Commonwealth of Kentucky

Water Resources Development Act
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01 December 2023

ANNUAL PERFORMANCE REPORT

for

Invasive Carp Research and Monitoring

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Table of Contents

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

Geographic Location: Tennessee and Cumberland rivers.

Project Objectives:

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

Project Highlights:

KDFWR

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

Methods:

KDFWR

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

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

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

During fall sampling, pectoral fin rays and otoliths were extracted from approximately 100 silver carp from each reservoir for aging or at least 20 per centimeter group. These invasive carp were collected during Paupier sampling, electrofishing, and active gill netting efforts conducted by KDFWR staff. Demographics data may also be collected from invasive carp captured through other KDFWR sampling efforts and included for analyses.

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

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

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

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

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

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

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

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

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

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

Results and Discussion:

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

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

<u>Paupier</u>

U.S. Fish and Wildlife Service sampled Kentucky Reservoir with their electrified Paupier net boat during the fall of 2023. Lengths and weights were collected for all species until N=30 per species and then counted. If a transect concluded with a species count over ~500, they were subsampled and counted by weight. The electrified Paupier sampling observed a silver carp CPUE (fish/hr) of 36 in Big Bear embayment, which was a significant decrease from previous years (Table 22). A significant drop in CPUE was observed in Pisgah from previous catch rates (Appendix B, Figure 2.). This trend data continues to support the hypothesis that the silver carp population in Kentucky reservoir is declining. According to the data in the 2023 USFWS Kentucky reservoir report "silver carp catch rates have decreased by approximately half during each sampling year" (Appendix B). Data from the Paupier sampling, compare to gill netting, theoretically creates less sampling bias and therefore a better fitting regression line when looking at Log10 transformed lengths and weights for silver carp; Kentucky Reservoir R^2=0.71 whereas Barkley reservoir R^2=0.60 (Figure 7 & 8).

ICHP

Length and weight data was collected on 1040 silver carp harvested by commercial fishers in 2023. Silver carp lengths ranged from 23.8 – 40.4 inches with an average of 31.4 inches, and weights ranged from 7.4– 33.3 lbs with an average of 13.0 lbs (Table 18). If this metric is used in correlation with the total pounds of silver carp harvested by commercial fishers through the ICHP in 2023, that would produce a rough estimate of 711,561 individual silver carp being removed from Kentucky waters through the ICHP in 2023 (9,275,293 lbs; Table 2). During ride-alongs, commercial fishers were observed using gill nets with a range of bar mesh sizes to target invasive carp (3.5” – 4.5” bar mesh; Table 19, Figure 14). Catch per unit effort of gill nets used to harvest silver carp were highest in gill nets with a bar mesh size of 3.75 (0.92 fish/yard), followed by 4” bar mesh which had a CPUE of 0.6 fish/yard. This has remained consistent with 2022 data and shows an increase from the previous three years (2019 - 2021) when the highest CPUE was in 3.25” and 3.5” bar mesh nets. There has been a change in the size gill net mesh commercial fishers are using in Barkley and Kentucky Reservoirs, this is likely due to the 2015 cohort of fish being recruited to the bigger size mesh.

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

Mark-Recapture

From October 2018 through February 2024, KDFWR received 50 tag returns from commercial fishing efforts. Forty came from Barkley reservoir and ten from Kentucky reservoir (Figure 9). Nine other tags have been returned from bowfishers, government agencies, or found along the riverbanks. Twelve of the returned fish were double tagged. The higher frequency of returned fish from Barkley reservoir compared to Kentucky reservoir is not surprising given most of the commercial fishing pressure occurs on Barkley (Reported under Objective 3). Data analysis is in progress with the assistance of the USGS CERC staff and a report is expected in 2024. Preliminary model results suggest high survival in both reservoirs in the first four years after tagging, followed by a large decrease in survival after four years (Figure. 16).

Barkley and Kentucky Reservoir Population Dynamics

A length-frequency histogram was created for silver carp harvested from Barkley and Kentucky Reservoirs from all harvest methods in 2023. Data suggested the 700mm size class of silver carp was dominant in both systems (Figures 1 & 2).

Age and Growth

Pectoral fin rays were collected from silver carp in Barkley and Kentucky Reservoirs in the fall of 2023 for aging. Barkley ages ranged from 4 to 10 years old, with age 6 being the most abundant. Kentucky ages ranged from 3 to 11 years old, with age 7 being the most abundant, (Figures 3 & 4). Data suggests a strong presence of three cohorts of silver carp behind the 2015 cohort (8-year-old fish). Since no age-0 silver carp have been collected in either reservoir since 2015, logic suggests that these fish continue to immigrate into the reservoirs through the lock systems.

Mortality

Catch-curve regressions were developed for the 2015 cohort of silver carp by lake. This cohort of silver carp is the only documented cohort known to occupy the lakes at age 0. Data for age frequencies were ln(x+1) transformed to compensate for heteroscedasticity. A Chapman-Robson analysis was performed to estimate annual mortality (Â) and instantaneous mortality (Z). Annual mortality for silver carp from Kentucky Reservoir was estimated at 36% and instantaneous mortality was estimated at 0.45 (N=240, $F_{1,2}$=46.62.40, P=0.002, R^2=0.92; Figure 5). Annual mortality for silver carp from Barkley Reservoir was estimated at 45% and instantaneous mortality was estimated at 0.60 (N= 205, $F_{1,2}$=11.92, P=0.03, R^2=0.74; Figure 6). Estimates of annual mortality in 2023 decreased from the vales reported in 2022. This is attributed to the wider time series of data for this cohort informing better model predictions.

Condition

Linear regressions were constructed to describe the log10 length-log10 weight relationship for silver carp in Barkley and Kentucky Reservoirs. The length-weight equation for Kentucky was estimated at Log10(weight(g)) = 2.769Log10(length(mm)) – 4.2843(Figure 7). The length-weight equation for Barkley was estimated at Log10(weight(g)) = 2.2971Log10(length(mm)) – 2.893 (Figure 8). Weights were predicted for Barkley Reservoir: 450mm (1590g), 650mm (3700g) and 800mm (5962g) and Kentucky Reservoir: 450mm (1155g), 650mm (3196g) and 800mm (5680g) (Table 1). Predicted weights remain higher for Barkley than for Kentucky and both reservoirs indicate that all length classes are predicted to weigh more than previous years.
Data collected from sampling in the fall (September through December) of 2023 was used to analyze relative weights (Wr). Relative weight was calculated using the equation Log10(Ws)= -5.15756 + 3.06842(Log10TL) for silver carp (Lamer 2015). The mean Wr for silver carp in Barkley Reservoir was 102 (N=439, S.E.=±0.5) and the mean Wr for silver carp in Kentucky Reservoir was 100 (N=374, S.E.=±0.5). These values are consistent with data collected from previous years.

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

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

Belanger also found silver carp in the Lower Cumberland River had a higher year-round relative activity index, when compared to silver carp in the Lower Tennessee River. The Lower

Tennessee River silver carp only had high RAI values during the summer. Belanger concluded that silver carp river kilometer has no significant relationship with temperature in either river. Temperature and discharge alone do not seem to be good predicators for silver carp movement behaviors even with two similar geographic and hydrologic systems.

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

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

<u>Invasive Carp Incentivized Fishing Program in Barkley and Kentucky Reservoirs</u>

Interest and participation in the KDFWR contract fishing program for invasive carp has varied greatly since it began in 2016. However, in 2019, refinements were made to the program and the number of fishers targeting invasive carp in Barkley and Kentucky Reservoirs increased, which heightened participation in the program. In 2023, contractors received $766,707.44 for invasive carp harvested from Barkley and Kentucky Reservoirs. This equates to over 9 million pounds of invasive carp harvested through the contract program in 2023, the largest harvest to date (Figure 10). Refinements to the program were made in 2021 which removed the varying pay out based on size of fish harvested. As of January 2024, the program now pays contractors $0.10 / lb for invasive carp harvested from Kentucky waters of the reservoirs regardless of the size of those fish.

<u>Carp Harvest Program Monitoring</u>

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

Since 2013, commercial fishers in Kentucky have harvested a total of 59,114,613 lbs of invasive carp, the majority was harvested through the ICHP (43,091,836 lbs silver carp, 286,890lbs bighead carp, 314,392lbs grass carp [2020-2023 only]; Table 2). Total harvest would be higher if grass carp were included for all years, however commercial fishing reports prior to 2020 did not delineate grass carp from common carp. Most invasive carp harvested in Kentucky are from Barkley Reservoir (Table 2). Commercial fishers typically prefer fishing Barkley Reservoir over Kentucky Reservoir as it is shallower, has more habitat to corral fish, less recreational traffic, and the fishers believe the silver carp are larger. From 2020 to 2023 there was a decrease in number of individual commercial fishers in Barkley Reservoir, but an increase in harvest, and from 2022 to 2023 there was an increase of almost 200 trips made on Barkley Reservoir as well as an increase in over 1.7 million lbs of carp removed, which indicates that commercial fishers are getting more efficient at removal. The amount of harvest of invasive carp from Kentucky Reservoir mirrored the decrease from 2021 to 2022 in 2023 but the number of individual fishers and trips increases from 2022 to 2023. (Table 2). The number of commercial fishers in Kentucky and associated trips under the ICHP program has varied annually. A decrease in fishing effort (numbers of trips) and invasive carp harvest in 2015 and 2017 was due to inconsistent market demands. Even though there was an increase in harvest from Barkley Reservoir and the Ohio River, statewide we saw a decrease in invasive carp harvest, this was likely due to losing commercial fishers to other states offering incentive programs (Table 2 & Figure 10). Factors affecting the increased efficiency are likely a combination of the 2015 cohort strength and improved commercial practices. Commercial fishers' adaptation in net sizes during the past several years helped facilitate the 2023 harvest as well as improvements to equipment such as boats, trucks, net rollers, cranes, and electronics. KDFWR's industrial flake ice machine was out of order for most of 2023 due to ongoing mechanical issues. The equipment is being evaluated for decommissioning and alternative mechanisms for industry support are being considered.

Invasive carp harvest data was summarized by month from January 2015 to December 2023 (Figures 11 & 12). Historically, the number of trips made by commercial fishers under the ICHP decreased during paddlefish season (November-March) and increased again when paddlefish season ended (Figure 11). This shift was expected as many commercial fishers fish Barkley and Kentucky Reservoirs, with a special net permit during paddlefish season, which allows gill netting in the lakes without fishing under the ICHP. However, this is no longer observed since commercial fishers are now targeting invasive carp year-round and are allowed to receive funds through the contract program administered by KDFWR for invasive carp harvested while fishing on their net permit. The highest number of commercial fishing trips recorded in a single month was 302 in January 2020; in 2021, number of trips was more standard across the months, whereas 2022 saw a lot of seasonal differences which has been mirrored in 2023 (Figure 11). Average total pounds of silver carp harvested per trip increased from 2022 and ranged from 2,919 – 6,124 pounds per month in 2023 (Figure 12).

Water conditions routinely affect invasive carp harvest rates, but seasonality is also a factor. KDFWR and MSU telemetry studies indicate that movement rates of silver carp increase in water temperatures between 61.5 ^{o}F and 86.0 ^{o}F (USFWS 2020). Fish become more active with rising water temperatures in the spring, and they become less susceptible to harvest when moving to the main channels from embayments. Commercial harvest rates also vary among fishers. The most successful fishers understand silver carp behavior better, and they use higher quality gear with larger boats that have higher weight capacities. In 2023, the average number of pounds harvested per trip was calculated for all ICHP fishers (N=35), and average pounds of silver carp harvested varied from 429 lbs/trip to 9,018 lbs/trip. Interestingly, not all fishermen with high catch rates fished frequently (Figure 13). The number of trips a commercial fisherman took in 2023 varied from 3 to 196, with an average of 61 trips. This only included the number of trips where harvest occurred. In 2023, 91% of the requests to fish ended with fish harvested. Some fishermen call in for whole weeks at a time, but may not go out every day, some cancelations were due to weather or equipment being down, other times, a fisherman may go out to gill net, scan around and not find a school of fish big enough to set their net on.

<u>Ride-Alongs</u>

KDFWR conducted 61 ride-alongs with 18 unique commercial fishers utilizing the ICHP January through December 2023 (Table 20 & Figure 15). During ride-alongs 34,010 yards of gill net were fished and 276,658 lbs of invasive carp were harvested. Most of the fishing effort observed during ride-alongs was on Barkley Reservoir(N=51), which is like fishing effort in general. Ride-alongs were also conducted in Kentucky Reservoir(N=10). Commercial fishers set nets primarily along secondary channels, on flats on the main lake, and in embayments. In previous years, the northern end of Barkley Reservoir received the most fishing pressure. However, in 2021 through 2023, fishing pressure observed through ride-alongs was more evenly distributed throughout Barkley and Kentucky Reservoirs (Figure 15). The mean effort per trip (yards of net fished) decreased in 2022 and 2023 compared to all previous years, which is reflective of the changing strategies that commercial fishers are employing to catch silver carp (active setting vs. dead setting nets) (Table 5). Average total weight of silver carp harvested per trip during ride-alongs in 2023 (4,491 lbs) was higher than 2022 (Table 6). There have been multiple instances were KDFWR observed during a ride along that a commercial fisher scanned with side scan technology and ended up not setting a net because they couldn't find a big enough school of invasive carp. This occurred on three occasions during 2021, six times during 2022, and nine times during 2023. KDFWR has begun to monitor zero net set trips and search time as a fisheries dependent trend to inform invasive carp stock assessments.

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

KDFWR staff continued to monitor seining practices under the current experimental gears program to determine efficacy in Kentucky waterways for removal of invasive carp and to determine the lasting impact on non-target fish species. Robbins Construction LTD harvested approximately 463,440 lbs of invasive carp from Barkley and Kentucky Reservoirs in 2023 with an average of 17,825 lbs/day which decreased from his 2022 average of 20,039 lbs/day. Additionally, Robbins harvested 831,206 lbs (20,273 lbs/day) of silver carp from the Cumberland River. >99% of the invasive carp harvested were silver carp and <1% were grass carp. Sport fish bycatch and other fish species that were not harvested were observed to have an 100% survival rate at the time of release.

While outside the scope of this report, it is worth noting that Robbins Construction LTD also harvested 597,482lbs (16,597 lbs/day) of silver carp from the Ohio River in 2023 through the contracted experimental efforts. Robbins seining in Kentucky waters yielded him a total of 1,691,614 lbs silver carp and an average of 16,423 lbs silver carp per day in 2023. His gill netting in Kentucky waters yielded him a total of 192,322 lbs of silver carp and an average of 8,362 lbs silver carp per day in 2023. His daily average while gill netting is 51% of what his daily average is while seining. This reaffirms the need to continue developing innovative approaches of harvest invasive carp in Kentucky waters.

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

Fish tagging is planned for the spring of 2024.

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.

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Appendix A:

KDFWR Figures and Tables:

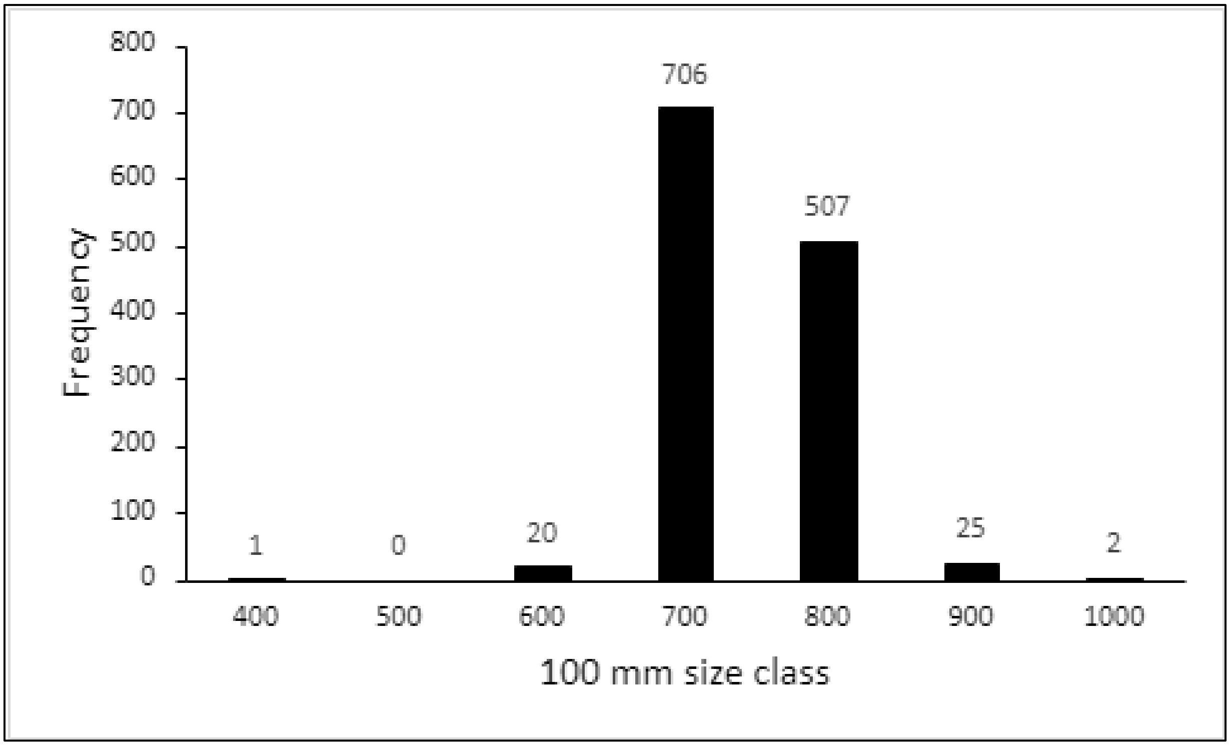

Figure. 1 Length-frequency distribution of silver carp collected from Barkley Reservoir, from all methods in 2023 (N=1261)

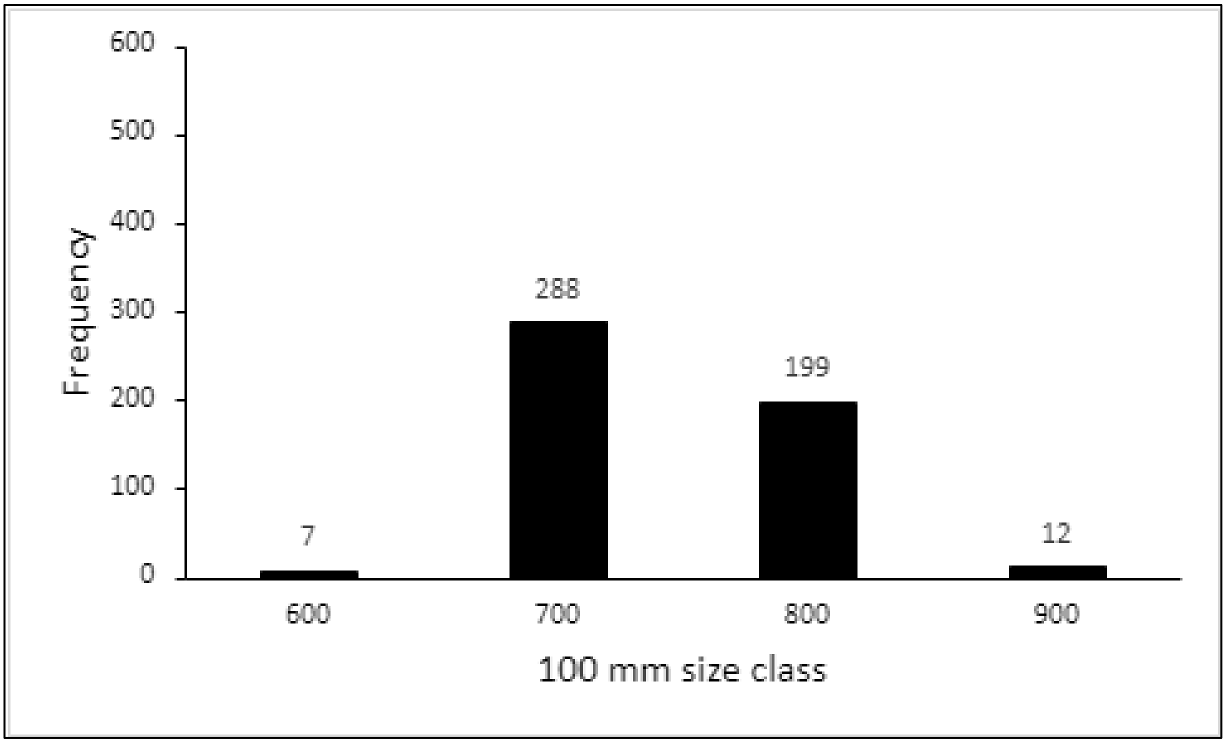

Figure 2. Length-frequency distribution of silver carp collected from Kentucky Reservoir, from all methods in 2023 (N=506).

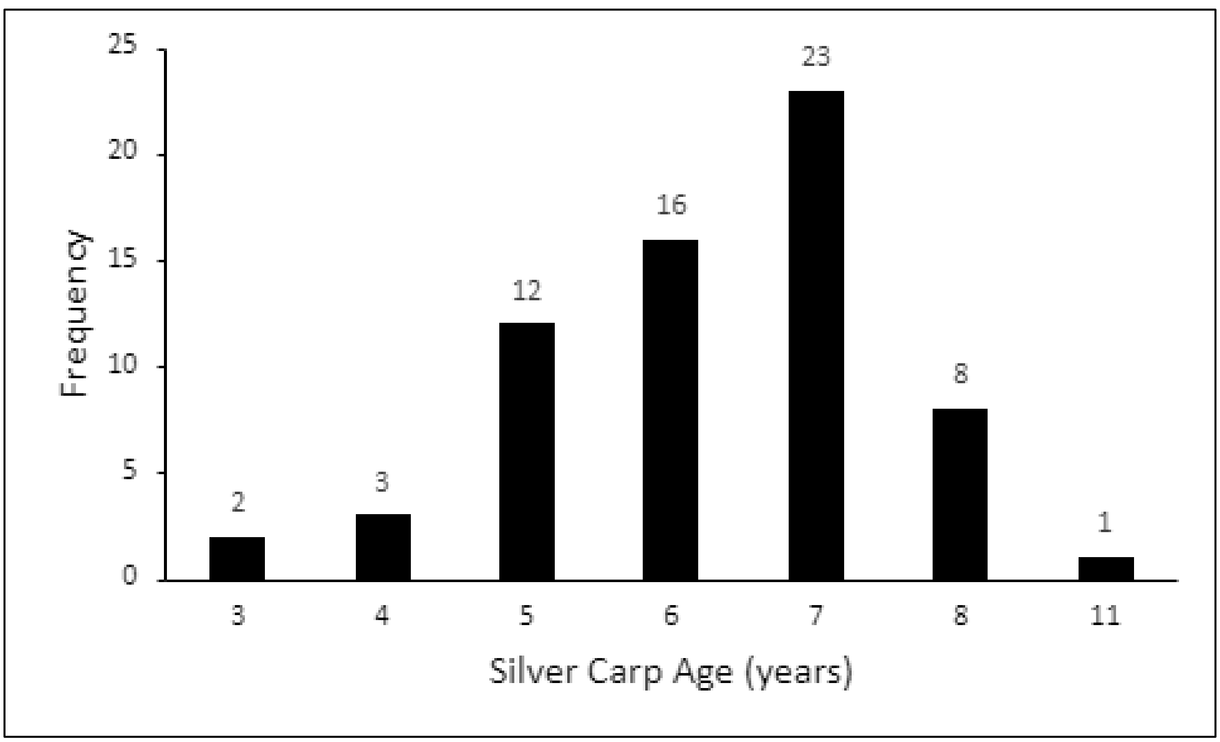

Figure 3. Age-frequency distribution for silver carp collected from Kentucky Reservoir in 2023 (N=65)

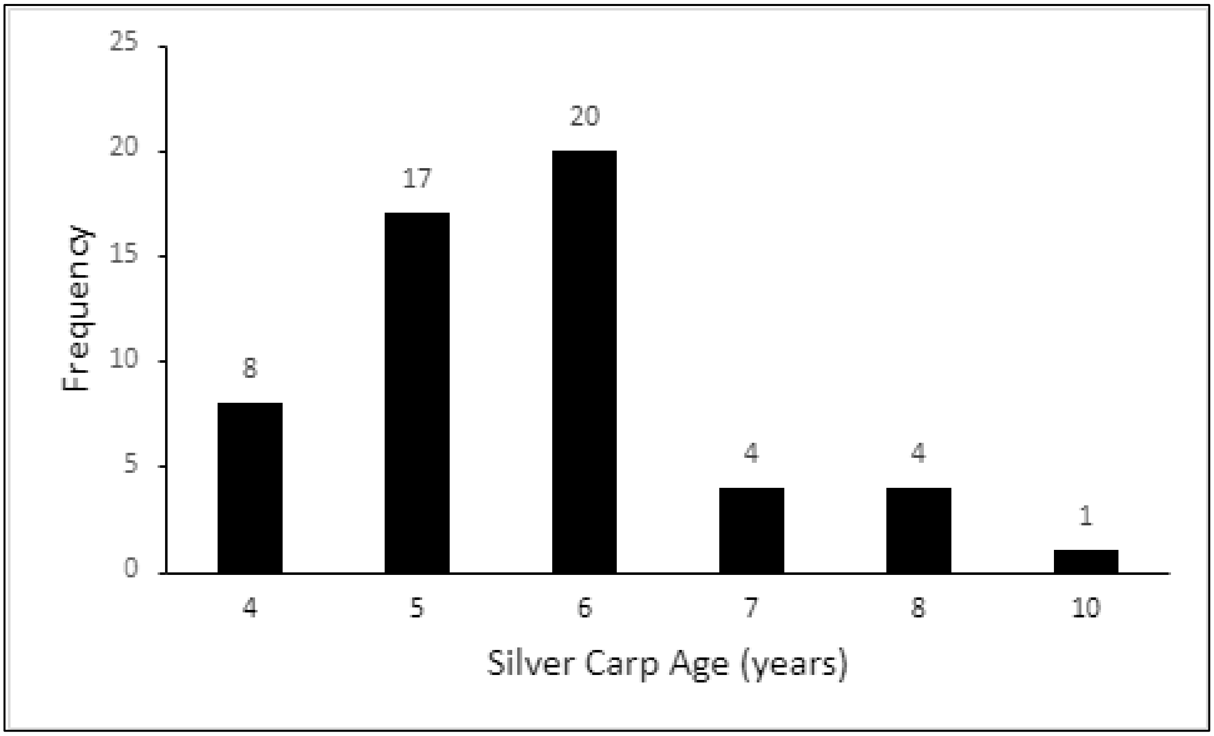

Figure 4. Age-frequency distribution for silver carp collected from Barkley Reservoir in 2023 (N=54).

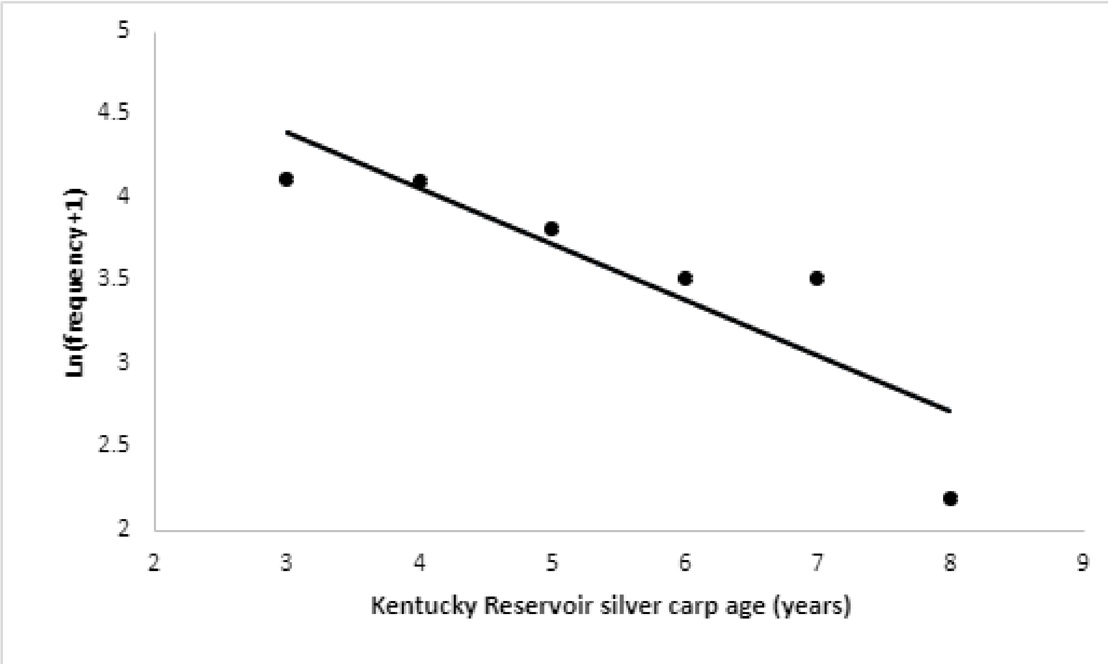

Figure 5. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Kentucky Reservoir in 2023 (N=240, F1,2=46.62, P=0.002, R2=0.92).

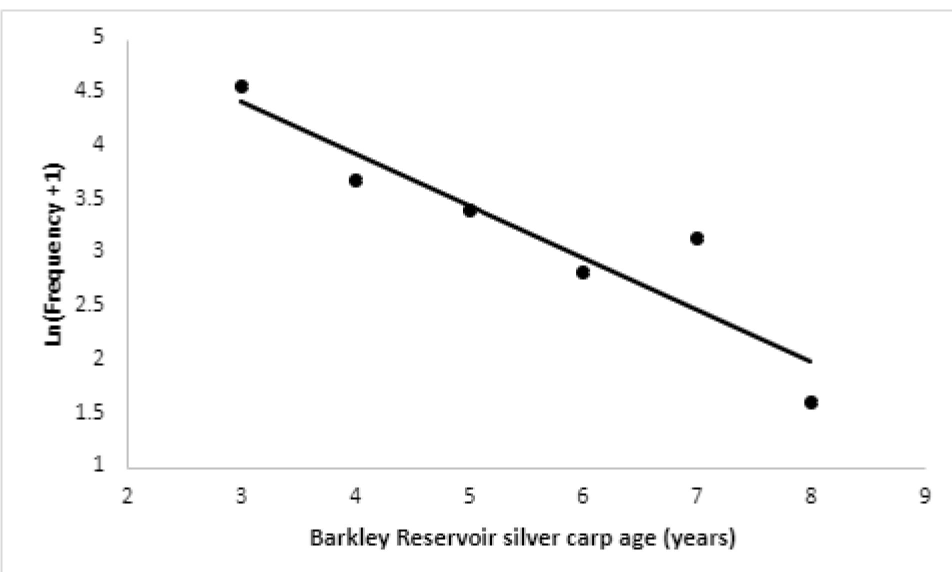

Figure 6. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Barkley Reservoir in 2023 (N=205, F1,2=11.92, P=0.03, R2= 0.74).

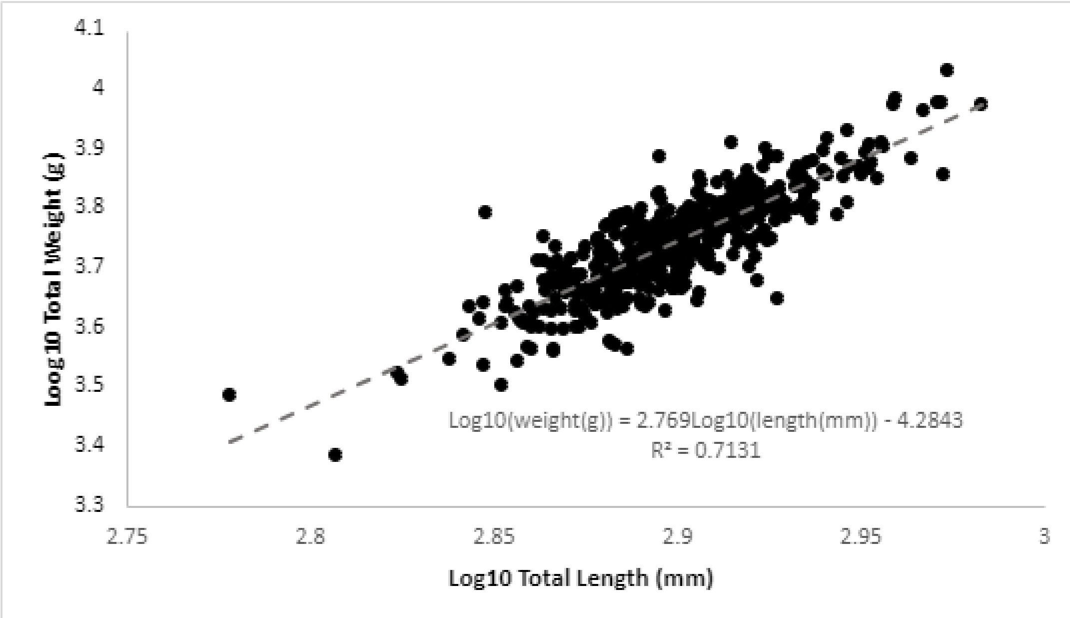

Figure 7. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Kentucky Reservoir in 2023 with a regression line describing the relationship between lengths and weights (N=505).

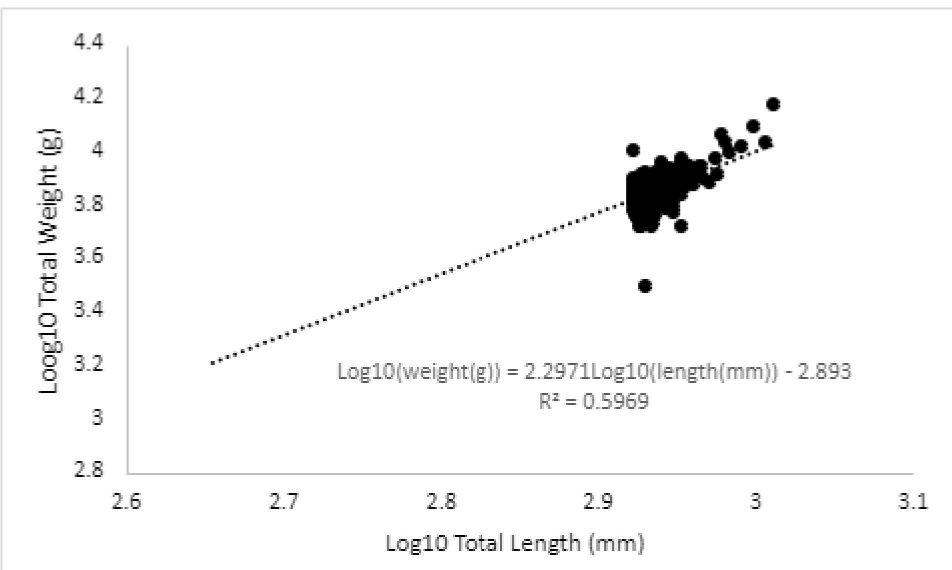

Figure 8. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Barkley Reservoir in 2023 with a regression line describing the relationship between lengths and weights (N=1201).

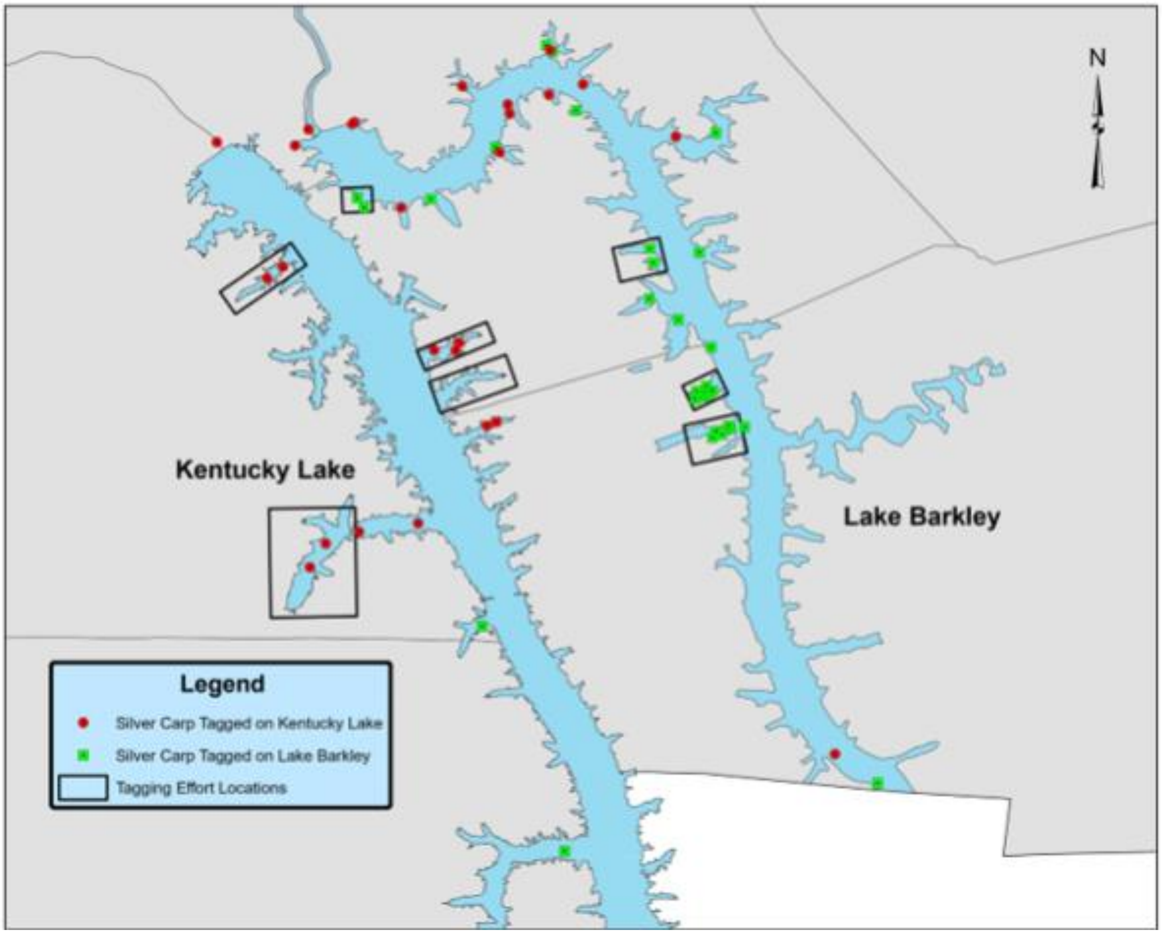

Figure 9. Locations of recaptured silver carp that were tagged as part of the mark-recapture effort to estimate abundance of silver carp in Barkley and Kentucky Reservoirs from October 2018- February 2024. (Two recaptured fish not displayed, one was captured in Hovey Lake, IN, other in Green River, KY)

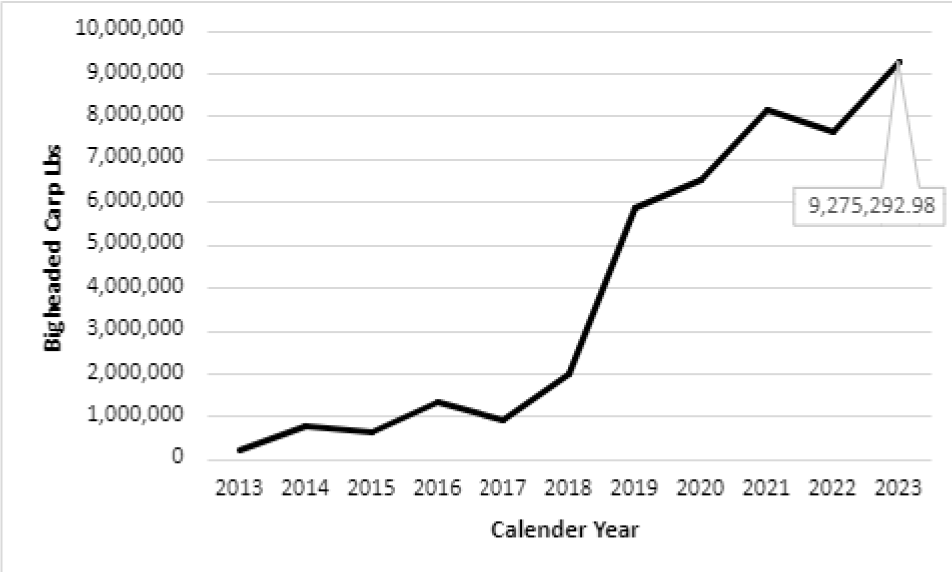

Figure 10. Pounds of bigheaded carp harvested through the Invasive Carp Harvest Program by calendar year. *2020 was the first year that grass carp harvest was tracked through the ICHP and accounted for an additional 111,190 lbs in 2020, 74,430 lbs in 2021, 55,805 lbs in 2022, and 72,967 lbs in2023.

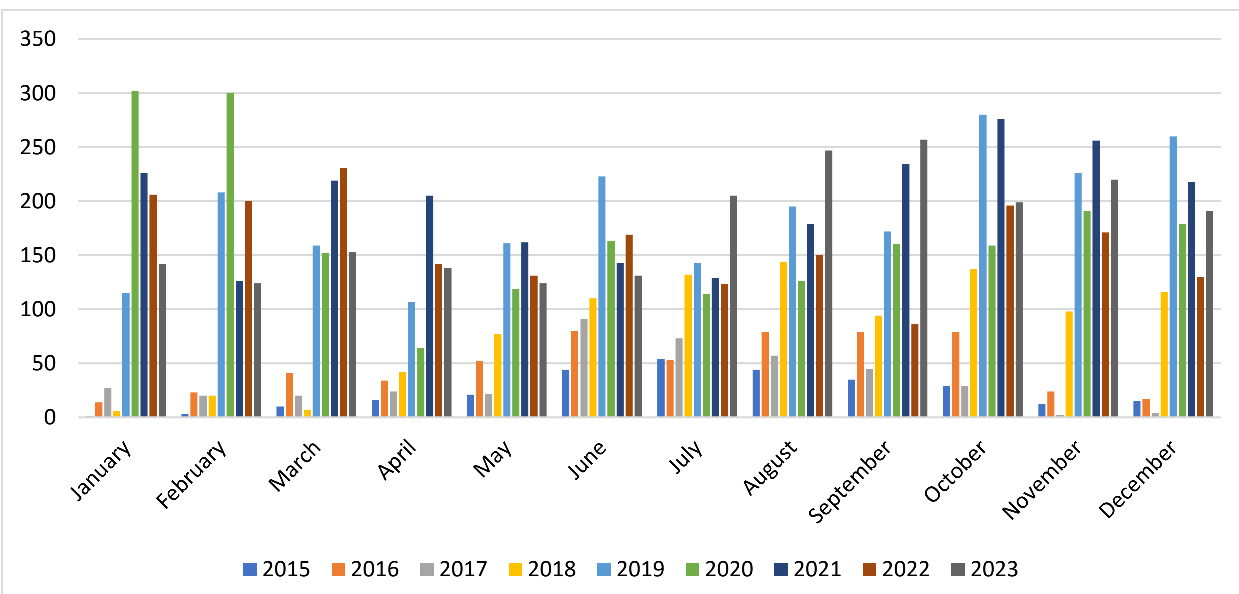

Figure 11. Number of fishing trips made monthly by commercial fishers fishing under the Invasive Carp Harvest Program from January 2015 - December 2023.

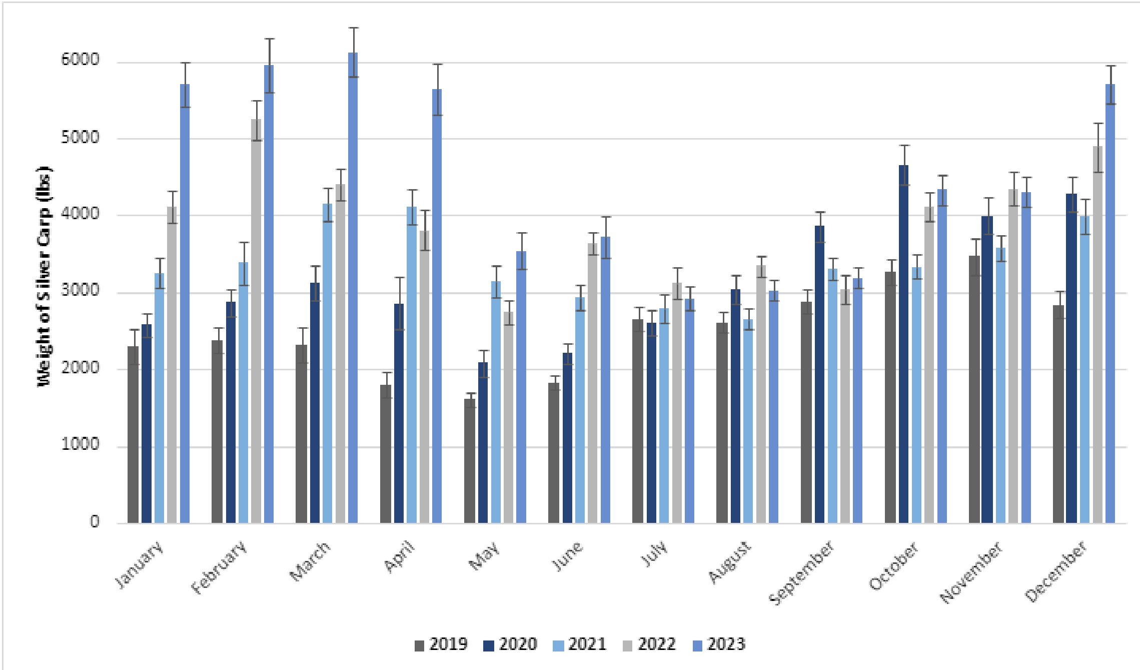

Figure 12. Monthly average total weight (lbs) of silver carp harvested per trip by commercial fishers fishing under the Invasive Carp Harvest Program January 2019 - December 2023. Error bars represent standard error values.

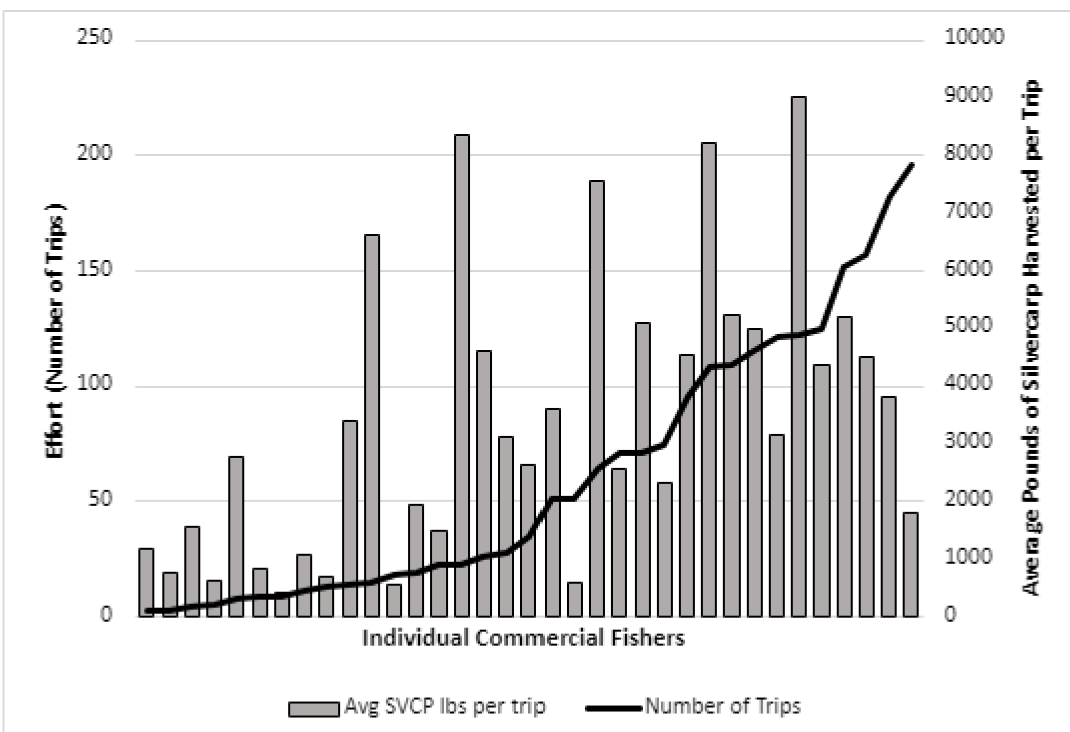

Figure 13. Average silver carp weight harvested per trip by individual commercial fishers compared to the number of trips taken by those fishers under the Invasive Carp Harvest Program in 2022.

