Project Title: Evaluation and Removal of Asian Carp in Tennessee and Cumberland River Basins

Geographic Location: Tennessee and Cumberland rivers and the northern section of the Tennessee-Tombigbee Waterway (Divide Cut and Bay Springs Lake).

Lead Agency: Tennessee Wildlife Resources Agency (TWRA; Cole Harty, cole.r.harty@tn.gov).

Participating Agencies: TWRA; Kentucky Department of Fish and Wildlife Resources (KDFWR); Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP); Alabama Department of Conservation & Natural Resources, Wildlife & Freshwater Fisheries Division (ALWFF); U.S. Fish and Wildlife Service (USFWS); U.S. Army Corps of Engineers; Tennessee Valley Authority; Tennessee Cooperative Fisheries Research Unit, Tennessee Technological University (TTU); Mississippi State University; and Murray State University.

Introduction:

All four species of Asian carp have been collected in the Tennessee and Cumberland River Basin (TNCR). The states of Kentucky, Tennessee, Mississippi and Alabama have significant recreational and ecological resources at risk due to Asian carp. State wildlife agencies have begun taking significant steps to manage and reduce the impacts of Asian carp, thanks in large part to funding made available by USFWS Asian Carp grants. For states to properly address the invasion of Asian carp, data must be collected to better understand Asian carp populations, the impact they have on native species and fisheries, and how effective fisheries management actions are at reducing their populations.

This project further develops standardized sampling protocols to assess abundance and population dynamics of Asian carp, and determine effectiveness of control measures. TWRA and KDFWR have invested in commercial carp removal programs, and the USFWS is funding a sound barrier experiment at Barkley Lock. To measure the success of these control measures, agencies need standardized sampling methods that will allow comparisons among water bodies over time. Foundational research on carp sampling has been conducted by USFWS, KDFWR, TWRA, and TTU using the USFWS Asian Carp Base Funds and local funding sources. These projects have tested many sampling methods, identifying the best methods currently available for sampling carp, and will continue to pursue alternative methods. This project will increase capacity for standardized sampling in Kentucky, Tennessee, Mississippi, and Alabama. The inclusion and participation of all four states is critical for the evaluation of carp populations in the TNCR.

This project directly supports the implementation of portions of the national management and control plan for Asian carp (Conover et al. 2007) and portions of the Ohio River Basin Asian carp control strategy framework (Ohio River Fisheries Management Team 2014).

Project Objectives:

1) Estimate Asian carp relative abundance, and population demographics in the Tennessee and Cumberland River basins to evaluate management actions.
2) Examine Asian carp impacts on native fish communities.
3) Target and remove Asian carp to suppress populations and reduce propagule pressure in the Tennessee and Cumberland River basins.

Project Highlights:

ALWFF

- ALWFF staff implemented field collections of Asian carp and associated data during January 2020, hiring an Aquatic Nuisance Species Coordinator in November, 2020.
- During this period, multiple collection attempts were made to determine Asian carp abundance and distribution using standard methods in Alabama waters of the Tennessee River. Collections were made in three reservoir pools (Pickwick, Wilson and Wheeler) and silver carp (n = 50) were captured during two fall collections at two tributaries, solely within Pickwick Reservoir.

KDFWR

- The 2015 year class of silver carp remain the dominant cohoort detected in Barkley and Kentucky lakes.
- Conducted community sampling in the Kentucky Tailwater to monitor for impacts of Asian carp on the native fish assemlage. CPUE of threadfin shad increased from previous years, but CPUE of many other species declined. Mean relative weights for gizzard shad, largemouth and smallmouth bass increased compared to previous years.
- Conducted community sampling in the Barkley Tailwater to monitor for impacts of Asian carp on the native fish assemlage. CPUE increased significantly from 2019 for threadfin shad. Mean relative weights for many species collected increased compared to previous years.
- Commercial fishers removed over 6.5 million pounds of bigheaded carps through the KDFWR Asian Carp Harvest Program in 2020. CPUE (fish/yard) was highest in 3.5” bar mesh gill nets.
- KDFWR staff conducted 30 ride-alongs with commercial fishers to monitor catch and bycatch data.
- Bycatch of sport fish reported by commercial fishers using the ACHP continued to be minimal (<1% of total bycatch), and survival rates remained over 90%.

- Commercial fishers registered with the Tennessee and Cumberland rivers contract fishing program received $453,925.21 for over 4.54 million pounds of Asian carp harvested from Kentucky Lake and Lake Barkley.
- KDFWR established a Master Agreement contract with two private entities to test Asian carp experimental gears in Kentucky waters. During 2020, one entity was active in the program and harvested approximatley 180,443 lbs of Asian carp over 16 days.
- KDFWR hosted the USGS to conduct the Modified-Unified Method for removal of Asian carp in two bays of Kentucky Lake over 16 days. Approximately 69,228 lbs of fish were removed during those efforts.
- KDFWR targeted removal with electrofishing removed 19,321 lbs of Asian carp from the Barkley Tailwaters and lower Cumberland River. Targeted gill netting efforts in Kentucky Lake and Lake Barkley removed approximately 7,043 lbs of Asian carp.
- KDFWR continued to retrieve and process black carp captured by commercial fishers. One Black Carp was reported caught in Lake Barkley on the Cumberland River. No captures were reported from the Tennessee River in 2020.

MDWFP

- Two Silver carp were captured through gillnetting and electrofishing in the Mississippi portion of Pickwick Lake, the canal section connecting the Yellow Creek Arm to Bay Springs Reservoir (Divide Cut Canal), and Bay Springs Reservoir.
- Limited analysis of MDWFP's historical electrofishing data did not show any major shifts in the fish assemblages that could be attributed to bigheaded carps' invasion and highlighted the need for standardizing the way collections are processed by MDWFP to ensure reliable long-term data.
- Review of historical TVA sampling data from Wheeler and Kentucky Lakes identified no detectable effect of bigheaded carps on the trends in gizzard shad densities already underway prior to invasive carp presence.

TWRA

- TWRA conducted Asian carp monitoring efforts on five reservoirs in the Tennessee and Cumberland River Basin.
- Catch rates of current samping methods in use require further evaluation to determine their utility. Concerns with low sample sizes and high variability appear to be limitations.
- Asian carp in upstream reservoirs, where observations suggest populations are less abundant, tend to be larger than those in downstream reservoirs with more abundant populations.
- No Asian carp less than 400 mm were observed or captured throughout sampling efforts. This suggests a lack of recruitment within the system and supports the hypothesis that

populations in the TNCR are largely driven by carp moving into the basin through navigation locks.

Methods:

Agency: ALWFF

Objective 1

With respect to standardized Asian carp sampling, the ALWFF made substantial initial efforts towards determining relative abundance and population demographics in the Tennessee River basin. These efforts were also combined with cooperative assistance with universities as well as other state and federal agencies. Initial sample work was comprised by standardized sampling, primarily gillnetting, at 33 GPS-fixed sites stretching across the lower three reservoir pools (i.e., Pickwick, Wilson and Wheeler Reservoirs) from the state border with Tennessee and Mississippi eastward to Guntersville Dam (Appendix A. Figure 1). During sampling efforts, all species were enumerated. Asian carp were sacrificed while length (nearest mm) and weight (body and female gonad, nearest 0.1 kg) data were taken on individuals for biological analyses. Additionally, carp were identified by sex prior to removal of otoliths and pectoral spines. Length-weight data were also taken for ecologically sensitive species (e.g., Paddlefish, *Polyodon spathula* and buffalos, *Ictiobus spp.*) prior to release. These data were examined under stereo microscopy in the Tanner laboratory.

Objective 3

All Asian carp collected during the 2020 project sampling period were removed during the fish survey work described in Objective 1. Active removal of fish is especially important to slow the upstream migration of Asian carp, since the leading edge of their migration in the Tennessee River Basin is located in Alabama. By-catch for sampling gears were recorded and non-target fish were released immediately after capture. Additional information was obtained through interaction with commercial and recreational anglers. This information has been used to inform potential sampling hotspots for future eradication efforts.

Agency: KDFWR

Objective 1

Standard Sampling

KDFWR used a combination of standardized sampling, mark-recapture efforts, and monitoring of commercial harvest to evaluate relative changes in Asian carp abundance in Kentucky and Barkley lakes. Standard sampling with gill nets was conducted at sixteen sites in Kentucky waters of Barkley and Kentucky lakes. These standard sites were selected to provide adequate sampling parameters, decrease conflict with anglers, and provide static locations to monitor changes in catch per unit effort (CPUE). Four embayment and four main channel sites were

selected on each lake. These sites were sampled once during spring (April), summer (July), and fall (October) (Appendix B. Figure 1). During each sampling period, a total of four nets were fished at each location and in orientations specific to each location. Sampling occurred when lake levels were greater than 354', and nets were set where water depths were a minimum of 13'. Nets were deployed one hour before sunset and retrieved one hour after sunrise the following morning (USA Sunrise Sunset Calendars, 2019). Specific Global Positioning System (GPS) coordinates were determined for all sets, and nets were set at the same locations each season and year of gill netting effort. Sinking gill nets (12' deep) were tied down to 10' every 8 linear feet. Each 100' panel of webbing was hung with 30" stretch in 16" ties. The mesh sizes included 3" square with 5 meshes per 16 linear inches of net, 4" square with 4 meshes per 16 linear inches of net, and 5" square with 3 meshes per 16 linear inches of net.

All webbing was constructed of 8 ply, 0.2-mm twist mesh. Cross ties for the nets were constructed with #15 white bonded twine through the webbing. Catch rates were analyzed by species and gill net mesh size.

Additionally, targets were set to record total length (mm), weight (g), gender, and gonad weight (g) measurements from subsamples consisting of 10 silver carp and 10 bighead carp at each discrete sample site. During fall sampling, pectoral fin rays were collected from a subsample of silver carp for aging. Due to COVID restrictions and the low sample size of silver carp collected through the standard sampling project, no gonadosomatic index was developed in 2020. Demographics were recorded for Asian carp collected during other KDFWR sampling efforts and included in analyses.

Asian Carp Harvest Program

Commercial fishers participating in the Asian Carp Harvest Program (ACHP) are required to provide KDFWR with daily reports that include fishing effort, type of gear, pounds harvested, and bycatch information. KDFWR staff occasionally accompanied commercial fishers (ride-along) to verify their harvest reports and collect additional information to that required on a standard commercial fishing report. After each ride-along was completed, data was taken from a random subsample of approximately 20 harvested silver carp, including weights, total lengths, and gender (using the pectoral fin ray).

Objective 2

Standard Sampling

During standard sampling described above (Objective 1), total length and weight data were collected from bigmouth buffalo (*Ictiobus cyprinellus*) and paddlefish (*Polyodon spathula*) to assess relative weights. The values were compared over time to asses if Asian carp negatively impact condition of these native fishes. These species are of greatest interest to this study

because they are often caught in gill nets and have been documented to compete for resources with Asian carp species (Irons et al. 2007, Schrank et al. 2003).

Standard Sport Fish Sampling

KDFWR staff collected length-weight data to monitor condition of black crappie (*Pomoxis nigromaculatus*), white crappie (*Pomoxis annularis*), largemouth bass (*Micropterus salmoides*), and blue catfish (*Ictalurus furcatus*) in Kentucky Lake and Lake Barkley. Sampling methods are standardized and described in KDFWR's 2020 annual report. Relative weights were compared to harvest rates of Asian carps to identify trends that may be associated with the increasing Asian carp harvest.

Asian Carp Harvest Program Monitoring

Commercial fishing reports and data collected during ride-alongs with commercial fishers were compiled to provide a summary for 2020 data and to determine if yearly trends are related to bycatch numbers, species caught, and survival rates.

Tailwater Electrofishing

Sampling was conducted in the Kentucky Dam tailwater of the Tennessee River (hereafter referred to as the Kentucky Tailwater) and Barkley Dam tailwater of the Cumberland River (hereafter referred to as the Barkley Tailwater) with pulsed DC electrofishing. Historically, sampling in the Kentucky Tailwater consisted of three 15-minute runs on each bank of the river. However, due to construction of the new lock chamber at Kentucky Lock and Dam, one of these runs is no longer possible. Additionally, fluctuating water levels increased the difficulty for sampling in November and only 2 runs were completed. Sampling in the Barkley Tailwater continued as previous years with two 15-minute runs on each bank. Electrofishing was conducted in a downstream direction along the banks (Appendix B. Figure 2). Spring sampling in each Tailwater was scheduled for one day each month (April, May, and June). However, due to high water events in 2020 (elevation >315ft), spring sampling only occurred in June. Fall sampling was conducted as scheduled in each Tailwater on one day of each month (September, October, and November). Two dippers were utilized to collect stunned fish, which were identified to the lowest taxonomic level possible, and total lengths (inches) were recorded. Weights (pounds) were also recorded during fall sampling. When large numbers (> 100) of any species were collected, random subsamples were utilized. Except for Asian carp species, all fish were released immediately after processing. Data collected in 2020 was compared to historical data to assess changes in the fish community over time.

<u>Objective 3</u>

Asian Carp Harvest Program Monitoring

Commercial fishers participating in the Asian Carp Harvest Program are required to provide daily reports including fishing effort, type of gear, pounds harvested, and bycatch information.

Ride-alongs were also conducted with commercial fishers occasionally to verify reports. Observers collected all data required on commercial harvest logs with the addition of GPS fishing locations and net soak time (Appendix B. Figure 3). Staff observed 16 different commercial fishers on 30 ride-alongs throughout the year. Ride-alongs were conducted when the fishermen were pulling their nets and harvesting fish, unless commercial fishers were using short net soak times or were drifting net sets. On those occasions, KDFWR staff observed the commercial fishers from start to finish. Ride-alongs were conducted while onboard with commercial fishers or from a department boat closely following the commercial fishers to record catch. After each ride-along was completed, data was recorded from a random subsample of approximately 20 silver carp harvested including weights, total length, and gender (using the pectoral fin ray). Observations were analyzed both in aggregate with fishers' daily reports and separately (i.e. ride-along data). Data was analyzed to determine number of fishing trips, amount and disposition of bycatch by species, and total pounds of Asian carp harvested.

Experimental Gears

Testing of the Modified-Unified Method (MUM) was led by the USGS Columbia Environmental Research Center and was conducted in Pisgah Bay and Smith Bay of Kentucky Lake February 3-19, 2021. This was the first use of the MUM in the state of Kentucky and in a reservoir of comparable size. KDFWR hosted these efforts and provided lodging, food, and coordination of staff and equipment needs. Many other agencies provided assistance throughout the project including the USFWS, TVA, USFS, TWRA, MDFWP, INDNR. A total of 16 days of effort was expended between the two sites. Specific methods were determined by the USGS as the project lead. Fish harvested were disposed of by SilverFin Solutions.

In 2020, KDFWR established a Master Agreement contract with two private entities to test Asian carp experimental gears in Kentucky waters. Through this program, contracted entities can use experimental methods for harvesting Asian carp, in an effort to increase removal efficiencies. However, contractors are required to accommodate KDFWR observers during all gear testing. KDFWR staff are responsible for data collection and monitoring of bycatch. One contractor was active in the program in 2020, Robbins Construction LLC, and utilized various seining methods for harvesting fish. Effort was expended as two days on Kentucky Lake, two days on the Ohio River and twelve days on the Mississippi River.

Sampling with the USFWS Columbia, MO Fish and Wildlife Conservation Office Paupier net was not possible in 2020 due to restrictions associated with COVID 19. However, KDFWR plans to continue coordination with the USFWS and other partners to develop standardized and targeted sampling with the Paupier net and electrified dozer trawl in the Tennessee and Cumberland River basins (Towne et al. 2020).

In 2020, KDFWR used targeted electrofishing to remove Asian carp in the Cumberland River below Lake Barkley Dam. Locations for the effort were determined from angler reports of high silver carp densities and high catch rates during previous removal efforts. Additionally, particular areas below Lake Barkley Dam routinely attract fish at certain water levels, which lends it to high catch rates for silver carp. Electrofishing runs were not standardized, and typically lasted until the boat was laden with fish. Fish were then transferred to a chase boat. Settings varied between 15-120 pps and voltage was adjusted as needed to achieve approximately 8 amps. Depending on the density of fish in an area and presence of recreational fishers, electrofishing runs in the tailwaters extended the length of the dam and down either bank. Electrofishing runs in the tributaries were conducted in either a back-and-forth pattern from bank to bank or straight down the channel depending on the width of the tributaries. Tributaries sampled were never wider than 50 feet at the mouth and generally much narrower.

KDFWR conducted gill netting effort targeting Asian carp in Kentucky and Barkley lakes. Gill nets ranged from 3", 3.5", 4", and 5" bar mesh. Net lengths and depths ranged from 100' to 2400' and 10' to 16', respectively. The technique used during these removal efforts did not require webbing to be tied down to create bags. All removal efforts were conducted during the day and utilized active methods of circling large schools of fish or blocking them in a cove at a depth where gill nets covered the entire water column. Subsequent to net deployment, boat motor noise was used to herd fish toward the nets. Crews typically proceeded to pull nets within an hour of setting them.

Agency: MDWFP

Objective 1

We initially intended to fish the section of Pickwick Lake within Mississippi, the canal section connecting the Yellow Creek Arm to Bay Springs Reservoir (Divide Cut Canal), and Bay Springs Reservoir using electrofishing and gillnetting. Approximately 12 h of single-boat electrofishing (60-Hz PDC) in Bay Springs Lake and 4 h in the Yellow Creek Arm of Pickwick Lake failed to detect bigheaded carps, so electrofishing was abandoned as a suitable collection gear. Gillnetting with 300-ft long nets (three 100-ft panels of 3, 4, and 5-in mesh each) was conducted in Pickwick and Bay Springs lakes. We were unable to sample the Divide Cut Canal because barge and boat traffic prevented safe deployment of gillnets in a relatively narrow canal (approximately 300 ft). Sampling in the Yellow Creek Arm of Pickwick Lake was also difficult because the arm is small and shallow, so fewer nets were fished each night (N=3). Moreover, gillnet sampling did not start until February 2020 because of delays in manufacturing our specialty gill nets.

Sampling with gillnetting was conducted seasonally (Appendix C. Table 1). Gillnets were fished overnight in backwater areas adjacent to the main channels to avoid boat and barge traffic. These gillnets are selective for large fish so in general catch rates are low.

Objective 2

MDWFP Data

MDWFP has been monitoring fish assemblages in Bay Springs Reservoir and the Yellow Creek Arm nearly annually for about three decades, and monitoring continues. Historical data were proposed to be used to assess potential changes in fish assemblages linked to bigheaded carps invasion. Analyses were to be based on multivariate species similarity matrices. Potential effects of bigheaded carps may include reduced abundances of planktivore fishes and declines in recruitment of centrarchid species.

We gathered the existing data which included 23 years (1986-2017) of electrofishing collections at Bay Springs Lake and 16 years (1992-2017) at Pickwick Lake. An examination of the data showed that over time, the species recorded in the data set varied, with some species consistently recorded in every collection (e.g., the major game and prey species) and other species not recorded every year. Moreover, in some years the major game species were grouped (e.g., basses, crappies, sunfishes) rather than listed separately as in most years. Therefore, we were not able to assess the full species assemblage as proposed. Instead, we limited analyses to those species that were consistently recorded over time, and we dropped from analysis years in which species were grouped. This selection reduced the data set to 19 years at Bay Springs Lake and 12 years at Pickwick Lake, and to six species in each lake.

TVA Data

Considering some of the issues identified with the MDWFP electrofishing dataset, we obtained and analyzed data collected by gillnetting and electrofishing by TVA in Kentucky and Wheeler reservoirs, in the Tennessee River above and below Pickwick Lake, respectively. We considered Kentucky Lake because it has the largest densities of bigheaded carps given it is the first reservoir in the Tennessee River system and has been the leading edge of the bigheaded carps invasion. We also considered Wheeler Lake because at the time the data were collected no bigheaded carps had been reported in this reservoir. We focused exclusively on gizzard shad because this species is adequately collected by both electrofishing and gillnetting, is often the most abundant species in reservoirs, individuals are planktivores during early life stages, and therefore may be in direct competition for food resources with bigheaded carps. Thus, we expected gizzard shad densities to decrease in Kentucky Lake after bigheaded carps were recorded, but to stay relatively constant at Wheeler Lake where bigheaded carps did not occur.

The TVA dataset spanned from 1990 to 2017, with occasional interruptions. The gillnets consisted of five 20-ft panels of various mesh sizes (1-3 in by 0.5 in increments). There was a

total of 12 to 36 nets fished per year in each reservoir with an average of 32 nets. These nets were fished on the bottom of the water column, set at dusk, left overnight, and retrieved the following morning. Electrofishing (60-Hz pulsed DC; 4-6 A) consisted of 10 min samples that covered roughly 300 yards in length. Both the gillnetting and electrofishing portions of the data include samples for 15 years from Kentucky Lake and 21 years from Wheeler Lake.

We applied a before-after-control-impact (BACI) model. Bigheaded carps were first reported in the Tennessee River in 2004 and as of 2017 bigheaded carps had not reached Wheeler Lake, the control lake.

Agency: TWRA

Objective 1

TWRA staff conducted Asian carp sampling with gill nets during summer (July-September) and fall (November-December) of 2020 on five reservoirs in the Tennessee and Cumberland River Basin to monitor relative abundance. Sampling was completed on Kentucky Lake (6 sites/season), Barkley Lake (3 sites/season), Pickwick Lake (1 site/season), Cheatham Lake (3 sites/season), and Old Hickory Lake (3 sites/season). Four nets were deployed during daytime hours at each site during each season and pulled the following morning. Nets were distributed in embayments from the mouth to the back of the embayment (approximately 10-foot depth). Individual nets were 300-ft in length with 100-ft panels of 3-, 4-, and 5-in mesh. Nets were 12-ft deep, hobbled to 10-ft every eight feet; nets had 0.5-in foamcore for the floatline and 65-lb leadcore for the lead line. The webbing used in each panel was constructed of 8 ply, 0.2-mm twist mesh.

In addition to gill net surveys, TWRA staff conducted targeted Asian carp surveys via boat mounted electrofishing on the same five reservoirs during the summer (July-September). Additional targeted Asian carp electrofishing surveys were completed during the fall (November-December) on Cheatham and Old Hickory lakes, but results are not included in this report. The number of sites sampled per reservoir was as follows: Kentucky (24 sites), Pickwick (6 sites), Barkley (8 sites), Cheatham (12 sites), and Old Hickory (12 sites). Electrofishing surveys were conducted during the daytime using a high-frequency pulsed DC boat electrofishing. Voltage and amperage were adjusted to achieve a 3,000-W power output, as possible (Stuck et al. 2015). Electrofishing transects included a variety of habitat types (i.e., backwaters, channel borders, shoreline areas, open water). Electrofishing runs were conducted for 15 minutes each.

Asian carp harvested commercially through the Asian Carp Harvest Incentive Program were sampled via visits and to wholesale fish dealers. Although these efforts were significantly impacted and diminished due to Covid-19, agency staff were able to collect data at two

wholesale fish dealers on two occasions over the summer (four market visits). Sub-samples of harvested fish were measured for total length and weight.

Results and Discussion:

Agency: ALWFF

Objective 1

ALWFF staff performed 165 man-days of effort using standardized sampling gear comprised of gillnets and a boat electrofisher. The relatively low catch rate (1.0/net-night) of Asian carp (n = 53; Appendix A. Table 1) and distribution of silver carp solely within Pickwick Reservoir strongly highlight the importance of eradicating this species within this water body, the current invasion front in the Tennessee River system. Laboratory examinations reveal individual silver carp (n = 50; Appendix A. Table 1) were mature adults, ranging in length from 735-1065 mm (29 - 42 in; average = 34 in) and averaged 7299 g (16.1 lb). Average age of silver carp was 4.5, ranging from 3 to 6 years old. We presume the absence of younger fish are a function of gear bias. Additionally, it is possible that these larger fish represent recent immigrants to this reservoir. The latter may be especially true given that captures have been in the lower third of this reservoir; however, this may also be a function of both the distribution of sampling efforts and the availability of tributary and backwater habitats. Given these data, substantial efforts should focus on determining Asian carp distribution and abundance in key areas to increase efficacy of eradication efforts.

Agency: KDFWR

Objective 1

Standard Sampling

Standard sampling data indicated no clear trend in overall catch rates for Asian carp (silver, bighead, and grass), in either lake unlike previous years (Appendix B. Table 1). Data for silver carp suggested that mean catch per unit effort (CPUE), reported as number of fish per linear yard of gill net, was highest on Lake Barkley in July but only slightly higher than October. Whereas, Kentucky Lake's CPUE was highest in October followed by April (Appendix B. Table 2). Overall Asian carp CPUE through standard sampling was low. In 2020, Lake Barkley had a mean CPUE of 0.008 fish/yard (S.E. ±0.001) whereas Kentucky Lake had a mean CPUE of 0.007 fish/yard (S.E. ±0.002).

Catch rates were compared between habitat types (main channel & embayment) within lakes. No significant difference in CPUE was detected for Lake Barkley ($N=24$, $T_{11}=0.21$, $P=0.42$) or Kentucky Lake ($N=24$, $T_{15}=1.61$, $P=0.13$). Catch rates were also compared between 2018, 2019 and 2020 for each lake separately; only data from July and October was included in the analysis, as no data was available for April in 2018. A significant difference was detected for both lakes,

Barkley (F (2,21) = 25.16 P = <0.001) and Kentucky (F (2,21) =11.35, P = <0.001; Appendix B. Table 2). Data suggested that catch rates of silver carp have been decreasing since 2018, however an inverse trend has been observed in commercial harvest in that time frame (Appendix B. Figure 4).

