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

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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); and Tennessee Cooperative Fisheries Research Unit, Tennessee Technological University (TTU)

Location of Activities: Tennessee and Cumberland rivers/reservoirs

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). 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 control strategy framework. 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 allow TN, KY, and AL to implement sampling programs. Ultimately, while Mississippi Department of Wildlife, Fisheries, and Parks is not requesting funding for this project for FY23, 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.

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 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 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. Implement exploitation study of invasive carp in Kentucky and Barkley reservoirs.

Project Highlights:

KDFWR

- Commercial fishers removed over 15.8 million pounds of invasive carp statewide and 14.3 million pounds of invasive carp through the Invasive Carp Harvest Program in 2024. CPUE (fish/yard) was highest in 4" bar mesh gill nets.
- KDFWR staff conducted 135 ride-alongs with commercial fishers in the invasive carp harvest program, to monitor catch rates and collect other data. Of the 107-entanglement gear ride-alongs, 20 ended with no nets being set.
- Commercial fishers enrolled in the subsidy contract fishing program received $1,019,768.16 for invasive carp harvested from Barkley and Kentucky reservoirs.
- KDFWR continued a MOU with two fishers to test invasive carp experimental gears in Kentucky waters. During 2024, the fishers harvested approximately 87,976 lbs. of invasive carp from Kentucky and Barkley Reservoirs, 50,006 lbs. from the Green River, 1,078,107 lbs. from the Ohio River, 403,211 lbs. from the Mississippi River, 55,635 lbs. from the Kentucky tailwater, and 2,236,555 lbs. in Barkley tailwater.
- KDFWR received five reports of black carp in the Ohio River during 2024.

TWRA

- Recruitment of invasive carp within the Tennessee and Cumberland rivers appears to remain low (i.e., young of year bigheaded carp are absent or undetectable). Therefore, population growth may be more sensitive to immigration than local recruitment.
- Invasive carp populations in Cheatham and Pickwick reservoirs appear to have relatively low abundances, and individuals are in good (robust) condition.
- 6,984,877 lbs. of invasive carp were harvested through the TCHIP program.
- 1,880 silver carp were tagged with high-reward tags in spring of 2024 in an effort to better understand exploitation and impact of harvest incentive programs on Kentucky and Barkley reservoirs.

ADCNR

- Staff completed sampling efforts at Pickwick and Wilson Lakes and more than doubled (i.e. 9 to 20) standard, fixed-location sites. Further, staff sample site repititions increased

from four in 2023 to six in 2024, thus allowing for a total sample effort of 120 transects per reservoir (i.e., 20 sites x 6 repititions). Gillnets were dropped from the occupancy strategy due poor efficacy and time utilized for non-target fish processing. This change allowed an increase to the number of electrofishing sample sites that can be accessed daily (See Results and Discussion).

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 eight nights during the months of October and November. 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.

During fall sampling, pectoral fin rays and otoliths were extracted from approximately 100 silver carp from each reservoir for aging or at twenty fish per ten-centimeter bin. 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.

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

KDFWR dedicated staff time towards observing commercial fishing and facilitating efforts to evaluate 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 evaluate impacts of commercial harvest on bycatch species.

To verify commercial fishers' reports, KDFWR frequently provided observers to record harvests (ride-alongs). Observers collected all data required on commercial harvest logs and GPS fishing locations, water temperature, net soak times, and other metrics. Ride-alongs are conducted as fishers pull their nets to harvest fish. When commercial fishers use short net soak times, drifting net sets, or active gill netting 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 evaluate 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 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.

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

To move towards higher removal of invasive carp, KDFWR worked with commercial fishers through a Memorandum of Understanding (MOU) to use gears and methods outside of legal means established in Kentucky's regulations. The experimental gears program had one fisher successful in large scale removal of invasive carp and was opened to new fisher applications in 2024.

Objective 5. Implement exploitation study of invasive carp in Kentucky and Barkley reservoirs.

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 Trawl

Dozer trawls were conducted in the fall (September – October 2024) in Kentucky (n=100), Barkley (n=20), Pickwick (n=20), and Cheatham Reservoirs (n=20). Kentucky Reservoir was divided into five sections to encompass the large reservoir (20 transects/section). Dozer trawls were conducted in every embayment on both left and right descending banks where water levels allowed sampling.

Dozer trawls were conducted with a 3.7 meter trawl attached to a 2.1 x 0.9 meter frame which was located off the bow. The dozer trawl was electrified by a curtain array located in front of the trawl frame. 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 and Gizzard Shad were separated and counted for all dozer trawl transects. All other by-catch were counted and released. Silver Carp 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.

Active Gill Netting

Active gill netting days were conducted during the fall in Kentucky, Barkley, Pickwick, and Cheatham reservoirs. Active gill net sets were based upon visual identification of invasive carp in schools (n=25 or more) using sidescan sonar on a Garmin ecomap fish finder. This is experimental active gill netting used to better understand presence/absence of invasive carp across reservoirs. This is being used to help augment the lower catch rates of the dozer trawl sampling.

Active gill net sets were conducted using two floating gill nets 600’ long x 24’ deep tied in a gang. Webbing was constructed with 8-ply monofilament with 0.2mm twist mesh, and a ½ inch foamcore with 30 lb. lead core. The mesh size used included 4” square with 8 meshes per 18 linear inches of net. Active set gill nets were deployed from the bow of the boat while driving in reverse when invasive carp were observed on the sidescan sonar. Gill nets were set in a circular motion completely encircling an area to minimize gaps that would allow escapement. Sampling only occurred in water depths with a maximum of 23’ this was done in order to have full water column coverage of nets. Boat motor noise was used to herd fish towards the nets for entanglement once nets were deployed. Invasive carp species were measured (mm), weighed (kg), and sexed. Bycatch was recorded and immediately returned into the water. Otoliths and left pectoral fin rays were collected from all invasive carp captured during the fall for age determination.

Standardized Electrofishing

Standardized electrofishing was utilized in Old Hickory Reservoir to monitor invasive carp populations upstream of Cheatham Reservoir. Invasive carp are present in relatively low abundance in Old Hickory Reservoir. Given the infrequent encounters with invasive carp in Old Hickory, electrofishing boats were utilized to cover greater area and optimize capture opportunities in the event invasive carp were encountered. Old Hickory Reservoir was split into 18 sampling locations. Each location was sampled for 600 continuous seconds. Any invasive carp collected were evaluated for length (mm), weight (kg), and sex. Any observations of invasive carp jumping or swimming to evade collection were recorded as observations. Otoliths and fin rays were also extracted for age determination.

Tennessee Wildlife Resource Agency/Tennessee Tech University

Kentucky, Pickwick, Cheatham, and Barkley reservoirs on the Tennessee and Cumberland rivers were systematically sampled to account for and assess spatial variation in relative densities of bigheaded carp across longitudinal gradients of reservoirs. Sampling reaches were chosen at approximately equally spaced intervals throughout each reservoir and based on sampling gear constraints (e.g., depth, barge traffic) and the advice of biologists familiar with the study systems (e.g., TWRA and USGS). Three strata were sampled in Kentucky and Barkley reservoirs — the

lacustrine (i.e., downstream), the transition, and the riverine (i.e., upstream). In Kentucky Reservoir, the downstream reach was located near Kentucky Dam, transition reach near Big Sandy embayment, and upstream reach near the Duck River (TTU Figure 1). In Barkley Reservoir, the downstream reach was located near Barkley Dam, transition reach near the Little River embayment, and upstream reach near the Saline Creek embayment (TTU Figure 1). Two strata were sampled in Pickwick Reservoir and Cheatham Reservoir — one upstream and one downstream reach in each reservoir. In Pickwick Reservoir, the downstream reach was located near Pickwick Dam and the upstream reach near Bear Creek embayment (TTU Figure 1). In Cheatham Reservoir, the downstream reach was located near Cheatham Dam and the upstream reach near Sycamore Creek (TTU Figure 1). During each sampling event, water temperature and geographic coordinates of sample locations were recorded.

Experimental monofilament gill nets consisted of two 45.7 m panels of either 76 mm and 89 mm square meshes (Type-I net) or 101 mm and 108 mm square meshes (Type-II net). All nets were 3.7 m in height, hobbled down to 2.4 m, and had a lead core bottom line and an 8 mm diameter foam core top line. Nets were set as floating sets and in gangs, with one of each net type deployed at a sampling site (i.e., one gang of two nets per sampling reach). Three sites were fished per sampling reach in all reservoirs using overnight gill-net sets. Sampling occurred three times at each reach across spring, summer, and fall seasons. Overnight sets were limited to the fall, spring, and early summer to minimize bycatch mortality. Net sets were placed in areas of low water velocity at depth ranges of 1.8-6 m. Catch per unit effort (CPUE) was calculated as mean catch per overnight net set. Additional sampling used an electrified dozer trawl to capture fish and surveil for young-of-year. Dozer trawl efforts took place in summer and fall at each sampling site on Kentucky and Barkley reservoirs. All electrofishing used pulsed-DC current (5-8 Amps, 535 Volts, 120 pulses per second). Catch per unit effort for dozer trawl transects were calculated as mean catch per transect.

Morphological metrics of all bigheaded carp captured were recorded. Bighead and Silver Carp were identified based on characteristics described by Kolar et al. (2007) and sex, total length (TL; mm), and weight (W; g) were recorded. Sex of fish was used to determine male to female ratios, and length and weight data were used to produce length-frequency histograms for each reservoir and to calculate condition for comparisons among reservoirs and years. Condition was calculated as relative weight using standard weight (W_s) equations developed by Lamer (2015; Silver Carp: $\log_{10} W_s = -5.15756 + 3.06842 * (\log_{10} TL)$; Bighead Carp: $\log_{10} W_s = -4.65006 + 2.88934 * (\log_{10} TL)$). Relative weight ($W_r$) of each fish was calculated as $W_r = W / W_s * 100$, and the standard weight equations were developed using the 50th regression line percentile technique (Wege and Anderson 1978). Therefore, fish with W_r of 100 would be considered average. Otoliths were taken from a subsample of collected fish to allow later extrapolation to an age-length key. Target otolith sample sizes were 5-10 fish per two-inch length group per reservoir. The left gonad of female bigheaded carp was removed and weighed (g) to allow for gonadosomatic index (GSI) to be calculated. To calculate GSI, the left gonad weight was multiplied by two, divided by the total body weight, and multiplied by 100.

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 Tennessee 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.

Objective 5. Implement exploitation study of invasive carp in Kentucky and Barkley reservoirs.

TNCR partners worked with USFWS and USGS staff that have experience conducting exploitation studies, modeling, and tagging to develop an exploitation study for Kentucky and Barkley reservoirs. TNCR partners established a plan to implement a 4-year project, tagging ~1,000 silver carp per reservoir for the first 3 years in Kentucky and Barkley reservoirs. The project utilizes a high-reward ($100) loop tag in every silver carp and incorporates 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. We will work with partners to conduct appropriate analyses for the duration of the project.

ADCNR

Evaluation of Population Abundance & Distribution – Boat electrofishing was conducted using a robust occupancy strategy similar to Sullivan et al. (2018). During October, pre-established sites (n=20, GPS-fixed) were electrofished with individual sites revisited an additional five times across the shortest span of consecutive days possible. Per protocol, sample transects (~0.25 miles) were electrofished by one boat for 5-min with boat speed maintained at 3.0 mph (ADCNR 2023). Typically, the boat crew travels upstream in contiguous transects and typically, but not always near the bank in water depths 2 to 16'. An ETS (model: Trident) electrofisher system was utilized with settings based on ambient reservoir conductivity (Miranda 2009). We attempted to delineate habitat types based on methods of Ratcliff et al. (2014).

All sample time effort (nearest s or min) and temperature (nearest 0.1 C) was recorded for either gillnets or electrofishing. Both the driver and dipper made continuous visual sweeps over the sampled areas to observe either stunned or jumping carp. Invasive carp that were witnessed but not collected were counted as an observance. Invasive carp encountered during all sampling efforts are documented and processed for demographic data (i.e., length, weight, sex, otoliths and pectoral spines; ADCNR 2023).

Eradication of Invasive Carp – Invasive carp encountered during sample efforts were processed for demographic data as above and then dispatched at the work site. In addition to electrofishing described above, gillnets also utilized during evaluation or eradication goals were standardized 300' sinking nets with 3, 4 and 5-inch mesh and either 10 or 5-foot panel depths. Nets set for eradication were generally set in targeted areas not based on pre-defined sites.

Results and Discussion:
KDFWR (all referenced Tables and Figures for KDFWR located in Appendix A & B)

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 2024. Lengths and weights were collected for all species until up to 30 individuals 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 13.9 in Big Bear embayment, which was a significant decrease from previous years (Table 6). Paupier data suggests a significant decline in CPUE of silver carp from Kentucky reservoir from 2019 through 2024. (Appendix B, Figure 2.). This trend data continues to support the hypothesis that the silver carp population in Kentucky reservoir is declining. Data from the Paupier sampling, compared 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=0.82 whereas Barkley reservoir R^2=0.69 (Figure 7 & 8).

Invasive Carp Harvest Program

Length and weight data was collected on 1999 silver carp harvested by commercial fishers in 2024 with 1711 of these fish being harvested from Kentucky and Barkley Reservoirs. Lengths ranged from 23.7 – 43.3 inches with an average of 31.8 inches, and weights ranged from 2.7–27.2 lbs. with an average of 13.2 lbs. for the ICHP program overall (Table 2). The average weight of fish caught in Kentucky and Barkley Reservoirs, when calculated separately from the overall ICHP program was found to be 14.3 lbs. which indicates overall condition is improved in fish living in the Kentucky and Barkley Reservoirs versus the Ohio, Tennessee, Cumberland, Mississippi, and Green River systems. If this metric is used in correlation with the total pounds of silver carp harvested by commercial fishers through the ICHP in 2024, that would produce a rough estimate of 993,140 individual silver carp being removed from Kentucky waters through the ICHP in 2024 (14,201,895 lbs.; Table 1). 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 3, Figure 12). Catch per unit effort of gill nets used to harvest silver carp were highest in gill nets with a bar mesh size of 4” (0.49 fish/yard), followed by 3.5” bar mesh which had a CPUE of 0.27 fish/yard. This showed a change from previous years towards a preference of larger gill net mesh sizes by the fishers. The data collected shows an increase from the previous three years (2020-2023) when the highest CPUE was in 3.5” and 3.75” bar mesh nets. The change in the size mesh size commercial fishers were using in Barkley and Kentucky Reservoirs, is likely due to an increase in the relative weight of the 2015 cohort of silver carp.

Five black carp were harvested by three commercial fishers in March and October of 2024 respectively. Lengths ranged from 39.25 in – 53.15 in, were caught in 4.25” to 6” mesh gill nets and all were sent off to research groups with USGS to investigate further.

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 2024. Data suggested the 800 mm size class of silver carp were dominant in both systems (Figures 1 & 2).

Age and Growth

Otoliths were collected from silver carp in Barkley and Kentucky Reservoirs in the fall of 2024 for aging. Barkley ages ranged from 4 to 8 years old, with age 6 being the most abundant. Kentucky ages ranged from 4 to 9 years old, with age 8 being the most abundant, (Figures 3 & 4). Data suggests a strong presence of three cohorts of silver carp behind the 2015 cohort (9-year-old fish). Since no age-0 silver carp have been collected in either reservoir since 2015, logically 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 reservoir. 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 Kentucky Reservoir was estimated at 50% and instantaneous mortality was estimated at 0.70 (N=245, F1,2=28.18.40, P=0.003, R2=0.85; Figure 5). Annual mortality for silver carp from Barkley Reservoir was estimated at 42% and instantaneous mortality was estimated at 0.55 (N= 279, F1,2=30.96, P=0.003, R2=0.86; Figure 6). Estimates of annual mortality in 2024 increased from the vales reported in 2023 in Kentucky Reservoir but decreased in Barkley Reservoir from 2023. 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 Log10(weight(g)) = 3.2598Log10(length(mm)) –5.7117(Figure 7). The length-weight equation for Barkley was estimated at Log10(weight(g)) = 2.7669Log10(length(mm)) – 4.2531 (Figure 8).

Data collected from sampling in the fall (September through December) of 2024 was used to analyze relative weights (Wr). Relative weight was calculated using the equation Log10(Ws)= -5.15756 + 3.06842(Log10TL) for silver carp (Lamer 2015). The mean Wr for silver carp in Barkley Reservoir was 103 (N=450, S.E.=±0.44) and the mean Wr for silver carp in Kentucky Reservoir was 99 (N=288, S.E.=±0.57). These values indicate improved condition over data collected from previous years.

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

No results to report.

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

Incentivized Invasive Carp 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 2024, contractors received $1,019,768.16 for invasive carp harvested from Barkley and Kentucky Reservoirs. This equates to over 10 million pounds of invasive carp harvested through the contract program in 2024, the largest harvest to date. Refinements to the program were made in 2021 which removed the varying pay out based on size of fish harvested. As of January 2025, 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.

Invasive Carp Harvest Program Monitoring

The Invasive Carp Harvest Program (ICHP) developed 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 74,986,008 lbs. (Figure 14.) of invasive carp, the majority was harvested through the ICHP (Table 1), however there is a portion of commercial harvest that occurs in the Ohio River Contract Fishing program and via regular commercial fishing outside the ICHP. 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 1). 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 2024 saw an increase in participation by fishers to levels seen in previous years. Overall, an increase in harvest was observed from 2023 to 2024, and from 2023 to 2024 there was an increase of almost 900 trips made on Barkley Reservoir as well as an increase in over 800,000 lbs. of carp removed over 2023's harvest. The amount of harvest of invasive carp from Kentucky Reservoir increased by approximately 40,000 lbs. from 2023 to 2024 and the number of individual fishers and trips increased from 2023 to 2024 (Table 1). The number of commercial fishers in Kentucky and associated trips under the ICHP program has varied annually. 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 2024 harvest as well as improvements to equipment such as boats, trucks, net rollers, cranes, and electronics.

Invasive carp harvest data was summarized by month from January 2020 to December 2024 (Figures 9 & 10). The highest number of commercial fishing trips recorded in a single month was 379 in October 2024; 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. In 2024, it was observed that there was an increase in number of trips every month compared to 2023 except for January and December which saw only a slight decrease from 2023 (Figure 9). Average total pounds of silver carp harvested per trip decreased from 2023 and ranged from 2,925-5,760 pounds per month in 2024 (Figure 10).

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 2024, the average number of pounds harvested per trip was calculated for all ICHP fishers (N=40), and average pounds of silver carp harvested varied from 256.6 lbs./trip to 8,488 lbs./trip. Interestingly, not all fishers with high catch rates fished frequently (Figure 11). The number of trips a commercial fishers took in 2024 varied from 1 to 223, with an average of 66 trips. This only included the number of trips where harvest occurred. In 2024, 52% of the requests to fish ended with fish harvested. Some fishers 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 fisher 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 135 ride-alongs with 19 unique commercial fishers utilizing the ICHP January through December 2024. Of those 135 ride-alongs, 107 were with fishers implementing entanglement gears. During entanglement ride-alongs 71,763 yards of gill net were fished and 373,768 lbs. of invasive carp were harvested (Table 4, Figure 13). Most ride-alongs were on Barkley Reservoir (N=79), while Kentucky Reservoir only had 21 ride alongs, which was representative of fishers' efforts divided between the two reservoirs. Commercial fishers using gill nets, 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 2024, fishing pressure observed through ride-alongs was more evenly distributed throughout Barkley and Kentucky Reservoirs (Figure 13). The mean effort per trip (yards of net fished) increased in 2024 (751 yds/trip) compared to 2023, which is reflective of the changing strategies that commercial fishers were employing to catch silver carp (active setting vs. dead setting nets) (Table 4). Effort was more comparable with observed efforts in 2020, 2021, and 2022. Average total weight of silver carp harvested per trip during ride-alongs in 2024 (4,452 lbs.), slightly lower than 2023 (Table 5). On multiple trips, KDFWR staff observed, a commercial fisher scan with side scan technology and not set 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, nine times during 2023, and twenty times in 2024. KDFWR has begun to monitor zero net set trips and search time as a fisheries dependent trend to inform invasive carp stock assessments.

KDFWR conducted 28 ride-alongs with two fishers implementing seining gears under the experimental gears MOU. Ride-alongs were on the Ohio River (N=7), Mississippi River (N=5), Green River (N=2), Cumberland River (N=11), Tennessee River (N=1), and Barkley Lake (N=3). A total of 28,600 linear feet of seine were deployed during these ride-alongs and 771,173 lbs. of silver carp were harvested. The average weight of silver carp harvested on ride-alongs with fishers under the experimental gears MOU was 30,847 lbs./day.

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 87,652 lbs. of invasive carp from Barkley Reservoir in 2024 with a daily average of 17,530 lbs./day which was consistent with his daily average in 2023 of 17,825 lbs./day. Additionally, Robbins harvested 2,236,555 lbs. (39,237 lbs./day) of silver carp from the Cumberland River and 55,635 lbs. of silver carp from the Tennessee River. 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 1,076,327 lbs. (33,635 lbs./day) of silver carp from the Ohio River, 371,413 lbs. (37,141 lbs./day) from the Mississippi River, and 50,006 lbs. (12,501 lbs./day) from the Green River in 2024 through the program. Robbins' seining in Kentucky waters yielded him a total of 3,877,588 lbs. of silver carp, averaging 34,315 lbs. of silver carp per day in 2024.

KDFWR staff monitored one new fisher under the experimental gears program, Jim Ed Gill. Gill fished 7 days under the experimental gears program in October and December of 2024 and harvested 32,614 lbs. of silver carp across the Ohio River, Mississippi River, and Barkley Reservoir. Mr. Gill will continue efforts in 2025 under this program.

Objective 5. Implement exploitation study of invasive carp in Kentucky and Barkley reservoirs.

KDFWR tagged 1040 silver carp in the Barkley & Kentucky Reservoirs as part of the TWRA lead exploitation project. Additional fish tagging is planned for the spring of 2025.

