

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)

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

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

Project Objectives:

1. Estimate invasive carp relative abundance and population demographics in the Tennessee and Cumberland River basins to evaluate management actions.
2. Examine variables affecting habitat usage by invasive carp to inform removal efforts.
3. Target and remove invasive carp to suppress populations and reduce propagule pressure in the Tennessee and Cumberland River basins.
4. Evaluate new and/or experimental methods and gears for targeting invasive carp for harvest.
5. Determine feasibility of conducting a large-scale exploitation study.

Project Highlights:

KDFWR

- Commercial fishers removed over 12.6 million pounds of invasive carp statewide and 9.3 million pounds of invasive carp through the Invasive Carp Harvest Program in 2023. CPUE (fish/yard) was highest in 3.75" bar mesh gill nets.
- KDFWR staff conducted 61 ride-alongs with commercial fishers in the carp harvest program, to monitor catch and bycatch data. Out of the 61 ride-alongs, 9 ended with no nets being set.
- Commercial fishers enrolled in the subsidy contract fishing program received \$766,707.44 for invasive carp harvested from Barkley and Kentucky reservoirs.
- KDFWR continued a MOU with one fisher to test invasive carp experimental gears in Kentucky waters. During 2023, the fisher harvested approximately 463,440 lbs of invasive carp from Kentucky and Barkley Reservoirs over 26 days and 831,206 lbs in Barkley tailwater over 41 days.
- KDFWR received three reports of black carp in the Ohio River during 2023.

TWRA

- No juvenile invasive carp were encountered or collected during sampling efforts

- Catch rates were low, with dozer trawls being more efficient in riverine sections during lower water
- Over 8,000,000 lbs of invasive carp were removed through the Tennessee Carp Harvest Incentive Program
- Plans have been developed for the implementation of a high-reward tag study to estimate exploitation and better understand the impact of harvest/removal programs on invasive carp populations

ADCNR

- To date, ADCNR completed the 2023 calendar year of fully implemented sampling efforts. Work during 2023 included standardized sampling approaches, as well as development of a new occupancy sampling approach. Staff further completed sampling of habitat and site areas for more efficient sampling across the three lower project reservoirs. A full-time biologist was hired to implement work goals. Occupancy and multiple-boat herding were implemented as new methods to increase efficiency and monitoring goals.

Methods:**KDFWR**

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

KDFWR partnered with the USFWS to conduct Paupier net sampling in Kentucky reservoir to 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 seven 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).

KDFWR's Invasive Carp Harvest Program (ICHP) 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 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. These invasive carp were collected during Paupier sampling, electrofishing, and active gill netting efforts conducted by KDFWR staff. Demographics data may also be collected from invasive carp captured through other KDFWR sampling efforts and included for analyses.

Objective 2. Examine variables affecting habitat usage by invasive carp to inform removal efforts.

KDFWR staff maintained a telemetry array in Kentucky and Barkley Reservoirs, at Kentucky and Barkley lock and dam, and along the Ohio, Tennessee, and Cumberland rivers to monitor tagged invasive carp movements throughout the TNCR. KDFWR coordinated and collaborated with partners on tracking and fish tagging as needed. io

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 ICHP 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 metrics. 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 on board the commercial fisher's boat. Observation records were compared to fishers' daily reports to assess commercial reporting accuracy. ICHP 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 Invasive 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.

Objective 4. Evaluate new and/or experimental methods and gears for targeting invasive carp for harvest.

KDFWR worked with one commercial fisher under a Memorandum of Understanding (MOU), to harvest invasive carp with gears and methods outside of legal means established in Kentucky's regulations.

Objective 5. Determine feasibility of conducting a large-scale exploitation study.

KDFWR staff collaborated with TWRA on the development and implementation of this project.

TWRA

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

Dozer trawls were conducted in summer (June 2023) and fall (October-November 2023) periods in Kentucky (n=200), Barkley (n=40), Pickwick (n=40), and Cheatham Reservoirs (n=40). Kentucky Reservoir was divided into five sections to encompass the large reservoir (n=20/section). Dozer trawls were conducted in every embayment on both left and right descending banks where water levels allowed sampling. Dozer trawl transects were conducted at sites within embayments with depths greater than 1.8 meters for 5 minutes at approximately 6.4 km/h. Voltage and amperage were adjusted to achieve power outputs greater than 4,000 watts. Invasive carp species were measured (mm), weighed (kg), and sexed. Threadfin Shad *Dorosoma petenense* and Gizzard Shad *D. cepedianum* were separated and counted for all dozer trawl transects. Length (mm) and weight (g) was collected for all Skipjack Herring *Alosa chrysochloris*. Smallmouth Buffalo *Ictiobus bubalus* were measured (mm) and weighed (kg) and all other by-catch was measured (mm) and released. Silver Carp *Hypophthalmichthys molitrix* that jumped or evaded capture were counted and recorded. Otoliths and left pectoral fin rays were collected from all invasive carp captured during the fall for age determination.

Standardized electrofishing was utilized in Old Hickory Reservoir to monitor invasive carp populations upstream of Cheatham Reservoir. Invasive carp populations are low in Old Hickory Reservoir, so electrofishing boats were utilized to cover greater area and optimize capture of invasive carp if located. Old Hickory Reservoir was split into 18 sampling locations (Figure 1). Each location was sampled for 600 continuous seconds. If invasive carp were collected, length (mm), weight (kg), and sex was recorded. Invasive carp observed jumping or swimming were also recorded. Otoliths and fin rays were extracted for age determination.

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

TWRA continued implementing its carp harvest incentive program, TCHIP. Three wholesale fish dealers were contracted to receive per pound-based reimbursement incentives for invasive carp purchased from commercial fishers fishing in Kentucky, Barkley, Pickwick, Cheatham, and Old Hickory lakes. From January through August, wholesale dealers received \$0.13 per pound in reimbursement and were required to pay out a minimum of \$0.15 per pound or \$0.18 per pound to fishers for fish less than 8 lbs. or greater than 8 lbs., respectively. Contracts with

wholesale dealers were amended and from September through December, reimbursements were \$0.14 per pound and pay out minimum to fishers was \$0.18 per pound regardless of fish size.

Objective 5. Determine feasibility of conducting a large-scale exploitation study.

TWRA worked with partners to gather information regarding implementation of exploitation studies and to scope what partners felt would best suit a project geared toward understanding exploitation of invasive carp in Kentucky and Barkley reservoirs.

ADCNR

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

Gillnet Sampling – ADCNR staff conducted gillnet sampling at eleven predetermined, GPS-fixed embayment and overbank areas on Pickwick (9 sites), Wilson (9 sites) and Wheeler (15 sites) Reservoirs during spring 2023 (ADCNR 2023; Figures 1-3). At each area, three gill nets were set and fished during daylight hours and fished while staff additionally electrofished adjacent transects (similar to Sullivan et al. 2018). Thus, net-sets were fished 1.2-2.5 hours. Sampling was repeated over four repetition days for each reservoir area x site and spring/fall season. During fall 2023, these same sites were re-examined; however, gillnetting was dropped from the strategy due to poor success and substantial time devoted to these efforts. Sites were initially adjusted for minimum distance (>0.20 mi) apart and depth (≥ 13 -ft). Standardized nets are 300-ft in length and comprised of 100-ft panels of 3-, 4-, and 5-in bar mesh. Standardized nets are 12-ft deep, hobbled to 10-ft every eight feet, featuring 0.5-in foam-core float line and 50- or 65-lb lead-core lead line. The multifilament webbing in net panels are constructed of 8 ply, 0.2-mm twist mesh. Additional custom nets were constructed as above except comprised of 7-foot panels hobbled to 5-feet for shallow conditions. Catch of all invasive carp species were recorded by mesh size and data on individual fish included total length (nearest mm), weight (nearest 0.01 kg), sex, left ovary weight (nearest g) and extraction of pectoral fins and otoliths. All other species were counted by mesh size. Length and weight data were recorded for environmentally sensitive species, including, Bigmouth Buffalo, Gizzard shad (subsampling) and Paddlefish (Schrack et al. 2003, Irons et al. 2007).

Electrofishing & Dozer Trawl – After structural repairs in 2022, ADCNR staff fully implemented use of an electrified dozer trawl during 2023 sampling. As with gillnetting, electrofishing sites ($n = 33$) were re-evaluated for habitat type and sample efficiency (i.e., preferred transect depths < 13 ft) and an additional area (McKiernan Creek) was implemented at Wilson Lake (Figure 2). Two areas were also added to Wheeler Lake (Round Island, Mallard/Fox Creeks; Figure 3). Multiple factors, such as travel logistics, habitat type (restricted to embayment and overbank) and area-depth availability were used in determining dimensions and location of sampling sites. Samples were conducted for 5 minutes at 3.0 mph, with transect distances of 0.25 miles. Fish sampling was performed as described above.

We further implemented multiple-boat electrofisher herding at Wilson and Wheeler Reservoirs within small coves (n=68 sites). Transects were comprised of 4-5 electrofisher boats running in tandem from mouth to enclosed end of each cove area, similar to that performed for annual USGS tagging efforts in lower Pickwick Lake. Demographic was taken on individual fish as in normal sampling.

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

Regardless of sampling method, when captured, all individual invasive carp were sacrificed upon completion of data collection needs to satisfy Objective 3.

Results and Discussion:

KDFWR (all referenced Tables and Figures for KDFWR located in Appendix A)

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

Paupier

U.S. Fish and Wildlife Service sampled Kentucky Reservoir with their electrified Paupier net boat during the fall of 2023. 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 observed a silver carp CPUE (fish/hr) of 36 in Big Bear embayment, which was a significant decrease from previous years (Table 22). A significant drop in CPUE was observed in Pisgah from previous catch rates (Appendix D, Figure 2.). This trend data continues to support the hypothesis that the silver carp population in Kentucky reservoir is declining. According to the data in the 2023 USFWS Kentucky reservoir report “silver carp catch rates have decreased by approximately half during each sampling year” (Appendix D). Data from the Paupier sampling, compare to gill netting, theoretically creates less sampling bias and therefore a better fitting regression line when looking at Log10 transformed lengths and weights for silver carp; Kentucky Reservoir $R^2=0.71$ whereas Barkley reservoir $R^2=0.60$ (Figure 7 & 8).

ICHP

Length and weight data was collected on 1040 silver carp harvested by commercial fishers in 2023. Silver carp lengths ranged from 23.8 – 40.4 inches with an average of 31.4 inches, and weights ranged from 7.4– 33.3 lbs with an average of 13.0 lbs (Table 18). If this metric is used in correlation with the total pounds of silver carp harvested by commercial fishers through the ICHP in 2023, that would produce a rough estimate of 711,561 individual silver carp being removed from Kentucky waters through the ICHP in 2023 (9,275,293 lbs; Table 2). During ride-alongs, commercial fishers were observed using gill nets with a range of bar mesh sizes to target invasive carp (3.5” – 4.5” 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 3.75 (0.92 fish/yard),

followed by 4" bar mesh which had a CPUE of 0.6 fish/yard. This has remained consistent with 2022 data and shows an increase from the previous three years (2019 - 2021) 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.

Three black carp were harvested by three commercial fishers in April, November, and December of 2023 respectively. Lengths ranged from 1096mm – 1349mm, were caught in 5" to 6" mesh gill nets and all were sent off to research groups with USGS to investigate further.

Mark-Recapture

From October 2018 through February 2024, KDFWR received 50 tag returns from commercial fishing efforts. Forty 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 riverbanks. Twelve of the returned fish were double tagged. The higher frequency of returned fish from Barkley reservoir compared to Kentucky reservoir is not surprising given most of the commercial fishing pressure occurs on Barkley (Reported under Objective 3). Data analysis is in progress with the assistance of the USGS CERC staff and a report is expected in 2024. Preliminary model results suggest high survival in both reservoirs in the first four years after tagging, followed by a large decrease in survival after four years (Figure. 16).

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 2023. 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 2023 for aging. Barkley ages ranged from 4 to 10 years old, with age 6 being the most abundant. Kentucky ages ranged from 3 to 11 years old, with age 7 being the most abundant, (Figures 3 & 4). Data suggests a strong presence of three cohorts of silver carp behind the 2015 cohort (8-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 ($\hat{A}$) and instantaneous mortality (Z). Annual mortality for silver carp from Kentucky Reservoir was estimated at 36% and instantaneous mortality was estimated at 0.45 ($N=240$, $F_{1,2}=46.62.40$, $P=0.002$, $R^2=0.92$; Figure 5). Annual mortality for silver carp from Barkley Reservoir was estimated at 45% and instantaneous mortality was estimated at 0.60 ($N=205$, $F_{1,2}=11.92$, $P=0.03$, $R^2=0.74$; Figure 6).

Estimates of annual mortality in 2023 decreased from the values reported in 2022. This is attributed 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 Kentucky was estimated at $\text{Log}_{10}(\text{weight(g)}) = 2.769\text{Log}_{10}(\text{length(mm)}) - 4.2843$ (Figure 7). The length-weight equation for Barkley was estimated at $\text{Log}_{10}(\text{weight(g)}) = 2.2971\text{Log}_{10}(\text{length(mm)}) - 2.893$ (Figure 8). Weights were predicted for Barkley Reservoir: 450mm (1590g), 650mm (3700g) and 800mm (5962g) and Kentucky Reservoir: 450mm (1155g), 650mm (3196g) and 800mm (5680g) (Table 1). Predicted weights remain higher for Barkley than for Kentucky and both reservoirs indicate that all length classes are predicted to weigh more than previous years.

Data collected from sampling in the fall (September through December) of 2023 was used to analyze relative weights (Wr). Relative weight was calculated using the equation $\text{Log}_{10}(\text{Ws}) = -5.15756 + 3.06842(\text{Log}_{10}\text{TL})$ for silver carp (Lamer 2015). The mean Wr for silver carp in Barkley Reservoir was 102 (N=439, S.E.=±0.5) and the mean Wr for silver carp in Kentucky Reservoir was 100 (N=374, S.E.=±0.5). These values are consistent with data collected from previous years.

Objective 2. Examine variables affecting habitat usage by invasive carp to inform removal efforts.

In 2023, Belanger found silver carp in the lower Cumberland River tended have a positive relationship with discharge, meaning during high discharge times silver carp were closer to the dam. Whereas silver carp in the Lower Tennessee River were not reacting the same way to high discharge times. In both the Lower Cumberland and Tennessee Rivers silver carp were most often found near the confluence, of the respective rivers, with the Ohio River.

Belanger also found silver carp in the Lower Cumberland River had a higher year-round relative activity index, when compared to silver carp in the Lower Tennessee River. The Lower Tennessee River silver carp only had high RAI values during the summer. Belanger concluded that silver carp river kilometer has no significant relationship with temperature in either river. Temperature and discharge alone do not seem to be good predictors for silver carp movement behaviors even with two similar geographic and hydrologic systems.

Being able to identify a positive correlation of silver carp movement to discharge, should be considered as an opportunity to develop passive mechanical harvest methods, as typical gill net or seine nets are difficult to effectively fish during high discharge times. These factors will also be useful when developing best management practices for deterrent such as the Bio-Acoustic Fish Fence, at locks.

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

Invasive Carp Incentivized 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 2023, contractors received \$766,707.44 for invasive carp harvested from Barkley and Kentucky Reservoirs. This equates to over 9 million pounds of invasive carp harvested through the contract program in 2023, the 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 January 2024, the program now pays contractors \$0.10 / lb for invasive carp harvested from Kentucky waters of the reservoirs regardless of the size of those fish.

