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

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

Statement of Need:

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 descriptions 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 will further develop 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 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. Ultimately, while Mississippi Department of Wildlife, Fisheries, and Parks is not requesting funding for this project for FY 2022, they are coordinating with TNCR states and will benefit from this project. The inclusion of all four states is critical for the evaluation of carp populations in the TNCR.

In this project, KDFWR will evaluate the response by the native fish community and their fisheries in the presence of invasive carp. The establishment of invasive carp in new areas have been shown to alter native fish communities (Irons et al. 2007) and result in shifting food webs (Collins and Wahl 2017). Fisheries managers seek to understand these dynamics to evaluate the effectiveness of control measures, and to keep stakeholders informed. This work will complement ongoing projects in the TNCR. In this project, KDFWR will evaluate the response of native fishes, such as gizzard shad, buffalo, and paddlefish, which compete directly with bigheaded carp for zooplankton.

The commercial fishing industry has been successful at harvesting carp using gillnets and has benefitted from harvest incentive programs developed by KDFWR and TWRA. 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 basins 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 basins.

Project Highlights:

KDFWR

- No age-0 silver carp have been collected in either reservoir since 2015, suggesting that these fish continue to immigrate into the reservoirs through the lock systems.
- Commercial fishers removed over 9.5 millions pound of invasive carp statewide and 7.3 million pounds of invasive carp through the Asian Carp Harvest Program in 2022. CPUE (fish/yard) was highest in 4" bar mesh gill nets.
- KDFWR staff conducted 59 ride-alongs with commercial fishers in the carp harvest program, to monitor catch and bycatch data. Out of the 59 ride-alongs, 6 ended with no nets being set.
- Commercial fishers enrolled in the subsidy contract fishing program received $672,218.49 for invasive carp harvested from Barkley and Kentucky reservoirs.
- KDFWR continued Master Agreement contracts with two private entities to test invasive carp experimental gears in Kentucky waters. During 2022, both entities were active in the program and harvested approximately 243,108 lbs of invasive carp from Kentucky and Barkley Lakes over 13 days.
- KDFWR received four reports of black carp in the Tennessee River during 2022 and none in the Cumberland River.

Agency: Kentucky Department of Fish and Wildlife Resources

Methods:

Objective 1: Estimate invasive carp relative abundance, and population demographics in the Tennessee and Cumberland River basins to evaluate management actions.

KDFWR used a combination of standardized sampling and monitoring of commercial harvest to evaluate relative changes in invasive carp abundance in Barkley and Kentucky reservoirs. Standard sampling with gill nets was conducted at sixteen sites on Barkley and Kentucky reservoirs. 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 sites and four main channel sites were selected on each reservoir. These sites were sampled once during the following seasons: spring (April), summer (July), and fall (October). A total of four nets were fished at each location during sampling periods and in orientations specific to each location. Sampling occurred when the lake level was greater than 354' in areas where water depth was a minimum of 13'. Nets were deployed, at least one hour before sunset and retrieved at least one hour after sunrise the following morning (according to the official rise and set tables). Specific coordinates were

determined for all sets, and nets were set at the same locations each season. Sinking experimental gill nets 10' deep, 300' total length, with 100' panels of 3", 4", and 5" mesh was fished overnight. The gill nets were 12' deep tied down to 10' every 8'. Each of the 100' panels of webbing was hung with 30" stretch in 16" ties (3" square, 5 meshes per 16" of linear net; 4" square, 4 meshes per 16" of linear net; and 5" square, 3 meshes per 16" of linear net). Webbing used in each panel was constructed of 8 ply, 0.2-mm twist mesh. Cross ties for these nets was constructed from #15 white bonded twine through the webbing. Catch rates and species captured were recorded for each gillnet mesh size.

KDFWR partnered with the USFWS to conduct Paupier net sampling in Kentucky reservoir to further inform relative abundance calculations and population demographics. KDFWR provided staff and tender boats to collect length, weights, and aging structures. Sampling design was informed by previous efforts with this gear type by the USFWS and agreed upon by basin partners. Sampling in Kentucky reservoir was done in six embayments over the course of four nights during the month of October. Transects were no more than five minutes long and number of transects per bay was calculated by shoreline distance (one transect/km).

The KDFWR Asian Carp Harvest Program (ACHP) requires commercial fishermen to report daily landing records. Occasionally the agency also provides observers to record harvests as the nets are retrieved (ride-alongs). Data collected during ride-alongs with commercial fishers allows KDFWR to estimate average weights of individual silver carp commercially harvested. This information was used inform analysis about invasive carp population demographics.

During the standard sampling described above, total lengths (mm), weights (g), sex and gonad weights (g) were recorded from a subsample of at least 20 bigheaded carp at each sample site, ride-along, or transect. During fall sampling, pectoral fin rays and otoliths were extracted from approximately 100 silver carp from each reservoir for aging or at least 20 per centimeter group. Demographics data may also be collected from invasive carp captured through other KDFWR sampling efforts and included for analyses.

Silver carp movement will be used to estimate periodicity of silver carp spawning attempts, and the data will be aligned with environmental factors to examine potential correlations if such attempts are recorded.

Objective 2: Examine invasive carp impacts on native fish communities.

During standard sampling for invasive carp conducted in the TNCR Evaluation and Removal Project: objective 1, total length and weight data was collected from bigmouth buffalo and paddlefish. During Paupier net sampling, total length and weight data was recorded for gizzard shad as well. Measurements were used for determining condition factors through relative weight analysis. Values will be monitored over time to determine if they will be useful to assess impacts that invasive carp may have on conditions of the native fishes. The species chosen for this assessment are often captured in gill nets and have been recognized as being vulnerable to competition for resources with invasive carp species (Irons et al. 2007, Schrank et al. 2003).
KDFWR conducted targeted sampling for gizzard shad with pulsed DC boat electrofishing for one week in both Barkley and Kentucky reservoirs. Electrofishing runs did not exceed 15 minutes of peddle time and ran parallel to shore in 3-8ft of water. Length and weight were taken from individuals collected. The first run started at sunset; the rest were done after sunset with LED lights on the front rail.

Barkley and Kentucky reservoirs' tailwaters was sampled with pulsed DC electrofishing in the fall to assess species composition, relative abundance, and condition of represented fish species. Sampling below Kentucky reservoir (Tennessee River) consisted of three 15-minute transects, moving downstream along each bank of the river. Sampling below Barkley reservoir (Cumberland River) consisted of two 15-minute transects, moving downstream along each bank of the river. Fall sampling was conducted one day each month in September, October, and November. Two staff collected fish with nets from the bow, and all fish of every species will be targeted. Data included species, total lengths (mm), and weights (g). When large numbers of a species are collected, measurements on a subsample of at least 25 individuals will be taken and extrapolated for that species. The data was compared to historical data collected by the KDFWR WFD personnel to assess changes in fish community over time.

Invasive carp harvest continues to increase from Kentucky and Barkley reservoirs, driven by the Asian Carp Harvest Program (ACHP) and the additional processors purchasing carp from western Kentucky. KDFWR continues to monitor conditions of sport fish species to identify trends that may be associated with the increased removal of invasive carps. Information on sport fish has been gathered routinely throughout the past few decades by KDFWR's Western Fisheries District (WFD). Lengthy data sets on black bass, crappie, and catfish in the two lakes are collected from standardized annual sampling. The information will be used to compare sport fish conditions (*W*r) with harvest rates of invasive carps to determine if there is a correlation.
In spring, summer and fall of 2022, KDFWR conducted the creel survey in the tailwaters of Barkley and Kentucky reservoirs. Random, non-uniform probability creel surveys were conducted from February 16, 2022 through November 15, 2022 in the Kentucky Tailwater and the Barkley Tailwater. The Kentucky Tailwater survey extends from the Kentucky Dam downstream to the Interstate 24 bridge. The Barkley Tailwater survey extends from Barkley Dam downstream to the US Hwy 62 bridge. Dates and periods for surveys each week were randomly selected, and creels were conducted in each tailwater at least 10 days per month in each tailwater, including a minimum of 3 weekend days. Each day was divided into three periods: morning, afternoon, and late evening. The late evening period was only utilized for a portion of the survey to collect snagging and bow fishing data. Daily, access point surveys consisting of instantaneous angler counts and angler interviews were be conducted from the bank; no boat was used. Timing of recreational fishers' counts are randomly chosen daily, and data was extrapolated accordingly to calculate daily average and total effort. An attempt to interview all recreational fishers each day was made. Data collected during the creel surveys was compared to historical surveys to determine changes in fish community, catch rates, angler use, and success. Recreational fishers were also administered an angler attitude questionnaire to gauge opinions regarding their levels of satisfaction with the fishery and on current or proposed regulations. Increasing invasive carp numbers in the tailwaters over the past decade has perpetuated a significant increase of bow fishing. During 2019, regulations were enacted in Kentucky to allow the sale of invasive carp harvested by recreational fishers. The 2022 creel survey provided data to assess the effects of the new regulation.

KDFWR continued to administer the Asian Carp Harvest Program (ACHP) and an Experimental Fishing Methods contract program to encourage largescale removal of invasive carp. As fishing effort and techniques develop and increase, there is potential for these activities to negatively impact native fish through excessive bycatch when fishers are attempting to target invasive carp. Commercial fishers on the ACHP are required to submit daily reports indicating species of bycatch, harvest status, or condition of bycatch upon release. KDWFR staff also collected this information during ride alongs with commercial fishers. These two data sets will be analyzed independently to determine if commercial fishing efforts are negatively impacting native fish species.

Objective 3: Target and remove invasive carp to suppress populations and reduce propagule pressure in the Tennessee and Cumberland River basins.

KDFWR continues to dedicate staff time towards observing commercial fishing and facilitating efforts to assess the impacts of targeted removal of invasive carp on non-target native species. Commercial fishers requesting to fish in the ACHP are required to provide daily landing reports including amount of fishing effort, the type of gear used, pounds of fish harvested, and bycatch. Fishers are also required to list the number of fish caught for each species, fish released, and disposition. The information is used to assess impacts of commercial harvest on bycatch species.

To verify commercial fishers' reports, KDFWR occasionally provides observers to record harvests (ride-alongs). Observers collect all data required on commercial harvest logs and record GPS fishing locations, water temperature, net soak times, and other meterics. Staff observe several individual fishers throughout the year. Ride-alongs are conducted as fishers pull their nets to harvest fish. When commercial fishers use short net soak times or drifting net sets, KDFWR staff observed during the entire effort. Ride-alongs are conducted from an agency boat located near the commercial fishers or on the commercial fisher's boat if there is adequate space. Observation records were compared to fishers' daily reports to assess commercial reporting accuracy. ACHP data was analyzed to determine the number of fishing trips, amount, and disposition of bycatch by species, and total pounds of invasive carp harvested.

KDFWR continues to offer contract fishing in Barkley and Kentucky reservoirs to ensure commercial fishing effort targeting invasive carp remains robust, to meet agency management objectives. Commercial fishers must apply for the contract program and once approved, will receive a designated price per pound for invasive carp species harvested from Barkley or Kentucky reservoirs. The Asian Carp Harvest Program is one of two programs Kentucky has implemented to increase commercial removal of invasive carp in the reservoirs. In 2018, KDFWR purchased and installed an industrial flake ice machine. Since that time KDFWR has maintained the unit to provide ice to commercial fishers targeting invasive carp. As demand continues to increase, upgrades and additional storage capacity for the ice machine and freezer will be required.

Since the commercial harvest programs for invasive carp have increased and KDFWR staff time is limited, KDFWR staff discontinued conducting targeted removal efforts during 2022.

Results and Discussion:

Objective 1: Estimate invasive carp relative abundance, and population demographics in the Tennessee and Cumberland River basins to evaluate management actions.

<u>Standard Sampling</u>

Standard sampling data continues to be variable across seasons and years in each reservoir.
Data for silver carp suggested that mean catch per unit effort (CPUE), reported as number of fish per linear yard of gill net, was evenly spread throughout different seasons, habitat types, and mesh size. Overall invasive carp CPUE through standard sampling was low (Table 14).

Paupier

U.S. Fish and Wildlife Service sampled Kentucky reservoir with their electrified paupier net boat during the fall of 2022. Lengths and weights were collected for all species until N=30 per species and then counted. If a transect concluded with a species count over ~500, they were subsampled and counted by weight. The electrified paupier sampling had a silver carp CPUE (fish/hr) of 105 in Big Bear embayment, which decreased significantly from previous catch rates (Table 22). The paupier sampling creates less sampling bias and therefore a better fitting regression line when looking at Log10 transformed lengths and weights for silver carp; Kentucky reservoir R^2=0.88 whereas Barkley reservoir R^2=0.75 (Figure 7 & 8).

ACHP

Length and weight data was collected on 1041 silver carp harvested by commercial fishers in 2022. Silver carp lengths ranged from 16.5 - 38.9 inches with an average of 29.9 inches, and weights ranged from 5.1 – 29.2 lbs with an average of 10.9 lbs (Table 18). If this metric is used in correlation with the total pounds of silver carp harvested by commercial fishers through the ACHP in 2022, that would produce a rough estimate of 695,662 individual silver carp being removed from Kentucky waters through the ACHP in 2022 (7,5822,713 lbs; Table 17). During ride-alongs, commercial fishers were observed using gill nets with a range of bar mesh sizes to target invasive carp (3.5” – 5” bar mesh; Table 19, Figure 14). Catch per unit effort of gill nets used to harvest silver carp were highest in gill nets with a bar mesh size of 4” (0.62 fish/yard), followed by 3.75” bar mesh which had a CPUE of 0.51 fish/yard. This has increased from previous three years when the highest CPUE was in 3.25” and 3.5” bar mesh nets. There has been a change in the size gill net mesh commercial fishers are using in Barkley and Kentucky reservoirs, this is likely due to the 2015 cohort of fish being recruited to the bigger size mesh.

Four black carp were harvested by one commerical fisher in January of 2022. Lengths ranged from 836mm – 942mm, were caught in 4” mesh gill nets and all were sent off to research groups with USGS to investigate further.

Mark-Recapture

From October 2018 through February 2023, KDFWR received 48 tag returns from commercial fishing efforts. Thirty-eight came from Barkley reservoir and ten from Kentucky reservoir (Figure 9). Nine other tags have been returned from bowfishers, government agencies, or found along the river banks. Twelve of the returned fish were double tagged. Ther higher frequency of returned fish from Barkley reservoir compared to Kentucky resevoir 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. 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 released. Data analysis is in progress with the assistance of the USGS CERC staff and a report is expected in 2023.

Barkley and Kentucky Reservoir Population Dynamics

A length-frequency histogram was created for silver carp harvested from Barkley and Kentucky reservoirs from all harvest methods in 2022. Data suggested the 700mm size class of silver carp was dominant in both systems (Figures 1 & 2)

Age and Growth

Pectoral fin rays were collected from silver carp in Barkley and Kentucky reservoirs in the fall of 2022 for aging. Barkley ages ranged from 4 to 8 years old, with age 7 being the most abundant. Kentucky ages ranged from 3 to 8 years old, with age 7 being the most abundant, (Figures 3 & 4). Data suggests a strong presence of two cohorts of silver carp behind the 2015 cohort (7 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 Barkley reservoir was estimated at 46% and instantaneous mortality was estimated at 0.62 (N= 201, F1,2=7.20, P=0.07, R2=0.71; Figure 6). Annual mortality for silver carp from Kentucky reservoir was estimated at 38% and instantaneous mortality was estimated at 0.48 (N=232, F1,2=29.40, P=0.01, R2=0.91; Figure 5). Estimates of annual mortaily in 2022 decreased from the vales reported in 2021. This is attribuited to the wider time series of data for this cohort informing better model predictions.

Condition

Linear regressions were constructed to describe the log10 length-log10 weight relationship for silver carp in Barkley and Kentucky reservoirs. The length-weight equation for Barkley was estimated at Log10(weight(g)) = 3.1151*Log10(length(mm))-5.289 (Figure 8). The length-weight equation for Kentucky was estimated at Log10(weight(g)) = 3.2649*Log10(length(mm))-5.7404 (Figure 7). Weights were predicted for Barkley reservoir: 450mm (946g), 650mm (2975g) and 800mm (5681g) and Kentucky reservoir: 450mm (836g), 650mm (2776g) and 800mm (5469g) (Table 15). Predicted weights remain higher for Barkley than for Kentucky, both reservoirs indicate that smaller fish (450mm & 650mm) are predicted to weigh less compared to previous years, unlike the larger silver carp (800mm) which increased this year.

Data collected from sampling in the fall of 2022 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 Barkley reservoir was 102 (N=349, S.E.=±0.5) and the mean Wr for silver carp in Kentucky reservoir was 97 (N=463,

S.E.=±0.4). These values are consistent with data collected from previous years. Only one bighead carp was collected in the fall, it was in Kentucky Lake and had a relative weight of 116.

Objective 2: Examine invasive carp impacts on native fish communities

Electrofishing

KDFWR sampled for YOY invasive carp nighttime boat electrofishing, in conjunction with sampling for projects under the monitoring of native fish project. This sampling occurred for a week on Barkley reservoir and a week on Kentucky reservoir in October of 2022. Sampling targeted young of year invasive carp, gizzard shad (GZSD), threadfin shad (TFSD), skipjack herring (SKJH) and emerald shiners. No YOY invasive carp were collected from either reservoir. The Midwest Lake Electrofishing Systems shock box was set to 120 Hertz, 25% duty cycle, 500 volts, 17-20 amps and 10,000-17,000 volts. On Kentucky Lake 6,572 Gizzard Shad, 1,848 Threadfin Shad, and 178 Skipjack Herring were collected. On Barkley Lake 4,990 Gizzard Shad, 3,046 Threadfin Shad, and 426 Skipjack Herring were collected. CPUE for gizzard shad was higher in Kentucky reservoir than Barkley reservoir for both gizzard shad below 180 mm and above 180 mm (Table 2).

Paupier

Sampling with USFWS collected a total of 40,564 fish with the electrified paupier net boat over four nights spent on Kentucky reservoir. This sampling was targeting young of year invasive carp, adult invasive carp, gizzard shad, threadfin shad, and skipjack herring. No YOY invasive carp were collected. CPUE of adult silver carp was lowest it has been in Big Bear embayment (105.9 fish/hr. Table 1), since paupier sampling has occurred. The missing years from 2020 – 2021 has been due to personnel constraints and the Covid pandemic.

Using data collected from both electrofishing and paupier sampling, condition of native baitfish was calculated to better understand the potential impacts invasive carp. Relative weight (Wr) of gizzard shad over 180mm was slightly higher from Kentucky reservoir at 91 compared to Barkley reservoir at 90 (Table 1). Paupier and EF sampling produced CPUE of similar results for gizzard shad (1045 & 1100, respectively) but paupier had much higher CPUEs for threadfin shad, skipjack herring and adult silver carp (Table 3).

Standard Sampling

Capture rates of species with potential direct competition from bigheaded carp (silver and bighead) were observed to be low in the 2022 standard sampling, which continues the trend observed in previous years. No bigmouth buffalo were caught in 2022 standard sampling nets. In Kentucky Lake paddlefish were observed to have a mean Wr of 84 (N=2, S.E. ±11) and in Lake Barkley paddlefish had a mean Wr of 80 (N=14, S.E ± 4,Wr equations from Blackwell et al 2000) . 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 2022, bycatch in Lake Barkley was comprised of 53
% scaled rough fish (Buffalo spp., Freshwater drum, Gar spp., etc.), 39% catfish spp. (Ictaluridae), 5% paddlefish and 4% sportfish. Bycatch in Kentucky lake was comprised of 47% scaled rough fish, 45% catfish spp., 1% paddlefish and 3% sportfish.

Kentucky and Barkley Tailwaters Electrofishing

Fall sampling with electrofishing in the Kentucky Tailwater resulted in the capture of 9,312 total fish comprised of 23 species during 4.5 hours of effort in 2022. Threadfin shad catch rates was the second highest since the study began in 2015 (1860 fish/hr. Table 6), but gizzard shad and skipjack herring stayed around the same as 2021. CPUE of sunfish species including bluegill and longear sunfish, increased from 2021 with a CPUE of 34 fish/hr and 5 fish/hr, respectively. Largemouth and smallmouth bass CPUE increased from 2021 and were similar to catch rates in 2020. Interestingly, for the third year in a row, striped mullet (*Mugil cephalus*) was collected during sampling efforts in the Kentucky Tailwater in 2021. A total of 4 striped mullet were collected ranging from 19 – 21 inches in total length, whereas 5 fish were collected in 2021 and 4 fish were collected in 2020 (Table 4). Silver carp CPUE dropped to the lowest catch rate since the study began in 2015 at 2 fish/hr (Table 6).

Fall sampling in the Barkley Tailwater resulted in the capture of 4,257 total fish comprised of 16 species over 3.0 hours of effort in 2022. Threadfin shad catch rates were like 2020 and 2017 with a CPUE of 1263 fish/hr (Table 7). Sunfish species such as bluegill and longear sunfish produced similar catch rates to 2021, which are some of the lowest catch rates for those species since the survey began in 2016 with a CPUE of 21 fish/hr and 16 fish/hr, respectively (Table 7). Largemouth bass catch rates in 2022 were the lowest observed, but smallmouth bass catch rates like previous years (Table 7). Silver carp CPUE during fall sampling in Barkley Tailwaters was the second lowest since 2016 (11 fish/hr; Table 7).

Length frequency distribution for silver carp collected in Kentucky Tailwater during fall sampling in 2022 ranged from 19-34 inches (N=9; Table 4). Silver carp lengths from Barkley Tailwater during fall sampling ranged from 19-32 inches (N=11; Table 5). 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.

Electrofishing for this project resulted in removal of 9 silver carp and 10 grass carp from Kentucky Tailwater and 32 silver carp from Barkley Tailwater in 2022.

Relative weights (Wr) were calculated for selected species collected during fall sampling to monitor fish condition (Tables 8 & 9). 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 decreased to a value of 89, the second highest observed since the survey began in 2015 (Table 8). Largemouth bass also recorded the second highest Wr since 2015 at 105 (Table 8). The mean relative weight for white bass increased slightly from 2021, but still isn't up to historical records. However, the mean relative weight for sauger (Wr = 71) decreased to the lowest values recorded for those species since the survey began (Table 8). Mean relative weight values for other species in the Kentucky Tailwater remained similar to previous years. In the Barkley Tailwaters, mean relative weight values increased for gizzard shad (Wr = 89) from 2021. Smallmouth bass mean relative weight increased to 95 and that is the same as 2017, which are the highest seen since 2016 (Table 9). All other species in the Barkley Tailwaters had similar mean relative weights to previous years.

Kentucky and Barkley Tailwater Creel

In 2022 survey results indicated that the fewest number of trips were made to Barkley tailwaters, and the second lowest number of fishing trips were estimated for Kentucky tailwaters (Figures 18 & 19). In 2022 creel survey results from Barkley tailwaters suggests that catch rates were the highest observed, at 2.4 fish/hour (Figure 20). Whereas Kentucky tailwater data suggested that fishers caught 1.89 fish/hour. This was a decrease of 0.9 fish/hour from the record high in 2019 (Figures 21).

Bowfishing made up 35% of the angling from Barkley tailwater and 12% from Kentucky tailwaters (Figure 16 & 17). These are the highest percentage of fishing methodologies reported since the method was included in the creel survey in 2016. Of the 35% of anglers in Barkley tailwaters that were bowfishing, 24% of those were by boat. The overall percentage of anglers in Barkley tailwaters by boat was 23%. Of the 12% of anglers in Kentucky tailwaters, only 4% of those were by boat. The overall percentage of anglers in Kentucky tailwaters by boat was 19%. The difference between Kentucky and Barkley tailwaters differences might be to due to shoreline access.

Part of the tailwater creel is an angler attitude survey where anglers are asked their satisfaction with the fishery. In the Barkley tailwaters respondents indicated Asian Carp were most fished for 42%) followed by catfish (29.6%), whereas Kentucky tailwaters anglers' fished for catfish (33.5%) more than Asian carp (16.5%). This would seem to indicate that the invasive carp have created a significant recreational opportunity, especially in Barkley tailwaters. Of those surveyed fishers, a small amount had indicated they had eaten Asian Carp (Barkley 25.4%, Kentucky 21.8%). Given invasive carp's abundance and being considered excellent table fare, more outreach is needed to expose the public to this abundant resource's potential. Of the 21 paddlefish anglers that were interviewed, 42.9% of them were somewhat satisfied with the paddlefish fishing in the Kentucky tailwaters were-as of the 33 interviews in the Barkley tailwaters, only 24.2% were somewhat satisfied (Appendix A & B).