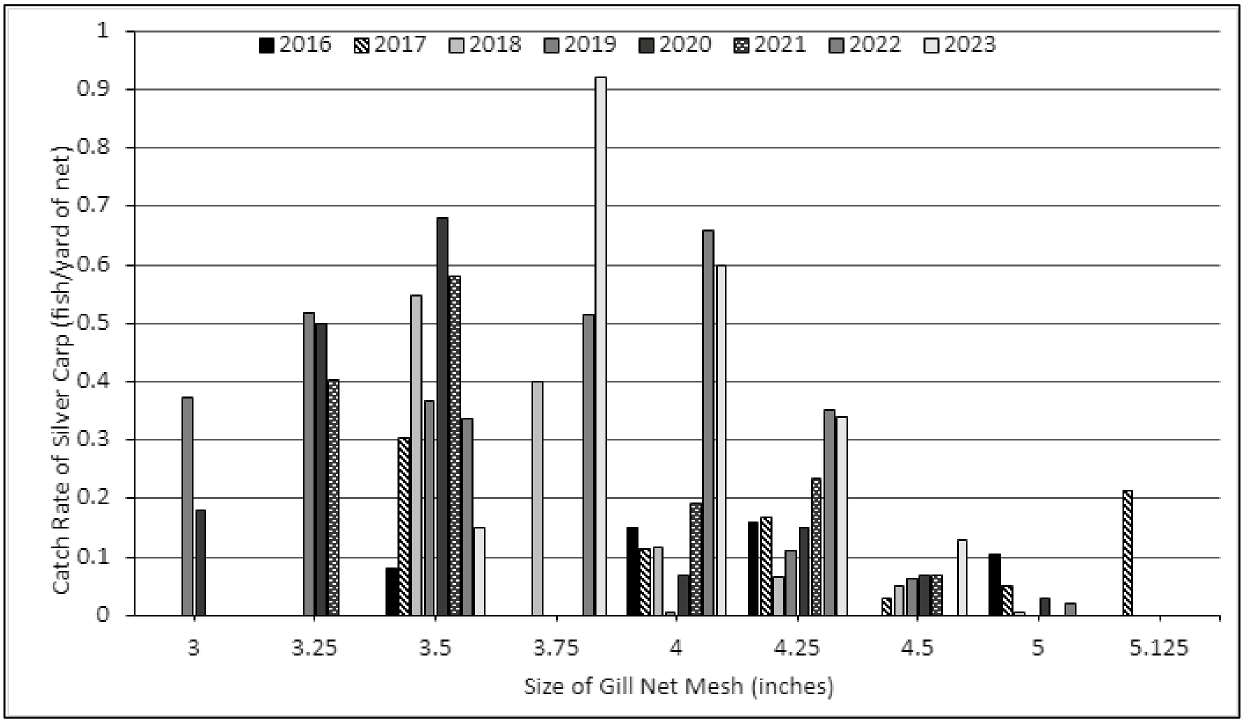

Figure 14. Catch rates (number of fish/yard of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Invasive Carp Harvest Program per year from 2016 through 2023.

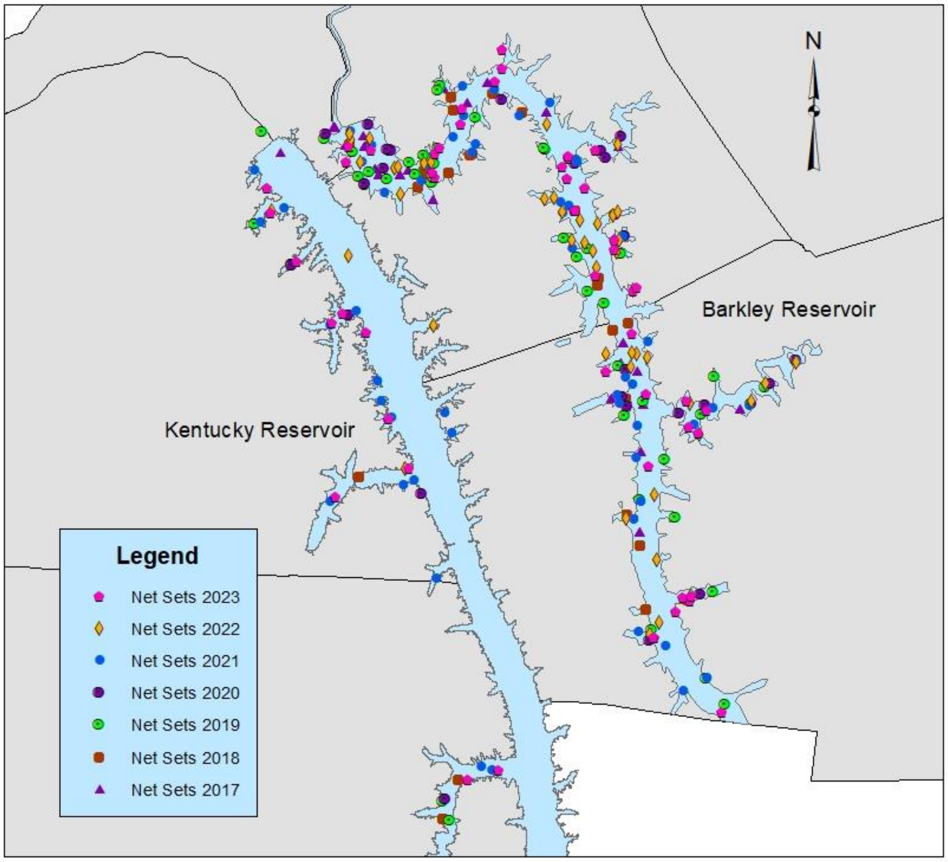

Figure 15. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff from 2017 through 2023.

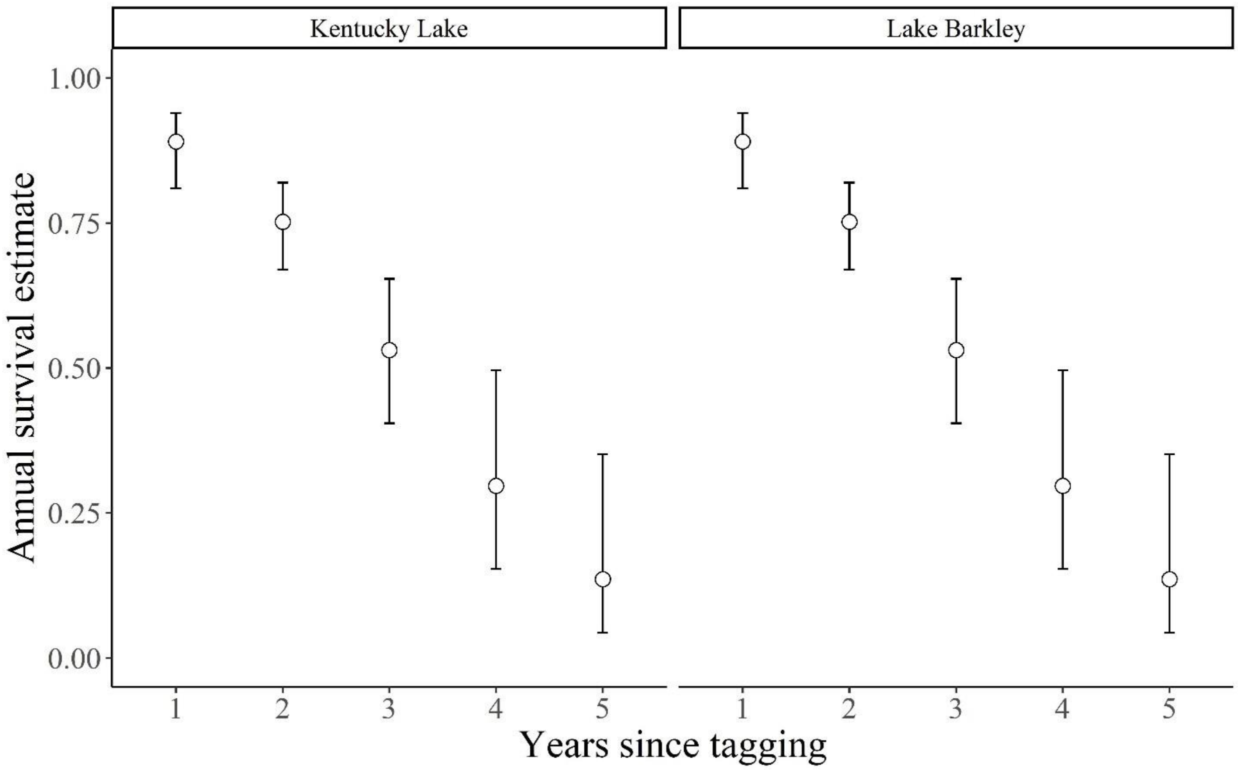

Figure 16. Estimated annual survival between Kentucky and Barkley Reservoirs, Kentucky, USA for Silver Carp tagged in September 2018. Error bars represent the 95% confidence intervals.

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

Reservoir	Year	Predicted weight(g) at 450mm	Predicted weight(g) at 650mm	Predicted weight(g) at 800mm
Barkley	2018	933	2789	5176
	2019	1076	2881	5024
	2020	1121	2974	5160
	2021	1038	2980	5403
	2022	946	2975	5681
	2023	1590	3700	5962
Kentucky	2018	950	2733	4963
	2019	930	2720	4987
	2020	986	2788	5018
	2021	994	2848	5301
	2022	836	2776	5469
	2023	1155	3196	5680

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

Water Body	Year	Number of Days/Trips	Number of fishers	Weight silver carp harvested (lbs)	Weight bighead carp harvested (lbs)	Weight grass carp harvested (lbs)
Barkley Reservoir	2013	45	5	187,022		
	2014	61	6	464,003	1,360	
	2015	189	12	472,487	10,278	
	2016	447	22	1,112,585	5,693	
	2017	345	15	826,016	9,669	
	2018*	835	23	1,762,830	25,932	
	2019	1,846	60	5,318,535	45,665	
	2020***	1,431	43	4,700,149	28,714	61,487
	2021	1,707	32	5,918,405	18,669	43,213
	2022	1,510	30	6,120,640	24,762	37,664
	2023	1,725	31	7,914,777	20,024	59,284
Kentucky Reservoir	2013	21	4	26,400	491	
	2014	82	3	193,786	992	
	2015	59	6	84,190	17,791	
	2016	52	8	96,652	2,884	
	2017	54	8	71,487	11,754	
	2018*	116	8	143,996	11,537	
	2019	140	28	233,806	1,978	
	2020***	426	27	1,601,822	4,196	40,882
	2021	587	28	2,154,845	4,227	27,514
	2022	309	20	1,184,756	3,074	8,666
	2023	338	25	1,174,586	3,953	3,773
Ohio River	2013					
	2014	11	1	74,879		
	2015	16	3	26,864	1,206	
	2016	30	5	90,012	3,216	
	2017	8	4	11,217	713	
	2018	21	4	37,553	70	
	2019	129	9	142,520	521	
	2020***	151	13	137,754	7,402	6,402
	2021	56	7	60,741	1,286	3,028
	2022	124	11	274,235	5,117	8,872
	2023	57	9	143,580	90	9,810
Statewide**	2013	76	7	243,121	491	
	2014	160	9	765,768	2,802	
	2015	283	16	617,062	32,800	
	2016	565	24	1,343,464	12,666	
	2017	414	21	921,288	23,272	
	2018*	982	29	1,945,693	37,739	
	2019	2,250	66	5,802,624	50,366	
	2020***	2,052	48	6,471,718	43,931	111,190
	2021	2,373	38	8,148,093	24,699	74,430
	2022	1,951	39	7,582,713	33,123	55,805
	2023	2,131	35	9,250,292	25,001	72,967

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

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

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

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

Year	Number Sampled	Average total length (inches)	Average weight (lbs)	S. E.
2015	206	33.2	15.2	0.12
2016	448	34.5	17.7	0.10
2017	416	34.0	16.1	0.10
2018	387	31.0	11.6	0.10
2019	924	27.9	8.1	0.09
2020	595	28.0	8.5	0.11
2021	949	27.9	8.9	0.07
2022	1041	29.9	10.9	0.09
2023	1040	31.4	13.0	0.08

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

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

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

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

*effort is calculated in yards of gillnet fished.

Table 6. Comparison of the average weight harvested per trip of silver carp, bighead carp and grass carp during KDFWR ride-alongs, and through commercial fishers reports for the Invasive Carp Harvest Program in 2016 - 2023. (S.E. = standard error)

Year		Silver Carp	S. E.	Bighead Carp	S. E.	Grass Carp	S. E.
2016	Ride Alongs	2,280	402.2	40	12.4	23	10.1
	Commercial Fisher Reports	2,378	70.5	22	3.3		
2017	Ride Alongs	2,386	395.0	25	8.2	24	9.4
	Commercial Fisher Reports	2,225	92.8	56	7.6		
2018	Ride Alongs	2,219	422.6	16	6.9	18.4	8.8
	Commercial Fisher Reports	1,981	54.2	38	4.0		
2019	Ride Alongs	3,353	475.7	23	7.2	60	19.3
	Commercial Fisher Reports	2,580	53.0	22	1.6		
2020*	Ride Alongs	4,775	677.5	41	14.8	46	15.5
	Commercial Fisher Reports	3,186	62.4	22	1.8	55	3.0
2021	Ride Alongs	3,389	353.2	31	9.4	20	4.0
	Commercial Fisher Reports	3,434	56.9	10	1.2	31	1.9
2022	Ride Alongs	3,731	365.5	147	64.6	28	9.2
	Commercial Fisher Reports	3,889	63.9	137	17.2	122	13.5
2023	Ride Alongs	4,492	441.7	10	4.7	34	17.0
	Commercial Fisher Reports	4,641	93.7	10	2.7	33	6.0

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

Table 7. Paupier net effort and catch rates from sampling conducted in Big Bear embayment of Kentucky Reservoir. (S.E. = Standard error)

Date	Net Hours	Number of Silver carp captured	Mean Silver carp CPUE (fish/hr)	S.E.	Number of Grass carp captured	Number of Bighead carp captured
Nov-16	9.12	1,406	168.9	23.0	3	
Oct-17	2.12	516	229.2	40.3		2
Oct-18	4.72	1496	308.3	61	1	2
Oct-19		442	~260	~60	1	
Oct-22	1.28	105	105.9	33.2		
Nov-23	0.66	24	36	9.07		

Appendix B:

2023 Kentucky Lake Silver Carp Population Assessment Summary Report

Columbia Fish and Wildlife Conservation Office

Jessica Howell, Pablo Oleiro, Jason Goeckler

Acknowledgements

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

Introduction

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

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

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

Methods

Study site

Eight embayments spanning the length of Kentucky Lake (Figure 1) were selected to be sampled based on prior years of sampling and partner input (Cole Harty, Tennessee Wildlife Resources Agency, and Josh Tompkins, Kentucky Department of Fish and wildlife Resources, personal communications). These included (in order from downstream to upstream): Sledd Creek ("Sledd" hereafter), Little Bear, Big Bear, Pisgah, Smith, Duncan Creek ("Duncan" hereafter), Jonathan Creek ("Jonathan" hereafter), and Big Sandy. Embayments sampled in 2023 largely overlapped with those sampled in 2022 and had some similarities with sites sampled in 2019 (Figure 1).

Data collection

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

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

Data analysis

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

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

Results

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

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

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

Discussion

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

These data trends suggest that Kentucky Lake Silver Carp are an aging and declining population. Catch rates of Silver Carp have decreased by approximately half during each sampling year. As Silver Carp abundance declines, an increase in the relative weight is expected, as is an increase in size structure as fish age. Further, in years where paupier sampling was conducted, no recruitment was observed. This is corroborated by similar electrified dozer trawl sampling conducted annually by Tennessee (MICRA 2022a). Recruitment is likely limited due to short open river distances (Kolar et al. 2007) in the Tennessee River and unsuitable spawning conditions. In addition, migration into Kentucky Lake is likely limited due to the presence of the BioAcoustic fish fence at Barkley Dam that prevents upstream movement (Cupp et al. 2021). Emigration rates are unknown, so population decreases in response to removal efforts could be overestimated. However, results suggest that management efforts through the Kentucky and Tennessee programs are likely having an impact on the population. Other factors such as limited immigration, potential emigration, natural mortality, and limited to no recruitment in the system may be further amplifying the effects of removal efforts. To minimize impacts from Silver Carp into the future, maintaining high exploitation is necessary. Modeling should be conducted using fisheries dependent and fisheries independent data to better understand what levels of exploitation are needed to exert population level effects to further reduce the impacts of Silver Carp on the ecosystem, economy, and recreation of Kentucky Lake. Future population assessments would be encouraged to ensure that management actions are having the desired effect.

TABLES

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

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

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

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

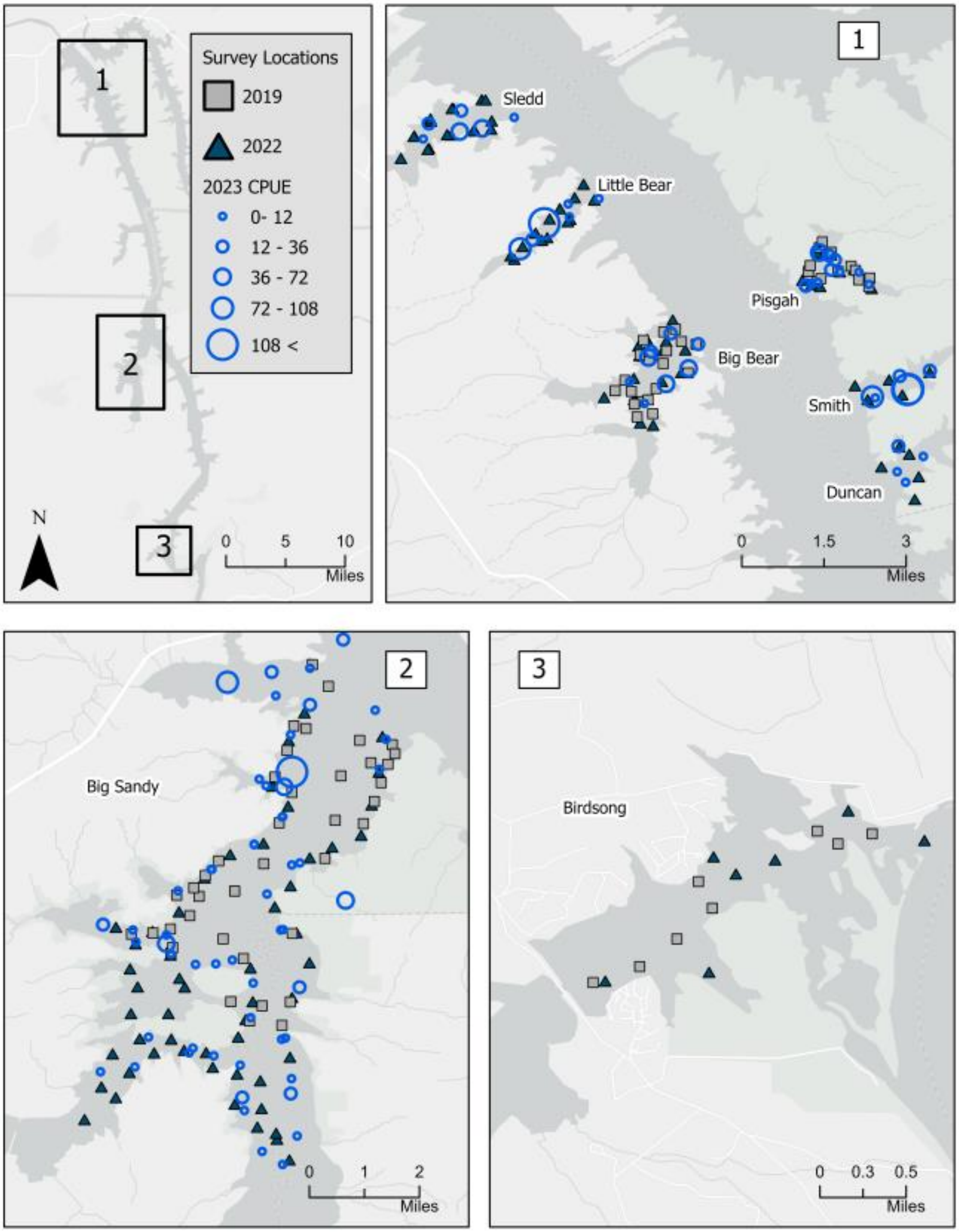
Survey Locations
2019
2022
2023 CPUE
0- 12
12 - 36
36 - 72
72 - 108
108 <
1
2
3
N
0 5 10
Miles
Sledd
Little Bear
Pisgah
Big Bear
Smith
Duncan
0 1.5 3
Miles
Big Sandy
0 1 2
Miles
Birdsong
0 0.3 0.5
Miles

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

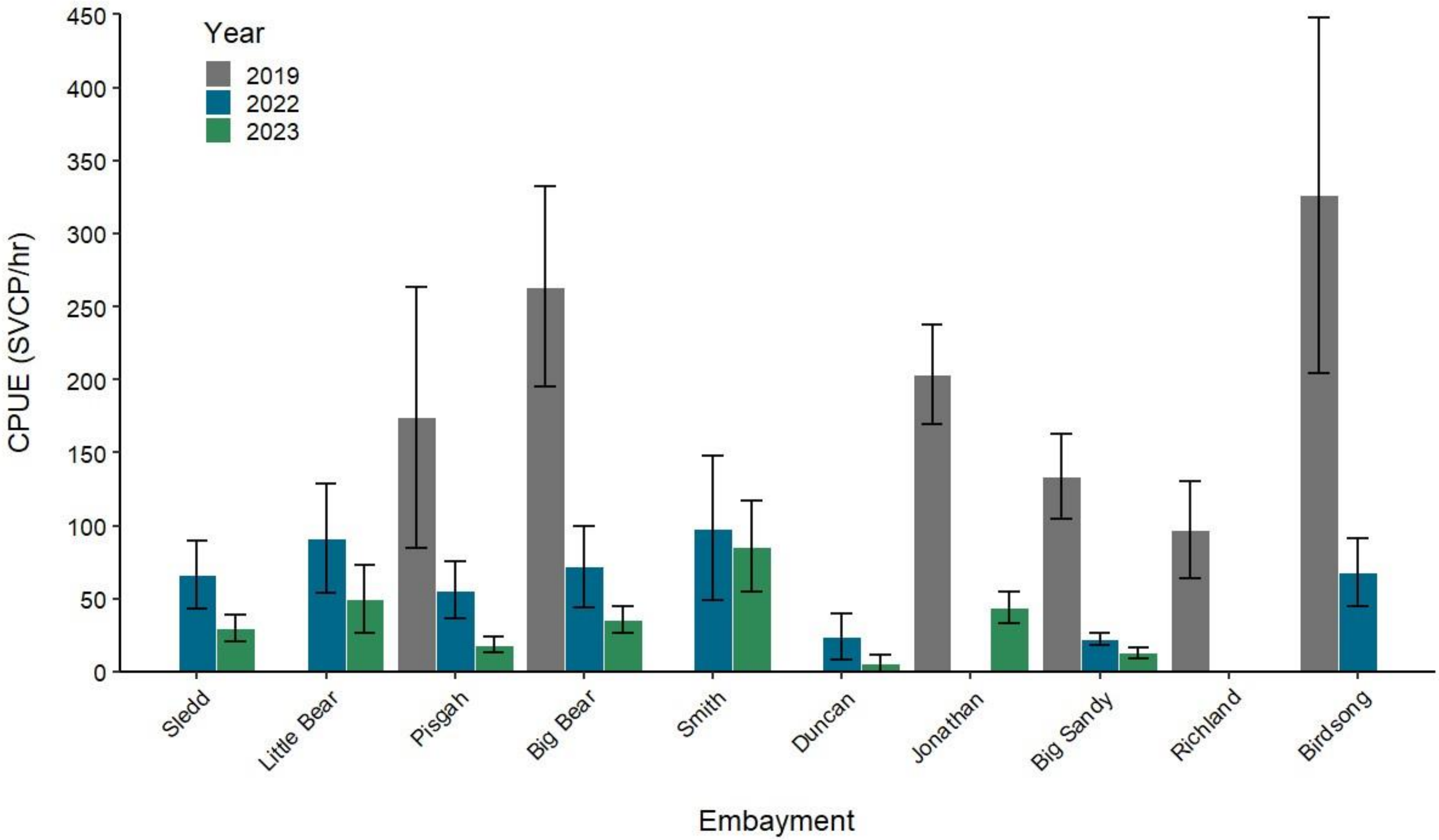

Figure 2. Catch per unit effort (CPUE) in Silver Carp (SVCP) per hour by embayment and year sampled. Error bars represent one standard error. Embayments are ordered from downstream to upstream. Missing bars indicate that the embayment was not sampled in that year.

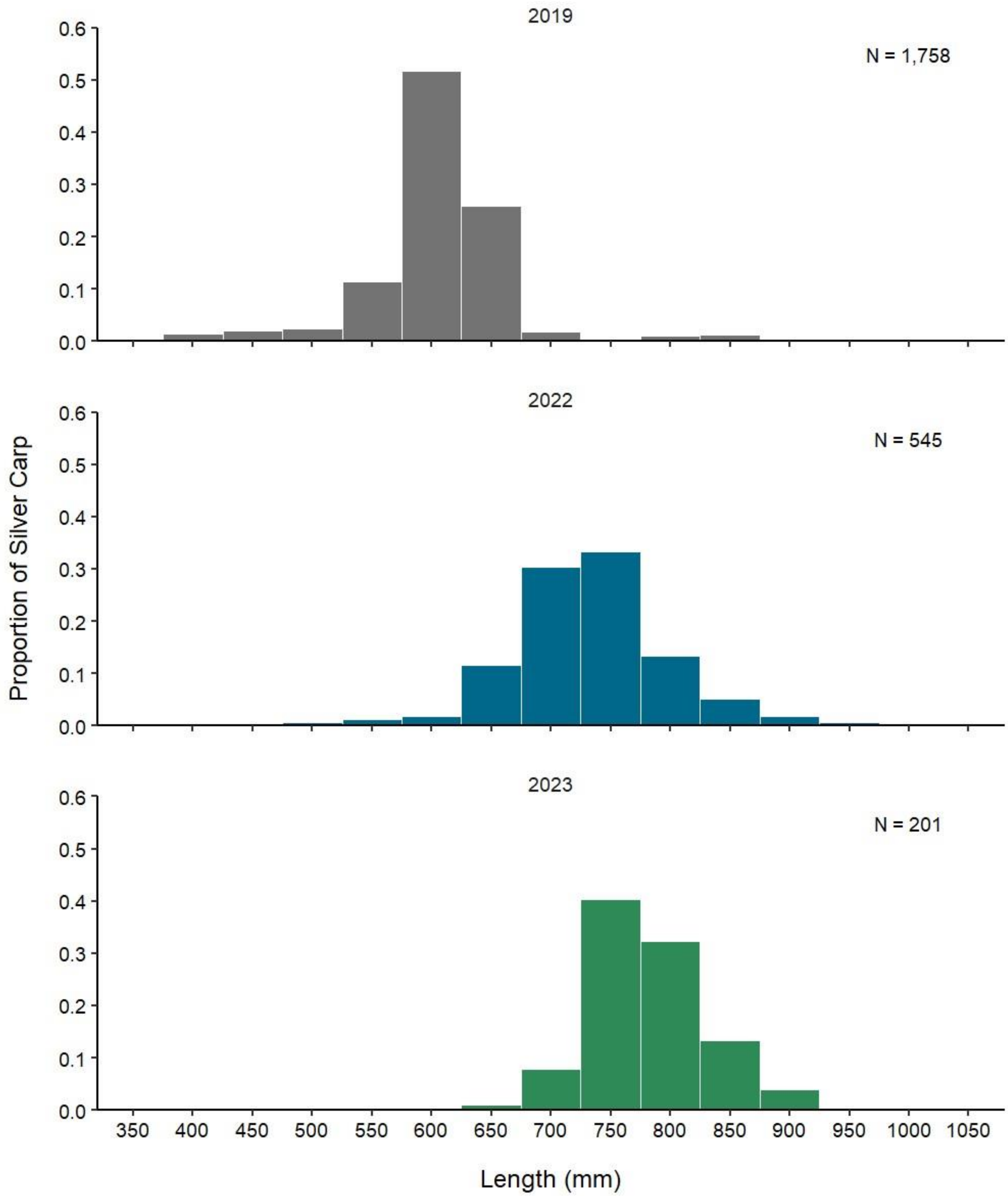

Figure 3. Relative length frequency of Silver Carp collected in Kentucky Lake in 2023 using the electrified paupier trawl. The number of Silver Carp for each year is included.

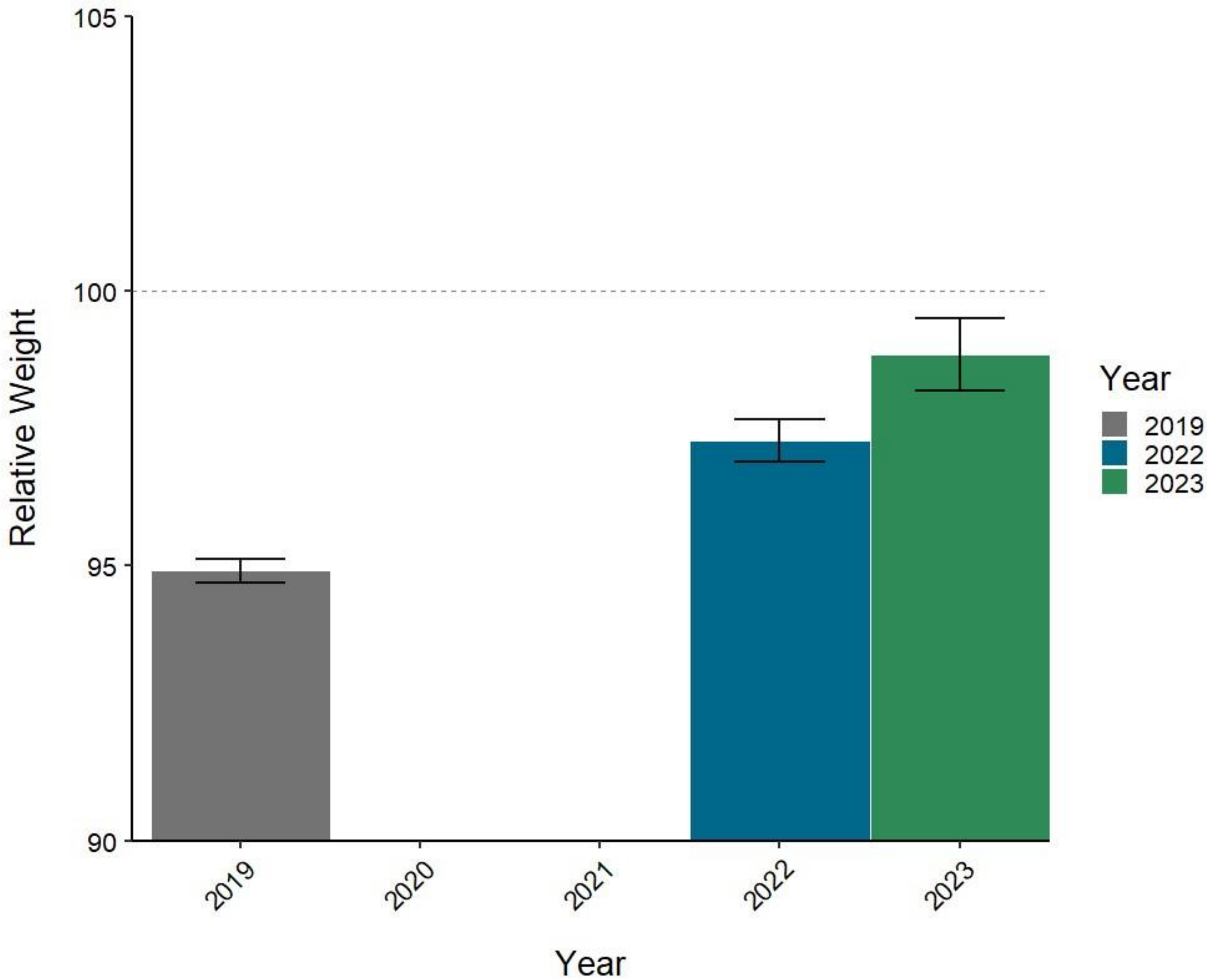

Figure 4. Relative weight (W_r) for Silver Carp (SVCP) by year for Kentucky Lake. Bars represent one standard error and the dotted horizontal line indicates an "average" body condition based on the standard weight equation. Missing bars indicate that no sampling was conducted in that year.

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APPENDIX B1A. – ALL FISH COLLECTIONS 2023

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

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

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

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

Project Title: Monitoring Invasive Carp Impacts on Native Fish Communities

Geographic Location: Tennessee and Cumberland Rivers Subbasin

Lead Agency: Kentucky Department of Fish and Wildlife Resources (KDFWR; Joshua Tompkins, Joshua.tompkins@ky.gov)

Cooperating Agency: Murray State University (MSU)

Statement of Need:

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

Project Objectives:

1. Assess impacts on native species that compete for food resources with invasive carp.
2. Examine invasive carp impacts on fish community assemblages in the tailwaters of dams on the Tennessee and Cumberland rivers.
3. Determine impacts of invasive carp on sport fisheries.
4. Monitor bycatch of native fish species collected through invasive carp harvest programs.

Project Highlights:

- Condition of gizzard shad dropped slightly compared to previous years in Barkley and Kentucky Reservoirs.
- Kentucky and Barkley Tailwaters have good fish community assemblages.
- Barkley and Kentucky Reservoirs saw normal ranges of fish condition and abundance during 2022.
- Kentucky Reservoir saw a decrease in sport fishing effort but saw an increase in catch rates.
- KDFWR personnel conducted 61 ride-alongs with commercial fishers. During which observers recorded 2.4% of bycatch with a 20% of mortality with that bycatch.
- 65.5% of sport fish anglers surveyed during Kentucky Reservoir's creel perceived a decrease in silver carp abundance over the past two years.
- Shad growth was observed to slow in both reservoirs around age 3.

Methods:

KDFWR

Objective 1. Assess impacts on native species that compete for food resources with invasive carp.

KDFWR conducted targeted sampling for shad species with pulsed DC boat electrofishing for one week in both Barkley and Kentucky Reservoirs. Electrofishing runs did not exceed 15 minutes of peddle time and ran parallel to shore in 3-8ft of water. Length and weight were taken from individuals collected. The sampling began at sunset and continued throughout the night. During Paupier net sampling, total length and weight data was recorded for shad species as well. Measurements were used for determining condition factors through relative weight analysis. Values will be monitored over time to determine if they will be useful to assess impacts that invasive carp may have on conditions of the native fishes. The species chosen for this assessment are often captured in gill nets and have been recognized as being vulnerable to competition for resources with invasive carp species (Irons et al. 2007, Schrank et al. 2003).

Objective 2. Examine invasive carp impacts on fish community assemblages in the tailwaters of dams on the Tennessee and Cumberland rivers.

Barkley and Kentucky Reservoirs' tailwaters were sampled with pulsed DC electrofishing in the fall to assess species composition, relative abundance, and condition of represented fish species. Sampling below Kentucky Reservoir (Tennessee River) consisted of three 15-minute transects, moving downstream along each bank of the river (Figure 2). Sampling below Barkley Reservoir (Cumberland River) consisted of two 15-minute transects, moving downstream along each bank of the river (Figure 2). Fall sampling was conducted one day each month in September, October, and November. Two staff collected fish with nets from the bow, netting targeted all species. Data included species, total lengths (mm), and weights (g). When large numbers of a species were collected, measurements on a subsample of at least 25 individuals were taken and extrapolated for that species. The data was compared to historical data collected by the KDFWR Western Fisheries District personnel to assess changes in fish community over time.

Objective 3. Determine impacts of invasive carp on sport fisheries.

Invasive carp harvest continues to increase from Kentucky and Barkley Reservoirs, driven by the Invasive Carp Harvest Program (ICHP) and the additional processors purchasing carp from Western Kentucky. KDFWR continues to monitor condition of sport fish species to identify trends that may be associated with the population dynamics of invasive carps. Information on sport fish has been gathered routinely throughout the past few decades by KDFWR's Western Fisheries District (WFD). Lengthy data sets on black bass, crappie, and catfish in the two reservoirs are collected from annual standardized sampling. The information was used to compare sport fish conditions (*W*r) with harvest rates of invasive carps to evaluate trends.

In 2023, KDFWR conducted the creel survey on Kentucky Reservoir. Random, non-uniform probability creel surveys were conducted (Appendix A). Dates and periods for surveys each week were randomly selected, and creels were conducted at least 20 days per month, including a minimum of 6 weekend days. Timing of recreational fishers' counts are randomly chosen daily, and data was extrapolated accordingly to calculate daily average and total effort. An attempt to interview all recreational fishers each day was made. Data collected during the creel surveys was compared to historical surveys to determine changes in fish community, catch rates, angler use, and success. Recreational fishers were also administered an angler attitude questionnaire to gauge opinions regarding their levels of satisfaction with the fishery and on current or proposed regulations.

Objective 4. Monitor bycatch of native fish species collected through invasive carp harvest programs.

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

Results and Discussion:

KDFWR

Objective 1. Assess impacts on native species that compete for food resources with invasive carp.

<u>Electrofishing</u>

Sampling occurred for a week on Barkley Reservoir and a week on Kentucky Reservoir in October of 2023. Sampling targeted, gizzard shad (GZSD), threadfin shad (TFSD), skipjack herring (SKJH) and emerald shiners. The Midwest Lake Electrofishing Systems shock box was set to 120 Hertz, 25% duty cycle, 200-265 volts, 7-18 amps and 2000-4200 watts. On Kentucky Reservoir 4,933 gizzard shad, 3,032 threadfin shad, and 69 skipjack herring were collected. On Barkley Reservoir 4,354 gizzard shad, 751 threadfin shad, and 751 skipjack herring were collected. CPUE for gizzard shad over 180 mm was greater in Barkley Reservoir, while CPUE for gizzard shad under 180 mm was greater in Kentucky Reservoir (Table 2).

Paupier

Sampling with USFWS collected a total of 17,782 fish with the electrified Paupier net boat over four nights spent on Kentucky Reservoir. This sampling was targeting young of year invasive carp, adult invasive carp, gizzard shad, threadfin shad, and skipjack herring. No YOY invasive carp were collected. CPUE of adult silver carp was lowest it has been in Big Bear embayment (36 fish/hr. Table 1), since Paupier sampling began in 2016. The missing years from 2020 – 2021 has been due to personnel constraints and the Covid pandemic.

Using data collected from both electrofishing and Paupier sampling, condition of native baitfish was calculated to better understand the potential impacts invasive carp. Relative weight (Wr) of gizzard shad over 180mm in 2023 was at an historical low in both reservoirs (Table 3). Paupier and EF sampling produced higher CPUEs for gizzard shad, threadfin shad, and adult silver carp but both the Paupier and standard electrofishing had similar CPUEs for skipjack herring (11 and 12(fish/hr), respectfully. Table 4).

Objective 2. Examine invasive carp impacts on fish community assemblages in the tailwaters of dams on the Tennessee and Cumberland rivers.

Kentucky and Barkley Tailwaters Electrofishing

Fall sampling with electrofishing in the Kentucky Tailwater resulted in the capture of 3,504 total fish comprised of 37 species during 4.5 hours of effort in 2023. Gizzard shad catch rates increased in 2023 compared to 2022 and 2021 (113 fish/hr compared to 47 and 44, Table 6). Threadfin shad catch rates decreased in 2023 but were within the historic range. CPUE of sunfish species including bluegill and longear sunfish, increased from 2022 with a CPUE of 38 fish/hr and 8 fish/hr, respectively. Largemouth bass CPUE was the highest observed since 2019 and smallmouth bass CPUE was the highest observed since 2015 at 43 per hour. Silver carp and grass carp CPUE remained the same in 2023 compared to 2022 at 2 fish/hr (Table 6).

Fall sampling in the Barkley Tailwater resulted in the capture of 8,359 total fish comprised of 33 species over 3.0 hours of effort in 2023. Threadfin shad catch rates was the second highest seen since 2016 with a CPUE of 2103 fish/hr (Table 7). Sunfish species such as bluegill and longear sunfish produced some of the lowest catch rates for those species since the survey began in 2016 with a CPUE of 10 fish/hr and 11 fish/hr, respectively (Table 7). Largemouth and smallmouth bass catch rates both increased in 2023 and the smallmouth bass CPUE was the second highest since 2016. Silver carp CPUE during fall sampling in Barkley Tailwaters was the second lowest since 2016 (6 fish/hr; Table 7).

Length frequency distribution for silver carp collected in Kentucky Tailwater during fall sampling in 2023 ranged from 27-34 inches (N=9; Table 8). Silver carp lengths from Barkley Tailwater during fall sampling ranged from 20-34 inches (N=22; Table 9). These ranges are much wider compared to silver carp collected during fall sampling in 2018 and 2019 and may indicate more mixing of the silver carp population in the Tailwaters, or that fish from a variety of locations are arriving at the tailwaters and looking for passage upstream. We observed similar size structure of skipjack herring, gizzard shad, and threadfin shad in both tailwaters (Table 8 and 9).

Relative weights (Wr) were calculated for selected species collected during fall sampling to monitor fish condition (Tables 10 & 11). Trends in fish condition are important in the current study, as any observed declines in condition of individual species may be an indicator of competition for resources and reflective of high invasive carp densities in the tailwaters. Low relative weight is generally characteristic of fish in poor health, whereas high values indicate fish in excellent health (Blackwell et al. 2000). However, ideal target ranges of Wr values have not been identified for all species and in every habitat type. Therefore, the Wr values compiled through this study will be used to assess changes in the Tailwater fish community over time. In the Kentucky Tailwater, the mean Wr of gizzard shad decreased to a value of 86, which is like 2019 and 2020 (Table 10). Largemouth bass also recorded the second highest Wr since 2015 at 111 while smallmouth bass saw the lowest Wr at 87 (Table 10). The mean relative weight for white bass increased slightly from 2022, but still isn't up to historical records. Mean relative weight values for other species in the Kentucky Tailwater remained like previous years. In the Barkley Tailwaters, mean relative weight values decreased for gizzard shad (Wr = 88) from 2022. Smallmouth bass mean relative weight decreased to 93 and that is similar as 2019 and 2020 (Table 11). Bluegill relative weight was a record high in 2023 at 100 (Table 11). All other species in the Barkley Tailwaters had similar mean relative weights to previous years.

Objective 3. Determine impacts of invasive carp on sport fisheries.

Standard Sport Fish Sampling

In Kentucky Reservoir, relative weight analysis was conducted for black crappie, white crappie, largemouth bass, and smallmouth bass (KDFWR 2022). Black and white crappie both exhibited mean relative weights that were higher than 2022 but were not outside of historical norms with *W*r of 98 and 99, respectively. Largemouth bass average *W*r also remained like values calculated for the previous four years (*W*r = 96). Many factors are known to impact sport fish condition and values recorded since invasive carp have become established in Kentucky Reservoir have not fluctuated outside of historical variations. The impacts to sport fish condition associated with this increased removal of invasive carp requires more years of data and will continue to be monitored.

In Barkley Reservoir, relative weight analysis was conducted for black crappie, white crappie, largemouth bass, and blue catfish (KDFWR 2022). Mean relative weights for both black and white crappie remained like previous years having *W*r of 96 and 89, respectively. Mean *W*r value for largemouth bass in 2022 was 103. Harvest of invasive carp from Barkley Reservoir has increased almost every year since the ICHP began in 2013. Comparable to Kentucky Reservoir, the sharp rise in harvest of invasive carp in 2019 corresponds with lower condition factors of sportfish species, which may be an indicator of high densities of adult invasive carp competing with these sport fish for resources. Therefore, the increase in condition of sport fish in Barkley Reservoir in subsequent years, may be influenced by a reduced competition with invasive carp as they are continually harvested. However, sport fish condition in the reservoirs is highly variable due to a variety of factors and will continue to be monitored in following years.

Kentucky Reservoir Creel

In 2023 survey results indicated that the fewest number of trips were made to Kentucky Reservoir, but fishing catches improved. Creel survey results suggests that catch rates improved recently and returned to the top end of the historical range (Table 16). In 2023 the methods of fishers on Kentucky Reservoir remained comparable to the previous surveys in which about 1/3 of anglers still fish while 40-60% of anglers using casting to catch fish (Figure 1).

Part of the Kentucky Reservoir's creel program is an angler attitude survey where anglers are asked their satisfaction with the fishery or about their knowledge of fishery related topics. Given invasive carp's abundance and being considered excellent table fare, a question is asked, "Are you aware that invasive Asian carp are generally considered to be excellent fish to eat?" and 74.5% of people answered "Yes", which has slightly increased since 2016 when only 60% of people said "Yes". 90% of people surveyed knew that commercial harvest of invasive carp occurs on Kentucky Lake, which has increased from 65% in 2020. When asked about their perception of silver carp abundance in Kentucky Reservoir over the past two years, 65.5% of the 330 individuals surveyed indicated a decrease in silver carp abundance, while 7.9% indicated a perceived increase in silver carp abundance. (Appendix A).

Objective 4. Monitor bycatch of native fish species collected through invasive carp harvest programs.

Invasive Carp Harvest Program Bycatch

According to the KDFWR ICHP regulation (301:KAR 1:152), commercial fishers are allowed to harvest a ratio of 65% Invasive carp to 35% scaled rough fish per month. All other fish caught in commercial gear must be released. Commercial fishers are required to submit daily reports that include bycatch species, number caught, number harvested, number released, and disposition upon release (moribund or alive). In previous years, increased effort by commercial fishers fishing under the ICHP has translated into a growing amount of bycatch. In 2023, the total number of bycatches reported decreased and was the lowest recorded since 2018 (when commercial fishing effort increased dramatically. Table 12). This reduction in bycatch per trip is attributed to changing practices of commercial fishers as most fishers have transitioned from passive setting to active setting of gill nets targeting schools of carp identified via their boat electronics. Scaled rough fish, primarily buffalo (*Ictiobus*) species, make up the majority of reported bycatch in commercial gill nets fished under the ICHP (Table 12). Bycatch of rough fish, and subsequent harvest is variable year to year based on what processors are willing to buy. Although commercial fishers on the ICHP are limited to how much of their bycatch they can harvest, KDFWR will continue to monitor this trend in future years. The number of sport fish, catfish, and paddlefish collected as bycatch all increased in 2023 from 2022 reporting levels, however rates were within historic levels. Survival rates of sportfish (86.0%) and paddlefish

(78.4%) decreased in comparison to previous years, and the survival rate of catfish remained similar (98.6%) (Table 12).

Survival rates of all bycatches caught during ride-alongs in 2023 was documented by KDFWR observers and was analyzed independent of commercial fisher reporting (Table 13). During ride-alongs, the survival rate of sport fish as bycatch decreased slightly in 2023 at 83%. Survival rates of catfish species observed as bycatch during ride-alongs was like previous years at 95%. Paddlefish survival rates observed during ride-alongs in 2023 returned to historical ranges unlike 2022's lowest survival rate. However, it is of note those 2022 values also represent the lowest sample size in recent history (Table 13).

A comparison for bycatch of paddlefish, catfish species, and sport fish species reported by commercial fishers through daily reports and information collected during ride-alongs shows a decrease since 2015 in number of sport fish captured per trip for most species (Table 14). We see an increase in bycatch of catfish species in 2023. However, bycatch reported captured per trip for recreationally and commercially important species such as paddlefish and catfish spp. is higher during ride-alongs than from fisheries dependent reports (Table 14). Data suggests 50-75% of bycatch is likely not reported in daily logs submitted to KDFWR by commercial fishers. However, ride-alongs account for a small percentage of the total number of trips made by commercial fishers (2.8% in 2023). To better identify and monitor under reporting of bycatch, KDFWR will continue to increase the number of ride-alongs conducted with commercial fishers targeting invasive carp. To date, there is no indication of negative impacts on the sport fishery resulting from the ICHP.

Bycatch of Paddlefish

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

Paddlefish survival was observed to be low in 2023 (47% during ride-alongs, 78% total ICHP) in relation to other species in the bycatch (Tables 12 & 13). A factor identified as possibly affecting paddlefish survival in gill nets is length of time the nets are left in the water (i.e. soak time). From conducting ride-alongs, it has been observed that the soak time of nets varies among fishers and depends on the location being fished, weather, and water temperature. Overall, fishers tend to leave nets in the water longer when water temperatures are cooler as it increases catch rates and like most fish, invasive carp will survive longer in the cooler temperatures. Therefore, water temperature and soak time have been recorded during ride alongs since 2017. The lowest mean soak time in 2023 was 3.5 and the two lowest soak times resulted in the highest percentage of paddlefish released alive (Table 15), the combination of soak times greater than 7 hours and rising water temperatures attributes to lower survival rates. However, commercial fishers are more frequently using active methods for targeting invasive carp with gill nets and soak times of nets decreased overall in 2023. To increase the sample size, water temperature and soak times will continue to be recorded during ride-alongs in 2024.

Murray State University

Objective 1. Assess impacts on native species that compete for food resources with invasive carp.

Activities and Methods:

Murray State University conducted sampling and aging of Gizzard Shad and Threadfin shad during 2021 through 2023. Shad were captured with nighttime boat electrofishing and surface trawling. Shad ages were determined by examining the sagittal otolith.

In our samples, shad catch rates tended to be higher in Lake Barkley for nighttime electrofishing (Table 17) and nighttime surface trawling (Table 18). Mean size of shad tended to be greater in Kentucky Lake (Tables 19 and 20) suggesting growth is related to density in these populations. Shad growth tends to slow down around age 3 in both lakes (Figures 3, 4, and 6). Relative weight of Gizzard Shad was below standard for both lakes across all lengths (Figure 5). Shad caught in the surface trawl were larger in Kentucky Lake (Figure 7 & 8). Otoliths were a reliable method for aging Gizzard shad (Tables 21 and 22). Mortality estimates for Gizzard Shad were much higher in fall samples compared to spring samples (Figure 9). Gizzard shad seem to spawn in late April / early May in both lakes (Figure 10). These data will be useful as a baseline to track potential changes in shad communities over time.

Recommendations:

- Continued monitoring of bycatch through the invasive carp harvest program. Increased staff effort will be required as the number of unique commercial trips increase, to properly evaluate potential impacts on native species through the program.
- Continued monitoring of native bait fish species within the reservoirs, to track population responses to the reduction of invasive carp biomass to determine if any remediation projects should be considered within the system.
- Continue education and outreach efforts to inform the public about commercial fishing efforts, to minimize user conflicts. This can be accomplished through continued creel efforts, boat ramp signage and public forums.

