Relative Population Densities of Asian Carp in the Tennessee River and Cumberland Rivers, Tributaries of the Ohio River

2018 Technical Report

Authors: Mark Rogers, Frank Fiss, Jessica Morris, Savannah Fernholz

Geographic Location: Ohio River Basin; Tennessee and Cumberland rivers

Participating Agencies: Kentucky Department of Fish and Wildlife Resources (KDFWR), Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP), Alabama Department of Conservation and Natural Resources, Tennessee Wildlife Resources Agency (TWRA), Tennessee Technological University (TTU), U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS).

Introduction:

In 2004, the USFWS and the Aquatic Nuisance Species (ANS) Task Force formed the Asian Carp Working Group in response to a request for the development of a national management and control plan for all species of Asian carp. The "Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States" was published in October, 2007, with the objective of "providing strategies and recommendations to address various aspects of prevention, control, and management" of the four Asian carp species (Conover et al. 2007). The goal of the plan is the complete extirpation of invasive Asian carp species from waters in the U.S. Since drafting the management plan, intensive research efforts have been conducted to expand knowledge of Asian carp in the U.S., particularly to assess population dynamics (e.g., growth, recruitment, and abundance), determine the potential for a commercial market, assess effective capture methods, and determine habitat use and diets. States in which Asian carp are well established, such as Arkansas, Missouri, and Illinois, have already conducted studies assessing population characteristics and local distributions and movement. States where Asian carp have more recently been found (i.e., Kentucky, Tennessee, South Dakota) are beginning to conduct research on the "leading edge" of distribution to determine local population characteristics, ecosystem effects, and potential management plans and control efforts.

Within the national management plan, sub-basin strategies for combating the spread of Asian carp help focus efforts within specific regions of the U.S. Since their introduction, Asian carp have spread into many of the major tributaries of the Mississippi River, including the Ohio River

(Conover et al. 2007). The Ohio River basin is comprised of the Ohio River watershed that spans 15 states, including Illinois, Indiana, Ohio, New York, Pennsylvania, Kentucky, West Virginia, Virginia, Maryland, Tennessee, North Carolina, South Carolina, Alabama, Mississippi and Georgia. The Ohio River Basin Asian Carp Control Strategy Framework reflects the goals of the national plan. The framework aims to prevent further spread of Asian carp throughout the basin, assess the specific ecological impacts of Asian carp invasion on the Ohio River and its tributaries, and develop control strategies for the four Asian carp species.

Research and monitoring on bigheaded carp (i.e., Silver carp *Hypophthalmichthyes* molitrix and Bighead carp *H. nobilis*) in the Tennessee and Cumberland rivers was initiated fairly recently, and both are tributaries of the Ohio River. Bighead Carp were first reported in Tennessee in 1994 and Silver Carp in 1989 (Kolar et al. 2007). In April, 2014, the Kentucky Department of Fish and Wildlife Resources (KDFWR) reported two large Asian carp die-offs below Kentucky and Barkley dams. Species included Bighead, Silver, and Grass Carp *Ctenopharyngodon idella*. Upon investigation, the die-offs were attributed to gas bubble disease, a condition caused by the exposure of fish to water supersaturated with gasses (KDFWR 2014b). Several carp specific fish kills also occurred in the spring and fall of 2017, with the cause attributed to the commonly found bacteria *Aeromonas hydrophila* (TWRA 2017). To date, Bighead Carp have been reported as far as Watts Bar Reservoir and Silver Carp as far as Wheeler Reservoir on the Tennessee River. Silver Carp have also been observed as far as Old Hickory Reservoir on the Cumberland River (USFWS 2016). A study conducted by Tennessee Tech University confirmed the presence of bigheaded carp in Kentucky Reservoir and Barkley Reservoir, and characteristics of both populations (including high growth rates, robustness, and skewed sex ratios) were indicative of the early stages of invasion and colonization (Ridgway 2016). However, the study was based on opportunistic sampling to gather initial population data without formal sampling design. As both species continue to spread throughout the Tennessee and Cumberland rivers, more systematically collected data is needed to determine their distribution and abundance.

