areas such as pools offer low-velocity areas in the main channel (Schwartz and Herricks 2005); therefore, we measured pool area using side-scan sonar (Humminbird Helix 12). The proportion of each of the slackwater channel units will be expressed as a proportion of the available habitat in each site. Because age-0 carp are associated with large woody debris in some systems (George et al. 2018), we also used side-scan sonar to quantify the percentage of large woody debris following the methods of Gordon et al. (1992).

We quantified several hydraulic variables to describe the fluvial dynamics of our sampling sites. Species often use specific depths within a water column (Lamouroux et al. 1998); therefore, we quantified the average thalweg depth by measuring depth at 10-m increments along the thalweg of the site using side-scan sonar. Further, because the shape of the channel dictates habitat availability (Thomson et al. 2001), we quantified width to depth ratios in each site. We measured three representative wetted width measurements using a rangefinder. Average thalweg depth of the site was then divided by the average widths. We will also obtain discharge data from the nearest USGS stream gauges to apply to sampling sites within the same stream segments to examine both detection and occupancy.

Some habitat metrics will be quantified using existing geospatial data. At the reach-scale, we will quantify distance to the nearest dam by measuring the distance from the most downstream point of our sites to the nearest upstream using National Hydrology Dataset (NHDplus) flowlines and ArcMap spatial analyst. We will also measure distance from our sites and the nearest upstream 5^{th} order tributary. Areas below dams and major tributary confluences are potential spawning locations for carp species (Kolar et al. 2007; George et al. 2018; Camacho et al. 2020).

At the stream segment scale, we will use the NHDplus flowlines and ArcMap spatial analyst to calculate stream sinuosity and slope. Sinuosity (i.e., channel migration of meandering rivers) affects fish habitat use including choice of spawning location (Fukushima 2001; Lazarus and Constantine 2013) and will be calculated by dividing the thalweg length by the straight line distance of the segment. (Camana et al. 2016). We will calculate river slope using ArcMap spatial analysis to determine the change in elevation between the upstream and downstream points of each stream segment and divide by the thalweg length (i.e., channel distance measured down the middle of the channel, Bain and Stevenson 1999).

We will also measure several habitat variables that may affect fish distributions at the catchment scale. We will measure drainage area (km^2) upstream of each site (i.e., catchment draining to each site) using NHDplus flow lines to determine the size and relative position of sites within the network. Because catchment lithology controls many local physicochemical conditions (Frissell et al. 1986; Stevenson 1997), we will quantify the dominant lithology that drains to each site. We will use United States Geological Survey's (USGS) National Geologic Map Database and the identify tool in ArcMap to determine the percentage of dominant lithology.

Adult fish sampling

We sampled for adult Silver Carp and Bighead Carp at 48 sites (Tables 1 and 2) throughout the lower Red River basin of Oklahoma, Texas, and Arkansas. Each site was approximately 1.5 to 2 river km (rkm). Access can be problematic in the lower Red River basin and thus, sites were selected based on accessibility (i.e., access to private lands and conditions conducive to boat launching) (Figure 2).

We sampled adult fishes using a combination of gillnets, hoop nets, and electrofishing because they have been shown useful for sampling both carp species in perceived low-density environments (Butler et al. 2019; Norman and Whitledge 2015). Three experimental sinking gillnets (54.8-m long for mainstem and 30.5-m long for tributary sampling with 8.9, 10.16, and 10.8-cm bar-length mesh panels) and three hoop nets (4.88-m long with a 1.2-m diameter opening) were placed throughout each site (Table 3). Gillnets were either deployed perpendicular to the shoreline or parallel if large amounts of woody debris were present near the shoreline. One gillnet was placed near each end of the site and the third net placed in the middle of the site at the narrowest portion of the channel to restrict carp movement. Hoop nets were placed parallel to the shoreline with the opening facing downstream in locations that included channel edges and channel crossovers but lacking extensive woody debris. Both gillnets and hoopnets were soaked for approximately 6 h. After net placement, we electrofished using an 80-amp Midwest Lakes Electrofishing Systems shocking unit using DC electrofishing (Midwest Lakes; Polo, Missouri). We used standard AFS electrofishing settings based on conductivity (i.e., though we tried several others- *see* below). Water conductivity in the tributaries was much lower than the mainstem Red River. As such, voltage was typically set to high range (pulsed DC current, >300 volts, 60Hz) for tributaries and low range (pulsed DC current, <300 volts, 60Hz) for the mainstem sites. Beginning at the upriver end of the site, the boat traversed downstream in a cloverleaf pattern with electrical current applied for 10-sec with 5-sec "off peddle" intervals to increase the effectiveness of capturing Silver Carp and to attempt to drive fish into the nets and shoreline (Bouska et al. 2017). Electrofishing continued until the entirety of the site was sampled.

Before we established our electrofishing protocol, we used several electrofishing settings at sites where carp were observed on previous occasions or during that trip. During experimental electrofishing trials, we used pulsed DC current at both low and high frequencies, with Hz ranging from 15 to 60 and a target amperage of 4 and 20, respectively. Boat electrofishing was also used to drive carp into set nets. All carp collected during our sampling events were euthanized. Total length (mm, +/- 1 mm), and weight (g, +/- 10 g), were recorded for captured carp, except for a few captured while our scale was malfunctioning.

Adult fish habitat

We quantified the physicochemical factors that may be related to carp distributions across multiple spatial scales. We quantified habitat factors at the catchment, segment, and reach scales. The habitat factors were either collected in the field or obtained using existing geospatial data (Table 7).

The catchment scale habitat factors we will consider are drainage area, disturbance, and lithology. Drainage area (km^2) is a coarse scale habitat factor that influences fish distributions, community structure, and species richness (Newall and Magnuson 1999; Osborne and Wiley 2011; Griffiths 2018) and will be measured using National Hydrography Database Plus (NHDplus) (https://apps.nationalmap.gov/downloader/#/) flow lines in ArcMap 10.6. Disturbance can affect fish community structure and distribution by altering nutrient flow and habitat availability and lead to decreased diversity throughout trophic levels (Scrimgeour et al. 2008; Wang et al. 2008; Johnson and Angeler 2014). We will use ArcMap 10.6 to create a buffer of the floodplain and classify land use type using the National Land Cover Database (NLCD). Each land type will receive a disturbance value using the Landscape Development Index (LDI) (Brown and Vivas 2005). Lithology constitutes the predominant bedrock of a riverscape and can alter sedimentation, pH, and control the macro and micronutrient cycling load within a catchment (Sarkar et al. 2007; Zeng et al. 2007; McDowell et al. 2013; Glaus et al. 2019). We will analyze lithology by classifying the dominant rock type in the catchment using United States Geological Survey's (USGS) National Geologic Map Database (https://mrdata.usgs.gov/geology/state/) and the identify tool in ArcMap 10.6.

The segment scale habitat factors we will quantify are sinuosity, slope, water temperature, and discharge. Stream sinuosity, the ratio of the straight-line segment of river to the channel distance (Rowe et al. 2009), is associated with habitat complexity (e.g., woody debris, canopy cover), backwater connection, and overall habitat variability (Nagayama and Nakamura 2018). Sinuous reaches in a river system can be areas of particular importance for specific species or life-history strategies (e.g., *Hucho perryi*; Fukushima et al. 2011), and carp in the Missouri River spawned larger quantities of eggs in more sinuous river segments (Deters et al. 2013). Sinuosity will be calculated by dividing the river kilometer (rkm) distance by the straight-line distance using the distance tool in ArcMap 10.6. Slope can affect the species richness of a river by influencing water velocity, channel morphology, and substrate which are often correlated with the stream gradient (Camana et al. 2016). Stream gradient may alter the availability of low-velocity habitat associated with carp presence. We will quantify slope using spatial analysis in ArcMap 10.6 by dividing the change in elevation from the upstream to downstream end of the segment by the segment length. Water temperature controls fish metabolism and can cause fish to alter distributions to meet the requirements for growth, forage, spawning, and social interactions (Sloat et al. 2005; Sloat and Osterback 2013; Kuparinen et al. 2011). For example, Coulter et al. (2017) found that Bighead Carp movement into backwater habitat increased as the Illinois River main-channel water temperature decreased. We will collect water temperature across stream segments using Onset HOBO MX2201 Pendant Wireless Temperature Data Loggers (Bourne, Massachusetts) (Figure 1). Discharge affects fish density and occurrence, habitat associations, recruitment success, and can be altered for mitigation purposes (Valdez et al. 2001; Gillete et al. 2006; Work et al. 2017; Love et al. 2017; Bašić et al. 2018). Silver Carp in the Illinois River have demonstrated relatively strong habitat associations related to discharge (Coulter et al. 2017). We will obtain discharge data from the nearest USGS stream gauges and calculate the 75^{th} percentile and the CV for discharge during the season (i.e., occupancy) and divide by the drainage area of the segment to compare discharge across rivers (i.e., Red River, Kiamichi, Blue River, ect.) to relate high discharge and discharge variability to carp presence.

At the reach scale (i.e., site), we will calculate the distance to the nearest upstream dam, percent slackwater, width to depth ratios, salinity, and chlorophyl-a. Bighead Carp and Silver Carp require an estimated 100 km of free-flowing river to successfully spawn (Kolar et al. 2007).

For example, flow alteration in the Yangtze River, caused by dam construction, has led to reduced recruitment for both Bighead Carp and Silver Carp (Duan et al. 2009). We will use NHDplus flowlines and ArcMap 10.6 spatial analyst to quantify the distance from the site to the nearest upstream dam. Slackwaters, areas of decreased velocity and depth (Vietz et al. 2013), are used as a refuge by juvenile fishes for increased growth and forage potential (Humphries et al. 2006). Slackwater habitats are also used by adult carp as refuge during high discharge events (Coulter et al. 2017; MacNamara et al. 2018) and may offer higher forage potential (Williamson and Garvey 2005). We calculated the percent slackwater by taking width and length measurement in the field using a handheld rangefinder. Width to depth ratios describe the structural variation of a stream channel where increasing ratios are emblematic of wider and shallower stream channels (Gordan et al. 1992; Dunham et al. 2002). Fishes have defined salinity tolerances and will use habitat within their salinity range over preferred dissolved oxygen and temperature ranges (e.g., *Acipenser brevirostrum*; Farrae et al. 2014). Abnormal salinity environments can hinder reproduction and in extreme instances lead to poor osmoregulation and eventual death (Oto et al. 2017; Neves et al. 2019). I will collect three salinity measurements (ppt) at the upper, middle, and bottom portions of each reach using a Yellow Springs Instrument (YSI pro dds) (Yellow Springs, Ohio). We collected three salinity measurements (ppt) at the upper, middle, and bottom portions of the site. Chlorophyll-a (chl-a) is widely used as a surrogate for productivity and algal biomass (Pinder et. al 1997). Carp are omnivores, consuming both zooplankton and phytoplankton (Calkins et a. 2012), and may be associated with varying chl-a densities in the basin. A water sample was collected using an integrating tube sampler to sample the top 2 m of the water column at the most downstream end of each site (Raikow et. al 2004). Within 24 h of water collection, three 500-mL subsamples were then placed into a 47-mm diameter filter tower (PALL, Port Washington, New York) and filtered through a 1-µm glass fiber filter. The filter was then placed into a light-proof container and frozen for later laboratory analysis. In the laboratory, we will soak the filters in 95% ethanol for 23 hours and then filter a second time. Chl-a (µg/L) will then be estimated using a fluorometer.

Fecundity estimates from female carp

We estimated the total eggs contained within the ovary of each female collected via sampling. We began by taking the total weight (g, +/- 1 g) of the ovary. We then took subsamples (0.3 – 0.5

g) from the anterior, middle, and posterior of the ovary and enumerated the eggs for each subsample. From these enumerated subsamples, we then estimated the average eggs per gram and extrapolated that to the respective ovary weight.

Objective 2. Determine habitat associations of large river fish assemblages

Native fish sampling

At each juvenile and adult site, we sampled native fishes using multiple gears as described for Objective 1. Briefly, sites targeting juvenile and smaller-bodied fishes was conducted using three gear types: mini-fyke nets, beach seines, and larval tows. Mini-fyke nets were set in 1-2 m of water for approximately 6 h during daylight. Beach seining was conducted within areas of the site that allowed for seining (i.e., depths <1m). Larval tows were conducted by towing an ichthyoplankton net upstream for approximately 10 min at each site. Identifiable species were enumerated and recorded for each gear used. All larval individuals and unknown species were preserved in a 70% ethanol solution for later identification in the lab. At sites targeting larger-bodied fishes, we conducted electrofishing and net surveys. Three gill nets and three hoop nets were placed throughout each site to soak for approximately 6 h. Following net placement, the site was sampled via boat electrofishing. All sampled fish were identified to species, and the sampling method associated with each catch was recorded.

Native fish habitat

At each site, we quantified the physicochemical factors that may also be related to native fish distributions as described for Objective 1. Briefly, we collected both detection and occupancy covariates. For juvenile and smaller-bodied fishes we quantified: water temperature (°C), dissolved oxygen (mg/L), turbidity (cm), discharge (m^3/s), salinity (ppt), average depth (m), width-to-depth ratio (m), zooplankton biomass (µg), large woody debris (%), forewater/backwater (%), and pools (%). We will also quantify several geospatial covariates: distance from dam, distance from confluence, sinuosity, slope, drainage area, and lithology. For adult and larger-bodied fishes we quantified chlorophyll-a (mg/L), salinity (ppt), water temperature (°C), water visibility (cm), discharge (m^3/s), max depth (m), and width-to-depth ratio (m). We will also calculate distance from dam, sinuosity, slope, drainage area, disturbance, and lithology using existing geospatial data and tools. Onset data loggers were set throughout the study area to record water temperature. Conductivity loggers were placed in several of the tributaries and one mainstem location.

Objective 3. Summarize the age structure of bighead carp sampled through fall 2021

Juvenile carp collection

We will collect age-0 Bighead and Silver Carp before they reach 60-mm total length (TL). It is difficult to enumerate daily bands in fish >100 days old (Long and Grabowski 2017). Therefore, we will collect age-0 Bighead and Silver Carp until they reach approximately 60-mm TL as they are estimated to reach the juvenile transition at 36 and 34-mm TL in China, respectively (Chapman 2006). By using a more liberal cutoff, we can determine band counts at the Red River latitude based on our daily ages.

All captured carp will be enumerated and measured; however, for catches with more than 50 individuals, we will randomly select five individuals from 5-mm length bins up to 60-mm (e.g., 0-5-mm, 5-10-mm, and 10-15-mm). If catches are less than 50 individuals per site, all fish will be kept for ageing. All captured carp will be euthanized using an overdose of tricane methanesulphonate (MS-222) (300 mg/L, Neiffer and Stamper 2009), then preserved in 1-L bottles containing 70% ethanol for future laboratory processing.

Juvenile carp otolith extraction, processing, and ageing

If we capture juvenile carp, then we will remove and mount lapilli otoliths to estimate hatch dates. Daily band deposition on lapilli otoliths has been validated to estimate spawning dates in age-0 carp (Lohmeyer and Garvey 2009; Williams 2020) and other cyprinid species (e.g., Sharpnose Shiners *Notropis oxyrhynchus*, Smalleye Shiners *Notropis buccula*, and Plains Minnow *Hybognathus placitus*, Durham and Wilde 2008). We will remove lapilli otoliths under a stereo dissection microscope using a fine-tipped probing needle and forceps to remove the otoliths from the top of the skull. Once the otoliths have been removed, we will place them in a petri dish. We will then mount the otoliths to slides using thermoplastic (Lakeside No. 70C, Monee, IL). We will melt the cement on the slide until it is pooled. The otoliths will then be placed convex side down in the cement and allowed to cool at ambient temperature.

The mounted otoliths will be polished in a circular pattern to allow band enumeration. We will polish the otoliths using diamond lapping paper (Diamond Lapping Film, 8" diameter, plain backing, Electron Microscopy Sciences, Hatfield, PA). Polishing will be complete once all the bands become visible at the nucleus (Campana and Neilson 1985).

We will quantify daily bands of age-0 carp to estimate spawning dates and average daily incremental growth rates. We will enumerate daily bands using a compound microscope. Daily bands will be counted from the outer edge toward the center to enhance accuracy (Campana and Moksness 1991). Two independent readers will count bands and record estimates. Band counts within 10% difference between readers will be averaged, if >10% differences exist, then readers will attempt to reach a consensus. If a consensus can still not be reached, the otolith will be removed from the dataset. We will also measure otolith radii (1-μm TL) from the central point of the otolith nucleus to the outer edge to estimate growth (Infinity analyze-7 software, Lumenera infinity 2 camera). We will also measure radii from the nucleus to the edge of otolith bands at 10-day increments to calculate average daily incremental growth (e.g., 0-10, 10-20, 30-40 days). We will estimate hatch dates by subtracting the daily band counts from the date of capture. We will calculate spawn dates by subtracting an additional day from estimated hatch dates (i.e. ~27-29 hour incubation, Chapman and George 2011).

Adult otolith extraction, processing, ageing, and growth

Lapilli otoliths were removed from all carp captured for age and growth analysis following Seibert and Phelps (2013). The lapilli otoliths, located at the posterior of the skull, were accessed using a hacksaw. A cut was made through the top of skull at the juncture of the preopercle and opercula. Otoliths were then removed using forceps and placed into coin envelopes marked with an individual fish number for later laboratory analysis.

In the laboratory, otoliths were sectioned and prepared for age estimation. First, the nucleus was marked on the exterior of the otolith with a ballpoint pen. The otolith was then placed in epoxy resin and allowed to harden for 24 h. After hardening, the otolith was sectioned with an isomet saw (Buehler IsoMet Low Speed Precision Cutter, Lake Bluff, Illinois) and a single 0.5 to 0.6-mm section was removed from the center of the otolith ensuring the inclusion of the nucleus. The sectioned otolith was then polished on each side with diamond lapping paper (Diamond Lapping Film, 8" diameter, plain backing, Electron Microscopy Sciences, Hatfield, PA). Subsequently, the sectioned otolith was mounted onto a slide with thermoplastic. The slide was then placed under a dissecting microscope equipped with a light source and imaged with a Luminera Infinity 2 (Tyledyne Luminera, Ontario). The images were saved for later age and growth analysis (Figures 3 and 4).

Two readers separately enumerated the annuli of the imaged otolith to age each fish. An annulus is a pair of translucent and opaque bands that continue uninterrupted around the nucleus (Dzul et al. 2012). The edge was counted as an annulus for fish captured prior to August 31st because an annulus will be created during the spawning season (Minard 1998; Ericksen 1999). There was no prior knowledge of the length, weight, or age estimation of either reader to avoid reader bias. If there was no consensus on the age of a fish, the readers discussed how they derived the age until a consensus was reached. We analyzed the between-reader agreement and mean-CV of otoliths compared to other structures to ensure that lapilli otoliths were the proper structure to use.

We will quantify the proportional growth of carp to determine how growth relates to their spatial distribution. The annuli and edge will be analyzed for proportional growth using Infinity Analyze 7 software 2 (Tyledyne Luminera, Ontario) (Quist and Isermann 2017). Otoliths will be measured for incremental growth along the same axis. The focus will be identified, and then individual radii distances will be recorded from the focus longitudinally to the outside edge of each opaque band to determine individual year growth (Weisberg et al. 2010). The distance from the focus to the edge will be used to relate incremental growth to fish length. Back calculation for age-at-length will be conducted using the Fraser-Lea method if the body-scale relationship is strongly correlated (R^2>0.80, Quist and Guy 2001). If the body-scale relationship is weak, then we will use the Dahl-Lea method (Quist and Isermann 2017). A von Bertalanffy growth model (vBGM) will be fit to both Silver Carp and Bighead Carp to assess growth using the previously collected back-calculated age-at-length data. Growth analysis can also be used to relate growth to environmental variation using a Weisberg model (Weisber et al. 2010). This catchment experiences relatively high year-to-year fluctuations in weather, resulting in years characterized by drought or high-water events. We hypothesize that carp growth will be related to the varying weather of the region, of which discharge, and water temperature can be used as surrogates. We will model the effects of mean discharge (m^3/s), the coefficient of variation (CV) of discharge, the mean water temperature (°C), and the CV of temperature on growth for both carp species during the growing season (April through September) for the catchment.

RESULTS

We completed sampling at 65 sites where we targeted juvenile carp and other small-bodied native fishes and 54 sites where we targeted adult carp and larger-bodied native fishes during the reporting period (Tables 1 and 2). We completed 149 surveys at our juvenile sampling sites and 170 surveys at our adult sampling sites. As expected, gillnets and electrofishing were most effective at capturing larger-bodied fishes, whereas fyke nets and seine hauls collected mainly smaller-bodied native fishes. Hoop nets and larval tows have not been as effective at collecting fishes as other gear types.

The experimental electrofishing settings were not as effective at collecting carp or getting carp to jump as the standard settings used during the initial fish assemblage shocking events. When carp were observed jumping, we were somewhat able to manipulate their swimming direction by using the electrofisher. On several instances, we were able to observe the wakes of carp being driven towards set gillnets as they attempted to escape the electric field. However, most carp that were actively driven towards the nets would either jump the net upon reaching it or turn around and swim away from it and around the electrofishing boat. We have also attempted to set our gillnets parallel to the bank and then electrofish between the net and bank as was suggested by Arkansas. Thus far, this has not resulted in any differences in our catch. We also baited hoop nets with cattle cubes, as was suggested by commercial fishermen in Arkansas, yet there was no increase in catch-rates of either carp species.

Objective 1. Determine the spatial and temporal extent of Bighead Carp and Silver Carp in the Red River basin of Oklahoma

We captured 287 carp throughout the lower Red River basin, 242 in the mainstem Red River and 45 individuals in tributary streams. Most carp captured in the mainstem Red River were sampled from connected oxbows and backwater locations (Table 8). Thus far, 8.0% (19 Silver Carp and 4 Bighead Carp) of carp have been collected in the main channel of the Red

River. Of the 45 carp collected from tributaries, most (i.e., 25) were captured in Choctaw Creek where sampling detection appears higher than the other deeper-water tributaries. The carp that were collected from the tributaries comprised 25 Bighead Carp and 20 Silver Carp. Visual confirmation of carp at a site but not captured during the survey was recorded 63 times (Table 9). Silver Carp have been either captured or visually confirmed in all sampled tributaries except the Blue River (Tables 8 and 9). Bighead Carp have been either captured or visually confirmed in all sampled tributaries except the Blue River and Buzzard Creek (Tables 8 and 9).

All Silver Carp and Bighead Carp collected were adults. No age-0 Silver Carp or Bighead Carp were sampled (or yet identified from larval samples). The Silver Carp collected ranged in length from 616 mm to 1091 mm (±1- mm, TL), whereas the Bighead Carp ranged from 949 mm to 1350 mm (±1- mm, TL) (Table 8). For Silver Carp, 130 males and 130 females were captured. For Bighead Carp, 40 males and 16 females were captured. Sex was determined for all but three carp.

The ovaries of female carp species occupied much of the body cavity and were typically full of well-developed eggs throughout the year. We estimated egg totals for 4 Bighead Carp and 8 Silver Carp (Table 8). Although Bighead Carp were larger than Silver Carp, the Silver Carp had a higher average total egg estimate (713,587) compared to Bighead Carp (486,897). Bighead Carp egg estimates ranged from 256,313 eggs to 722,638 eggs. Silver Carp egg estimates ranged from 233,739 eggs to 1,110,147 eggs.

Objective 2. Determine habitat associations of large river fish assemblages

Habitat metrics are currently being compiled to relate to detection and occupancy of native fishes. We placed temperature loggers at sites in the tributaries and throughout the mainstem Red River (Figures 1 and 2). Several conductivity loggers have been placed at tributary sites, and one mainstem site. One temperature logger and two conductivity loggers from sites below Lake Texoma on the mainstem Red River were stolen and therefore, data were unavailable. We have since avoided setting loggers at those locations. Additionally, two temperature loggers from the tributaries were also stolen. However, some data were downloaded from these loggers before they went missing. Several additional conductivity loggers were deployed during low flows, including two tributary locations and one mainstem location.

Water temperature data showed similar trends between the mainstem Red River and the tributaries. The Oklahoma and Arkansas portions of the Red River showed similar patterns throughout the year (Figure 5). Summer water temperatures averaged near 30°C for both sections of the Red River (Table 10). Average winter water temperatures were between 10 and 11.5°C on the Red River. Mean daily water temperatures were slightly more variable in the tributaries (Figure 6). Average summer water temperatures on the tributaries ranged from 27°C to 30°C. Winter water temperatures average between and 9 and 10°C for all tributaries (Table 10).

Water conductivity data showed the key differences among the tributaries. Water conductivity in the Kiamichi River is much lower than the other major tributaries samples (Figure 7). Conductivity is typically between 50 and 200 μc/cm in the Kiamichi River, whereas it is typically between 1300 and 1600 μc/cm in Choctaw Creek. The other tributaries had conductivity values ranging between 500 and 800 μc/cm. Conductivity in the mainstem Red River near Fulton AR, ranged from 75 μc/cm to nearly 1500. μc/cm. This large range is due to influence from a tributary with very low conductivity that flows into the Red River approximately 1.5km upstream from the logger's location.

Habitat differences were evident when comparing the Red River of Oklahoma and Arkansas and tributary sites. On average, Red River sites in Arkansas were deeper and narrower (narrower wetted widths) compared to mainstem Red River sites in Oklahoma (Table 11). Additionally, the Arkansas portion of the Red River contained more available backwater habitats due to the presence of dikes. As such, species collection tables were divided into three groups based on habitat differences: the Arkansas portion of the Red River (Table 12), the Oklahoma portion of the Red River (Table 13), and major tributaries of the Red River sampled (Table 14 & 15).

We do not have evidence to suggest many of these riverine populations differed based on the changes in river morphology (i.e., between AR and OK). Arkansas allows regulated commercial fishing, whereas Oklahoma and Texas do not (thereby possibly affecting population numbers). However, no differences in length-weight relationships were observed when plotted separately indicating these are likely populations that mix, or regulations either do not affect or equally affect all length distributions. Because of this observation, length-weight relationships, and length-frequency histograms for the most commonly observed large-bodied fishes were constructed using data combined from all sites (i.e., to improve the relationship).

A total of 129,302 fishes, comprising 74 species and 44 genera, were identified during sampling of the lower Red River basin. Many vouchered fishes have been reviewed in the laboratory. Of the three mainstem river sections sampled, species diversity was highest in the Arkansas section of the Red River (66, Table 12), followed by the Oklahoma section of the Red River (63, Table 13), the major Oklahoma tributaries sampled (57, Table 14), and finally the major Texas tributaries sampled (38, Table 15). The most abundant species was Red Shiner (66,040), followed by Bullhead Minnow (13,689), Mississippi Silverside (7,707), and Western Mosquitofish (7,406). Of the 74 fish species, four of those were non-native including Bighead Carp, Silver Carp, Common Carp, and Grass Carp. The genera that contained the most species collected was Lepomis (6, Table 16). Length-frequency histograms were created for the seven most common large-bodied species: Smallmouth Buffalo (Figure 8), Bigmouth Buffalo (Figure 9), Black Buffalo (Figure 10), Longnose Gar (Figure 11), River Carpsucker (Figure 12), Flathead Catfish (Figure 13), and Blue Sucker (Figure 14). Additionally, a log-transformed length-weight relationship was also calculated for each of the species (Figures 15-21). As the weather got cooler and water levels dropped, we observed an increase in capture of several more species that are considered relatively rare in the basin including Blue Sucker (Figure 22) and Shovelnose Sturgeon (Figure 23).

Objective 3. Summarize the age structure of bighead carp sampled through fall 2021

The lapilli otolith had the highest between-reader agreement of 0.81 for Silver Carp and 0.72 for Bighead Carp (Figure 24) and lowest mean-CV of 2.82 for Silver Carp and 3.47 for Bighead Carp (Figure 25). Thus far, we have aged a subsample of the Bighead Carp and Silver Carp (Table 8, Figures 3 and 4). The Silver Carp age ranged from 3 to 13 years old, with the most (25%) being 5 years old (Figure 26). Silver Carp age ranged from 3 to 15 years old with the majority being age 5 (20%) and 9 (20%) years old (Figure 27).

We conducted a von Bertalanffy growth model for Silver Carp estimating the theoretical maximum length ($L\infty$) and the growth coefficient (K) while keeping the age when length is zero (t0) constant at 0. Silver Carp $L\infty$ was 928.4 and K was 0.5604 (Figure 28). We conducted a Chapman-Robson catch-curve to assess mortality for Silver Carp and found that instantaneous mortality (Z) was 0.287 and annual mortality (A) was 0.25 (Figure 29).

