Project Title: Evaluation and Removal of Invasive Carp in the Tennessee and Cumberland Basins

Geographic Location: Tennessee and Cumberland rivers and reservoirs

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

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

Statement of Need:
As of 2019, all four species of invasive carp have been collected in the Tennessee and Cumberland rivers (TNCR). The states of Kentucky, Tennessee, Mississippi, and Alabama have significant recreational and ecological resources at risk due to invasive carp. This project is needed to help implement 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). The project objectives and activities below consist of important steps to monitor, control, and better understand the impacts of invasive carp in the TNCR, all of which are identified goals of the sub-basin management plan. As individual TNCR states have initiated their carp programs, agencies have recognized the need to align sampling methods to collectively address invasive carp on a basin-wide scale. Partners in the TNCR are committed to identifying and reconciling differences in methodology to meet the broader goals of a basin-wide framework.

This project further develops standardized protocols to assess abundance and population dynamics of invasive carp and determine effectiveness of control measures. TWRA and KDFWR have invested in commercial carp removal programs, and the USFWS has funded 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 and over time. Foundational research on carp sampling has been conducted by USFWS, KDFWR, TWRA, and TTU using the USFWS Invasive Carp Base Funds and local funding sources. These projects have tested many sampling methods, identifying the best available methods for sampling carp. This project will increase capacity for standardized sampling in TN, KY, and AL.

In this project, KDFWR evaluates the response by the native fish community and their fisheries in the presence of invasive carp. Fisheries managers need to understand these dynamics to evaluate the effectiveness of control levels, and to keep stakeholders informed. This work will complement ongoing projects in the TNCR. For example, all state agencies have been monitoring native sport fisheries in the TNCR, and the TVA has a long-term monitoring program for native fish communities in the Tennessee Valley.

The commercial fishing industry has been successful at harvesting carp using gillnets. Increasing harvest rates remains important if commercial fishing will be used as a means of population control. Due to cost and restrictions on commercial gear types, the private sector cannot easily test new methods. Development of more efficient carp removal methods would greatly benefit the TNCR and potentially other basins. As part of this project, the KDFWR and MSU will continue to evaluate new gears that could be used by resource managers and commercial fishers. This work will benefit all partners in the TNCR as we need highly effective removal methods that are designed for the habitats associated with the TNCR.

Project Objectives:

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

Project Highlights:

KDFWR

- No age-0 silver carp have been collected in either reservoir since 2015, suggesting that populations are sustained by immigration into the reservoirs through the lock systems.
- KDFWR is pursuing analysis of silver carp mark-recapture data with USGS Columbia Environmental Research Center.
- Conducted community sampling in the Kentucky and Barkley Tailwaters to monitor for impacts of invasive carp on the native fish assemlage. Catch per unit effort of several species declined from previous years as did mean relative wieghts, which may indicate negative impacts to the fishery.
- Commercial fishers removed over 8.2 million pounds of invasive carp through the KDFWR Asian Carp Harvest Program in 2021. CPUE (fish/yard) was highest in 3.5” bar mesh gill nets.
- KDFWR staff conducted 59 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 were over 98%.

- Commercial fishers registered with the Kentucky Lake and Lake Barkley contract fishing program received $646,072.68 for over 7 million pounds of invasive carp harvested from Kentucky Lake and Lake Barkley.
- KDFWR continued Master Agreement contracts with two private entities to test invasive carp experimental gears in Kentucky waters. During 2021, one entity was active in the program and harvested approximately 238,351 lbs of invasive carp from Kentukcy and Barkley lakes over 16 days.
- KDFWR did not receive any reports of black carp in the Tennessee or Cumberland rivers during 2021.

TWRA

- TWRA conducted invasive carp monitoring efforts on four reservoirs in the Tennessee and Cumberland River Basin.
- Catch rates of current samping methods in use required further evaluation to determine their utility. Concerns with low sample sizes and high variability appeared to be limitations.
- Invasive carp in upstream reservoirs, where observations suggested populations were less abundant, tended to be larger than those in downstream reservoirs with more abundant populations.
- Invasive carp less than 500 mm were not observed or captured throughout sampling efforts. This suggested a lack of recruitment within the system and supported the hypothesis that populations in the TNCR are largely driven by carp migrating into the basin through navigation locks.

ALWFF

- To date, the ALWFF has completed the 2021 calendar year of fully implemented sampling efforts. This has been made possible by the addition of a functional ETS electrofishing boat, complete with Dozer-trawl, as well as, the addition of one full-time Biologist Aide. Staff also completed sampling maps and addition of 105 standard, fixed-site electrofishing sites across the three project reservoirs.

Methods:

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 invasive 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 A. 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, 2021). 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. Demographics were recorded for invasive carp harvested 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 evaluate if invasive 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 invasive 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 2021 annual District Fisheries Management report. Relative weights were compared to harvest rates of invasive carps to identify trends that may be associated with the increasing invasive 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 of 2021 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. Sampling in the Kentucky Tailwater consisted of three 15-minute runs on the west bank and two 15-minute runs on the east bank. 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 A. Figure 2). Spring sampling in each Tailwater was conducted on one day each month (April, May, and 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 invasive carp species, all fish were released immediately after processing. Data collected in 2021 was compared to historical data to assess changes in the fish community over time.

Objective 3

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 A. Figure 3). Staff observed 18 different

commercial fishers on 59 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 (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

KDFWR continued the Master Agreement (M.A.) contract with two vendors to test invasive carp experimental gears in Kentucky waters. Through this program, contracted entities can use experimental methods for harvesting invasive carp, 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, however if the contractor is operating under a scientific collector permit then data reporting is the responsibility of the contractor in accordance with the permit requirements. In 2021, Robbins Construction LLC, conducted 16 days of effort on the Lake Barkley and Kentucky Lake, 20 days on the Mississippi river and 4 days on the lower Ohio river. This contractor used various seines and seining methods for harvesting fish.

Silverfin Solutions (SFS) was the other contractor with a M.A. contract in 2021. Silverfin Solution's focus in 2021 was working with the United States Geological Survey (USGS) Columbia Environmental Research Center to remove and dispose of all invasive carp captured in the Modified Unified Method (MUM) work. Silverfin Solutions also assessed sites in Western Kentucky for future work, once equipment is received. The USGS conducted MUM effort in several bays on Kentucky lake in 2021. Field work was refined based on information from field in 2020 and incorporated new approaches and equipment into the process.

Sampling with the USFWS Columbia, MO Fish and Wildlife Conservation Office Paupier net was not possible in 2021 due to restrictions associated with COVID 19 and staff shortages. 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).

KDFWR conducted gill netting effort targeting invasive carp in Kentucky and Barkley lakes. Gill nets ranged from 3", 3.5", 4" bar mesh. Net lengths and depths ranged from 1200 to 2400' and 16' to 24', 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. After 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.

Murray State University

Murray State University (MSU) with assistance from Kentucky Department of Wildlife Resources (KDFWR) began a fine-scale telemetry project on Kentucky Lake and Lake Barkley in May 2021. This study was initiated to supplement the ongoing large-scale telemetry analysis under the 'Deterrent Strategy Planning for Asian Carp in the Ohio River Basin' project.

Tagged Fish

A large number of tagged fish from existing projects are present in both reservoirs and we had no trouble finding sufficient number of fish to track. So, no fish were tagged for this project in 2021. We plan to tag several resident fish in Kentucky Lake once the spring harvest begins in 2022.

Tracking Effort

The fine-scale telemetry project differs from the existing large-scale telemetry project in the type of effort expended to track the Silver Carp. In the fine-scale study, we are not using the existing network of passive receivers much but instead we are using boat-mounted hydrophones to determine the location of fish on a smaller scale.

To determine our ability to locate tagged Silver Carp with the boat-mounted hydrophones, we attached a test tag to a small float tethered to an anchor. This setup allowed us to place the test tag in a known location and held the test tag off the substrate as if it were inside a fish. Once the test tag was hidden within the lake, researchers without knowledge of the tag's location attempted to find the tag with the boat-mounted hydrophones. Their estimate of the tag's location was compared to the actual location to provide insight into how accurately we can expect to locate a tagged fish. As the test tag was being located, the intensity of the signal in decibels was recorded at several locations near the test tag.

The mean distance (± SE) between the estimated and actual tag location was 47.2 ± 21.8 m. Our measurements suggest that a signal intensity greater than 85 decibels (on the "near" setting of the VR100 hydrophone receiver) is necessary to achieve this level of accuracy (Appendix B. Figure 1). Note that this level of accuracy is possible for an immobile tag, but a tagged fish might be startled by the boat; thus, we estimate our ability to locate tagged fish would be between 50 – 100 m of the actual fish location.

Our tracking effort was split between two strategies: 24-hour diel activity and macrohabitat use. The 24-hour diel activity data were collected by locating a Silver Carp and then relocating that fish approximately every hour for 24 hours. We usually did not relocate the fish between midnight and 4 AM for safety reasons. Every time the fish was located, we anchored the boat and measured both wind speed and direction.

Diel activity was recorded on 12 different days. Sometimes weather or equipment failure would interrupt the effort such that we could record several locations for a fish, but not for an entire 24-hour period. Thus, we had incomplete data on 9 more days (8 Silver Carp and 1 Paddlefish). We also collected incomplete data on one day due to a Silver Carp whose location was lost before the end of the 24-hour period.

Complete diel activity data was collected for 11 different Silver Carp (1 Silver Carp was followed on 2 separate dates). As mentioned above, incomplete data was collected for 9 other Silver Carp and 1 Paddlefish. During these excursions, we occasionally detected other fish whose general location was recorded to be entered into the large-scale database. We found 29 other Silver Carp, 3 other Paddlefish, 1 Freshwater Drum, 5 Smallmouth Buffalo, and 1 unknown fish which were entered into the large-scale database.

To collect the macrohabitat use data, we traveled along 1 side of the reservoir, stopping every 1 km or less to listen for tagged fish. Once a fish was detected, we determined the location of the fish within 100 m. After tracking in 1 direction for approximately 2.5 hours we repeated these measurements on the opposite side of the reservoir during the return trip in the opposite direction. We collected data in this manner on 37 separate days during which we recorded habitat for 43 Silver Carp, 10 Paddlefish, 3 Freshwater Drum, 3 Smallmouth Buffalo, and 4 unknown fish.

Tennessee Wildlife Resources Agency

Objective 1

TWRA staff conducted invasive carp sampling with gill nets during summer (May-August) and fall (September-November) 2021, on four reservoirs in the Tennessee and Cumberland River Basin to monitor relative abundance. Sampling was completed on Kentucky Reservoir (6 sites/season), Barkley Reservoir (3 sites/season), Pickwick Reservoir (1 site/season), and Cheatham Reservoir (2 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 (depths greater than approximately 10-foot depth). Individual nets were 300-ft in length with 100-ft panels of 3-, 4-, and 5-inch mesh. Nets were 12-ft deep, hobbled to 10-ft every eight feet; nets had 0.5-inch 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. All invasive carp species were measured (mm), weighed (kg), and sexed. All bycatch was recorded and released. Mesh size was recorded for all fish captured.

TWRA staff also conducted targeted invasive carp surveys via electrified dozer trawls (n=50) on Kentucky Reservoir during the fall 2021 (September-November). Dozer trawl samples were conducted during the day using an MLES Infinity electrofishing box. Voltage and amperage were adjusted to achieve a 3,500 watt power output. Dozer trawl transects were conducted in embayments greater than 1.8 meters deep for 5 minutes each. All invasive carp species were measured (mm), weighed (kg), and sexed. All bycatch was counted and released. Dozer trawls were scheduled on Kentucky, Barkley, Pickwick, and Cheatham reservoirs during summer (May-August) and fall (September-November), but sampling was not completed due to motor failure. The number of intended dozer trawl samples on each reservoir were as follows: Kentucky (n=125), Barkley (n=75), Pickwick (n=25), and Cheatham (n=25).

Invasive carp harvested commercially through TWRA's Asian Carp Harvest Incentive Program (ACHIP; described further below) were sampled via visits to wholesale fish dealers. TWRA staff conducted five commercial market surveys during 2021. Sub-samples of silver carp and all bighead carp encountered were measured for length (mm) and weight (g).

Objective 3

TWRA continued implementing its carp harvest incentive program, ACHIP. Three wholesale fish dealers were contracted to receive per pound-based reimbursement incentives for invasive carp purchased from commercial fishers fishing in Kentucky and Barkley lakes. Wholesale dealers received $0.13 per pound in reimbursement and were required to pay out a minimum of $0.15 per pound or $0.18 per pound to fishers for fish less than 8 lbs. or greater than 8 lbs., respectively.

Alabama Division of Wildlife & Freshwater Fisheries (ALWFF)

Gillnet Sampling – ALWFF staff conducted gillnet sampling at predetermined, GPS-fixed embayment sites on Pickwick (3 sites), Wilson (2 sites) and Wheeler (3 sites) Reservoirs (Appendix D. Figure 1). At each site, four gill nets were set and fished overnight. Each site was sampled during the summer and fall seasons. Standardized nets are 300-ft in length and comprised of 100-ft panels of 3-, 4-, and 5-in bar mesh. Standardized nets are 12-ft deep, hobbled to 10-ft every eight feet, featuring 0.5-in foam-core float line and 65-lb lead-core lead line. The multifilament webbing used in each net panel is constructed of 8 ply, 0.2-mm twist mesh. Catch of all invasive carp species were recorded by mesh size and data on individual fish included total length (nearest mm), weight (nearest 0.01 kg), sex, left ovary weight (nearest g) and extraction of pectoral fins and otoliths. All other species were counted by mesh size, while Bigmouth Buffalo and Paddlefish also required recording of length and weight data.

Dozer Trawl & Electrofishing – ALWFF staff planned to conduct electrified dozer trawls as a standard method of sampling. However, due to purchasing issues for an outboard motor, the Dozer trawl was not implemented. Nonetheless, a 16-foot shock boat equipped with a 5.0 Smith-Root GPP was implemented without the trawl mechanism. This boat was used at each of three Alabama reservoirs (i.e., Pickwick, Wilson, and Wheeler) where 35 GPS-fixed sites were established in each reservoir. Multiple factors, such as travel logistics, habitat type and availability as well as statistical robustness based on a power analysis model were used in determining number and location of sampling sites. Surveys were implemented in summer and fall months and conducted during the daytime. Sampling transects includes a variety of habitat types (i.e., backwaters, main channel borders, embayments, side channels/islands and overbank areas). Each trawl sample was conducted for 5 minutes at 3.0 mph, typically running a transect of 0.25 to 0.30 miles. Future plans are to allow interval sampling of these fixed sites using a dozer trawl with data analysis via a repeated-measures ANOVA model.

Objective 3 Note – Regardless of sampling method, all individual invasive carp were sacrificed upon completion of data collection needs to satisfy, in part, Objective 3.

Sampling Gear Note – A newly functional electrified dozer trawl, utilizing an ETS Trident package, will replace boat-mounted electrofishing as the standard electrofishing method in spring 2022; however, boat-mounted electrofishing will still be utilized on an as needed basis and in special circumstances, such as for the newly proposed tailwater assessments currently performed by TWRA. The specifications of ALWFF's dozer trawl should be much like those currently operated by TTU and USFWS's Columbia Field Office.

Results and Discussion:

KDFWR

Objective 1

Standard Sampling

Standard sampling data continues to be variable across seasons and years in each reservoir. (Appendix A. 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 in April. Whereas Kentucky Lake's CPUE was highest in October followed by July (Appendix A. Table 2). Overall invasive carp CPUE through standard sampling was low. In 2021, Lake Barkley had a mean CPUE of 0.012 silver carp/yard (S.E. ±0.002) whereas Kentucky Lake had a mean CPUE of 0.008 silver carp/yard (S.E. ±0.003).

A length-frequency histogram was created for silver carp harvested from Barkley and Kentucky lakes from all harvest methods in 2021. Data suggested the 600mm size class of silver carp was dominant in Kentucky Lake whereas the 700mm size class was dominant in Lake Barkley (Appendix A. Figures 4 & 5).

Age & Growth

Pectoral fin rays were collected from silver carp in Barkley and Kentucky lakes in the fall of 2021 for aging. Lake Barkley ages ranged from 3 to 7 years old, with age 5 being the most abundant. Kentucky Lake ages ranged from 2 to 10 years old, with age 6 being the most abundant, (Appendix A. Figures 6 & 7). Data suggests a strong presence of two cohorts of silver carp behind the 2015 cohort (6 year old fish). Since no age-0 silver carp have been collected in either reservoir since 2015, logic suggests that these fish continue to immigrate into the reservoirs through the lock systems.

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 ln(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 55% and instantaneous mortality was estimated at 0.81 (N= 179, F1,2=48.99, P=0.02, R2=0.96; Appendix A. Figure 8). Annual mortality for silver carp from Kentucky Lake was estimated at 45% and instantaneous mortality was estimated at 0.59 (N=199, F1,2=18.51, P=0.05, R2=0.90; Appendix A. Figure 9).

Condition

Linear regressions were constructed to describe the log10 length-log10 weight relationship for silver carp in Barkley and Kentucky lakes. The length-weight equation for Lake Barkley was estimated at Log10(weight(g)) = 2.8663*Log10(length(mm))-4.5885 (Appendix A. Figure 10). The length-weight equation for Kentucky Lake was estimated at Log10(weight(g)) = 2.909*Log10(length(mm))-4.7207 (Appendix A. Figure 11). Weights were predicted for Lake Barkley: 450mm (1038g), 650mm (2980g) and 800mm (5403g) and Kentucky Lake: 450mm (994g), 650mm (2848g) and 800mm (5301g) (Appendix A. Table 3). Predicted weights remain higher for Lake Barkley than for Kentucky Lake, both lakes indicate an upward trend.

Data collected from sampling in the fall of 2021 was used to analyze relative weights (Wr). Relative weight was calculated using the equation Log10(Ws)= -5.15756 + 3.06842(Log10TL) for silver carp and Log10(Ws)= -4.65006 + 2.88934(Log10TL) for bighead carp (Lamer 2015). The mean Wr for silver carp in Lake Barkley was 94 (N=183, S.E.=±0.81) and the mean Wr for silver carp in Kentucky Lake was 93 (N=132, S.E.=±1.20). These values are consistent with data

collected from previous years. The mean Wr for bighead carp in Kentucky Lake (n=15) and Lake Barkley (n=1) was 106 (S.E.=±2.72).

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 2022, KDFWR received 43 tag returns from commercial fishing efforts. Thirty-three came from Lake Barkley and ten from Kentucky Lake (Appendix A. Figure 12). 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 most of the 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. Many fish were harvested in 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 most 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 three tag returns from bow-fishers harvesting tagged fish outside of the reservoirs where they were tagged and released. Data analysis is in progress with the assistance of the USGS CERC staff.

Asian Carp Harvest Program Monitoring

Length and weight data was collected on 949 silver carp harvested by commercial fishers in 2021. Silver carp lengths ranged from 15.5 - 38.0 inches with an average of 27.9 inches, and

weights ranged from 4.0 – 21.3 lbs with an average of 8.9 lbs (Appendix A. Table 4). If this metric is used in correlation with the total pounds of silver carp harvested by commercial fishers through the ACHP in 2021, that would produce a rough estimate of 915,516 individual silver carp being removed from Kentucky waters through the ACHP in 2021 (8,148,093 lbs; Appendix A. Table 5). During ride-alongs, commercial fishers were observed using gill nets with a range of bar mesh sizes to target invasive carp (3.25" – 4.5" bar mesh; Appendix A. Table 6, Figure 13). 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" (0.58 fish/yard), followed by 3.25" bar mesh which had a CPUE of 0.40 fish/yard. This is similar to the previous three 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 A. Table 6). Information collected from fish harvested through the ACHP was also used in the above demographics analysis.

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 2021 standard sampling, which continues the trend observed in previous years. Bigmouth buffalo were observed to have a mean Wr of 87 (N=3, S.E. ±15) in Kentucky Lake. Paddlefish were observed to have a mean Wr of 95 (N=16, S.E. ±5). 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.

During standard sampling in 2021, bycatch in Lake Barkley was comprised of 68% scaled rough fish (Buffalo spp., Freshwater drum, Gar spp., etc.), 22% catfish spp. (Ictaluridae), 8% paddlefish and 2% sportfish. Bycatch in Kentucky lake was comprised of 59% scaled rough fish, 38% catfish spp., 4% paddlefish and 2% sportfish.

Gizzard shad (Dorosoma cepedianum) collected by traditional boat electrofishing in October 2021, were measured and used to estimate relative weight values (Wr), using the formula presented in Blackwell et al. 2000. Gizzard shad from Lake Barkley were estimated to have a mean Wr of 90 (N=34, S.E.=1.0) and gizzard shad from Kentucky Lake were estimated to have a mean Wr of 92 (N=85, S.E.=0.5). Data suggests that relative weights for gizzard shad are remain at or above 90 over the past several years (Appendix A. Table 7). No gizzard shad greater than 11.0 inches were collected from Lake Barkley in 2021.

Standard Sport Fish Sampling

In Kentucky Lake, relative weight analysis was conducted for black crappie, white crappie, blue catfish, and largemouth bass (KDFWR 2020). Black and white crappie both exhibited mean relative weights that were lower than 2020, but were not outside of historical norms with *W*r of 85.31 and 83.73 respectively (Appendix A. Figure 14). Largemouth bass average *W*r also remained similar to values calculated for the previous four years (*W*r = 91.04). Sampling for blue catfish began in 2004 and has been inconsistent. However, in 2021 blue catfish average *W*r was within the range of values calculated for previous years (*W*r = 102.0). Historical mean relative weight values were charted along with pounds of invasive carp removed from Kentucky Lake through the commercial fishery (Appendix A. Figure 14). Harvest of invasive carp from Kentucky Lake through the ACHP increased significantly in 2020 from previous years, and again in 2021 to 2,366,990 pounds harvested. However, the impacts to sport fish condition associated with this increased removal of invasive 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 invasive carp have become established in Kentucky Lake have not fluctuated outside of historical variations.

In Lake Barkley, relative weight analysis was conducted for black crappie, white crappie, largemouth bass, and blue catfish (KDFWR 2020). Mean relative weights for both black and white crappie decreased slightly from 2020, but remained similar to previous years having *W*r of 96.8 and 92.6, respectively (Appendix A. Figure 15). Mean *W*r value for largemouth bass in 2021 was 102.1, which is higher than most previous years. Sampling for blue catfish in Lake Barkley began in 2004, but has been inconsistent. Mean *W*r for blue catfish collected in 2021 was similar to previous years (Wr = 102.0). Historical relative weight values were charted along with pounds of invasive carp removed from Lake Barkley through the commercial fishery (Appendix A. Figure 15). Harvest of invasive carp from Lake Barkley has increased almost every year since the ACHP began in 2013 spiking in 2021 to over 6.2 million pounds. Similar to Kentucky Lake, the sharp rise in harvest of invasive carp in 2019 corresponds with lower condition factors of sportfish species, which may be an indicator of high densities of adult invasive carp competing with these sport fish for resources. Therefore, the increase in condition of sport fish in Lake Barkley in subsequent years, may be influenced by a reduced competition with invasive 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. In 2021, the total number of bycatch reported increased slightly from 2020, but still remained lower than numbers reported in 2018 and 2019 (Appendix A. Table 8). This reduction in bycatch per trip is attributed to changing practices of commercial fishers as most fishers have transitioned from passive setting to active setting of gill nets targeting schools of carp identified via their boat electronics. Scaled rough fish, primarily buffalo (*Ictiobus*) species, make up the majority of reported bycatch in commercial gill nets fished under the ACHP (Appendix A. Table 8). In 2021, the percentage of scaled rough fish harvested by ACHP fishers increased almost 10% from 2020 (Appendix A. Table 8). This is likely a result of processors utilizing these fish, as well as invasive carp, for other products such as fertilizer or fish meal instead of only food items as in previous years. Although commercial fishers on the ACHP are limited to how much of their bycatch they can harvest, KDFWR will continue to monitor this trend in future years. The number of sport fish, catfish, and paddlefish collected as bycatch all decreased in 2021 compared to recent years. Survival rates of sportfish (98.4%) and catfish (87.7%) increased in comparison to previous years, and the survival rate of paddlefish remained similar (81.0%) (Appendix A. Table 8).

Survival rates of all bycatch caught during ride-alongs in 2021 was documented by KDFWR observers and was analyzed independent of commercial fishers reporting (Appendix A. Table 9). During ride-alongs, the survival rate of sport fish in bycatches increased from previous years to a high of 100%. Survival rates of catfish species observed as bycatch during ride-alongs was similar to previous years at 95%. Paddlefish survival rates observed during ride-alongs in 2021 were the highest observed since 2016, but still remained significantly lower than what commercial fishers reported (69%; Appendix A. Tables 8 & 9).

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 A. Table 10). 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 A. Figure 16). 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 (2.5% in 2021). 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 through the ACHP (Appendix A. Tables 5 & 8).

Paddlefish survival was observed to be low in 2021 (69% during ride-alongs, 81% total ACHP) in relation to other species in the bycatch (Appendix A. Tables 8 & 9). Since much of the ACHP effort is during the summer months (i.e. warmer water temperatures), paddlefish are vulnerable bycatch in this fishery. Another factor identified as possibly affecting paddlefish survival in gill nets is length of time the nets are left in the water (i.e. soak time). From conducting ride-alongs, it has been observed that the soak time of nets varies among fishers and depends on the location being fished, weather, and water temperature. Overall, fishers tend to leave nets in the water longer when water temperatures are cooler as it increases catch rates and like most fish, invasive carp will survive longer in the cooler temperatures. Therefore, water temperature and soak time have been recorded during ride alongs since 2017. Figure 17 (Appendix A) exhibits data from each trip where paddlefish were observed as bycatch and indicates a trend of declining survival rates associated with rising water temperatures. However, it is also important to note that the majority of paddlefish are caught in nets with soak times of over 8 hours (Appendix A. Figure 18). Therefore, the combination of soak times greater than 8 hours and rising water temperatures attributes to higher catch rates of paddlefish and lower survival rates. However, commercial fishers are more frequently using active methods for targeting invasive carp with gill nets and soak times of nets decreased overall in 2021. To increase the sample size, water temperature and soak times will continue to be recorded during ride-alongs in 2022.