Objective:

1. Conduct targeted sampling for the purpose of surveillance, early detection, distribution, and relative population characteristics of Asian carp in the Tennessee and Cumberland rivers.

Within Objective 1 there are three sub-components that are addressed below in methods, and results.

1-a. Use catch data to assess spatial variation in relative densities of bigheaded carp in lower impoundments of the Tennessee and Cumberland rivers.

1-b. Assess population characteristics (i.e., size structure, condition, and sex characteristics) of bigheaded carp within selected reservoirs of the Tennessee and Cumberland rivers.

1-c. Assess the efficacy of standardized sampling methods for capturing bigheaded carp in large impoundments.

Methods:

Reservoirs on the Tennessee and Cumberland rivers were systematically sampled to assess spatial variation in relative densities of bigheaded carp across their longitudinal gradients. Sampling reaches were chosen at approximately equally spaced intervals throughout each reservoir and based on sampling gear constraints (e.g., depth, barge traffic) and the advice of biologists familiar with the study systems (e.g., TWRA and USGS). One reach was sampled in the lacustrine (downstream), transition, and riverine (upstream) zones of Kentucky Reservoir and Barkley Reservoir. In Kentucky Reservoir, the downstream reach was located near Kentucky Dam, transition reach near Big Sandy embayment, and upstream reach near the Duck River (Figure 1). In Barkley Reservoir, the downstream reach was located near Barkley Dam, transition reach near the Little River embayment, and upstream reach near the Saline Creek embayment (Figure 1). One reach was sampled in the upstream and downstream zones of Pickwick Reservoir and Cheatham Reservoir. In Pickwick Reservoir, the downstream reach was located near Pickwick Dam and upstream reach near Bear Creek embayment (Figure 1). In Cheatham Reservoir, the downstream reach was located near Cheatham Dam and upstream reach near Sycamore Creek (Figure 1). During each sampling event, water temperature and global positioning system (GPS) coordinates of sample locations were recorded.

The sampling design and procedure was similar to protocols used by commercial fishers in Kentucky and Tennessee and the methods described by Welker and Drobish (2010) and Ridgway (2016). Experimental monofilament gill nets were used, and each net consisted of two 45.7 m panels of either 76 and 89 mm square meshes (Type-I net) or 101 and 108 mm square meshes (Type-II net). All nets were 3.7 m in height, hobbled down to 2.4 m, and had a lead core bottom line and an 8 mm diameter foam core top line. Nets were set as floating sets and in gangs, with one of each net type deployed at a sampling site. Four sites were fished per sampling reach in all reservoirs using short, 2-hour gill net sets in summer 2017. Three sites were fished per sampling reach in all reservoirs using overnight gill net sets in fall 2017 and spring. summer and fall 2018. Overnight sets were limited to the fall, spring, and early summer to minimize bycatch mortality, with specific concern for American paddlefish *Polyodon spathula* (Bettoli and Scholten 2006; but see below). Net sets were placed in areas of low water velocity at depth ranges of 1.8-6 m. Catch-per-unit effort (CPUE) was calculated as mean catch in a gang per duration of net set. High-frequency pulsed DC boat electrofishing is an effective sampling method for bigheaded carp in riverine systems (Collins et al. 2015; Bouska et al. 2017) and has been used to capture Asian carp in areas of low fish density (Hayer et al. 2014). An electrofishing boat outfitted with a Midwest Lake Electrofishing Systems (MLES) Infinity Box powered by a Honda EG5000X generator was used. Booms extended 2.1 m beyond the bow of the boat and were equipped with two MLES Hexagon Plate Anode Arrays, each with 6 cable droppers. Crews consisted of one boat driver and two dip netters. Electrofishing transect samples were 10 minutes of active sampling, and nine transects were completed at each sampling reach in all reservoirs during summer 2017. During 2018, electrofishing effort was greatly reduced due to low catch rates in 2017.