TWRA

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

Dozer Trawl

A total of 100 Silver Carp were captured via electrified dozer trawls on all reservoirs for the fall. Fall 2024 catch rates of Silver Carp (n=100) were greater than fall catch rates in 2023 (n=48) and percent capture rates were also greater in the fall 2024 than the fall 2023 in all reservoirs except Cheatham Reservoir and Section 2 of Kentucky Reservoir (TWRA Table 1)**.** Catch per unit effort was highest in Barkley Reservoir and lowest in Pickwick Reservoir for fall sampling events (TWRA Table 2). Dozer trawl sampling was most conducive in riverine environments such as Barkley Reservoir, Cheatham Reservoir, and upstream sections of Kentucky Reservoir. Invasive carp catch rates with the dozer trawl decreased as surface area and water depth increased. No invasive carp were captured in Pickwick Reservoir via dozer trawl, likely due to greater water depths and low abundance of invasive carp.

Active Gill Netting

A total of 152 invasive carp were captured via active gill netting through 4 net sets during the fall. Active nets were set in Kentucky Reservoir (n=1), Cheatham Reservoir (n=1), and Barkley Reservoir (n=2). Catch rates were heavily influenced by weather, water conditions, and limiting user conflicts. Catch rates were highest on Barkley Reservoir with 18.22 invasive carp per net hour and lowest on Kentucky Reservoir with 10.7 invasive carp per net hour.

Standardized Electrofishing

Standardized electrofishing was conducted on Old Hickory Reservoir during summer 2024. One Silver Carp was collected in Bledsoe Creek and two were observed in Bledsoe Creek; no other invasive carp were observed or collected.

Tennessee Wildlife Resources Agency/Tennessee Tech University

Effort and Catch – One hundred-eighty overnight-gill net sets were completed during 2024 on the Tennessee and Cumberland rivers — 54 on each Kentucky and Barkley reservoirs and 36 on each Pickwick and Cheatham reservoirs. Additionally, 151 dozer trawls were completed — 75 on Kentucky Lake and 76 on Barkley Lake. In total, 561 bigheaded carp were captured — 555 Silver Carp and 6 Bighead Carp. Total bigheaded carp catches decreased 30% since 2023. Catch per unit effort has remained low (range = 0.0–0.8 fish per gang) for Bighead Carp in all reservoirs among all years (TTU Table 1). For Silver Carp, catch per unit effort was lower in all reservoirs in 2024 than in 2023 (TTU Table 2, TTU Figure 2). The highest CPUE in 2024 was in Barkley Lake with 8 fish per gang, a decrease from 2023 with 13.4 fish per gang.

Length Distribution by Reservoir and Year – Mean length of fish captured by gill netting has increased over time in all reservoirs. Using ANCOVA, we found significant effects on total length among reservoirs, among years, and an interaction between reservoir and years. Post-hoc simple linear regression analysis for each lake indicated the relationship between total length and year had a positive slope for each lake. The flatest slope was Cheatham Lake (slope = 13.638, 95CI = 1.587-15.690) and the steepest slope was Kentucky Lake (slope = 29.030, 95CI = 27.161-30.898; TTU Figure 3). Thus, average length continues to increase across years in all reservoirs. This indicates that smaller, younger individuals have not recently recruited to the population. Visual inspection of length-frequency histograms (TTU Figures 4–7) further demonstrates the temporal shift in fish length and the lack of replacement of smaller, younger fish in all reservoirs except Cheatham. In 2024, there may be evidence of a smaller age class presence or the size class gap is due to no fish 700-759 mm were captured.

Condition of Silver Carp by Reservoir and Year – Using an ANCOVA, we found significant effects between total length among years ($p < 0.001$), among reservoirs ($p < 0.001$) and an interaction between reservoir and years ($p < 0.001$). Post-hoc simple linear regression analysis done with lakes grouped indicated the relationship between relative weight and year had a positive slope (slope = 1.283, 95CI = 1.130-1.437, $p = < 0.001$). Therefore, mean condition of the grouped Silver Carp populations was positively correlated with sampling year. An increase in condition across years could suggest a decrease in competition has allowed fish of the same size to achieve higher condition, or it could be the result of fish continuing to grow in mass despite nearing asymtotic length. Measures of condition that compare length and weight—including relative weight (TTU Table 3)—may experience increased variation as length asymptotes and weight continues to increase. Therefore, higher weight to length ratios (i.e., higher condition) could be the result of younger, smaller fish not recruiting to the system and older larger fish gaining mass quicker than length.

Gear Selectivity and Young of Year Detection – Sampling methods, including dozer trawling, did not capture any young-of-the-year Silver Carp. The shortest Silver Carp captured in 2024 was 677 mm TL by gill net. The shortest Silver Carp collected by dozer trawling was 740 mm TL.

This was an increase over shortest fish collected in 2023 for gillnetting (624 mm TL) and dozer trawling (653 mm TL).

Length-frequency histograms of Silver Carp captured using dozer trawls and gill nets are similar for Barkley Lake, however, very few were collected by dozer trawl in Kentucky Lake (TTU Figures 8 & 9), and bootstraped-Kolomogorov-Smirnov tests failed to detect a difference in length distributions of Silver Carp captured by the two sampling methods in Kentucky Lake ($D = 0.037$; $p = 0.960$) or in Barkley Lake ($D = 0.230$; $p = 0.065$). Furthermore, Welche's t-tests were conducted to evaluate the difference between the mean total length of fish sampled using these methods. No difference was detected in Barkley Lake ($t(43) = 1.48$; $p = 0.147$) or in Kentucky Lake ($t(2.07) = 1.55$; $p = 0.258$) with the mean total length of fish captured by gill netting (mean = 812; SE = 3.29) being smaller than the mean total length of fish captured by dozer trawling (mean = 851; SE = 25.1). These results indicate that dozer trawl and gill netting yielded similar selectivity related to length of fish in Barkley Lake and Kentucky Lake. Nonetheless, gear selectivity does not appear to be related to the lack of sampled fish less than 500 mm because neither gear captured fish less than 677 mm. This indicates that fish less than about 500 mm are not present in this population. Therefore, it is unlikely that any detectable local reproduction or immigration of young of year fish from the Ohio River or tributaries has occurred in recent years.

Fisheries Independent Catch – From 2017–2024, 32,708 kg of Silver Carp have been removed from the Tennessee and Cumberland rivers during gill-net sampling events for this study (TTU Figure 10, TTU Table 4). The largest mass of Silver Carp removed has most often been from Barkley Lake. However, the mass of fish removed has widely varied among sampling events and ANCOVA analysis failed to detect a difference among lakes ($p = 0.091$) and did not detect any interaction between lakes and years ($p = 0.092$). There was a differece detected among years ($p = 0.009$). Trends in catch per unit effort data may be less pronounced when comparing mass of fish captured because fish captured in locations with lower density may be heavier on average than fish in higher densitry locations. An important distinction between mass of fish removed during this research and mass of carp removed by commericial fishers is that we use standardized sampling, while commercial fishers target their sampling areas to maximize catch for profit.

Weight of Fish (e.g., when do fish reach 8 pounds?) – The weight-length regression for Silver Carp in the Tennessee and Cumberland rivers with all lakes and years pooled is $\log_{10}(WT) = -5.3442 + 3.12919 \times \log_{10}(TL)$ where WT = mass in grams and TL = total length in mm. Therefore, a Silver Carp of 3,629 g (8 pounds) is estimated to be 711 mm in total length. In 2024, nearly all of fish collected in Kentucky Lake and Barkley Lake were larger than 3,629 g (TTU Table 5). All fish captured in Cheatham Lake and Pickwick Lake were over 3,629 g.

Sex Ratios and GSI – In 2024, female to male sex ratios for Cheatham Lake (1.00) were balanced and Barkley (0.79) was nearly balanced (TTU Table 6). Kentucky Lake (0.6) sex ratios decreased 27 % and Pickwick Lake (0.45) increased 136 % since 2023. Sex ratios in this population have historically varied widely from 1:1, possibly due to early stages of invasion (see Fernholz 2018 and Ridgway 2016).

Gonadosomatic index of fish captured by gill netting has increased over time in all reservoirs. Using ANCOVA, we found significant effects on GSI among years ($p < 0.001$), and no significant effects among reservoirs ($p = 0.493$) or interactions between reservoir and years ($p = 0.505$; TTU Figure 11). Post-hoc simple linear regression analysis done separately for each lake indicated the relationship between GSI and year had a positive slope for each lake (TTU Figure 11) ranging from 0.937 at Cheatham Lake (95CI = 0.606-1.267) to 11.221 at Pickwick Lake (95CI = 0.908-1.534). Increases in GSI over time, may be the result of the population consisting of older fish than during previous samples. Gonadosomatic index typically increases as fish become more fecund with age.

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

In 2024, the Tennessee Carp Harvest Incentive Program (TCHIP) resulted in the removal of 6,984,877 lbs. of invasive carp from the TNCR (primarily Kentucky and Barkley reservoirs). TWRA also worked with contracted wholesale fish dealers to distribute gill net webbing to fishers participating in TCHIP.

Objective 5. Implement exploitation study of invasive carp in Kentucky and Barkley reservoirs.

In spring of 2024, TNCR partners tagged 1,880 silver carp with reward tags. During the first ~9 months of this project, 76 tag reports were received. Most reported Silver Carp were returned by commercial fishers. This data will be analyzed and reported on more thoroughly as the project matures.

ADCNR

Pickwick & Wilson, Reservoirs – As noted in the highlights section, ADCNR staff electrofished Pickwick and Wilson Lakes and by more than doubling the number (i.e. 9 in 2023, increased to 20 in 2024) of standard, fixed-location sites (Figures 1-3). This provided a total sample effort of 120 sites and 10-h pedal time effort per reservoir, increasing the statistical efficacy and power of our carp occupancy sampling program. As in past years, Silver Carp were only captured or witnessed in Pickwick Lake (n=10) and none were captured in Wilson Lake (Table 1).

During 2024, relatively few gillnets were set to capture invasive carp as compared to 2023 (Table 1, 2; Figure 4). Six gill nets were set in Pickwick Lake during November eradication efforts and Silver Carp (n=6) were captured. Six gill nets set in areas of prior carp captures did not yield capture of any invasive carp in Wilson Lake. Despite some limited success, we removed day-set gill nets from our occupancy sampling protocol given the inefficacy of that gear. We note that during 2023, no carp were captured among 132 gillnet sets which was comprised of 7.5 miles of nets and 446 staff hours. Moreover, despite short net sets (soak time effort = 247 h; mean effort/net = 1.87 h) 273 non-target fish were processed for catch data and returned to the lake site.

Appendix A – KDFWR Figures and Tables

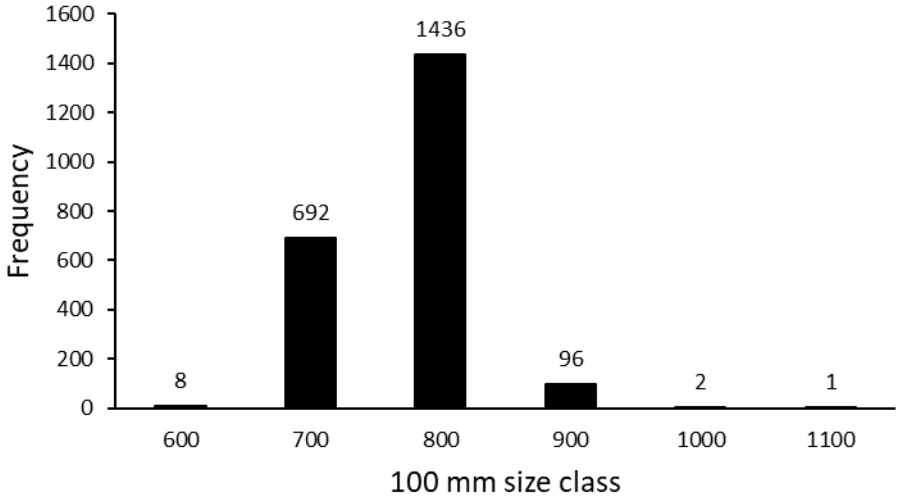


Figure 1. Length-frequency distribution of silver carp collected from Barkley Reservoir, from all methods in 2024 (N=2235).

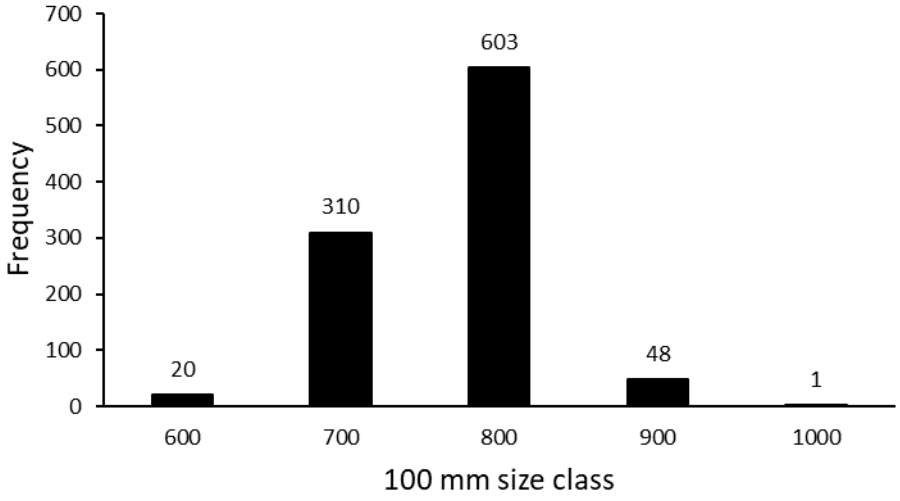


Figure 2. Length-frequency distribution of silver carp collected from Kentucky Reservoir, from all methods in 2024 (N=982).

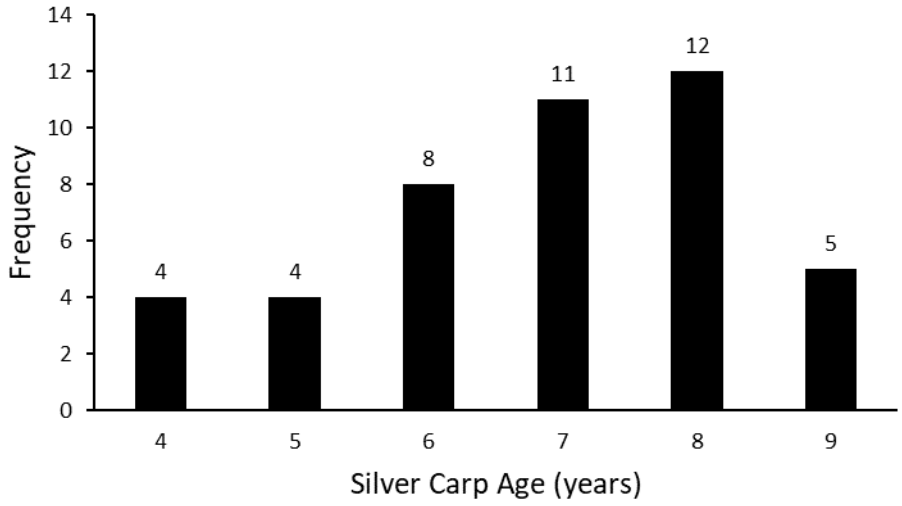


Figure 3. Age-frequency distribution for silver carp collected from Kentucky Reservoir in 2024 (N=44)

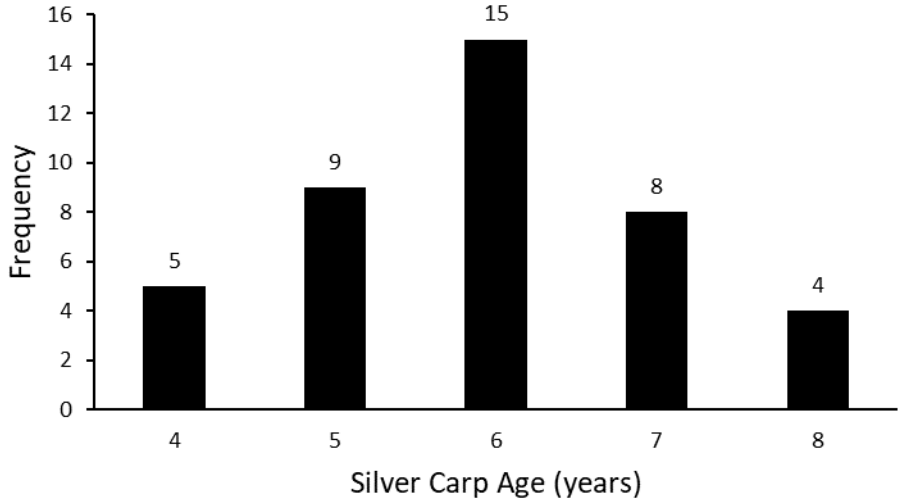


Figure 4. Age-frequency distribution for silver carp collected from Barkley Reservoir, in 2024 (N=41).

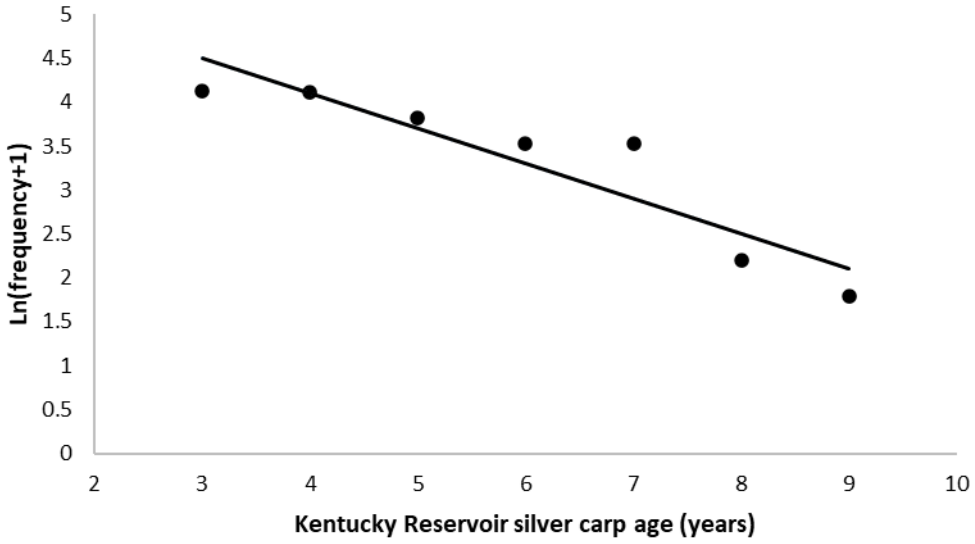


Figure 5. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Kentucky Reservoir in 2024 (N=245, F1,2=28.18, P=0.003, R2=0.85).

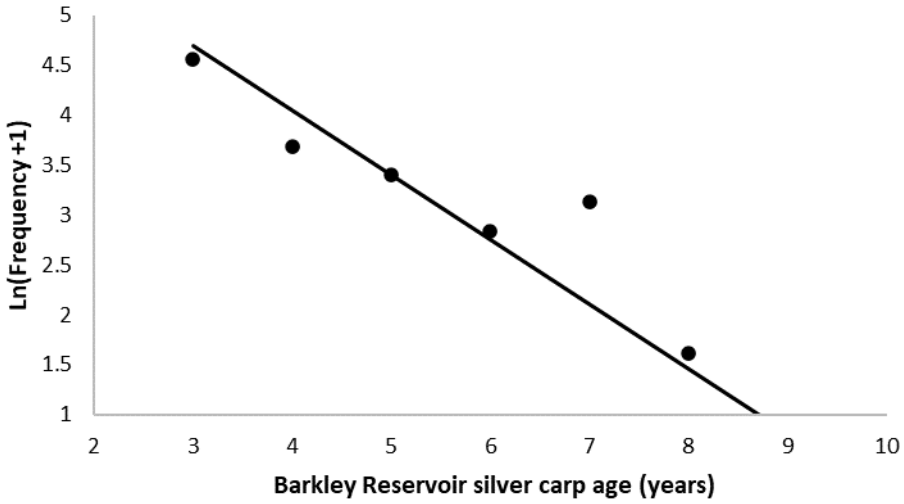


Figure 6. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Barkley Reservoir in 2024 (N=279, F1,2=30.96, P=0.003, R2= 0.86).

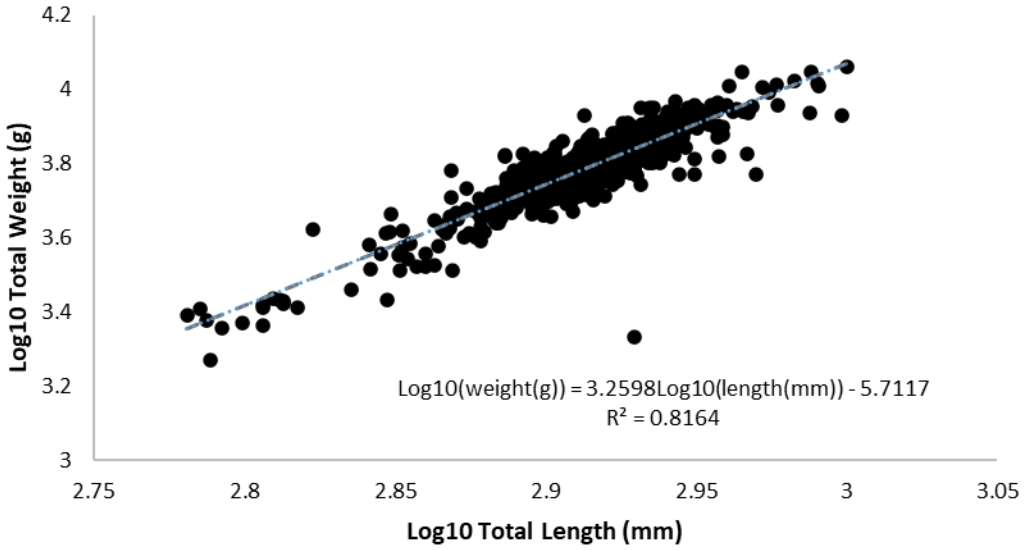


Figure 7. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Kentucky Reservoir in 2024 with a regression line describing the relationship between lengths and weights (N=580).