Kentucky and Barkley Tailwaters Electrofishing

Spring sampling with electrofishing in the Kentucky Tailwater resulted in the collection of 942 individual fish comprised of 28 species through 3.75 hrs of electrofishing. Gar, black bass, and cyprinid species made up the highest percentages of the catch with 22%, 20%, and 19% respectively (Appendix A. Figure 19). Smallmouth bass catch rate was the highest since the survey began in 2015 with a CPUE of 34 fish/hour (Appendix A. Table 11). However, most other sportfish had catch rates lower than or similar to previous years. The majority of rough fish exhibited catch rates within the range of previous surveys, with the exception of gizzard shad which had the lowest catch rate since 2015 when the survey began (16 fish/hr; Appendix A. Table 11). Silver carp CPUE in the Kentucky Tailwater during spring sampling remained similar to the previous two survey years (5 fish/hr; Appendix A. Table 11).

Spring sampling for 2021 in the Barkley Tailwaters resulted in the collection of 1,271 individual fish, comprised of 34 species, through 3.0 hours of effort. Cyprinid species made up the highest

percentage of the total catch with 37%, followed by gar species with 17%, and sunfish species with 11% (Appendix A. Figure 20). Similar to Kentucky Tailwaters, the smallmouth bass catch rate was the highest since the survey began in 2016 (16 fish/hr; Appendix A. Table 12). However, catch rates for largemouth bass, bluegill, and redear sunfish declined from previous survey years. In contrast to Kentucky Tailwaters, gizzard shad catch rates in the Barkley Tailwaters were the highest recorded since the survey began in 2016 with 27 fish/hr. Silver carp CPUE increased slightly from 2020, but remained similar to catch rates produced in previous years (20 fish/hr; Appendix A. Table 12).

Although spring sampling in the Kentucky and Barkley tailwaters has been conducted in most years during the survey's history, 2015-2021, the amount of effort has been variable (Appendix A. Tables 11 & 12). The Tailwaters can be volatile and often produce conditions in which sampling is not possible due to high water levels and high flows, especially in the spring months of this survey. Additionally, the utility of data collected in the spring months is limited to catch rates and length frequencies of species collected, which are highly impacted by time of year and sampling effort. Therefore, KDFWR is considering discontinuing spring sampling efforts after the 2022 field season, to best utilize funding and staff time for projects that will inform management strategies.

Fall sampling with electrofishing in the Kentucky Tailwater resulted in the capture of 3,133 total fish comprised of 29 species during 3.75 hours of effort in 2021. Like previous years, Clupeid species were the most abundant group collected, comprising 90% of the total catch during sampling in 2021 (Appendix A. Figure 21). Threadfin shad (Dorsoma petenense), made up the majority of Clupeids caught (Appendix A. Tables 13 & 14). Catch rates for other bait fish including gizzard shad and skipjack herring declined from the 2020 survey but remained within the range of previous years (Appendix A. Table 14). CPUE of sunfish species including bluegill and longear sunfish, were the lowest since the survey began in 2016 with a CPUE of 4 fish/hr and 2 fish/hr, respectively. Largemouth and smallmouth bass were the most prominent sport fish species collected in the Kentucky Tailwater during fall sampling in 2021 with 19 and 21 fish collected, respectively. However, the CPUE for largemouth bass in 2021 was the lowest since the survey began in 2015 (5 fish/hr; Appendix A. Table 13). CPUE for Morone spp. and bluegill also declined in 2021 compared to previous years. Interestingly, for the second year in a row, striped mullet (*Mugil cephalus*) was collected during sampling efforts in the Kentucky Tailwater in 2021. A total of 5 striped mullet were collected ranging from 19 – 22 inches in total length, whereas 4 fish were collected in 2020 (Appendix A. Table 14). Silver carp retained a similar CPUE and portion of the percent total catch as was documented in the previous four years (Appendix A. Figure 21 & Table 14).

Fall sampling in the Barkley Tailwater resulted in the capture of 1,721 total fish comprised of 27 species over 3.0 hours of effort in 2021. Complementary to previous years, Clupeid species,

were still the most abundant species group collected in Barkley Tailwater during fall sampling in 2021, comprising 72% of the total catch (Appendix A. Figure 22). Similar to the Kentucky Tailwater, threadfin shad made up the majority of Clupeids caught. However, gizzard shad catch rates were the lowest recorded with a CPUE of 8 fish/hr (Appendix A. Tables 15 & 16). Sunfish species such as bluegill and longear sunfish produced the lowest catch rates for those species since the survey began in 2016 with a CPUE of 21 fish/hr and 14 fish/hr, respectively (Appendix A. Table 15). Largemouth bass catch rates in 2021 were near the lowest observed, but smallmouth bass catch rates remained higher than most previous years (Appendix A. Table 15). Silver carp CPUE during fall sampling in Barkley Tailwaters remained similar to 2020 (24 fish/hr; Appendix A. Table 15).

Length frequency distribution for silver carp collected in Kentucky Tailwater during fall sampling in 2021 ranged from 18-35 inches (N=32; Appendix A. Table 13). Silver carp lengths from Barkley Tailwater during fall sampling ranged from 18-32 inches (N=71; Appendix A. Table 16). These ranges are much wider compared to silver carp collected during fall sampling in 2018 and 2019 and may indicate more mixing of the silver carp population in the Tailwaters, or that fish from a variety of locations are arriving at the tailwaters and looking for passage upstream.

Silver carp and grass carp were collected in both tailwaters during fall sampling efforts, and a single bighead carp was collected in the Kentucky Tailwater. Electrofishing for this project resulted in removal of 32 silver carp from Kentucky Tailwater and 71 silver carp from Barkley Tailwater in 2021.

Relative weights (Wr) were calculated for selected species collected during fall sampling to monitor fish condition (Appendix A. Tables 17 & 18). 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 Invasive 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 Wr values have not been identified for all species and in every habitat type. Therefore, the Wr values compiled through this study will be used to assess changes in the Tailwater fish community over time. In the Kentucky Tailwater, the mean Wr of gizzard shad increased to a value of 92, the highest observed since the survey began in 2015 (Appendix A. Table 17). However, the mean relative weight for largemouth bass (Wr = 87), white bass (Wr = 86), and sauger (Wr = 78) all decreased to the lowest values recorded for those species since the survey began (Appendix A. Table 17. Figure 23). Silver carp mean relative weight remained the same as observed in 2020 (Wr = 76: Appendix A. Table 17). Mean relative weight values for other species in the Kentucky Tailwater remained similar to previous years. In the Barkley Tailwaters the mean Wr for silver carp remained similar to the low observed in 2020 (Wr = 77; Appendix A. Table 18). 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 2021, mean relative weight values also remained low for gizzard shad (Wr = 73), yellow bass (Wr = 74), smallmouth bass (Wr = 81), and smallmouth buffalo (Wr = 78) (Appendix A. Table 18, Figure 24). Conversely, the mean relative weight values for largemouth bass (Wr = 101), redear sunfish (Wr = 101), and bluegill (Wr = 118) remained high compared to those observed in previous years (Appendix A. Table 18, Figure 24). Sampling in fall of 2021 produced more low mean relative weight scores than most previous surveys which may be an indication of increased competition with silver carp for both space and food in the tailwaters. Therefore, continued data collection and further analysis with currently available data is warranted and will be pursued by KDFWR. Additionally, the creel survey to be conducted in the tailwaters in 2022, will yield important data from anglers regarding catch rates for comparison to previous years.

Objective 3

Asian Carp Contract Fishing Program in Kentucky Lake and Lake Barkley

Interest and participation in the KDFWR contract fishing program for invasive carp has varied greatly since it began in 2016. However, in 2019, refinements were made to the program and the number of fishers targeting invasive carp in Kentucky and Barkley lakes increased, which heightened participation in the program. In 2021, contractors received $646,072.68 for invasive carp harvested from Kentucky Lake and Lake Barkley. This equates to over 7 million pounds of Asian carp harvested through the contract program in 2021, the largest harvest to date (Appendix A. Table 19). Refinements to the program were made in 2021 which removed the varying pay out based on size of fish harvested. As of October 2021, the program now pays contractors $0.08 / lb for invasive carp harvested from Kentucky waters of the lakes regardless of the size of those fish.

Asian Carp Harvest Program Monitoring

The Asian Carp Harvest Program (ACHP) created by KDFWR allows commercial fishers to target invasive 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 invasive carp from Kentucky waters, especially Kentucky Lake and Lake Barkley.

Since 2013, commercial fishers in Kentucky have harvested a total of 26,673,217 lbs of invasive carp through the ACHP (26,258,831 lbs silver carp, 228,766 lbs bighead carp, 185,620 lbs grass carp [2020-2021 only]; Appendix A. 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. The majority of invasive carp harvested in Kentucky are from Lake

Barkley (Appendix A. Table 5). Commercial fishers typically 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. However, the amount of effort by commercial fishers and harvest of invasive carp from Kentucky Lake has increased substantially in 2020 and 2021 (Appendix A. Table 5). 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 invasive 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 2021, the number of commercial fishers participating in the ACHP decreased to 38 individuals. However, those fishers made the most trips ever recorded through the ACHP with 2,373 days of effort. This translates to an increase in effort per commercial fisher (approximately 62 trips/fisher) indicating that commercial fishers in Kentucky are transitioning to full time fishing for invasive carp rather than inconsistent efforts as seen in previous years. Additionally, commercial fishers harvested an excess of 8.2 million pounds of invasive carp through the ACHP in 2021, indicating an increase in harvest efficiency for commercial fishers targeting invasive carp (Appendix A. Table 5 & Figure 25). Factors affecting the increased efficiency are likely a combination of the 2015 silver 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 2021 record harvest as well as improvements to equipment such as boats, trucks, net rollers, cranes, and electronics. KDFWR also continues to maintain an industrial flake ice machine to provide free ice to ACHP fishers to help keep their catch fresh.

Invasive carp harvest data was summarized by month from January 2015 to December 2021 (Appendix A. Figures 26 & 27). 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 A. Figure 26). 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 2021, this trend was not apparent as commercial fishers are now targeting invasive carp year round, and are allowed to receive funds through the contract program administered by KDFWR for invasive 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, however, effort was much more consistent through 2021 with number of trips ranging from 126 – 276 per month (Appendix A. Figure 26). Total pounds of silver carp harvested per month closely follows the trend of number of trips made and ranged from 2,652 – 4,142 pounds per month in 2021 (Appendix A. Figure 27). Market demand for food grade fish has decreased since February of 2020, however, other markets for non-food products such as fish meal, fertilizer, and lobster bait have increased.

Water conditions routinely affect invasive 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 ºF and 86.0 ºF (USFWS 2020). 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 behavior better, and they use higher quality gear with larger boats that have higher weight capacities. In 2021, the average number of pounds harvested per trip was calculated for all ACHP fishers (N=38), and average pounds of silver carp harvested varied from 396 lbs/trip to 7,431 lbs/trip. Interestingly, not all fishermen with high catch rates fished frequently (Appendix A. Figure 28).

Ride-Alongs

KDFWR conducted 59 ride-alongs with 18 different commercial fishers utilizing the ACHP January through December 2021 (Appendix A. Table 20 & Figure 3). During ride-alongs 42,193 yards of gill net were fished and 201,159 lbs of invasive carp were harvested. The majority of fishing effort observed during ride alongs was in Lake Barkley (N=39), which is similar to fishing effort in general. Ride-alongs were also conducted in Kentucky Lake (N=20). Commercial fishers set nets primarily along secondary channels, on flats in the main lake, and in embayments. In previous years, the northern end of Lake Barkley received the most fishing pressure. However, in 2021 the fishing pressure observed through ride alongs was more evenly distributed throughout Lake Barkley and Kentucky Lake (Appendix A. Figure 3). The mean effort per trip (yards of net fished) decreased in 2021 compared to all previous years, which is reflective of the changing strategies that commercial fishers are employing to catch silver carp (active setting vs. dead setting nets) (Appendix A. Table 20). Average total weight of silver carp harvested per trip during ride-alongs in 2021 (3,389 lbs) was lower than 2020 (Appendix A. Table 21). This is also reflective of changing strategies as commercial fishers may not expend effort of deploying and retrieving nets if they do not find schools of silver carp to target. This occurred on three occasions during ride alongs, and may also be an indication of changing population dynamics or densities of silver carp in the lakes. Average weight of individual silver carp harvested during ACHP ride-alongs in 2021 was similar to 2020 (Appendix A. Table 4).

Experimental Gears

Contracted Experimental Efforts

Robbins Construction LTD harvested approximately 238,351 lbs of invasive carp from Barkley and Kentucky Lakes in 2021 (14,896 lbs/day). 99% of the invasive carp harvested were silver carp and >1% were bighead carp. Sport fish bycatch and other fish species that were not harvested were observed to have an 95% survival rate at the time of release. While outside the scope of this report it is worth noting that Robbins Construction LTD also harvested 501,637 lbs

(26,401 lbs/day) of silver carp from the Mississippi River and 56,271 lbs (14,067 lbs/day) of silver carp from the Ohio River in 2021 through the contracted experimental efforts.
Robbins Construction LTD continued to modify equipment to improve harvest efficiencies. Such modifications included the addition of two power blocks for pulling gear and reducing personnel fatigue. These power blocks were installed on a custom-built boat, that was modified for hauling and rapidly deploying seine nets. This equipment adds to their previous investment of net reels and a boat mounted crane. Furthermore, Robbins Construction LTD was able to acquire additional netting to lengthen their seine used in 2020 and invest in material for a new seine with a bag to hold fish and further modify their gear from 2020. Their seines ranged from 900' to 2400' in length with a bar mesh of 2" to 2.5".

Electrofishing
Due to staffing shortages, no trips were made in 2021 for targeted electrofishing removal of invasive carp in either Barkley or Kentucky Lake tailwaters.

Gill netting
During 2021, KDFWR staff did not conduct any targeted gill netting for invasive carp, solely for removal purposes. However, through the course of collecting invasive carp in support of the deterrents project and additional demographic collections KDFWR harvested 6,056 lbs. of silver carp and 87 lbs. of grass carp over 5 days of effort (Kentucky n=2, Barkley n=3).

Murray State University

Diel Activity
For all Silver Carp, we determined the distance between successive locations as the shortest distance which the fish could swim while remaining in the water (i.e. not necessarily the straight line distance). This distance was divided by the time between locations to estimate the swim rate in m/s. Each swim rate was labeled with the general time of day based on sunrise and sunset. "Dawn" was the time period 1 hour before sunrise until 1 hour after sunrise, while "Dusk" was a similar time period around sunset. "Day" and "Night" were the appropriate periods between dawn and dusk. A repeated measures ANOVA indicated that Silver Carp mean swimming speed was significantly lower at Dawn compared to Dusk ($F_{3,34} = 3.91$, $p = 0.02$), but no significant differences were otherwise detected (Appendix B. Figure 2).

During 24-hour tracking, fish generally stayed in the same macrohabitat. However, we wished to investigate the factors which influenced the location of each fish. To determine if wind affected the fish, we first calculated the fetch in meters for 8 directions (at 45 degree intervals) at each fish location. Then, we used the wind data which was measured at that fish location to determine which of these 8 fetch values represented the actual wind at the time of that location. Finally, we

multiplied the proper fetch by the wind speed to calculate the Relative Exposure Index (REI) at each fish location in m^2/s (Rohweder et al. 2008). The REI measures the general "windiness" or wind energy at a location. We buffered each fish location based on the distance between successive locations so that we could determine the area to which each fish could potentially have swum. Random points (N = 15) were chosen within each buffer and REI was also calculated at each of these random points. A paired t-test was used to compare the mean REI of the random points to the actual REI of each fish location. Mean REI was not significantly different between the fish locations and the random locations for both Kentucky Lake (t_{202} = 0.56, p = 0.57, Appendix B. Figure 3) and Lake Barkley (t_{38} = 1.28, p = 0.21, Appendix B. Figure 4).

Using similar techniques, we investigated if water depth or bottom slope where Silver Carp were found was different from random locations. Bathymetric maps were supplied by Navionics (www.navionics.com) and adjusted based upon lake level for each fish location; then, depth at each fish location was compared to 15 random locations near each fish. Mean depth at each fish location was not significantly different from random locations in Kentucky Lake (t_{278} = -0.51, p = 0.61, Appendix B. Figure 5) and Lake Barkley (t_{40} = 1.67, p = 0.10, Appendix B. Figure 6).

Bottom slope was calculated from the depth maps and then compared between fish locations and random locations. Mean slope was not significantly different between random locations and fish locations in Kentucky Lake (t_{277} = -0.63, p = 0.53, Appendix B. Figure 7) and Lake Barkley (t_{40} = -0.02, p = 0.98, Appendix B. Figure 8).

Macrohabitat Use Results

We used a 5-habitat system to classify macrohabitat in the reservoirs: thalweg, side channel, coves (greater than 5 ha but less than 100 ha surface area), major coves (greater than or equal to 100 ha), and the canal (Appendix B. Figure 9).

The amount of each macrohabitat available (based on surface area) was calculated separately for each reservoir based upon the extent which was tracked while looking for Silver Carp. This included the lower portion of Kentucky Lake from the dam upstream to the Paris Landing bridge, and it included the lower portion of Lake Barkley from the dam upstream to Devil's Elbow Bay. All fish locations were labeled based upon the macrohabitat in which they were found, and then amount each habitat was used was compared to the amount available. A log-ratio chi squared test indicated that Silver Carp habitat use was not significantly different from random in both Kentucky Lake (X^2 = 78.3, df = 112, p = 0.99) and Lake Barkley (X^2 = 55.9, df = 68, p = 0.85, Appendix B. Table 1). We performed similar analyses by season for each lake but found no habitat use significantly different from random.

Surface water temperature was obtained for each date from the Hancock Biological Station website (https://www.murraystate.edu/qacd/cos/hbs/hbs.htm) and then compared among habitats used by Silver Carp. Although fish seemed to use major coves more at cooler temperatures and the thalweg more at higher temperatures, a Kruskal-Wallis test showed that median temperature was not significantly different among habitats ($X^2 = 6.6$, df = 3, p = 0.08, Appendix B. Figure 10).

Informing Removal Efforts

The results from the fine-scale movement study can help Asian Carp removal by determining the conditions and locations which are most amenable to harvest. Silver Carp were most active during the 2 hours around sunset which might be a more efficient time to target these fish. Although no patterns were detected relative to the effects of wind, water depth, or bottom slope, we are just beginning to collect these data and patterns may yet emerge. As we collect more data we will look for patterns which differ seasonally, by sex, by size, or by fish origin. Although we found no pattern to the habitats used by Silver Carp, we feel that further data collection might reveal preferences for different habitats in different seasons or water temperatures. Such information would be very helpful to focus harvest and removal efforts.

Future Plans

Once the spring harvest of Silver Carp begins in 2022, we intend to tag several "resident" Silver Carp in Kentucky Lake to supplement the fish which will be tagged by other agencies and other projects. We will continue tracking fish for both the 24-hour activity and the macrohabitat use studies, and we are considering extending our tracking effort to the lower Tennessee and Cumberland Rivers. As our sample size increases, we hope to be able to investigate more factors which might influence activity and habitat use such as fish size, sex, or origin.

New Harvest Methods

SilverFin Solutions (SFS) was subcontracted to test several harvest methods for Silver Carp. Most of 2021 was spent building / procuring the gear needed for these methods, so no carp harvest occurred last year. SFS was able to clear the substrate in 5 areas in Kentucky Lake to enhance the harvest of fish with the Modified – Unified Method (MUM). SFS also assisted the USGS with the MUM by providing a lift crane on a barge and preparing for the removal of fish.

TWRA

Objective 1

TWRA staff conducted 96 net nights (2,119 hours) of gill netting effort in 2021, resulting in the collection of 255 silver carp, 14 bighead carp, 14 grass carp, and 0 black carp (Appendix C. Table 1). Gill netting hours remained similar in Kentucky, Barkley, and Pickwick reservoirs

between 2020 and 2021. Gill netting hours decreased at Cheatham due to a reduction in sampling sites from 3 sites/season in 2020 to 2 sites/season in 2021. This reduction in sites was implemented based on limited suitable gill net sampling habitat in Cheatham and lessons learned from the 2020 field season.

Silver carp were similar in mean lengths in Kentucky and Barkley Reservoirs (p=0.189) but differed significantly between Barkley and Cheatham Reservoirs (p=0.019) and Kentucky and Pickwick Reservoirs (p=0.003). Length frequency histograms indicate most silver carp captured in Kentucky, Barkley, and Cheatham Reservoirs are between 700mm and 800mm (Appendix C. Figure 1 – 3). Larger individuals were captured in all three reservoirs but were more abundant in Cheatham Reservoir. A length frequency histogram was not created for Pickwick due to low sample size. Catch rates of silver carp are typically lower during the fall sampling events, but further years of sampling are needed to determine whether a seasonal trend in CPUE exists (Appendix C. Table 2). The majority of silver carp were captured in 4-inch mesh on all four reservoirs representing 84.7% of the silver carp catch on Kentucky Reservoir, 86.4% on Barkley Reservoir, 66.7% on Pickwick Reservoir, and 77.4% on Cheatham Reservoir (Appendix C. Table 3). Gill nets (n=16) were also set in Old Hickory Reservoir in 2021 and invasive carp were not captured.

Targeted shocking was replaced by electrified dozer trawl samples in Kentucky, Barkley, Pickwick, and Cheatham reservoirs; however, due to equipment issues (motor failure), dozer trawl transects were only implemented on Kentucky Lake and a limited number of transects (n=50) were completed. We expect this sampling to resume in 2022. A total of 19.8 hours of dozer trawl sampling was conducted on Kentucky Reservoir during the summer which resulted in 31 silver carp being captured (Appendix C. Table 4). Targeted boat electrofishing sites have been implemented on Old Hickory Reservoir for future sampling seasons.

In five market visits during 2021, TWRA staff sampled the catch of 13 commercial fishing outings, of which 12 were collected in Kentucky Reservoir and 1 was collected in Barkley Reservoir. In total, data was collected on 630 silver carp and 15 bighead carp from Kentucky Reservoir and 38 silver carp and 3 bighead carp from Barkley Reservoir. Mean length of commercially harvested silver carp sampled from Kentucky Reservoir was 742 mm (n=630; SD=±66) and from Barkley Reservoir was 721 mm (n=38; SD=±56).

Objective 3

TWRA's ACHIP resulted in the removal of 7,470,459 lbs. of invasive carp from Kentucky and Barkley lakes in 2021 (Appendix C. Figure 4). By March 2021, wholesale fish dealers completed projects using TWRA awarded grants (state funding) that significantly increased their capacity to store and move invasive carp. As a result of the increased capacity, harvest increased from an

average of 203,951 lbs. per month from March to December of 2020, to 666,963 lbs. per month from March to December of 2021.

Alabama Division of Wildlife & Freshwater Fisheries (ALWFF)

ALWFF staff increased sampling efforts at a much wider scale, implementing fixed electrofishing sites (n = 105) across habitat types, as well as maintaining prior fixed-site (n = 32) gillnetting efforts (Appendix D. Tables 1 and 2). Despite expansion of these efforts, overall CY 2021 catch numbers of invasive carp was lower by nearly 2.5-fold compared to 2020. It is interesting to note the similar catch rate of all fish species in 2021 compared to 2020 (Appendix D. Table 2). However, unlike 2020 where all carp were captured at one sample area (i.e., Second Creek, Pickwick Reservoir) and seven gillnet sets, carp captured in 2021 came from nearly a dozen locations, and both gear-types, albeit, primarily from Pickwick Lake. Given our relatively small data collection over less than two years, we note the only glaring pattern is that no Silver Carp have been collected from reservoirs upstream of Pickwick Lake during our standardized sample efforts. We also note that further expanded sampling efforts have likely expanded our ability to capture existing immigrant fish and further sampling will likely provide improved knowledge on increasing catch rate success at key sample areas.

We note here outside of our sampling efforts that three individual Silver Carp were captured by other individuals as reported to our office; two fish in Shoal and McKiernan Creeks, Wilson Lake, in March-April, as well as one fish in Raccoon Creek in Guntersville Lake. Our concern in these sightings are the apparent expansions into upstream water bodies.

Recommendation:

All Partners

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

- As basin partners begin sampling or continue efforts currently in place, data should be collected, compiled, and analyzed as congruently as possible to more succinctly identify trends in invasive 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.

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 invasive carp populations in the lower reaches of Kentucky and Barkley lakes, and this type of data collection will be expanded throughout the basin.

- KDFWR will be pursuing assisitance with data anlysis to identify trends within the fish communities of Kentucky and Barkley tailwaters that may be associated with invasive carp densities and determining management strategies.

- 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 invasive carp present in the basin. Therefore, effort towards identifying and testing other methods for removing invasive carp should be expanded. Commercial seining shows considerable promise for efficiently removing carp at rates higher than traditional gill netting, and invasive 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.

TWRA

- Further analysis regarding the power of existing sampling efforts to detect change in relative abundance is ongoing. This will be important in determining appropriate sample sizes and strategies for various gears.

ALWFF

Given the relatively short time scale of our data collections to date, we feel continuation of both standardized gillnetting and electrofishing should continue unchanged, excepting expansion of both methods in spring months (i.e., late March-early May), with the potential to also expand electrofishing at tailwater dams locations that may reveal propagule expansions or progeny of

spawning efforts in relatively unsampled areas. This would entail a new project as currently performed by TWRA and would commence in FY2023.

Outside of the aforementioned, we do not feel a need for further studies or actions outside of expanding our sampling regime. Given our results to date, it would be of interest for all agencies to compare sample efficacy, especially with respect to seasonal efforts. However, we do not believe this action would necessarily inform agency decisions to change sample strategies. We currently do not have any changes or additions to management actions, though this may change with discussions among other TNCR agency biologists.

References:

Blackwell, B. G., M. L. Brown, and D. W. Willis. 2000. Relative weight (*Wr*) status and current use in fisheries assessment and management. Reviews in Fisheries Science 8: 1-44.

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

Kentucky Department of Fish and Wildlife Resources. 2020. Western fisheries district, Project 1: lakes and tailwaters. Annual Performance Report, District Fisheries Management. 1-94.

Rohweder, J., J. T. Rogala, B. L. Johnson, D. Anderson, S. Clark, F. Chamberlin, and K. Runyon. 2008. Application of wind fetch and wave models for habitat rehabilitation and enhancement projects. U. S. Geological Survey Open-File Report 2008 – 1200. 43 p.

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

Seibert, J.R., and Q.E. Phelps. 2013. Evaluation of aging structures for silver carp from Midwestern U.S. rivers. North American Journal of Fisheries Management 33: 839–844.

Stuck, J.G., A.P. Porreca, D.H. Wahl, and R.E. Columbo. 2015. Contrasting population demographics of invasive silver carp between an impounded and free-flowing river. North American Journal of Fisheries Management 35:114–122.