Standard Sport Fish Sampling

In Kentucky reservoir, relative weight analysis was conducted for black crappie, white crappie, blue catfish, and largemouth bass (KDFWR 2021). Black and white crappie both exhibited mean relative weights that were higher than 2021 but were not outside of historical norms with *W*r of 91 and 87, respectively. Largemouth bass average *W*r also remained similar to values calculated for the previous four years (*W*r = 94). Many factors are known to impact sport fish condition and values recorded since invasive carp have become established in Kentucky reservoir have not fluctuated outside of historical variations. 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.

In Barkley reservoir, relative weight analysis was conducted for black crappie, white crappie, largemouth bass, and blue catfish (KDFWR 2021). Mean relative weights for both black and white crappie remained similar to previous years having *W*r of 98 and 100, respectively. Mean *W*r value for largemouth bass in 2022 was 100. Harvest of invasive carp from Barkley reservoir has increased almost every year since the ACHP began in 2013. Similar to Kentucky reservoir, 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 Barkley reservoir 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 2022, the total number of bycatch reported decreased and was the lowest recorded since 2018 (when commercial fishing effort increased dramatically. Table 12). 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 (Table 12). Bycatch of rough fish, and subsequent harvest is variable year to year based on what processors are willing to buy. 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 2022 compared to recent years. Survival rates of sportfish (93.6%) and catfish (98.8%) decreased in comparison to previous years, and the survival rate of paddlefish remained similar (81.0%) (Table 12).

Survival rates of all bycatch caught during ride-alongs in 2022 was documented by KDFWR observers and was analyzed independent of commercial fishers reporting (Table 11). During ride-alongs, the survival rate of sport fish in bycatches decreased from previous years to 83%. Survival rates of catfish species observed as bycatch during ride-alongs was like previous years at 95%. Paddlefish survival rates observed during ride-alongs in 2021 were the lowest observed since 2016, but still was also the lowest number of paddlefish caught (Table 11).

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 (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 B. 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 (3% in 2022). 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 is showing a declining trend even though effort is increasing through the ACHP (Table 12).

Paddlefish survival was observed to be low in 2022 (28% during ride-alongs, 81% total ACHP) in relation to other species in the bycatch (Tables 11 & 12). A 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. The lowest mean soak time was 3.25 and the typically the lower mean soak times result in a higher survival rate (Table 13), 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 2022. To increase the sample size, water temperature and soak times will continue to be recorded during ride-alongs in 2023.

Objective 3: Target and remove invasive carp to suppress populations and reduce propagule pressure in the Tennessee and Cumberland River basins.

Invasive Carp Contract Fishing Program in Barkley and Kentucky Reservoirs

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 Barkley and Kentucky Reservoirs increased, which heightened participation in the program. In 2022, contractors received $672,218.49 for invasive carp harvested from Barkley and Kentucky Reservoirs. This equates to over 7 million pounds of invasive carp harvested through the contract program in 2022, the second largest harvest to date (Figure 10). 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 reservoirs regardless of the size of those fish.

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 Barkley and Kentucky Reservoirs.

Since 2013, commercial fishers in Kentucky have harvested a total of 34,344,858 lbs of invasive carp through the ACHP (33,841,544 lbs silver carp, 261,889 lbs bighead carp, 241,425 lbs grass carp [2020-2022 only]; Table 17). 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 Barkley Rservoir (Table 17). Commercial fishers typically prefer fishing Barkley Reservoir over Kentucky Reservoir as it is shallower, has more embayments to corral fish, less recreational traffic, and the

fishers believe the silver carp are larger. From 2020 to 2022 there was a decrease in number of individual commercial fishers in Barkley Reservoir, but an increase in harvest, and from 2021 to 2022 there was a decrease of almost 200 trips made on Barkley Reservoir, but an increase in over 200,000 lbs of carp removed, which indicates that commerical fishers are getting more efficent at removal. The amount of harvest of invasive carp from Kentucky Reservoir increased substantially in 2020 and 2021, but saw a decrease in 2022 for the number of fishers, number of trips and in harvest. (Table 17). 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. Even though there was an increase in harvest from Barkley Reservoir and the Ohio River, statewide we saw a decrease in invasive carp harvest, this was likely due to loosing commercial fishers to other states offering incetive programs (Table 17 & Figure 10). Factors affecting the increased efficiency are likely a combination of the 2015 cohort strength and improved commercial practices. Commercial fishers' adaptation in net sizes during the past several years helped facilitate the 2022 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 ice to ACHP fishers.

Invasive carp harvest data was summarized by month from January 2015 to December 2022 (Figures 11 & 12). 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 (Figure 11). This shift was expected as many commercial fishers fish Barkley and Kentucky Reservoirs, with a special net permit during paddlefish season, which allows gill netting in the lakes without fishing under the ACHP. However, this is no longer observed since 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; in 2021, number of trips was more standard across the months, whereas 2022 saw a lot of seasonal differences (Figure 11). Average total pounds of silver carp harvested per trip increased from 2021 and ranged from 2,741 – 5239 pounds per month in 2022 (Figure 27).

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 ^{o}F and 86.0 ^{o}F (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 2022, the average number of pounds harvested per trip was calculated for all ACHP fishers (N=39), and average pounds of silver carp harvested varied from 20 lbs/trip to 8,272 lbs/trip. Interestingly, not all fishermen with high catch rates fished frequently (Figure 13) The number of trips a commercial fisherman took in 2022 varied from 1 to 208, with an average of 50 trips. This only included the number of trips where harvest occured. In 2022, 63% of the requests to fish ended with fish harvested. Some fisherman call in for whole weeks at a time, but may not go out every day, some cancelations were due to weather or equipment being down, other times, a fisherman may go out to gill net, scan around and not find a school of fish big enough to set their net on.

Ride-Alongs

KDFWR conducted 59 ride-alongs with 16 unique commercial fishers utilizing the ACHP January through December 2022 (Table 20 & Figure 15). During ride-alongs 39,658 yards of gill net were fished and 203,994 lbs of invasive carp were harvested. The majority of fishing effort observed during ride alongs was on Barkley Reservoir(N=46), which is similar to fishing effort in general. Ride-alongs were also conducted in Kentucky Reservoir(N=4) and the Ohio River(N=1). Commercial fishers set nets primarily along secondary channels, on flats on the main lake, and in embayments. In previous years, the northern end of Barkley Reservoir received the most fishing pressure. However, in 2021 and 2022, fishing pressure observed through ride alongs was more evenly distributed throughout Barkley and Kentucky Reservoirs (Figure 15). The mean effort per trip (yards of net fished) decreased in 2021 and 2022 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) (Table 20). Average total weight of silver carp harvested per trip during ride-alongs in 2022 (3,731 lbs) was higher than 2021 (Table 21). This is reflective that the commercial fishers are getting more efficent at setting gill nets. There has been multiple instances were KDFWR observed during a ride along that a commercial fisher scanned with side scan technology and ended up not setting a net because they couldn't find a big enough school of invasive carp. This occurred on three occasions during 2021 and six times during 2022. KDFWR has began to mointor zero net set trips and search time as fisheries dependent trends to inform invasive carp stock assesments..

Experimental Gears

Robbins Construction LTD harvested approximately 240,467 lbs of invasive carp from Barkley and Kentucky Reservoirs in 2022 with an average of 20,039 lbs/day which increased from his 2021 average of 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 100% survival rate at the time of release. While outside the scope of this report it is worth noting that Robbins Construction LTD also harvested 31,073 lbs (10,357 lbs/day) of silver carp from the Ohio River and 140,524 lbs (28,104 lbs/day) of silver carp from the Mississippi River in 2022 through the contracted experimental efforts. Robbins seining in Kentucky waters yeilded him a total of 412,064 lbs silver carp and an average of 20,603 lbs silver carp per day in 2022. His gill netting in Kentucky waters yielded him a total of 595,606 lbs of silver carp and an average of 8,272 lbs silver carp per day in 2022. His daily average while gill netting is 40% of what his daily average is while seining. Which reaffirms the need to continue developing inovative approaches of harvest.

Recommendation:

-Continue to work with partner agencies to develop SOPs for gears, methods, data collection and storage to improve basin wide stock assessments.

-KDFWR will continue to conduct commercial observations to monitor catch and reporting meterics independent of commercial reporting.

-Continue to build and refine the Experimental Gears and Methods program to develop alternatives to gill netting, with the aim being to further increase statewide invasive carp removal.

-Continue to fund the invasive carp subsidy program and alter as needed.

-Discontinue Spring tailwater community surveys because of inconsistent data collection due to unfavorable water conditions.

-Discontinue Standard sampling with gill nets, because the data gained from this method lacks power. Investigate alternative sampling methods to determine relative abundance and changes in the reservior invasive carp populations.

Literature Cited:

Blackwell, Brian & Brown, Michael & Willis, David. (2000). Relative Weight (Wr) Status and Current Use in Fisheries Assessment and Management. Reviews in Fisheries Science - REV FISH SCI. 8. 1-44. 10.1080/10641260091129161.

Collins, S.F., and D.H. Wahl. 2017. Invasive planktivores as mediators of organic matter exchanges within and across ecosystems. Oecologia 184: 521–530.

Conover, G., R. Simmonds, and M. Whalen, editors. 2007. Management and control plan for bighead, black, grass, and silver carps in the United States. Asian Carp Working Group, Aquatic Nuisance Species Task Force, Washington, D.C. 223 pp. Available from: https://www.asiancarp.us/Documents/Carps_Management_Plan.pdf

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.

Lamer, J. T. (2015). Bighead and silver carp hybridization in the Mississippi River Basin: Prevalence, distribution, and post-zygotic selection. Doctoral dissertation. Champaign, IL: University of Illinois at Urbana-Champaign.

Schrank, S. J., Guy, C. S. & Fairchild, J. F. (2003). Competitive interactions between age-0 bighead carp and paddlefish. Transactions of the American Fisheries Society 132, 1222–1228.

"USA Sunrise Sunset Calendars." *Sunrise Sunset Calendars - Home*, 2022, www.sunrisesunset.com/USA/Kentucky/.

Figures:

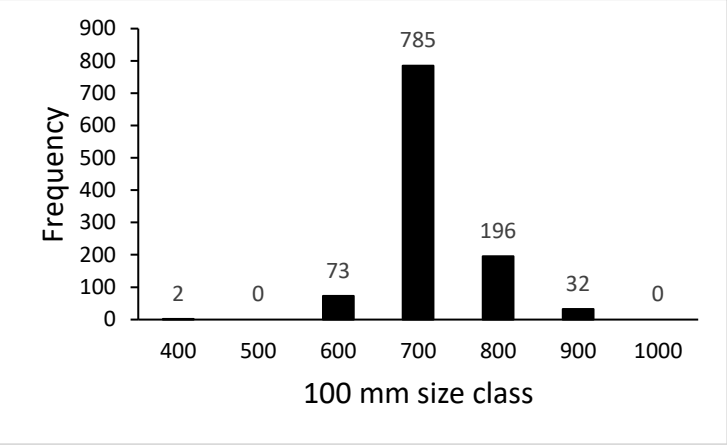


Figure. 1 Length-frequency distribution of silver carp collected from Barkley Reservoir, from all methods in 2022 (N=1088)

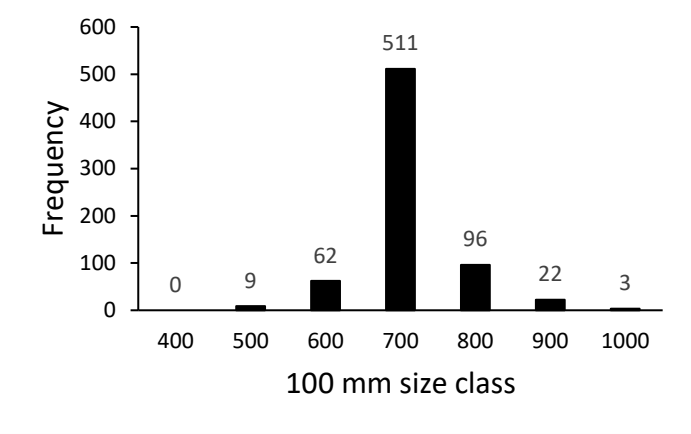


Figure 2. Length-frequency distribution of silver carp collected from Kentucky Reservoir, from all methods in 2022 (N=703).

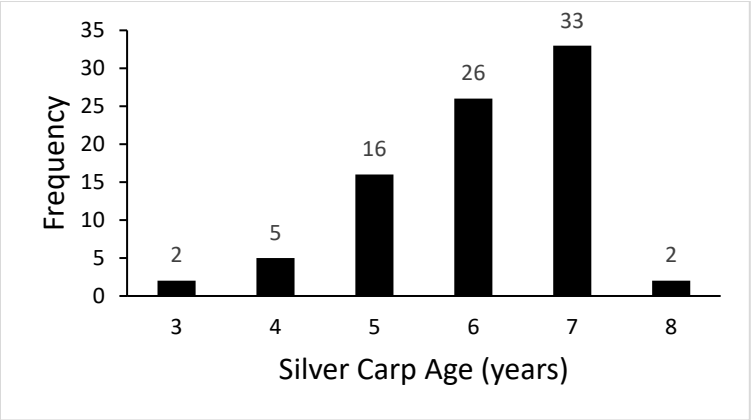


Figure 3. Age-frequency distribution for silver carp collected from Kentucky Reservoir in 2022 (N=84)

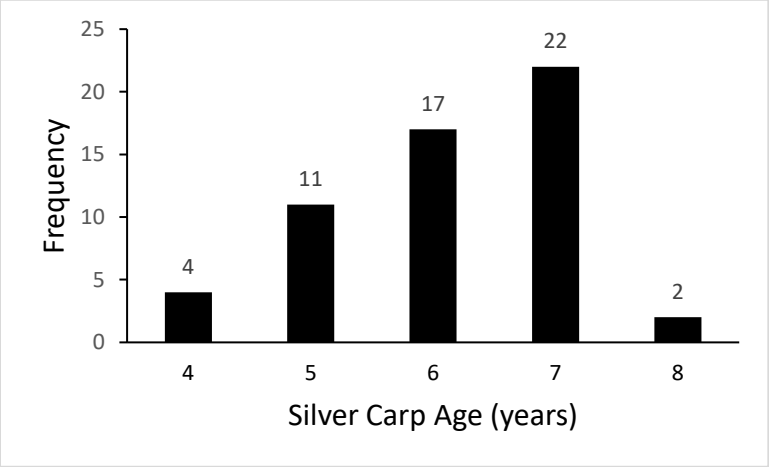


Figure 4. Age-frequency distribution for silver carp collected from Barkley Reservoir in 2022 (N=56).

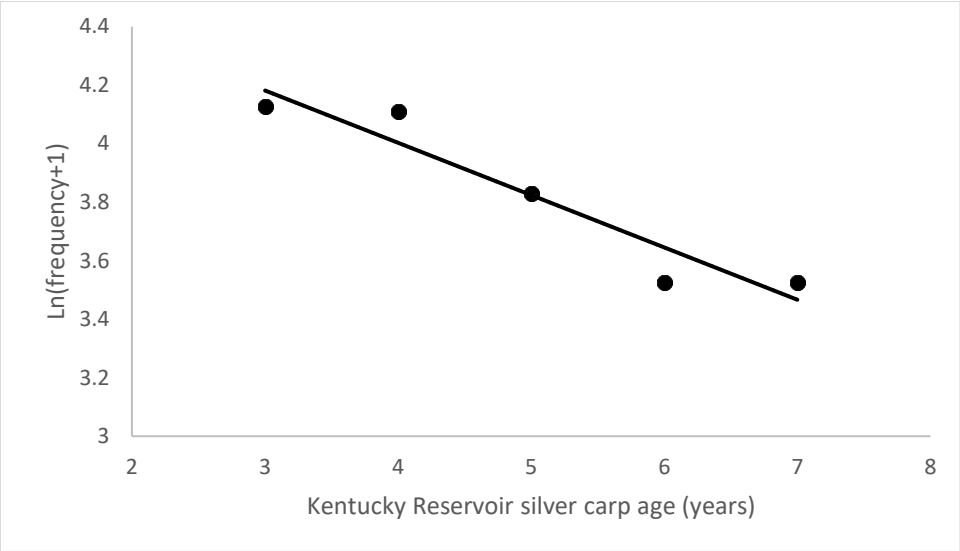


Figure 5. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Kentucky Reservoir in 2022 (N=232, F1,2=29.40, P=0.01, R2=0.91).

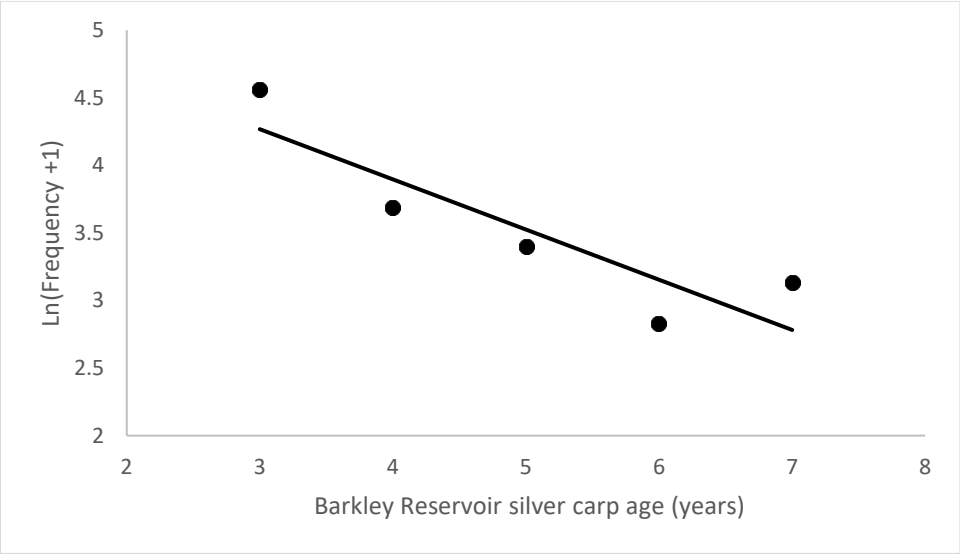


Figure 6. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Barkley Reservoir in 2022 (N=201, F1,2=7.20, P=0.07, R2= 0.71).

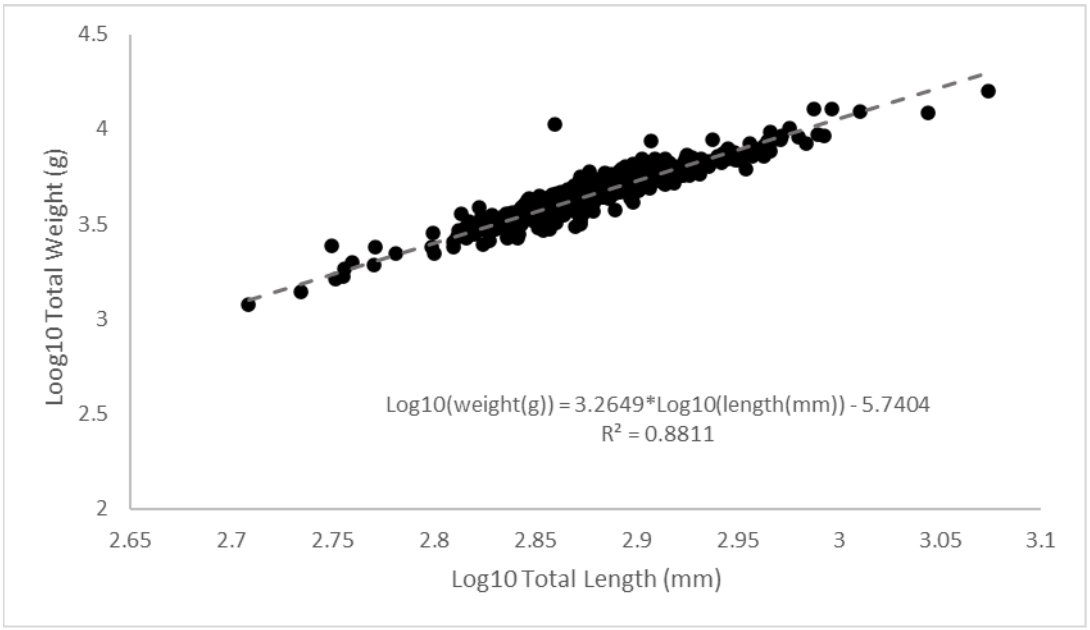


Figure 7. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Kentucky Reservoir in 2022 with a regression line describing the relationship between lengths and weights (N=702).

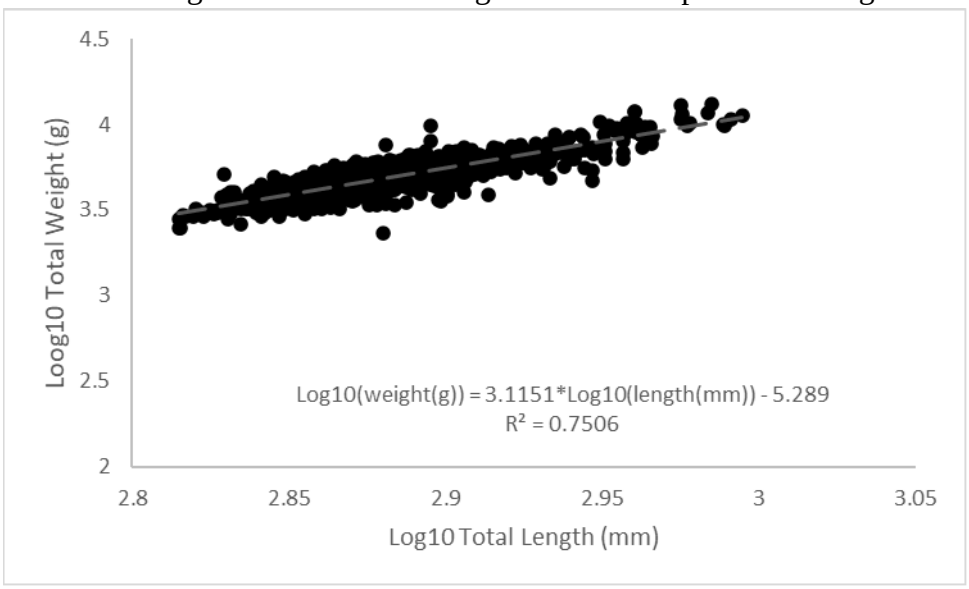


Figure 8. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Barkley Reservoir in 2022 with a regression line describing the relationship between lengths and weights (N=1084).