DISCUSSION

Objective 1. Determine the spatial and temporal extent of Bighead Carp and Silver Carp in the Red River basin of Oklahoma

Many age-0 fishes are difficult to detect in large river systems (Brewer and Ellersieck 2011), including Bighead and Silver Carp (Roth et al. 2020). Carp are extremely difficult to sample (Wanner and Klumb 2009; Bouska et al. 2017; Roth et al. 2020) and detection is reported at approximately 38% in the presumably highly populated Illinois River basin (Coulter et al. 2018). We selected sampling gears following Collins et al. (2017), who found both mini-fyke nets and beach seines to be the most efficient for capturing age-0 carp. However, we did not detect age-0 carp either due to extremely low sampling detection (i.e., possible during the very wet 2021), lack of spawning in Oklahoma, or other influences. Camacho (2016), Collins et al. (2017), and Chick et al. (2020a) have reported stark differences in the successful collection of larval and juvenile carp in successive years. For example, Collins et al. (2017) collected 39,398 Silver Carp in 2014; however, they collected only 116 in 2015. During the same years, Camacho (2016) captured a higher density of eggs and larval fish in 2014 than in 2015. Our 2021 (i.e., extremely wet) and 2022 (i.e., extremely dry) sampling seasons may be emblematic of extremely low capture years where adults chose not to reproduce (or reproduced further downriver). Because carp in the lower Red River basin have not been documented in densities as high as the Upper Mississippi River, sampling inefficiencies may be exacerbated.

Sand bed streams of the Central Great Plains, including the Red River are extremely dynamic and continuously shift over time (e.g., a backwater may be present during the wet months and absent during the dry months). Due to the constant shifts and extreme conditions associated with sand bed streams, detection of fishes is quite variable and often imperfect (Mollenhauer et al. 2018). The extensive high flow events observed in 2021 certainly influenced our ability to successfully detect juveniles of both species of carp (Figure 30). Alternatively, the extensive drought conditions of 2022 may have not been favorable conditions for carp spawning (Figure 31). In June 2021, Red River discharge reached near 2,549 m^3/s (90,000 ft^3/s), roughly 1,982 m^3/s (70,000 ft^3/s) higher than the 78-year median (USGS gage 07337000). However, in June 2022, Red River discharge reached near 80 m^3/s (2,825 ft^3/s), which is roughly 260 m^3/s

(9,180 ft^3/s) lower than the 78-year median (USGS gage 07337000). Discharge is assumed to be a spawning cue for carp and both our seining efficiency and mini-fyke net effort may have been affected by high flows. Moreover, because carp are pelagophils, their eggs may have washed much further downriver during these extremely high flows. Another possibility is the abnormally high and low flows created unfavorable spawning conditions.

Most of the adult Bighead Carp and Silver Carp were captured in either the tributaries or backwater habitats on the mainstem Red River. Carp exhibit very strong gear avoidance behaviors, and this certainly relates to poor detection in the mainstem Red River. However, Coulter et al. (2016) through acoustic telemetry, demonstrated that outside of large migratory movements, Silver Carp were highly associated with backwater environments and remained in those locations throughout the summer months. The limited amount of connected backwater in the Red River basin from Denison Dam to the Arkansas-Louisiana border may limit preferred habitat, but additional years of data are needed given the extreme variations in flow. Moreover, a tracking study would be very useful for determining where and when these fish reside in certain locations.

We did not sample individuals of either species younger than age 3. Coulter et. al (2018) showed that the larger individuals are more likely to be located on the fringe of the species distribution as they are primarily responsible for expanding the species range. These fish may not have recruited within the Red River and could be originally from a different basin (i.e., Mississippi River) expanding the invasion front. A telemetry effort would be helpful to monitor carp movement within the Red River and determine the origin of these fish. However, it is important to note that occasional Bighead Carp were collected early in their invasion and now we observe both Bighead and Silver Carp throughout the basin except for the Blue River. We suspect they also occur in the lower Blue River, but we have just not observed them due to the extensive amounts of woody debris and difficult access in that river.

Objective 2. Determine habitat associations of large river fish assemblages

Throughout the sampling period, we documented 74 different fishes throughout the lower Red River basin. Relatively few sampling efforts covering this spatial extent have been devoted to collecting data on the native fish assemblage within the lower Red River basin. From 1995 to

2001, Buchanan et al. (2003) sampled the Arkansas portion of the Red River and reported the collection of 72 fish species. Of the 72 species collected from 1995 to 2001, we collected 60 from all sample sites. In addition to the 60 species caught from Buchanan et al. (2003), we collected seven unique species including: American Eel, Bluntnose Minnow, Flier, Mooneye, Quillback, Sand Shiner, and Smallmouth Bass.

Fish diversity was highest in the Arkansas portion of the Red River, where the Red River is typified by both pools within the thalweg throughout the year as well as sections of shallow braided channels during low flow. There are abundant wing dikes and rip-rap lined banks throughout the Arkansas portion, directing flow to established channels. The river in the Oklahoma portion has little to no artificial channelization, allowing for a more dynamic, though shallower channel. However, the wing dikes and levees in Arkansas create unique habitat that may effectively "attract" some species. We know that Pirate Perch has been sampled from Oklahoma waters (Brewer, Unpublished data), so we suspect we may find additional species as we continue to sample. However, the shallow braided stretches of the Red River in Oklahoma provide habitat niches that are favorable for some small-bodied fishes such as the Western Sand Darter, where 40 individuals were captured compared to the 19 captured in Arkansas. Only one unique species was observed in Oklahoma tributaries; however, its capture was historically significant. One American Eel was collected in the Kiamichi River (33.99742, -95.3722) in August 2021, and to our knowledge it is the first documented capture within our study area since 1973 (Buchanan et al. 2003).

Two species that have been considered species of concern: Blue Suckers and Shovelnose Sturgeon, were seldom captured prior to November. However, we captured more individuals in the mainstem Red River as temperature and discharge decreased. Abnormally high spring and summer flows occurred in 2021 in the lower Red River basin followed by lower winter and spring 2022 flows. Sampling full species assemblages is increasingly difficult as river size, flow, and turbidity increase (Flotemersch et al. 2006), and the high spring 2021 flows could have limited capture efficiency of these and other species. It is thought that adult Blue Suckers move into tributaries to spawn in late winter or early spring and migrate back into the mainstem of large rivers afterwards (Neely et al. 2009; Dyer and Brewer 2020), but little is published on their over-wintering habitats (with the following exceptions). Shovelnose Sturgeon use shallow (1.0 - 2.0 m) water depths, over sand substrate, and relatively low velocities (Quist et al. 1999) when they overwinter in the Kansas River, which is consistent with our habitat observations. Although it is likely that lower water levels, decreased turbidity, and cooler water temperatures contributed to our increased catch rate (i.e., higher capture efficiency), our results suggest these species use shallow water over sand substrate and slower flowing habitats for winter refugia (hence our catch increasing in these habitats). Our increased catch of these species serves as a good reminder that sampling seasonally is important to document information on species considered to be of conservation concern. These results also indicate that our sampling for these species was less efficient at other times of the year and therefore, winter monitoring for these species may be advantageous for determining population trends.

Objective 3. Summarize the age structure of bighead carp sampled through fall 2021

We did not collect any carp younger than age 3. Coulter et. al (2018) showed that the larger individuals are more likely to be located on the fringe of the species distribution as they are primarily responsible for expanding the species range. These fish may not have recruited within the Red River and could have originated in a different basin (i.e., Mississippi River) expanding the invasion front. A telemetry effort would be helpful to determine the source of these fishes.

Although we have only aged a subset of the carp collected thus far, Silver Carp appear to have a faster growth-rate (*K*) with a higher theoretical maximum length ($L\infty$) in the Red River catchment compared to traditionally surveyed catchments. A carp meta-analysis of populations in the middle Mississippi rivers found the $L\infty$ was 802.826 mm and *K* was 0.445 (Tsehaye et al. 2013). However, Sullivan et. al (2021) found that populations of Silver Carp in the Illinois River had lower $L\infty$ and *k* values that ranged from 691 to 740-mm and 0.28 to 0.23, respectfully.

III. RECOMMENDATIONS

For higher precision, we suggest managers use the lapilli otolith for determining demographics of both carp species. The lapilli otolith is considered the most consistent structure for ageing carp. Seibert and Phelps (2013) used a sample of 120 Silver Carp and found that lapilli otoliths had the highest between-reader agreement and precision compared to fin-rays, post-cleithrum, and vertebrae. No study has been conducted in a similar manner for Bighead

Carp, but many managers use lapilli otoliths assuming they have a similar precision as found with Silver Carp. We have conducted a preliminary comparison of ageing structures similar to Seibert and Phelps (2013) and found that lapilli otoliths had the highest precision for both Silver Carp and Bighead Carp in the lower Red River catchment.

Results from native fish sampling indicate seasonal sampling is important to determining population trends if that is the agency goal. Several species of conservation concern had much higher catch during winter sampling likely due to both habitat use and an increase in capture efficiency. Blue sucker and Shovelnose Sturgeon, as examples, were most prevalent in our samples during December. An examination of the discharge and temperature conditions that occurred during that time would help determine the best sampling period for those species, which could fluctuate each year based on environmental conditions. Moreover, these data are also important for understanding the long-term use of the upper Red River and tributaries by very rare species such as the American Eel.

This project is intertwined with several other ongoing efforts in Arkansas, Texas, and a second year of funding provided by the U.S. Fish and Wildlife Service. Completion of occupancy models will be done after we complete additional sampling that will also allow us to calculate detection probability of carp which is no doubt low. Based on the data collected from the first year, it appears that backwater habitat is important for non-native carp. We regularly sample both bighead and silver carps in these habitats and these areas might be fruitful locations for larger scale removal efforts including traps that target only carp. However, the same habitats are also important for Paddlefish, an economically important species that we also regularly sample at these same locations. The tradeoffs of repeated sampling to remove carp from these areas while increasing mortalities of native fishes would be an important consideration. We also sample Paddlefish at other locations, and they appear relatively broadly distributed across the lower basin of Oklahoma and Arkansas. Building artificial backwater habitat for the sole purpose of attracting carp for removal may also be a consideration.

Although we did not observe successful reproduction by carp yet, many adults were full of developed oocytes and the environmental conditions may not be appropriate yet to induce spawning at these locations. In 2021, there were extensive floods during the spring and summer; thus, sampling was difficult, and spawning could have been missed due to low detection. Alternatively, 2022 has been extremely dry and hot and may not be conducive to reproduction.

Periodic spawns with entire years of no spawning have been observed in the Kansas River so is not surprising to observe it in the Red River. We caution that as the densities of carp increase in the lower basin, this situation may change quickly (just as Silver Carp have quickly invaded the area). Future monitoring efforts that target river locations near backwater or other slackwater habitats will likely prove valuable for determining the future status of non-native carp in the lower Red River.

Significant Deviations:
None.

Equipment Purchased During Grant (Cumulative):
None.

Prepared by: Shannon Brewer, Dennis Devries, John Dattilo, Paul Ramsey, and Ben Birdsall

Approved by: Richard Snow, Assistant Chief of Fisheries
Oklahoma Department of Wildlife Conservation

Andrea K. Crews, Federal Aid Coordinator
Oklahoma Department of Wildlife Conservation

REFERENCES

Bain, M. B., and N. J. Stevenson. 1999. Aquatic Habitat Assessment: Common Methods. American Fisheries Society, Bethesda, Maryland.

Balian, E. V., C. Lévêque, H. Segers, and K. Martens. 2008. Freshwater Animal Diversity Assessment. Page Hydrobiologia, editor Ostracodology - linking Bio- and Geosciences. Springer.

Bayley, P. B., and R. A. Herendeen. 2000. The Efficiency of a Seine Net. Transactions of the American Fisheries Society 129(4):901–923.

Bašić, T., J. R. Britton, R. J. Cove, A. T. Ibbotson, and S. D. Gregory. 2018. Roles of discharge and temperature in recruitment of a cold-water fish, the European grayling Thymallus thymallus, near its southern range limit. Ecology of Freshwater Fish 27(4):940–951.

Blackburn, T. M., P. Pyšek, S. Bacher, J. T. Carlton, R. P. Duncan, V. Jarošík, J. R. U. Wilson, and D. M. Richardson. 2011. A proposed unified framework for biological invasions. Trends in Ecology and Evolution 26(7):333–339.

Bouska, W. W., D. C. Glover, K. L. Bouska, and J. E. Garvey. 2017. A Refined Electrofishing Technique for Collecting Silver Carp: Implications for Management. North American Journal of Fisheries Management 37(1):101–107.

Bozek, M. A., and W. A. Hubert. 1992. Segregation of resident trout in streams as predicted by three habitat dimensions. Canadian Journal of Zoology 70(5):886–890.

Brewer, S. K., and M. R. Ellersieck. 2011. Evaluating two observational sampling techniques for determining the distribution and detection probability of age-0 smallmouth bass in clear, warmwater streams. North American Journal of Fisheries Management 31(5):894–904.

Brown, M. T., and B. M. Vivas. 2005. Landscape Development Intesity Index. Environmental Monitoring and Assessment 101(1):289–309.

Buck, E. H., C. V Stern, H. F. Upton, and C. Brougher. 2010. Asian Carp and the Great Lakes Region.

Buchanan, T., D. Wilson, L. Claybrook, and W. Layher. 2003. Fishes of the Red River in Arkansas. Journal of the Arkansas Academy of Science 57(1):18–26.

Butler, S. E., A. P. Porreca, S. F. Collins, J. A. Freedman, J. J. Parkos, M. J. Diana, and D. H. Wahl. 2019. Does fish herding enhance catch rates and detection of invasive bigheaded carp? Biological Invasions 21(3):775–785.

Calkins, H. A., S. J. Tripp, and J. E. Garvey. 2012. Linking silver carp habitat selection to flow and phytoplankton in the Mississippi River. Biological Invasions 14(5):949–958.

Camacho, C. A. 2016. Asian carp reproductive ecology along the upper Mississippi River invasion front. Iowa State University.

Camacho, C. A., C. J. Sullivan, M. J. Weber, and C. L. Pierce. 2020. Invasive Carp Reproduction Phenology in Tributaries of the Upper Mississippi River. North American Journal of Fisheries Management.

Camana, M., R. B. Dala-Corte, and F. G. Becker. 2016. Relation between species richness and stream slope in riffle fish assemblages is dependent on spatial scale. Environmental Biology of Fishes 99(8–9):603–612. Environmental Biology of Fishes.

Campana, M. B., and J. Neilson. 1985. Microstructure of fish otoliths. Canadian Journal of Fisheries and Aquatic Sciences 42(5):1014–1032.

Campana, S. E., and E. Moksness. 1991. Accuracy and precision of age and hatch date estimates from otolith microstructure examination. ICES Journal of Marine Science 48(3):303–316.

Catalano, M. J., M. A. Bozek, and T. D. Pellett. 2007. Effects of Dam Removal on Fish Assemblage Structure and Spatial Distributions in the Baraboo River, Wisconsin. North American Journal of Fisheries Management 27(2):519–530.

Carey, M. P., and D. H. Wahl. 2010. Native fish diversity alters the effects of an invasive species on food webs. Ecology 91(10):2965–2974.

Chapman, D. C. 2006. Early Development of Four Cyprinids Native to the Yangtze River, China. U.S. Geological Survey Data Series 239:51.

Chapman, D. C., and A. E. George. 2011. Developmental rate and behavior of early life stages of bighead carp and silver carp. USGS Scientific Investigations Report 2011–5076:11.

Chick, J. H., C. E. Colaninno, A. M. Beyer, K. B. Brown, C. T. Dopson, A. O. Enzerink, S. R. Goesmann, T. Higgins, N. Q. Knutzen, E. N. Laute, P. M. Long, P. L. Ottenfeld, A. T. Uehling, L. C. Ward, K. A. Maxson, E. N. Ratcliff, B. J. Lubinski, and E. J. Gittinger. 2020a. Following the edge of the flood: use of shallow-water habitat by larval silver carp Hypophthalmichthys molitrix in the upper Mississippi river system. Journal of Freshwater Ecology 35(1):95–104. Taylor & Francis.

Chick, J. H., D. K. Gibson-Reinemer, L. Soeken-Gittinger, and A. F. Casper. 2020b. Invasive silver carp is empirically linked to declines of native sport fish in the Upper Mississippi River System. Biological Invasions 22(2):723–734.

Clark, S. J., J. R. Jackson, and S. E. Lochmann. 2007. A Comparison of Shoreline Seines with Fyke Nets for Sampling Littoral Fish Communities in Floodplain Lakes. North American Journal of Fisheries Management 27(2):676–680.

Collins, S. F., M. J. Diana, S. E. Butler, and D. H. Wahl. 2017. A Comparison of Sampling Gears for Capturing Juvenile Silver Carp in River–Floodplain Ecosystems. North American Journal of Fisheries Management 37(1):94–100. Taylor & Francis.

Cooke, S. L. 2016. Anticipating the spread and ecological effects of invasive bigheaded carps (Hypophthalmichthys spp.) in North America: a review of modeling and other predictive studies. Biological Invasions 18(2):315–344.

Coulter, A. A., D. Keller, J. J. Amberg, E. J. Bailey, and R. R. Goforth. 2013. Phenotypic plasticity in the spawning traits of bigheaded carp (Hypophthalmichthys spp.) in novel ecosystems. Freshwater Biology 58(5):1029–1037.

Coulter, A. A., E. J. Bailey, D. Keller, and R. R. Goforth. 2016. Invasive Silver Carp movement patterns in the predominantly free-flowing Wabash River (Indiana, USA). Biological Invasions 18(2):471–485.

Coulter, A. A., D. Schultz, E. Tristano, M. K. Brey, and J. E. Garvey. 2017. Restoration Versus Invasive Species: Bigheaded Carps' Use of A Rehabilitated Backwater. River Research and Applications 33(5):662–669.

Coulter, A. A., M. K. Brey, M. Lubejko, J. L. Kallis, D. P. Coulter, D. C. Glover, G. W. Whitledge, and J. E. Garvey. 2018. Multistate models of bigheaded carps in the Illinois River reveal spatial dynamics of invasive species. Biological Invasions 20(11):3255–3270.

Coulter, D. P., P. Wang, A. A. Coulter, G. E. Van Susteren, J. J. Eichmiller, J. E. Garvey, and P. W. Sorensen. 2018. Nonlinear relationship between Silver Carp density and their eDNA concentration in a large river. PLoS ONE 14(6):1–16.

DeGrandchamp, K. L., J. E. Garvey, and L. A. Csoboth. 2007. Linking Adult Reproduction and Larval Density of Invasive Carp in a Large River. Transactions of the American Fisheries Society 136(5):1327–1334.

Deters, J. E., D. C. Chapman, and B. Mcelroy. 2013. Location and timing of Asian carp spawning in the Lower Missouri River. Environmental Biology of Fishes 96(5):617–629.

Dewitz, J. 2019. National Land Cover Database (NLCD) 2016 Products. U.S. Geological Survey data release.

Duan, X., S. Liu, M. Huang, S. Qiu, Z. Li, K. Wang, and D. Chen. 2009. Changes in abundance of larvae of the four domestic Chinese carps in the middle reach of the Yangtze River, China, before and after closing of the Three Gorges Dam. Environmental Biology of Fishes 86(1):13–22.

Dudgeon, D., A. H. Arthington, M. O. Gessner, Z. I. Kawabata, D. J. Knowler, C. Lévêque, R. J. Naiman, A. H. Prieur-Richard, D. Soto, M. L. J. Stiassny, and C. A. Sullivan. 2006. Freshwater biodiversity: Importance, threats, status and conservation challenges. Biological Reviews of the Cambridge Philosophical Society 81(2):163–182.

Dunham, J. B., B. S. Cade, and J. W. Terrell. 2002. Influences of Spatial and Temporal Variation on Fish-Habitat Relationships Defined by Regression Quantiles. Transactions of the American Fisheries Society 131(1):86–98.

Durham, B. W., and G. R. Wilde. 2008. Validation of Daily Growth Increment Formation in the Otoliths of Juvenile Cyprinid Fishes from the Brazos River, Texas. North American Journal of Fisheries Management 28(2):442–446.

Dyer, J. J., and S. K. Brewer. 2020. Seasonal movements and tributary-specific fidelity of blue sucker Cycleptus elongatus in a Southern Plains riverscape. Journal of Fish Biology 92(1):279–292.

Dzul, M. C., D. B. Gaines, J. R. Fischer, M. C. Quist, and S. J. Dinsmore. 2012. Evaluation of otoliths of Salt Creek pupfish (Cyprinodon salinus) for use in analyses of age and growth. Southwestern Naturalist 57(4):412–417. Southwestern Association of Naturalists.

Eggleton, M. A., J. R. Jackson, and B. J. Lubinski. 2010. Comparison of Gears for Sampling Littoral-Zone Fishes in Floodplain Lakes of the Lower White River, Arkansas. North American Journal of Fisheries Management 30(4):928–939.

Ericksen, R. (n.d.). Scale Aging Manual for Coastal Cutthroat Trout from Southeast Alaska. Alaska Department of Fish and Game 99(4):50.

Fago, D. 1998. Comparison of Littoral Fish Assemblages Sampled with a Mini-Fyke Net or with a Combination of Electrofishing and Small-Mesh Seine in Wisconsin Lakes. North American Journal of Fisheries Management 18(3):731–738.

Farrae, D. J., S. E. Albeke, K. Pacifici, N. P. Nibbelink, and D. L. Peterson. 2014. Assessing the influence of habitat quality on movements of the endangered shortnose sturgeon. Environmental Biology of Fishes 97(6):691–699.

Flotemersch, J. E., J. B. Stribling, and M. J. Paul. 2006. Concepts and approaches for the bioassessment of non-wadeable streams and rivers. Environmental Protection.

Freeze, M., and S. Henderson. 1982. Distribution and Status of the Bighead Carp and Silver Carp in Arkansas. North American Journal of Fisheries Management:197–200.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management 10(2):199–214.

Fukushima, M. 2001. Salmonid Habitat-Geomorphology Relationships in Low-Gradient Streams. Ecology 82(5):1238–1246.

Galat, D. L., G. W. Whitledge, and G. T. Gelwicks. 2004. Influence of lateral connectivity on larval fish assemblage structure and habitat use in lower Missouri River floodplain water bodies.

Garcia, T., E. A. Murphy, P. R. Jackson, and M. H. Garcia. 2015. Application of the FluEgg model to predict transport of Asian carp eggs in the Saint Joseph River (Great Lakes tributary). Journal of Great Lakes Research 41(2):374–386.

George, A. E., T. Garcia, B. H. Stahlschmidt, and D. C. Chapman. 2018. Ontogenetic changes in swimming speed of silver carp, bighead carp, and grass carp larvae: Implications for larval dispersal. PeerJ 2018(11):1–18.

Gibson-Reinemer, D. K., L. E. Solomon, R. M. Pendleton, J. H. Chick, and A. F. Casper. 2017. Hydrology controls recruitment of two invasive cyprinids: Bigheaded carp reproduction in a navigable large river. PeerJ 2017(9).

Gillette, D. P., J. S. Tiemann, D. R. Edds, and M. L. Wildhaber. 2006. Habitat use by a Midwestern U.S.A. riverine fish assemblage: effects of season, water temperature and river discharge. Journal of Fish Biology 68(5):1494–1512.

Glaus, G., R. Delunel, L. Stutenbecker, N. Akçar, M. Christl, and F. Schlunegger. 2019. Differential erosion and sediment fluxes in the Landquart basin and possible relationships to lithology and tectonic controls. Swiss Journal of Geosciences 112(2):453–473.

Gordon, N. D., T. A. McMahon, and B. L. Finlayson. 1992. Stream Hydrology: An Introduction for Ecologists. John Wiley & Sons, Ltd, Chichester, England.

Griffiths, D. 2018. Why does freshwater fish species richness differ between Pacific and Atlantic drainages of the Americas? Journal of Biogeography 45(4):784–792.

Hargrave, C. W., and C. M. Taylor. 2010. Spatial and Temporal Variation in Fishes of the Upper Red River Drainage (Oklahoma – Texas). The Southwestern Naturalist 55(2):149–159.

Humphries, P., R. A. Cook, A. J. Richardson, and L. G. Serafini. 2006. Creating a disturbance: manipulating slackwaters in a lowland river. River Research and Applications 22(5):525–542.

Hintz, W. D., D. C. Glover, B. C. Szynkowski, and J. E. Garvey. 2017. Spatiotemporal Reproduction and Larval Habitat Associations of Nonnative Silver Carp and Bighead Carp. Transactions of the American Fisheries Society 146(3):422–431. Taylor & Francis.

Horton, J.D., 2017, The State Geologic Map Compilation (SGMC) geodatabase of the conterminous United States (ver. 1.1, August 2017): U.S. Geological Survey data release, https://doi.org/10.5066/F7WH2N65.

Imhof, J. G., J. Fitzgibbon, and W. K. Annable. 1996. A hierarchical evaluation system for characterizing watershed ecosystems for fish habitat. Canadian Journal of Fisheries and Aquatic Sciences 53(SUPPL. 1):312–326.

Irons, K. S., G. G. Sass, M. A. McClelland, and T. M. O'Hara. 2011. Bigheaded carp invasion of the LaGrange reach of the Illinois River: insights from the long term resource monitoring program. American Fisheries Society Symposium: 74:31–50.

Irons, K. S., G. G. Sass, M. A. McClelland, and J. D. Stafford. 2007. Reduced condition factor of two native fish species coincident with invasion of non-native Asian carps in the Illinois River, U.S.A. Is this evidence for competition and reduced fitness? Journal of Fish Biology 71(SUPPL. D):258–273.

Johnson, R. K., and D. G. Angeler. 2014. Effects of agricultural land use on stream assemblages: Taxon-specific responses of alpha and beta diversity. Ecological Indicators 45:386–393.

Jurajda, P. 1999. Comparative nursery habitat use by 0+ fish in a modified lowland river. River Research and Applications 15(1–3):113–124.

Kelly, A., C. Engle, M. L. Armstrong, M. Freeze, and A. J. Mitchell. 2011. History of introductions and governmental involvement in promoting the use of grass, silver, and bighead carps. Invasive Asian Carps In North America:163–174.

Kolar, C. S., D. C. Chapman, W. R. Courtenay Jr., C. M. Housel, J. D. Williams, and D. P. Jennings. 2005. Asian Carps of the Genus Hypophthalmichthys (Pisces, Cyprinidae) -- A Biological Synopsis and Environmental Risk Assessment. Environmental Research (April):183.

Kolar, C. S., D. C. Chapman, W. R. Courtenay Jr., C. M. Housel, J. D. Williams, and D. P. Jennings. 2007. Bigheaded Carps: A Biological Synopsis and Environmental Risk Assesment. American Fisheries Society, Bethesda, Maryland.

Kuparinen, A., J. M. Cano, J. Loehr, G. Herczeg, A. Gonda, and J. Merila. 2011. Fish age at maturation is influenced by temperature independently of growth. Oecologia 167(2):435–444. Springer.

Lamouroux, N., H. Capra, and M. Pouilly. 1998. Predicting habitat suitability for lotic fish: linking statistical hydraulic models with multivariate habitat use models. Regulated Rivers: Research and Management 14(1):1–11.

Lazarus, E. D., and J. A. Constantine. 2013. Generic theory for channel sinuosity. Proceedings of the National Academy of Sciences of the United States of America 110(21):8447–8452.

Lohmeyer, A. M., and J. E. Garvey. 2009. Placing the North American invasion of Asian carp in a spatially explicit context. Biological Invasions 11(4):905–916.

Lombardi, P. M., F. L. Rodrigues, and J. P. Vieira. 2014. Longer is not always better: The influence of beach seine net haul distance on fish catchability. Zoologia 31(1):35–41.

Long, J. M., and T. M. Grabowski. 2017. Otoliths. Pages 189–219 *in* M. C. . Quist and D. A. Isermann, editors. Age and Growth of Fishes: Principals and Techniques. American Fisheries Society, Bethesda, Maryland.

Longing, S. D., and B. E. Haggard. 2010. Distributions of Median Nutrient and Chlorophyll Concentrations across the Red River Basin, USA. Journal of Environmental Quality 39(6):1966–74. American Society of Agronomy, Madison, United States.

Love, S. A., Q. E. Phelps, S. J. Tripp, and D. P. Herzog. 2017. The importance of shallow-low velocity habitats to juvenile fish in the middle Mississippi River. River Research and Applications 33:321–327.

Lovell, S. J., S. F. Stone, and L. Fernandez. 2006. The Economic Impacts of Aquatic Invasive Species: A Review of the Literature. Agricultural and Resource Economics Review 35(1):195–208. Cambridge University Press.

Matthews, W. J., and E. Marsh-Matthews. 2007. Extirpation of Red Shiner in Direct Tributaries of Lake Texoma (Oklahoma-Texas): A Cautionary Case History from a Fragmented River-Reservoir System. Transactions of the American Fisheries Society 136(4):1041–1062.

Maavara, T., C. T. Parsons, C. Ridenour, S. Stojanovic, H. H. Dürr, H. R. Powley, and P. Van Cappellen. 2015. Global phosphorus retention by river damming. Proceedings of the National Academy of Sciences of the United States of America 112(51):15603–15608. National Academy of Sciences.

MacNamara, R., D. Glover, J. Garvey, W. Bouska, and K. Irons. 2016. Bigheaded carps (Hypophthalmichthys spp.) at the edge of their invaded range: using hydroacoustics to assess population parameters and the efficacy of harvest as a control strategy in a large North American river. Biological Invasions 18(11):3293–3307.

McDowell, W. H., R. L. Brereton, F. N. Scatena, J. B. Shanley, N. V. Brokaw, and A. E. Lugo. 2013. Interactions between lithology and biology drive the long-term response of stream chemistry to major hurricanes in a tropical landscape. Biogeochemistry 116:175–186. Springer.

Minard, E. M., and Dye. March. Rainbow Trout Sampling and Aging Protocol. Alaska Department of Fish and Game 98(2):38.