Towne, K., E. Pherigo, W. Doyle, J. Kallis, and J. Goekler. 2020. Relative abundance and length distribution of silver carp in Kentucky Lake. Columbia Fish and Wildlife Conservation Office Sampling Report. United State Fish and Wildlife Service.

"USA Sunrise Sunset Calendars." *Sunrise Sunset Calendars - Home*, 2020, www.sunrisesunset.com/USA/Kentucky/.

United States Geological Survey and United States Fish and Wildlife Service. 2017. Shipping, handling, and data protocols for wild captured black carp and grass carp.

United States Fish and Wildlife Service. 2020. Ohio River Basin Asian carp monitoring and response plan interim summary report: Deterrent strategy planning for Asian carp in the Ohio River basin.

Appendix A: Figures and Tables – KDFWR:

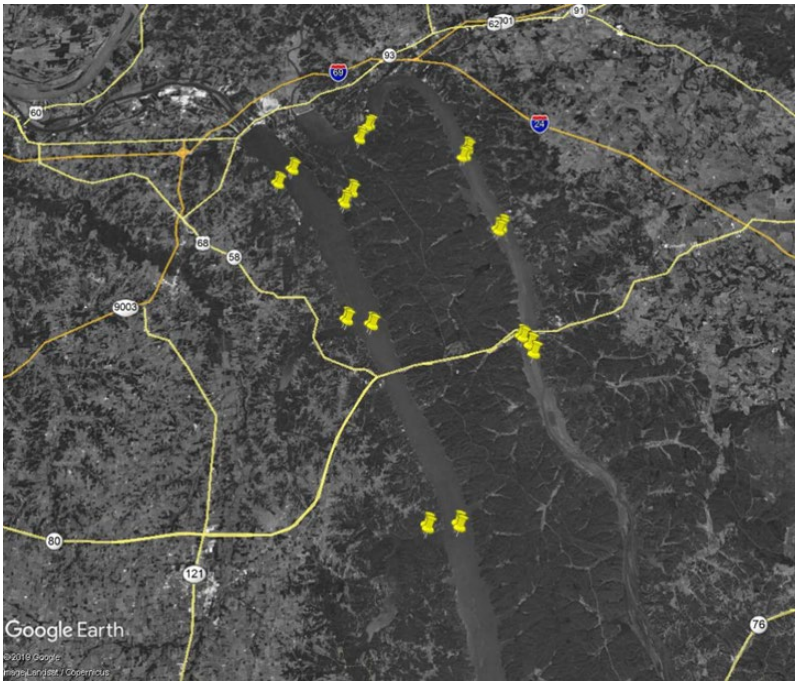

Figure 1. Location of standard sampling sites, where gill nets were fished by Kentucky Department of Fish and Wildlife Resources in 2021.

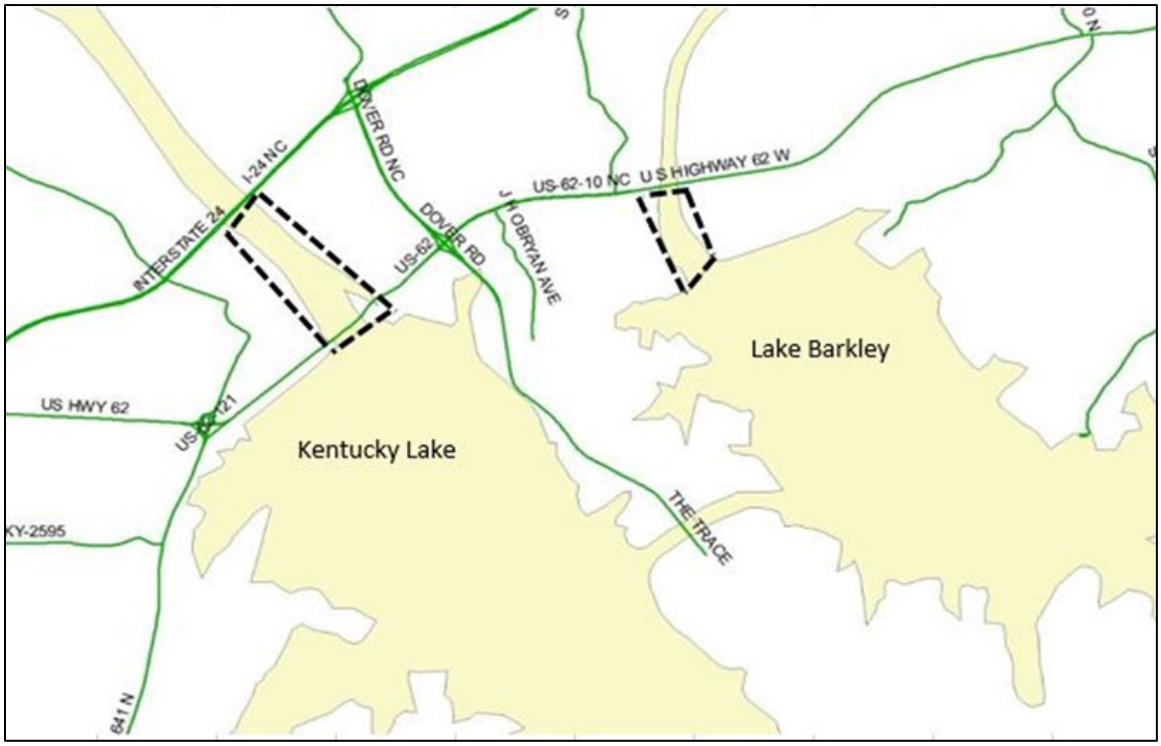

Figure 2. The tailwater electrofishing at Kentucky Tailwater extended from the dam downstream to the Interstate 24 bridge. The electrofishing at Barkley Tailwater extended from the dam

downstream to the US Hwy 62 bridge. Sample areas are outlined by dashed line.

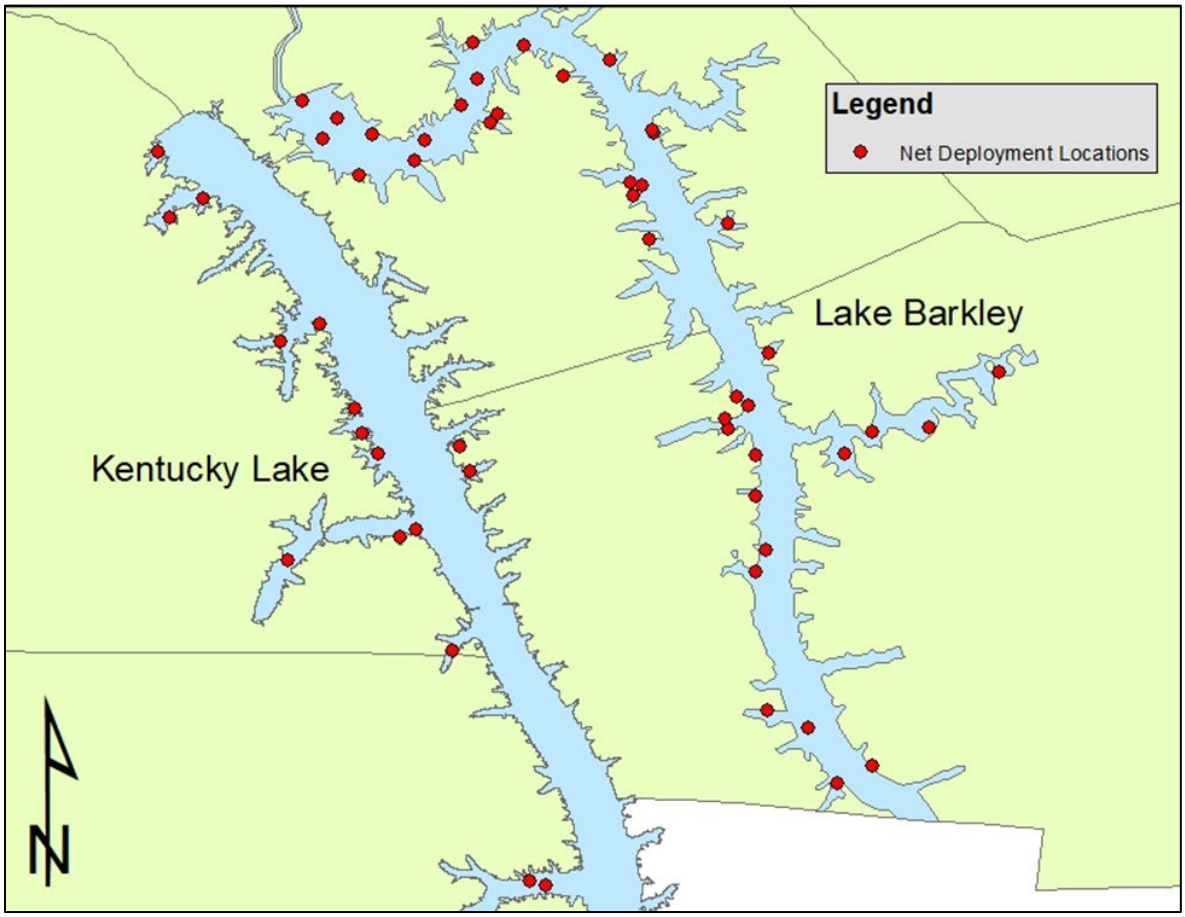

Figure 3. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff in 2021.

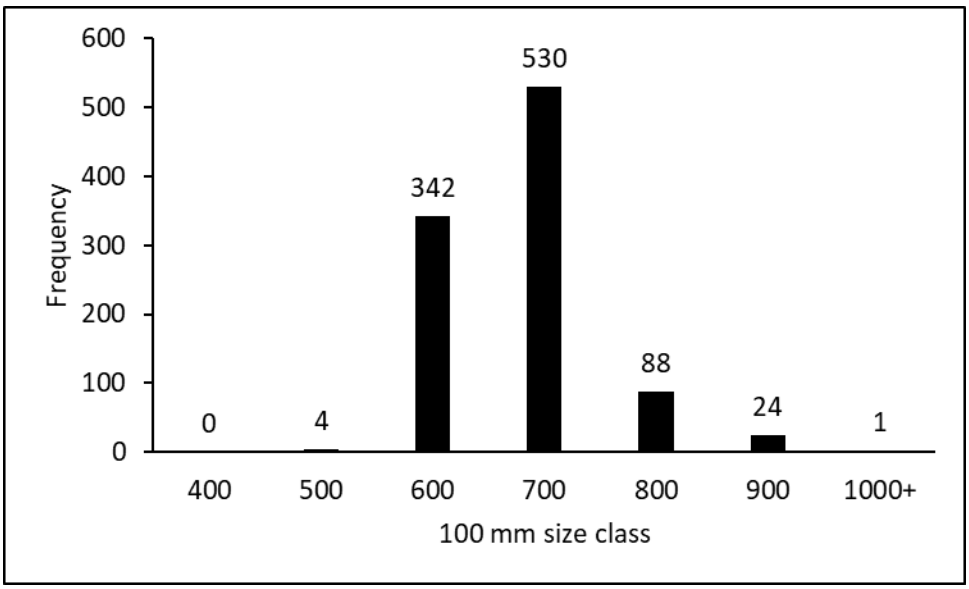

Figure 4. Length-frequency distribution of silver carp collected from Lake Barkley, from all methods in 2021 (N=989).

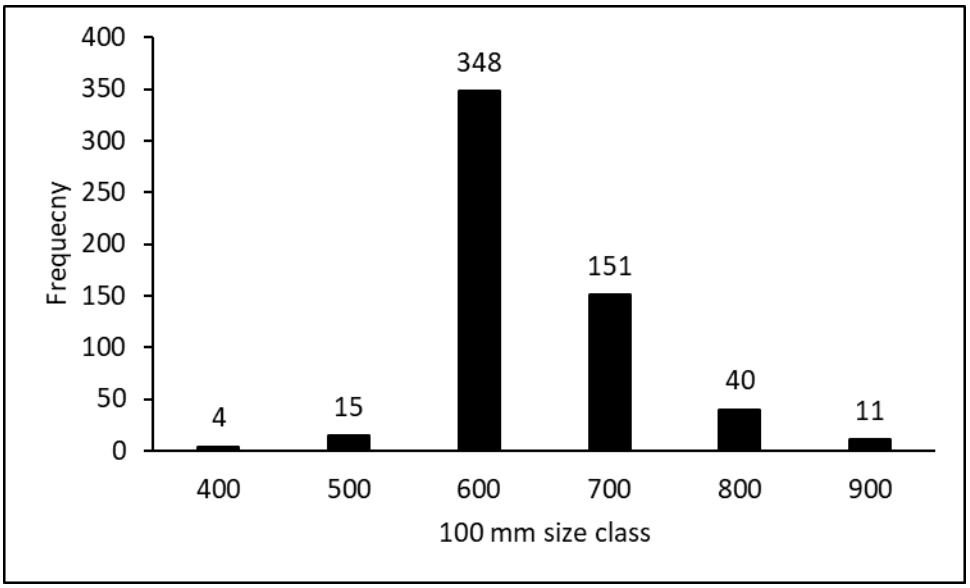

Figure 5. Length-frequency distribution of silver carp collected from Kentucky Lake, from all methods in 2021 (N=569).

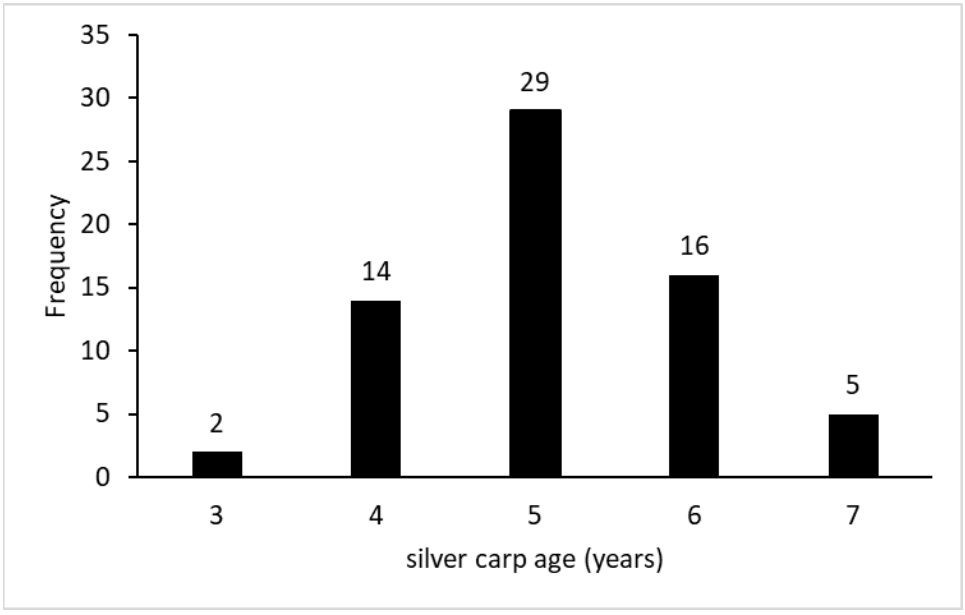

Figure 6. Age-frequency distribution for silver carp collected from Lake Barkley in 2021 (N=66).

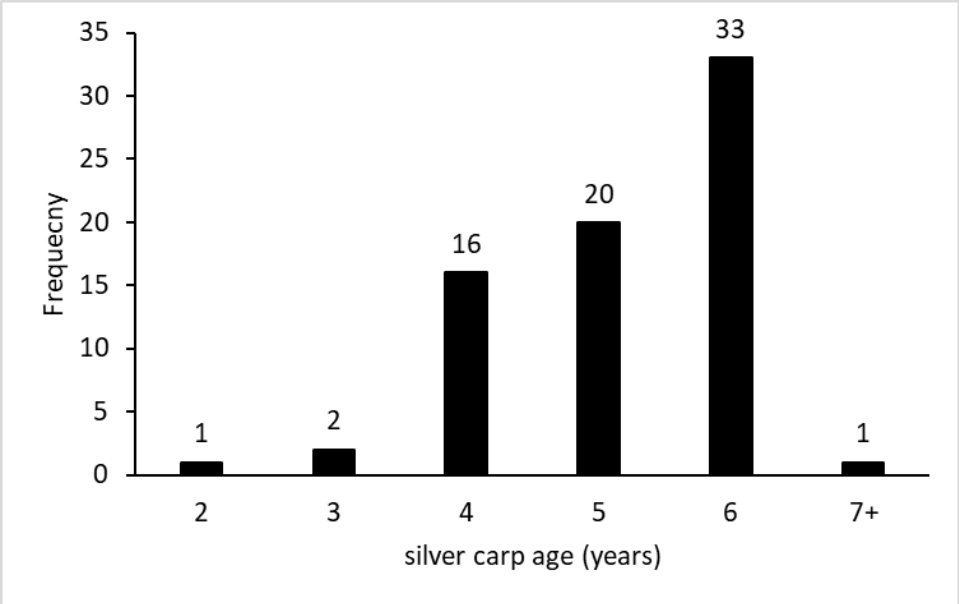

Figure 7. Age-frequency distribution for silver carp collected from Kentucky Lake in 2021 (N=73).

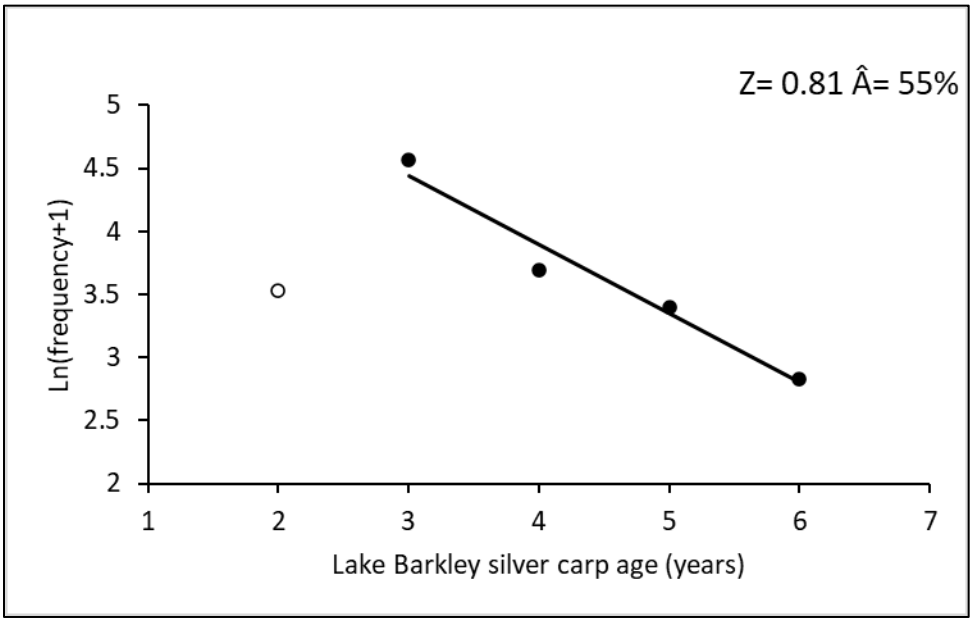

Figure 8. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Lake Barkley in 2021 (N=179, F1,2=48.99, P=0.02, R2= 0.96). The open circle represents fish not considered fully recruited to the gears used for data collection and thus not used to estimate A or Z.

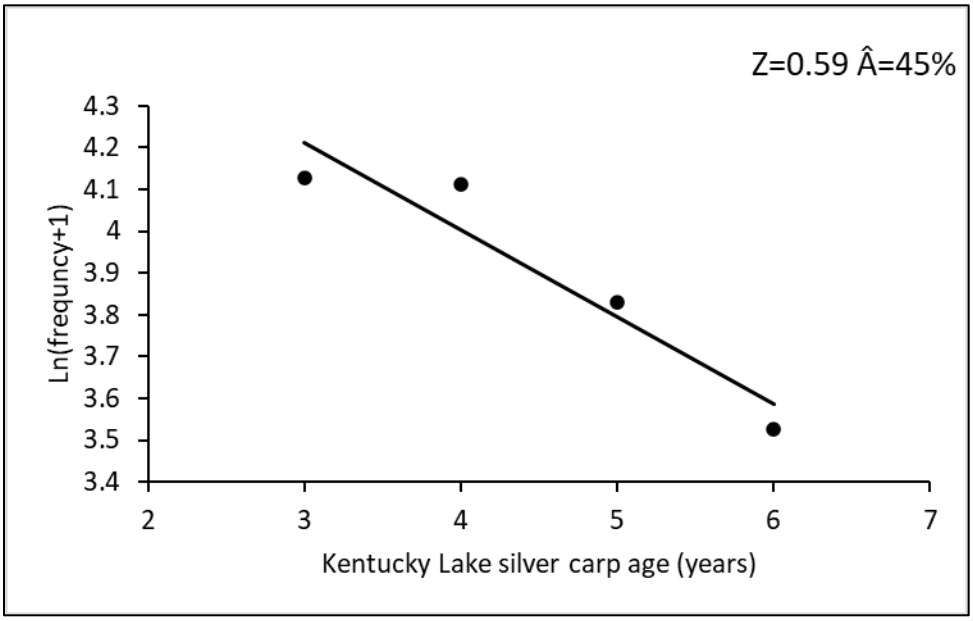

Figure 9. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Kentucky Lake in 2021 (N=199, F1,2=18.51, P=0.05, R2=0.90).

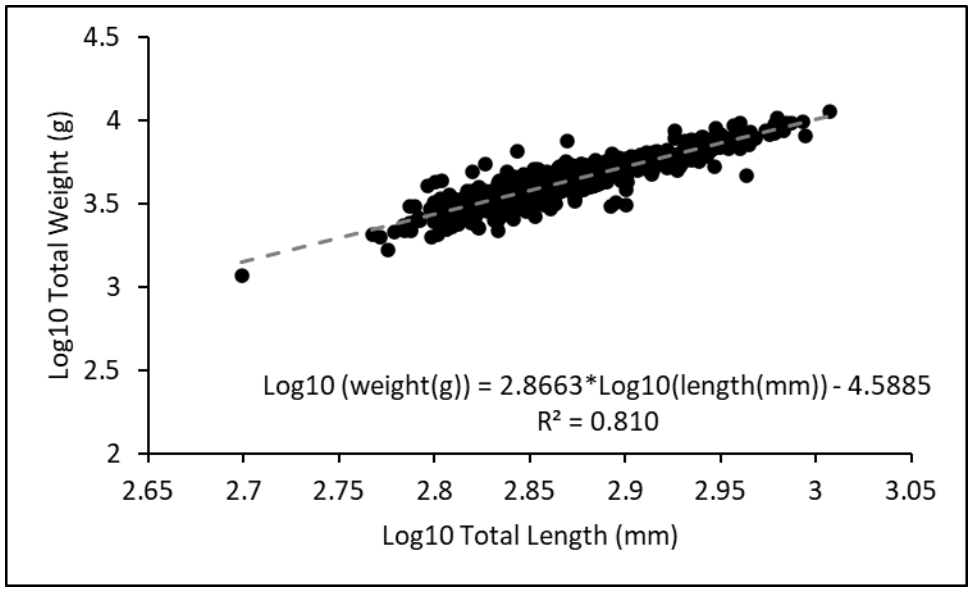

Figure 10. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Lake Barkley in 2021 with a regression line describing the relationship between lengths and weights (N=986).

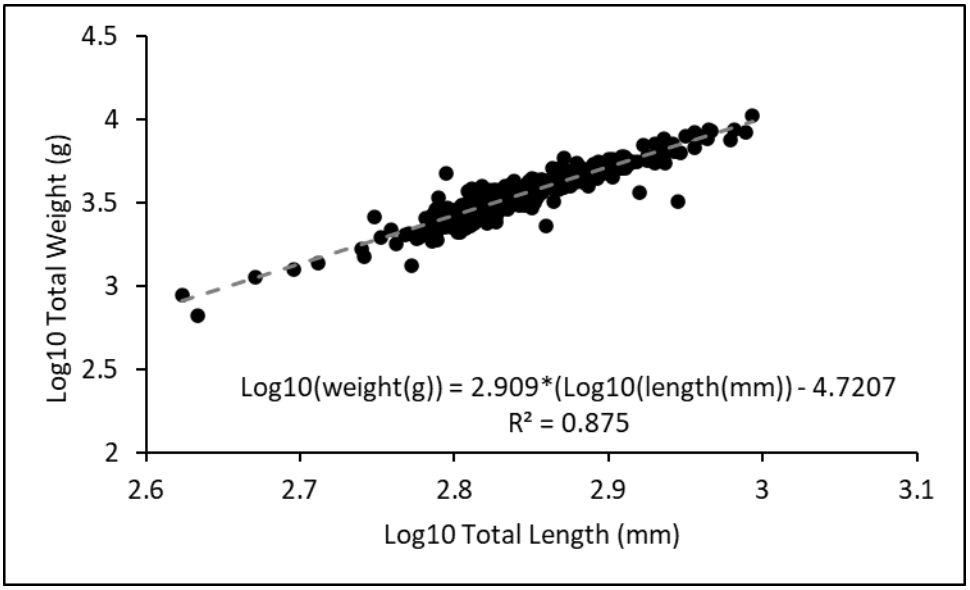

Figure 11. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Kentucky Lake in 2021 with a regression line describing the relationship between lengths and weights (N=569).