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Tables and Figures:

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

Date	Net Hours	Number of Silver carp captured	Mean Silver carp CPUE (fish/hr)	S.E.	Number of Grass carp captured	Number of Bighead carp captured
Nov-16	9.12	1,406	168.9	23.0	3	
Oct-17	2.12	516	229.2	40.3		2
Oct-18	4.72	1496	308.3	61	1	2
Oct-19		442	~260	~60	1	
Oct-22	1.28	105	105.9	33.2		
Nov-23	0.66	24	36	9.07		

Table 2. Comparison of Catch Per Unit Efforts (CPUE, fish/hour) across embayment's and reservoirs of baitfish with night-time electrofishing in the fall of 2023.

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Blood River	1.5	35	257	1144	13	3
Jonathan	1.5	41	2459	624	5	1
Big Bear	1.5	55	301	125	21	1
Sledd Creek	1.5	125	17	128	7	2
*Kentucky Reservoir**	*6*	*64*	*759*	*505*	*12*	*1*

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Demumbers/Willow	1.5	42	247	239	14	15
Eddy Creek	1.5	233	1135	51	3	2
Little river	1.5	116	382	105	1	13
Honker Bay	1.5	36	712	109	1	0
*Barkley Reservoir**	*6*	*107*	*619*	*125*	*5*	*8*

* Mean CPUE for each reservoir

Table 3. Relative weight (*Wr*) values of gizzard shad collected from boat electrofishing and Paupier net sampling in Barkley and Kentucky Reservoirs in fall of 2017-2023.

Kentucky Reservoir			
Year	No.	Wr	S.E.
2023	546	84	0.36
2022	1527	91	0.3
2021	85	92	0.5
2020	95	92	0.8
2019	80	92	0.9
2018	268	103	1.70
2017	82	155	1.63

Barkley Reservoir			
Year	No.	Wr	S.E.
2023	392	86	0.32
2022	440	90	0.49
2021	34	90	1
2020	47	93	0.7
2019	69	94	1
2018	35	92	3.08
2017	125	87	1.99

*Gizzard Shad Relative Weights based on formula presented in Balckwell et al. 2000.

Table 4. Paupier Net and Night-time Electrofishing (EF) sampling CPUEs for Kentucky Reservoir in fall of 2023.

Location	**Effort (hr)**	**GZSD CPUE (fish/hr)**	**TFSD CPUE (fish/hr)**	**SKJH CPUE (fish/hr)**	**SVCP CPUE (fish/hr)**
KY Reservoir Mean EF *	6	823	505	12	1
*KY Reservoir Mean Pauiper **	*3.9*	*2309*	*2117*	*11*	*36*

Big Bear EF	1.5	356	125	21	1
Big Bear Pauiper	*0.66*	*2303*	*20*	*9*	*36*
Sledd Creek EF	1.5	142	128	7	2
Sledd Creek Pauiper	*0.5*	*2466*	*16*	*2*	*30*

* Includes embayment's other than Big Bear and Sledd Creek

Table 6. Comparison of fall electrofishing CPUE for selected species collected in Kentucky Lake tailwaters in 2015 (effort = 1.0 hours), 2016 (effort = 1.75 hours), 2017 (effort = 4.5 hours), 2018 (effort = 1.25 hours), 2019 (effort = 3.75 hours). 2020 (effort = 2.75 hours), 2021 (effort = 3.75 hours), 2022 (effort = 4.5 hours), and 2023 (effort = 4.5 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Fall 2015		Fall 2016		Fall 2017		Fall 2018		Fall 2019		Fall 2020		Fall 2021		Fall 2022		Fall 2023	
	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.
Skipjack herring	22	8.4	1	0.6	18	9.5	2	1.6	510	200.3	89	22.3	44	17.6	25	13.9	2	0.7
Gizzard shad	275	58.6	184	78.0	163	61.1	22	10.2	240	92.1	163	69.7	44	21.4	47	11.4	113	30.7
Threadfin shad	251	176.3	1690	1251.0	1263	637.0	2557	1845.1	27	14.9	712	241.1	665	291.6	1860	795.2	330	138.7
Grass carp	13	1.9	6	2.5	2	0.7			6	2.8	8	4.7	1	0.8	2	0.7	2	0.5
Silver carp	6	2.6	44	22.4	4	1.6	9	6.9	4	2.0	9	4.9	9	3.1	2	0.7	2	0.8
Smallmouth buffalo	10	2.6	9	3.7	5	2.1	1	0.8	8	3.0	2	0.8	4	1.3	5	1.2	2	0.7
Bigmouth buffalo					1	0.4	2	1.0					< 1	0.3	<1	0.4	<1	0.2
Black buffalo	6	2.0	3	1.9	< 1	0.2			1	0.4	< 1	0.4			<1	0.4		
Blue catfish					< 1	0.2			< 1	0.3					<1	0.2		
Channel catfish			1	0.6	1	0.9			< 1	0.3					1	0.6	<1	0.4
Flathead catfish			4	1.2	4	1.4			3	1.4	< 1	0.4	1	0.4	1	0.5	2	0.7
White bass	8	4.3	7	4.0	< 1	0.3	6	5.6	4	1.9	5	2.5	3	1.8	1	0.7	5	1.3
Yellow bass	162	83.5	17	13.3	26	4.1	7	4.3	18	7.8	3	1.6	1	0.4	6	3.1	11	4.3
Striped bass					2	1.0	2	1.0							<1	0.2	<1	0.2
Bluegill	96	29.2	41	11.8	128	30.7	20	4.0	127	48.8	26	5.9	4	2.1	34	8.2	38	6.9
Longear sunfish	14	14.0	48	12.0	80	25.0	7	4.8	67	15.4	10	3.9	2	1.2	5	1.6	8	2.3
Redear sunfish	1	1.0	6	2.3	6	1.6			15	3.9	2	1.1	1	0.4	2	1.0	<1	0.3
Smallmouth bass	9	2.5	21	5.2	11	3.2	2	1.0	29	12.3	10	2.8	6	2.6	15	4.1	43	6.7
Spotted bass	1	1.0	1	0.6	3	1.4	1	0.8	3	1.4					<1	1	2.63	1
Largemouth bass	62	19.8	86	9.4	35	4.3	7	2.9	29	6.2	15	3.6	5	1.7	13	3.2	19	2.7
White crappie	2	2.0	1	0.7	1	0.4			3	1.9					<1	0.2	<1	0.2
Black crappie	2	2.0	1	0.6	3	1.7			2	1.5								
Sauger	1	1.0			1	0.4							1	0.5	<1	0.2	1	0.3
Freshwater drum	13	5.7	6	1.5	4	0.7	4	2.2	8	2.5	11	2.8	5	1.4	15	12.5	12	9.4
White bass/Striped bass hybrid	1	1.0	1	1.1	1	0.5									<1	0.4	1	0.4
Striped mullet											1	1.0	1	0.8	<1	0.6		

Table 7. Comparison of fall electrofishing CPUE for all species collected in Lake Barkley tailwaters in 2016 (effort = 1.99 hours), 2017 (effort = 3.0 hours), 2018 (effort = 1.0 hour), 2019 (effort = 3.0 hours), 2020 (effort = 2.75 hours), 2021 (effort = 3.0 hours), 2022 (effort = 3.0 hours), and 2023 (effort = 3.0 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Fall 2016		Fall 2017		Fall 2018		Fall 2019		Fall 2020		Fall 2021		Fall 2022		Fall 2023	
	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.	CPUE (fish/hr)	S.E.
Skipjack herring	< 1	0.5	8	2.9	35	18.0	324	158.4	41	10.78	28	10.9	17	7.3	11	3.6
Gizzard shad	209	52.4	104	18.2	23	8.1	362	224.8	189	49.03	8	5.0	38	14.5	113	34.6
Threadfin shad	4598	1818.7	1252	602.1	67	12.8	30	18.8	1298	719.49	378	182.4	1263	352.9	2103	985.2
Grass carp	5	2.6	1	0.5			6	1.7	3	1.22	3	0.7			1	0.4
Silver carp	4	2.0	14	7.7	29	17.2	42	33.4	23	6.58	24	6.4	11	2.5	6	2.1
Smallmouth buffalo	15	7.6	10	2.7	1	1.0	5	3.2	10	3.75	3	1.6	13	4.8	5	2.6
Bigmouth buffalo	1	0.9	< 1	0.3	1	1.0										
Black buffalo			1	0.7									<1	0.33	1	0.37
Channel catfish	< 1	0.4	1	0.5					1	0.49			<1	0.33		
Flathead catfish	8	3.6	6	3.1			22	5.9	4	1.57	2	1.2	4	1.3	1	0.4
White bass	7	3.9	3	1.1	3	3.0	1	0.7	1	0.56	2	1.4	6	2.9	4	2.6
Yellow bass	2	0.7	28	16.0			4	3.0	3	1.24	2	1.0	<1	0.7	1	0.4
Striped bass	1	0.9	2	1.4	1	1.0	< 1	0.3	2	1.25					<1	0.33
Bluegill	46	15.3	56	14.6	70	14.5	50	13.2	37	11.66	21	5.9	21	6.4	10	2.2
Longear sunfish	102	25.0	83	16.8	46	25.4	153	30.5	41	10.06	14	4.7	16	4.1	11	4.5
Redear sunfish	8	2.1	3	1.2	2	1.2	3	1.2	2	0.83	3	1.2	<1	0.3	1	0.4
Smallmouth bass	7	2.3	9	1.2	4	1.6	29	7.2	8	1.53	13	3.0	12	2.1	23	6.1
Spotted bass	2	1.0	< 1	0.3	1	1.0	7	2.0	1	1.09			<1	0.45	<1	0.28
Largemouth bass	48	8.0	55	10.3	13	5.0	30	8.1	26	11.01	15	5.1	6	2.3	15	3.2
White crappie	4	1.5	1	0.7			< 1	0.3	< 1	0.36						
Black crappie			2	1.3			< 1	0.3	< 1	0.36	<1	0.3			1	0.37
Freshwater drum			5	1.5	7	4.7	9	3.4	8	1.87	5	1.7	11	3.0	4	1.3
White bass/ Striped bass	< 1	0.4	3	2.3	4	4.0			1	0.73	1	1.0	<1	0.3		

Table 8. Length frequency and CPUE (fish/hr) for select species of fish collected during 4.5 hours of electrofishing at the Kentucky Tailwater in fall of 2023. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																																TOTAL	CPUE (fish/hr)	S. E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32			
Skipjack herring					1	3	3		2																								9	2	0.7
Gizzard shad*		1	6	13	4	45	59	57	51	59	25	54	13	8	2						1												541	113	30.7
Threadfin shad*		33	221	34																													1713	330	138.7
Grass carp																					3		2	1					1	1			8	2	0.5
Common Carp																						1	1	2			1	1					6	1	0.5
Silver carp																											1	4			2	2	9	2	0.8
Emerald Shiner*	13	54	62	1																													242	47	20.9
Smallmouth buffalo												1	2	2	2	2		1	1														11	2	0.7
Channel Catfish																				1		1											2	0	0.4
Flathead catfish							1		1	2	2	2	1									1											10	2	0.7
White bass			1	2	5	8	8	1								1																	26	5	1.3
Yellow bass		1	14	7	17	9	6	2																									56	11	4.3
Bluegill		95	33	47	10	11	3																										199	38	6.9
Longear sunfish		16	12	9	6																												44	8	2.3
Redear sunfish					1	1																											2	0	0.3
Smallmouth bass		1	18	43	68	56	26	3	1	1	3	1	2				1	1															225	43	6.7
Spotted Bass				1	6	3	3	1																									14	2.63	0.96
Largemouth bass		1	3	6	13	18	17	12	8	2	4	3	4	3	2	1	1		1														99	19	2.7
White Crappie				1																													1	0.19	0.19
Freshwater drum*			1	7	21	2	1									2		1	1		4												63	11.7	9.35
White bass/Striped bass hybrid				1	1	1																											3	0.56	0.4

* species were randomly subsampled

Table 9. Length frequency and CPUE (fish/hr) for select species of fish collected during 3.0 hours of electrofishing at the Barkley Tailwater in fall of 2023. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																																		TOTAL	CPUE (fish/hr)	S. E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34			
Skipjack herring			1	1	1	9	16	8	3	1																									40	11	3.6
Gizzard shad*		1	2	11	15	28	22	23	34	29	24	23	14	2	3																				354	113	34.6
Threadfin shad*		77	216	12																															7321	2103	985.2
Grass carp																									1				1	1					3	1	0.4
Silver carp																				1	1	1	1		1	1	2		2	3	4	3	1	1	22	6	2.1
Smallmouth buffalo																	3	4	6	1	4														18	5	2.6
Flathead catfish								1									1																		2	1	0.4
White bass						1	2	3	1		4	4																							15	4	2.6
Yellow bass						1					1																								2	1	0.4
Bluegill		3	3	4	15	7	3																												35	10	2.2
Longear sunfish		9	11	12	8																														40	11	4.5
Redear sunfish					1					1	1																								3	1	0.4
Smallmouth bass				6	13	17	9	1	9	5	4	4	3	2	3	2	1																		79	23	6.2
Largemouth bass					3	5	20	5	1		1	1	5	3	1	3	1	3																	52	15	3.2
Black crappie											1		1																						2	1	0.4
Sauger																2																			2	1	0.4
Freshwater drum															1	1	1	3	4	3	1														14	4	1.3

* species were randomly subsampled

Table 10. Mean relative weight (Wr) and standard error for a subsample of fish collected during fall electrofishing at Kentucky Tailwaters in 2016 - 2023. (S.E. = standard error)

Species	2016			2017			2018			2019			2020			2021			2022			2023		
	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.
Gizzard shad	45	72	1.6	215	83	0.7	21	77	2.0	152	85	0.5	66	85	1.6	79	92	6.0	126	89	1.1	128	86	0.9
Blue catfish				1	108					1	99								1	84				
Channel catfish	1	102		1	105					1	100								5	101	7.4			
Flathead catfish	7	98	6.2	19	100	6.3				11	99	6.2	1	106		1	123							
Yellow bass	29	84	1.8	104	83	2.2	7	90	12.3	33	80	4.6	4			3	88	8.6						
White bass	13	99	2.6	2	97	20.4	7	108	1.3	8	90	3.3	9	95	5.1	8	86	5.9	2	88	4.4	3	91	4.2
Striped bass							1	101											1	87				
White bass/Striped bass	2	81	7.5																2	109	7.3			
Bluegill	49	103	3.7	220	93	2.2	18	89	6.4	148	94	0.8	41	93	8.3	11	97	4.0	28	86	4.6	14	86	6.9
Redear sunfish	10	85	6.9	28	93	3.3				42	97	2.3	4	85	5.3	2	104	4.2	6	102	23.6			
Smallmouth bass	13	91	2.0	9	92	3.4	1	82		4	92	5.5	6	100	4.9	9	95	4.9	12	93	3.3	6	87	3.9
Spotted bass	1	123		6	109	3.1				1	117								1	84				
Largemouth bass	89	102	1.7	117	97	1.9	7	93	5.5	41	99	1.7	26	113	8.4	17	87	4.9	33	105	2.7	12	111	10.3
White crappie	2	90	8.7	3	76	7.3				4	84	3.0												
Black crappie				12	90	2.7																		
Sauger				3	97	21.8										4	78	4.2	1	71		1	83	
Freshwater drum	11	100	2.7	17	92	3.3	5	89	3.8	21	92	2.9	29	91	3.3	18	90	5.6	25	92	2.4	1	89	
Smallmouth buffalo	15	79	1.5	22	77	1.4	1	78		29	100	3.2	6	81	2.7	14	93	14.3						
Bigmouth buffalo				3	86	1	2	75	7.4															
Silver carp	75	89	1.6	19	82	2.4	11	73	3.2	15	81	1.2	26	76	1.7	32	76	2.0						

Table 11. Mean relative weight (Wr) and standard error for a subsample of fish collected during fall electrofishing at Barkley Tailwaters in 2016 - 2023. (S.E. = standard error)

Species	2016			2017			2018			2019			2020			2021			2022			2023		
	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.
Gizzard shad	96	70	1.6	176	80	0.9	18	75	2.5	45	91	1.2	53	96	4.2	20	73	3.1	82	89	1.5	171	88	1.7
Channel catfish	1	67		2	92	1.0							2	111	5.6				1	110				
Flathead catfish	13	94	1.7	17	106	5.8				66	99	3.8	10	96	3.4	6		6.8						
Yellow bass	2	88	8.7	73	79	1.3				11	87	4.5	7	85	4.5	3	74	8.3						
White bass	11	96	3.7	8	86	2.2	3	98	4.9	3	85	7.7	2	115	1.8	3	96	6.4	16	90	3.0	15	109	14.7
Striped Bass				2	90	5.9				1	109		5	108	5.6									
White bass/Striped bass hybrid				9	89	2.7	4	103	4.6				2	102	2.8	3	73	5.0	1	99				
Bluegill	49	111	3.1	107	104	2.5	31	115	8.3	85	103	1.6	63	102	2.3	29	118	10.6	27	102	6.2	26	100	3.9
Redear sunfish	17	93	2.1	9	97	3.7	2	106	14.6	9	101	3.9	4	101	13.0	4	101	12.4	1	45		3	77	8.1
Smallmouth bass	4	86	3.6	11	95	3.8	3	87	5.6	22	92	2.5	11	93	2.5	7	81	4.4	15	95	2.8	43	93	2.0
Spotted bass	3	107	11.0				1	125		3	106	10.1	2	103	9.4				2	104.91	2.4	1	75.23	
Largemouth bass	37	101	1.9	118	95	1.2	10	95	3.4	58	98	1.6	41	101	4.3	20	101	7.1	10	102	4.0	24	96	5.1
White crappie				3	88	6.6				1	92		1	116										
Black crappie				5	86	6.3				1	76		1	85		1	93					2	86	0.9
Freshwater drum	6	84	4.4	14	97	3.0	7	82	3.5	27	103	2.3	22	96	2.3	14	92	2.1	33	95	2.5	14	92	3.0
Smallmouth buffalo	21	84	1.4	28	84	1.6	1	99		16	92	1.9	27	81	1.4	9	78	2.6						
Bigmouth buffalo	2	88	4.0	1	79		1	84																
Silver carp	9	81	2.9	41	83	2.1	29	83	2.7	70	83	1.5	64	77	1.2	70	78	1.3						

Table 12. Number and disposition of bycatch from commercial fishing efforts under the Invasive Carp Harvest Program by calendar year, January - December. Survival rate is defined as fish that swam away upon being released from the net. Harvest of scaled rough fish is permitted under the Invasive Carp Harvest Program.

Year	Sport Fish*		Scaled Rough Fish**		Catfish Species		Paddlefish		Total number of bycatch
	Number Caught	Survival Rate %	Number Caught	% Harvested	Number Caught	Survival Rate %	Number Caught	Survival Rate %	
2013	29	100.0	7,132	93.7	100	97.0	305	90.5	7,566
2014	78	92.3	4,505	75.1	128	99.2	120	65.0	4,831
2015	97	89.7	7,462	80.5	719	95.0	980	65.0	9,258
2016	115	75.7	10,811	76.1	719	95.5	573	68.2	12,218
2017	25	92.0	9,565	91.8	541	95.7	314	75.5	10,445
2018	46	71.7	25,703	86.1	1201	98.3	200	85.5	27,150
2019	171	93.6	32,861	80.7	1512	98.7	296	80.7	34,841
2020	148	92.5	17,394	78.8	768	99.2	222	85.7	18,592
2021	126	98.4	19,433	87.7	733	99.0	126	81.0	20,418
2022	47	93.6	11,335	80.2	568	98.8	58	81.0	12,008
2023	93	86.0	10,427	66.6	1008	98.6	236	78.4	11,764

*Sport fish are defined in 301 KAR 1:060

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

Table 13. Species composition, number of individuals captured, and survival rate of species observed in bycatch during KDFWR ride-alongs with commercial fishers fishing under the Invasive Carp Harvest Program in 2016 - 2023. Survival rate of fish is defined as fish that swim away after release.

		2016		2017		2018		2019		2020		2021		2022		2023	
	Species	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate
Sport Fish	White bass	1	<1%					1	100%			2	100%	1	100%		
	Yellow bass	20	50%	1	100%	6	33%	4	75%			1	100%			3	100%
	Striped bass	19	79%	1	100%	3	33%	5	80%	10	80%	1	100%	2	50%		
	Hybrid striped bass	2	100%			1	100%	5	80%	2	100%	1	100%				
	Sauger	1	<1%	2	100%	3	33%	4	75%	2	50%	3	100%	3	66%	1	100%
	Largemouth bass	1	100%	5	80%	3	67%	25	80%	4	75%	9	100%	2	100%	1	<1%
	Smallmouth bass							4	100%							1	100%
	Redear sunfish	1	100%			2	50%	6	83%			1	100%	2	100%		100%
	Black crappie					5	50%	1	100%	1	100%					1	100%
	White crappie			1	100%	6	67%	2	50%			1	100%			1	<1%
	Total	46	88%	10	96%	29	54%	57	82%	19	81%	19	100%	10	83%	8	75%
Catfish species	Blue catfish	27	74%	47	94%	42	91%	96	95%	32	100%	38	92%	62	97%	43	93%
	Channel catfish	10	80%	17	82%	12	100%	13	100%	5	100%	16	96%	3	100%	11	100%
	Flathead catfish	9	89%	19	100%	8	88%	40	100%	7	100%	26	100%	28	89%	8	100%
	Total	46	81%	83	92%	62	93%	149	98%	44	100%	80	95%	93	95%	62	95%
	Paddlefish	83	48%	62	48%	38	32%	63	48%	26	50%	16	69%	7	28%	17	47%
Rough Fish*	Lake sturgeon					1	100%					1	100%				
	Shovelnose sturgeon									3	100%						
	Skipjack herring	23	17%	47	13%	18	<1%	79	<1%	16	<1%	25	36%	29	52%	85	<1%
	Smallmouth buffalo	145	99%	13	85%	98	100%	186	98%	103	100%	173	99%	236	99%	249	99%
	Bigmouth buffalo	8	100%	4	100%	7	100%	34	97%	14	100%	12	75%	6	100%	16	100%
	Black buffalo	17	94%			2	100%	4	100%	1	100%					2	100%
	Common carp	48	98%	33	94%	27	100%	479	84%	36	97%	17	100%	10	100%	21	100%
	Gizzard shad	5	<1%	3	33%			3	<1%	1	100%					1	100%
	Freshwater drum	76	67%	27	52%	73	71%	71	63%	40	82%	54	94%	56	89%	50	76%
	River carpsucker	3	100%					35	97%	41	100%	5	100%	2	100%		
	Spotted gar					2	50%	3	100%	1	100%	2	100%	1	100%	4	100%
	Longnose gar	8	88%	9	44%			9	67%	3	100%	3	100%	7	100%	3	33%
	Shortnose gar	9	44%	1	100%	2	50%	11	55%	5	100%	5	100%	1	100%	6	100%
	Total	571	77%	365	72%	392	83%	1277	87%	329	98%	299	92%	348	93%	437	71%

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

Table 14. Comparison for number of paddlefish, catfish, and sport fish caught per trip as reported by commercial fishers fishing under the Invasive Carp Harvest Program versus observations made by KDFWR staff during ride-alongs in 2016-2023. (S.E. = standard error).

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

	2020				2021				2022				2023			
Species	ICHP	S.E.	Ride-alongs	S.E.	ICHP	S.E.	Ride-alongs	S.E.	ICHP	S.E.	Ride-alongs	S.E.	ICHP	S.E.	Ride-alongs	S.E.
Paddlefish	0.11	0.01	0.87	0.49	0.05	0.01	0.28	0.13	0.03	0.01	0.15	0.09	0.13	0.03	0.28	0.13
Blue catfish	0.19	0.01	1.07	0.34	0.15	0.01	0.66	0.2	0.19	0.02	1.35	0.38	0.41	0.08	0.70	0.2
Channel catfish	0.05	0.01	0.17	0.11	0.05	0.01	0.28	0.08	0.06	0.01	0.07	0.05	0.67	0.01	0.18	0.08
Flathead catfish	0.06	0.01	0.23	0.09	0.04	0.01	0.45	0.19	0.03	0.01	0.61	0.23	0.74	0.02	0.13	0.05
Catfish*	0.08	0.01			0.16	0.01			0.08	0.02			0.33	0.12		
Largemouth bass	0.02	<0.01			0.02	<0.01	0.16	0.06	0.01	<0.01	0.04	0.03	<0.01	<0.01	0.02	0.02
Smallmouth bass	0.02	<0.01	0.13	0.06	<0.01	<0.01			<0.01	<0.01			<0.01	<0.01	0.02	0.02
Bass**					<0.01	<0.01			<0.01	<0.01			0.01	<0.01		
Hybrid striped bass	<0.01	<0.01	0.07	0.07			0.02	0.02								
Striped bass	0.01	<0.01	0.33	0.33	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.04	0.03	0.01	0.01		
Yellow bass	<0.01	<0.01			<0.01	<0.01	0.02	0.02					0.01	<0.01	0.05	0.04
White bass	<0.01	<0.01			<0.01	<0.01	0.03	0.02	<0.01	<0.01	0.02	0.02	0.01	0.01		
Sauger	0.01	<0.01	0.07	0.05	0.01	<0.01	0.05	0.03	<0.01	<0.01	0.07	0.04	<0.01	<0.01	0.02	0.02
Crappie	<0.01	<0.01	0.03	0.03	<0.01	<0.01	0.02	0.02	<0.01	<0.01			0.01	<0.01	0.03	0.02
Redear sunfish	<0.01	<0.01			<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.04	0.03	<0.01	<0.01		
Yellow perch													<0.01	<0.01		

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

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

Table 15. Number and survival rate of paddlefish captured by commercial fishers during KDFWR ride-alongs under the Invasive Carp Harvest Program for each month paddlefish were observed caught in 2017 - 2023.

Year	Month	No. paddlefish captured	% released alive	Mean water temp (°F)	Mean soak time (hours)
2017	April	6	0%	67.6	13
	May	15	33%	68.5	10
	June	35	60%	79.5	8.3
	September	2	50%	74	10
	December	4	75%	50	21.3
2018	April	4	75%	54.9	11
	May	9	60%	66.1	10.2
	June	12	35%	81.7	10.6
	August	12	0%	82.9	11.6
2019	February	43	61%	46.9	11.4
	March	1	0%	49.8	11
	April	3	33%	60.25	9.7
	May	7	14%	74	6.4
	June	4	0%	76.9	11.3
	August	2	0%	84.1	8.8
	October	3	67%	69.8	8.2
2020	March	9	89%	49.1	7.8
	May	5	20%	66.1	6.5
	September	11	36%	77	7.25
	October	1	100%	68.6	8.8
2021	March	3	100%	57.5	3.25
	May	5	80%	63	13
	July	4	0%	87	9
	October	4	100%	71	11.25
2022	May	4	0%	75	8.5
	August	2	50%	80.5	3.625
	September	1	100%	76	5.5
2023	April	2	50%	60.5	3.5
	June	4	25%	79.5	7.5
	July	1	0%	82	7
	August	3	0%	84	11.75
	October	7	86%	72.4	4.25

Table 16. Kentucky Reservoir creel survey fishing pressure and catch rates from 1964 through 2023.

YEAR	Fishing Trips # fishing trips	Fishing Pressure Total Angler Hours	Average Trip Length (hours)	Catch Rates Fish/Hour
1964	316,201	1,712,549	5.4	0.98
1978	343,440	1,181,882	3.4	
1979	213,138	917,413	4.3	
1984	440,368	1,175,264	2.7	
1985	304,722	1,253,296	4.1	0.91
1986	261,735	1,167,826	4.5	1.16
1987	334,373	1,316,938	3.9	1.25
1991	298,186	1,278,559	4.3	1.13
1998	84,049	337,169	4.0	0.81
2003	207,357	980,132	4.7	1.31
2004	376,210	1,351,675	3.6	1.24
2007	285,078	1,077,120	3.8	1.48
2011	228,393	982,665	4.3	1.59
2015	188,601	841,143	4.5	1.09
2017	173,145	855,798	4.9	1.60
2020	146,711	617,660	4.2	0.82
2023	98,550	449,112	4.6	1.50

Table 17. Average nighttime electrofishing catch per unit effort (CPUE, fish/hour) for Gizzard Shad and Threadfin Shad from Kentucky Lake and Lake Barkley during 2021 and 2022. Standard error shown in parenthesis.

	Kentucky Lake		Lake Barkley		Mann-Whitney U
	N	CPUE	N	CPUE	
All Gizzard Shad	1,647	66 (14)	4,434	233 (56)	W = 55, p-value = 1.6e-5
Gizzard Shad ≥180mm	1,401	56 (13)	1,120	59 (7)	W = 139.5, p-value = 0.02
Gizzard Shad ≥280mm	334	13 (4)	137	7 (2)	W = 237, p-value = 0.78
All Threadfin Shad	729	29 (15)	1,134	60 (36)	W = 191, p-value = 0.27

Table 18. Average nighttime surface trawling catch per unit effort (CPUE, fish/minute) for Gizzard Shad and Threadfin Shad from Kentucky Lake and Lake Barkley during 2021 and 2022. Standard error shown in parenthesis. Surface trawling was conducted only in Kentucky Lake during 2021.

	Kentucky Lake		Lake Barkley	
	N	**CPUE**	**N**	**CPUE**
Gizzard Shad	3,095	5 (2.9)	6,671	51 (16.4)
Threadfin Shad	29,233	44 (10.8)	25,170	191 (57.1)

Table 19. Sample size (N), mean length (mm) with standard error shown in parentheses and length range of shad collected from Kentucky Lake and Lake Barkley nighttime electrofishing surveys during 2021-2022.

	Kentucky Lake			Lake Barkley		
	N	**Mean Length**	**Range**	**N**	**Mean Length**	**Range**
Gizzard Shad	1,647	232.8 (1.4)	66-367	4,434	130.7 (1.0)	34-438
Threadfin Shad	729	89.4 (0.4)	58-167	1,134	82.3 (0.3)	53-158

Table 20. Sample size (N), mean length (mm) with standard error shown in parentheses and length range of shad collected from Kentucky Lake and Lake Barkley nighttime surface trawling surveys during 2021-2022.

	Kentucky Lake			Lake Barkley		
	N	**Mean Length**	**Range**	**N**	**Mean Length**	**Range**
Gizzard Shad	3,095	64.3 (0.3)	33-275	6,761	68.4(0.2)	25-208
Threadfin Shad	29,233	75.2 (0.1)	31-172	25,170	64.9 (0.1)	28-141

Table 21. Precision of two readers estimating the age of Gizzard Shad otoliths collected during the fall of 2021 from Kentucky Lake and Lake Barkley. ACV is the average coefficient of variation.

Fall 2021	N	Agreement	±1	±2	±3	ACV	SD
Kentucky Lake	98	92.9%	6.1%	1.0%	0.0%	1.6	6.0
Lake Barkley	108	90.7%	9.3%	0.0%	0.0%	1.5	5.4

Table 22. Precision of two readers estimating the age of Gizzard Shad otoliths collected during the spring of 2022 from Kentucky Lake and Lake Barkley. ACV is the average coefficient of variation.

Spring 2022	N	Agreement	±1	±2	±3	ACV	SD
Kentucky Lake	118	79.7%	19.5%	0.8%	0.0%	3.3	7.2
Lake Barkley	118	86.4%	12.7%	0.0%	0.8%	2.2	6.6

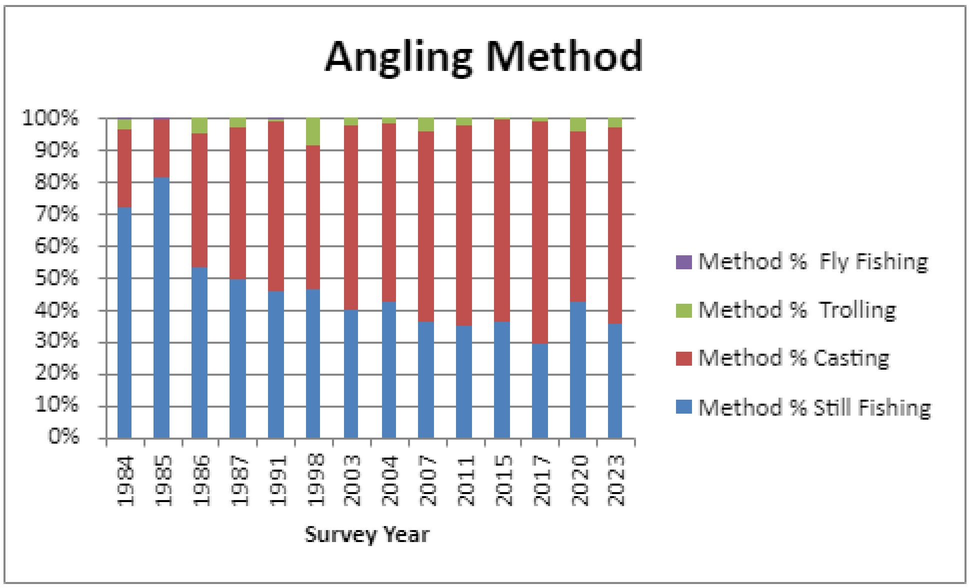


Figure 1. Angling method for fishing on Kentucky Reservoir 1984-2023.

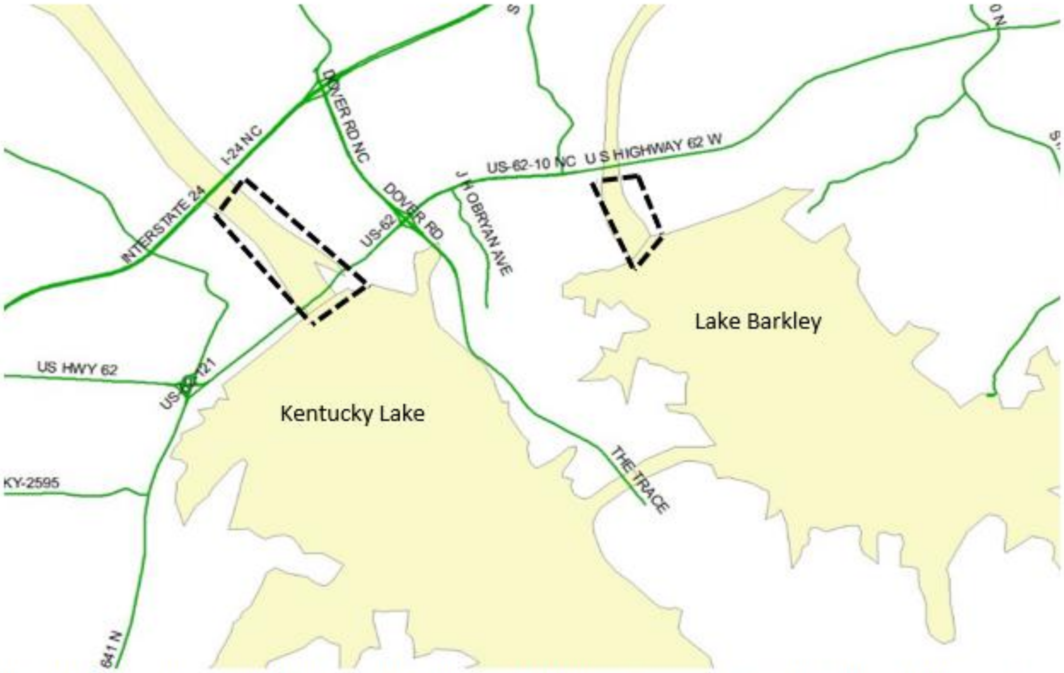
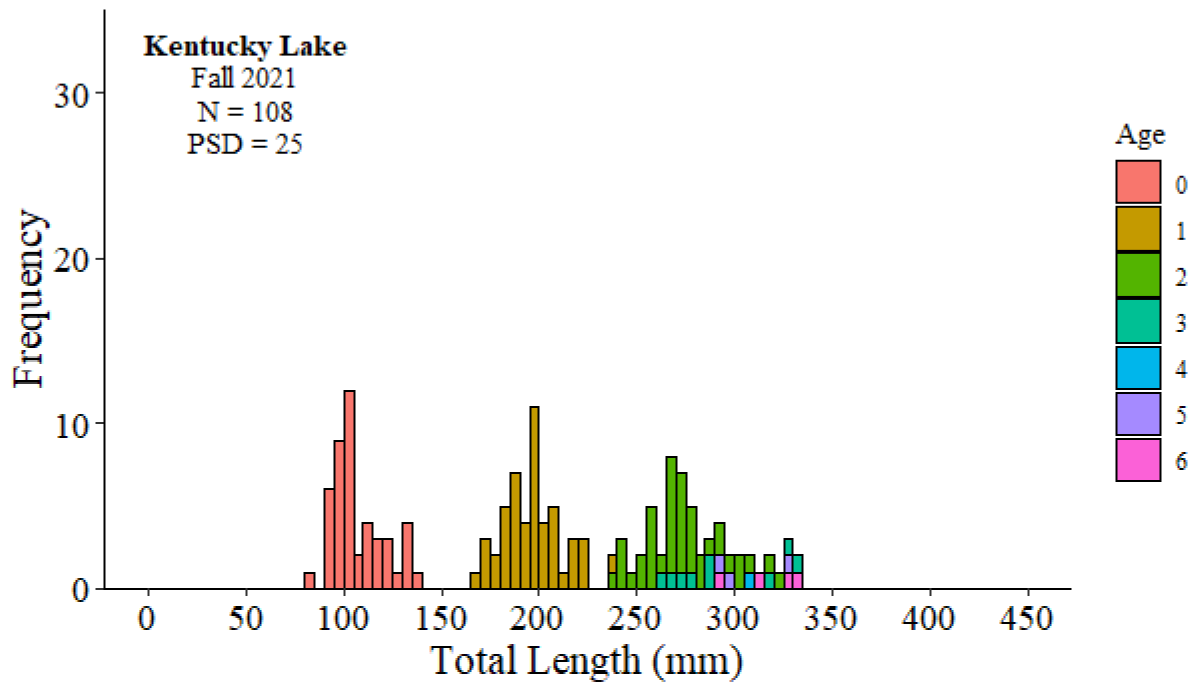


Figure 2. The tailwater electrofishing at Kentucky Tailwater extended from the dam downstream to the Interstate 24 bridge. The electrofishing at Barkley Tailwater extended from the dam downstream to the US Hwy 62 bridge. Sample areas are outlined by dashed line.



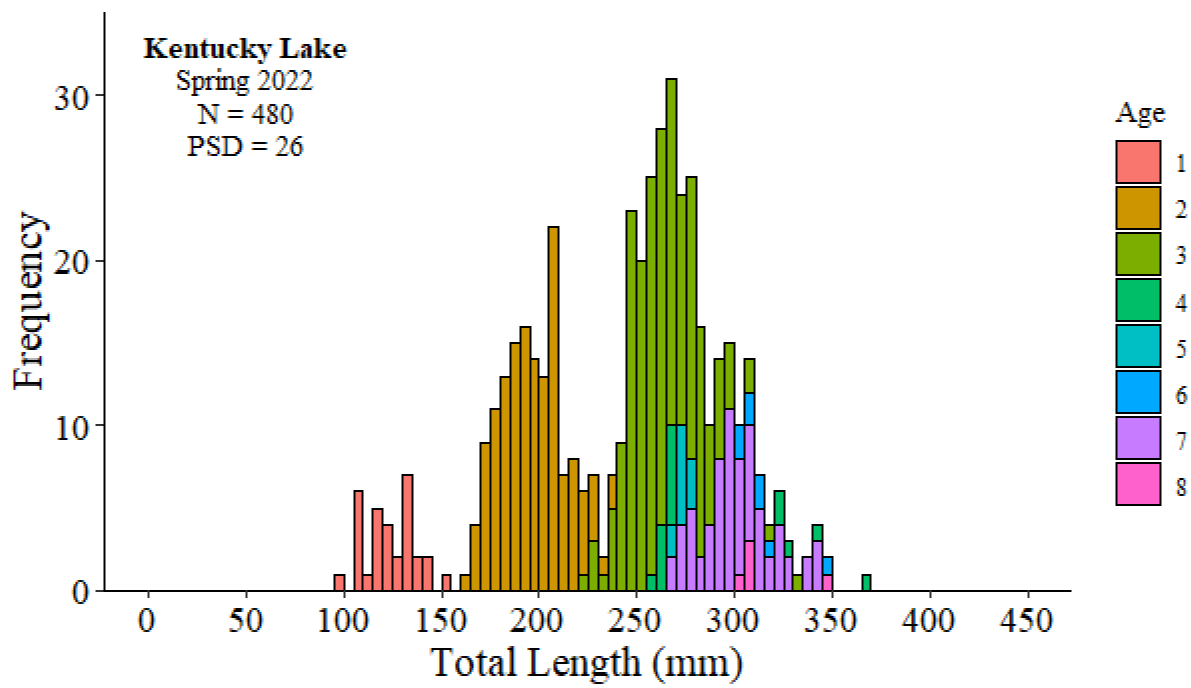


Figure 3. Length-age histograms of Gizzard Shad captured by nighttime electrofishing during fall 2021 (top) and spring 2022 (bottom) from Kentucky Lake. Sample size (N) and Proportional Size Distribution (PSD) values are also shown.

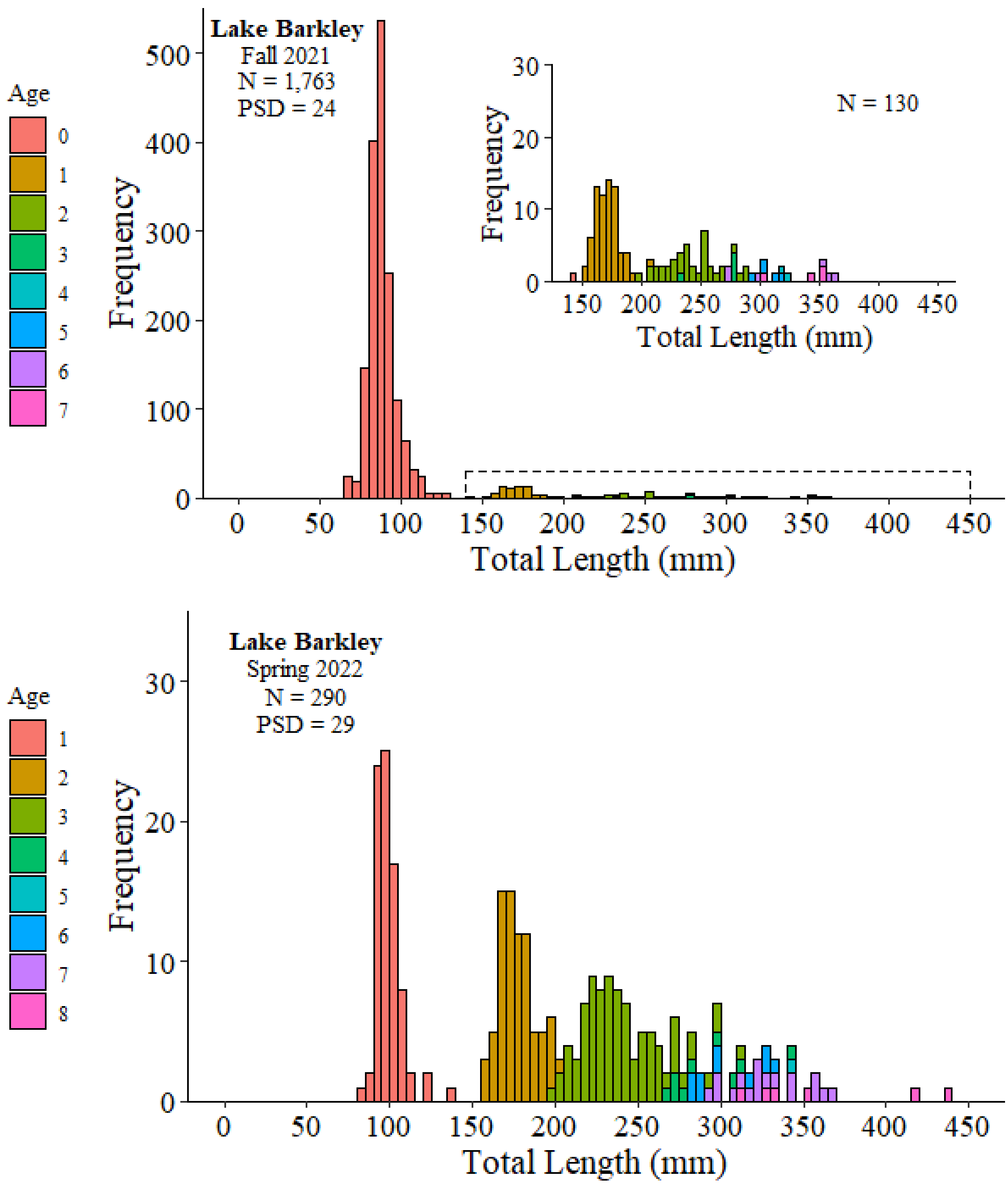


Figure 4. Length-age histograms of Gizzard Shad captured by nighttime electrofishing during fall 2021 (top) and spring 2022 (bottom) from Lake Barkley. Note the differences in y-axis between the plots, the top plot is also zoomed in on fish ≥150mm for comparison. Sample size (N) and Proportional Size Distribution (PSD) values are also shown.

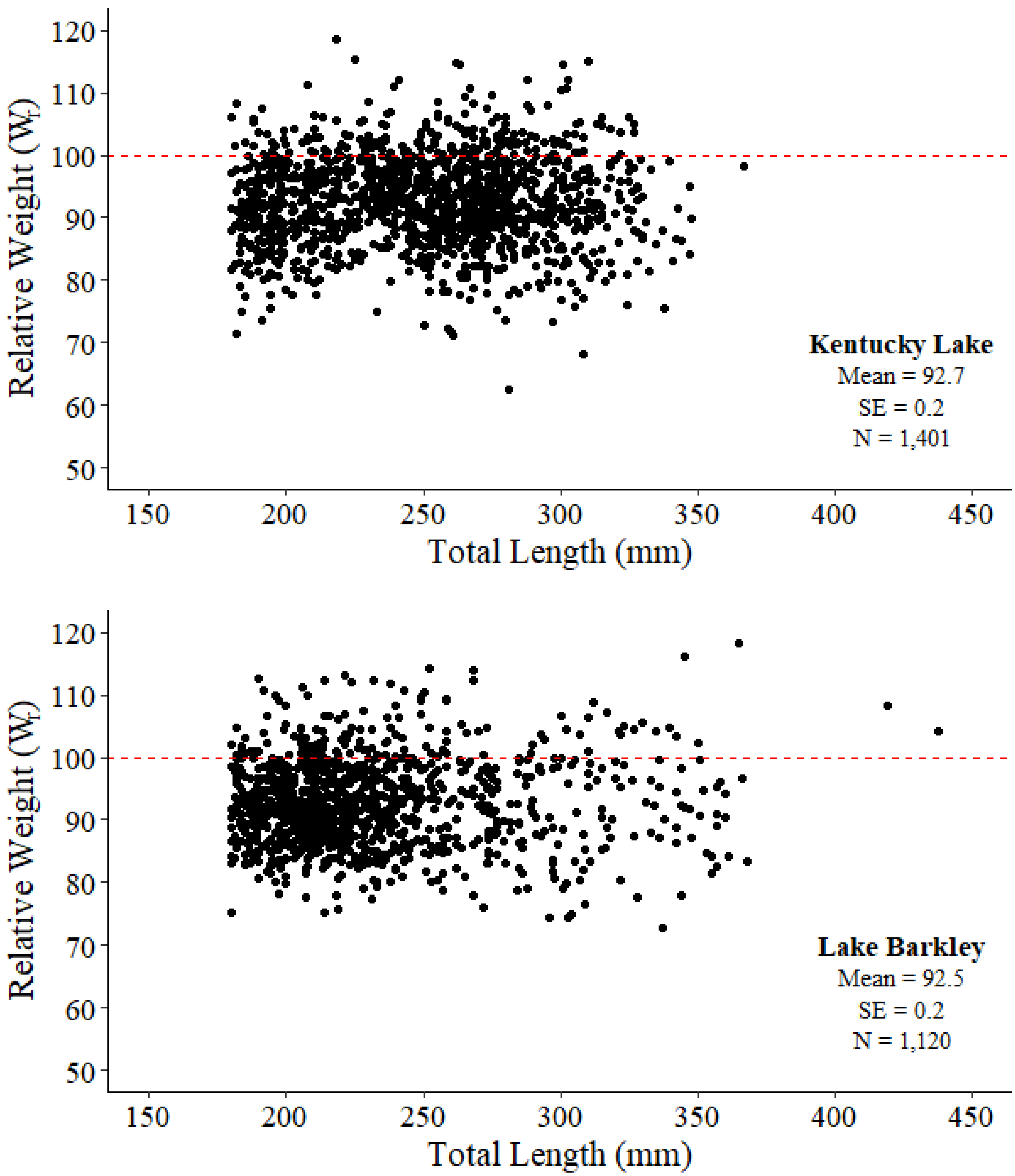


Figure 5. Scatterplot of total length (mm) and relative weight (W_r) of Gizzard Shad captured from Kentucky Lake (top) and Lake Barkley (bottom) during 2021 and 2022. Dashed red line represents a relative weight of 100 or equal to the 75th percentile for Gizzard Shad.