Mollenhauer, R., D. Logue, and S. K. Brewer. 2018. Quantifying Seining Detection Probability for Fishes of Great Plains Sand-Bed Rivers. Transactions of the American Fisheries Society 147(2):329–341.

Mollenhauer, R., Y. Zhou, and S. K. Brewer. 2019. Multiscale Habitat Factors Explain Variability in Stream Fish Occurrence in the Ozark Highlands Ecoregion, USA. Copeia 107(2):219–231.

Nagayama, S., and F. Nakamura. 2018. The significance of meandering channel to habitat diversity and fish assemblage: a case study in the Shibetsu River, northern Japan. Limnology 19(1):7–20.

Neely, B. C., M. A. Pegg, and G. E. Mestl. 2009. Seasonal use distributions and migrations of blue sucker in the middle Missouri River. Ecology of Freshwater Fish 18(3):437–444.

Neiffer, D. L., and M. A. Stamper. 2009. Fish sedation, anesthesia, analgesia, and euthanasia: Considerations, methods, and types of drugs. ILAR Journal 50(4):343–360.

Newall, P. R., and J. J. Magnuson. 1999. The Importance of Ecoregion Versus Drainage Area on Fish Distributions in the St. Croix River and its Wisconsin Tributaries. Environmental Biology of Fishes 55(3):245–254.

Neves, L. do C., F. Cipriano, J. P. S. Lorenzini, K. S. de L. Cipriano, L. P. G. Junior, C. L. Nakayama, R. K. Luz, and K. C. M. Filho. 2019. Effects of salinity on sexual maturity and reproduction of Poecilia velifera. Aquaculture Research 50(10):2932–2937.

Nielsen, D. L., H. Gigney, and G. Watson. 2009. Riverine habitat heterogeneity: the role of slackwaters in providing hydrologic buffers for benthic microfauna. Hydrobiologia 638(1):181

Norman, J. D., and G. W. Whitledge. 2015. Recruitment sources of invasive Bighead carp (Hypopthalmichthys nobilis) and Silver carp (H. molitrix) inhabiting the Illinois River. Biological Invasions 17(10):2999–3014.

Osborne, L. L., and M. J. Wiley. 1992. Influence of Tributary Spatial Position on the Structure of Warmwater Fish Communities. Canadian Journal of Fisheries and Aquatic Sciences 49(4):671–681.

Oto, Y., M. Nakamura, H. Murakami, and R. Masuda. 2017. Inconsistency between salinity preference and habitat salinity in euryhaline gobiid fishes in the Isazu River, northern Kyoto Prefecture. Journal of Ethology 35(2):203–211.

Pinder, L. C. V., A. F. H. Marker, A. C. Pinder, J. K. G. Ingram, D. V. Leach, and G. D. Collett. 1997. Concentrations of suspended chlorophyll a in the Humber rivers. Science of The Total Environment 194–195:373–378.

Quist, M. C., J. S. Tillma, M. N. Burlingame, and C. S. Guy. 1999. Overwinter Habitat Use of Shovelnose Sturgeon in the Kansas River. Transactions of the American Fisheries Society (128):522–527.

Quist, M. C., and C. S. Guy. 2001. Growth and mortality of prairie stream fishes: relations with fish community and instream habitat characteristics. Ecology of Freshwater Fish 10(2):88–96.

Quist, M. C., C. S. Guy, R. J. Bernot, and J. L. Stephen. 2004a. Factors related to growth and survival of larval walleyes: implications for recruitment in a southern Great Plains reservoir. Fisheries Research 67(2):215–225.

Quist, M. C., W. A. Hubert, and D. J. Isaak. 2004b. Fish assemblage structure and relations with environmental conditions in a Rocky Mountain watershed. Canadian Journal of Zoology 82(10):1554–1565. Canadian Science Publishing NRC Research Press, Ottawa, Canada.

Quist. M. C. and Isermann, D. A., editors. 2017. Age and growth of fishes: principles and techniques. American Fisheries Society, Bethesda, Maryland.

Raikow, D. F., O. Sarnelle, A. E. Wilson, and S. K. Hamilton. 2004. Dominance of the noxious cyanobacterium Microcystis aeruginosa in low-nutrient lakes is associated with exotic zebra mussels. Limnology and Oceanography 49(2):482–487.

Reichert, J. M., B. J. Fryer, K. L. Pangle, T. B. Johnson, J. T. Tyson, A. B. Drelich, and S. A. Ludsin. 2010. River-plume use during the pelagic larval stage benefits recruitment of a lentic fish. Canadian Journal of Fisheries and Aquatic Sciences 67(6):987–1004.

Reid, A. J., A. K. Carlson, I. F. Creed, E. J. Eliason, P. A. Gell, P. T. J. Johnson, K. A. Kidd, T. J. MacCormack, J. D. Olden, S. J. Ormerod, J. P. Smol, W. W. Taylor, K. Tockner, J. C. Vermaire, D. Dudgeon, and S. J. Cooke. 2019. Emerging threats and persistent conservation challenges for freshwater biodiversity. Biological Reviews 94(3):849–873.

Rolls, R. J., I. O. Growns, T. A. Khan, G. G. Wilson, T. L. Ellison, A. Prior, and C. C. Waring. 2013. Fish recruitment in rivers with modified discharge depends on the interacting effects of flow and thermal regimes. Freshwater Biology 58(9):1804–1819.

Roth, D. R., J. J. Pesik, E. L. Effert-Fanta, D. H. Wahl, and R. E. Colombo. 2020. Comparison of Active and Passive Larval Sampling Gears in Monitoring Reproduction of Invasive Bigheaded Carps in Large-River Tributaries. North American Journal of Fisheries Management.

Rowe, D. C., C. L. Pierce, and T. F. Wilton. 2009. Physical Habitat and Fish Assemblage Relationships with Landscape Variables at Multiple Spatial Scales in Wadeable Iowa Streams. North American Journal of Fisheries Management 29(5):1333–1351.

Sampson, S. J., J. H. Chick, and M. A. Pegg. 2009. Diet overlap among two Asian carp and three native fishes in backwater lakes on the Illinois and Mississippi rivers. Biological Invasions 11(3):483–496.

Sarkar, D., R. Datta, R. Hannigan, and R. Hannigan. 2007. Concepts and Applications in Environmental Geochemistry. Elsevier Science & Technology, Oxford, UNITED KINGDOM.

Sass, G. G., C. Hinz, A. C. Erickson, N. N. McClelland, M. A. McClelland, and J. M. Epifanio. 2014. Invasive bighead and silver carp effects on zooplankton communities in the Illinois River, Illinois, USA. Journal of Great Lakes Research 40(4):911–921.

Schrank, S. J., P. J. Braaten, and C. S. Guy. 2001. Spatiotemporal Variation in Density of Larval Bighead Carp in the Lower Missouri River. Transactions of the American Fisheries Society 130(5):809–814.

Schrank, S. J., C. S. Guy, and J. F. Fairchild. 2003. Competitive Interactions between Age-0 Bighead Carp and Paddlefish. Transactions of the American Fisheries Society 132(6):1222–1228. Taylor & Francis.

Schwartz, J. S., and E. E. Herricks. 2005. Fish use of stage-specific fluvial habitats as refuge patches during a flood in a low-gradient Illinois stream. Canadian Journal of Fisheries and Aquatic Sciences 62(7):1540–1552.

Scrimgeour, G. J., P. J. Hvenegaard, and J. Tchir. 2008. Cumulative Industrial Activity Alters Lotic Fish Assemblages in Two Boreal Forest Watersheds of Alberta, Canada. Environmental Management 42(6):957–970.

Seibert, J. R., and Q. E. Phelps. 2013. Evaluation of Aging Structures for Silver Carp from Midwestern U.S. Rivers. North American Journal of Fisheries Management 33(4):839–844.

Sloat, M. R., and A.-M. K. Osterback. 2013. Maximum stream temperature and the occurrence, abundance, and behavior of steelhead trout (Oncorhynchus mykiss) in a southern California stream. Canadian Journal of Fisheries and Aquatic Sciences 70(1):64–74. NRC Research Press.

Sloat, M. R., B. B. Shepard, R. G. White, and S. Carson. 2005. Influence of Stream Temperature on the Spatial Distribution of Westslope Cutthroat Trout Growth Potential within the Madison River Basin, Montana. North American Journal of Fisheries Management 25(1):225–237.

Spacapan, M. M., J. F. Besek, G. G. Sass, and M. R. Ryan. 2016. Perceived Influence and Response of River Users to Invasive Bighead and Silver Carp in the Illinois River.

Stevenson, R. J. 1997. Scale-dependent determinants and consequences of benthic algal heterogeneity. Journal of the North American Benthological Society 16(1):248–262.

Sullivan, C. J., M. J. Weber, C. L. Pierce, D. H. Wahl, Q. E. Phelps, and R. E. Colombo. 2021. Spatial variation in invasive silver carp population ecology throughout the upper Mississippi River basin*. Ecology of Freshwater Fish 30(3):375–390.

Thomson, J. R., M. P. Taylor, K. A. Fryirs, and G. J. Brierley. 2001. A geomorphological framework for river characterization and habitat assessment. Aquatic Conservation: Marine and Freshwater Ecosystems 11(5):373–389.

Tsehaye, I., M. Catalano, G. Sass, D. Glover, and B. Roth. 2013. Prospects for Fishery-Induced Collapse of Invasive Asian Carp in the Illinois River. Fisheries 38(10):445–454.

U.S. Geological Survey. 2016. National Water Information System data available on the World Wide Web (USGS Water Data for the Nation).

U.S. Geological Survey. 2017. National Hydrography Dataset Plus (NHDPlus) - USGS National Map Downloadable Data Collection.

Valdez, R. A., T. L. Hoffnagle, C. C. McIvor, T. McKinney, and W. C. Leibfried. 2001. Effects of a Test Flood on Fishes of the Colorado River in Grand Canyon, Arizona. Ecological Applications 11(3):686–700. Ecological Society of America.

Vetter, B. J., A. R. Cupp, K. T. Fredricks, M. P. Gaikowski, and A. F. Mensinger. 2015. Acoustical deterrence of Silver Carp (Hypophthalmichthys molitrix). Biological Invasions 17(12):3383–3392. Springer International Publishing.

Vietz, G. J., M. J. Sammonds, and M. J. Stewardson. 2013. Impacts of flow regulation on slackwaters in river channels. Water Resources Research 49(4):1797–1811.

Wang, L., T. Brenden, P. Seelbach, A. Cooper, D. Allan, R. Clark, and M. Wiley. 2008. Landscape Based Identification of Human Disturbance Gradients and Reference Conditions for Michigan Streams. Environmental Monitoring and Assessment 141(1):1–17.

Wang, L., D. Infante, J. Lyons, J. Stewart, and A. Cooper. 2011. Effects of dams in river networks on fish assemblages in non-impoundment sections of rivers in Michigan and Wisconsin, USA. River Research and Applications 27(4):473–487.

Wanner, G. a., and R. a. Klumb. 2009. Asian Carp in the Missouri River: analysis from multiple Missouri River habitat and fisheries programs. National Invasive Species Countil materials Paper 10.

Weisberg, S., G. Spangler, and L. S. Richmond. 2010. Mixed effects models for fish growth. Canadian Journal of Fisheries and Aquatic Sciences 67(2):269–278. NRC Research Press.

Williams, J. A. 2020. Age-0 Silver Carp Otolith Microchemistry and Microstructure Reveals Multiple Early-Life Environments And Protracted Spawning in the Upper Mississippi River. Western Illinois University, Macomb, Illinois, USA.

Williamson, C. J., and J. E. Garvey. 2005. Growth, Fecundity, and Diets of Newly Established Silver Carp in the Middle Mississippi River. Transactions of the American Fisheries Society 134(6):1423–1430. Taylor & Francis.

Work, K., K. Codner, and M. Gibbs. 2017. How could discharge management affect Florida spring fish assemblage structure? Journal of Environmental Management 198:266–276.

Zamor, R. M., and G. D. Grossman. 2007. Turbidity Affects Foraging Success of Drift-Feeding Rosyside Dace. Transactions of the American Fisheries Society 136(1):167–176.

Zeng, F.-W., C. A. Masiello, and W. C. Hockaday. 2011. Controls on the origin and cycling of riverine dissolved inorganic carbon in the Brazos River, Texas. Biogeochemistry 104(1/3):275–291. Springer.

Table 1. Surveys conducted with the river, date, target life stage, state, latitude, and longitude for sampling that occurred in the mainstem of the Red River. The latitude and longitude were measured at the most downstream portion of each site.

River	Date	Stage	State	Latitude	Longitude
Red River	5/23/2021	Adult	OK	33.75426	-96.41081
Red River	5/24/2021	Adult	OK	33.85966	-95.0235
Red River	5/25/2021	Adult	OK	33.68924	-94.68239
Red River	6/29/2021	Adult	AR	33.55708	-94.04868
Red River	6/30/2021	Adult	OK	33.88111	-95.50545
Red River	7/1/2021	Adult	OK	33.86761	-95.03386
Red River	7/5/2021	Adult	AR	33.60915	-93.8242
Red River	7/8/2021	Adult	OK	33.89959	-95.06521
Red River	7/9/2021	Adult	AR	33.56842	-94.38122
Red River	7/12/2021	Adult	AR	33.58881	-94.37804
Red River	7/13/2021	Adult	AR	33.43524	-93.73965
Red River	7/13/2021	Adult	AR	33.09082	-93.85964
Red River	7/16/2021	Adult	OK	33.65393	-94.56868
Red River	7/18/2021	Adult	AR	33.5515	-94.39453
Red River	7/20/2021	Adult	OK	33.71146	-94.73273
Red River	7/26/2021	Adult	OK	33.87724	-95.48534
Red River	7/29/2021	Adult	OK	33.65393	-94.56868
Red River	8/4/2021	Adult	AR	33.58881	-94.37804
Red River	8/5/2021	Adult	OK	33.90802	-95.06658
Red River	8/9/2021	Adult	OK	33.81967	-96.55652
Red River	8/10/2021	Adult	OK	33.71665	-96.36472
Red River	8/16/2021	Adult	OK	33.66246	-94.64803
Red River	8/18/2021	Adult	AR	33.60932	-93.85986
Red River	8/23/2021	Adult	OK	33.80257	-94.9285
Red River	8/24/2021	Adult	AR	33.56842	-94.38122
Red River	8/26/2021	Adult	OK	33.64846	-94.54315
Red River	8/27/2021	Adult	OK	33.87724	-95.48534
Red River	8/30/2021	Adult	AR	33.06602	-93.83293
Red River	8/31/2021	Adult	AR	33.39703	-93.71171
Red River	9/1/2021	Adult	AR	33.1568	-93.81832
Red River	9/2/2021	Adult	AR	33.60915	-93.8242
Red River	9/7/2021	Adult	OK	33.95053	-95.24028
Red River	9/8/2021	Adult	OK	33.8897	-95.52022
Red River	9/17/2021	Adult	OK	33.71146	-94.73273

Red River	9/21/2021	Adult	AR	33.58881	-94.37804
Red River	9/22/2021	Adult	AR	33.5515	-94.39453
Red River	10/4/2021	Adult	AR	33.57537	-94.08128
Red River	10/5/2021	Adult	AR	33.55708	-94.04868
Red River	10/6/2021	Adult	AR	33.60932	-93.85986
Red River	10/7/2021	Adult	OK	33.66246	-94.64803
Red River	10/8/2021	Adult	AR	33.39703	-93.71171
Red River	10/11/2021	Adult	AR	33.5998	-94.44686
Red River	10/14/2021	Adult	OK	33.64846	-94.54315
Red River	10/20/2021	Adult	OK	33.87724	-95.48534
Red River	10/21/2021	Adult	AR	33.43524	-93.73965
Red River	11/1/2021	Adult	AR	33.5515	-94.39453
Red River	11/2/2021	Adult	AR	33.07597	-93.8387
Red River	11/8/2021	Adult	AR	33.55708	-94.04868
Red River	11/9/2021	Adult	OK	33.69385	-94.71692
Red River	11/11/2021	Adult	AR	33.60915	-93.8242
Red River	11/15/2021	Adult	AR	33.5515	-94.39453
Red River	11/30/2021	Adult	OK	33.64846	-94.54315
Red River	12/1/2021	Adult	AR	33.39703	-93.71171
Red River	12/6/2021	Adult	AR	33.60932	-93.85986
Red River	12/7/2021	Adult	AR	33.59526	-94.42342
Red River	12/8/2021	Adult	AR	33.09082	-93.85964
Red River	12/9/2021	Adult	OK	33.88111	-95.50545
Red River	12/13/2021	Adult	OK	33.76464	-96.41476
Red River	12/14/2021	Adult	AR	33.55226	-94.04026
Red River	12/16/2021	Adult	AR	33.55718	-94.0195
Red River	1/6/2022	Adult	AR	33.07597	-93.8387
Red River	1/10/2022	Adult	AR	33.39703	-93.71171
Red River	1/11/2022	Adult	AR	33.5515	-94.39453
Red River	1/12/2022	Adult	AR	33.58881	-94.37804
Red River	1/18/2022	Adult	AR	33.34793	-93.71021
Red River	1/24/2022	Adult	OK	33.87724	-95.48534
Red River	1/31/2022	Adult	AR	33.60915	-93.8242
Red River	2/1/2022	Adult	AR	33.59526	-94.42342
Red River	2/2/2022	Adult	OK	33.88111	-95.50545
Red River	2/7/2022	Adult	OK	33.61833	-94.55481
Red River	2/8/2022	Adult	OK	33.77695	-96.42174
Red River	2/14/2022	Adult	OK	33.64846	-94.54315
Red River	2/16/2022	Adult	OK	33.95053	-95.24028
Red River	2/18/2022	Adult	OK	33.87724	-95.48534
Red River	2/23/2022	Adult	OK	33.61833	-94.55481

Red River	3/1/2022	Adult	OK	33.75426	-96.41081
Red River	3/3/2022	Adult	OK	33.88111	-95.50545
Red River	3/7/2022	Adult	OK	33.71146	-94.73273
Red River	3/8/2022	Adult	OK	33.66246	-94.64803
Red River	3/9/2022	Adult	OK	33.64846	-94.54315
Red River	3/15/2022	Adult	AR	33.56842	-94.38122
Red River	3/22/2022	Adult	AR	33.59526	-94.42342
Red River	3/23/2022	Adult	AR	33.58881	-94.37804
Red River	3/24/2022	Adult	AR	33.56842	-94.38122
Red River	3/29/2022	Adult	AR	33.55718	-94.0195
Red River	3/31/2022	Adult	AR	33.07597	-93.8387
Red River	4/1/2022	Adult	AR	33.39703	-93.71171
Red River	4/4/2022	Adult	AR	33.60915	-93.8242
Red River	4/5/2022	Adult	AR	33.5515	-94.39453
Red River	4/6/2022	Adult	AR	33.34793	-93.71021
Red River	4/7/2022	Adult	OK	33.65393	-94.56868
Red River	4/11/2022	Adult	AR	33.5998	-94.44686
Red River	4/12/2022	Adult	AR	33.09082	-93.85964
Red River	4/19/2022	Adult	OK	33.88111	-95.50545
Red River	4/21/2022	Adult	OK	33.95053	-95.24028
Red River	4/25/2022	Adult	AR	33.55708	-94.04868
Red River	4/26/2022	Adult	AR	33.57537	-94.08128
Red River	4/29/2022	Adult	AR	33.58881	-94.37804
Red River	5/2/2022	Adult	AR	33.06602	-93.83293
Red River	5/3/2022	Adult	OK	33.65393	-94.56868
Red River	5/4/2022	Adult	OK	33.80257	-94.9285
Red River	5/6/2022	Adult	AR	33.5515	-94.39453
Red River	5/11/2022	Adult	AR	33.14741	-93.83134
Red River	5/12/2022	Adult	AR	33.13784	-93.82909
Red River	5/13/2022	Adult	OK	33.90802	-95.06658
Red River	5/17/2022	Adult	OK	33.66246	-94.64803
Red River	5/18/2022	Adult	OK	33.64846	-94.54315
Red River	5/23/2022	Adult	AR	33.14741	-93.83134
Red River	5/27/2022	Adult	AR	33.09082	-93.85964
Red River	5/28/2022	Adult	AR	33.58881	-94.37804
Red River	6/5/2022	Adult	AR	33.55708	-94.04868
Red River	6/6/2022	Adult	OK	33.80257	-94.9285
Red River	6/7/2022	Adult	AR	33.57537	-94.08128
Red River	6/8/2022	Adult	AR	33.60915	-93.8242
Red River	6/9/2022	Adult	AR	33.39703	-93.71171
Red River	6/13/2022	Adult	AR	33.13784	-93.82909

Red River	6/15/2022	Adult	AR	33.5998	-94.44686
Red River	6/16/2022	Adult	OK	33.65393	-94.56868
Red River	6/17/2022	Adult	AR	33.34793	-93.71021
Red River	6/20/2022	Adult	OK	33.88111	-95.50545
Red River	6/21/2022	Adult	AR	33.58881	-94.37804
Red River	6/23/2022	Adult	OK	33.95053	-95.24028
Red River	6/24/2022	Adult	OK	33.90802	-95.06658
Red River	6/27/2022	Adult	OK	33.66246	-94.64803
Red River	6/30/2022	Adult	OK	33.87724	-95.48534
Red River	5/21/21	Age-0	OK	33.87013	-95.04429
Red River	5/21/21	Age-0	OK	33.86112	-95.03146
Red River	5/23/21	Age-0	OK	33.74709	-96.40119
Red River	5/24/21	Age-0	OK	33.8201	-95.04424
Red River	5/24/21	Age-0	OK	33.86019	-95.005002
Red River	5/25/21	Age-0	OK	33.69325	-94.65464
Red River	6/29/21	Age-0	AR	33.58209	-94.06972
Red River	6/29/21	Age-0	AR	33.57293	-94.06393
Red River	6/30/21	Age-0	OK	33.89479	-95.51753
Red River	6/30/21	Age-0	OK	33.89701	-95.50625
Red River	7/1/21	Age-0	OK	33.86821	-95.04794
Red River	7/1/21	Age-0	OK	33.86411	-95.03178
Red River	7/3/21	Age-0	OK	33.71037	-94.73074
Red River	7/5/21	Age-0	AR	33.60696	-93.84081
Red River	7/5/21	Age-0	AR	33.61398	-93.81815
Red River	7/6/21	Age-0	OK	33.96144	-95.22825
Red River	7/6/21	Age-0	OK	33.9551045	-95.230929
Red River	7/7/21	Age-0	OK	33.85587	-95.86673
Red River	7/7/21	Age-0	OK	33.85098	-95.85825
Red River	7/8/21	Age-0	OK	33.91925	-95.0779
Red River	7/9/21	Age-0	AR	33.56543	-94.38145
Red River	7/10/21	Age-0	OK	33.66207	-94.64456
Red River	7/11/21	Age-0	OK	33.72306	-94.78044
Red River	7/12/21	Age-0	AR	33.58073	-94.36604
Red River	7/13/21	Age-0	AR	33.43079	-93.7422
Red River	7/14/21	Age-0	AR	33.09698	-93.85526
Red River	7/16/21	Age-0	OK	33.65722	-94.56345
Red River	7/18/21	Age-0	AR	33.549957	-94.31302
Red River	7/20/21	Age-0	OK	33.71098	-94.73068
Red River	7/21/21	Age-0	AR	33.58427	-94.4208
Red River	7/21/21	Age-0	AR	33.58951	-94.44394
Red River	7/21/21	Age-0	AR	33.59219	-94.4448

Red River	7/22/21	Age-0	OK	33.84723	-96.07549
Red River	7/26/21	Age-0	OK	33.8885	-95.46908
Red River	7/26/21	Age-0	OK	33.8775	-95.48549
Red River	7/29/21	Age-0	OK	33.64172	-94.55186
Red River	7/29/21	Age-0	OK	33.65556	-94.5419
Red River	7/31/21	Age-0	OK	33.71037	-94.73074
Red River	8/4/21	Age-0	AR	33.56526	-94.3829
Red River	8/5/21	Age-0	OK	33.91751	-95.0818
Red River	8/9/21	Age-0	AR	33.07613	-93.83746
Red River	8/9/21	Age-0	AR	33.06145	-93.82997
Red River	8/10/21	Age-0	AR	33.10633	-93.86211
Red River	8/10/21	Age-0	AR	33.14479	-93.84147
Red River	8/12/21	Age-0	AR	33.39787	-93.7123
Red River	8/12/21	Age-0	AR	33.394423	-93.71021
Red River	8/13/21	Age-0	AR	33.61343	-93.82169
Red River	8/13/21	Age-0	AR	33.55794	-93.79581
Red River	8/16/21	Age-0	OK	33.66207	-94.64456
Red River	8/18/21	Age-0	AR	33.60696	-93.84081
Red River	8/24/21	Age-0	AR	33.58073	-94.36604
Red River	8/26/21	Age-0	OK	33.65556	-94.5419
Red River	8/27/21	Age-0	OK	33.8775	-95.48549
Red River	8/30/21	Age-0	AR	33.06145	-93.82997
Red River	8/31/21	Age-0	AR	33.39787	-93.7123
Red River	9/1/21	Age-0	AR	33.15117	-93.82481
Red River	9/2/21	Age-0	AR	33.61343	-93.82169
Red River	9/7/21	Age-0	OK	33.96144	-95.22825
Red River	9/8/21	Age-0	OK	33.89479	-95.51753
Red River	9/17/21	Age-0	OK	33.71037	-94.73074
Red River	9/20/21	Age-0	OK	33.84723	-96.07549
Red River	9/21/21	Age-0	AR	33.56526	-94.3829
Red River	9/22/21	Age-0	AR	33.549957	-94.31302
Red River	10/4/21	Age-0	AR	33.58209	-94.06972
Red River	10/5/21	Age-0	AR	33.57293	-94.06393
Red River	10/6/21	Age-0	AR	33.60696	-93.84081
Red River	10/7/21	Age-0	OK	33.66207	-94.64456
Red River	10/8/21	Age-0	AR	33.39787	-93.7123
Red River	10/11/21	Age-0	AR	33.58951	-94.44394
Red River	10/13/21	Age-0	OK	33.65556	-94.5419
Red River	10/20/21	Age-0	OK	33.8775	-95.48549
Red River	10/21/21	Age-0	AR	33.43079	-93.7422
Red River	11/1/21	Age-0	AR	33.54755	-94.39191

Red River	11/2/21	Age-0	AR	33.07613	-93.83746
Red River	11/8/21	Age-0	AR	33.57293	-94.06393
Red River	11/9/21	Age-0	OK	33.6891	-94.71021
Red River	11/11/21	Age-0	AR	33.61398	-93.81815
Red River	11/15/21	Age-0	AR	33.54755	-94.39191
Red River	11/30/21	Age-0	OK	33.65556	-94.5419
Red River	12/1/21	Age-0	AR	33.394423	-93.71021
Red River	5/23/22	Age-0	AR	33.09698	-93.85526
Red River	5/23/22	Age-0	AR	33.1014	-93.85952
Red River	5/26/22	Age-0	AR	33.394423	-93.71021
Red River	5/26/22	Age-0	AR	33.39787	-93.7123
Red River	5/27/22	Age-0	AR	33.60468	-93.83881
Red River	5/27/22	Age-0	AR	33.61374	-93.8195
Red River	5/28/22	Age-0	OK	33.88944	-95.46395
Red River	5/28/22	Age-0	OK	33.8775	-95.48549
Red River	5/29/22	Age-0	AR	33.56572	-94.38213
Red River	5/29/22	Age-0	AR	33.57875	-94.36662
Red River	6/4/22	Age-0	OK	33.75796	-96.41139
Red River	6/4/22	Age-0	OK	33.7517	-96.40832
Red River	6/6/22	Age-0	OK	33.86875	-95.04412
Red River	6/6/22	Age-0	OK	33.86764	-95.03414
Red River	6/7/22	Age-0	AR	33.07613	-93.83746
Red River	6/7/22	Age-0	AR	33.05964	-93.82763
Red River	6/8/22	Age-0	AR	33.39787	-93.7123
Red River	6/8/22	Age-0	AR	33.39442	-93.71021
Red River	6/9/22	Age-0	AR	33.61374	-93.8195
Red River	6/9/22	Age-0	AR	33.60468	-93.83881
Red River	6/11/22	Age-0	OK	33.71037	-94.73074
Red River	6/11/22	Age-0	OK	33.68483	-94.70619
Red River	6/14/22	Age-0	AR	33.58951	-94.44394
Red River	6/14/22	Age-0	AR	33.59219	-94.4448
Red River	6/15/22	Age-0	AR	33.58209	-94.06972
Red River	6/15/22	Age-0	AR	33.57043	-94.06522
Red River	6/16/22	Age-0	OK	33.58209	-94.06972
Red River	6/16/22	Age-0	OK	33.57043	-94.06522
Red River	6/17/22	Age-0	AR	33.39787	-93.7123
Red River	6/17/22	Age-0	AR	33.39442	-93.71021
Red River	6/20/22	Age-0	OK	33.88862	-95.55178
Red River	6/20/22	Age-0	OK	33.89679	-95.51546
Red River	6/23/22	Age-0	AR	33.07613	-93.83746
Red River	6/23/22	Age-0	AR	33.05964	-93.82763

Red River	6/24/22	Age-0	AR	33.55794	-93.79581
Red River	6/24/22	Age-0	AR	33.56409	-93.81904
Red River	6/25/22	Age-0	OK	33.91751	-95.0818
Red River	6/27/22	Age-0	OK	33.66446	-94.64451
Red River	6/27/22	Age-0	OK	33.68948	-94.647
Red River	6/29/22	Age-0	OK	33.86875	-95.04412
Red River	6/29/22	Age-0	OK	33.86764	-95.03414
Red River	6/30/22	Age-0	OK	33.75796	-96.41139
Red River	6/30/22	Age-0	OK	33.7517	-96.40832

Table 2. Site locations (latitude [Lat], longitude [Long]), sample dates, target life stage, and state for sampling that occurred in the tributaries of the lower Red River basin. The latitude and longitude were measured at the most downstream portion of each site. Repeat sampling events occurred at these sites within the same seasons. We include the Texas tributaries of the Red River as they are fish within the same population as Oklahoma Red River fishes.