Carp Harvest Program Monitoring

The Invasive Carp Harvest Program (ICHP) 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 ICHP. Implementation of the ICHP 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 59,114,613 lbs of invasive carp, the majority was harvested through the ICHP (43,091,836 lbs silver carp, 286,890lbs bighead carp, 314,392lbs grass carp [2020-2023 only]; Table 2). 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. Most invasive carp harvested in Kentucky are from Barkley Reservoir (Table 2). Commercial fishers typically prefer fishing Barkley Reservoir over Kentucky Reservoir as it is shallower, has more habitat to corral fish, less recreational traffic, and the fishers believe the silver carp are larger. From 2020 to 2023 there was a decrease in number of individual commercial fishers in Barkley Reservoir, but an increase in harvest, and from 2022 to 2023 there was an increase of almost 200 trips made on Barkley Reservoir as well as an increase in over 1.7 million lbs of carp removed, which indicates that commercial fishers are getting more efficient at removal. The amount of harvest of invasive carp from Kentucky Reservoir mirrored the decrease from 2021 to 2022 in 2023 but the number of individual fishers and trips increases from 2022 to 2023. (Table 2). The number of commercial fishers in Kentucky and associated trips under the ICHP 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 losing commercial fishers to other states offering incentive programs (Table 2 & 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 2023 harvest as well as improvements to equipment such as boats, trucks, net rollers, cranes, and electronics. KDFWR's industrial flake ice machine was out

of order for most of 2023 due to ongoing mechanical issues. The equipment is being evaluated for decommissioning and alternative mechanisms for industry support are being considered.

Invasive carp harvest data was summarized by month from January 2015 to December 2023 (Figures 11 & 12). Historically, the number of trips made by commercial fishers under the ICHP 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 ICHP. 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 which has been mirrored in 2023 (Figure 11). Average total pounds of silver carp harvested per trip increased from 2022 and ranged from 2,919 – 6,124 pounds per month in 2023 (Figure 12).

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 °F and 86.0 °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 2023, the average number of pounds harvested per trip was calculated for all ICHP fishers (N=35), and average pounds of silver carp harvested varied from 429 lbs/trip to 9,018 lbs/trip. Interestingly, not all fishermen with high catch rates fished frequently (Figure 13). The number of trips a commercial fisherman took in 2023 varied from 3 to 196, with an average of 61 trips. This only included the number of trips where harvest occurred. In 2023, 91% of the requests to fish ended with fish harvested. Some fishermen 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 61 ride-alongs with 18 unique commercial fishers utilizing the ICHP January through December 2023 (Table 20 & Figure 15). During ride-alongs 34,010 yards of gill net were fished and 276,658 lbs of invasive carp were harvested. Most of the fishing effort observed during ride-alongs was on Barkley Reservoir (N=51), which is like fishing effort in general. Ride-alongs were also conducted in Kentucky Reservoir (N=10). 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 through 2023, 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 2022 and 2023 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 5). Average total weight of silver carp harvested per trip during ride-alongs in 2023 (4,491 lbs) was higher than 2022 (Table 6). There have been multiple instances where 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, six times during 2022, and nine times during 2023. KDFWR has begun to monitor zero net set trips and search time as a fisheries dependent trend to inform invasive carp stock assessments.

Objective 4. Evaluate new and/or experimental methods and gears for targeting invasive carp for harvest.

KDFWR staff continued to monitor seining practices under the current experimental gears program to determine efficacy in Kentucky waterways for removal of invasive carp and to determine the lasting impact on non-target fish species. Robbins Construction LTD harvested approximately 463,440 lbs of invasive carp from Barkley and Kentucky Reservoirs in 2023 with an average of 17,825 lbs/day which decreased from his 2022 average of 20,039 lbs/day. Additionally, Robbins harvested 831,206 lbs (20,273 lbs/day) of silver carp from the Cumberland River. >99% of the invasive carp harvested were silver carp and <1% were grass 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 597,482lbs (16,597 lbs/day) of silver carp from the Ohio River in 2023 through the contracted experimental efforts. Robbins seining in Kentucky waters yielded him a total of 1,691,614 lbs silver carp and an average of 16,423 lbs silver carp per day in 2023. His gill netting in Kentucky waters yielded him a total of 192,322 lbs of silver carp and an average of 8,362 lbs silver carp per day in 2023. His daily average while gill netting is 51% of what his daily average is while seining. This reaffirms the need to continue developing innovative approaches of harvest invasive carp in Kentucky waters.

Objective 5. Determine feasibility of conducting a large-scale exploitation study.

Fish tagging is planned for the spring of 2024.

TWRA (all referenced Tables and Figures for TWRA located in Appendix B)

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

A total of 78 Silver Carp were captured via electrified dozer trawls on all reservoirs for both summer and fall. Fewer Silver Carp (n=30) were captured during summer (n=30) than fall (n=48) and percent capture rates were also greater in the fall than the summer in all reservoirs except Barkley Reservoir (Table 1). The number of invasive carp captured and CPUE were highest in

Barkley Reservoir and lowest in Pickwick Reservoir in both summer and fall samples. (Table 1 & 2). Dozer trawl sampling was most effective in riverine environments such as Barkley Reservoir, Cheatham Reservoir, and upstream sections of Kentucky Reservoir, where percent capture rates and CPUEs were higher. Few invasive carp were captured in Kentucky Reservoir during summer pool, but catch increased in Kentucky Reservoir during fall when water levels receded for winter drawdown. No Silver Carp were captured by dozer trawl in Pickwick during either season.

Standardized electrofishing was conducted on Old Hickory Reservoir during summer 2023. One invasive carp was collected in Brumley Branch, and one invasive carp was observed in Spencer Creek; no other invasive carp were observed or collected.

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

TWRA's TCHIP resulted in the removal of 8,008,301 lbs of invasive carp from Kentucky, Barkley, Pickwick, Cheatham, and Old Hickory reservoirs in 2023.

Objective 5. Determine feasibility of conducting a large-scale exploitation study.

Various options were shared with TNCR partners by USFWS staff and USGS staff with experience conducting exploitation studies, modeling, and tagging. TNCR partners considered the options shared and established a plan to implement a 4-year project, tagging 1,000 silver carp each for the first 3 years in Kentucky and Barkley reservoirs. The project will utilize a high-reward (\$100) loop tag in every silver carp and incorporate a high-reward jaw band in 25% of the loop-tagged carp to estimate tag retention. Unique IDs on each tag will allow biologists to gain insight about carp movement in relation to original tagging location and may offer insight into schooling behavior. Informational material will be shared with the commercial fishing industry to increase awareness of the project, though specifics regarding tagging locations will not be distributed. We will work with partners to conduct appropriate analyses for the duration of the project. Tagging is set to begin in spring of 2024.

ADCNR (all referenced Tables and Figures for ADCNR located in Appendix C)

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

Overall, expansion of sample efforts within a robust occupancy-strategy and multiple-EF boat herding for invasive carp was higher by 21% for electrofishing person hours and 1.75-fold for pedal hours (Tables 1, 2). For gillnets, net-sets were reduced by 12% and person-hours were less than half that of 2022. This was primarily due to an emphasis on occupancy-strategy sampling with increased repetitions, but reduced soak time (short-day vs all night) for nets. Regardless, total catch of invasive carp was low (Tables 1, 2; Figure 4). In all four years, Silver Carp were captured only in Pickwick Reservoir with most White Amur captured in Wheeler and

Wilson. Reconnaissance sampling at Gunter'sville Reservoir did not yield any invasive carp. During 2022, far more than half of Silver Carp were captured during exclusive sample targeting Objective 3 goals (EF = 53%; GN = 95%). Moreover, the use of occupancy strategies in desirable habitats increased the frequency of visual sightings of Silver Carp, as well as reduced the number of non-target fish by more than two-fold compared to prior years (Table 2; ADCNR 2023). Occupancy sampling was also more efficient for mileage traveled and number of samples completed per sample period, given the same number of staff utilized (ADCNR 2023). Despite small numbers of Silver Carp collected since 2020, we note the only pattern is that no Silver Carp have been collected from reservoirs upstream of Pickwick Reservoir during our standardized sample efforts. We further note that expanding our sampling efforts towards an intensive occupancy sample strategy should expand our ability to better evaluate expansion of carp spatial distributions and possibly catch rates within invaded areas in Alabama waters.

Multiple-boat electrofisher herding during fall 2023 only yielded two adult Grass carp (Table 1).

Recommendations:

KDFWR

- 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 metrics 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 incentive program and alter as needed.
- Continue to work on strategies to determine immigration rates from the Ohio river into the reservoirs. This information will be an important factor for the continued development of carp population models.

TWRA

- Continue to work with partner agencies to develop SOPs for gears, methods, data collection and storage to improve basin wide stock assessments.
- Continue supporting commercial removal efforts through the Tennessee Carp Harvest Incentive Program.
- Continue efforts to describe impacts of currently implemented management strategies.

ADCNR

- Given our sample collections to date, we feel expansion of standardized gillnetting and electrofishing should continue for Objective 1 monitoring within an occupancy sample strategy. However, this strategy would be excluded if sampling using either or both

gears, combined with modifications (e.g., herding) increase carp catches specifically during Objective 3 work.

- Currently, we do not feel a need for expansion of new studies or actions outside of expanding our sampling regime. Planning for 20203 includes expansion of new sample areas in Wilson (1 area) and Wheeler (2 to 3 areas) Reservoirs. Currently, we do not anticipate changes or additions to management actions, though this may change with needs as per discussions among other TNCR partner agency staff.

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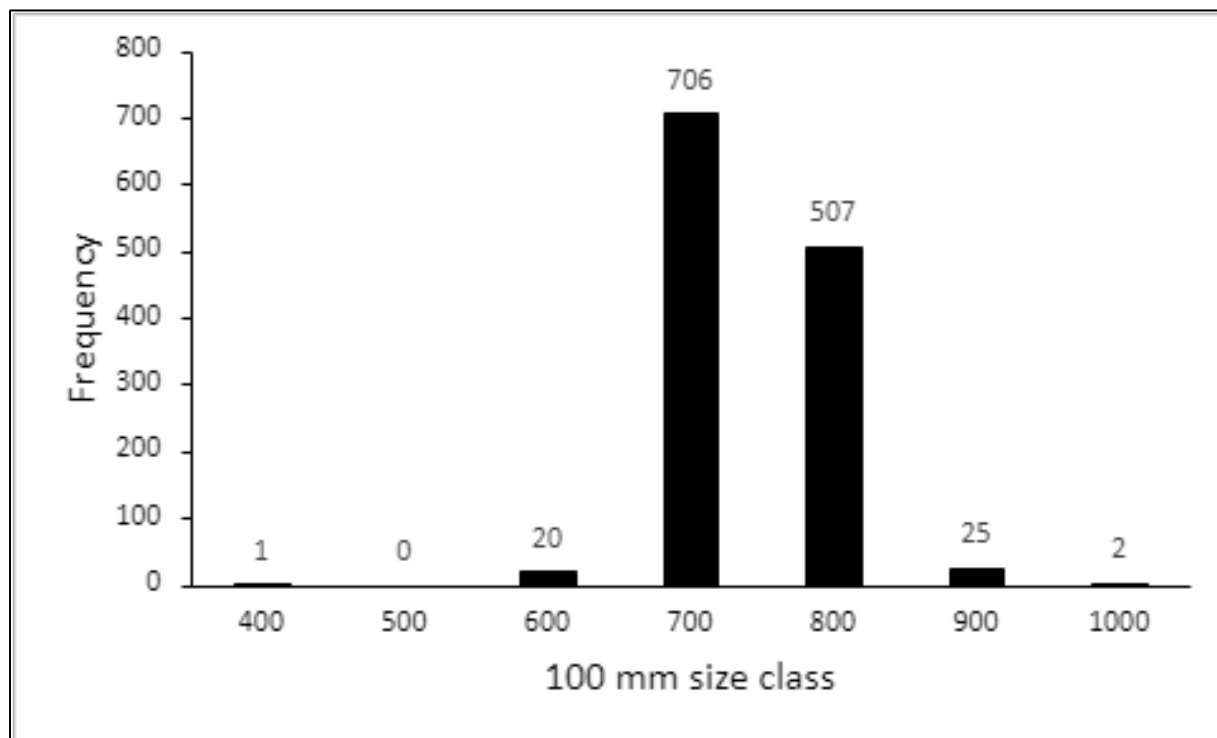
Appendix A:**KDFWR Figures and Tables**

Figure. 1 Length-frequency distribution of silver carp collected from Barkley Reservoir, from all methods in 2023 (N=1261)

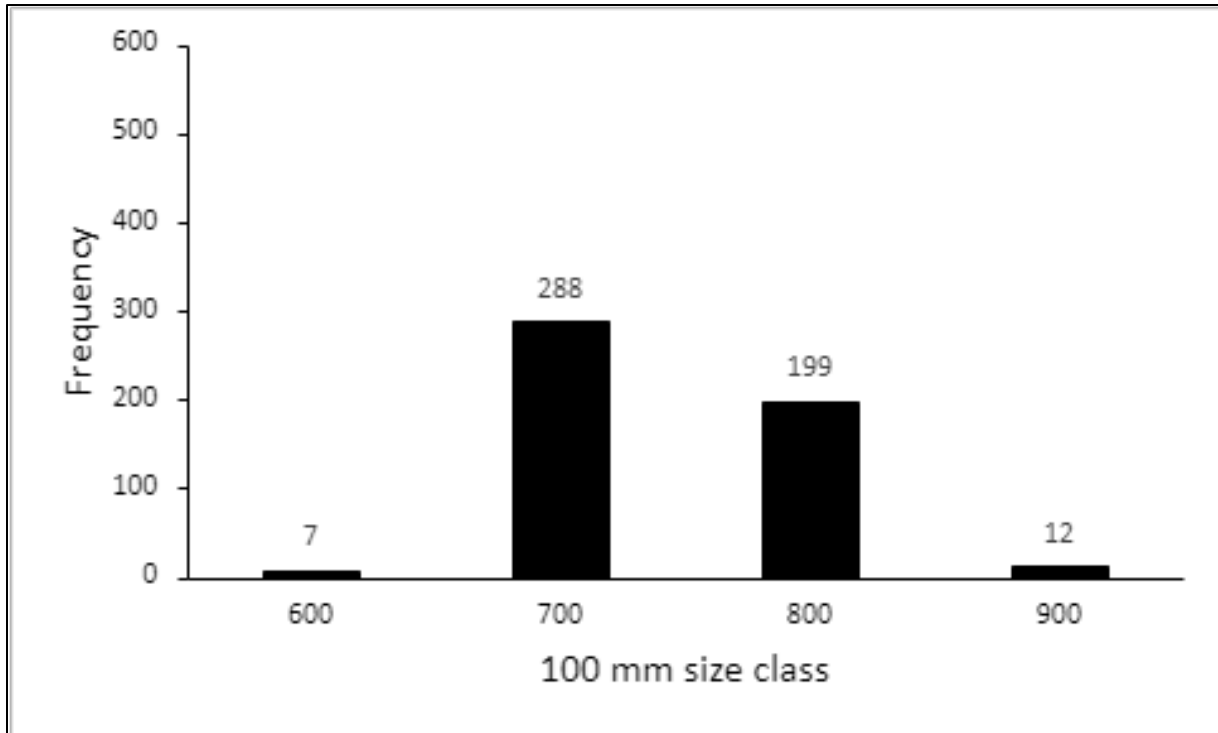


Figure 2. Length-frequency distribution of silver carp collected from Kentucky Reservoir, from all methods in 2023 (N=506).