A length-frequency histogram was created for silver carp collected from Barkley and Kentucky lakes from all capture methods in 2020. Data suggested the 600mm size class of silver carp dominated harvest from both lakes (Appendix B. Figures 5 & 6). However, smaller size classes of silver carp were not collected in 2020 due to the absence of data from Paupier net sampling that had been conducted in the fall of previous years. The USFWS Paupier net crew was unable to sample in Kentucky waters in 2020 as a result of COVID restrictions.

Age & Growth

Pectoral fin rays were collected from silver carp in Barkley and Kentucky lakes in the fall of 2020 for aging. Ages ranged from 4 to 7 years old within Lake Barkley (N=55) and from 4 to 9 years old within Kentucky Lake (N=61), with age 5 silver carp being the most abundant in both lakes (Appendix B. Figures 7 & 8). This data indicates that the 2015 cohort still dominates the silver carp population in the lakes.

Mortality

Catch-curve regressions were developed for the 2015 cohort of silver carp by lake. This cohort of silver carp is the only documented cohort known to occupy the lakes at age-0. Data for age frequencies were $\log_{10}(x+1)$ transformed to compensate for heteroscedasticity. A Chapman-Robson analysis was performed to estimate annual mortality (Â) and instantaneous mortality (Z). Annual mortality for silver carp from Lake Barkley was estimated at 63% and instantaneous mortality was estimated at 0.99 (N= 196, $F_{1,1}$=11.75, P=0.181, R^2=0.92; Appendix B. Figure 9). Annual mortality for silver carp from Kentucky Lake was estimated at 53% and instantaneous mortality was estimated at 0.75 (N=166, $F_{1,1}$=3.78, P=0.302, R^2=0.79; Appendix B. Figure 10). The higher mortality rate estimate for Lake Barkley is consistent with previous years and may be a result of greater Asian carp commercial fishing effort and harvest occurring in Lake Barkley compared to Kentucky Lake.

Condition

Linear regressions were constructed to describe the $\log_{10}$ length-$\log_{10}$ weight relationship for silver carp in Barkley and Kentucky lakes. The length-weight equation for Lake Barkley was estimated at $\text{Log}_{10}(\text{weight(g)}) = 2.6535*\text{Log}_{10}(\text{length(mm)})-3.9907$ (Appendix B. Figure 11). The length-weight equation for Kentucky Lake was estimated at $\text{Log}_{10}(\text{weight(g)}) = 2.8261*\text{Log}_{10}(\text{length(mm)})-4.5043$ (Appendix B. Figure 12). Weights were predicted for Lake Barkley: 450mm (1121g), 650mm (2974g) and 800mm (5160g) and Kentucky Lake: 450mm

(986g), 650mm (2788g) and 800mm (5018g) (Appendix B. Table 3). Predicted weights remain higher for Lake Barkley than for Kentucky Lake, consistent with analysis from previous years.

Data collected from sampling in the fall of 2020 was used to analyze relative weights (*W*r). Relative weight was calculated using the equation $Log_{10}(W_s)$= -5.15756 + 3.06842(Log_{10}TL) for silver carp and $Log_{10}(W_s)$= -4.65006 + 2.88934(Log_{10}TL) for bighead carp (Lamer 2015). The mean *W*r for silver carp in Lake Barkley was 94 (N=112, S.E.=±0.73) and the mean *W*r for silver carp in Kentucky Lake was 96 (N=67, S.E.=±0.89). These values are consistent with data collected from previous years. The mean *W*r for bighead carp in Kentucky Lake was 97 (N=3), no bighead carp were collected in Lake Barkley in the fall of 2020.

Gonadosomatic Index (GSI)

Due to COVID restrictions and the low sample size of silver carp collected through the standard sampling project, no gonadosomatic index was developed in 2020.

Sex ratios were calculated for silver carp in both lakes from aggregated data in 2020. Lake Barkley was calculated to be comprised of 51% males (N=271) and 49% females (N=258), a 0.95:1 ratio. Kentucky Lake was calculated to be comprised of 46% males (N=107) and 54% females (N=128), a 0.84:1 ratio. The values for Lake Barkley have been consistent since monitoring began remaining near a 1:1 ratio. However, Kentucky Lake's ratio was observed to skew towards females in 2020 but the data set was smaller than in previous years.

Mark-Recapture Effort

KDFWR worked with personnel from Tennessee Wildlife Resources Agency (TWRA), Tennessee Tech University (TTU), U.S. Fish and Wildlife Service (USFWS), United States Geological Service (USGS), Murray State University (MSU), and volunteers from United States Forest Service at Land Between the Lakes (LBL) to tag silver carp in Barkley and Kentucky lakes in late September 2018. Fish were tagged with a Floy Tag Company, FT-4 Lock-on tag, with a unique identification number. Initially the targeted sample size was 500 fish per lake, with a subset of 20% of tagged fish receiving a secondary tag. The primary tag was placed posterior of the dorsal fin and the secondary tag was placed anterior of the dorsal fin. Fish were collected using short set gill nets (<4 hours) and D.C. electrofishing. Tagging effort occurred over eight days (four on each lake), and 1,292 silver carp were tagged. A total of 619 silver carp were tagged from Lake Barkley with a mean length of 684mm and a mean weight of 3,830 grams. In Kentucky Lake, 673 silver carp were tagged and had a mean length of 627mm and a mean weight of 2,570 grams.

From October 2018 through February 2021, KDFWR received 36 tag returns from commercial fishing efforts. Twenty-seven came from Lake Barkley and nine from Kentucky Lake (Appendix B. Figure 13). Eight of the returned fish were double tagged. The higher frequency

of returned fish from Lake Barkley compared to Kentucky Lake is not surprising given the majority of commercial fishing pressure occurs on Barkley (Reported under Objective 3).

Data collected from harvested fish indicated that all fish grew from the time of initial tagging to the point when they were harvested. Inspection of tag insertion locations indicated good healing of the marked fish. All recovered fish exhibited localized redness around the tag insertion, however none showed signs of infection. The majority of fish were collected in approximately the same embayment where they were tagged. This is an interesting observation because telemetry data has shown that a portion of the silver carp population in the lakes exhibit large scale movement patterns at certain times (USFWS 2019). The tag return data suggests that the majority of the fish returned have developed site fidelity, however, we have not distinguished specific behavioral or environmental characteristics that draw them to a constricted geographic area, relative to the area that is available for use. Although, there have been a few tag returns from bow-fishers harvesting tagged fish hundreds of river miles away from their release locations after tagging.

Asian Carp Harvest Program Monitoring

Length and weight data was collected on 595 silver carp harvested by commercial fishers. Silver carp ranged from 4.2 – 20.7 lbs with an average of 8.5 lbs (Appendix B. Table 4). If this metric is used in correlation with the total pounds of silver carp harvested by commercial fishers through the ACHP in 2020, that would produce a rough estimate of 761,378 individual silver carp being removed from Kentucky waters through the ACHP in 2020 (6,471,718 lbs; Appendix B. Table 5). During ride-alongs, commercial fishers were observed using gill nets with a range of bar mesh sizes to target Asian carp (3" – 5" bar mesh; Appendix B. Table 6). Catch per unit effort of gill nets used to harvest silver carp were highest in gill nets with a bar mesh size of 3.5" (0.68 fish/yard), followed by 3.25" bar mesh which had a CPUE of 0.50 fish/yard. This is similar to the previous two years when the highest CPUE was in 3.25" and 3.5" bar mesh nets. However, no ride-alongs were conducted with commercial fishers utilizing gill nets with smaller sizes of bar mesh prior to 2019 (Appendix B. Table 6). Information collected from fish harvested through the ACHP was also used in the above demographics analysis.

Black Carp

In 2020, one black carp was harvested from Lake Barkley by a commercial fisher using gill nets set to target silver carp. According to the commercial fisher, the gill net that the black carp was caught in was set in approximately 20ft of water and on a ridge containing shells. The net mesh size was 4.5" bar mesh. The black carp was a female and had a total length of 43.3 inches and weighed 36.0 lbs, making it the largest black carp collected from Lake Barkley to date (Appendix B. Figure 14). The fish was dissected by KDFWR staff and portions of the carcass sent on ice to the respective laboratories for analysis (USGS and USFWS, 2017).

Objective 2

Standard Sampling

Capture rates of species with potential direct competition from bigheaded carp (silver and bighead) were observed to be low in the 2020 standard sampling, which continues the trend observed in previous years (Appendix B. Tables 7 & 8). Bigmouth buffalo were observed to have a mean *W*r of 88 (N=5) in Kentucky Lake and paddlefish catch rates through standard sampling were not significant enough to be reported at this time. These species will continue to be monitored and data will be collected opportunistically. Increased data collection through a gear such as the Paupier net and increased ride alongs with commercial fishers targeting paddlefish, would be very valuable in future assessments of these native species.

Bycatch frequency during standard sampling in 2020 was similar to the frequencies observed in 2019. In Lake Barkley catfish spp. (*Ictaluridae*) comprised 33.9% of the bycatch, followed by freshwater drum (*Aplodinotus grunniens*) (25.5%) and smallmouth buffalo (*Ictiobus bubalus*) (19.4%). In Kentucky Lake catfish spp. comprised 26.9% of the bycatch, followed by smallmouth buffalo (32.5%) and freshwater drum (15.6%) (Appendix B. Tables 7 & 8).

Gizzard shad (*Dorosoma cepedianum*) collected by traditional boat electrofishing in October 2020, were measured and used to estimate relative weight values (*W*r), using the formula presented in Blackwell et al. 2000. Gizzard shad from Lake Barkley were estimated to have a mean *W*r of 93 (N=47, S.E.=0.7) and gizzard shad from Kentucky Lake were estimated to have a mean *W*r of 92 (N=95, S.E.=0.8). Data suggests that relative weights have been increasing in Lake Barkley since 2017. Gizzard shad from Kentucky Lake have also exhibited an increase in relative weight since 2017 (Appendix B. Table 9).

Standard Sport Fish Sampling

In Kentucky Lake, 450 black crappie, 273 white crappie, 190 largemouth bass, and 19 blue catfish were measured and used for relative weight analysis (KDFWR 2020). Black and white crappie both exhibited the highest mean relative weights since 2016 with Wr of 92.4 and 90.1 respectively (Appendix B. Figure 15). Largemouth bass average *W*r also improved in comparison to the previous 4 years (*W*r = 94.8). Sampling for blue catfish began in 2004 and has been inconsistent. However, in 2020 blue catfish average *W*r was similar to previous years (*W*r = 112.0). Historical mean relative weight values were charted along with pounds of Asian carp removed from Kentucky Lake through the commercial fishery (Appendix B. Figure 15). Harvest of Asian carp from Kentucky Lake through the ACHP increased significantly in 2020 from previous years to 1,646,900 pounds harvested. However, the impacts to sport fish condition associated with this increased removal of Asian carp requires more years of data and will continue to be monitored. Many factors are known to impact sport fish condition and values recorded since Asian carp have become established in Kentucky Lake have not fluctuated outside of historical variations.

In Lake Barkley, 133 black crappie, 424 white crappie, 146 largemouth bass, and 113 blue catfish were measured and used for relative weight analysis (KDFWR 2020). Mean relative weights for both black and white crappie increased from 2019, but remained similar to previous years having *W*r of 98.0 and 96.0, respectively (Appendix B. Figure 16). Mean *W*r value for largemouth bass in 2020 was 104.6, which is the highest recorded mean *W*r since monitoring began in 1985. Sampling for blue catfish in Lake Barkley began in 2004, but has been inconsistent. Mean *W*r for blue catfish collected in 2020 was also higher than all previous years (Wr = 104.5). Historical relative weight values were charted along with pounds of Asian carp removed from Lake Barkley through the commercial fishery (Appendix B. Figure 16). Harvest of Asian carp from Lake Barkley has increased almost every year since the ACHP began in 2013 spiking in 2019 to over 5.3 million pounds. Similar to Kentucky Lake, the high harvest of Asian carp in 2019 corresponds with lower condition factors of sportfish species, which may be an indicator of high densities of adult Asian carp competing with these sport fish for resources. Therefore, the increase in condition of sport fish in Lake Barkley in 2020, may be influenced by a reduced competition with Asain carp as they are continually harvested. However, sport fish condition in the reservoirs is highly variable due to a variety of factors and will continue to be monitored in following years.

Asian Carp Harvest Program Bycatch

According to the KDFWR ACHP regulation (301:KAR 1:152), commercial fishers are allowed to harvest a ratio of 65% Asian carp to 35% scaled rough fish per month. All other fish caught in commercial gear must be released. Commercial fishers are required to submit daily reports that include bycatch species, number caught, number harvested, number released, and disposition upon release (moribund or alive). In previous years, increased effort by commercial fishers fishing under the ACHP has translated into a growing amount of bycatch (Appendix B. Table 10). However, in 2020, the total number of bycatch reported decreased from 2018 and 2019 (18,592 fish) even though commercial fishing effort remained similar (2,052 trips; Appendix B. Table 5). This reduction in bycatch may be attributed to changing practices of commercial fishers as most fishers have transitioned from passive setting to active setting of gill nets. Scaled rough fish, primarily buffalo (*Ictiobus*) species, make up majority of reported bycatch in commercial gill nets fished under the ACHP (Appendix B. Table 10). The number of catfish caught in commercial nets under the ACHP decreased in 2020 (N = 768) from 2019 (N = 1512), and the survival rate of this taxa remained high at 99.2%. Total number of sport fish in the bycatch of the ACHP decreased in 2020 from 2019, but remained higher than all other previous years (n=148). The survival rate for sport fish species in 2020 remained similar to 2019 (92.5%; Appendix B. Table 10). This high survival rate is likely due to the change in commercial fishing methods that began in 2019. The number of paddlefish reported captured as bycatch decreased in 2020 (n=222) from 2019 (n=296), and remains lower than most previous years. The mean

survival rate of paddlefish reported by commercial fishers increased slightly to 85.7% in 2020 (Appendix B. Table 10).

Survival rates of all bycatch caught during ride-alongs in 2020 was documented by KDFWR observers and was analyzed independent of commercial fishers reporting (Appendix B. Table 12). During ride-alongs, the survival rate of sport fish in bycatches decreased from 2019, and still remained lower than what was reported by commercial fishers (81%). However, in relation to total bycatch, the number of sport fish captured was low (4% during ride-alongs in 2020). Survival rates of catfish species observed as bycatch during ride-alongs was the highest recorded, since 2016, and was similar to values reported by commercial fishers in 2020 (100%; Appendix B. Tables 10 & 12). Paddlefish survival rates observed during ride-alongs in 2020 were higher than observed in 2019, but still remained significantly lower than what commercial fishers reported (50%; Appendix B. Tables 10 & 12).

A comparison for bycatch of paddlefish, catfish species, and sport fish species reported by commercial fishers through daily reports and information collected during ride-alongs shows a decrease since 2015 in number of sport fish captured per trip for most species (Appendix B. Table 11). However, bycatch reported captured per trip for recreationally and commercially important species such as paddlefish and catfish spp. is higher during ride-alongs than from commercial fishing reports (Appendix B. Figure 17). Data suggests 50-75% of bycatch is likely not reported in daily logs submitted to KDFWR by commercial fishers. However, ride-alongs account for a small percentage of the total number of trips made by commercial fishers (<2%). To better identify and monitor under reporting of bycatch, KDFWR will continue to increase the number of ride-alongs conducted with commercial fishers targeting Asian carp. To date, there is no indication of negative impacts on the sport fishery resulting from the ACHP.

Bycatch of Paddlefish

As KDFWR monitors sport fish bycatch through the ACHP it also provides the opportunity to monitor other species that compete directly with Asian carp such as paddlefish. Paddlefish are considered a species of conservation need as their life history traits and value of their roe has potential to result in recruitment overfishing of the population. Consequently, there is a need to closely monitor impacts of the ACHP on paddlefish. Generally, experienced commercial fishers can avoid capturing large numbers of paddlefish when they are targeting Asian carp by carefully selecting fishing locations. The number of paddlefish captured is variable over time, but did show an increasing trend that is now declining even though effort is increasing (Appendix B. Tables 5 & 12).

Paddlefish survival was observed to be low in 2020 (50% during ride-alongs, 85.7% total ACHP) in relation to other species in the bycatch (Appendix B. Tables 10 & 12). Since much of the ACHP effort is during the summer months (i.e. warmer water temperatures), paddlefish are

vulnerable bycatch in this fishery. Therefore, water temperatures have been recorded during ride-alongs conducted since 2016 (Appendix B. Table 13). Another factor identified as possibly affecting paddlefish survival in gill nets was length of time the nets are left in the water (i.e. soak time), and has been recorded since 2017 (Appendix B. Table 13). From conducting ride-alongs, it has been observed that the soak time of nets varies among fishermen and depends on the location being fished, weather, and water temperature. Overall, fishermen tend to leave nets in the water longer when water temperatures are cooler as it increases catch rates and like most fish, Asian carp will survive longer in the cooler temperatures. Although sample sizes are small, observations from ride-alongs in 2019 and 2020 indicate that paddlefish survival rates decrease as water temperature increases. It has also been suggested that since paddlefish have an elongated operculum, it may be more likely for a gill net to restrict the water flow over their gills than other fish species. There did not appear to be a difference in the survival rate of paddlefish based on soak time of nets in 2020. However, commercial fishers are more frequently using active methods for targeting Asian carp with gill nets and soak times of nets decreased overall in 2020. To increase the sample size, water temperature and soak times will continue to be recorded during ride-alongs in 2021.

Kentucky and Barkley Tailwaters Electrofishing

Spring sampling with electrofishing in the Kentucky Tailwater was conducted only in the month of June. This sampling effort resulted in the collection of 211 individual fish comprised of 21 species through 1.25 hrs of electrofishing. Sunfish species made up the highest percent of the catch (31.9%), followed by Catostomidae species (24.8%; Appendix B. Figure 18). Largemouth and smallmouth bass produced lower catch rates than most previous survey years with CPUE of 14 fish/hr and 2 fish/hr, respectively. However, this decline may be due to the reduced sampling effort in 2020 compared to previous survey years. Silver carp CPUE in the Kentucky Tailwater during spring sampling remained similar to 2018 (3 fish/hr; Appendix B. Table 14).

Spring sampling for 2020 in the Barkley Tailwaters was also only conducted in June, and resulted in the collection of 326 individual fish, comprised of 22 species, through 1.0 hr of effort. Similar to Kentucky Tailwater, sunfish species made up the highest percentage of the total catch with 46.8% (Appendix B. Figure 19). Black bass species made up the second highest percentage of the catch at 14.8%, which is in accordance with previous spring surveys at Barkley Tailwater (Appendix B. Figure 19). Flathead catfish catch rates increased in 2020 compared to all previous survey years (26 fish/hr; Appendix B. Table 15). Silver carp CPUE declined from the 2018 survey and remained similar to catch rates produced in 2017 (13 fish/hr; Appendix B. Table 15).

Fall sampling with electrofishing in the Kentucky Tailwater resulted in the capture of 2,293 total fish comprised of 28 species during 2.75 hrs of effort in 2020. This is a decrease in effort from previous years due to reasons stated above. Similar to previous years, Clupeid species were the most abundant group collected, comprising 88.6% of the total catch during sampling in 2020

(Appendix B. Figure 20). Threadfin shad (*Dorsoma petenense*), made up the majority of Clupeids caught, indicating a higher presence than in 2019 (Appendix B. Tables 16 & 17). In 2019, sampling produced the highest percent of total catch and CPUE (510 fish/hr) of skipjack herring (*Alosa chrysochloris*) since the survey began in 2015 (Appendix B. Table 17), sampling in 2020 produced the second highest CPUE for skipjack with 89 fish/hr (Appendix B. Table 17). CPUE of sunfish species including bluegill and longear sunfish, decreased from the high numbers collected in 2019, and was low compared to most previous year as well comprising only 3.6% of the total catch (Appendix B. Figure 20 & Table 17). Largemouth and smallmouth bass (*Micropterus dolomieu*) were the most prominent sport fish species collected in the Kentucky Tailwater during fall sampling in 2020 with a CPUE of 15 fish/hr and 10 fish/hr, respectively (Appendix B. Table 16). However, CPUE for bass and most other sport fish species in 2020 declined compared to CPUE in 2019. A new species, striped mullet (*Mugil cephalus*), was collected during sampling efforts in the Kentucky Tailwater in 2020. A total of 4 striped mullet were collected through electrofishing, pictures were taken, and the fish were released alive. Silver carp retained a similar CPUE and portion of the percent total catch as was documented in previous years (Appendix B. Figure 20 & Table 17).

Fall sampling in the Barkley Tailwater resulted in the capture of 4,824 total fish comprised of 33 species in 2.75 hrs of effort in 2020. Complementary to previous years, Clupeid species, were still the most abundant species group collected in Barkley Tailwater during fall sampling in 2020, comprising 87.1% of the total catch (Appendix B. Figure 21). Similar to the Kentucky Tailwater, threadfin shad made up the majority of Clupeids caught, producing the highest CPUE since 2016 (1298 fish/hr; Appendix B. Table 18). Indicating a rebound in the threadfin shad population from low CPUE in 2019. Sunfish species such as bluegill (*Lepomis macrochirus*) and longear sunfish (*Lepomis megalotis*) produced low catch rates in comparison to previous years and made up only 4.6% of the total catch (Appendix B. Table 18 & Figure 21). Black bass (largemouth, smallmouth, and spotted) catch rates declined from 2019, but remained similar to other survey years (Appendix B. Table 18). Silver carp CPUE during fall sampling in Barkley Tailwaters decreased in 2020 from surveys conducted in 2018 and 2019 (23 fish/hr; Appendix B. Table 19).

Length frequency distribution for silver carp collected in Kentucky Tailwater during fall sampling in 2020 ranged from 17-28 inches (N=26; Appendix B. Table 16). Silver carp lengths from Barkley Tailwater during fall sampling ranged from 18-29 inches, and was dominated by the 23-27 inch classes (N=64; Appendix B. Table 19). These ranges are similar to silver carp collected during fall sampling in 2018 and 2019, with the exception of the dominant inch classes increasing slightly.

Silver carp and grass carp were collected in both tailwaters during fall sampling efforts, however no bighead carp were collected in either season. Electrofishing for this project resulted in

removal of 26 silver carp from Kentucky Tailwater and 64 silver carp from Barkley Tailwater in 2020. Targeted electrofishing sampling for silver carp conducted by KDFWR removed over 2,800 silver carp from the Barkley Tailwaters and lower Cumberland River in 2020.

Relative weights (*Wr*) were calculated for selected species collected during fall sampling to monitor fish condition (Appendix B. Tables 20 & 21). Trends in fish condition are important in the current study, as any observed declines in condition of individual species may be an indicator of competition for resources and reflective of high Asian carp densities in the tailwaters. Low relative weight is generally characteristic of fish in poor health, whereas high values indicate fish in excellent health (Blackwell et al. 2000). However, ideal target ranges of *W*r values have not been identified for all species and in every habitat type. Therefore, the *W*r values compiled through this study will be used to assess changes in the Tailwater fish community over time. In the Kentucky Tailwater, the mean *W*r of gizzard shad remained at a value of 85, the highest observed since the survey began in 2015 (Appendix B. Table 20). The mean relative weight for largemouth bass (*W*r = 113) and smallmouth bass (*W*r = 100) in 2020 was also the highest recorded since 2015. Silver carp mean relative weight declined slightly from 2019 (*W*r = 76: Appendix B. Table 20). Mean relative weight values for other species in the Kentucky Tailwater remained similar to previous years. In the Barkley Tailwaters the mean *W*r for silver carp decreased compared to previous years (*W*r = 77; Appendix B. Table 21). This decline is a factor that will continue to be monitored as a low mean relative weight for silver carp could also be an indication of increased competition for resources in the tailwaters as the silver carp population grows. During sampling in the Barkley Tailwater in 2019, mean relative weight values observed for gizzard shad (*W*r = 96), channel catfish (*W*r = 111), white bass (*W*r = 115), and largemouth bass (*W*r = 101) were the highest recorded since the survey began in 2016. Mean relative weight values for other species remained similar to those observed in previous years (Appendix B. Table 21).

The Western Fisheries District branch of the KDFWR fisheries division collected some data on sportfish in the Kentucky and Barkley tailwaters previous to this study. Data was collected from fish in both tailwaters in the fall of 2002, and 2011 (KDFWR, 2003 and 2012). Fish were collected through standardized electrofishing runs, measured, and weighed. Using this historical data, comparisons of sport fish catch rates and condition were made to the information presented in this report. These comparisons did not reveal any appreciable declines in sport fish numbers or condition since Asian carp have become abundant in the tailwaters. Recreationally important fish species in the Kentucky and Barkley tailwaters including: catfish, *Morone* spp. (white bass, yellow bass, striped bass, and hybrid striped bass), black bass, sunfish, and crappie, still exhibit good condition despite the high densities of Asian carp in these areas.