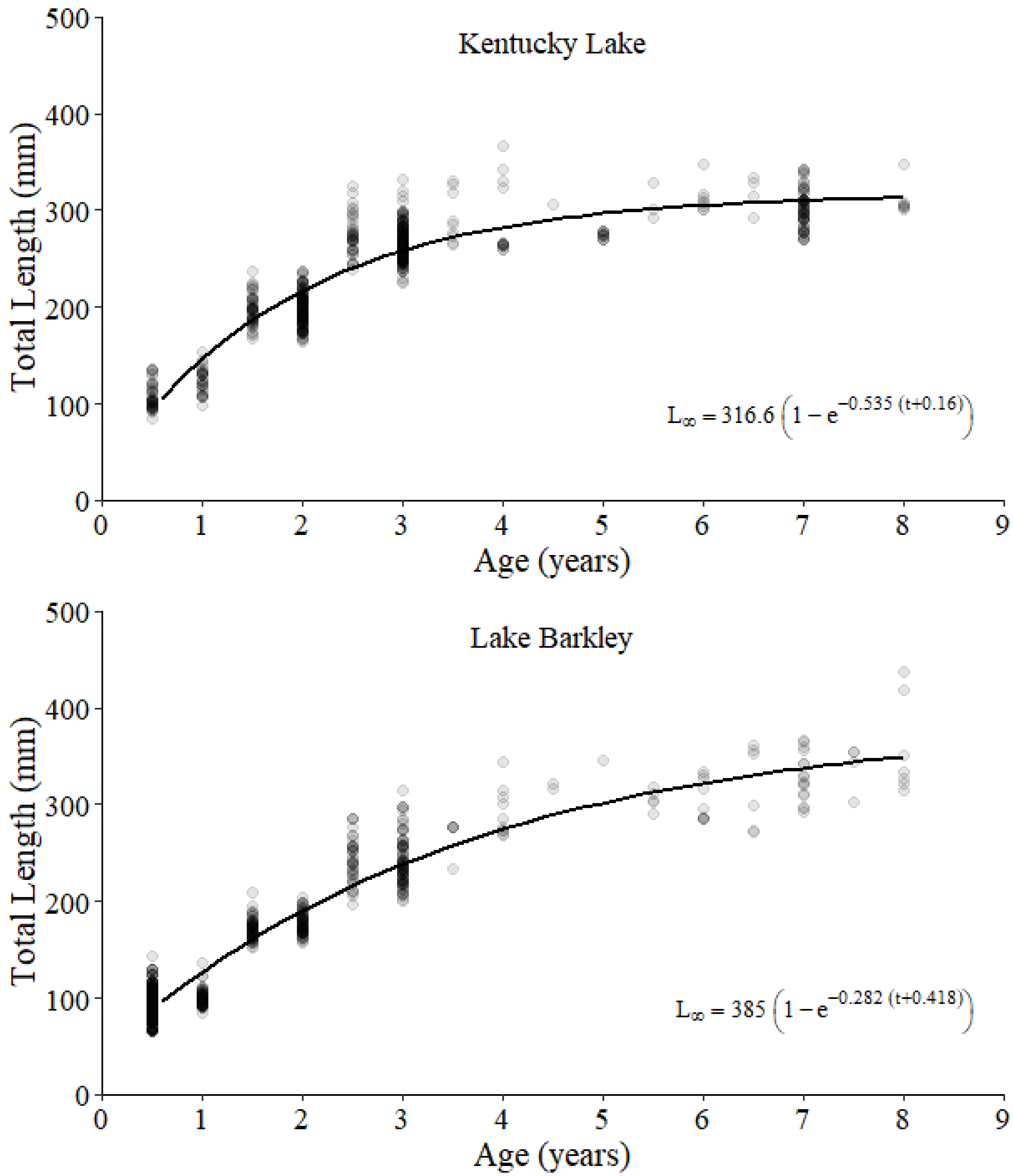


Figure 6. Kentucky Lake (top) and Lake Barkley (bottom) Gizzard Shad von Bertalanffy growth curve calculated from otoliths collected during October 2021 and April/May 2022. Gizzard Shad collected in October 2021 were given ages of half years to account for that year's growth.

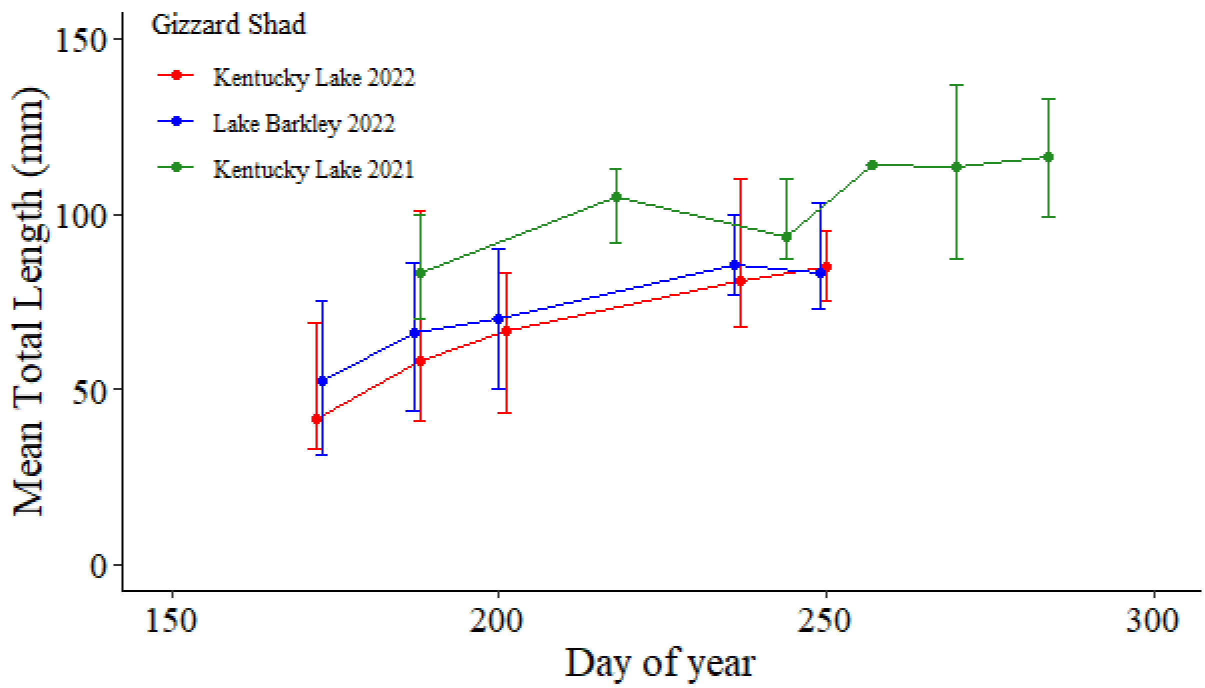


Figure 7. Mean length of young of year (YOY) Gizzard Shad by day of year captured during surface trawling surveys. Surface trawling only occurred on Lake Barkley during 2022. Error bars represent minimum and maximum lengths.

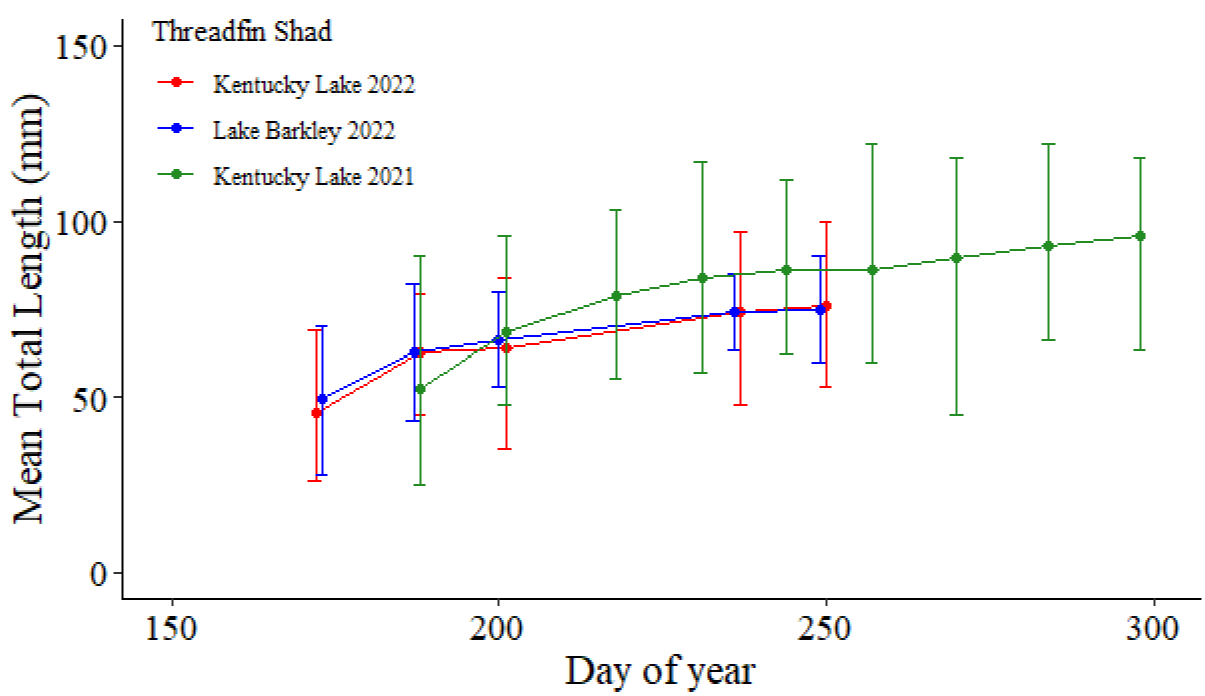


Figure 8. Mean length of young of year (YOY) Threadfin Shad by day of year captured during surface trawling surveys. Surface trawling only occurred on Lake Barkley during 2022. Error bars represent minimum and maximum lengths.

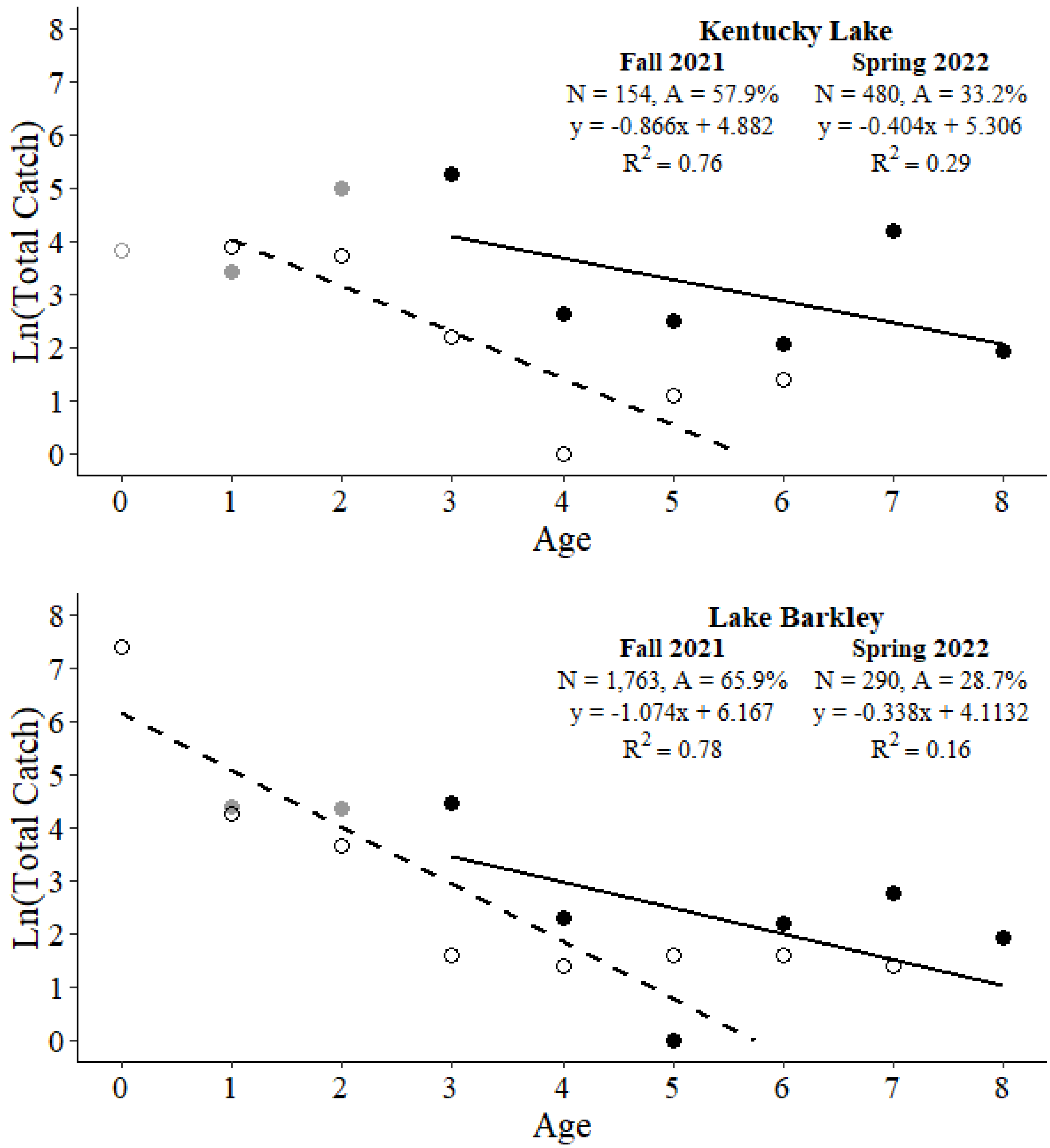


Figure 9. Weighted catch-curve regressions for Gizzard Shad in Kentucky Lake (top) and Lake Barkley (bottom) from fall 2021 (open circles/dashed line) and spring 2022 (filled circles/solid line). Grey dots represent year classes not included in regression analysis.

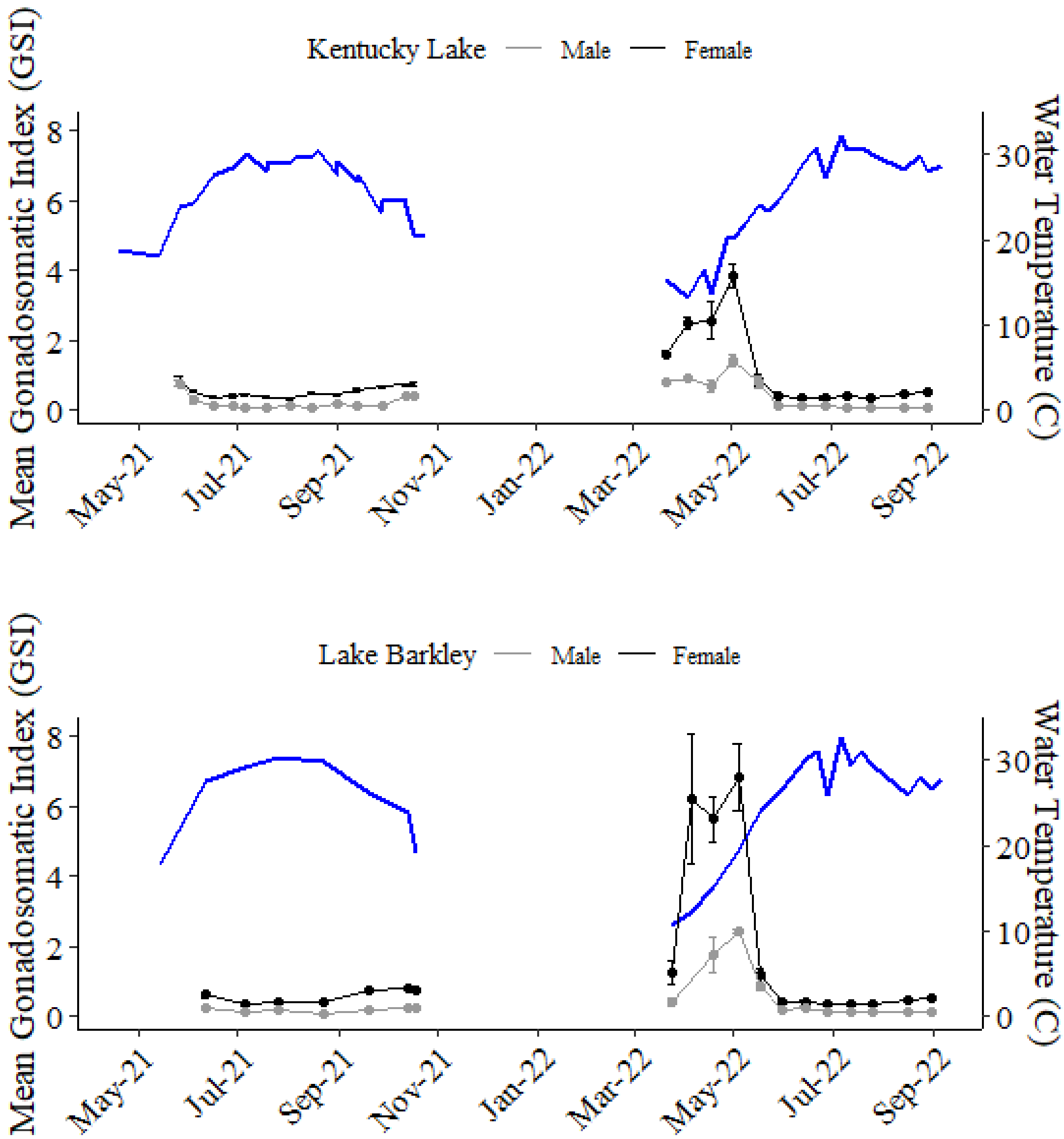
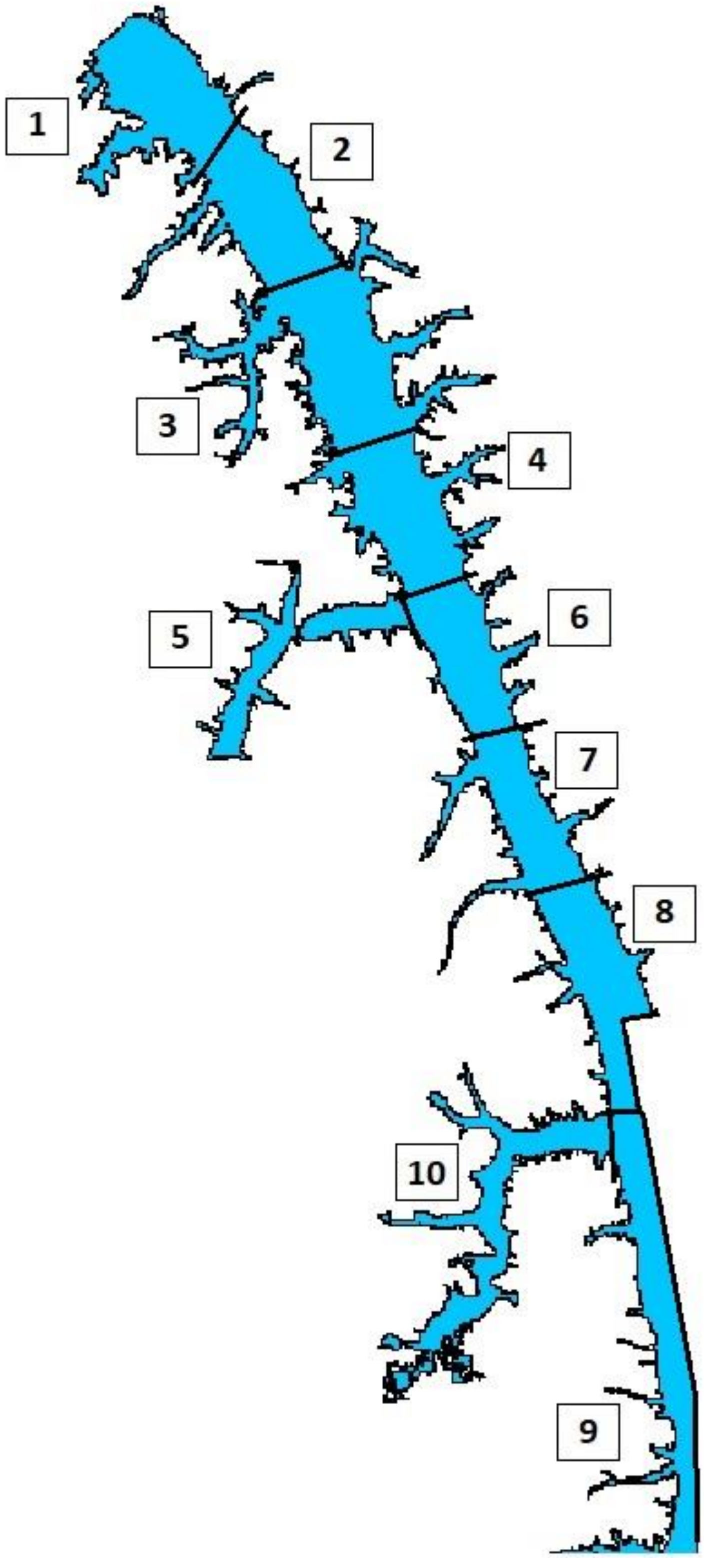


Figure 10. Mean gonadosomatic index (GSI) by date for male (gray) and female (black) Gizzard Shad from Kentucky Lake (top) and Lake Barkley (bottom). Error bars are standard error of mean. Blue line represents mean water temperature (C) recorded during sampling.

Appendix A. Kentucky Reservoir Creel Survey Areas 2023.



Appendix B. KENTUCKY RESERVOIR ANGLER ATTITUDE SURVEY 2023

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

2. Name ____ (**Optional**) and Zip Code _____________________

3. On average, how many times do you fish Kentucky Lake in a year? N=330

First time here 1.8% 1-4 22.4% 5-10 7.9% More than 10 67.9%

4. Which species of fish do you fish for at Kentucky Lake (**check all that applies**)? N=330
Redear 13.9% Bluegill 28.8% Black bass 62.1% Crappie 50.3% Catfish 26.4% White Bass 7.0% Yellow Bass 4.8%
Striped Bass 2.1% Silver Carp 0.3% Gar 0.3% Sauger 0.6% Hybrid Striped Bass 0.3%

5. Which one species do you fish for most at Kentucky Lake (**check only one**)? N=330
Redear 0.6% Bluegill 5.2% Black bass 53.3% Crappie 30.0% Catfish 9.1% White Bass 1.2% Yellow Bass 0.6%

Answer the following questions for each species you fish for – (see question 4)

Redear Anglers

6. In general, what level of satisfaction or dissatisfaction do you have with Redear fishing at Kentucky Lake? N=46
Very satisfied 6.5% Somewhat satisfied 37.0% Neutral 23.9% Somewhat dissatisfied 23.9%
Very dissatisfied 8.7%

6a. If you responded with somewhat or very dissatisfied in question (6) – what is the single most important reason for your dissatisfaction? N=15
Number of fish 86.7% Size of fish 0.0% Not happy with regulations 0.0% Poor weather 13.3%

Bluegill Anglers

7. In general, what level of satisfaction or dissatisfaction do you have with the Bluegill fishing at Kentucky Lake? N=95
Very satisfied 23.2% Somewhat satisfied 42.1% Neutral 17.9% Somewhat dissatisfied 12.6%
Very dissatisfied 4.2%

7a. If you responded with somewhat or very dissatisfied in question (7) – what is the single most important reason for your dissatisfaction? N=16
Number of fish 81.3% Size of fish 18.8% Not happy with regulations 0.0%

Black Bass Anglers

8. In general, what level of satisfaction or dissatisfaction do you have with the black bass fishing at Kentucky Lake? N=204
Very satisfied 19.6% Somewhat satisfied 43.6% Neutral 16.2% Somewhat dissatisfied 15.2%
Very dissatisfied 5.4%

8a. If you responded with somewhat or very dissatisfied in question (8) – what is the single most important reason for your dissatisfaction? N=42
Number of fish 71.4% Size of fish 7.1% Not happy with regulations 0.0% Lake levels 4.8% Asian carp 4.8%
Poor weather 2.4% No grass anymore 2.4% Poor knowledge 2.4% Doesn't fish enough 2.4% Cormorants 2.4%

Crappie Anglers

9. In general, what level of satisfaction or dissatisfaction do you have with crappie fishing at Kentucky Lake? N=165
Very satisfied 19.4% Somewhat satisfied 31.5% Neutral 15.8% Somewhat dissatisfied 24.2%
Very dissatisfied 9.1%

9a. If you responded with somewhat or very dissatisfied in question (9) – what is the single most important reason for your dissatisfaction? N=55

Number of fish 87.3% Size of fish 0.0% Not happy with regulations 0.0% Asian carp 5.5% Poor weather 1.8%
Bad time of year 3.6% Lake levels 1.8%

Catfish Anglers

10. In general, what level of satisfaction or dissatisfaction do you have with the catfish fishing at Kentucky Lake? N=87
Very satisfied 41.4% Somewhat satisfied 37.9% Neutral 12.6% Somewhat dissatisfied 5.7%
Very dissatisfied 2.3%

10a. If you responded with somewhat or very dissatisfied in question (10) – what is the single most important reason for your dissatisfaction? N=7
Number of fish 85.7% Size of fish 0.0% Not happy with regulations 0.0% Too much commercial fishing 0.0%
Water levels 14.3%

White Bass Anglers

1. In general, what level of satisfaction or dissatisfaction do you have with the White Bass fishing at Kentucky Lake? N=23
Very satisfied 26.1% Somewhat satisfied 47.8% Neutral 17.4% Somewhat dissatisfied 8.7%
Very dissatisfied 0.0%

11a. If you responded with somewhat or very dissatisfied in question (11) – what is the single most important reason for your dissatisfaction? N=2
Number of fish 50.0% Size of fish 0.0% Not happy with regulations 0.0% Asian carp 50.0%

All Anglers

2. When you fish for crappie at Kentucky Lake, do you use some form of real-time, forward-facing sonar like livescope or a similar system? N=166
Yes 50.0% No 50.0%

12a. If "Yes", how often do you use it while crappie fishing? N=83
Always 72.3% Frequently 9.6% Occasionally 7.2% Rarely 10.8% Never 0.0%

3. When you fish for crappie at Kentucky Lake, how often do you release keeper size fish (>10")? N=164
Always 3.7% Frequently 22.0% Occasionally 32.9% Rarely 12.8% Never 28.7%

13a. If you release them, what is the number one reason you release a keeper size crappie? N=119
Only caught a few 37.0% Release large females 15.1% Release large fish 18.5%
Too close to the size limit 4.2% Only keep larger fish 5.0% Only practice catch and release 10.1%
Release everything under 11" 0.8% Only keeps fish when guiding 0.8% Only keep fish out of cold water 1.7%
Only keeps a few per trip 0.8% Freezer is already full 0.8% Don't eat fish 0.8% Culling 0.8%
Already caught a limit 3.4%

14. If you fish for catfish in Kentucky Lake, which is more important to you: catching trophy fish, or catching more keeper size fish to eat? N=87 Trophy fish 9.2% Catching keeper fish to eat 65.5% Both equally important 16.1% No opinion 9.2%

15. If you fish for catfish, would you support or oppose a statewide 12-inch minimum size limit on catfish? N= 87
Support 78.2% Oppose 19.5% No Opinion 2.3%

16. Are you satisfied with the current size and creel limits on all sport fish at Kentucky Lake? N=330 Yes 87.9% No 12.1%

16a. If you responded "No" to Question 16, which species are you dissatisfied with and what size and creel limits would you prefer? N=40

LMB minimum size 14" 5.0%	LMB minimum size 18" 5.0%	LMB minimum size 20" 2.5%
LMB slot limit 2.5%	LMB creel limit 3/day 2.5%	SMB minimum size 14" 5.0%
SMB minimum size 18" 12.5%	SMB minimum size 21" 2.5%	SMB minimum size 24" 2.5%
SMB slot limit 2.5%	SMB creel limit 3/day 2.5%	Crappie minimum size 8" 2.5%
Crappie minimum size 9" 2.5%	Crappie minimum size 11" 17.5%	Crappie minimum size 12" 25.0%
Crappie slot limit 5.0%	Crappie slot limit 10-12" 2.5%	Crappie slot limit 10-14" 2.5%
Crappie slot limit 9-14" 2.5%	Crappie creel limit 15/day 22.5%	Crappie creel limit 10/day 7.5%
RES minimum size 10" 2.5%	RES creel limit 20/day 2.5%	RES creel limit 15/day 2.5%
RES creel limit 10/day 2.5%	Catfish minimum size 16" 2.5%	Yellow Bass creel limit 30/day 2.5%
BLG creel limit 30-40/day 2.5%	BLG creel limit 20/day 2.5%	Bass tournaments limit 3/angler 2.5%

17. Have you participated in an organized fishing tournament on any body of water within the last 12 months? N=330
Yes 38.2% No 61.8%

17a. If "Yes", were any of the tournaments an alternative format (catch, photo, release; onboard weighing, etc) N=126
Yes 4.8% No 95.2%

17b. To help us learn more about fishing tournaments in Kentucky, would you support or oppose a regulation requiring tournaments to post upcoming tournament dates and locations on our website? N=126
Support 86.5% Oppose 7.9% No Opinion 5.6%

17c. Would you support or oppose a regulation requiring tournaments to report their fishing effort and catch to our department? N=126
Support 77.8% Oppose 15.1% No Opinion 7.1%

18. Silver carp are the most abundant of the 4 invasive Asian carp species in Kentucky Lake and often jump when disturbed. Based on your personal experience on the water, how do you feel the abundance of silver carp has changed in Kentucky Lake in the past two years? N=330
Increasing 7.9% Decreasing 65.5% No Change 13.9% No Opinion 12.7%

19. Are you aware that invasive Asian carps are generally considered to be excellent fish to eat? N=329
Yes 74.5% No 25.5%

20. Are you aware that commercial harvest of invasive Asian carps occurs on Kentucky Lake? N=329
Yes 90.0% No 10.0%

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

Geographic Location: Tennessee and Cumberland rivers

Statement of Need:

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

Invasive carp reproductive success has not been definitively confirmed above Kentucky and Barkley dams in the Tennessee and Cumberland rivers (TNCR) despite the observation of large numbers of young of year carp during the fall of 2015. Limited evidence of successful invasive carp reproduction, including collection of eggs by Tennessee Valley Authority and one genetically identified larval silver carp from TWRA (2017), has been detected during larval sampling efforts and the 2015-year class remains a dominant cohort of fish captured during sampling efforts since 2016. The larval and juvenile sampling in this plan is critical for understanding the source of carp in the TNCR and making relative management decisions (location and amount of harvest and deterrence projects).

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

Project Objectives:

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

Project Highlights:

KDFWR

- No young of year invasive carp were found in Barkley or Kentucky reservoirs in 2023.
- Catch rates of adult silver carp during, paupier sampling in 2023 on Kentucky Lake were the lowest recorded since surveys began.
- No young of year invasive carp were found in the lower Tennessee and Cumberland Rivers in 2023

Methods:

KDFWR

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

KDFWR sampled for young of year (YOY) invasive carp and native baitfish in Barkley and Kentucky reservoirs. This work was conducted for one week on each reservoir in the fall. From each reservoir, 4 embayment's were chosen based on size and boat ramp availability. If YOY invasive carp were collected, then length and weights were recorded, and specimens were kept for further analysis. Environmental parameters such as water surface temperature, reservoir elevation, discharge, and depth were recorded at the sample locations. Boat electrofishing was conducted during the nighttime. Transects did not exceed 15 minutes of peddle time. Sampling was conducted with an MLES box at ~250 volts, ~20 amps, and ~3,000 watts.

KDFWR partnered with the U.S. Fish and Wildlife Service (USFWS) to conduct paupier net sampling in Kentucky reservoir to further inform population demographics and to search for YOY invasive carp. KDFWR provided staff and tender boats to collect length, weights, and aging structures. Sampling design was be informed by previous efforts with this gear type by the USFWS and agreed upon by basin partners. Sampling in Kentucky reservoir was conducted in seven embayments over the course of four 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 conducted targeted sampling for YOY Black Carp and other invasive carps in the lower Tennessee and Cumberland Rivers. Sampling locations were chosen based on the hydrologic similarity to the location where YOY Black Carp were collected previously in Kentucky. Sampling effort did not exceed 30 days. Areas were sampled with beach seine and backpack electrofishing as accessible. If YOY or juveniles were collected; length and weight were recorded, and the specimens were preserved for additional analysis. Most sites were sampled using a backpack electrofisher (Smith-Root LR-24) for variable durations depending on amount of habitat available to sample. Seining with 20' x 5' and 15' x 5' (1/8" mesh) seines was done at six sites, but proved to be difficult because of the deep, soft mud substrate.

Results and Discussion:

KDFWR

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

Electrofishing

KDFWR sampled for YOY invasive carp with nighttime boat electrofishing, in conjunction with sampling for projects under the monitoring of native fish project. This sampling occurred for four nights on Barkley reservoir and four nights on Kentucky reservoir in October of 2023. Sampling targeted young of year invasive carp, gizzard shad (GZSD), threadfin shad (TFSD), skipjack herring (SKJH) and emerald shiners. Sampling on Kentucky reservoir resulted in 8,043 total fish caught and 57% of those were gizzard shad over 180mm. Sampling on Barkley reservoir resulted in 5,179 total fish caught, out of which 72% were gizzard shad over 180mm. No YOY invasive carp were collected from either reservoir. Adult silver carp catch rates were low in both reservoirs, 1 fish/hr in Kentucky reservoir and 8 fish/hr in Barkley reservoir (Appendix B. Table 2)

Paupier

Sampling with USFWS collected a total of 17,782 fish with the electrified paupier net boat over four nights spent on Kentucky reservoir. This sampling was targeting young of year invasive carp, adult invasive carp, gizzard shad, threadfin shad, and skipjack herring. No YOY invasive carp were collected. CPUE of adult silver carp was lowest since paupier surveys began in Big Bear embayment (36 fish/hr. Appendix B. Table 1). The missing years from 2020 – 2021 was due to logistic constraints and the Covid pandemic.

Black Carp YOY Sampling:

KDFWR sampled for YOY invasive carp at 24 sites along the lower Ohio River, 9 sites along the Mississippi River, 11 sites along the lower Tennessee River and 11 sites along the lower Cumberland River (Table 3). No sites in the lower Tennessee and Cumberland rivers had YOY invasive carps collected. YOY invasive carp and one YOY black carp were collected in the lower Ohio River in 2023 (Figure 1).

Appendix B. Tables and Figures

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

Date	Net Hours	Number of Silver carp captured	Mean Silver carp CPUE (fish/hr)	S.E.	Number of Grass carp captured	Number of Bighead carp captured
Nov-16	9.12	1,406	168.9	23.0	3	
Oct-17	2.12	516	229.2	40.3		2
Oct-18	4.72	1496	308.3	61	1	2
Oct-19		442	~260	~60	1	
Oct-22	1.28	105	105.9	33.2		
Nov-23	0.66	24	36	9.07		

Table 2. Comparison of Catch Per Unit Efforts (CPUE, fish/hour) across embayment's and lakes of baitfish with night-time electrofishing in the fall of 2023.

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Blood River	1.5	35	257	1144	13	3
Jonathan	1.5	41	2459	624	5	1
Big Bear	1.5	55	301	125	21	1
Sledd Creek	1.5	125	17	128	7	2
*Kentucky Lake**	*6*	*64*	*759*	*505*	*12*	*1*

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Demumbers/Willow	1.5	42	247	239	14	15
Eddy Creek	1.5	233	1135	51	3	2
Little river	1.5	116	382	105	1	13
Honker Bay	1.5	36	712	109	1	0
*Barkley Lake**	*6*	*107*	*619*	*125*	*5*	*8*

* Mean CPUE for each reservoir

Table 3. Summary of YOY invasive carp captures in Western Kentucky during 2022 and 2023.

2022	# of Sites Sampled	Sites with YOY Invasive Carp	Sites with YOY Black Carp
Ohio River	21	2	1
Mississippi River			
Tennessee River	2		
Cumberland River			
Total	23	2	1
2023	**# of Sites Sampled**	**Sites with YOY Invasive Carp**	**Sites with YOY Black Carp**
Ohio River	24	3	1
Mississippi River	9	2	
Tennessee River	11		
Cumberland River	11		
Total	55	5	1

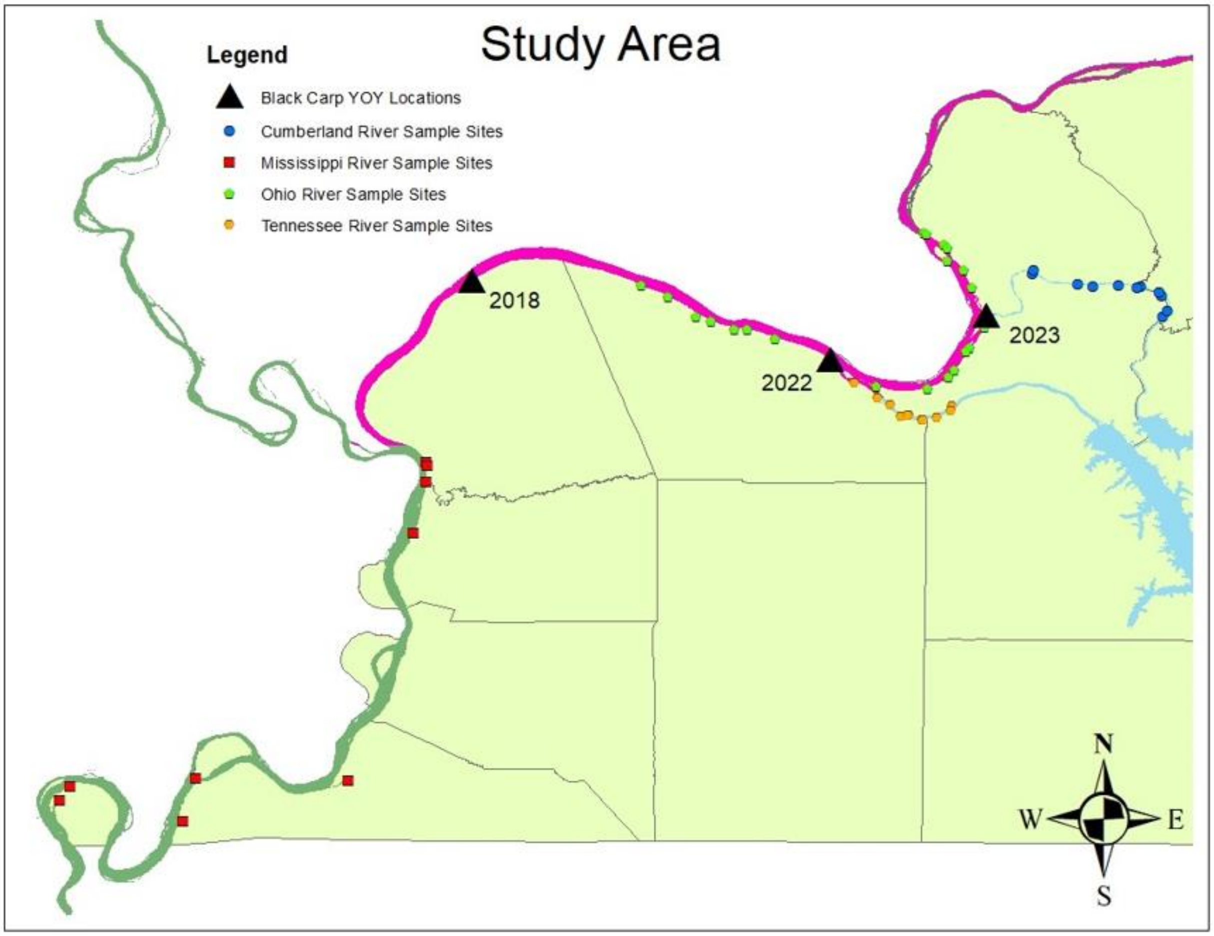


Figure 1. Site localities sampled for YOY invasive carps during 2023, as well as locations of YOY Black Carp captures in 2018, 2022, and 2023.

Recommendation:

- KDFWR recommends the continued effort to survey for young of year invasive carp in the Tennessee and Cumberland River sub-basin.
- This project serves as an early detection program and will inform management response and decision making, if YOY invasive carp are detected within the sub-basin.

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

Geographic Location: Ohio River Basin

2023 Project Objectives:

1) Determine the extent and locations of invasive carp recruitment in the Ohio River.

Project Highlights:

KDFWR

- Targeted YOY Black Carp sampling occurred at 24 sites along the lower Ohio River.
  - One YOY Black Carp was collected at one backwater site near Smithland, KY
  - YOY invasive carp were collected at 3 sites along the lower Ohio River

Methods:

KDFWR

For analysis purposes and for the remainder of this report, the phrase "invasive carp" will be referring to Silver and Bighead carps (*Hypophthalmichthys* spp.) only. YOY will be defined as fish less than 150 mm, and juvenile will be defined as fish between 150 to 400 mm (likely 1 to 2 years old) which have undeveloped gonads and are not capable of spawning. Adult invasive carp are defined as fish greater than 400 mm with mature, identifiable gonads.

Black Carp YOY Sampling:
KDFWR conducted targeted sampling for YOY Black Carp in the lower Ohio River from the confluence with the Mississippi River to above Smithland lock and dam. Sampling locations were chosen based on the hydrologic similarity to the location where YOY Black Carp were collected previously in Kentucky. Sampling effort did not exceed 30 days. Areas were sampled with beach seine and backpack electrofishing as accessible. If juveniles were collected; length and weight were recorded, and the specimens were preserved for additional analysis as needed. Most sites were sampled using a backpack electrofisher (Smith-Root LR-24) for variable durations depending on amount of habitat available to sample. Seining with 20' x 5' and 15' x 5' (1/8" mesh) seines was done at six sites, but proved to be difficult because of the deep, soft mud substrate.

Results:

KDFWR

Black Carp YOY Sampling:

KDFWR sampled for YOY invasive carp at 24 sites along the lower Ohio River, 9 sites along the Mississippi River, 11 sites along the lower Tennessee River and 11 sites along the lower Cumberland River (Table 1). Five sites sampled had YOY invasive carp and one of those sites had one YOY invasive Black Carp. All specimens were fixed in formalin and identification was verified in the laboratory. The YOY Grass Carp and Black Carp were identified by removing pharyngeal teeth and comparing their morphology (Figure 2).

Discussion:

KDFWR

Efforts in 2023 revealed the presence of YOY Black Carp at a single location out of 55 sites sampled along the lower Ohio, Mississippi, Tennessee, and Cumberland River. The location was along the Ohio River shoreline at river mile 920, directly upstream of the Cumberland River confluence of the Ohio River. This site is 27 miles upstream of Gar Creek, where the single YOY fish was collected in 2018, and 15 river miles upstream of the site that YOY Black Carp were collected in 2022 (Figure 1). The 2022 and 2023 sites have similar habitat characteristics; both are close to the main river channel, shallow (< 1 m), muddy backwaters that may be a nursery area at higher water levels but can become isolated during low river stage. This occurrence is further evidence of consistent, albeit low, Black Carp reproduction in the lower Ohio River drainage in Western Kentucky. No juvenile or adult Black Carp were captured or observed during sampling. Although currently available collection data indicates Black Carp are now established and reproducing in the lower Ohio River drainage, it suggests their dispersal into the area has been more recent and they are less common than Grass and Silver carps.

Recommendations:

KDFWR recommends continuing to develop and geographically expand invasive carp YOY surveys in the lower Ohio River basin with an emphasis on searching for YOY Black Carp. Continued effort is planned for 2024.

Figures and Tables:

Table 1. Summary of YOY invasive carp captures in Western Kentucky during 2022 and 2023.

2022	# of Sites Sampled	Sites with YOY Invasive Carp	Sites with YOY Black Carp
Ohio River	21	2	1
Mississippi River			
Tennessee River	2		
Cumberland River			
Total	23	2	1
2023	**# of Sites Sampled**	**Sites with YOY Invasive Carp**	**Sites with YOY Black Carp**
Ohio River	24	3	1
Mississippi River	9	2	
Tennessee River	11		
Cumberland River	11		
Total	55	5	1

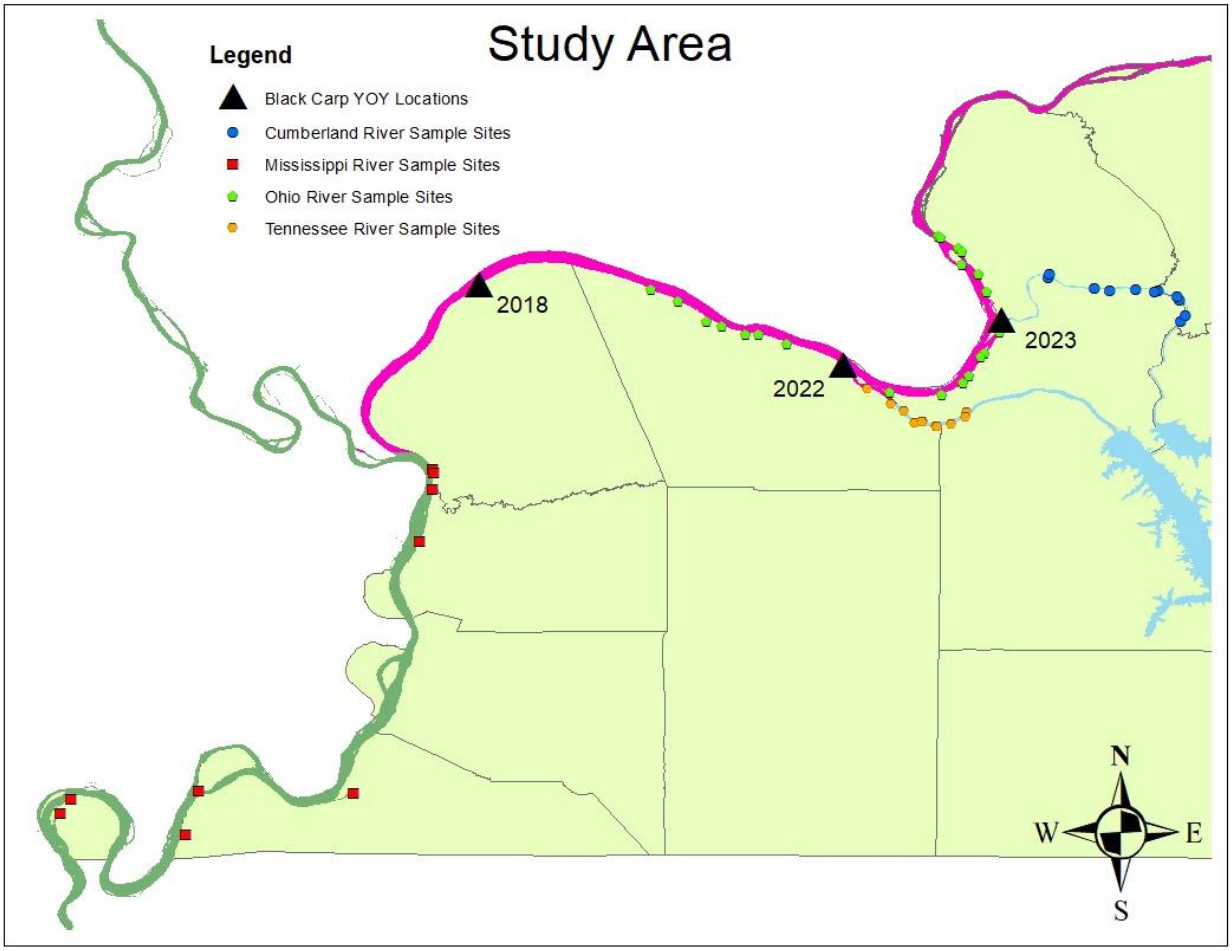


Figure 1. Site localities sampled for YOY invasive carps during 2023, as well as locations of YOY Black Carp captures in 2018, 2022, and 2023.

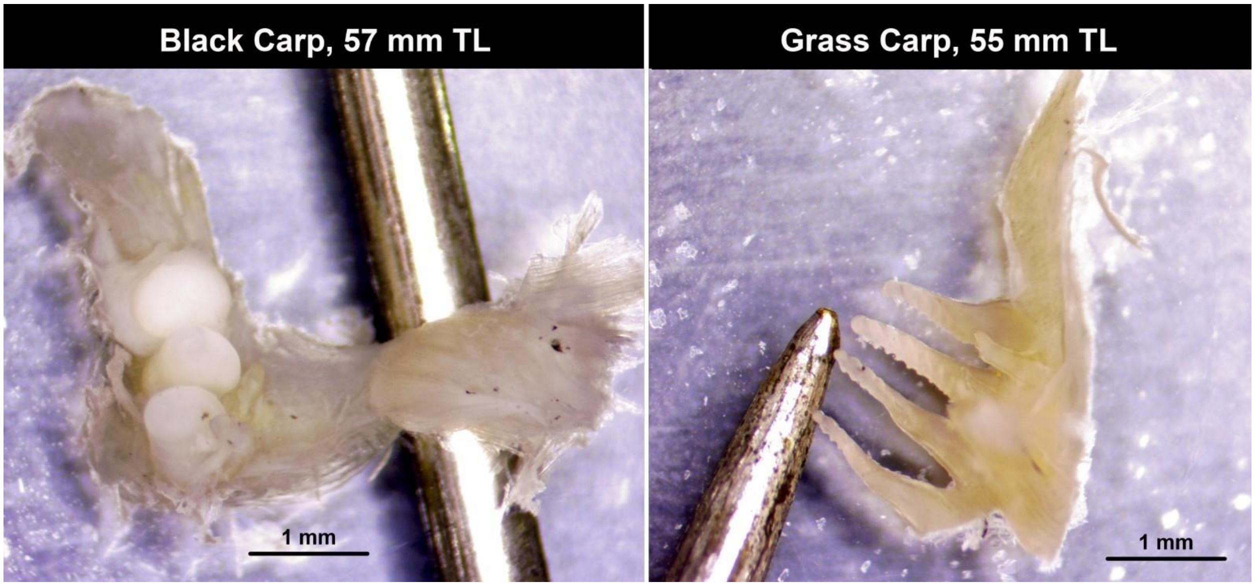


Figure 2. Comparison of pharyngeal tooth morphology between YOY Black and Grass carps of approximately the same size. Shown for each species is the dissected right pharyngeal arch. Black Carp has single row of 4 molar-like teeth (3 are visible). Grass Carp has two rows of slender, grooved teeth: 4 on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

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

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

Lead Agency: Kentucky Department of Fish and Wildlife Resources (KDFWR; Joshua Tompkins, Joshua.tompkins@ky.gov)

Participating Agencies: Tennessee Wildlife Resource Agency (TWRA)**,** Kentucky Department of Fish and Wildlife Resources (KDFWR), Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP), Alabama Department of Conservation and Natural Resources, U.S. Army Corps of Engineers (USACE), Tennessee Valley Authority (TVA), Murray State University, Tennessee Technological University (TTU), U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS).