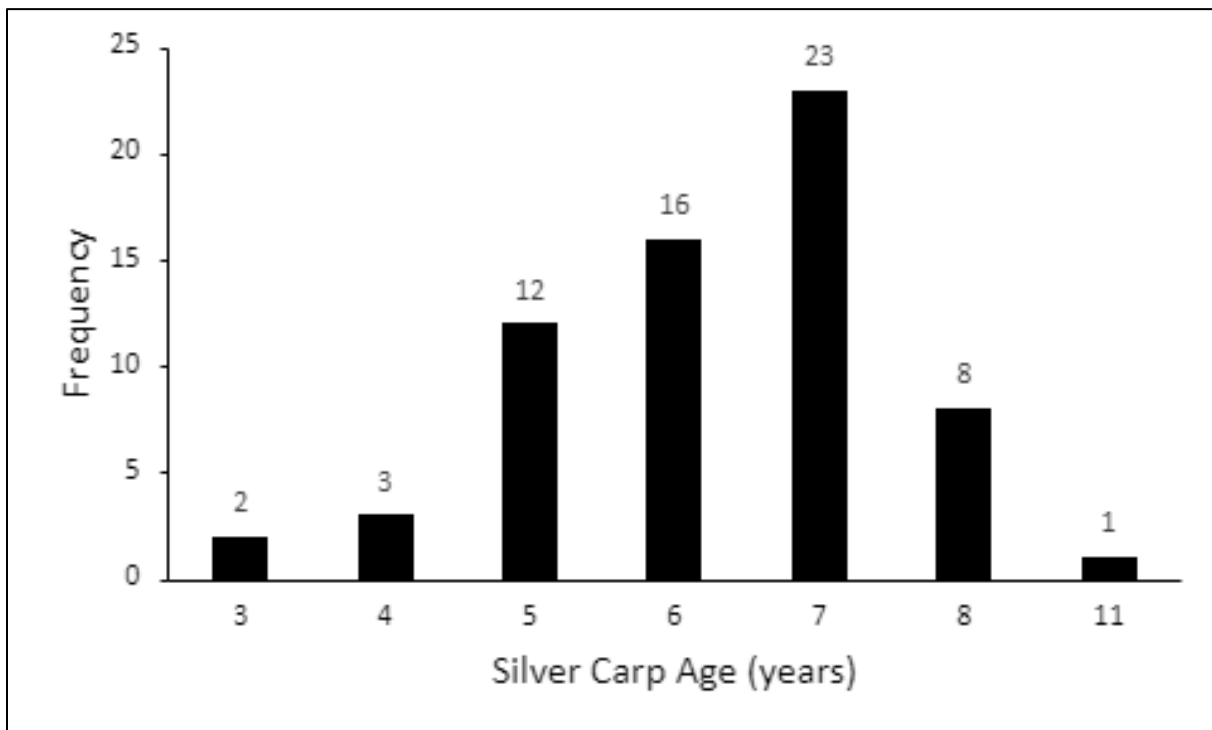


Figure 3. Age-frequency distribution for silver carp collected from Kentucky Reservoir in 2023 (N=65)

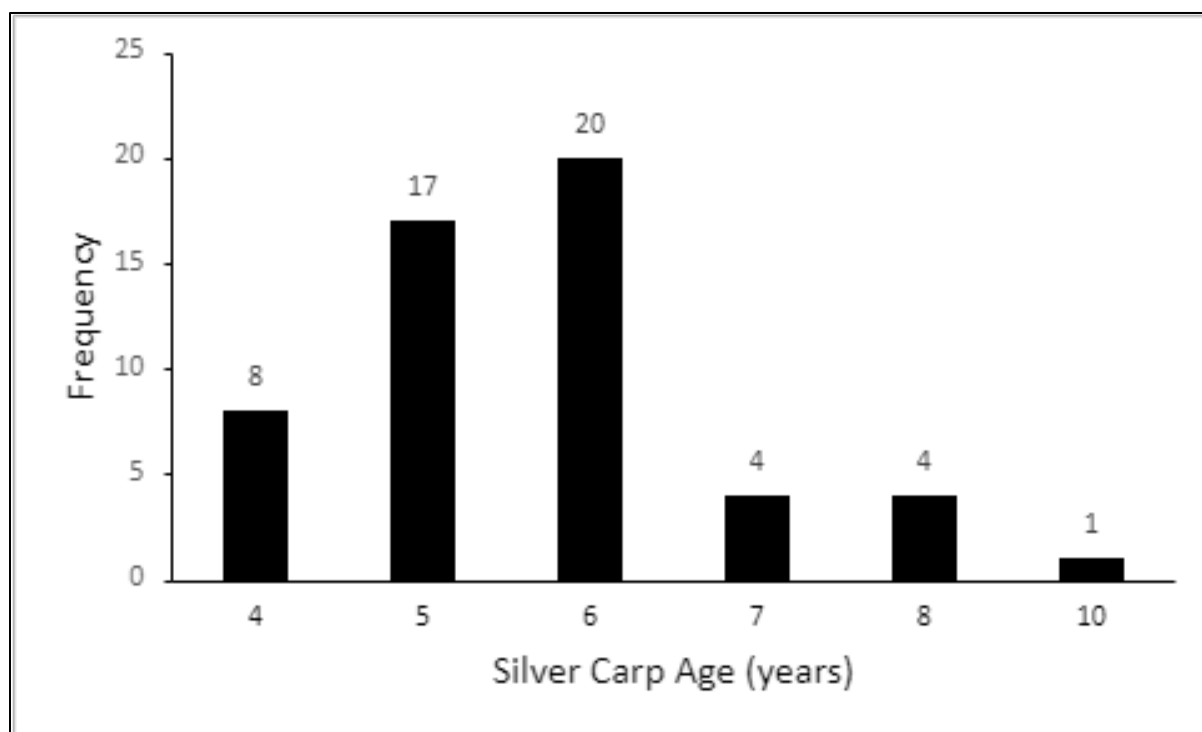


Figure 4. Age-frequency distribution for silver carp collected from Barkley Reservoir in 2023 (N=54).

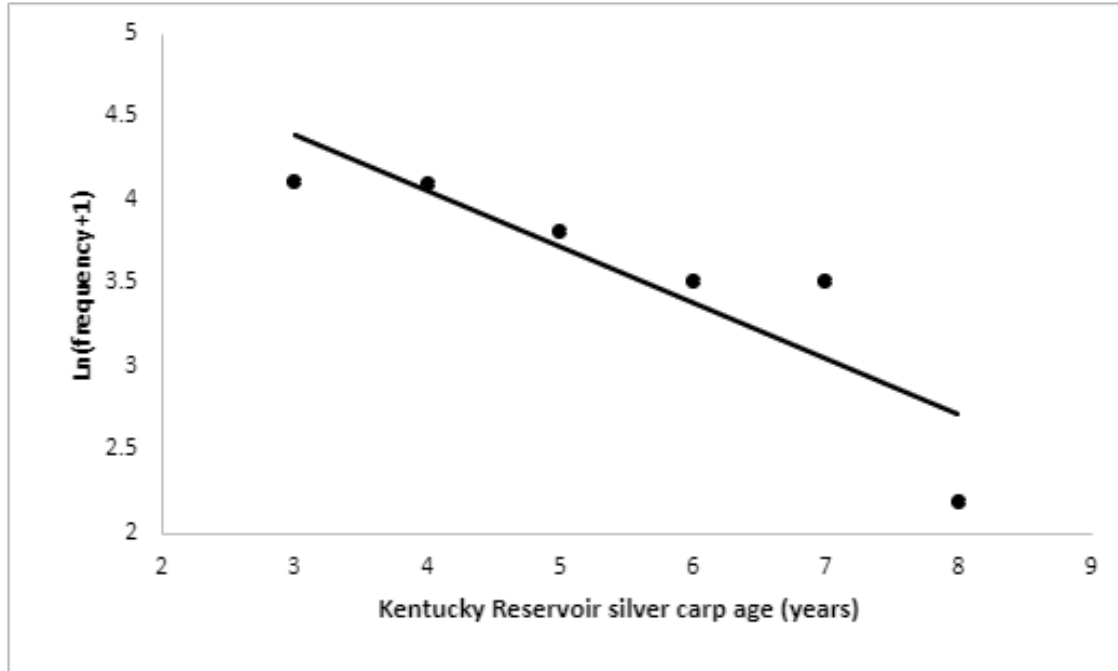


Figure 5. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Kentucky Reservoir in 2023 (N=240, $F_{1,2}=46.62$, $P=0.002$, $R^2=0.92$).

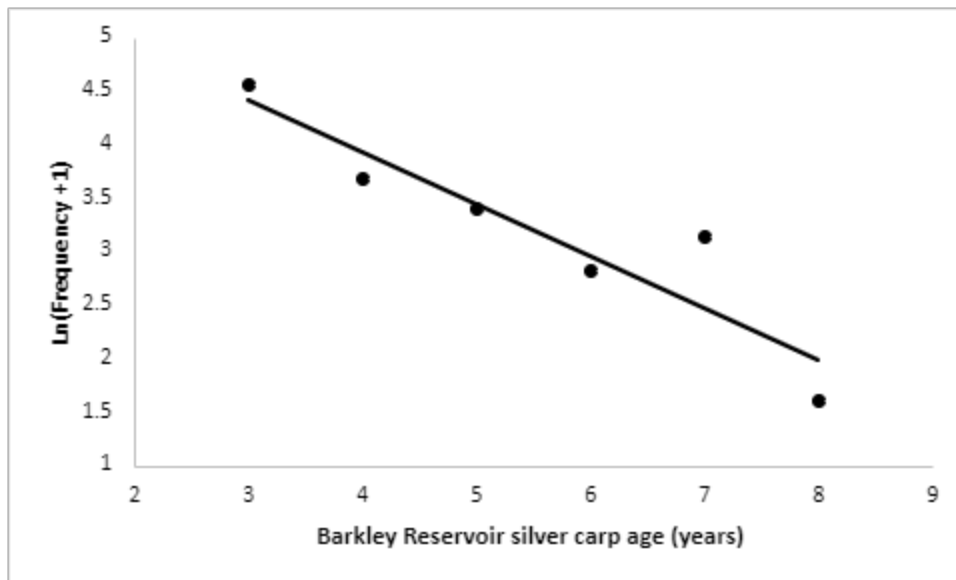


Figure 6. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Barkley Reservoir in 2023 (N=205, $F_{1,2}=11.92$, $P=0.03$, $R^2=0.74$).

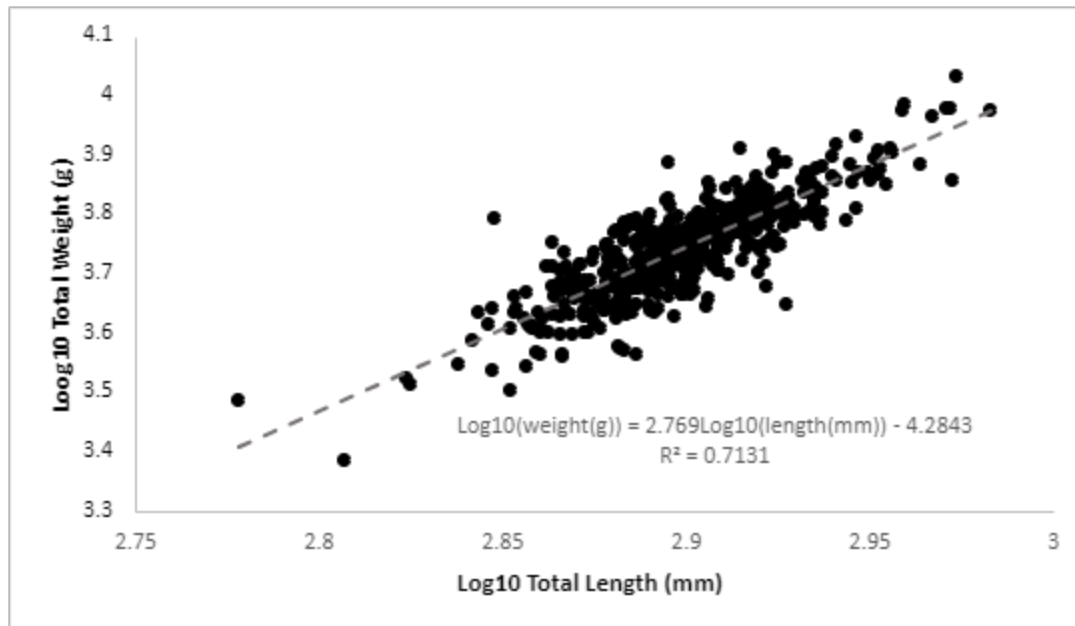


Figure 7. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Kentucky Reservoir in 2023 with a regression line describing the relationship between lengths and weights (N=505).

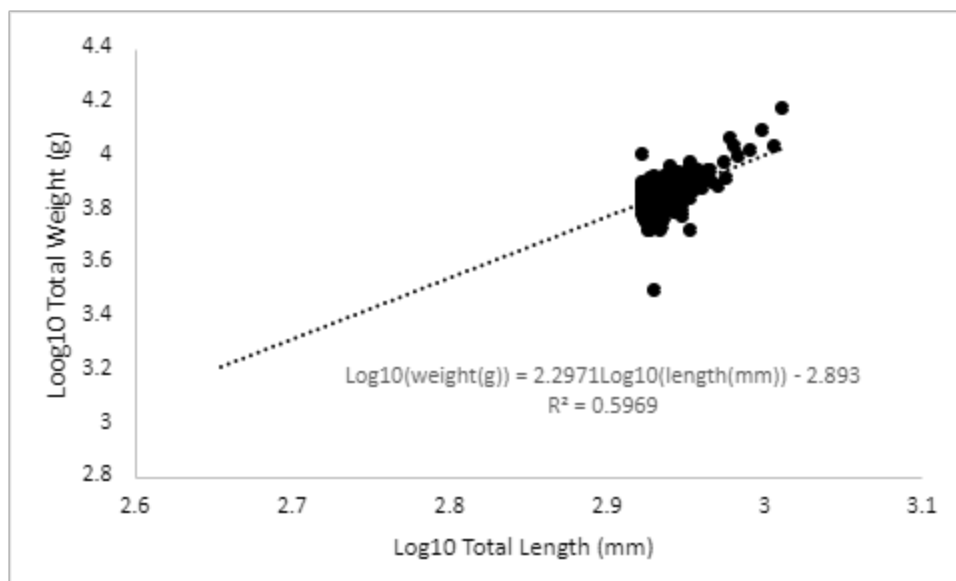


Figure 8. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Barkley Reservoir in 2023 with a regression line describing the relationship between lengths and weights (N=1201).