Objective 3

Asian Carp Contract Fishing Program in the Tennessee and Cumberland Rivers Systems

Interest and participation in the KDFWR contract fishing program for Asian carp has varied greatly since it began in 2016. However, refinements to the system in 2019 increased participation in the program. In 2020, contractors received $453,925.56 for Asian carp harvested from Kentucky Lake, Lake Barkley, and their respective tailwaters. This equates to over 4.5 million pounds of Asian carp harvested through the program in 2020 (Appendix B. Table 24). Refinements to the program to allow for varying pay out based on size of fish harvested have made it more difficult to track the exact weight of fish removed.

Asian Carp Harvest Program Monitoring

The Asian Carp Harvest Program (ACHP) created by KDFWR allows commercial fishers to target Asian carp in waters where commercial fishing with gill nets is otherwise restricted. The data in this section is compiled from daily and monthly reports submitted by commercial fishers participating in the ACHP. Implementation of the ACHP has been a key element in the increased harvest of Asian carp from Kentucky waters, especially Kentucky Lake and Lake Barkley.

Since 2013, commercial fishers in Kentucky harvested a total of 18,425,995 lbs of Asian carp through the ACHP (18,110,738 lbs silver carp, 204,067 lbs bighead carp, 111,190 lbs grass carp [2020 only]; Appendix B. Table 5). Total harvest would be higher if grass carp were included for all years, however commercial fishing reports prior to 2020 did not delineate grass carp from common carp. Therefore, only grass carp harvest from 2020 is included in the total. Grass carp harvest will continue to be included in future reports. The majority of Asian carp harvested in Kentucky are from Lake Barkley (Appendix B. Table 5). Commercial fishers prefer fishing Lake Barkley over Kentucky Lake as it is shallower, has more embayments to corral fish, less recreational traffic, and the fishers believe the silver carp are larger. Number of commercial fishers in Kentucky and associated trips under the ACHP program has varied annually. A decrease in fishing effort (numbers of trips) and Asian carp harvest in 2015 and 2017 was due to inconsistent market demands. In 2019, the number of fishers targeting Asian carp doubled, and fishing effort more than doubled. In 2020, 48 commercial fishers made 2,052 trips through the ACHP, which is a decrease in both fishers and effort through the program from 2019. However, it was an increase in effort per commercial fisher (approximately 43 trips/fisher). Additionally, commercial fishers harvested an excess of 6.6 million pounds of Asian carp through the ACHP in 2020, indicating an increase in harvest efficiency for commercial fishers targeting Asian carp (Appendix B. Table 5 & Figure 4). Factors affecting the increased efficiency are likely a combination of the 2015 Asian carp year class becoming fully recruited to the fishery and improved commercial practices. Commercial fishers' adaptation in net sizes during the past several years helped facilitate the 2020 record harvest, and the highest CPUE of silver carp during ride-alongs (0.68 fish/yard; Appendix B. Table 6 & Figure 22). KDFWR also continuees to maintain an industrial flake ice machine to provide free ice to ACHP fishers to help keep their catch fresh.

Asian carp harvest data was summarized by month from January 2013 to December 2020 (Appendix B. Figures 25 & 26). Historically, the number of trips made by commercial fishers under the ACHP decreased during paddlefish season (November-March) and increased again when paddlefish season ended (Appendix B. Figure 23). This shift was expected as many commercial fishers fish Kentucky Lake and Lake Barkley with a special net permit during paddlefish season, which allows gill netting in the lakes without fishing under the ACHP. However, in late 2018 and through 2020, this trend was not apparent as commercial fishers are now targeting Asian carp year round, and are allowed to receive funds through the contract program administered by KDFWR for Asian carp harvested while fishing on their net permit. The highest number of commercial fishing trips recorded in a single month was 302 in January 2020, followed by 300 trips in February 2020. Total pounds of silver carp harvested per month closely follows the trend of number of trips made with February of 2020 having the highest weight recorded (859,783 lbs). Average pounds of silver carp harvested per trip has varied by year. Except in July, the average pounds of silver carp harvested per trip was higher in every month of 2020 than in 2019 (Appendix B. Figure 24). Market demand for food grade fish decreased after February of 2020 due to COVID 19, and therefore impacted effort and harvest by commercial fishers for the majority of the year.

Water conditions routinely affect Asian carp harvest rates, but seasonality is also a factor. KDFWR and MSU telemetry studies indicate that movement rates of silver carp increase in water temperatures between 61.5 ^{o}F and 86.0 ^{o}F (USFWS 2019). Fish become more active with rising water temperatures in the spring, and they become less susceptible to harvest when moving to the main channels from embayments. Commercial harvest rates also vary among fishers. The most successful fishers understand silver carp tendencies better, and they use higher quality gear with larger boats that have higher weight capacities. In 2020, the average number of pounds harvested per trip was calculated for all fishers who made 10 or more fishing trips (N=34), and average pounds of silver carp harvested varied from 133 lbs/trip to 6,956 lbs/trip. Interestingly, not all fishermen with high catch rates fished frequently (Appendix B. Figure 25).

Ride-Alongs

KDFWR conducted 30 ride-alongs with 16 different commercial fishers utilizing the ACHP January through December 2020 (Appendix B. Figure 3). During ride-alongs 30,208 yards of gill net were fished and 145,855 lbs of Asian carp were harvested. The majority of fishing effort observed during ride alongs was in Lake Barkley (N=24), which is similar to fishing effort in general. Ride-alongs were also conducted in Kentucky Lake (N=5), and the Ohio River (N=1). Commercial fishers set nets primarily along secondary channels, on flats in the main lake, and in embayments. The northern end of Lake Barkley received the most fishing pressure. This may be a result of the ease of access, as it is shorter distance for commercial fishers to drive and transport fish. Another factor may be the sinuosity of Lake Barkley at this location which

reduces impacts from high winds. Additionally, in 2020, Lyon County, KY continued offering a subsidy for Asian carp harvested from Lake Barkley waters within the county boundaries, which encompasses the northern portion of Lake Barkley. The county's subsidy program was independent of KDFWR contract incentives, and commercial fishers could participate in both programs.

In Lake Barkley, average total weight of silver carp harvested per trip increased during 2020 (5,094 lbs) from all previous years (Appendix B. Table 22). Average total weight of silver and bighead carp harvested per trip during all ride-alongs in 2020 (4,775 lbs and 41 lbs respectively) was also higher than those averages for the ACHP as a whole in 2020 (Appendix B. Table 23). Average weight of individual silver carp harvested during all ACHP ride-alongs in 2020 was similar to 2019 (Appendix B. Table 4).

Experimental Gears

Modified-Unified Method

Conducting the MUM in Kentucky Lake required significant time, personnel, and equipment. The efforts resulted in the removal of 69,228 lbs of fish, most of which were Asian carp (4,327 lbs /day). Additionally, great insight was gained through the process regarding improvements in efficiencies and interagency coordination. However, the utility of the MUM for mass removal of Asian carp in a system like Kentucky Lake is yet to be proven, as the harvest rate (lbs /day) was less than what an average commercial fishing trip can harvest with substantially less manpower. However, with some modifications, the MUM style of harvest may be more efficient, and KDFWR plans to continue exploring the method. The 2020 MUM event on Kentucky Lake was also capitalized upon by an interagency media event that garnered national attention towards the efforts being expended towards controlling Asian carp.

Contracted Experimental Efforts

The only active contractor (Robbins Construction LTD) in the experimental gears program harvested approximately 206,052 lbs of fish in 2020 (12,878 lbs/ day). Of the total harvest, 87% were silver carp, 0.6% were other Asian carp species (bighead and grass crap) and the remaining 12.4% were comprised of rough fish species (primarily buffalo species and common carp). Sport fish bycatch and other fish species that were not harvested were observed to have an 87% survival rate at the time of release. The harvest rate (lbs/day) produced by Robbins Construction LTD was substantially higher than what was produced during the MUM efforts or average commercial fishing harvest rates. Robbins Construction LTD conducted many hours of research and scouting for ideal harvest areas using boat mounted electronics prior to fishing activity, and then exploited areas where congregations of fish occurred in the system naturally to maximize efforts. They also invested in equipment such as boat mounted cranes and net reels to increase efficiency and reduce the amount of manpower needed to handle large quantities of fish. Robbins

Construction LTD took responsibility to coordinate with processors for waterside pick up of fish on occassions when large quantities were corralled.

Electrofishing

Five trips were made in the Barkley Tailwater area and associated tributaries for Asian carp removal efforts. A total of 19,321 lbs of Asian carp were removed in 3.4 hours of electrofishing. The average CPUE was estimated at 815 fish/hr. A random sample of 20 silver carp were individually weighed and measured from all days of effort. Mean total length and weight of these fish was 27.05 inches and 6.75 lbs, respectively.

Gill netting

During 2020, KDFWR crews fished a total of 4,400 linear yards of gill nets during targeted removal efforts, and harvested approximately 7,043 lbs of Asian carp. Gill nets were fished during 2 trips to Kentucky Lake, and 7 species were captured. Asian carp comprised 97% of fish numbers collected (8 grass carp and 363 silver carp). Gill nets were fished during 4 trips in Lake Barkley, and 4 species were collected. Asian carp totaled 98% of the fish collected (1 grass carp, 598 silver carp). Asian carp CPUE differed by bar mesh size yielding the following; 3" (0.038 fish/yd.), 3.5" (0.445 fish/yd.), 4" (0.047 fish/yd.), and 5" (0.000 fish/yd.), respectively for both reservoirs combined. In 2020 KDFWR staff were able to expand the variety of mesh size and depth of gill nets for use, however due to the limited number of staff and restrictions associated with COVID 19, targeted removal effort was much lower in 2020, than in previous years.

Agency: MDWFP

Objective 1

As mentioned in the methods section, no bigheaded carp were detected in 16 h of electrofishing and this method was abandoned. Overall, 63 fish were collected with gill nets over 12 net-nights at Pickwick Lake and 146 fish over 25 net-nights at Bay Springs Lake. Two Silver Carp were collected at Bay Springs Lake and none at the Yellow Creek Arm of Pickwick Lake. Thus, catch of bigheaded carps (Bighead Carp and Silver Carp) per net night were 0.08 at Bay Springs and 0 at Pickwick. Similarly, the proportion of nets with bigheaded carp were 0.08 at Bay Springs and 0 at Pickwick. These catch rates are substantially lower than those reported in Kentucky and Barkley lakes (Appendix C. Figure 1). These latter reservoirs are at the entrance to the Tennessee and Cumberland rivers, respectively, and have the earliest established populations of bigheaded carps in the Tennessee River system.

Objective 2

MDWFP Data

A multivariate (6 species) analysis of covariance (lake as class variable, year as covariate) applied with a PERMANOVA (i.e., permutation multivariate analysis of variance) identified a significant interaction (P=0.007) between reservoir and year. This interaction suggested that percentage composition changed over time but in different ways between lakes. Further single species analyses to inspect the multivariate interaction revealed that two species showed no temporal trend in percentage composition (bluegill and white crappie). Spotted bass increased over time in percentage composition at Bay Springs but showed no significant temporal trend at Pickwick, largemouth bass increased in percentage composition at Pickwick but remained relatively constant at Bay Springs, black crappie increased over time in Pickwick but decreased at Bay Springs, and redear sunfish decreased over time at Pickwick and remained relatively constant at Bay Springs. This limited analysis of MDWFP's electrofishing data did not show any major shifts in the fish assemblages that could be attributed to bigheaded carps invasion. These results were expected considering bigheaded carps abundance at both reservoirs was nil or very low during the period analyzed. However, the analysis did show the need for standardizing the way collections are processed by MDWFP to ensure reliable long-term data.

TVA Data

Overall, 498 gillnet nights were fished at Kentucky Lake and 627 at Wheeler Lake. Annual catch per effort (standardized to 30 net nights) averaged 281 gizzard shad (min-max = 36-579) at Kentucky Lake and 138 at Wheeler Lake (23-360). Overall, 975 electrofishing samples were taken at Kentucky Lake and 1,231 at Wheeler Lake. Annual catch per effort (standardized to 1 h) averaged 219 gizzard shad (min-max = 38-669) at Kentucky Lake and 140 at Wheeler Lake (32-386).

Results indicated that gizzard shad began decreasing in density in both reservoirs well before the bigheaded carps invasion and that the decrease continued after 2004 (Appendix C. Figure 2). A change point analysis confirmed there was no change in trajectory in Kentucky Lake after 2004 once bigheaded carps had established. Thus, this analysis identified no detectable effect of bigheaded carps on the trends in gizzard shad densities already underway pre 2004.

Agency: TWRA

Objective 1

TWRA staff conducted 128 net nights of gill netting effort, resulting in the collection of 137 silver carp. On both Kentucky and Barkley reservoirs, summer catch rates in 2020 declined from observed catch rates in 2019, but fall catch rates remained similar (Appendix D. Table 1). In Kentucky Lake, 72.5% of silver carp collected during summer were captured in 3-inch mesh, whereas 58% of silver carp collected during fall were captured in 4-inch mesh. At Lake Barkley, 73% and 87.5% of silver carp captured during summer and fall, respectively, were captured in 4-inch mesh. Catch rates at Pickwick and Cheatham reservoirs appear similar to what was

observed at Kentucky and Barkley; however, uncertainties regarding sample size and variability continue to limit the utility of this metric. All silver carp collected via gill nets in Pickwick and Cheatham reservoirs were captured in 4-inch and 5-inch mesh. No silver carp were captured at Old Hickory Lake via gill nets. A total of three bighead carp were captured by gill nets; two in Kentucky Lake (one in summer and one in fall) and one in Cheatham Lake (fall).

A total of 15.5 hours of electrofishing was conducted by TWRA staff during the summer season, resulting in the collection of 175 silver carp. Catch rates were highest on downstream reservoirs (Kentucky and Barkley), whereas lower catch rates were observed on upstream reservoirs (Pickwick, Cheatham, and Old Hickory) (Appendix D. Table 2). The collection of two silver carp in Old Hickory Lake was noteworthy. This was the first TWRA collection of silver carp in Old Hickory, though not the first documentation of the species in the reservoir. Both individuals collected were large males (TL $\geq$ 915 mm; WT $\geq$ 9710 g). Otoliths were collected and await processing. No bighead carp were captured during summer electrofishing efforts.

In four market visits during July and August of 2020, TWRA personnel sampled the silver and bighead carp catch of 7 commercial fishers. Of the seven catches sampled, five were collected on Kentucky Lake and two were collected on Lake Barkley. Mean total length of subsampled silver carp from Kentucky Lake and Lake Barkley was 765 mm (n=154; SD=±100) and 728 mm (n=65; SD=±56), respectively. In the seven catches sampled, a total of nine bighead carp were caught and only one of those was captured in Lake Barkley. Fisheries dependent sampling of this nature will be further developed and pursued in the coming year.

Meaningful characterizations associated with this data are difficult to make due to small sample sizes. Recognizing these limitations, there are several observations made based on anecdotal information and the data collected. In general, silver carp collected throughout the sampling area were in good condition. Silver carp in upstream reservoirs tended to be larger than those in downstream reservoirs. No silver carp less than 400 mm were encountered, suggesting limited to no recruitment of juveniles within the systems.

Recommendations:

All Partners

-Partners in the Tennessee and Cumberland River Basin have initiated substantail efforts to take on the Asian carp invasion. New programs being developed by partners are largely dependent on funding provided through the USFWS Asian carp grants. Continued funding opportunities will be required for partners to advance their efforts.

-Recognize need to standardize collections as possible and working together in the basin.

-As basin partners begin sampling or continue efforts currently in place, data should be compiled and analyzed congruently to more succinctly identify trends in Asian carp population characteristics throughout the basin and inform removal efforts.

-Continue and increase harvest efforts, with identified need for expansion to leading edge populations.

-Need for linking information/data collection back to potential or current management actions.

Agency: ALWFF

-ALWFF staff recommend that monitoring should be expanded on all three lower reservoir pools to incorporate both standardized electrofishing and gill net sampling that examines additional habitats (e.g., backwaters, creeks, pinch points) within both the mainstem channels and tributaries. Additional work may include initial examination of young-of-year Asian carp. These efforts would satisfy **Objective 1**.

-Given the current distribution of Silver Carp in Pickwick Reservoir, we intend to focus substantial efforts in supplemental eradication sampling using the gears and methods described above (methods) to satisfy **Objective 3**.

-ALWFF staff are currently building a dozer trawl electrofisher that should be online in June 2021. This key equipment will aid in both **Objectives 1 and 3**.

Agency: KDFWR

-To increase capture rates and sample sizes in the variable habitats found in the basin, additional gear types are being planned as funding allows. Methods for these gears will be clearly outlined and should be standardized across the basin. Data collected by KDFWR has been useful for identifying trends in demographics of Asian carp populations in the lower reaches of Kentucky and Barkley lakes, and this type of data collection will be expanded throughout the basin.

-It is reccommended that targeted removal of Asian carp be continued through 2021.

-KDFWR also suggests that increased observations of commercial fishers through ride-alongs be conducted to reduce differences in reporting.

-Commercial fishing effort throughout the basin is increasing, but relies almost entirely on gill nets as their method of harvest. Gill nets are size selective and the mesh sizes used do not capture

all year classes of Asian carp present in the basin. Therefore, effort towards identifying and testing other methods for removing Asian carp should be expanded. Commercial seining shows considerable promise for efficiently removing carp at rates higher than traditional gill netting, and Asian carp harvest areas and associated regulations are planned to facilitate that gear type in Kentucky. KDFWR plans to significantly increase efforts with experimental gear types in Kentucky and Barkley lakes, including research to broaden the scope of the USGS Modified Unified Method and testing promising new pelagic harvest techniques.

Agency: TWRA

-Conduct power analyses on sampling schemes.

-Work with partners to continue standardization of methodology.

-Augment low sample sizes with supplemental sampling.

-Support commercial removal efforts.

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Appendix A. ALWFF Tables and Figures

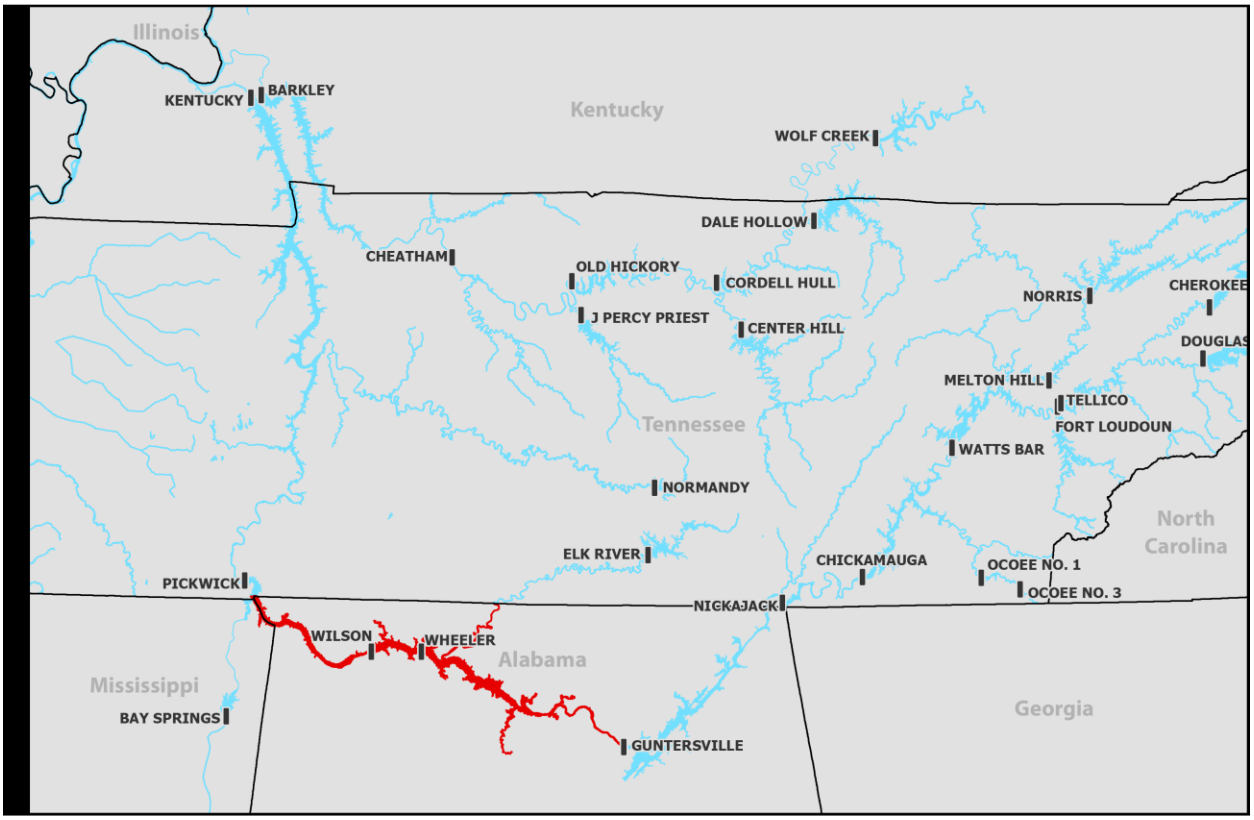

Figure 1. Areas in red indicate the Asian carp study area for ALWFF on the Tennessee River in Alabama.

Table 1. Summary of effort and catch data for monitoring, eradication and reconnaisance of Asian carp populations in four Tennessee River reservoirs of Alabama.

Sample Effort Parameter	**TN River Reservoirs (downstream to upstream)**				
Gill Netting	**Pickwick**	**Wilson**	**Wheeler**	**Guntersville**	**Total**
Man-days	60	45	54		**159**
Samples (Net sets/nights)	20	15	18		**53**
Net hours (nearest 0.1 h)	381.2	306.0	356.4		**1043.6**
All fish (n)	237	140	253		**630**
Fish species (n)	14/21	10/21	14/21		**21**
Silver Carp (n)	50	0	0		**50**
Other asian Carp Species (n) *	0	1	2		**3**
CPUE (Asian Carp/net-night)	2.5	0.1	0.1		**1.0**
CPUE (Asian Carp/net-h)	0.1	< 0.1	< 0.1		**0.1**
Electrofishing					
Man-days	4		2		**6**
Target Task	Assess distribution		Assess distribution		
Sample method	Target EF		Target EF		
Reconnaisance					
Man-days	8	4	8	6	**26**
Target Task	Site assess	Site assess	Site assess	Site assess	
Sample method	Sonar	Sonar	Sonar	Sonar	
Agency / Univ. Assistance					
Man-days	1			2	**3**
Target Task	Assist TTU			Assist TTU	
Sample method	Tagging AC			Telemetry data	

* Other Asian carp species include: White Amur (n=3), Bighead Carp and Black Carp (both n = 0); but do not include Common Carp (n=7).

Appendix B. KDFWR Tables and Figures

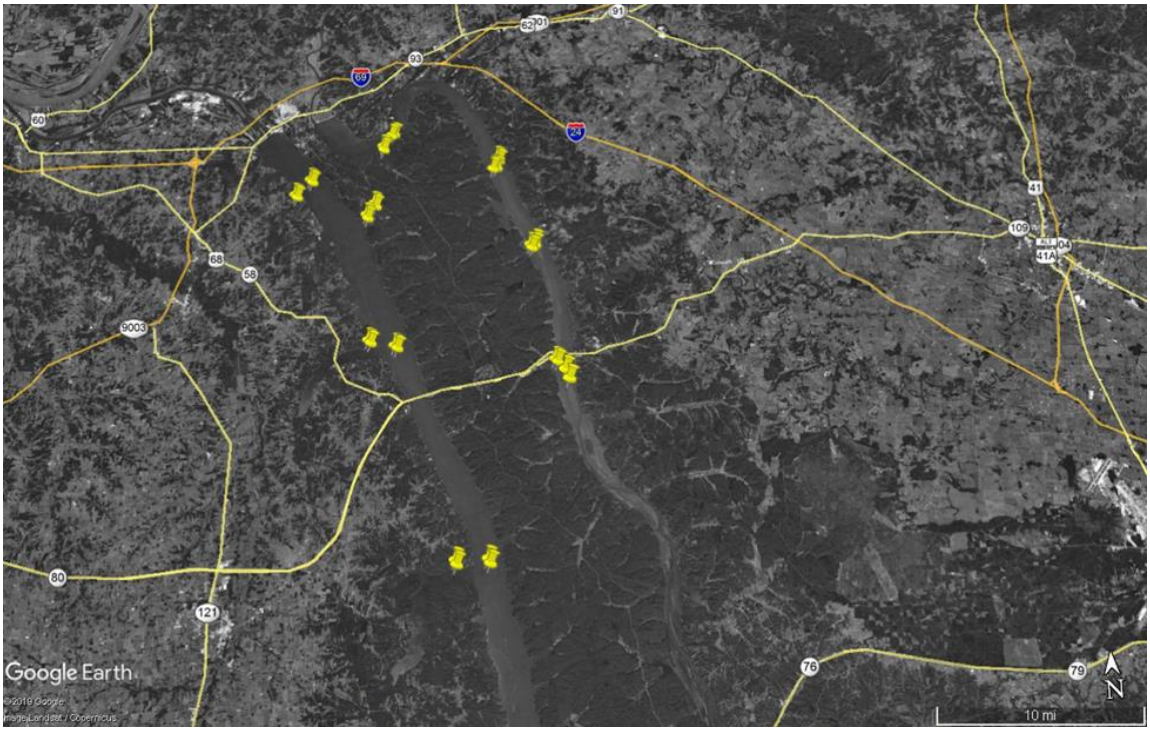

Figure 1. Location of standard sampling sites, where gill nets were fished by Kentucky Department of Fish and Wildlife Resources in 2020.