Bighead and Silver Carp were identified based on characteristics described by Kolar et al. (2007); measured (total length (TL), mm), weighed (g), sexed, and the left gonad was weighed (g) for females to estimate gonadosomatic index (i.e., gonad weight divided by body weight; GSI). Lapilli otoliths were also collected from a subsample of total fish catch for age estimation. Otoliths were assessed using a crack method following Ridgway (2016), but due to low agreement new methods for cross sectioning (informed by KDFWR) are being implemented.

Bycatch in gill nets was enumerated by reservoir, species, and season and mortalities were recorded.

Seasonality and gear-specific catches were evaluated among gears (i.e., gill net set times, electrofishing, and cast netting). Cast nets have previously been used to target YOY Bighead and silver carp (Ridgway 2016), and cast nets were used in the present study to sample for YOY bigheaded carp during July and August 2017. Cast nets had a 5.4 m diameter with 9.5 mm monofilament mesh. Nine sites were sampled with ten throws of the cast net at each reach in all reservoirs. In 2018, cast netting effort was reduced (see below).

Results and Discussion:

A completed Master's thesis by Savannah Fernholz, that included 2017 through summer 2018, sampling is attached. A manuscript from Savannah's work is in preparation. Standardized sampling bigheaded carp in large southeastern reservoirs is a new challenge. For this report, we included some of that information from Ferhnolz's thesis that included 2017 data and also focused on 2018 results for comparability through time.

Objective 1-a)

Standardized, systematic gill nets captured 1549 Asian carp in 2018 comprised of 9 bighead carp and 1540 silver carp across the four study reservoirs along the Tennessee and Cumberland rivers. With standardized nets, catch per unit effort was highest during summer (last week of May through June; 15.3 per net set) and lowest in spring (March through April; 4.9 per net set). Total catch and catch per unit effort was highest in Barkley Reservoir and similar, but lower, at Pickwick Reservoir and Cheatham Reservoir (Table 1). Within reservoirs we saw variability among sites (see below). Results from our standardized, systematic sampling illustrate seasonality of catches with implications for standardized, cross-state sampling.

Importantly, standardized systematic sampling does not target areas of high density that fisheries-dependent data would likely reflect. Indeed, the design is purposely intended to sample where fish may not have been present last year, but if populations are expanding may be captured in following years. The variability of data within a reservoir illustrates the importance of a spatially stratified design for monitoring. For example, within Barkley Reservoir, that had highest average catch per effort, across site catches varied significantly and ranged from 29.3 fish per gill net set to 4.6 fish per gill net set (Table 2). Targeted commercial fisheries could certainly capture more fish as a removal method than a standardized monitoring survey, yet commercial fisheries are unprofitable in some areas and highlight the need for spatially stratified agency monitoring to inform population expansion and leading edge.

Objective 1-b)

Length-frequencies of catch showed no size-selectivity(figure 2) with mesh sizes we used after adjustments from Ridgeway (2016). Sizes did not differ between electrofishing and gill net catches. Using combined data across from 2017 through summer of 2018, catch data suggest that the 2015 year class was the last young of year in the system, and those now exceed 400mm due to fast initial growth that quickly approaches asymptotic length at age (Figure 3). The average age of fish did not differ among reservoirs (Figure 4).

Age estimation was completed for 277 Silver Carp otoliths and 44 Bighead Carp otoliths. Silver and Bighead Carp ages ranged from 2 to 11 years old. Percent agreement between two blind readings of Silver Carp otoliths was 31%, and 58% of disagreements differed by a single year. Percent agreement between blind readings of Bighead Carp otoliths was 50%, with 59% of disagreements differing by one year. Lapilli otoliths are the smallest of the otoliths, and thus, hard to ensure the core and annuli are fully represented. Improved methods are being developed across the invasion area to enhance age estimation. Improved methods from cooperators are being adopted into this project to enhance age estimation. Continued age estimation from the study reservoirs is suggested to understand age structure and adult (spawning) population characteristics for informing recruitment potential and control needs.