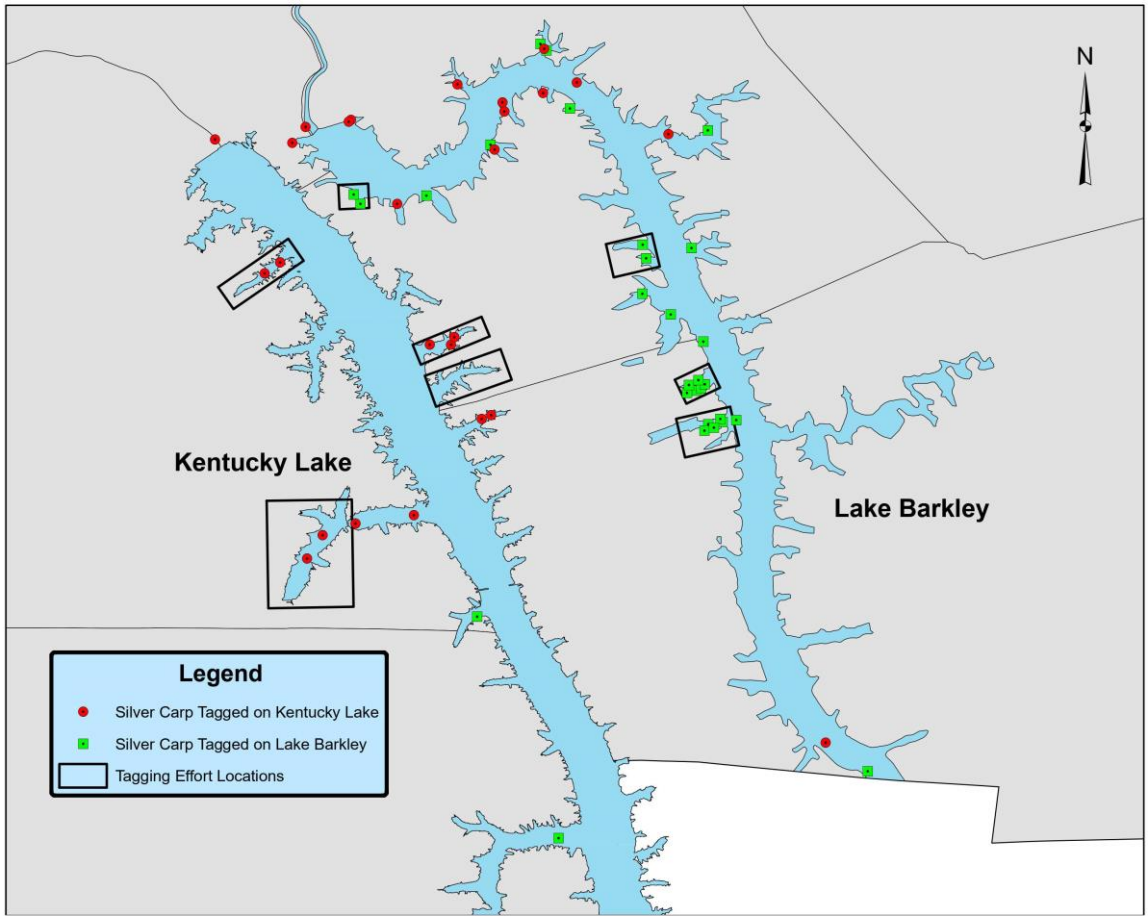


Figure 9. Locations of recaptured silver carp that were tagged as part of the mark-recapture effort to estimate abundance of silver carp in Barkley and Kentucky reservoirs from October 2018- February 2023. (Two recaptured fish not displayed, one was captured in Hovey Lake, IN, other in Green River, KY)

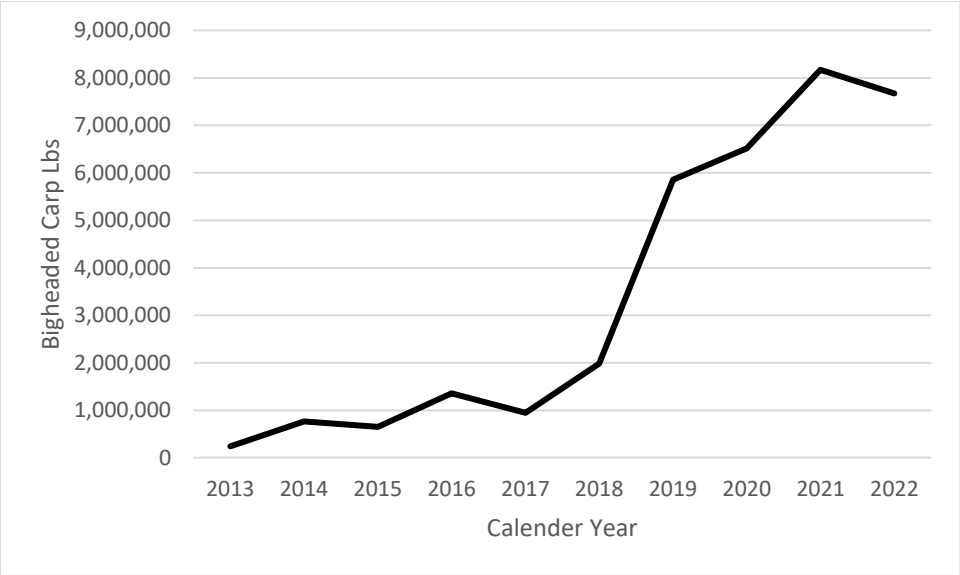


Figure 10. Pounds of bigheaded carp harvested through the Asian Carp Harvest Program by calendar year. *2020 was the first year that grass carp harvest was tracked through the ACHP and accounted for an additional 111,190 lbs in 2020 74,430 lbs in 2021, and 55,805 lbs in 2022.

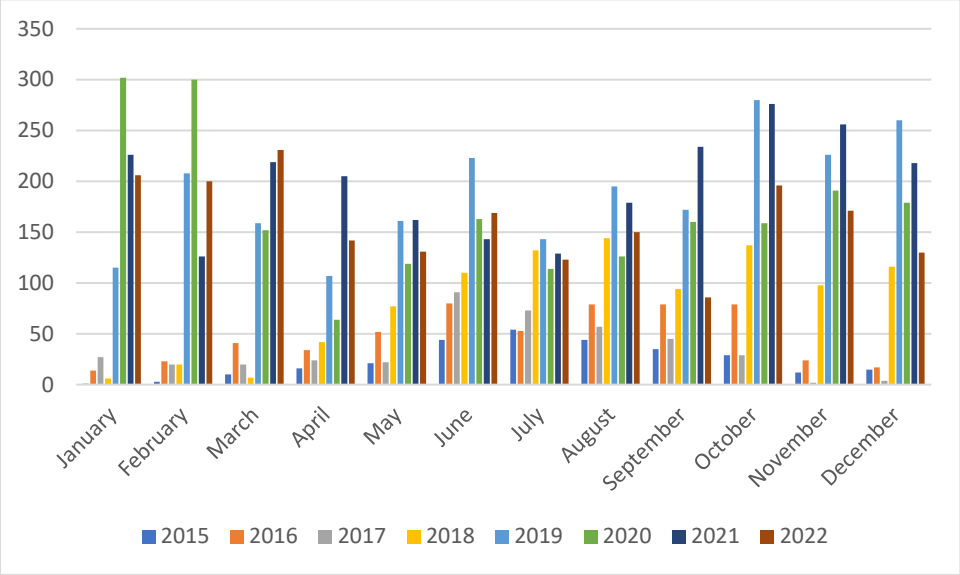


Figure 11. Number of fishing trips made monthly by commercial fishers fishing under the Asian Carp Harvest Program from January 2015 - December 2022.

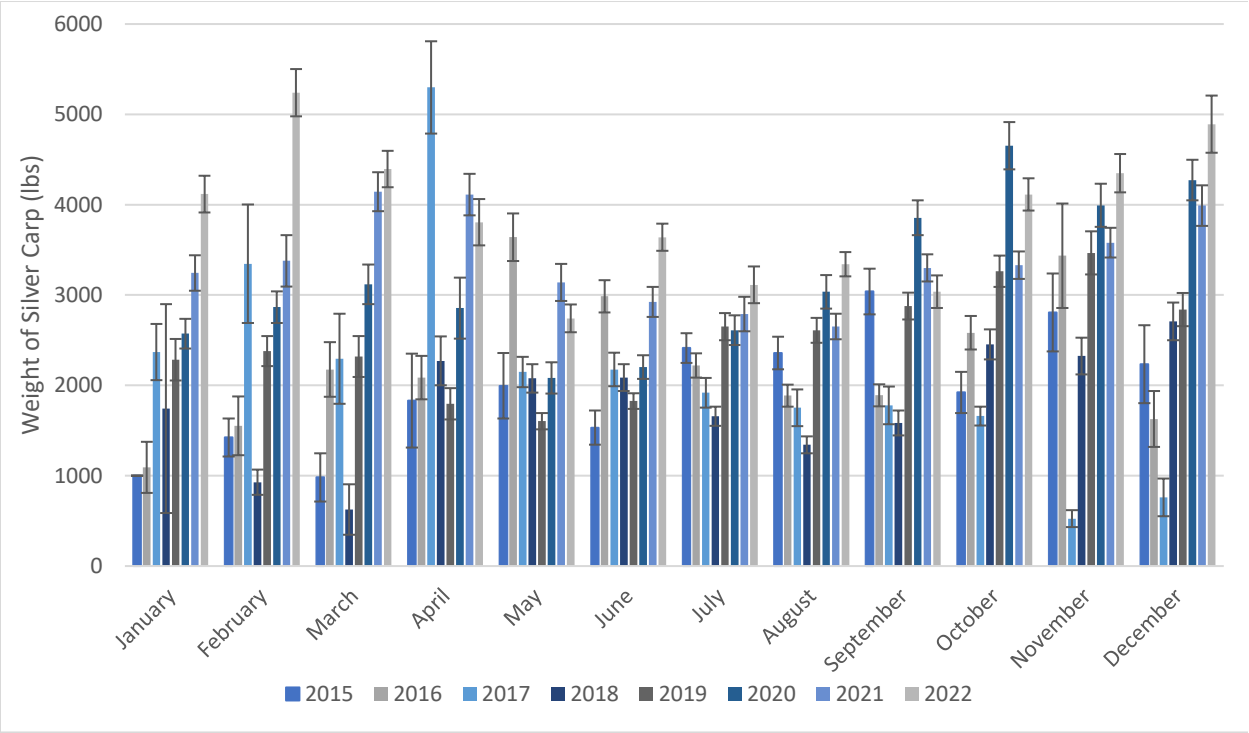


Figure 12. Monthly average total weight (lbs) of silver carp harvested per trip by commercial fishers fishing under the Asian Carp Harvest Program January 2015 - December 2022. Error bars represent standard error values.

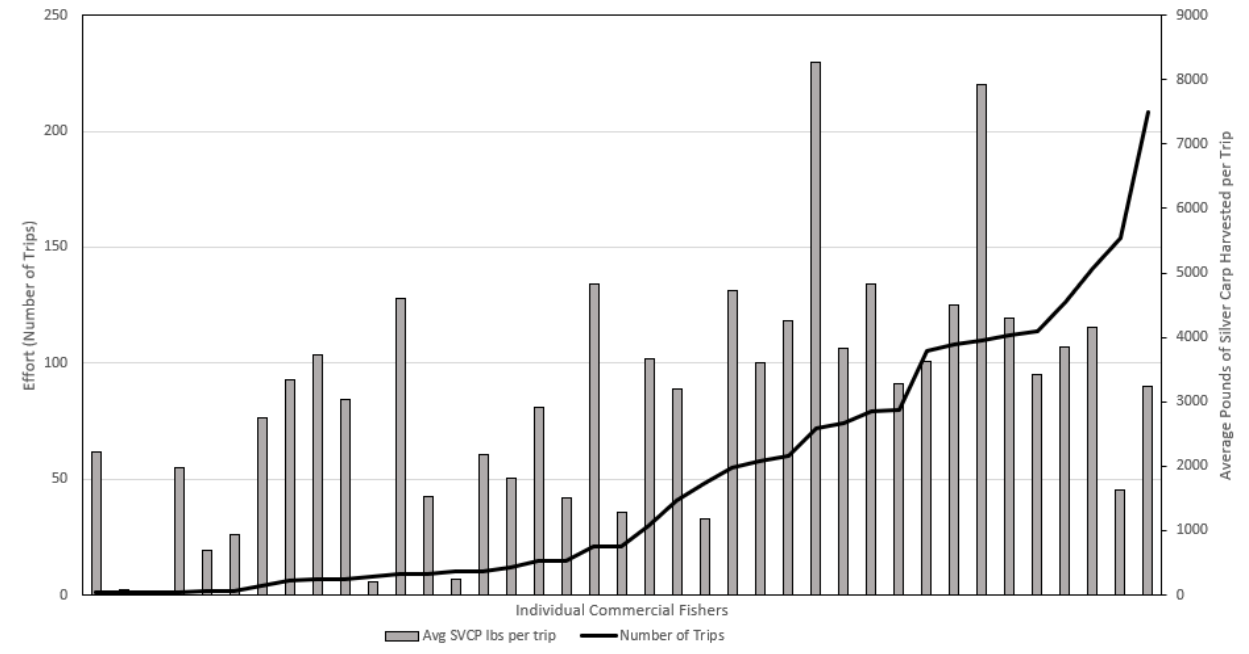


Figure 13. Average silver carp weight harvested per trip by individual commercial fishers compared to the number of trips taken by those fishers under the Asian Carp Harvest Program in 2022.

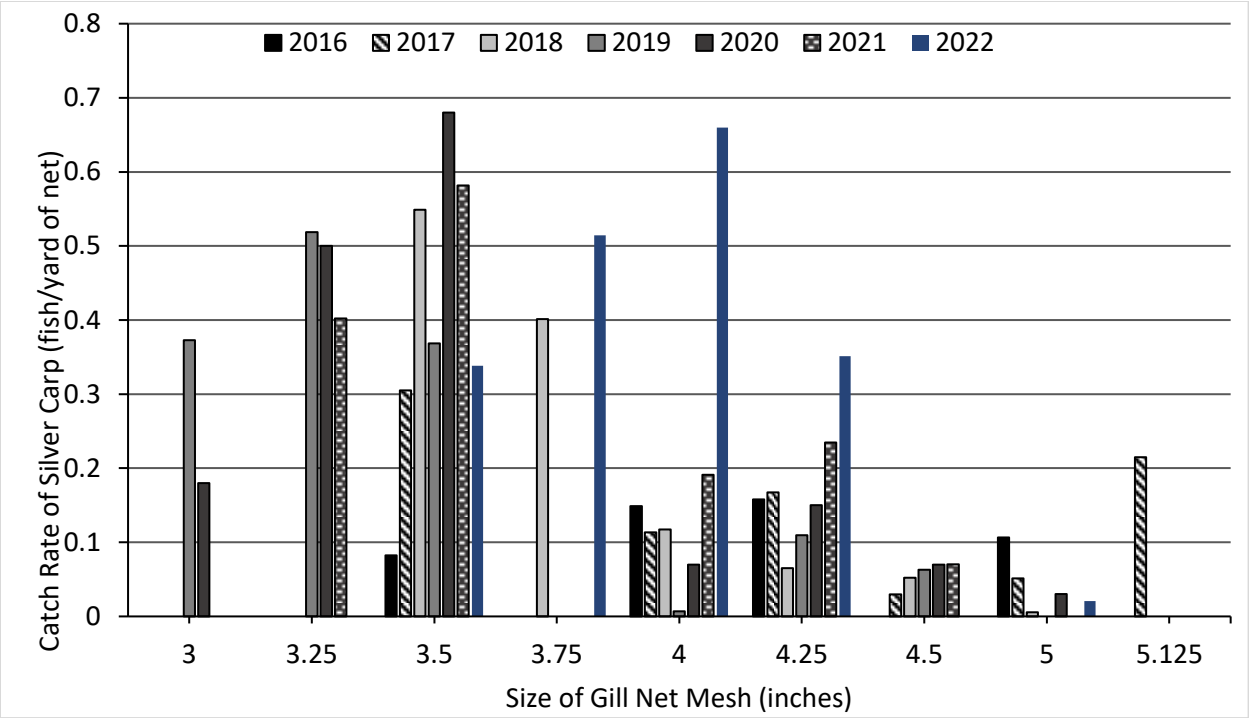


Figure 14. Catch rates (number of fish/yard of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program per year.

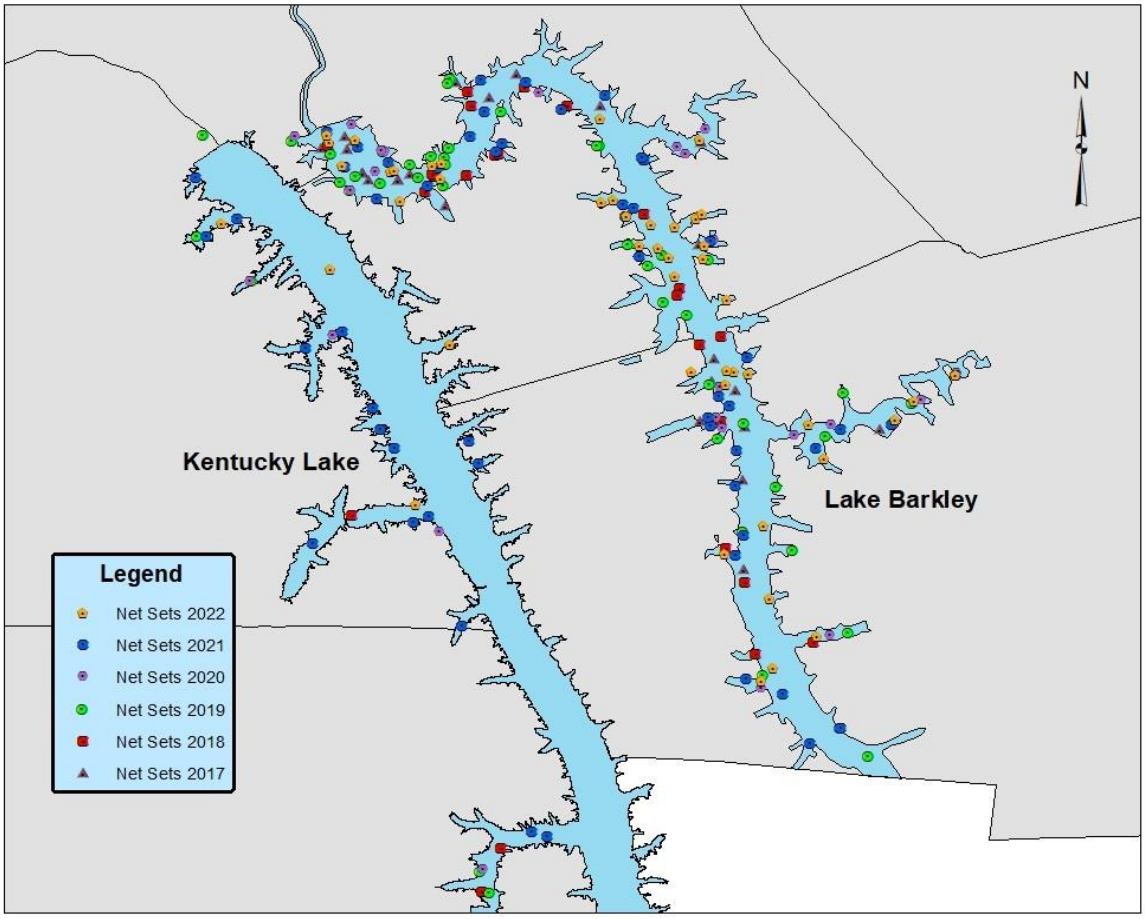


Figure 15. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff from 2017 through 2022.

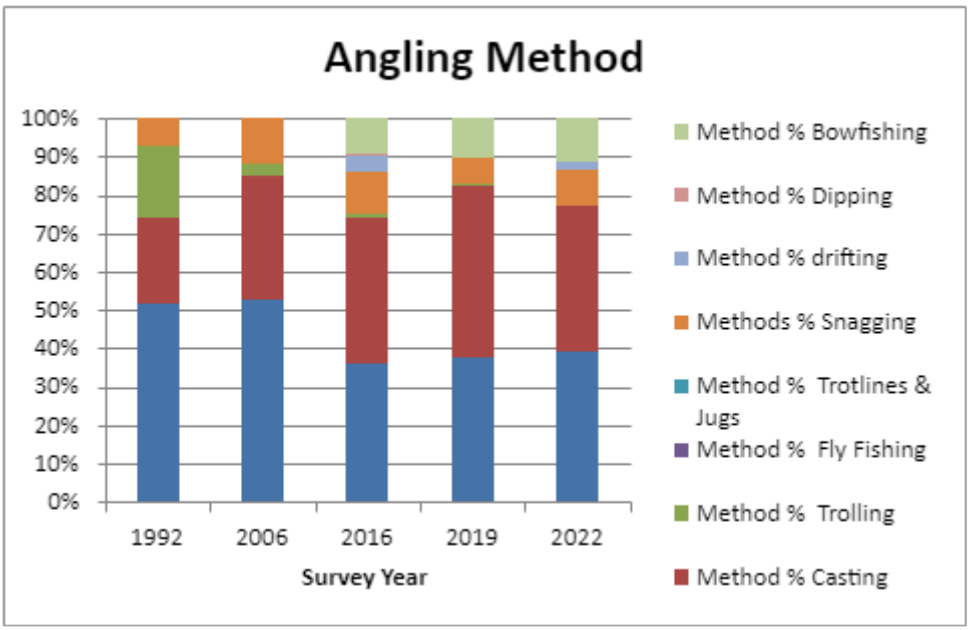


Figure 16. Angling method for fishers in Kentucky Tailwaters.

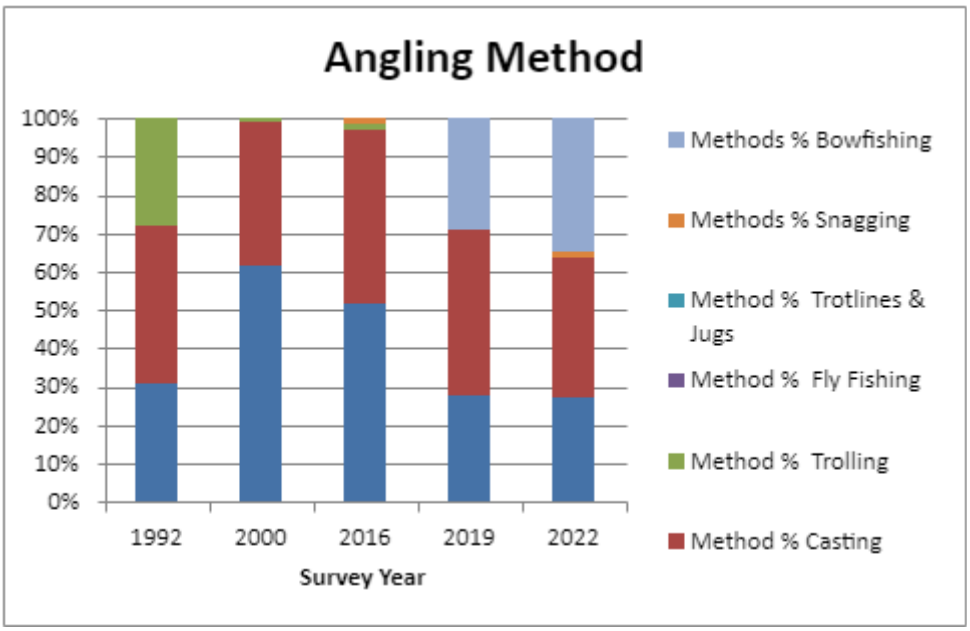


Figure 17. Angling method for fishers in Barkley Tailwaters.

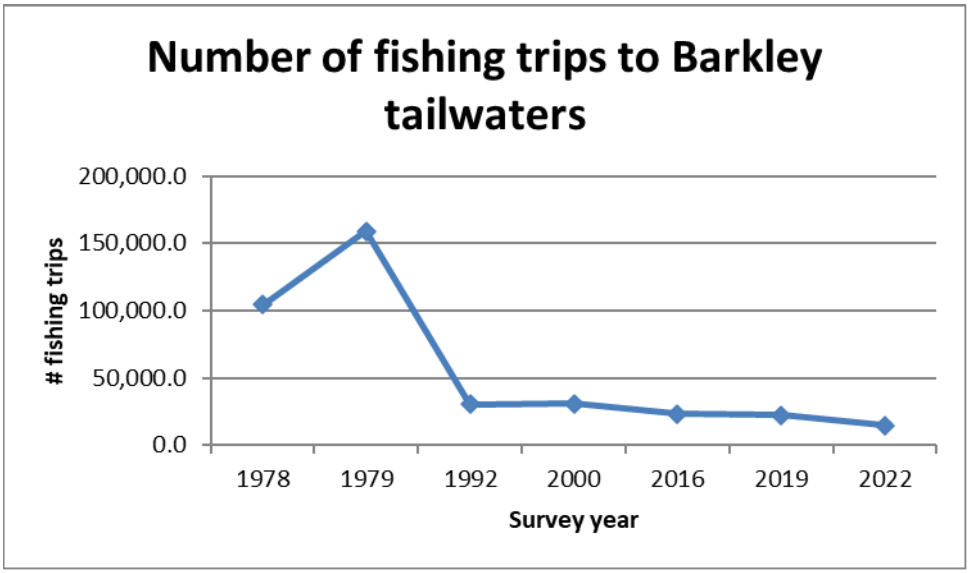


Figure 18. Number of fishing trips to Barkley Tailwaters

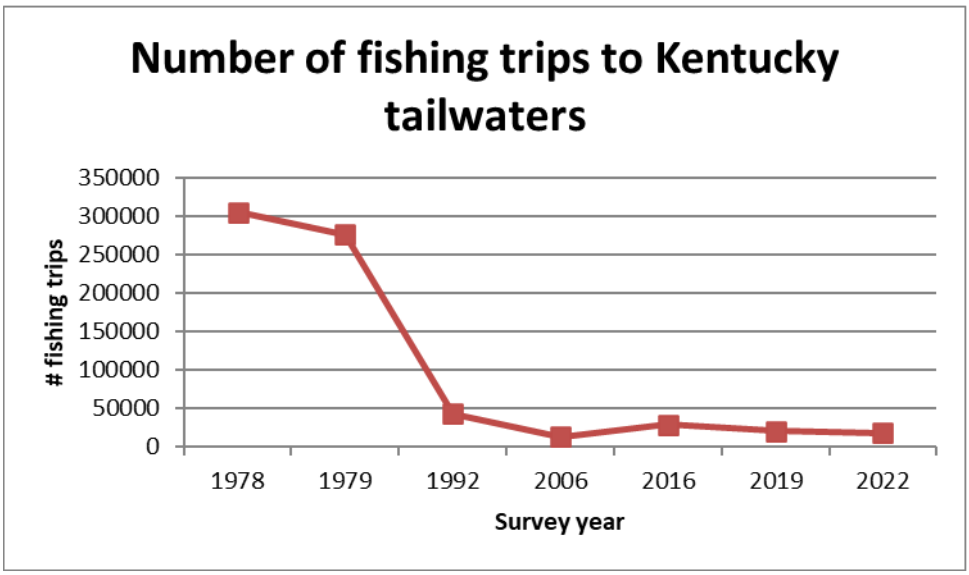


Figure 19. Number of fishing trips to Kentucky Tailwaters.