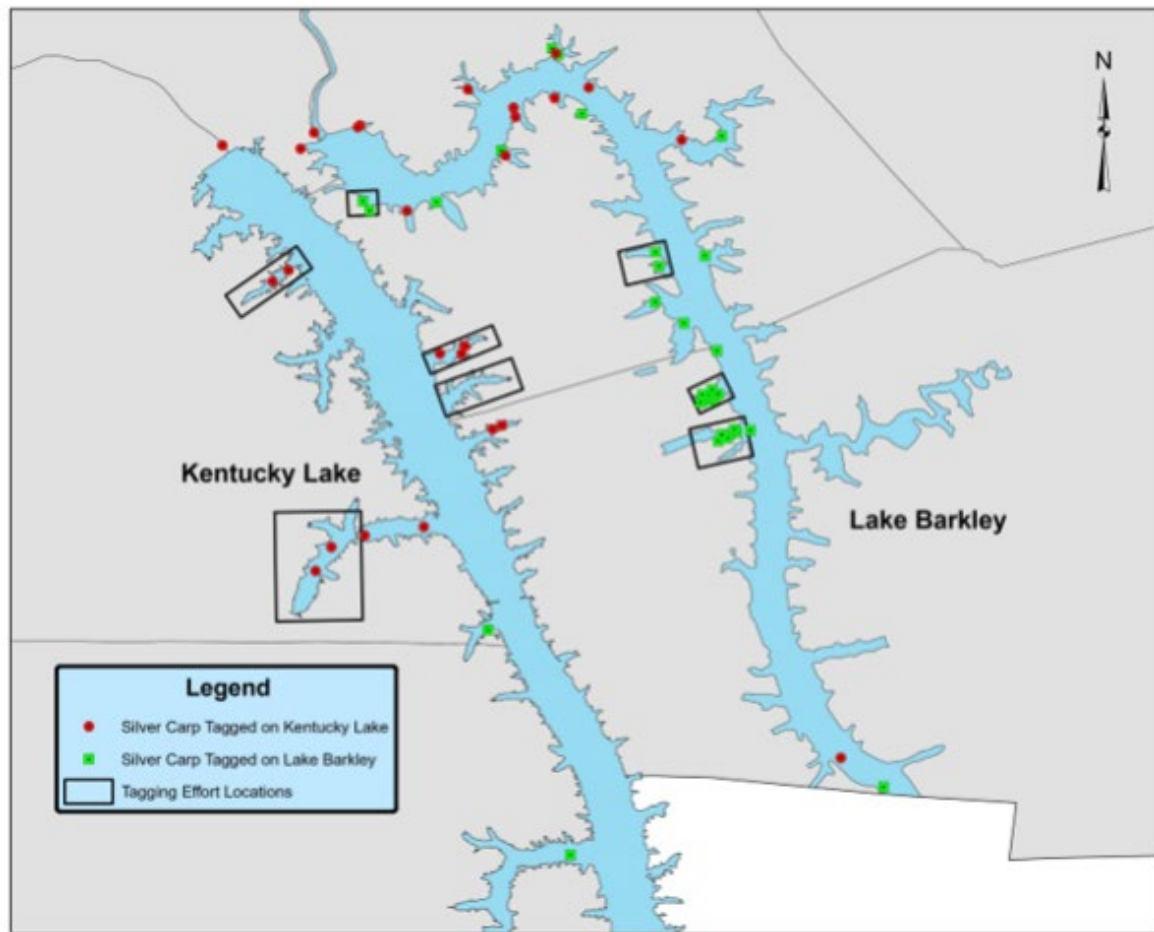


Figure 9. Locations of recaptured silver carp that were tagged as part of the mark-recapture effort to estimate abundance of silver carp in Barkley and Kentucky Reservoirs from October 2018- February 2024. (Two recaptured fish not displayed, one was captured in Hovey Lake, IN, other in Green River, KY)

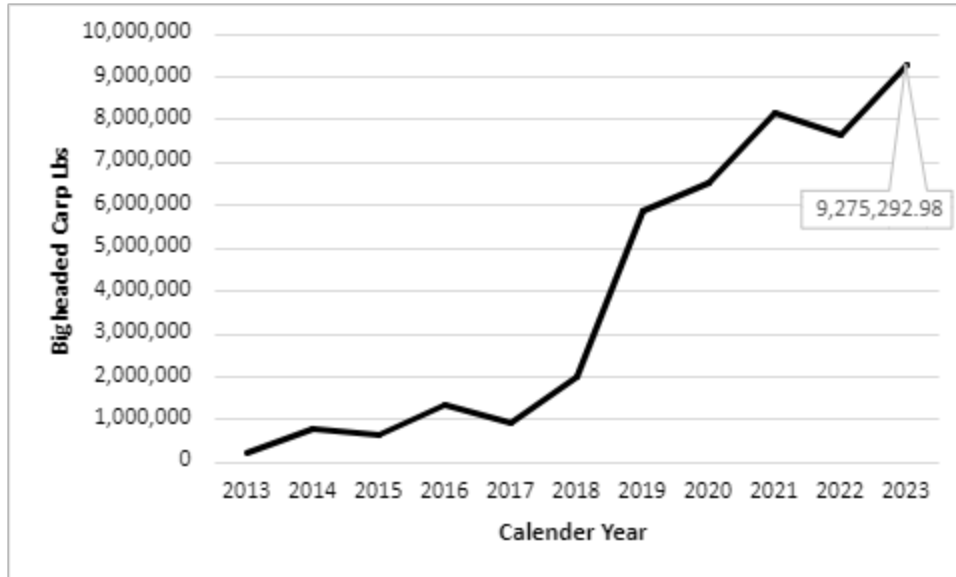


Figure 10. Pounds of bigheaded carp harvested through the Invasive Carp Harvest Program by calendar year. *2020 was the first year that grass carp harvest was tracked through the ICHP and accounted for an additional 111,190 lbs in 2020, 74,430 lbs in 2021, 55,805 lbs in 2022, and 72,967 lbs in 2023.

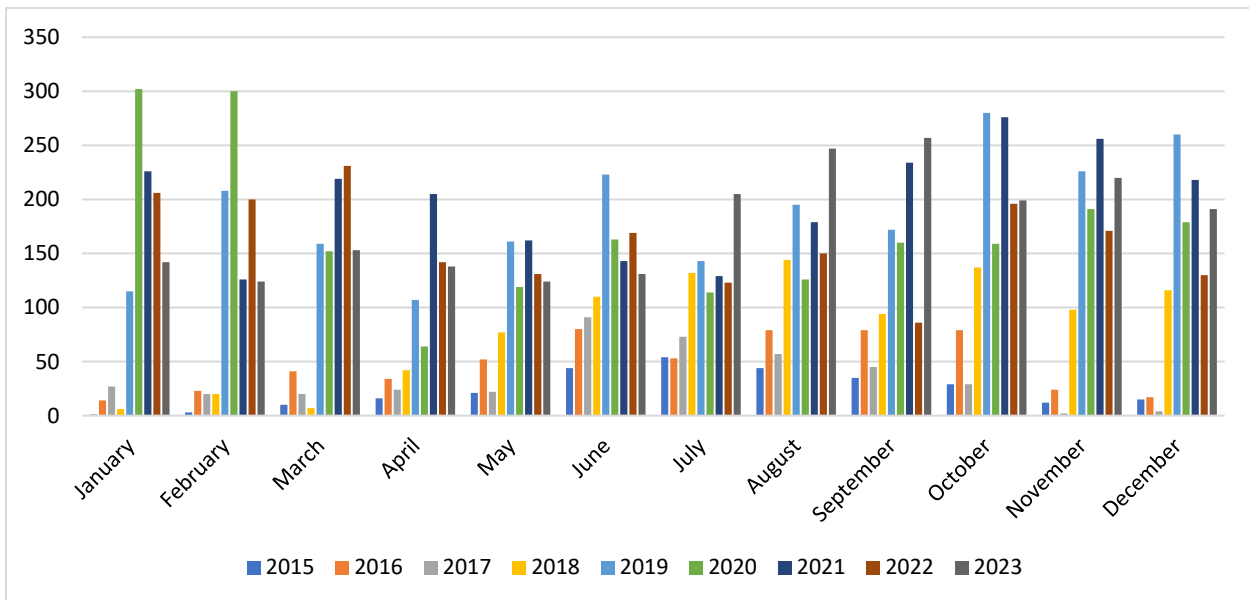


Figure 11. Number of fishing trips made monthly by commercial fishers fishing under the Invasive Carp Harvest Program from January 2015 - December 2023.

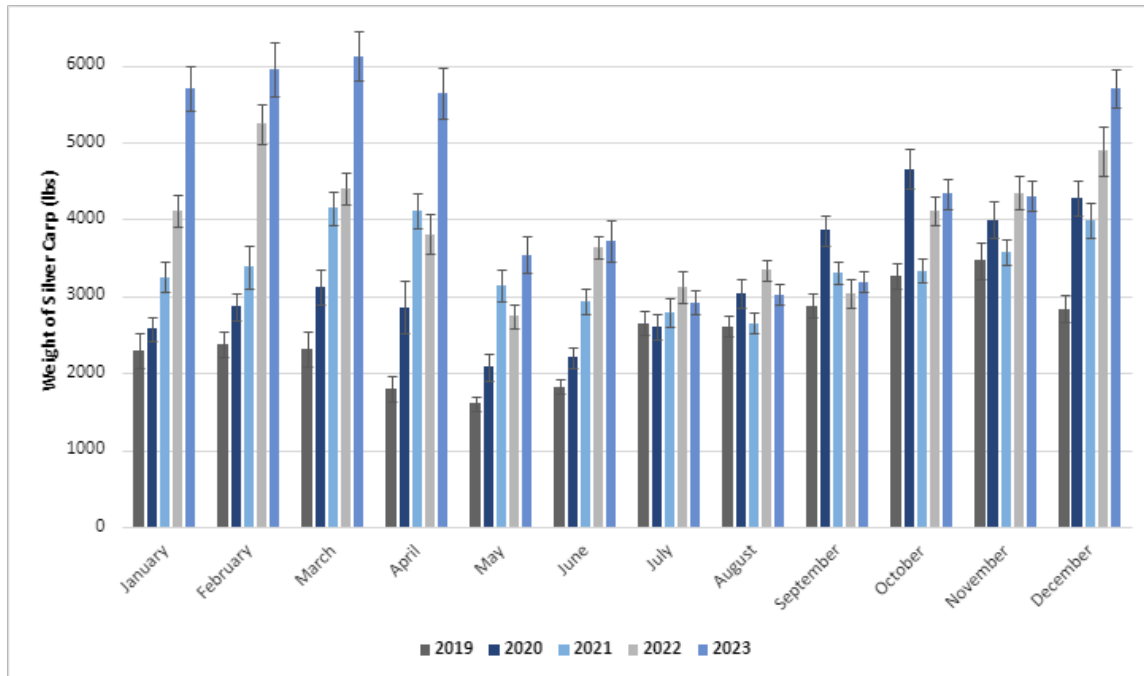


Figure 12. Monthly average total weight (lbs) of silver carp harvested per trip by commercial fishers fishing under the Invasive Carp Harvest Program January 2019 - December 2023. Error bars represent standard error values.

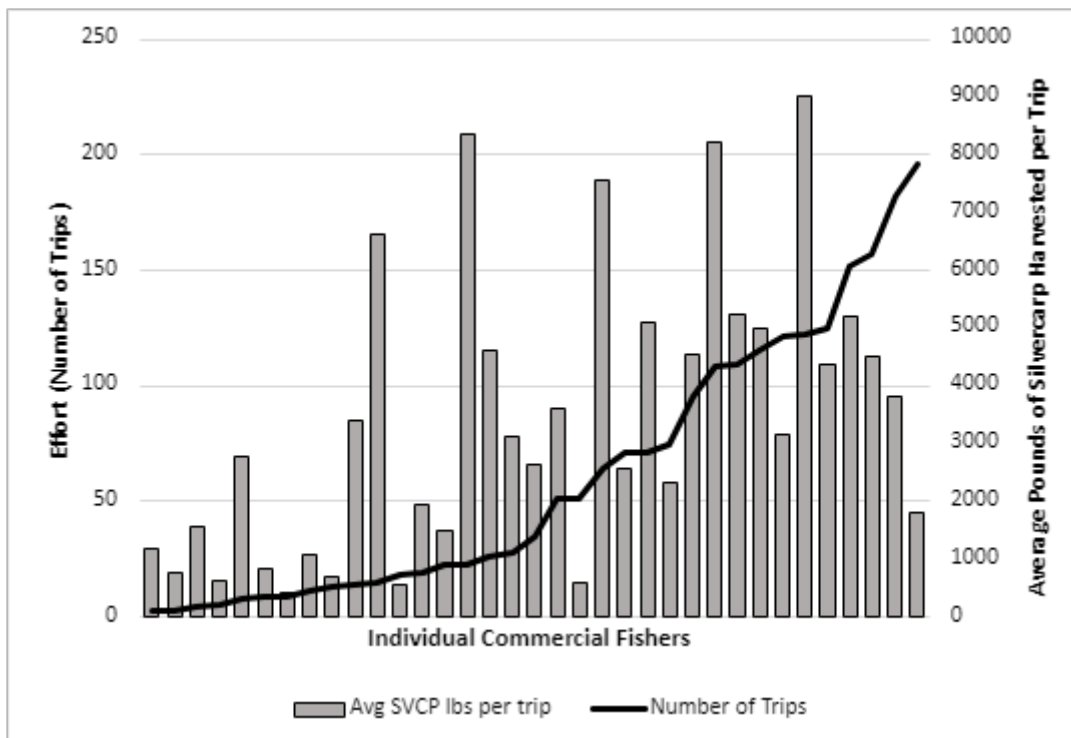


Figure 13. Average silver carp weight harvested per trip by individual commercial fishers compared to the number of trips taken by those fishers under the Invasive Carp Harvest Program in 2022.

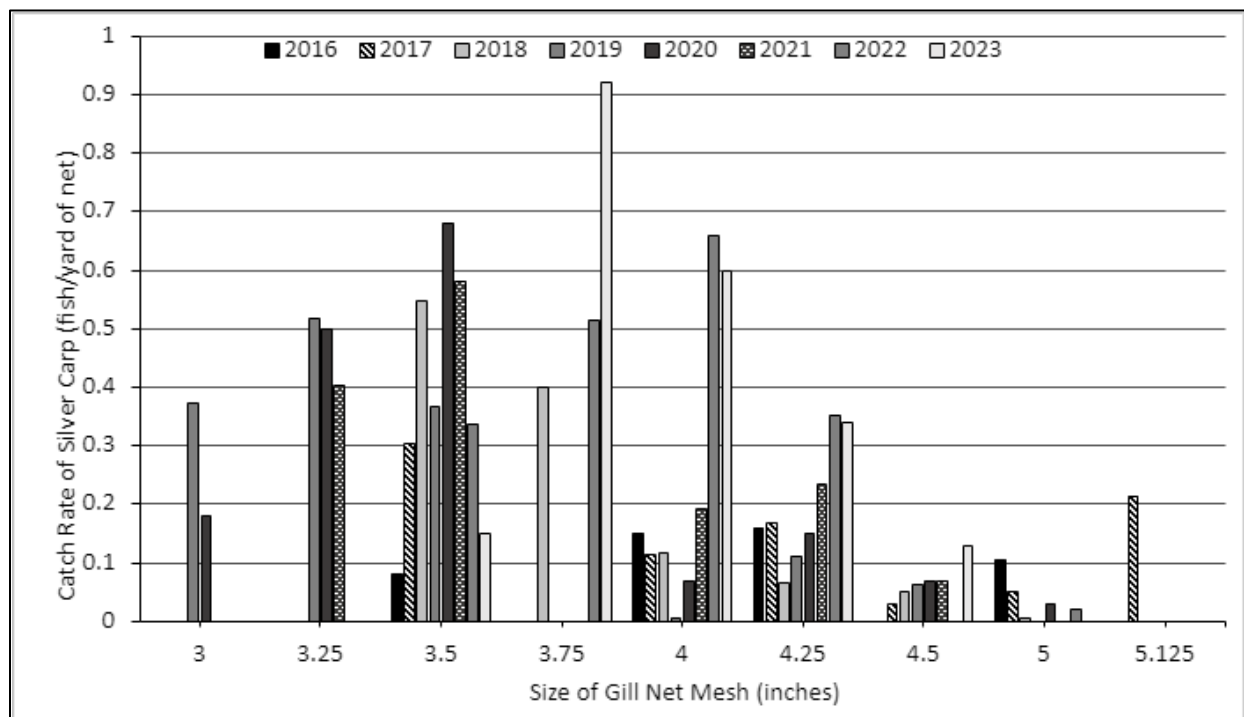


Figure 14. Catch rates (number of fish/yard of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Invasive Carp Harvest Program per year from 2016 through 2023.