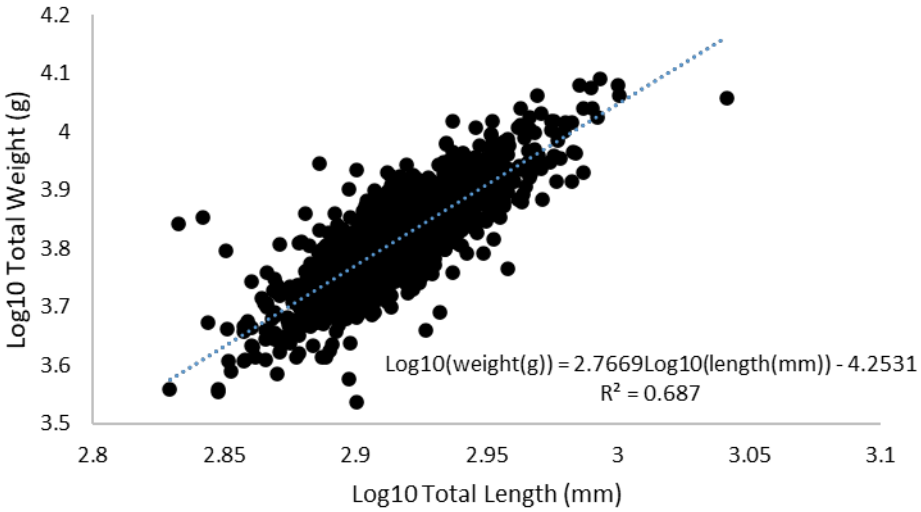


Figure 8. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Barkley Reservoir in 2024 with a regression line describing the relationship between lengths and weights (N=1572).

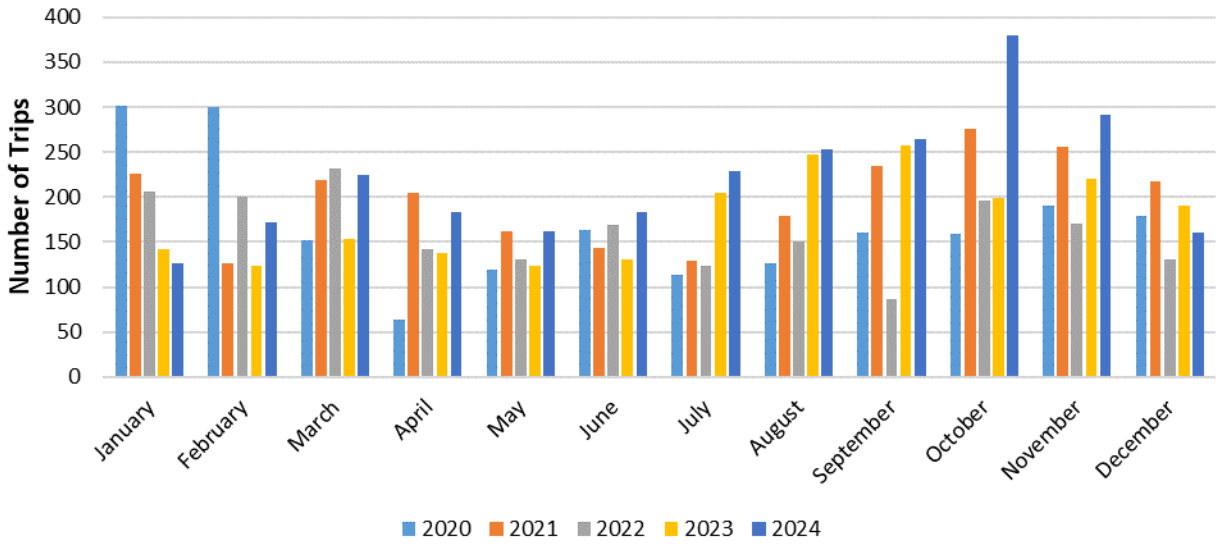


Figure 9. Number of fishing trips made monthly by commercial fishers fishing under the Invasive Carp Harvest Program from January 2020 - December 2024.

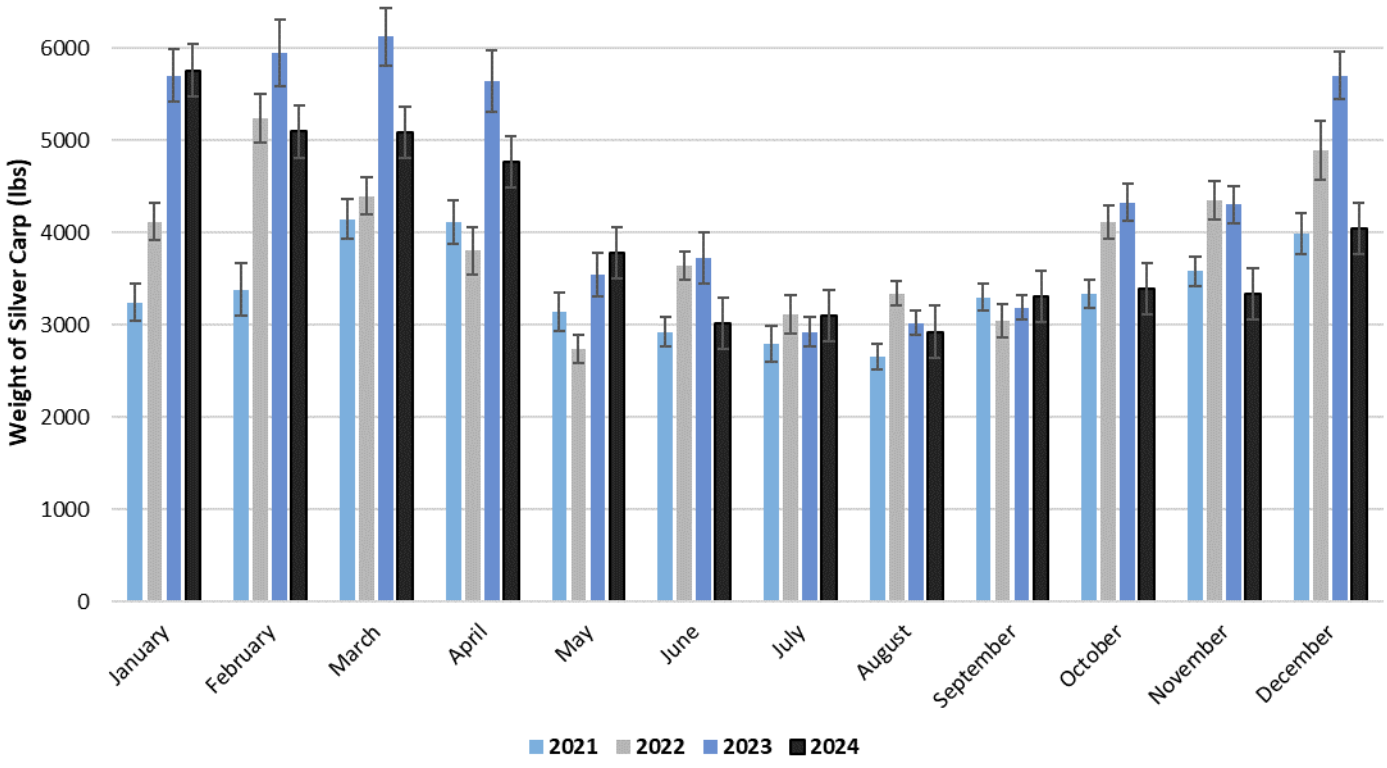


Figure 10. Monthly average total weight (lbs.) of silver carp harvested per trip by commercial fishers fishing under the Invasive Carp Harvest Program January 2021 - December 2024. Error bars represent standard error values.

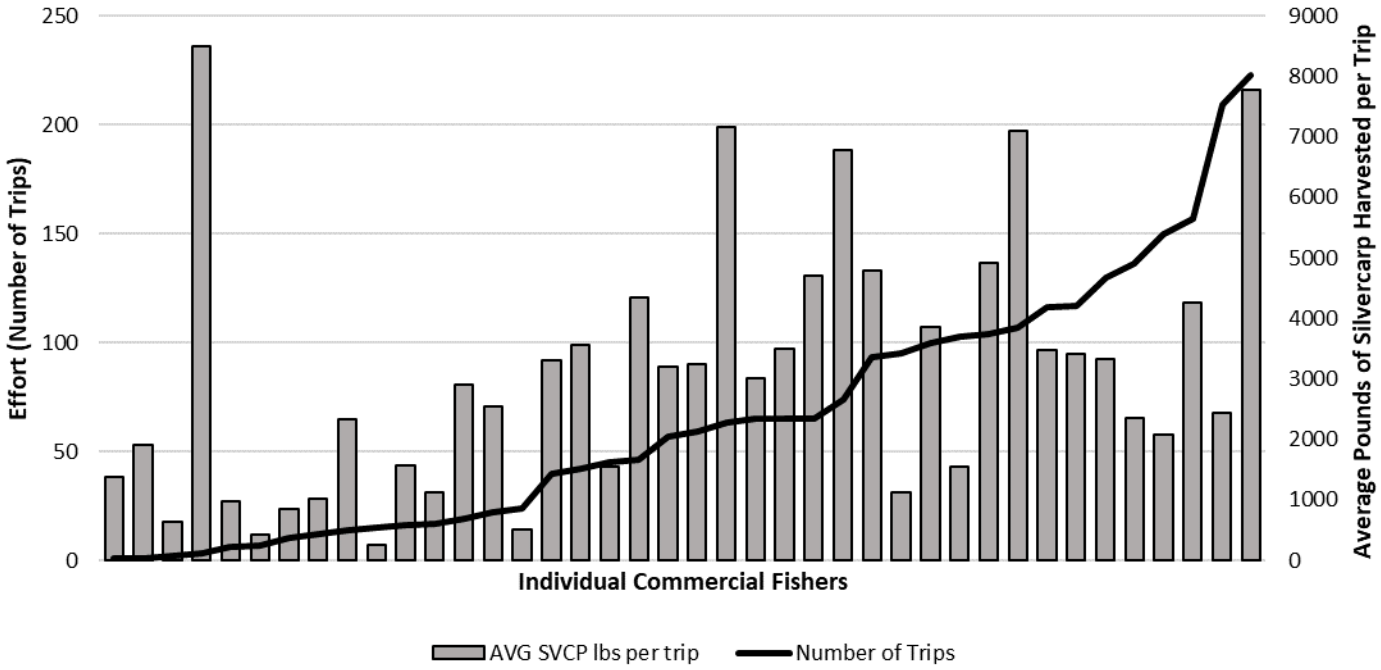


Figure 11. Average weight harvested per trip by individual commercial fishers compared to the number of trips that ended in harvest taken by those fishers under the Invasive Carp Harvest Program in 2024.

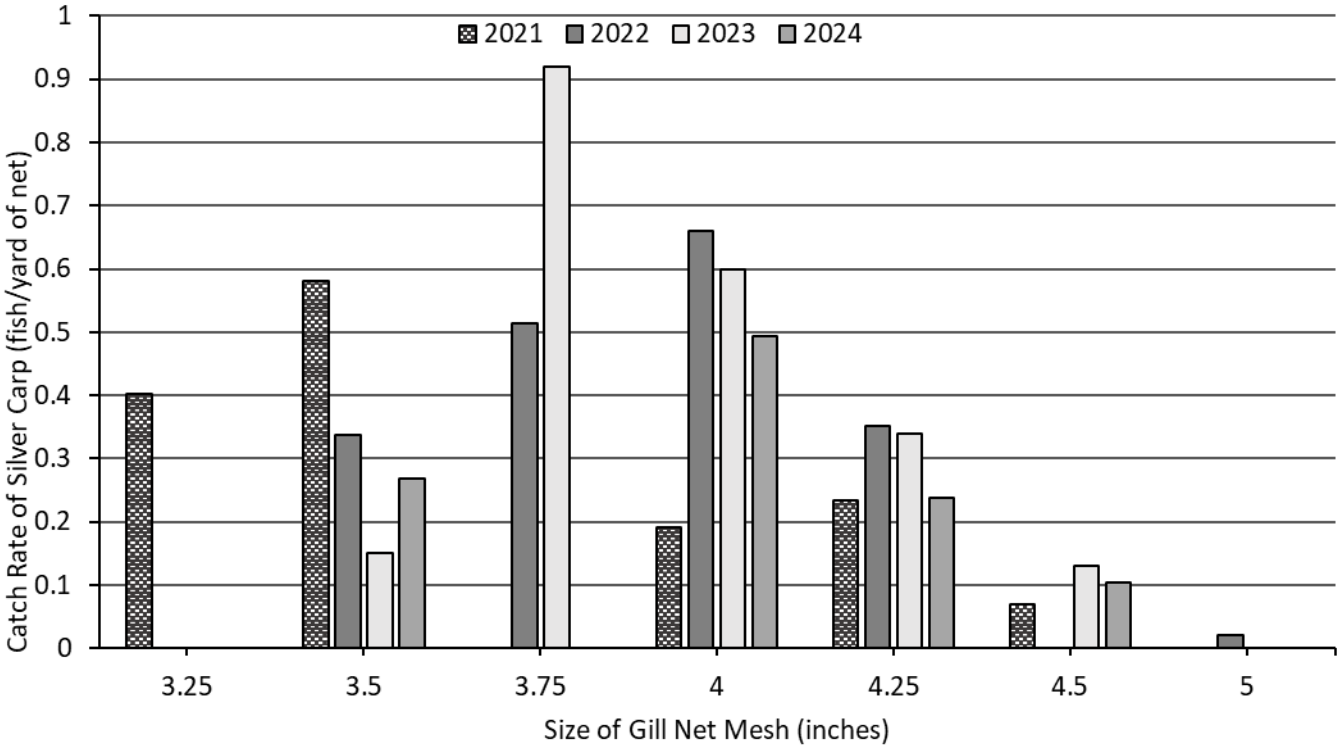


Figure 12. Catch rates (number of fish / yards of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Invasive Carp Harvest Program from 2021 through 2024.

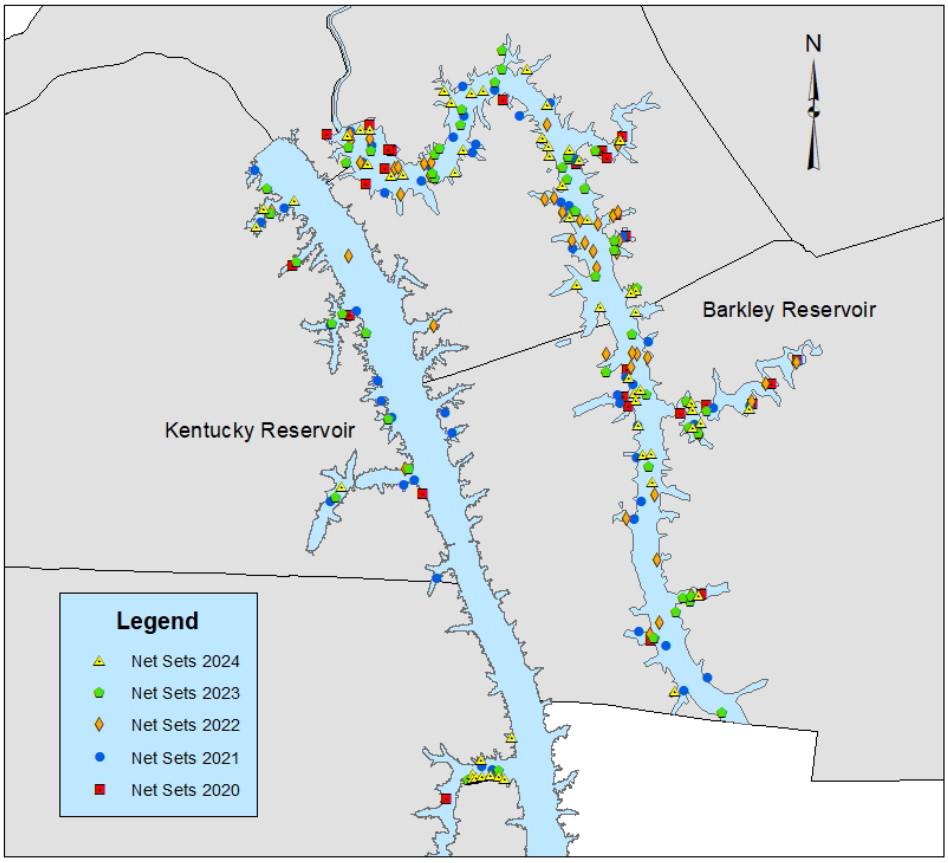


Figure 13. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff from 2020 through 2024.

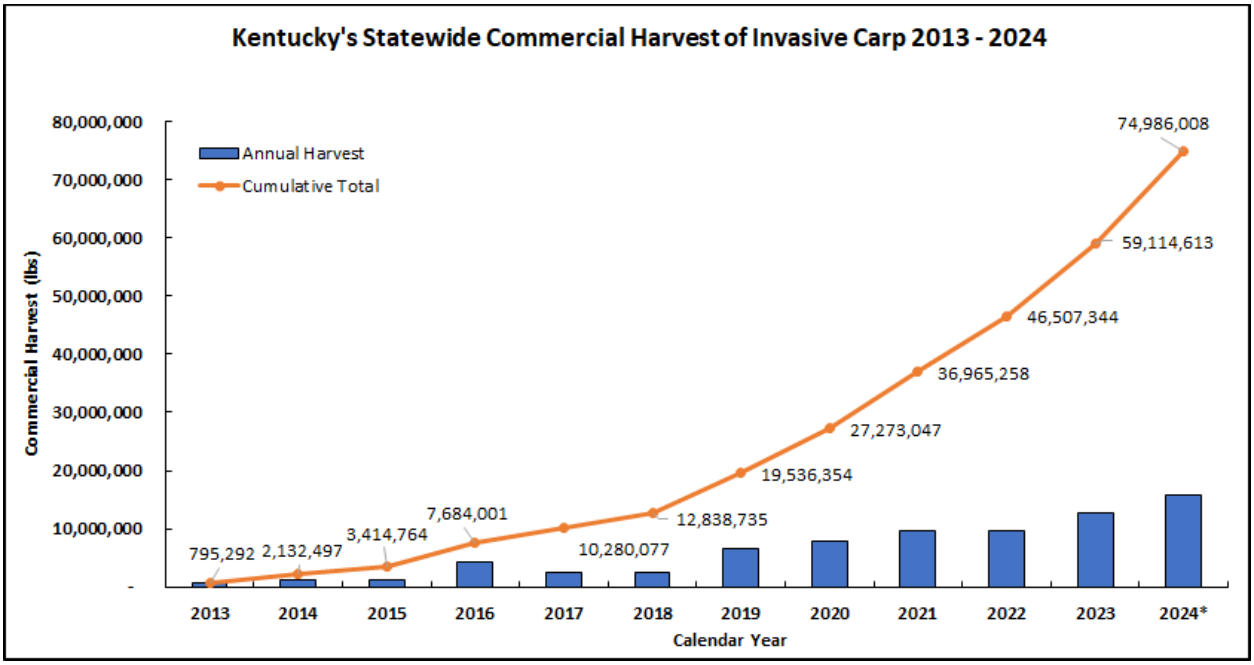


Figure 14. Kentucky's statewide reported commercial harvest of invasive carp in all programs from 2013-2024.

Table 1. Effort and catch rates from gill-netting reported by commercial fishers participating the Invasive Carp Harvest Program by calendar year, January - December 2020 - 2024.

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	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
	2024	2,626	38	8,686,362	16,683	54,358
Kentucky Reservoir	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
	2024	487	28	1,213,612	12,065	4,132
Ohio River	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
	2024	192	6	117,219		
Statewide *	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
	2024	2,629	40	14,201,895	34,094	87,644

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

Table 2. Average length and weight of silver carp harvested during ride-alongs with commercial fishers under the Invasive Carp Harvest Program 2020-2024.

Year	Number Sampled	Average total length (inches)	Average weight (lbs)	S. E.
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
2024	1999	31.8	13.2	0.08

Table 3. Number of bighead carp, grass carp, and silver carp captured by gill-net mesh size as observed during KDFWR ride-alongs with commercial fishers participating in the Invasive Carp Harvest Program 2020 - 2024. (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
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	
2024	3.5	400	107	0.27		
	4	27,367	13,527	0.49	39	26
	4.25	36,097	8,614	0.24	65	28
	4.5	6,567	679	0.10	15	8

Table 4. Fishing effort and total weight (lbs) of Invasive carp harvested during KDFWR ride-alongs with commercial fishers participaing in the Invasive Carp Harvest Program 2020 - 2024.

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)
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
2024	71,763	751	38.3	107	19	3,190	369,561	1017

*effort is calculated in yards of gillnet fished.

Table 5. 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 - 2024. (S.E. = standard error)

Year		Silver Carp	S. E.	Bighead Carp	S. E.	Grass Carp	S. E.
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
2024	Ride Alongs	4,452	425.4	114	26.2	54	13.3
	Commercial Fisher Reports	3,810	61.2	214	21.6	351	56.9

Table 6. Paupier net effort and catch rates from sampling conducted in Big Bear embayment of Kentucky Reservoir in 2024. (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	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		
Nov-24	1.67	22	13.2	14.3		1

Appendix B:

Project Title: Kentucky Lake Silver Carp Assessment

Geographic Locations: Kentucky Lake embayments: Big Bear, Big Sandy, Blood River, Cypress Springs, Duncan Creek, Jonathan Creek, Little Bear, Sledd Creek, Smith Bay, Panther Creek, Pisgah Bay

Lead Agency: Kellie Hanser (kellie_hanser@fws.gov) U.S. Fish and Wildlife Service (USFWS) Columbia Fish and Wildlife Conservation Office (FWCO)

Participating Agencies: Cole Harty (cole.r.harty@tn.gov) Tennessee Wildlife Resources Agency (TWRA); Joshua Tompkins (joshua.tompkins@ky.gov) Kentucky Department of Fish and Wildlife Resources (KDFWR)

Statement of Need:

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 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 established incentivized harvest programs to reduce the Silver Carp populations in Kentucky Lake and other reservoirs. The KDFWR invasive carp harvest program (ICHP) has resulted in the removal of 43.3 million pounds of invasive carp from 2013 to 2023 (KDFWR 2023; MICRA 2022a). The TWRA's Tennessee carp harvest incentive program (TCHIP) as resulted in the removal of nearly 30 million pounds of invasive carp from 2018 to 2022 (TWRA 2023; MICRA 2022a).