Gonadosomatic Index (GSI) provides an indicator of how much energy is invested into egg production and an index of spawning time. GSI values were collected for 18 Bighead Carp and 818 Silver Carp. Bighead Carp GSI ranged from 0.06% to 11.4% of total body weight ($n = 18$; mean GSI = 1.87%, SE = 0.92), and Silver Carp GSI ranged from 0.04% to 22.0% ($n = 818$; mean GSI = 1.41%, SE = 0.08). GSI did not significantly differ between spring and summer, but were significantly higher than in the fall. High GSI in spring and summer was expected, but also suggested a protracted potential spawning season that has implications for potential successful reproduction. Analysis of Variance indicated that mean GSI was highest in Cheatham Reservoir (n = 95; mean GSI = 4.41%, SE = 0.39; $P \leq 0.001$), followed by Pickwick Reservoir (n = 144; mean GSI = 1.17%, SE = 0.12; $P \leq 0.04$), and mean GSI was similar between Barkley Reservoir (n = 406; mean GSI = 1.00%, SE = 0.08) and Kentucky Reservoir (n = 173; mean GSI = 0.94%, SE = 0.13; $P = 0.39$). Highest GSI in Cheatham and Pickwick reservoirs does support invasion species theory for population expansion, however the ability for bigheaded carp to reproduce in Tennessee and Cumberland rivers is still not known.

Objective 1-c)

Short set gill nets were ineffective for catching bigheaded carps relative to overnight gill net sets (Table 2 and Table 3), and thus, in 2018 only overnight sets were used. Short set gill nets were initially used due to bycatch concerns. Overnight gill nets did catch significantly more total bycatch than short-set gill nets, but that is due to them catching more fish in total. Total bycatch included 27 species with the majority being buffalo *Ictiobus spp*. and common carp *Cyprinus carpio*. Bycatch mortality differed among seasons and the majority of mortalities (67%) were skipjack herring *Alosa chysochloris*.

During 2017 and 2018 cast nets only captured one adult fish. The use of cast nets was implemented as an early detection tool for recruitment of juveniles, however a lack of abundant young-of-year in 2017 and 2018 resulted in zero catches. Electrofishing catch rates were also very low. Electrofishing catch per effort (number per ten minutes of effort) ranged from 1.1 at Barkley Reservoir to 0.0 at Pickwick Reservoir in 2017 and 2018. Thus, more influence was placed on gill net sampling in 2018. Following experiences working with USFWS, an electrofishing boat was outfitted to replicate the dozier trawl and will be used to replace electrofishing and cast netting in 2019.

Extreme spring rains in winter 2018 and the U.S. federal government shutdown in December to January 2019 greatly impacted winter sampling capability. Sampling sites that provided conditions for sampling were limited. Starting in 2019, KDFWR and TWRA initiated a standardized monitoring program that will allow comparable data across jurisdictions using similar gear and sampling timing. The current project described above has contributed to the planning and will supplement their efforts following similar protocols.

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Table 1. 2018 Catch and catch per unit effort per gill net set.

Reservoir	River	total catch	CPUE
Barkley	Cumberland	806	15.8
Cheatham	Cumberland	171	5.18
Kentucky	Tennessee	403	7.8
Pickwick	Tennessee	169	4.7

Table 2. 2018 site-specific catch, effort, and catch per effort from a systematic sampling design.

River	Reservoir	Site	Number caught	Number Net Nights	Catch per Net
Tennessee	Kentucky	Dam	102	16	6.4
Tennessee	Kentucky	Big Sandy	175	18	9.7
Tennessee	Kentucky	Duck River	126	18	7.0
Tennessee	Pickwick	Dam	93	18	5.2
Tennessee	Pickwick	Bear Creek	76	18	4.2
Cumberland	Barkley	Dam	73	16	4.6
Cumberland	Barkley	Little River	528	18	29.3
Cumberland	Barkley	Saline Creek	205	17	12.1
Cumberland	Cheatham	Dam	148	17	8.7
Cumberland	Cheatham	Sycamore Creek	23	16	1.4

Table 3. Total short-set gill net effort, catch, and catch per effort (CPUE) by reservoir.