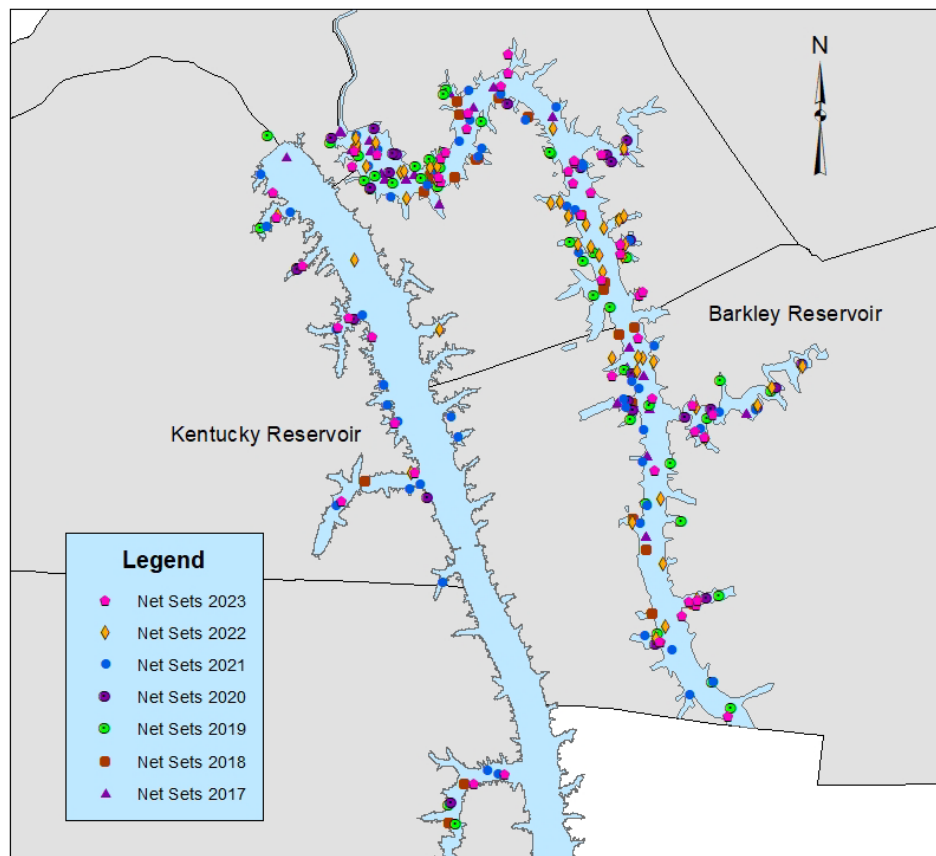


Figure 15. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff from 2017 through 2023.

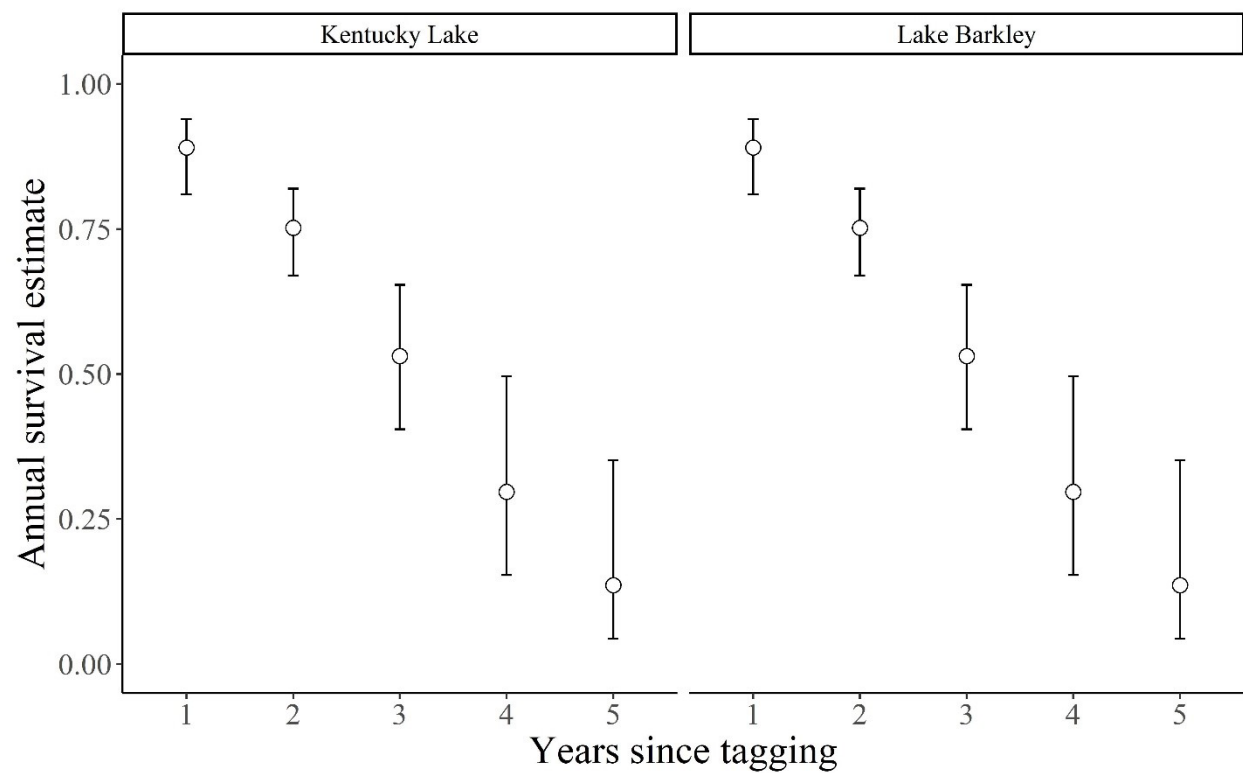


Figure 16. Estimated annual survival between Kentucky and Barkley Reservoirs, Kentucky, USA for Silver Carp tagged in September 2018. Error bars represent the 95% confidence intervals.

Table 1. A summation of estimated weights at three lengths for silver carp collected from Barkley and Kentucky reservoirs through all methods from 2018 through 2023.

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
	2023	1590	3700	5962
Kentucky	2018	950	2733	4963
	2019	930	2720	4987
	2020	986	2788	5018
	2021	994	2848	5301
	2022	836	2776	5469
	2023	1155	3196	5680

Table 2. Measures of effort and catch while gillnetting reported by commercial fishers fishing under the Invasive Carp Harvest Program by calendar year, January -December 2013 - 2023.

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 Reservoir	2013	45	5	187,022		
	2014	61	6	464,003	1,360	
	2015	189	12	472,487	10,278	
	2016	447	22	1,112,585	5,693	
	2017	345	15	826,016	9,669	
	2018*	835	23	1,762,830	25,932	
	2019	1,846	60	5,318,535	45,665	
	2020***	1,431	43	4,700,149	28,714	61,487
	2021	1,707	32	5,918,405	18,669	43,213
	2022	1,510	30	6,120,640	24,762	37,664
	2023	1,725	31	7,914,777	20,024	59,284
Kentucky Reservoir	2013	21	4	26,400	491	
	2014	82	3	193,786	992	
	2015	59	6	84,190	17,791	
	2016	52	8	96,652	2,884	
	2017	54	8	71,487	11,754	
	2018*	116	8	143,996	11,537	
	2019	140	28	233,806	1,978	
	2020***	426	27	1,601,822	4,196	40,882
	2021	587	28	2,154,845	4,227	27,514
	2022	309	20	1,184,756	3,074	8,666
	2023	338	25	1,174,586	3,953	3,773
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
	2023	57	9	143,580	90	9,810
Statewide**	2013	76	7	243,121	491	
	2014	160	9	765,768	2,802	
	2015	283	16	617,062	32,800	
	2016	565	24	1,343,464	12,666	
	2017	414	21	921,288	23,272	
	2018*	982	29	1,945,693	37,739	
	2019	2,250	66	5,802,624	50,366	
	2020***	2,052	48	6,471,718	43,931	111,190
	2021	2,373	38	8,148,093	24,699	74,430
	2022	1,951	39	7,582,713	33,123	55,805
	2023	2,131	35	9,250,292	25,001	72,967

*In 2018 KDFWR began allowing commercial fishermen to receive subsidy funds from the Invasive Carp Harvest Program while fishing on their net permit, which allows them to harvest catfish and paddlefish.

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

***2020 was the first year that Grass carp harvest was reported separately from common carp harvest through the ICHP.

Table 3. Average length and weight of silver carp harvested during ride-alongs with commercial fishers under the Invasive Carp Harvest Program 2015-2023.

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
2023	1040	31.4	13.0	0.08

Table 4. Number of bighead carp, grass carp, and silver carp captured by gill net mesh size as observed during KDFWR ride-alongs with commercial fishers fishing under the Invasive Carp Harvest Program 2016 - 2023. (CPUE = catch per unit effort)

Year	Net Bar Mesh Size (inches)	Effort (linear yards of net)	Number of Silver carp	carp CPUE (fish/yard)	Number of Bighead carp	Number of Grass carp
2016	3.5	1,883	155	0.08		17
	4	2,067	308	0.15		1
	4.25	9,300	1,469	0.16	8	12
	5	16,983	1,811	0.11	44	13
	6	1,067	3	0.00		
2017	3.5	200	61	0.31	4	1
	4	1,983	225	0.11	1	1
	4.25	23,400	3,918	0.17	19	31
	4.5	2,283	68	0.03		
	5	4,125	212	0.05	3	1
	5.125	400	86	0.22	4	2
2018	3.5	6,883	3,778	0.55	8	24
	3.75	167	67	0.40		
	4	3,250	381	0.12	4	3
	4.25	14,100	920	0.07	54	8
	4.5	2,767	145	0.05	4	
	5	867	5	0.01	1	
2019	3	2,967	1,106	0.37	2	5
	3.25	9,600	4,979	0.52	10	83
	3.5	39,300	14,483	0.37	30	177
	4	300	2	0.01	0	0
	4.25	3,700	406	0.11	18	3
	4.5	2,567	162	0.06	5	1
	5	67	0	0.00	0	0
2020	3	100	18	0.18		
	3.25	3,933	1,968	0.50	2	17
	3.5	21,692	14,792	0.68	33	169
	4	533	38	0.07		
	4.25	2,100	319	0.15	6	
	4.5	1,583	104	0.07	5	
	5	267	9	0.03	4	
2021	3.25	2,117	851	0.40		6
	3.5	35,093	20,416	0.58	73	134
	4	2,583	494	0.19	17	3
	4.25	1,100	258	0.23	17	
	4.5	1,450	102	0.07	4	
2022	3.5	11,000	3,699	0.34	10	11
	3.75	17,292	8,812	0.51	22	12
	4	5,033	3,136	0.62	32	4
	4.25	56,667	2,784	0.05	39	
	5	667	10	0.01		
2023	3.5	1,200	174	0.15		
	3.75	2,767	2,547	0.92	5	3
	4	28,193	16,843	0.60	74	46
	4.25	2,983	1,003	0.34	3	2
	4.5	2,133	273	0.13	4	

Table 5. Fishing effort and total weight (lbs) of Invasive carp harvested during KDFWR ride-alongs with commercial fishers fishing under the Invasive Carp Harvest Program 2015 - 2023.

Year	Effort *	Mean effort per trip	S. E.	Number of ride alongs	Number of fishers	Total WT of bighead carp harvested (lbs)	Total WT of silver carp harvested (lbs)	Total WT of grass carp harvested (lbs)
2015	31,583	1,053	78.4	32	8	4,086	68,139	855
2016	30,700	1,096	73.2	28	4	1,067	69,765	630
2017	32,225	1,040	88.6	31	9	763	73,958	746
2018	32,193	1,238	86.1	26	11	957	60,938	583
2019	57,433	1,197	79.8	48	19	1,123	160,981	2,916
2020	30,208	1,007	58.0	30	16	1,226	143,257	1,372
2021	42,193	728	53.0	58	18	1,780	198,249	1,130
2022	39,658	778	55.9	51	16	2,227	203,994	297
2023	34,010	654	40.6	61	18	2,064	273,994	600

*effort is calculated in yards of gillnet fished.

Table 6. 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 Invasive Carp Harvest Program in 2016 - 2023. (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
2023	Ride Alongs	4,492	441.7	10	4.7	34	17.0
	Commercial Fisher Reports	4,641	93.7	10	2.7	33	6.0

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

Table 7. 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-19		442	~260	~60	1	
Oct-22	1.28	105	105.9	33.2		
Nov-23	0.66	24	36	9.07		

Appendix B:**TWRA Tables and Figures**

Table 1. Summary of Silver Carp (SVCP) that evaded capture, were captured, and the percent capture rates for each section of Kentucky Reservoir, Barkley Reservoir, Pickwick Reservoir, and Cheatham Reservoir.

SVCP Capture Rates 2023				
Season	Location	SVCP Evaded 2023	SVCP Caught 2023	Percent Captured 2023
Summer	Kentucky S1	24	0	0%
Summer	Kentucky BS	9	0	0%
Summer	Kentucky S2	34	1	2.9%
Summer	Kentucky S3	17	1	5.9%
Summer	Kentucky S4	11	0	0%
Summer	Pickwick	1	0	0%
Summer	Barkley	245	21	8.6%
Summer	Cheatham	68	7	10.3%
Fall	Kentucky S1	29	1	3.4%
Fall	Kentucky BS	47	1	2.1%
Fall	Kentucky S2	262	11	4.2%
Fall	Kentucky S3	159	9	5.7%
Fall	Kentucky S4	82	4	4.9%
Fall	Pickwick	0	0	0%
Fall	Barkley	389	14	3.6%
Fall	Cheatham	158	8	5.1%

Table 2. Summary of dozer trawl season, CPUE (Carp/5-min and Carp/hr) for each section of Kentucky Reservoir, Pickwick Reservoir, Barkley Reservoir, and Cheatham Reservoir in Summer and Fall 2023.

Catch Per Unit Effort Dozer Trawl			
Season	Location	Carp/5-min	Carp/hr
Summer	Kentucky S1	0	0
Summer	Kentucky BS	0	0
Summer	Kentucky S2	0.05	0.6
Summer	Kentucky S3	0.05	0.6
Summer	Kentucky S4	0	0
Summer	Pickwick	0	0
Summer	Barkley	1.05	12.6
Summer	Cheatham	0.35	4.2
Fall	Kentucky S1	0.05	0.6
Fall	Kentucky BS	0.05	0.6
Fall	Kentucky S2	0.55	6.6
Fall	Kentucky S3	0.45	5.4
Fall	Kentucky S4	.2	2.4
Fall	Pickwick	0	0
Fall	Barkley	0.7	8.4
Fall	Cheatham	0.4	4.8

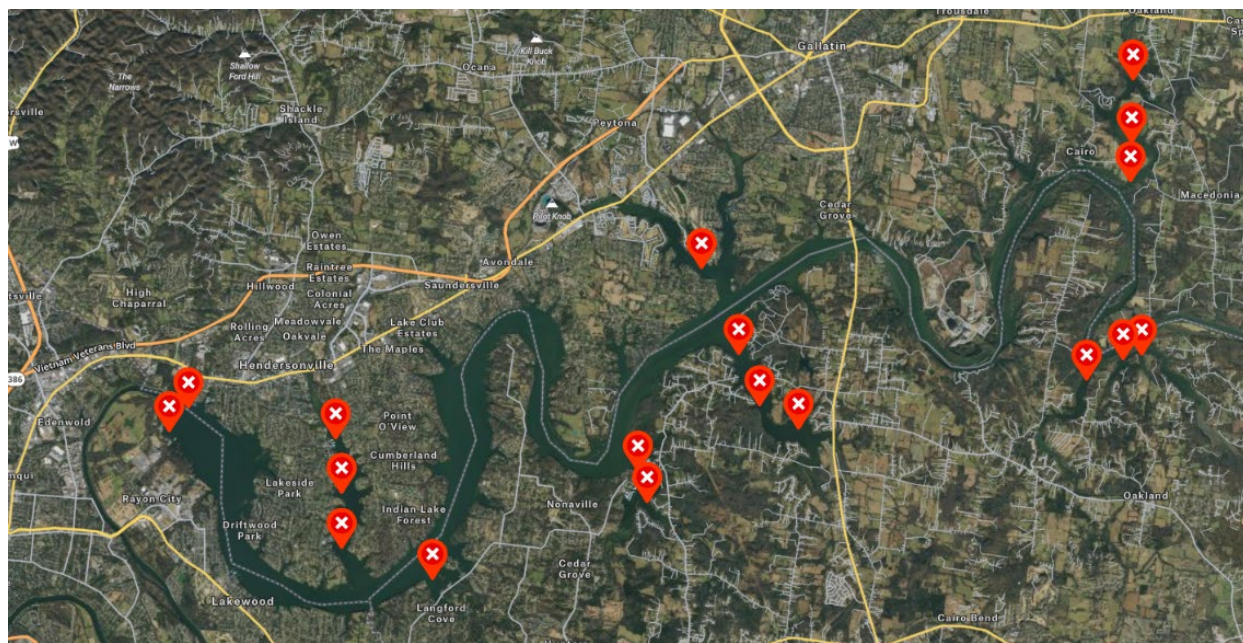


Figure 1. Standardized electrofishing locations for Old Hickory Reservoir.