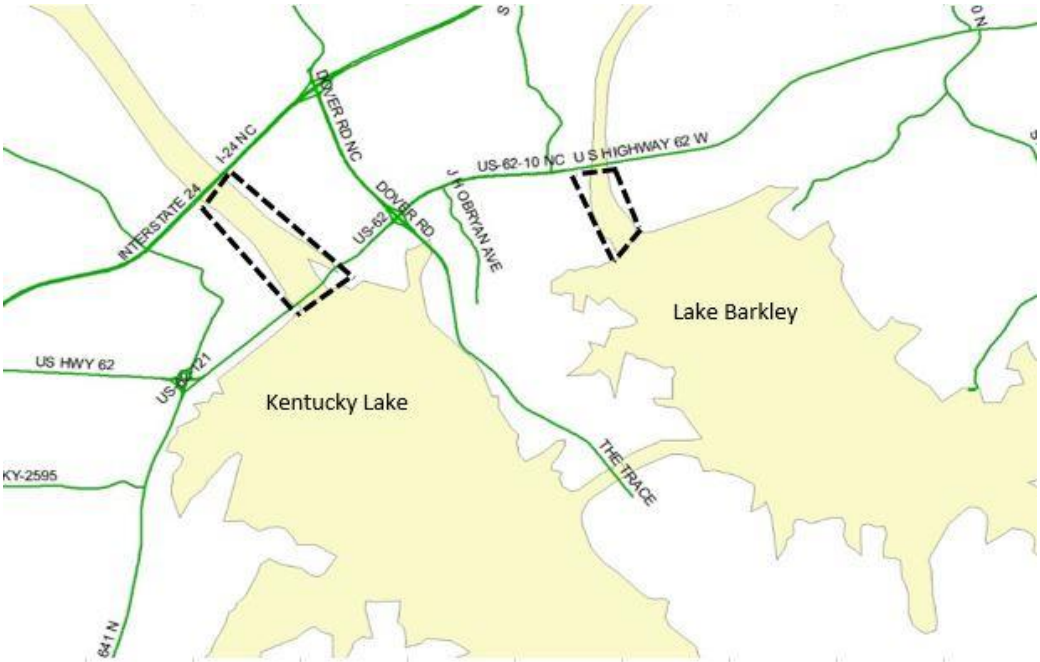

Figure 2. The tailwater electrofishing at Kentucky Tailwater extended from the dam downstream to the Interstate 24 bridge. The electrofishing at Barkley Tailwater extended from the dam downstream to the US Hwy 62 bridge. Sample areas are outlined by dashed line.

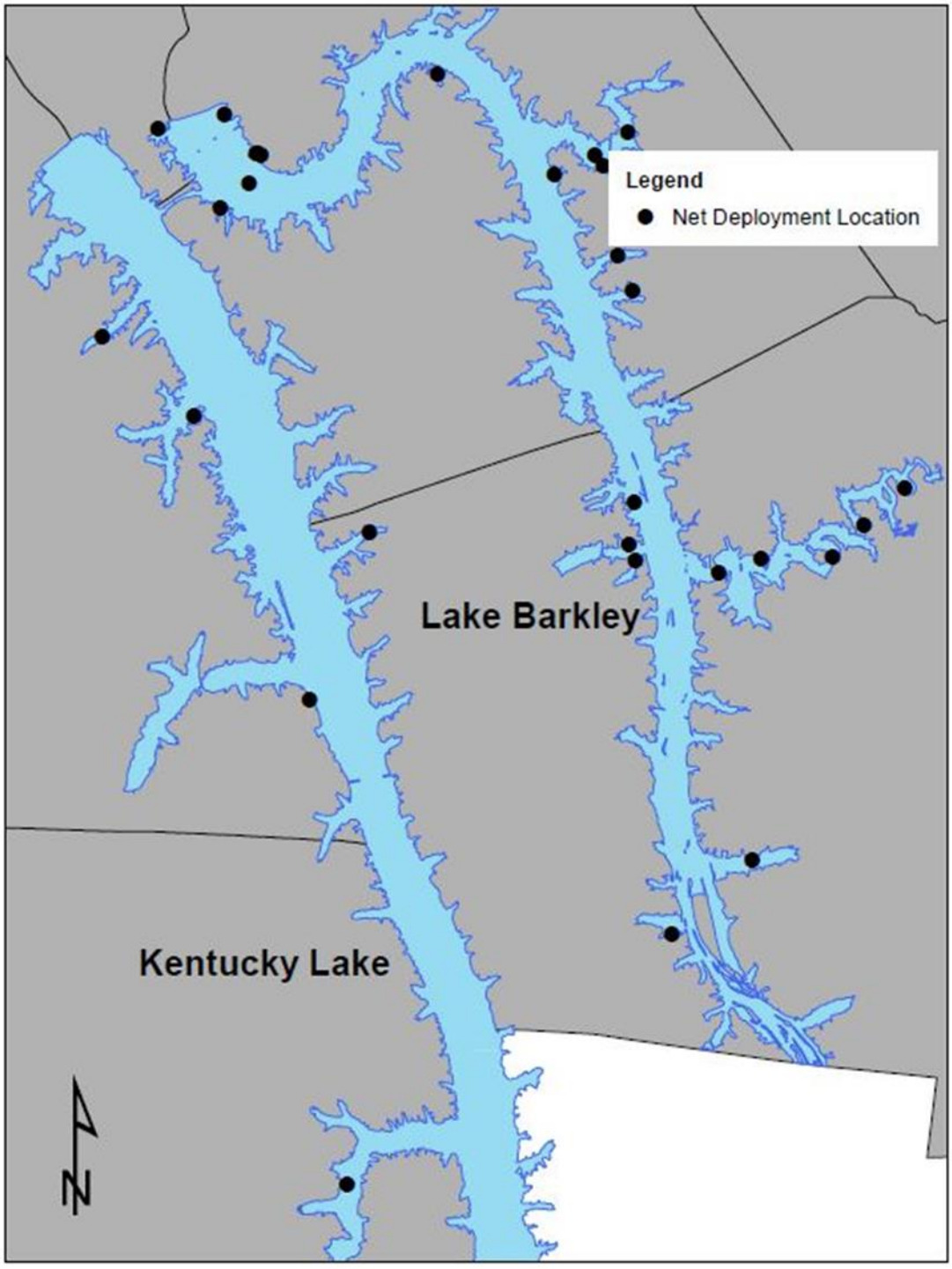

Figure 3. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff in 2020.

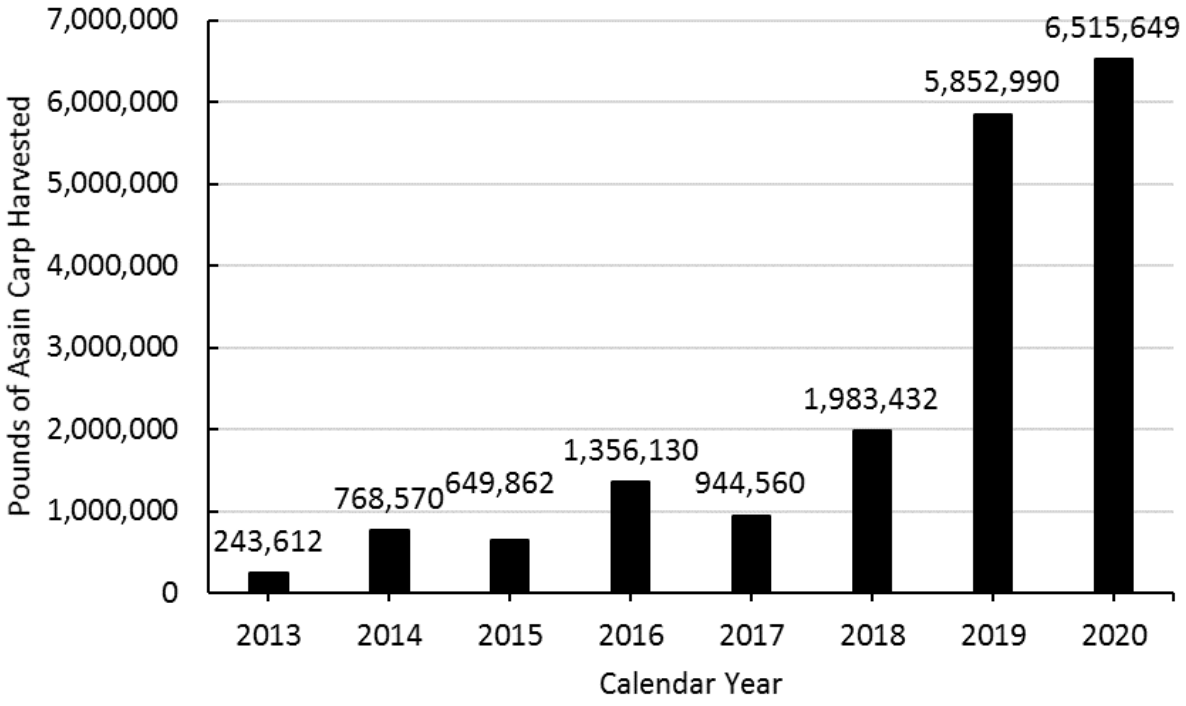

Figure 4. Pounds of Bigheaded carp harvested through the Asian Carp Harvest Program by calendar year. 2020 was the first year that grass carp harvest was tracked through the ACHP and accounted for an additional 111,190 lbs of Asian carp species harvested through the ACHP in 2020.

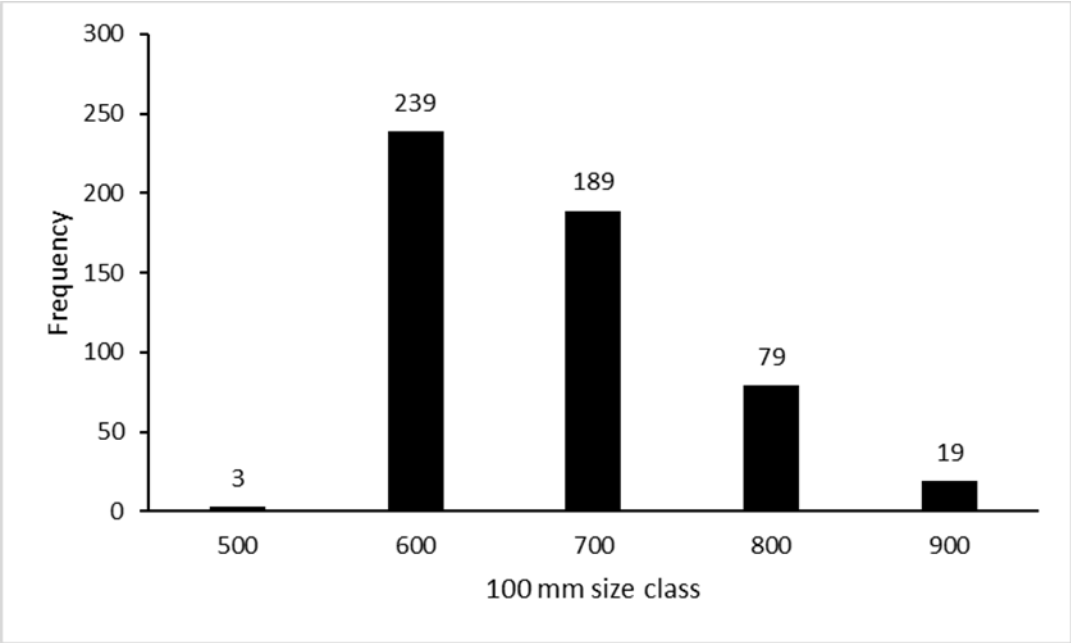

Figure 5. Length-frequency distribution of silver carp collected from Lake Barkley, from all methods in 2020 (N=529).

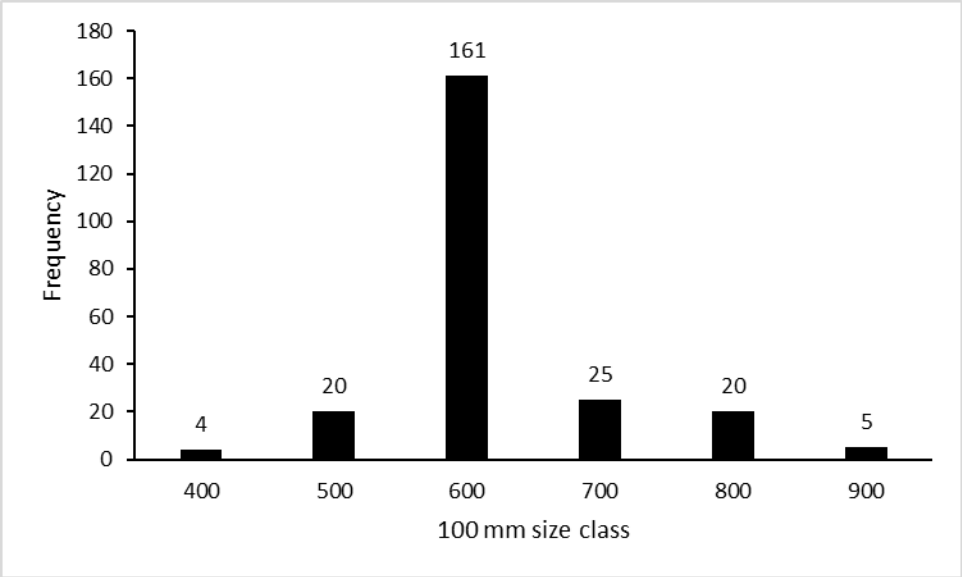

Figure 6. Length-frequency distribution of silver carp collected from Kentucky Lake, from all methods in 2020 (N=235).

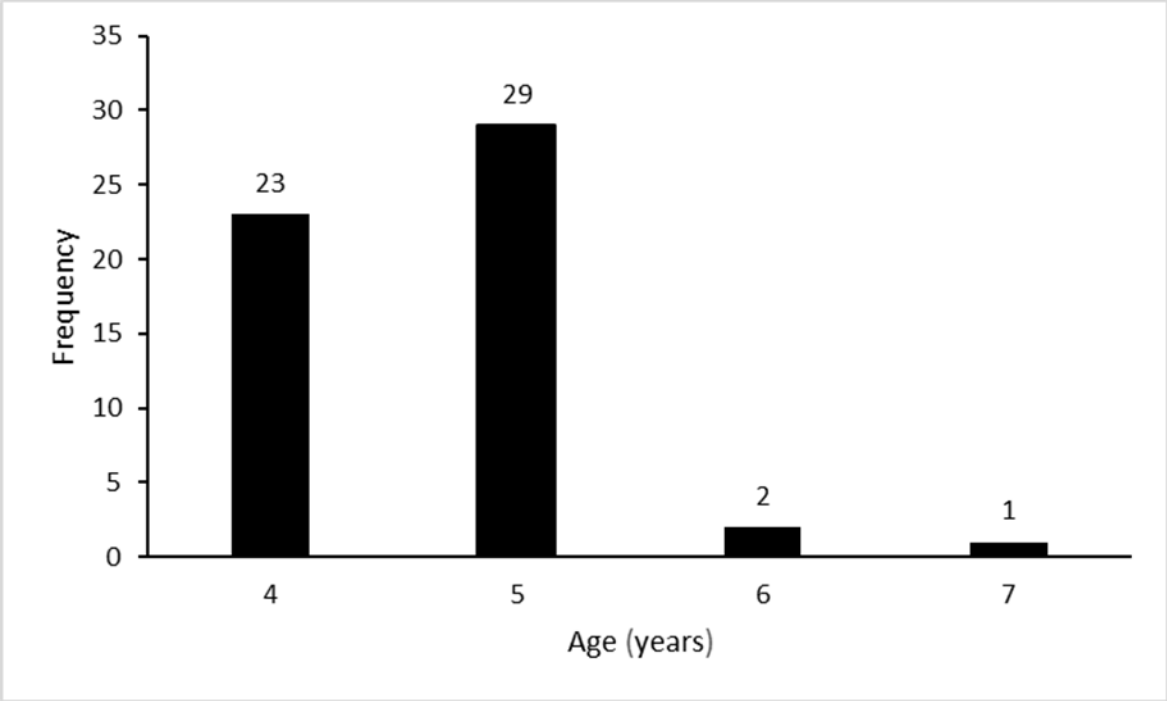

Figure 7. Age-frequency distribution for silver carp collected from Lake Barkley in 2020 (N=55).

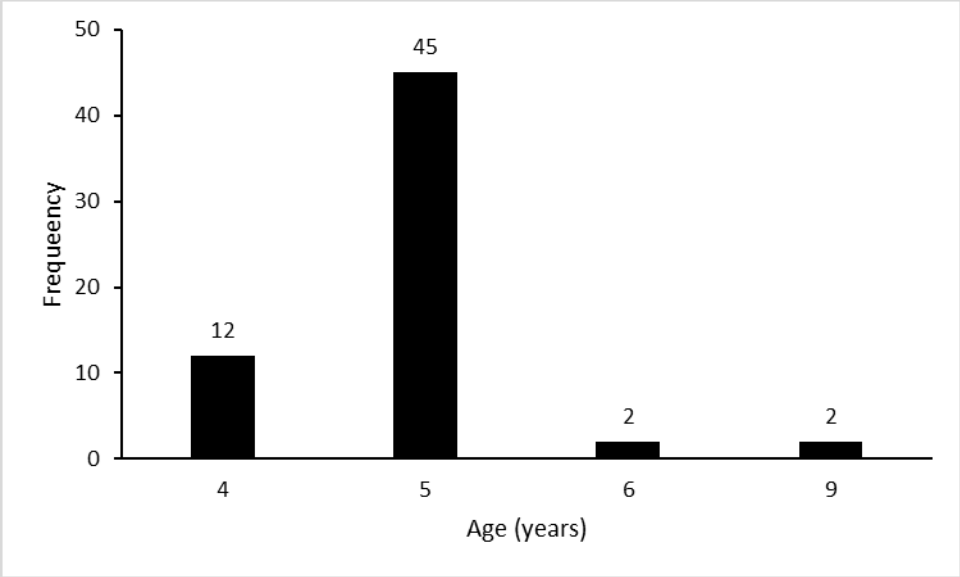

Figure 8. Age-frequency distribution for silver carp collected from Kentucky Lake in 2020 (N=61).

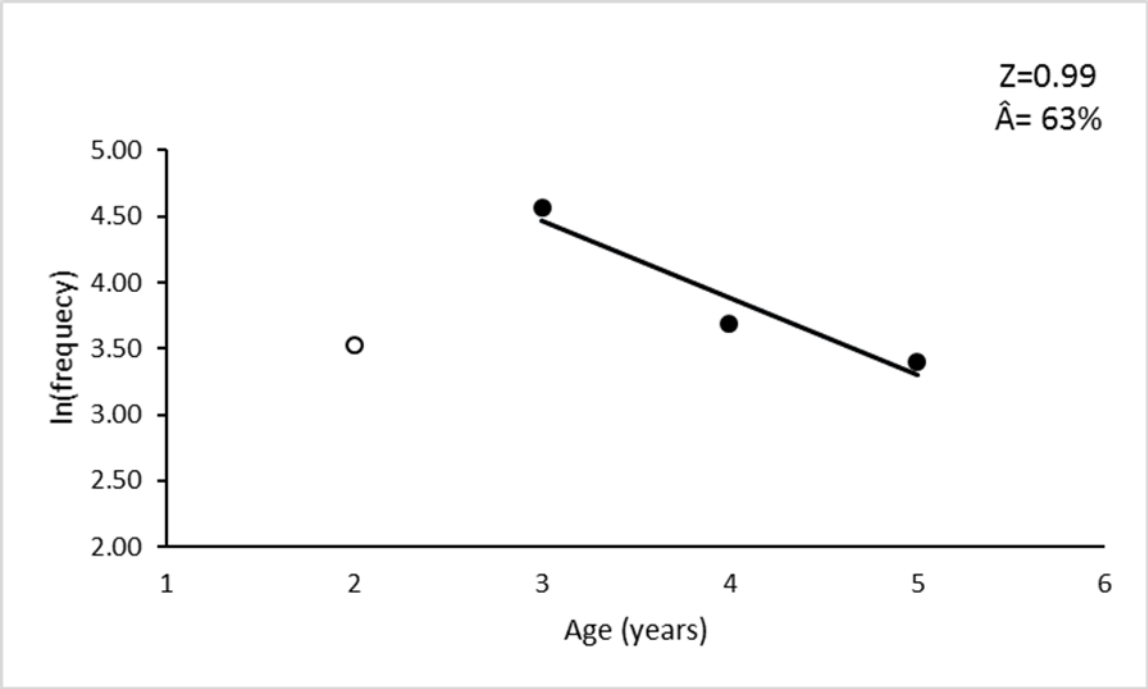

Figure 9. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Lake Barkley in 2020 (N=196, F1,1=11.75, P=0.180, R2= 0.92). The open circle represnets fish not considered fully recruited to the gears used for data collection and thus not used to estimate A or Z.

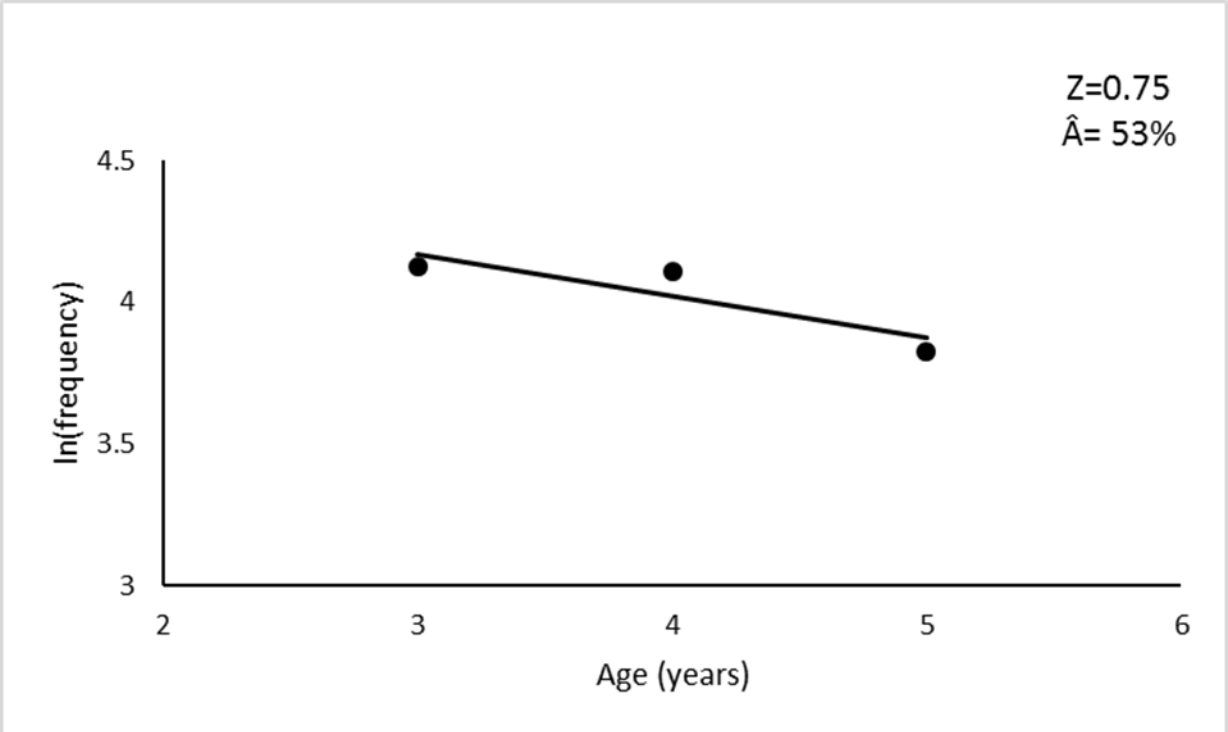

Figure 10. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Kentucky Lake in 2020 (N=166, F1,1=3.78, P=0.302, R2= 0.79).

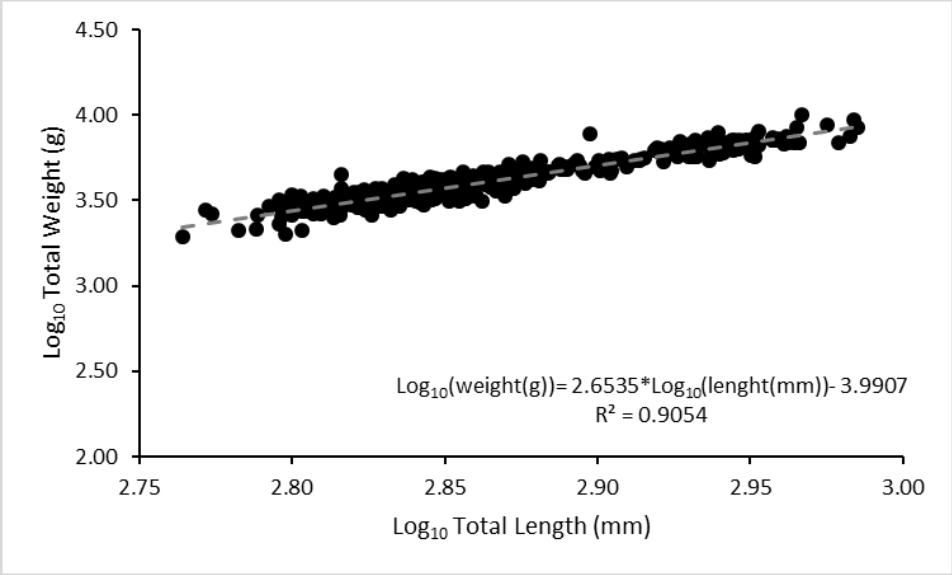

Figure 11. A scatterplot of Log10 transformed lengths and weights for silver carp collected from Lake Barkley in 2020 with a regression line describing the relationship between lengths and weights (N=530).