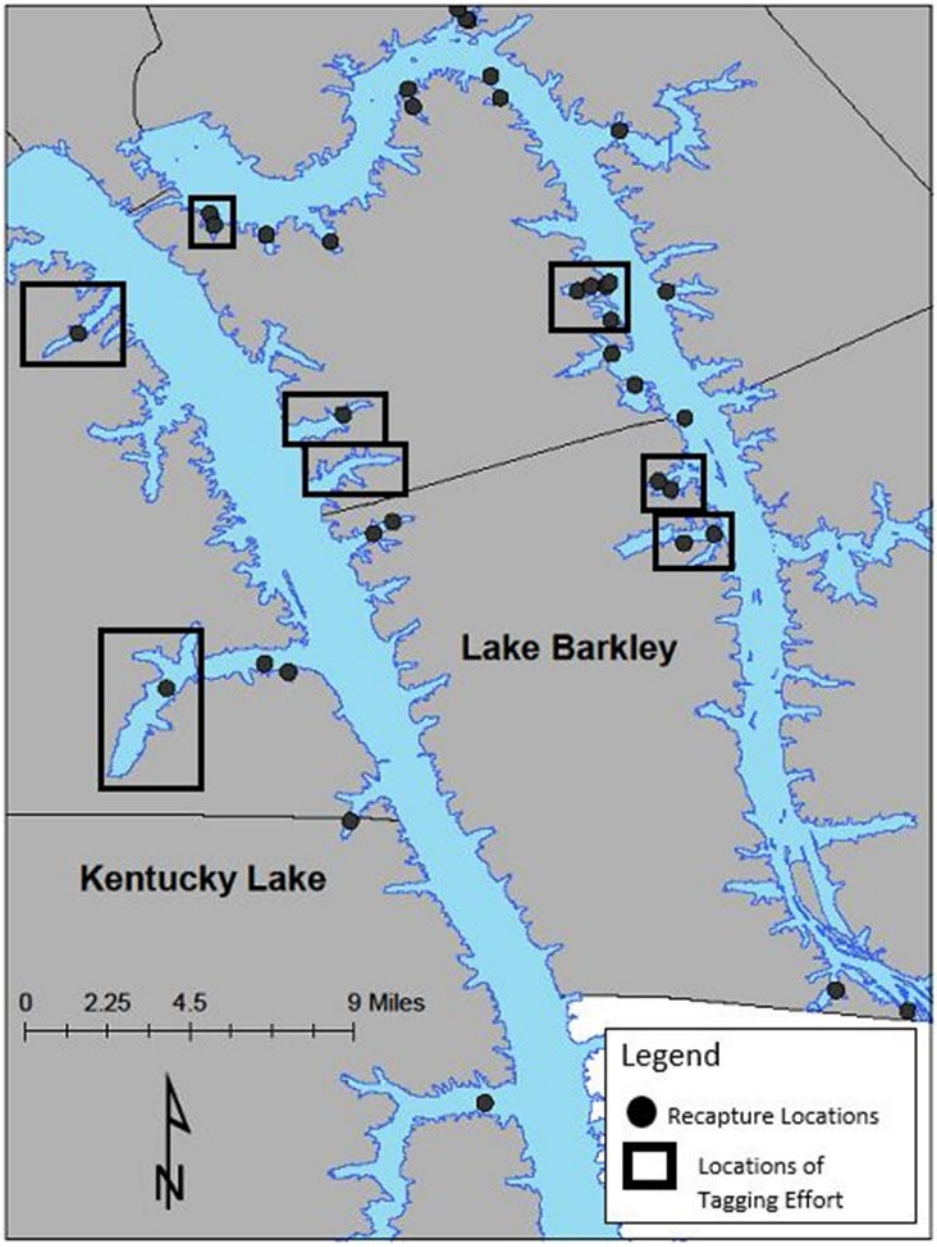

Figure 12. Locations of recaptured silver carp that were tagged as part of the mark-recapture effort to estimate abundance of silver carp in Barkley and Kentucky lakes.

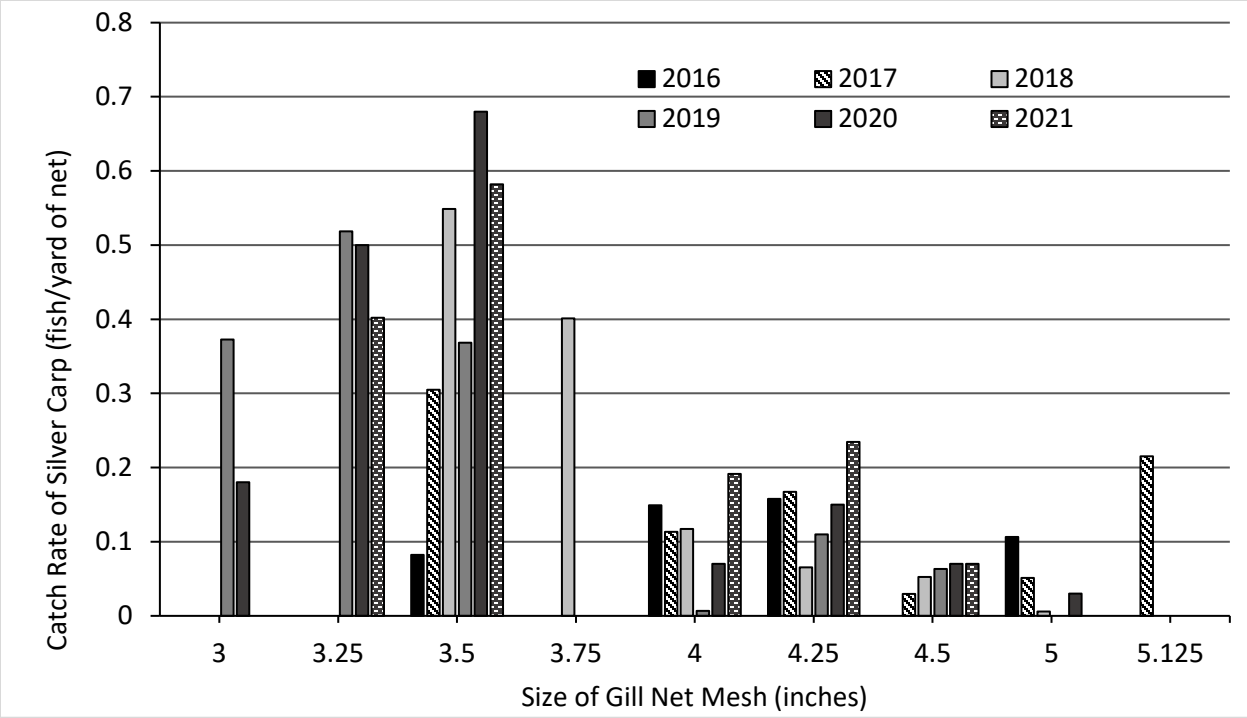

Figure 13. Catch rates (number of fish/yard of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program.

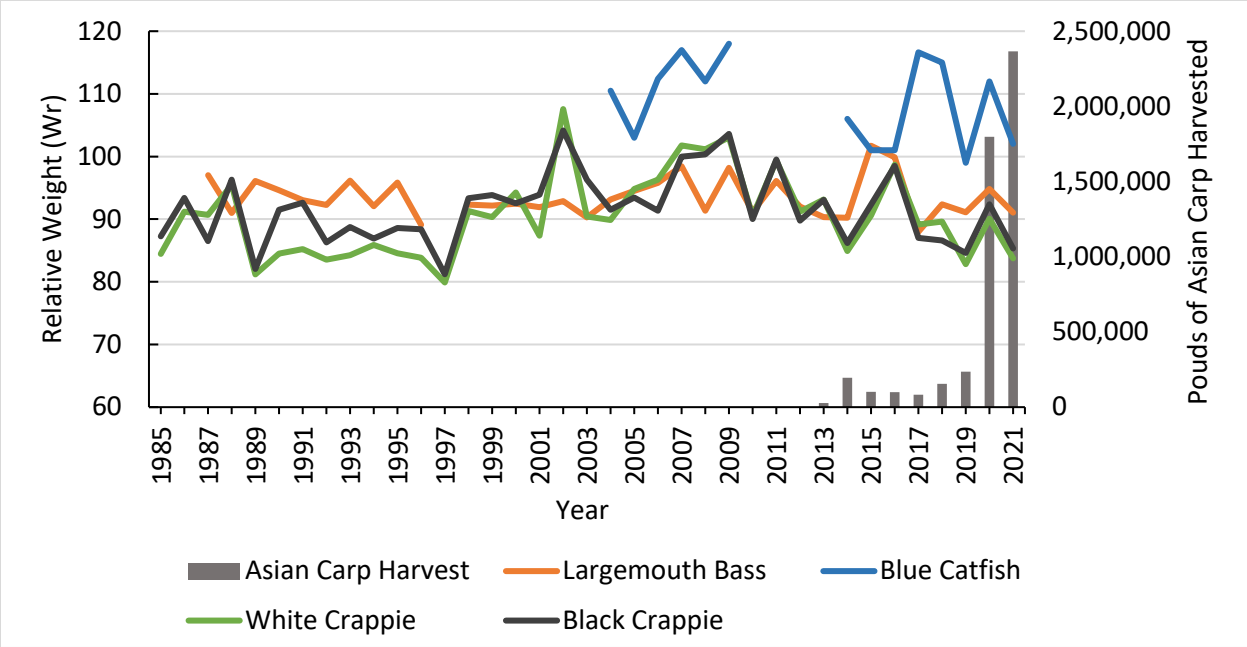

Figure 14. Mean relative weights of popular sport fish species sampled in Kentucky Lake annually, plotted against pounds of invasive carp harvested from Kentucky Lake by commercial

fishers under the Asian Carp Harvest Program since the program began in 2013.

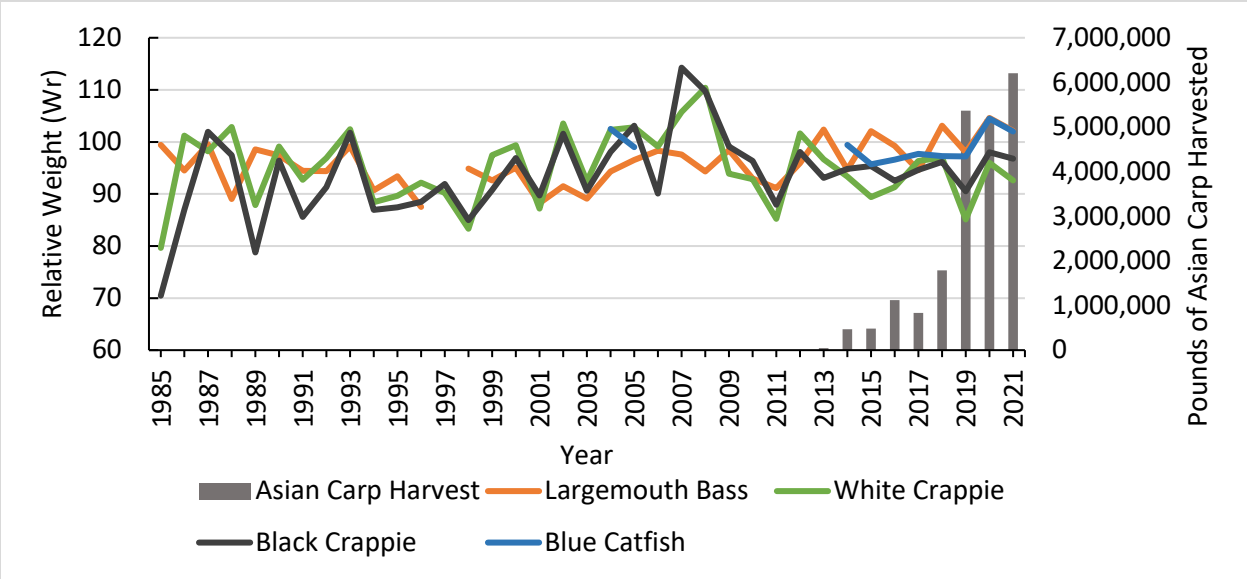

Figure 15. Mean relative weights of popular sport fish species sampled in Lake Barkley annually, plotted against pounds of invasive carp harvested from Lake Barkley by commercial fishers under the Asian Carp Harvest Program since the program began in 2013.

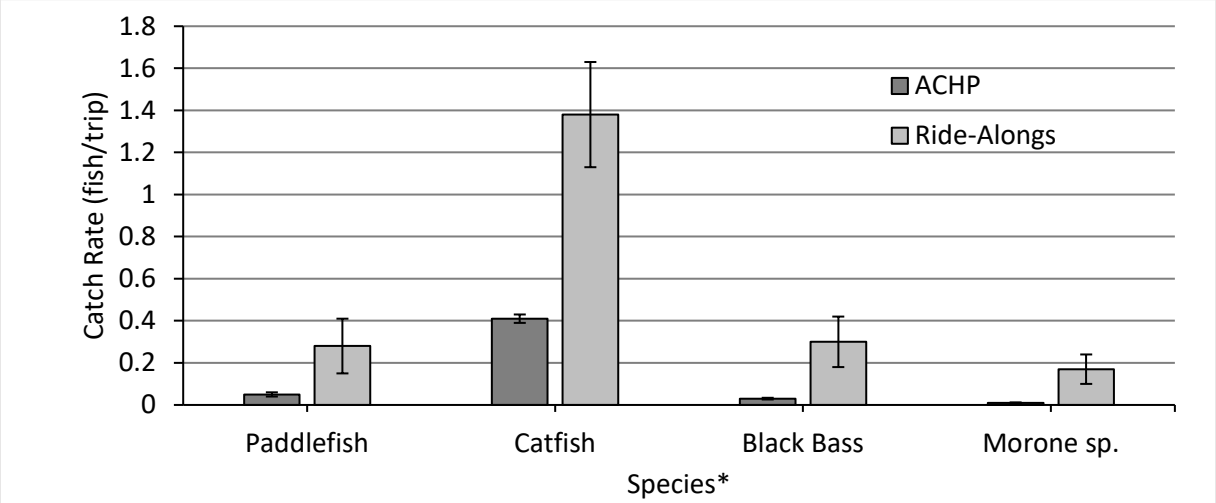

Figure 16. Comparison of catch rates (fish/trip) for some common bycatch species as reported by commercial fishers utilizing the Asian Carp Harvest Program (ACHP) and through KDFWR ride-alongs with commercial fishers in 2021. Error bars represent Standard Error values.

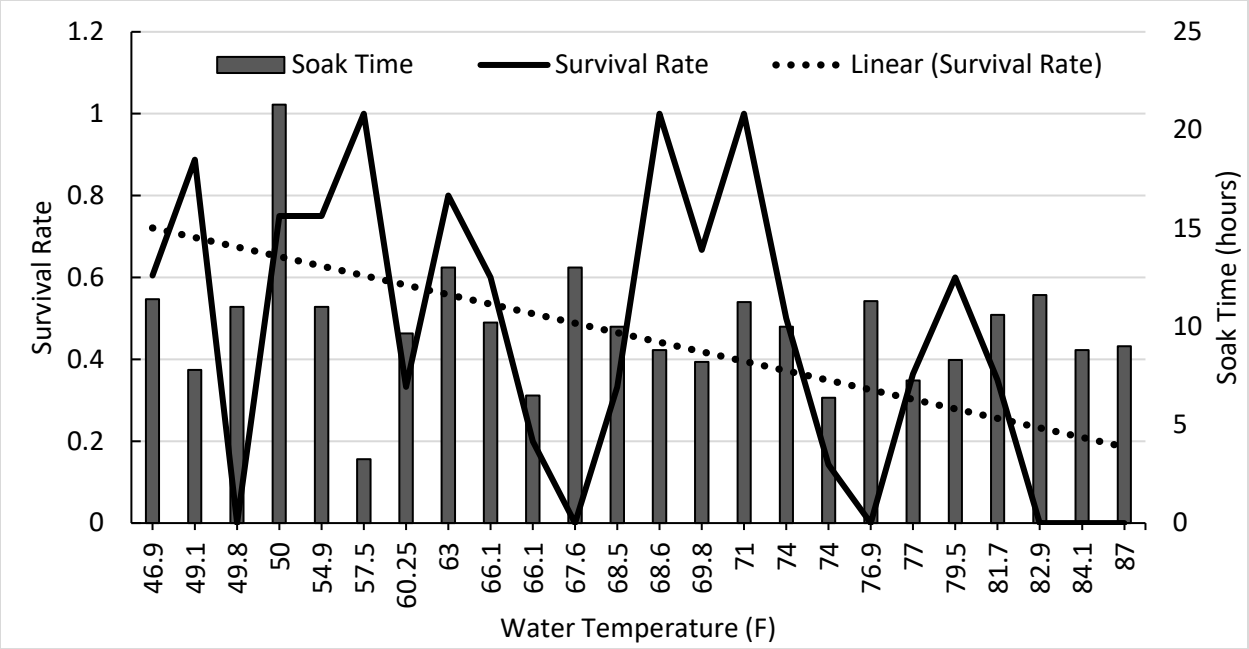

Figure 17. Survival rates of paddlefish observed caught as bycatch during ride alongs with commercial fishers on the Asian Carp Harvest Program.

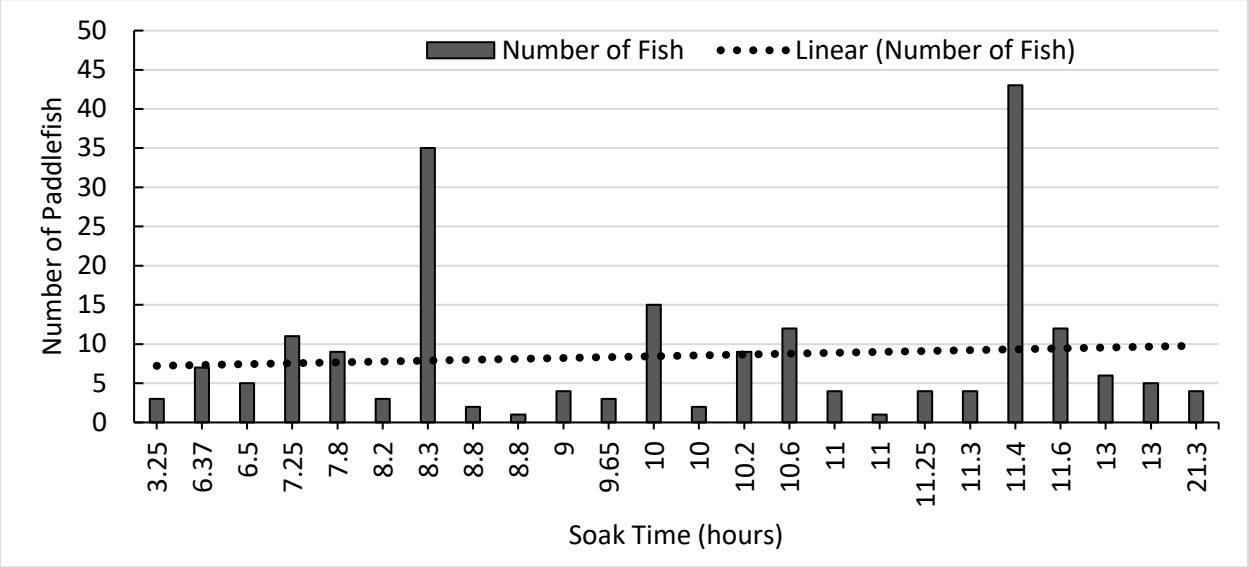

Figure 18. Number of paddlefish observed caught as bycatch during ride alongs with commercial fishers under the Asian Carp Harvest Program 2017 - 2021.

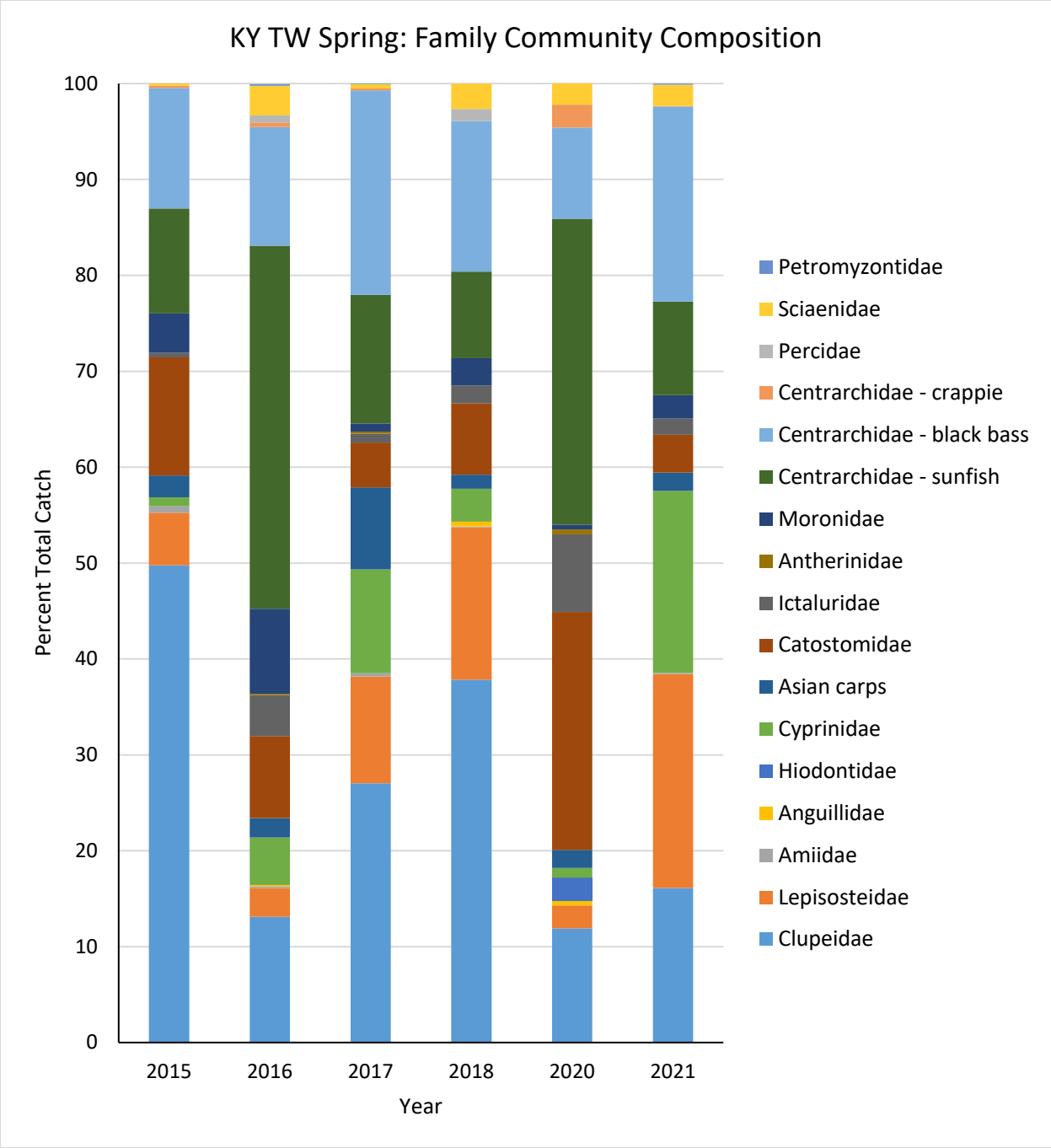

Figure 19. Comparison of percent total catch by number of each family identified from spring community sampling via electrofishing in the Kentucky Tailwater 2015-2021. Spring sampling was not conducted in 2019.

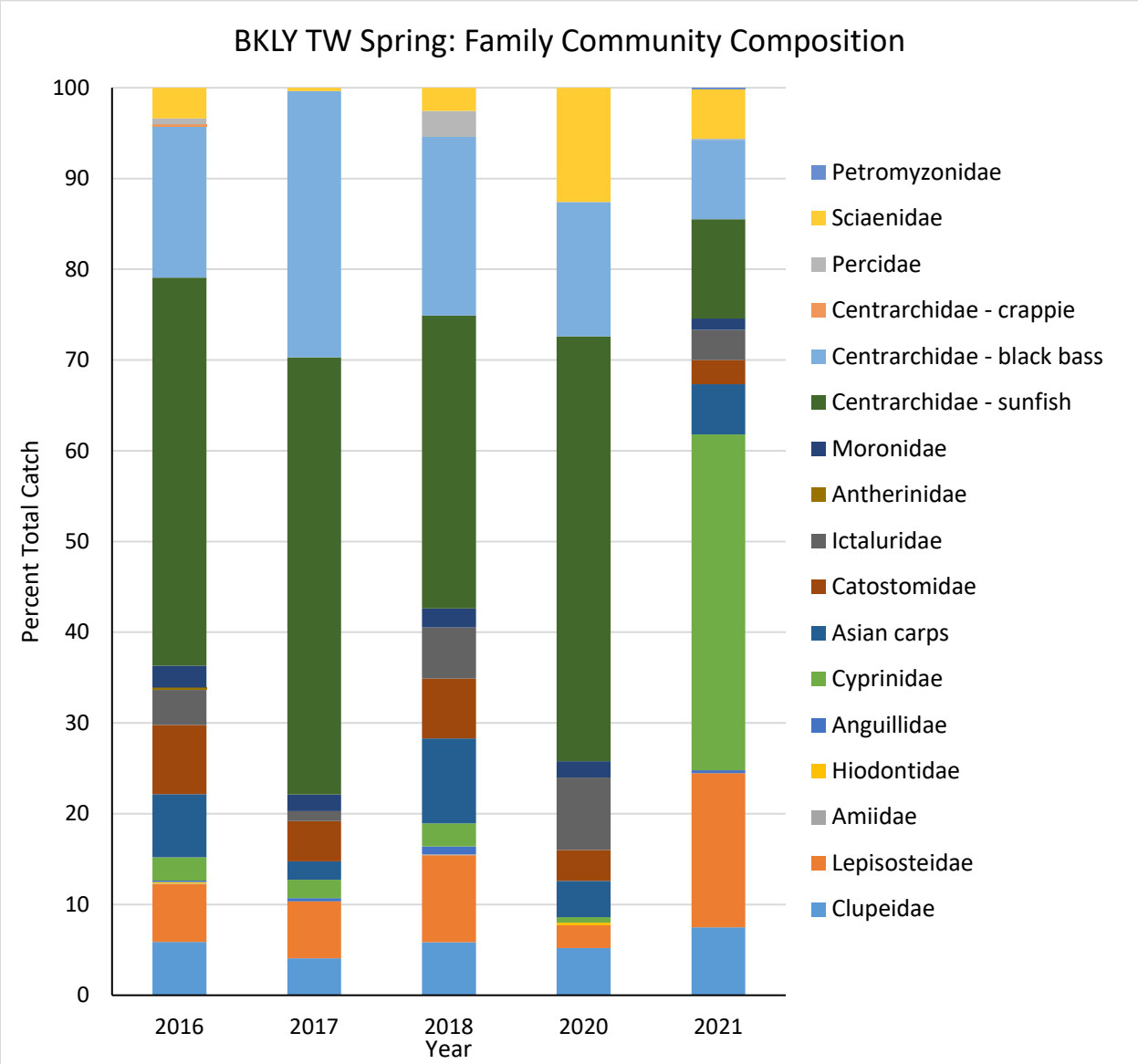

Figure 20. Comparison of percent total catch by number of each family identified from spring community sampling via electrofishing in the Barkley Tailwater 2016-2021. Spring sampling was not conducted in 2019.