Appendix C:**ADCNR Tables and Figures**

Table 1. Summary of ADCNR, CY2023 effort and catch data during monitoring, eradication and field reconnaissance of invasive carp populations in four Tennessee River reservoirs in Alabama. Effort and catch-per-unit (CPUE) data are rounded to nearest whole number, though CPUE were rounded to nearest 0.01.

Sample Effort Parameter	TN River Reservoirs (downstream to upstream)				Row Total or Mean
	Pickwick	Wilson	Wheeler	Guntersville	
<i>Electrofishing effort</i>					
Estimated person hours	184	357	344	0	885
Samples (transects)	72	118	162	0	352
Electrofishing hours	6	15	20	0	41
<i>Electrofishing catch</i>					
Silver Carp (n)	1	0	0	0	1
White amur (n)	0	1	3	0	4
CPUE (invasive carp/hr)	0.35	0.06	0.15	0	0.56
<i>Gill Netting effort</i>					
Estimated person hours	48	164	234	0	446
Samples (net sets)	36	36	60	0	132
Soak time (hours)	58	67	122	0	247
Miles of nets	2	2	3	0	7
<i>Gill Netting Catch</i>					
All fish (n)	24	150	99	0	273
Fish species (n)	26	22	27	0	75
Silver Carp (n)	0	0	0	0	0
White amur (n) *	0	0	1	0	1
Hybrid carp (n)	0	0	0	0	0
CPUE (all fish/net)	0.67	4.17	1.67	0	6.51
CPUE (invasive carp/net)	0	0	0.02	0	0
<i>Other field work:</i>					
Estimated person hours (dates)				41 (3 dates)	
Target Task	Site assessment	Assess gear	Assist USGS, MS FWP	Telemetry receiver download, maintenance	
Sample method	Bottom sonar	DC output	Boat EF		

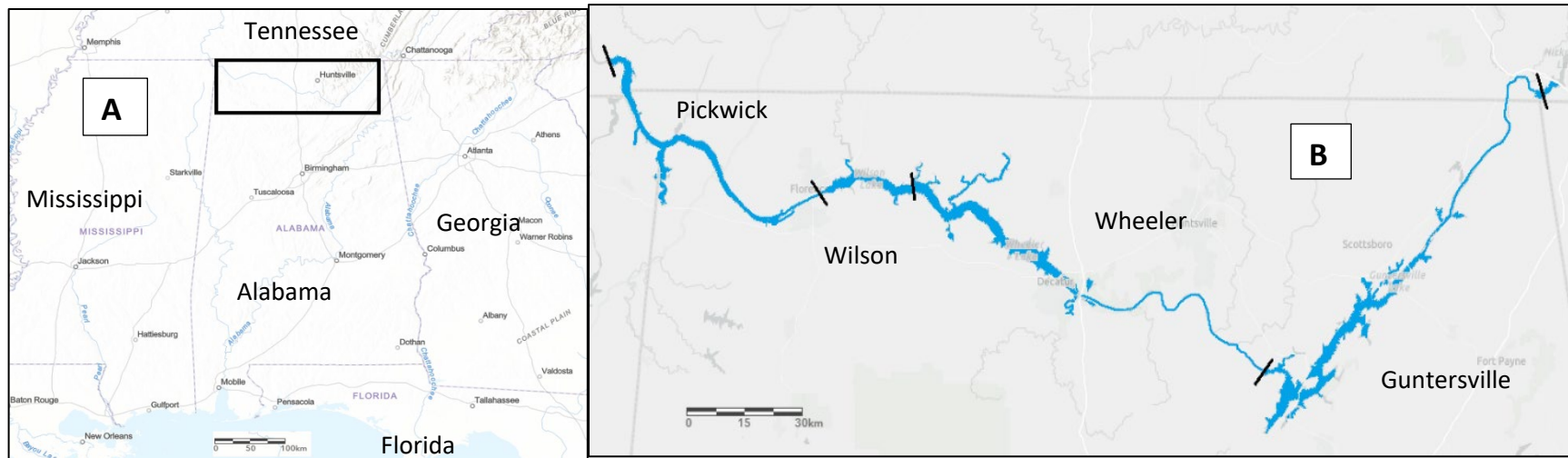


Figure 1. Position of the Tennessee River (box inset) in Alabama (A) and the relative locations of reservoirs and dams (B) in Alabama and contiguous waters of Mississippi and Tennessee.

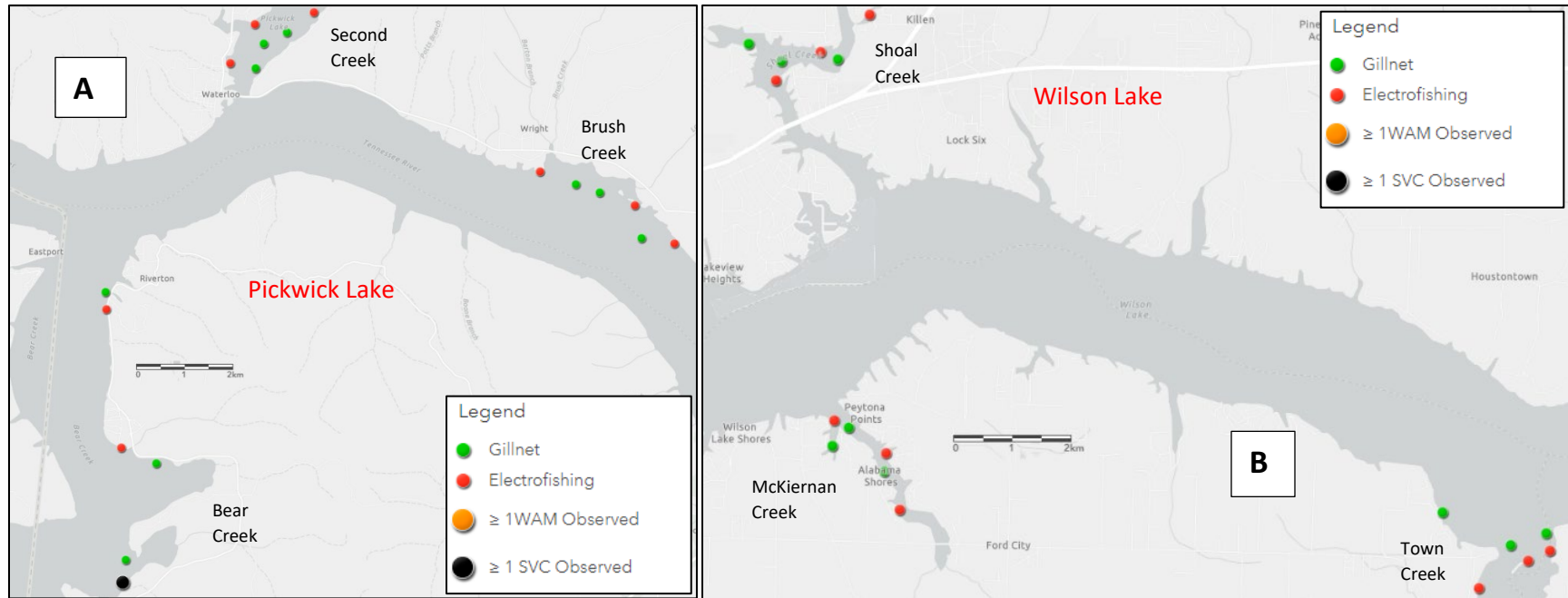


Figure 2. Reservoir position and relative numbers of Silver Carp (black dots) and Grass Carp (orange dots) collected at sample area occurrences in Pickwick Lake (A), Tennessee River, Alabama. Locations of 2023 paired gillnet and electrofisher sample sites (green or red dots) within each transect. Panel (B) displays Wilson Lake.

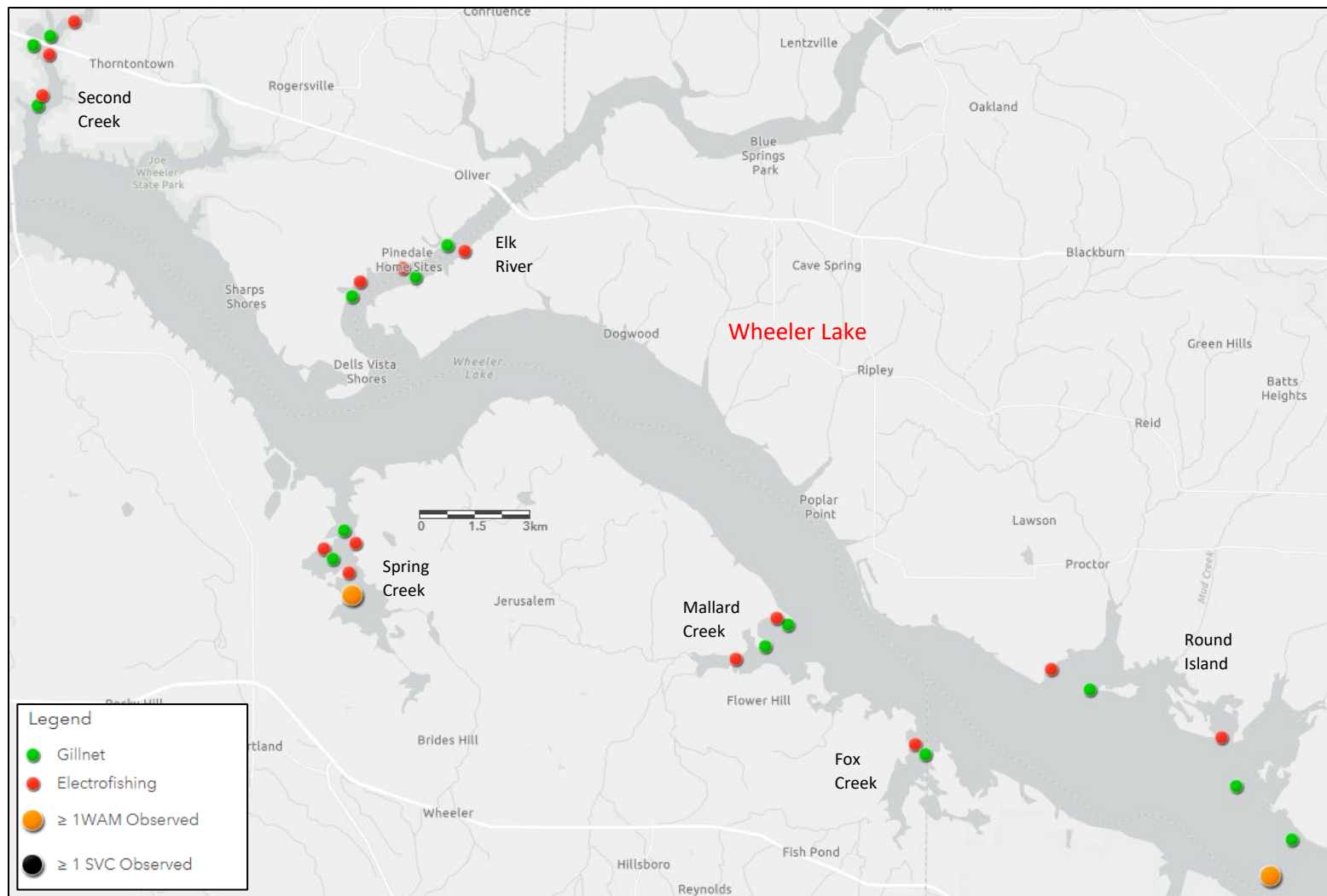


Figure 3. Wheeler Lake (A) in the Tennessee River, Alabama. Locations of 2023 paired gillnet and electrofisher sample sites (green or red dots) within each transect displays relative locations of 2023 sample sites.

Table 2. ADCNR standard sample efforts and catch rates, CY 2020 - 2023 at three Alabama reservoirs in the Tennessee River. Invasive carp species captured with gill nets and boat EF gears include Silver Carp (SVC) and White Amur (WAM).

CY *	Carp catch (n)	Gill net			Boat or Dozer trawl electrofisher			
		Sets (n)	Soak (hr)	Carp / net	Days (n)	Transects (n)	Effort (hr)	Catch (n / hr)
2020	53	53	1043	1.00	6	15	3	0.00
2021	26	64	1191	0.41	32	280	35	0.55
2022	51	149	1109	0.34	35	226	24	0.64
2023	6	132	247	0.01	31	346	41	0.12

* 2022, 68% of 149 gill nets set were daytime occupancy-strategy sets; average soak time = 1.5 hours.

* 2023, all gillnet sets were daytime occupancy strategy with average soak time = 2.1 h.

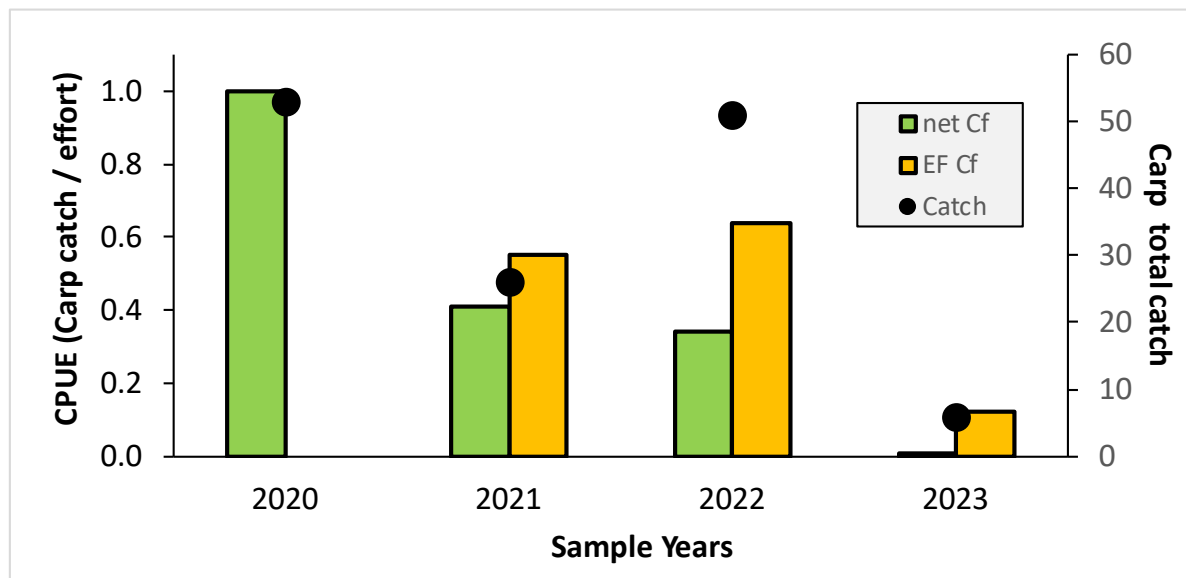


Figure 4. Sample effort by ADCNR staff (electrofishing days; gillnet sets) in three Alabama reservoirs on the Tennessee River, CY2020 through 2023. Black dots show total catch (n) of invasive carp (Silver and Grass Carp) for captured and sighted fish.