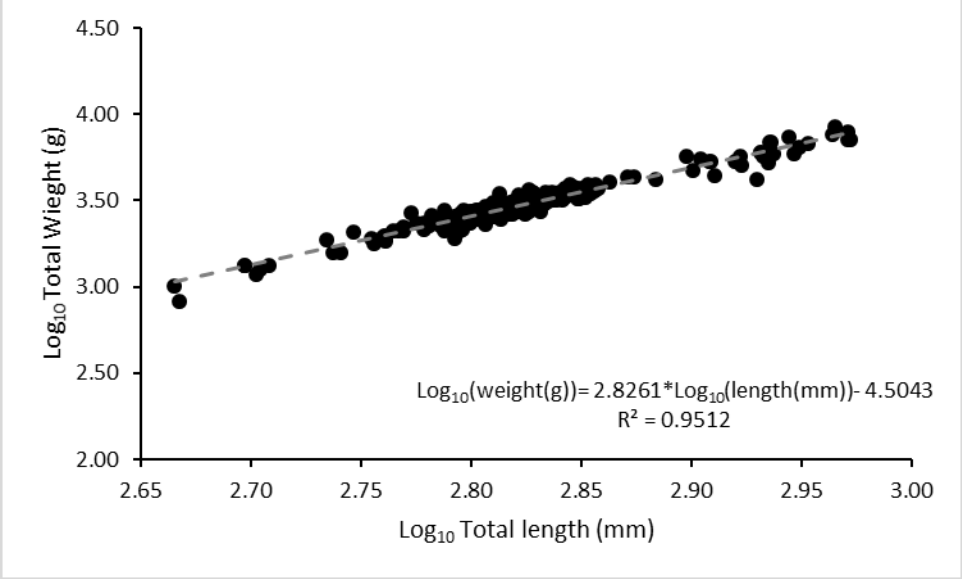

Figure 12. A scatterplot of Log10 transformed lengths and weights for silver carp collected from Kentucky Lake in 2020 with a regression line describing the relationship between lengths and weights (N=236).

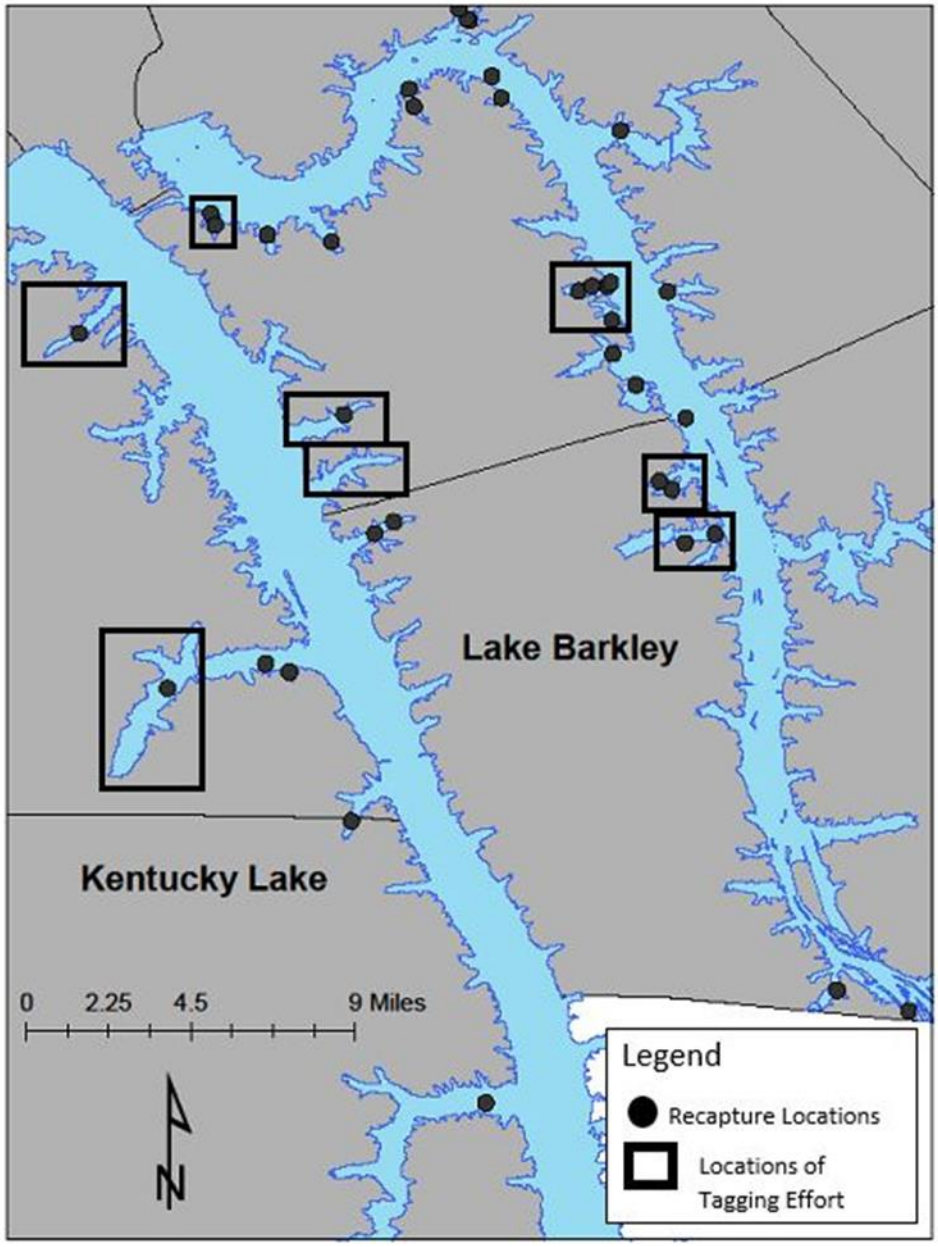

Figure 13. Locations of recaptured silver carp that were tagged as part of the mark-recapture effort to estimate abundance of silver carp in Barkley and Kentucky lakes.

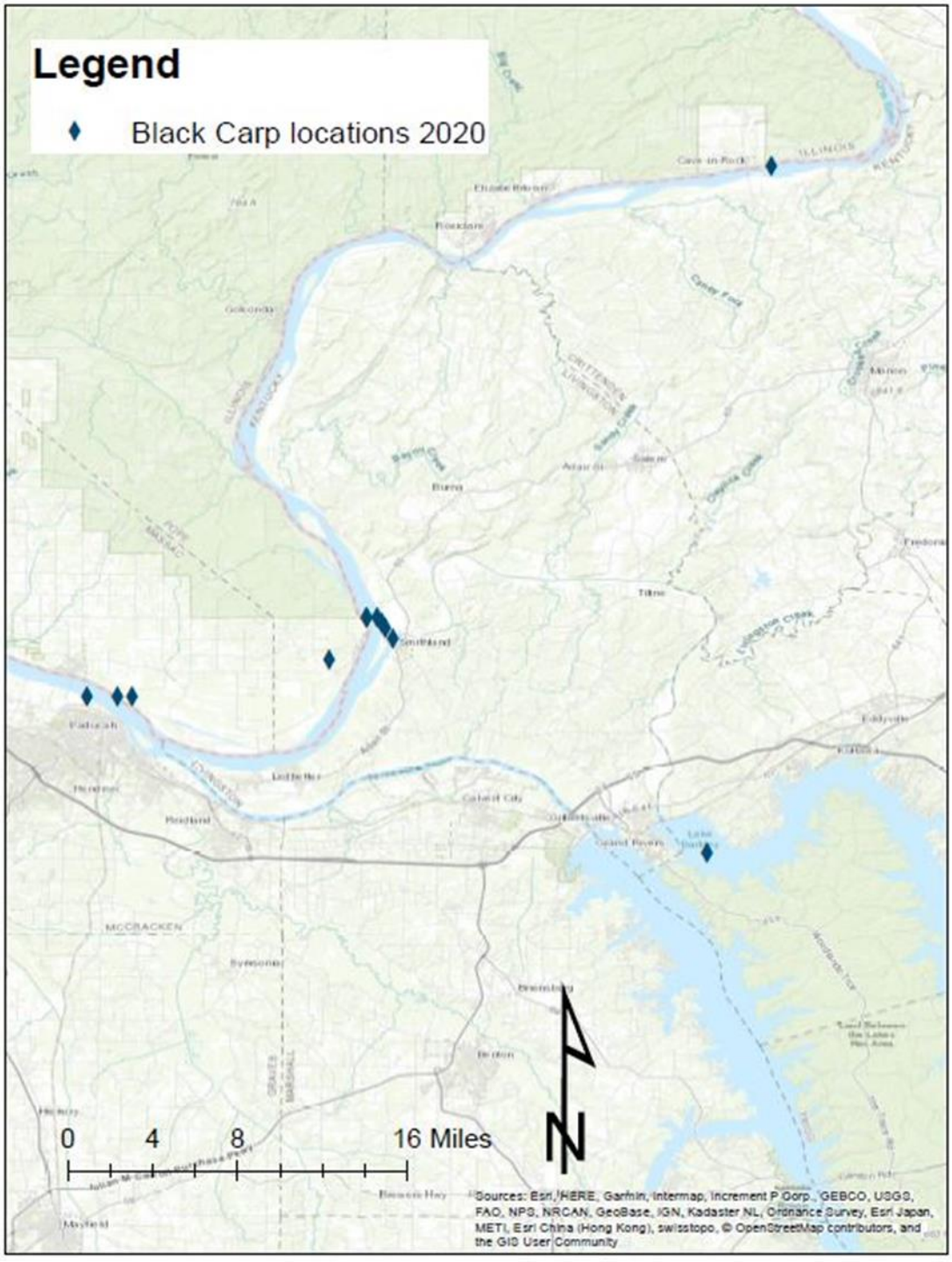

Figure 14. Locations of black carp captures reported in 2020 by commecial fishers to KDFWR. Additional fish from the Ohio and Mississippi rivers were captured and sent to Illinois or the USGS by commercial fishers.

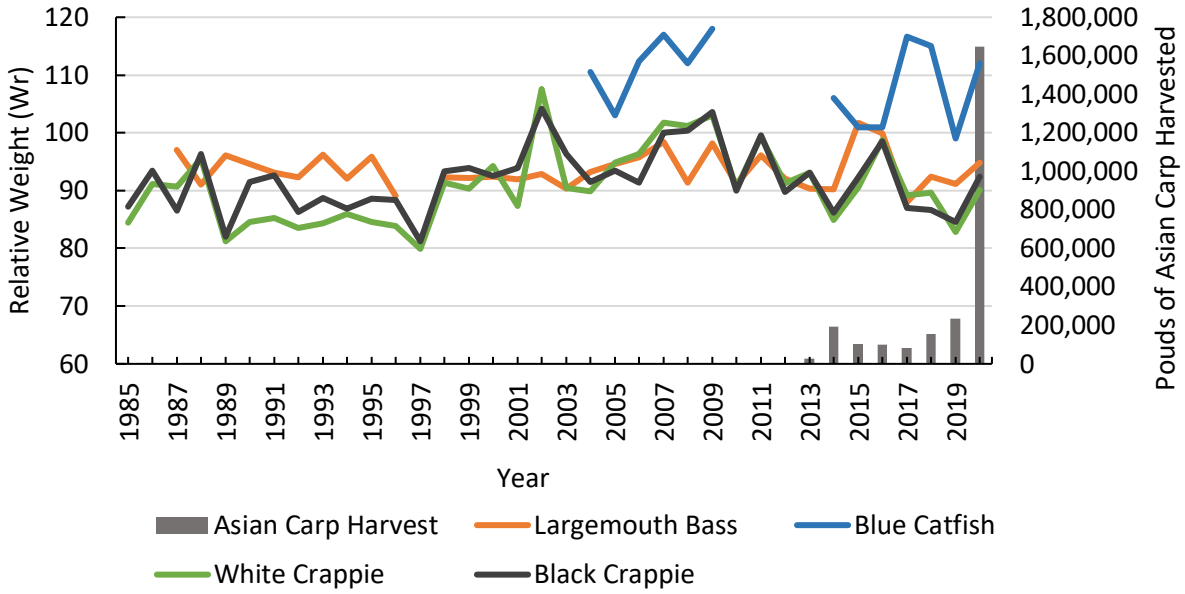

Figure 15. Mean relative weights of popular sport fish species sampled in Kentukcy Lake annually, plotted against pounds of Asian carp harvested from Kentucky Lake by commercial fishers under the Asian Carp Harvest Program since the program began in 2013.

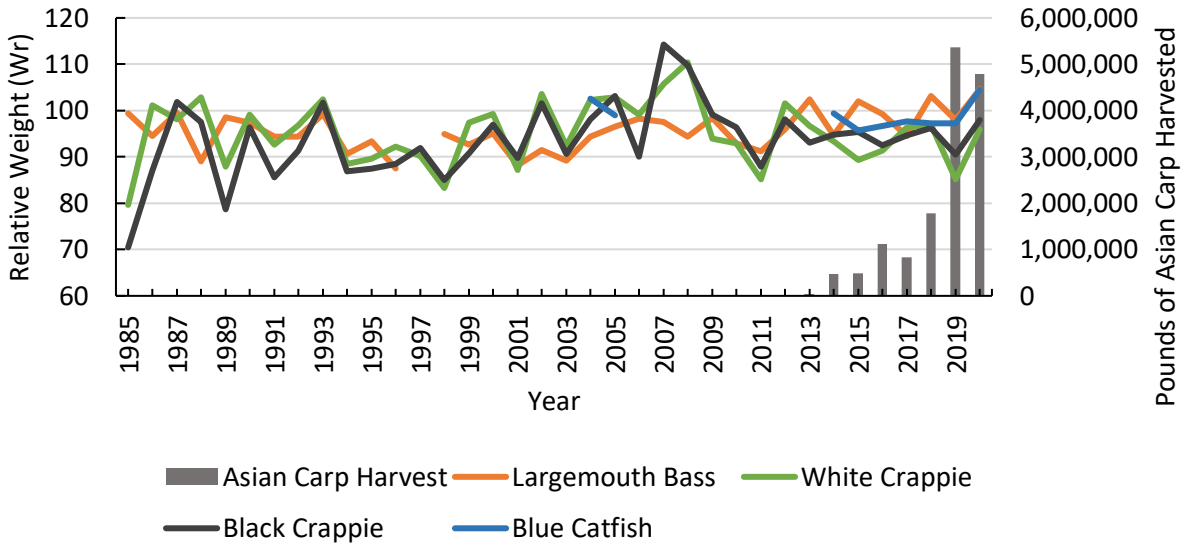

Figure 16. Mean relative weights of popular sport fish species sampled in Lake Barkley annually, plotted against pounds of Asian carp harvested from Lake Barkley by commercial fishers under the Asian Carp Harvest Program since the program began in 2013.

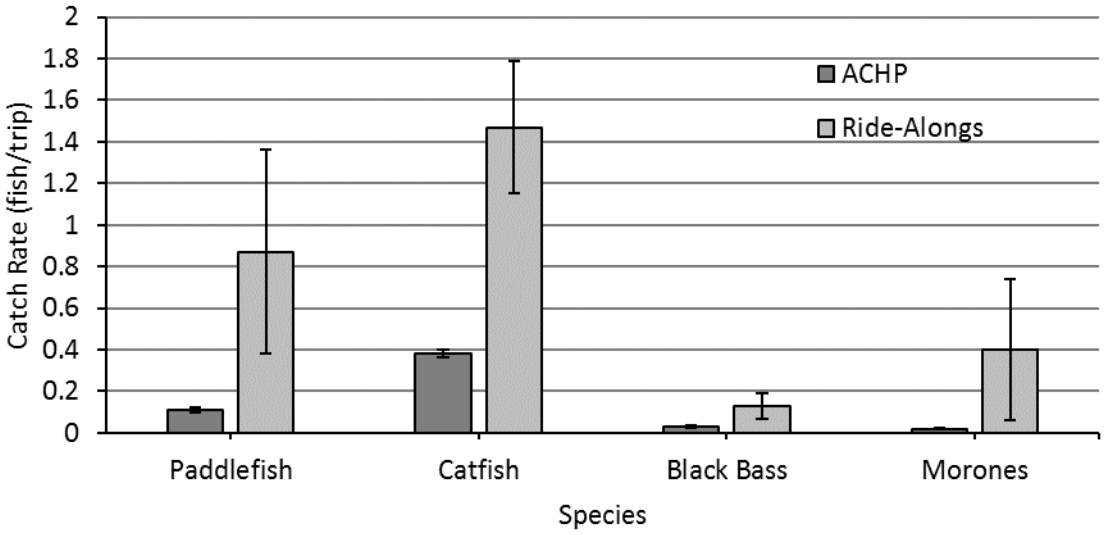

Figure 17. Comparison of catch rates (fish/trip) for some commercially and recreationally important species reported as bycatch by commercial fishers utilizing the Asian Carp Harvest Program (ACHP) and through KDFWR ride-alongs with commercial fishermen. Error bars represent Standard Error values.

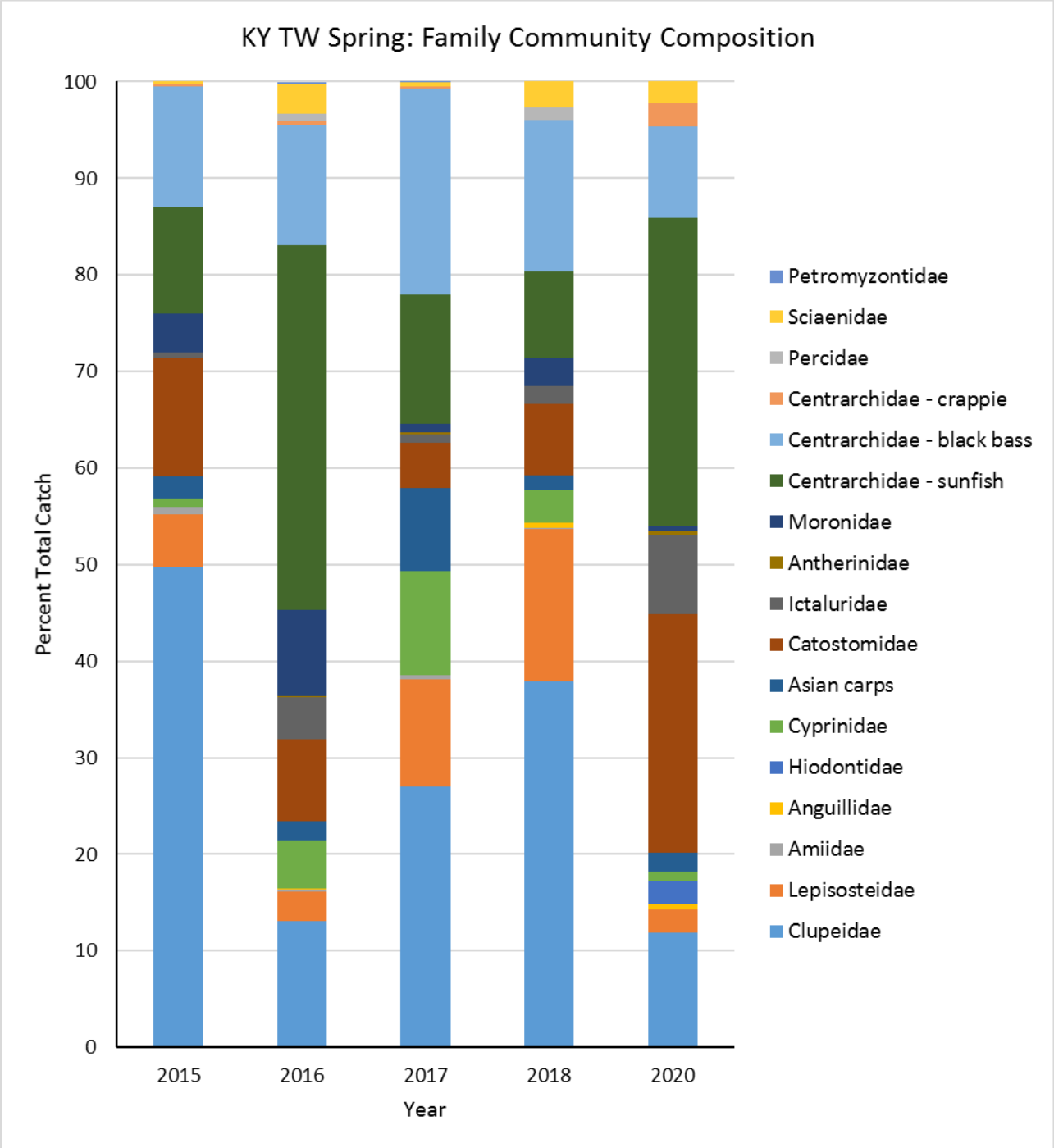

Figure 18. Comparison of percent total catch by number of each family identified from spring community sampling via electrofishing in the Kentucky Tailwater 2015-2020. Spring sampling was not conducted in 2019.

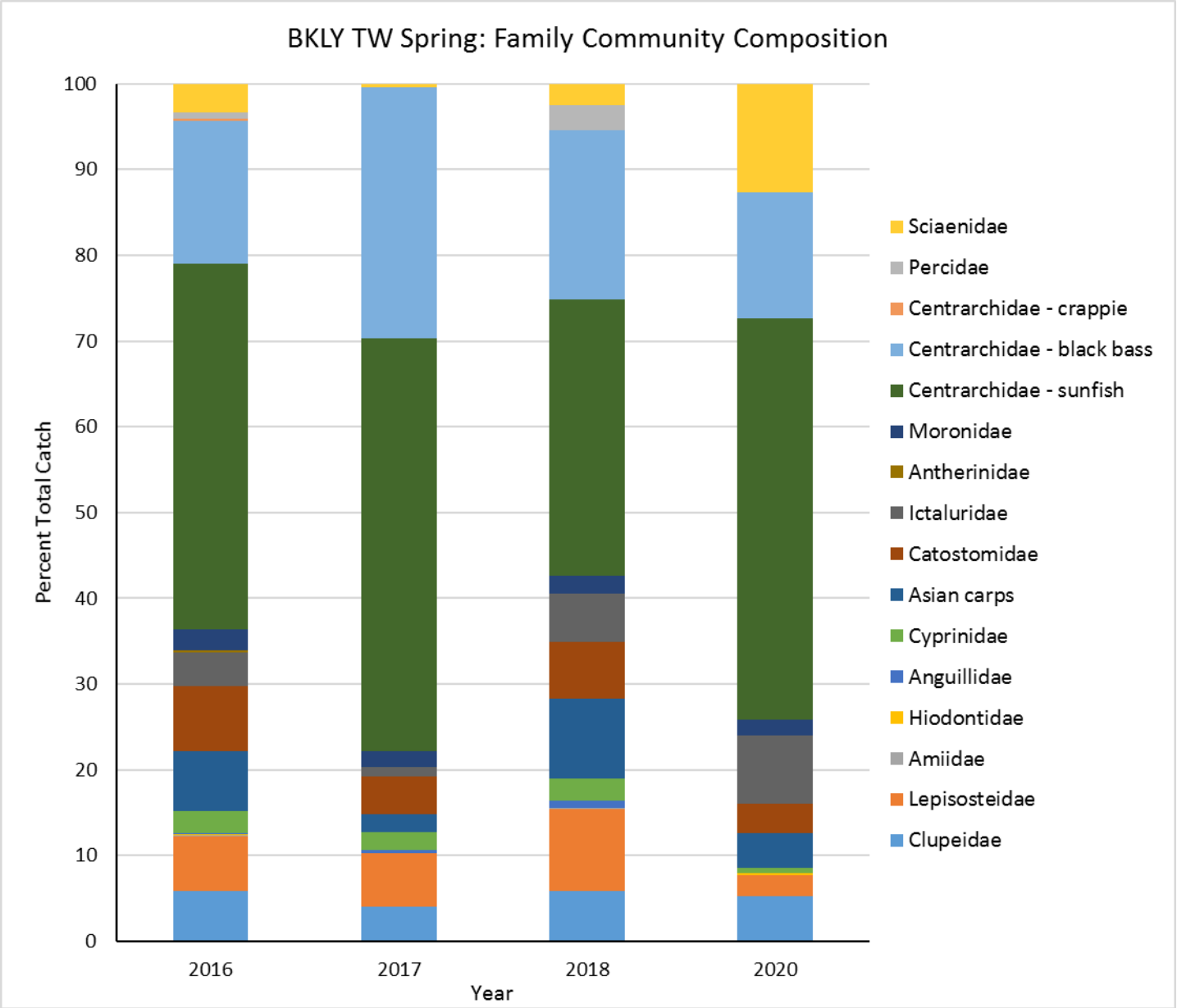

Figure 19. Comparison of percent total catch by number of each family identified from spring community sampling via electrofishing in the Barkley Tailwater 2016-2020. Spring sampling was not conducted in 2019.