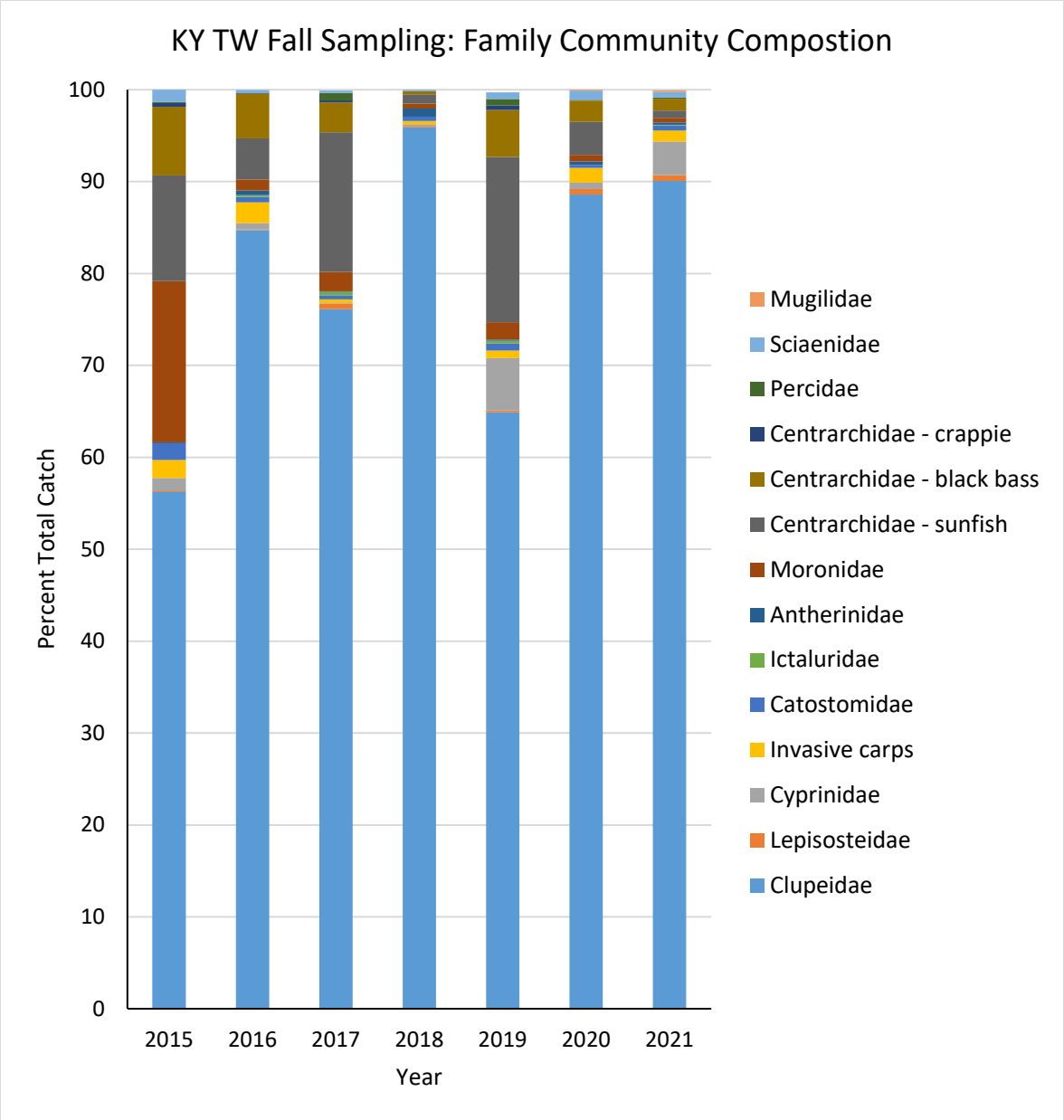

Figure 21. Comparison of percent total catch by number of each family identified from fall community sampling via electrofishing in the Kentucky Tailwater 2015-2021.

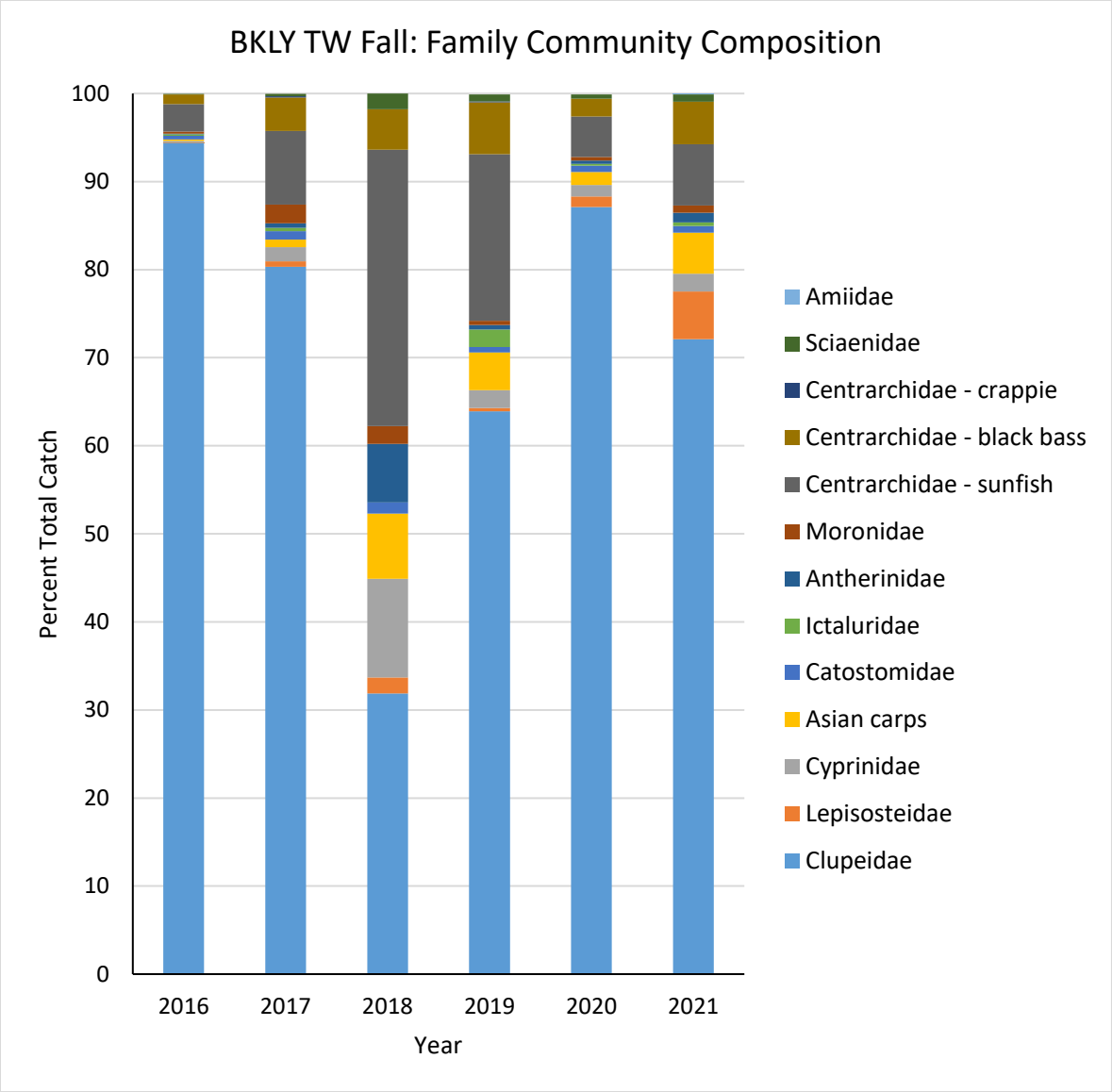

Figure 22. Comparison of percent total catch by number of each family identified from fall community sampling via electrofishing in the Barkley Tailwater 2016-2021.

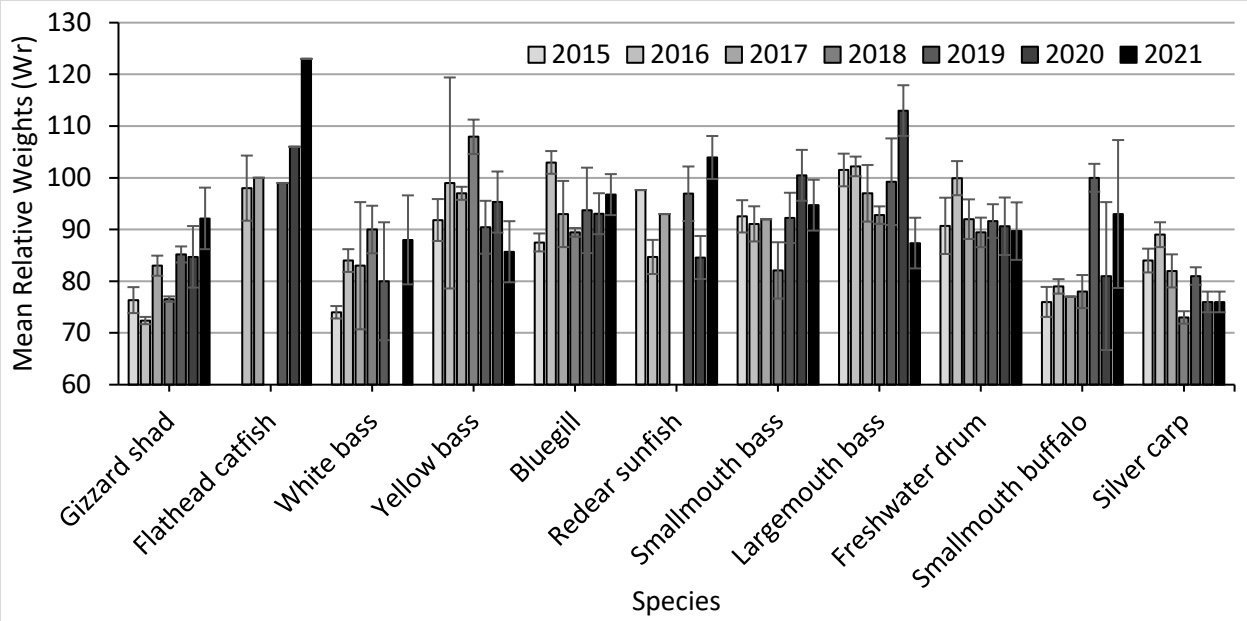

Figure 23. Mean relative weights (*W*r) of select species sampled through shoreline electrofishing in the Kentucky Tailwaters during the fall season 2015-2021.

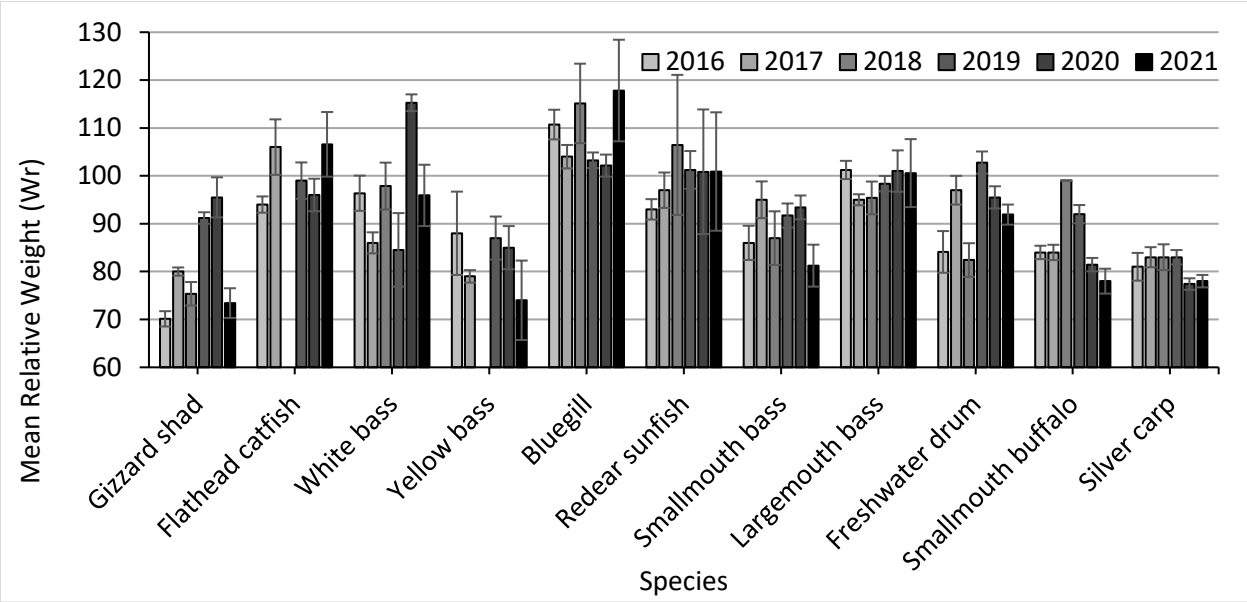

Figure 24. Mean relative weights (*W*r) of select species sampled through shoreline electrofishing in the Barkley Tailwaters during the fall season 2016-2021.

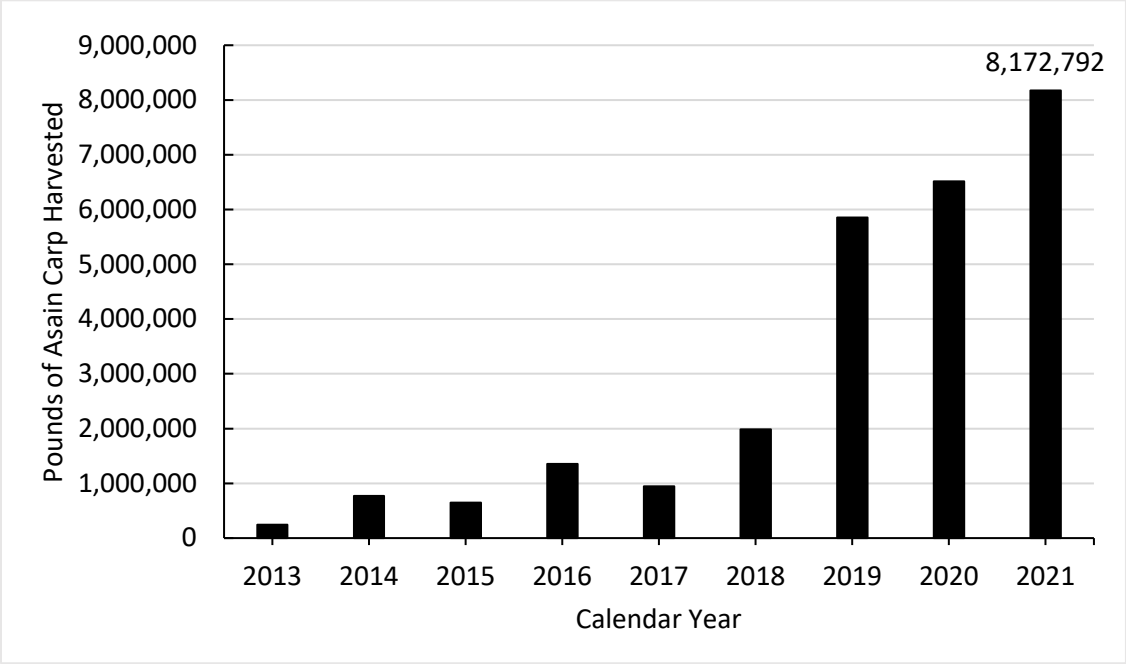

Figure 25. Pounds of Bigheaded carp harvested through the Asian Carp Harvest Program by calendar year. *2020 was the first year that grass carp harvest was tracked through the ACHP and accounted for an additional 111,190 lbs of invasive carp species harvested through the ACHP in 2020 and 74,430 lbs in 2021.

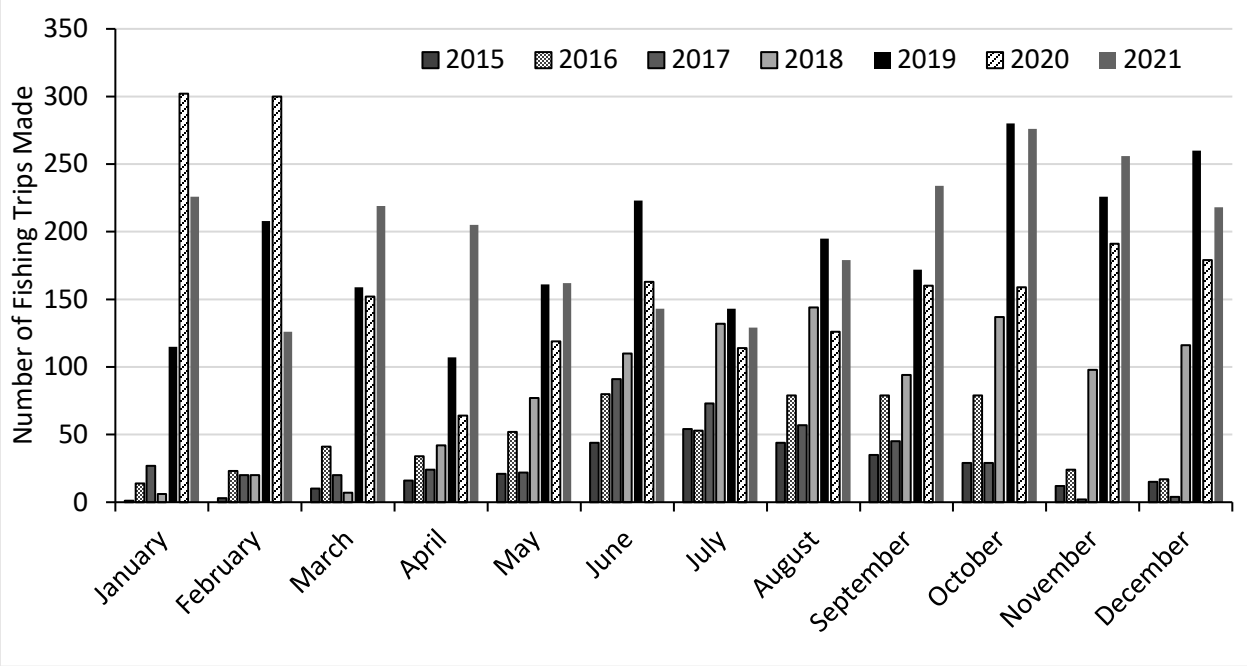

Figure 26. Number of fishing trips made monthly by commercial fishers fishing under the Asian Carp Harvest Program from January 2015 - December 2021.

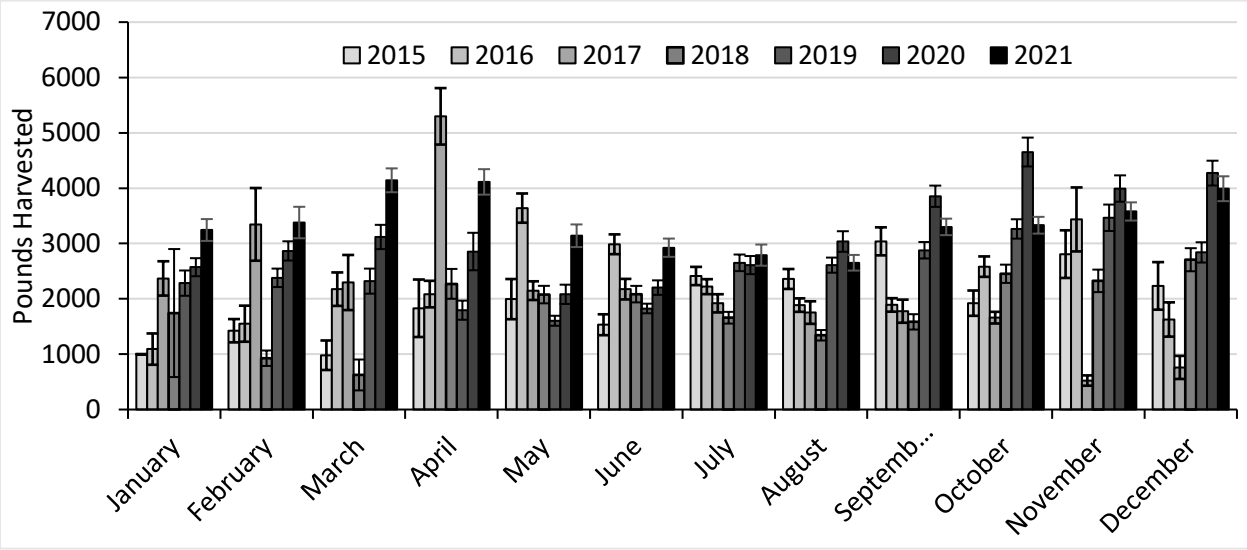

Figure 27. Monthly average total weight (lbs) of silver carp harvested per trip by commercial fishers fishing under the Asian Carp Harvest Program January 2015 - December 2021. Error bars represent standard error values.

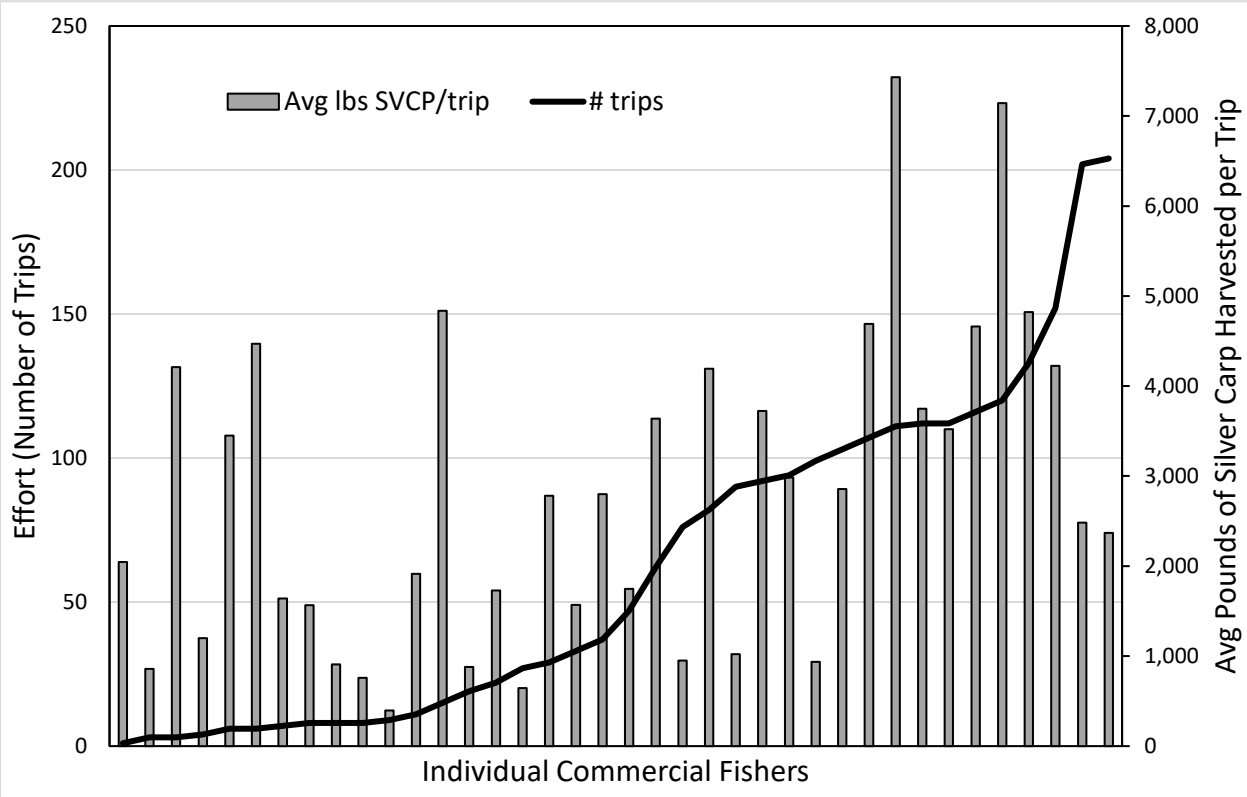

Figure 28. Average weight harvested per trip by individual commercial fishers compared to the

number of trips taken by those fishers under the Asian Carp Harvest Program in 2021.

Table 1. The number of invasive carp collected during each standard sampling period by lake in 2018-2021.

2021								
	Barkley Reservoir				Kentucky Reservoir			
Species Captured	April	July	October	Total	April	July	October	Totals
Bighead carp	3	16	1	20	0	10	15	25
Grass carp	0	4	0	4	0	6	3	9
Silver carp	39	43	31	113	12	25	38	75
Totals	42	63	32	137	12	41	56	109

2020								
	Barkley Reservoir				Kentucky Reservoir			
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	13	43	33	89	27	26	58	111

2019								
	Barkley Reservoir				Kentucky Reservoir			
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	77	68	51	196	114	93	66	273

2018								
	Barkley Reservoir				Kentucky Reservoir			
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
		322	199	521		492	509	1001

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 2021. 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	0.038	0.006	0.016
		July	0.004	0.023	0.004	0.010
		October	0.002	0.008	0.000	0.003
	Embayment	April	0.002	0.023	0.002	0.009
		July	0.006	0.041	0.004	0.017
		October	0.004	0.043	0.002	0.016
			Bar mesh size			
	Site	Month	3"	4"	5"	Mean Total CPUE
Kentucky Lake	Main Channel	April	0.000	0.000	0.000	0.000
		July	0.000	0.004	0.000	0.001
		October	0.009	0.019	0.000	0.009
	Embayment	April	0.006	0.011	0.006	0.008
		July	0.009	0.028	0.006	0.014
		October	0.011	0.028	0.004	0.014

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 2021.

Reservoir	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
	2021	1038	2980	5403
Kentucky	2018	950	2733	4963
	2019	930	2720	4987
	2020	986	2788	5018
	2021	994	2848	5301

Table 4. Average length and weight of silver carp harvested during ride-alongs with commercial fishers under the Asian Carp Harvest Program 2015-2021.

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
2021	949	27.9	8.9	0.07

Table 5. Measures of effort and catch reported by commercial fishers fishing under the Asian Carp Harvest Program by calendar year, January -December 2013 - 2021.

Water Body	Year	Number of Days/Trips	Number of fishers	Weight silver carp harvested (lbs)	Weight bighead carp harvested (lbs)	Weight grass carp harvested (lbs)
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
	2021	1,707	32	5,918,405	18,669	43,213
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
	2021	587	28	2,154,845	4,227	27,514
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
	2021	56	7	60,741	1,286	3,028
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
	2021	2,373	38	8,148,093	24,699	74,430

*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.