Appendix D:

2023 Kentucky Lake Silver Carp Population Assessment Summary Report



Columbia Fish and Wildlife Conservation Office

Jessica Howell, Pablo Oleiro, Jason Goeckler

ACKNOWLEDGEMENTS

Thank you to Cole Harty (Tennessee Wildlife Resources Agency) and Josh Tompkins (Kentucky Department of Fish and Wildlife Resources) for their role in setting the priority and objectives as well as ensuring that we had the knowledge and resources to complete this project. Field assistance for Kentucky was led by Matt Dollenbacher with assistance from Justin Lambert, Tyler Befus, and Clayton Adams. Field assistance was also provided by Tennessee Wildlife Resources Agency. Field support from U.S. Fish and Wildlife Service was provided by Kevin Drews, Thomas Olinger, Jeremiah Smith, and Savannah Blower. Additional support through discussions and reviews were provided by the staff at Columbia Fish and Wildlife Conservation Office.

INTRODUCTION

Invasive Silver Carp were first reported as established in Kentucky Lake in 2004 (Nico et al. 2023) and have the potential to impact recreational users by reducing sportfish populations and through their tendency to jump, which can harm boaters. Silver Carp can impact native filter-feeding prey species such as Gizzard Shad through direct competition for food, as seen in changes in relative weight (W_r) and catch rates of Gizzard Shad in response to Bighead and Silver Carp abundances in the Illinois River (Love et. al 2018).

The states of Kentucky and Tennessee have worked to establish removal efforts in Kentucky Lake and other state waters to reduce Silver Carp populations through incentive programs. Kentucky Department of Fish and Wildlife Resources launched an incentive program for commercial fisherman in 2016, whereas Tennessee Wildlife Resources Agency established a similar program in 2018 (MICRA 2022b). From 2013 – 2022, over 15 million kg of invasive carp have been removed from the Commonwealth of Kentucky, of which over 2.5 million kg were Silver Carp removed from Kentucky Lake (MICRA 2022b). In 2022, over 3.4 million kg of invasive carp were removed from the Tennessee portions of Kentucky and Barkley lakes (MICRA 2022b).

To supplement ongoing invasive carp demographic sampling, Columbia Fish and Wildlife Conservation Office implemented standardized sampling protocols in Kentucky Lake embayments using the electrified paupier trawl (hereafter paupier), starting in fall of 2019 (Towne et al. 2022). Fall sampling using a standardized approach with the paupier has now occurred in 2019, 2022, and 2023, with COVID-19 and personnel constraints precluding sampling in 2020 and 2021. Based on partner input, the objective of this study was to provide catch rates, size distribution, and body condition of Silver Carp in Kentucky Lake using the paupier.

METHODS

Study site

Eight embayments spanning the length of Kentucky Lake (Figure 1) were selected to be sampled based on prior years of sampling and partner input (Cole Harty, Tennessee Wildlife Resources Agency, and Josh Tompkins, Kentucky Department of Fish and wildlife Resources, personal communications). These included (in order from downstream to upstream): Sledd Creek (“Sledd” hereafter), Little Bear, Big Bear, Pisgah, Smith, Duncan Creek (“Duncan” hereafter), Jonathan Creek (“Jonathan” hereafter), and Big

Sandy. Embayments sampled in 2023 largely overlapped with those sampled in 2022 and had some similarities with sites sampled in 2019 (Figure 1).

Data collection

Paupier transects were conducted using pulsed DC at 64 hertz and 25% duty cycle between 23 October 2023 and 3 November 2023 at night (at least one hour after sunset) to maximize Silver Carp catch rates (Ridgway et al. 2020). Tennessee Wildlife Resources Agency and Kentucky Department of Fish and Wildlife Resources each provided a tender boat to assist with fish processing. Five-minute paupier transects operated at 4.8 kph were conducted in each embayment, with variable numbers of transects per embayment based on available shoreline habitat to target one transect per km of shoreline. The paupier was typically operated in nearshore habitats no deeper than 4.6 m (as informed by Towne et al. 2022 data) except when depth contours required greater depth to keep frames fully submerged (1.5 m). A 600 m buffer was maintained between transects.

For each transect, total length (mm) and weight (g) was measured for all non-shad species and for the first ten each of Gizzard and Threadfin shad. All remaining shad were enumerated, either individually or through estimates derived from batch weights. Batch weights consisted of identifying and weighing the first 50 shad as a batch, then weighing remaining shad and proportionately assigning species and counts (modified from Ratcliff et al. 2014).

Data analysis

Catch per unit effort (CPUE; fish/hr), body condition (W_r), and length structure was summarized for eight Kentucky Lake embayments. All embayments except Jonathan and Duncan had multiple nights of sampling. In a preliminary observation, no pattern was discernable in CPUE between repeated nights of sampling, so all samples were included. CPUE for Silver Carp was calculated for fish at or above stock size (250 mm; Phelps and Willis 2013). Incremental PSDs were calculated to facilitate comparisons within Kentucky Lake through time (Gabelhouse 1984) using Silver Carp PSD length categories in Phelps and Willis (2013). Silver Carp W_r was calculated using a standard weight equation developed by Lamer (2015), which was based on the 50th percentile, meaning that a relative weight value of 100 is considered an average body condition.

Data used in comparisons were not normally distributed so a Kruskal-Wallis test was used for CPUE and W_r comparisons between years for each species where $\alpha = 0.05$. A clustered Kolmogorov-Smirnov test was used to compare size structure across years for each species (fishmethods package in R; Nelson 2023), where the p-value indicates statistical significance, and the D statistic indicates the likelihood of being drawn from the same distribution (zero for highly likely and one is not likely). Data comparisons used all available data pooled across embayments in 2023 to increase statistical power given low sample sizes and individual fish collections within embayments. All statistical analyses, summaries, and figures were performed or produced in R (RStudio version 2023.06.1+524; R Core Team 2021).

RESULTS

In 2023, sampling was conducted during similar timeframes and lake level conditions compared to prior years. Sampling was conducted in mid-October through early November in all three years, with lake levels averaging around 18.2 m above sea level. In 2023, a total of 105 transects averaging 3.7 m in depth were conducted across eight embayments, with a slight decline in effort and spatial distribution of samples in 2023 compared to 2019 and 2022 (Figure 1; Table 1).

Although total catch increased, Silver Carp CPUE declined compared to previous years. Overall, 28 species were observed among 166,758 caught fish (Appendix B1a), which represented an increase of 61.4 % total fish collected when compared to 2022. Threadfin Shad ($N = 124,946$) and Gizzard Shad ($N = 40,985$) were the most common species observed, comprising 74.9 % and 24.6 % of the total catch, respectively. A total of 201 Silver Carp were captured, which was less than one percent of the total catch. Silver Carp CPUE appeared to decline in all surveyed embayments (Figure 2) compared to 2019 and 2022, though sample size precluded the ability to statistically test for differences. Overall Kentucky Lake Silver Carp CPUE significantly declined from 48.2 fish/hr in 2022 to 23.7 fish/hr in 2023 (Kruskal-Wallis test; $P < 0.01$; Table 1).

Silver Carp length and relative weights for 2023 collections were similar to 2022 but different from 2019. In 2023, Silver Carp ranged from 641 mm to 961 mm in length (mean = 806 mm). Length distribution comparisons of Silver Carp were statistically significant for each pairwise comparison (Kolmogorov-Smirnov test, $P < 0.01$), but D statistics indicate that while the 2019 length distribution was likely different from 2022 ($D = 0.8$) and 2023 ($D = 0.9$) length distributions, the 2022 and 2023 length distributions were more similar ($D = 0.3$). As expected, larger fish were observed in 2023 (range = 641 – 961 mm; mean = 806.6 mm) compared to 2022 (range = 511 – 1062 mm; mean = 757.9 mm) and 2019 (range = 370 – 1070 mm; mean = 633.6 mm) in both the length frequency histogram (Figure 3) and proportional size distributions (Table 2). Silver Carp W_r was higher in 2023 (98.8 ± 0.7 ; mean $\pm$ SE) than in 2019 (94.9 ± 0.2) and 2022 (97.3 ± 0.4). However, the only statistically significant difference was between 2019 and 2023 (Kruskal-Wallis test, $P < 0.01$; Figure 4). Silver Carp weights ranged between 2,240 grams and 9,960 grams (mean = 5,805 grams). Female Silver Carp represented 53.5% of Silver Carp collected.

DISCUSSION

While the effort and spatial distribution of sampling in 2023 was lower than in 2019 and 2022, paupier Silver Carp catchability should be comparable given that survey timing, environmental conditions, and lake levels were similar to previous years. The overall number of fish caught was higher compared to previous years, mainly due to the number of prey species caught (e.g., Gizzard Shad and Threadfin Shad). Across all three years we observed a decline in Silver Carp catch rates, a slightly increased W_r , an increasing size structure, and no sub-stock (< 250 mm) Silver Carp.

These data trends suggest that Kentucky Lake Silver Carp are an aging and declining population. Catch rates of Silver Carp have decreased by approximately half during each sampling year. As Silver Carp abundance declines, an increase in the relative weight is expected, as is an increase in size structure as fish age. Further, in years where paupier sampling was conducted, no recruitment was observed. This is corroborated by similar electrified dozer trawl sampling conducted annually by Tennessee (MICRA

2022a). Recruitment is likely limited due to short open river distances (Kolar et al. 2007) in the Tennessee River and unsuitable spawning conditions. In addition, migration into Kentucky Lake is likely limited due to the presence of the BioAcoustic fish fence at Barkley Dam that prevents upstream movement (Cupp et al. 2021). Emigration rates are unknown, so population decreases in response to removal efforts could be overestimated. However, results suggest that management efforts through the Kentucky and Tennessee programs are likely having an impact on the population. Other factors such as limited immigration, potential emigration, natural mortality, and limited to no recruitment in the system may be further amplifying the effects of removal efforts. To minimize impacts from Silver Carp into the future, maintaining high exploitation is necessary. Modeling should be conducted using fisheries dependent and fisheries independent data to better understand what levels of exploitation are needed to exert population level effects to further reduce the impacts of Silver Carp on the ecosystem, economy, and recreation of Kentucky Lake. Future population assessments would be encouraged to ensure that management actions are having the desired effect.

TABLES

Table 1. Total number of paupier transects completed, and number of Silver Carp collected per embayment in 2023. Embayments are listed in order from downstream (closest to dam) to upstream. Columns for number of Silver Carp (SVCP) with respective average catch per unit effort (fish/hr; CPUE), standard error of CPUE (in parentheses), and relative standard error (RSE) per species for embayment and pooled across embayments.

Embayment	Transects	SVCP		
		#	CPUE	RSE
Sledd Creek	6	15	30 (9)	31
Little Bear	6	25	50 (23)	47
Pisgah Bay	13	21	19 (5)	28
Big Bear	8	24	36 (9)	25
Smith	6	44	86 (31)	37
Duncan Creek	4	2	6 (6)	100
Jonathan Creek	5	11	44 (11)	24
Big Sandy	57	59	13 (4)	30
Totals 2023	105	201	24 (7)	16
Totals 2022	133	546	49 (7)	14
Totals 2019	114	1,758	184 (23)	12

Table 2. Proportional size distribution (PSD) and incremental PSDs for Silver Carp in Kentucky Lake for paupier collections in fall of 2019, 2022 and 2023. PSD size classes for Silver Carp are defined as stock at 250 mm, quality at 450 mm, preferred at 560 mm, memorable at 740 mm, and trophy at 930 mm (Phelps and Willis 2013).

PSD increment	2019	2022	2023
PSD	98.0	100	0
PSD S-Q	2.0	0	0
PSD Q-P	5.7	0.3	0
PSD P-M	88.8	34.7	0.07
PSD M-T	3.0	64.4	0.89
PSD T+	0.5	0.6	0.02

FIGURES

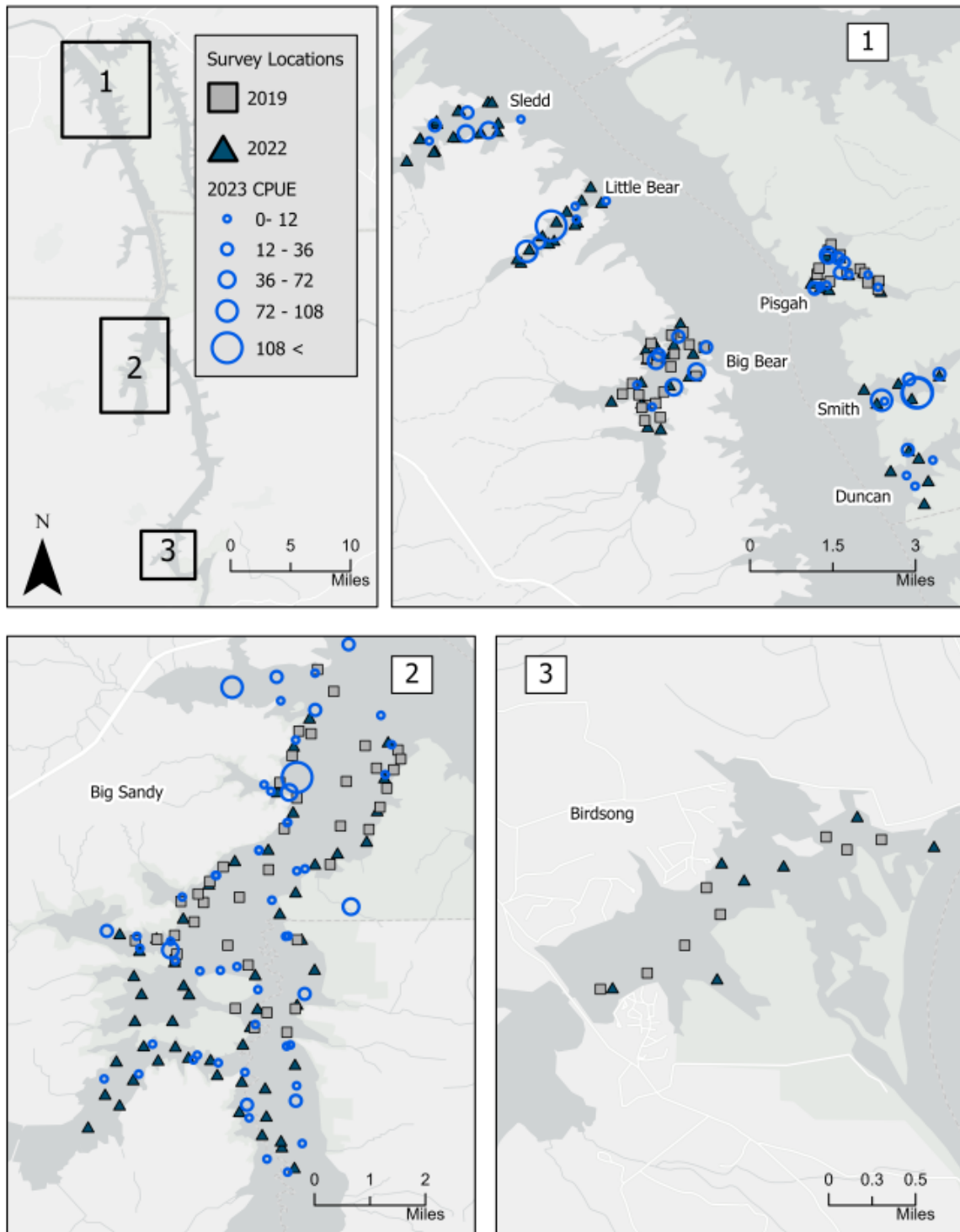


Figure 1. Map of electrified paupier trawl sampling locations in 2019, 2022, and 2023. Silver Carp catch per unit effort (CPUE; fish/hr) is indicated by varying size circles for 2023.