River	Date	Stage	State	Latitude	Longitude
Blue River	7/30/2021	Adult	OK	33.88604	-95.93205
Blue River	12/2/2021	Age-0	OK	33.88968	-96.03165
Blue River	6/1/2022	Age-0	OK	33.88968	-96.03165
Blue River	6/21/2022	Age-0	OK	33.88968	-96.03165
Blue River	7/25/2021	Age-0	OK	33.88968	-96.03165
Blue River	7/30/2021	Age-0	OK	33.88672	-95.93274
Bois d’Arc Creek	6/13/2022	Age-0	TX	33.82604	-95.85771
Bois d’Arc Creek	6/28/2022	Age-0	TX	33.83860	-95.84394
Bois d’Arc Creek	6/28/2022	Age-0	TX	33.82376	-95.86087
Bois d’Arc Creek	6/5/2022	Age-0	TX	33.8386	-95.84394
Bois d'Arc	7/7/2021	Adult	TX	33.83864	-95.84481
Bois d'Arc	7/23/2021	Adult	TX	33.83864	-95.84481
Bois d'Arc Creek	7/23/2021	Age-0	TX	33.83904	-95.84554
Buzzard Creek	5/9/2022	Adult	OK	33.90033	-95.05406
Buzzard Creek	6/29/2022	Adult	OK	33.90033	-95.05406
Choctaw	8/10/2021	Adult	TX	33.72021	-96.37333
Choctaw	8/11/2021	Adult	TX	33.72223	-96.41024
Choctaw	11/16/2021	Adult	TX	33.72021	-96.37333
Choctaw	11/17/2021	Adult	TX	33.72223	-96.41024
Choctaw	12/15/2021	Adult	TX	33.72223	-96.41024
Choctaw	12/15/2021	Adult	TX	33.72021	-96.37333
Choctaw	2/22/2022	Adult	TX	33.72021	-96.37333
Choctaw	3/2/2022	Adult	TX	33.72223	-96.41024
Choctaw	4/13/2022	Adult	TX	33.72021	-96.37333
Choctaw	6/3/2022	Adult	TX	33.72223	-96.41024
Choctaw	6/4/2022	Adult	TX	33.72021	-96.37333
Choctaw	6/22/2022	Adult	TX	33.72223	-96.41024
Choctaw Creek	6/19/2022	Age-0	TX	33.71934	-96.37152
Choctaw Creek	6/19/2022	Age-0	TX	33.72056	-96.39847
Choctaw Creek	6/3/2022	Age-0	TX	33.71934	-96.37152
Choctaw Creek	6/3/2022	Age-0	TX	33.72056	-96.39847
Cutoff 41	5/26/2021	Adult	OK	33.75583	-94.77789

Garland Creek	5/16/2022	Adult	OK	33.92473	-95.08337
Garland Creek	6/24/2022	Adult	OK	33.92473	-95.08337
Garland Creek	6/25/22	Age-0	OK	33.92132	-95.07783
Kiamichi	5/20/2021	Adult	OK	33.99742	-95.3722
Kiamichi	5/22/2021	Adult	OK	33.98678	-95.3671
Kiamichi	7/6/2021	Adult	OK	33.95071	-95.24384
Kiamichi	7/15/2021	Adult	OK	33.94832	-95.29562
Kiamichi	8/13/2021	Adult	OK	33.99742	-95.3722
Kiamichi	10/18/2021	Adult	OK	33.99742	-95.3722
Kiamichi	10/19/2021	Adult	OK	33.95071	-95.24384
Kiamichi	11/18/2021	Adult	OK	33.99742	-95.3722
Kiamichi	11/29/2021	Adult	OK	33.94832	-95.29562
Kiamichi	1/19/2022	Adult	OK	33.99742	-95.3722
Kiamichi	2/10/2022	Adult	OK	33.95071	-95.24384
Kiamichi	2/15/2022	Adult	OK	33.94832	-95.29562
Kiamichi	2/21/2022	Adult	OK	33.99742	-95.3722
Kiamichi	4/18/2022	Adult	OK	33.99742	-95.3722
Kiamichi	5/25/2022	Adult	OK	33.99742	-95.3722
Kiamichi	5/26/2022	Adult	OK	33.95071	-95.24384
Kiamichi	6/23/2022	Adult	OK	33.95071	-95.24384
Kiamichi	10/18/2021	Age-0	OK	33.99847	-95.37379
Kiamichi	10/19/2021	Age-0	OK	33.95063	-95.24294
Kiamichi	11/18/2021	Age-0	OK	33.99847	-95.37379
Kiamichi	11/29/2021	Age-0	OK	33.94789	-95.29356
Kiamichi	5/20/2021	Age-0	OK	33.99847	-95.37379
Kiamichi	5/22/2021	Age-0	OK	33.97406	-95.3653
Kiamichi	5/25/2022	Age-0	OK	33.99781	-95.37130
Kiamichi	6/18/2022	Age-0	OK	33.95360	-95.29409
Kiamichi	6/18/2022	Age-0	OK	33.94789	-95.29356
Kiamichi	7/15/2021	Age-0	OK	33.94789	-95.29356
Kiamichi	7/31/2021	Age-0	OK	33.95063	-95.24294
Muddy Boggy	7/2/2021	Adult	OK	33.94339	-95.60174
Muddy Boggy	7/27/2021	Adult	OK	33.93557	-95.63493
Muddy Boggy	7/28/2021	Adult	OK	33.92844	-95.65096
Muddy Boggy	5/31/2022	Adult	OK	33.92844	-95.65096
Muddy Boggy	6/1/2022	Adult	OK	33.93833	-95.60911
Muddy Boggy	5/31/2022	Age-0	OK	33.93026	-95.65183
Muddy Boggy	5/31/2022	Age-0	OK	33.93462	-95.63018
Muddy Boggy	6/22/2022	Age-0	OK	33.94197	-95.59824
Muddy Boggy	6/22/2022	Age-0	OK	33.93462	-95.63018
Muddy Boggy	7/2/2021	Age-0	OK	33.94364	-95.59466

Muddy Boggy	7/27/2021	Age-0	OK	33.94197	-95.59824
Muddy Boggy	7/28/2021	Age-0	OK	33.93462	-95.63018
Muddy Boggy	7/28/2021	Age-0	OK	33.93026	-95.65183
Pine Creek	8/3/2021	Adult	TX	33.86477	-95.30788
Pine Creek	6/14/2022	Adult	TX	33.86477	-95.30788
Pine Creek	6/28/2022	Adult	TX	33.86477	-95.30788
Pine Creek	8/3/2021	Age-0	TX	33.87271	-95.30436

Table 3. The dimensions of each sampling net with the target life-history stage indicated.

Gear	Length	Height	Mesh size	Target stage
Gillnet	100’	12’	3.5”, 4”, 4.25”	Adult
Gillnet	180’	12’	3.5”, 4”, 4.25”	Adult
Hoop net	16’	4’	3”	Adult
Seine	15’	6’	1/8”	Age-0
Seine	11’	6’	1/32”	Age-0
Mini-fyke net	4’	2’	1/8”	Age-0
Larval tow	1.65m	0.5m	500µm	Age-0

Table 4. Field-collected environmental variables for detection modeling of age-0 and small-bodied native and invasive fishes of the lower Red River basin.

Scale	Covariate	Unit	Gear
Reach	Temperature	°C	YSI Pro DSS
Reach	Dissolved oxygen	mg/L	YSI Pro DSS
Reach	Clarity	cm	Secchi Disk
Segment	Discharge	m^3/s	USGS Stream Gauge

Table 5. Field-collected environmental variables for relating to occupancy of age-0 and small-bodied native and invasive fishes of the lower Red River basin.

Scale	Covariate	Unit	Gear
Reach	Salinity	ppt	YSI Pro DSS
Reach	Average depth	m	Humminbird Helix 12
Reach	W:D	m	Range
Reach	Zooplankton biomass	µg	Planktonic Net
Reach	Large woody debris	%	Humminbird Helix 12
Reach	Backwater	%	Rangefinder
Reach	Pools	%	Humminbird Helix 12
Segment	Discharge	m^3/s	USGS Stream Gauge

Table 6. Environmental variables, their sources, and associated web links for relating to age-0 and small-bodied fish occupancy. These variables will be calculated using existing geospatial data. These data will be used for completed occupancy modeling after we complete the second year of data collection.

Scale	Covariate	Source	Website
Reach	Distance from dam	NHDplus flowlines	https://apps.nationalmap.gov/downloader/#/
Reach	Distance from confluence	NHDplus flowlines	https://apps.nationalmap.gov/downloader/#/
Segment	Sinuosity	NHDplus flowlines	https://apps.nationalmap.gov/downloader/#/
Segment	Slope	NHDplus flowlines	https://apps.nationalmap.gov/downloader/#/
Catchment	Drainage area	NHDplus flowlines	https://apps.nationalmap.gov/downloader/#/
Catchment	Lithology	USGS National Geologic Map Database	https://mrdata.usgs.gov/geology/state/

Table 7. Habitat factors that will be quantified at various spatial scales and related to occupancy of adult fishes. Occupancy modeling will be completed after the second year of the study, so we have enough data to complete the analyses. Units are provided for each variable.

Habitat factor	Scale	Data source	Unit	URL	Citation
Drainage area	Catchment	NHD+	km^2	https://apps.nationalmap.gov/downloader/#/	(U.S. Geological Survey 2017)
Disturbance	Catchment	NLCD	LDI	https://apps.nationalmap.gov/downloader/#/	(Dewitz 2019)
Lithology	Catchment	U.S. Geological Survey	%	https://mrdata.usgs.gov/geology/state/	(Horton 2017)
Sinuosity	Segment	ArcMap		https://apps.nationalmap.gov/downloader/#/	(U.S. Geological Survey 2017)
Slope	Segment	ArcMap	%	https://apps.nationalmap.gov/downloader/#/	(U.S. Geological Survey 2017)
Temperature	Segment	Loggers	°C		
Discharge	Segment	U.S. Geological Survey	m^3/s	https://waterdata.usgs.gov/nwis/rt	(U.S. Geological Survey 2016)
Distance to Dam	Reach	ArcMap	rkm	https://apps.nationalmap.gov/downloader/#/	(U.S. Geological Survey 2017)
Percent slackwater	Reach	Field collection	%		
Width to depth	Reach	Field collection			
Salinity	Reach	YSI pro dds	ppt		
Chlorophyll-a	Reach	Water sample	mg/L		

Table 8. Demographic information of most Bighead Carp (BHC) and Silver Carp (SVC) collected during sampling events. The sample date, site, and gears used are provided. Total length (TL, mm), weight (W, g), and sex (male [M] or female [F]) of each fish are provided. The preliminary age estimates (Age est) using otoliths are provided. These carp were sampled using gillnets (GN), electrofishing (EF), or jumped in the boat during a survey (JM). Lastly, estimated egg counts for some female fish is provided.

River	Date	Latitude	Longitude	Species	TL	TW	Gear	Sex	Age	Eggs
Red River	7/5/2021	33.60915	-93.8242	SVC	710	3880	EF	F	4	233,740
Bois d'Arc	7/7/2021	33.83864	-95.84481	BHC	1048	12840	GN	F	3	561,374
Red River	7/9/2021	33.56842	-94.38122	SVC	897	7260	GN	M	-	-
Red River	7/12/2021	33.58881	-94.37804	SVC	912	7460	GN	M	-	-
Kiamichi	7/15/2021	33.94832	-95.29562	SVC	708	3850	GN	M	3	-
Red River	7/16/2021	33.65393	-94.56868	BHC	1240	-	GN	F	4	256,314
Bois d'Arc	7/23/2021	33.83864	-95.84481	BHC	1245	-	GN	M	10	-
Bois d'Arc	7/23/2021	33.83864	-95.84481	BHC	1090	-	GN	F	9	618,524
Red River	8/4/2021	33.56842	-94.38122	BHC	1108	13670	GN	M	4	-
Red River	8/4/2021	33.56842	-94.38122	SVC	808	6460	EF	M	6	-
Choctaw	8/10/2021	33.72021	-96.37333	BHC	1097	14220	GN	F	3	722,638
Choctaw	8/10/2021	33.72021	-96.37333	BHC	1100	13480	GN	M	5	-
Choctaw	8/10/2021	33.72021	-96.37333	BHC	1140	15180	GN	M	5	-
Choctaw	8/10/2021	33.72021	-96.37333	BHC	990	9260	GN	M	5	-
Choctaw	8/10/2021	33.72021	-96.37333	SVC	850	7600	GN	M	6	-
Choctaw	8/11/2021	33.72223	-96.41024	BHC	1069	12000	GN	M	8	-
Choctaw	8/11/2021	33.72223	-96.41024	SVC	851	8100	EF	M	7	-
Choctaw	8/11/2021	33.72223	-96.41024	SVC	882	8350	EF	F	4	1,217,828
Red River	8/23/2021	33.80257	-94.9285	BHC	1230	21500	GN	-	5	-
Red River	8/24/2021	33.56842	-94.38122	BHC	960	17500	GN	-	5	-
Red River	8/24/2021	33.56842	-94.38122	SVC	850	9000	EF	-	4	-
Red River	8/24/2021	33.56842	-94.38122	SVC	752	5020	EF	F	4	720,804

Red River	8/24/2021	33.56842	-94.38122	SVC	783	6300	GN	-	3	-
Red River	9/21/2021	33.58881	-94.37804	SVC	876	8500	JM	F	3	462,370
Red River	9/21/2021	33.58881	-94.37804	SVC	752	4800	GN	F	3	308,066
Red River	10/24/2021	33.58881	-94.37804	SVC	952	9500	GN	-	7	-
Red River	10/24/2021	33.58881	-94.37804	SVC	830	6000	JM	-	3	-
Choctaw	11/16/2021	33.72021	-96.37333	BHC	1205	18000	GN	M	6	-
Choctaw	11/16/2021	33.72021	-96.37333	BHC	1033	10025	EF	F	7	407,264
Choctaw	11/16/2021	33.72021	-96.37333	SVC	932	10750	GN	F	3	1,022,782
Choctaw	11/16/2021	33.72021	-96.37333	SVC	765	6000	EF	F	4	381,742
Choctaw	11/16/2021	33.72021	-96.37333	SVC	1020	12050	EF	F	8	1,110,148
Choctaw	12/15/2021	33.72021	-96.37333	BHC	1225	23000	EF	F	8	1,322,169
Choctaw	12/15/2021	33.72021	-96.37333	SVC	902	8000	GN	M	7	-
Choctaw	1/4/2022	33.72021	-96.37333	BHC	974	11000	EF	M	6	-
Choctaw	1/4/2022	33.72021	-96.37333	SVC	911	8500	EF	F	5	-
Choctaw	1/5/2022	33.72021	-96.37333	BHC	1252	-	EF	F	13	-
Red River	1/6/2022	33.07597	-93.8387	SVC	750	4750	GN	M	5	-
Red River	1/6/2022	33.07597	-93.8387	SVC	820	5500	GN	M	8	-
Red River	1/12/2022	33.58881	-94.37804	SVC	915	11000	EF	F	-	-
Red River	1/12/2022	33.58881	-94.37804	SVC	865	8600	EF	M	10	-
Red River	1/12/2022	33.58881	-94.37804	SVC	902	8600	EF	M	11	-
Red River	1/12/2022	33.58881	-94.37804	SVC	904	7000	EF	M	9	-
Red River	1/12/2022	33.58881	-94.37804	SVC	894	7000	EF	M	8	-
Red River	1/12/2022	33.58881	-94.37804	SVC	848	7000	EF	M	5	-
Red River	1/12/2022	33.58881	-94.37804	SVC	850	7700	EF	M	9	-
Red River	1/12/2022	33.58881	-94.37804	SVC	899	10000	EF	F	6	-
Red River	1/12/2022	33.58881	-94.37804	SVC	868	7000	EF	M	7	-
Red River	1/12/2022	33.58881	-94.37804	SVC	945	12600	EF	F	6	-
Red River	1/12/2022	33.58881	-94.37804	SVC	815	7500	EF	M	5	-
Red River	1/12/2022	33.58881	-94.37804	SVC	852	8000	EF	F	4	-

Red River	1/12/2022	33.58881	-94.37804	SVC	1090	15200	EF	F	13	-
Red River	1/12/2022	33.58881	-94.37804	SVC	842	7500	EF	F	5	-
Red River	1/12/2022	33.58881	-94.37804	SVC	926	11500	EF	M	-	-
Red River	1/12/2022	33.58881	-94.37804	SVC	915	11400	EF	F	12	-
Red River	1/12/2022	33.58881	-94.37804	SVC	1036	12900	EF	F	11	-
Red River	1/12/2022	33.58881	-94.37804	SVC	872	9500	EF	F	4	-
Red River	1/12/2022	33.58881	-94.37804	SVC	945	11800	EF	F	7	-
Red River	1/12/2022	33.58881	-94.37804	SVC	821	6250	EF	M	6	-
Red River	1/12/2022	33.58881	-94.37804	SVC	828	6750	GN	M	5	-
Red River	1/12/2022	33.58881	-94.37804	SVC	828	8000	GN	M	8	-
Red River	1/12/2022	33.58881	-94.37804	SVC	822	8200	GN	F	6	-
Red River	1/12/2022	33.58881	-94.37804	SVC	820	8750	GN	M	5	-
Red River	1/18/2022	33.34793	-93.71021	SVC	872	6750	EF	M	5	-
Kiamichi	1/19/2022	33.99742	-95.3722	BHC	1092	12400	EF	F	8	-
Red River	2/8/2022	33.77695	-96.42174	BHC	1152	17200	GN	M	5	-
Red River	2/8/2022	33.77695	-96.42174	BHC	1020	11600	EF	M	4	-
Red River	2/8/2022	33.77695	-96.42174	BHC	1232	20450	GN	M	10	-
Red River	2/8/2022	33.77695	-96.42174	SVC	928	10000	GN	M	5	-
Red River	2/8/2022	33.77695	-96.42174	SVC	834	7400	GN	F	7	-
Red River	2/8/2022	33.77695	-96.42174	SVC	878	7100	GN	M	-	-
Red River	2/8/2022	33.77695	-96.42174	SVC	892	8000	GN	M	9	-
Red River	2/8/2022	33.77695	-96.42174	SVC	920	8900	GN	M	5	-
Red River	2/8/2022	33.77695	-96.42174	SVC	798	6000	GN	M	4	-
Red River	2/8/2022	33.77695	-96.42174	SVC	828	6400	GN	M	5	-
Red River	2/8/2022	33.77695	-96.42174	SVC	780	6250	GN	F	5	-
Red River	2/8/2022	33.77695	-96.42174	SVC	818	6000	GN	M	6	-
Red River	2/8/2022	33.77695	-96.42174	SVC	854	7600	GN	M	-	-
Choctaw	3/2/2022	33.72223	-96.41024	SVC	797	5750	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	BHC	1052	17100	GN	M	15	-

Red River	3/15/2022	33.56842	-94.38122	SVC	938	9478	EF	-	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	870	6732	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	898	8860	EF	F	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	829	4768	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	811	6406	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	910	8076	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	888	8718	EF	F	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	920	8616	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	919	9728	EF	F	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	813	6668	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	939	9402	EF	F	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	1021	12646	EF	F	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	900	9776	EF	F	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	922	7674	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	902	8484	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	818	6486	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	933	8404	EF	M	-	-
Red River	3/15/2022	33.56842	-94.38122	SVC	920	9034	EF	M	12	-
Red River	3/15/2022	33.56842	-94.38122	SVC	874	8328	EF	F	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	875	7622	EF	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	999	11980	EF	F	10	-
Red River	3/15/2022	33.56842	-94.38122	SVC	954	9654	EF	M	10	-
Red River	3/15/2022	33.56842	-94.38122	SVC	988	11412	EF	F	7	-
Red River	3/15/2022	33.56842	-94.38122	SVC	882	8256	EF	M	10	-
Red River	3/15/2022	33.56842	-94.38122	SVC	832	7998	GN	M	11	-
Red River	3/15/2022	33.56842	-94.38122	SVC	902	8340	GN	M	10	-
Red River	3/15/2022	33.56842	-94.38122	SVC	847	7836	GN	M	6	-
Red River	3/15/2022	33.56842	-94.38122	SVC	900	7878	GN	M	9	-
Red River	3/15/2022	33.56842	-94.38122	SVC	920	8904	GN	M	6	-

Red River	3/15/2022	33.56842	-94.38122	SVC	790	5890	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	792	6700	GN	M	6	-
Red River	3/15/2022	33.56842	-94.38122	SVC	901	7256	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	870	7832	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	798	6592	GN	M	4	-
Red River	3/15/2022	33.56842	-94.38122	SVC	901	7518	GN	M	7	-
Red River	3/15/2022	33.56842	-94.38122	SVC	905	8166	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	834	7080	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	844	5888	GN	M	6	-
Red River	3/15/2022	33.56842	-94.38122	SVC	833	6996	GN	M	4	-
Red River	3/15/2022	33.56842	-94.38122	SVC	911	9292	GN	M	10	-
Red River	3/15/2022	33.56842	-94.38122	SVC	772	5470	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	802	9546	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	910	9098	GN	M	9	-
Red River	3/15/2022	33.56842	-94.38122	SVC	946	11584	GN	F	4	-
Red River	3/15/2022	33.56842	-94.38122	SVC	800	6306	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	894	8016	GN	M	8	-
Red River	3/15/2022	33.56842	-94.38122	SVC	858	6208	GN	M	5	-
Red River	3/15/2022	33.56842	-94.38122	SVC	856	7390	GN	M	6	-
Red River	3/23/2022	33.58881	-94.37804	BHC	968	8870	GN	F	9	-
Red River	3/23/2022	33.58881	-94.37804	SVC	858	5982	GN	M	10	-
Red River	3/23/2022	33.58881	-94.37804	SVC	862	7488	GN	M	9	-
Red River	3/23/2022	33.58881	-94.37804	SVC	874	9482	GN	M	-	-
Red River	3/23/2022	33.58881	-94.37804	SVC	912	9138	GN	M	7	-
Red River	3/23/2022	33.58881	-94.37804	SVC	854	7824	GN	F	5	-
Red River	3/23/2022	33.58881	-94.37804	SVC	740	-	EF	F	8	-
Red River	3/23/2022	33.58881	-94.37804	SVC	820	6300	GN	F	5	-
Red River	3/23/2022	33.58881	-94.37804	SVC	838	7134	EF	M	5	-
Red River	3/23/2022	33.58881	-94.37804	SVC	850	6974	EF	M	7	-

Red River	3/23/2022	33.58881	-94.37804	SVC	890	8000	GN	M	12	-
Red River	3/23/2022	33.58881	-94.37804	SVC	784	5300	EF	M	6	-
Red River	3/23/2022	33.58881	-94.37804	SVC	930	-	EF	F	11	-
Red River	3/23/2022	33.58881	-94.37804	SVC	808	5964	GN	M	7	-
Red River	3/23/2022	33.58881	-94.37804	SVC	1040	12200	EF	F	9	-
Red River	3/23/2022	33.58881	-94.37804	SVC	928	-	EF	F	6	-
Red River	3/24/2022	33.56842	-94.38122	BHC	104	17600	GN	M	11	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1200	18000	GN	M	6	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1114	15500	GN	M	9	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1180	16500	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1164	18500	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1142	15300	GN	M	9	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1206	18300	GN	M	9	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1148	16400	GN	M	10	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1092	15400	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1050	1300	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1062	9784	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1090	14500	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1299	20000	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1123	14600	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1151	14600	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1210	16100	GN	M	9	-
Red River	3/24/2022	33.56842	-94.38122	BHC	1120	18400	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	788	5850	GN	M	5	-
Red River	3/24/2022	33.56842	-94.38122	SVC	876	6502	GN	M	13	-
Red River	3/24/2022	33.56842	-94.38122	SVC	918	9408	GN	M	10	-
Red River	3/24/2022	33.56842	-94.38122	SVC	908	8700	GN	M	11	-
Red River	3/24/2022	33.56842	-94.38122	SVC	850	6914	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	852	6302	GN	M	5	-

Red River	3/24/2022	33.56842	-94.38122	SVC	824	5912	GN	M	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	1070	15600	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	1056	13250	GN	M	10	-
Red River	3/24/2022	33.56842	-94.38122	SVC	992	11288	GN	F	10	-
Red River	3/24/2022	33.56842	-94.38122	SVC	968	10756	GN	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	873	7524	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	918	8322	EF	M	10	-
Red River	3/24/2022	33.56842	-94.38122	SVC	988	10432	EF	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	1050	13500	EF	F	11	-
Red River	3/24/2022	33.56842	-94.38122	SVC	886	9752	EF	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	966	10716	EF	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	924	9352	EF	M	10	-
Red River	3/24/2022	33.56842	-94.38122	SVC	830	6824	EF	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	838	7328	EF	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	976	12020	EF	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	874	9176	GN	F	5	-
Red River	3/24/2022	33.56842	-94.38122	SVC	878	6896	GN	M	7	-
Red River	3/24/2022	33.56842	-94.38122	SVC	960	10902	GN	F	9	-
Red River	3/24/2022	33.56842	-94.38122	SVC	936	11272	GN	F	5	-
Red River	3/24/2022	33.56842	-94.38122	SVC	794	5698	GN	M	7	-
Red River	3/24/2022	33.56842	-94.38122	SVC	998	10056	GN	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	1010	13400	GN	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	946	10834	GN	F	10	-
Red River	3/24/2022	33.56842	-94.38122	SVC	904	11096	GN	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	888	9218	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	916	8822	GN	M	8	-
Red River	3/24/2022	33.56842	-94.38122	SVC	912	9860	GN	F	5	-
Red River	3/24/2022	33.56842	-94.38122	SVC	920	11484	GN	F	6	-
Red River	3/24/2022	33.56842	-94.38122	SVC	856	8964	GN	F	-	-

Red River	3/24/2022	33.56842	-94.38122	SVC	938	1200	GN	F	8	-
Red River	3/24/2022	33.56842	-94.38122	SVC	948	11300	GN	F	8	-
Red River	3/24/2022	33.56842	-94.38122	SVC	885	9200	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	875	9260	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	820	6000	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	818	5858	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	806	6158	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	888	9212	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	878	7626	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	980	10894	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	904	10266	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	898	9604	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	910	8956	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	852	6174	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	864	7476	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	866	9756	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	928	9302	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	816	6510	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	890	8332	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	934	9078	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	941	9136	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	902	8780	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	874	10392	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	830	6382	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	920	10268	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	976	10612	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	870	8194	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	928	99654	GN	M	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	942	9370	GN	M	-	-

Red River	3/24/2022	33.56842	-94.38122	SVC	891	8850	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	822	8978	GN	F	-	-
Red River	3/24/2022	33.56842	-94.38122	SVC	1042	13700	GN	F	-	-
Red River	4/4/2022	33.60915	-93.8242	SVC	891	9000	EF	M	11	-
Choctaw	4/13/2022	33.72223	-96.41024	BHC	1258	17000	GN	F	-	-
Choctaw	4/13/2022	33.72223	-96.41024	BHC	1152	12500	GN	F	-	-
Choctaw	4/13/2022	33.72223	-96.41024	SVC	842	7100	EF	M	-	-
Red River	4/29/2022	33.58881	-94.37804	SVC	915	9000	EF	F	-	-
Red River	5/4/2022	33.80257	-94.9285	SVC	888	8000	GN	F	-	-
Red River	5/13/2022	33.90802	-95.06658	BHC	1063	10600	GN	M	-	-
Garland Creek	5/13/2022	33.92473	-95.08337	SVC	937	9400	EF	F	-	-
Kiamichi	5/26/2022	33.95071	-95.24384	BHC	1050	9300	GN	M	-	-
Kiamichi	5/26/2022	33.95071	-95.24384	BHC	1068	11400	GN	M	-	-
Kiamichi	5/26/2022	33.95071	-95.24384	SVC	752	4750	EF	M	-	-
Kiamichi	5/26/2022	33.95071	-95.24384	SVC	887	7100	GN	M	-	-
Kiamichi	5/26/2022	33.95071	-95.24384	SVC	859	6500	GN	M	-	-
Red River	5/28/2022	33.58881	-94.37804	BHC	1004	11892	GN	M	-	-
Red River	5/28/2022	33.58881	-94.37804	BHC	1198	16750	EF	F	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	789	4338	GN	M	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	912	8876	GN	M	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	813	6324	GN	M	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	886	8662	GN	F	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	919	11388	GN	F	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	850	8168	GN	M	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	869	8812	EF	F	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	616	9122	EF	M	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	850	10284	EF	F	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	921	12020	GN	F	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	907	9692	EF	F	-	-

Red River	5/28/2022	33.58881	-94.37804	SVC	891	9318	EF	F	-	-
Red River	5/28/2022	33.58881	-94.37804	SVC	1350	27750	EF	F	-	-
Muddy Boggy	6/1/2022	33.94339	-95.60174	SVC	892	7600	GN	-	-	-
Choctaw	6/3/2022	33.72223	-96.41024	SVC	831	7100	JM	-	-	-
Choctaw	6/4/2022	33.72021	-96.37333	SVC	-	-	GN	-	-	-
Choctaw	6/4/2022	33.72021	-96.37333	SVC	-	-	GN	-	-	-
Red River	6/5/2022	33.55708	-94.04868	SVC	964	9500	JM	M	-	-
Red River	6/5/2022	33.55708	-94.04868	SVC	891	8000	GN	M	-	-
Red River	6/6/2022	33.80257	-94.9285	BHC	1298	-	EF	F	-	-
Red River	6/6/2022	33.80257	-94.9285	BHC	1016	-	GN	M	-	-
Red River	6/16/2022	33.65393	-94.56868	BHC	1050	16600	GN	-	-	-
Red River	6/21/2022	33.58881	-94.37804	BHC	1172	15250	EF	M	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	940	12000	EF	F	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	992	12250	EF	F	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	999	12250	EF	F	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	1014	13500	EF	F	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	985	8750	EF	F	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	952	8250	EF	M	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	949	11000	JM	F	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	942	7500	EF	M	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	901	7400	JM	M	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	1062	13800	EF	F	-	-
Red River	6/21/2022	33.58881	-94.37804	SVC	849	7100	GN	M	-	-
Kiamichi	6/23/2022	33.95071	-95.24384	BHC	1015	10300	GN	F	-	-
Kiamichi	6/23/2022	33.95071	-95.24384	BHC	1250	25250	GN	M	-	-
Kiamichi	6/23/2022	33.95071	-95.24384	BHC	1048	11600	GN	M	-	-
Garland Creek	6/24/2022	33.92473	-95.08337	BHC	1122	14900	GN	F	-	-
Garland Creek	6/24/2022	33.92473	-95.08337	BHC	1333	13700	GN	M	-	-
Garland Creek	6/24/2022	33.92473	-95.08337	BHC	949	11100	GN	M	-	-

Red River	6/24/2022	33.90802	-95.06658	SVC	1091	12000	EF	F	-	-
Garland Creek	6/24/2022	33.92473	-95.08337	SVC	928	-	EF	M	-	-
Pine Creek	6/28/2022	33.86477	-95.30788	BHC	952	10200	GN	M	-	-
Red River	6/30/2022	33.87724	-95.48534	SVC	900	-	GN	M	-	-

Table 9**.** Carp visually confirmed but not collected during sampling in throughout the Red River basin. The observations indicate the date, location, and species observed.