Introduction: Adult bigheaded carp (i.e., Bighead Carp *Hypophthalmichthys nobilis* and Silver Carp *H. moltrix*) have invaded the Ohio River and tributaries of the Ohio River including the Tennessee and Cumberland rivers. Efforts to deter invading bigheaded carp and minimize future invasions are increasing. However, decisions on placement of bigheaded carp deterrents and the ability to evaluate efficacy of implemented deterrents requires baseline data and monitoring of bigheaded carp movements and abundance. Within the Ohio River, movement data have been collected to inform pool-to-pool movement and estimate trade-offs between deterrent location, deterrent effectiveness, and removal efforts for population control. Increased data within the Ohio River would further support these evaluations. In the Tennessee and Cumberland rivers, baseline movement and lock and dam passage data are at initial phases of collection. Therefore, continued collection of these data is critical to understanding potential deterrent locations and deterrent effectiveness warranted.

Adult bigheaded carp have been recognized in the Tennessee and Cumberland rivers (tributaries to the Ohio River) for the last three decades. A large recruitment event in 2015 caused a significant increase in abundance within the Tennessee and Cumberland rivers. These waterways are multi-jurisdictional and include waters within Kentucky, Tennessee, Mississippi, and Alabama. Thus, bigheaded carp invasions are a threat to multiple agencies and the valuable sport fisheries and ecosystems in their respective states. Bigheaded carp reports suggest increasing immigration upstream in both tributaries, however there are many uncertainties regarding abundances, movement rates and temporal patterns, and local recruitment of bigheaded carp in the Tennessee and Cumberland rivers. Currently, sub-basin agencies and universities are collaborating to enhance that preliminary work by surveying relative densities to inform control needs, monitor movements through locks and dams to inform lock management and deterrents, and determine if local recruitment is occurring in the reservoirs. The proposed projects described below will fill knowledge gaps necessary for understanding movement within the Ohio River tributaries and lock and dam passage.

Efforts to understand and control invasive carp in the Tennessee River and Cumberland River have been increasingly supported in the last few years and federal funding can further enhance control and management capabilities.

Project Objectives:

1. Develop recommendations of deterrent types and locations to control movement of invasive carps.
    1. Specific to the Tennessee and Cumberland Rivers
    2. Specific to the Ohio River
    3. Specific to the Tennessee- Tombigbee Waterway
2. Collect baseline movement information for native species and invasive carps among reservoirs and water bodies to inform deterrent efficacy and lock and dam passage.
3. Provide support to research activities associated with deterrent development and testing.

Agency: KDFWR

Activities and Methods:

Objective 1. Develop recommendations of deterrent types and locations to control movement of invasive carps.

KDFWR participated in 20 structured decision-making meetings with collaborating agencies to provide data and expert opinion on the distribution of invasive carp populations, identify available deterrent methods, and prioritize installation and maintenance of deterrents in the Tennessee, Cumberland, and Tombigbee waterways.

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

The VEMCO stationary receiver array was maintained and improved as needed. Data from the array was shared with partners to inform movement characteristics of invasive carp and some native species within the Tennessee and Cumberland rivers. Data collected through this effort assisted with the publication of the *Multimodal Invasive Carp Deterrent Study at Barkley Lock and Dam- Status Update through 2022* by Fritts et al. 2023.

KDFWR also assisted the USFWS with testing of a Bio-Acoustic Fish Fence (BAFF) technology on the downstream approach to Barkley Lock chamber. In the spring KDFWR led the tagging of, 618 fish with acoustic transmitters, to support deterrent and movement projects. Fish tagged consisted of 494 silver carp, 40 grass carp, 3 lake sturgeon, 13 blue suckers, 20 smallmouth buffalo, 28 paddlefish and 20 freshwater drum. This was the final large multispecies tagging event for the BAFF project. In subsequent years, a smaller number of silver carp will be tagged to maintain active fish within the TNCR array.

Objective 3. Provide support to research activities associated with deterrent development and testing.

KDFWR continued to provide onsite support and maintenance of the BAFF deterrent and the associated telemetry array at Barkley Lock for the duration of 2023.

Agency: Murray State University

Activities and Methods:

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

Murray State University used both stationary and mobile methods to track several native species throughout the Lower Cumberland River and Lower Tennessee River from 2022 through 2023. We tracked Paddlefish, Smallmouth Buffalo, Freshwater Drum, Alligator Gar, and Blue Suckers. We only obtained enough data to make any conclusions for Paddlefish and Smallmouth Buffalo.

Results and Discussion:

In the Lower Cumberland River, Paddlefish tended to be found more downstream as water temperatures rose (Figure 1) while Smallmouth Buffalo were more upstream during warmer temperatures (Figure 2). In general, Smallmouth Buffalo selected for the area below the dam and against the rest of the Lower Cumberland (Figure 3). A Relative Activity Index (RAI) was constructed for these species which compared each sample date's movement rate to the maximum movement rate for that species in that river. Both Paddlefish and Smallmouth Buffalo RAI tended to be higher in the fall and winter (Figures 4 and 6) and increased with discharge (Figures 5 and 7) in the Lower Cumberland River.

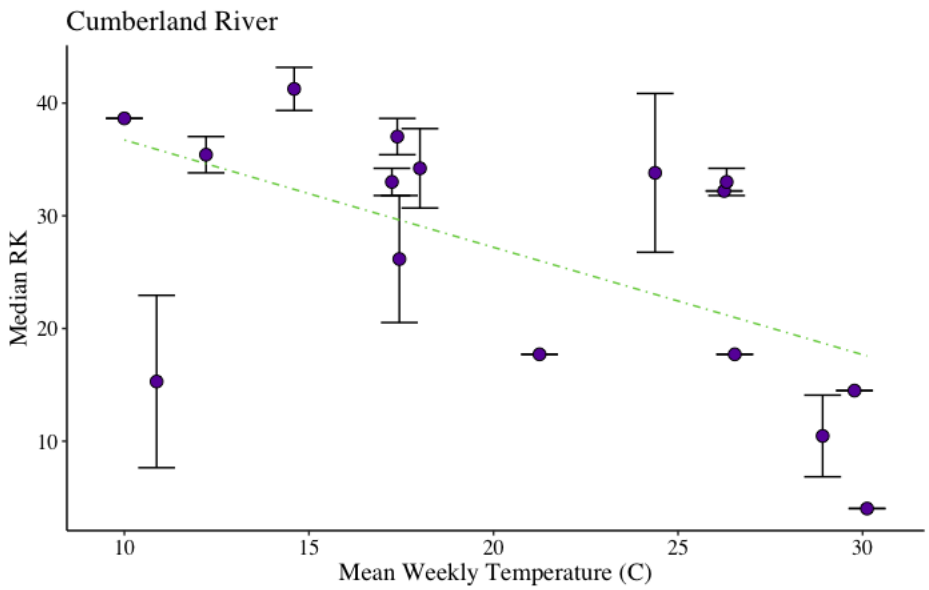

Figure 1. Median river kilometer (RK) of Paddlefish compared to mean weekly temperature (C). Paddlefish median RK showed a statistically significant negative relationship with temperature after controlling for discharge ($R^2 = 0.30$, $F_{2,12} = 3.94$, $p = 0.04$). Error bars are interquartile range.

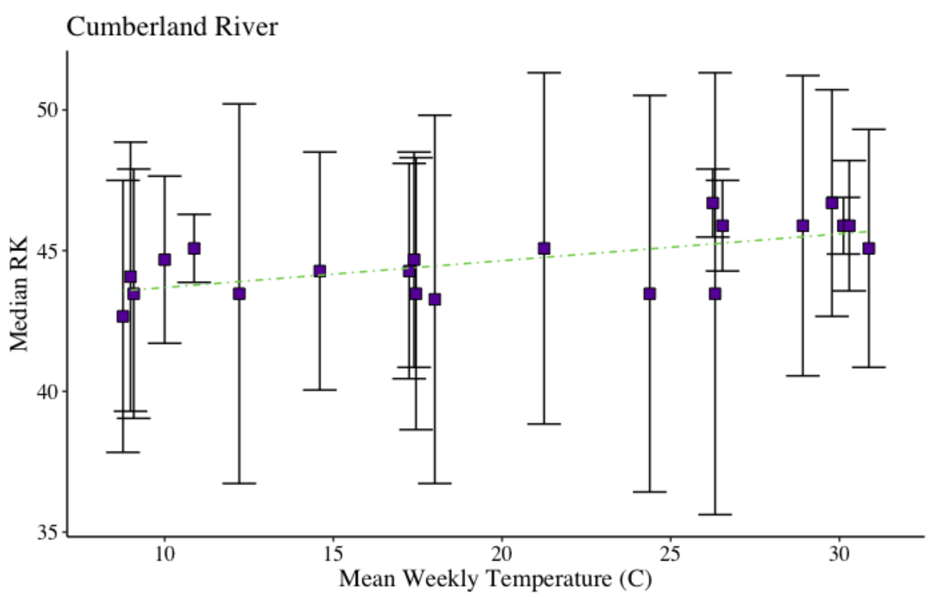

Figure 2. Median RK of Smallmouth Buffalo compared to mean weekly temperature (C). Smallmouth Buffalo median RK showed a significant positive relationship with temperature after controlling for discharge ($R^2 = 0.60$, $F_{2,17} = 15.52$, $p < 0.01$). Error bars are interquartile range.

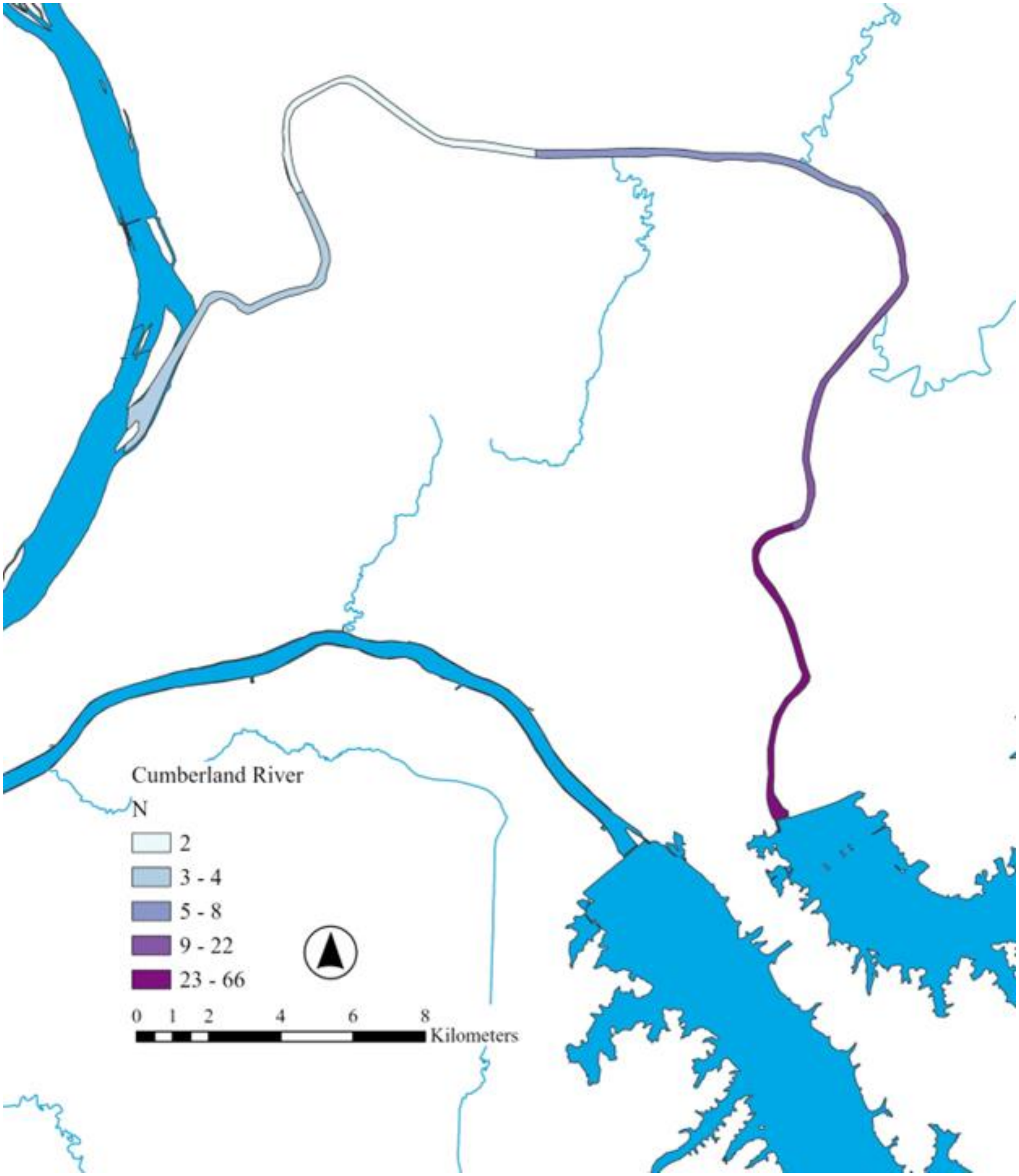

Figure 3. Total number of unique Smallmouth Buffalo located within each section of the Cumberland River. Each section is 20% of the length of the river. Smallmouth Buffalo demonstrated significant selection for the dam section and against the lower, mid, and mouth sections (log ratio $X^2 = 685.42$, df = 332, $p < 0.01$).

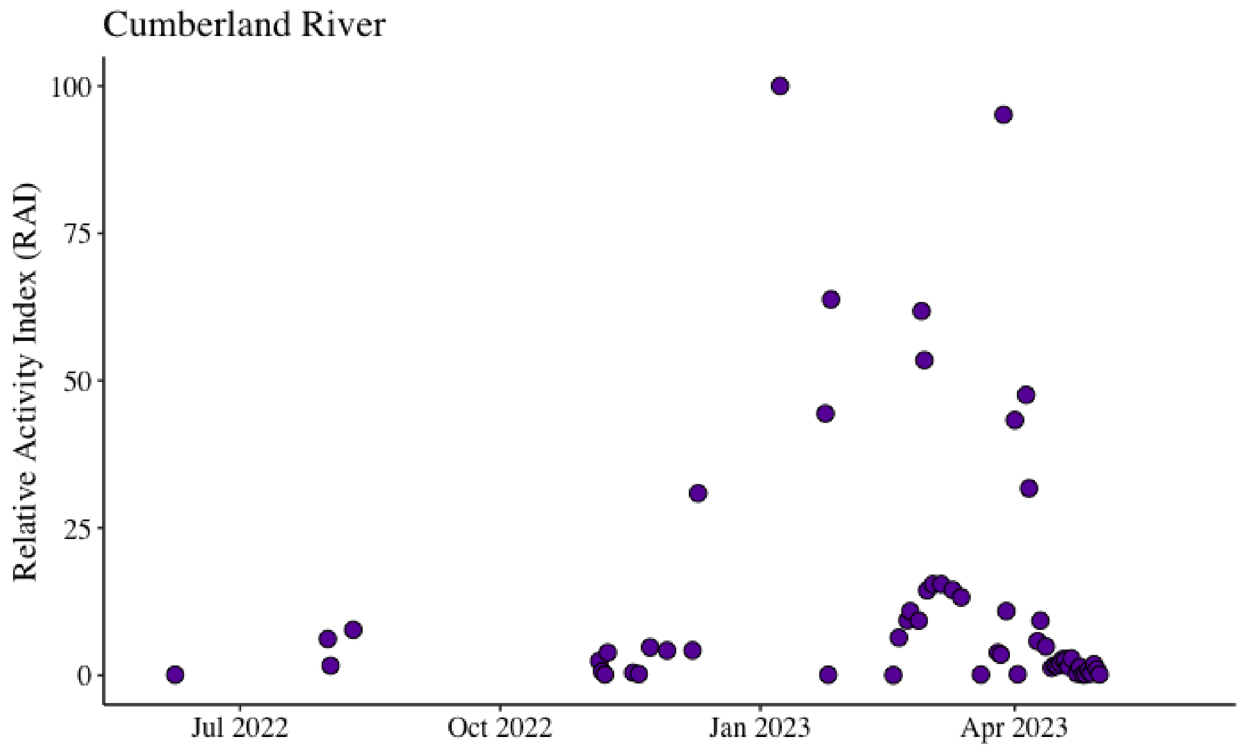

Figure 4. Paddlefish relative activity index (RAI) in the Cumberland River. Paddlefish show an increased activity during the winter and spring.

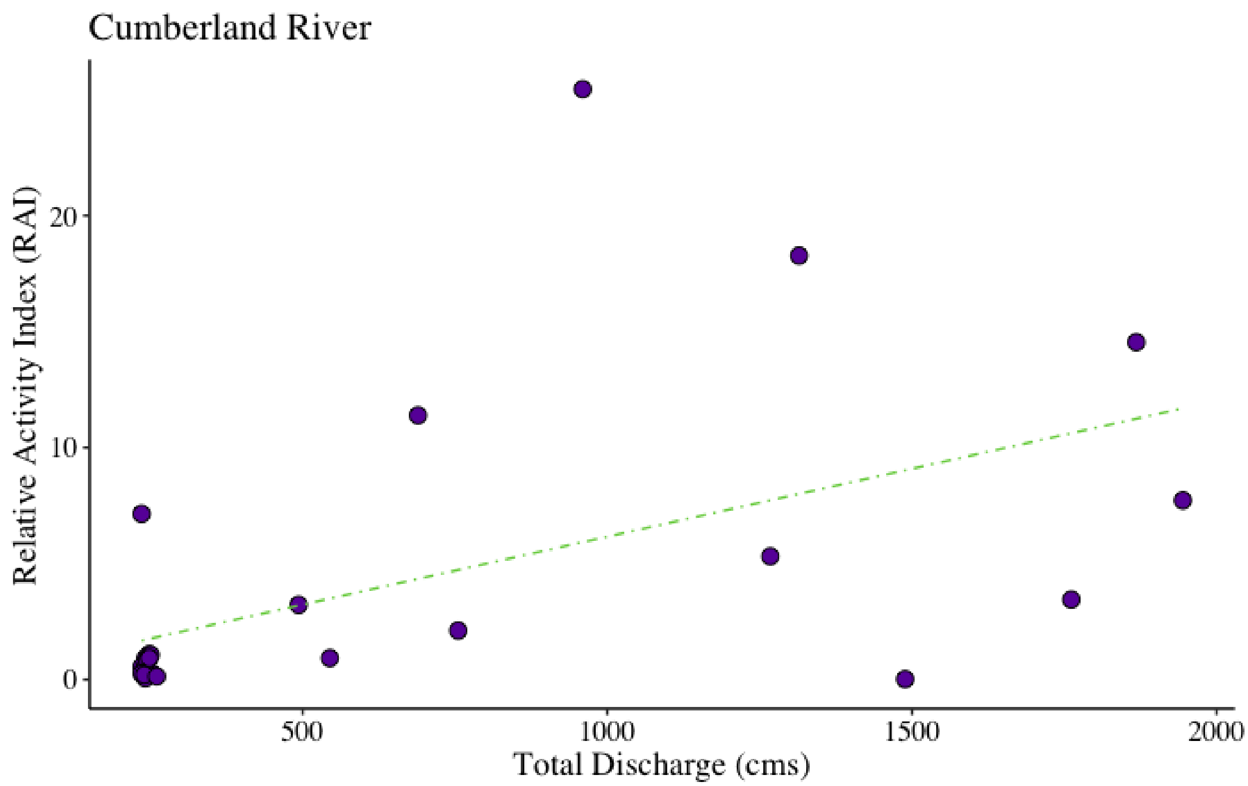

Figure 5. Paddlefish relative activity index (RAI) compared to discharge (cms) in the Cumberland River. RAI showed a significant positive relationship with discharge after controlling for temperature ($R^2 = 0.22$, $F_{2,24} = 4.66$, $p = 0.02$).

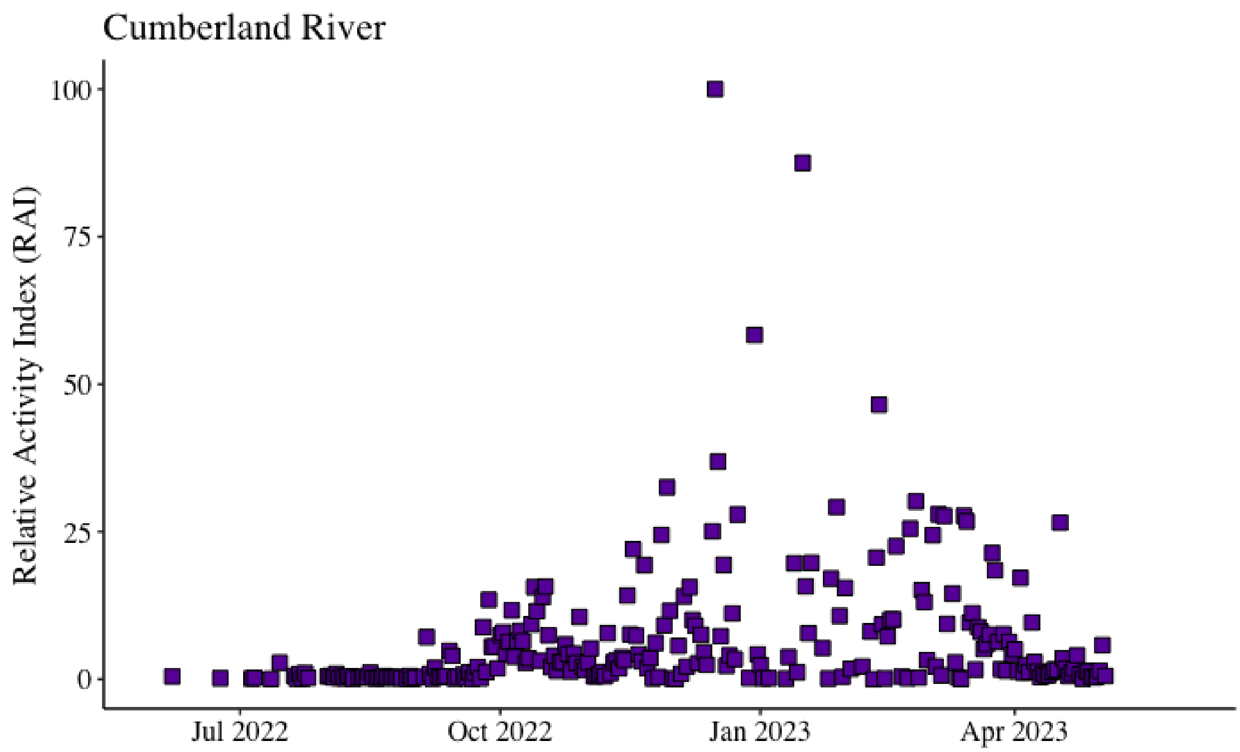

Figure 6. Smallmouth Buffalo relative activity index (RAI) in the Cumberland River. Smallmouth Buffalo activity peaked during the winter.

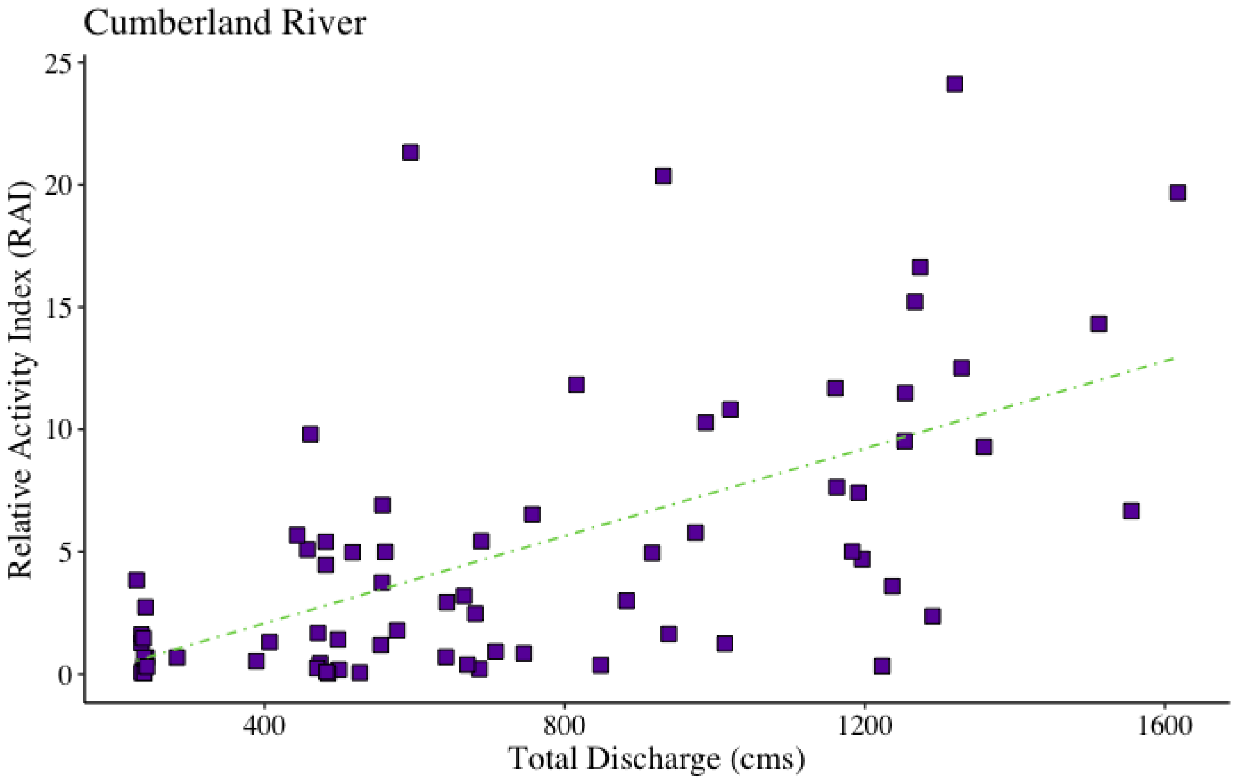

Figure 7. Relative activity index (RAI) in the Cumberland River for Smallmouth Buffalo compared to discharge (cms). RAI showed a significant positive relationship with discharge after controlling for temperature ($R^2 = 0.36$, $F_{2,72} = 21.80$, $p < 0.01$).

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Title: Early detection and evaluation of Invasive carp removal in the Ohio River

Geographic Location: Ohio River basin, extending from the J.T. Myers Pool (RM 845.9) to the R.C. Byrd pool (RM 279.2) along with the New Cumberland (RM 54.4), Montgomery Island (RM 31.7), Dashields (RM 13.3) and Emsworth (RM 6.2) pools of the Ohio River, in addition to the Wabash, Allegheny, and Monongahela rivers.

Lead agencies: Kentucky Department of Fish and Wildlife Resources (KDFWR) & West Virginia Division of Natural Resources (WVDNR)

Participating Agencies: Illinois Department of Natural Resources (ILDNR), Indiana Department of Natural Resources (INDNR), Pennsylvania Fish and Boat Commission (PFBC), Southern Illinois University (SIU), U.S. Fish and Wildlife Service (USFWS), West Virginia University (WVU)

Statement of Need:

Invasive species are responsible for undesirable economic and environmental impacts across the nation (Lovell and Stone 2005, Pimentel et al. 2005, Jelks et al. 2008). Negative impacts of Invasive carp in the United States are a major concern because of their tolerance and adaptability to a wide range of environmental conditions (Kolar et al. 2005, Zhang et al. 2016). Their ability to quickly colonize novel habitats with dense populations have caused significant impacts on tourism and recreation, and potentially threaten native ecosystems throughout the entire Mississippi River basin, including the Ohio River sub-basin. In response, it is necessary to gather information on invasive carp distributions, behavior, and population characteristics in the Ohio River basin (ORB). This information will be used to assess management actions related to their removal, suppression, and containment.

The tasks outlined in this document would add a sixth year of multi-agency and university surveillance and data collection focused on Invasive carp early detection and removal primarily above Cannelton Dam. Collaborative efforts have included fish community sampling, targeted Invasive carp sampling, and incorporation of unique data such as hydroacoustics. The primary goal of these projects is to provide an accurate population trend assessment of Invasive carp control and response efforts. In addition, fish community data may aid in determining impacts of carp on native fish assemblages. This project provides an ongoing, coordinated approach to assess Invasive carp management and suppression in the ORB.

Objectives:

1. Evaluate management actions using changes in relative abundance, population characteristics, and distribution of invasive carps within intensive management zones.
2. Monitor long-term trends in native fish communities as indicators of change due to Invasive carp invasion.
3. Survey Invasive carp presence in upstream areas where they are rarely detected to inform response and containment efforts.
4. Determine spatial distributions (hotspots) and densities of Invasive carps in the lower Wabash River to inform and assess harvest.
5. Utilize hydroacoustics surveys to determine biomass densities and verify patterns of relative abundance for Invasive carp species within strategic management zones.

Project Highlights:

- With current sampling efforts being unable to capture Bighead, Grass and/or Black carps with any regularity, Silver Carp are still the primary focus of management efforts in the middle Ohio River. In the R.C. Byrd pool, captures of Silver Carp are increasing making both Silver and Bighead carp a priority in that pool. In other upstream pools located ahead of the Silver Carp invasion front, Bighead Carp continue to be the top priority.
- With the lower precision involved in tracking the long-term trends in abundance through Silver Carp catch rates, other methods for monitoring and evaluation, (i.e. hydroacoustics and occupancy modeling) are in development to estimate abundance and inform decision making.
- After the start of contract fishing in 2019, the next two years (2020-2021) of sampling resulted in relatively stable Silver Carp catch rates. An increase in CPUE in 2022 caused concern that there were some shifting characteristics of the overall population, but in 2023, those numbers were back to average indicating 2022 catches may have been an anomaly.
- Preliminary results of the Community Size Spectra (CSS) analysis suggests that invasive carp populations in the Cannelton to RC Byrd pools have not yet reach a threshold of abundance to negatively influence the size structure of the native fish community. This was corroborated by an analysis of zooplankton in the same pool. Baseline CSS are being developed for upstream pools.
- There was no substantial range expansion for either Bighead or Grass Carp during this project period, however, Black Carp have now been found in the upper Wabash River. Also, young Silver Carp <300mm were captured in Meldahl Pool during a fish tagging event in the spring of 2023.
- Acoustic telemetry results of the White and Wabash indicate some site and habitat selection is occurring with Silver carp, although there is no uniform pattern. There is still some information on habitat selection of log jams that could imform removal effort and/or commercial fishers.
- Successive years of positive eDNA results for invasive carp DNA in the Racine Pool and the Muskingum River suggest targeted sampling for carp may be warranted in those areas.

Methods:

Clarification of this Document's Terminology

With carp populations still expanding throughout the Mississippi River basin, they will undoubtedly move into new areas being managed by agencies that have no previous encounters with the species. And yet, at some point, each and every one of them will have to mitigate the impacts that these highly disruptive fish have on their resource. As a result, it has become increasingly important to clarify the terminology used in any related technical documents, which include these annual reports. Hence, the following is a list of defined terms that required further explanation in the project's previous reports.

- *Invasive Carp*: One of four fish species originating from the Asian continent (Silver Carp, Bighead Carp, feral/diploid Grass Carp, and Black Carp).
- *Bigheaded Carp*: One of two *Hypophthalmichthys* spp. (i.e. Silver (*H. molitrix*) & Bighead (*H. nobilis*) carp), or a hybrid of the two.
- *Community Size Spectra (CSS)*: An approach to describe the size structure of fish communities by quantifying the decrease in abundance among increasing body size classes.
- *Establishment Front*: Furthest upstream range of invasive carp where the population demonstrates both reproduction and successful recruitment.
- *Invasion Front*: Furthest upstream extent where invasive carp reproduction has been observed (eggs, embryos, or larvae), but lacks evidence of successful recruitment.
- *Presence Front*: Furthest upstream extent where adult invasive carp have been sampled, but there is no evidence of reproduction.
- *Targeted Sampling*: Use of standard sampling gear/techniques to target invasive carp while purposely excluding all other native species.

Objective 1:

Spring Standardized Targeted Sampling (Cannelton – R.C. Byrd)

In the spring of each year, project partners conduct targeted sampling of invasive carp to obtain the data needed to estimate a relative abundance for the selected pools. The funding increases that were initially realized in 2021 continued to facilitate a large, targeted sampling effort in the current reporting period as well. During spring 2023 (11 April – 8 June), field crews from four agencies conducted targeted sampling for invasive carp in five pools of the Ohio River that stretched from Cannelton Pool (RM721) within the establishment front to R.C. Byrd pool (RM 237) within the presence front, excluding Meldahl Pool (Figure 1). Fixed sampling sites within each pool were pulled from a stratified-random design process completed in 2015. This produced an extremely high number of sites per pool and, although it would have been statistically ideal to sample all sites each year, funding and personnel are too limited to sample annually. Sites were chosen based on suitability of habitat and access, and approximately 24 fixed electrofishing sites were selected per pool. To ensure coverage within each pool, sites were divided between the mainstem river, island back-channels, tributaries/embayments, and dam tailwaters., with tributary sites being the most common. The mainstem river was the most abundant habitat type in each pool, but its size, depth and low-quality habitat created an area where it is very difficult to regularly sample invasive carp with the current gear-types. Tributaries are more vulnerable to the available gear used, therefore made up the majority of the sampling locations. This decision was also influenced by the abundance of telemetry data demonstrating that bigheaded carp spend a great deal of their time in these tributaries. In addition 8-12 gill net sites were incorporated into the targeted sampling within the last two pools on the upstream end (Greenup & RC Byrd) due to the lower abundances of bigheaded carps in these pools.

Electrofishing transects were conducted during the daytime and standardized at 900 seconds in a general downstream direction using a single dipper. Invasive carp were specifically targeted using increased driving speeds and allowable pursuit of fish upon sightings. During active sampling, most of the non-target species were ignored, but special attention was given to any small, shad-like species to avoid the possible misidentification of juvenile invasive carps. Relative abundance was inferred using CPUE data and compared to previous years to determine if there were changes in the mean and median fish caught per transect. Gill nets used in targeted sampling were typically 45m (150ft) in length, 3m (14ft hobbled to 10ft) in depth, and constructed of large mesh (12.5cm (5") bar mesh) with a foam core float line that keeps them suspended near the surface. The nets were set perpendicular from the shoreline and fished for two hours, during which noise and water disturbance is created with the intention of driving any bigheaded carps into the entanglement gear. Relative abundance was inferred using CPUE data and comparisons to previous years were only used to identify any changes in the number of fish caught per net as an indication of invasion advancement.

Assessing Invasive Carp Population Demographics

Population demographics information was collected on a subset of fish, post-spawn, between August and October 2023. Field crews from four agencies (KDFWR, INDNR, WVDNR, and USFWS) sampled for invasive carp via boat electrofishing and gill netting. Data was used to determine sex ratios, length distributions, age distributions, and report body condition of fish collected in the Cannelton, McAlpine, and Markland pools. Length distributions were formed using 25 mm length bins. Ages were estimated using lapilliar otoliths (Cannelton: n = 251; McAlpine: n = 244; and Markland: n = 20) encased in epoxy and thin-sectioned using agreed upon methods that were developed in 2021 during an invasive carp ORB workshop. Age distributions were summarized by percent total and visualized within a histogram.

Length-weight relationships were derived from log10 transformed lengths and weights of captured fish. A single regression line was used to compare length-weight relationships to previous years. The equations developed for the ORB as well as other waterbodies are reported below (Tables 1 and 2) in the form of:

$$\log10[Weight\_g] = a + b * \log10[Length\_mm]$$

Lastly, body condition was reported using relative weight equations developed by James Lamer (Lamer 2015). Condition was only reported using data from post spawn-fish, collected between the months of August and October. Differences in body condition were compared between Cannelton, McAlpine, and Markland pools in 2023 and for Cannelton and McAlpine in previous years.

Development of an Effective Monitoring Program

With the invasive carps' tendency to behave much differently than native fish communities, KDFWR initiated a pilot study to determine whether occupancy modeling could become an effective substitute for current abundance measures that were initially developed for sportfish populations. During these efforts, all surveys included half-mile boat electrofishing transects that were conducted in a downstream direction using a single dipper. All sites were visited on three occasions to account for imperfect detection. During each survey, a power goal was implemented with the intention of transferring a minimum of 3000 watts from water to fish (Gutreuter et al. 1995). At the conclusion of each transect, the presence/absence of carp was documented along with the data that was collected from captured fish. Invasive carp occupancy and detection were estimated via the use of a hierarchical model that is available in the 'unmarked' R package (Fiske and Chandler 2011).

Sampling efforts in 2023 took place in McAlpine Pool of the Ohio River, one pool upstream from the 2022 sampling conducted in Cannelton Pool. Following previous sample design, McAlpine Pool was divided into upper middle, and lower sections with 13 randomized sites in each. The proportion of tributary to mainstem river sites was based on the number of accessible tributaries within each river section.

<u>Objective 2:</u>

Trends in Native Fish Communities

Fish community monitoring was conducted in May and June 2023 at the tailwaters of Montgomery (New Cumberland Pool), Dashields (Montgomery Pool), and Emsworth (Dashields Pool) locks and dams on the Ohio River, the tailwater of Lock 8 (Pool 7) on the Allegheny River, and the tailwater of Braddock (Emsworth) lock and dam on the Monongahela River. Five consecutive 10-minute runs were conducted on each bank beginning either immediately downstream of the lock chamber or as close as possible to the dam wall for a total of 100 minutes of shock time. Electrofishing was conducted using an ETS MBS unit operated at 30% duty cycle, 60pps, and between 150-550 V pulsed DC. All fish species were targeted and enumerated in the field or retained for identification in the laboratory if field identification was not practical. Gamefish species were measured and weighed.

Fall fish community monitoring was conducted in the Greenup, R.C. Byrd, Racine and Emsworth pools of the Ohio River, Allegheny River, and Monongahela Rivers as well as the lower two miles of Chartiers Creek using gill nets and night electrofishing. For WV waters, electrofishing surveys were completed during the daytime in the Greenup and R.C. Byrd pools in October 2023. Only at mainstem sites were sampled to compliment WVU's community size-spectra analysis, but still using the same fixed sites identified in 2015. Electrofishing surveys in the Racine pool were conducted at the same fixed sites selected from a previous stratified-random design from 2022. Surveys consisted of 900 second timed transects beginning at the marked coordinates and continued downstream in the mainstem river and large tributaries. Surveys of small tributaries and embayments began at the marked coordinates and continued upstream to the completion of the timed transect, or until navigation was blocked, upon which the remainder of the timed transect was completed in the main channel just downstream of the mouth. All species were collected during these surveys. Schools of small fish (minnows and shad) were sub-sampled by dipping a portion of each school encountered. Small shad-like fish were examined closely to identify potential juvenile invasive carp. All fish were identified to species; non-minnow species were measured for total length (mm). Up to 20 fish of a single species per transect were measured for total weight (g). Gill net surveys were also conducted in fall 2023 at the same fixed sites as in previous years. Gill net sets consisted of two hour sets during the day using nets 45m (150ft) in length, 3m (14ft hobbled to 10ft) in depth, and constructed of 10cm (5") with a foam core float line to keep them suspended at top water. Each net set was actively monitored, and effort was expended to run fish into the nets with boat noise. All by-catch was identified to species and recorded, and any non-target fish (excluding invasive carps) were released immediately after capture.

For community sampling in PA waters, 61 randomly selected sites in were sampled from September 15th through October 30th. For each site, sampling consisted of a 2hr minimum gill net set using either 8cm, 10cm, or 13cm (3", 4", or 5", respectively) bar mesh as well as a 15-minute night electrofishing run (ETS MBS unit, 25% duty cycle, 60pps, 100-550volts). All individuals captured in gill nets were enumerated and gamefish were also measured. For electrofishing, a subset of ten individuals per species per 25mm size class greater than 125mm total length were measured and weighed for use in WVU's community size-spectra analysis. Individuals smaller than 125mm were identified, enumerated, and released if field identification was possible. Otherwise, individuals were retained for identification and enumeration in the laboratory. Laboratory identification is still ongoing.

Fish community monitoring was also conducted in the Greenup, R.C. Byrd, Racine and Montgomery pools of the Ohio River using seines in August and October 2023. Boat ramp seine hauls were conducted at select boat ramps located directly on or adjacent to the mainstem Ohio River in the Greenup, R.C. Byrd and Racine pools. One seine haul was conducted at each ramp with a 9m (30ft) seine with 0.5cm (3/16") mesh and a 1.8m (6ft bag) with smaller mesh (3mm or 1/8" mesh). Seine hauls were completed within the boundaries of the concrete structure boundary of each boat ramp. Beach seining was employed at six fixed locations in the Montgomery Pool using a 30m (100ft) seine with 1cm (3/8") mesh. One seine haul was conducted at each of the six locations. For all seine hauls, species readily identifiable in the field were enumerated and released; all other species were retained for identification and enumeration in the laboratory.

Using Community Size Spectra to Monitor the Impacts of Invasive Carp

WVU staff continue to focus on applying community size-spectra to fish assemblage data (i.e. "community data") to assess food web level impacts of invasive carp and to establish benchmarks for restoration. Invasive carp management needs to work toward scientifically defensible targets but establishing those targets has been challenging. Community size spectra (CSS) describe the size structure of communities by quantifying the decrease in abundance among increasing body size classes and it accounts for all species captured in standard surveys. CSS have been used extensively as indicators of fishery sustainability (and over-fishing) and to set targets in marine systems and research in both marine and freshwater ecosystems has grown during the last decade due in large part to a large research investment by the European Union (Blanchard et al. 2014, Petchy and Belgrano 2010). The CSS essentially measures the ratio of large individuals to small individuals in the community and summarizes the immense complexity of food web dynamics into two simple parameters, the slope and centered y-intercept (termed elevation) of a line, which have direct biological meaning representing ecological efficiency and ecological capacity, respectively (Murry and Farrell 2014). The CSS slope and elevation are fairly stable in large river systems (Murry and Farrell 2014) but do react in predictable ways to environmental change including changes in species dominance (Broadway et al. 2015) and large-bodied low trophic position fish species (Murry et al. 2024). Large-bodied low trophic position fish, such as invasive carp will tend to reduce the slope of the CSS (which is typically steeper under piscivore dominance). In 2023, WVU researchers completed the second year of their research efforts toward (1) understanding the dynamics of CSS relative the carp invasion, (2) evaluating the effectiveness of CSS as a community-level indicator of invasive carp impacts, (3) the use of CSS to establish community-level pool-specific restoration goals, and (4) evaluate the sensitivity of CSS to use as an early warning indicator.

WVU worked with state partners (KDFWR, WVDNR, PFBC, and USFWS) to collate existing community boat electrofishing data for CSS analyses. CSS was used to compare community size structure pre- and post-invasion in impacted pools to unimpacted (invaded vs non-invaded pools). This initial analysis established baseline conditions throughout all pools (e.g. mean CSS parameter values and degree of natural inter-annual and inter-pool variation). Data provided by state partners include fish lengths and weights derived from community electrofishing surveys conducted from 1994-present. Data for the Cannelton, McAlpine, Markland and Meldahl pools of the Ohio River was collected 2015-2020 by KDFWR. Data for the Greenup and R.C. pools were collected by WVDNR from 2016-2022. We received data for the La Grange pool of the Illinois River from the Illinois Natural History Survey from surveys conducted 1994 - 2021. We utilized earlier years' data in impacted pools as well as long-term averages in upstream unimpacted pools to serve as a reference (historic target condition). We assessed 'normal' or expected interannual variation in CSS from the upstream unimpacted (or lightly impacted) pools to provide a range in target values for conservation of native fishes.

In addition to the Ohio River fish data, WVU field crews collected monthly zooplankton samples. Zooplankton were identified to a broad taxonomic group (copepods, Cladocera, rotifer, veligers) counted and individuals were measured. Impacts of invasive carp were assessed by employing a BACI design and samples were compared to published surveys from 30 years earlier. Normalized Biomass Size Spectra (NBSS), an ataxic approach that expresses community structure as a function of body size instead of taxonomic identity was used to assess potential effects of invasive carp on zooplankton. Additionally, seasonality of the NBSS model and how it changed throughout the season was analyzed.

<u>Objective 3:</u>

Monitoring Ahead of the Invasion Front

Targeted sampling for Invasive Carp was conducted in November 2023 in the Montgomery Pool and December 2023 in the New Cumberland Pool of the Ohio River. Sampling was conducted in the Montgomery Slough (RM 949.78 to 950.11) where positive eDNA hits for Bighead Carp were found historically. Gill nets used in sampling were 90m (300ft) in length, ~4m (12ft) in depth, and constructed of 8cm, 10cm, or 13cm (3", 4", or 5", respectively) bar mesh. Three gill nets were fished for approximately 24 hours each. Three gill nets of the same size and mesh were also fished in the New Cumberland Pool for approximately 24 hours each.

Incidental sampling for Asian Carp was conducted using boat electrofishing through targeted gamefish surveys on each of the Three Rivers. Nighttime boat electrofishing using a ETS MBS electrofishing unit operated at 60pps, 30% duty cycle, and 150-550V was conducted in March/April on Pool 4, Pool 5, Pool of the Allegheny River and the Maxwell and Elizabeth Pools of the Monongahela River. Sampling consisted of four non-overlapping 10-minute runs on each bank beginning immediately downstream of the lock and dam for 80 minutes of total effort in each pool, with the exception of Pool 9 on the Allegheny River where sites were selected by targeting the best available habitat. Adult Sander species were targeted during these surveys and presence/absence of invasive carp species was recorded. Sampling in October occurred at four fixed sites in Pool 4 of the Allegheny River, four fixed sites in the Emsworth Pool, and five fixed sites in the Charleroi Pool of the Monongahela River for a total effort of 6.77hrs. Gear type and settings were the same as in the March Sander surveys. Black Bass were the primary target of the October surveys and presence/absence of invasive carp species was recorded. In November, nighttime boat electrofishing was conducted on the Monongahela River in the Grays Landing and Emsworth Pools, the Allegheny River in Pool 2 and Pool 7, and the Ohio River in the Montgomery and Dashields pools. Sampling was conducted via pulsed DC night boat electrofishing and gear type and settings were the same as in the spring Sander surveys. Sampling consisted of four non-overlapping 10-minute runs on each bank beginning immediately downstream of the lock and dam for 80 minutes of total effort in each pool. Adult Sander species were targeted during these surveys and presence/absence of invasive carp species was recorded.

To determine if Silver or Bighead Carps may be present in tributaries of the upper Ohio River, the USFWS Lower Great Lakes FWCO collected 90 water samples for eDNA analysis from each of seven tributaries in the R.C. Byrd, Racine Pool, Belleville, New Cumberland and Montgomery pools of the Ohio River in 2023 (Table 3). All eDNA sampling followed the USFWS (2023) Quality Assurance Project Plan. Following collection, eDNA samples were shipped to the USFWS Whitney Genetics Lab for processing and the results reported to state partners.

Objective 4:

Spatial Distribution in the Wabash and White rivers

Within the Mississippi River and its tributaries, target-removal has shown temporary success in decreasing local densities (MacNamara et al., 2016). This harvest-control method relies on the assumption that silver carp aggregate within the river. However two distinct movement strategies have been found in silver carp in a free-flowing system (Prechtel et al., 2018; Coulter et al., 2022), creating the need to evaluate the movement patterns of silver carp in other rivers to effectively manage their populations. Objectives were: (1) Uncover if intraspecific variation in dispersal exists among silver carp the lower Wabash River; (2) Observe if distance traveled differs across seasons. (3) Determine the level of betweenness among individuals.

Thirty-five VR2 receivers have been deployed since 2022 throughout the Wabash River from the confluence with the Ohio River to 214 river miles upstream (near Terre Haute, Indiana) and within the White River, from its confluence with the Wabash River to 50 miles upstream (Figure 2). Receiver deployments followed the methods described above and receivers were retrieved and were downloaded monthly when river conditions allowed. As in 2022, extended periods of low water during 2023 prevented portions of the receiver array from being retrieved, especially during autumn (Figure 3). Tagging of invasive carps in the Wabash River followed the methods for the Ohio River, above. A total of 537 Silver Carps have been tagged since 2021 at multiple locations in the Wabash River, with 207 tagged in spring and fall 2023 (Table 4).

Fine-scale habitat selection by tagged adult Silver Carps was assessed throughout the Wabash and White Rivers from 2021-2023. Monthly active tracking events occurred throughout the 305 rkm of the Wabash River from Terre Haute, IN to the confluence of the Ohio River and the lower 105 rkm of the White River from Maysville, IN to its confluence with the Wabash River in Mt. Carmel, IL. During active tracking, the boat was maneuvered downstream while towing an omnidirectional hydrophone (Vemco VH165). Once a transmitter was detected, the fish's position was triangulated by using a submersible directional hydrophone (Vemco VH110). Habitat characteristics including macrohabitat type (channel border open, inside river bend, outside river bend) and microhabitat type (log jam, rip-rap, run, thalweg) were recorded at each fish's location.

To assess selection, available habitat within the study area was quantified using a randomized sampling regime. The study area was split into three sections: Upper Wabash, Lower Wabash and White River. The Wabash was separated at Mt. Carmel, IL where the confluence with the White River nearly doubles total discharge. In each of the three sections, random sites were generated based on the total length of the section. Sites spanned 1 km in length with enough sites in each section to cover roughly 5% of the total length. Availability of macro and microhabitats were estimated in each site and averaged across sections to give the proportion of available habitat for each section. Manly log-likelihood chi-squared tests (Manly et. al 2002) were used to determine if fish used habitats in different proportions than their availability, indicating selection. Manly selection ratios (Manly et. al 2002) were calculated to determine the direction and strength of selection patterns both within the entire study reach and individual river sections.