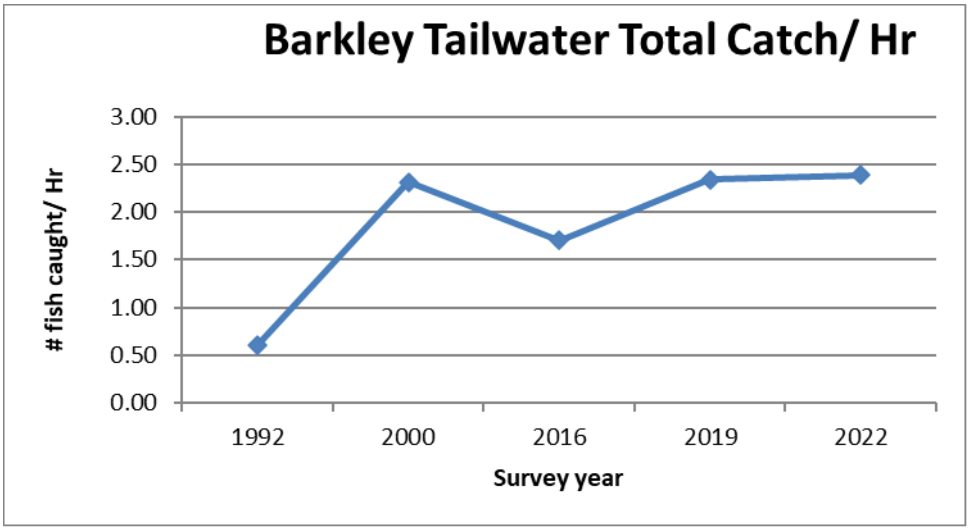


Figure 20. Barkley tailwater total catch per hour.

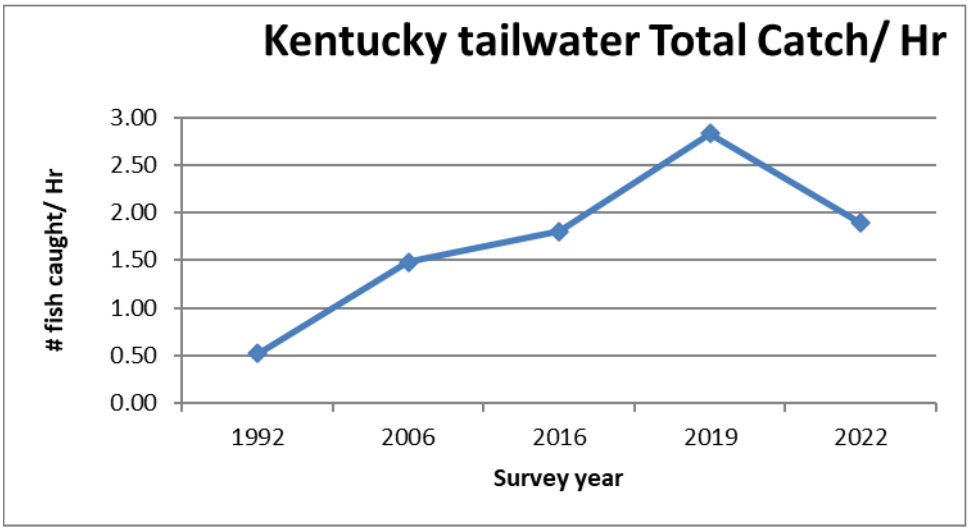


Figure 21. Kentucky tailwater total catch per hour.

Tables:

Table 1. Relative weight (Wr) values of gizzard shad collected from boat electrofishing and paupier net sampling in Barkley and Kentucky reservoirs in fall of 2017-2022. Gizzard shad relative weights based on formula presented in Blackwell et al. 2000.

Kentucky Reservoir

Year	No.	Wr	S.E.
2022	1527	91	0.3
2021	85	92	0.5
2020	95	92	0.8
2019	80	92	0.9
2018	268	103	1.70
2017	82	155	1.63

Barkley Reservoir

Year	No.	Wr	S.E.
2022	440	90	0.49
2021	34	90	1
2020	47	93	0.7
2019	69	94	1
2018	35	92	3.08
2017	125	87	1.99

Table 2. Comparison of of CPUEs across embayments and reservoirs of baitfish with nighttime electrofishing in the fall of 2022. * Mean CPUE for each reservoir

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Blood River	1.5	139	1145	451	3	0
Jonathan	1.5	75	1613	189	8	0
Big Bear	1.5	139	823	431	27	1
Sledd Creek	1.5	110	356	309	81	0
Kentucky Res.*	6	116	984	345	30	0

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Demumbers/Willow	1.5	72	491	1293	10	3
Eddy Creek	1.5	182	481	71	59	0
Little River	1.5	105	763	248	56	0
Honker Bay	1.5	45	1169	412	194	0
Barkley Res.*	6	101	726	506	80	1

Table 3. Paupier Net and Night-time Electrofishing (EF) sampling CPUEs for Kentucky Reservoir in fall of 2022. *Includes embayments other than Big Bear and Sledd Creek

Location	**Effort (hr)**	**GZSD CPUE (fish/hr)**	**TFSD CPUE (fish/hr)**	**SKJH CPUE (fish/hr)**	**SVCP CPUE (fish/hr)**
KY Res. Mean EF *	6	1100	345	30	0
KY Res. Mean Pauiper *	5.32	1045	4766	131	72
Big Bear EF	1.5	962	431	27	1
Big Bear Pauiper	1.28	3193	3349	123	82
Sledd Creek EF	1.5	466	309	81	0
Sledd Creek Pauiper	1.42	1077	12165	293	66

Table 4. Length frequency and CPUE (fish/hr) for select species of fish collected during 4.5 hours of electrofishing at the Kentucky Tailwater in fall of 2022. (CPUE = catch per unit

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	34			
Skipjack herring*		1	9	49	6	1		2	2	1																								114	25	13.9
Gizzard shad*			9	22	16	10	12	17	32	17	17	19	7	8																				211	47	11.4
Threadfin shad*		50	176	1	1																													8372	1860	795.2
Grass carp																				1	1			2					1	1	4			10	2	0.7
Common Carp																				1	1	1	2											5	1	0.7
Silver carp																			1	1			1			1	3					1	1	9	2	0.7
Emerald Shiner		22	48	3																														133	30	17.0
Smallmouth buffalo												2	6	2	2	3	4	1	1						1			1						23	5	1.2
Blue Catfish																			1															1	0	0.2
Channel Catfish																		1	2	2														5	1	0.6
Flathead catfish						2		1		1											1													5	1	0.5
White bass				2		2	1																											5	1	0.7
Yellow bass		2	5	1	9	4	3	2	1																									27	6	3.1
Bluegill	7	56	29	28	20	8	3																											151	34	8.2
Longear sunfish		4	9	5	3	1																												22	5	1.6
Redear sunfish				2	3	6																												11	2	1.0
Smallmouth bass		1	13	12	15	15	6	3			1	1	2																					69	15	4.1
Spotted Bass						1	1							1																				4	0.89	0.52
Largemouth bass				4	4	3	15	11	5	3	2		2		2	3		3	1	1														59	13.11	3.23
White Crappie		1																																1	0.22	0.22
Freshwater drum			6	12	1	1	1			1						1		3	2	2		2												69	15.33	12.54
White bass/Striped bass hybrid														1	1																			2	0.44	0.3
Striped Mullet																			1	2	1													4	0.89	0.61

* species were randomly subsampled

Table 5. 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 2022. (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			6	19	16	7	4																											52	17	7.3
Gizzard shad*			2	3	6	13	16	17	17	15	8	5	3	1																				113	38	14.5
Threadfin shad*		48	205	4																														3789	1263	325.9
Grass carp																																				
Silver carp																			1	1	1	1		3	3	8	3	2	3	4	1	1		32	11	2.5
Smallmouth buffalo															3	4	9	11	6	3	1	1												38	13	4.8
Flathead catfish							3				3	3	2		1			1																13	4	1.3
White bass					1	1	4	2	2	3	3	1																						17	6	2.9
Yellow bass			2																															2	1	0.7
Bluegill	20	19	17	5	1	1	1																											64	21	6.4
Longear sunfish	2	4	23	19																														48	16	4.1
Redear sunfish			1																															1	0	0.3
Smallmouth bass		1	3	11	5	3	2	2	4	3	1																							35	12	2.1
Largemouth bass				1	2	5			1	2		2	3		2																			18	6	2.3
Black crappie								1																										1	<1	0.3
Freshwater drum												1	3	1	8	4	5	8	3														33	11	3.0
White bass/Striped bass hybrid																1																		1	0	0.3

* species were randomly subsampled

Table 6. 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), 2021 (effort = 3.75 hours), and 2022 (effort = 4.5 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Fall 2015		Fall 2016		Fall 2017		Fall 2018		Fall 2019		Fall 2020		Fall 2021		Fall 2022	
	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.	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	25	13.9
Gizzard shad	275	58.6	184	78.0	163	61.1	22	10.2	240	92.1	163	69.7	44	21.4	47	11.4
Threadfin shad	251	176.3	1690	1251.0	1263	637.0	2557	1845.1	27	14.9	712	241.1	665	291.6	1860	795.2
Grass carp	13	1.9	6	2.5	2	0.7			6	2.8	8	4.7	1	0.8	2	0.7
Silver carp	6	2.6	44	22.4	4	1.6	9	6.9	4	2.0	9	4.9	9	3.1	2	0.7
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	5	1.2
Bigmouth buffalo					1	0.4	2	1.0					< 1	0.3	<1	0.4
Black buffalo	6	2.0	3	1.9	< 1	0.2			1	0.4	< 1	0.4			<1	0.4
Blue catfish					< 1	0.2			< 1	0.3					<1	0.2
Channel catfish			1	0.6	1	0.9			< 1	0.3					1	0.6
Flathead catfish			4	1.2	4	1.4			3	1.4	< 1	0.4	1	0.4	1	0.5
White bass	8	4.3	7	4.0	< 1	0.3	6	5.6	4	1.9	5	2.5	3	1.8	1	0.7
Yellow bass	162	83.5	17	13.3	26	4.1	7	4.3	18	7.8	3	1.6	1	0.4	6	3.1
Striped bass					2	1.0	2	1.0							<1	0.2
Bluegill	96	29.2	41	11.8	128	30.7	20	4.0	127	48.8	26	5.9	4	2.1	34	8.2
Longear sunfish	14	14.0	48	12.0	80	25.0	7	4.8	67	15.4	10	3.9	2	1.2	5	1.6
Redear sunfish	1	1.0	6	2.3	6	1.6			15	3.9	2	1.1	1	0.4	2	1.0
Smallmouth bass	9	2.5	21	5.2	11	3.2	2	1.0	29	12.3	10	2.8	6	2.6	15	4.1
Spotted bass	1	1.0	1	0.6	3	1.4	1	0.8	3	1.4					<1	1
Largemouth bass	62	19.8	86	9.4	35	4.3	7	2.9	29	6.2	15	3.6	5	1.7	13	3.2
White crappie	2	2.0	1	0.7	1	0.4			3	1.9					<1	0.2
Black crappie	2	2.0	1	0.6	3	1.7			2	1.5						
Sauger	1	1.0			1	0.4							1	0.5	<1	0.2
Freshwater drum	13	5.7	6	1.5	4	0.7	4	2.2	8	2.5	11	2.8	5	1.4	15	12.5
White bass/Striped bass hybrid	1	1.0	1	1.1	1	0.5									<1	0.4
Striped mullet											1	1.0	1	0.8	<1	0.6

Table 7. 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), 2021 (effort = 3.0 hours), and 2022 (effort = 3.0 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Fall 2016		Fall 2017		Fall 2018		Fall 2019		Fall 2020		Fall 2021		Fall 2022	
	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	< 1	0.5	8	2.9	35	18.0	324	158.4	41	10.78	28	10.9	17	7.3
Gizzard shad	209	52.4	104	18.2	23	8.1	362	224.8	189	49.03	8	5.0	38	14.5
Threadfin shad	4598	1818.7	1252	602.1	67	12.8	30	18.8	1298	719.49	378	182.4	1263	352.9
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	11	2.5
Smallmouth buffal	15	7.6	10	2.7	1	1.0	5	3.2	10	3.75	3	1.6	13	4.8
Bigmouth buffalo	1	0.9	< 1	0.3	1	1.0								
Black buffalo			1	0.7									<1	0.33
Channel catfish	< 1	0.4	1	0.5					1	0.49			<1	0.33
Flathead catfish	8	3.6	6	3.1			22	5.9	4	1.57	2	1.2	4	1.3
White bass	7	3.9	3	1.1	3	3.0	1	0.7	1	0.56	2	1.4	6	2.9
Yellow bass	2	0.7	28	16.0			4	3.0	3	1.24	2	1.0	<1	0.7
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	21	6.4
Longear sunfish	102	25.0	83	16.8	46	25.4	153	30.5	41	10.06	14	4.7	16	4.1
Redear sunfish	8	2.1	3	1.2	2	1.2	3	1.2	2	0.83	3	1.2	<1	0.3
Smallmouth bass	7	2.3	9	1.2	4	1.6	29	7.2	8	1.53	13	3.0	12	2.1
Spotted bass	2	1.0	< 1	0.3	1	1.0	7	2.0	1	1.09			<1	0.45
Largemouth bass	48	8.0	55	10.3	13	5.0	30	8.1	26	11.01	15	5.1	6	2.3
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	11	3.0
Striped bass hybrid	< 1	0.4	3	2.3	4	4.0			1	0.73	1	1.0	<1	0.3

Table 8. Mean relative weight (Wr) and standard error for a subsample of fish collected during fall electrofishing at Kentucky Tailwaters in 2015 - 2022. (S.E. = standard error)

Species	2015				2016				2017				2018				2019				2020				2021				2022			
	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.	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		126	89	1.1	
Blue catfish									1	108							1	99											1	84		
Channel catfish					1	102			1	105							1	100											5	101	7.4	
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		2	88	4.4	
Striped bass													1	101															1	87		
bass/Striped bass hybrid					2	81	7.5																						2	109	7.3	
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		28	86	4.6	
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		6	102	23.6	
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		12	93	3.3	
Spotted bass	1	103	0.0		1	123			6	109	3.1						1	117											1	84		
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		33	105	2.7	
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		1	71		
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		25	92	2.4	
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 9. Mean relative weight (Wr) and standard error for a subsample of fish collected during fall electrofishing at Barkley Tailwaters in 2016 - 2022. (S.E. = standard error)

Species	2016				2017				2018				2019				2020				2021				2022			
	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	96	70	1.6		176	80	0.9		18	75	2.5		45	91	1.2		53	96	4.2		20	73	3.1		82	89	1.5	
Channel catfish	1	67			2	92	1.0										2	111	5.6						1	110		
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		16	90	3.0	
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		1	99		
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		27	102	6.2	
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		1	45		
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		15	95	2.8	
Spotted bass	3	107	11.0						1	125			3	106	10.1		2	103	9.4						2	104.91	2.4	
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		10	102	4.0	
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		33	95	2.5	
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 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 2016-2022. (S.E. = standard error).

	2016				2017				2018				2019				2020				2021				2022			
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.	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	0.03	0.01	0.15	0.09
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	0.19	0.02	1.35	0.38
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	0.06	0.01	0.07	0.05
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	0.03	0.01	0.61	0.23
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			0.08	0.02		
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	0.01	<0.01	0.04	0.03
Smallmouth bass	<0.01												<0.01	<0.01	0.08	0.05	0.02	<0.01	0.13	0.06	<0.01	<0.01			<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			<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	<0.01	<0.01	0.04	0.03
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	<0.01	<0.01	0.02	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	<0.01	<0.01	0.07	0.04
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	<0.01	<0.01		
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	<0.01	<0.01	0.04	0.03

*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. 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 - 2022. Survival rate of fish is defined as fish that swim away after release.

		2016		2017		2018		2019		2020		2021		2022	
	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	Number captured	Survival rate
Sport Fish	White bass	1	<1%					1	100%			2	100%	1	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%	2	50%
	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%	3	66%
	Largemouth bass	1	100%	5	80%	3	67%	25	80%	4	75%	9	100%	2	100%
	Smallmouth bass							4	100%						
	Redear sunfish	1	100%			2	50%	6	83%			1	100%	2	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%	10	83%
Catfish species	Blue catfish	27	74%	47	94%	42	91%	96	95%	32	100%	38	92%	62	97%
	Channel catfish	10	80%	17	82%	12	100%	13	100%	5	100%	16	96%	3	100%
	Flathead catfish	9	89%	19	100%	8	88%	40	100%	7	100%	26	100%	28	89%
	Total	46	81%	83	92%	62	93%	149	98%	44	100%	80	95%	93	95%
	Paddlefish	83	48%	62	48%	38	32%	63	48%	26	50%	16	69%	7	28%
Rough Fish*	Lake sturgeon					1	100%					1	100%		
	Shovelnose sturgeon									3	100%				
	Skipjack herring	23	17%	47	13%	18	<1%	79	<1%	16	<1%	25	36%	29	52%
	Smallmouth buffalo	145	99%	13	85%	98	100%	186	98%	103	100%	173	99%	236	99%
	Bigmouth buffalo	8	100%	4	100%	7	100%	34	97%	14	100%	12	75%	6	100%
	Black buffalo	17	94%			2	100%	4	100%	1	100%				
	Common carp	48	98%	33	94%	27	100%	479	84%	36	97%	17	100%	10	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%	56	89%
	River carpsucker	3	100%					35	97%	41	100%	5	100%	2	100%
	Spotted gar					2	50%	3	100%	1	100%	2	100%	1	100%
	Longnose gar	8	88%	9	44%			9	67%	3	100%	3	100%	7	100%
	Shortnose gar	9	44%	1	100%	2	50%	11	55%	5	100%	5	100%	1	100%
	Total	571	77%	365	72%	392	83%	1277	87%	329	98%	299	92%	348	93%

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

Table 12. 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
	Caught	Survival Rate %	Number Caught	% Harvested	Caught	Survival Rate %***	Caught	Survival Rate %***	of bycatch
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
2022	47	93.6	11,335	80.2	568	98.8	58	81.0	12,008

*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 13. Number and survival rate of paddlefish captured by commercial fishers during KDFWR ride-alongs under the Asian Carp Harvest Program for each month paddlefish were observed caught in 2016 - 2022.

Year	Month	No. paddlefish captured	% released alive	Mean water temp (˚F)	Mean soak time (hours)
2017	April	6	0%	67.6	13
	May	15	33%	68.5	10
	June	35	60%	79.5	8.3
	September	2	50%	74	10
	December	4	75%	50	21.3
2018	April	4	75%	54.9	11
	May	9	60%	66.1	10.2
	June	12	35%	81.7	10.6
	August	12	0%	82.9	11.6
2019	February	43	61%	46.9	11.4
	March	1	0%	49.8	11
	April	3	33%	60.25	9.7
	May	7	14%	74	6.4
	June	4	0%	76.9	11.3
	August	2	0%	84.1	8.8
	October	3	67%	69.8	8.2
2020	March	9	89%	49.1	7.8
	May	5	20%	66.1	6.5
	September	11	36%	77	7.25
	October	1	100%	68.6	8.8
2021	March	3	100%	57.5	3.25
	May	5	80%	63	13
	July	4	0%	87	9
	October	4	100%	71	11.25
2022	May	4	0%	75	8.5
	August	2	50%	80.5	3.625
	September	1	100%	76	5.5

Table 14. A summation of catch per unit effort (CPUE) for silver carp collected in Barkley and Kentucky Reservoirs, by month and habitat type in 2022. CPUE reported in fish/linear yard of gill net.

			Bar mesh size			
	Site	Month	3"	4"	5"	Mean Total CPUE
Barkley Reservoir	Main Channel	April	0.000	0.002	0.000	0.001
		July	0.001	0.003	0.000	0.001
		October	0.000	0.004	0.000	0.001
	Embayment	April	0.000	0.002	0.000	0.001
		July	0.001	0.004	0.000	0.002
		October	0.002	0.005	0.000	0.002
			Bar mesh size			
	Site	Month	3"	4"	5"	Mean Total CPUE
Kentucky Reservoir	Main Channel	April	0.000	0.000	0.000	0.000
		July	0.001	0.003	0.001	0.002
		October	0.000	0.001	0.000	0.000
	Embayment	April	0.000	0.002	0.000	0.001
		July	0.000	0.002	0.000	0.001
		October	0.000	0.002	0.001	0.001

Table 15. A summation of estimated weights at three lengths for silver carp collected from Barkley and Kentucky Reservoirs through all methods from 2018 through 2022.

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
	2022	946	2975	5681
Kentucky	2018	950	2733	4963
	2019	930	2720	4987
	2020	986	2788	5018
	2021	994	2848	5301
	2022	836	2776	5469

Table 16. Summary of Invasive carp harvest and expenditures of Subsidy funds under the Asian Carp Harvest Program 2016-2022.

Total funds paid out
$4,706.06
$9,596.05
$36,136.98
$210,163.21
$453,925.56
$646,072.68
$672,218.49

Table 17. Measures of effort and catch reported by commercial fishers fishing under the Asian Carp Harvest Program by calendar year, January -December 2013 - 2022.

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)
Barkley	2013	45	5	187,022		
Reservoir	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
	2022	1,510	30	6,120,640	24,762	37,664
Kentucky	2013	21	4	26,400	491	
Reservoir	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
	2022	309	20	1,184,756	3,074	8,666
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
	2022	124	11	274,235	5,117	8,872
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	

Table 18. Average length and weight of silver carp harvested during ride-alongs with commercial fishers under the Asian Carp Harvest Program 2015-2022.

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
2022	1041	29.9	10.9	0.09

Table 19. 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 – 2022. (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

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 - 2022.

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 grass ca harveste (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	58	18	1,780	198,249	1,130
2022	39,658	778	55.9	59	16	2,227	203,994	297

*Effort is calculated in yards of gillnet fished.