To supplement ongoing invasive carp demographic sampling, Columbia Fish and Wildlife Conservation Office implemented sampling in Kentucky Lake embayments using the electrified paupier trawl (hereafter, "paupier"), starting in fall of 2019 (Towne et al. 2022). Fall sampling with the paupier has now occurred in 2019 and 2022 – 2024, 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.

Project Objectives:

1. Provide catch rates, size distribution, and body condition of Silver Carp in Kentucky Lake using the electrified paupier trawl.

Project Highlights

- A total of 170 electrified paupier trawls were completed in 2024 resulting in the capture of 269 Silver Carp.
- On average, 19 Silver Carp per hour were collected across Kentucky Lake embayments. Silver Carp average length was 822 millimeters.
- No young of year Silver Carp were sampled in 2024 efforts.

Methods:

Site Selection

Eleven embayments spatially distributed throughout Kentucky Lake (Figure 1) were selected to be sampled based off prior years of sampling, spatial distribution, and partner input. The embayments sampled in order from downstream to upstream are: Sledd Creek (hereafter, "Sledd"), Little Bear, Pisgah Bay (hereafter, "Pisgah"), Big Bear, Smith Bay (hereafter, "Smith"), Duncan Creek (hereafter, "Duncan"), Jonathan Creek (hereafter, "Jonathan"), Blood River, Panther (hereafter, "Panther"), Cypress Spring, and Big Sandy. Embayments were the targeted habitat type due to time and environmental limitations and prior years success at sampling Silver Carp.

Field Collection

Nighttime paupier transects were conducted over three weeks from 24 October 2024 to 7 November 2024. Paupier sampling began one hour after sunset to maximize Silver Carp catch (Ridgway et al. 2020) and typically operated in nearshore habitats no deeper than 4.6 m (Towne et al. 2022) except when depth contours required greater depth to keep the frames fully submerged. A standard paupier transect is typically five minutes in length and is operated at 4.8 kph, following the contour of the shoreline. The number of transects per embayment varied based on length of available shoreline habitat. One paupier transect was completed per shoreline kilometer to maintain a buffer between transects. All embayments had one night of sampling to collect data except for Big Bear, Duncan, Sledd, Pisgah, Smith, and Big Sandy. Big Sandy was sampled three consecutive nights in 2024 without repeat sampling due to available habitat. The other listed embayments were sampled twice in 2024 to increase sample size. The TWRA and KDFWR each provided a tender boat to assist with fish processing.

Due to ongoing development of the novel electrified paupier trawl, power goal tables are still in refinement and have varied through years of data collection. Prior to the 2024 field collections, fishing threshold data was collected in October 2024 in Lake Barkley to optimize power settings for a low conductivity system. Therein, the goal table used in 2024 efforts was changed compared to previous years' collections as seen by differing amperage and power values (Table 1).

All fish sampled were identified to species, enumerated, and then measured for total length (TL; mm) and weight (g). All individuals less than 200 mm TL were not weighed due to scale sensitivity. For shad species, only the first twenty of each species per transect were measured and weighed before the remaining were enumerated either through physical counts or estimates derived from batch weight. Batch weights were obtained by identifying and weighing the first 50 shad as a batch, then weighing the remaining shad and proportionately assigning species and counts (modified from Ratcliff et al. 2014). Silver Carp that jumped into the vessel were marked as 'volunteer' and not included in relative abundance estimates.

Data Analysis

Catch per unit effort (CPUE), body condition, and size structure was summarized among all the embayments sampled within a year. The CPUE for Silver Carp was calculated as number of fish at or above stock size (250 mm: Phelps and Willis 2013) per hour. Relative standard error (RSE) of CPUE was calculated to estimate precision of catches, with a target RSE of ≤ 25 (Dumont and Schlechte 2004). To compare body condition, relative weight was calculated using the observed weight and the standard weight equation specific to Silver Carp (Lamer 2015). The relative weight equation was developed using a 50^{th} percentile approach (Wege and Anderson 1978;

Lamer 2015), which defines a Silver Carp in average condition as having a relative weight of 100. A Kruskal-Wallis test (Nelson 2023) was used to compare the relative weight among years. If the model was significant, a Dunn's Test (Dinno 2024) was completed to determine which year comparisons were statistically different. Non-parametric tests were used due to data non-normality. All statistical analyses, summaries, and figures were performed or produced in R (R 4.4.2; R Core Team 2024).

Results and Discussion

In 2024, the electrified paupier trawl completed a total of 170 transects across eleven embayments within a span of three weeks, resulting in 10 nights of sampling and the collection of 269 Silver Carp (Table 2). The number of transects completed has increased compared to previous years, with 114 transects in 2019, 133 transects in 2022, and 105 transects in 2023. A total of 44,473 fish representing 32 species (Appendix BA) were collected in 2024. Gizzard and Threadfin shad represented 96.7% of the total catch, whereas Silver Carp represented 0.006% of the total catch. Silver Carp were collected in all embayments.

Silver Carp relative abundance varied across embayments (Table 2). Movement data have shown that Silver Carp are mobile between habitats in Kentucky Lake (Umland et al. 2024); therefore, transects were grouped together to provide an overall embayment relative abundance estimate (Table 2; Figure 2). A continued decline was observed in the average relative abundance (Figure 2). The length of Silver Carp collected in 2024 varied from 615-972 mm with a mean length of 822 mm. The average length of Silver Carp was lowest in 2019 and has increased annually in subsequent years of sampling (Figure 3). No age zero Silver Carp were observed in 2024 or in previous years of paupier sampling as shown in the length data (Figure 3). Successful recruitment through spawning is likely limited due to short open river distances (Kolar et al. 2007) in the Tennessee River. Because of an increasing size structure with limited natural recruitment, the data suggests a declining population of Silver Carp. As abundances decline, an increase in size structure and relative weight is expected as the population continues to age, and more resources become available. Although mean relative weight of Silver Carp was below average, all Silver Carp appeared to be in good condition, with an average relative weight of 98 (Figure 4). No Silver Carp sampled during 2024 efforts appeared to be emaciated, indicating resources such as space or food have not become limiting yet. Statistically, there was no difference between the relative weight across years except for 2019. The 2019 relative weight was statistically lower ($P < 0.001$) than 2022, 2023, and 2024, which were not different (Figure 4).

Invasive species demographic rates can alter in response to changes in densities either by natural or human intervention. With the removal of Silver Carp in a quantity large enough to impact the population, trends in data would be expected, such as a decline in relative abundance, increase of relative weight, and increase in growth. Despite differences in power that could be affecting catch (Table 1), the paupier data potentially show an aging, declining Silver Carp population found within the embayments as shown in the catch and lengths. However, other population dynamic components such as mortality and migration need to be considered when interpreting observed population declines. Fishing mortality due to removal efforts in conjunction with natural fish mortality, immigration, or emigration would have an impact on the Silver Carp population in Kentucky Lake. Further research into these components, particularly immigration and emigration, within the Tennessee River system and its connection to the Cumberland River basin are needed to better understand data trends (MICRA 2022b; Umland et al. 2024).

Maintaining high exploitation through the incentivized harvest programs is necessary. Furthermore, modeling efforts, as being done by state and federal partners, should continue to 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.

Table and Figures

Table 1: *The average power used as well as the range of ambient conductivity, voltage, and amperage values recorded during sampling between 2019 and 2024. The average amperage at match conditions (i.e. when the fish and water conductivity both equal 100 µS/cm; Reynolds and Kolz 2012) was calculated to compare the amount of amperage used between years.*

Year	Conductivity Range	Volt Range	Amp Range	Avg Amp @ Match	Average Power
2019	50 - 155	355 - 628	16.5 - 30.3	23.6	12,017
2022	87 - 169	210 - 449	14.6 - 20.5	13.3	4,918
2023	74 - 178	248 - 562	12 - 19	13	5,209
2024	80 - 183	280 - 584	18 - 28.5	20.3	9,303

Table 2: *Total number of completed paupier transects, overall number of fish collected, and number of Silver Carp with respective average catch per unit effort (CPUE; fish/hr), standard error (SE) and relative standard error (RSE) for Silver Carp. Data is shown for each embayment sampled in 2024 as well as pooled across embayments. Embayments are listed in alphabetical order.*

Embayment	Transects	Fish Collected	Silver Carp		
			#	CPUE	RSE
Big Bear	19	5,515	22	13.9(4.4)	31.9
Big Sandy	53	21,425	75	17(4.9)	28.8
Blood River	19	2,578	30	18.9(6)	31.5
Cypress Spring	6	1,313	15	30(13.4)	44.7
Duncan	10	561	10	12(6.9)	57.7
Jonathan	19	4,040	34	21.5 (7.1)	33
Little Bear	6	1,212	25	50(17.6)	35.3
Panther	6	1,449	16	32(14.4)	45.1
Pisgah	13	2,242	19	17.8(5.3)	29.6
Sledd	11	3,293	13	14.3(5.6)	38.8
Smith	8	845	10	15(10.3)	68.9
Total 2024	**170**	**44,473**	**269**	**19(2.3)**	**12**

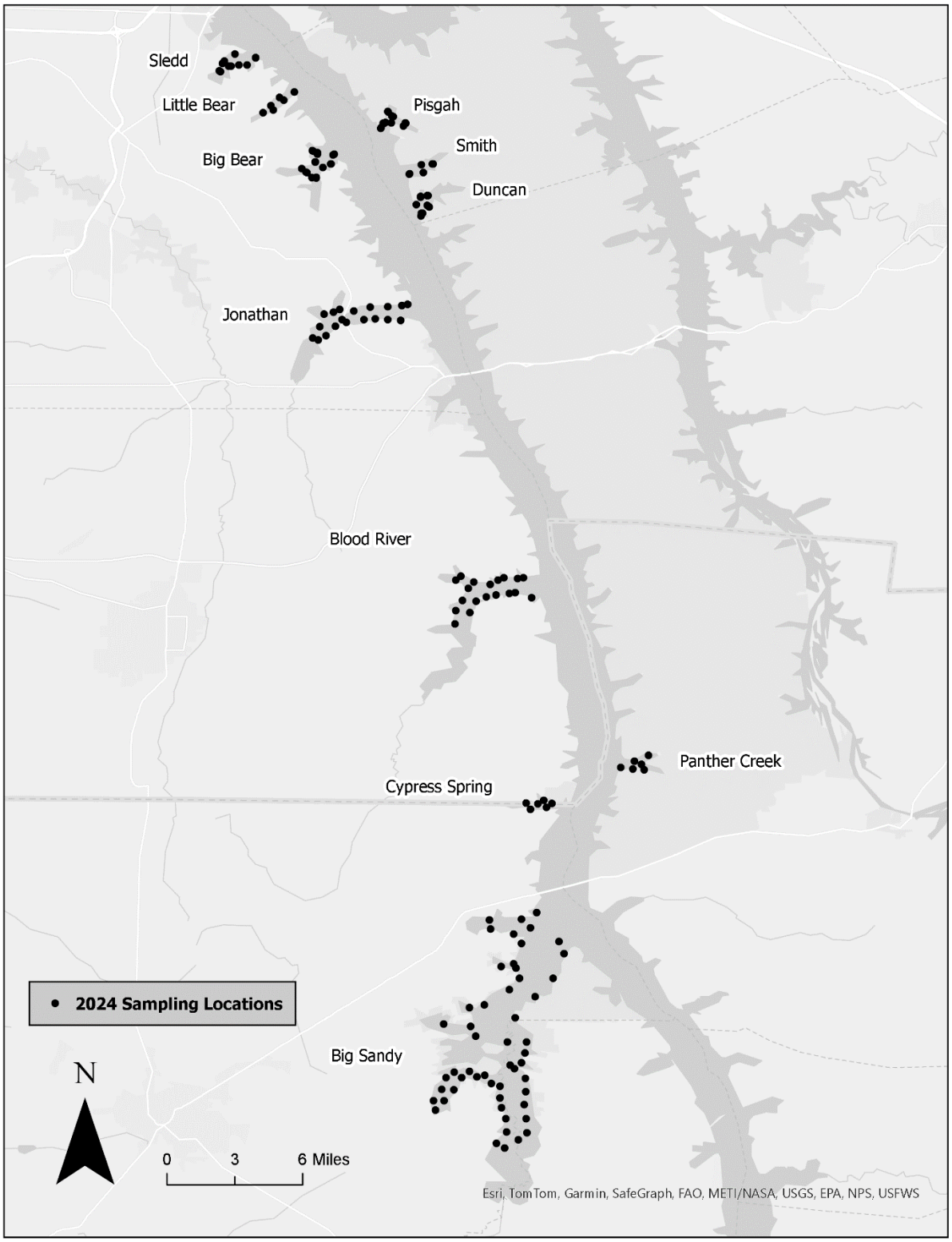


Figure 1: *Map of electrified paupier trawl sampling locations in 2024.*

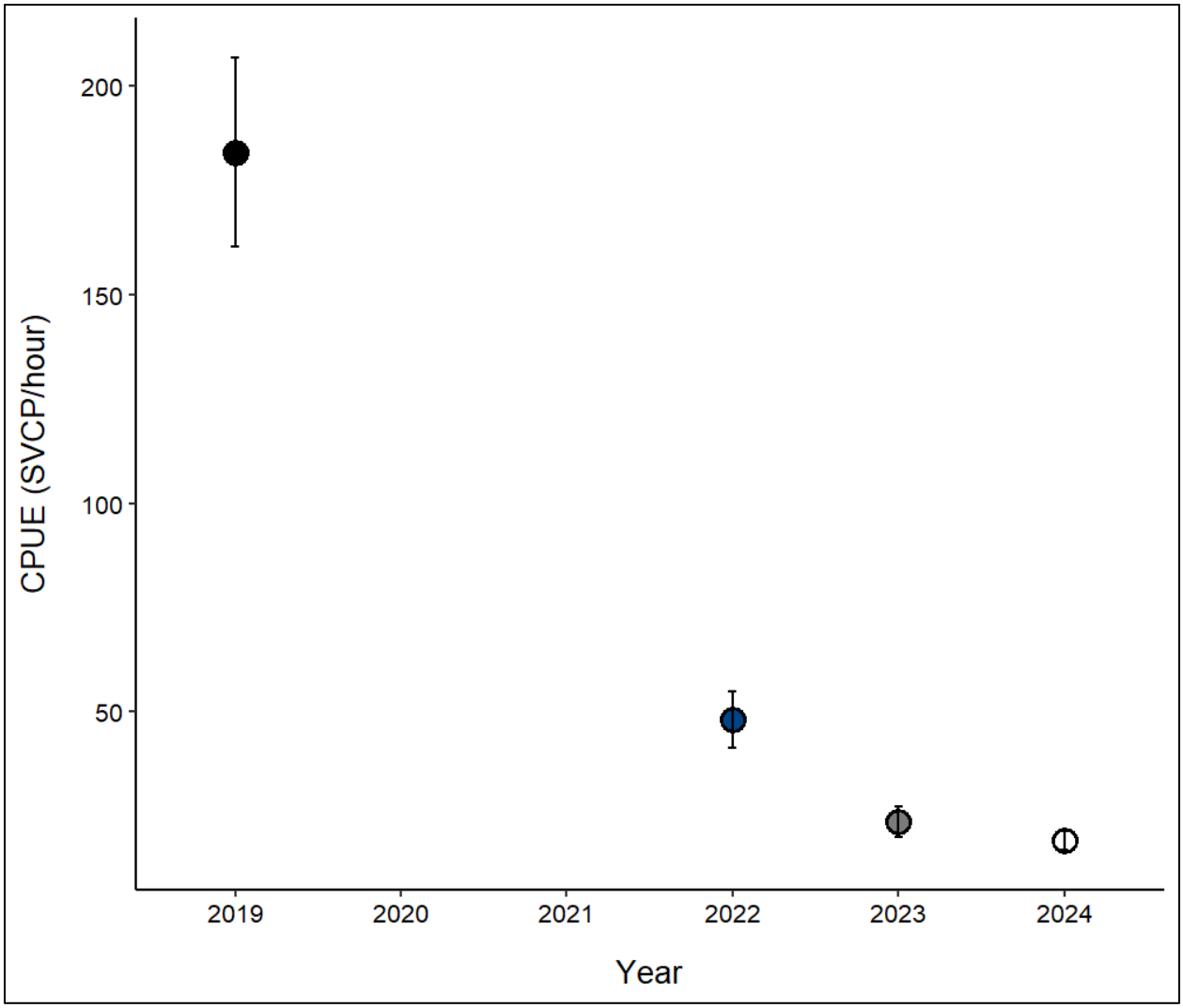


Figure 2: *Kentucky Lake catch per unit effort (CPUE) of Silver Carp (SVCP) by year. Error bars represent one standard error.*

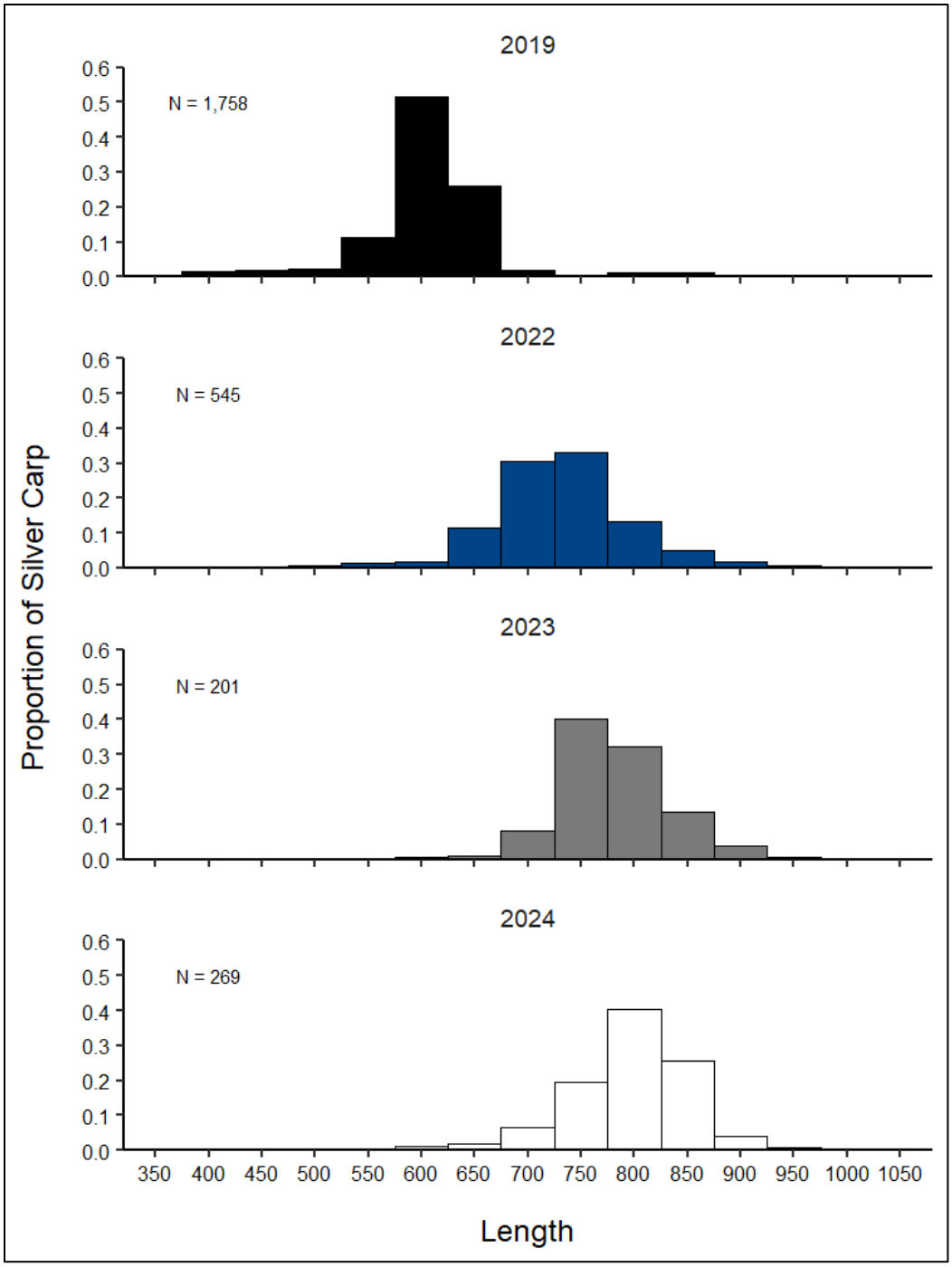


Figure 3: *Relative length frequency of Silver Carp collected with the paupier in Kentucky Lake in 2024. The number of Silver Carp per 50 mm length bin collected by each year is included for each respective graph.*

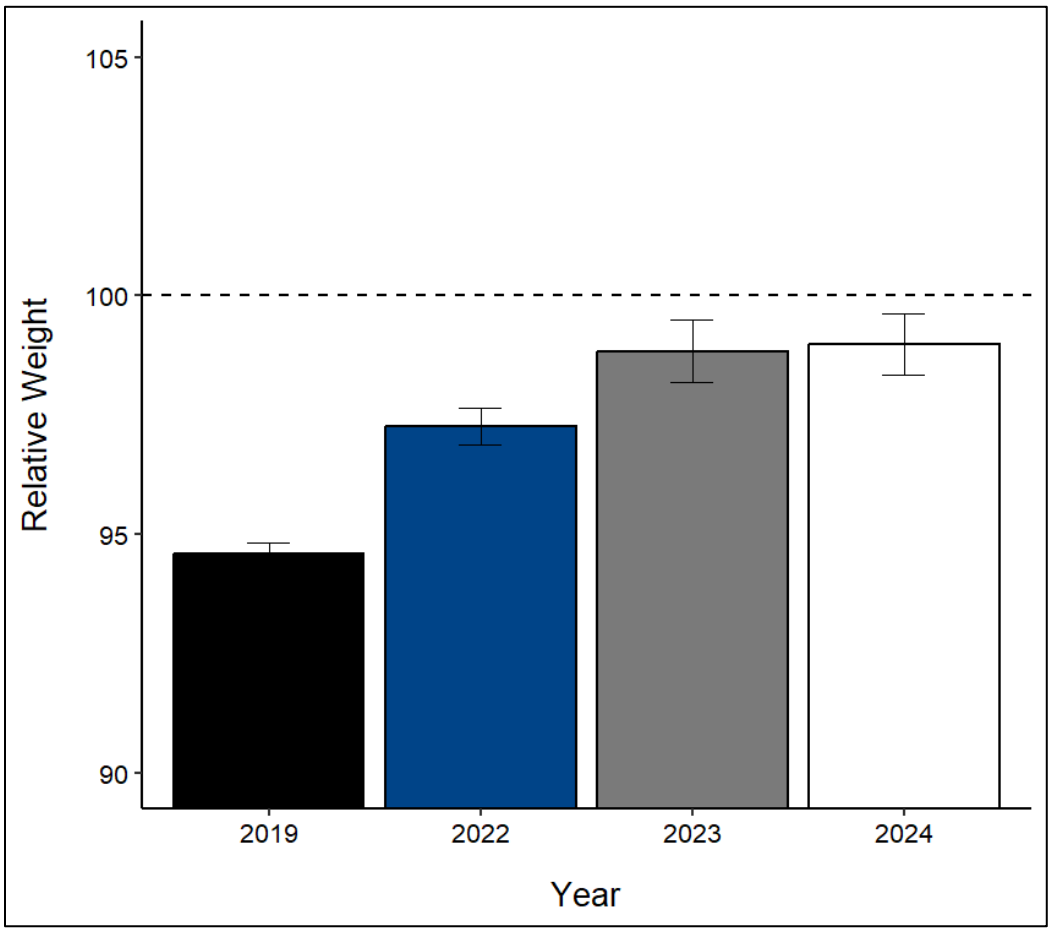


Figure 4: *Relative weight for Silver Carp (SVCP) by year for Kentucky Lake. Bars represent one standard error and the dashed horizontal line indicates an "average" body condition based on the standard weight equation (Lamer 2015).*

References

Dinno A. 2024. dunn.test: Dunn's Test of Multiple Comparisons Using Rank Sums. R package version 1.3.6. URL https://CRAN.R-project.org/package=dunn.test .