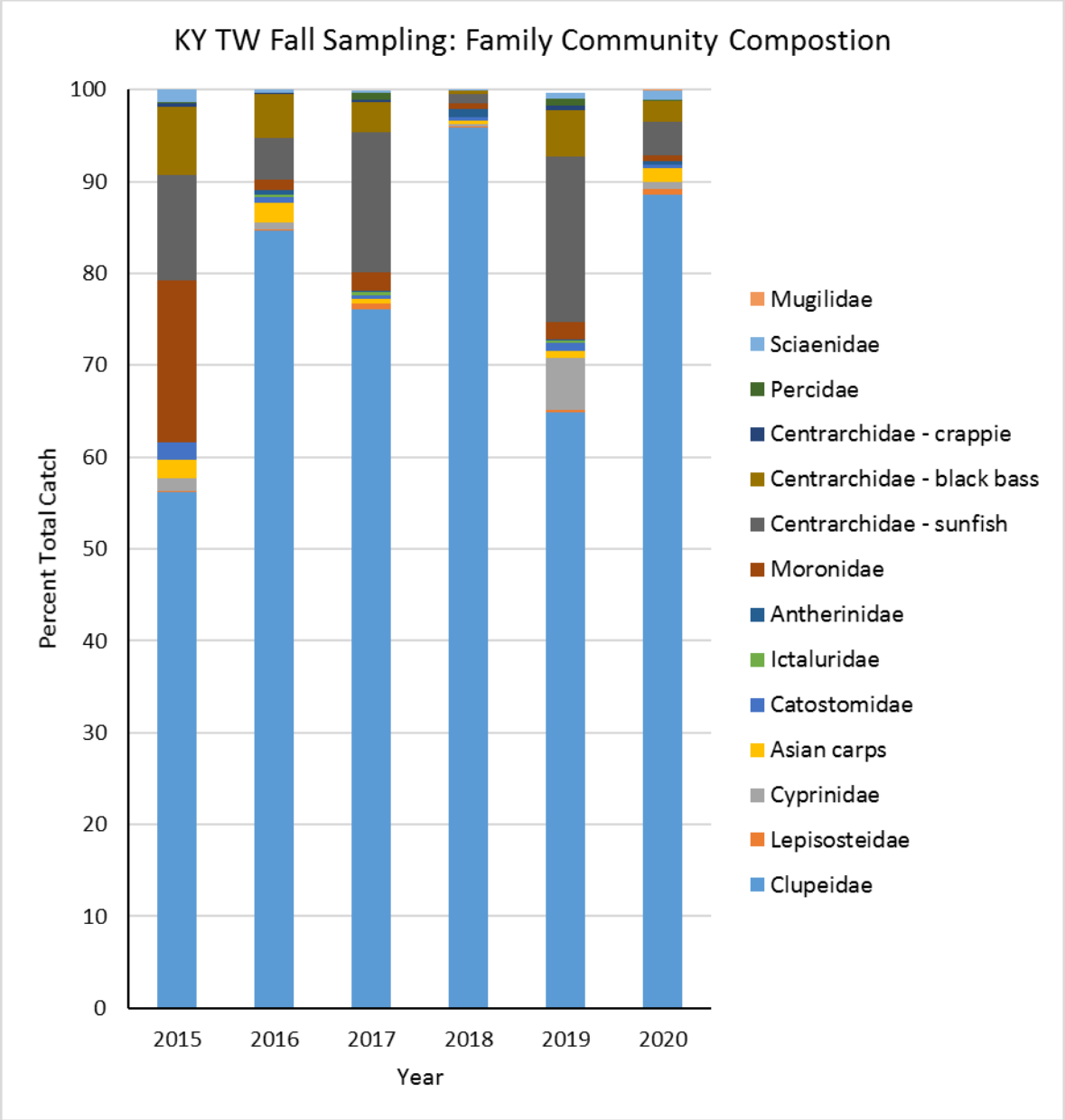

Figure 20. Comparison of percent total catch by number of each family identified from fall community sampling via electrofishing in the Kentucky Tailwater 2015-2020.

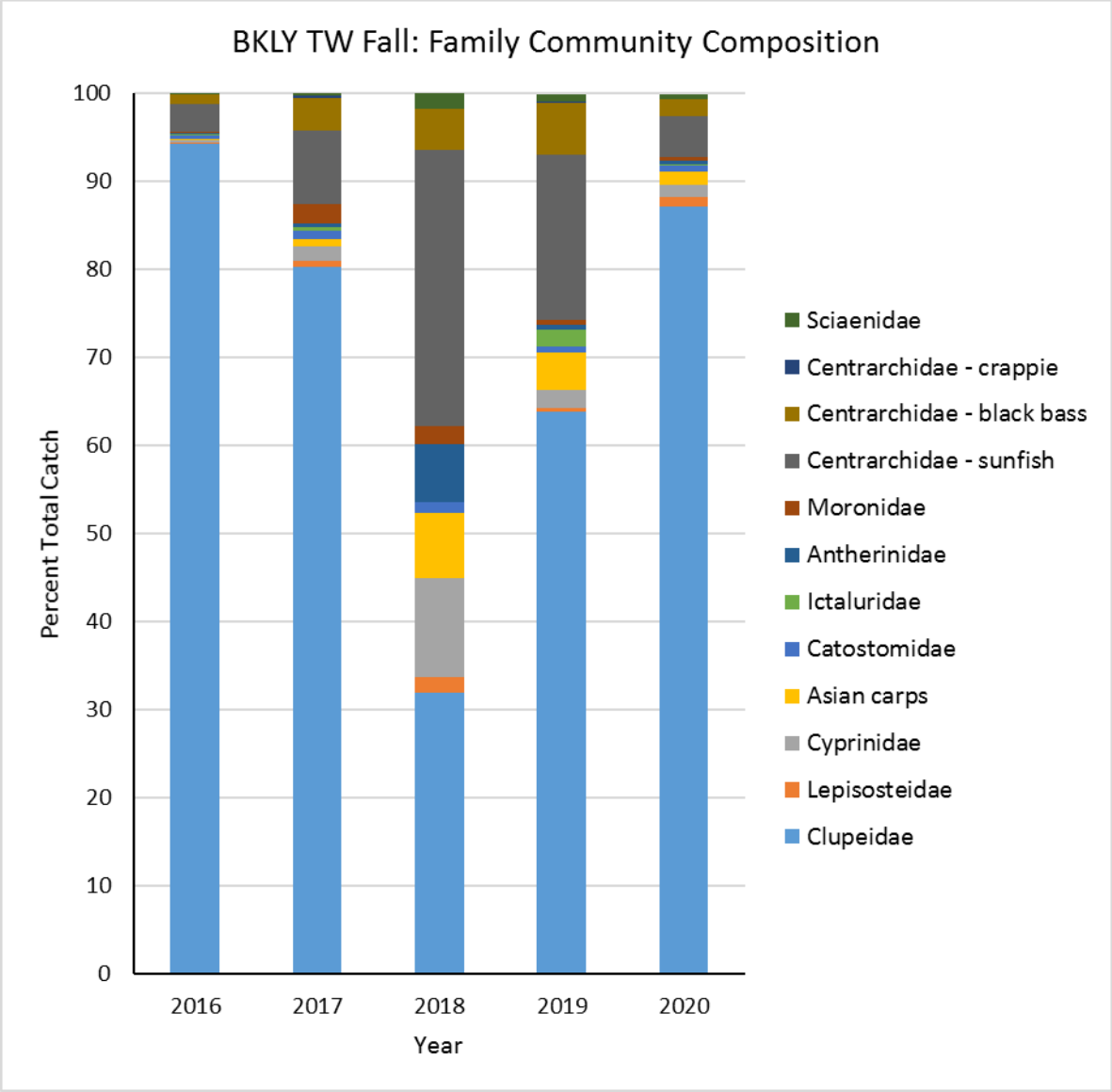

Figure 21. Comparison of percent total catch by number of each family identified from fall community sampling via electrofishing in the Barkley Tailwater 2016-2020.

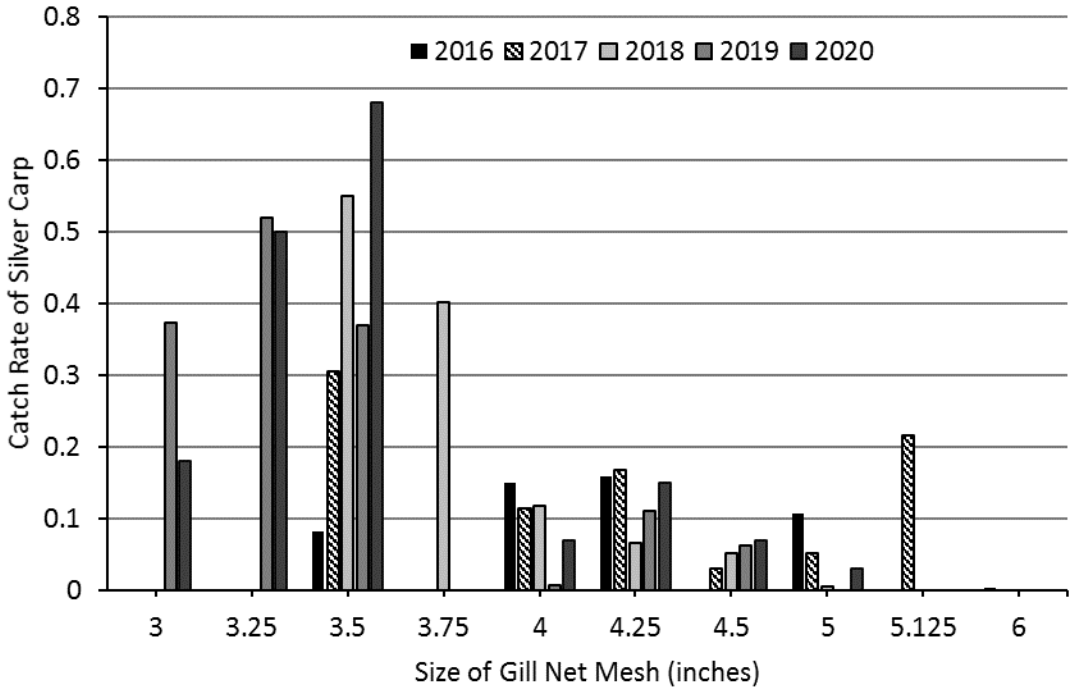

Figure 22. Catch rates (number of fish / yard of net) of silver carp by gill net mesh size during ride-alongs with commercial fishers fishing under the Asian Carp Harvest Program 2016-2020.

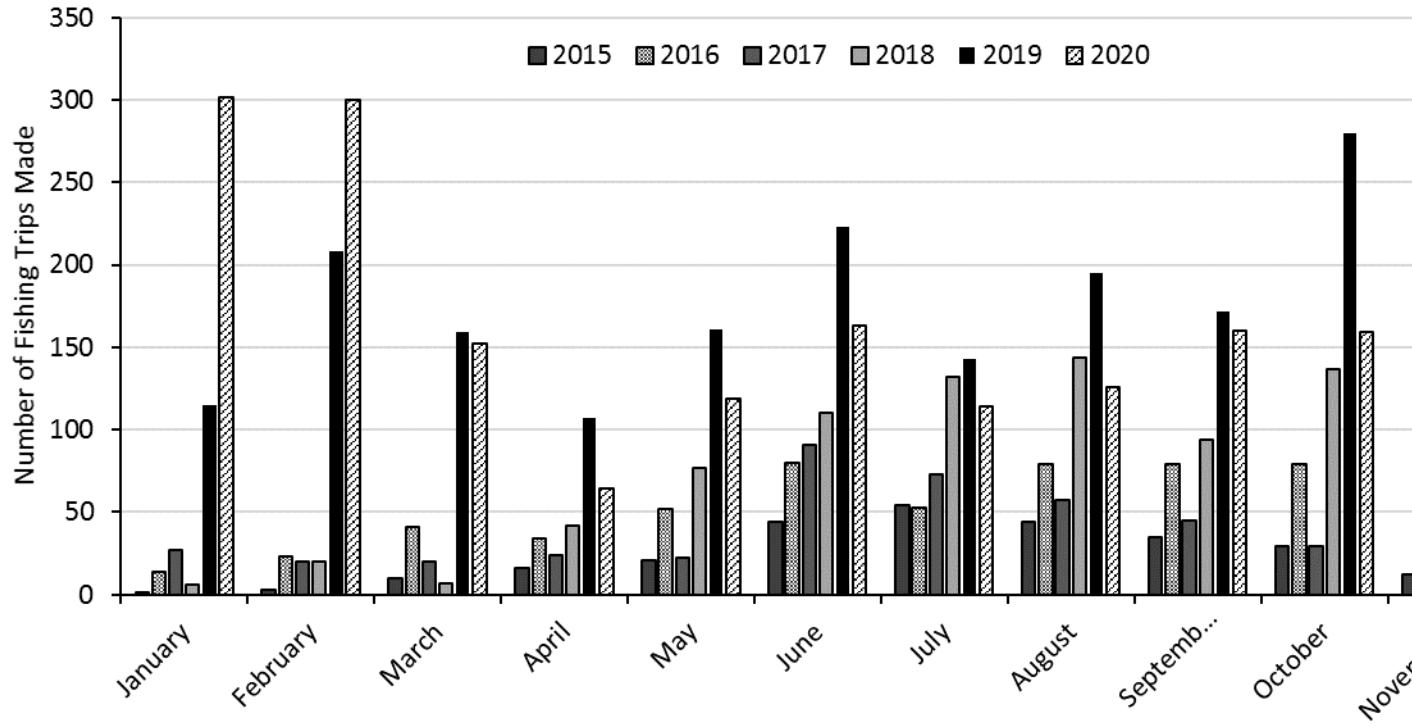

Figure 23. Number of fishing trips made monthly by commercial fishers fishing under the Asian Carp Harvest Program from January 2015 - December 2020.

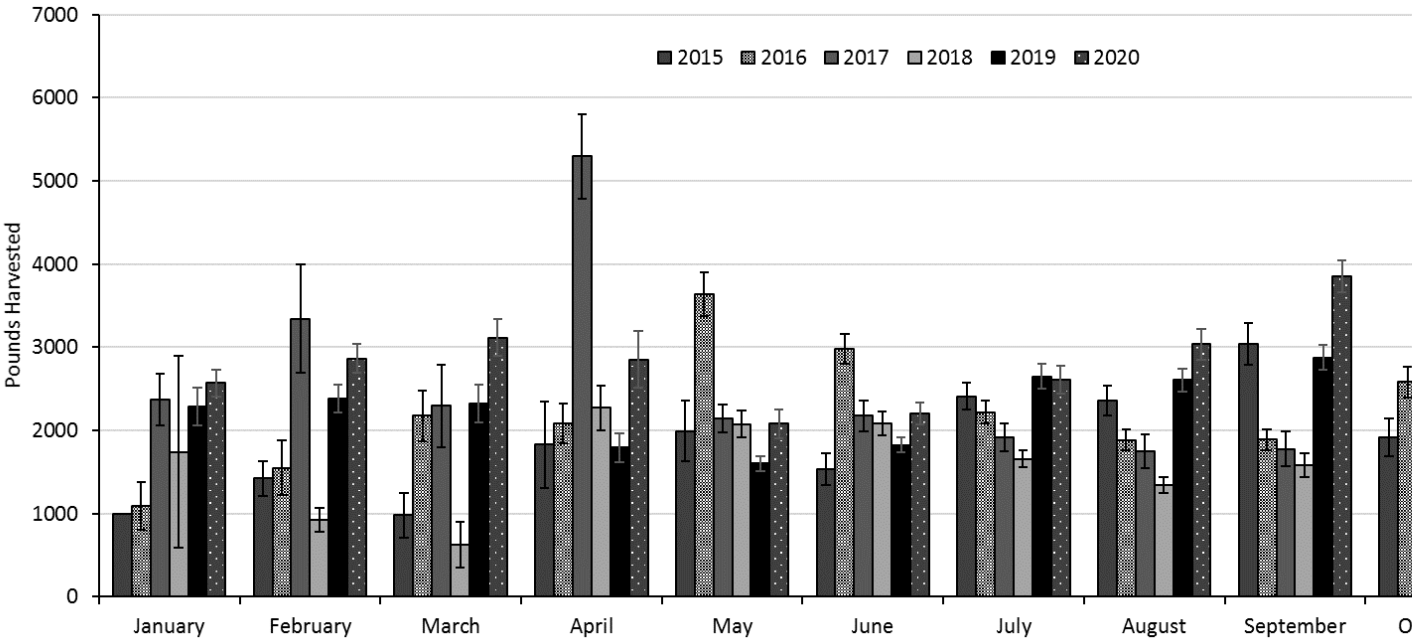

Figure 24. Monthly average total weight (lbs) of silver carp harvested per trip by commercial fishers fishing under the Asian Carp Harvest Program January 2015 - December 2020. Error bars represent standard error values.

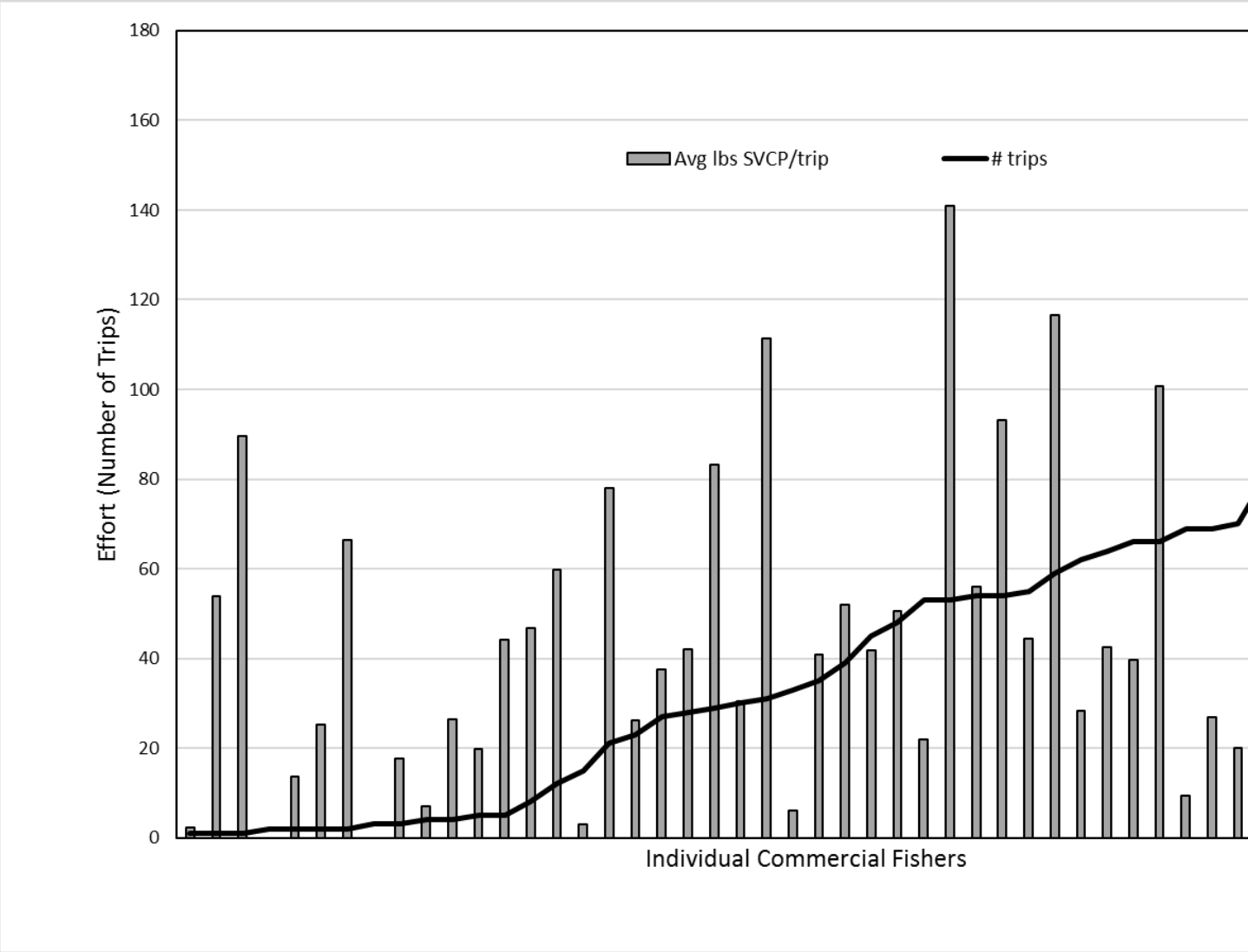

Figure 25. Average weight harvested per trip by individual commercial fishers compared to the number of trips taken by those fishers under the Asian Carp Harvest Program in 2020.

Table 1. The number of Asian carp collected during each standard sampling period by lake in 2018-2020.

2020								
	Lake Barkley				Kentucky Lake			
Species Captured	April	July	October	Total	April	July	October	Totals
Bighead carp	1	7	0	8	7	7	3	17
Grass carp	0	3	1	4	2	5	19	26
Silver carp	12	33	32	77	18	14	36	68
Totals	22	53	35	110	31	30	63	124

2019								
	Lake Barkley				Kentucky Lake			
Species Captured	April	July	October	Totals	April	July	October	Totals
Bighead carp	3	4	2	9	4	12	1	17
Grass carp	0	0	1	1	1	0	4	5
Silver carp	74	64	48	186	109	81	61	251
Totals	100	76	69	245	121	96	70	287

2018								
	Lake Barkley				Kentucky Lake			
Species Captured	April	July	October	Totals	April	July	October	Totals
Bighead carp		13	3	16		11	3	14
Grass carp		4	3	7		4	12	16
Silver carp		305	193	498		477	494	971
Totals		331	212	543		505	522	1027

Table 2. A summation of catch per unit effort (CPUE) for silver carp collected in Barkley and Kentucky lakes, by month and habitat type in 2020. CPUE reported in fish/linear yard of gill net.

			Bar mesh size			
	Site	Month	3"	4"	5"	Mean Total CPUE
Lake Barkley	Main Channel	April	0.004	0.004	0.000	0.003
		July	0.021	0.013	0.006	0.013
		October	0.005	0.013	0.000	0.006
	Embayment	April	0.002	0.011	0.002	0.005
		July	0.000	0.019	0.004	0.008
		October	0.009	0.034	0.004	0.016
			Bar mesh size			
	Site	Month	3"	4"	5"	Mean Total CPUE
Kentucky Lake	Main Channel	April	0.012	0.006	0.000	0.006
		July	0.006	0.002	0.000	0.003
		October	0.003	0.003	0.005	0.003
	Embayment	April	0.017	0.000	0.000	0.006
		July	0.015	0.004	0.000	0.006
		October	0.045	0.013	0.002	0.020

Table 3. A summation of estimated weights at three lengths for silver carp collected from Barkley and Kentucky lakes through all methods from 2018 through 2020.

Lake	Year	Predicted weight(g) at 450mm	Predicted weight(g) at 650mm	Predicted weight(g) at 800mm
Barkley	2018	933	2789	5176
	2019	1076	2881	5024
	2020	1121	2974	5160
Kentucky	2018	950	2733	4963
	2019	930	2720	4987
	2020	986	2788	5018

Table 4. Average length and weight of silver carp harvested during ride-alongs with commercial fishers under the Asian Carp Harvest Program 2015-2019.

Year	Number Sampled	Average total length (inches)	Average weight (lbs)	S. E.
2015	206	33.2	15.2	0.12
2016	448	34.5	17.7	0.10
2017	416	34.0	16.1	0.10
2018	387	31.0	11.6	0.10
2019	924	27.9	8.1	0.09
2020	595	28.0	8.5	0.11

Table 5. Measures of effort and catch reported by commercial fishers fishing under the Asian Carp Harvest Program by calendar year, January -December 2013 - 2020.

Water Body	Year	Number of Days/Trips	Number of fishers	Weight silver carp harvested (lbs)	Weight bighead carp harvested (lbs)	Number of grass carp harvested
Lake Barkley	2013	45	5	187,022		
	2014	61	6	464,003	1,360	
	2015	189	12	472,487	10,278	
	2016	447	22	1,112,585	5,693	
	2017	345	15	826,016	9,669	
	2018*	835	23	1,762,830	25,932	
	2019	1,846	60	5,318,535	45,665	
	2020***	1,431	43	4,700,149	28,714	61,487
Kentucky Lake	2013	21	4	26,400	491	
	2014	82	3	193,786	992	
	2015	59	6	84,190	17,791	
	2016	52	8	96,652	2,884	
	2017	54	8	71,487	11,754	
	2018*	116	8	143,996	11,537	
	2019	140	28	233,806	1,978	
	2020***	426	27	1,601,822	4,196	40,882
Ohio River	2013					
	2014	11	1	74,879		
	2015	16	3	26,864	1,206	
	2016	30	5	90,012	3,216	
	2017	8	4	11,217	713	
	2018	21	4	37,553	70	
	2019	129	9	142,520	521	
	2020***	151	13	137,754	7,402	6,402
Statewide**	2013	76	7	243,121	491	
	2014	160	9	765,768	2,802	
	2015	283	16	617,062	32,800	
	2016	565	24	1,343,464	12,666	
	2017	414	21	921,288	23,272	
	2018*	982	29	1,945,693	37,739	
	2019	2,250	66	5,802,624	50,366	
	2020***	2,052	48	6,471,718	43,931	111,190

*In 2018 KDFWR began allowing commercial fishermen to receive subsidy funds from the Asian Carp Harvest Program while fishing on their net permit, which allows them to harvest catfish and paddlefish. Commercial fishing effort from net permit holders that received subsidy funds is included in this table for 2018 and 2019.