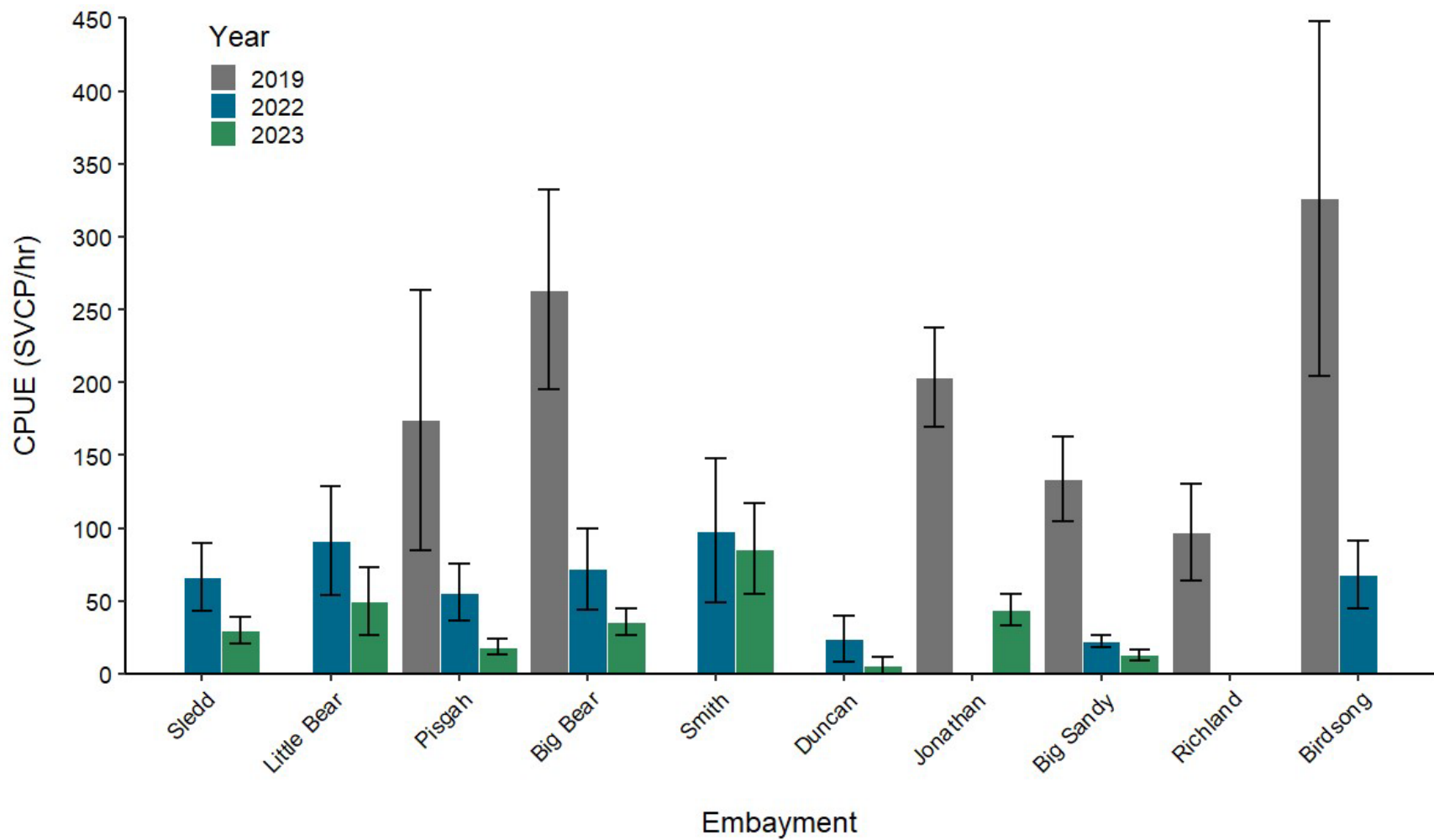


Figure 2. Catch per unit effort (CPUE) in Silver Carp (SVCP) per hour by embayment and year sampled. Error bars represent one standard error. Embayments are ordered from downstream to upstream. Missing bars indicate that the embayment was not sampled in that year.

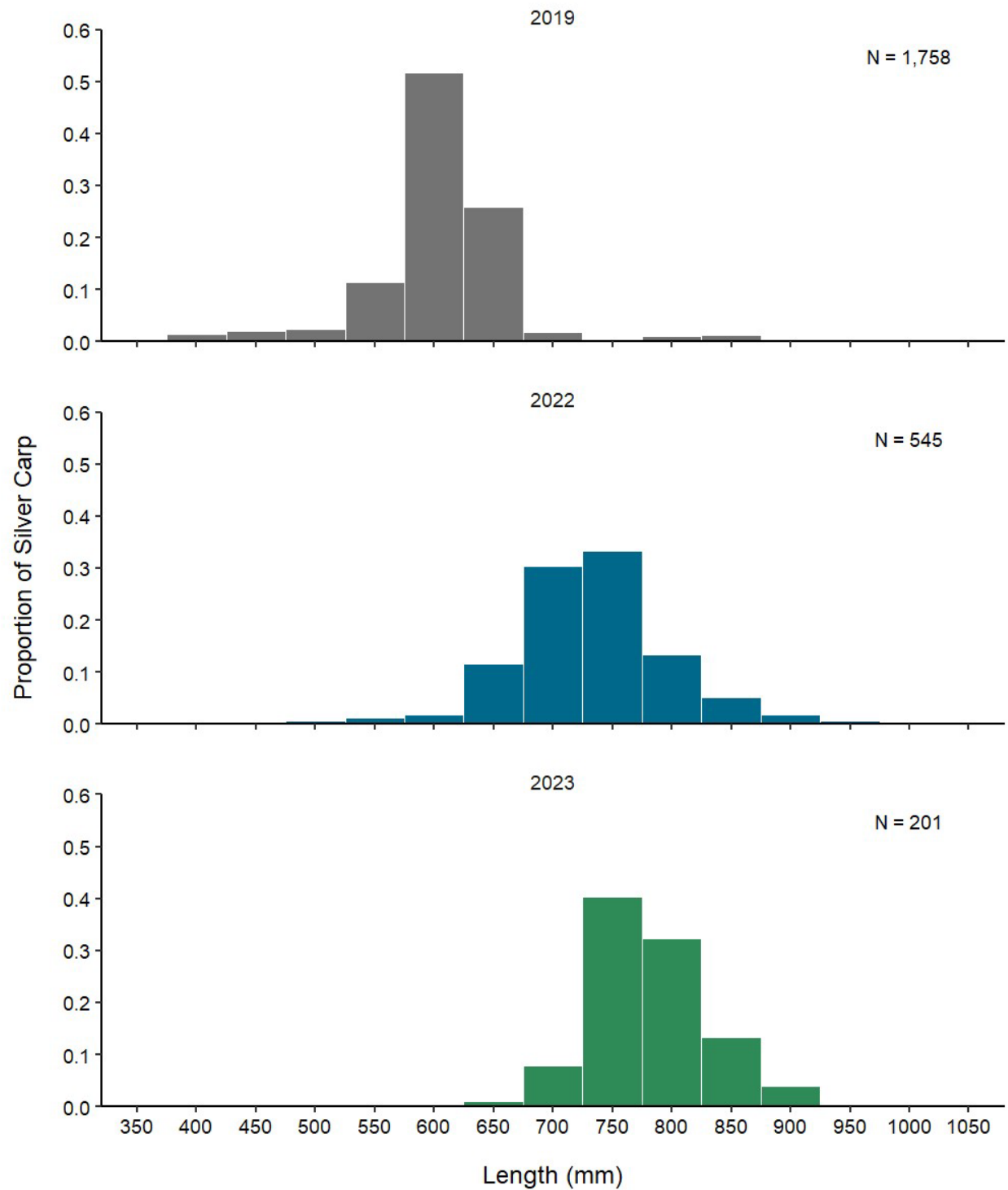


Figure 3. Relative length frequency of Silver Carp collected in Kentucky Lake in 2023 using the electrified paupier trawl. The number of Silver Carp for each year is included.

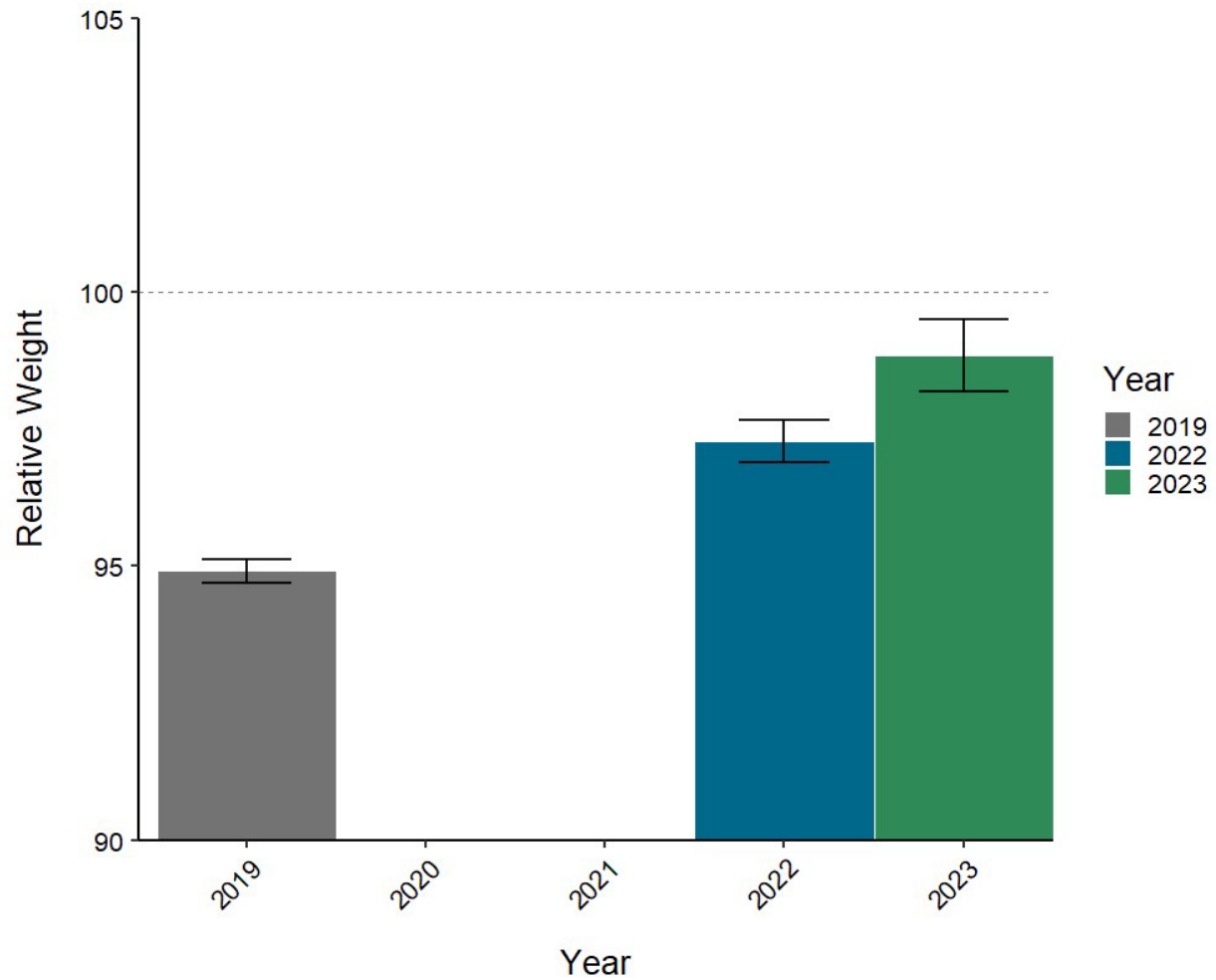


Figure 4. Relative weight (W_r) for Silver Carp (SVCP) by year for Kentucky Lake. Bars represent one standard error and the dotted horizontal line indicates an “average” body condition based on the standard weight equation. Missing bars indicate that no sampling was conducted in that year.

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APPENDIX B1A. – ALL FISH COLLECTIONS 2023

Table A.1. All fish collected with the paupier in standardized sampling in fall 2023. Total number of paupier transects (T) are indicated per embayment.

Fish Species	Sledd Creek T = 6	Little Bear T = 6	Pisgah Bay T = 13	Big Bear T = 8
Gizzard shad	1,233	43	287	1,520
Golden shiner	1	3	-	1
Silver carp	15	25	21	24
Skipjack herring	1	5	16	6
Smallmouth bass	1	1	-	-
Striped bass x White bass	1	-	-	-
Threadfin shad	8	6	71	13
Shortnose gar	-	1	-	-
Yellow bass	-	3	2	2
Black crappie	-	-	-	1
Largemouth bass	-	-	-	-
Striped bass	-	-	-	-
Longnose gar	-	-	-	-
Smallmouth buffalo	-	-	-	-
Brook silverside	-	-	-	-
Emerald shiner	-	-	-	-
White crappie	-	-	-	-
Bigmouth buffalo	-	-	-	-
Blue catfish	-	-	-	-
Bluegill	-	-	-	-
Channel catfish	-	-	-	-
Freshwater drum	-	-	-	-
Golden redhorse	-	-	-	-
Redear sunfish	-	-	-	-
Shorthead redhorse	-	-	-	-
Spotted gar	-	-	-	-
Spotted sucker	-	-	-	-
White bass	-	-	-	-
Total	1,260	87	397	1,567

Table A.1, continued. All fish collected with the paupier in standardized sampling in fall 2023. Total number of paupier transects (T) are indicated per embayment.

Fish Species	Smith T = 6	Duncan Creek T = 4	Jonathan Creek T = 5	Big Sandy T = 57
Gizzard shad	4,220	43	1,661	31,978
Golden shiner	-	-	-	7
Silver carp	44	2	11	59
Skipjack herring	1	1	13	115
Smallmouth bass	3	1	-	1
Striped bass x White bass	-	-	-	-
Threadfin shad	20	8	8,401	116,419
Shortnose gar	-	1	-	1
Yellow bass	-	-	8	58
Black crappie	-	-	-	25
Largemouth bass	1	-	-	1
Striped bass	1	-	-	-
Longnose gar	-	1	-	-
Smallmouth buffalo	-	1	-	9
Brook silverside	-	-	1	46
Emerald shiner	-	-	23	121
White crappie	-	-	5	38
Bigmouth buffalo	-	-	-	3
Blue catfish	-	-	-	2
Bluegill	-	-	-	9
Channel catfish	-	-	-	35
Freshwater drum	-	-	-	1
Golden redhorse	-	-	-	2
Redear sunfish	-	-	-	1
Shorthead redhorse	-	-	-	3
Spotted gar	-	-	-	3
Spotted sucker	-	-	-	7
White bass	-	-	-	32
Total	4,290	58	10,123	148,976