**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 - 2021. (CPUE = catch per unit effort)

Year	Net Bar Mesh Size (inches)	Effort (linear yards of net)	Number of Silver carp	Silver carp CPUE (fish/yard)	Number of Bighead carp	Number of Grass carp
2016	3.5	1,883	155	0.08		17
	4	2,067	308	0.15		1
	4.25	9,300	1,469	0.16	8	12
	5	16,983	1,811	0.11	44	13
	6	1,067	3	0.00		
2017	3.5	200	61	0.31	4	1
	4	1,983	225	0.11	1	1
	4.25	23,400	3,918	0.17	19	31
	4.5	2,283	68	0.03		
	5	4,125	212	0.05	3	1
	5.125	400	86	0.22	4	2
2018	3.5	6,883	3,778	0.55	8	24
	3.75	167	67	0.40		
	4	3,250	381	0.12	4	3
	4.25	14,100	920	0.07	54	8
	4.5	2,767	145	0.05	4	
	5	867	5	0.01	1	
2019	3	2,967	1,106	0.37	2	5
	3.25	9,600	4,979	0.52	10	83
	3.5	39,300	14,483	0.37	30	177
	4	300	2	0.01	0	0
	4.25	3,700	406	0.11	18	3
	4.5	2,567	162	0.06	5	1
	5	67	0	0.00	0	0
2020	3	100	18	0.18		
	3.25	3,933	1,968	0.50	2	17
	3.5	21,692	14,792	0.68	33	169
	4	533	38	0.07		
	4.25	2,100	319	0.15	6	
	4.5	1,583	104	0.07	5	
	5	267	9	0.03	4	
2021	3.25	2,117	851	0.40		6
	3.5	35,093	20,416	0.58	73	134
	4	2,583	494	0.19	17	3
	4.25	1,100	258	0.23	17	
	4.5	1,450	102	0.07	4	

Table 7. Relative weight (Wr) values of gizzard shad collected with boat electrofishing from Barkley and Kentucky lakes in October 2017-2021.

	Lake Barkley								
	Length group								
	7.0-11.0 in			>11.0 in			Total		
Year	No.	Wr	S.E.	No.	Wr	S.E.	No.	Wr	S.E.
2021	34	91	0.9				34	90	1
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
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		
Year	No.	Wr	S.E.	No.	Wr	S.E.	No.	Wr	S.E.
2021	36	93	0.6	49	91.31	1	85	92	0.5
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
2017	40	84	0.9	4	85	1.1	44	84	0.8

Table 8. 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
2021	126	98.4	19,433	87.7	733	99.0	126	81.0	20,418

*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 - 2021 only account for fish that were dead or alive upon release and not those that were harvested.

Table 9. 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 - 2021. Survival rate of fish is defined as fish that swim away after release.

		2016		2017		2018		2019		2020		2021	
	Species	Number captured	Survival rate	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%			2	100%
	Yellow bass	20	50%	1	100%	6	33%	4	75%			1	100%
	Striped bass	19	79%	1	100%	3	33%	5	80%	10	80%	1	100%
	Hybrid striped bass	2	100%			1	100%	5	80%	2	100%	1	100%
	Sauger	1	<1%	2	100%	3	33%	4	75%	2	50%	3	100%
	Spotted bass	1	100%										
	Largemouth bass	1	100%	5	80%	3	67%	25	80%	4	75%	9	100%
	Smallmouth bass							4	100%				
	Redear sunfish	1	100%			2	50%	6	83%			1	100%
	Black crappie					5	50%	1	100%	1	100%		
	White crappie			1	100%	6	67%	2	50%			1	100%
	Total	46	88%	10	96%	29	54%	57	82%	19	81%	19	100%
Catfish species	Blue catfish	27	74%	47	94%	42	91%	96	95%	32	100%	38	92%
	Channel catfish	10	80%	17	82%	12	100%	13	100%	5	100%	16	96%
	Flathead catfish	9	89%	19	100%	8	88%	40	100%	7	100%	26	100%
	Total	46	81%	83	92%	62	93%	149	98%	44	100%	80	95%
Rough Fish*	Paddlefish	83	48%	62	48%	38	32%	63	48%	26	50%	16	69%
	Lake sturgeon					1	100%					1	100
	Shovelnose sturgeon									3	100%		
	Skipjack herring	23	17%	47	13%	18	<1%	79	<1%	16	<1%	25	36
	Smallmouth buffalo	145	99%	13	85%	98	100%	186	98%	103	100%	173	99%
	Bigmouth buffalo	8	100%	4	100%	7	100%	34	97%	14	100%	12	75%
	Black buffalo	17	94%			2	100%	4	100%	1	100%		
	Common carp	48	98%	33	94%	27	100%	479	84%	36	97%	17	100%
	Gizzard shad	5	<1%	3	33%			3	<1%	1	100%		
	Freshwater drum	76	67%	27	52%	73	71%	71	63%	40	82%	54	94%
	River carpsucker	3	100%					35	97%	41	100%	5	100%
	Quillback									1	100%		
	Mooneye	3	<1%									1	100
	Chestnut lamprey	1	<1%										
	Threadfin shad	1	<1%										
	Blue sucker	49	80%					2	100%				
	Spotted sucker											1	100
	Spotted gar					2	50%	3	100%	1	100%	2	100%
	Longnose gar	8	88%	9	44%			9	67%	3	100%	3	100%
	Shortnose gar	9	44%	1	100%	2	50%	11	55%	5	100%	5	100%
	Total	571	77%	365	72%	392	83%	1277	87%	329	98%	299	92%

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

Table 10. 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 2016-2021. (S.E. = standard error).

	2016				2017				2018				2019				2020				2021			
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.	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	0.05	0.01	0.28	0.13
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	0.15	0.01	0.66	0.2
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	0.05	0.01	0.28	0.08
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	0.04	0.01	0.45	0.19
Catfish*	0.07	0.02			0.17	0.05			0.23	0.04			0.21	0.03			0.08	0.01			0.16	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			0.02	<0.01	0.16	0.06
Smallmouth bass	<0.01												<0.01	<0.01	0.08	0.05	0.02	<0.01	0.13	0.06	<0.01	<0.01		
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							<0.01	<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			0.02	0.02
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	<0.01	<0.01	0.02	0.02
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			<0.01	<0.01	0.02	0.02
White bass	<0.01		0.07	0.05									<0.01	<0.01	0.02	0.02	<0.01	<0.01			<0.01	<0.01	0.03	0.02
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	0.01	<0.01	0.05	0.03
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	<0.01	<0.01	0.02	0.02
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			<0.01	<0.01	0.02	0.02

*Commercial fishers do not always delineate species of catfish on their reports, therefore this row accounts for those catfish that were not identified to 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 11. Comparison of spring electrofishing CPUE values for select 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), 2020 (effort = 1.25 hours), and 2021 (effort = 3.75). (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		Kentucky Spring 2021	
	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.
Paddlefish			< 1	0.2								
Spotted gar	< 1	0.1	3	2.1			1	0.7			1	0.6
Skipjack herring	1	0.4	< 1	0.2	1	0.5	1	0.7			25	21.2
Gizzard shad	24	4.8	52	14.7	122	83.3	126	70.7	20	6.1	16	4.6
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	5	1.3
Smallmouth buffalo	3	1.0	27	6.1	13	3.3	19	4.6	38	10.5	8	1.6
Bigmouth buffalo	2	1.0	1	0.3	4	1.6	3	1.6			1	0.4
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			1	0.8
Flathead catfish			19	5.5	4	1.3	6	2.4	14	3.7	3	1.1
White bass	1	0.6	8	2.1	1	0.8	2	1.4			6	3.0
Yellow bass	1	0.5	31	12.3	3	1.3	5	5.0				
Striped bass									1	0.8	< 1	0.3
Bluegill	2	0.7	92	16.3	30	5.6	14	3.2	29	8.9	14	4.6
Longear sunfish	3	1.8	74	15.2	25	6.9	15	3.9	22	9.9	9	4.1
Redear sunfish	1	0.3	3	1.1	2	1.2	1	0.5	3	1.5	1	0.5
Smallmouth bass	1	0.8	10	2.5	13	3.2	6	2.6	2	1.6	34	8.0
Spotted bass	< 1	0.3	1	0.5	11	4.2	1	0.5			<1	0.3
Largemouth bass	5	1.6	46	5.2	76	7.9	46	9.2	14	3.3	17	5.3
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	6	1.7
White bass / Striped bass hybrid			2	0.8			2	2.3				

Table 12. Comparison of spring electrofishing CPUE values for select 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), 2020 (effort = 1.0 hours), and 2021 (effort = 3.0 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Barkley Spring 2016		Barkley Spring 2017		Barkley Spring 2018		Barkley Spring 2020		Barkley Spring 2021	
	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			4	1.6	2	1.5	1	1.0	4	1.2
Gizzard shad	19	8.1	18	14.1	24.5	18.4	15	1.0	27	17.4
Threadfin shad	6	5.0					1	1.0	1	1.0
Grass carp	7	2.9	1	1.0	0.5	0.5			2	0.6
Silver carp	24	9.8	10	2.6	42	28.4	13	7.2	20	3.8
Smallmouth buffalo	23	3.6	22	3.5	28	6.7	11	3.4	8	2.4
Bigmouth buffalo	1	0.6	2	1.2	1	1.0			1	0.5
Black buffalo	1	0.8			0.5	0.5				
Shorthead redhorse									< 1	0.3
Channel catfish	1	0.8			0.5	0.5				
Flathead catfish	16	5.5	6	2.6	25	5.4	26	7.8	14	3.5
White bass	8	3.6	6	3.5	7.5	4.2	4	2.8	5	2.7
Yellow bass	2	1.0	4	4.0	2	1.1	2	1.2		
Striped bass	1	1.1							< 1	0.3
White bass / Striped bass hybrid									< 1	0.3
Green sunfish	1	0.8	2	1.2	2	1.1	4	2.8	1	0.5
Bluegill	69	16.1	55	26.9	56.5	31.2	64	15.9	20	6.1
Longear sunfish	110	23.6	183	83.6	80.5	42.4	70	18.5	24	4.7
Redear sunfish	10	2.6	20	5.9	7	2.0	14	6.6	2	0.8
Smallmouth bass	10	2.7	3	3.0	10.5	2.3	10	4.2	16	3.5
Spotted bass	1	0.6					3	1.9	< 1	0.3
Largemouth bass	64	6.2	155	35.3	79	10.6	35	5.3	21	4.2
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	23	6.2

Table 13. Length frequency and CPUE (fish/hr) for select species of fish collected during 3.75 hours of electrofishing at the Kentucky Tailwater in fall of 2021. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																																	TOTAL	CPUE (fish/hr)	S. E.
	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	28	30	31	33	34	35	37	40			
Skipjack herring*		16	76	15	2						1																							165	44	17.6
Gizzard shad*		5	3	2	3	2	7	7	15	16	11	11	7	2		1																		165	44	21.4
Threadfin shad*	6	163	85																															2492	665	291.6
Grass carp																		1	1					2				1						5	1	0.8
Silver carp																	1		2	4		3	3	6	6	3	1		1	1	1			32	9	3.1
Bighead Carp																																1		1	<1	0.3
Smallmouth buffalo										1		3		5	3	1		1															1	15	4	1.3
Bigmouth Buffalo														1																				1	<1	0.3
Flathead catfish							1	1																										2	1	0.4
White bass	2	1	1	1	1	1	1	3	1				1																					13	3	1.8
Yellow bass					1	1	1																											3	1	0.4
Bluegill	4			2	6	3																												15	4	2.1
Longear sunfish			3	5																														8	2	1.2
Redear sunfish										2																								2	1	0.4
Smallmouth bass			3	6	3		5	2				2																						21	6	2.6
Largemouth bass				1					2	2	3			3	3	2	1	1				1												19	5	1.7
Sauger						1								2	1																			4	1	0.5
Freshwater drum			1	2	2			1						1	1	3	1		2	2	2	1	1											20	5	1.4
Striped mullet																		1	2	1	1													5	1	0.8

* species were randomly subsampled

Table 14. Comparison of fall electrofishing CPUE for selected species collected in Kentucky Lake tailwaters 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). 2020 (effort = 2.75 hours), and 2021 (effort = 3.75 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	2015		2016		2017		2018		2019		2020		2021	
	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.	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	44	17.6
Gizzard shad	275	58.6	184	78.0	163	61.1	22	10.2	240	92.1	163	69.7	44	21.4
Threadfin shad	251	176.3	1690	1251.0	1263	637.0	2557	1845.1	27	14.9	712	241.1	665	291.6
Grass carp	13	1.9	6	2.5	2	0.7			6	2.8	8	4.7	1	0.8
Silver carp	6	2.6	44	22.4	4	1.6	9	6.9	4	2.0	9	4.9	9	3.1
Bighead Carp													< 1	0.3
Smallmouth buffalo	10	2.6	9	3.7	5	2.1	1	0.8	8	3.0	2	0.8	4	1.3
Bigmouth buffalo					1	0.4	2	1.0					< 1	0.3
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	1	0.4
White bass	8	4.3	7	4.0	< 1	0.3	6	5.6	4	1.9	5	2.5	3	1.8
Yellow bass	162	83.5	17	13.3	26	4.1	7	4.3	18	7.8	3	1.6	1	0.4
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	4	2.1
Longear sunfish	14	14.0	48	12.0	80	25.0	7	4.8	67	15.4	10	3.9	2	1.2
Redear sunfish	1	1.0	6	2.3	6	1.6			15	3.9	2	1.1	1	0.4
Smallmouth bass	9	2.5	21	5.2	11	3.2	2	1.0	29	12.3	10	2.8	6	2.6
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	5	1.7
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							1	0.5
Freshwater drum	13	5.7	6	1.5	4	0.7	4	2.2	8	2.5	11	2.8	5	1.4
White bass/Striped bass hybrid	1	1.0	1	1.1	1	0.5								
Striped mullet											1	1.0	1	0.8

Table 15. Comparison of fall electrofishing CPUE for all species collected in Lake Barkley tailwaters in 2016 (effort = 1.99 hours), 2017 (effort = 3.0 hours), 2018 (effort = 1.0 hour), 2019 (effort = 3.0 hours), 2020 (effort = 2.75 hours), and 2021 (effort = 3.0 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	2016		2017		2018		2019		2020		2021	
	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	< 1	0.5	8	2.9	35	18.0	324	158.4	41	10.78	28	10.9
Gizzard shad	209	52.4	104	18.2	23	8.1	362	224.8	189	49.03	8	5.0
Threadfin shad	4598	1818.7	1252	602.1	67	12.8	30	18.8	1298	719.49	378	182.4
Grass carp	5	2.6	1	0.5			6	1.7	3	1.22	3	0.7
Silver carp	4	2.0	14	7.7	29	17.2	42	33.4	23	6.58	24	6.4
Smallmouth buffalo	15	7.6	10	2.7	1	1.0	5	3.2	10	3.75	3	1.6
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	2	1.2
White bass	7	3.9	3	1.1	3	3.0	1	0.7	1	0.56	2	1.4
Yellow bass	2	0.7	28	16.0			4	3.0	3	1.24	2	1.0
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	21	5.9
Longear sunfish	102	25.0	83	16.8	46	25.4	153	30.5	41	10.06	14	4.7
Redear sunfish	8	2.1	3	1.2	2	1.2	3	1.2	2	0.83	3	1.2
Smallmouth bass	7	2.3	9	1.2	4	1.6	29	7.2	8	1.53	13	3.0
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	15	5.1
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	<1	0.3
Freshwater drum			5	1.5	7	4.7	9	3.4	8	1.87	5	1.7
White bass/ Striped bass	< 1	0.4	3	2.3	4	4.0			1	0.73	1	1.0

Table 16. Length frequency and CPUE (fish/hr) for select species of fish collected during 3.0 hours of electrofishing at the Barkley Tailwater in fall of 2021. (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	29	30	31	32	35			
Skipjack herring			19	42	20		2	1	1																								85	28	10.9
Gizzard shad						3	1	4	2	1	4	3	4	1																			23	8	5.0
Threadfin shad*		6	68	106	1	3	1																										1133	378	182.4
Grass carp																												1	3	1	2	1	1	9	3	0.7
Silver carp																		1	1	2	1	3	2	6	8	13	18	7	5	1	2	1		71	24	6.4
Smallmouth buffalo													2				2	3		1	1													9	3	1.6
Flathead catfish											1				2		1					1				1			1					7	2	1.2
White bass			3			1	1	1																									6	2	1.4
Yellow bass			2	1		1	1																										5	2	1.0
Bluegill	1	8	23	2	12	9	8																										63	21	5.9
Longear sunfish			3	14	25	1																											43	14	4.7
Redear sunfish		1	1	1	1				1	3																							8	3	1.2
Smallmouth bass				7	16	9	1	2		1		1		1		1																	39	13	3.0
Largemouth bass				1	2	13	8	1	1	4	4	2		1	1	2		1	2		1												44	15	5.1
Black crappie									1																								1	<1	0.3
Freshwater drum														1		6	2		3		1				1								14	5	1.7
White bass/Striped bass hybrid																1			1					1										3	1	1.0

* species were randomly subsampled

Table 17. Mean relative weight (*Wr*) and standard error for a subsample of fish collected during fall electrofishing at Kentucky Tailwaters in 2015 - 2021. (S.E. = standard error)

Species	2015			2016			2017			2018			2019			2020			2021		
	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.	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	79	92	6.0
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		1	123	
Yellow bass	29	74	1.2	29	84	1.8	104	83	2.2	7	90	12.3	33	80	4.6	4			3	88	8.6
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	8	86	5.9
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	11	97	4.0
Redear sunfish	1	98	0.0	10	85	6.9	28	93	3.3				42	97	2.3	4	85	5.3	2	104	4.2
Smallmouth bass	6	93	3.1	13	91	2.0	9	92	3.4	1	82		4	92	5.5	6	100	4.9	9	95	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	17	87	4.9
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										4	78	4.2
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	18	90	5.6
Smallmouth buffalo	10	76	2.9	15	79	1.5	22	77	1.4	1	78		29	100	3.2	6	81	2.7	14	93	14.3
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	32	76	2.0

Table 18. Mean relative weight (Wr) and standard error for a subsample of fish collected during fall electrofishing at Barkley Tailwaters in 2016 - 2021. (S.E. = standard error)

Species	2016			2017			2018			2019			2020			2021		
	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	96	70	1.6	176	80	0.9	18	75	2.5	45	91	1.2	53	96	4.2	20	73	3.1
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	6		6.8
Yellow bass	2	88	8.7	73	79	1.3				11	87	4.5	7	85	4.5	3	74	8.3
White bass	11	96	3.7	8	86	2.2	3	98	4.9	3	85	7.7	2	115	1.8	3	96	6.4
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	3	73	5.0
Bluegill	49	111	3.1	107	104	2.5	31	115	8.3	85	103	1.6	63	102	2.3	29	118	10.6
Redear sunfish	17	93	2.1	9	97	3.7	2	106	14.6	9	101	3.9	4	101	13.0	4	101	12.4
Smallmouth bass	4	86	3.6	11	95	3.8	3	87	5.6	22	92	2.5	11	93	2.5	7	81	4.4
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	20	101	7.1
White crappie				3	88	6.6				1	92		1	116				
Black crappie				5	86	6.3				1	76		1	85		1	93	
Freshwater drum	6	84	4.4	14	97	3.0	7	82	3.5	27	103	2.3	22	96	2.3	14	92	2.1
Smallmouth buffalo	21	84	1.4	28	84	1.6	1	99		16	92	1.9	27	81	1.4	9	78	2.6
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	70	78	1.3

Table 19. Summary of invasive carp harvest and expenditures of Subsidy funds under the Asian Carp Harvest Program 2016-2021.

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
2021	$646,072.68

Table 20. Fishing effort and total weight (lbs) of invasive carp harvested during KDFWR ride-alongs with commercial fishers fishing under the Asian Carp Harvest Program 2015 - 2021.

Year	Effort *	Mean effort per trip	S. E.	Number of ride alongs	Number of fishers	Total WT of bighead carp harvested (lbs)	Total WT of silver carp harvested (lbs)	Total WT of grass carp harvested (lbs)
2015	31,583	1,053	78.4	32	8	4,086	68,139	855
2016	30,700	1,096	73.2	28	4	1,067	69,765	630
2017	32,225	1,040	88.6	31	9	763	73,958	746
2018	32,193	1,238	86.1	26	11	957	60,938	583
2019	57,433	1,197	79.8	48	19	1,123	160,981	2,916
2020	30,208	1,007	58.0	30	16	1,226	143,257	1,372
2021	42,193	728	53.0	59	18	1,780	198,249	1,130

*effort is calculated in yards of gillnet fished.

Table 21. 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 - 2021. (S.E. = standard error)

Year		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
2021	Ride Alongs	3,389	353.2	31	9.4	20	4.0
	Commercial Fisher Reports	3,434	56.9	10	1.2	31	1.9

*2020 was the first year that grass carp harvest through the Asian Carp Harvest Program was required on commercial fishing reports.

Appendix B: Figures and Tables – Murray State:

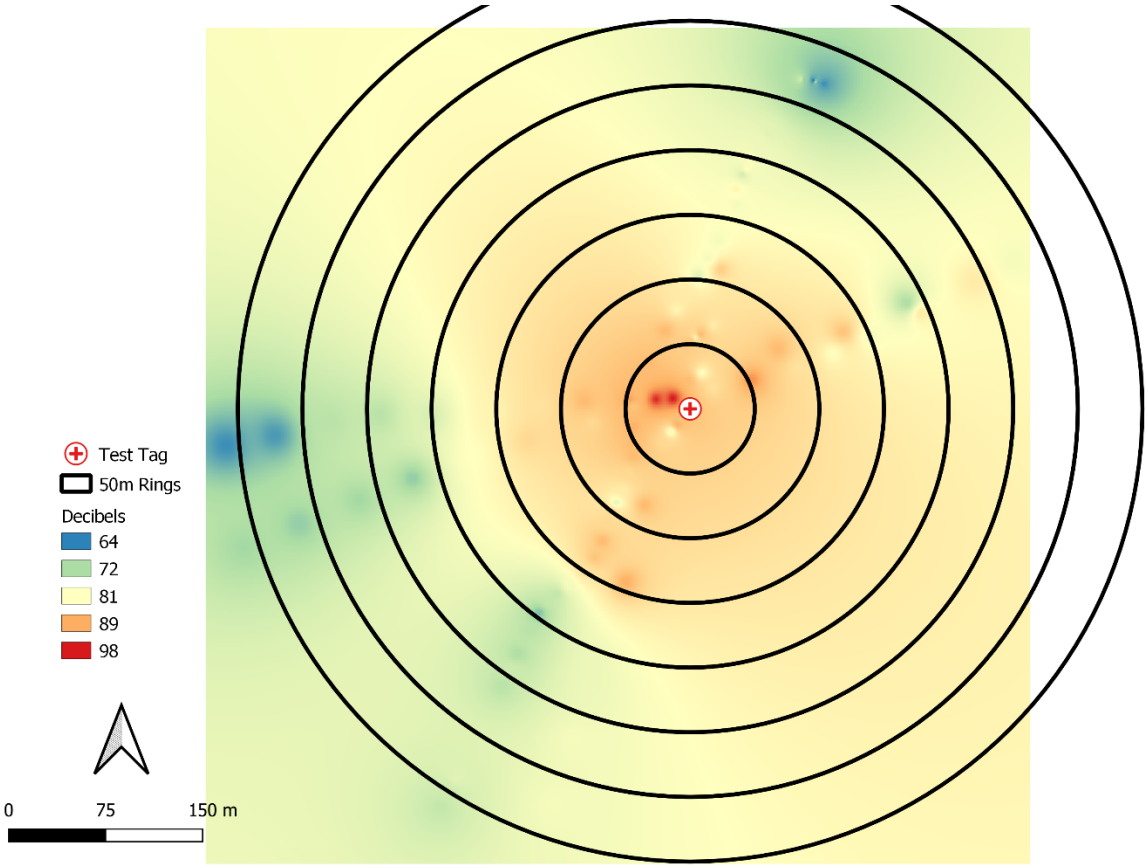

Figure 1. Signal intensity (decibels) compared to distance from the test tag. Rings are plotted at 50 m intervals.

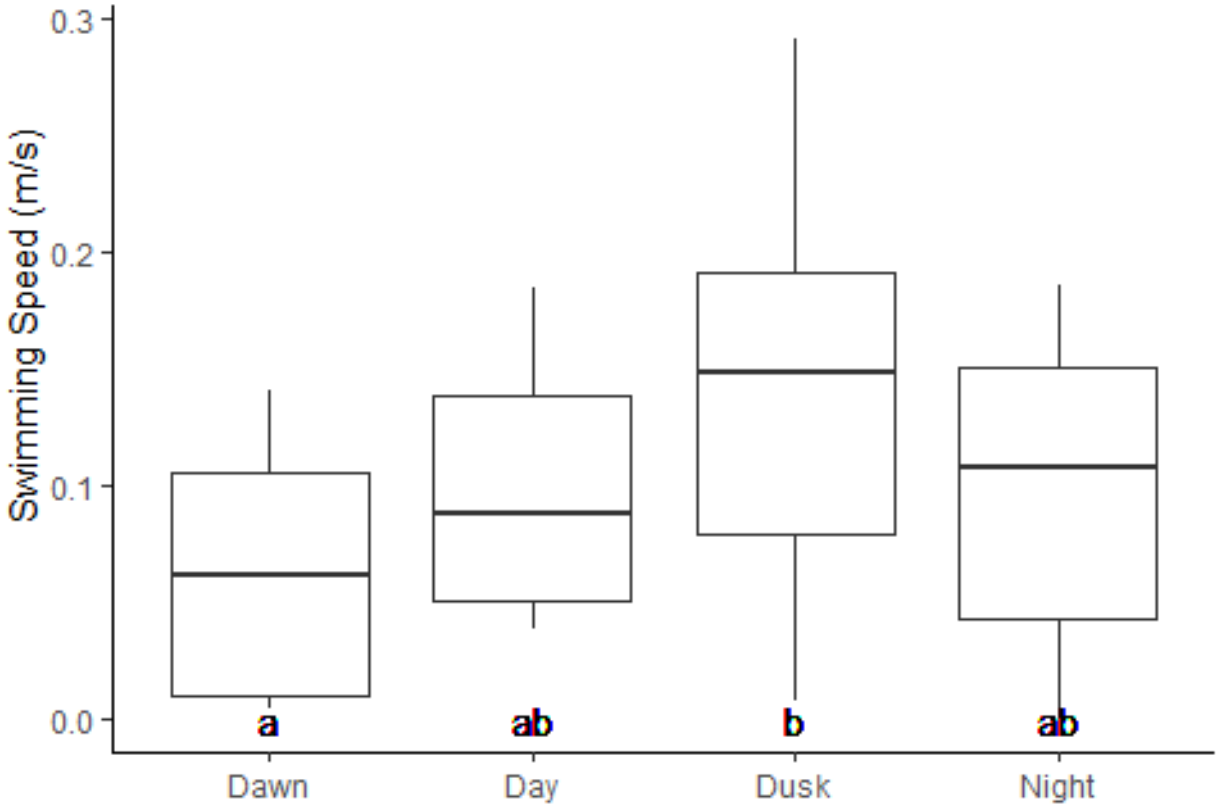

Figure 2. Boxplot comparing Silver Carp swimming speed (m/s) among several time periods. Central horizontal lines indicate the median swimming speed while box ends indicate the first and third quantiles. Time periods with different letters were significantly different based on a repeated measures ANOVA ($F_{3,34} = 3.91$, $p = 0.02$).