<u>Objective 5:</u>

Hydroacoustics Analysis

The Carterville FWCO completed hydroacoustic sampling during October and November 2023 in the Cannelton and Newburgh pools of the Ohio River. Hydroacoustic data collection followed methods as described in the Large River Hydroacoustics Mobile Survey Standard Operating Procedure, Region 3 USFWS. Briefly, we deployed a BioSonics DTX echosounder multiplexing two, 200 kHz, side-looking split-beam transducers offset in angle to maximize water column coverage (Figure 4). Both transducers were deployed from the vessel's port side at a depth of 0.5 m on a bracket mounted to a mechanical rotator. The rotator ensured that the transducers tilted downward at appropriate angles such that the top edge of the shallow beam was parallel with the water surface. Hydroacoustic data collection was split among main channel, side channel, backwater, and tributary habitats. Within each pool, we collected hydroacoustic data in all side channels >0.8km in length, navigable tributaries (up to 3.2km from confluence), and backwaters because invasive carps often inhabit these areas. In the main channel, we selected 15% and 25% (based on analysis of data from full pool scans during 2021-2022) of available 0.8-km sites for data collection using a random sampling approach for Cannelton and Newburgh pools, respectively. This resulted in 109km and 90km of main channel transects for Cannelton and Newburgh pools, respectively. Transducer direction (shore vs thalweg) was randomly assigned to each main channel site. Both shore- and thalweg-facing transects were completed along each bank for all side channels with widths great enough to ensure sample area of thalweg-facing transects didn't overlap (i.e., thalweg facing hydroacoustic beams on opposite banks don't overlap in the middle of the side channel). In narrow side channels, two shore-facing transects were completed. Tributary data collection consisted of shore-facing transects with the boat centered within the channel and completed in both the upstream and downstream direction to ensure both banks were sampled. In backwaters, data were collected along the shoreline with the transducers facing towards shore. Calibration data were collected for both transducers prior to each survey to adjust hydroacoustic measurements.

Hydroacoustic data processing followed methods outlined in MacNamara et al. (2016) and the Large River Hydroacoustics Mobile Survey Standard Operating Procedure, Region 3 USFWS using Echoview Version 13.0. Raw data and calibration files were imported into a mobile survey template for processing. Processing included a 1-m nearfield exclusion zone, bottom-line exclusions, and removal of bad data regions where wake disturbance or vegetation contributed to poor data quality. A single target detection algorithm (split beam method 2) facilitated the detection of individual fish targets using parameters suggested in Parker-Stetter et al. (2009). Using the equation developed by Love (1971), we estimated the target strength (TS) of 250mm fish during each survey and used that value as a TS threshold to remove fish less than 250mm from analyses. Groups of individual targets originating from the same fish were combined to make individual fish tracks to reducing the potential of overcounting. Fish targets and sample volume estimates were then exported from Echoview for further analysis.

To apportion hydroacoustic targets to fish species, the Carterville FWCO, INDNR, and KDFWR collected community data using an electrified dozer trawl and boat electrofishing. Community data collection followed the same hydroacoustics sampling design detailed above with two exceptions: 1) side channel and main channel sites were larger (1.6km) to ensure that sites were long enough to complete electrofishing transects and 2) due to logistical limitations, only 35 main channel community sites were sampled per pool (Figure 5). Deployments of both community sampling gears (dozer trawl and boat electrofishing) were planned for all sites, but deployment of the gear was at the discretion of the boat operator based on river conditions (e.g., water velocity and debris). Deployment of each gear was standardized to allow for comparisons among sites. The dozer trawl was deployed for 5-minutes at ~4.8km/h, following the Long-Term River Monitoring power goal tables to maximize catch. Boat electrofishing transects were 15 minutes in a general downstream direction with one dip netter. A power goal, intended to transfer a minimum of 3000 Watts from water to fish, was implemented (Gutreuter et al. 1995) at a 40% duty-cycle and 80 pulses per second (pulsed DC). All fish greater than 250mm were identified to species, weighed (g), and measured (total length; TL).

To reduce bias in our hydroacoustic estimates, we used a Bayesian hierarchical model to account for uncertainty in TS measurements and a paucity of community data at hydroacoustic sites. For this analysis, we modified the methods described in DuFour et al. (2021). Briefly, we used a fitted quadratic regression model to calculate the probability of a fish being a Silver Carp given its length (Figure 6). Our most complex model describing the fish community included pool, habitat, TL, and TL^2 as fixed effects and community site nested within habitat and both community site and habitat nested within pool as random effects using a Bernoulli distribution. We compared the most complex model and four models containing a subset of variables from the full model using k-fold cross validation (CV). The most parsimonious model describing the community data had TL and TL^2 as fixed effects and Community Site as a random effect; therefore, the results of this model were used in subsequent calculations. We also modeled TS as a function of individual fish track to obtain a mean TS and credible intervals (CrI's) for each fish track. Mean TS and CrI's were converted to total length (TL) using the multi-species, side-aspect equation developed by Love (1971) (Figure 7).

Importantly, TL based on TS is uncertain, as are the model parameters describing the fish community. To account for this uncertainty, we integrate across TL and the model parameters to estimate the probability that an individual is a Silver Carp based on its TS (for details see DuFour et al. 2021). To solve this integration, we used Monte Carlo simulations (n = 1000) to estimate the number of Silver Carp at each site and converted this abundance to density by dividing by the volume of water sampled by hydroacoustics (i.e., Wedge_Volume_Sampled). To examine the potential effects of habitat and pool on the Silver Carp density, we calculated the mean and 90% CrI's by habitat and pool. Non-overlapping CrI's were used to indicate significant differences between habitats and among pools.

Our models differ from those described in DuFour et al. (2021) in three ways. First, because Silver Carp make up a large proportion of fish between 500mm and 900mm in our community sampling, but Silver Carp < 500 or > 900 mm are rarely captured, we use a quadratic regression to describe the probability of a fish of a given length being a Silver Carp rather than a logistic regression as in DuFour et al. (2021). Second, following discussions of our analyses with M. DuFour, we determined that converting TS to backscattering cross section was not necessary and modelled TS directly. Third, we used k-fold CV rather than leave-one-out (LOO) CV for model selection because model diagnostics suggested that LOO CV likely resulted in biased model selection criteria and k-fold CV is a reliable alternative to this method (Vehtari et al. 2017).

<u>Results:</u>

Spring Standardized Targeted Sampling (Cannelton – R.C. Byrd)

During spring 2023, KDFWR and INDNR used 35.25 hours of targeted boat electrofishing to successfully collect a total of 394 fish across three different species of invasive carp, which included Silver (98.4%), Grass (1.2%) and Bighead (0.3%) carps (Table 5). As in previous years, most of the invasive carp were captured from the 48 electrofishing sites located within the Cannelton Pool (n = 326 invasive carp). The other 93 transects completed in two different pools of the middle to upper Ohio River contributed less than 18% of the overall catch (n = 68 carp), which included 60 invasive carp from the McAlpine Pool and only 8 from Markland. Catch per unit effort slightly decreased in Cannelton Pool, with last years targeted monitoring results being the highest in years past with 8.70 invasive carp/transect. The 2023 average catch was 6.79 invasive carp/transect. The 2023 catch rates for Silver Carp in pools located directly upstream of Cannelton remained extremely low and included an average of 1.33 fish/transect for McAlpine and only 0.17 fish/transect in the Markland Pool. The average catch rates per pool for other invasive carp species also remained negligible. Upon completion of the 2023 targeted sampling efforts, KDFWR managed to capture a total of 5 Grass Carp and one Bighead Carp, which are similar results to those obtained in previous years.

Spring targeted boat electrofishing in the Greenup and R.C. Byrd pools by WVDNR zero invasive carps over 9.5hrs of effort. Spring gill netting in these pools yielded one Bighead Carp and one Silver Carp from 2700ft of net over 18 sets (Table 6). The most common bycatch species in these pools was Common Carp.

Assessing Invasive Carp Population Demographics

By the end of the reporting period, a total of 17 Bighead Carp and 5 Grass Carp had been captured during the 2023 sampling efforts in the middle Ohio River. Most of the Bighead Carp were captured during fall gill net sampling efforts in Markland Pool to collect data for age & growth analysis and the ongoing length/weight regression that is being constructed for Bighead Carp (Figure 8). The 5 Grass Carp captured in 2023 were via boat electrofishing in Cannelton Pool; total lengths ranged from 777 mm to 824 mm. With the small number of both Bighead and Grass Carp collected in 2023, there will be no additional demographics provided for either species.

The length frequency data collected during the 2023 reporting period was different than in previous years. Only about 1% of the fish caught in 2023 had total lengths of 600 mm or less (Figure 9). The majority of Silver Carp caught from the McAlpine Pool during this period had total lengths that ranged from 750 to 850 mm (29.5 – 33.5 in) and the length distribution did not fit an obvious bimodal pattern as it had in previous years. During 2023, the overall sample of Silver Carp obtained from McAlpine consisted of 48% male and 52% female fish, which was slightly more balanced than in Cannelton where males represented 41.3% of captures and females 58.7% (Figure 10). As in previous years, the sample of Silver Carp (n = 21) caught from the Markland Pool in 2023 exhibited a wide range of total lengths from 750mm to 1050mm, with around 24% of those captured being around 975mm (Figure 10).

Silver Carp sampled from the Cannelton Pool in 2023 were estimated to be between 2 and 12 years old (Figure 11). Age-4 and age-5 fish continued to be the most frequently sampled (63.0%) similar to both 2021 (65.0%) and 2022 (64.6%) samples. Silver Carp collected from the McAlpine Pool in 2023 exhibited a narrower age range of 4 to 11 years (Figure 12). However, the most frequently encountered age group of Silver Carp from McAlpine increased from 2022 to age-5 and age-6 fish, which made up more than 72% of the 2023 sample.

Body condition of Silver Carp collected in Fall 2023 was determined using relative weight (W_r) equations generated from over eight years of length-weight measurements (Figure 13). The average W_r of Silver Carp collected from Cannelton in 2023 was nearly 108, which was an increase from the mean W_r of carp collected in past years (Figure 14). Similar comparisons of body condition for Silver Carp in the McAlpine Pool have determined that the mean W_r of fish caught in 2023 (108) was also up slightly from the average condition (W_r = 97) of carp in 2022. A comparison of average body condition across three consecutive pools of the middle Ohio River continues to indicate that Silver Carp in Cannelton and McAlpine have a similar length-weight relationship, but in the Markland Pool, the same species appears to have substantially higher average relative weights (Figure 15).

Development of an Effective Monitoring Program

Building on the previous project efforts in Cannelton Pool (2022), KDFWR moved sampling efforts upstream along the Ohio River in 2023. The occupancy project sampling design was implemented in McAlpine Pool, an area known to have a lower density of Silver Carp in comparison to the establishment front in Cannelton pool. Through July-August 2023, KDFWR conducted electrofishing transects at 39 sites that were visited on three different occasions for a total of 117 sampling events. Silver Carp were observed during at least one visit to 18 (46.2%) of these sites and during all three visits to 5 sites (12.8%). Data is being analyzed by WVU to provide further insight on the number of site visits needed for accuracy and the probability of Silver Carp occupancy and detection across the middle Ohio River.

Native Fish Communities

Fish Community sampling in the Greenup, R.C. Byrd and Racine pools of the Ohio River was conducted by WVDNR in October 2023 and consisted of 9.25hrs of effort. Electrofishing surveys yielded data from 48 fish species (Table 7). Gizzard Shad and Emerald Shiner constituted the bulk of collected fishes in both pools comprising approximately 38% and 15% of the total catch between all pools, respectively. Bluegill and Sauger were the most caught sportfish species. Smallmouth buffalo and Freshwater drum were the most caught non-sport fishes. Relative weights (where applicable) were within the mean for all species (Table 8). Seventeen gill net surveys (3,900ft of net) were conducted by WVDNR in the R.C. Byrd and Racine pools in fall 2023. Two Bighead Carp and one Silver Carp were removed from the R.C. Byrd pool during fall gill netting. Gill net bycatch included only two additional species of fish (Table 9).

Tailwater fish community monitoring by PFBC in Pool 7 of the Allegheny River, the Emsworth Pool of the Monongahela River, and the New Cumberland, Montgomery, and Dashields pools of the Ohio River was conducted in May/June 2023 and consisted of 1.67hrs of effort per pool using pulsed DC night electrofishing. Total number of species captured ranged from 30 to 37 at each of the five tailwaters sampled, with individual fish counts ranging from 985 to 1,311 fish captured at each of the tailwaters. Emerald Shiner, Mimic Shiner, Smallmouth Bass, and Walleye comprised approximately 55% of the total catch between all pools (Table 10). No Invasive Carp were captured during these surveys. Randomized pool wide fish community sampling took place in September and October 2023 on the Emsworth pool of the Ohio River and associated navigable tributaries. A total of 65 sites were sampled using night electrofishing and gill nets. Laboratory fish identification and data entry is still ongoing and will be reported on in next year's report. However, no adult invasive Carp species were captured or observed during the sampling events.

Laboratory identification and data summary was completed for randomized pool wide fish community sampling from 2022 during summer 2023. In summary, 34 sites in the Montgomery Pool of the Ohio River (including lower Raccoon Creek and the lower Beaver River) and 21 sites in the Dashields Pool on the Ohio River were sampled using gill nets and night electrofishing. A total of 82 fish representing 10 species and 49 fish representing four species were captured using gill nets from the Montgomery and Dashields pools, respectively. Smallmouth Buffalo and Common Carp were the two most abundant species captured and comprised 81% of the gill net sample. Night electrofishing was performed for a total of 13.75hrs and captured 15,320 fish in the Montgomery Pool and 17,004 fish in the Dashields pool. Sixty-one different species were captured; however, the majority of the individuals sampled electrofishing were Emerald Shiners (81%; Table 11). No invasive Carp were captured during these fish community surveys. Data from these surveys has been compiled, QA/QC'd, and provided to WVU for use in their CSS analysis.

Thirteen boat ramp seine hauls were conducted by WVDNR in the Greenup, R.C. Byrd and Racine pools in Fall 2023. Seine hauls yielded 3,111 fish from 30 different species (Table 12). The number of fish collected varied greatly by site (9-646 individuals) and was likely due to river conditions.

Channel Shiners were the most collected species in all pools, which is a contrast to previous years, where Emerald Shiners have dominated the catch. Young of year Gizzard shad were also more abundant in 2023 than in previous years. No invasive carps were collected. Mean diversity abundance over the sampling period will be used as a metric for the diversity of the small, more littoral fishes of the mainstem Ohio River. Beach seining was conducted by PFBC on the Montgomery Island Pool in August 2023. No invasive carp species were collected. A total of 2,290 individuals of 20 different species were captured. Gizzard Shad and Emerald Shiner comprised 42% and 22% of the total catch, respectively (Table 13).

Using Community Size Spectra to Monitor the Impacts of Invasive Carp

We used a community size spectra approach to evaluate fish community structure and compare size spectra across spatial and temporal gradients of silver carp abundances. Data provided by state partners allowed for the assessment of CSS across all pools. Results show the Illinois River CSS has changed predictably (i.e. lower slope) in response to the invasion of silver carp (Figure 16). While there has been an increase of silver carp in the Ohio River, densities have not reached the threshold required to impact CSS (Figure 17). While specific removal targets were not obtained from using CSS, CSS alongside adaptive management could be used for the management of silver carp. A baseline CSS has been developed for the Dashields pool, and one for the Montogomery pool is forthcoming. In addition, USFWS-Ohio River unit has collected monthly fish data across 4-6 pools of the upper Ohio River and that data will be used to develop baseline CSS in those pools and test scenarios to increase sampling efficiency in the future.

For more details, see Appendix A: The effect of silver carp on large river community size spectra. B.Novak. Master's Thesis, WVU 2023.

The zooplankton monitoring scheme was successfully integrated into the field sampling regime with ichthyoplankton tows in spring and summer 2023. Thirty tows were completed between May 22 and July 12 upstream of the Markland dam (Table 14). No differences in zooplankton community composition across the different carp invasion fronts were found. However, large-bodied copepods were more abundant and emerging earlier throughout the year while smaller-bodied rotifers were less abundant (Figure 18). No significant differences of NBSS models were found across carp invasion fronts, although there were trends in the data suggesting potential impacts could occur. Our findings suggest densities of invasive carp have not reached the threshold to produce negative effects on the zooplankton community. The NBSS models did change throughout the year and followed along with typical observed zooplankton phenology. A notable finding to report is that on average (across pools and months) *Dreissenid* veligers were over half of the organisms sampled.

For more details, see Appendix B: Effects of Invasive Species on Ohio River Zooplankton. S. Johnston. Master's Thesis, WVU 2023.

Monitoring Ahead of the Invasion Front

Targeted gill net sampling for invasive carp by PFBC in the New Cumberland and Montgomery pools of the Ohio River did not collect any invasive carp species. A total of 45 individuals representing nine species were captured during targeted gill net sampling (Table 15). River

Carpsucker and Hybrid Striped Bass were the two most common species captured and each comprised 27% of the total catch on the Ohio River, respectively. Additional scheduled sampling in mid-December was canceled due to high flows and excessive debris.

In addition, PFBC tracks incidental captures of Invasive carp through other various projects. Efforts in 2023 included targeted gamefish surveys for Sander spp in March/April and November at 11 tailwaters in the Allegheny, Monongahela, and Ohio Rivers and targeted surveys for black bass at 13 fixed sites in one pool of the Allegheny River and two pools of the Monongahela River in October 2023. No Invasive Carp species were captured or observed in any of the targeted gamefish surveys in March, April, October, or November 2023.

USFWS collected 950 eDNA water samples from seven tributaries within the Ohio River Basin (Table 2). Of those, six samples tested positive for invasive carp eDNA. Four samples were positive for the Bighead Carp marker, two in Mill Creek (Racine Pool), one in Tombleson Run (Racine Pool) and one in the Beverly Pool of the Muskingum River (Belleville Pool) whereas one sample in Tombleson Run and the Lowell Pool of the Muskingum River were positive for the non-specific invasive carp (either Bighead or Silver Carp) marker. This is the second consecutive year with a positive detection of invasive carp eDNA in the Beverly Pool of the Muskingum River. Continued sampling of these sites will guide the future need to use traditional sampling gear to monitor the invasive carp invasion front.

Spatial Distribution in the Wabash and White rivers

The retriever array in the Wabash River was difficult to reach and download during 2023 due to prolonged periods of low water levels, where most receivers were either inaccessible by boat or buried under sand in the riverbed. Only two receivers were able to be retrieved and downloaded in 2023, although a crew (with shovels and a winch) will be deployed in early spring 2024 to locate and unbury receivers. To improve receiver retrievals in the future, SIU will be experimenting with different deployment designs that cater to the rapidly changing hydrology and riverbed of the Wabash River. The “Swiss Sled” prototype (Figure 19) has been designed to improve the ability to pull receivers from the river bed onto a tether onshore. The sled is sufficiently large and heavy to remain upright on the river bottom but contains holes that reduce weight and allow the sled to be pulled out of sand. This prototype will be tested in the Wabash River in spring 2024.

An analysis of available Silver Carp movement data collected during 2021 through 2023 in the Wabash River revealed that greater detections and higher average distance moved occurred in spring than other months (Figure 20). Consistent with other research on movement in the Wabash River, the majority of Silver Carp remained near the location of release although a few moved greater than 60 km (Figure 21). A network graph was used to visualize the connectivity among tagged individuals within the Wabash River (Figure 22). Nodes depict individual fish and lines connect fish that cross within 2 km of each other within a 24-hour period. In the Wabash River, connectivity degree ranged from 0 to 19 with most fish remaining between Vincennes, IN and Grayville, IL (approximately a 65 km range).

Between 2021 and 2023, 537 Silver Carp were tagged in the Wabash and White Rivers. Of these 537 fish, only 33 fish transitioned from the Wabash River system to the Ohio River (Table 16). On average it was 300 days from tagging in the Wabash River for an individual fish to be detected in the

Ohio River. Fish tagged at the Mt. Carmel site were the most often detected in the Ohio River (15/33 detected fish), followed by those tagged at Hutsonville (7/33). Interestingly, while the majority of the fish (139) were tagged at the New Harmony, IL site and it was the closest to the confluence of the Wabash and the Ohio River, only 5 fish tagged there were later detected in the Ohio River. Hazelton, IN was the only tagging site on the White River, and only 2 of the 55 fish tagged were detected in the Ohio River. No fish tagged in Merom, IN were detected in the Ohio River, likely because this site is relatively far from the confluence (227 km) and had the fewest tagged fish (42). In the Ohio River, fish were most commonly detected at Smithland Lock and Dam (15 unique fish), Brookport Bridge (8 unique fish) and J.T. Meyers Lock and Dam (7 unique fish). This indicates that carp originating from the Wabash River tend to go downstream in the Ohio River, toward the Mississippi River (Figure 23).

Silver Carps detected in the Wabash and White Rivers selected for both macro-(χ^2=376.72, df=216, $p<0.05$) and micro-habitats (χ^2=442.78, df=336, $p<0.05$) disproportionately to available habitat. Fish were not randomly distributed across habitats, but actively selected for specific habitat types. Throughout the entire study area, outside bends were positively selected while both channel border open and inside bends were slightly avoided (Figure 24). Outside bend areas are generally deeper than the other macro habitats, which likely contributes to individuals selecting for these areas. Logjam and rip-rap micro-habitats were selected for while run and thalweg areas were avoided (Figure 25). Micro-habitat selection patterns can likely be attributed to differences in flow across available habitats. Logjam and rip-rap areas generally have slower flow and provide a velocity refuge that allows silver carp to limit energetic output. Run and thalweg areas have much higher flow which requires individuals to constantly swim to maintain position.

Though habitat selection was apparent throughout the entire study area, longitudinal variation influenced how individuals used habitat in each river section. In the lower portion of the Wabash, Silver Carps selected for outside bends much more than any other macro-habitat type (Figure 26). This was not the case in the upper Wabash where there were no obvious patterns in macro-habitat selection. Additionally, individuals in the White River selected for channel border open areas and did not select for or avoided other habitat types (Figure 3). Compared to the other sections of the study area, the lower Wabash is much wider and dominated by sandy substrates so outside bends are likely the only deep areas available to silver carp. Micro-habitat use between sections was more similar with fish selecting for logjams across all sections (Figure 27). Run and thalweg habitats were generally avoided in in all sections, though in the lower Wabash, individuals slightly selected for thalweg habitats (Figure 27). Rip-rap areas had less clear patterns of habitat selection with high variability in the lower Wabash and slightly positive selection in the upper Wabash (Figure 27). Logjams seem to be universally selected for throughout the study area and may be useful areas to target for large-scale removals or commercial harvest. However, most habitat selection patterns are not uniform throughout the study area so, depending on where removal efforts occur, different habitats may need to be targeted to maximize harvest.

Hydroacoustics Analysis

Community data comprised samples from 95 electrofishing and dozer trawl sites (Cannelton = 44, Newburgh = 51). Boat electrofishing collected more total fish > 250 mm (n = 656) than dozer trawling (n = 174). A total of 158 Silver Carp were captured with more Silver Carp captured with boat electrofishing (n=112) than the dozer trawl (n=46).

Model results suggest the greatest mean Silver Carp densities occurred in the Salt River and Little Pigeon Creek in Cannelton and Newburgh pools, respectively (for site-specific estimates, contact the Carterville FWCO). Silver Carp densities were less than 5 fish/1000m^3 at all sites. Longitudinal trends exist within Newburgh Pool but not Cannelton Pool with Silver Carp densities increasing in the downstream direction (Figure 28). Habitat differences existed both within and among pools. On average, tributaries had the greatest Silver Carp densities followed by backwater (Newburgh only), side channel (Newburgh only) and main channel sites (Table 17). Cannelton Pool had greater Silver Carp densities than Newburgh Pool in main channel habitats, whereas tributary density was greater in Newburgh Pool.

Discussion:

In past years, Silver Carp populations displayed strong bimodal length frequency distributions in both the Cannelton and McAlpine pools. In 2023 that was no longer the case, with bimodal distributions weaking substantially indicating year-class strength for a single age-class. This may be evidence of a previously failed spawn or just an increase in mortality (or emigration) rates of the larger individuals. Additionally, the body condition of Silver Carp in the McAlpine and Cannelton pools showed higher mean relative weights than in previous years. Smaller length classes were not seen in the 2023 Markland Pool data as opposed to last year. This reflects the patterns seen historically in Markland which is dominated by larger fish that more than likely immigrated into that stretch of the river. The smaller range of length classes in Markland Pool, and the lack of bimodal length distributions in McAlpine and Cannelton pools have provided further evidence that we are in the midst of a long-term shift in the Silver Carp populations that have established themselves within the middle Ohio River. Additionally, during a fish tagging event in April of 2023, three silver carp each less than 300mm were captured in Meldahl Pool of the Ohio River. This indicates a need to target Meldahl Pool for age and growth data collection moving forward. More Silver Carp are being captured in the R.C. Byrd Pool and there are increasing positive eDNA hits in the Racine Pool indicating the need for continued monitoring possibly up to Racine Pool.

In response to the results of the 2021 Kentucky River occupancy pilot project and the 2022 sampling in Cannelton Pool, KDFWR continued to test if occupancy modeling could be applicable to the ongoing management of the invasive carp populations in the middle Ohio River. We continue to sample across a perceived abundance gradient so a fourth year of sampling will be conducted within the Markland Pool during summer 2024. During these efforts, the actual catches of invasive carp will continue to be tracked along with the presence/absence data. KDFWR expects that both the detection and occupancy probabilities will decline as the Silver Carp sampling efforts continue to shift further upstream. The objective of these combined efforts is to demonstrate how a less data intensive monitoring protocol can still be used to recommend specific sampling approaches.

Community Size Spectra

We observed trends in CSS slope (the Establishment front being flatter than both the invasion and presence front) on the Ohio River, although they were not statistically significant, suggesting that invasive carp densities may have not yet reached a level where they are impacting food web structure. Consistent with this suggestion are the results from the recent zooplankton survey of the Ohio River showing that large-bodied zooplankton did not decrease in abundance compared to before the Silver Carp invasion. This is in contrast to a study conducted on the Illinois River, where there is evidence of decreasing CSS in the presence of invasive carp. The on-going commercial and contract fishery harvest of Silver Carp in high density areas of the Ohio River could be slowing the spread of silver carp in the Ohio River through reduction of densities. These commercial and contract fishing efforts may be effective in keeping Silver Carp under the impact threshold.

White and Wabash Rivers

Movement data within the Wabash and White rivers are very limited at this juncture, but patterns of Silver Carp movement in the Wabash River appear to differ substantially from other highly studied rivers such as the Illinois River. In the Illinois River, patterns of movement are restricted, perhaps by structures such as locks and dams and limited suitable habitat. Analysis of the net movement of Silver Carp suggests that fish more freely move among receiver locations in the Wabash River. A converse explanation is that the rapidly changing flow and geomorphology of the Wabash River cause Silver Carp to move more frequently. Further analyses of these patterns will aid commercial harvest operations to more efficiently remove Silver Carp. The apparent lack of Silver Carp moving (only about 6%) from the Wabash River into the Ohio River mainstem is surprising. However, the mouth of the Wabash River feeding into the Ohio River is often blocked by aggradation of Ohio River bed material during periods of low flow, perhaps reducing the connectivity into the river, especially during years of low discharge such as 2022 through 2023. Identifying conditions (e.g., high flow) when populations in the Ohio and Wabash rivers become connected may aid in identifying times to direct harvest near the confluence.

Though habitat selection was apparent throughout the entire study area of the Wabash and White rivers, longitudinal variation influenced how individuals used habitat in each river section. Logjams seem to be universally selected for throughout the study area and may be useful areas to target for large-scale removals or commercial harvest. However, most habitat selection patterns are not uniform throughout the study area so, depending on where removal efforts occur, different habitats may need to be targeted to maximize harvest.

Hydroacoustics

We found that both habitat and pool significantly affected mean Silver Carp density. These results support previous research evaluating density gradients across invasion fronts (MacNamara et al. 2016; Erickson et al. 2021) and Silver Carp habitat use (DeGrandchamp et al. 2008; Gillespie et al. 2017; Pretchel et al. 2018). Due to the paucity of backwater data (N = 1), we lack confidence in any conclusions reached regarding the backwater data in Newburgh Pool. Our results suggest that Silver Carp densities are greater in tributaries than in either main channel or side channel habitats. This finding agrees with previous literature (Pretchel et al. 2018) that Silver Carp densities increase in tributary habitats. However, some literature suggest that tributary usage is less than mainstem usage in some Ohio River pools (Gillespie et al. 2017). These conflicting results suggest that fine-scale environmental characteristics may have a greater impact on Silver Carp habitat use than large-scale habitat features as suggested by Glubzinski et al. (2021).

The longitudinal trends in our data support previous literature (DeGrandchamp et al. 2008; MacNamara et al. 2016) and the findings from 2021-2022 hydroacoustic surveys describing invasion ecology within impounded rivers. Once populations become established upstream of a barrier, they expand their range upstream toward the next barrier. For Silver Carp, this expansion is often comprised of larger individuals (MacNamara et al. 2016; Lenaerts et al. 2021). The apparent longitudinal gradient in our Newburgh Pool density estimates may depict this upstream expansion but more information is needed to evaluate longitudinal changes in fish size within these pools.

Density estimates obtained from side-looking hydroacoustics have increased levels of uncertainty because bias is introduced from multiple sources. For example, target strength, which is converted to fish length, is a stochastic variable which depends on the physical (e.g., fish length and swim bladder presence) and behavioral (e.g., swimming direction and vertical movements) characteristics of the insonified fish (Foote 1980; Ona 1990; Boswell et al. 2009). For example, the orientation of insonified fish targets relative to the transducer greatly affects measured TS (Boswell et al. 2009; Johnson et al. 2019a). We use a side-aspect TS-TL equation to convert TS measurements to TL (Love 1971). This equation assumes fish are oriented perpendicular to the transducer at the time of sampling. Deviation from this assumption affects the total number of fish targets included in analyses and fish size estimated from TS (Boswell et al. 2009; Johnson et a. 2019a). Because we orient our transects parallel to the current, fish facing against or with the current will be oriented near-perpendicular to the transducer, validating our use of a side-aspect equation. In areas with reduced current (backwaters), target orientation relative to the transducer may deviate from perpendicular causing the use of Love’s 1971 equation to bias density and size estimates. Some additional sources of bias in side-looking hydroacoustic estimates include near-surface effects on sound propagation (Balk et al 2017), subjectivity during processing (i.e., interpretation of echograms, exclusion lines, and editing of fish tracks), and apportioning of hydroacoustic targets to species using community data.

Although hydroacoustics accurately samples pelagic fish populations (Johnson et al. 2019b), the use of community data to apportion hydroacoustic targets to species can bias estimates. The tools we used to collect community data (dozer trawl and boat electrofishing) have size and species-related biases. For example, boat electrofishing is biased towards large individuals (Chick et al. 1999; Bayley and Austin 2002). Because community data are used to apportion hydroacoustic targets to species, these gear-specific biases are transferred to the hydroacoustic estimates. The combination of gears used here should reduce the effects of gear-specific biases, improving our assessment of the fish assemblage. Further, our Bayesian hierarchical models incorporate much of the uncertainty inherent to hydroacoustic estimates, reducing bias contributed by community sampling gears (DuFour et al. 2021).

Our use of Bayesian hierarchical modeling improves Silver Carp estimates by incorporating uncertainty from TS measurements, thresholding, and community sampling in the models. Previous methods ignored these sources of uncertainty, likely biasing density estimates. Additionally, this approach provides the capability of inferring the probability of a fish being a Silver Carp for lengths that have no community data. The ability to infer the probability of a fish target being a Silver Carp for areas lacking Silver Carp catch data improves our estimates by reducing the effect of sparse or missing community data. Further, this approach is applicable in multiple situations because it has the flexibility to incorporate different patterns within species composition data as well as variable data distributions within the hydroacoustics data, which are affected by site characteristics and sampling design.

Recommendations:

- Targeted, standardized sampling should continue to add to our body of evidence indicating changes in relative abundances of invasive carps along the invasion front. In the meantime, occupancy modeling should continue to be explored to determine its use and efficacy in monitoring distributions and evaluating change in carp populations in the Ohio River, especially in areas of low abundance. Also, the absence of younger fish in Markland Pool this year as opposed to last, and the shift in body condition and length distributions in McAlpine and Cannelton pools, it is recommended that surveys for young-of-year recruitment continue in order to track any further changes in Silver Carp populations across the invasion front.
- With increasing catches of Silver Carp in the R.C. Byrd Pool, it is recommended that removal efforts increase in that pool to prevent any further invasion upstream.
- The eDNA project can be improved by increasing sample numbers and expanding the areas sampled. The Lower Great Lakes and the Carterville FWCOs recommend increasing eDNA sampling in West Virginia and adding two Kentucky reservoirs that are on the Salt and Licking rivers to the eDNA sampling.
- The new sampling design and analytical approach used during 2023 moved the hydroacoustic program closer to our goal of using side-looking hydroacoustics to evaluate Silver Carp densities within Ohio River pools. We recommend the continuation and further evaluation and development of the sampling design and analytical approaches to maximize the usefulness of the hydroacoustics program. Our results provide initial insights into Silver Carp densities throughout two Ohio River pools and the habitats within those pools. The approaches outlined within this report should be used in additional pools with established Silver Carp populations (e.g., Smithland Pool.), during future years to acquire a robust dataset that can be used to inform management decisions and evaluate the hydroacoustics program.

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Table 1. Length-Weight equations and the estimated weights of Silver Carp (450mm & 800mm) for eight different systems that contribute to the Mississippi River Basin. Published data for systems outside of the Ohio River Basin was obtained from Hayer et al. 2014.

System (w/-Specific Locales)	Length-Weight Regression Equation	Predicted weight (g) for 450mm	Predicted weight (g) for 800mm	Reference
Ohio River	Log10 Weight_g = -5.22 + 3.09(Log10 Length_mm)	952	5631	ORB Technical Report 2022
Illinois River	Log10 Weight_g = -5.29 + 3.12(Log10 Length_mm)	972	5856	Irons et al. 2011
Middle Mississippi River	Log10 Weight_g = -5.29 + 3.11(Log10 Length_mm)	915	5477	Williamson and Garvey 2005
Missouri River (Gavins Point)	Log10 Weight_g = -6.92 + 3.70(Log10 Length_mm)	788	6628	Wanner and Klumb 2009
Missouri River (Interior Highlands)	Log10 Weight_g = -5.35 + 3.13(Log10 Length_mm)	900	5453	Wanner and Klumb 2009
Big Sioux River (Missouri River tributary)	Log10 Weight_g = -5.53 + 3.21(Log10 Length_mm)	970	6150	Hayer et al. 2014
James River (Missouri River tributary)	Log10 Weight_g = -5.26 + 3.11(Log10 Length_mm)	981	5869	Hayer et al. 2014
Vermillion River (Missouri River tributary)	Log10 Weight_g = -4.82 + 2.90(Log10 Length_mm)	748	3971	Hayer et al. 2014

Table 2. Length-Weight equations and the estimated weights of Bighead Carp (450mm & 800mm) at five locations within the Mississippi River Basin. Published data was used for river systems located outside of the Ohio River Basin.

System-(w/ Specific Locales)	Length-Weight Regression Equation	Predicted weight (g) for 450mm	Predicted weight (g) for 800mm	Reference
Ohio River	Log10 Weight_g = -4.57 + 2.86(Log10 Length_mm)	1043	5406	ORB Technical Report 2022
Illinois River (La Grange)	Log10 Weight_g = -4.84 + 2.95(Log10 Length_mm)	970	5298	Irons et al. 2010
Missouri River (Males)	Log10 Weight_g = -5.42 + 3.15(Log10 Length_mm)	866	5306	Schrank and Guy 2002
Missouri River (Females)	Log10 Weight_g = -5.40 + 3.13(Log10 Length_mm)	803	4860	Schrank and Guy 2002
Missouri River (Gavins Point)	Log10 Weight_g = -4.86 + 2.96(Log10 Length_mm)	985	5409	Wanner and Klumb 2009
Missouri River (Interior Highlands)	Log10 Weight_g = -4.30 + 2.75(Log10 Length_mm)	991	4825	Wanner and Klumb 2009

Table 3. Location, number of samples and results of eDNA sample collection conducted in the Racine, Belleville, New Cumberland and Montgomery pools of the Ohio River in 2023.

Site	Pool	N	Negative	Bighead eDNA	Silver eDNA	Bighead AND Silver	Bighead OR Silver	No Results	Field Blanks
Sandy Creek, WV	Racine	90	90	0	0	0	0	0	10
Tombleson Run, WV	Racine	90	88	1	0	0	1	0	10
Mill Creek, WV	Racine	90	88	2	0	0	0	0	10
Kanawha River, WV	R.C. Byrd	90	90	0	0	0	0	0	10
Little Beaver Creek, PA	New Cumb.	90	90	0	0	0	0	0	10
Raccoon Creek, PA	Montgomery	90	90	0	0	0	0	0	10
Beaver River, PA	Montgomery	90	90	0	0	0	0	0	10
Muskingum River, OH	Belleville								
Devola Pool		80	41	0	0	0	0	39	8
Lowell Pool		80	77	0	0	0	1	2	8
Beverly Pool		80	79	1	0	0	0	0	8
Luke Chute Pool		80	80	0	0	0	0	0	8

Table 4. Number of silver carp radio-tagged at each location in the Wabash River system 2021-2023

Wabash River Telemetry Tagging of Silver Carp				
Tagging Location	**River**	**No. Fish**	**Latitude**	**Longitude**
Hazelton, IN	White	55	38.49	-87.54
Hutsonville, IL	Wabash	98	39.11	-87.65
Merom, IN	Wabash	42	39.06	-87.57
Mt. Carmel, IL	Wabash	109	38.42	-87.74
New Harmony, IN	Wabash	139	38.13	-87.94
Vincennes, IN	Wabash	94	38.80	-87.53

Table 5. Electrofishing effort and the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per transect) of three species of Invasive carp captured in five pools of the Ohio River from spring targeted sampling in 2023. 95% confidence intervals are in brackets.

2023 Spring Boat Electrofishing							
	Ohio River Pools						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	All Pools
Sampling Dates	11 April – 8 June						
Effort (Hours)	12.00	11.25	12.00	-	3.5	6	44.75
# Transects	48	45	48	-	14	25	180
Invasive Carp Counts							
Bighead Carp	0	1	0	-	0	0	1
Grass Carp	5	0	0	-	0	0	5
Silver Carp	321	59	8	-	0	0	388
All Carp	326	60	8	-	0	0	394
CPUE (fish/transect)							
Bighead Carp	0.00	0.02 (0.0-0.31)	0.00	-	0.00	0.00	
Grass Carp	0.10 (0.0-0.37)	0.00	0.00	-	0.00	0.00	
Silver Carp	6.69 (5.57-7.81)	1.31 (0.66-1.96)	0.17 (0.0-0.55)	-	0.00	0.00	
All Inv. Carp	6.79 (5.68-7.90)	1.33 (0.68-1.98)	0.17 (0.0-0.55)	-	0.00	0.00	

Table 6. Total catch of targeted gill netting conducted in the Greenup and R.C. Byrd pools of the Ohio River in 2023.

2023 Spring Gill Netting By-Catch			
	Ohio River Pool		
Species	Greenup	R.C. Byrd	Total
Bighead Carp	1	-	1
Silver Carp	-	1	1
Blue Catfish	-	1	1
Channel Catfish	-	-	0
Common Carp	-	2	2
Flathead Catfish	1	-	1

Table 7: Total number of fish captured per pool including abundance (Catch Per Unit Effort (CPUE)) and condition (Relative Weight (Wr; where applicable)) estimators during fall community electrofishing surveys conducted in the Greenup, R.C. Byrd and Racine pools in 2023.

	Greenup Pool			Racine Pool			R.C. Byrd Pool		
	2.5 hrs (10 Transects)			5.5 hrs (22 Transects)			1.25 hrs (5 Transects)		
Species	**N**	**Wr**	**Mean CPUE no/hr (95% CL)**	**N**	**Wr**	**Mean CPUE no/hr (95% CL)**	**N**	**Wr**	**Mean CPUE no/hr (95% CL)**
Black Buffalo	1	-	0.4 (0.8)	1	-	0.2 (0.4)	-	-	-
Black Crappie	1	-	0.4 (0.8)	1	-	0.2 (0.4)	-	-	-
Bluegill Sunfish	9	-	3.6 (2.1)	187	92	34.0 (29.7)	8	-	6.4 (8.8)
Bluntnose Minnow	-	-	-	4	-	0.7 (0.8)	-	-	-
Bowfin	4	-	1.6 (1.7)	-	-	-	-	-	-
Bullhead Minnow	1	-	0.4 (0.8)	10	-	1.8 (2.1)	-	-	-
Channel Catfish	8	92.9	3.2 (2.6)	7	87.8	1.3 (1.2)	-	-	-
Channel Shiner	69	-	27.6 (32.1)	35	-	6.4 (5.1)	19	-	15.2 (19.3)
Common Carp	8	114	3.2 (2.6)	15	107.8	2.7 (1.7)	-	-	-
Eastern Banded Killifish	-	-	-	2	-	0.4 (0.5)	-	-	-
Emerald Shiner	250	-	100.0 (50.0)	179	-	32.5 (17.9)	79	-	63.2 (55.8)
Flathead Catfish	1	77.1	0.4 (0.8)	1	84.8	0.2 (0.4)	-	-	-
Freshwater Drum	44	104.4	17.6 (11.4)	25	101.4	4.5 (2.2)	6	92.9	4.8 (4.6)
Gizzard Shad	520	94.7	208.0 (145.2)	606	88.9	110.2 (81.1)	176	88.3	140.8 (98.6)
Golden Redhorse	52	-	20.8 (11.9)	7	-	1.3 (1.5)	1	-	0.8 (1.6)
Green Sunfish	1	-	0.4 (0.8)	6	-	1.1 (2.1)	-	-	-
Highfin Carpsucker	7	-	2.8 (2.6)	8	-	1.5 (1.5)	1	-	0.8 (1.6)
Hybrid Striped Bass	10	100.3	4.0 (3.1)	14	96.8	2.5 (1.9)	3	92.5	2.4 (3.1)
Hybrid Sunfish	-	-	-	1		0.2 (0.4)	-	-	-
Johnny Darter	-	-	-	1		0.2 (0.4)	-	-	-
Largemouth Bass	12	106.2	4.8 (3.1)	25	98.1	4.5 (2.2)	-	-	-
Logperch	8	-	3.2 (2.3)	-	-	-	-	-	-
Longear Sunfish	4	-	1.6 (1.3)	13	-	2.4 (3.7)	-	-	-
Longnose Gar	13	77	5.2 (4.7)	9	82.6	1.6 (1.3)	5	78	4.0 (2.5)
Mirror Carp	-	-	-	1	-	0.2 (0.4)	-	-	-
Muskellunge	-	-	-	1	80.3	0.2 (0.4)	-	-	-
Northern Hog Sucker	7	-	2.8 (2.0)	5	-	0.9 (0.9)	3	-	2.4 (4.7)
Orangespotted Sunfish	1	-	0.4 (0.8)	2	-	0.4 (0.5)	-	-	-
Quillback Carpsucker	5	-	2.0 (1.7)	29	-	5.3 (7.7)	4	-	3.2 (6.3)
Redear Sunfish	-	-	-	11	95.2	2.0 (1.4)	-	-	-
River Carpsucker	13	91.1	5.2 (3.5)	10	96.4	1.8 (1.2)	2	95.3	1.6 (3.1)
River Redhorse	16	-	6.4 (4.2)	6	-	1.1 (1.8)	5	-	4.0 (4.9)
Spotfin Shiner	3	-	1.2 (1.7)	2	-	0.4 (0.5)	1	-	0.8 (1.6)
Sauger	60	80.5	24.0 (15.5)	46	82.4	8.4 (4.4)	9	75.6	7.2 (4.6)
Silver Chub	1	-	0.4 (0.8)	-	-	-	-	-	-

Silver Redhorse	10	-	4.0 (2.6)	44	-	8.0 (5.0)	5	-	4.0 (4.3)
Skipjack Herring	11	-	4.4 (2.5)	16	-	2.9 (1.7)	3	-	2.4 (1.9)
Smallmouth Bass	35	96.1	14.0 (11.5)	14	86.7	2.5 (2.2)	9	87.8	7.2 (2.9)
Smallmouth Buffalo	103	78.7	41.2 (17.6)	193	78.1	35.1 (12.4)	16	77.5	12.8 (3.8)
Smallmouth Redhorse	91	-	36.4 (16.5)	17	-	3.1 (2.7)	11	-	8.8 (6.3)
Spotted Bass	54	108.8	21.6 (16.7)	16	108.4	2.9 (1.9)	2	123	1.6 (1.9)
Spotted Sucker	5	-	2.0 (2.7)	25	-	4.5 (5.9)	-	-	-
Walleye	1	87.7	0.4 (0.8)	-	-	-	2	84.9	1.6 (3.1)
Warmouth Sunfish	-	-	-	3	90.8	0.5 (0.8)	-	-	-
Western Banded Killifish	-	-	-	12	-	2.2 (2.0)	-	-	-
White Crappie	-	-	-	2	85.5	0.4 (0.7)	-	-	-
Yellow Bullhead	-	-	-	1	-	0.2 (0.4)	-	-	-
Yellow Perch	2	90.9	0.8 (1.1)	-	-	-	-	-	-

Table 8. Average relative weight (W_r) calculated by species and pool from community surveys conducted in the Greenup, R.C. Byrd and Racine pools of the Ohio River 2023 by WVDNR (Bister et al. (2000) and Nuemann et. al. (2012)). Outliers were removed from analysis. Comparisons with the pool average from 2017-2023 data are also included.

2023 Fall Community Sampling - Relative Weight						
Pool	**Greenup**		**R.C. Byrd**		**Racine**	
Species	**2023 W_r**	**Mean W_r**	**2023 W_r**	**Mean W_r**	**2023 W_r**	**Mean W_r**
Black crappie		96		98		
Bluegill		91		90	92	93
Channel catfish	93	88		86	88	92
Common carp	114	109		99	108	105
Flathead catfish	77	83		86	85	89
Freshwater drum	104	98	93	96	101	99
Gizzard shad	95	85	88	85	89	88
Green sunfish		107		92		
Hybrid striped bass	100	91	93	86	97	91
Largemouth bass	106	101		102	98	103
Longnose gar	77	79	78	80	83	78
Redear sunfish		83		88	95	103
River carpsucker	91	94	95	91	96	95
Sauger	81	83	76	83	82	89
Smallmouth bass	96	92	88	87	87	88
Smallmouth buffalo	78	79	76	78	78	79
Spotted bass	109	98	123	102	108	104
Walleye		89	85	92		82
Warmouth		93		99	91	91
White bass		90		93		84
White crappie		88		95	85	91
Yellow Perch	91	88		92		

Table 9. Gillnetting effort (feet of net), catch and species counts from fall gill net surveys conducted in the Greenup and R.C. Byrd pools in 2023.

2023 Fall Gillnetting		
Pool	**R.C. Byrd**	**Greenup**
Effort (ft)	1950	1800
Soak Time (hrs)	25.7	31.3
Number of Sites	7	9
Species		
Bighead Carp	1	-
Paddlefish	1	-
Silver Carp	-	-

Table 10. Total number of fish captured per pool and percent of total captured at five pools combined in the Allegheny, Monongahela, and Ohio Rivers during spring tailwater night electrofishing surveys in 2023. (A=Allegheny, M=Monongahela, O=Ohio)

Species Captured	**Pool 7 (A)**	**Emsworth (M)**	**New Cumberland (O)**	**Montgomery (O)**	**Dashields (O)**	**Total**	**Percent**
Bigeye Chub		2			3	5	0.09%
Black Crappie			1			1	0.02%
Black Redhorse	47	5	7	6	2	67	1.20%
Bluebreast Darter				2		2	0.04%
Bluegill	19	3	2	4	1	29	0.52%
Bluntnose Minnow	10	21	4	34	24	93	1.66%
Brook Silverside	1	1				2	0.04%
Channel Catfish	2		9	1	6	18	0.32%
Channel Darter		1	15	1		17	0.30%
Channel Shiner	8	84	43	42	31	208	3.72%
Common Carp		1	3		1	5	0.09%
Emerald Shiner	79	58	147	202	550	1036	18.52%
Flathead Catfish	2	1			1	4	0.07%
Freshwater Drum		14	5	9	10	38	0.68%
Gizzard Shad	1	7	3	14	2	27	0.48%
Golden Redhorse	185	38	103	43	19	388	6.94%
Green Sunfish	3		2			5	0.09%
Greenside Darter	6	18	20	31	17	92	1.64%
Johnny Darter		14	38	14	14	80	1.43%
Largemouth Bass			3			3	0.05%
Logperch	29	8	42	33	80	192	3.43%
Longhead Darter	5	2	6	5	25	43	0.77%
Longnose Gar	7	39	29	14	10	99	1.77%
Mimic Shiner	95	323	101	236	254	1009	18.04%
Mooneye	1					1	0.02%
Muskellunge			2	1		3	0.05%
Northern Hog Sucker	38	3	4	8	1	54	0.97%
Ohio Lamprey	4					4	0.07%
Pumpkinseed		1	1		1	3	0.05%
Quillback	4	1	43	17	32	97	1.73%
Rainbow Darter			1		1	2	0.04%
River Carpsucker			8	5	5	18	0.32%
River Redhorse	72	10	27	12	2	123	2.20%
Rock Bass	37	32	6	8	9	92	1.64%
Sauger	2	16	50	23	14	105	1.88%
Silver Chub			1			1	0.02%
Silver Redhorse	173	13	59	29	21	295	5.27%
Smallmouth Bass	104	191	106	141	111	653	11.68%
Smallmouth Buffalo	3	6	44	6	7	66	1.18%
Smallmouth Redhorse	74	21	13	8	3	119	2.13%
Spotfin Shiner	10		4	10		24	0.43%
Streamline Chub				10	5	15	0.27%
Walleye	253	91	29	21	48	442	7.90%
White Bass		2	4		1	7	0.13%
Yellow Perch	6					6	0.11%
Totals	1280	1027	985	990	1311	5593	
Total Species	30	31	37	31	33	45	

Table 11. Total number of fish captured per pool by gear type in the Montgomery and Dashields pools of the Ohio River in September and October 2022. GN = Gill Net, NTEF = Night Electrofishing.