River	Date	Latitude	Longitude	Species
Bois d'Arc	7/23/2021	33.83864	-95.84481	Silver Carp
Buzzard Creek	5/9/2022	33.90033	-95.05406	Silver Carp
Choctaw	8/10/2021	33.72021	-96.37333	Silver Carp
Choctaw	8/11/2021	33.72223	-96.41024	Silver Carp
Choctaw	11/16/2021	33.72021	-96.37333	Silver Carp
Choctaw	12/15/2021	33.72021	-96.37333	Silver Carp
Choctaw	4/13/2022	33.72021	-96.37333	Silver Carp
Choctaw	6/4/2022	33.72021	-96.37333	Silver Carp
Choctaw	6/22/2022	33.72223	-96.41024	Silver Carp
Garland Creek	5/16/2022	33.92473	-95.08337	Silver Carp
Garland Creek	6/24/2022	33.92473	-95.08337	Silver Carp
Kiamichi	11/29/2021	33.94832	-95.29562	Silver Carp
Kiamichi	2/10/2022	33.95071	-95.24384	Silver Carp
Kiamichi	5/26/2022	33.95071	-95.24384	Silver Carp
Kiamichi	6/23/2022	33.95071	-95.24384	Silver Carp
Muddy Boggy	7/2/2021	33.94339	-95.60174	Silver Carp
Muddy Boggy	7/27/2021	33.93557	-95.63493	Silver Carp
Muddy Boggy	7/28/2021	33.92844	-95.65096	Silver Carp
Muddy Boggy	5/31/2022	33.92844	-95.65096	Silver Carp
Muddy Boggy	6/1/2022	33.93833	-95.60911	Silver Carp
Pine Creek	8/3/2021	33.86477	-95.30788	Bighead Carp
Pine Creek	6/14/2022	33.86477	-95.30788	Silver Carp
Pine Creek	6/28/2022	33.86477	-95.30788	Silver Carp
Pine Creek	6/28/2022	33.86477	-95.30788	Bighead Carp
Red River	7/5/2021	33.60915	-93.8242	Silver Carp
Red River	7/9/2021	33.56842	-94.38122	Silver Carp
Red River	7/12/2021	33.58881	-94.37804	Silver Carp
Red River	7/16/2021	33.65393	-94.56868	Silver Carp
Red River	7/29/2021	33.65393	-94.56868	Silver Carp
Red River	7/29/2021	33.65393	-94.56868	Bighead Carp
Red River	8/4/2021	33.58881	-94.37804	Silver Carp
Red River	8/24/2021	33.56842	-94.38122	Silver Carp
Red River	8/31/2021	33.39703	-93.71171	Silver Carp
Red River	9/21/2021	33.58881	-94.37804	Silver Carp
Red River	10/8/2021	33.39703	-93.71171	Silver Carp
Red River	10/14/2021	33.64846	-94.54315	Silver Carp

Red River	11/11/2021	33.60915	-93.8242	Silver Carp
Red River	1/12/2022	33.58881	-94.37804	Silver Carp
Red River	1/18/2022	33.34793	-93.71021	Silver Carp
Red River	2/8/2022	33.77695	-96.42174	Silver Carp
Red River	3/3/2022	33.88111	-95.50545	Silver Carp
Red River	4/1/2022	33.39703	-93.71171	Silver Carp
Red River	4/4/2022	33.60915	-93.8242	Silver Carp
Red River	4/5/2022	33.5515	-94.39453	Silver Carp
Red River	4/19/2022	33.88111	-95.50545	Silver Carp
Red River	4/21/2022	33.95053	-95.24028	Silver Carp
Red River	4/26/2022	33.57537	-94.08128	Silver Carp
Red River	4/29/2022	33.58881	-94.37804	Silver Carp
Red River	5/4/2022	33.80257	-94.9285	Silver Carp
Red River	5/6/2022	33.5515	-94.39453	Silver Carp
Red River	5/12/2022	33.13784	-93.82909	Silver Carp
Red River	5/28/2022	33.58881	-94.37804	Silver Carp
Red River	6/5/2022	33.55708	-94.04868	Silver Carp
Red River	6/6/2022	33.80257	-94.9285	Silver Carp
Red River	6/7/2022	33.57537	-94.08128	Silver Carp
Red River	6/8/2022	33.60915	-93.8242	Silver Carp
Red River	6/13/2022	33.13784	-93.82909	Bighead Carp
Red River	6/15/2022	33.5998	-94.44686	Silver Carp
Red River	6/16/2022	33.65393	-94.56868	Silver Carp
Red River	6/17/2022	33.34793	-93.71021	Silver Carp
Red River	6/17/2022	33.34793	-93.71021	Bighead Carp
Red River	6/21/2022	33.58881	-94.37804	Silver Carp
Red River	6/24/2022	33.90802	-95.06658	Silver Carp

Table 10. Seasonal water temperature (°C) data from loggers placed throughout the mainstem Red River and major tributaries with the corresponding season (Spring [March 1st – May 31st], Summer [June 1st – August 31st], Fall [September 1st – November 30st], Winter [December 1st – February 28th]), standard deviation (SD), and coefficient of variation (CV).

River	Season	Mean	Range	SD	CV
Red River, OK	Fall	15.31	14.43	3.78	0.25
Red River, OK	Spring	19.11	20.49	5.05	0.26
Red River, OK	Summer	29.80	10.06	2.59	0.09
Red River, OK	Winter	10.24	17.04	4.07	0.40
Red River, AR	Fall	14.91	12.28	2.52	0.17
Red River, AR	Spring	19.51	18.63	5.17	0.27
Red River, AR	Summer	30.70	7.06	2.22	0.07
Red River, AR	Winter	11.45	16.45	3.91	0.34
Bois D'Arc	Fall	14.77	10.03	2.39	0.16
Bois D'Arc	Spring	19.39	19.37	5.01	0.26
Bois D'Arc	Summer	30.36	8.44	2.24	0.07
Bois D'Arc	Winter	10.38	12.34	3.51	0.34
Blue River	Fall	14.20	11.48	2.63	0.19
Blue River	Spring	19.20	20.17	5.08	0.26
Blue River	Summer	27.14	7.01	1.87	0.07
Blue River	Winter	9.61	12.44	3.43	0.36
Kiamichi	Fall	14.84	17.09	4.68	0.32
Kiamichi	Spring	17.56	19.95	5.64	0.32
Kiamichi	Summer	27.31	7.00	2.44	0.09
Kiamichi	Winter	9.74	19.59	4.39	0.45
Muddy Boggy	Fall	14.82	9.32	2.21	0.15
Muddy Boggy	Winter	11.28	9.43	3.20	0.28
Pine Creek	Fall	12.27	13.13	3.24	0.26
Pine Creek	Spring	19.09	19.51	4.98	0.26
Pine Creek	Summer	28.60	9.10	2.62	0.09
Pine Creek	Winter	9.24	15.71	3.92	0.42

Table 11. Mean values for several field collected habitat variables. Secchi is in centimeters. Wetted width and max depth are in meters.

River	Secchi	Wetted width	Max depth
Red River OK	44.43	56.80	2.85
Red River AR	28.80	53.17	4.21
Blue River	46.06	11.68	2.37
Bois D'Arc	43.86	12.00	4.05
Buzzard Creek	48.67	6.96	1.87
Choctaw Creek	28.02	12.42	1.50
Garland Creek	29.67	8.79	1.59
Kiamichi	40.81	18.66	3.50
Muddy Boggy	27.47	28.84	4.41
Pine Creek	49.33	8.15	3.41

Table 12. The number of individuals collected through June 30, 2022, by species and by sampling gear (EF=electrofishing, FN= mini-fyke net, GN = gillnet, HN=hoopnet, LT=larval tow, SE=seine) from the Arkansas portion of the Red River (Bighead Carp and Silver Carp collections/observations are not included here). Scientific names are reported in Appendix A.

Species	EF	GN	HN	FN	LT	SE	Total
Alligator Gar	3	26	1	-	-	-	30
American Eel	1	-	-	-	-	-	1
Bigmouth Buffalo	46	223	-	-	-	2	271
Black Buffalo	12	77	1	-	-	-	90
Black Crappie	3	-	-	90	-	6	99
Blackstripe Topminnow	1	-	-	9	-	18	28
Blacktail Shiner	1	-	-	-	-	48	49
Blue Catfish	19	26	-	-	-	2	47
Blue Sucker	112	17	7	-	-	-	136
Bluegill	30	-	-	479	-	459	968
Bluntnose Darter	-	-	-	3	-	-	3
Brook Silverside	-	-	-	4	-	96	100
Bullhead Minnow	15	-	-	724	-	4121	4860
Catostomidae spp.	-	-	-	-	1	-	1
Channel Catfish	3	2	-	7	-	13	25
Chub Shiner	1	-	-	193	-	1975	2169
Common Carp	3	9	-	-	-	-	12
Dusky Darter	-	-	-	51	-	17	68
Emerald Shiner	55	-	-	2560	6	1335	3956
Flathead Catfish	68	1	-	1	-	2	72
Flier	-	-	-	1	-	-	1
Freshwater Drum	53	3	1	29	-	36	122
Gizzard Shad	320	10	-	262	1	990	1583
Golden Shiner	-	-	-	-	-	5	5

Golden Topminnow	-	-	-	11	-	11	22
Grass Carp	3	31	-	-	-	-	34
Green Sunfish	23	-	-	3	-	15	41
Largemouth Bass	4	-	-	-	-	-	4
Lepomis spp.	-	-	-	59	1	95	155
Logperch	-	-	-	27	-	12	39
Longear Sunfish	23	-	-	33	-	5	61
Longnose Gar	52	54	3	7	-	8	124
Mississippi Silverside	33	-	-	367	-	1542	1942
Mississippi Silvery Minnow	-	-	-	-	-	1	1
Mosquitofish	-	-	-	361	-	2173	2534
Orangespotted Sunfish	16	-	-	1127	-	674	1817
Paddlefish	7	48	-	-	-	-	55
Pallid Shiner	-	-	-	-	-	2	2
Pirate Perch	-	-	-	-	-	21	21
Pomoxis spp.	-	-	-	-	-	23	23
Quillback	-	-	-	1	-	3	4
Red Shiner	145	-	-	8856	9	27688	36698
Redear Sunfish	-	-	-	-	-	3	3
River Carpsucker	162	2	3	19	-	135	321
River Darter	-	-	-	3	-	2	5
Sand Shiner	-	-	-	20	-	-	20
Shoal Chub	-	-	-	21	-	160	181
Shortnose Gar	32	5	1	44	-	-	82
Shovelnose Sturgeon	4	1	-	-	-	-	5
Silver Chub	16	-	-	120	-	254	390
Silverband Shiner	-	-	-	-	-	11	11
Skipjack Herring	-	-	-	2	-	3	5
Slough Darter	-	-	-	2	-	4	6
Smallmouth Bass	1	2	-	-	-	-	3
Smallmouth Buffalo	62	195	10	1	-	-	268

Spotted Bass	37	-	-	28	-	351	416
Spotted Gar	14	-	-	2	-	1	17
Striped Bass	2	-	-	-	-	-	2
Tadpole Madtom	1	-	-	2	-	-	3
Threadfin Shad	223	-	-	956	3	1523	2705
Warmouth	3	-	-	27	-	17	47
Western Sand Darter	-	-	-	3	-	16	19
Western Starhead Topminnow	-	-	-	2	-	-	2
White Bass	11	-	-	-	-	161	172
White Crappie	18	-	2	657	-	176	853
Yellow Bullhead	-	-	-	1	-	-	1

Table 13. The number of individuals collected through June 30, 2022, by species and by sampling gear (EF=electrofishing, FN= mini-fyke net, GN = gillnet, HN=hoopnet, LT=larval tow, SE=seine) collected from the Oklahoma portion of the Red River (Bighead Carp and Silver Carp collections/observations are not included in the table).

	EF	GN	HN	FN	LT	SE	Total
Alligator Gar	-	14	-	1	-	-	15
Bigmouth Buffalo	33	103	-	1	-	8	145
Black Buffalo	17	120	1	1	-	-	139
Black Crappie	-	-	-	6	1	5	12
Blackspotted Topminnow	-	-	-	-	-	1	1
Blackstripe Topminnow	-	-	-	2	-	2	4
Blacktail Shiner	-	-	-	4	-	28	32
Blue Catfish	11	38	1	1	-	2	53
Blue Sucker	144	4	1	-	-	-	149
Bluegill	15	-	-	74	-	66	155
Bluntnose Minnow	3	-	-	-	-	-	3
Brook Silverside	-	-	-	-	-	1	1
Bullhead Minnow	17	-	-	627	-	3566	4210
Catostomidae spp.	-	-	-	-	-	4	4
Channel Catfish	21	4	-	4	-	4	33
Chestnut Lamprey	1	-	-	-	-	-	1
Chub Shiner	1	-	-	281	1	1241	1524
Common Carp	2	3	-	0	-	-	5
Dusky Darter	-	-	-	0	-	2	2
Emerald Shiner	19	1	-	184	-	255	459
Flathead Catfish	36	4	-	1	-	-	41
Freshwater Drum	37	1	-	11	-	31	80
Ghost Shiner	-	-	-	1	-	-	1
Gizzard Shad	274	2	-	1274	-	505	2055

Golden Redhorse	-	-	-	-	-	1	1
Golden Topminnow	-	-	-	3	-	2	5
Goldeye	1	-	-	-	-	-	1
Grass Carp	1	30	-	-	-	-	31
Green Sunfish	6	-	-	9	-	10	25
Lepomis spp.	-	-	-	47	-	101	148
Logperch	-	-	-	7	-	6	13
Longear Sunfish	8	-	-	76	-	35	119
Longnose Gar	57	97	5	20	-	7	186
Mississippi Silverside	3	-	-	76	-	5491	5570
Mosquitofish	-	-	-	35	-	1204	1239
Orangespotted Sunfish	6	-	-	10	-	27	43
Paddlefish	1	30	-	-	-	-	31
Pallid shiner	-	-	-	-	-	2	2
Plains Killifish	-	-	-	-	-	5	5
Pomoxis spp.	-	-	-	-	-	2	2
Quillback	5	1	-	-	17	-	23
Red Shiner	116	1	-	4540	3	19414	24074
Redear Sunfish	1	-	-	23	-	-	24
River Carpsucker	167	5	-	87	-	318	577
River Darter	-	-	-	-	-	1	1
Sand Shiner	-	-	-	1	-	22	23
Shoal Chub	-	-	-	9	-	367	376
Shortnose Gar	21	3	1	31	-	9	65
Shovelnose Sturgeon	10	1	-	-	-	-	11
Silver Chub	1	-	-	23	-	52	76
Slough Darter	-	-	-	1	-	-	1
Smallmouth Bass	-	1	-	-	-	-	1
Smallmouth Buffalo	101	230	18	1	-	-	350
Spotted Bass	8	-	-	91	-	199	298
Spotted Gar	19	-	1	1	-	-	21

Striped Bass	6	-	-	-	-	-	6
Suckermouth Minnow	-	-	-	2	-	11	13
Tadpole Madtom	1	-	-	-	-	-	1
Threadfin Shad	90	-	-	2248	-	584	2922
Warmouth	2	-	-	2	-	17	21
Western Sand Darter	-	-	-	1	-	39	40
White Bass	5	-	-	120	-	91	216
White Crappie	7	-	-	91	1	147	246

Table 14. The number of individuals collected through June 30, 2022, by species and by sampling gear (EF=electrofishing, FN= mini-fyke net, GN = gillnet, HN=hoopnet, LT=larval tow, SE=seine) collected from the Oklahoma tributaries of the Red River (Bighead Carp and Silver Carp collections/observations are not included in the table).

Species	EF	GN	HN	FN	LT	SE	Total
Alligator Gar	1	16	-	1	-	-	18
American Eel	1	-	-	-	-	-	1
Bigmouth Buffalo	70	204	-	1	-	-	275
Black Buffalo	8	45	-	-	-	-	53
Black Crappie	-	-	-	1	-	9	10
Blackstripe Topminnow	1	-	-	4	-	14	19
Blacktail Shiner	25	-	-	111	-	533	669
Blue Catfish	11	28	-	-	-	-	39
Blue Sucker	1	2	1	-	-	681	685
Bluegill	23	1	-	121	-	65	210
Bluntnose Darter	-	-	-	-	-	1	1
Bluntnose Minnow	2	-	-	-	-	-	2
Brook Silverside	-	-	-	0	-	12	12
Bullhead Minnow	42	-	-	476	-	2393	2911
Channel Catfish	3	10	-	4	-	14	31
Chestnut Lamprey	2	-	-	-	-	-	2
Chub Shiner	-	-	-	2	-	8	10
Common Carp	2	3	-	-	-	-	5
Dusky Darter	-	-	-	8	-	8	16

Emerald Shiner	72	-	-	5	-	36	113
Flathead Catfish	4	2	-	2	-	-	8
Freshwater Drum	31	22	-	-	-	1	54
Gizzard Shad	214	58	-	3	-	240	515
Grass Carp	3	11	1	-	-	-	15
Green Sunfish	4	-	-	0	-	2	6
Largemouth Bass	4	-	-	1	-	-	5
Lepomis spp.	-	-	-	24	-	163	187
Logperch	-	-	-	5	-	19	24
Longear Sunfish	25	1	-	32	-	64	122
Longnose Gar	65	22	2	1	-	3	93
Mississippi Silverside	26	-	-	9	-	46	81
Mooneye	1	-	-	-	-	-	1
Mosquitofish	1	-	-	11	-	1701	1713
Orangespotted Sunfish	2	1	-	19	-	25	47
Paddlefish	3	63	-	-	-	-	66
Pallid Shiner	-	-	-	4	-	-	4
Pomoxis spp.	-	-	-	-	-	1	1
Red Shiner	213	2	-	373	9	3153	3750
Redear Sunfish	-	-	-	-	-	1	1
River Carpsucker	243	3	-	2	-	61	309
River Darter	-	-	-	1	-	2	3
Sand Shiner	-	-	-	-	1	1	2
Shoal Chub	-	-	-	-	-	1	1

Shortnose Gar	16	3	-	3	-	1	23
Silver Chub	-	-	-	3	-	10	13
Slough Darter	-	-	-	1	-	24	25
Smallmouth Bass	2	-	1	-	-	-	3
Smallmouth Buffalo	90	121	-	-	-	1	212
Spotted Bass	16	-	-	4	-	192	212
Spotted Gar	30	1	-	1	-	-	32
Striped Bass	-	1	-	-	-	-	1
Suckermouth Minnow	-	-	-	-	-	7	7
Tadpole Madtom	-	-	-	-	-	2	2
Threadfin Shad	134	-	-	10	2	509	655
Warmouth	1	-	-	2	-	4	7
White Bass	3	-	-	-	-	1	4
White Crappie	20	1	1	32	-	63	117

Table 15. The number of individuals collected through June 30, 2022, by species and by sampling gear (EF=electrofishing, FN= mini-fyke net, GN = gillnet, HN=hoopnet, LT=larval tow, SE=seine) collected from the Texas tributaries of the Red River (Bighead Carp and Silver Carp collections/observations are not included in the table).

Species	EF	GN	HN	FN	LT	SE	Total
Alligator Gar	0	2	0	-	-	-	2
Bigmouth Buffalo	13	17	2	-	-	-	32
Black Buffalo	6	25	0	-	-	-	31
Blacktail Shiner	2	0	0	-	-	9	11
Blue Catfish	0	8	0	-	-	-	8
Blue Sucker	1	0	0	-	-	-	1
Bluegill	0	0	0	36	-	13	49
Brook Silverside	0	0	0	9	-	33	42
Bullhead Minnow	0	0	0	79	-	629	708
Channel Catfish	0	0	0	1	-	-	1
Common Carp	0	6	0	-	-	-	6
Emerald Shiner	3	0	0	1	-	2	6
Flathead Catfish	1	0	1	-	-	-	2
Freshwater Drum	2	0	0	1	-	1	4
Gizzard Shad	13	0	0	-	-	49	62
Grass Carp	0	14	0	-	-	-	14
Green Sunfish	0	0	0	5	-	7	12
Logperch	0	0	0	1	-	-	1
Longear Sunfish	2	0	0	11	-	15	28
Longnose Gar	13	4	0	4	-	3	24

Mississippi Silverside	2	0	0	1	-	111	114
Mosquitofish	0	0	0	10	-	1910	1920
Orangespotted Sunfish	3	0	0	16	-	10	29
Paddlefish	1	8	0	-	-	-	9
Red Shiner	2	0	0	132	-	1384	1518
River Carpsucker	9	0	1	-	-	10	20
Sand Shiner	0	0	0	-	-	1	1
Shortnose Gar	9	1	0	6	-	-	16
Slough Darter	0	0	0	-	-	2	2
Smallmouth Buffalo	15	47	5	-	-	-	67
Spotted Bass	0	0	0	16	-	-	16
Spotted Gar	7	0	0	-	-	-	7
Suckermouth Minnow	0	0	0	-	-	2	2
Tadpole Madtom	0	0	0	-	-	-	0
Threadfin Shad	0	0	0	2	-	60	62
Warmouth	0	0	0	4	-	-	4
White Bass	1	0	0	-	-	1	2
White Crappie	0	0	0	14	-	18	32

Table 16. List of genera, the number of species within each genus, the total sampled, and the percent of total of all fishes sampled. Due to the disproportionately high observations of Red Shiner (*Cyprinella*), the percent of total was calculated without including Red Shiner counts(indicated using *).

Genus	Species count	Total collected	Percent of total
Alosa	1	5	< 0.01%
Ameiurus	1	1	< 0.01%
Ammocrypta	2	61	0.10%
Anguilla	1	2	< 0.01%
Aphredoderus	1	21	0.03%
Aplodinotus	1	259	0.41%
Atractosteus	1	65	0.10%
Carpiodes	1	1227	1.94%
Carpoides	1	27	0.04%
Centrarchus	1	1	< 0.01%
Ctenopharyngodon	1	94	0.15%
Cycleptus	1	971	1.53%
Cyprinella	1 (1)*	761 (66040)*	1.20%
Cyprinus	1	28	0.04%
Dorosoma	2	10559	16.69%
Etheostoma	2	38	0.06%
Fundulus	4	84	0.13%
Gambusia	1	7406	11.71%
Hiodon	1	2	< 0.01%
Hiodontiformes	1	1	< 0.01%
Hybognathus	1	1	< 0.01%
Hybopsis	1	8	< 0.01%
Hypophthalmichthys	2	287	0.45%

Ichthyomyzon	1	3	< 0.01%
Ictalurus	2	237	0.37%
Ictiobus	3	1933	3.06%
Labidesthes	1	155	0.25%
Lepisosteus	3	690	1.09%
Lepomis	6	4329	6.84%
Macrhybopsis	2	1037	1.64%
Menidia	1	7707	12.18%
Micropterus	3	958	1.51%
Morone	2	403	0.64%
Moxostoma	1	1	< 0.01%
Notemigonus	1	16	0.03%
Notropis	5	8295	13.11%
Noturus	1	6	< 0.01%
Percina	3	172	0.27%
Phenacobius	1	22	0.03%
Pimephales	2	13694	21.65%
Polyodon	1	161	0.25%
Pomoxis	2	1395	2.21%
Pylodictis	1	123	0.19%
Scaphirhynchus	1	16	0.03%

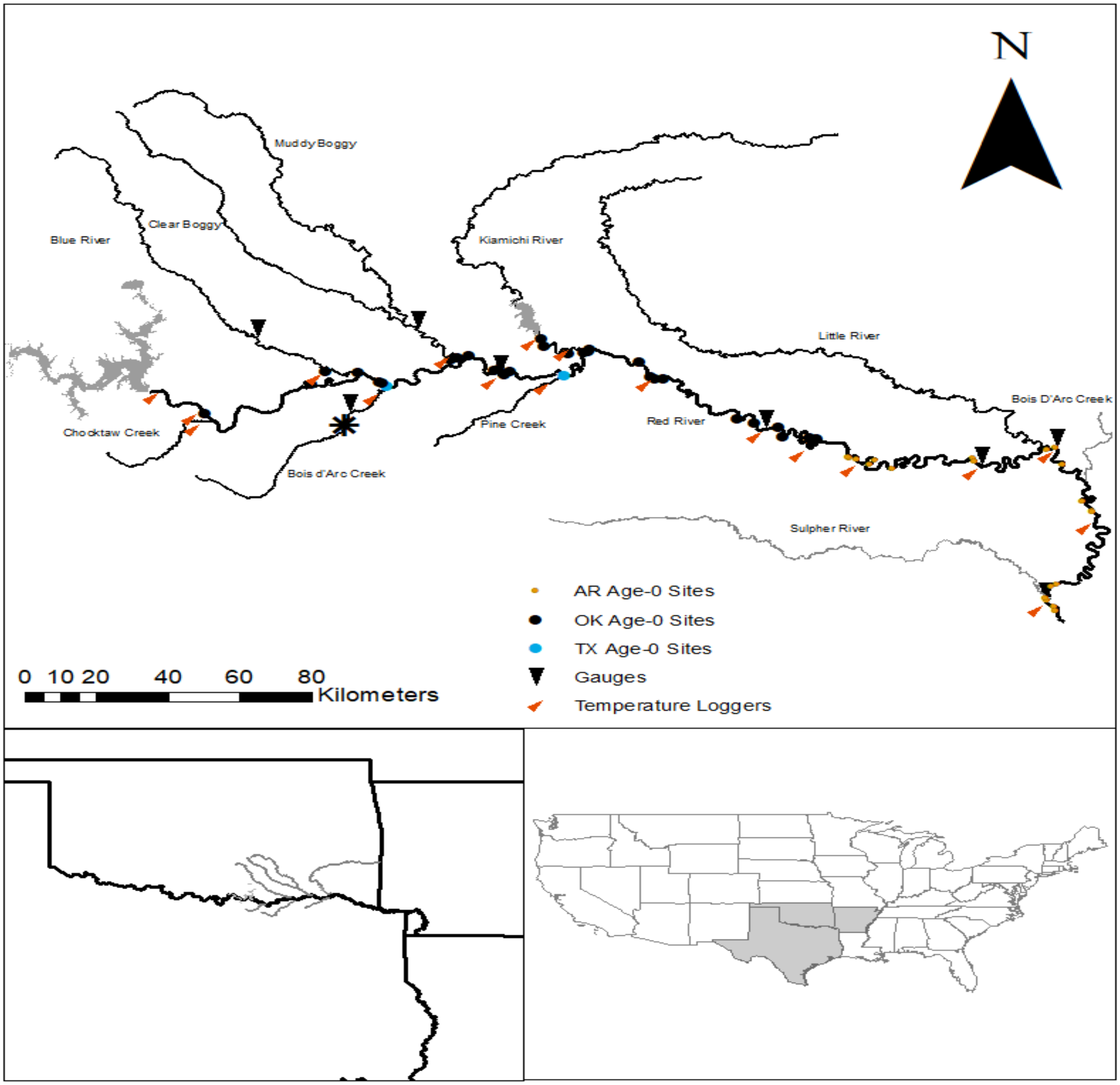

Figure 1. Age-0 fish sampling locations (circles) in the lower Red River basin. The circle colors reflect the state where the sample site was located (blue = TX, black = OK, orange = AR). The gray lines represent major rivers with black arrows denoting U.S. Geological Survey stream gauges and the red arrow denoting temperature loggers. Each site was sampled 1-3 times using seines, mini-fyke nets, and larval tows.