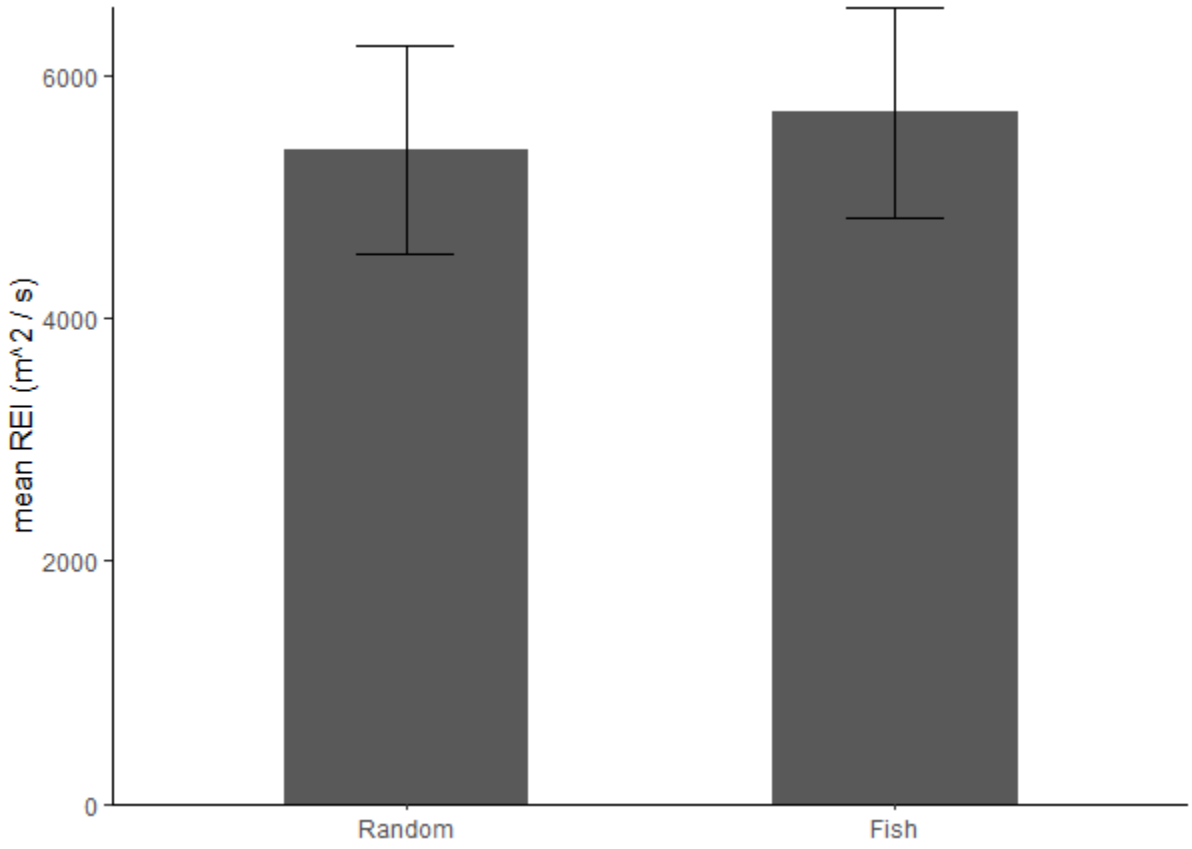

Figure 3. Mean Relative Exposure Index (REI) for random locations and fish locations in Kentucky Lake. Mean REI was not significantly different based on a paired t-test ($t_{202} = 0.56$, $p = 0.57$). Error bars represent the standard error.

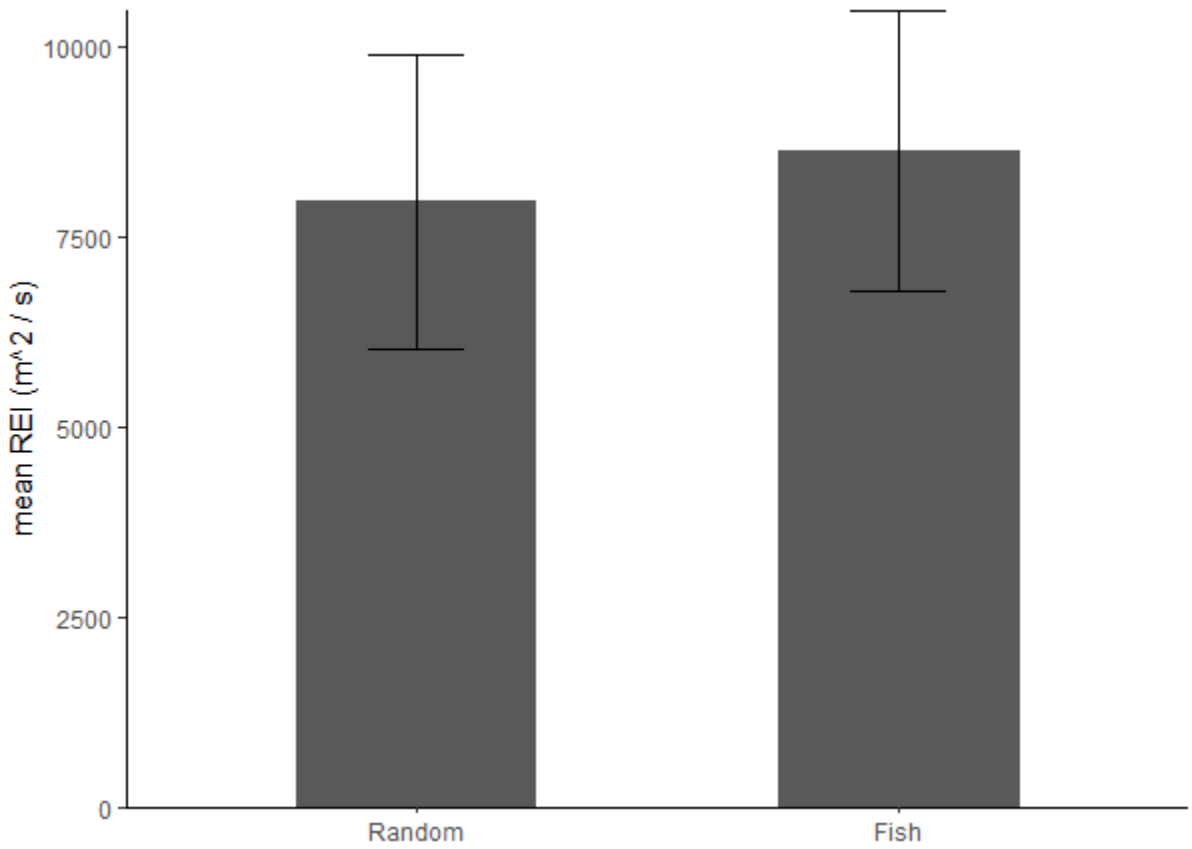

Figure 4. Mean Relative Exposure Index (REI) for random locations and fish locations in Lake Barkley. Mean REI was not significantly different based on a paired t-test ($t_{38} = 1.28$, $p = 0.21$). Error bars represent the standard error.

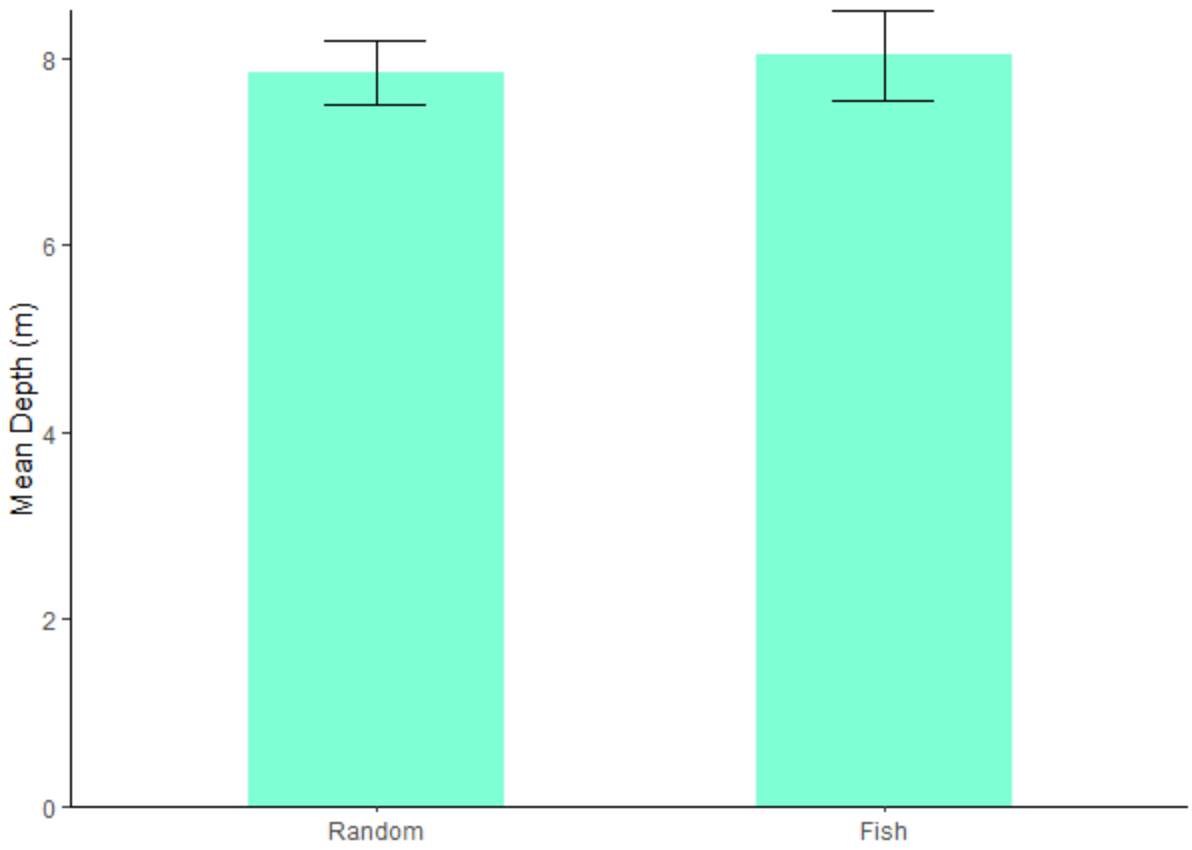

Figure 5. Mean depth (m) for random locations and fish locations in Kentucky Lake. Mean depth was not significantly different based on a paired t-test (t_{278} = -0.51, p = 0.61). Error bars represent the standard error.

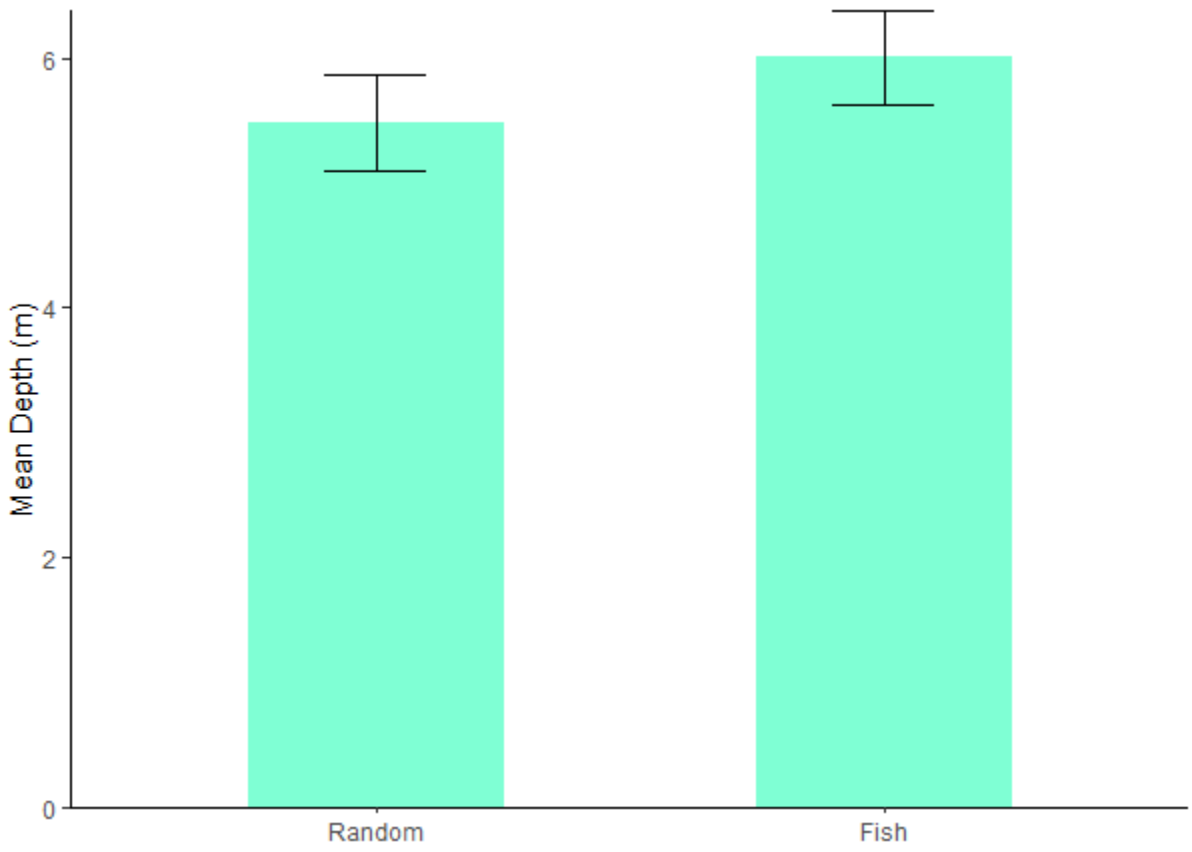

Figure 6. Mean depth (m) for random locations and fish locations in Lake Barkley. Mean depth was not significantly different based on a paired t-test ($t_{40} = 1.67$, $p = 0.10$). Error bars represent the standard error.

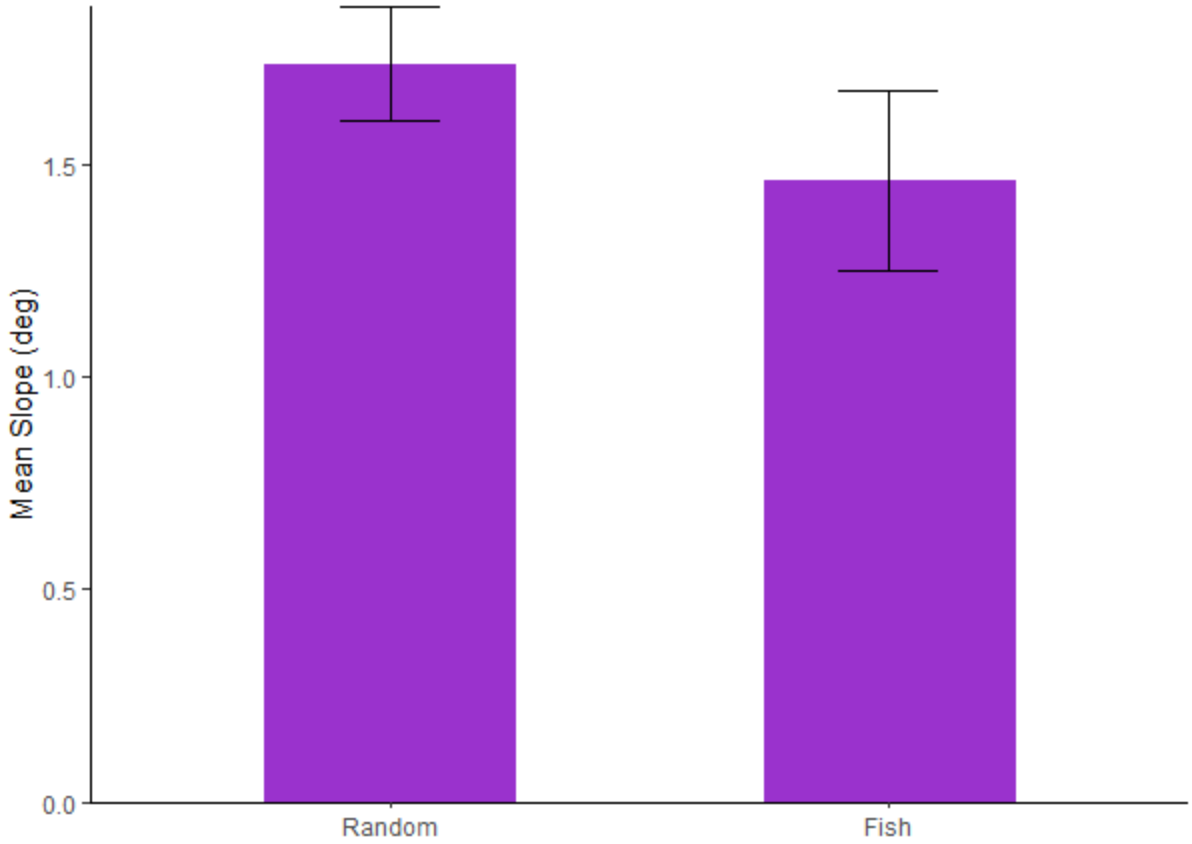

Figure 7. Mean slope (degrees) for random locations and fish locations in Kentucky Lake. Mean slope was not significantly different based on a paired t-test (t_{277} = -0.63, p = 0.53). Error bars represent the standard error.

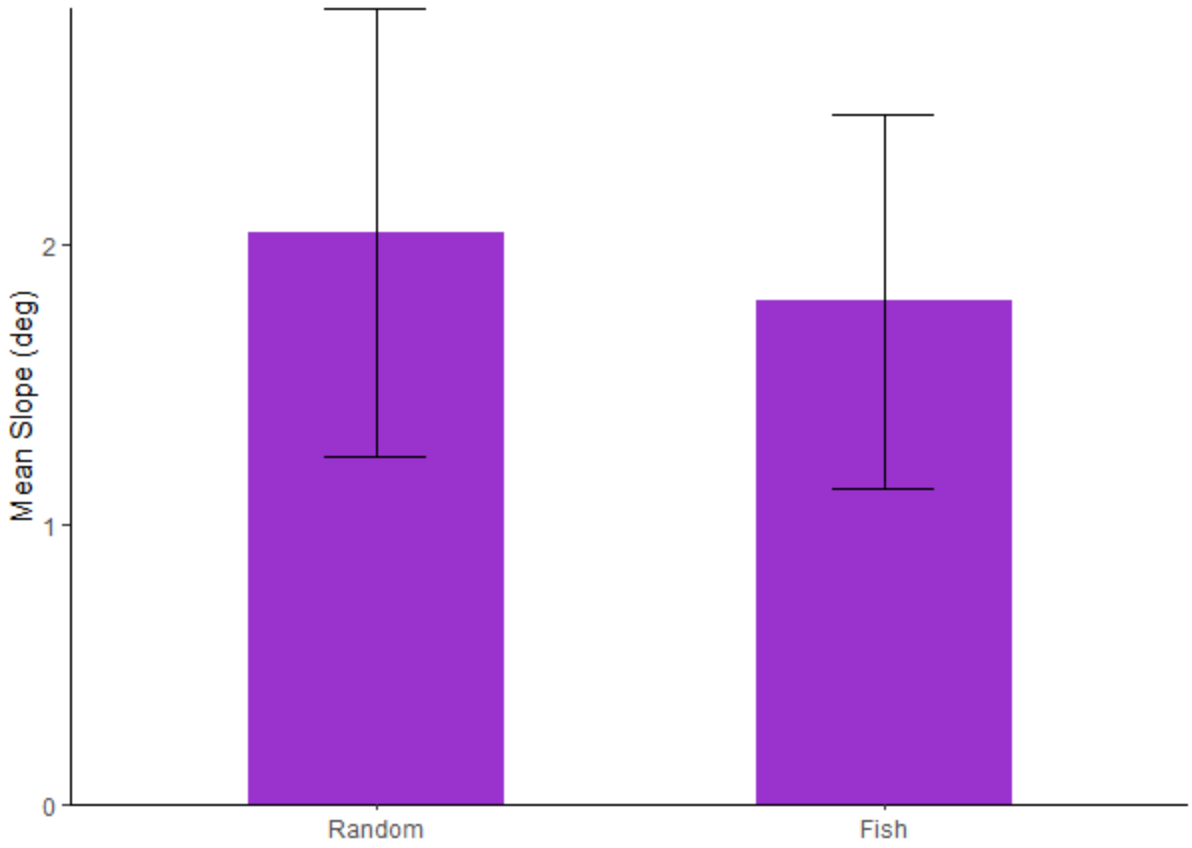

Figure 8. Mean slope (degrees) for random locations and fish locations in Lake Barkley. Mean slope was not significantly different based on a paired t-test (t_{40} = -0.02, p = 0.98). Error bars represent the standard error.

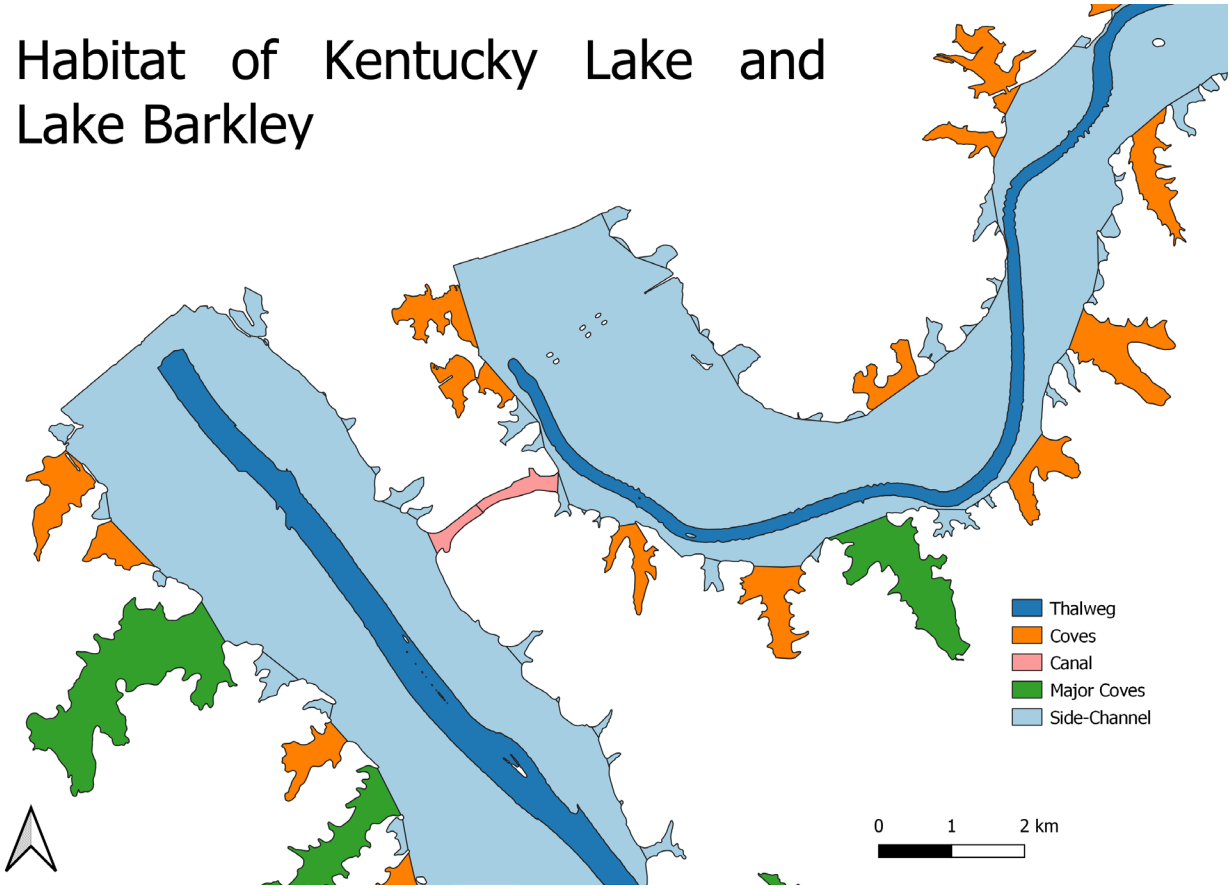

Figure 9. Example of the 5 macrohabitat types. Coves had a surface area greater than 5 ha but less than 100 ha, while major coves had a surface area greater than or equal to 100 ha.