Table 21. Comparison of the average weight harvested per trip of silver carp, bighead carp and grass carp during KDFWR ride-alongs, and through commercial fishers reports for the Asian Carp Harvest Program in 2016 - 2022. (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
2022	Ride Alongs	3,731	365.5	147	64.6	28	9.2
	Commercial Fisher Reports	3,889	63.9	137	17.2	122	13.5

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

Table 22. Paupier net effort and catch rates from sampling conducted in Big Bear embayment of Kentucky Reservoir. (S.E. = Standard error)

Date (month-year)	Net Hours	Number of Silver carp captured	Mean Silver carp CPUE (fish/hr)	S.E.	Number of Grass carp captured	Numbe Bighe carp captu
Nov-16	9.12	1,406	168.9	23.0	3	
Oct-17	2.12	516	229.2	40.3		2
Oct-18	4.72	1496	308.3	61	1	2
Oct-22	1.28	105	105.9	33.2		

Appendix A. LAKE BARKLEY TAILWATER ANGLER ATTITUDE SURVEY 2022

1. Have you been surveyed this year? Yes - stop survey No – continue

2. Zip Code _____

3. How many times do you fish the Lake Barkley Tailwaters each year? N=168

First time here 11.3% 1 to 4 27.4% 5-10 19.0% More than 10 42.3%

4. What angling techniques do you use when fishing at Lake Barkley Tailwaters (**check all that apply**)? N=168

Rod and reel 73.8% Snagging 0.0% Bowfishing 48.8% Castnet 0.6%

5. Which species of fish do you fish for at Lake Barkley Tailwaters (**check all that apply**)? N=169

Asian carp 46.7% Catfish 46.2% Striped Bass/White Bass/Hybrids 26.6% Skipjack 23.1% Paddlefish 19.5%

Gar 13.0% Black Bass 11.8% Panfish 3.6% Drum 2.4% Crappie 1.8% Bait Fish 1.8% Buffalo 1.8%
Anything 1.8% Bow species 1.2% Sauger 0.6% Walleye 0.6% Suckers 0.6%

6. Which one species do you fish for most at Lake Barkley Tailwaters (**check only one**)? N=169

Asian carp 42.0% Catfish 29.6% Skipjack 13.0% Striped Bass/White Bass/Hybrids 9.5% Black Bass 2.4% Panfish 1.8% Paddlefish 0.6% Bait Fish 0.6% Anything 0.6%

Answer the following questions for each species you fish for – (see question 5)

Striped Bass/White Bass/Hybrid Anglers

7. In general, what level of satisfaction do you have with Striped Bass/White Bass/Hybrid fishing at Lake Barkley Tailwaters? N=45

Very satisfied 8.9% Somewhat satisfied 42.2% Neutral 24.4% Somewhat dissatisfied 20.0%

Very dissatisfied 4.4% No opinion 0.0%

7a. If you responded with somewhat or very dissatisfied in question (7) – what is the single most important reason for your dissatisfaction? N=11

Number of fish 63.6% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0%
Asian carp 36.4%

Crappie Anglers

8. In general, what level of satisfaction do you have with crappie fishing at Lake Barkley Tailwaters? N=3

Very satisfied 0.0% Somewhat satisfied 0.0% Neutral 33.3% Somewhat dissatisfied 66.7%

Very dissatisfied 0.0% No opinion 0.0%

8a. If you responded with somewhat or very dissatisfied in question (8) – what is the single most important reason for your dissatisfaction? N=2

Number of fish 50.0% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0% Asian carp 0.0% Lock approach closed to fishing 50.0%

Black Bass Anglers

9. In general, what level of satisfaction do you have with the black bass fishing at Lake Barkley Tailwaters? N=19

Very satisfied 10.5% Somewhat satisfied 42.1% Neutral 36.8% Somewhat dissatisfied 5.3%

Very dissatisfied 5.3% No opinion 0.0%

9a. If you responded with somewhat or very dissatisfied in question (9) – what is the single most important reason for your dissatisfaction? N=2

Number of fish 100.0% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0% Asian carp 0.0%

Catfish Anglers

10. In general, what level of satisfaction do you have with the catfish fishing at Lake Barkley Tailwaters? N=78

Very satisfied 29.5% Somewhat satisfied 44.9% Neutral 14.1% Somewhat dissatisfied 10.3%

Very dissatisfied 1.3% No opinion 0.0%

10a. If you responded with somewhat or very dissatisfied in question (10) – what is the single most important reason for your dissatisfaction? N=9

Number of fish 33.3% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0% Asian carp 33.3% Too much commercial fishing 11.1% Dislike electrofishing surveys 11.1% Too many snags 11.1%

Paddlefish Anglers

11. In general, what level of satisfaction do you have with the Paddlefish fishing at Lake Barkley Tailwaters? N=33

Very satisfied 15.2% Somewhat satisfied 24.2% Neutral 45.5% Somewhat dissatisfied 15.2%

Very dissatisfied 0.0% No opinion 0.0%

11a. If you responded with somewhat or very dissatisfied in question (11) – what is the single most important reason for your dissatisfaction? N=5

Number of fish 80.0% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0% Asian carp 20.0%

Bow Anglers

12. How many trips do you make to bow fish in Kentucky during the months of March – August? N=82

First time 2.4% 1-10 39.0% 11-20 17.1% 21-30 9.8% 31-40 3.7% 41-50 4.9% 51-60 3.7% 61-70 0.0% 71-80 3.7% 81-90 0.0% 91-100 2.4% 101+ 13.4%

13. On average how many pounds of the following species do you harvest per trip bowfishing?

Pounds of Invasive carp N=82

0-50 35.4% 51-100 23.2% 101-150 2.4% 151-200 12.2% 201-250 3.7% 251-300 4.9%

301-350 4.9% 351-400 3.7% 401-450 0.0% 451-500 3.7% 501+ 6.1%

Pounds of Buffalo N=82

0 54.9% 1-10 19.5% 11-20 6.1% 21-30 6.1% 31-40 0.0% 41-50 3.7% 51-100 3.7% 101+ 6.1%

Pounds of Gar N=82

0 22.0% 1-10 35.4% 11-20 18.3% 21-30 7.3% 31-40 3.7% 41-50 6.1% 51-100 3.7% 101+ 3.7%

Pounds of Other N=80

0 78.8% 1-10 10.0% 11-20 2.5% 21-30 1.3% 31-40 0.0% 41-50 2.5% 51-100 3.8% 101+ 1.3%

14. How many paddlefish do you shoot per year in Kentucky? N=82

First time 1.2% 0 48.8% 1 18.3% 2 4.9% 3 3.7% 4 2.4% 5 4.9% 6 3.7% 8 2.4% 10 6.1% 20 1.2% 50 2.4%

14a. The current statewide season for snagging paddlefish is February 1 – May 10. Would you support creating a paddlefish season for bowfishing that aligned with these dates? N=82

Support 48.8% Oppose 41.5% No opinion 9.8%

All Anglers

15. Are you aware that you can sell harvested Asian carp to local fish processors with a recreational fishing license? N=169

Yes 59.2% No 40.8%

15a. If yes, have you ever sold Asian carp to any area processors? N=98 Yes 23.5% No 76.5%

15b. If NO on 15a, what is the single most important reason you haven't sold to a processor? N=75

Don't know the buyers 9.3% No way to transport 6.7% Don't get enough to bother 64.0%

They don't pay enough 6.7% Tournament disposes of them 1.3% Too much time 1.3%

Takes too long to get paid 1.3% Take them home to eat 1.3% Live far away and there's no local Asian carp to sell 1.3% Just recently learned of it 1.3% First time fishing at Barkley tailwaters 2.7% Don't want to pay taxes 1.3%

Don't need the money 1.3%

16. What do you normally do with Asian carp that you catch? N=169

Eat 1.8% Sink 43.2% Let go alive 16.0% Use for bait 13.0% Sell 5.3% Never caught one 11.8% Fertilizer 4.1% Tournament disposes 1.8% Throw on rocks 0.6% Give to someone else 1.8%

Sink or sell depending on proximity to buyers 0.6%

17. Have you ever tried eating Asian carp? N= 169

Yes 25.4% No 74.6%

18. Are you satisfied with the current size and creel limits on all sport fish at the Lake Barkley Tailwaters? N=169

Yes 97.6% No 2.4%

18a. If not, which species are you dissatisfied with and what species size and creel limits would you prefer? N=4

White Bass minimum length 13" 25.0% Daily limit of 5 fish 25.0% Remove trophy catfish regulation 25.0%

Crappie minimum length 9" 25.0%

Appendix B. KENTUCKY LAKE TAILWATER ANGLER ATTITUDE SURVEY 2022

1. Have you been surveyed this year? Yes - stop survey No – continue

2. Zip Code _____

3. How many times do you fish the Kentucky Lake Tailwaters each year? N=188

First time here 9.0% 1 to 4 23.9% 5-10 16.0% More than 10 51.1%

4. What angling techniques do you use when fishing at Kentucky Lake Tailwaters (**check all that apply**)? N=188

Rod and reel 87.8% Snagging 16.0% Bowfishing 21.8%

5. Which species of fish do you fish for Kentucky Lake Tailwaters (**check all that apply**)? N=188

Catfish 51.1% Skipjack 27.1% Asian carp 26.1% Black Bass 22.9% Striped Bass/White Bass/Hybrids 21.3% Paddlefish 11.2% Crappie 8.0% Gar 7.4% Panfish 7.4% Anything 4.8% Sauger 4.3% Bluegill 3.2%

Bait Fish 2.7% Shad 0.5% Yellow bass 0.5% Drum 0.5% Bow species 0.5%

6. Which one species do you fish for most at Kentucky Lake Tailwaters (**check only one**)? N=188

Catfish 33.5% Asian carp 16.5% Skipjack 13.8% Black Bass 10.6% Striped Bass/White Bass/Hybrids 10.1% Anything 4.8% Bait Fish 2.7% Panfish 2.1% Crappie 1.6% Paddlefish 1.6% Sauger 1.1% Yellow bass 0.5% Bluegill 0.5% Carp 0.5%

Answer the following questions for each species you fish for – (see question 5)

Striped Bass/White Bass/Hybrid Anglers

7. In general, what level of satisfaction do you have with Striped Bass/White Bass/Hybrid fishing Kentucky Lake Tailwaters? N=40

Very satisfied 17.5% Somewhat satisfied 40.0% Neutral 17.5% Somewhat dissatisfied 22.5%

Very dissatisfied 2.5% No opinion 0.0%

7a. If you responded with somewhat or very dissatisfied in question (7) – what is the single most important reason for your dissatisfaction? N=10

Number of fish 80.0% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0%
Asian carp 20.0%

Crappie Anglers

8. In general, what level of satisfaction do you have with crappie fishing at Kentucky Lake Tailwaters? N=15

Very satisfied 0.0% Somewhat satisfied 20.0% Neutral 53.3% Somewhat dissatisfied 26.7%

Very dissatisfied 0.0% No opinion 0.0%

8a. If you responded with somewhat or very dissatisfied in question (8) – what is the single most important reason for your dissatisfaction? N=4

Number of fish 50.0% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0% Asian carp 50.0%

Black Bass Anglers

9. In general, what level of satisfaction do you have with the black bass fishing at Kentucky Lake Tailwaters? N=43

Very satisfied 4.7% Somewhat satisfied 62.8% Neutral 20.9% Somewhat dissatisfied 11.6%

Very dissatisfied 0.0% No opinion 0.0%

9a. If you responded with somewhat or very dissatisfied in question (9) – what is the single most important reason for your dissatisfaction? N=5

Number of fish 80.0% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0% Asian carp 20.0%

Catfish Anglers

10. In general, what level of satisfaction do you have with the catfish fishing at Kentucky Lake Tailwaters? N=96

Very satisfied 24.4% Somewhat satisfied 46.2% Neutral 37.2% Somewhat dissatisfied 10.3%

Very dissatisfied 5.1% No opinion 0.0%

10a. If you responded with somewhat or very dissatisfied in question (10) – what is the single most important reason for your dissatisfaction? N=12
Number of fish 75.0% Size of fish 0.0% Not happy with regulations 8.3% Too many anglers 0.0% Asian carp 0.0% Bank access closed for construction 8.3% Difficult to snag 8.3%

Paddlefish Anglers

11. In general, what level of satisfaction do you have with the Paddlefish fishing at Kentucky Lake Tailwaters? N=21

Very satisfied 4.8% Somewhat satisfied 42.9% Neutral 33.3% Somewhat dissatisfied 9.5%

Very dissatisfied 4.8% No opinion 4.8%

11a. If you responded with somewhat or very dissatisfied in question (11) – what is the single most important reason for your dissatisfaction? N=3

Number of fish 100.0% Size of fish 0.0% Not happy with regulations 0.0% Too many anglers 0.0% Asian carp 00.0%

Bow Anglers

12. How many trips do you make to bow fish in Kentucky during the months of March – August? N=41

0-10 29.3% 11-20 26.8% 21-30 7.3% 31-40 2.4% 41-50 2.4% 51-60 2.4% 61-70 4.9%

71-80 2.4% 81-90 0.0% 91-100 7.3% 101+ 14.6%

13. On average how many pounds of the following species do you harvest per trip bowfishing?

Pounds of Invasive carp N=41

0-50 53.7% 51-100 26.8% 101-150 2.4% 151-200 7.3% 201-250 2.4% 251-300 2.4%

301-350 2.4% 351-400 0.0% 401-450 0.0% 451-500 0.0% 501+ 4.9%

Pounds of Buffalo N=41

0 65.9% 1-10 19.5% 11-20 4.9% 21-30 2.4% 31-40 2.4% 41-50 0.0% 51-100 2.4% 101+ 2.4%

Pounds of Gar N=41

0 24.4% 1-10 34.1% 11-20 24.4% 21-30 0.0% 31-40 4.9% 41-50 7.3% 51-100 4.9% 101+ 0.0%

Pounds of Other N=37

0 86.5% 1-10 2.7% 11-20 8.1% 21-30 0.0% 31-40 0.0% 41-50 2.7% 51-100 0.0% 101+ 0.0%

14. How many paddlefish do you shoot per year in Kentucky? N=41

0 61.0% 1 9.8% 2 9.8% 3 2.4% 7 2.4% 10 4.9% 15 4.9% 25 2.4% 30 2.4%

14a. The current statewide season for snagging paddlefish is February 1 – May 10. Would you support creating a paddlefish season for bowfishing that aligned with these dates? N=41

Support 36.6% Oppose 41.5% No opinion 22.0%

All Anglers

15. Are you aware that you can sell harvested Asian carp to local fish processors with a recreational fishing license? N=188

Yes 45.7% No 54.3%

15a. If yes, have you ever sold Asian carp to any area processors? N=86 Yes 4.7% No 95.3%

15b. If NO on 15a, what is the single most important reason you haven't sold to a processor? N=82

No way to transport 6.1% Don't get enough to bother 78.0% They don't pay enough 2.4%

Tournament disposes of them 1.2% Too far too travel 1.2% Out of state 1.2%

Not worth the effort 1.2% Never caught one 1.2% No local markets where they're from 1.2% Just never done it 1.2% Slimy, messy boat 1.2% Don't want to 1.2%

Don't want them in the boat 1.2% Buyers not open 24/7 1.2%

16. What do you normally do with Asian carp that you catch? N=188

Eat 0.5% Sink 37.8% Let go alive 19.1% Use for bait 13.8% Never caught one 22.3% Fertilizer 2.7% Throw on rocks 2.1% Give to someone else 1.6%

17. Have you ever tried eating Asian carp? N= 188

Yes 21.8% No 78.2%

18. Are you satisfied with the current size and creel limits on all sport fish at the Kentucky Lake Tailwaters? N=188

Yes 96.8% No 3.2%

18a. If not, which species are you dissatisfied with and what species size and creel limits would you prefer? N=6

Statewide crappie minimum length 8-9” 16.7% Wants a daily creel limit on catfish 16.7%

Catfish minimum length 10” 16.7% Remove trophy catfish regulation 16.7% Skipjack daily limit 50 16.7% Slot limit on blue catfish 16.7% Catfish maximum length 30” 16.7%

Add a maximum length limit on paddlefish 16.7%

Project Title: Early Detection of Invasive Carp Reproduction and Population Expansion in the Tennessee and Cumberland Rivers

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

Statement of Need:
Invasive carp have been present in the Tennessee and Cumberland rivers for over two decades. They negatively impact fisheries where they are present and pose a significant threat to waters upstream of their leading edge. In response to the ongoing invasion, state and federal wildlife agencies have undertaken efforts to reduce the current populations and are working to prevent further invasion. An increased understanding of invasive carp reproduction where the species' occur and increased surveillance for population expansion beyond the leading edge have significant implications for informing management actions such as targeted removal efforts and deterrent strategies.

Invasive carp reproductive success has not been definitively confirmed above Kentucky and Barkley dams in the Tennessee and Cumberland rivers (TNCR) despite the observation of large numbers of young of year carp during the fall of 2015. Limited evidence of successful invasive carp reproduction, including collection of eggs by Tennessee Valley Authority and one genetically identified larval silver carp from TWRA, has been detected during larval sampling efforts and the 2015 year class remains the dominant cohort of fish captured during sampling efforts since 2016. The larval and juvenile sampling in this plan are critical for understanding the source of carp in the TNCR and making relative management decisions (location and amount of harvest and deterrence projects).

In addition to monitoring for invasive carp recruitment in reservoirs with existing populations, surveillance and monitoring efforts are needed in waters upstream of the existing leading edge, including in adjacent, connected basins such as the Tennessee-Tombigbee Waterway. Reports/encounters with individual invasive carp in upstream reservoirs and connected basins are infrequent, but important to informing our understanding of the invasion front and documenting range expansion.

The Tennessee–Tombigbee Waterway is a 234-mile (377 km) navigation system that connects the navigation systems of the Tennessee, Ohio, and Mississippi Rivers with navigable waters of the Mobile River Basin and the Gulf of Mexico via a cut canal in northeast Mississippi and ten lock and dam structures (Supplemental Map; Green, 1985). Currently, the invasion front of bigheaded carps in the Tennessee River is Pickwick Dam (Post van der Burg, 2021), approximately 8 miles (12.9 km) from the cut canal of the Tennessee–Tombigbee Waterway. Targeted bigheaded carp sampling efforts between Pickwick Dam and Jamie L. Whitten Lock and Dam (Bay Springs Lake) have resulted in a few carp detections, although those detections have increased in Pickwick Reservoir since 2020 as targeted invasive carp efforts have increased (C. Harty, Tennessee Wildlife Resources Authority, pers. comm.; S. Miranda, Mississippi State University, pers. comm.). The Mississippi Department of Wildlife, Fisheries and Parks (MDWFP) and the Alabama Division of Wildlife and Freshwater Fisheries (ALWFF) are concerned about the risk of bigheaded carp's invasion into the Tennessee–Tombigbee Waterway and subsequent waters of the Mobile River Basin warrant continued and expanded sampling. This project will serve as a monitoring program for early detection of invasive carp beyond the currently recognized leading edge of the invasion. It will provide pertinent information on the status and distribution of invasive bigheaded carps in the Tennessee–Tombigbee Waterway, which will aid in the development of a management

and control strategy for invasive carps in the Tennessee-Tombigbee Waterway, preventing further invasion into the Mobile Basin.

Project Objectives:

1. Conduct systematic sampling to monitor for and document invasive carp and recruitment.
2. Develop and implement monitoring programs for early detection of invasive carp in waters upstream of the current leading edge.
3. Determine invasive carp relative densities and assess sampling needs in the Tennessee-Tombigbee Waterway.

Project Highlights:

- No young of year invasive carp were found in Barkley or Kentucky Reservoirs

Methods:

Objective 1. Conduct systematic sampling to monitor for and document invasive carp recruitment.

KDFWR sampled for invasive carp young of year (YOY) in Barkley and Kentucky reservoirs. This work was conducted for one week on each reservoir in the fall. From each reservoir, 4 embayment's were chosen based on size and boat ramp availability. If YOY invasive carp are collected, then length and weights will be recorded, and specimens will be kept for further analysis if desired. Environmental parameters such as water surface temperature, reservoir elevation, discharge, and depth were recorded for the sample locations. Boat electrofishing will be conducted during the nighttime. This sampling will also be used to look at condition of baitfish in each reservoir to look at the effects invasive carp have on native baitfish. Transects will not exceed 15 minutes of peddle time. Sampling was conducted with an MLES box at 500 volts, 19-30 amps, and 10,000-16,000 watts.

KDFWR partnered with the U.S. Fish and Wildlife Service (USFWS) to conduct paupier net sampling in Kentucky reservoir to further inform population demographics and to search for YOY invasive carp. KDFWR provided staff and tender boats to collect length, weights, and aging structures. Sampling design was be informed by previous efforts with this gear type by the USFWS and agreed upon by basin partners. Sampling in Kentucky reservoir was done in six embayments over the course of four nights during the month of October. Transects were no more than five minutes long and number of transects per bay was calculated by shoreline distance (one transect/km).

Results and Discussion:
Objective 1. Conduct systematic sampling to monitor for and document invasive carp recruitment.

<u>Electrofishing</u>
KDFWR sampled for YOY invasive carp nighttime boat electrofishing, in conjunction with sampling for projects under the monitoring of native fish project. This sampling occurred for a week on Barkley reservoir and a week on Kentucky reservoir in October of 2022. Sampling targeted young of year invasive carp, gizzard shad

(GZSD), threadfin shad (TFSD), skipjack herring (SKJH) and emerald shiners. No YOY invasive carp were collected from either reservoir.

Paupier

Sampling with USFWS collected a total of 40,564 fish with the electrified paupier net boat over four nights spent on Kentucky reservoir. This sampling was targeting young of year invasive carp, adult invasive carp, gizzard shad, threadfin shad, and skipjack herring. No YOY invasive carp were collected. CPUE of adult silver carp was lowest it has been in Big Bear embayment (105.9 fish/hr. Table 1), since paupier sampling has occurred. The missing years from 2020 – 2021 has been due to personnel constraints and the Covid pandemic.

Table 1. Paupier net effort and catch rates from sampling conducted in Big Bear embayment of Kentucky Reservoir. (S.E. = Standard error)

Date	Net Hours	Number of Silver carp captured	Mean Silver carp CPUE (fish/hr)	S.E.	Number of Grass carp captured	Number of Bighead carp captured
Nov-16	9.12	1,406	168.9	23.0	3	
Oct-17	2.12	516	229.2	40.3		2
Oct-18	4.72	1496	308.3	61	1	2
Oct-22	1.28	105	105.9	33.2		

Objective 2. Develop and implement monitoring programs for early detection of invasive carp in waters upstream of the current leading edge.

KDFWR participated in meetings with partners, sharing data and insight where applicable.

Objective 3. Determine invasive carp relative densities and assess sampling needs in the Tennessee-Tombigbee Waterway.

KDFWR participated in meetings with partners, sharing data and insight where applicable.

Recommendation:

-KDFWR recommends to sample for YOY invasive carp in the lower Tennessee and Cumberland Rivers and continue to monitor within Barkley and Kentucky reservoirs.

Literature Cited:

Green, S. R. 1985. An overview of the Tennessee-Tombigbee Waterway. Environmental Geology and Water Sciences 7: 9–13.

Post van der Burg, M., D.R., Smith, A.R., Cupp, M.W., Rogers, and D.C., Chapman. 2021. Decision analysis of barrier placement and targeted removal to control invasive carp in the Tennessee River Basin: U.S. Geological Survey Open-File Report 2021–1068.

Project Title: Abundance and distribution of early life stages of invasive carp in the Ohio River

Geographic Location: Ohio River from confluence of Mississippi River to Belleville Pool

Statement of Need:

Acquiring a full understanding of the early life history information is imperative for evaluating the population status (i.e., extent of invasion). Identifying the specific locations that differentiate both the extent of spawning and recruitment is crucial information for implementation of management or control efforts (e.g. targeted removal efforts, informing barrier or deterrent placement, etc). In order to identify these locations, quantifying abundance and distribution of invasive carp early life stages is needed. For the purposes of this plan, the term 'invasive carp' is referring to Silver Carp and Bighead Carp (*Hypophthalmichthys* species), also known as bigheaded carp.

In order to limit the negative impacts of invasive carp populations and their further spread, efforts have increased to understand the distribution and abundance of invasive carp in the waters they currently inhabit. Previous sampling efforts on the Ohio River have documented adult invasive carp presence as far upstream as Robert C. Byrd Dam near Gallipolis Ferry, West Virginia. Densities of adult invasive carp are highest downstream of McAlpine Lock and Dam (Louisville, KY) and substantially decline farther upstream. In 2021, YOY and juvenile invasive carp were captured in Cannelton and Markland pools, respectively. However, since 2016 the majority of Ohio River YOY have been consistently captured in J.T. Myers Pool.

Suspected reproduction of non-indigenous bigheaded carp, through the morphometric identification of invasive carp-type larvae, was documented in Meldahl Pool in 2016 by EA Engineering. In addition, genetically confirmed bigheaded carp eggs and larvae were collected as far upstream as Markland Pool in 2021. Previous efforts have been successful in collecting invasive carp eggs, embryos, and larvae in the Ohio River. However, defined spawning locations and the spatial extent of spawning in the Ohio River remains a knowledge gap. Multiple years of data collection covering a broader spatial extent under a variety of environmental conditions will be necessary to fully understand invasive carp early life history among pools.

Project Objectives:

1) Determine the upstream extent of invasive carp spawning activity in the Ohio River above Markland Dam.
2) Identify locations of the Ohio River in which spawning occurs.
3) Determine the extent and locations of invasive carp recruitment in the Ohio River.
4) Identify characteristics of potential invasive carp nursery areas when juvenile invasive carp are encountered.
5) Evaluate the feasibility of drain structure modifications to limit invasive carp recruitment from Hovey Lake.
6) Determine the propagule source of invasive carp in large tributaries of the Ohio River.

Project Highlights:

- Out of the 23 sites sampled along the lower Ohio River, only one had YOY black carp

Methods:

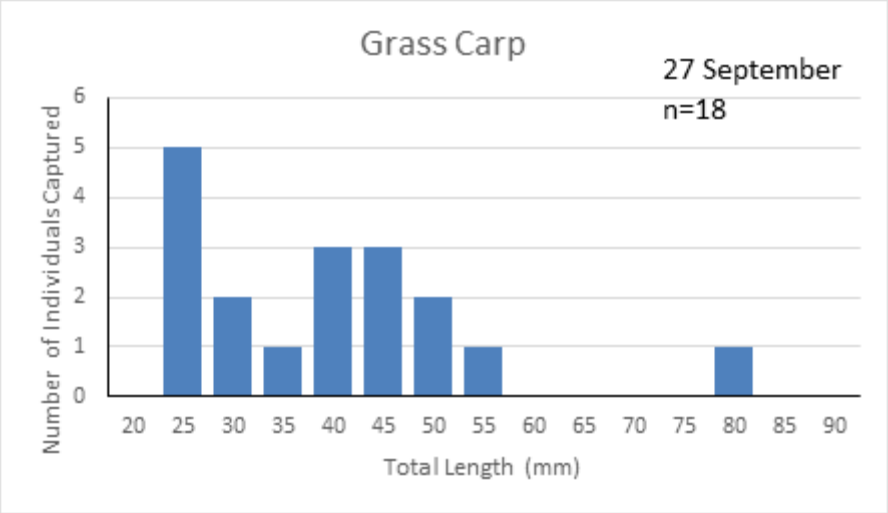
Objective 3. Determine the extent and locations of invasive carp recruitment in the Ohio River.