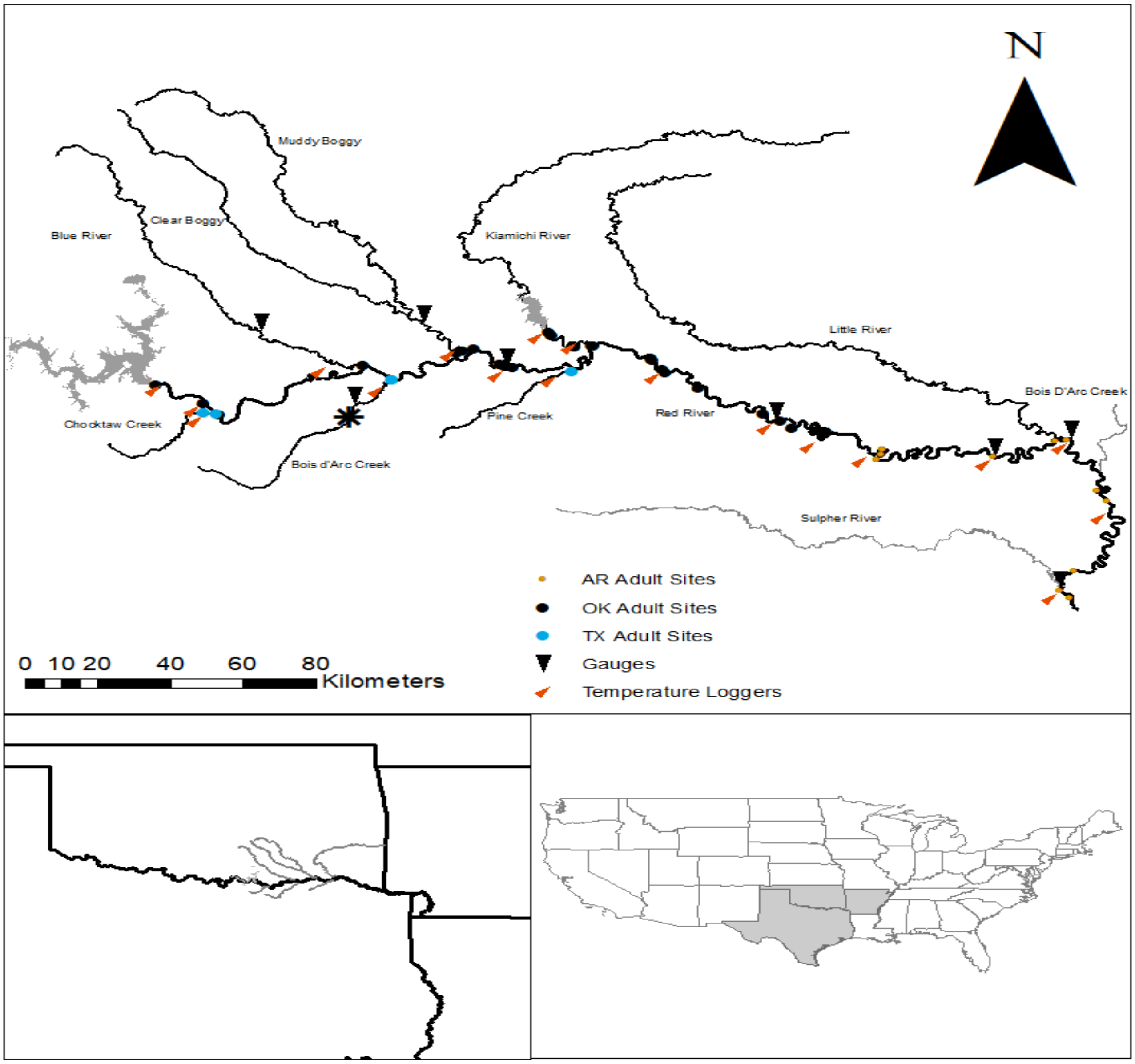

Figure 2. Adult fish sampling locations (circles) in the lower Red River basin. The circle colors reflect the state where the sample site is located. The circle colors reflect the state where the sample site was located (blue = TX, black = OK, orange = AR). The gray lines represent major rivers with black arrows denoting U.S. Geological Survey stream gauges and the red arrow denoting temperature loggers. Each site was sampled 1-3 times using gillnets, electrofishing, and hoop nets.

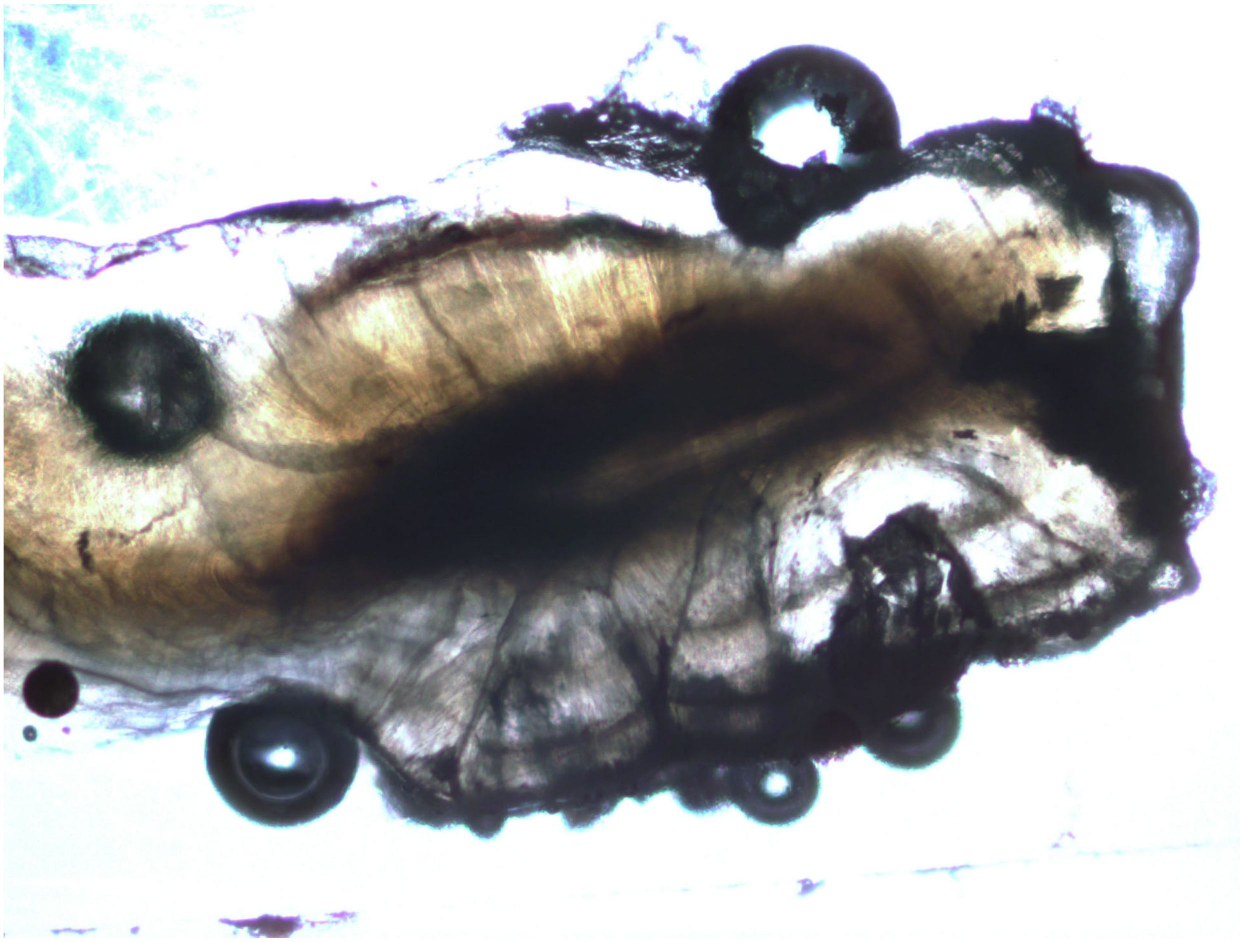

Figure 3. Sectioned lapilli otolith extracted from a Silver Carp during electrofishing surveys.

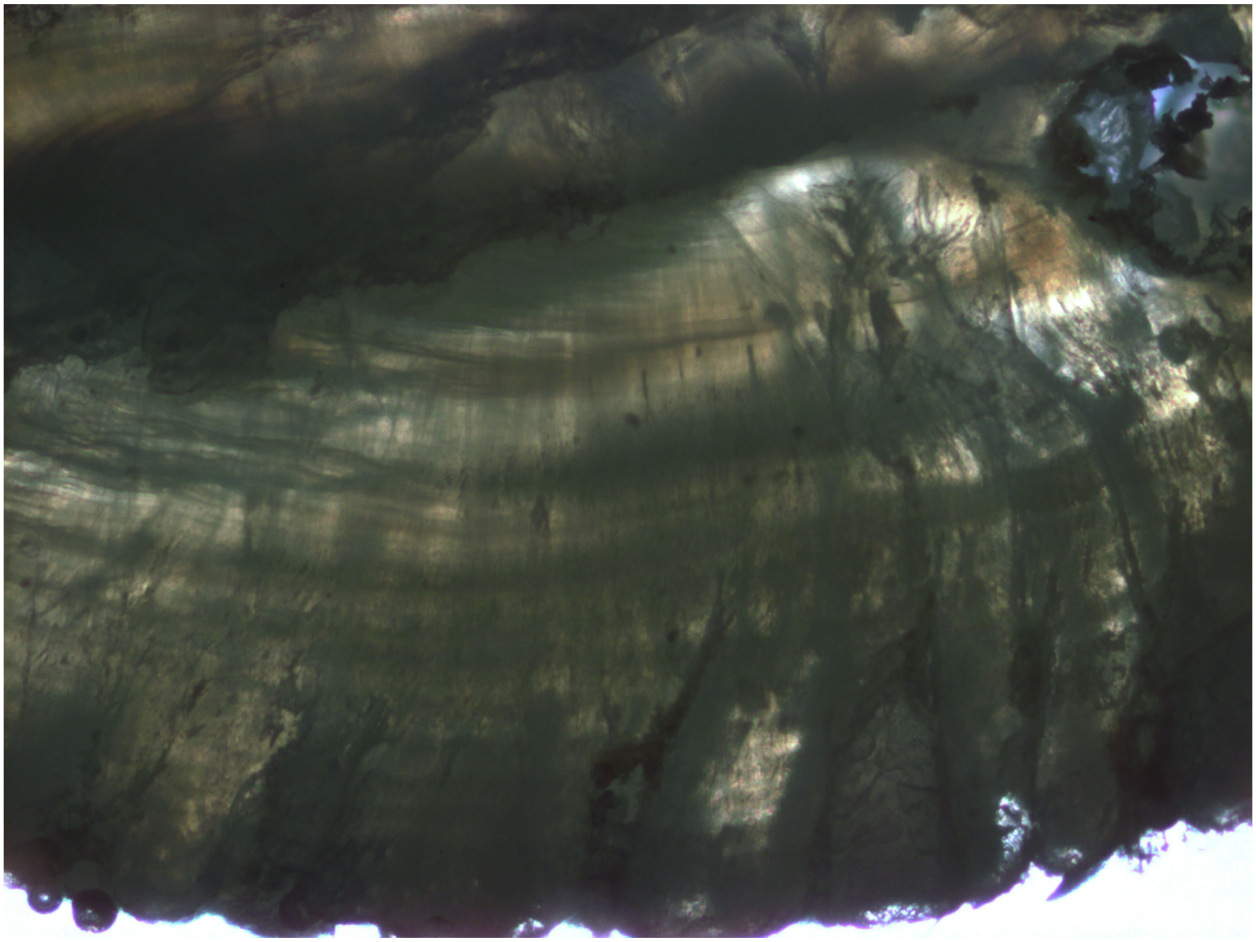

Figure 4. Sectioned lapilli otolith extracted from a Bighead Carp using gillnets.

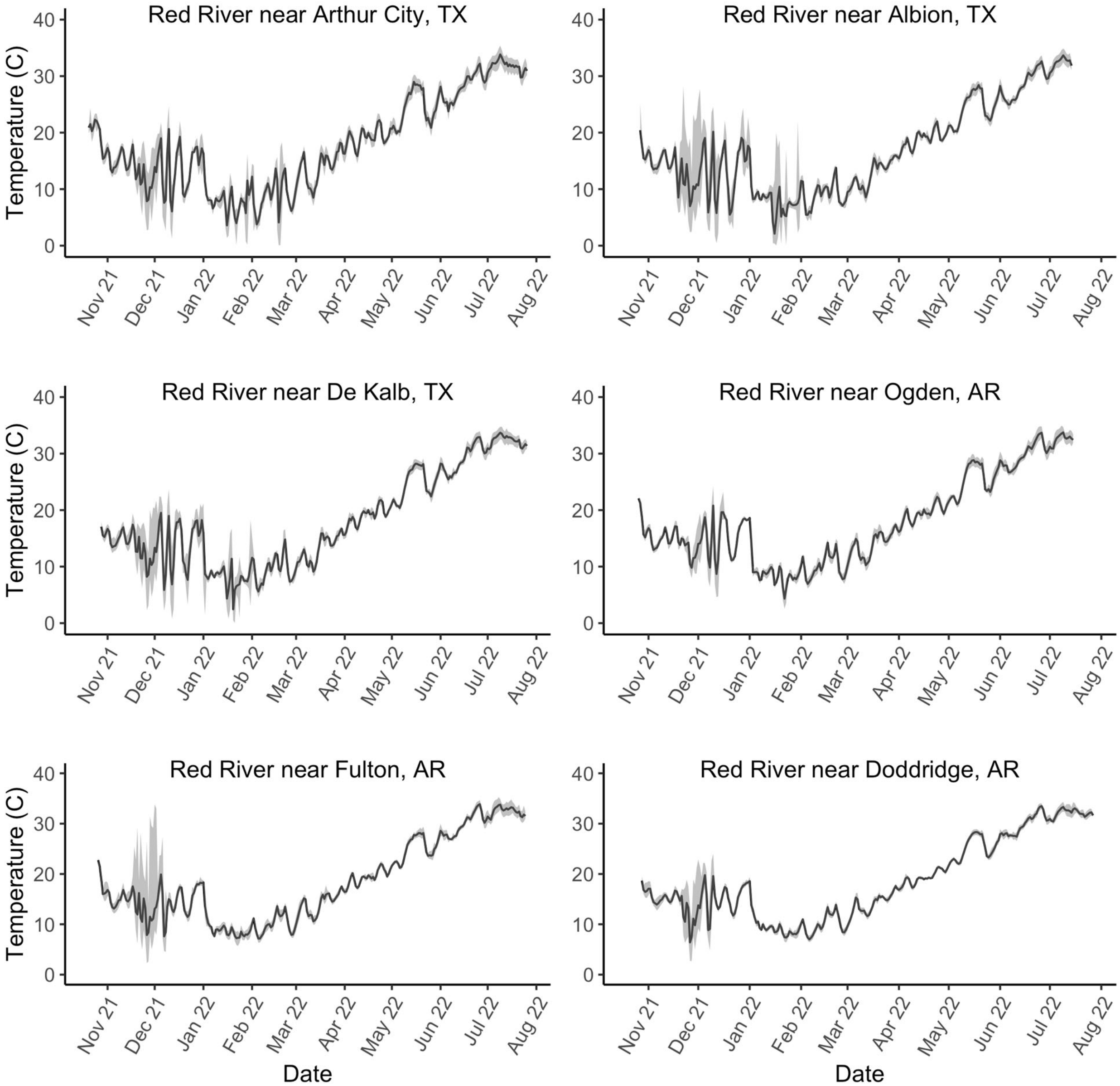

Figure 5. Daily mean water temperature data from loggers placed at locations on mainstem Red River. Gray shading indicates the observed daily maximum and minimum range.

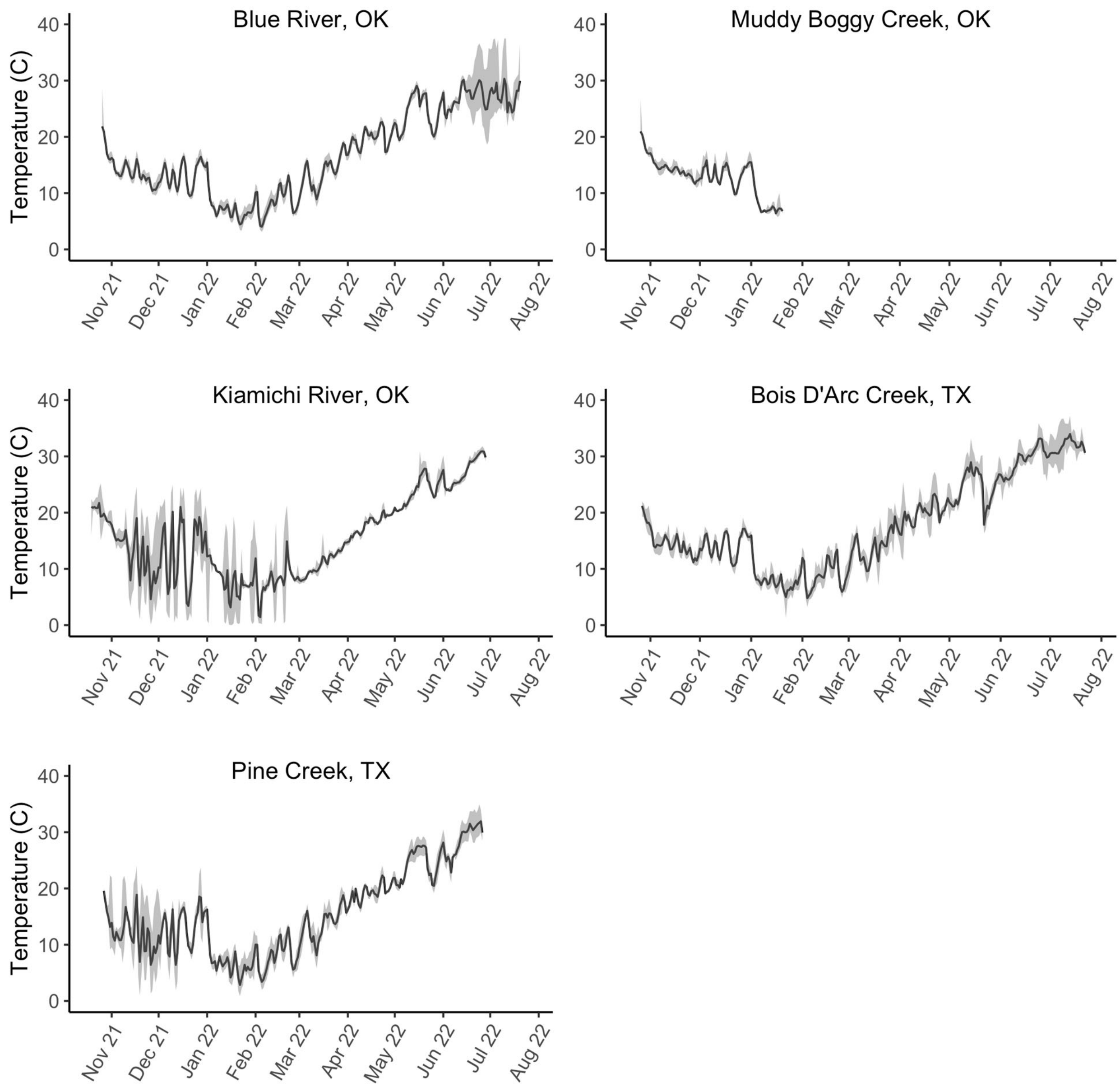

Figure 6. Daily mean water temperature data from loggers placed at locations in major tributaries. Gray shading indicates the observed daily maximum and minimum range. Two loggers (Muddy Boggy and Choctaw) were stolen from their mounted locations.

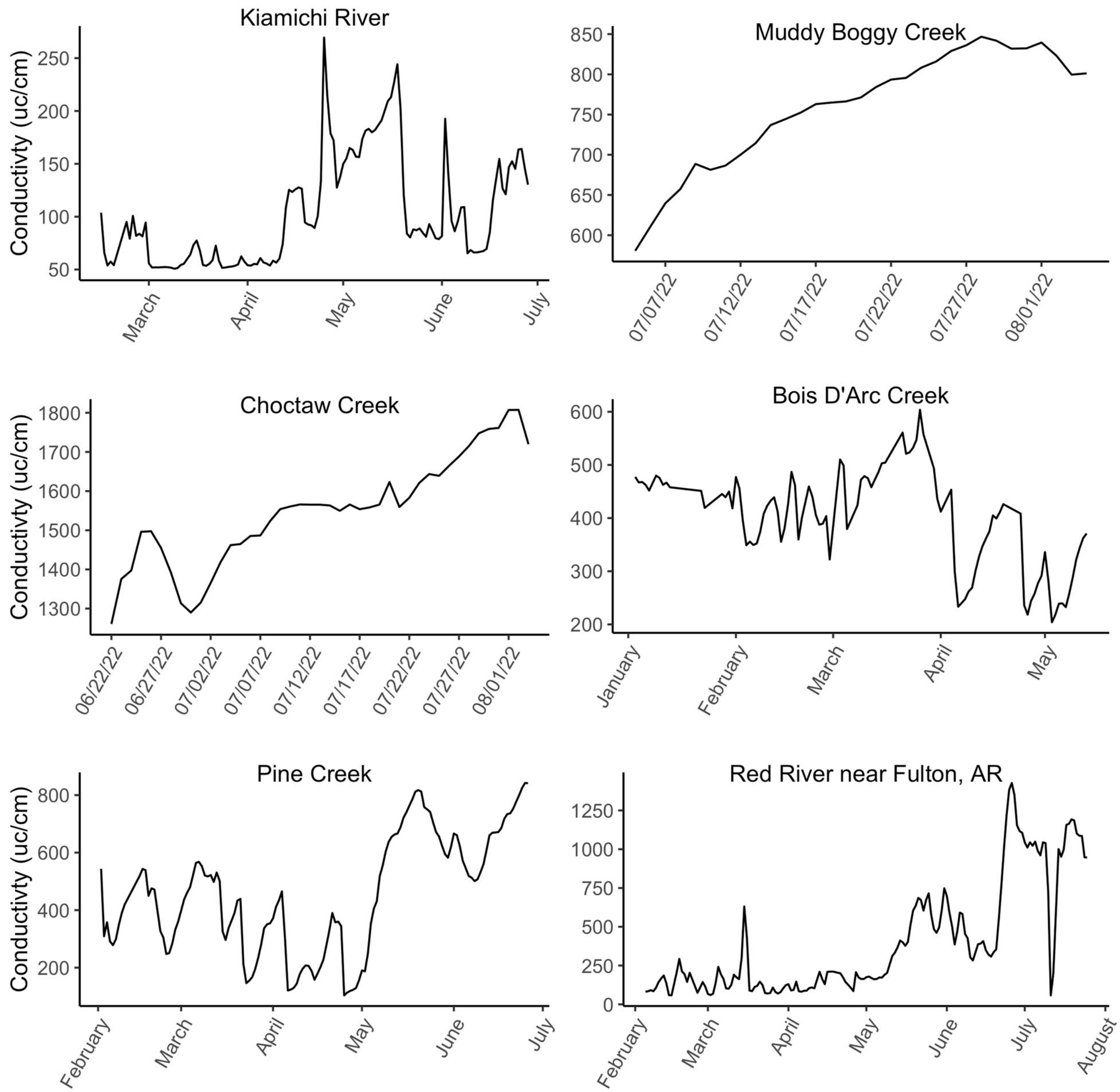

Figure 7. Daily (2022) mean water conductivity data from loggers placed throughout the study area.

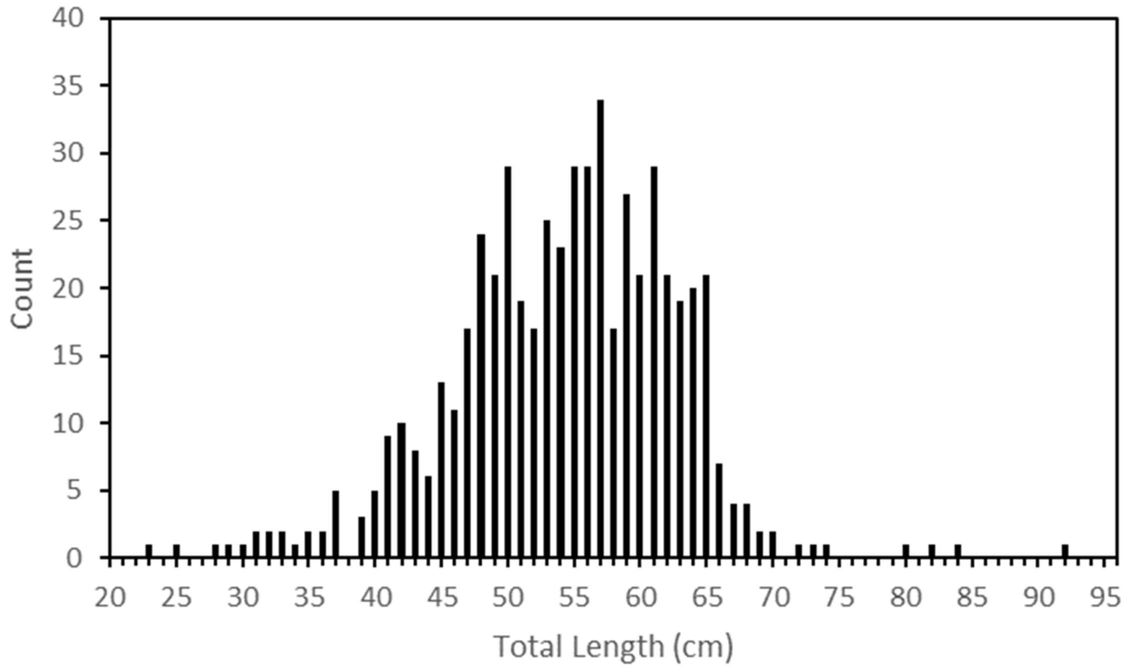

Figure 8. Length frequency (total length, cm) of Smallmouth Buffalo sampled from the lower Red River catchment using gillnets, hoop nets, and electrofishing (n=556).

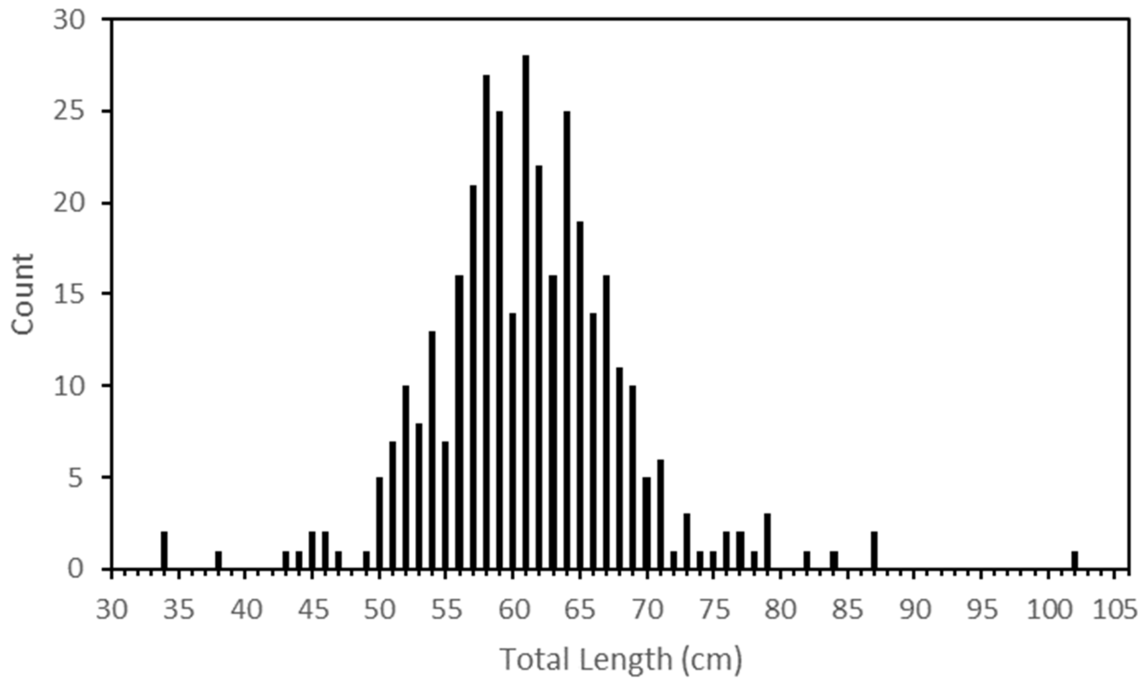

Figure 9. Length frequency (total length, cm) of Bigmouth Buffalo sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=356).