Species Captured	Montgomery (GN)	Dashields (GN)	Total Catch (GN)	Montgomery (NTEF)	Dashields (NTEF)	Total Catch (NTEF)
Banded Darter				1	2	3
Banded Killifish				1		1
Bigeye Chub				2	8	10
Black Crappie				6	1	7
Black Redhorse				21	17	38
Bluegill				180	187	367
Bluntnose Minnow				151	147	298
Bowfin				1		1
Brook Silverside				42	76	118
Central Stoneroller				1	2	3
Channel Catfish	2		2	32	6	38
Channel Shiner				495	161	656
Common Carp	27	10	37	39	17	56
Creek Chub				2	1	3
Emerald Shiner				11834	14501	26335
Flathead Catfish	3		3	6	1	7
Freshwater Drum	4	2	6	82	9	91
Ghost Shiner				2	1	3
Gizzard Shad				365		365
Golden Shiner				1		1
Golden Redhorse				138	69	207
Greenside Darter					2	2
Green Sunfish				2	18	20
Johnny Darter				3	3	6
Largemouth Bass				5		5
Logperch				2	9	11
Longhead Darter				1	13	14
Longnose Gar	1		1	1	2	3
Meanmouth Bass					1	1
Mimic Shiner				451	826	1277
Mooneye				1		1
Muskellunge				1	1	2
Northern Hog Sucker				6	21	27
Northern Pike				5		5
Pumpkinseed				7	6	13
Quillback				21	50	71
Rainbow Darter					1	1
River Carpsucker	8		8	105	25	130
River Chub				1	1	2
River Redhorse	1		1	21	35	56
Rock Bass				32	37	69
Rosyface Shiner				28	6	34
Sand Shiner				15		15
Sauger				221	105	326

Silver Chub				2		2
Silver Redhorse		1	1	27	28	55
Silver Shiner				8		8
Smallmouth Bass	2		2	271	193	464
Smallmouth Buffalo	33	36	69	153	72	225
Smallmouth Redhorse				69	105	174
Spotfin Shiner				61	29	90
Spottail Shiner				2		2
Spotted Bass				43	23	66
Trout Perch				1		1
Streamline Chub				2	19	21
Striped Bass - Hybrid	1		1			0
Walleye				197	134	331
Warmouth				1		1
White Bass				141	22	163
White Crappie				1		1
White Sucker				9	9	18
Yellow Perch				1	1	2
Totals	**82**	**49**	**131**	**15320**	**17004**	**32323**
Total Species	**10**	**4**	**11**	**58**	**48**	

Table 12. Fish captured by species and percent total abundance from boat ramp seine hauls conducted in the Greenup, R.C. Byrd and Racine pools of the Ohio River in Fall 2023.

2023 Ohio River Boat Ramp Seines									
	Racine (3 Sites)			R.C. Byrd (5 Sites)			Greenup (5 Sites)		
Species	**N**	**% Catch**	**Pool Ave**	**N**	**% Catch**	**Pool Ave**	**N**	**% Catch**	**Pool Ave**
Black Redhorse	-	-		1	0.09%	0.02%	-	-	
Bluegill	19	8.88%	5.84%	4	0.34%	1.55%	1	0.06%	0.98%
Bluntnose Minnow	2	0.93%	0.59%	19	1.64%	0.41%	2	0.12%	0.34%
Bullhead Minnow	-	-		-	-		1	0.06%	0.38%
Central Stoneroller	-	-		16	1.38%	0.23%	3	0.17%	0.04%
Channel Shiner	69	32.34%	29.42%	690	66.70%	58.25%	729	41.97%	31.06%
Common Carp	-	-		9	0.78%	0.13%	-	-	
Cyprinella Spp.	9	4.21%		-	-		2	0.12%	
Eastern Banded Killifish	-	-	0.04%	-	-	0.02%	2	0.12%	0.03%
Emerald Shiner	37	17.29%	42.49%	364	31.38%	38.39%	542	31.2%	58.56%
Gambusia spp.	17	7.94%	4.05%	4	0.34%	0.54%	-	-	0.01%
Gizzard Shad	18	8.41%	4.21%	16	1.38%	0.40%	364	20.96%	6.22%
Golden Redhorse	3	1.40%	0.70%	2	0.17%	0.03%	50	2.88%	0.72%
Green Sunfish	-	-		2	0.17%	0.03%			
Highfin Carpsucker	3	1.40%	0.70%	2	0.17%	0.03%	3	0.17%	0.04%
Johnny Darter	1	0.47%	0.24%	-	-	0.01%	-	-	0.01%
Largemouth Bass	-	-		1	0.09%	0.02%	-		
Logperch	-	-		-	-		1	0.06%	
Northern Hogsucker	1	0.47%	0.24%	-	-		-	-	
Orangespotted Sunfish	-	-		4	0.34%	0.12%	-	-	0.01%
Quillback	9	4.21%	2.11%	-	-		-	-	
River Redhorse	-	-		4	0.34%	0.06%	1	0.06%	0.02%
River shiner									0.30%
Silver Chub	-	-		-	-		1	0.06%	0.08%
Silver Redhorse	-	-		4	0.34%	0.06%	5	0.29%	0.09%
Smallmouth Redhorse	1	0.47%	0.24%	4	0.34%	0.06%	27	1.55%	0.42%
Spotfin Shiner	1	0.47%	0.43%	9	0.78%	0.24%	2	0.12%	0.16%
Spotted Bass	-	-		-	-		1	0.06%	0.03%
Steelcolor shiner	-	-	0.12%	5	0.43%	0.15%	-	-	
Western Banded Killifish	24	11.21%	6.53%	-	-		-	-	
Total	**214**			**1160**			**1737**		

Table 13. Species and number captured with percent of total catch during annual beach seine surveys in the Montgomery Island Pool from 2023.

2023 Ohio River Beach Seines		
Species Captured	**Number**	**Percent Abundance**
Bigeye Chub	85	3.71%
Bluegill	42	1.83%
Bluntnose Minnow	116	5.07%
Brook Silverside	33	1.44%
Channel Shiner	174	7.60%
Emerald Shiner	499	21.79%
Gizzard Shad	953	41.62%
Golden Redhorse	4	0.17%
Largemouth Bass	1	0.04%
Logperch	18	0.79%
Longnose Gar	1	0.04%
Mimic Shiner	253	11.05%
Muskellunge	1	0.04%
Sand Shiner	3	0.13%
Silver Shiner	1	0.04%
Smallmouth Bass	29	1.27%
Spotfin Shiner	63	2.75%
Streamline Chub	11	0.48%
White Perch	2	0.09%
White Sucker	1	0.04%
Totals	2290	

Table 14. Temporal distribution of zooplankton samples collected in the Ohio River 2021-2023.

		# of zooplankton samples					
Site	**Year**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
Kyger Creek	2021	1	3	1	-	-	1
Guyandotte River	2021	1	3	1	-	-	-
Scioto River	2021	1	3	1	-	-	1
J.M. Stuart Plant	2021	1	3	1	-	-	-
Little Miami River	2021	-	3	1	-	-	-
Hogan Creek	2021	1	2	1	-	-	-
Kyger Creek	2022	1	2	2	1	1	1
Guyandotte River	2022	-	2	2	1	1	1
Scioto River	2022	-	2	2	1	1	1
J.M. Stuart	2022	1	2	2	1	1	1
Little Miami River	2022	1	2	2	1	1	1
Hogan Creek	2022	-	2	2	1	1	1
Ohio River at Louisville	2022	-	2	2	1	1	1
Ohio River at Concordia	2022	-	2	2	1	1	1
Point Pleasant boat ramp	2023	1	2	-	-	-	-
Ohio River at Kanawha River	2023	1	1	2	-	-	-
Guyandotte River	2023	-	-	1	-	-	-
Ohio River at Guyandotte River	2023	-	1	1	-	-	-
Scioto River 357	2023	1	-	1	-	-	-
Ohio River at RM 373	2023	-	1	-	-	-	-
Ohio River at RM 396	2023	-	1	-	-	-	-
Ohio River at RM 405	2023	-	1	-	-	-	-
Little Three Mile Creek 406	2023	1	1	-	-	-	-
Ohio River at J.M. Stuart	2023	1	1	1	-	-	-
Ohio River at RM 429	2023	-	1	-	-	-	-
Little Miami River 464	2023	1	-	-	-	-	-
Ohio River at Little Miami	2023	1	-	-	-	-	-
Ohio River at RM 484	2023	1	-	-	-	-	-
Hogan Creek 497	2023	1	1	1	-	-	-
Ohio River at Hogan Creek	2023	1	-	1	-	-	-
Ohio River at RM 514	2023	1	-	-	-	-	-
Ohio River at RM 528	2023	-	1	-	-	-	-

Table 15. Total number of fish captured per pool from gill net sampling at Montgomery Slough (Montgomery Pool) and near Phyllis and Georgetown Islands (New Cumberland Pool) in the Ohio River in November/December 2023.

Species	Montgomery Pool	New Cumberland Pool	Total
Common Carp	8		8
Freshwater Drum		2	2
River Carpsucker	12		12
Sauger	1		1
Silver Redhorse		2	2
Smallmouth Buffalo	3	2	5
Striped Bass Hybrid	5	7	12
Tiger Muskellunge		1	1
Walleye	1	1	2
Totals	**30**	**15**	**45**

Table 16. Number of unique fish detected at each receiver location in the Ohio River 2021-2023. For locations with multiple receivers (e.g. lock and dam structures) detections from all receivers were pooled, and the number of unique fish are reported.

Wabash River Fish Detections on Ohio River Receivers			
Receiver Location	**No. Fish**	**Latitude**	**Longitude**
Brookport, IL	8	37.11	-88.63
Cannelton L&D	2	38.12	-86.41
Clover Creek	1	37.84	-86.63
J.T. Meyers L&D	7	37.80	-87.99
Newburgh L&D	3	37.83	-87.04
Smithland L&D	15	37.16	-88.43
Tennessee River	2	37.03	-88.53

Table 17. Number of sites (N) and mean and upper and lower 90% credible intervals (CrI) for Silver Carp density (SVC/1000m^3) within main channel (MC), side channel (SC), and tributary (TRIB), habitats within Cannelton and Newburgh pools.

Pool	Habitat	N	Mean SVCP Density	Average Lower 90% CrI	Average Upper 90% CrI
Cannelton	MC	131	0.096	0.094	0.097
Cannelton	Trib	18	1.530	1.520	1.540
Newburgh	BW	1	1.68	1.67	1.69
Newburgh	MC	102	0.050	0.049	0.051
Newburgh	SC	34	0.113	0.110	0.115
Newburgh	Trib	5	1.860	1.840	1.880

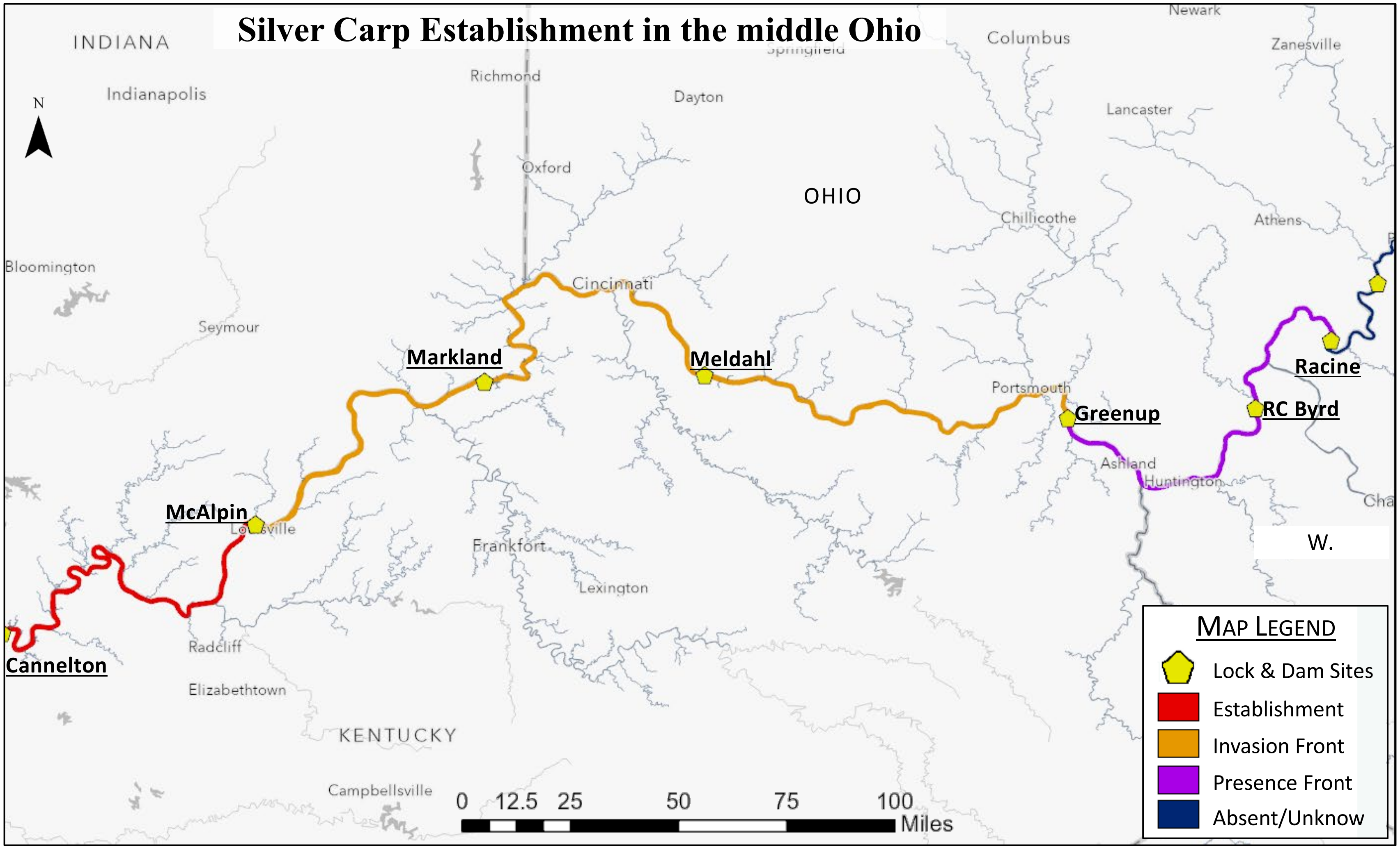


Figure 1. A section of the middle Ohio River consisting of six pools (Cannelton - Racine) that are colored according to the Silver Carp population's invasion status in 2023. A pool's status is reevaluated each year following the analysis of sampling data that's collected for several ongoing research projects in the Ohio River Basin.

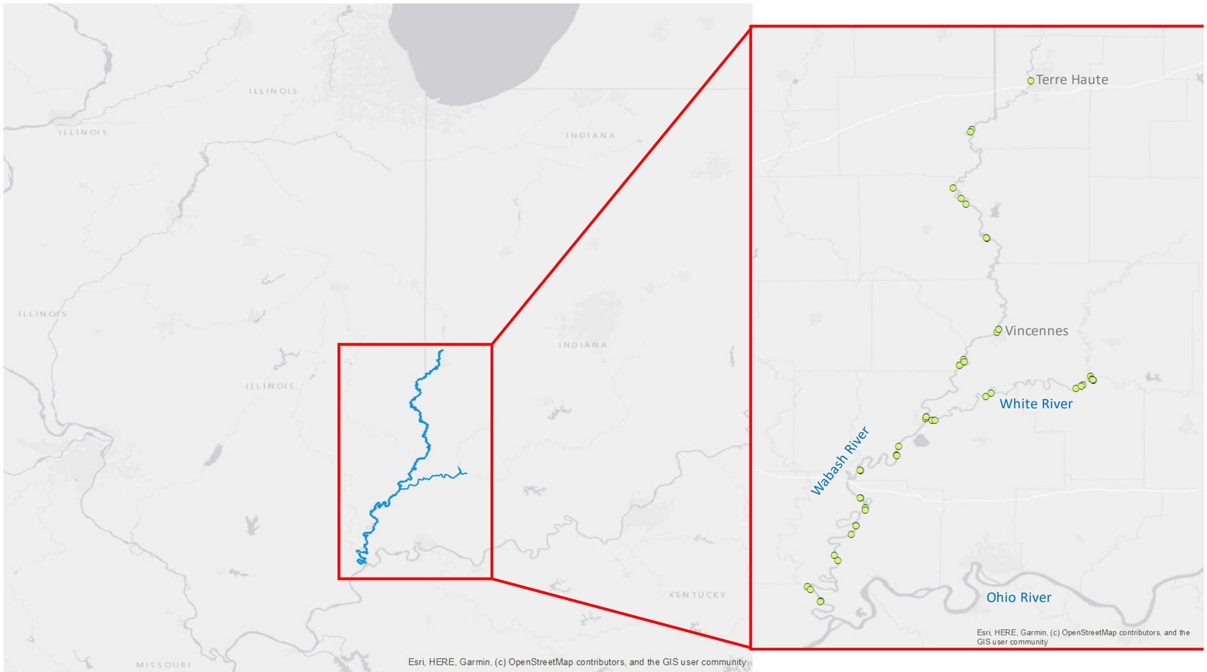


Figure 2. Map of Vemco VR2 receiver array locations within the Wabash and White Rivers.

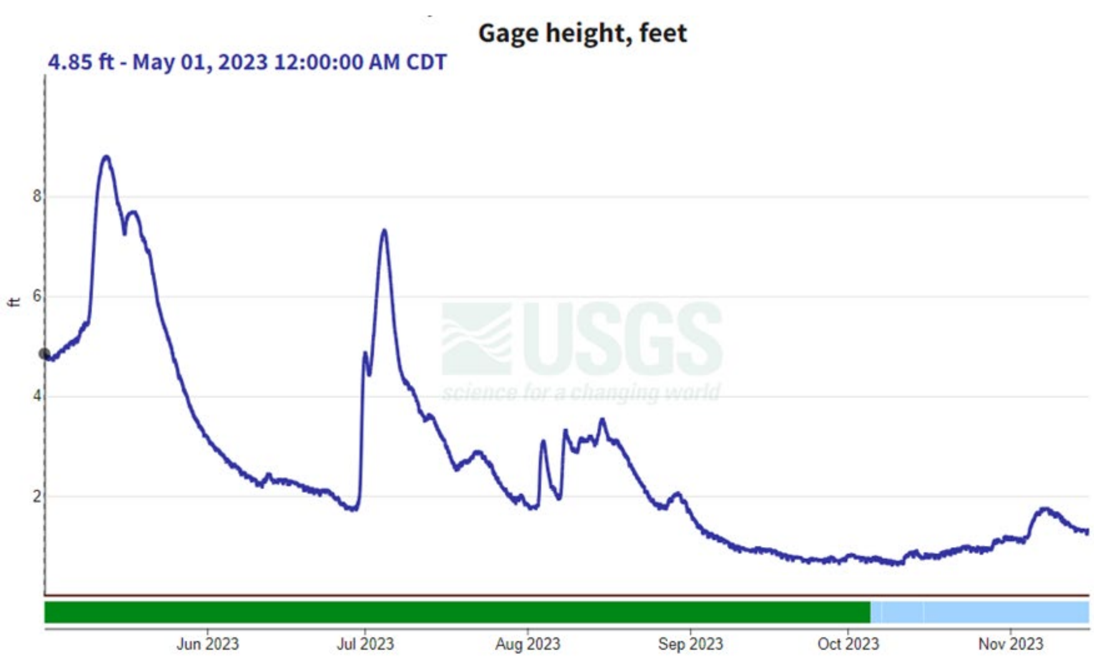


Figure 3. Gauge height at USGS Gauge 03378500 graph at New Harmony, IN on the Wabash River indicating low water in late 2023 preventing the retrieval of some receivers in the Wabash River.

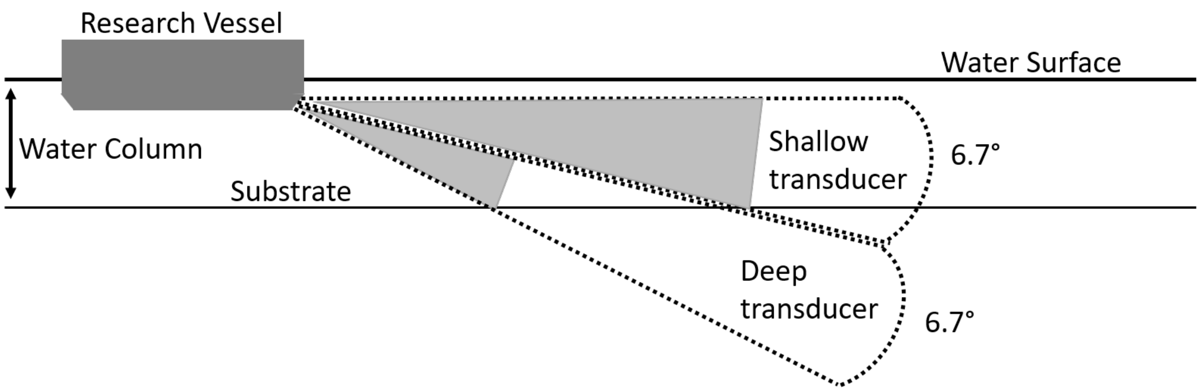


Figure 4. Depiction of hydroacoustic beams with transducers offset to maximize water column coverage for two split-beam echosounders. Figure modified from McNamara et al. 2016.

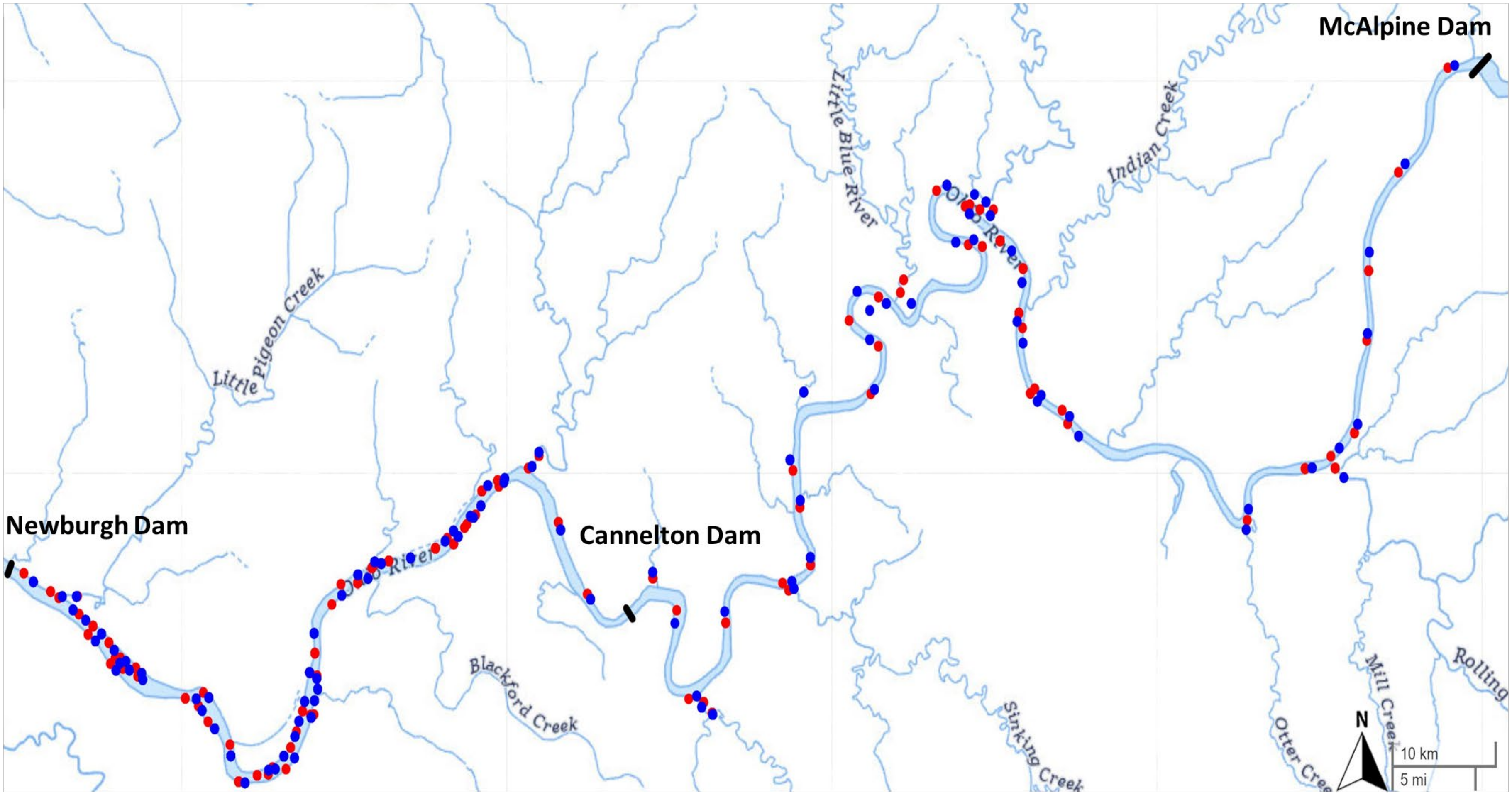
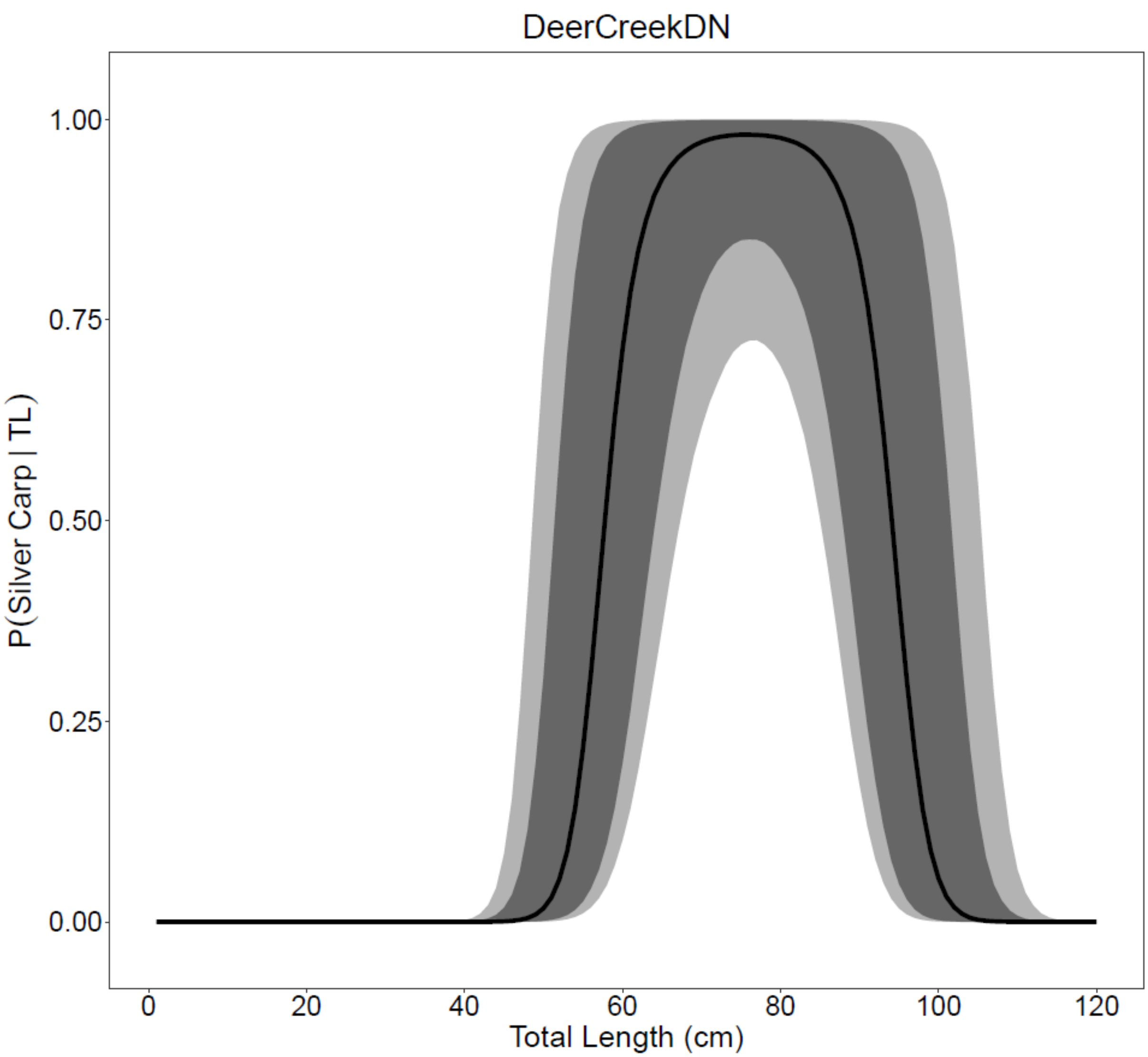


Figure 5. Map of dozer trawl (red) and boat electrofishing (blue) sites in Cannelton and Newburgh pools during October 2022. Community data were used to apportion hydroacoustic targets to species. Black lines across the river indicate dam locations.



Figure

Figure 6. Estimated probability of a fish being a Silver Carp given its total length for the downstream portion of Deer Creek. The dark line is the median probability, and the gray-shaded areas represent the 90% (light) and 75% (dark) credible intervals, respectively.

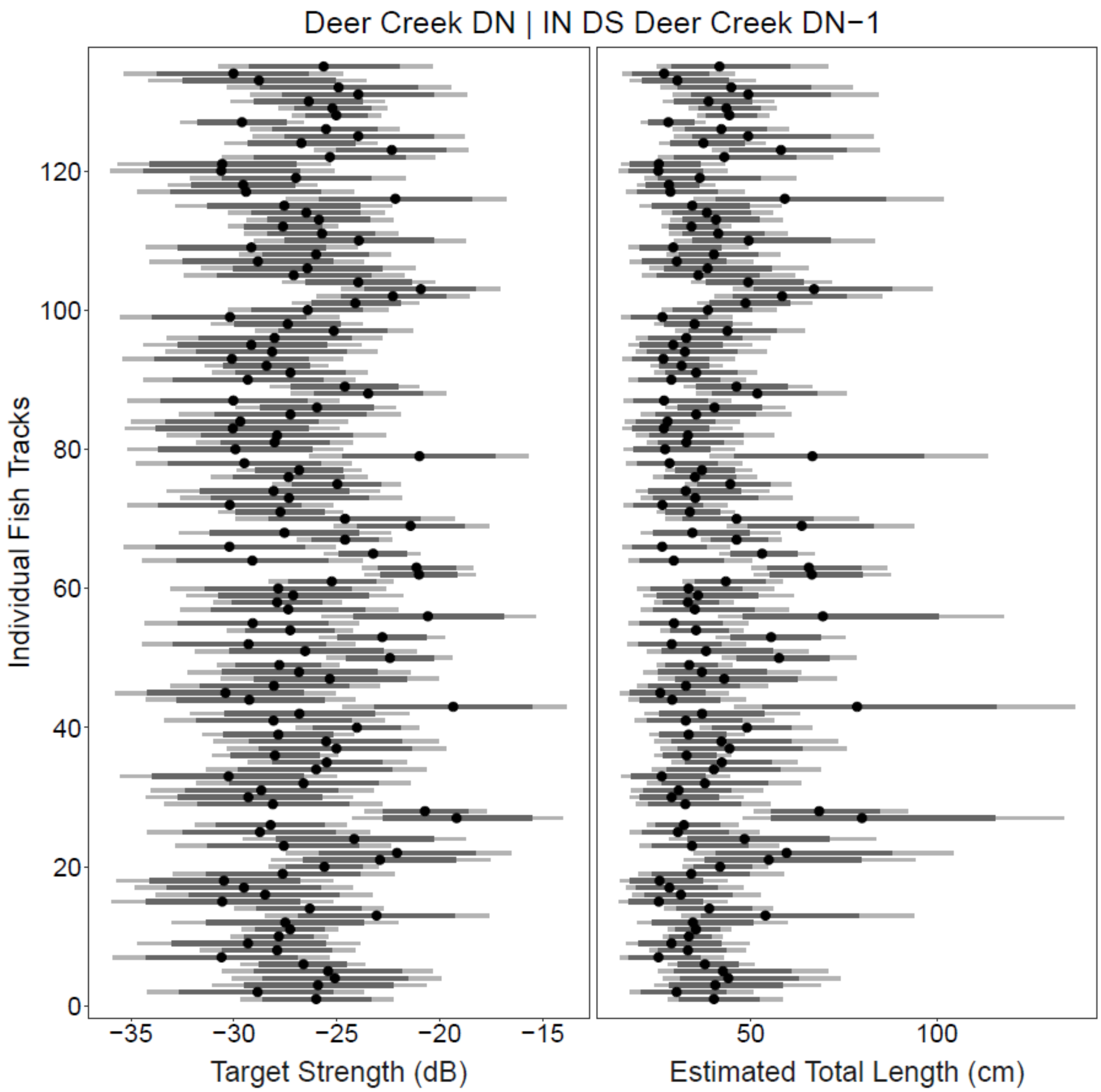


Figure 7. Estimated mean TS (dB) and TL (cm) for all fish tracks at Deer Creek for the downstream, shore-facing transect. Black dots represent the estimated median TS and TL. Dark and light gray lines represent 75% and 90% credible intervals, respectively.

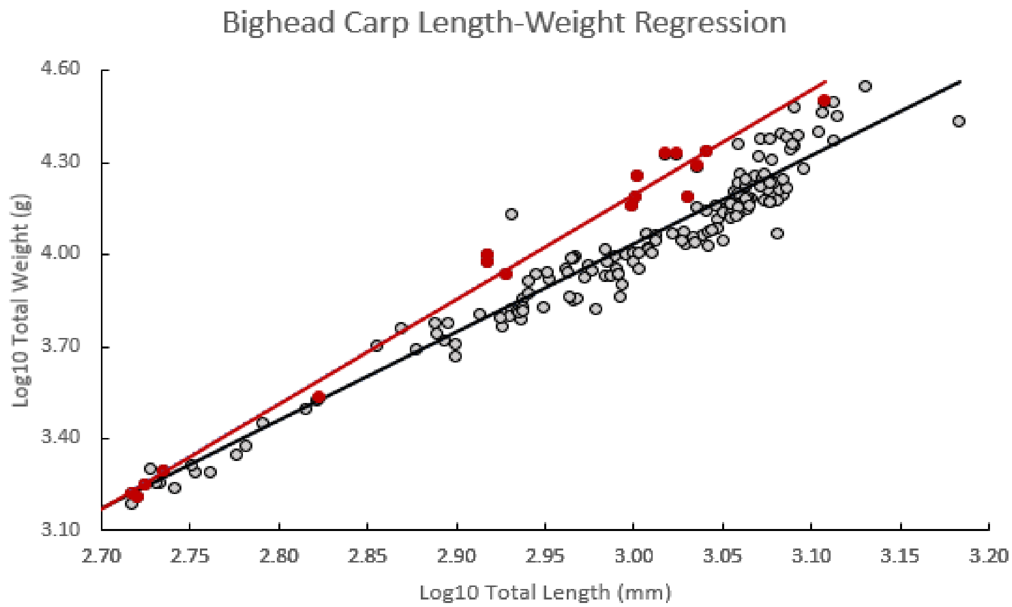


Figure 8. The log-transformed length-weight relationship of Bighead Carp collected from the middle Ohio River. The darker circles illustrate the length and weights of the fish sampled through 2022, while the Bighead Carp collected in 2023 and resulting regression line are provided in red. The dark line represents a regression equation (see Table 2) generated from all of the length-weight data collected between 2015 and 2023.

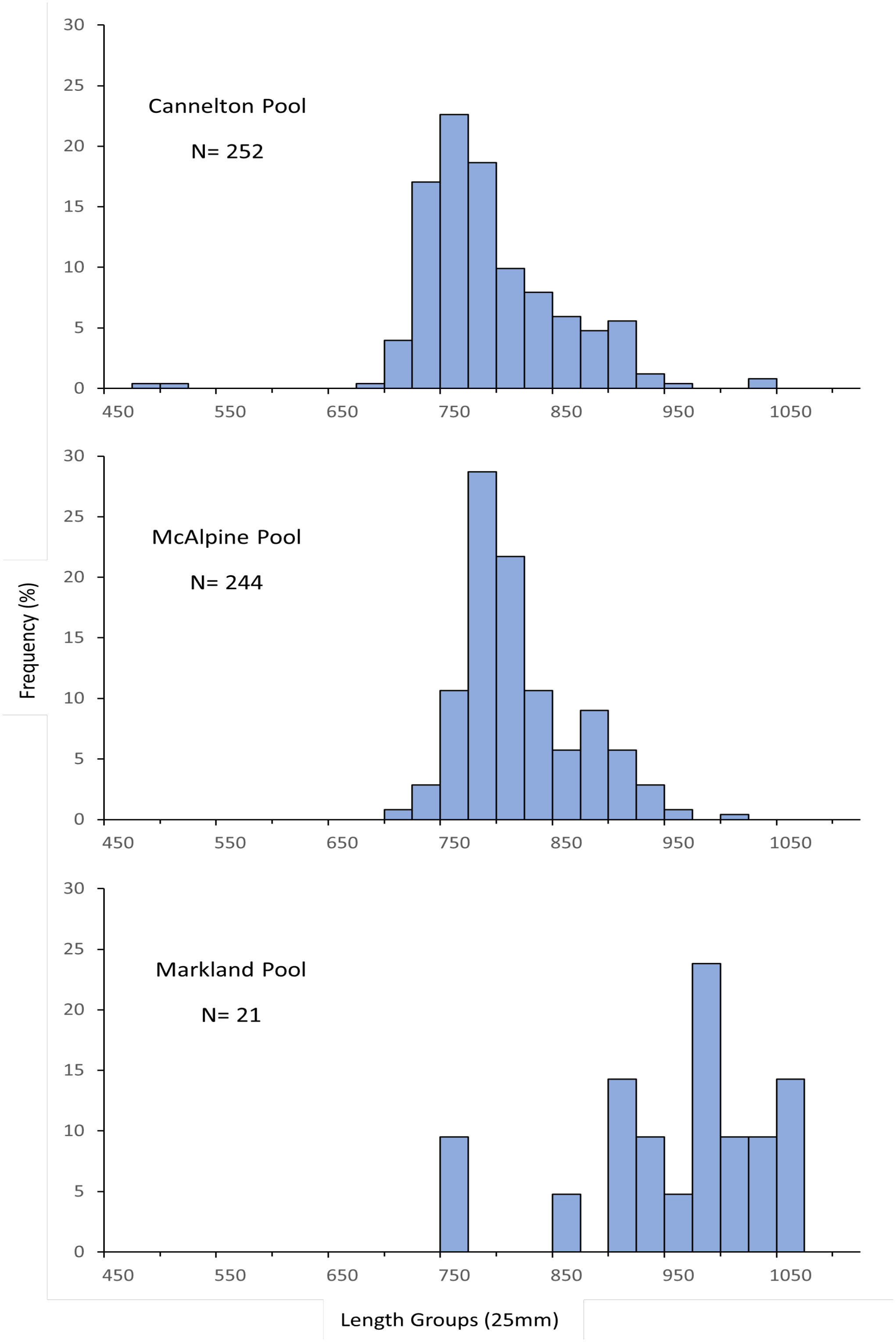


Figure 9. The length frequency distribution (25mm bins) for Silver Carp collected from the Cannelton, McAlpine and Markland pools in 2023.

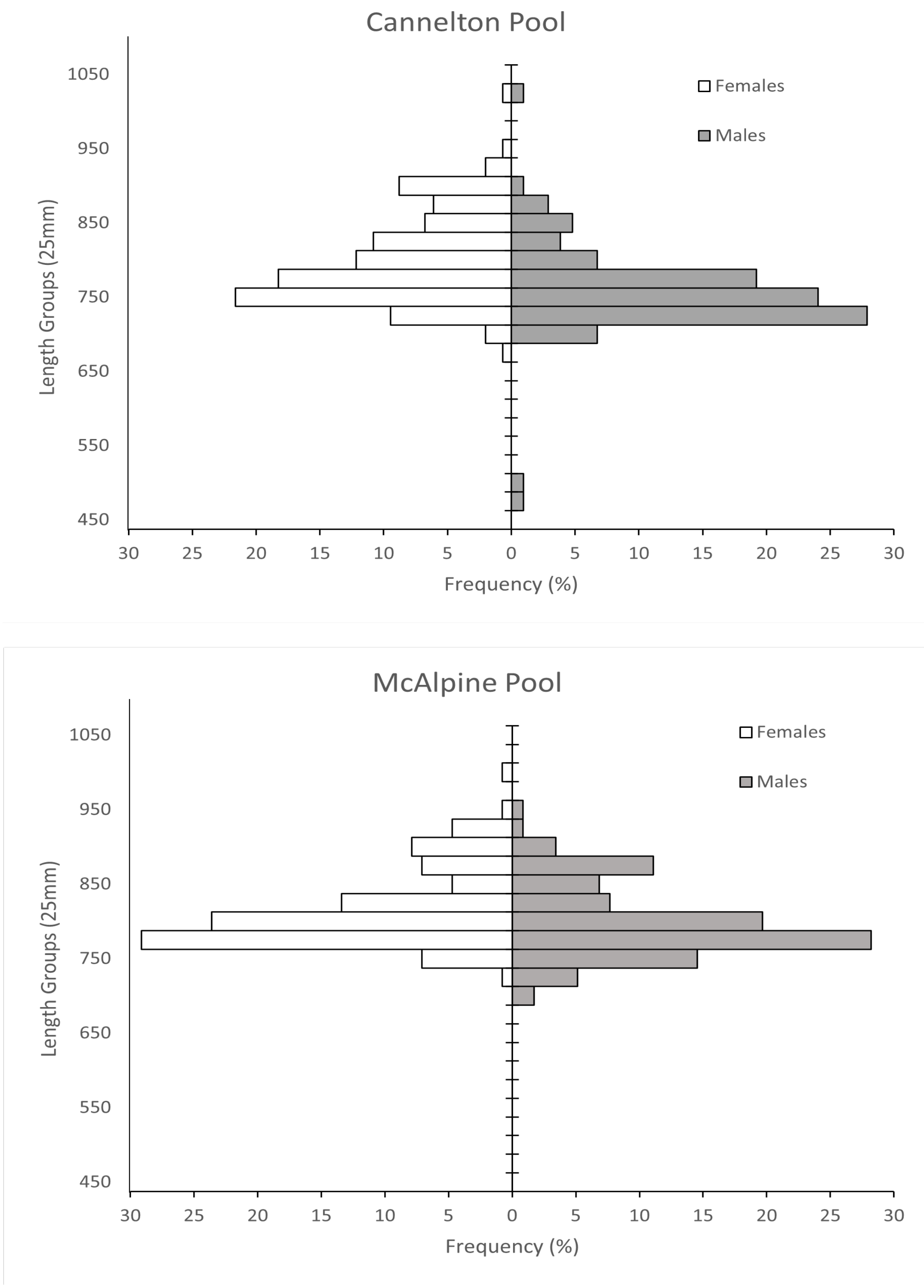


Figure 10. Length frequency (25 mm bins) distributions for male and female Silver Carp collected from the Cannelton and McAlpine pools during 2023.

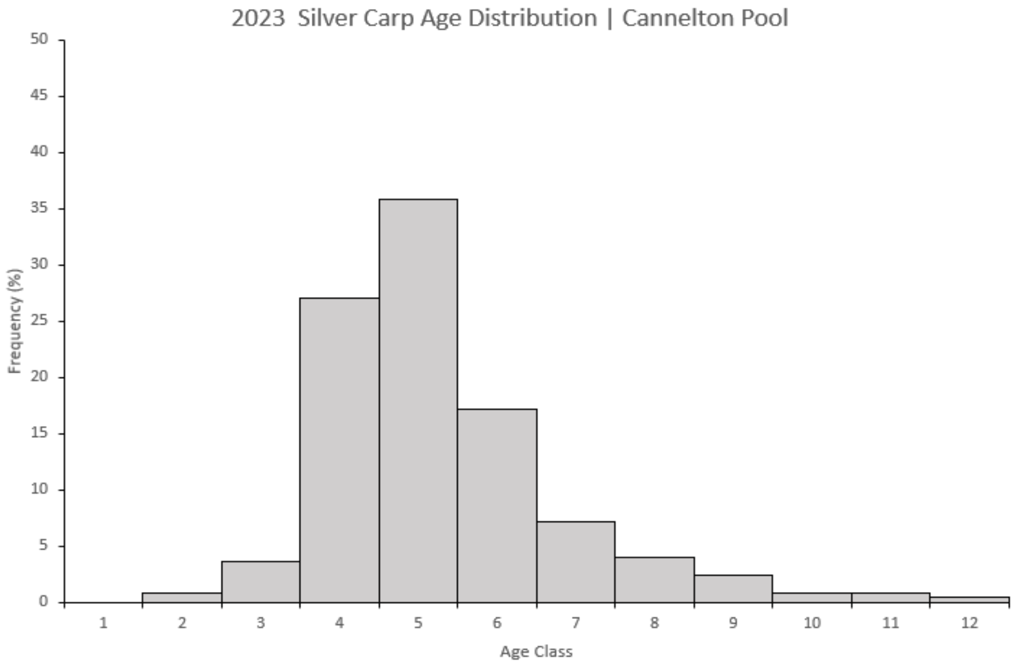


Figure 11. Age distribution of Silver Carp that were collected from the Cannelton Pool in fall 2023.

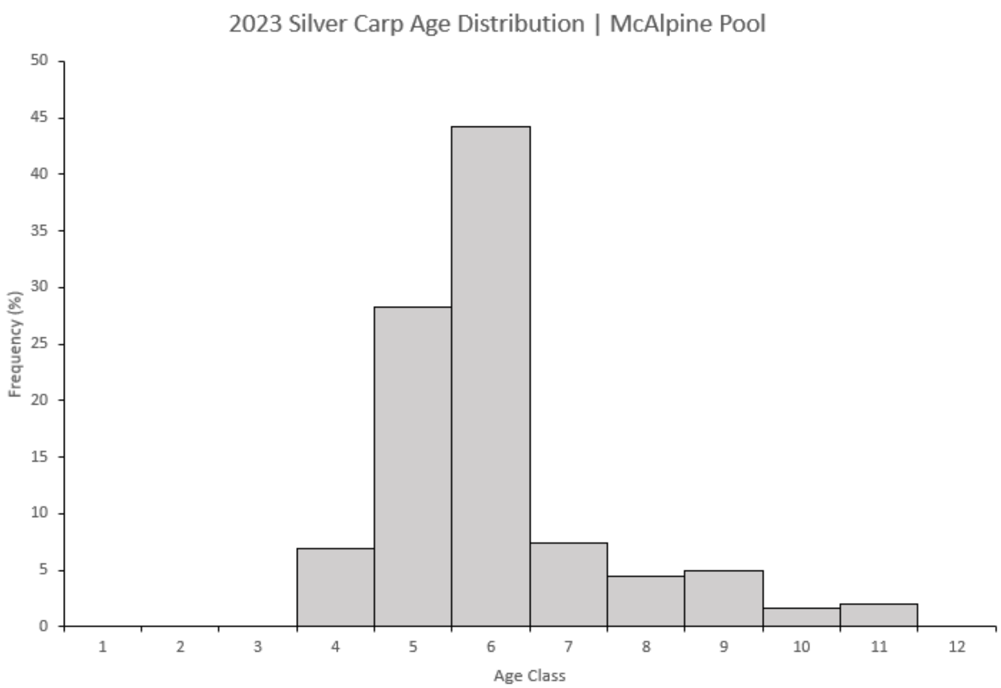


Figure 12. Age distribution of Silver Carp that were collected from the McAlpine Pool in fall 2023.

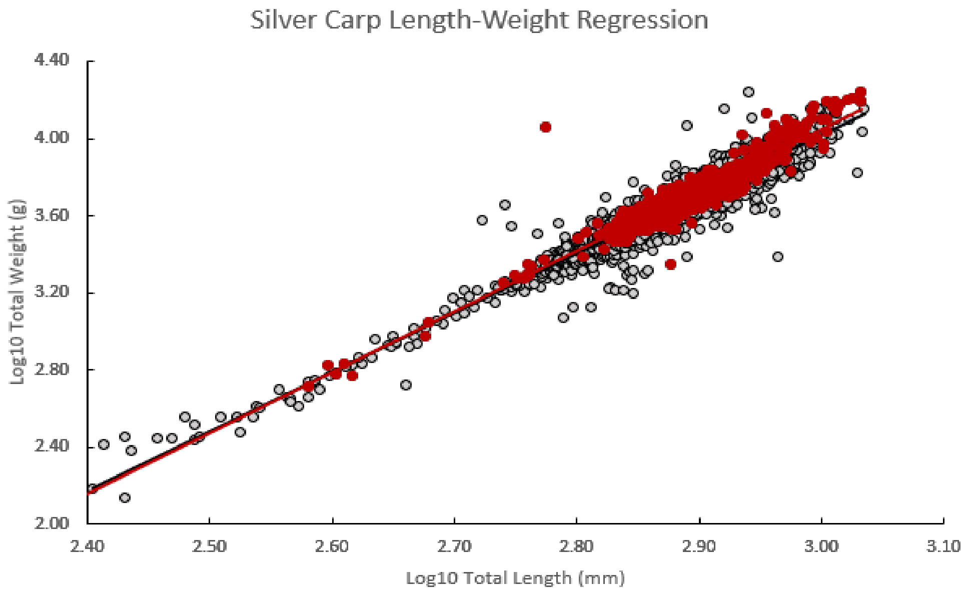


Figure 13. The log-transformed length-weight relationship of the Silver Carp collected from the middle Ohio River. Darker circles illustrate lengths & weights of Silver Carp sampled in 2015 – 2022. The length-weight data from 2023 and the resulting regression line is provided in red. The dark line represents the regression equation (see Table 1) generated from the entire Silver Carp length-weight dataset from 2015 through 2023.