Summary variable	Kentucky	Barkley	Cheatham	Pickwick
# of nets set	28.0	24.0	14.0	16.0
# of Carp caught	14.0	30.0	4.0	0.0
CPUE (per net set)	0.5	1.3	0.3	0.0

Table 4. Total overnight gill net effort, catch, and catch per unit effort (CPUE) by reservoir.

Summary variable	Kentucky	Barkley	Cheatham	Pickwick
# of nets set	72	69	45	48
# of carp caught	445	1075	273	248
CPUE (per net set)	6.2	15.6	6.1	5.2

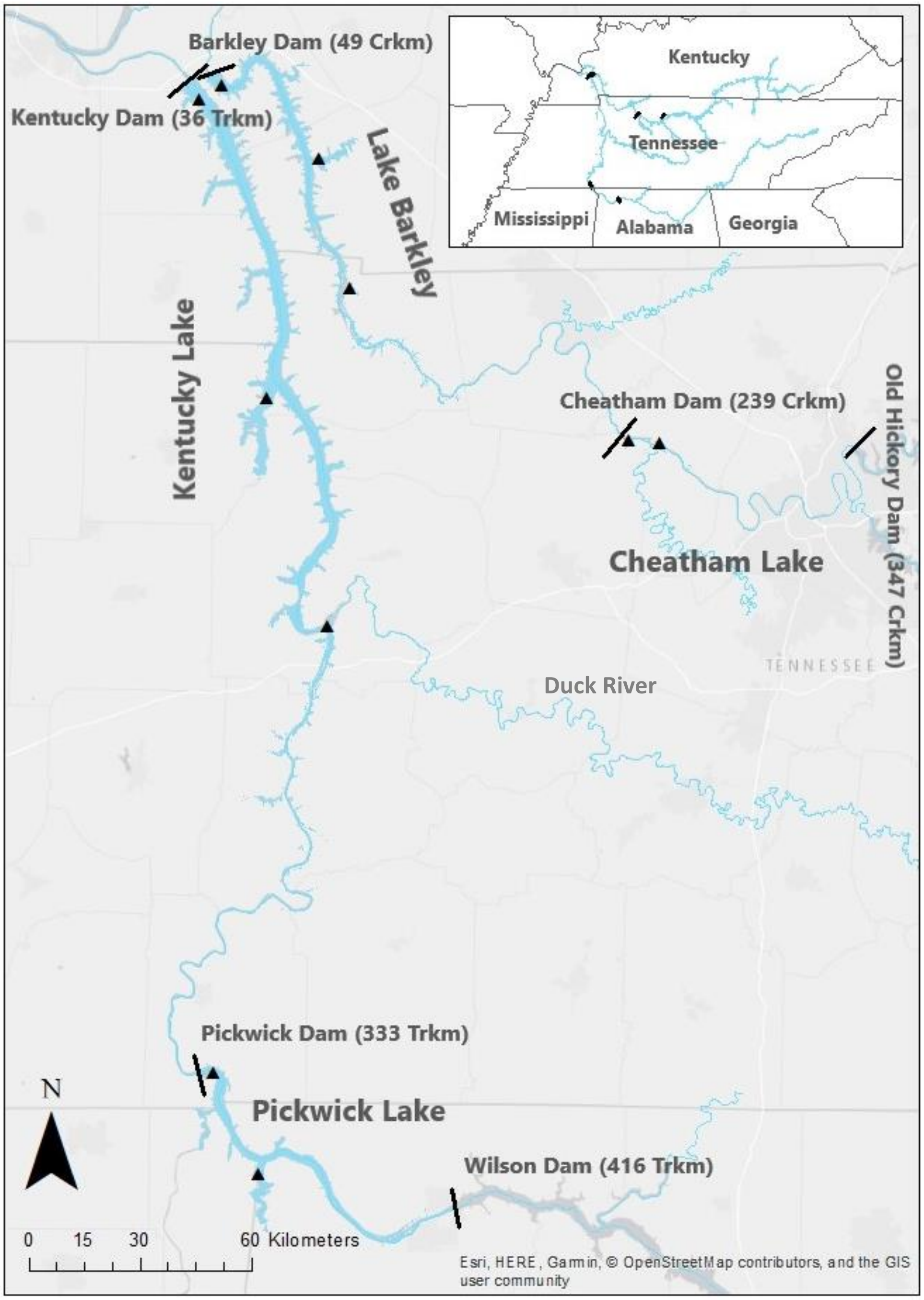

Figure 1. Locations on the Tennessee and Cumberland river reservoirs where bigheaded carp were sampled using standardized methods in 2017 and 2018.