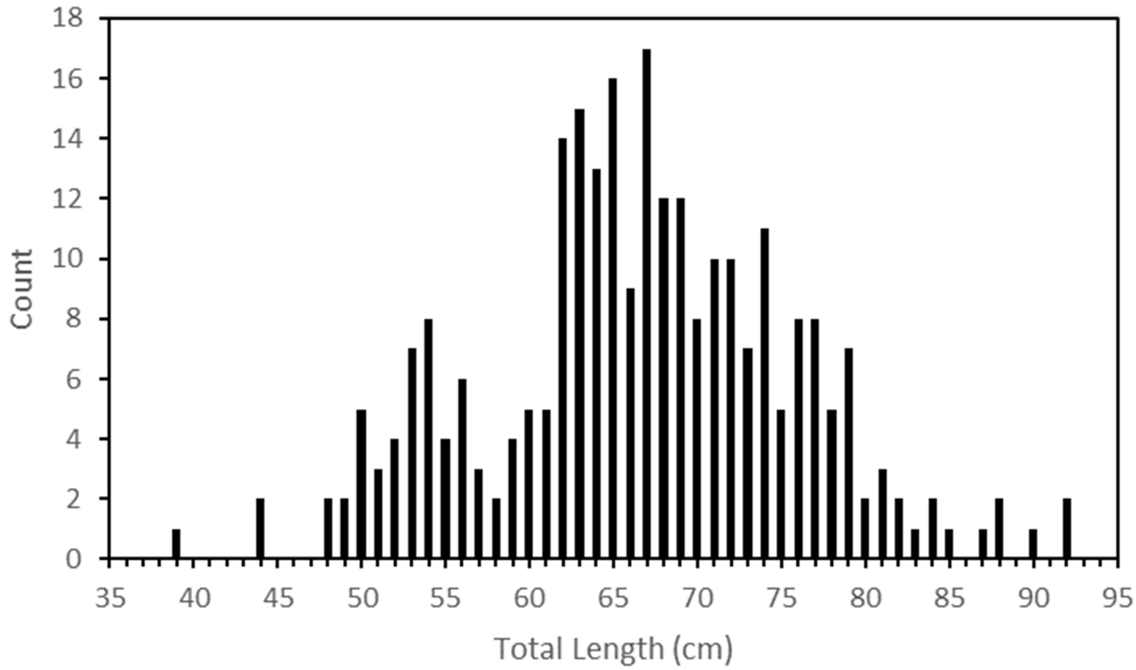

Figure 10. Length frequency (total length, cm) of Black Buffalo sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=267).

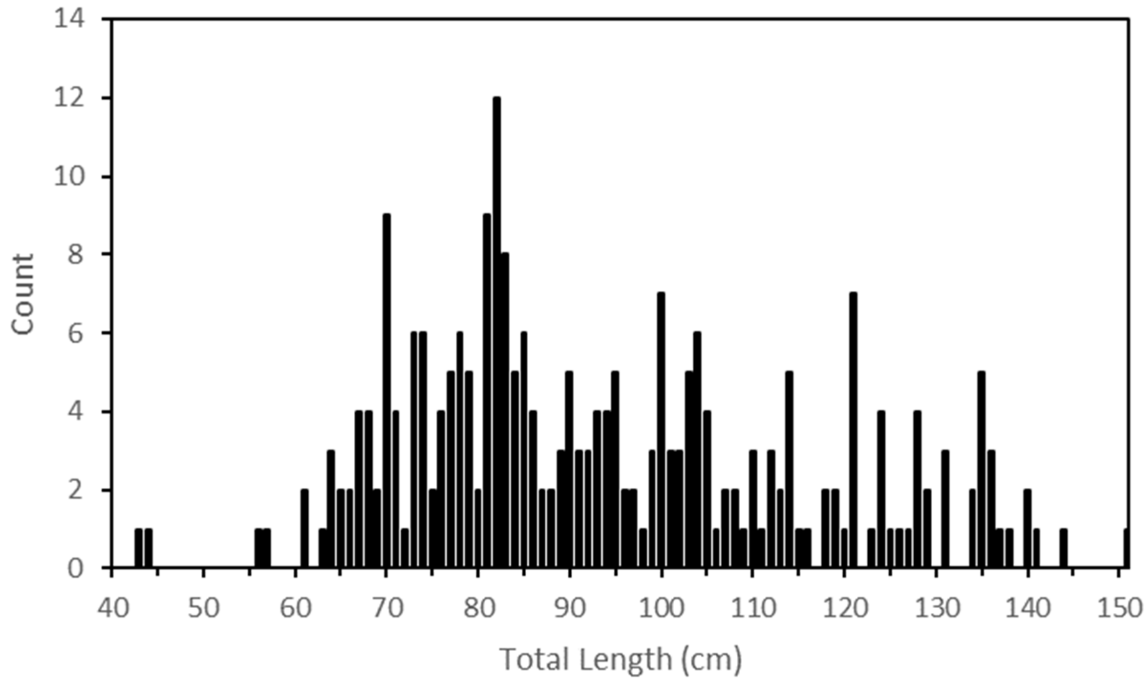

Figure 11. Length frequency (total length, cm) of Longnose Gar sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=254).

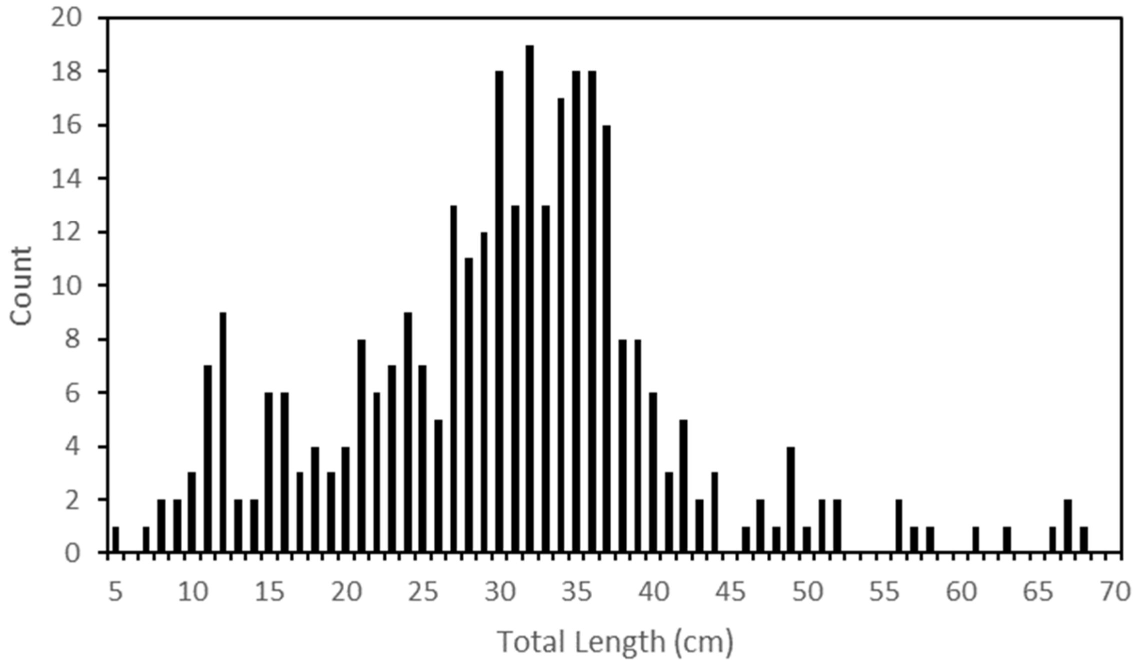

Figure 12. Length frequency (total length, cm) of River Carpsucker sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=325).

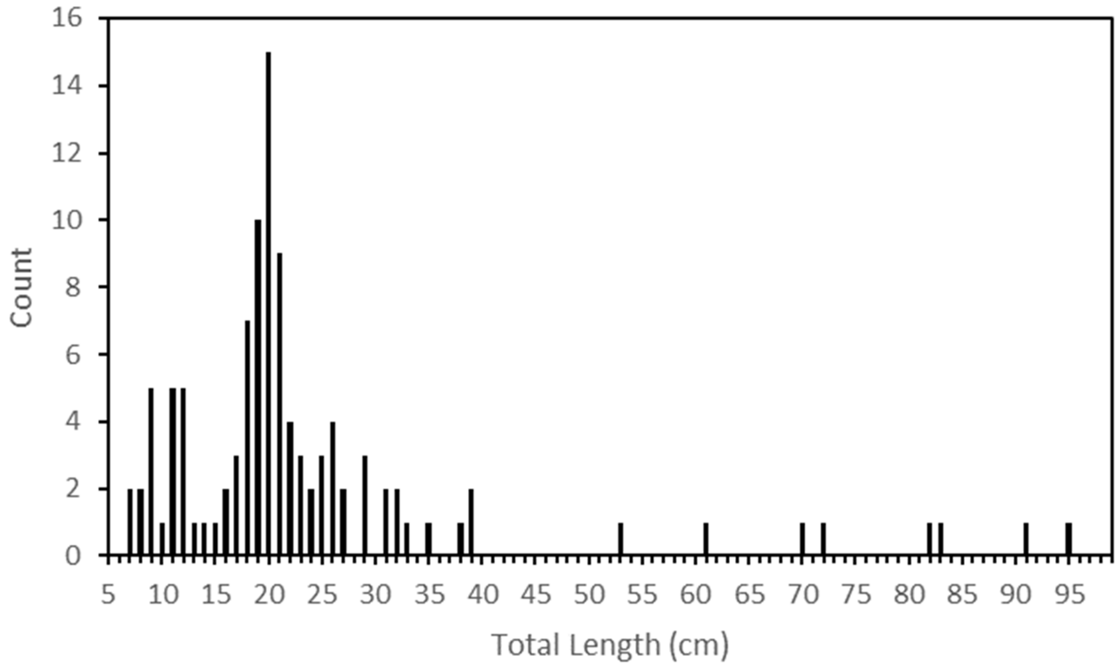

Figure 13. Length frequency (total length, cm) of Flathead Catfish sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=109).

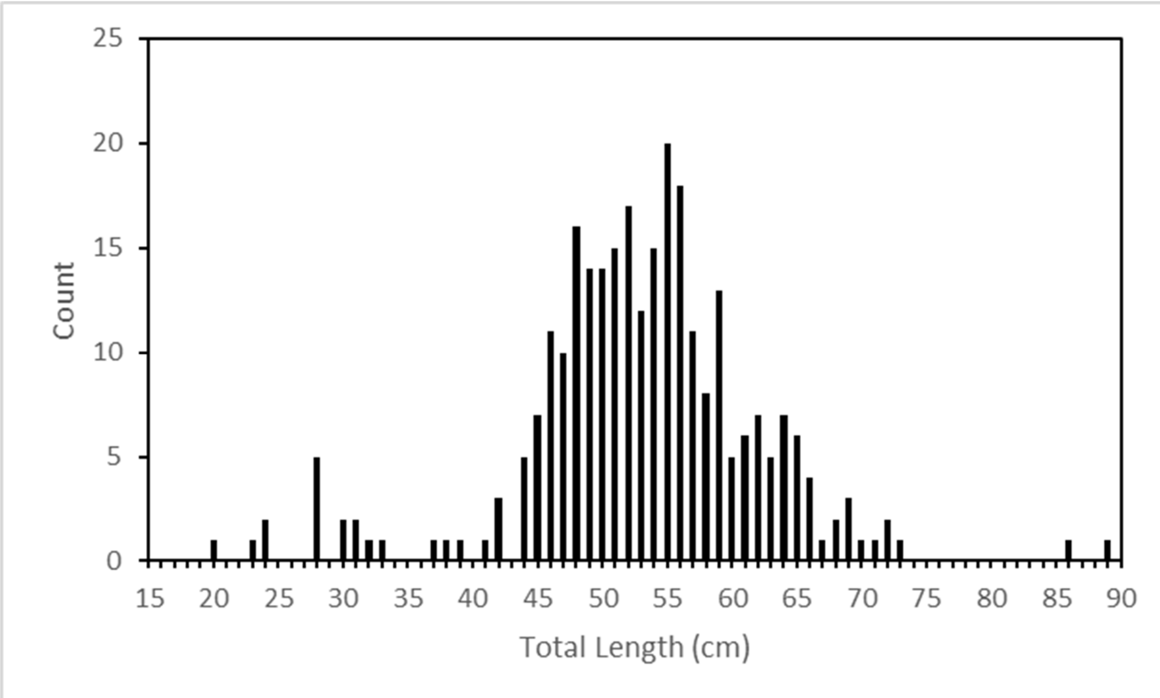

Figure 14. Length frequency (total length, cm) of Blue Sucker sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=284).

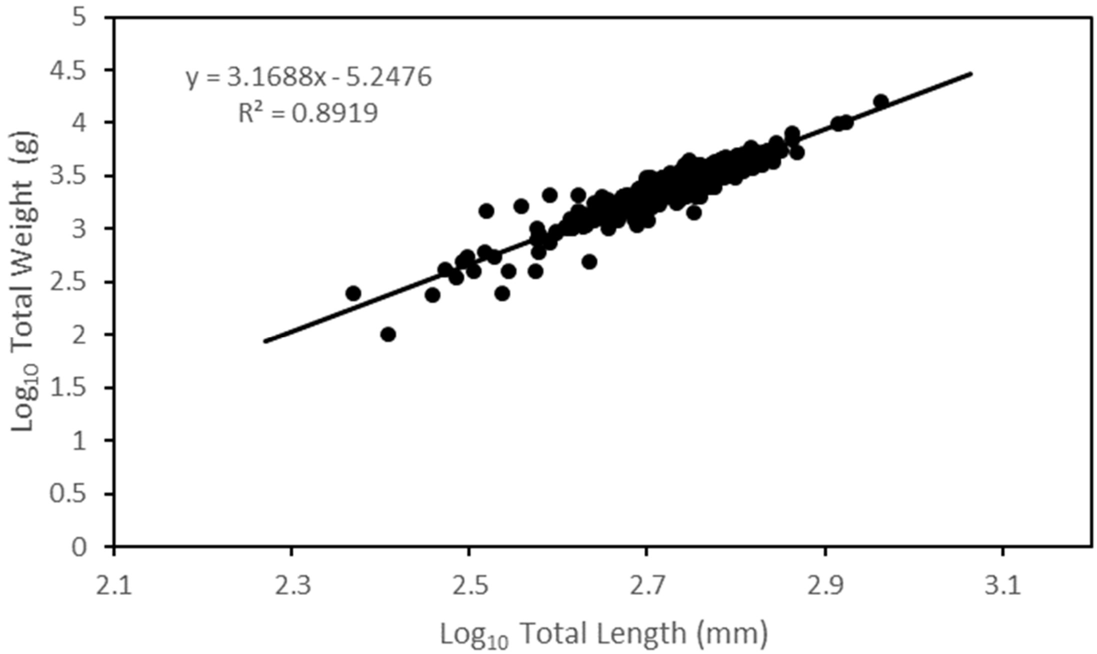

Figure 15. Relationship between the Log_{10} length (mm) and Log_{10} weight (g) for Smallmouth Buffalo sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=5204).

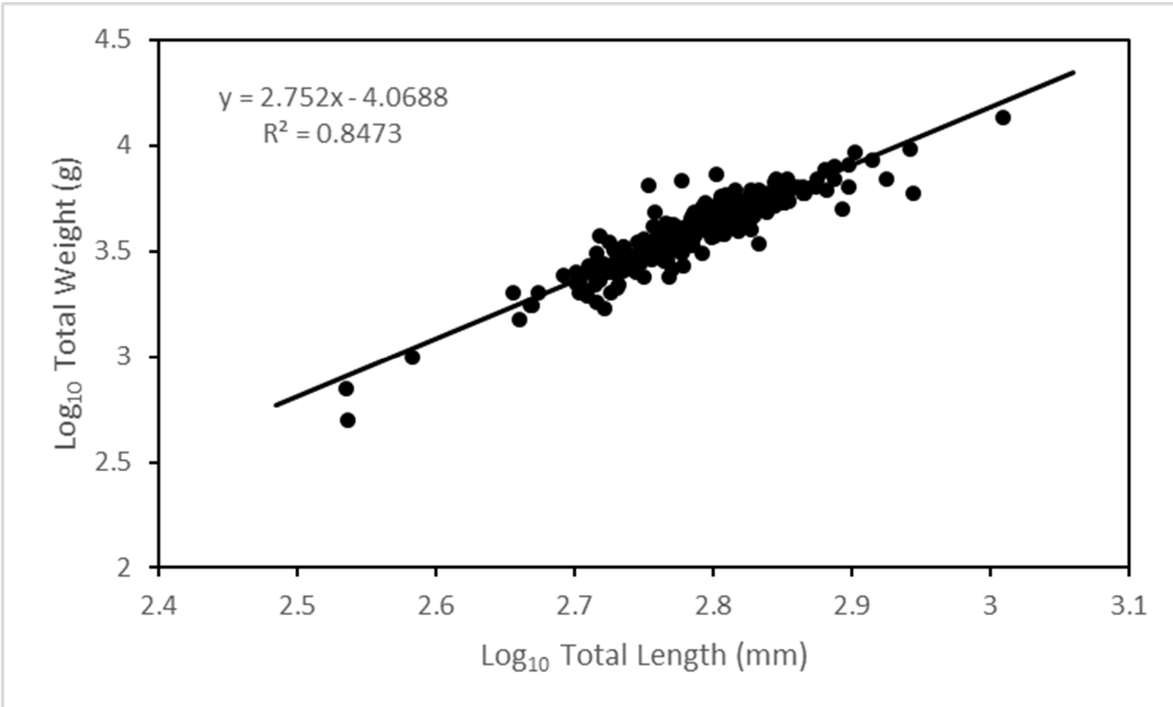

Figure 16. Relationship between the Log_{10} length (mm) and Log_{10} weight (g) for Bigmouth Buffalo sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=343).

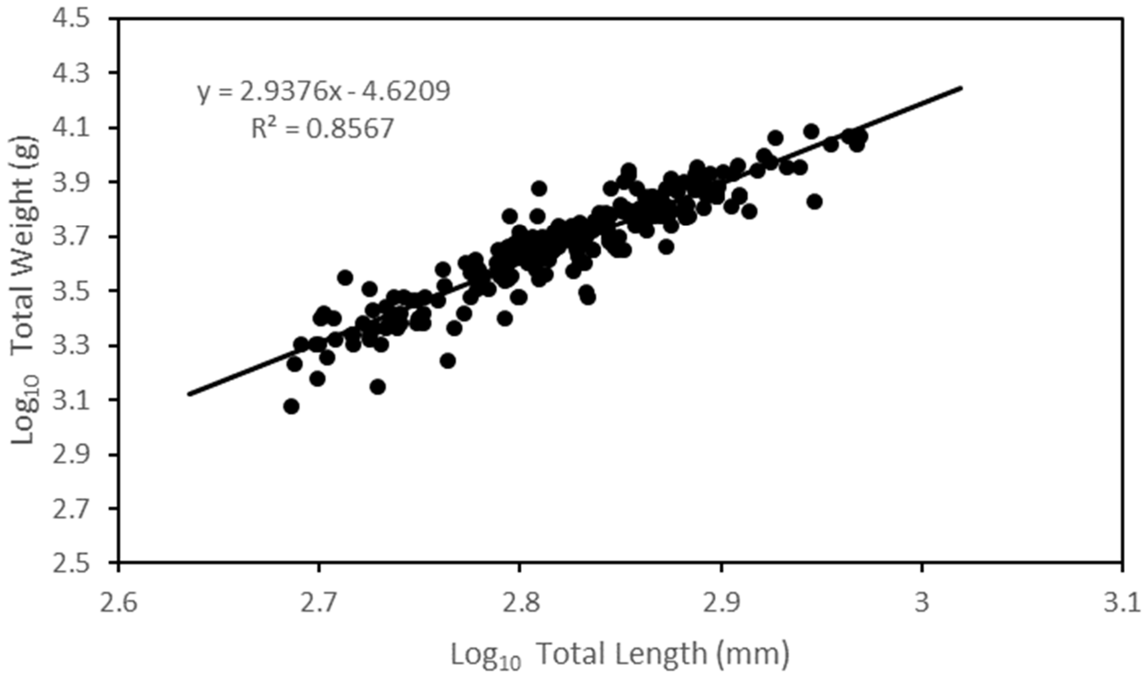

Figure 17. Relationship between the Log_{10} length (mm) and Log_{10} weight (g) for Black Buffalo sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=248).

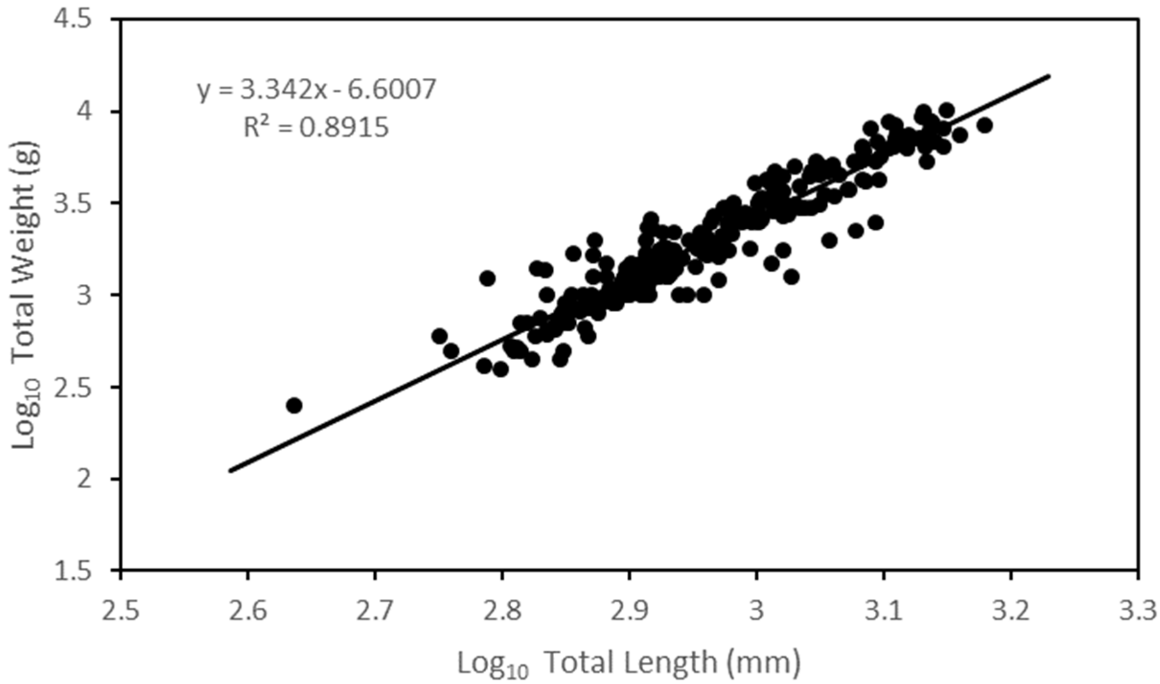

Figure 18. Relationship between the Log_{10} length (mm) and Log_{10} weight (g) for Longnose Gar sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=249).

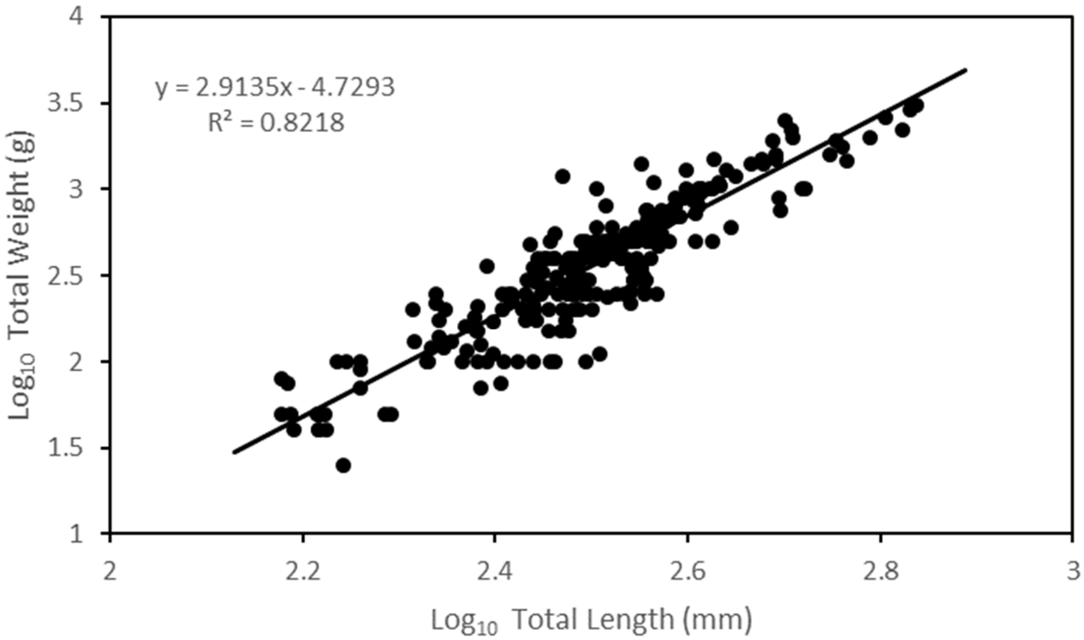

Figure 19. Relationship between the Log_{10} length (mm) and Log_{10} weight (g) for River Carpsucker sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=267).

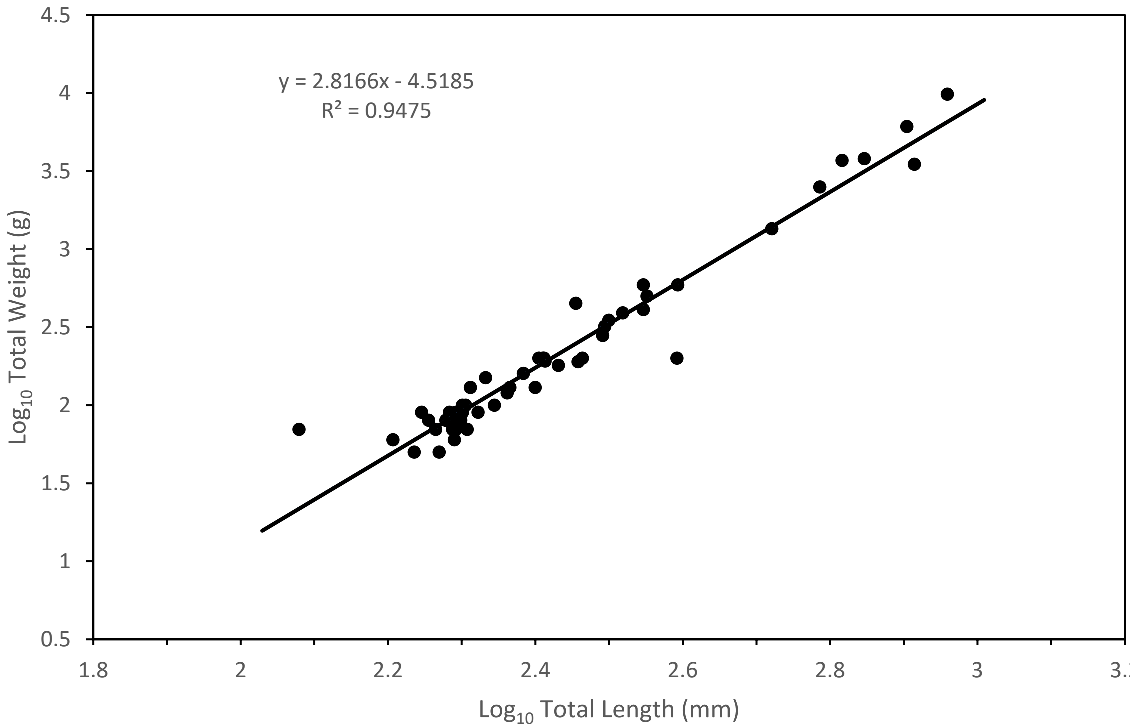

Figure 20. Relationship between the Log_{10} length (mm) and Log_{10} weight (g) for Flathead Catfish sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=63).