Dumont, S. C., and W. Schlechte. 2004. Use of resampling to evaluate a simple random sampling design for general monitoring or fishing in Texas reservoirs. North American Journal of Fisheries Management 24:408-416.

Kentucky Department of Fish and Wildlife Resources (KDFWR) – Fisheries Division. 2023. Annual performance report for invasive carp research and monitoring. Commonwealth of Kentucky. https://fw.ky.gov/Fish/Pages/Invasive-Carp-Information.aspx.

Kolar, C. S., D. C. Chapman, W. R. Courtenay Jr, C. M. Housel, J. D. Williams, and D. P. Jennings. 2007. Bigheaded carps: a biological synopsis and environmental risk assessment. American Fisheries Society, Special Publication 33, Bethesda, Maryland.

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

Love, S. A., N. J. Lederman, R. L. Anderson, J. A. DeBoer, and A. F. Casper. 2018. Does aquatic invasive species removal benefit native fish? The response of Gizzard Shad (*Dorosoma cepedianum*) to commercial harvest of Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*). Hydrobiologia 817:403-412.

Mississippi Interstate Cooperative Resource Association (MICRA). 2022a. Evaluation and removal of invasive carp in the Tennessee and Cumberland basins. Tennessee and Cumberland Rivers Sub-Basin Annual Summary Report, hosted by Mississippi Interstate Cooperative Resource Association: http://www.micrarivers.org/tennessee-cumberland-sub-basin-annual-summary-reports/.

Mississippi Interstate Cooperative Resource Association (MICRA). 2022b. Deterrent strategy planning for invasive carp in the Ohio River basin. Tennessee and Cumberland Rivers Sub-Basin Annual Summary Report, hosted by Mississippi Interstate Cooperative Resource Association: https://micrarivers.org/tennessee-cumberland-sub-basin-annual-summary-reports/.

Nelson. G. A. 2023. fishmethods: Fishery Science Methods and Models. R package version 1.12-1. https://CRAN.R-project.org/package=fishmethods .

Nico, L. G., P. Fuller, and J. Li. 2023. Hypophthalmichthys molitrix (Valenciennes in Cuvier and Valenciennes, 1844): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=549, Revision Date: 5/12/2022, Peer Review Date: 1/22/2015, Access Date: 1/20/2023.

Phelps, Q. E. and D. W. Willis. 2013. Development of an Asian carp size structure index and application through demonstration. North American Journal of Fisheries Management 33:338-343.

R Core Team. 2024. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ratcliff, E. N., E. J. Gittinger, T. M. O'Hara, and B. S. Ickes. 2014. Long Term Resource Monitoring Program Procedures: Fish Monitoring, 2nd edition. A Program Report submitted to the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program. June 2014. Program Report LTRMP 2014-P001. 88 pp. including Appendixes A–G.

Reynolds, J. B. and A. L. Kolz. 2012. Electrofishing. Pages 305-361 *in* A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries techniques, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Ridgway, J. L., J. M. Goeckler, J. Morris, and J. J. Hammen. 2020. Diel influences on Silver Carp catch rates using an electrified paupier in lentic habitats. North American Journal of Fisheries Management 40:1023-1031.

Tennessee Wildlife Resources Agency. 2023. Fiscal Year 2022-2023 Annual Report. Nashville, Tennessee. https://www.tn.gov/twra/about-the-twra/annual-reports.html.

Towne, K., E. Pherigo, J. Kallis, and J. Goeckler. 2022. Relative abundance and length distribution of Silver Carp in Kentucky Lake. U.S. Fish and Wildlife Service, Columbia Fish and Wildlife Service Conservation Office, Columbia, Missouri.

Umland, L. G., T. W. Spier, and N. J. Klein. 2024. Macrohabitat Use of Silver Carp (Hypophthalmichthys molitrix) in Kentucky Reservoir and Barkley Reservoir. Journal of the Kentucky Academy of Science 84(1).

Wege, G. J. and R. O. Anderson. 1978. Relative weight (Wr): a new index of condition for largemouth bass. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publication 5:79-91.

Appendix BA.

Table BA.1: *All fish collected with the paupier in standardized sampling in fall 2024. Embayments are listed in alphabetical order.*

Fish Species	Big Bear	Big Sandy	Blood River	Cypress Spring	Duncan	Jonathan
Bighead Carp	1	3	0	0	0	1
Black Buffalo	3	0	0	0	0	0
Bluegill	21	61	15	8	4	41
Bigmouth Buffalo	1	7	1	0	0	0
Channel Catfish	2	81	3	0	0	30
Freshwater Drum	2	15	0	1	0	6
Gizzard Shad	5,291	14,918	2,167	1,222	409	3,613
Largemouth Bass	12	6	8	1	1	5
Redear Sunfish	3	7	1	0	0	14
River Carpsucker	1	0	0	0	0	0
Sauger	3	2	1	0	2	0
Skipjack Herring	13	8	6	0	5	6
Smallmouth Buffalo	1	43	7	3	0	22
Smallmouth Bass	1	0	2	0	0	0
Spotted Sucker	29	48	41	18	0	33
Spotted Gar	1	15	5	0	0	6
Silver Carp	22	76	30	15	10	35
Thredfin Shad	75	5,987	245	33	119	153
White Bass	5	17	3	5	6	6
White Crappie	10	55	17	4	0	34
Yellow Bass	18	37	22	1	3	30
Black Crappie	0	2	0	0	0	0
Emerald Shiner	0	2	1	0	0	0
Golden Shiner	0	5	0	1	0	1
Longnose Gar	0	5	0	2	0	3
Paddlefish	0	1	0	0	0	0
Shortnose Gar	0	14	2	0	0	1
Unidentified Cyprinid	0	8	0	0	0	0
Unidentified Moxostoma	0	2	0	0	0	0
Unidentified Morone	0	1	0	0	0	0
Longear Sunfish	0	0	1	0	0	0
Grass Carp	0	0	0	0	1	0
Shorthead Redhorse	0	0	0	0	1	0
Warmouth	0	0	0	0	0	1
Striped Bass	0	0	0	0	0	0
Total	**5,515**	**21,426**	**2,578**	**1,314**	**561**	**4,041**

Table BA.1: *All fish collected with the paupier in standardized sampling in fall 2024.*

Fish Species	Little Bear	Panther Creek	Pisgah	Sledd	Smith
Bighead Carp	0	0	0	0	0
Black Buffalo	0	0	0	0	0
Bluegill	1	1	12	7	4
Bigmouth Buffalo	0	1	2	0	0
Channel Catfish	0	0	0	2	0
Freshwater Drum	0	2	2	0	0
Gizzard Shad	1,140	1,394	2,084	3,129	749
Largemouth Bass	1	3	3	6	1
Redear Sunfish	0	1	2	0	0
River Carpsucker	0	0	1	0	0
Sauger	0	0	0	0	0
Skipjack Herring	1	0	5	6	0
Smallmouth Buffalo	1	1	4	3	0
Smallmouth Bass	0	1	4	0	2
Spotted Sucker	0	1	20	5	6
Spotted Gar	0	0	1	0	0
Silver Carp	25	16	19	14	10
Thredfin Shad	35	14	49	110	57
White Bass	4	6	19	3	9
White Crappie	0	0	0	2	0
Yellow Bass	1	6	10	6	3
Black Crappie	0	0	0	0	0
Emerald Shiner	1	0	0	0	0
Golden Shiner	0	0	0	0	0
Longnose Gar	1	1	1	0	0
Paddlefish	0	0	0	0	0
Shortnose Gar	1	1	0	0	0
Unidentified Cyprinid	0	0	0	0	0
Unidentified Moxostoma	0	0	0	0	0
Unidentified Morone	0	0	0	0	0
Longear Sunfish	0	0	1	1	2
Grass Carp	0	0	0	0	0
Shorthead Redhorse	0	0	1	0	2
Warmouth	0	0	0	0	0
Striped Bass	0	0	3	0	0
Total	**1,212**	**1,449**	**2,243**	**3,294**	**845**

Appendix C – TWRA and TTU Tables and Figures

TWRA 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.

Location	SVCP Evaded 2024	SVCP Evaded 2023	SVCP Caught 2024	SVCP Caught 2023	Percent Captured 2024	Percent Captured 2023
Kentucky S1	94	29	6	1	6.4%	3.4%
Kentucky BS	64	47	7	1	10.9%	2.1%
Kentucky S2	77	262	3	11	3.9%	4.2%
Kentucky S3	145	159	9	9	6.2%	5.7%
Kentucky S4	214	82	16	4	7.5%	4.9%
Pickwick	0	0	0	0	NA	NA
Barkley	590	389	53	14	8.9%	3.6%
Cheatham	121	158	6	8	4.9%	5.1%

TWRA Table 2. Summary of dozer trawl catch per unit effort per 5-minute trawl (CPUE/5-min) and catch per unit effort per 1-hour of trawls (CPUE/hr) for each section of Kentucky Reservoir, Pickwick Reservoir, Barkley Reservoir, and Cheatham Reservoir in Fall 2024.

Location	CPUE/5-min	CPUE/hr
Kentucky S1	0.3	3.6
Kentucky BS	0.35	4.2
Kentucky S2	0.15	1.8
Kentucky S3	0.45	5.4
Kentucky S4	0.8	9.6
Pickwick	0	0
Barkley	2.6	31.2
Cheatham	0.3	3.6

TTU Table 1. Catch per unit effort (CPUE; mean fish per gang) of bighead carp in overnight gillnet sets during 2017–2024 by reservoir and year. Standard error (SE) expressed in parentheses.

Year	Barkley	Cheatham	Kentucky	Pickwick
2017	0.2(0.1)	0	0.8(0.6)	0
2018	0.1(0.1)	0.2(0.1)	0.1(0.1)	0
2019	0.5(0.2)	0.8(0.6)	0.1(0.1)	0
2020	0.7(0.2)	0.1(0.1)	0.1(0.1)	0.2(0.1)
2021	0.1(0.1)	0.6(0.3)	0.1(0.1)	0.1(0.1)
2022	0.1(0.1)	0(0)	0.3(0.2)	0.1(0.1)
2023	0.1(0.1)	0(0)	0.1(0.1)	0.2(0.2)
2024	0.1(0)	0.1(0.1)	0.1(0)	0.1(0.1)

TTU Table 2. Catch per unit effort (CPUE; mean fish per gang) of silver carp in overnight gillnet sets during 2017–2024 by reservoir and year. Standard error (SE) expressed in parentheses.

Year	Barkley	Cheatham	Kentucky	Pickwick
2017	30(8.8)	16.7(4.4)	3.9(1.1)	13.3(5.7)
2018	27.8(6.7)	8.8(2.8)	13.4(2.5)	9.4(2.9)
2019	33.7(5.1)	13.4(3.5)	19.3(3.3)	22(10.8)
2020	32.7(3.4)	15.8(4)	12.3(2.7)	1.5(0.5)
2021	18.3(2.2)	11(2.8)	6.4(1.2)	2.2(0.9)
2022	15.1(2.5)	7.2(2.5)	10.7(2.4)	2.1(0.7)
2023	13.4(2.1)	5(1.3)	6.6(1.1)	1.1(0.3)
2024	8(1.5)	2(0.6)	5.7(1.2)	1(0.3)

TTU Table 3. Mean relative weight of silver carp captured in overnight gill nets in each reservoir by year with standard error denoted in parentheses.

Year	Barkley	Cheatham	Kentucky	Pickwick
2017	94.2 (0.5)	105.0 (1.2)	93.9 (1.4)	102.8 (0.9)
2018	93.5 (0.3)	102.8 (0.8)	92.6 (0.4)	107.0 (0.8)
2019	96.6 (0.6)	103.7 (0.8)	92.6 (0.4)	108.6 (0.7)
2020	95.5 (0.5)	108.0 (0.9)	93.7 (0.6)	105.4 (3.2)
2021	98.4 (0.6)	107.8 (1.1)	98.3 (0.8)	117.4 (2.4)
2022	100.2(0.6)	109(0.9)	100.2(0.8)	108(2.5)
2023	101.8(0.5)	109(1.7)	100.6(0.8)	108(5.8)
2024	105.4(0.8)	102.7(2)	103.3(0.8)	105.4(3)

TTU Table 4. Kilograms of silver carp removed using overnight gill nets by lake and year.

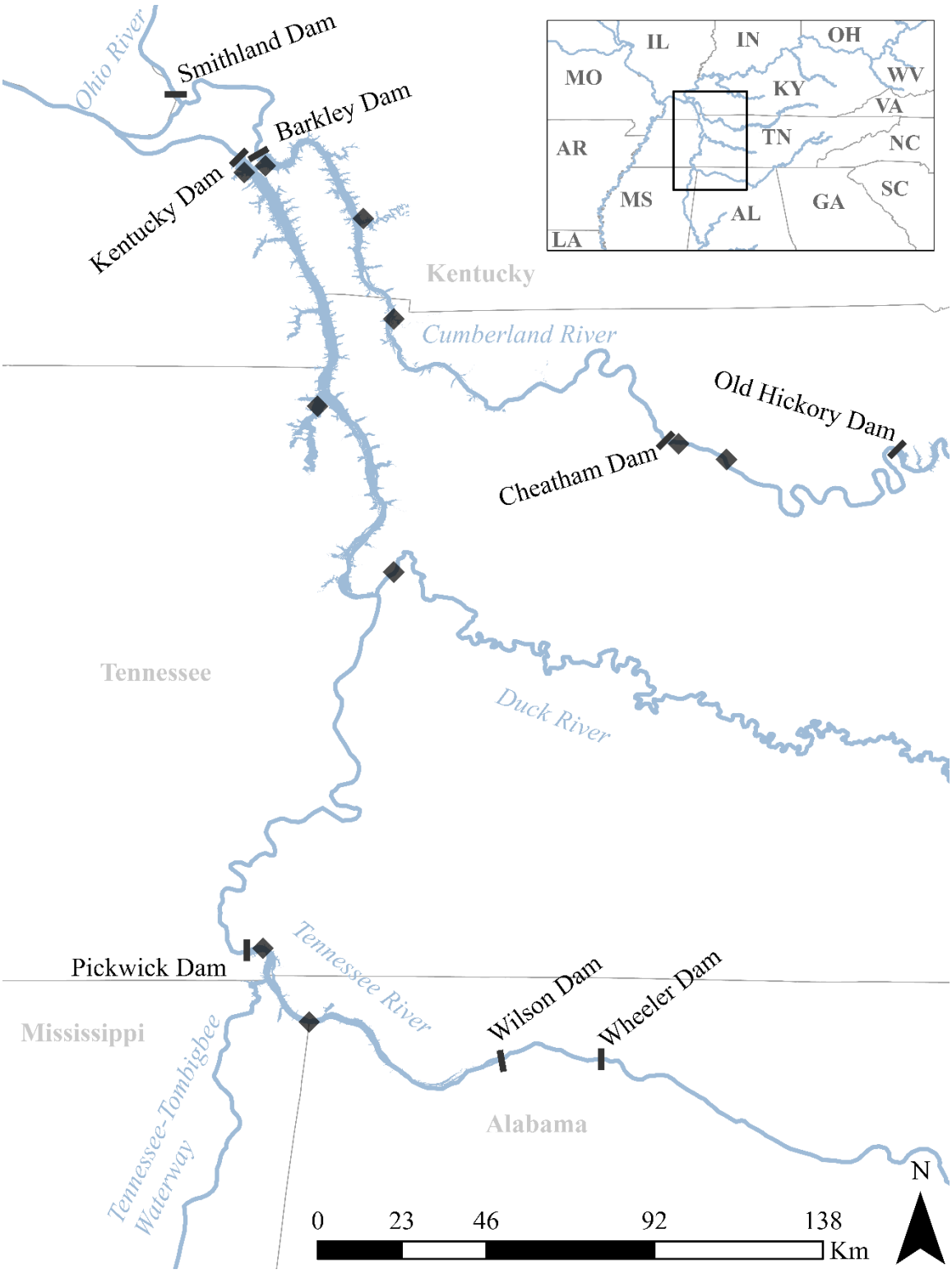
Year	Barkley	Cheatham	Kentucky	Pickwick
2017	934	553	202	363
2018	2,781	976	1,154	825
2019	2,194	1,087	742	927
2020	2,382	1,105	815	160
2021	2,254	1,360	820	352
2022	2,160	867	1,383	294
2023	2,040	675	976	177
2024	1,629	257	1,162	138

TTU Table 5. Percentage of Silver Carp exceeding 3,629 g (8 pounds) among years and by lake.

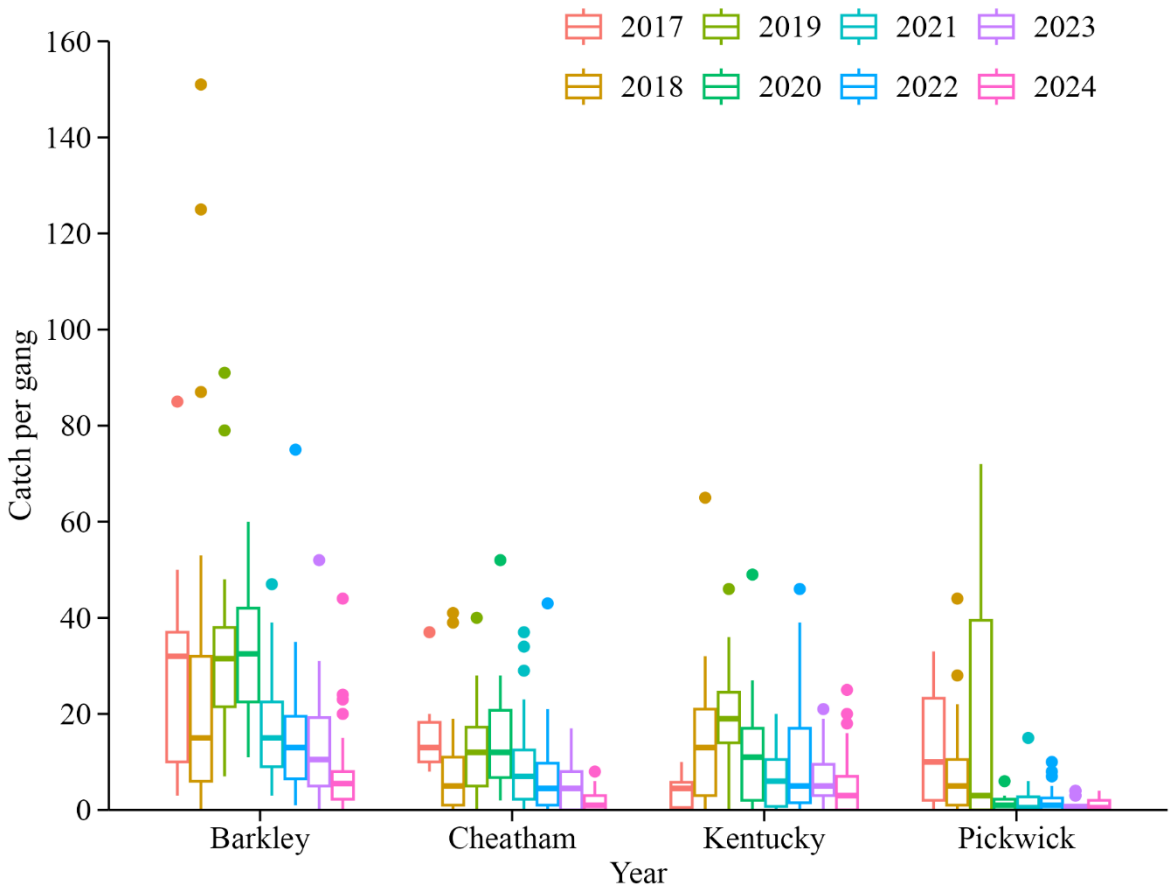
Year	Barkley	Cheatham	Kentucky	Pickwick
2017	24	93	46	87
2018	22	90	20	85
2019	34	93	8	100
2020	49	96	21	100
2021	78	99	57	100
2022	85	100	76	100
2023	97	100	94	100
2024	98	100	98	100

TTU Table 6. Sex ratio (i.e., females per male) of silver carp captured in overnight gill nets in each reservoir by year.