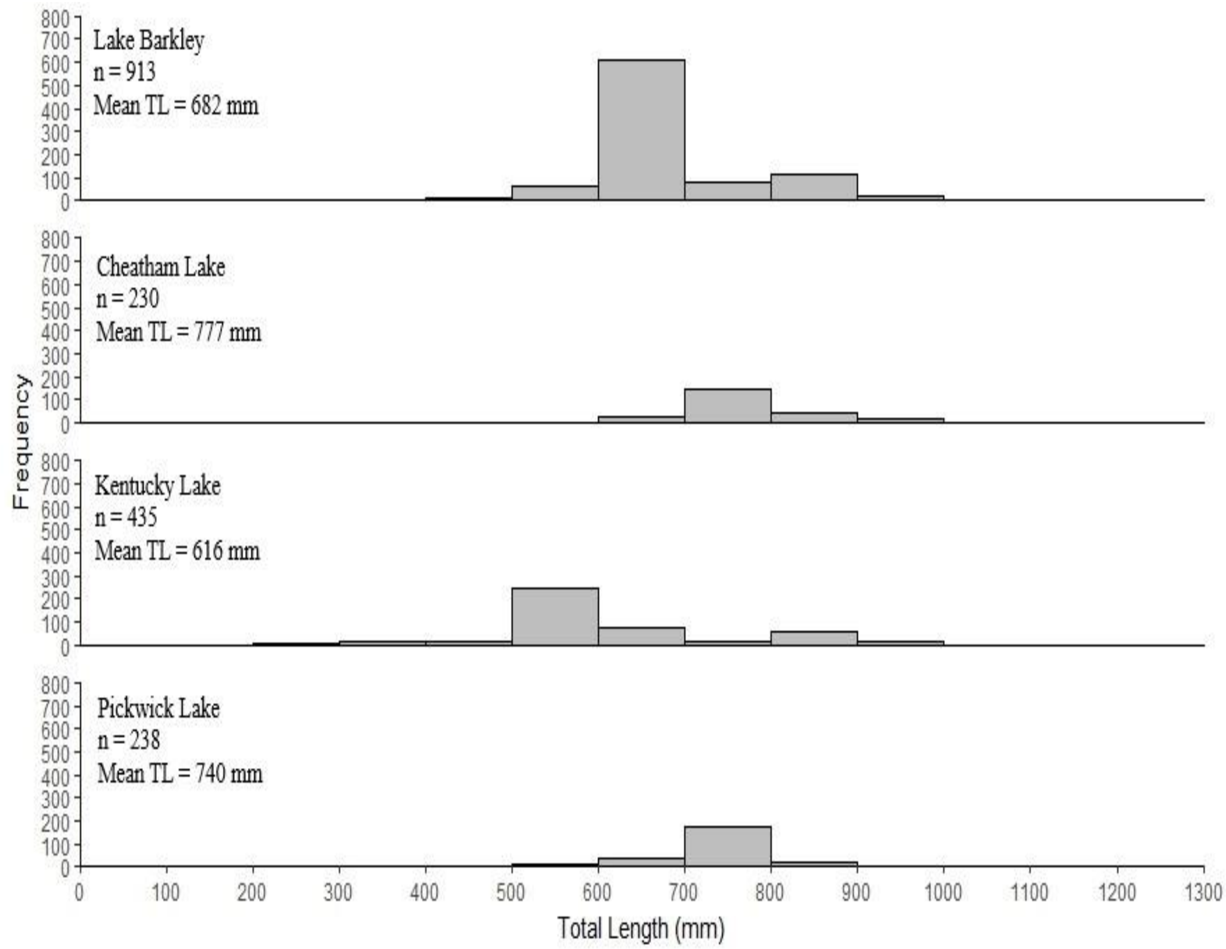

Figure 2. Length distribution of catches by reservoir.

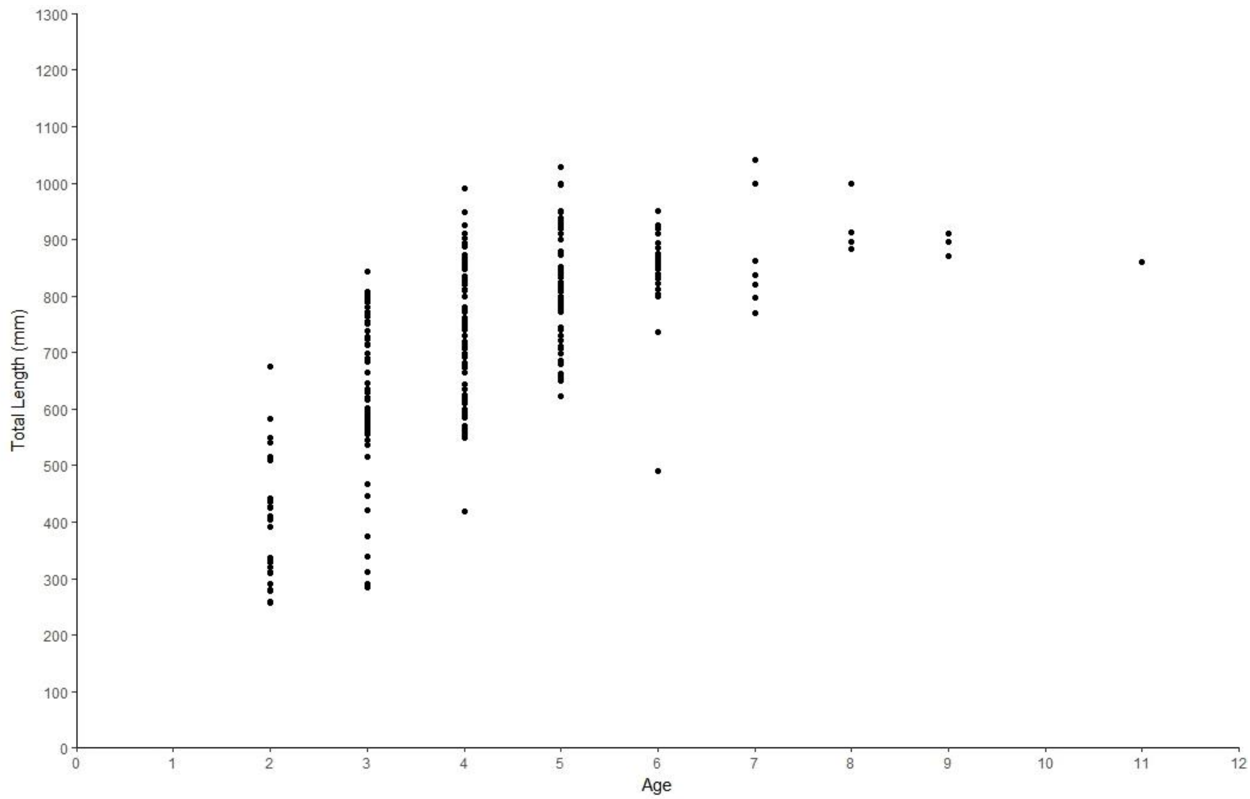

Figure 3. Length-at-age distribution for bigheaded carp captured among reservoirs in 2017 and 2018.