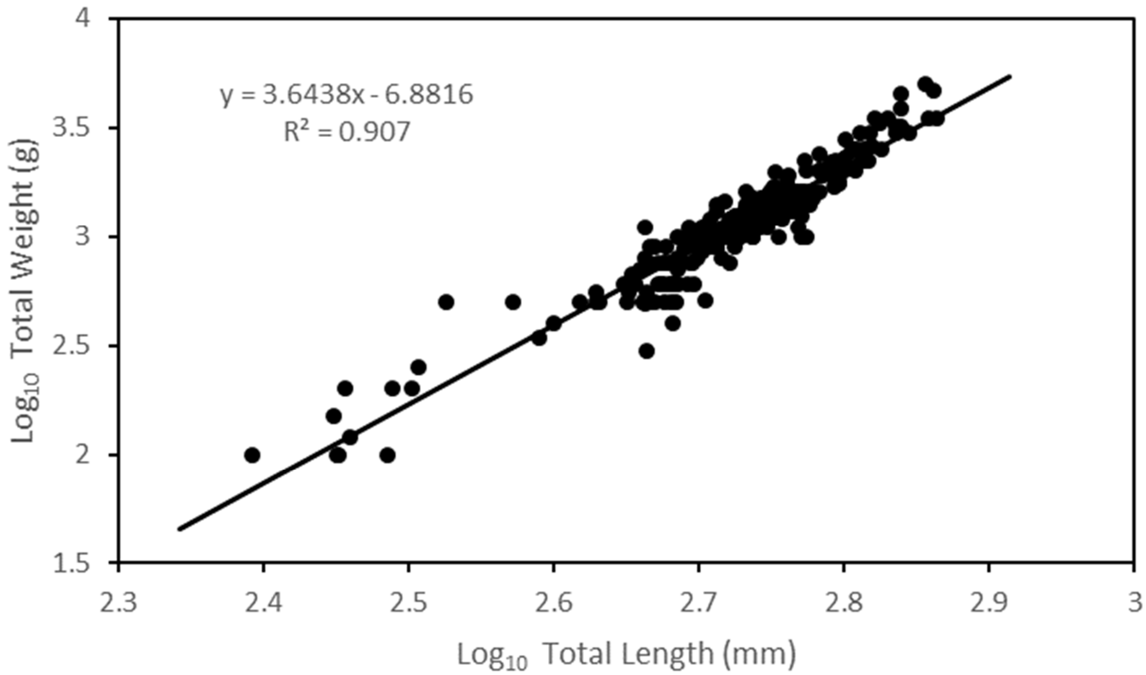

Figure 21. Relationship between the Log_{10} length (mm) and Log_{10} weight (g) for Blue Sucker sampled throughout the Red River basin using gillnets, hoop nets, and electrofishing (n=279).

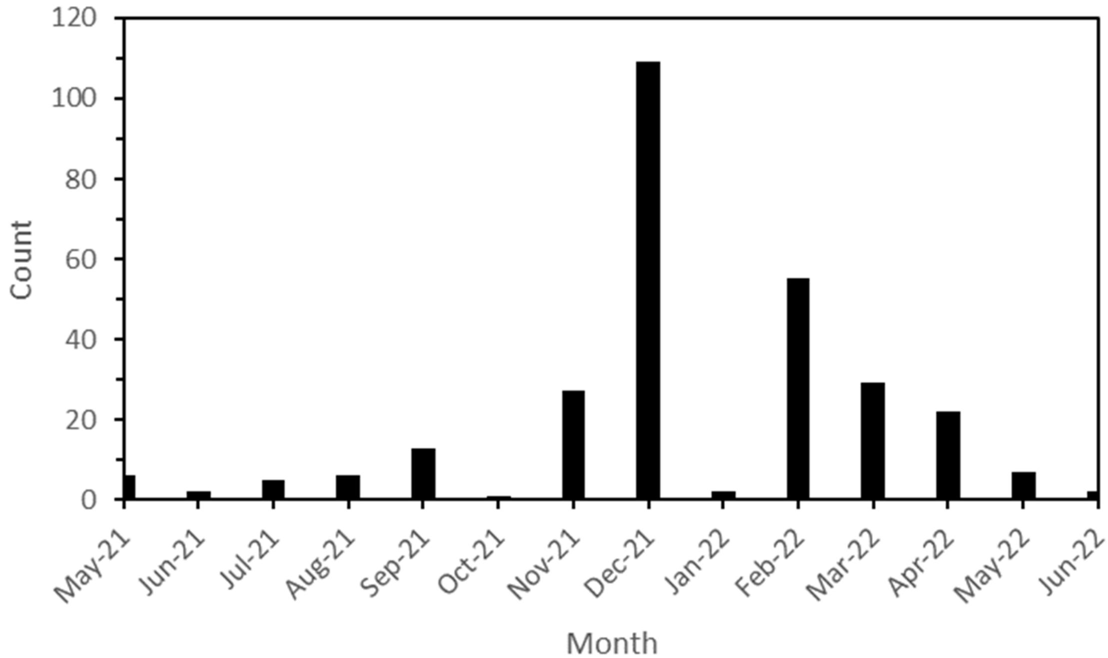

Figure 22. Total number of captured Blue Suckers by each sample month. Catch reflected used a combination of fish sampled using gillnets, hoop nets, and electrofishing in the lower Red River basin (n=285).

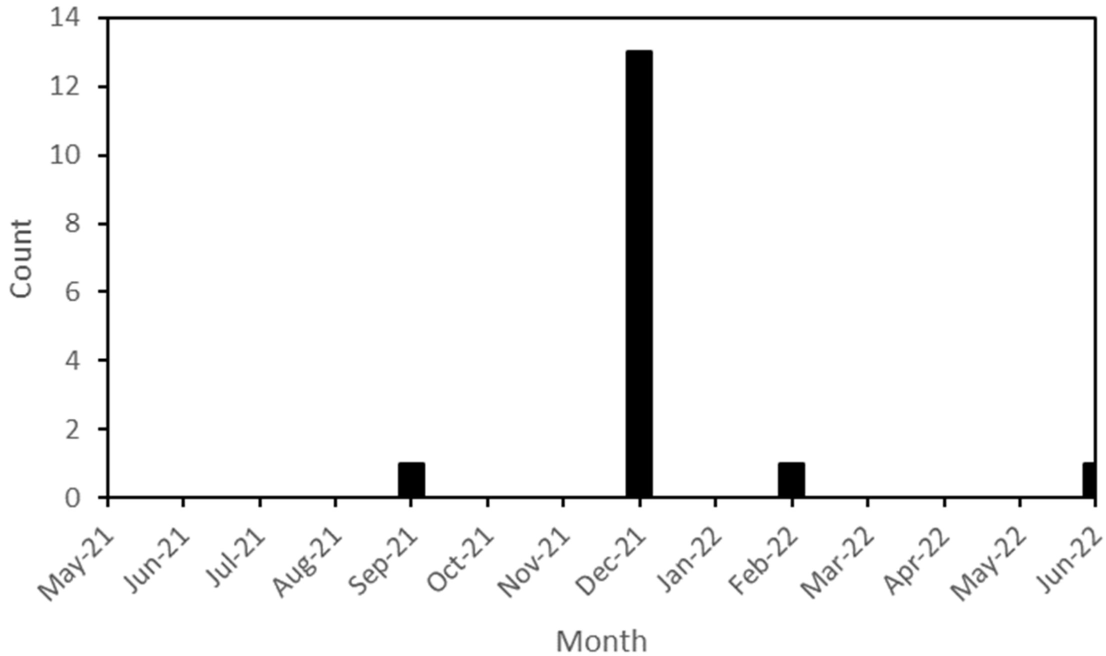

Figure 23. Total number of captured Shovelnose Sturgeon by each sample month. Catch reflected used a combination of fish sampled using gillnets, hoop nets, and electrofishing in the lower Red River basin (n=16).

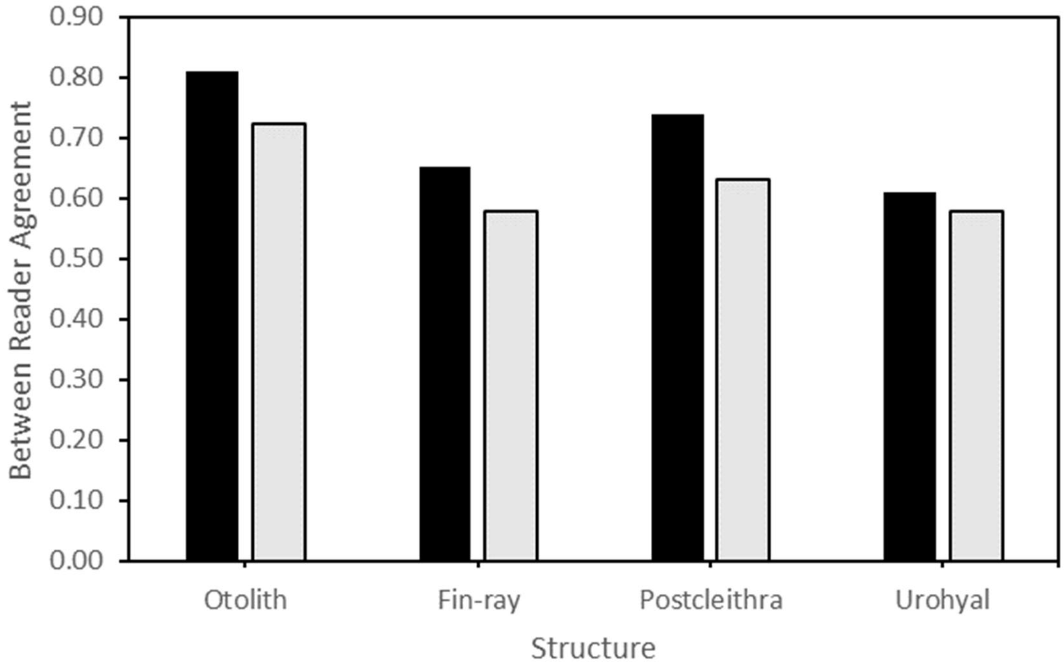

Figure 24. The between-reader-agreement for ageing structures for Silver Carp (black bars) and Bighead Carp (gray bars) collected from the lower Red River catchment. These data will be more robust after we complete the ageing associated with 2022 sampling.

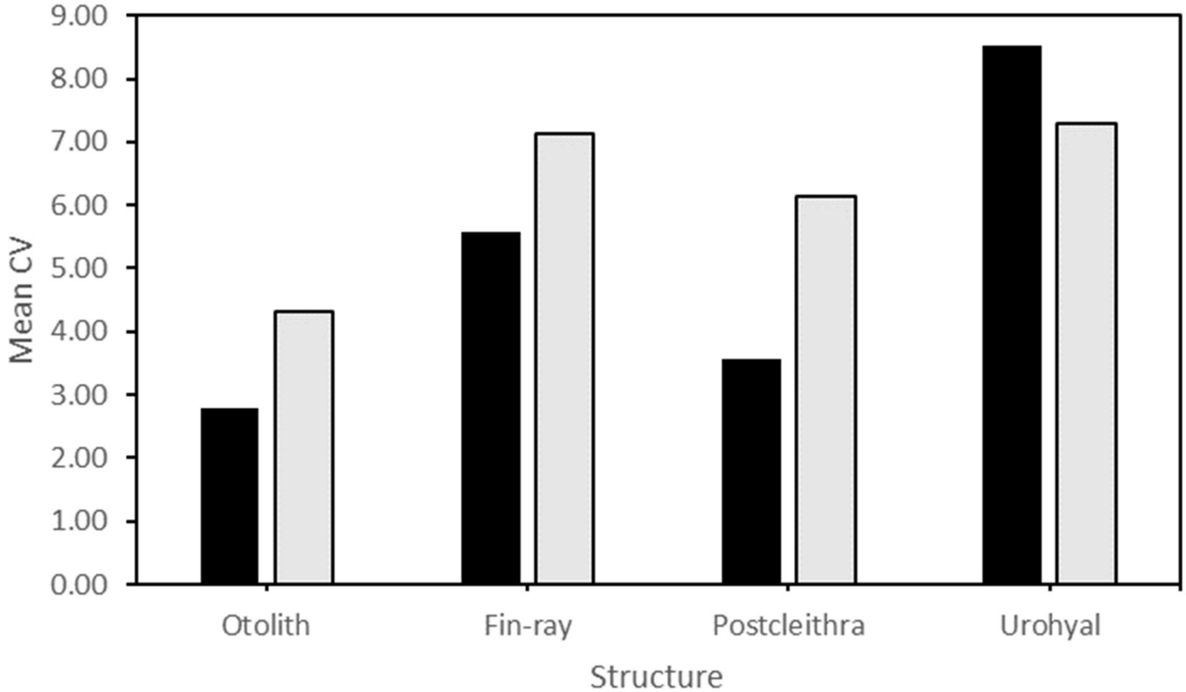

Figure 25. The mean CV associated with ageing structures for Silver Carp (black bars) and Bighead Carp (gray bars) collected from the lower Red River catchment. These data will be more robust after we complete the ageing associated with 2022 sampling.

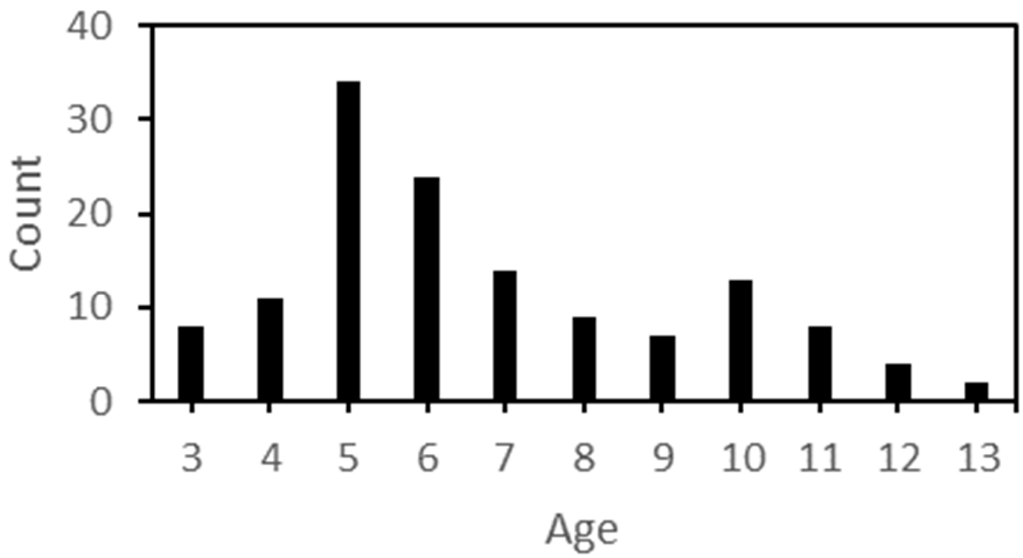

Figure 26. Age frequency of Silver Carp collected from the lower Red River catchment These data will be more robust after we complete the ageing associated with 2022 sampling.

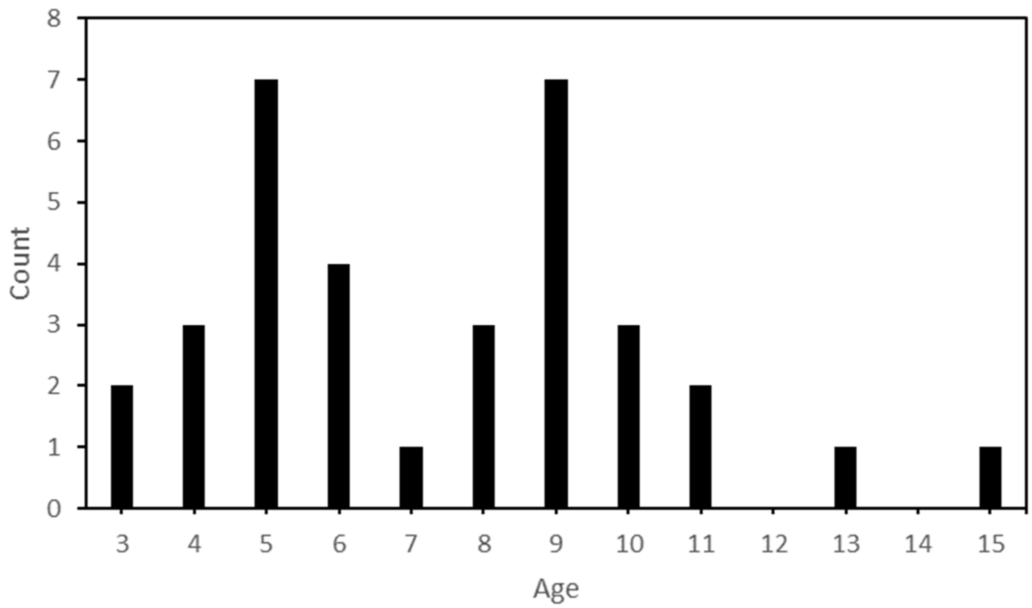

Figure 27. Age frequency of Bighead Carp collected from the lower Red River catchment. These data will be more robust after we complete the ageing associated with 2022 sampling.

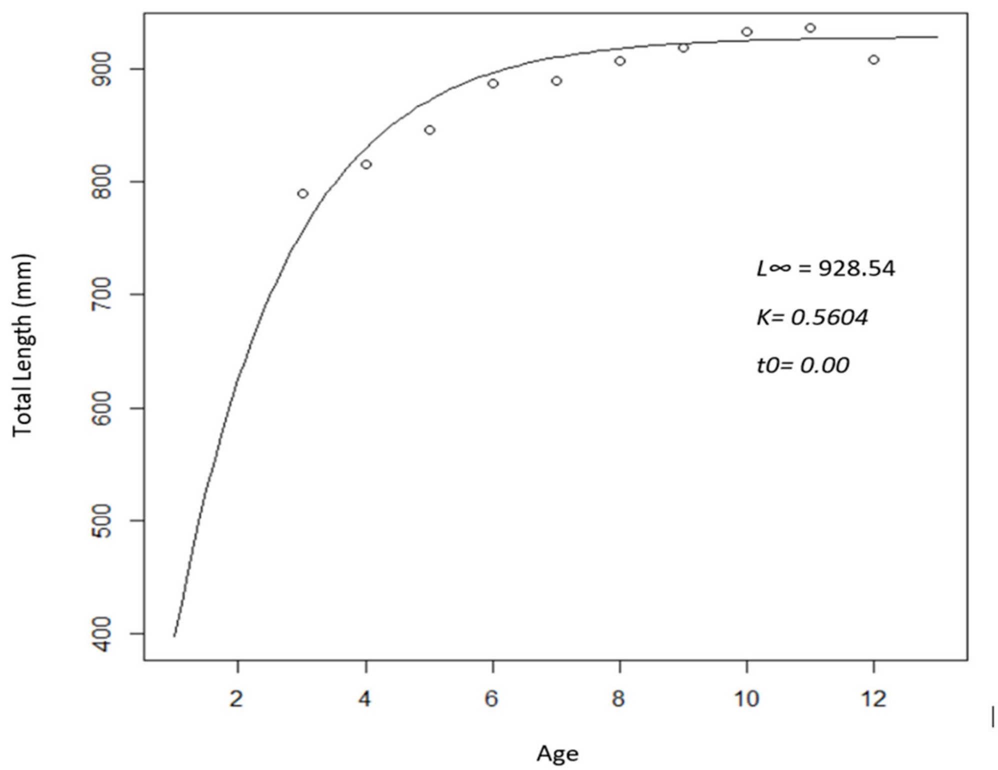

Figure 28. A von Bertalanffy growth curve with the corresponding theoretical maximum length (*L*∞)), growth coefficient (*K*), and time when length was zero (*t0*) for Silver Carp collected from the lower Red River catchment. These data will be more robust after we complete the ageing associated with 2022 sampling.

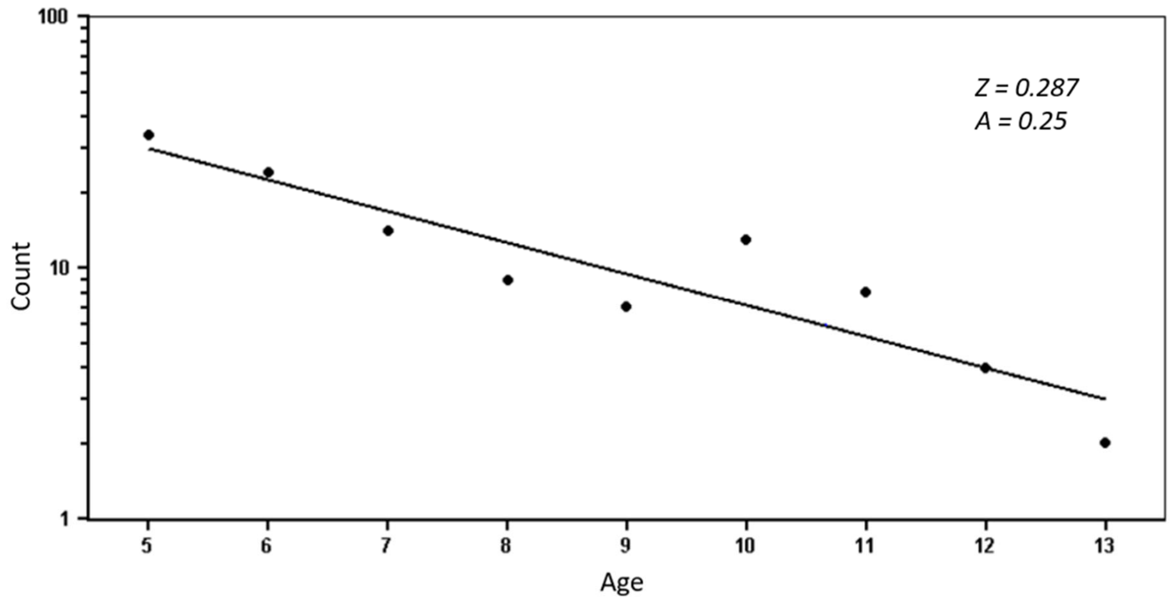

Figure 29. A Chapman-Robson catch-curve with the corresponding instantaneous mortality estimate (*Z*) and annual mortality estimate (*A*) for Silver Carp collected from the lower Red River catchment. These data will be more robust after we complete the ageing associated with 2022 sampling.

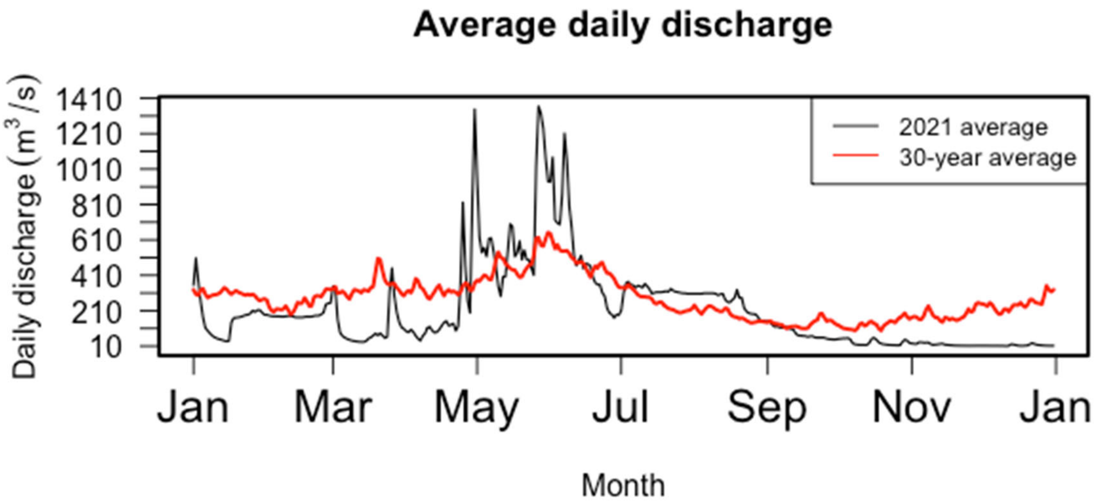

Figure 30. Average daily discharge over the 2021 sampling period. The red line indicates the 30-year average discharge conditions. Data are from U.S. Geological Survey, stream gauge 07335500 at Arthur City, TX.

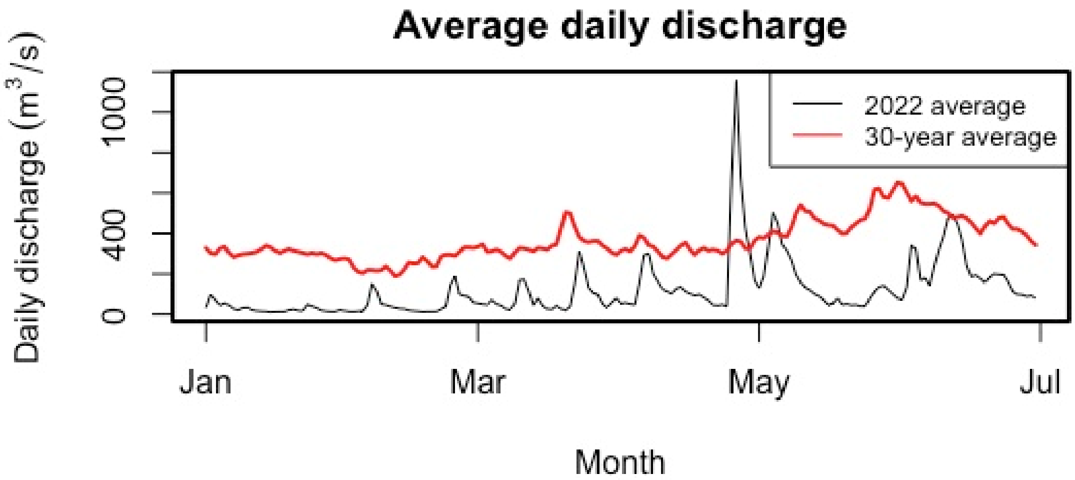

Figure 31. Average daily discharge over the 2022 sampling period (January 1st – June 30th). The red line indicated the 30-year average discharge conditions. Data are from U.S. Geological Survey, stream gauge 07335500 at Arthur City, TX.

Appendix A. The common name with the corresponding scientific name for fish species sampled in the lower Red River basin.

Common Name	Scientific Name
Alligator Gar	*Atractosteus spatula*
American Eel	*Anguilla rostrata*
American Paddlefish	*Polyodon spathula*
Bigeye Shiner	*Notropis boops*
Bigmouth Buffalo	*Ictiobus cyprinellus*
Black Buffalo	*Ictiobus niger*
Black Crappie	*Pomoxis nigromaculatus*
Blackside Darter	*Percina maculata*
Blackspotted Topminnow	*Fundulus olivaceus*
Blackstripe Topminnow	*Fundulus notatus*
Blacktail Shiner	*Cyprinella venusta*
Blue Catfish	*Ictalurus furcatus*
Blue Sucker	*Cycleptus elongatus*
Bluegill	*Lepomis macrochirus*
Bluntnose Darter	*Etheostoma chlorosomum*
Bluntnose Minnow	*Pimephales notatus*
Brook Silverside	*Labidesthes sicculus*
Bullhead Minnow	*Pimephales vigilax*
Channel Catfish	*Ictalurus punctatus*
Chestnut Lamprey	*Ichthyomyzon castaneus*
Chub Shiner	*Notropis potteri*
Common Carp	*Cyprinus carpio*
Dusky Darter	*Percina sciera*
Emerald Shiner	*Notropis atherinoides*
Fathead Minnow	*Pimephales promelas*
Flathead Catfish	*Pylodictis olivaris*
Flier	*Centrarchus macropterus*
Freckled Madtom	*Noturus nocturnus*
Freshwater Drum	*Aplodinotus grunniens*
Ghost Shiner	*Notropis buchanani*
Gizzard Shad	*Dorosoma cepedianum*
Golden Redhorse	*Moxostoma erythrurum*
Golden Shiner	*Notemigonus crysoleucas*
Golden Topminnow	*Fundulus chrysotus*
Goldeye	*Hiodon alosoides*
Grass Carp	*Ctenopharyngodon idella*
Green Sunfish	*Lepomis cyanellus*
Hybrid Sunfish	*Lepomis spp.*

Largemouth Bass	*Micropterus salmoides*
Logperch	*Percina caprodes*
Longear Sunfish	*Lepomis megalotis*
Longnose Gar	*Lepisosteus osseus*
Mississippi Silverside	*Menidia audens*
Mississippi Silvery Minnow	*Hybognathus nuchalis*
Mooneye	*Hiodon tergisus*
Mosquitofish	*Gambusia affinis*
Orangespotted Sunfish	*Lepomis humilis*
Pallid Shiner	*Hybopsis amnis*
Pirate Perch	*Aphredoderus sayanus*
Plains Killifish	*Fundulus zebrinus*
Pugnose Minnow	*Opsopoeodus emiliae*
Quillback	*Carpiodes cyprinus*
Red Shiner	*Cyprinella lutrensis*
Redear Sunfish	*Lepomis microlophus*
Redspotted Sunfish	*Lepomis miniatus*
River Carpsucker	*Carpiodes carpio*
River Darter	*Percina shumardi*
Sand Shiner	*Notropis stramineus*
Shoal Chub	*Macrhybopsis hyostoma*
Shortnose Gar	*Lepisosteus platostomus*
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*
Silver Chub	*Macrhybopsis storeriana*
Silverband Shiner	*Notropis shumardi*
Skipjack Herring	*Alosa chrysochloris*
Slough Darter	*Etheostoma gracile*
Smallmouth Buffalo	*Ictiobus Bubalus*
Spotted Bass	*Micropterus punctulatus*
Spotted Gar	*Lepisosteus oculatus*
Spotted Sucker	*Minytrema melanops*
Striped Bass	*Morone saxatilis*
Suckermouth Minnow	*Phenacobius mirabilis*
Tadpole Madtom	*Noturus gyrinus*
Threadfin Shad	*Dorosoma petenense*
Warmouth	*Lepomis gulosus*
Western Sand Darter	*Ammocrypta clara*
Western Starhead Topminnow	*Fundulus blairae*
White Bass	*Morone chrysops*
White Crappie	*Pomoxis annularis*
Yellow Bullhead	*Ameiurus natalis*