**Effort and harvest occurs under the ACHP in other water bodies to a lesser degree and is included in the statewide totals.

***2020 was the first year that Grass carp harvest was reported seperately from common carp harvest through the ACHP.

Table 6. Number of bighead carp and silver carp captured by gill net mesh size as observed during KDFWR ride-alongs with commercial fishers fishing under the Asian Carp Harvest Program 2016 - 2020. (CPUE = catch per unit effort)

Year	Net Bar Mesh Size (inches)	Effort (yards)	Number of Silver carp	Silver carp CPUE (fish/yard)	Number of Bighead carp	Number of Grass carp
2016	3.5	1883	155	0.08		17
	4	2067	308	0.15		1
	4.25	9300	1469	0.16	8	12
	5	16983	1811	0.11	44	13
	6	1067	3	0.00		
2017	3.5	200	61	0.31	4	1
	4	1983	225	0.11	1	1
	4.25	23400	3918	0.17	19	31
	4.5	2283	68	0.03		
	5	4125	212	0.05	3	1
	5.125	400	86	0.22	4	2
2018	3.5	6883	3778	0.55	8	24
	3.75	167	67	0.40		
	4	3250	381	0.12	4	3
	4.25	14100	920	0.07	54	8
	4.5	2767	145	0.05	4	
	5	867	5	0.01	1	
2019	3	2967	1106	0.37	2	5
	3.25	9600	4979	0.52	10	83
	3.5	39300	14483	0.37	30	177
	4	300	2	0.01	0	0
	4.25	3700	406	0.11	18	3
	4.5	2567	162	0.06	5	1
	5	67	0	0.00	0	0
2020	3	100	18	0.18		
	3.25	3933	1968	0.5003814	2	17
	3.5	21692	14792	0.6819104	33	169
	4	533	38	0.0712946		
	4.25	2100	319	0.1519048	6	
	4.5	1583	104	0.065698	5	
	5	267	9	0.0337079	4	

Table 7. The number of fish captured by species and percent of total by-catch during standard sampling with gill nets from Lake Barkley in 2019 and 2020.

Species Captured	April(20)	July(20)	October(20)	Totals	Percent %
Bigmouth buffalo	0	1	0	1	0.6
Black buffalo	1	0	0	1	0.6
Black crappie	0	1	0	1	0.6
Blue catfish	10	23	6	39	23.6
Channel catfish	2	5	4	11	6.7
Flathead catfish	0	2	4	6	3.6
Freshwater drum	1	30	11	42	25.5
Gizzard shad	0	0	1	1	0.6
Largemouth bass	0	1	1	2	1.2
Paddlefish	1	0	0	1	0.6
Redear sunfish	0	0	2	2	1.2
River carpsucker	0	2	0	2	1.2
Sauger	1	0	0	1	0.6
Shortnose gar	0	1	1	2	1.2
Skipjack herring	0	4	15	19	11.5
Smallmouth buffalo	4	16	12	32	19.4
Stripped bass	0	0	1	1	0.6
Yellow bass	0	1	0	1	0.6
Totals	20	87	58	165	

Species Captured	April(19)	July(19)	October(19)	Totals	Percent %
Bigmouth buffalo	0	1	0	1	0.6
Blue catfish	15	12	16	43	27.6
Channel catfish	0	1	1	2	1.3
Flathead catfish	2	3	2	7	4.5
Freshwater drum	5	22	20	47	30.1
Lake sturgeon	2	0	0	2	1.3
Largemouth bass	0	0	1	1	0.6
Longnose gar	0	0	1	1	0.6
Paddlefish	3	6	0	9	5.8
Redear sunfish	0	0	1	1	0.6
River carpsucker	1	2	2	5	3.2
Shortnose gar	0	2	0	2	1.3
Skipjack herring	0	1	1	2	1.3
Smallmouth buffalo	4	14	13	31	19.9
Striped bass	1	0	0	1	0.6
Yellow bass	0	1	0	1	0.6
Totals	33	65	58	156	

Table 8. The number of fish captured by species and percent of total by-catch during standard sampling with gill nets from Kentucky Lake in 2019 and 2020.

Species Captured	April(20)	July(20)	October(20)	Totals	Percent %
Bigmouth buffalo	0	3	2	5	2.4
Blue catfish	11	8	14	33	15.6
Channel catfish	3	8	5	16	7.5
Flathead catfish	3	2	3	8	3.8
Freshwater drum	3	15	15	33	15.6
Largemouth bass	1	0	3	4	1.9
Longnose gar	6	1	2	9	4.2
River carpsucker	3	8	6	17	8.0
Sauger	2	2	1	5	2.4
Shortnose gar	0	1	0	1	0.5
Skipjack herring	1	0	8	9	4.2
Smallmouth buffalo	2	29	38	69	32.5
Striped bass	0	0	1	1	0.5
Yellow bass	0	0	1	1	0.5
Totals	35	78	99	212	

Species Captured	April(19)	July(19)	October(19)	Totals	Percent %
Bigmouth buffalo	0	2	1	3	1.2
Black Buffalo	0	2	0	2	0.8
Blue catfish	20	11	4	35	14.5
Channel catfish	2	1	2	5	2.1
Flathead catfish	5	1	5	11	4.6
Freshwater drum	6	46	16	68	28.2
Largemouth bass	3	0	2	5	2.1
Longnose gar	2	1	0	3	1.2
Paddlefish	0	1	0	1	0.4
River carpsucker	2	9	7	18	7.5
Shortnose gar	0	1	0	1	0.4
Skipjack herring	0	1	0	1	0.4
Smallmouth buffalo	2	33	50	85	35.3
Striped bass	2	0	0	2	0.8
White crappie	1	0	0	1	0.4
Totals	45	109	87	241	

Table 9. Relative weight (*W*r) values of gizzard shad collected with boat electrofishing from Barkley and Kentucky lakes in October 2017-2020.

Lake Barkley

		Length group								
		7.0-11.0 in			>11.0 in			Total		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
Gizzard shad	2020	43	94	0.7	4	91	2.3	47	93	0.7
	2019	60	94	1.1	9	93	2.3	69	94	1.0
	2018	30	90	1.1	1	99		31	90	1.1
	2017	110	83	0.7	0			110	83	0.7

Kentucky Lake

		Length group								
		7.0-11.0 in			>11.0 in			Total		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
Gizzard shad	2020	63	93	1.1	32	91	1.1	95	92	0.8
	2019	41	96	0.8	26	93	1.3	80	92	0.9
	2018	57	86	1.1	7	86	2.5	64	86	1.0
	2017	40	84	0.9	4	85	1.1	44	84	0.8

Table 10. Number and disposition of bycatch from commercial fishing efforts under the Asian Carp Harvest Program by calendar year, January - December. Survival rate is defined as fish that swam away upon being released from the net. Harvest of scaled rough fish is permitted under the Asian Carp Harvest Program.

Year	Sport Fish*		Scaled Rough Fish**		Catfish Species		Paddlefish		Total number of bycatch
	Number	Survival Rate %	Number Caught	% Harvested	Number	Survival Rate %***	Number	Survival Rate	
2013	29	100.0	7,132	93.7	100	97.0	305	90.5	7,566
2014	78	92.3	4,505	75.1	128	99.2	120	65.0	4,831
2015	97	89.7	7,462	80.5	719	95.0	980	65.0	9,258
2016	115	75.7	10,811	76.1	719	95.5	573	68.2	12,218
2017	25	92.0	9,565	91.8	541	95.7	314	75.5	10,445
2018	46	71.7	25,703	86.1	1201	98.3	200	85.5	27,150
2019	171	93.6	32,861	80.7	1512	98.7	296	80.7	34,841
2020	148	92.5	17,394	78.8	768	99.2	222	85.7	18,592

*Sport fish are defined in 301 KAR 1:060

**Scaled Rough fish are defined in 301 KAR 1:152

***In 2018 KDFWR began allowing commercial fishermen to receive subsidy funds from the Asian Carp Harvest Program while fishing on their net permit, which allows them to harvest catfish and paddlefish. Therefore, the survival rates for 2018 - 2020 only account for fish that were dead or alive upon release and not those that were harvested.

Table 11. Comparison for number of paddlefish, catfish, and sport fish caught per trip as reported by commercial fishers fishing under the Asian Carp Harvest Program versus observations made by KDFWR staff during ride-alongs in 2016-2020. (S.E. = standard error).

	2016				2017				2018				2019				2020			
Species	ACHP	S.E.	Ride-alongs	S.E.	ACHP	S.E.	Ride-alongs	S.E.	ACHP	S.E.	Ride-alongs	S.E.	ACHP	S.E.	Ride-alongs	S.E.	ACHP	S.E.	Ride-alongs	S.E.
Paddlefish	1.02	0.08	2.96	0.60	0.90	0.12	2.00	0.95	0.22	0.03	1.54	0.53	0.13	0.02	1.31	0.80	0.11	0.01	0.87	0.49
Blue catfish	0.74	0.06	1.21	0.28	0.63	0.08	1.52	0.33	0.47	0.04	1.75	0.37	0.08	0.01	2.00	0.45	0.19	0.01	1.07	0.34
Channel catfish	0.08	0.02	0.36	0.16	0.06	0.02	0.55	0.20	0.09	0.01	0.50	0.13	0.08	0.03	0.27	0.08	0.05	0.01	0.17	0.11
Flathead catfish	0.38	0.04	0.39	0.17	0.41	0.06	0.61	0.19	0.14	0.02	0.33	0.13	0.06	0.01	0.83	0.21	0.06	0.01	0.23	0.09
Catfish*	0.07	0.02			0.17	0.05			0.23	0.04			0.21	0.03			0.08	0.01		
Largemouth bass	0.08	0.70	0.04	0.04	0.01	<0.01	0.16	0.06	0.01	<0.01	0.08	0.06	0.02	0.01	0.52	0.24	0.02	<0.01		
Smallmouth bass	<0.01												<0.01	<0.01	0.08	0.05	0.02	<0.01	0.13	0.06
Spotted bass	<0.01		0.04	0.04													<0.01	<0.01		
Bass**	0.02	0.02			0.02	0.01			0.01	<0.01			0.02	0.01						
Hybrid striped bass	<0.01		0.07	0.05					<0.01	<0.01	0.04	0.04	<0.01	<0.01	0.10	0.05	<0.01	<0.01	0.07	0.07
Striped bass	0.12	0.03	0.68	0.37	0.02	<0.01	0.03	0.03	0.01	<0.01	0.08	0.06	0.01	0.01	0.10	0.05	0.01	<0.01	0.33	0.33
Yellow bass	0.04	0.02	0.71	0.45	<0.01	<0.01	0.03	0.03	0.01	<0.01	0.25	0.15	<0.01	<0.01	0.08	0.07	<0.01	<0.01		
White bass	<0.01		0.07	0.05									<0.01	<0.01	0.02	0.02	<0.01	<0.01		
Sauger	<0.01		0.04	0.04	<0.01	<0.01	0.06	0.04	<0.01	<0.01	0.13	0.70	<0.01	<0.01	0.08	0.07	0.01	<0.01	0.07	0.05
Crappie	0.01	0.01					0.03	0.03	0.01	0.01	0.29	0.21	<0.01	<0.01	0.06	0.05	<0.01	<0.01	0.03	0.03
Redear sunfish	0.01		0.04	0.04	<0.01	<0.01			<0.01	<0.01	0.04	0.04	<0.01	<0.01	0.13	0.07	<0.01	<0.01		

*Commercial fishers do not always delineate species of catfish on their reports, therefore this row accounts for those catfish that were not identified species

**Commercial fishers do not always delineate what species of black bass they catch, therefore this row accounts for black bass that were not identified to species

Table 12. Species composition, number of individuals captured, and survival rate of species observed in bycatch during KDFWR ride-alongs with commercial fishers fishing under the Asian Carp Harvest Program in 2016 - 2020. Survival rate of fish is defined as fish that swim away after release.

		2016		2017		2018		2019		2020	
	Species	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate
Sport Fish	White bass	1	<1%					1	100%		
	Yellow bass	20	50%	1	100%	6	33%	4	75%		
	Striped bass	19	79%	1	100%	3	33%	5	80%	10	80%
	Hybrid striped bass	2	100%			1	100%	5	80%	2	100%
	Sauger	1	<1%	2	100%	3	33%	4	75%	2	50%
	Spotted bass	1	100%								
	Largemouth bass	1	100%	5	80%	3	67%	25	80%	4	75%
	Smallmouth bass							4	100%		
	Redear sunfish	1	100%			2	50%	6	83%		
	Black crappie					5	50%	1	100%	1	100%
	White crappie			1	100%	6	67%	2	50%		
	Total	46	88%	10	96%	29	54%	57	82%	19	81%
Catfish species	Blue catfish	27	74%	47	94%	42	91%	96	95%	32	100%
	Channel catfish	10	80%	17	82%	12	100%	13	100%	5	100%
	Flathead catfish	9	89%	19	100%	8	88%	40	100%	7	100%
	Total	46	81%	83	92%	62	93%	149	98%	44	100%
	Paddlefish	83	48%	62	48%	38	32%	63	48%	26	50%
Rough Fish*	Lake sturgeon					1	100%				
	Shovelnose sturgeon									3	100%
	Skipjack herring	23	17%	47	13%	18	<1%	79	<1%	16	<1%
	Smallmouth buffalo	145	99%	13	85%	98	100%	186	98%	103	100%
	Bigmouth buffalo	8	100%	4	100%	7	100%	34	97%	14	100%
	Black buffalo	17	94%			2	100%	4	100%	1	100%
	Common carp	48	98%	33	94%	27	100%	479	84%	36	97%
	Gizzard shad	5	<1%	3	33%			3	<1%	1	100%
	Freshwater drum	76	67%	27	52%	73	71%	71	63%	40	82%
	River carpsucker	3	100%					35	97%	41	100%
	Quillback									1	100%
	Mooneye	3	<1%								
	Chestnut lamprey	1	<1%								
	Threadfin shad	1	<1%								
	Blue sucker	49	80%					2	100%		
	Spotted gar					2	50%	3	100%	1	100%
	Longnose gar	8	88%	9	44%			9	67%	3	100%
	Shortnose gar	9	44%	1	100%	2	50%	11	55%	5	100%
	Total	571	77%	365	72%	392	83%	1277	87%	329	98%

* Rough fish capture numbers only include fish that were released and does not include fish that were harvested.

Table 13. Number and survival rate of paddlefish captured by commercial fishers during KDFWR ride-alongs under the Asian Carp Harvest Program for each month paddlefish were observed caught in 2016 - 2020.

Year	Month	Number paddlefish captured	% released alive	Mean water temp (℉)	Mean soak time (hours)
2016	March	4	50.0%	54.4	
	April	15	66.7%	62.5	
	May	9	55.6%	69.4	
	June	44	45.5%	81.9	
	July	2	0.0%	81.5	
	August	1	100.0%	81.5	
	September	8	62.5%	80.5	
2017	April	6	0.0%	67.6	13.0
	May	15	33.3%	68.5	10.0
	June	35	60.0%	79.5	8.3
	September	2	50.0%	74	10.0
	December	4	75%	50	21.3
2018	April	4	75.0%	54.9	11.0
	May	9	60.0%	66.1	10.2
	June	12	35.0%	81.7	10.6
	August	12	0.0%	82.9	11.6
2019	February	43	60.5%	46.9	11.4
	March	1	0.0%	49.8	11
	April	3	33.3%	60.25	9.7
	May	7	14.3%	74	6.4
	June	4	0.0%	76.9	11.3
	August	2	0.0%	84.1	8.8
	October	3	66.7%	69.8	8.2
2020	March	9	88.8%	49.1	7.8
	May	5	20%	66.1	6.5
	September	11	36.36%	77	7.25
	October	1	100%	68.6	8.8

Table 14. Comparison of spring electrofishing CPUE values for all species captured in the Kentucky Lake tailwaters during sampling in 2015 (effort = 2.33 hours), 2016 (effort = 4.65 hours), 2017 (effort = 3.0 hours), 2018 (effort = 3.0 hours), and 2020 (effort = 1.25 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Kentucky Spring 2015		Kentucky Spring 2016		Kentucky Spring 2017		Kentucky Spring 2018		Kentucky Spring 2020	
	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.
Paddlefish			< 1	0.2						
Skipjack herring	1	0.4	< 1	0.2	1	0.5	1	0.7		
Gizzard shad	24	4.8	52	14.7	122	83.3	126	70.7	20	6.1
Threadfin shad			8	4.1	3	1.6	2	1.7		
Grass carp	< 1	0.3	3	1.1	1	1.0	2	1.2		
Silver carp	1	0.3	6	2.3	38	17.2	3	1.6	3	1.5
Smallmouth buffalo	3	1.0	27	6.1	13	3.3	19	4.6	38	10.5
Bigmouth buffalo	2	1.0	1	0.3	4	1.6	3	1.6		
Black buffalo			2	1.1	1	0.5				
Blue catfish			< 1	0.3						
Channel catfish	< 1	0.2	1	0.7	< 1	0.3	< 1	0.3		
Flathead catfish			19	5.5	4	1.3	6	2.4	14	3.7
White bass	1	0.6	8	2.1	1	0.8	2	1.4		
Yellow bass	1	0.5	31	12.3	3	1.3	5	5.0		
Striped bass									1	0.8
Green sunfish			4	1.5	2	1.3	1	0.5		
Orangespotted sunfish			< 1	0.2	3	1.7	< 1	0.3		
Bluegill	2	0.7	92	16.3	30	5.6	14	3.2	29	8.9
Longear sunfish	3	1.8	74	15.2	25	6.9	15	3.9	22	9.9
Redear sunfish	1	0.3	3	1.1	2	1.2	1	0.5	3	1.5
Smallmouth bass	1	0.8	10	2.5	13	3.2	6	2.6	2	1.6
Spotted bass	< 1	0.3	1	0.5	11	4.2	1	0.5		
Largemouth bass	5	1.6	46	5.2	76	7.9	46	9.2	14	3.3
White crappie			1	0.9	< 1	0.3			3	3.2
Black crappie	< 1	0.1	1	0.3	1	0.5			1	0.8
Sauger			1	0.6			1	0.5		
Freshwater drum	< 1	0.1	14	3.4	2	0.9	9	2.9	4	1.3
White bass/Striped bass hybrid			2	0.8			2	2.3		

Table 15. Comparison of spring electrofishing CPUE values for all species captured in the Lake Barkley tailwaters during sampling in 2016 (effort = 2.75 hours), 2017 (effort = 0.92 hours), 2018 (effort = 2.0 hours), and 2020 (effort = 1.0 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Barkley Spring 2016		Barkley Spring 2017		Barkley Spring 2018		Barkley Spring 2020	
	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.
Skipjack herring			4	1.6	2	1.5	1	1.0
Gizzard shad	19	8.1	18	14.1	24.5	18.4	15	1.0
Threadfin shad	6	5.0					1	1.0
Grass carp	7	2.9	1	1.0	0.5	0.5		
Silver carp	24	9.8	10	2.6	42	28.4	13	7.2
Smallmouth buffa	23	3.6	22	3.5	28	6.7	11	3.4
Bigmouth buffalo	1	0.6	2	1.2	1	1.0		
Black buffalo	1	0.8			0.5	0.5		
Channel catfish	1	0.8			0.5	0.5		
Flathead catfish	16	5.5	6	2.6	25	5.4	26	7.8
White bass	8	3.6	6	3.5	7.5	4.2	4	2.8
Yellow bass	2	1.0	4	4.0	2	1.1	2	1.2
Striped bass	1	1.1						
Green sunfish	1	0.8	2	1.2	2	1.1	4	2.8
Bluegill	69	16.1	55	26.9	56.5	31.2	64	15.9
Longear sunfish	110	23.6	183	83.6	80.5	42.4	70	18.5
Redear sunfish	10	2.6	20	5.9	7	2.0	14	6.6
Smallmouth bass	10	2.7	3	3.0	10.5	2.3	10	4.2
Spotted bass	1	0.6					3	1.9
Largemouth bass	64	6.2	155	35.3	79	10.6	35	5.3
White crappie	< 1	0.4						
Black crappie	1	0.7						
Sauger	< 1	0.4						
Freshwater drum	15	3.4	2	2.0	11.5	4.3	41	17.6

Table 16. Length frequency and CPUE (fish/hr) for select species of fish collected during 2.75 hours of electrofishing at Kentucky Tailwater in fall of 2020. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																										TOTAL	CPUE (fish/hr)	S. E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	27	28 - 33			
Skipjack herring*		32	74	31	21	2																						246	89	22.3
Gizzard shad*		6	61	1	1	6	27	13	7	11	5	2	1															449	163	69.7
Threadfin shad*		57	105	3																								1957	712	241.1
Grass carp																	3	6	2	3				1	1	1	5	22	8	4.7
Silver carp																	3	4	1	2	3	2	4	5		1	1	26	9	4.9
Smallmouth buffalo														1		2	1					2						6	2	0.8
Black buffalo																			1									1	0	0.4
Flathead catfish									1																			1	0	0.4
White bass			1	2	1	2	2	1	1		1			2														13	5	2.5
Yellow bass			2		4			1																				7	3	1.6
Bluegill*	2	28		9	21	9	2																					71	26	5.9
Longear sunfish		4	5	8	10																							27	10	3.9
Redear sunfish			1	1	1	1	1																					5	2	1.1
Smallmouth bass		1	2	3	9	6	2	1		1	1						1											27	10	2.8
Largemouth bass			1	2	2	3	7	7	5	2	2	3	3		1	3												41	15	3.6
Freshwater drum				1	3	2							1	3	3	2	2		3	3	2	1	1	1	1	1		30	11	2.8
Striped mullet																		1	1	1			1					4	1	1.0

* species were randomly subsampled

Table 17. Comparison of fall electrofishing CPUE for selected species collected at Kentucky Tailwater in 2015 (effort = 1.0 hours), 2016 (effort = 1.75 hours), 2017 (effort = 4.5 hours), 2018 (effort = 1.25 hours), 2019 (effort = 3.75 hours), and 2020 (effort = 2.75 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	2015		2016		2017		2018		2019		2020	
	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.
Skipjack herring	22	8.4	1	0.6	18	9.5	2	1.6	510	200.3	89	22.3
Gizzard shad	275	58.6	184	78.0	163	61.1	22	10.2	240	92.1	163	69.7
Threadfin shad	251	176.3	1690	1251.0	1263	637.0	2557	1845.1	27	14.9	712	241.1
Grass carp	13	1.9	6	2.5	2	0.7			6	2.8	8	4.7
Silver carp	6	2.6	44	22.4	4	1.6	9	6.9	4	2.0	9	4.9
Smallmouth buffalo	10	2.6	9	3.7	5	2.1	1	0.8	8	3.0	2	0.8
Bigmouth buffalo					1	0.4	2	1.0				
Black buffalo	6	2.0	3	1.9	< 1	0.2			1	0.4	< 1	0.4
Blue catfish					< 1	0.2			< 1	0.3		
Channel catfish			1	0.6	1	0.9			< 1	0.3		
Flathead catfish			4	1.2	4	1.4			3	1.4	< 1	0.4
White bass	8	4.3	7	4.0	< 1	0.3	6	5.6	4	1.9	5	2.5
Yellow bass	162	83.5	17	13.3	26	4.1	7	4.3	18	7.8	3	1.6
Striped bass					2	1.0	2	1.0				
Bluegill	96	29.2	41	11.8	128	30.7	20	4.0	127	48.8	26	5.9
Longear sunfish	14	14.0	48	12.0	80	25.0	7	4.8	67	15.4	10	3.9
Redear sunfish	1	1.0	6	2.3	6	1.6			15	3.9	2	1.1
Smallmouth bass	9	2.5	21	5.2	11	3.2	2	1.0	29	12.3	10	2.8
Spotted bass	1	1.0	1	0.6	3	1.4	1	0.8	3	1.4		
Largemouth bass	62	19.8	86	9.4	35	4.3	7	2.9	29	6.2	15	3.6
White crappie	2	2.0	1	0.7	1	0.4			3	1.9		
Black crappie	2	2.0	1	0.6	3	1.7			2	1.5		
Sauger	1	1.0			1	0.4						
Freshwater drum	13	5.7	6	1.5	4	0.7	4	2.2	8	2.5	11	2.8
White bass/Striped bass hybric	1	1.0	1	1.1	1	0.5						
Striped mullet											1	1.0

Table 18. Comparison of fall electrofishing CPUE for selected species collected at Barkley Tailwater in 2016 (effort = 1.99 hours), 2017 (effort = 3.0 hours), 2018 (effort = 1.0 hour), 2019 (effort = 3.0 hours), and 2020 (effort = 2.75 hours). (CPUE=catch per unit effort;