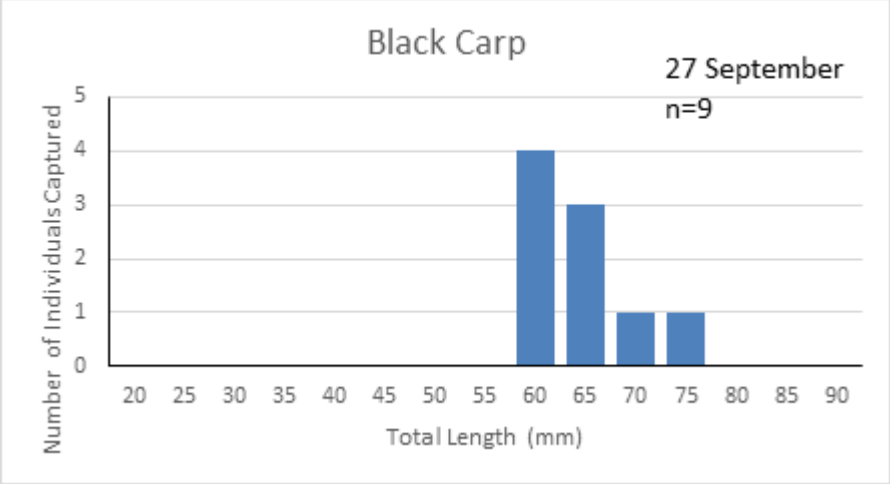
KDFWR conducted targeted sampling for young of year (YOY) Black carp in the lower Ohio river from the confluence with the Mississippi river to Smithland lock and dam. Sampling locations were chosen based on the hydrologic similarity to the location where YOY Black carp were collected previously in Kentucky. Sampling effort did not exceed 10 days. Areas were be sampled with beach seine and backpack electrofishing as available. If YOY or juveniles are collected; length and weight will be recorded, and the specimens will be preserved for additional analysis as needed. Most sites (16 of 23) were sampled using a backpack electrofisher (Smith-Root LR-24) for variable durations depending on amount of habitat available to sample. Seining with 20’ x 5’ and 15’ x 5’ (1/8” mesh) seines was attempted at four sites but proved to be ineffective due to the difficulty of wading through deep, soft mud, which made sampling in general difficult at most sites.

Results and Discussion:

Objective 3. Determine the extent and locations of invasive carp recruitment in the Ohio River.

KDFWR sampled for YOY invasive carp at 23 sites along the lower Ohio River. A total of 67 fish species representing 17 families were collected or observed at 20 sites sampled that had fish. Two sites sampled had age-0 invasive carp. The first site had YOY grass, silver, and common carp. The second site had common, grass, silver, and black age-0 invasive carps (Figure 1). The first site was a plunge pool of a tributary that was no longer connected to the Ohio River. The second site was a shallow backwater that was also no longer connected to the Ohio River. All specimens were fixed in formalin to be brought back to the lab to be properly identified. The YOY grass carp and black carp were identified by pulling out pharyngeal teeth and comparing their morphology (Figure 2, Thomas, M. 2022)





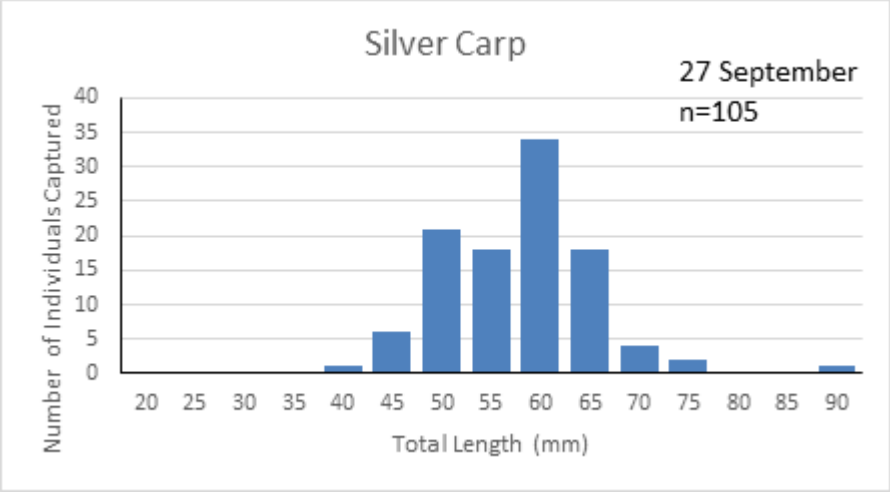


Figure 1. Length frequency distributions of grass, black and silver carp collected in the shallow backwater along the Ohio River.

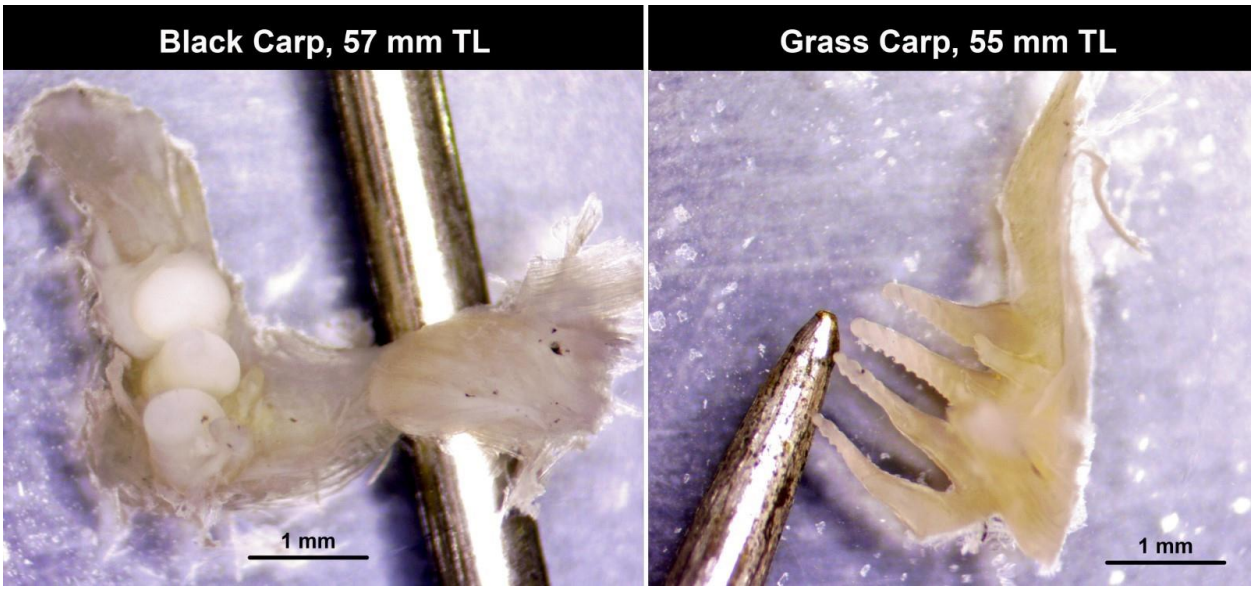


Figure 2. Comparison of pharyngeal tooth morphology between small juvenile Black and Grass carps of approximately the same size. Shown for each species is the dissected right pharyngeal arch. Black Carp has single row of 4 molar-like teeth (3 are visible). Grass Carp has two rows of slender, grooved teeth; 4 on inner row (visible) and 2 on outer row (obscured).

Recommendations:

KDFWR recommends increasing invasive carp YOY sampling in the lower Ohio River with an emphasis on searching for YOY black carp.

References:

Thomas, M. 2022 “Surveys for Age-0 Black Carp in Floodplain Habitats along the Lower Ohio River in Western Kentucky” (KDFWR, *Ichthyologist and Program Coordinator)*

Project Title: Deterrent Strategy Planning for Asian Carp in The Ohio River Basin

Geographic Location: Tennessee and Cumberland rivers including Mississippi, Alabama,Tennessee, and Kentucky.

Introduction:

Adult Silver Carp *Hypophthalmichthys moltrix* and Bighead Carp *H. nobilis* (bigheaded carp, collectively) have invaded the Ohio River Basin. Silver Carp were first reported in the state of Tennessee 1989, and Bighead Carp were reported in 1994 (Kolar et al. 2007). Despite over three decades of occupancy data suggesting presence in Tennessee, bigheaded carp invasion may still be in early stages as evidenced by skewed sex ratios, high growth rates, and robustness (Ridgway 2016). Bigheaded carp are highly effective planktivores that can impose considerable ecosystem changes by altering planktonic communities (Sass et al. 2014). Due to the ability to move through locks, bigheaded carp are capable of invading new reservoirs or perpetuating immigration into already invaded systems. Therfore, detering bigheaded carp from imigrating into vulnerable reservoirs will help to prevent and ameliorate bigheaded carp invasions. Furthermore, surveliance and detections of changes in the leading edge of invasion will inform prioritization of management actions.

Data regarding pool-to-pool movement and lock-and-dam passage will inform placement of deterrents that minimize trade-offs. Furthermore, baseline data will allow efficacy of deterrents to be measured after implimentation. This project supports the goals of the Ohio River Basin Asian Carp Control Strategy Framework including prevention, monitoring, and response. The specific strategy supported is to evaluate the use of deterrent barriers at strategic locations to limit further dispersal of bigheaded carp in the Ohio River Basin.

Project Objectives:

1) Characterize the need for deterrents and evaluate priority locations for deterrent placement to control movement of bigheaded carp in the Tennessee and Cumberland rivers.
2) Collect baseline movement information among reservoirs to inform bigheaded carp deterrent efficacy and lock-and-dam passage.

Project Highlights:

KDFWR/MSU

The BAFF system has been observed to reduce silver carp crossing the deterrent by atleast 50% when ON. Silver carp were observed to exit the reservoirs in the spirng. The macrohabitats which were studied are too coarse, and more fine-scaled habitats are being considered. Preliminary data suggest that Silver Carp do not show a noticeable pattern in their distribution in the Lower Cumberland River (Figure 13) but they seem to cluster near RK 20 in the Lower Tennessee River.

Methods:

KDFWR

Objective 1. Characterize the need for deterrents and evaluate priority locations for deterrent placement to control movement of bigheaded carp in the Tennessee and Cumberland rivers.

KDFWR participated in annual meetings with collaborating agencies to provide updates on the distribution of invasive carp populations, identify available deterrent methods, and prioritize installation and maintenance of deterrents in the TNCR. To identify and make necessary changes to the prioritized list of where deterrents to invasive carp movements are needed. Deterrent placement will be characterized by locations that will strategically reduce the potential of invasive carp expansion upstream in the Tennessee, and Cumberland rivers. Locations for field testing of available deterrent strategies will be paramount. KDFWR will further investigate the need for and priority locations that may warrant an invasive carp deterrent structure. Strategic Decision-Making protocols evaluation and determination for the best approach of engaging the partnership in discussions is ongoing.

KDFWR continued to work with multiple agency partners to monitor the pool-to-pool movements of invasive carp in the middle and lower Ohio River. Movements of invasive carp among pools and comparisons of the possible open river conditions at various Locks & Dams will be used to determine the best options for the placement of invasive carp deterrent technologies.

Objective 2. Collect baseline movement information among reservoirs to inform bigheaded carp deterrent efficacy and lock-and-dam passage.

KDFWR continued partnering with Murray State University to conduct tracking of tagged invasive carp within Barkley and Kentucky reservoirs, through the lock and dams and interactions with the Ohio River. Parameters considered for this project include seasonal and diurnal movements, distances traveled, passage via dam or lock, direction of travel, and speed of travel. The VEMCO stationary receiver array was maintained and improved as needed. Passage of invasive carp through other lock chambers on the Tennessee and Cumberland rivers is also being assessed by partners and sharing of data is essential. In order to quantify fish passage and ultimately assess deterrence strategies in these river systems, tagging of additional invasive carp and placement of supplementary receivers is essential.

KDFWR also assisted the USFWS with testing of a Bio-Acoustic Fish Fence (BAFF) technology on the downstream approach to Barkley Lock chamber. In spring and fall, silver carp were tagged below the lock structure with VEMCO transmitters. Some native fish species were implanted with VEMCO acoustic transmitters to assess movement around and through the lock structure throughout testing of the BAFF system. These included 20 individuals of the following species: smallmouth buffalo, paddlefish, and freshwater drum. Fish were collected by electrofishing and gill netting, and then surgically implanted with transmitters. All VEMCO telemetry receivers were maintained, and data collected monthly. Analysis of data collected in the Kentucky portions of the Tennessee and Cumberland rivers continued to be a joint effort with Murray State University. Receiver locations, acoustic tag numbers, and data collected were communicated to project partners. Data collected by all partner agencies were used to determine when fish passage through lock chambers is greatest and how deterrents could best be utilized on the Tennessee and Cumberland rivers. KDFWR staff lead efforts to implant silver carp with acoustic transmitters from HTI as well. The number of fish implanted, and

timing of efforts were determined by the BAFF research group. The HTI 3-D movement detection system requires a complex array of hydrophones around Barkley Dam. KDFWR assisted with deployment of hydrophones and maintenance of the array throughout the study. The equipment associated with the BAFF is contained in two Conex containers on Barkley Lock. KDFWR performed maintenance on the equipment onsite including changing filters, monitoring oil levels, and adjusting pressure released by the air compressor as needed. The BAFF research team has study design requiring the BAFF to be turned on and off at weekly intervals, for which KDFWR was responsible. To prevent damage to the BAFF, a fishing and boating restriction zone has been defined in KDFWR regulations which includes the lock canal approaching the system (Evaluation of a Bio-Acoustic Fish Fence (BAFF) at Barkley Lock and Dam: Study Design, USFWS).

Murray State University

Objective 2. Collect baseline movement information among reservoirs to inform bigheaded carp deterrent efficacy and lock-and-dam passage.

MSU conducted tracking of tagged Asian Carp within Kentucky and Barkley lakes to determine diurnal movements, distances traveled, and habitat usage. Manual tracking effort increased substantially to better inform fine scale movements of Silver Carp in Kentucky Lake. Additional silver carp in Kentucky Lake will be collected and surgically implanted with transmitters for this study. Transmitters which indicate fish depth were used in order to gain more information on the behavior of Silver Carp. Native Paddlefish, which have been tagged for other projects, were be tracked on a fine scale to estimate the habitat overlap between these species and Silver Carp. MSU conducted analysis on information downloaded from stationary receivers in the TNCR basin.

Results and Discussion:

KDFWR

Based on data analyzed by the BAFF research group the field testing of this deterrent is indicating there is atleast a 50% reduction in BAFF crossing of silver carp when the system is ON (Appendix A). Final report for the BAFF study is anticipated in 2024.

Murray State University

Tracking Silver Carp Movement in Kentucky Lake

<u>Effort</u>

KDFWR captured, tagged, and released 184 fish below Lake Barkley dam in 2022 (Table 1). Since 2016, KDFWR has tagged 688 Silver Carp and 269 native fish (Table 2). Overall, if we include the fish we tagged plus those fish tagged by other agencies, and if we include all stationary receivers and active tracking, we have had live detections on 7 Alligator Gar, 10 Bighead Carp, 1 Black Carp, 6 Blue Suckers, 108 Freshwater Drum, 6 Grass Carp, 1 Gulf Sturgeon, 4 Lake Sturgeon, 90 Paddlefish, 1635 Silver Carp, 137 Smallmouth Buffalo, 1 Walleye, and 362 unknown fish.

Most of the effort in this project was expended to service the passive receivers. The passive receivers were checked or deployed on 28 different dates in Lake Barkley (28 receivers), 36 different dates in Kentucky Lake (35 different receivers), and 13 different dates on the Ohio River (18 receivers).

Results- Fish Movement

We are going to start comparing fish movement in the reservoirs to movement in the rivers below each dam. Mean daily speed (km / day) varied among species and reservoirs (Table 3).

Results – Dam Passage

The number of crossings was dominated by Silver Carp because they contain the most tags. Silver Carp mostly leave the lake in spring, but this is when most native species are crossing up into the reservoirs. The carp come back and cross into the reservoirs mostly in summer (Table 4).

Table 1. *Summary of fish captured, tagged, and released in the Lake Barkley tailwaters by KDFWR in 2022.*

		Total Length (mm)	Weight (g)
Species	N	Mean ± SE	Mean ± SE
Bighead Carp	9	999 ± 38	9,980 ± 1,047
Blue Sucker	5	790 ± 16	5,522 ± 617
Freshwater Drum	20	505 ± 11	1,768 ± 134
Grass Carp	5	745 ± 39	4,176 ± 582
Lake Sturgeon	1	1,142 ± NA	11,430 ± NA
Paddlefish	19	963 ± 56	6,893 ± 649
Silver Carp	105	711 ± 6	3,605 ± 108
Smallmouth Buffalo	20	489 ± 9	1,765 ± 93

Table 2. *Number of fish tagged by KDFWR in Lake Barkley, Kentucky Lake, and their tailwaters since 2016.*

Species	2016	2017	2018	2019	2020	2021	2022	Total
Bighead Carp							9	9
Blue Sucker							5	5
Freshwater Drum				6	32	32	20	90
Grass Carp							5	5
Lake Sturgeon							1	1
Paddlefish				16	22	13	19	70
Silver Carp	69	66	44	144	150	75	140	688
Smallmouth Buffalo				23	40	20	20	103

Table 3. *Mean daily swimming speed (km / day, ± SE) for all species tracked in Kentucky Lake and Lake Barkley.*

Name	Cumberland	Tennessee
Bighead Carp	98.8 ± 53.9	27.3 ± 15.4
Freshwater Drum	19 ± 3.6	12.3 ± 4.1
Grass Carp	1.7 ± 1.5	8.2 ± 7.5
Lake Sturgeon	10.1 ± NA	
Paddlefish	15.5 ± 5	9.7 ± 1.5
Silver Carp	17.4 ± 1.5	24.5 ± 1.5
Smallmouth Buffalo	1.5 ± 0.7	8.9 ± 3.8
Uknown Species	13.1 ± 6.2	9.1 ± 4.1

Table 4. *Summary of number of dam crossings by species, season, and direction.*

	Winter		Spring		Summer		Fall	
Species	Down	Up	Down	Up	Down	Up	Down	Up
Bighead Carp	-	-	-	1	2	5	-	1
Freshwater Drum	-	1	4	14	2	2	1	1
Grass Carp	-	-	-	3	-	1	-	-
Lake Sturgeon	-	-	-	1	-	-	-	-
Paddlefish	1	4	2	26	10	2	18	15
Silver Carp	57	11	234	62	25	127	41	50
Smallmouth Buffalo	-	-	-	3	2	4	1	2
TOTAL	58	16	240	110	41	141	61	69

Fine-Scale Telemetry

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 project which started in 2017.

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 2022.

Tracking Effort

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. Each location 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. Diel activity was recorded on 25 days in Kentucky Lake and 9 days in Lake Barkley (Table 1).

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. Fish were located for macrohabitat analysis on 43 days in Kentucky Lake and 23 days in Lake Barkley (Table 2).

Diel Activity Results

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.

Mean swimming speed over a 24-hour period was not significantly different among sex (Figure 1) or residency (Figure 2). The mean swimming speed was positively related to water temperature (both reservoirs combined) (Figure 3). Mean swimming speed was lower at dawn, but these results were not statistically significant (Figure 4). Wind speed did not influence mean swimming speed in Kentucky Lake but had a positive effect on mean swimming speed in Lake Barkley (Figure 5).

During diel 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 fish location, 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 mean swimming rate so that we could determine the area to which each fish could potentially have swum. Random points (N = 10) 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 and Lake Barkley (Figure 6). We considered that the fish might not be relating to wind on a given day, but instead chose their overall location based on its general wind energy. So, we performed the same analysis but this time we used the total fetch in each of the fish locations compared to random locations. However, again we found no significant difference in mean fetch between the fish locations and the random locations in both Kentucky Lake and Lake Barkley (Figure 7).

During this portion of the tracking study, we tracked a single fish with a depth-sensing tag in the area of Little Bear cove. Over the 24-hour period this fish spent most of its time in the upper 1 m of water with a single excursion down to 3 m in the late evening (Figure 8). We used the diel tracking data to estimate the daily home range size for each fish. All locations were used to obtain a kernel density estimate of home range size based upon the 90^{th} percentile of locations. This home range was clipped to include only those portions which were in

the water, and then the total area was calculated for the clipped home range. Daily home range size was not significantly different among sexes (Figure 9) or residency (Figure 10). Mean daily home range size was not significantly different between the reservoirs (Figure 11).

Digital maps of both reservoirs were partitioned into 5 macrohabitat types: thalweg (deepest channel through the main body of the lake), side channel (main body of the lake excluding the thalweg), coves (> 5 ha but < 100 ha), major coves (> 100 ha), and the canal which connects the reservoirs (Figure 12). A log-ratio chi-squared analysis suggested that the fish were not selecting for or against any macrohabitat in Kentucky Lake (Table 3) and Lake Barkley (Table 4). We feel that the macrohabitats which we studied are too coarse, and we are investigating more fine-scaled habitats.

Lower Tennessee and Cumberland River Tracking

The portions of the Tennessee and Cumberland Rivers below each dam but above their confluence with the Ohio River represent a unique habitat, but the movement patterns of Silver Carp and other fish species have not been studied there. Tracking fish in these areas might give insight into behaviors which cause the fish to crowd below the dams, which in turn might influence their rate of crossing into the reservoirs.

Starting in June 2022, we tracked the lower portion of each river from the dam to the confluence with the Ohio. We tracked one river per week, alternating rivers every week (26 weeks total). The boat was stopped approximately every 1 km to listen for fish; the large number of fish in these locations necessitated using 2 hydrophones simultaneously in order to record all fish detected.

Preliminary data suggest that Silver Carp do not show a noticeable pattern in their distribution in the Lower Cumberland River (Figure 13) but they seem to cluster near RK 20 in the Lower Tennessee River (Figure 14). We will be investigating the habitat and flow of both rivers to try and explain any patterns we find. We also have deployed several stationary receivers in smaller tributaries of both these rivers to measure the use of these tributaries by both Silver Carp and native fish species.