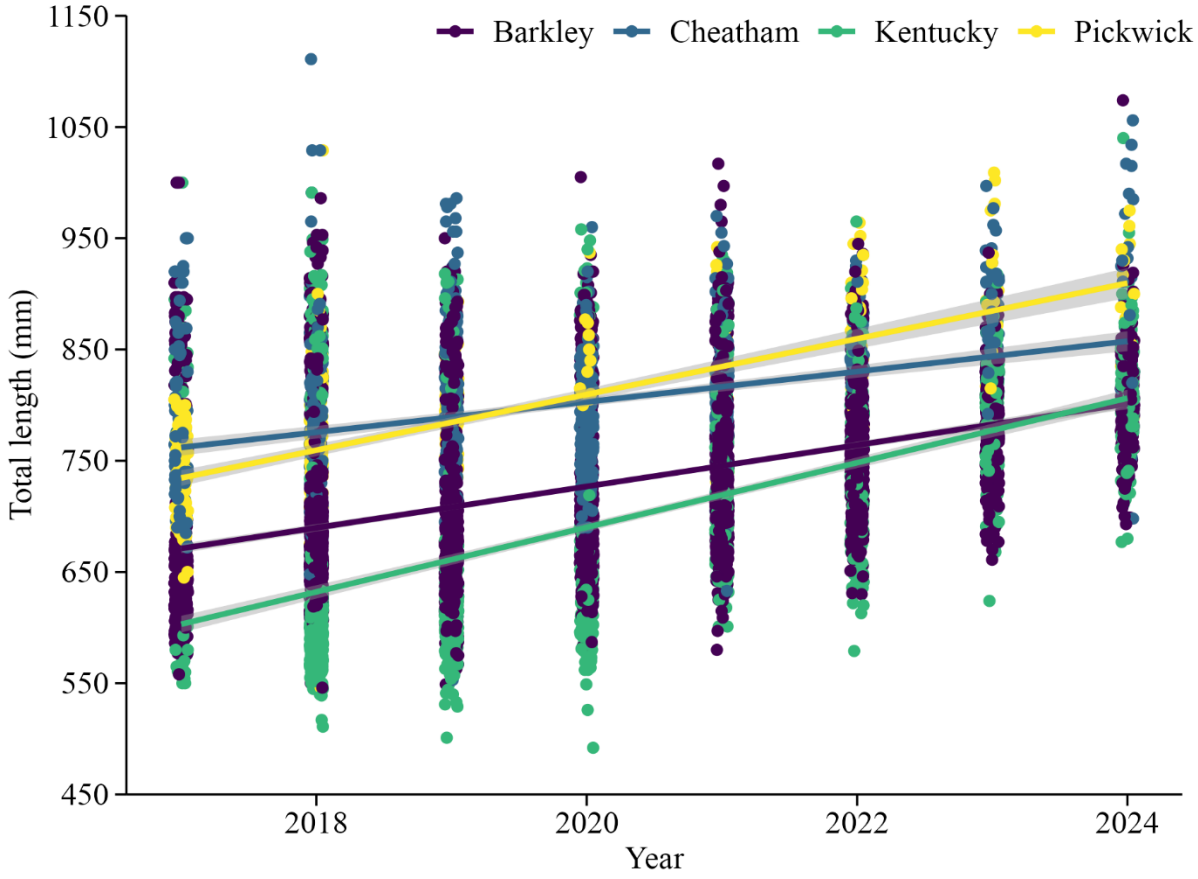
Year	Barkley	Cheatham	Kentucky	Pickwick
2017	0.93	0.59	0.43	1.03
2018	0.83	0.95	0.77	2.07
2019	0.81	0.71	1.12	1.19
2020	0.72	1.02	1.07	0.64
2021	1.12	1.09	1.02	1.06
2022	0.87	0.74	1.06	1.06
2023	0.63	0.73	0.82	0.19
2024	0.79	1.00	0.6	0.45



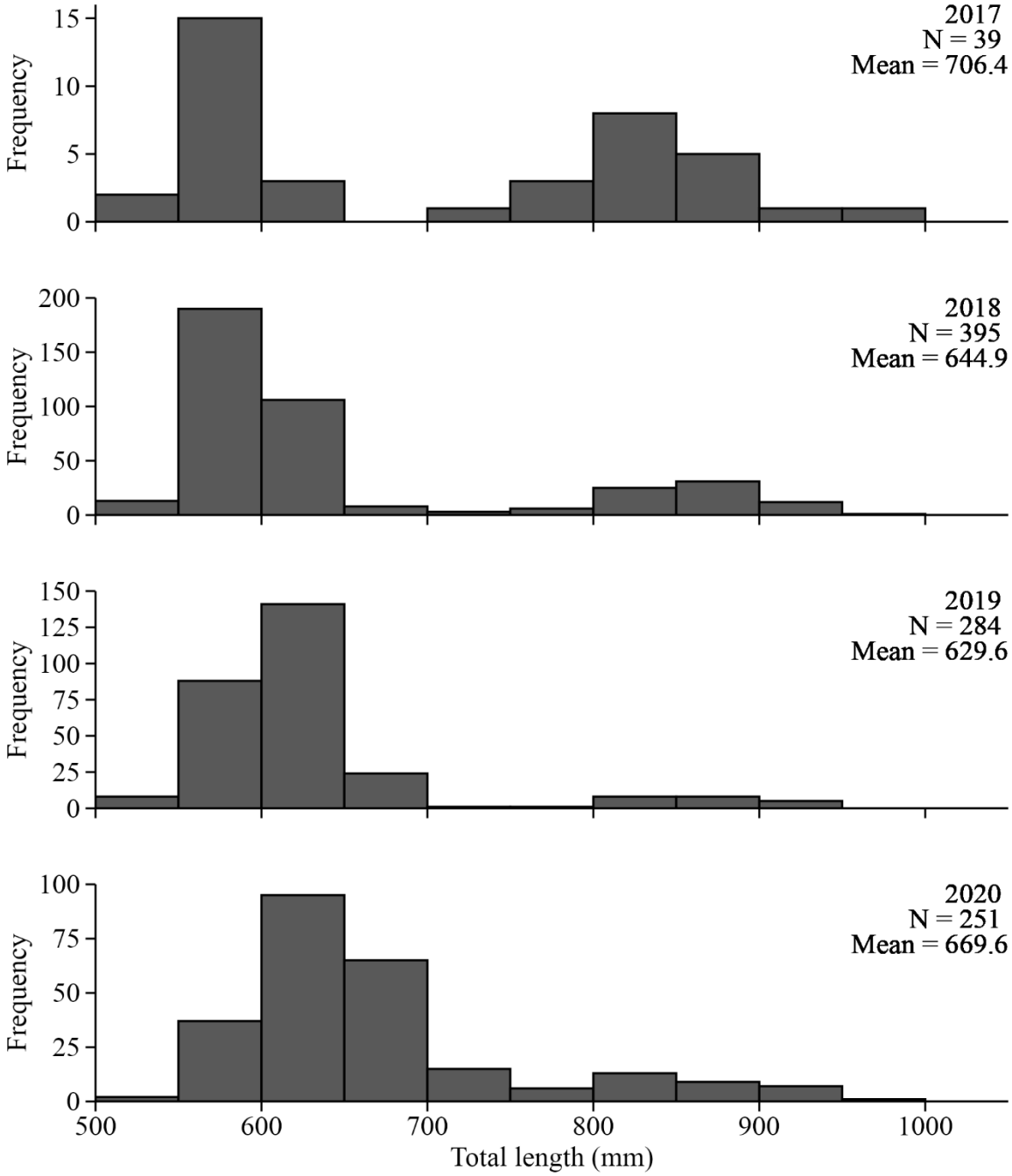
TTU Figure 1. Map of the study area with systematic sampling sites denoted. Lock and dam locations are denoted by | and sampling sites are denoted by black diamonds.



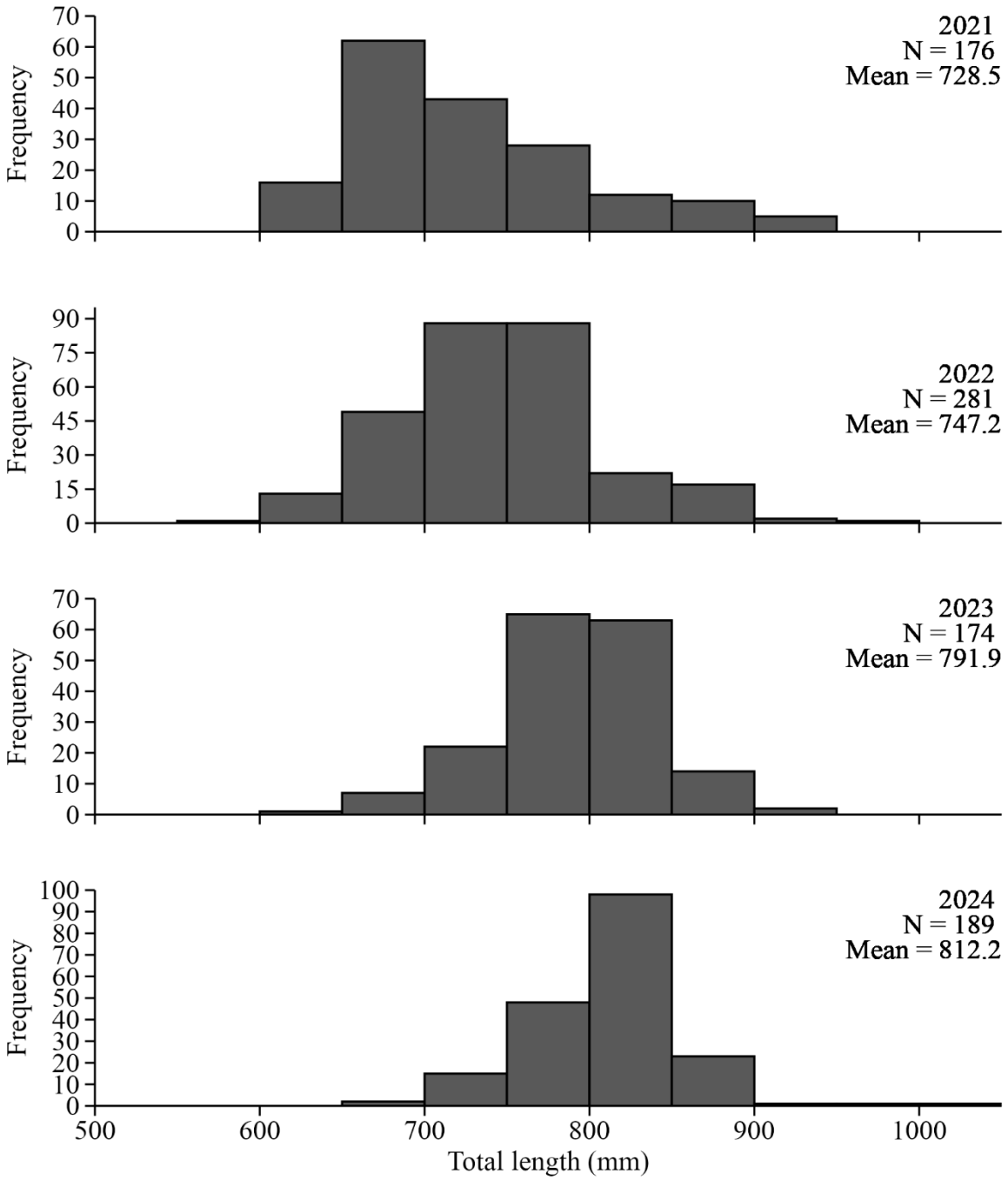
TTU Figure 2. Boxplot of silver carp captured per overnight gill net set in Barkley, Cheatham, Kentucky, and Pickwick reservoirs during 2017–2024. Box ends represent the 25th and 75th quantiles, horizontal lines are the median, the upper whisker extends to the largest observation no further than 1.5 x interquartile range (IQR) from the 75th quantile, and the lower whisker extends to the smallest observation no further than 1.5 x IQR from the 25th quantile.



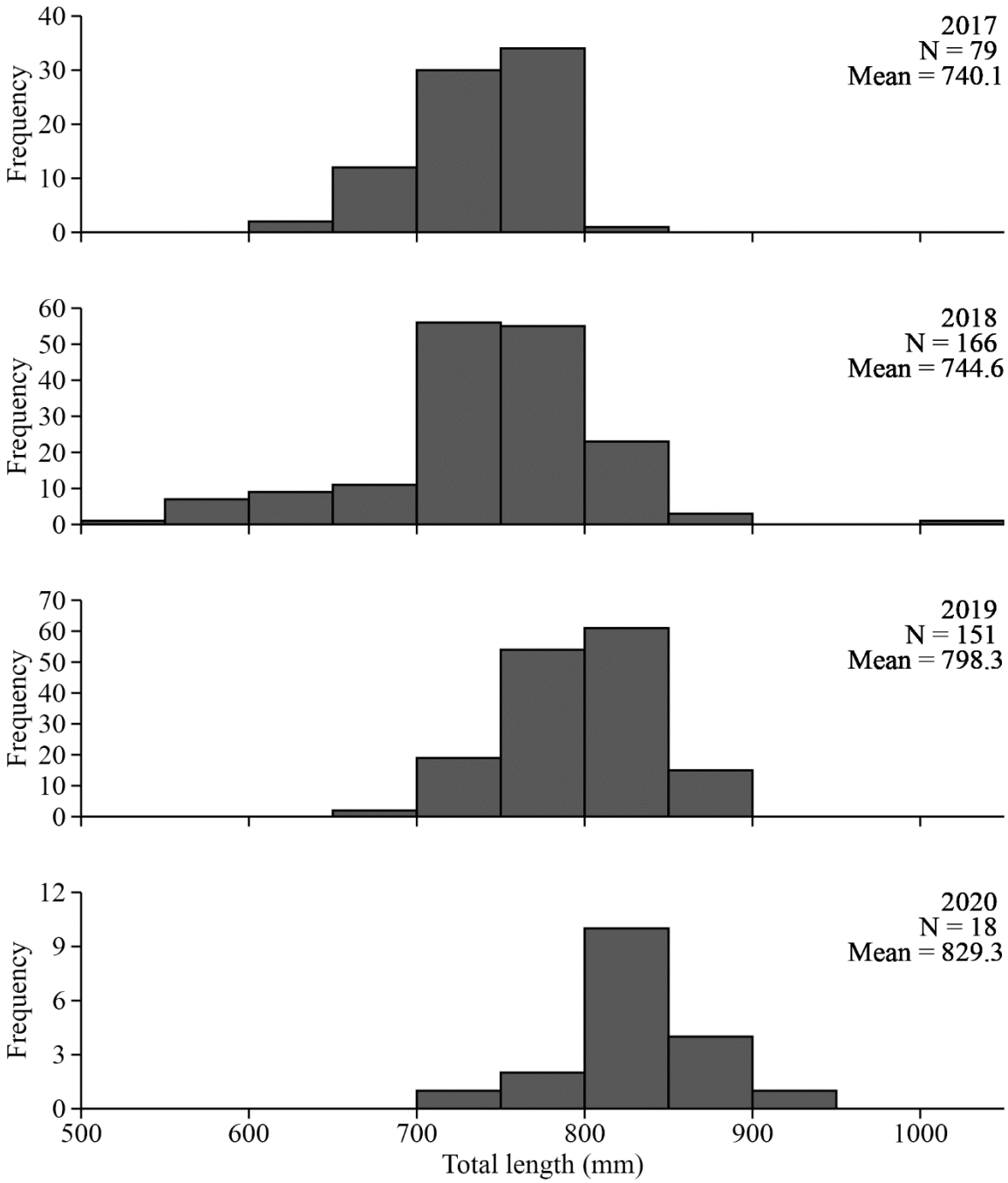
TTU Figure 3. Regression of total length (mm) of silver carp by year. Data grouped by reservoir. Area around each line indicates the 95% confidence interval.



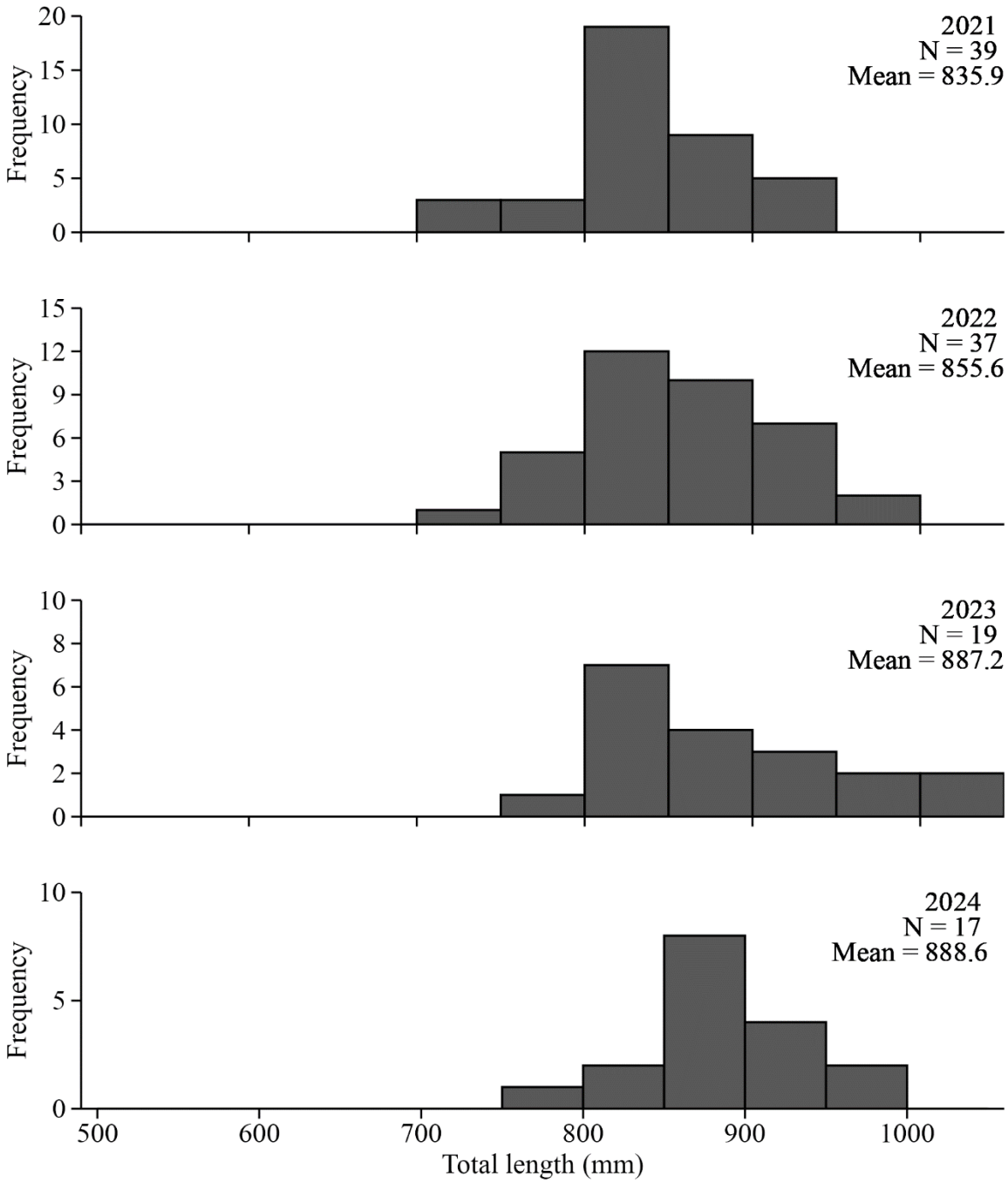
TTU Figure 4. Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Kentucky Reservoir.