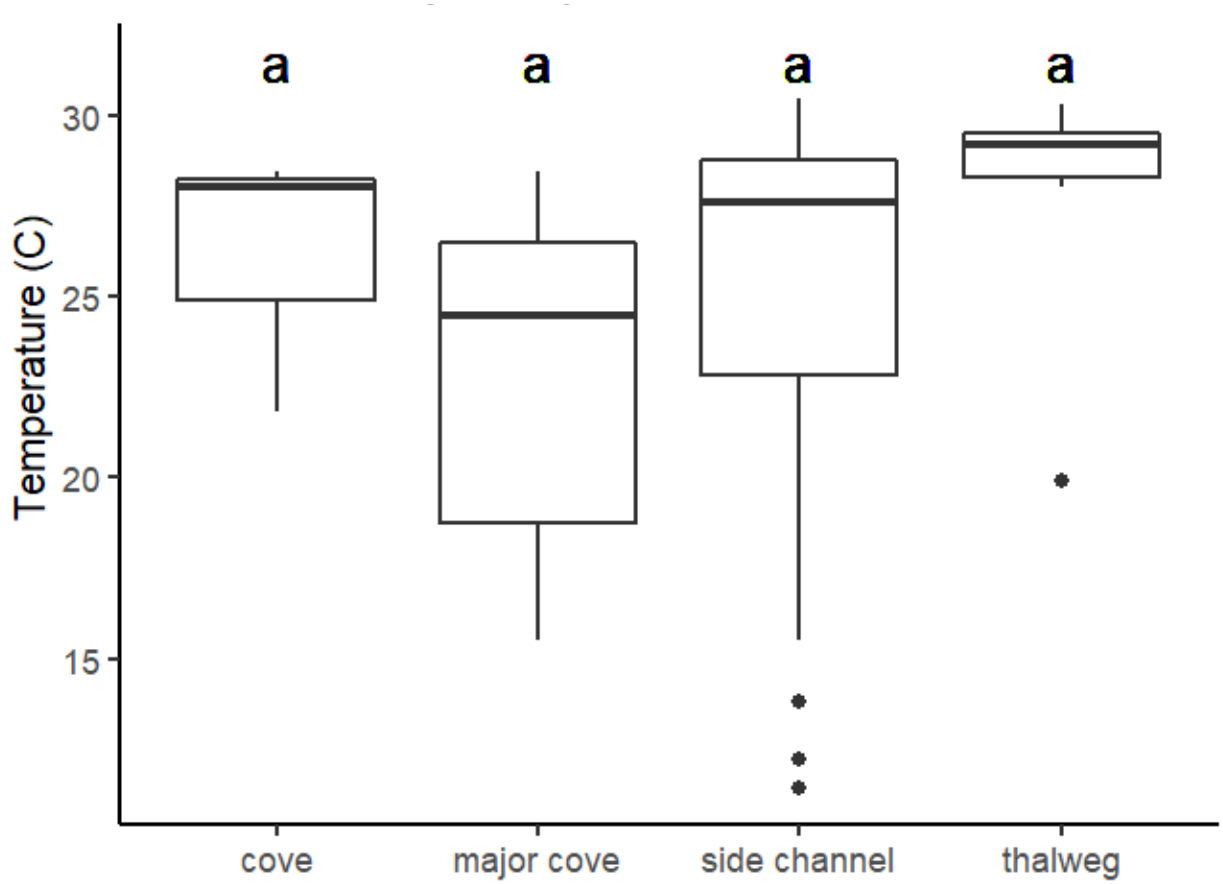

Figure 10. Boxplot comparing temperature (C) among the macrohabitats used by Silver Carp. Central horizontal lines indicate the median temperature while box ends indicate the first and third quantiles. Macrohabitat median temperatures were not significantly different based on a Kruskal-Wallis test ($X^2 = 6.6$, df = 3, p = 0.08).

Table 1. Comparison of the available macrohabitats to their use by Silver Carp in both Kentucky Lake and Lake Barkley. Macrohabitat examples are shown in Figure 9.

	Kentucky Lake		Lake Barkley	
	Pct. Available	Pct. Used	Pct. Available	Pct. Used
Cove	5.1	3.8	10.1	6.9
Major Cove	22.3	17.0	28.0	13.8
Side Channel	59.2	67.9	55.2	62.0
Thalweg	12.3	11.3	6.5	17.3
Canal	0.1	0.0	0.1	0.0
N	27		16	
X^2	78.3		55.9	
df	112		68	
p	0.99		0.85	

Appendix C: Figures and Tables – TWRA:

Table 1. Summary of gill netting effort (hours) and invasive carp demographics for Kentucky, Barkley, Pickwick, and Cheatham Reservoirs.

	Kentucky Reservoir		Barkley Reservoir		Pickwick Reservoir		Cheatham Reservoir	
Year	2020	2021	2020	2021	2020	2021	2020	2021
Net Hours	1,029.30	1,065.19	532.70	522.00	168.20	171.80	564.00	361.02
Invasive Carp Collected								
Silver Carp	59	137	39	59	11	6	28	53
Grass Carp	17	4	4	6	0	3	10	1
Bighead Carp	2	12	0	1	0	0	1	1
Black Carp	0	0	0	0	0	0	0	0
Silver Carp Captured (mm)								
< 250mm	0	0	0	0	0	0	0	0
251mm-475mm	0	0	1	0	0	0	0	0
476mm-650mm	10	3	2	0	0	0	0	0
≥ 651mm	49	134	36	59	11	6	28	53

Table 2. Summary of gill netting effort (sets) and silver carp demographics for Kentucky, Barkley, Pickwick, and Cheatham reservoirs in 2020 and 2021. Effort is separated between summer and fall sampling events for all four reservoirs. (SE = standard error, SD = standard deviation).

2020								
	Kentucky Reservoir		Barkley Reservoir		Pickwick Reservoir		Cheatham Reservoir	
Months	July	Oct	July	Oct	July	Oct	July	Nov
Net Sets	24	24	12	12	4	4	12	12
Silver Carp Captured	40	19	15	24	7	4	18	10
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)	0.83 (0.34)
Mean TL (SD)	711 (±79)	691 (±79)	753 (±75)	770 (±89)	894 (±66)	871 (±56)	838 (±67)	819 (±78)
Length Range	595-923	528-904	652-912	480-920	837-1014	816-927	761-1013	763-1025
2021								
	Kentucky Reservoir		Barkley Reservoir		Pickwick Reservoir		Cheatham Reservoir	
Months	July	Oct	July	Oct	July	Oct	July	Nov
Net Sets	31	24	12	12	4	4	8	8
Silver Carp Captured	41	96	49	10	3	3	37	16
Silver carp/net (SE)	1.32 (0.31)	4.00 (0.78)	4.08 (0.99)	0.83 (0.21)	0.75 (0.48)	0.75 (0.48)	4.63 (0.99)	2.00 (0.53)
Mean TL (SD)	781 (±89)	784 (±54)	757 (±47)	802 (±66)	851 (±30)	890 (±40)	785 (±33)	826 (±67)
Length Range	567-926	641-1004	677-889	732-960	817-871	846-924	703-870	730-1006

Table 3. Summary of gill netting efforts and silver carp demographics by mesh size in Kentucky, Barkley, Pickwick, and Cheatham reservoirs in 2021. (SE = standard error, SD = standard deviation)

	Mesh Size (inch)		
	3	4	5
Kentucky Reservoir			
Silver Carp Captured	12	116	9
Silver Carp/mesh size (SE)	0.22 (0.22)	2.11 (1.16)	0.16 (0.19)
Mean TL (SD)	724 (92)	777 (48)	913 (77)
Length Range	567-869	641-904	735-1004
Barkley Reservoir			
Silver Carp Captured	5	51	3
Silver Carp/mesh size (SE)	0.21 (0.40)	2.13 (1.74)	0.13 (0.21)
Mean TL (SD)	766 (46)	757 (43)	889 (72)
Length Range	725-840	677-876	817-960
Pickwick Reservoir			
Silver Carp Captured	0	4	2
Silver Carp/mesh size (SE)	0 (0)	0.5 (0.80)	0.25 (0.28)
Mean TL (SD)	0	857 (35)	898 (37)
Length Range	0	817-900	871-924
Cheatham Reservoir			
Silver Carp Captured	2	41	10
Silver Carp/mesh size (SE)	0.13 (0.26)	2.56 (1.61)	0.63 (0.72)
Mean TL (SD)	762 (83)	786 (30)	852 (73)
Length Range	703-820	730-870	742-1006

Table 4. Summary of effort, silver carp catch, and silver carp size characteristics from Fall 2021 invasive carp dozer trawls on Tennessee and Cumberland River reservoirs. (SE = standard error, SD = standard deviation). *Unable to complete sampling due to equipment failure.

	Kentucky	Barkley*	Pickwick*	Cheatham*
Sites	50	0	0	0
Silver carp captured	31	0	0	0
Silver carp/min (SE)	0.12 (0.03)	0	0	0
Mean TL (SD)	754 (±74)	0	0	0
Length Range	523-961	0	0	0

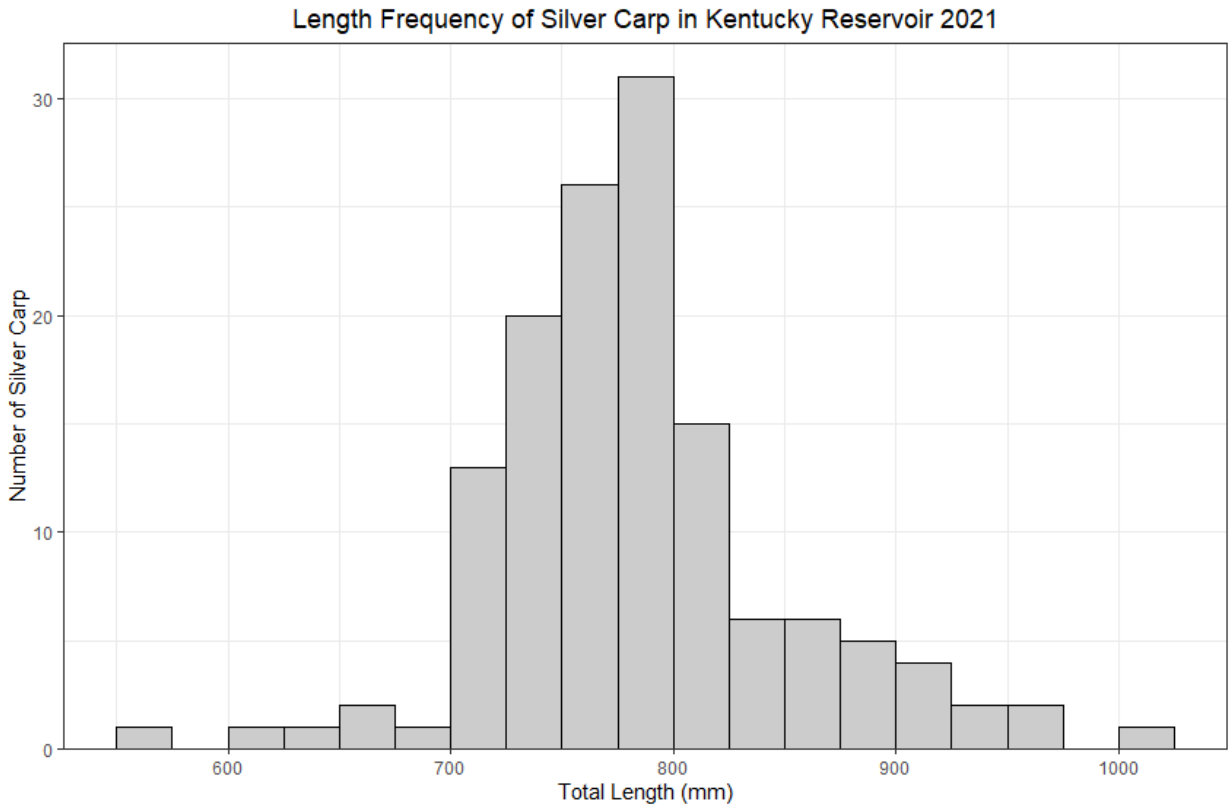

Figure 1. Length frequency histograms of silver carp captured in Kentucky Reservoir via gill net sampling in 2021.

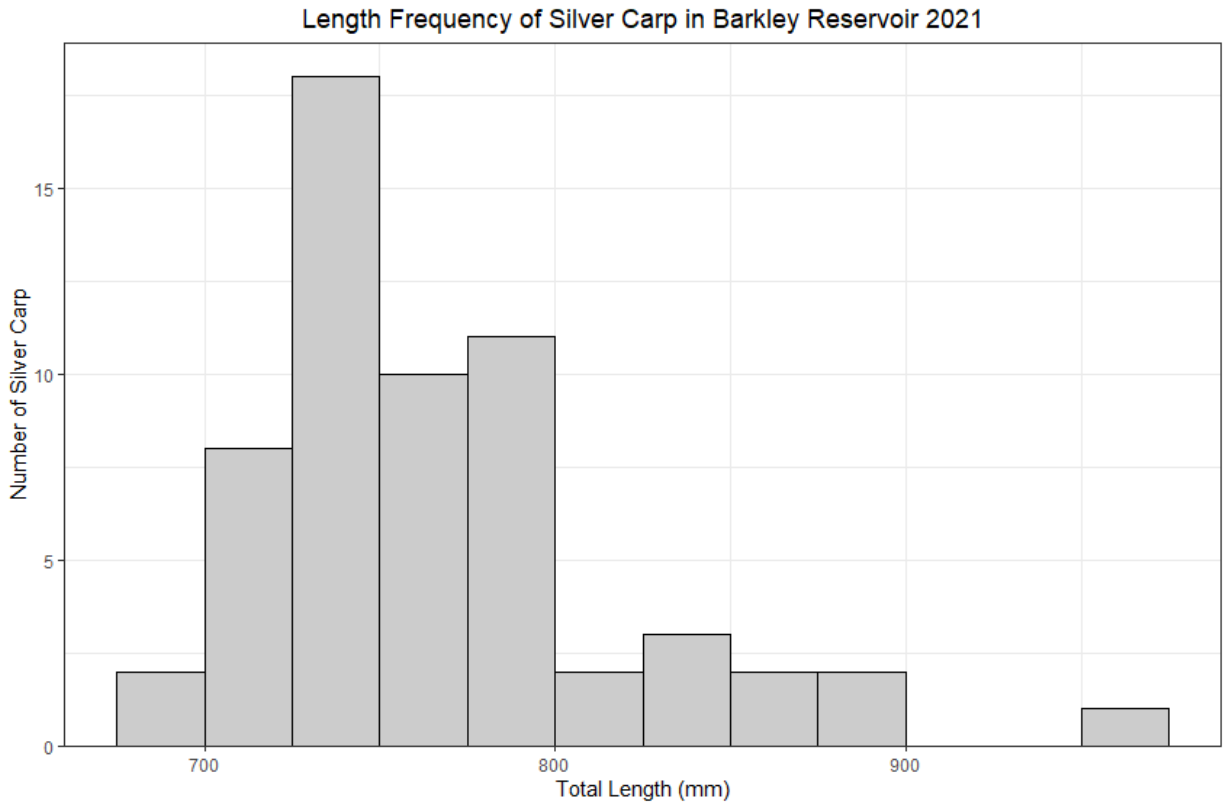

Figure 2. Length frequency histograms of silver carp captured in Barkley Reservoir via gill net sampling in 2021.

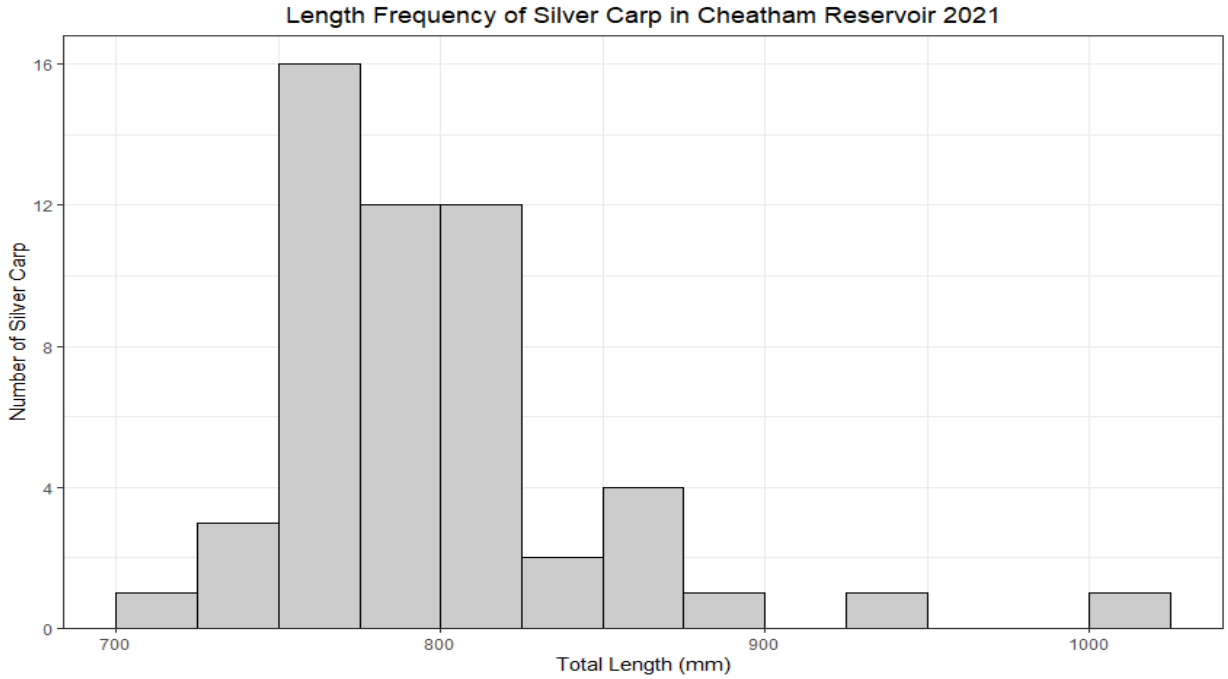

Figure 3. Length frequency histograms of silver carp captured in Cheatham Reservoir via gill net sampling in 2021.

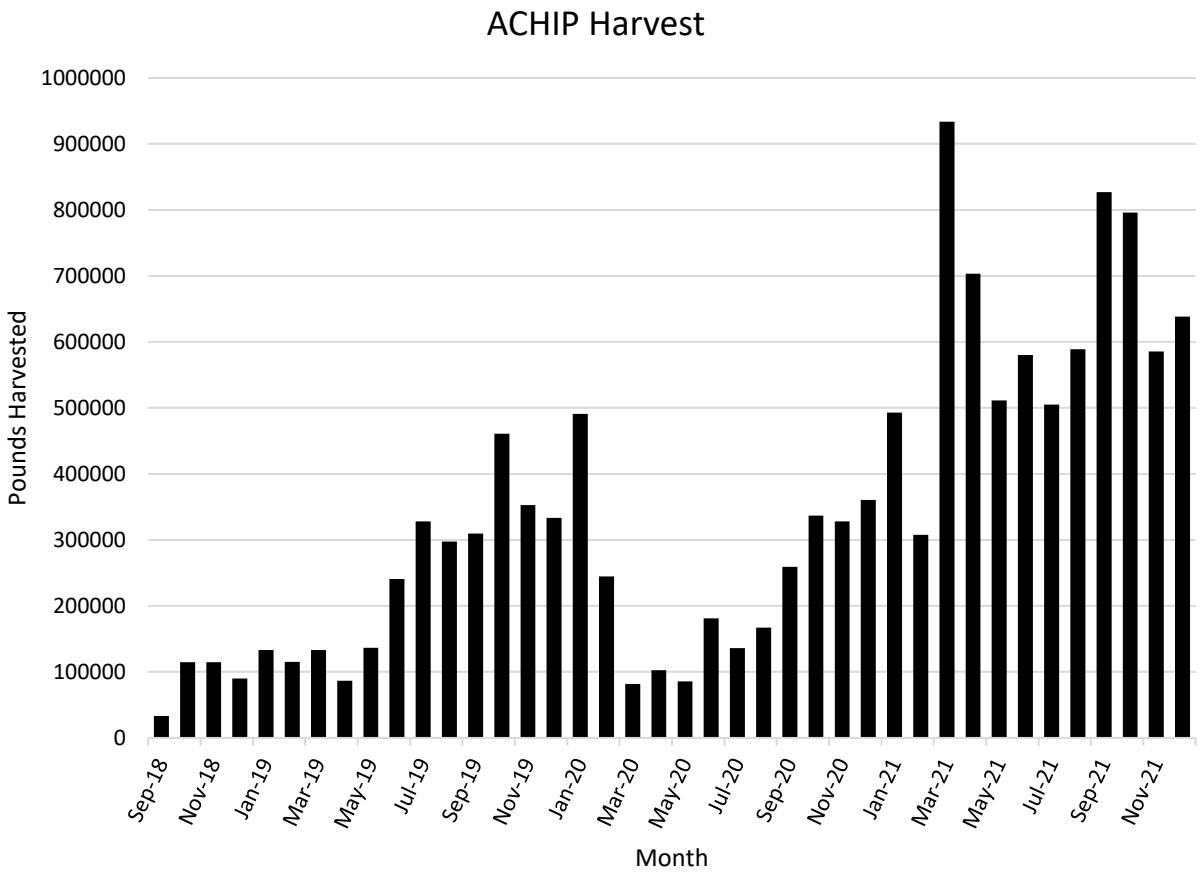

Figure 4. Incentivized harvest (pounds) of invasive carp per month through TWRA ACHIP from program inception in September 2018 to December 2021.

Appendix D: Figures and Tables – ALWFF:

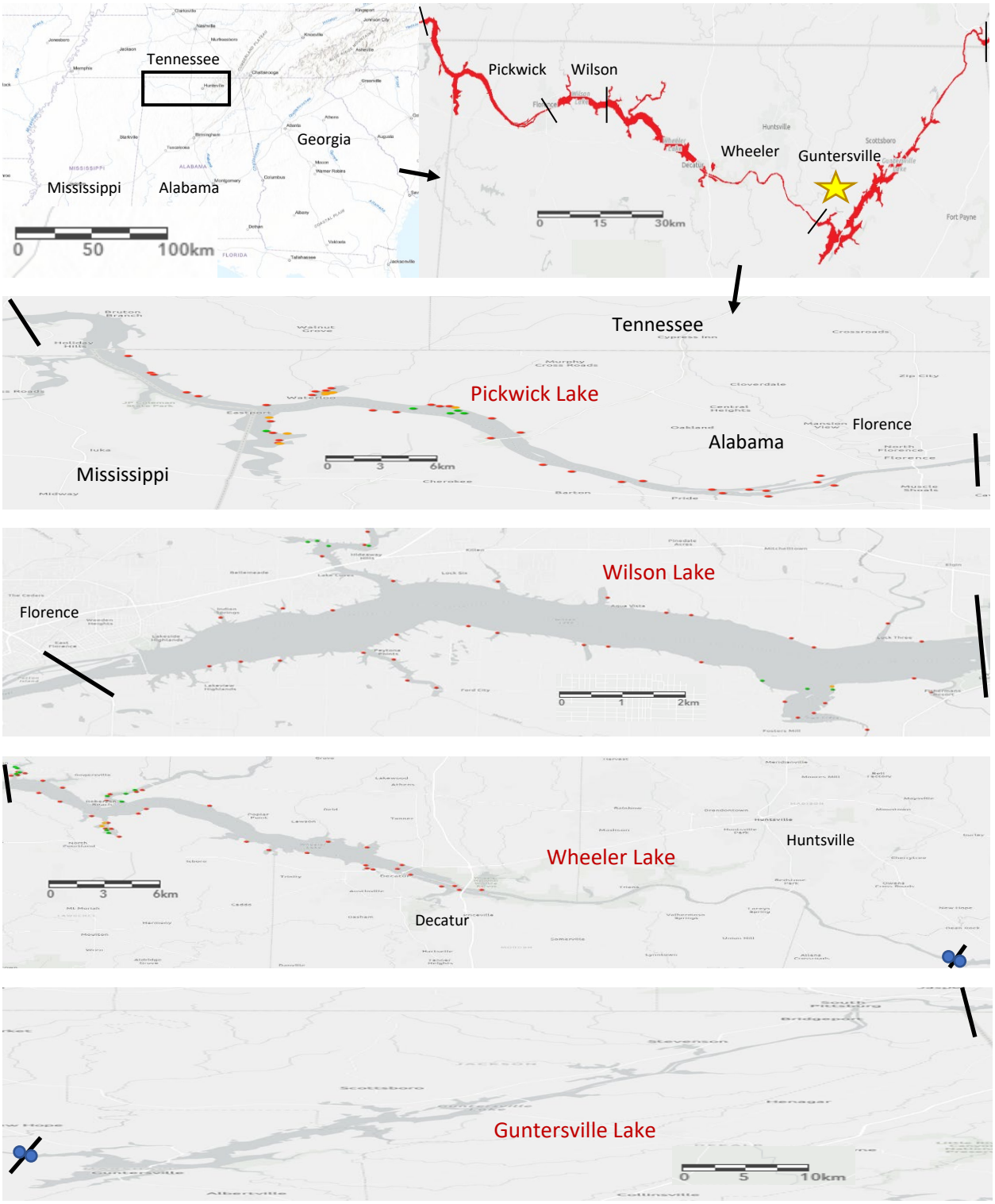

Figure 1. Southeastern states and northern Alabama study areas, including four Alabama reservoirs in the Tennessee River valley. The golden star (top right panel) denotes Guntersville Lake which is currently not part of the biological monitoring program (Objective 1) for invasive carp. Double blue dots denote telemetry receiver sites monitored above and below Guntersville dam by ALWFF staff.

Table 1. Summary of CY 2021 effort and catch data during monitoring, eradication and field reconnaissance of invasive carp populations in four Tennessee River reservoirs in Alabama. Effort and catch-per-unit data are rounded to nearest 0.1.

Sample Effort Parameter	**TN River Reservoirs (downstream to upstream)**				
	Pickwick	**Wilson**	**Wheeler**	**Guntersville**	**Row Total or Column *Mean***
Electrofishing effort					
Estimated person hours	285	133	134	0	**552**
Samples (transects)	101	97	82	0	**280**
Electrofishing hours	13.5	11.8	9.2	0	**34.5**
Electrofishing catch					
Silver Carp (n)	12	0	0	0	**12**
White amur (n)	2	4	1	0	**7**
CPUE (invasive carp/hr)	*1.0*	*0.3*	*0.1*	0	***0.6***
Gill Netting effort					
Estimated person hours	300	185	290	0	**775**
Samples (net sets)	24	16	24	0	**64**
Miles of nets	1.4	0.9	1.4	0	**3.6**
Gill Netting Catch					
All fish (n)	245	348	276	0	**869**
Fish species (n)	16	16	11	0	**43**
Silver Carp (n)	20	0	0	0	**20**
White amur (n) *	0	1	5	0	**6**
Hybrid carp (n)	0	0	0	0	**0**
CPUE (all fish/net)	*10.2*	*21.8*	*11.5*	*0*	***13.6***
CPUE (invasive carp/net)	*0.8*	*0.1*	*0.2*	*0*	***0.4***
Reconnaissance, telemetry					
Estimated person hours	17	0	0	48	**65**
Target Task	Reconnaissance			Telemetry	
Sample method	Bottom sonar			Receiver download	

Table 2. Summary of ALWFF standard sample efforts and catch rates, CY 2020 and 2021 at four Alabama reservoirs in the Tennessee River. Invasive carp species captured include, Silver Carp (SVC) and White Amur (WAM).

CY	Gillnet (miles)	Net-sets (n)	SVC / WAM (n)	All invasive carp/net-set	Total fish/net-set)	Electrofish (days)
2020	3.01	53	50 / 3	1.00	11.9	6
2021	3.64	64	20 / 6	0.41	13.6	32