Table 1. *Total diel activity tracking effort by season and lake.*

		Days tracked	Total hours tracked
Kentucky	Combined	25	498
	Spring	3	59
	Summer	18	358
	Fall	4	72
Barkley	Combined	9	183
	Spring	1	25
	Summer	5	105
	Fall	3	53

Table 2. *Total macrohabitat analysis tracking effort by season and lake.*

		Days tracked	Total hours tracked
Kentucky	Combined	43	258
	Spring	11	58
	Summer	25	172
	Fall	6	26
	Winter	1	2
Barkley	Combined	23	125
	Spring	4	21
	Summer	16	82
	Fall	2	15
	Winter	1	7

Table 3. *Summary of Silver Carp use compared to available macrohabitat in Kentucky Lake.*

Kentucky Lake						
	% Available	% Used All Seasons	% Used Spring	% Used Summer	% Used Fall	% Used Winter
Canal	0.01%	1.37%	0%	1.9%	0%	0%
Cove	5.10%	2.06%	4.17%	0.95%	6.25%	0%
Major Cove	23.3%	13.01%	29.17%	5.71%	31.25%	100%
Side Channel	59.2%	73.29%	58.33%	79.04%	62.5%	0%
Thalweg	12.3%	10.27%	8.33%	12.38%	0%	0%
N Size		59	19	48	13	1
		Chi Square: 223.9 df: 268 Pvalue: 0.9	Chi Square: 43.8 df: 76 Pvalue: 0.9	Chi Square: 158.3 df: 192 Pvalue: 0.9	Chi Square: 29.1 df: 52 Pvalue: 0.9	

Table 4. *Summary of Silver Carp use compared to available macrohabitat in Lake Barkley.*

Lake Barkley						
	% Available	% Used All Seasons	% Used Spring	% Used Summer	% Used Fall	% Used Winter
Canal	0.20%	.10%	5.55%	0%	0%	0%
Cove	10.10%	6.92%	11.11%	6.06%	14.29%	0%
Major Cove	28%	7.69%	5.55%	7.07%	28.57%	0%
Side Channel	55.20%	77.69%	72.22%	79.79%	57.14%	83.33%
Thalweg	6.5%	6.92%	5.55%	6.06%	0%	16.67%
N Size		67	16	55	7	5
		Chi Square: 190 df: 268 Pvalue: 0.9	Chi Square: 42.2 df: 64 Pvalue: 0.9	Chi Square: 149.1 df: 220 P value: 0.9	Chi Square: 14.4 df: 28 Pvalue: 0.9	Chi Square: 11.4 df: 20 Pvalue: 0.9

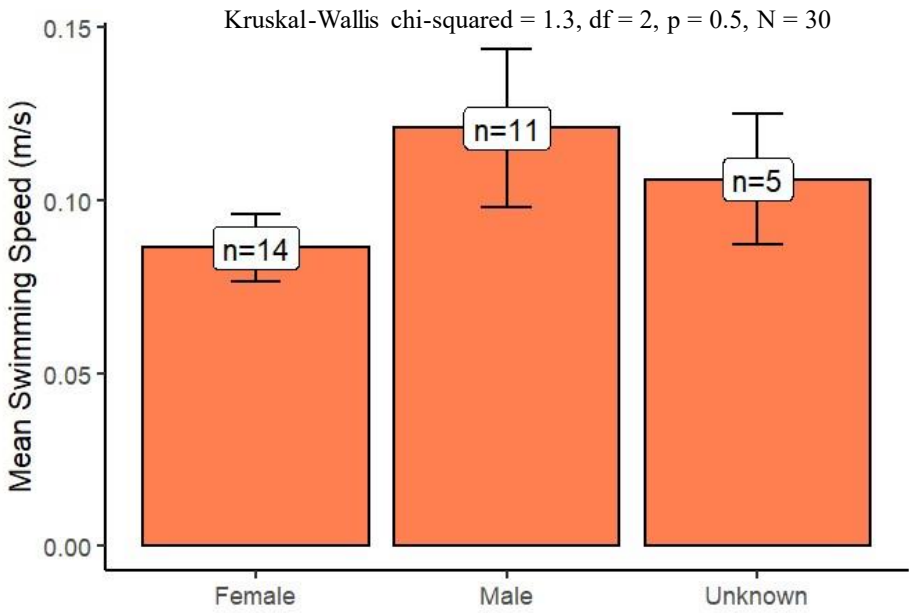


Figure 1. *Mean Silver Carp swimming speed (± SE) among known and unknown sex within Kentucky Lake and Lake Barkley. A Kruskal-Wallis test suggested that swimming speed was not significantly different among sex.*

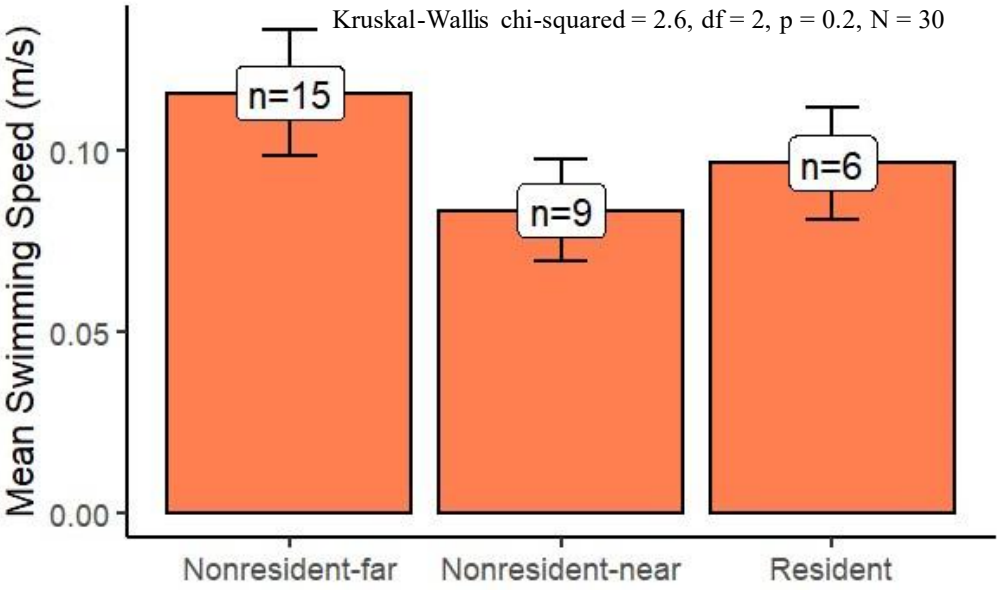


Figure 2. *Mean Silver Carp swimming speed (± SE) among residency status within Kentucky Lake and Lake Barkley. A Kruskal-Wallis test suggested that swimming speed was not significantly different among residencies. Nonresident-far fish were tagged at Lake Pickwick tailwaters or in Lake Pickwick. Nonresident-near fish were tagged below either Kentucky Lake or Lake Barkley tailwaters, and resident fish were tagged in Lake Barkley or Kentucky Lake.*

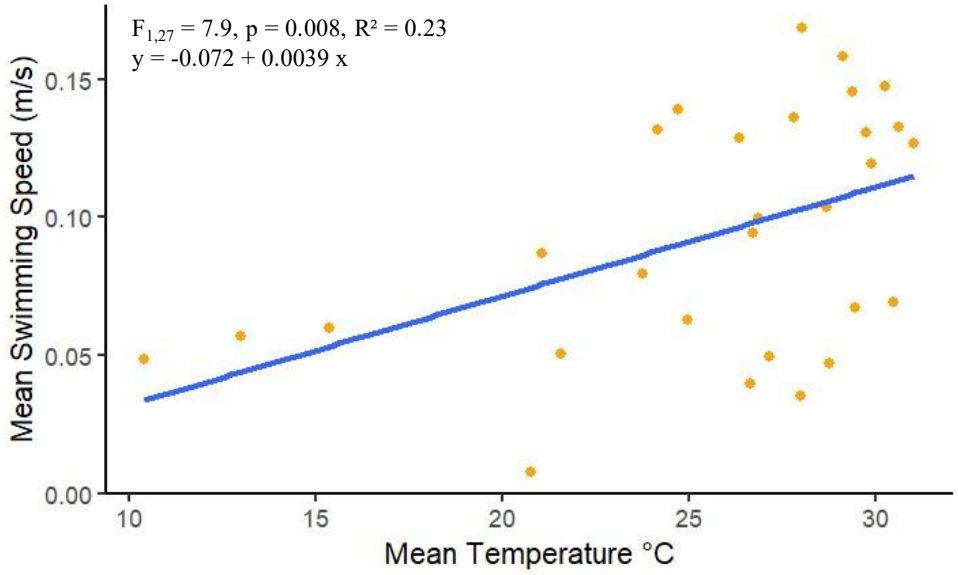


Figure 3. *Scatterplot comparing swim rates of Silver Carp to surface temperature within both lakes. A linear regression suggested that temperature had a significant, positive effect on swim rates.*

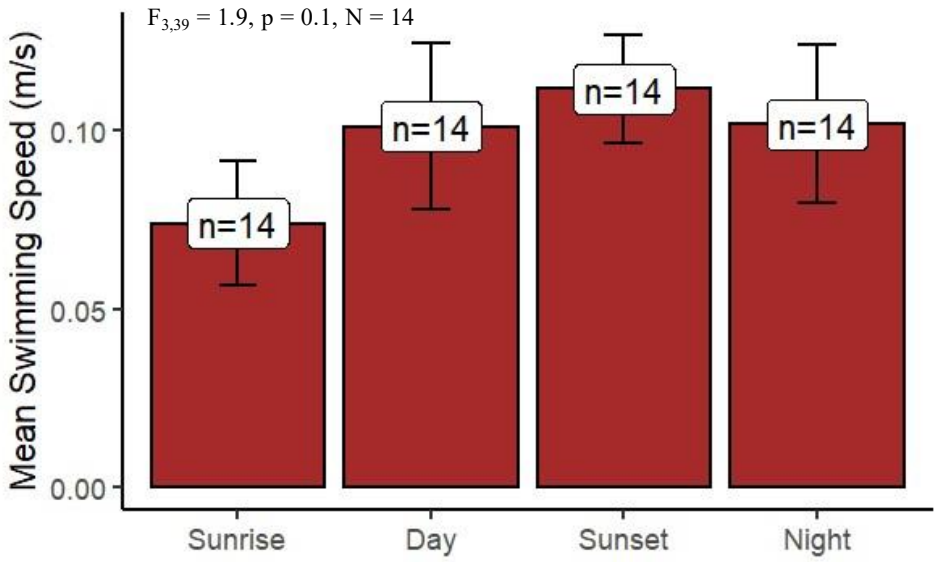


Figure 4. *Mean Silver Carp swim rate throughout the day. Sunrise and sunset are the period 1 hour on either side of sunrise or sunset. A repeated-measures ANOVA suggested that swimming speed was not significantly different among time periods.*

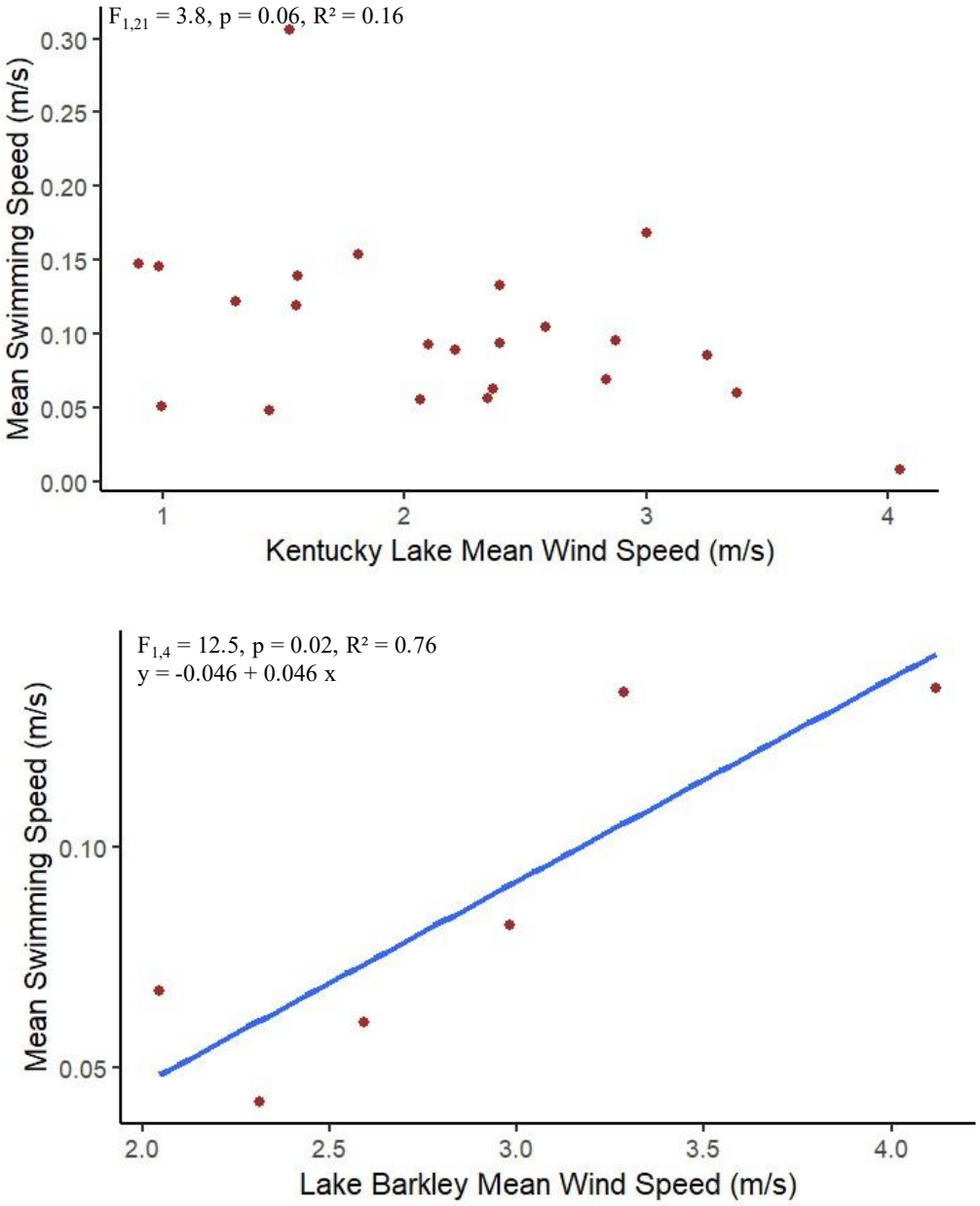


Figure 5. *Scatterplot comparing swim rates of Silver Carp within Kentucky Lake and Lake Barkley. A linear regression suggested that wind did not have an effect on swim rates in Kentucky Lake but wind did have an effect on swim rates in Lake Barkley.*

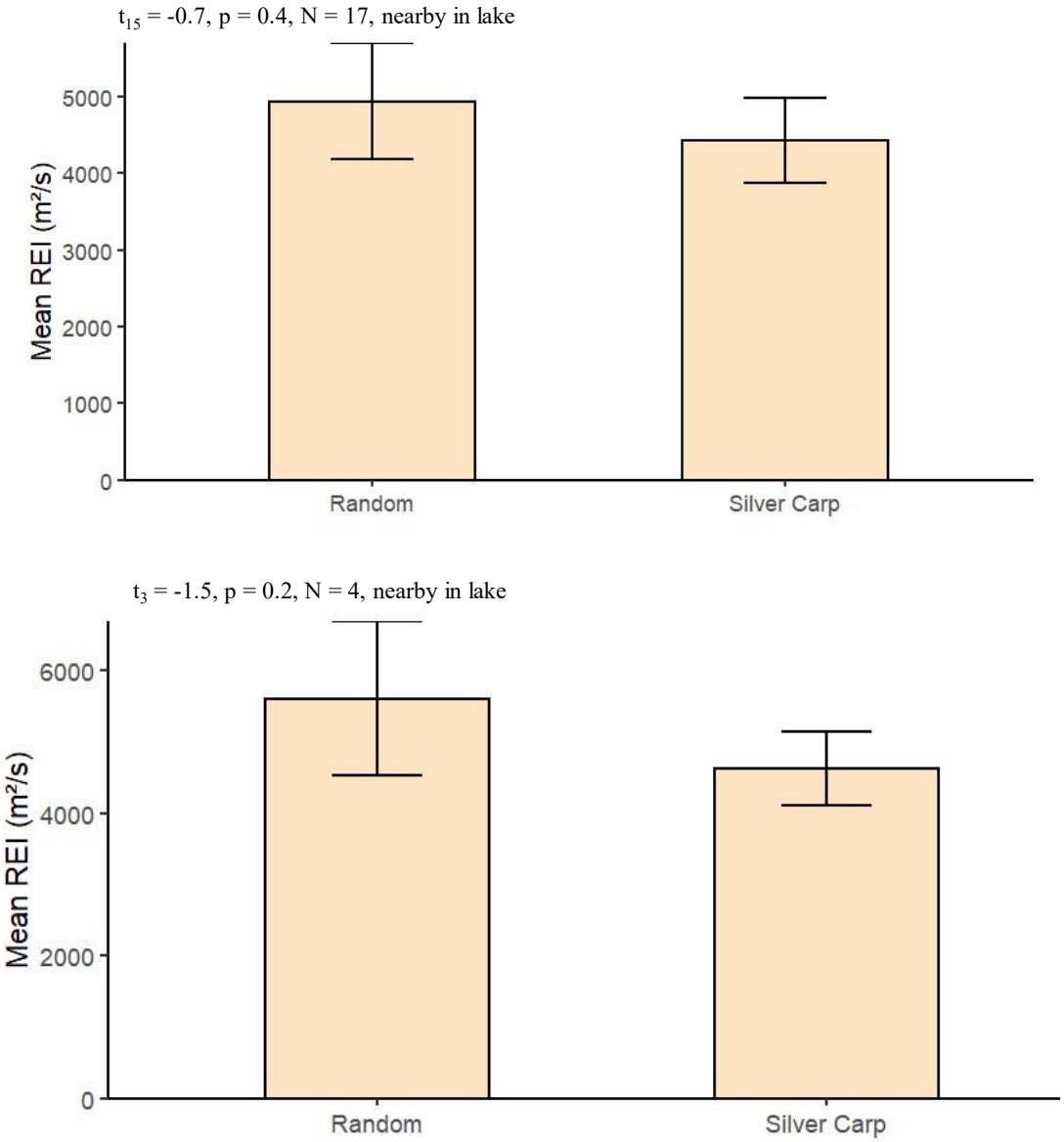


Figure 6. *Mean relative exposure index (REI) for nearby random locations and Silver Carp locations in Kentucky Lake (top) and Lake Barkley (bottom). A paired t-test suggested that mean REI was not significantly different between groups for either lake.*

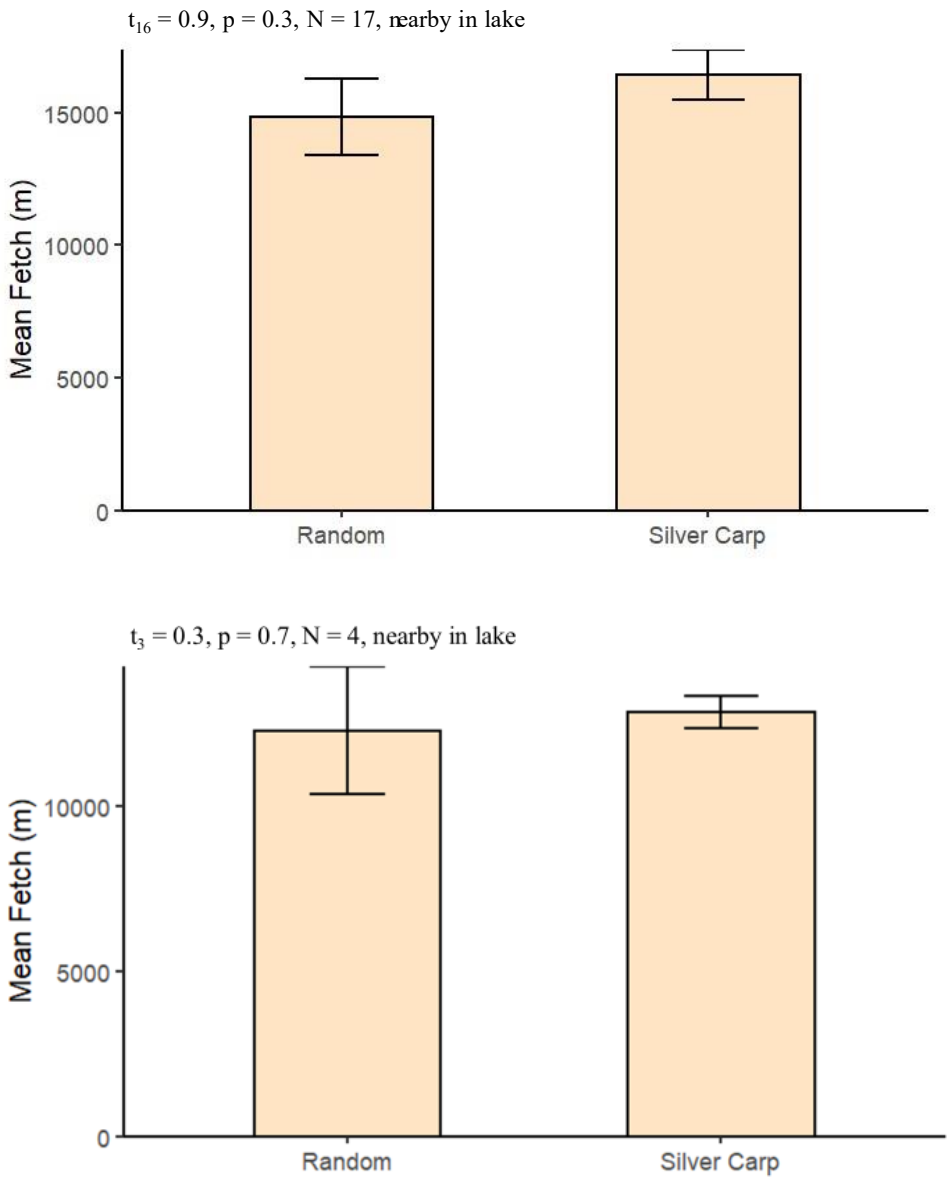


Figure 7. *Mean fetch for nearby random locations and Silver Carp locations in Kentucky Lake (top) and Lake Barkley (bottom). A paired t-test suggested that mean fetch was not significantly different between groups for either lake.*

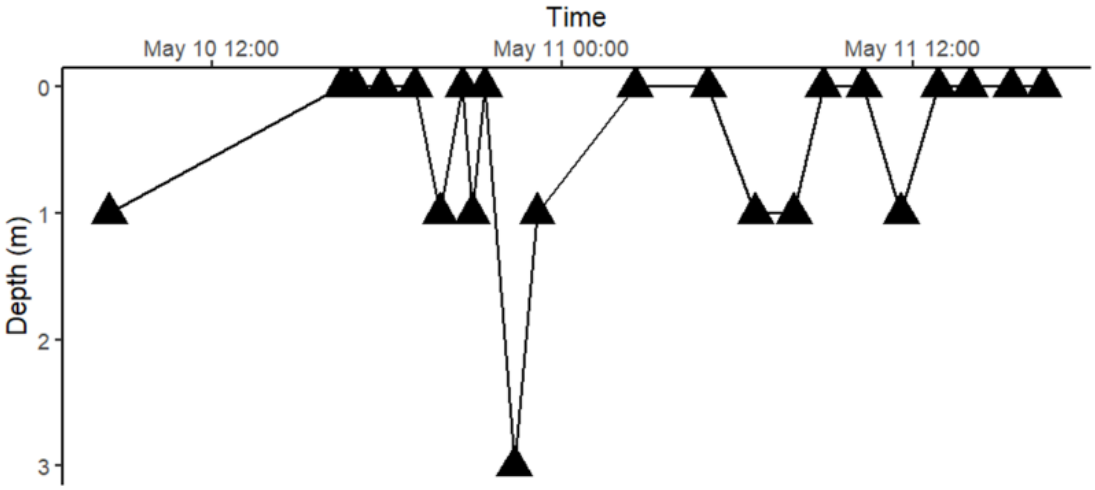


Figure 8. *Depths utilized over a 24-hour period by a single Silver Carp in Little Bear cove on Kentucky Lake.*

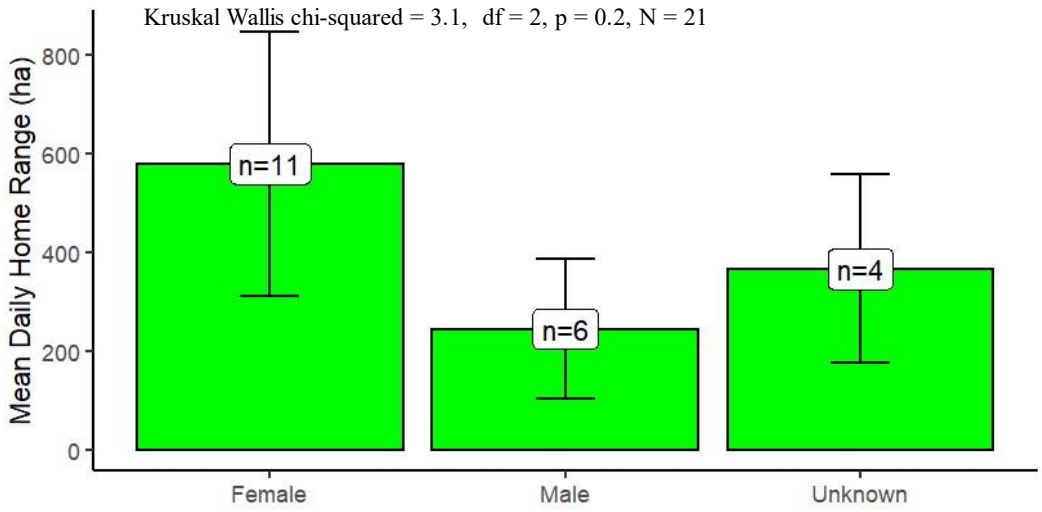


Figure 9. *Mean Silver Carp daily home range (± SE) among sex. A Kruskal-Wallis test suggested that daily home range size was not significantly different among sexes.*