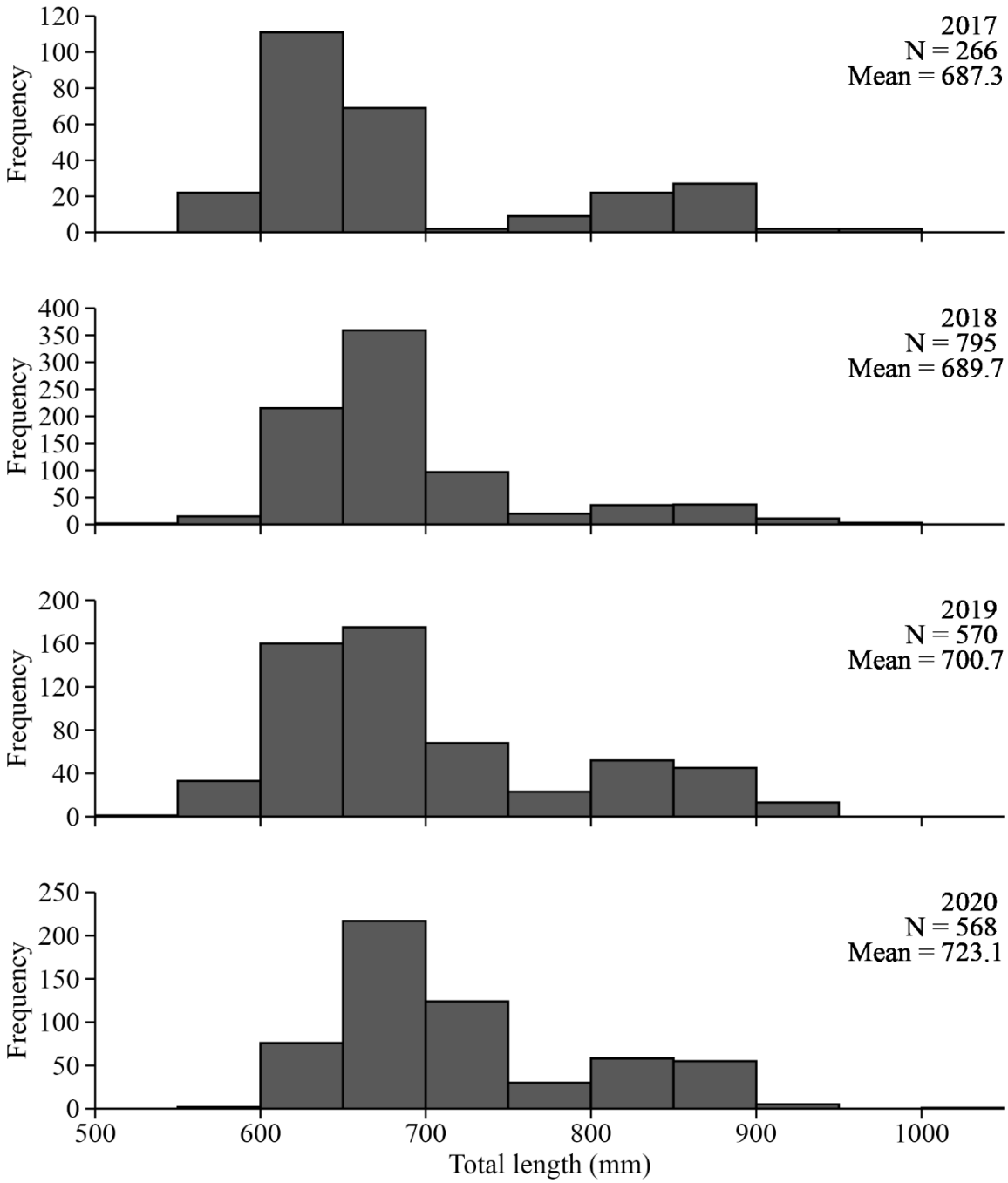
TTU Figure 4 (continued). Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Kentucky Reservoir.



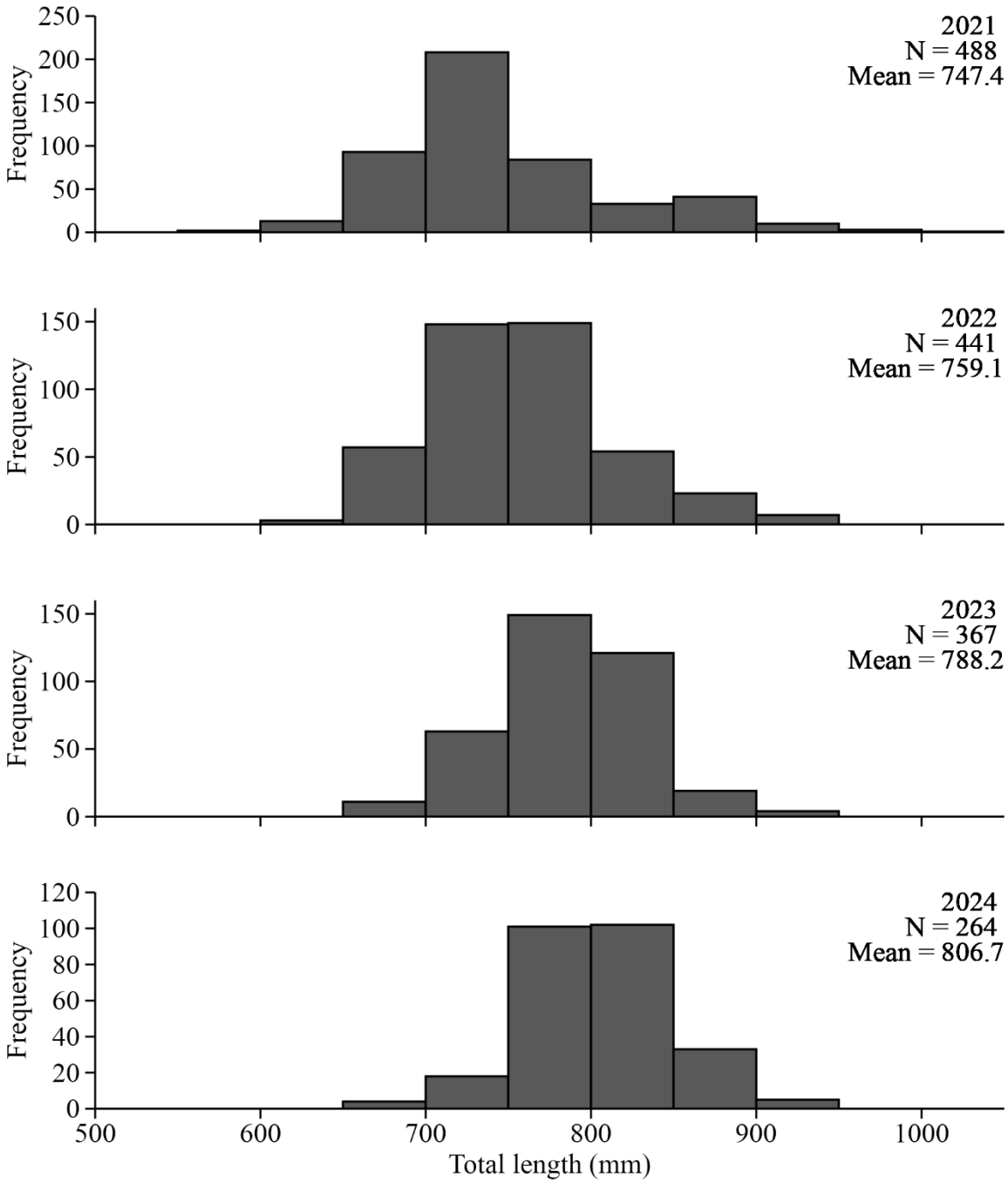
TTU Figure 5. Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Pickwick Reservoir.



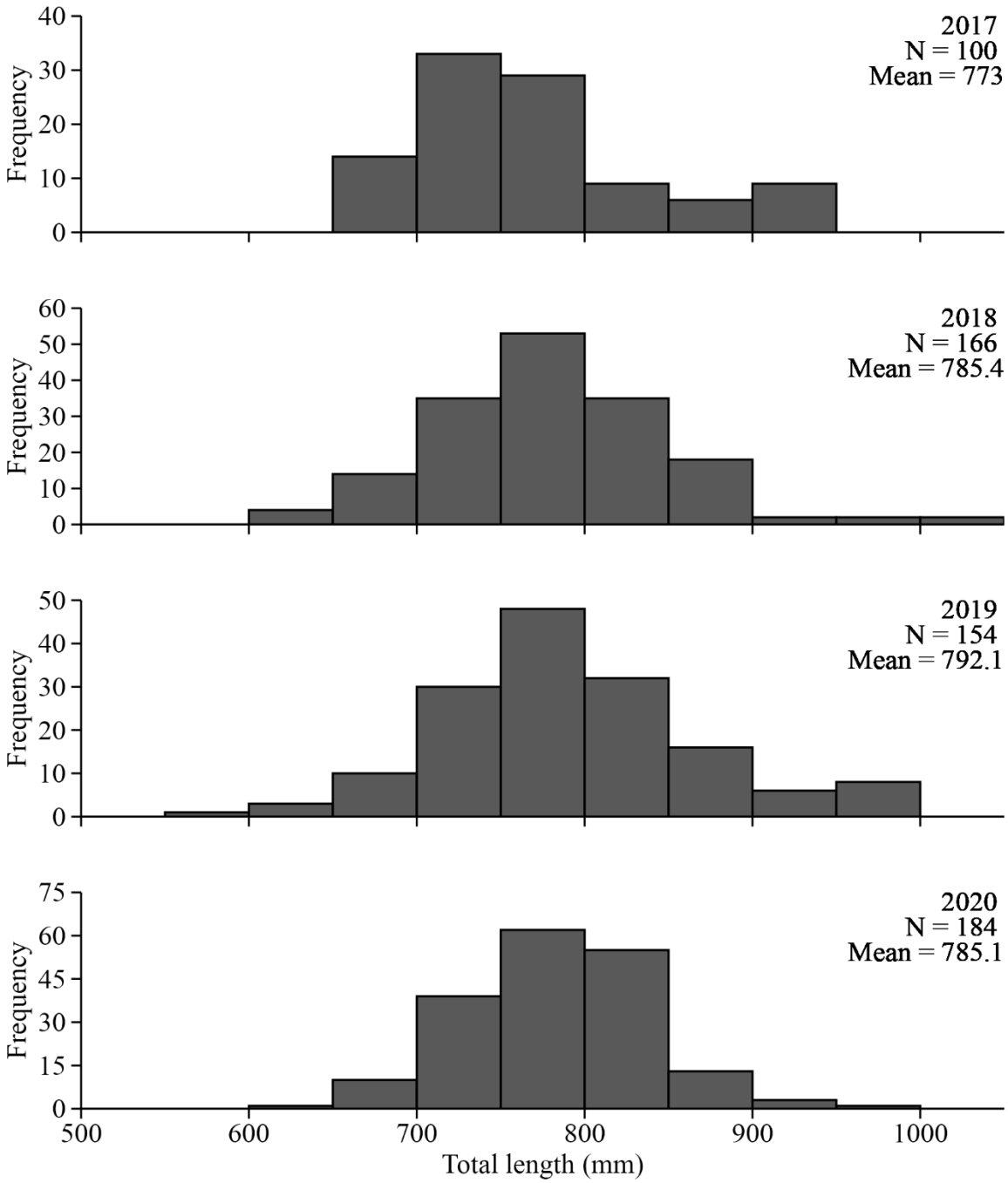
TTU Figure 5 (continued). Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Pickwick Reservoir.



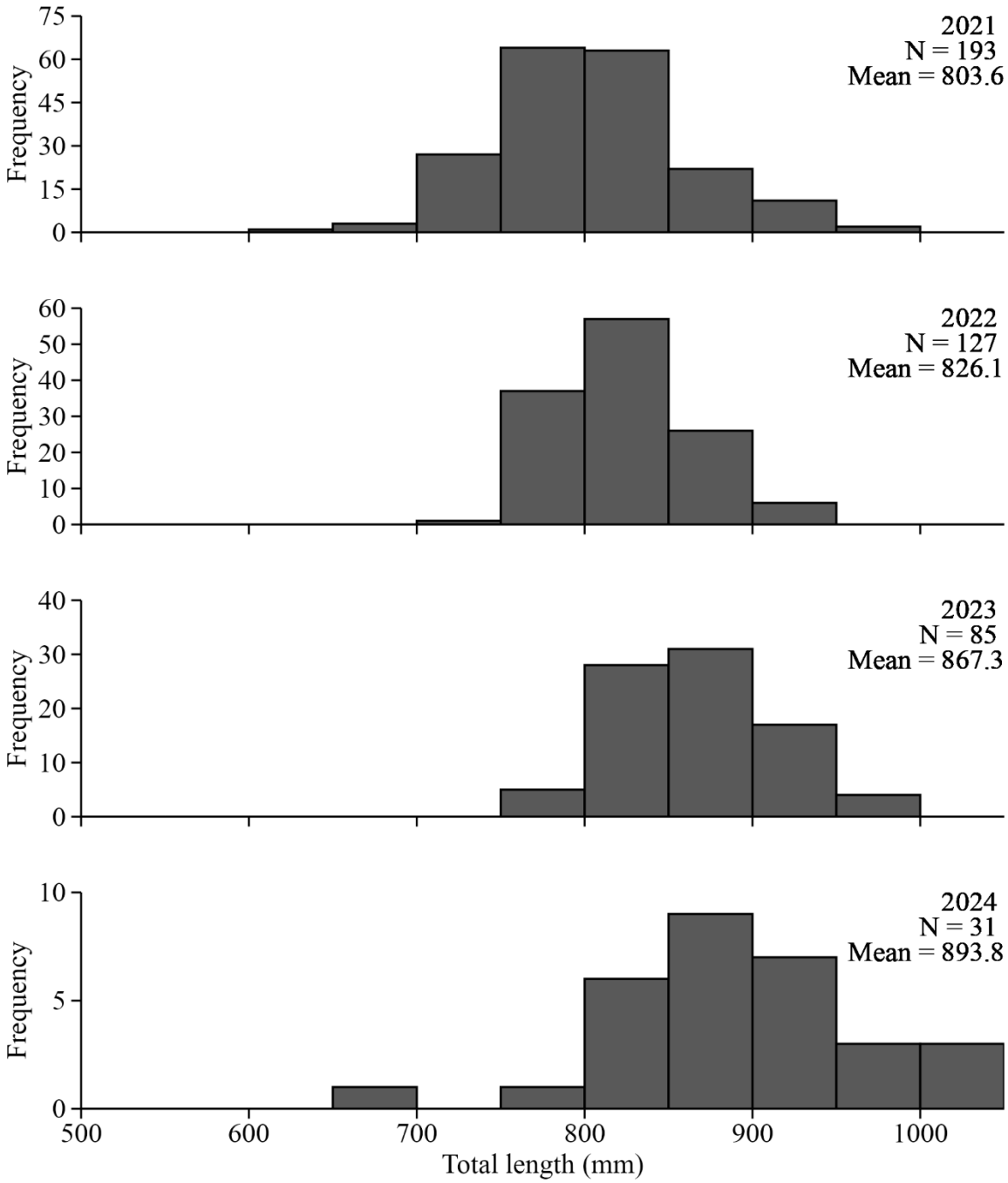
TTU Figure 6. Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Barkley Reservoir.



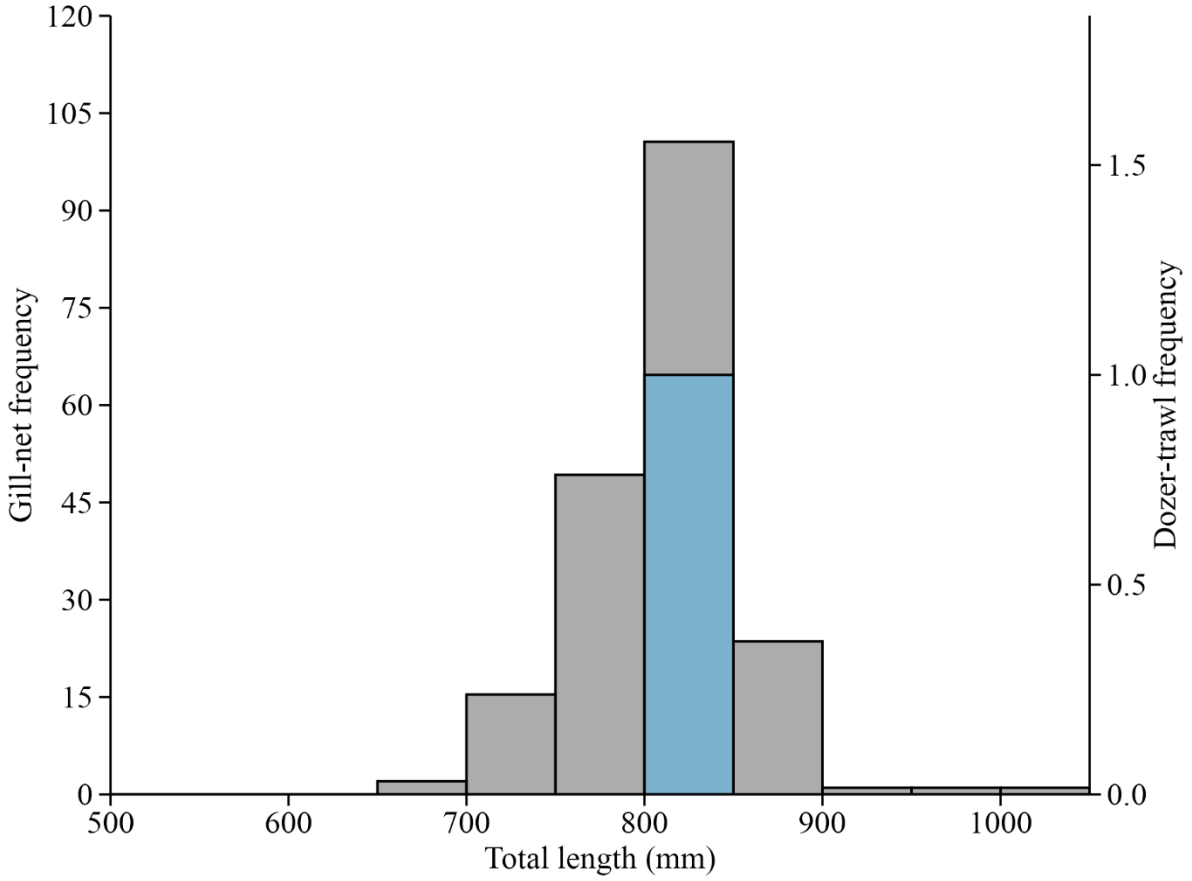
TTU Figure 6 (continued). Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Barkley Reservoir.



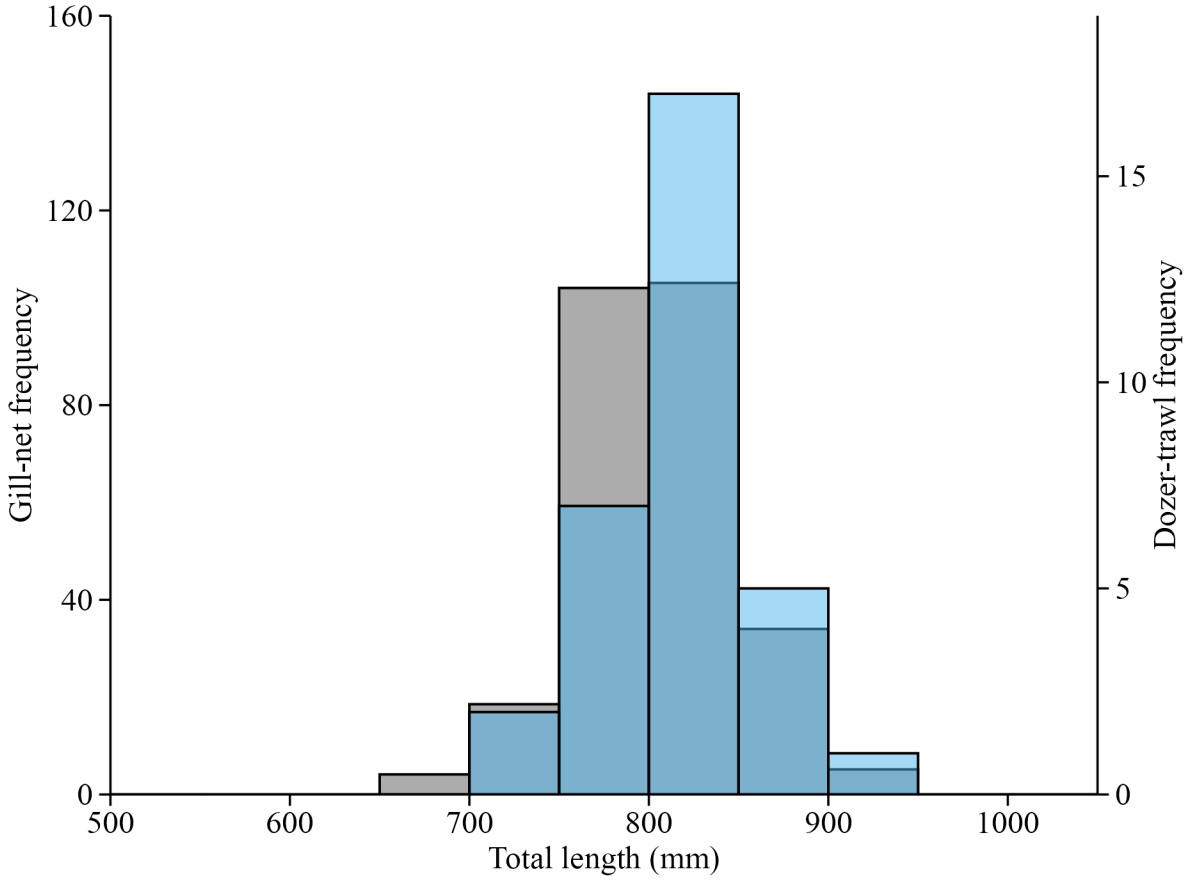
TTU Figure 7. Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Cheatham Reservoir.