Species	2016		2017		2018		2019		2020	
	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.
Skipjack herring	< 1	0.5	8	2.9	35	18.0	324	158.4	41	10.78
Gizzard shad	209	52.4	104	18.2	23	8.1	362	224.8	189	49.03
Threadfin shad	4598	1818.7	1252	602.1	67	12.8	30	18.8	1298	719.49
Grass carp	5	2.6	1	0.5			6	1.7	3	1.22
Silver carp	4	2.0	14	7.7	29	17.2	42	33.4	23	6.58
Smallmouth buffalo	15	7.6	10	2.7	1	1.0	5	3.2	10	3.75
Bigmouth buffalo	1	0.9	< 1	0.3	1	1.0				
Black buffalo			1	0.7						
Channel catfish	< 1	0.4	1	0.5					1	0.49
Flathead catfish	8	3.6	6	3.1			22	5.9	4	1.57
White bass	7	3.9	3	1.1	3	3.0	1	0.7	1	0.56
Yellow bass	2	0.7	28	16.0			4	3.0	3	1.24
Striped bass	1	0.9	2	1.4	1	1.0	< 1	0.3	2	1.25
Bluegill	46	15.3	56	14.6	70	14.5	50	13.2	37	11.66
Longear sunfish	102	25.0	83	16.8	46	25.4	153	30.5	41	10.06
Redear sunfish	8	2.1	3	1.2	2	1.2	3	1.2	2	0.83
Smallmouth bass	7	2.3	9	1.2	4	1.6	29	7.2	8	1.53
Spotted bass	2	1.0	< 1	0.3	1	1.0	7	2.0	1	1.09
Largemouth bass	48	8.0	55	10.3	13	5.0	30	8.1	26	11.01
White crappie	4	1.5	1	0.7			< 1	0.3	< 1	0.36
Black crappie			2	1.3			< 1	0.3	< 1	0.36
Freshwater drum			5	1.5	7	4.7	9	3.4	8	1.87
White bass / Striped bass	< 1	0.4	3	2.3	4	4.0			1	0.73

Table 19. Length frequency and CPUE (fish/hr) for select species of fish collected during 2.75 hours of electrofishing at Barkley Tailwater in fall of 2020. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																											TOTAL	CPUE (fish/hr)	S. E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28 - 30			
Skipjack herring*		15	63	19	3	5	1	1																					114	41	10.8
Gizzard shad*		2	60	6	4	14	29	22	13	5	4			1	1														519	189	49.0
Threadfin shad*	2	34	123	1																									3569	1298	719.5
Grass carp																		1	2	3	1							1	8	3	1.2
Silver carp																		1		1			7	9	12	14	8	12	64	23	6.6
Smallmouth buffalo					1										1	3	4	6	10	1		1							27	10	3.8
Channel catfish																	1							1					2	1	0.5
Flathead catfish						1		1	2	1	1		2	1														1	10	4	1.6
White bass					1							1	1																3	1	0.6
Yellow bass					3	3	1																						7	3	1.2
Striped bass															1		1						1			1		1	5	2	1.3
Bluegill*		8	40	16	18	6	1																						102	37	11.7
Longear sunfish*		6	11	50	40																								113	41	10.1
Redear sunfish	1			1	1					2																			5	2	0.8
Smallmouth bass				2	6	3		4	5		1								1										22	8	1.5
Spotted bass					1				1					1															3	1	1.1
Largemouth bass				1	6	13	10	7	8	3	3	4	3	1	1	7	2		2										71	26	11.0
White crappie									1																				1	0	0.4
Black crappie									1																				1	0	0.4
Freshwater drum													4	2	2	1		7	1	4	1								22	8	1.9
White bass/Striped bass hybrid																					1	1							2	1	0.7

* species were randomly subsampled

Table 20. Mean relative weight (*Wr*) and standard error for a subsample of fish collected during fall electrofishing at Kentucky Tailwaters in 2015 - 2020. (S.E. = standard error)

Species	2015			2016			2017			2018			2019			2020		
	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.
Gizzard shad	19	76	2.5	45	72	1.6	215	83	0.7	21	77	2.0	152	85	0.5	66	85	1.6
Blue catfish							1	108					1	99				
Channel catfish				1	102		1	105					1	100				
Flathead catfish				7	98	6.2	19	100	6.3				11	99	6.2	1	106	
Yellow bass	29	74	1.2	29	84	1.8	104	83	2.2	7	90	12.3	33	80	4.6	4	58	11.4
White bass	7	92	4.1	13	99	2.6	2	97	20.4	7	108	1.3	8	90	3.3	9	95	5.1
Striped bass										1	101							
White bass/Striped bass hybrid				2	81	7.5												
Bluegill	69	88	1.7	49	103	3.7	220	93	2.2	18	89	6.4	148	94	0.8	41	93	8.3
Redear sunfish	1	98	0.0	10	85	6.9	28	93	3.3				42	97	2.3	4	85	5.3
Smallmouth bass	6	93	3.1	13	91	2.0	9	92	3.4	1	82		4	92	5.5	6	100	4.9
Spotted bass	1	103	0.0	1	123		6	109	3.1				1	117				
Largemouth bass	42	102	3.2	89	102	1.7	117	97	1.9	7	93	5.5	41	99	1.7	26	113	8.4
White crappie	2	79	0.9	2	90	8.7	3	76	7.3				4	84	3.0			
Black crappie	1	91	0.0				12	90	2.7									
Sauger	1	87	0.0				3	97	21.8									
Freshwater drum	12	91	5.4	11	100	2.7	17	92	3.3	5	89	3.8	21	92	2.9	29	91	3.3
Smallmouth buffalo	10	76	2.9	15	79	1.5	22	77	1.4	1	78		29	100	3.2	6	81	2.7
Bigmouth buffalo							3	86	1	2	75	7.4						
Silver carp	6	84	2.3	75	89	1.6	19	82	2.4	11	73	3.2	15	81	1.2	26	76	1.7

Table 21. Mean relative weight (*Wr*) and standard error for a subsample of fish collected during fall electrofishing at Barkley Tailwaters in 2016 - 2020. (S.E. = standard error)

Species	2016			2017			2018			2019			2020		
	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.
Gizzard shad	96	70	1.6	176	80	0.9	18	75	2.5	45	91	1.2	53	96	4.2
Channel catfish	1	67		2	92	1.0							2	111	5.6
Flathead catfish	13	94	1.7	17	106	5.8				66	99	3.8	10	96	3.4
Yellow bass	2	88	8.7	73	79	1.3				11	87	4.5	7	85	4.5
White bass	11	96	3.7	8	86	2.2	3	98	4.9	3	85	7.7	2	115	1.8
Striped Bass				2	90	5.9				1	109		5	108	5.6
White bass/Striped bass hybrid				9	89	2.7	4	103	4.6				2	102	2.8
Bluegill	49	111	3.1	107	104	2.5	31	115	8.3	85	103	1.6	63	102	2.3
Redear sunfish	17	93	2.1	9	97	3.7	2	106	14.6	9	101	3.9	4	101	13.0
Smallmouth bass	4	86	3.6	11	95	3.8	3	87	5.6	22	92	2.5	11	93	2.5
Spotted bass	3	107	11.0				1	125		3	106	10.1	2	103	9.4
Largemouth bass	37	101	1.9	118	95	1.2	10	95	3.4	58	98	1.6	41	101	4.3
White crappie				3	88	6.6				1	92		1	116	
Black crappie				5	86	6.3				1	76		1	85	
Freshwater drum	6	84	4.4	14	97	3.0	7	82	3.5	27	103	2.3	22	96	2.3
Smallmouth buffalo	21	84	1.4	28	84	1.6	1	99		16	92	1.9	27	81	1.4
Bigmouth buffalo	2	88	4.0	1	79		1	84							
Silver carp	9	81	2.9	41	83	2.1	29	83	2.7	70	83	1.5	64	77	1.2

Table 22. Fishing effort and total weight (lbs) of Asian carp harvested during KDFWR ride-alongs with commercial fishers fishing under the Asian Carp Harvest Program on Lake Barkley 2015 - 2020. (S.E. = standard error)

Year	Effort *	Mean effort per trip	S. E.	Number of ride alongs	Number of fishers	Total WT of bighead carp harvested (lbs)	Mean total WT of bighead carp harvested/trip (lbs)	S. E.	Total WT of silver carp harvested (lbs)	Mean total WT of silver carp harvested/trip (lbs)	S. E.
2015	17850	1116	50.5	16	5	1608	101	43.1	35130	2196	256.6
2016	25135	1143	70.4	22	4	704	32	13.7	61533	2797	481.8
2017	30491	1089	90.1	28	8	558	20	6.3	69459	2481	421.3
2018	23260	1108	81.7	21	10	362	17	7.8	49248	2345	477.1
2019	52367	1247	251.8	42	19	838	20	6.7	142102	3383	498.0
2020	23775	990	57.6	24	13	682	28	10.9	122271	5094	796.2

*effort is calculated in yards of gillnet fished.

Table 23. Comparison of the average weight harvested per trip of silver carp and bighead carp during KDFWR ride-alongs, and through commercial fishers reports for the Asian Carp Harvest Program in 2016 - 2020. (S.E. = standard error)

		Silver Carp	S. E.	Bighead Carp	S. E.	Grass Carp	S. E.
2016	Ride Alongs	2,280	402.2	40	12.4	23	10.1
	Commercial Fisher Reports	2,378	70.5	22	3.3		
2017	Ride Alongs	2,386	395.0	25	8.2	24	9.4
	Commercial Fisher Reports	2,225	92.8	56	7.6		
2018	Ride Alongs	2,219	422.6	16	6.9	18.4	8.8
	Commercial Fisher Reports	1,981	54.2	38	4.0		
2019	Ride Alongs	3,353	475.7	23	7.2	60	19.3
	Commercial Fisher Reports	2,580	53.0	22	1.6		
2020*	Ride Alongs	4,775	677.5	41	14.8	46	15.5
	Commercial Fisher Reports	3,186	62.4	22	1.8	55	3.0

*2020 was the first year that Grass Carp harvest through the Asian Carp Harvest Program was recorded.

Table 24. Summary of Asian carp harvest and expenditures of Subsidy funds under the Asian Carp Harvest Program 2016-2020.

Year	Total funds paid out
2016	$4,706.06
2017	$9,596.05
2018	$36,136.98
2019	$210,163.21
2020	$453,925.56

Appendix C. MDWFP Tables and Figures

Table 1. Fish collections at Bay Springs Lake and the Yellow Creek Arm of Pickwick Lake, February-December, 2020. Fish were collected with 300-ft experimental gillnets.

Time period	Location	Nets fished	Species (number collected)
02/07/2020	Pickwick	3	Blue Catfish (29), Channel Catfish (8), Common Carp (3), Largemouth Bass (1), Skipjack Herring (3), Spotted Gar (1)
02/08/2020	Bay Springs	4	Blue Catfish (3), Largemouth Bass (1), **Silver Carp** (1), Skipjack Herring (1), White Bass (1), White Crappie (1)
04/29/2020	Bay Springs	6	Blue Catfish (5), Common carp (4), Flathead Catfish (9), Largemouth Bass (5), Longnose Gar (8), Smallmouth Buffalo (1)
04/30/2020	Pickwick	3	Blue Catfish (4), Skipjack Herring (2), Smallmouth Buffalo (1)
05/27/2020	Bay Springs	4	Blue Catfish (7), Common Carp (18), Flathead Catfish (3), Freshwater Drum (10), Largemouth Bass (2), Skipjack Herring (1), Smallmouth Buffalo (2), Spotted Gar (1)
07/22/2020	Pickwick	3	Blue Catfish (1), Common Carp (4), Flathead Catfish (1), Freshwater Drum (4), Skipjack Herring (1), Smallmouth Buffalo (3)
07/23/2020	Bay Springs	4	Blue Catfish (3), Common Carp (6), Flathead Catfish (4), Freshwater Drum (3), Skipjack Herring (1), Spotted Gar (5)
09/30/2020	Bay Springs	5	Blue Catfish (8), Common carp (23), Flathead Catfish (6), Skipjack Herring (1), Smallmouth Buffalo (2)
12/07/2020	Bay Springs	7	Minimal bycatch mainly consisting of Blue Catfish, Flathead Catfish and Common Carp.
12/09/2020	Pickwick	3	Minimal bycatch mainly consisting of Blue Catfish, Flathead Catfish and Common Carp.

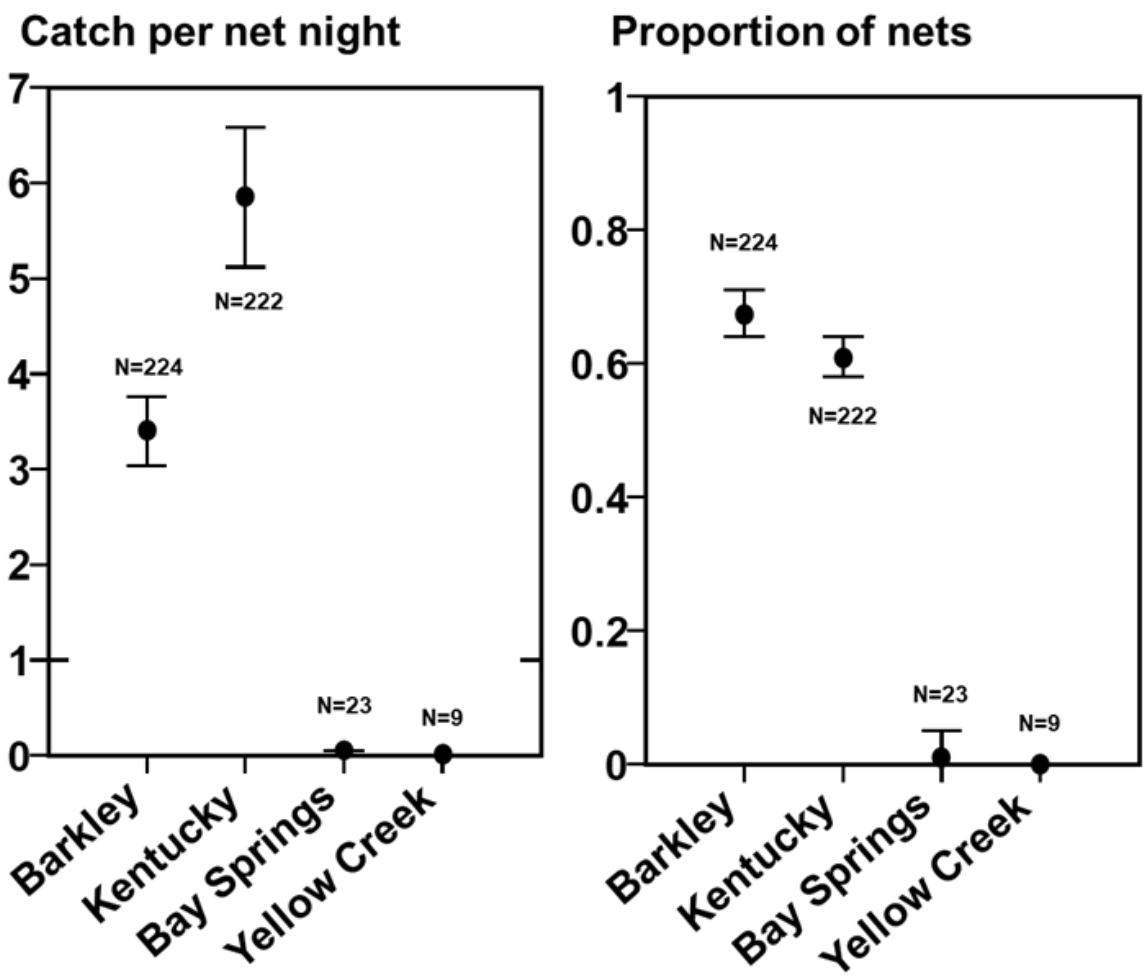

Figure 1. Catch of bigheaded carps in standard 300-ft gillnets fished at Barkley, Kentucky, Bay Springs, and Yellow Creek Arm of Pickwick lakes. Estimates are given in terms of catch per net night and fraction of nets fished that collected bigheaded carps. Whiskers represent 1 SE and N the number of nets fished. Data for Barkley and Kentucky lakes was provided by the Kentucky Department of Fish and Wildlife.

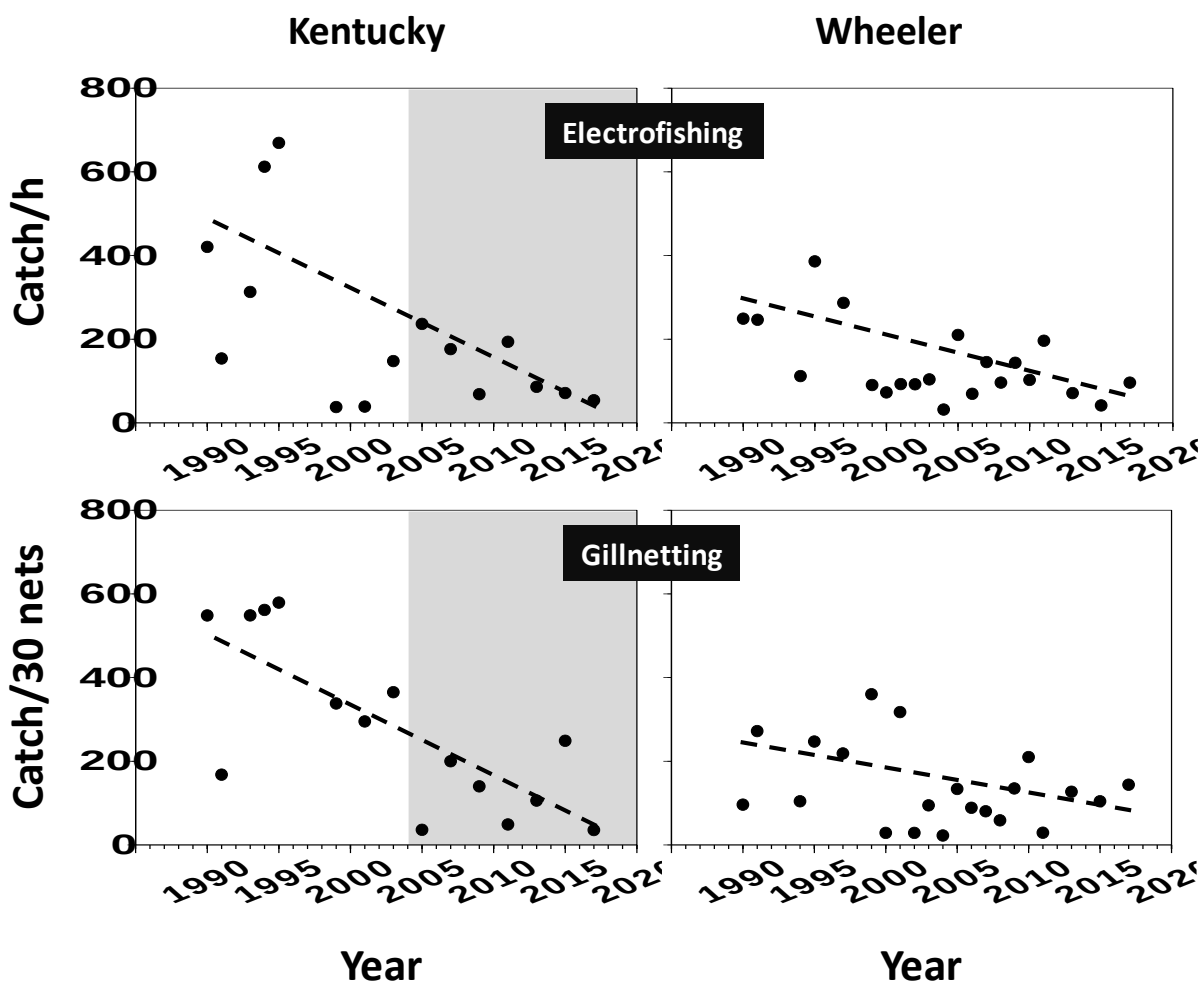

Figure 2. Catch of gizzard shad by electrofishing and experimental gillnets in Kentucky and Wheeler lakes, 1990-2017. Bigheaded carps were first detected in Kentucky Lake in 2004 (shaded area) but had not been detected in Wheeler Lake as of 2017. Gizzard shad density declined during the study period, but the decline began before bigheaded carps invaded the Tennessee River and there was no change in the slope of the decline after invasion, suggesting no effect by bigheaded carps on gizzard shad populations. Data provided by TVA.

Appendix D. TWRA Tables and Figures

Table 1. Summary of effort, silver carp catch, and silver carp size characteristics from standard Asian carp gill netting on Tennessee and Cumberland River reservoirs in 2019 and 2020. (SE = Standard Error; SD = Standard Deviation)

	2019					
	Kentucky Reservoir			Barkley Reservoir		
Month	May	July	Nov	May	July	Nov
Net Sets	24	24	24	12	8	8
Silver carp captured	96	124	17	12	20	15
Silver carp/net (SE)	4.00 (0.89)	5.17 (1.23)	0.71 (0.24)	1.00 (0.46)	2.50 (0.89)	1.88 (0.69)
Mean TL (SD)	610 (±59)	683 (±97)	663 (±99)	716 (±44)	769 (±86)	727 (±61)
Length Range	522 - 934	567 - 992	566 - 894	641 - 781	638 - 879	641 - 834

	2020						
	Kentucky Reservoir		Barkley Reservoir		Pickwick Reservoir		Cheatham
Month	July	Nov	July	Nov	July	Nov	July-Sept
Net Sets	24	24	12	12	4	4	12
Silver carp captured	40	19	15	24	7	4	18
Silver carp/net (SE)	1.67 (0.42)	0.79 (0.26)	1.25 (0.41)	2.00 (0.51)	1.75 (0.75)	1.00 (0.71)	1.50 (0.68)
Mean TL (SD)	711 (±79)	691 (±79)	753 (±75)	770 (±89)	894 (±66)	871 (±56)	838 (±67)
Length Range	595-923	528-904	652-912	480-920	837-1014	816-927	761-1013

Table 2. Summary of effort, silver carp catch, and silver carp size characteristics from summer 2020 Asian carp electrofishing on Tennessee and Cumberland River reservoirs. Electrofishing took place for 15 minutes/site. (SE = Standard Error; SD = Standard Deviation)

	Kentucky	Barkley	Pickwick	Cheatham
Sites	24	12	6	12
Silver carp captured	100	56	4	13
Silver carp/min (SE)	0.28 (0.07)	0.47 (0.15)	0.04 (0.03)	0.07 (0.05)
Mean TL (SD)	699 (±57)	712 (±38)	842 (±51)	796 (±77)
Length Range	561-920	629-830	770-890	704-1000

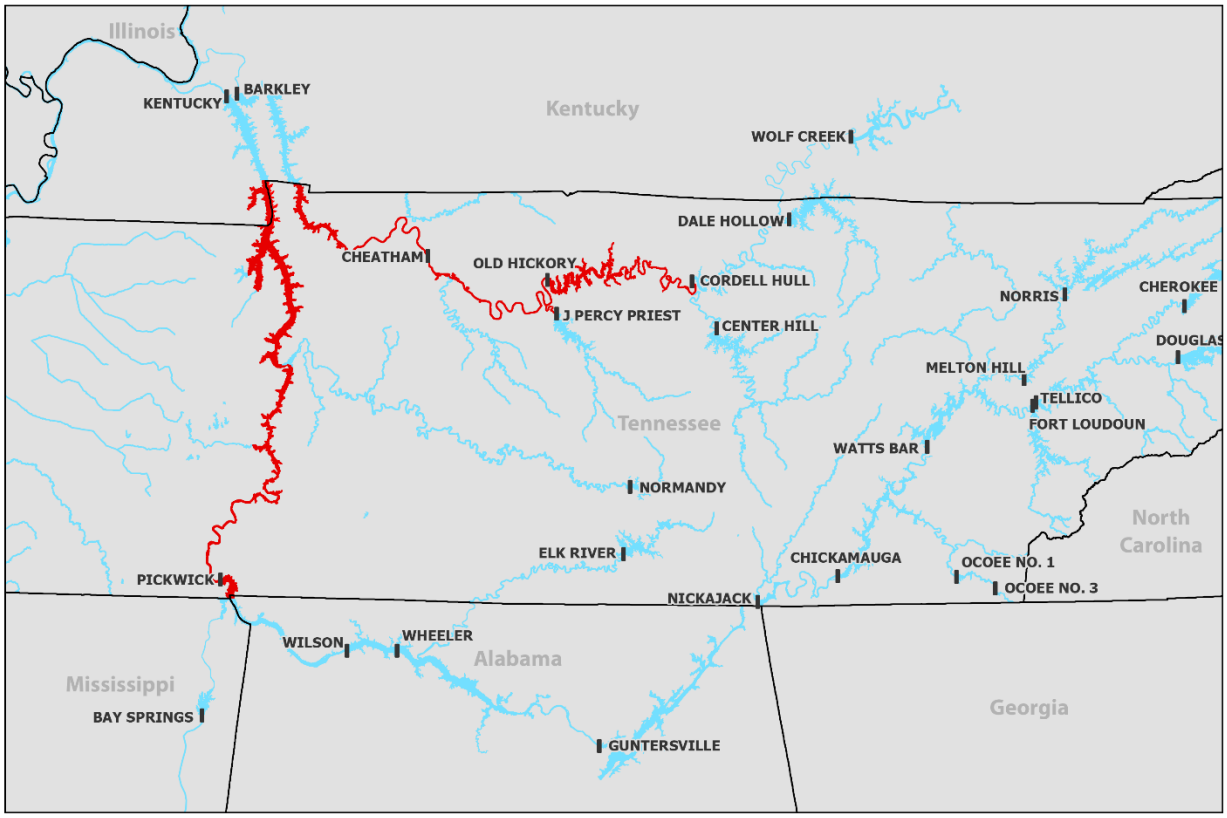

Figure 1. Map highlighting project area (red) for TWRA Asian carp activities in Tennessee and Cumberland River reservoirs.