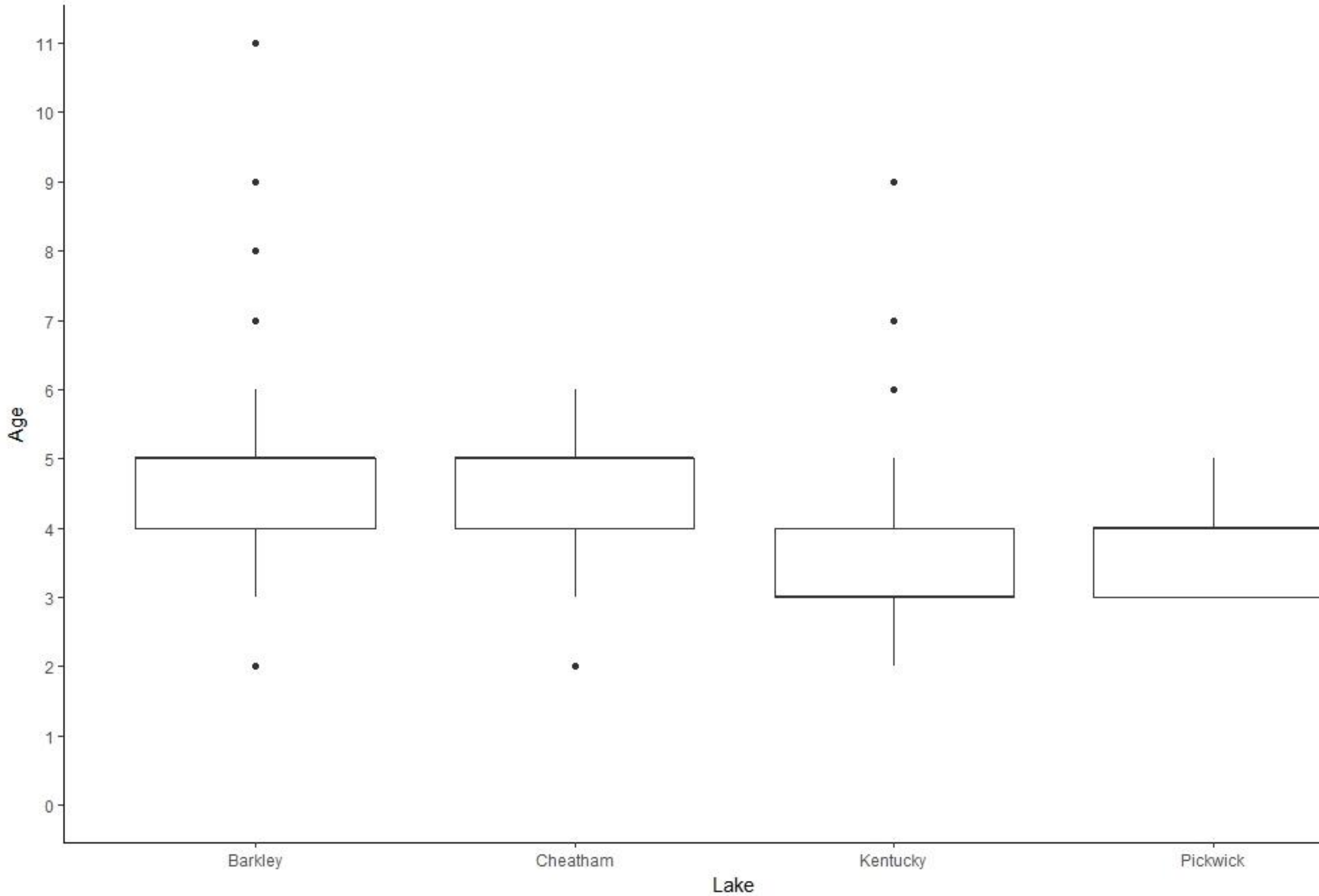

Figure 4. Age distribution by reservoir for Silver Carp captured in 2017 and 2018.