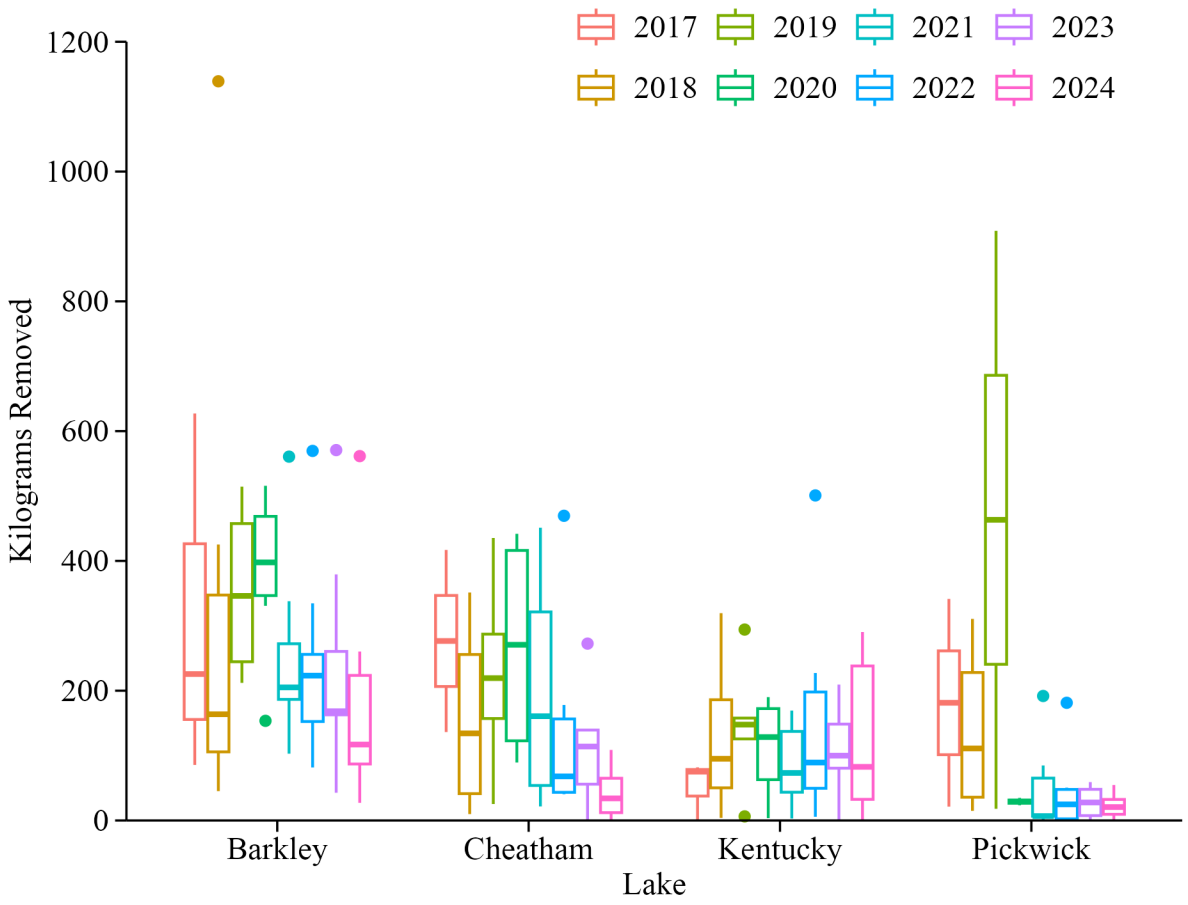
TTU Figure 7 (continued). Length frequency histograms of silver carp captured in overnight gill net sets (dark grey) over eight years—2017–2024— in Cheatham Reservoir.



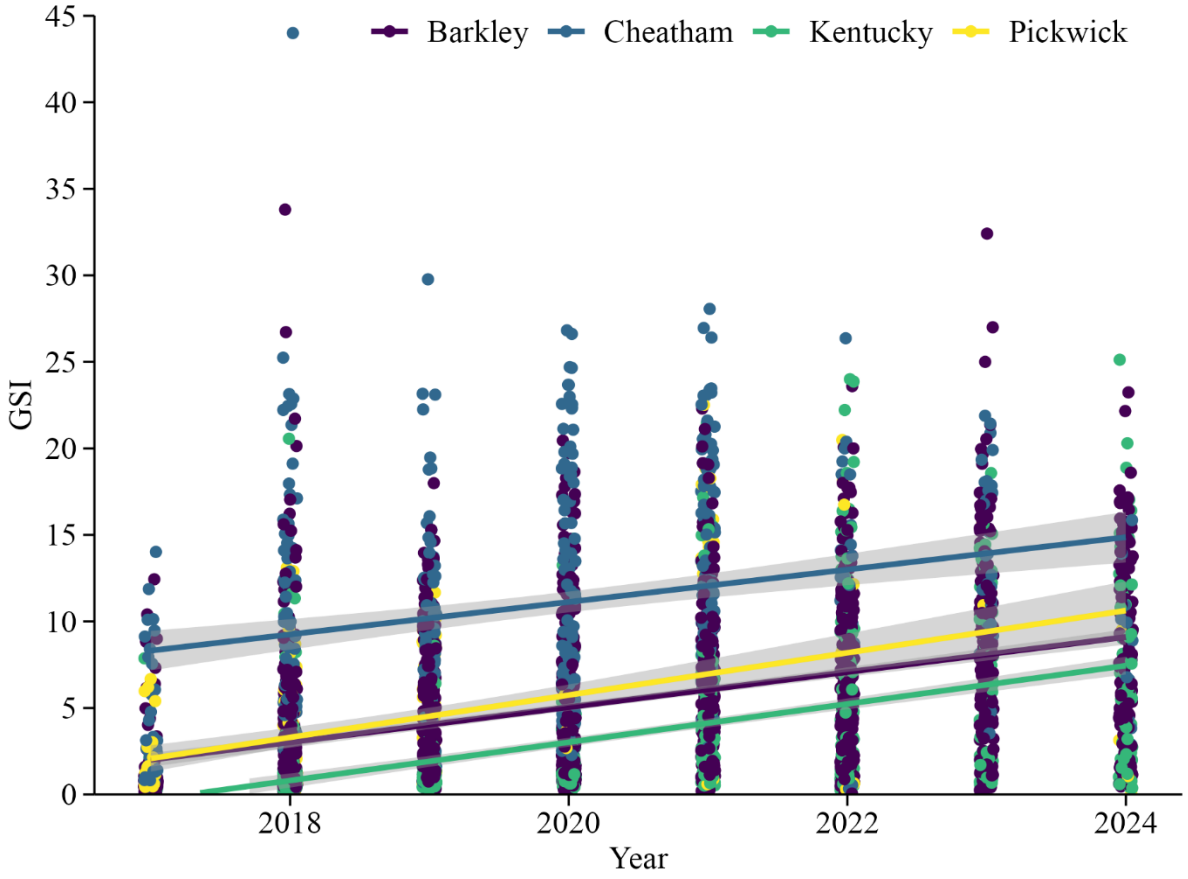
TTU Figure 8. Length frequency distributions of dozer trawls (light blue) and gill nets (grey) in Kentucky Lake during 2024. Bars are translucent to allow overlap to be identified. Note: frequencies of gears are plotted on different scales to allow easier visual comparison of distributions.



TTU Figure 9. Length frequency distributions of dozer trawls (light blue) and gill nets (grey) in Barkley Lake during 2024. Bars are translucent to allow overlap to be identified. Note: frequencies of gears are plotted on different scales to allow easier visual comparison of distributions.



TTU Figure 10. Kilograms of Silver Carp removed per sampling event by year and reservoir. Analysis of covariance found no significant differences among reservoirs, years, nor an interaction between lakes and years.



TTU Figure 11. Regression of gonadosomatic index (GSI) of silver carp by year. Data grouped by reservoir. Area around each line indicates the 95% confidence interval.

ADCNR APPENDIX FIGURES

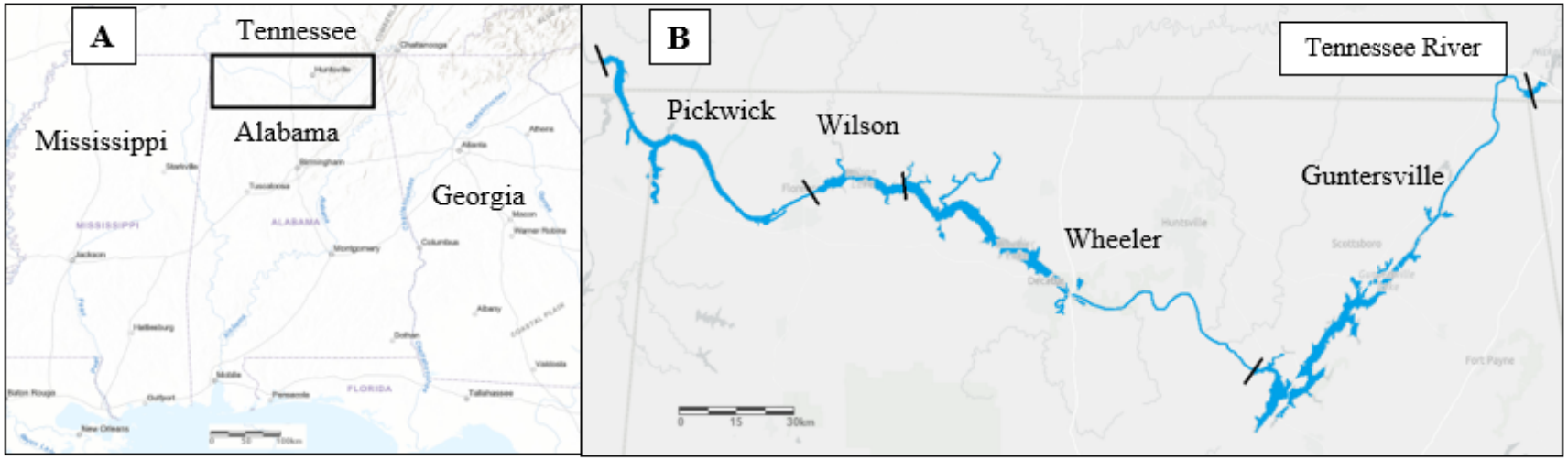


Figure 1. Tennessee River basin in Alabama (A) and relative locations of reservoirs and dams (B) in Alabama and shared state waters.

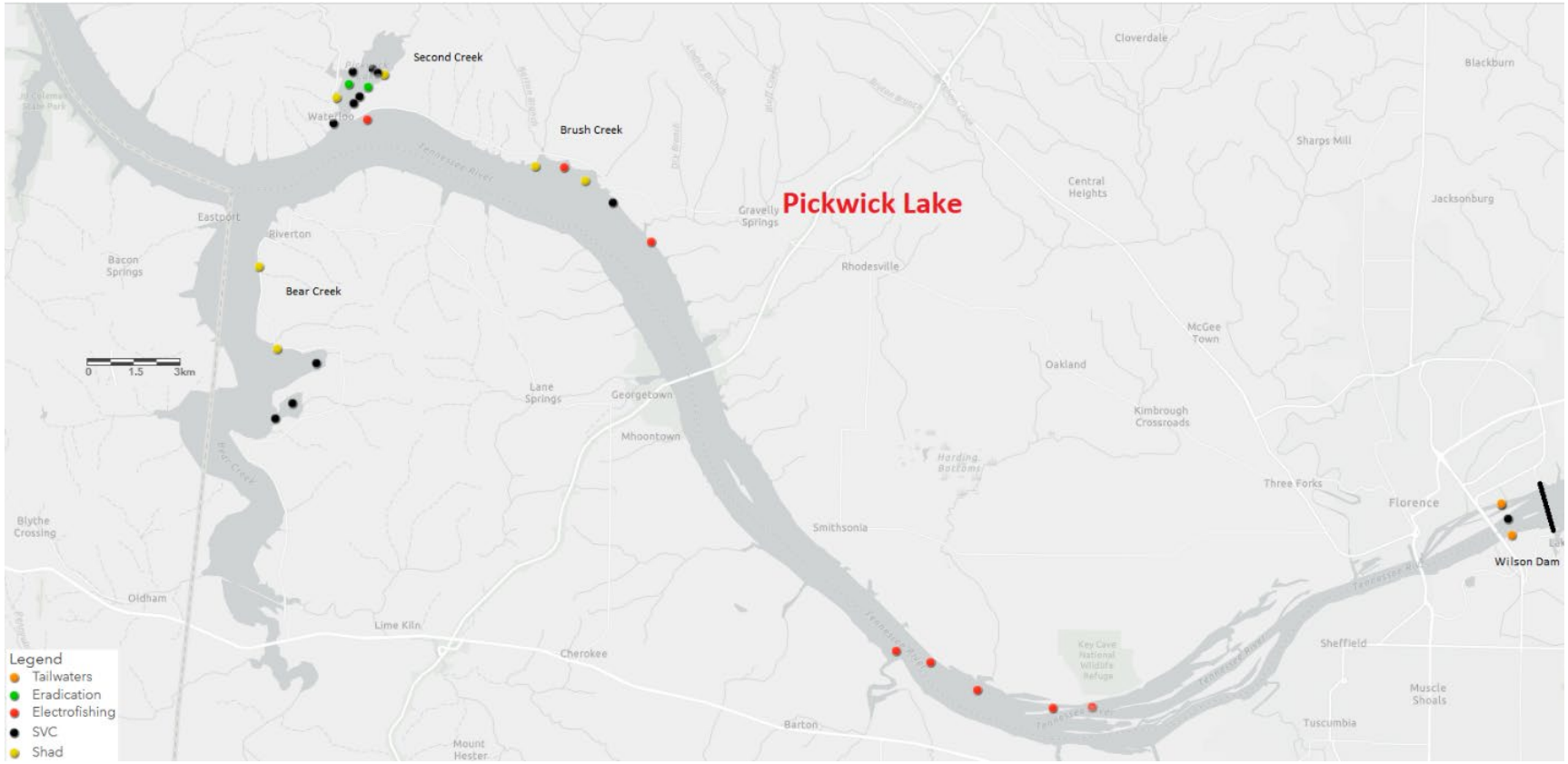


Figure 2. Reservoir sample areas in Pickwick Lake, Tennessee River, Alabama. Locations of 2024 electrofisher sample sites (dots) include standardized, GPS-fixed locations for occupancy (red). Others include carp-shad dozer trawl (yellow), tailwater (orange) transects and gillnet eradication (green) sites. Silver Carp collected or witnessed at sites are denoted by black dots.

Figure 3. Reservoir sample areas in Wilson Lake, Tennessee River, Alabama. Locations of 2024 electrofisher sample sites (dots) include standardized, GPS-fixed location for occupancy (red). multi-boat herding (blue), carp-shad dozer trawl (yellow) and tailwater (orange) transects. Silver Carp collected or witnessed at sites are denoted by black dots.

Table 1. Summary of ADCNR, CY2024 effort and catch data during monitoring and eradication of invasive carp populations in four Tennessee River reservoirs in Alabama. Effort and catch-per-unit (CPUE) data are rounded to nearest whole number; CPUE are rounded to nearest 0.1.

Sample Effort Parameter	**TN River Reservoirs (downstream to upstream)**				
	Pickwick	**Wilson**	**Wheeler**	**Guntersville**	**Row Total or *Mean***
Electrofishing effort					
Estimated person hours	135	126	0	0	**261**
Samples (transects)	120	120	0	0	**240**
Electrofishing hours	10	10	0	0	**20**
Electrofishing catch					
Silver Carp (n)	10	0	0	0	**10**
White amur (n)	0	1	0	0	**1**
CPUE (invasive carp/hr)	1	0.1	0	0	**0.6**
Gill Netting effort					
Estimated person hours	60	80	0	0	**140**
Samples (net sets)	6	6	0	0	**12**
Soak time (hours)	109	105	0	0	**214**
Miles of nets	0.34	0.34	0	0	**0.7**
Gill Netting Catch					
All fish (n)	117	36	0	0	**153**
Fish species (n)	14	10	0	0	**24**
Silver Carp (n)	6	0	0	0	**6**
White amur (n) *	0	0	0	0	**0**
Hybrid carp (n)	0	0	0	0	**0**
CPUE (all fish/net)	19.5	6	0	0	**25.5**
CPUE (invasive carp/net)	1	0	0	0	**1**
Other field work:					
Estimated person hours (dates)		42 (3 dates)		66 (3 dates)	
Target Task		Telemetry receiver download, install, maint.			
Reservoir areas		Wilson Dam		Guntersville Dam	

Table 2. ADCNR standard sample efforts and catch rates, CY 2020 - 2024 at three Alabama reservoirs in the Tennessee River. Invasive carp species captured by gill nets and boat EF gears include Silver Carp (SVC) and White Amur (WAM).

	Gill net				Boat or Dozer trawl electrofisher			
CY *	Carp catch (n)	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
2024	17	12	214	0.50	12	240	20	0.55

* 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.

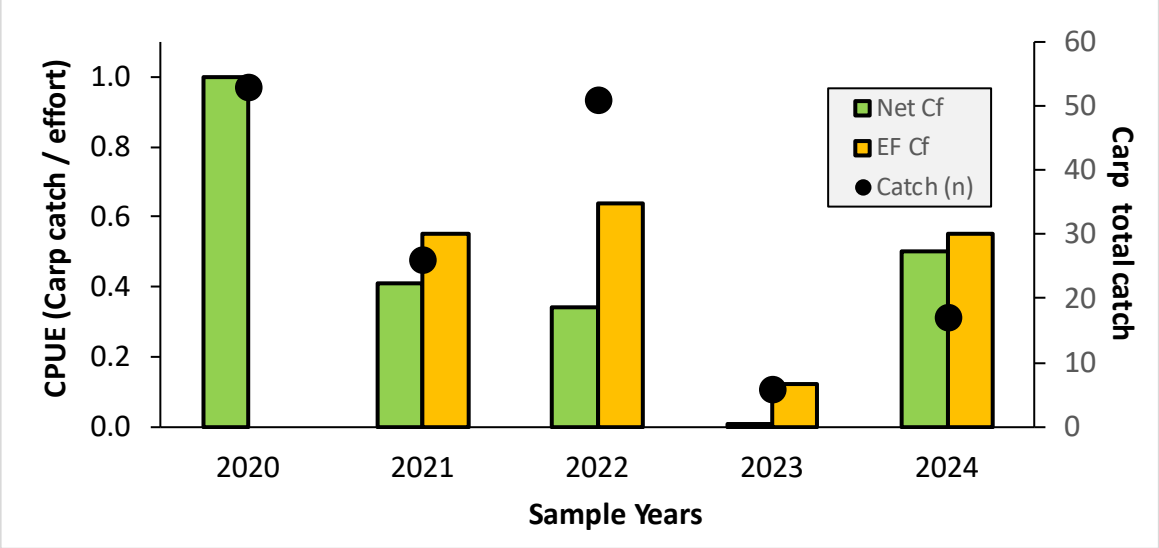


Figure 4. Sample effort by ADCNR staff (electrofishing days; gillnet sets) in three Alabama reservoirs on the Tennessee River, CY2020 through 2024. Black dots show total catch (n) of invasive carp (Silver and Grass Carp) for captured and sighted fish.

Recommendation:

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 monitoring for evidence of invasive carp recruitment.
- Continue to implement the Tennessee Carp Harvest Incentive Program.
- Continue efforts to estimate exploitation and better understand the impact of removal efforts.

ADCNR

Currently, we do not feel a need for expansion of new studies or actions outside of expanding our current sampling regime. Planning for 2025 includes expansion of new sample areas and establishment of additional sites in Wheeler Reservoir. Future strategy will continue with occupancy sampling and reservoir sample frequency will be reduced, sampling 25-33% (n=1 reservoir every 3 or 4 years) among each of four Tennessee River reservoirs annually, each as a meaningful management unit. 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.

References:

ADCNR. 2023. Invasive Carp Monitoring Plan in Alabama Waters of Tennessee River Reservoirs. Draft report (January 3, 2023), 10 pp.

Belanger, Miranda. 2023. Silver Carp *Hypophthalmichthys molitrix* movements in the Lower Cumberland and Lower Tennessee River. Master Thesis. Murray State University. https://digitalcommons.murraystate.edu/etd/314/

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. Invasive Carp Working Group, Aquatic Nuisance Species Task Force, Washington, D.C. 223 pp. Available from: https://www.Invasivecarp.us/Documents/Carps_Management_Plan.pdf

DeGrandchamp, K.L., J.E. Garvey, J.E. Colombo. 2008. Movement and habitat selection by invasive carps in a large river. Transactions of the American Fisheries Society 137: 45–56.

Fernholz, S. 2018. Relative densities, population characteristics, and sampling efficiency of bighead and silver carp in reservoirs of the Tennessee River and Cumberland River. M. S. Thesis, Tennessee Tech University, Cookeville, TN.

Gutreuter, S., R. Burkhardt, and K. Lubinski. 1995. Long term resource monitoring program procedures: fish monitoring. Onalaska, Wisconsin.

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 Invasive carps in the Illinois River, U.S.A. Is this evidence for competition and reduced fitness? Journal of Fish Biology 71:258-273.

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.

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.

McNamara, R., D. P. Coulter, D. C. Glover, A. E. Lubejko and J. E. Garvey. 2018. Acoustically derived habitat associations of sympatric invasive bigheaded carps in a large river ecosystem. River Research Applications 2018:1–10.

Miranda, L. E. S. 2009. Standardizing electrofishing power for boat electrofishing. In S. Bonar, W. Hubert, A. Hubert, & D. Willis (Eds.), *Standard methods for sampling North American freshwater fishes*. Bethesda, MD: American Fisheries Society.

Ohio River Basin Invasive Carp Control Strategy Framework. Ohio River Fisheries Management Team, October 24, 2014. http://www.micrarivers.org.php7-35.lan3-1.websitetestlink.com/wp-content/uploads/2018/08/ORFMT_Invasive_Carp_Strategy.pdf

Padgett, Ashley N. 2021. Lower Food Web Selectivity by Bigheaded Carp in Southeastern Reservoirs. Master's Thesis. Tennessee Technological University, Cookeville, Tennessee

Quist, M.C., K.G. Gerow, O.R. Bower and W.A. Hubert. 2006. Random versus fixed-site sampling when monitoring relative abundance of fishes in headwater streams of the upper Colorado River Basin. North American Journal of Fisheries Management 26:1011-1019.

Ratcliff, E. N., E. J. Gittinger, T. M. O'Hara, and B. S. Ickes. 2014. Long Term Resource Monitoring Program Procedures: Fish Monitoring, 2nd edition. A Program Report submitted to the U.S. Army Corps of Engineers' Upper Mississippi River Restoration Environmental Management Program. June 2014. Program Report LTRMP 2014-P001. 88 pp. including Appendixes A–G.

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.

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.

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.

Sullivan, C.J., M.J. Weber, C.L. Pierce, and C.A. Camacho. 2018. Influence of river discharge on Grass Carp occupancy dynamics in south-eastern Iowa rivers. River Research and Applications 35:60-67.

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

USFWS (U.S. Fish and Wildlife Service). 2016. Annual summary of activities and expenditures to manage the threat of Asian Carp in the Upper Mississippi and Ohio river basins. Available: https://www.asiancarp.us/Documents/WRRDA2016.pdf (October 2018).

Wege, G. W. and R. O. Anderson. 1978. Relative weight (Wr): A new index of condition for largemouth bass. In G. D. Novinger and J. G. Dillard (Eds.), *New approaches to the management of small impoundments* (pp. 79–91). Bethesda, MD: North Central Division American Fisheries Society.