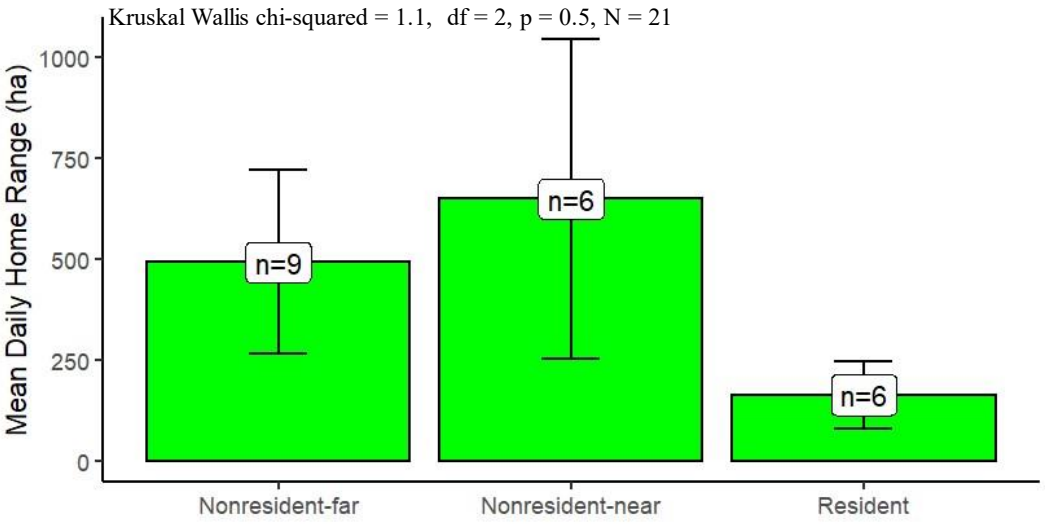


Figure 10. *Mean Silver Carp daily home range (± SE) among residencies. A Kruskal-Wallis test suggested that daily home range size was not significantly different among residencies. All tagged fish were assigned a residency status based on their tagging location. For example, a fish tagged in Pickwick reservoir or at the Pickwick tailwaters was classified as "non-resident far". Fish tagged within Kentucky Lake and Lake Barkley were assigned as "residents" and fish tagged in the tailwaters of Kentucky Lake and Lake Barkley were called "non-resident near".*

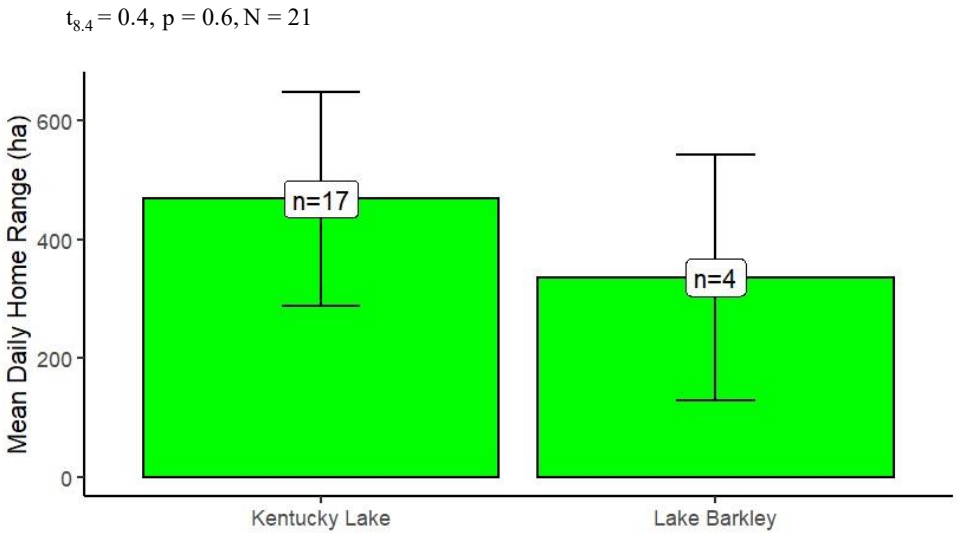


Figure 11. *Mean Silver Carp daily home range (± SE) in Kentucky Lake and Lake Barkley. A Welch's t test suggested that daily home range size was not significantly different between lakes.*

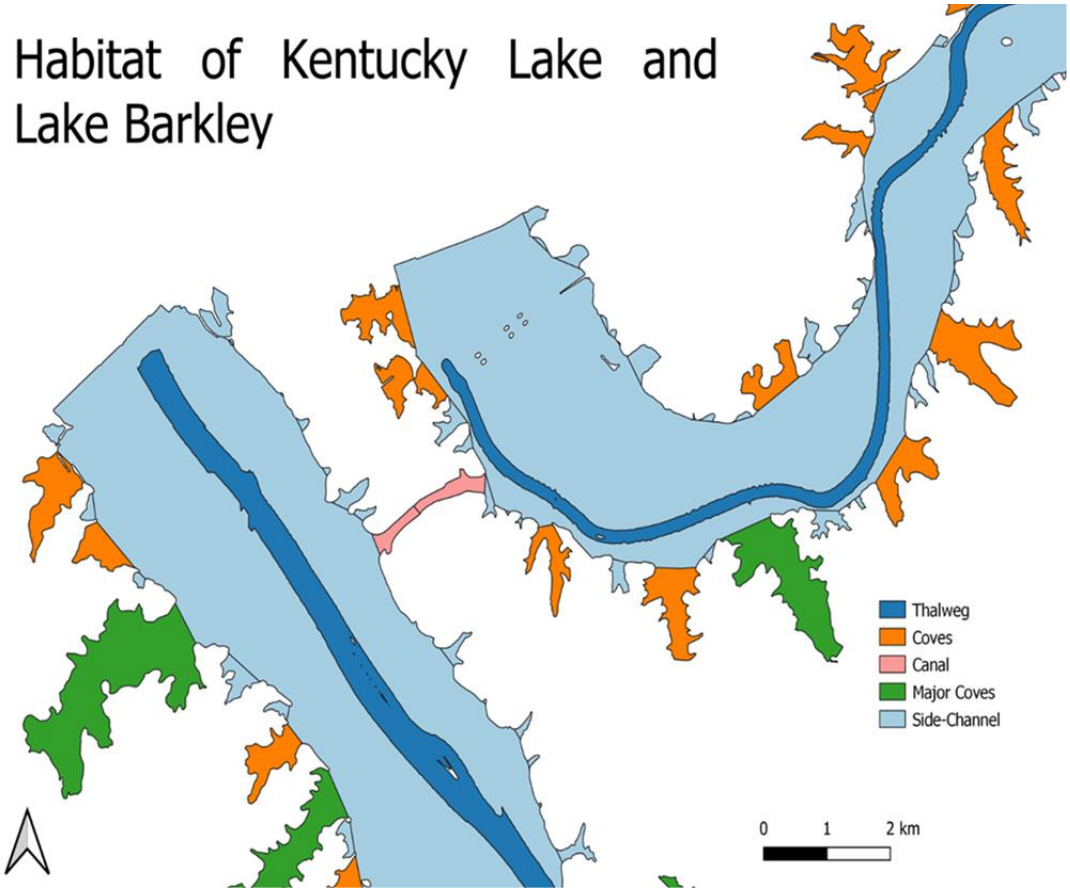


Figure 12. *Example of the 5 macrohabitat types evaluated within each lake. Each lake's thalweg was evaluated as being > 20m of depth. Coves were > 5 ha but less than 100 ha, and major coves were > 100 ha. The side-channel included the remaining areas of the lake, excluding the canal between Kentucky Lake and Lake Barkley.*

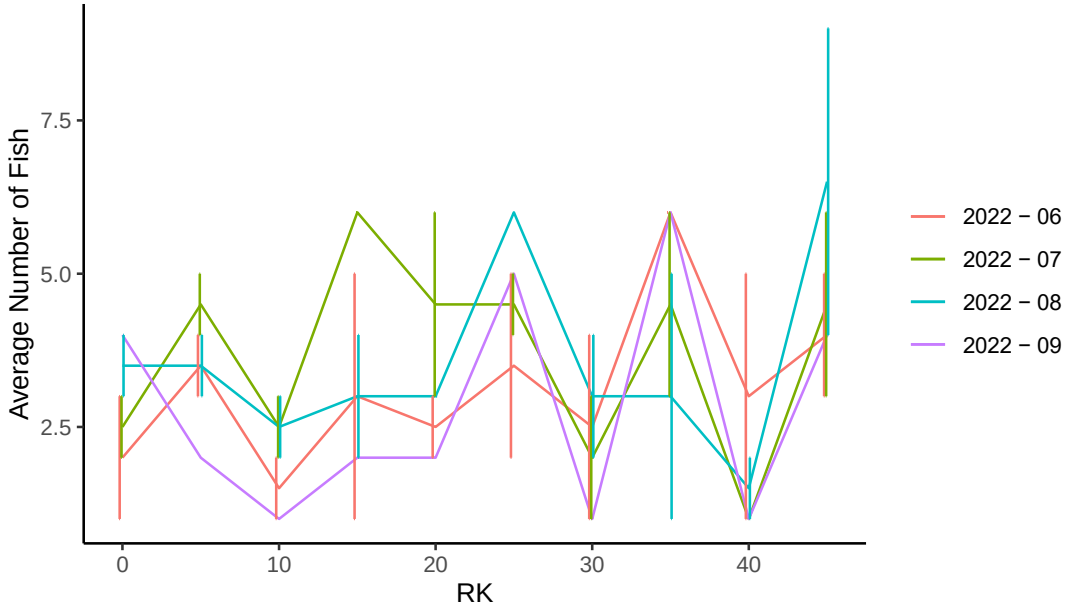


Figure 13. *Average number (with SE) of Silver Carp located in the Cumberland River at 5 km intervals per month. No clear pattern or grouping is shown.*

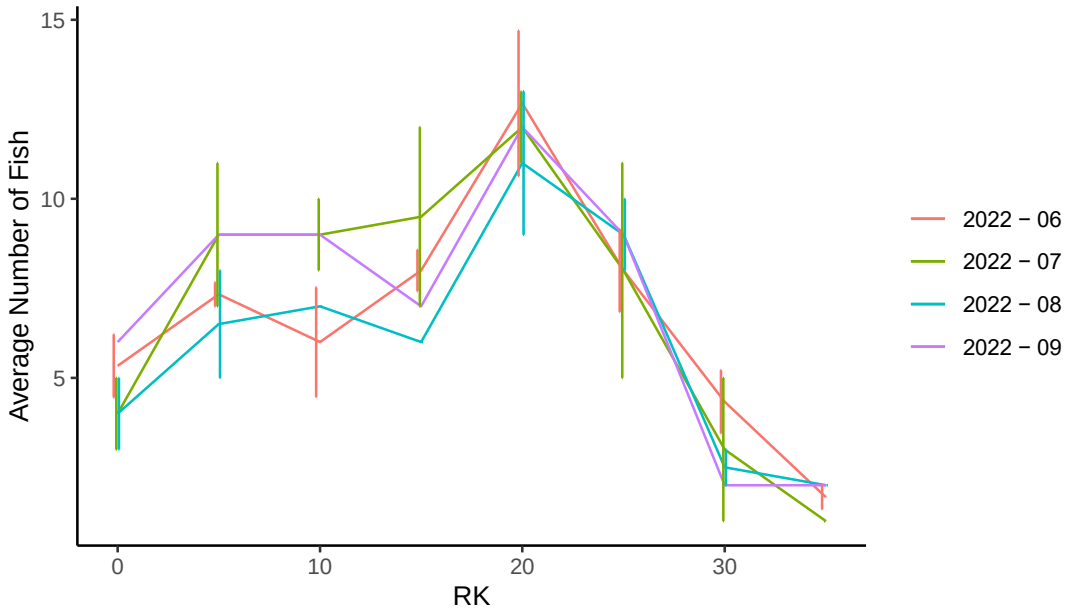


Figure 14. *Average number (with SE) of Silver Carp located in the Tennessee River at 5km intervals per month. A clear grouping is show at RK 20.*

Recommendation:

The receiver network continues to produce useful data, and as more native fish migrate into the lakes we will be able to collect better data on the movement patterns of these species. With the large number of tagged fish being released in the tailwaters, future analysis will focus on movement patterns through the dams and interactions with the Ohio River.

Plans for 2023 include continuing to tag more bigheaded carp for further passage evaluations and monitoring. Likewise, additional tag drags through the lock systems will allow for greater understanding of receiver detections and help ensure reliable detections. Analyses of data are ongoing. Future efforts will characterize environmental conditions during passage events (e.g., flow) and temporal trends of passage events (e.g., diel or annual patterns) will be evaluated. Continued telemetry efforts will allow for a better understanding of the capabilities of bigheaded carp to continue moving upstream in the Tennessee and Cumberland rivers.

Literature Cited:

Kolar, C., D. Chapman, W. Courtenay, C. Housel, J. Williams and D. Jennings. 2007. Asian carps of the genus *Hypophthalmichthys* (Pisces, Cyprinidae) – A Biological Synopsis and Environmental Risk Assessment. American Fisheries Society Special Publication 33, Bethesda.

Ridgway, J. L. 2016. Sampling and population characteristics of bighead carp and silver carp in the Tennessee and Cumberland River systems. Master's Thesis. Tennessee Technological University, Cookeville, Tennessee.

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.

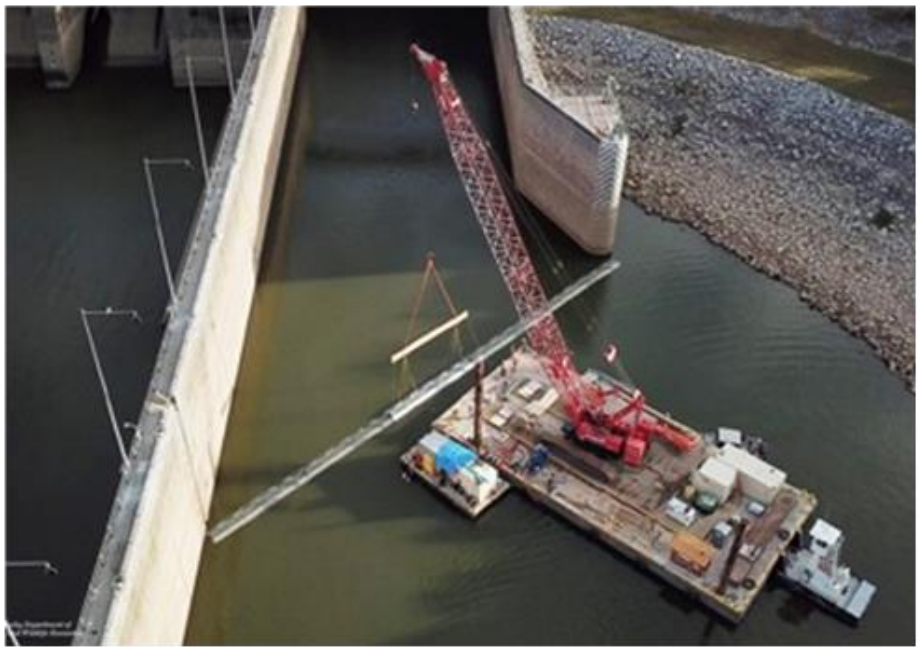
Sass, G. G., C. Hinz, A. C. Erickson, N. N. McClelland, M. A. McClelland, and J. M. Epifanio. 2014. Invasive bighead and silver carp effects on zooplankton communities in the Illinois River, Illinois, USA. Journal of Great Lakes Research 40: 911–921.

U.S. Fish & Wildlife Service

Lake Barkley BioAcoustic Fish Fence Effectiveness Study

Questions and Answers

Four species of invasive carp—bighead, black, grass and silver—can be found within the waters of the United States. The surge of invasive carp threatens the country's renowned aquatic biodiversity, outdoor economies and way of life. Federal, state, university and industry partners have joined together to test a new and innovative fish deterrent technology to slow the carps' upstream push. A BioAcoustic Fish Fence, or BAFF, has been deployed on the downstream side of Barkley Lock in Kentucky to determine its effectiveness at reducing the movement of invasive carp through a lock chamber.



Kentucky Department of Fish and Wildlife Resources

The BAFF, or BioAcoustic Fish Fence, being installed at Lake Barkley Lock and Dam.

U.S. Geological Survey

What is a BioAcoustic Fish Fence, or BAFF? How does it work?

Developed by Fish Guidance Systems, the BAFF is designed to deter or guide fish using sound, strobe lights, and air bubbles. The BAFF in the downstream approach channel at Barkley Lock may deter invasive carp from using the lock to move into Lake Barkley.

A line of bubbles runs diagonally across the lock approach channel between the walls. Sound is projected within the air bubbles where it is amplified and trapped. Some sound and light may escape the water and be detected by boaters. At night, flashing white lights can be visible, especially when water levels are low.

The BAFF has the potential to deter the movement of fish without impeding navigation.

How long will the BAFF be in place?

Currently, the BAFF is scheduled for removal in fall 2023 and the study will conclude after three years of data collection. The BAFF may remain in place longer to evaluate additional BAFF settings or to collect additional fish behavior data. If effective, partners may also pursue a permanent installation.

How effective is a BAFF at stopping invasive carp?

The purpose of this project is to evaluate the BAFF's effectiveness in a field setting. Tests conducted by the University of Minnesota found that a BAFF was 97% effective at blocking bighead carp without habituation in a lab setting.

Why isn't an electric dispersal barrier being used at Lake Barkley?

Electric dispersal barriers have been installed and tested in the Chicago Area Waterway System. This project is specifically designed to field test the BAFF as an alternative type of deterrent for deterring invasive carp passage through a lock chamber.

Why is fishing restricted around the BAFF?

Fishing and recreational boating are prohibited from the outer canal wall to the lock chamber to protect the BAFF and telemetry receivers from getting damaged by anglers or anchors. Restricted areas are clearly marked.

How is the BAFF effectiveness study funded?

The project is funded by the U.S. Environmental Protection Agency's Great Lakes Restoration Initiative, U.S. Fish and Wildlife Service and the U.S. Geological Survey.

Who is leading this project?

The U.S. Fish and Wildlife Service in collaboration with the U.S. Army Corps of Engineers, U.S. Geological Survey, Kentucky Department of Fish and Wildlife Resources, Tennessee Wildlife Resources Agency, University of Minnesota and others. Fish Guidance Systems is a technology partner.

USFWS

Electro-fishing silver carp at the tailwaters of Lake Barkley Lock and Dam.

How does the study track fish movement?

The study uses an HTI telemetry system to triangulate the positions of silver carp that were translocated below the BAFF to determine BAFF crossings with high precision. We also use a pre-existing archival VEMCO telemetry array to determine the distribution of several fish species that were tagged and released at various capture locations and then tracked to determine BAFF crossing rates indirectly.

What effect will the BAFF have on the movement of other fish species?

The sounds emitted by the BAFF affect invasive carp because they are very sensitive to sound, particularly at certain frequencies. Many native fish species do not have this same sensitivity, but may be affected by the combination of sounds, lights and bubbles. This project will also study whether the BAFF influences the movements of native fish using the same approach of telemetry tagging and tracking. Lab studies indicate that while the BAFF does deter some native fish, they may be less affected than invasive carp.

Why is Barkley Lock and Dam an ideal test site for a BAFF?

Barkley lock approach offers a number of advantages. We know invasive carp are present and pass upstream through the lock. As a result, we can study whether the BAFF will slow their rate of passage. Another advantage is that the only pathway for fish to get from below the dam into Lake Barkley is to pass through the lock.

What else is being done to address invasive carp in the Tennessee and Cumberland systems?

State agencies, including Kentucky Department of Fish and Wildlife Resources and Tennessee Wildlife Resources Agency, along with U.S. Fish and Wildlife Service and U.S. Geological Survey are conducting multiple management and research projects in the Ohio, Tennessee and Cumberland rivers to inform decisions on control including deterrent placement and harvest for invasive carp.

As of spring 2021, commercial fishers have harvested more than twenty million pounds of invasive carp from Kentucky and Tennessee waters, including Lake Barkley and Kentucky Lake, as part of an incentives harvest program.

Partners are also evaluating experimental methods and gears for increasing efficiencies of removing invasive carp from our waterways

References

CE Dennis et al. 2019. A complex sound coupled with an air curtain blocks invasive carp passage without habituation in a laboratory flume. Biological Invasions 21:2837-2855.

CE Dennis & PW Sorensen. 2020. High-intensity light blocks bighead carp in a laboratory flume. Management of Biological Invasions 11:441-460.

Contact Information

For BAFF project questions:

Hannah Bergemann Great Lakes Region
U.S. Fish and Wildlife Service
Hannah_Bergemann@fws.gov
612/427 1881

Dan Chapman
South Atlantic-Gulf Region
U.S. Fish and Wildlife Service
Dan_Chapman@fws.gov 404/679 4028

For BAFF navigation questions:

Greg Bishop
USACE – Nashville District
Gregory.A.Bishop@usace.army.mil

January 2022

Reference to any specific commercial product, process, or service, or the use of any trade, firm or corporation name does not constitute endorsement, recommendation, or favoring by the Department of the Interior.

U.S. Fish & Wildlife Service

Lake Barkley BioAcoustic Fish Fence Effectiveness Study Project Status Update

January 2022

This information and data are deliberative and pre-decisional!

We recently concluded the first year of a three-year study using a fine-scale HTI telemetry system and translocated silver carp and a course-scale VEMCO telemetry system and non-translocated fish to assess BAFF effectiveness by turning it on and off weekly. Upstream BAFF crossings were as follows:

Winter 2020-2021
Based on HTI telemetry of translocated fish, 57 silver carp crossed the BAFF when off and 4 crossed while on (14:1 ratio).

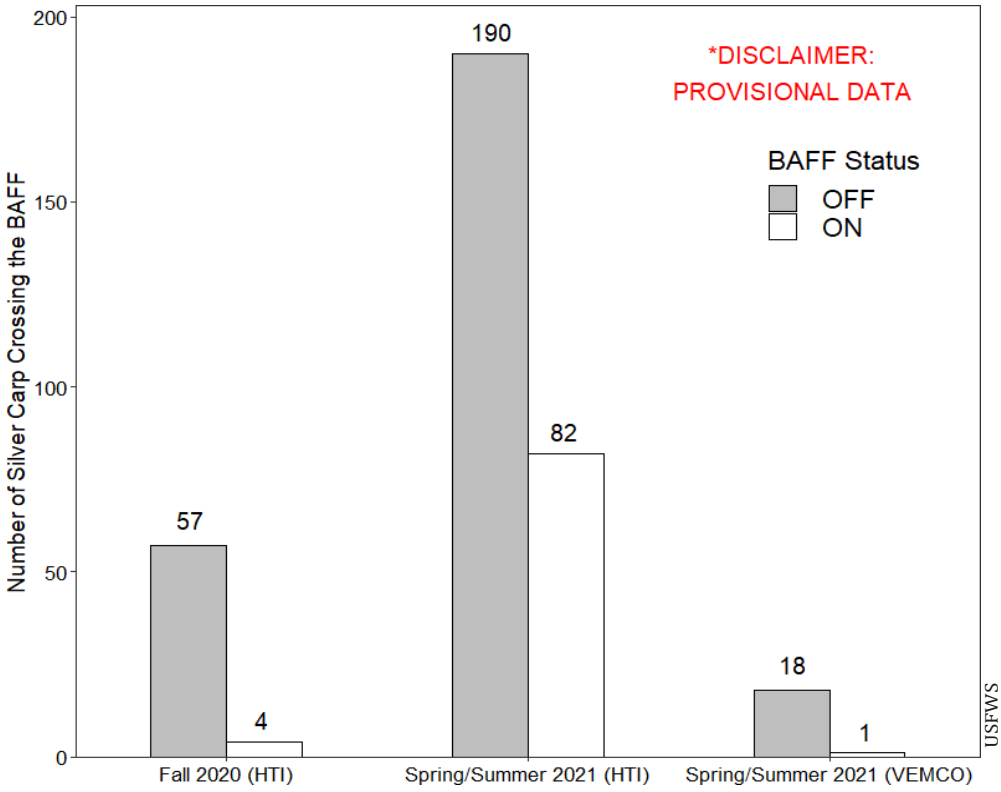
Spring/Summer 2021
Based on HTI telemetry of translocated fish, 190 silver carp crossed the BAFF when off and 82 crossed while on (2:1 ratio).

Based on VEMCO telemetry of non-translocated fish:

- 18 silver carp crossed the BAFF when off and 1 crossed while on (18:1 ratio).
- 7 freshwater drum crossed the BAFF when off and 2 crossed while on (4:1 ratio).
- 8 paddlefish crossed the BAFF when off and 7 crossed while on (1:1 ratio).
- 1 smallmouth buffalo crossed the BAFF when off and 0 crossed while on (1:0 ratio).

We will be exploring possible reasons for the variability between silver carp crossing rates for the two telemetry systems. Possible explanations include the small sample size to date and that HTI fish were translocated from Lake Barkley into the tailwater while VEMCO fish were captured and released in various locations. Future data analysis will also include measuring probabilities of a fish approaching and leaving the BAFF vs approaching and crossing
the BAFF. These additional analyses will also allow us to account for how other environmental factors like water depth, lock operations, and season might influence these behaviors, and consequently, BAFF effectiveness.

Data users are cautioned to consider carefully the provisional nature of the information before using it for decisions that involve substantial monetary or operational consequences. We will implant acoustic transmitters in over 1500 more silver carp during the project and will continue to track fish through Fall 2023 with a final report anticipated in 2024.



Provisional data depicting Silver Carp crossings of the BAFF in Off/On cycles during Fall 2020 (HTI only) and Spring/Summer 2021 (HTI and VEMCO).
Disclaimer: Data are provisional and subject to revision until they have been thoroughly reviewed and received final approval.