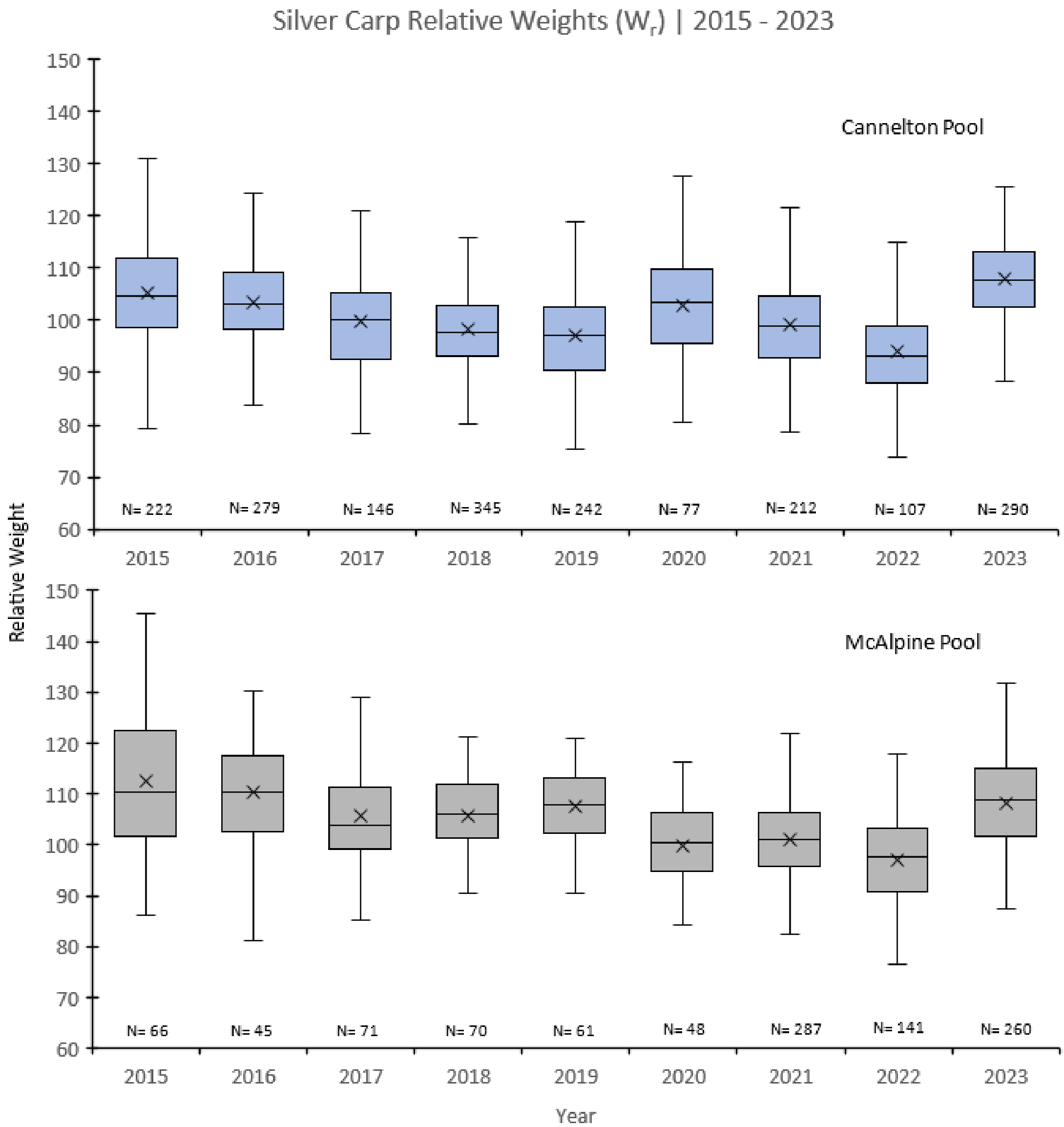


Figure 14. Relative weight (W_r) comparisons for Silver Carp captured from the Cannelton and McAlpine pools in August – October of 2015 through 2023. The standard weights needed for the W_r calculations were generated using the 50th percentile regression methods outlined in Lamer et al, 2015.

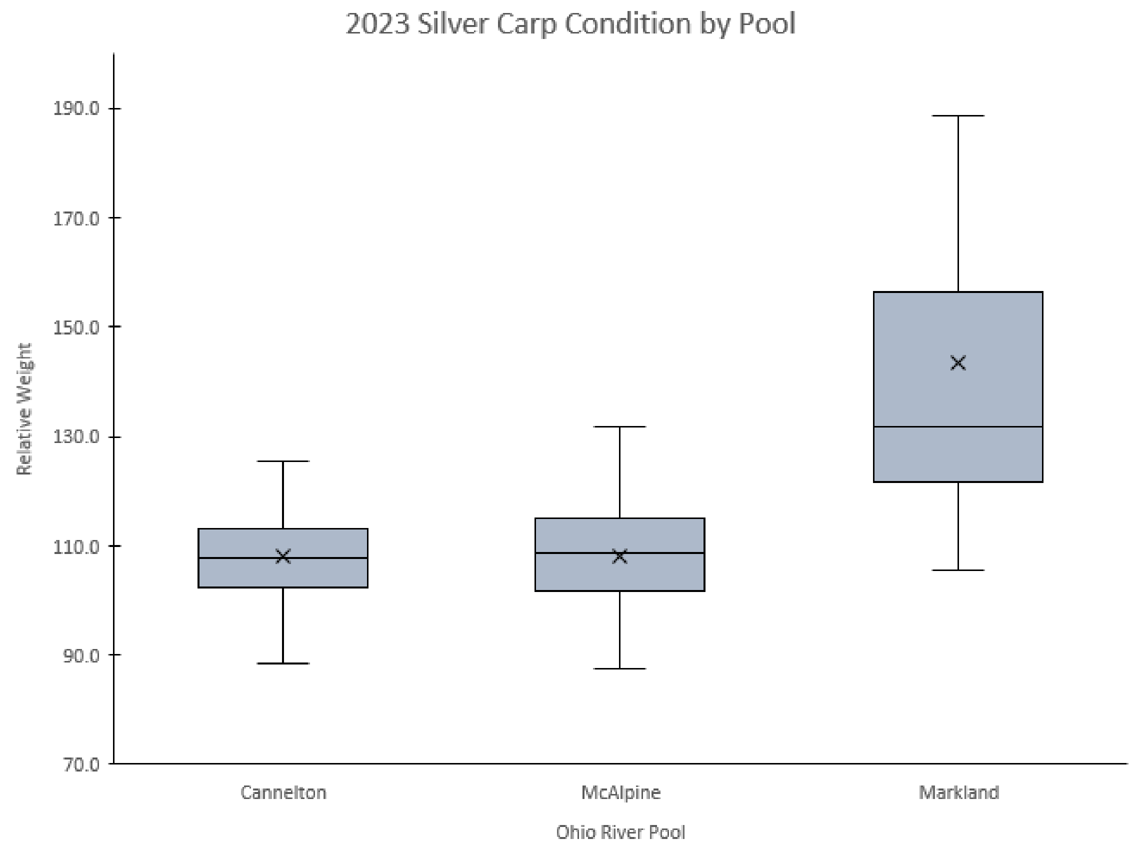


Figure 15. Relative weight (W_r) comparisons for Silver Carp collected in August – October 2023 from the Cannelton, McAlpine and Markland pools of the middle Ohio River. The standard weights needed for the W_r calculations were generated using the 50th percentile regression methods outlined in Lamer et al, 2015.

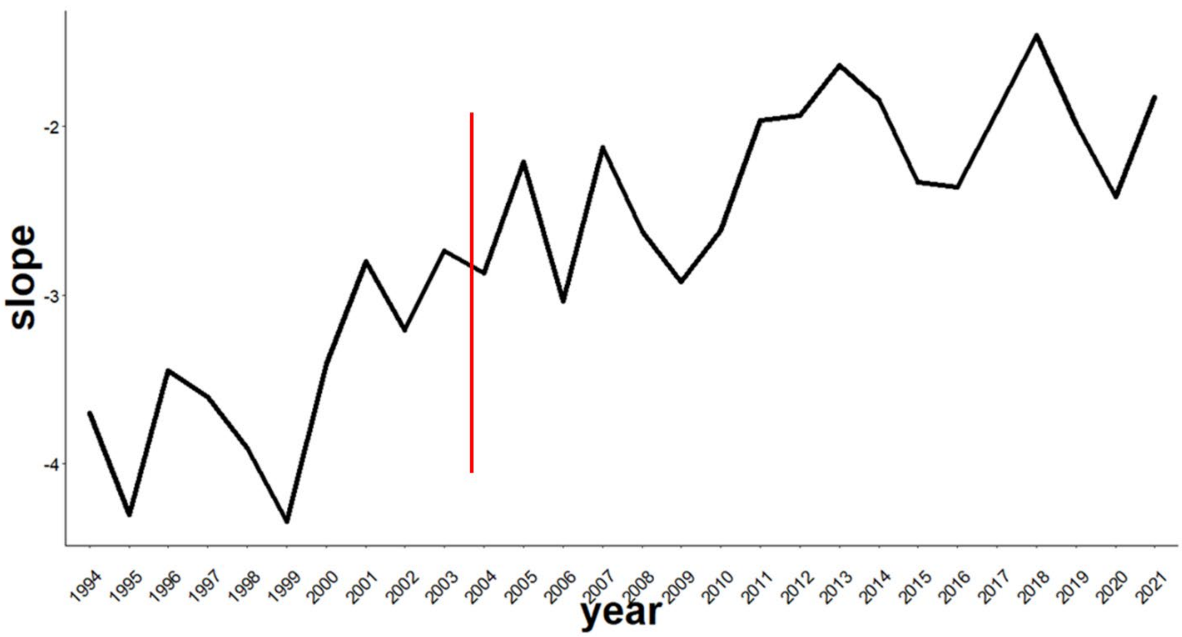


Figure 16. CSS slope for the Illinois River. CSS slope flattened (higher ecological efficiency) over the data collection period. The first large silver carp spawn in the Illinois River was documented in 2000. The red line indicates when the silver carp from the spawning event started recruiting to electrofishing starting in 2004 when silver carp CPUE jumped from 2.29fish/hr to 12.29 fish/hr.

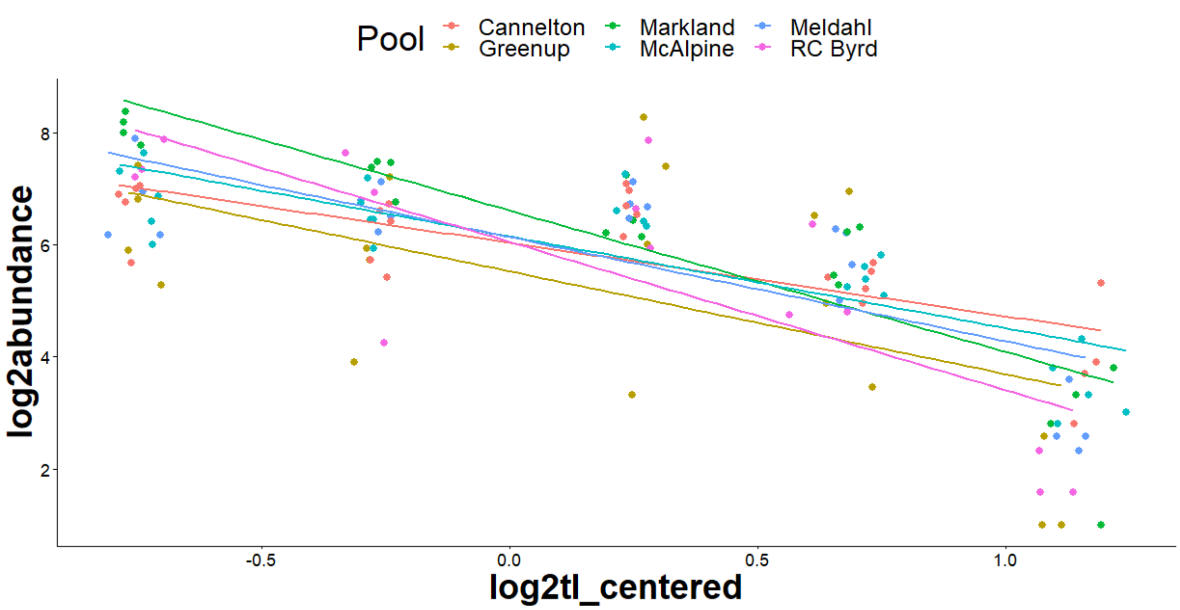


Figure 17. Regression of CSS graphed by pool for the Ohio River. The mean slopes from downstream to upstream are: Cannelton: -1.31, McAlpine: -1.64, Markland: -2.53, Meldahl: -1.86, Greenup: -1.84, RC Byrd: -176 No significant differences were determined.

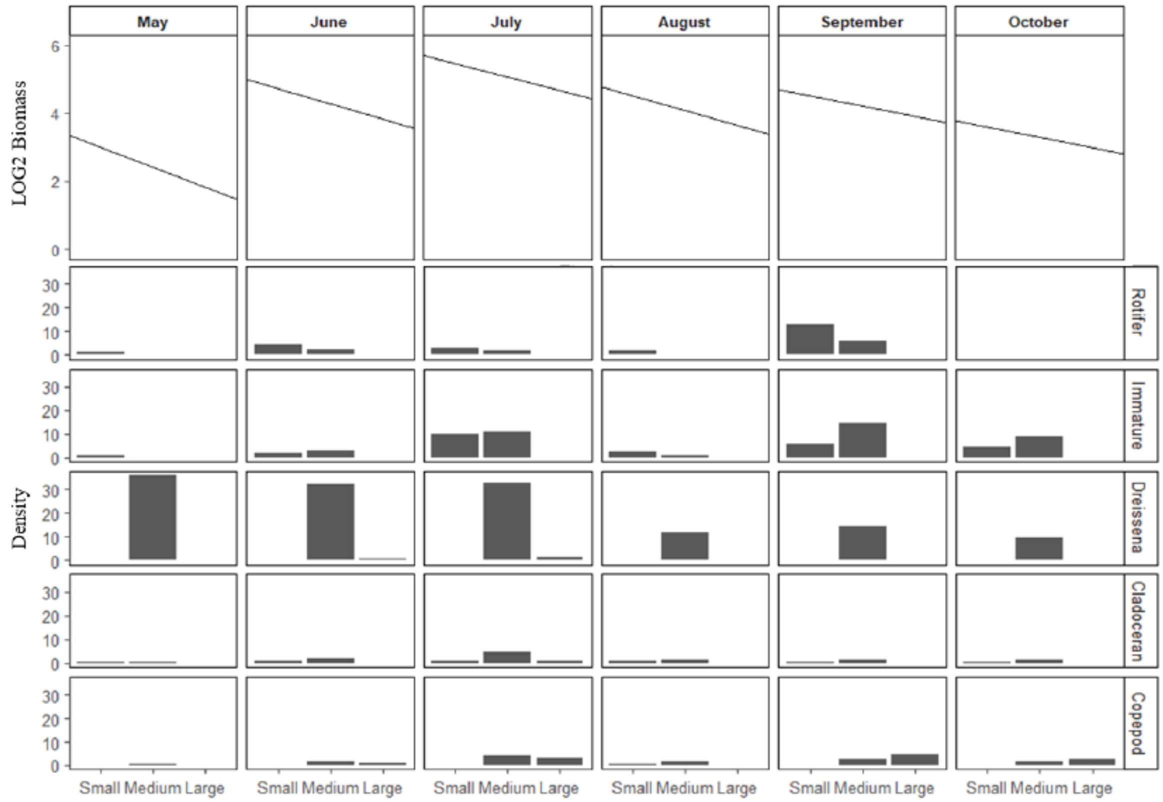


Figure 18. Average NBSS model for zooplankton collected monthly (May-October) from Markland Pool to R.C. Byrd Pool in the Ohio River, with breakdown of size class density for each aspect of the zooplankton community for each month.

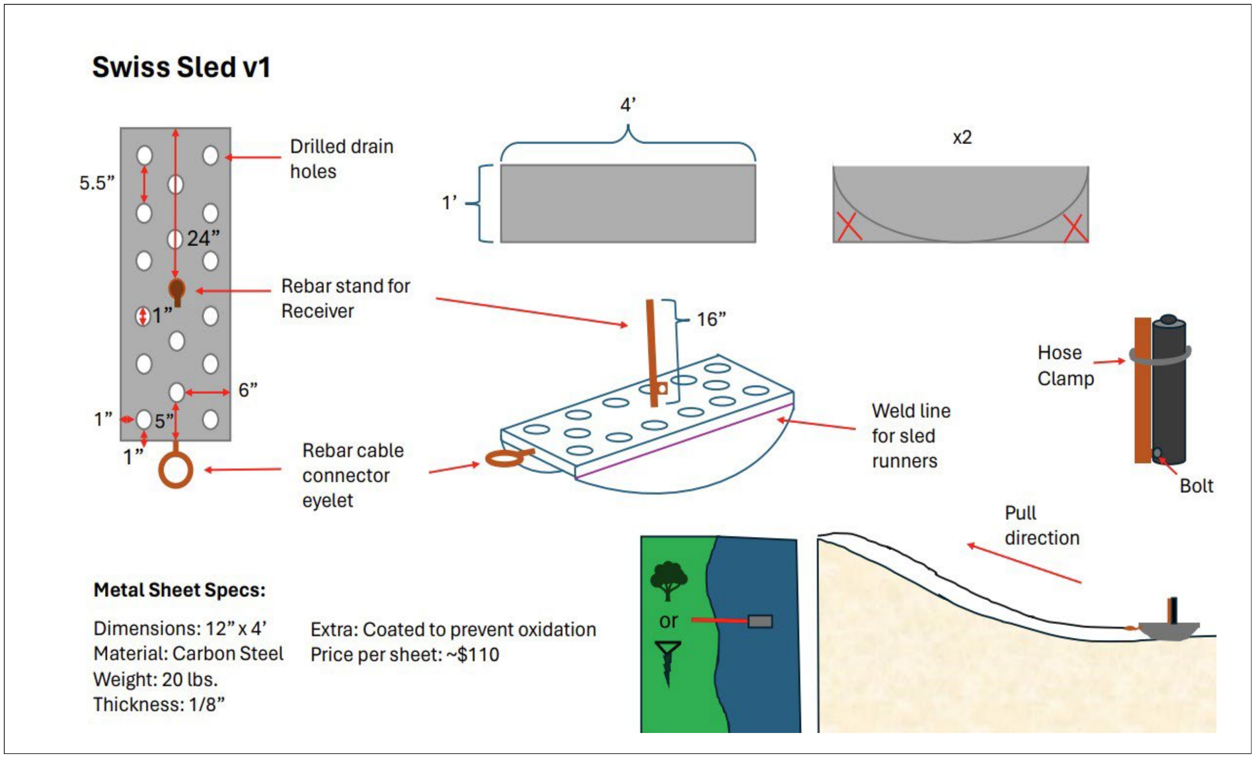


Figure 19. Figure depicting of the “Swiss Sled” design prototype for telemetry receiver deployment that will be developed for deployment on the Wabash and White Rivers to allow for receiver access in the event of low water and or siltation.

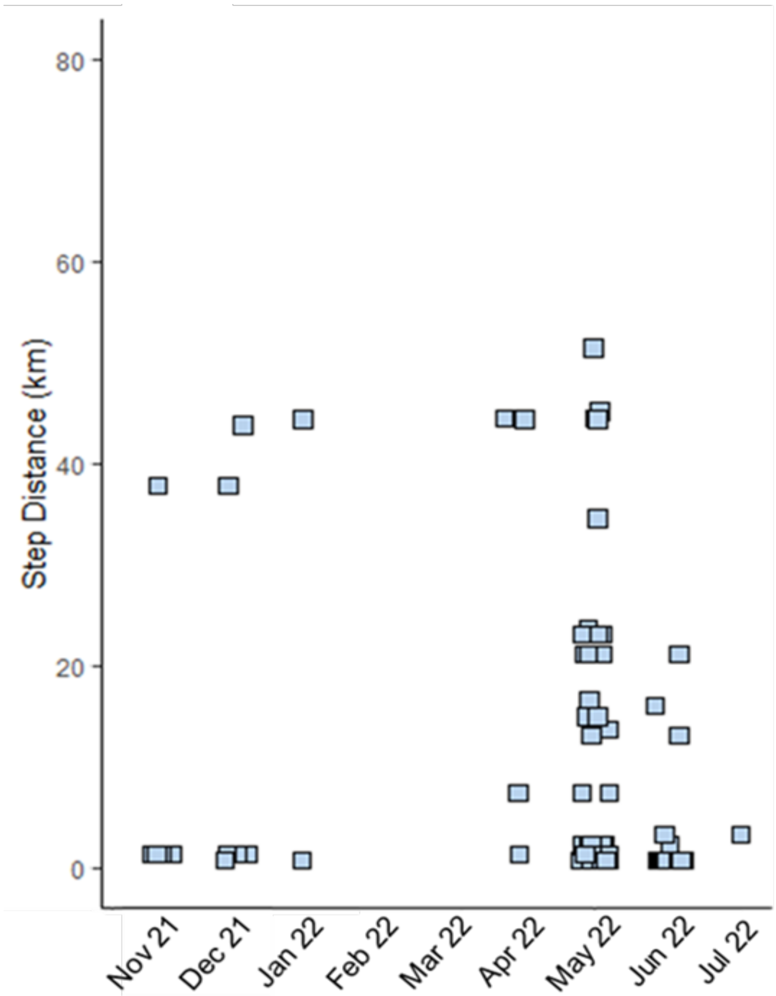


Figure 20. Available Silver Carp movement data collected in the Wabash River 2021-2023.

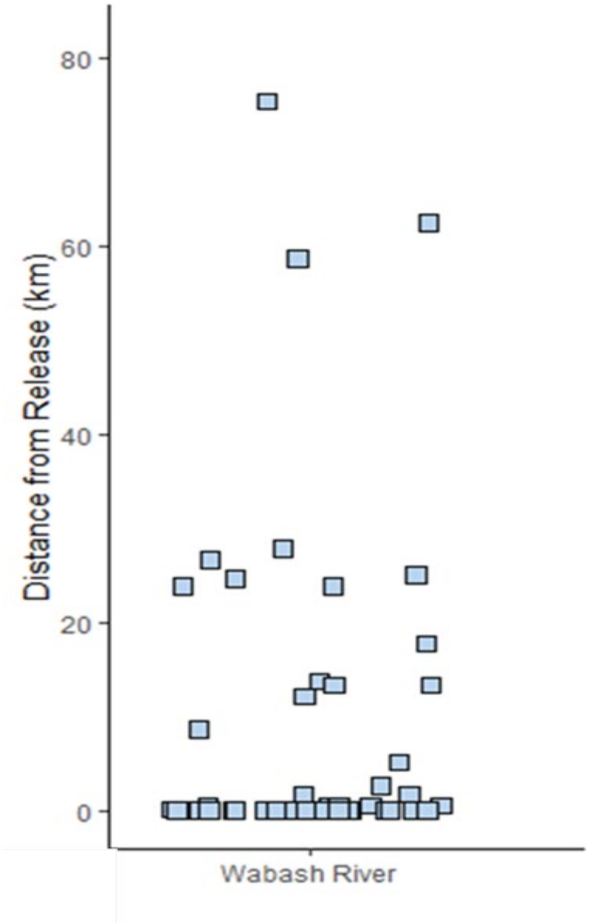


Figure 21. Distance telemetry tagged Silver Carp moved from the location of release post-tagging in the Wabash River.

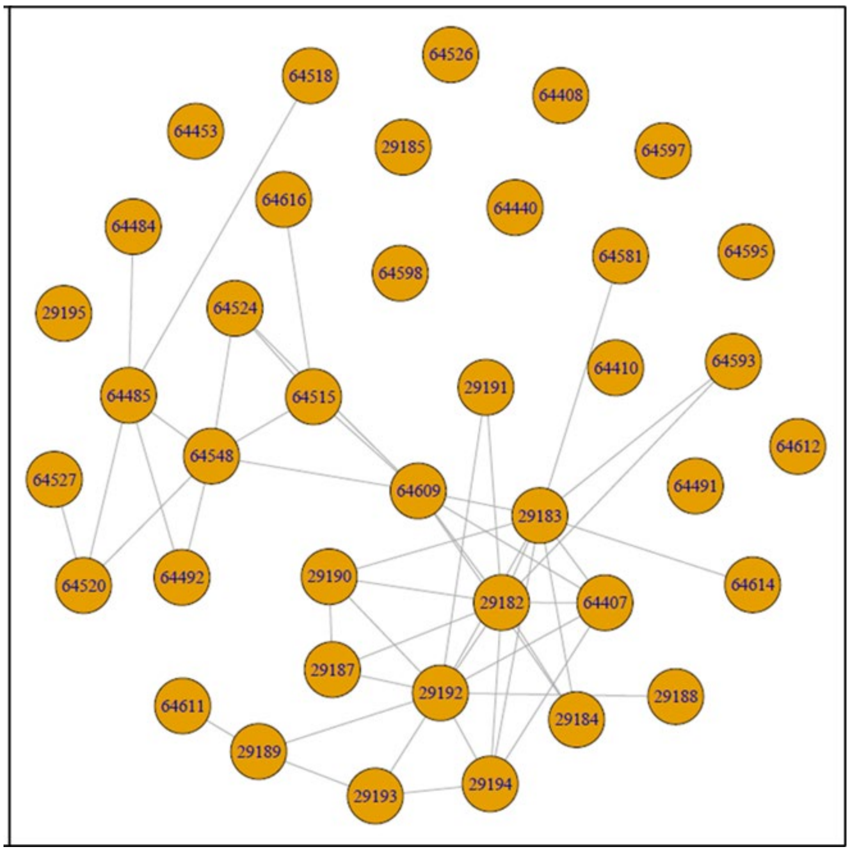


Figure 22. A network graph to allow for the visualization of connectivity among telemetry tagged Silver Carp within the Wabash River.

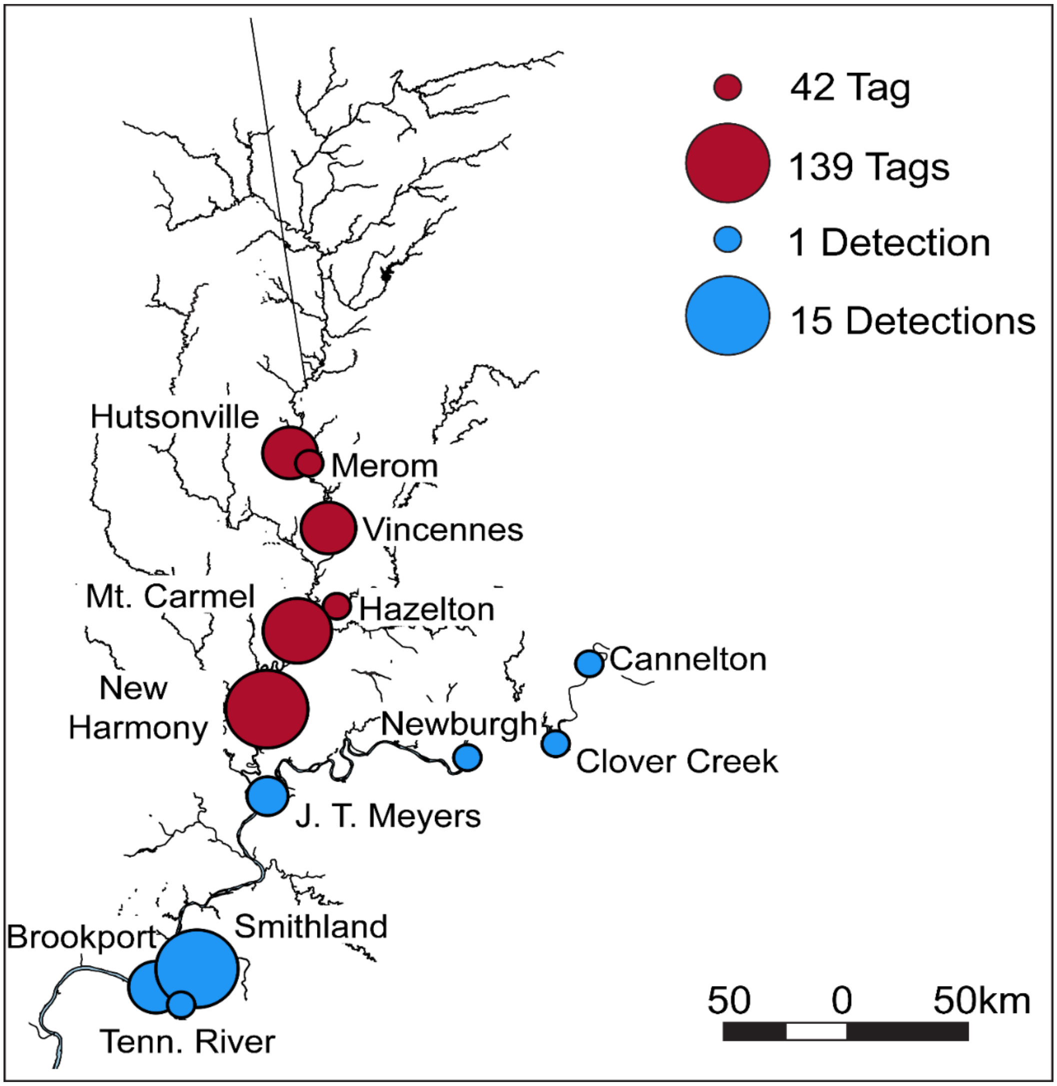


Figure 23. Map of tagging sites in the White and Wabash rivers (Red) and receiver locations (blue) in the Ohio River from 2021-2023. For locations with multiple receivers (e.g. lock and dam structures) detections from all receivers were pooled, and the number of unique fish are reported.

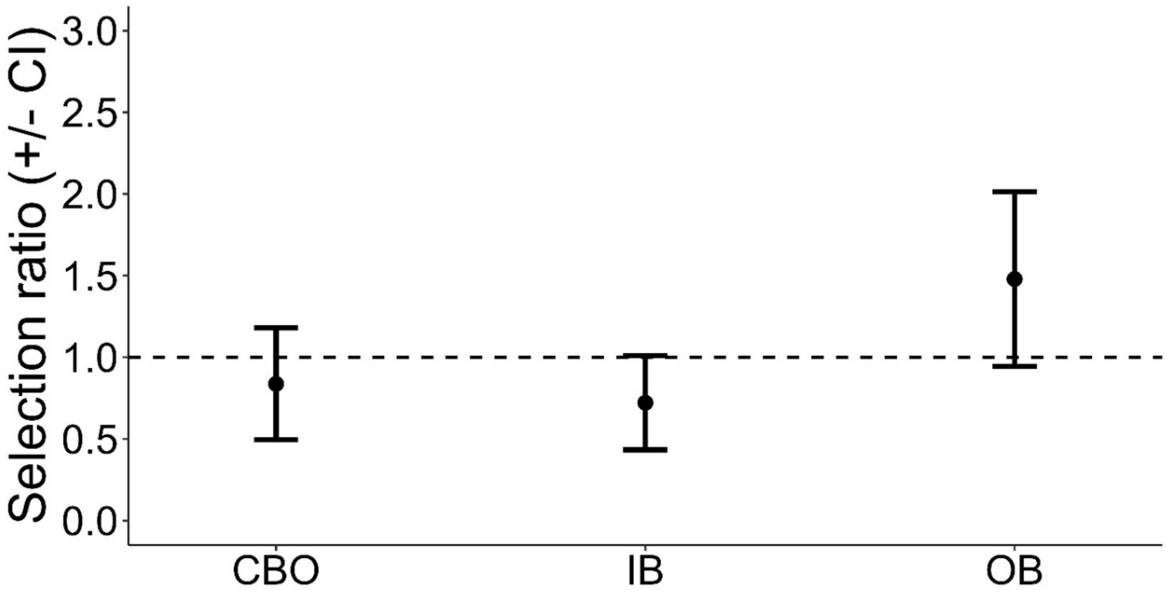


Figure 24. Selection ratios with 95% confidence intervals for macro-habitat use by telemetry tagged Silver Carp (channel border open, inside bend and outside bend) in the Wabash and White Rivers. Values above one indicate positive selection while values below one indicate avoidance. These ratios were calculated using 305 detections of 108 unique individuals from 2021 to 2023.

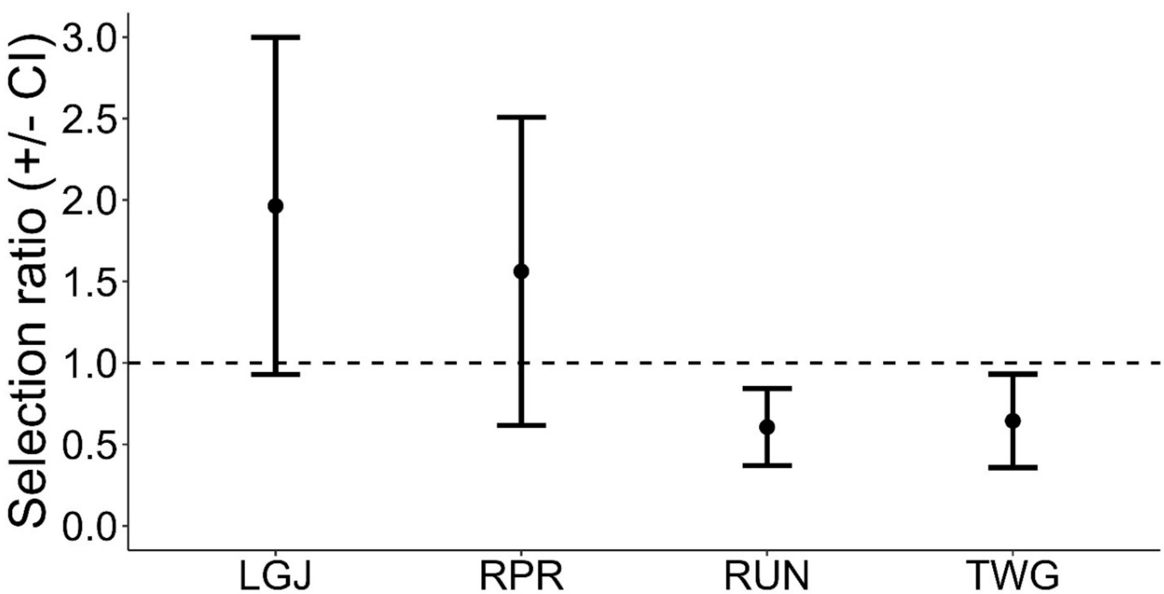


Figure 25. Selection ratios with 95% confidence intervals for micro-habitat (logjam, rip-rap, run and thalweg) use by telemetry tagged Silver Carp in the Wabash and White Rivers. Values above one indicate positive selection while values below one indicate avoidance. These ratios were calculated using 322 detections of 112 unique individuals from 2021 to 2023.

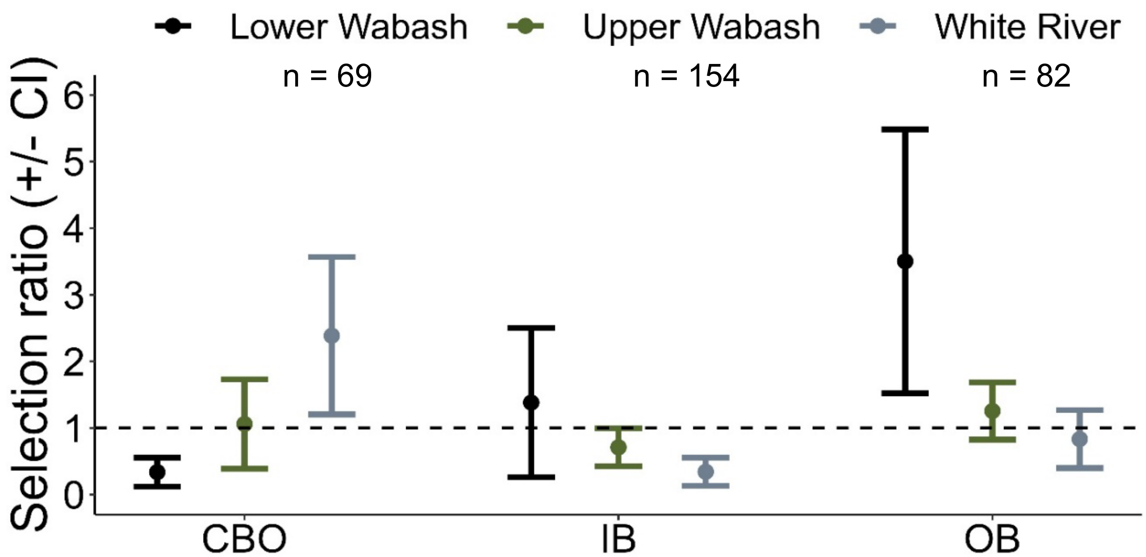


Figure 26. Selection ratios with 95% confidence intervals for macro-habitat use by telemtey tagged Silver Carp within the Lower Wabash (Mt. Carmel, IL to Ohio River confluence), Upper Wabash (Terre Haute, IN to Mt. Carmel, IL) and White River (Maysville, IN to confluence with Wabash). Values above one indicated positive selection while values below one indicate aviodance. These ratios were calculated using 305 detections of 108 unique individuals from 2021 to 2023.

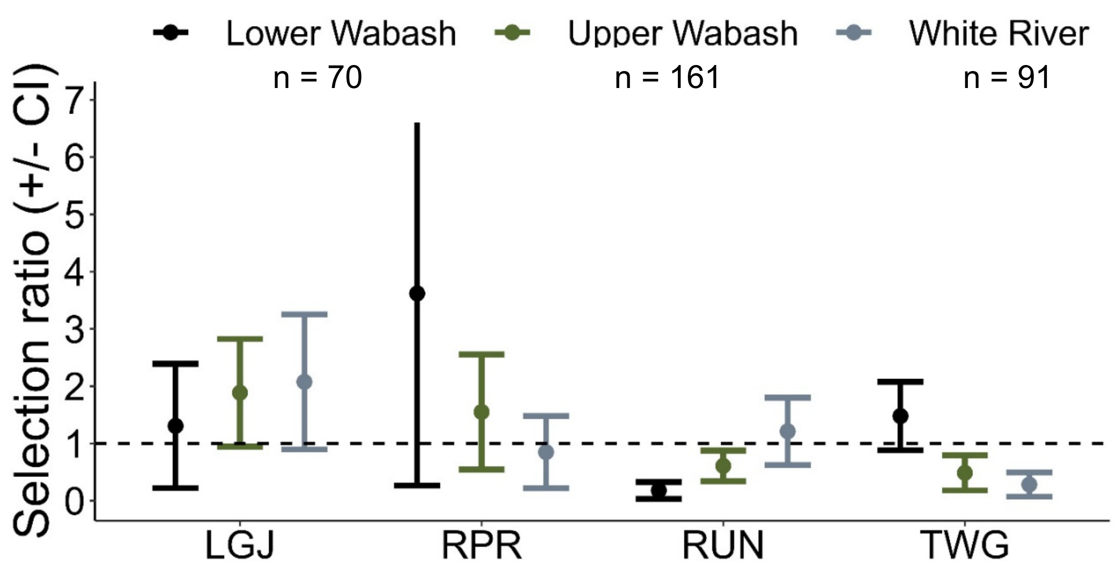


Figure 27. Selection ratios with 95% confidence intervals for micro-habitat use by telemtey tagged Silver Carp within the Lower Wabash (Mt. Carmel, IL to Ohio River confluence), Upper Wabash (Terre Haute, IN to Mt. Carmel, IL) and White River (Maysville, IN to confluence with Wabash). Values above one indicated positive selection while values below one indicate aviodance. These ratios were calculated using 322 detections of 112 unique individuals from 2021 to 2023.

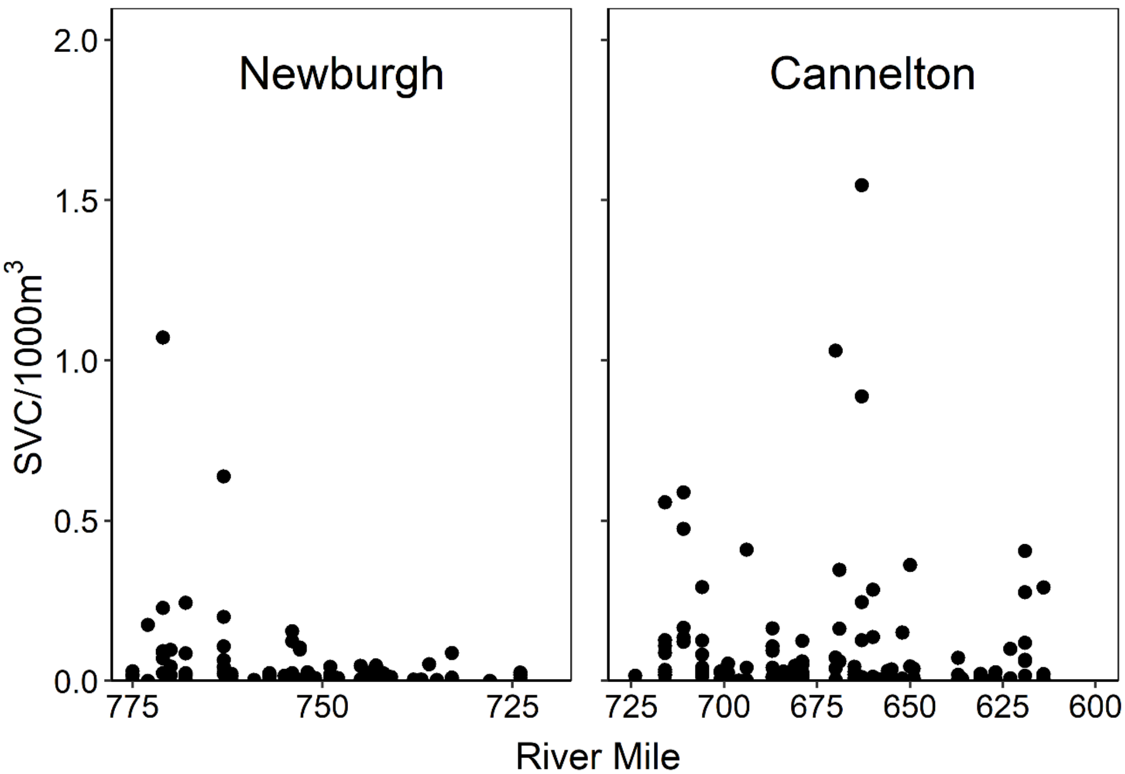


Figure 28. Hydroacoustically derived Silver Carp (SVC) density with river mile for main channel sites in Newburgh and Cannelton pools during October and November 2023. River miles decrease from downstream to upstream within the Ohio River (left to right on x-axis).

Abundance and distribution of early life stages of invasive carp in the Ohio River: 2023 Technical Report

Geographic Location: Ohio River Basin

Participating Agencies: Indiana Department of Natural Resources (INDNR) Kentucky Department of Fish and Wildlife Resources (KDFWR), West Virginia University (WVU), United States Fish and Wildlife Service (USFWS), West Virginia Division of Natural Resources (WVDNR), Eastern Illinois University (EIU), Southern Illinois University (SIU).

Statement of Need:

The negative effects of Silver (*Hypophthalmichthys molitrix*) and Bighead Carp (*Hypophthalmichthys nobilis*), also known as invasive carp, have been widely documented throughout their introduced range. These effects are numerous and varied in nature, some with direct implications to native biota (Irons et al. 2007, Sampson et al. 2009). Additionally, Black Carp (*Mylopharyngodon* piceus) are becoming more prevalent in the Ohio River and pose a threat to native mollusks (Poulton et al. 2019). Research investigating what factors lead to invasive carp range expansion is critical for the control of these invasive fishes, and mitigation of the deleterious effects they can cause.

Extensive research efforts have been directed toward invasive carp reproduction in terms of timing, location, and environmental conditions. Invasive carp exhibit a boom-and-bust pattern of reproduction, with strong year classes usually linked with large, sustained flooding and critical temperature ranges (DeGrandchamp et al. 2007). Although some understanding of their reproductive requirements exist, evidence suggests spawning of these species is possible over wider environmental ranges (Coulter et al. 2013), and in more habitats (i.e., tributaries) than previously thought (Kocovsky et al. 2012). Juvenile invasive carp are extremely mobile and may also elicit clumped distributions among static environments, requiring a variety of different gear types to effectively sample various habitats throughout the Ohio River (Collins et al. 2017; Molinaro 2020). In addition, factors promoting successful reproduction and recruitment remain uncertain. Identifying these factors is critical in suppressing the spread of these invasive fishes into novel environments.

Previous confirmed invasive carp spawning events have occurred in downstream tributaries (i.e., Wabash River) and as far upstream as McAlpine Locks and Dam (L&D), and physical signs of spawning (i.e., spawning patches) have been observed as far upstream as Markland Pool for Silver Carp and Meldahl Pool for Bighead Carp. Reproduction of *Hypophthalmichthys* spp. was detected by the presence of genetically confirmed Bighead and Silver Carp eggs as far upstream as RM 463 (near Cincinnati, OH) in 2021. To support the Ohio River Fish Management Team (ORFMT) Basin Framework objectives (ORFMT 2014), this project was initiated in 2016 in an effort to improve capabilities to detect early stages of invasion and spawning populations of invasive carp (Strategy 2.8) and also monitor upstream range expansion and changes in distribution and abundance (Strategy 2.3). Results of sampling prior to 2023 determined the extent of recruitment as far upstream as Markland Pool, with the majority of young-of-year (YOY) and juvenile detections below Newburgh L&D in J.T. Myers Pool (Jansen and Stump 2017, Roth 2018, Jansen 2021). Specifically, Hovey Lake in J.T. Myers Pool is a known recruitment area and therefore has been a focus for research over the past couple years to evaluate the timing and conditions which allow YOY invasive carp to enter the lake.

In addition to the Basin Framework, this project directly supports the National Plan (Conover et al. 2007) by assisting in the forecast and detection of invasive carp range expansions (Strategy 3.2.4), determining life history characteristics (Strategy 3.3.1), and assembling information about the distribution, biology, life history, and population dynamics of Bighead and Silver Carp (Strategy 3.6.2). Additionally, the results of this project will help managers make informed decisions during future planning efforts regarding resource allocation for invasive carp deterrent and control strategies.

2023 Project Objectives:

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

Project Highlights:

- Ohio River invasive carp reproduction appeared to be limited in 2023, as evident by lower than usual egg, larvae, and YOY captures throughout the field season.
- Eight sites were sampled above Markland Locks and Dam (RM 532) via ichthyoplankton tows from May to August, 2023. Suspicious eggs (n = 25) and larvae (n = 4) were sorted from samples and sent to Whitney Genetics Lab for verification of species. Most samples were genetically confirmed shiner species and Freshwater Drum; none were invasive carp.
- No *Hypophthalmichthys* eggs or larvae were collected in the Ohio River proper throughout 2023 sampling efforts.
- One *Hypophthalmichthys* larvae was collected in the Green River of J.T. Myers Pool. Invasive carp larvae were not captured in other sampled tributaries of the Ohio River.
- Targeted surface trawling effort expanded further upstream in 2023, but only one Silver Carp YOY was captured in J.T. Myers Pool.
- Targeted YOY Black Carp sampling occurred at 24 sites along the lower Ohio River. One YOY Black Carp was collected at one backwater site near Smithland, KY, and YOY invasive carp were collected at three sites along the lower Ohio River
- Ichthyoplankton sampling in the Wabash River and its tributaries visually identified 2,621 invasive carp larvae and 599 eggs. The Little Wabash River and adjacent mainstem Wabash River sites produced the greatest density of invasive carp larvae.
- YOY invasive carp appear to be entering Hovey Lake through the water control structure in Bayou Drain as soon as lake and river levels equalize, and corresponding flow through the structure becomes minimal.

Methods:

For analysis purposes and for the remainder of this report, the phrase “invasive carp” will be referring to Silver and Bighead carps (*Hypophthalmichthys* spp.) only. In addition, both “YOY” and “immature” are collectively referring to “juvenile” invasive carp; “YOY” will be defined as fish less than 150 mm, and “immature” will define fish between 150 to 400 mm (likely 1 to 2 years old) which have undeveloped gonads and are not capable of spawning. Adult invasive carp are defined as fish greater than 400 mm with mature, identifiable gonads. Additionally, the term “suspect *Hypophthalmichthys*” is referring to an egg, advanced egg, or larvae with morphometric characteristics aligning with bigheaded carps, while the terms "suspicious egg/larvae" refers to specimens that do not have 100% of the morphometric characteristics of bigheaded carps but still warrant genetic confirmation.

Ichthyoplankton tows:
To evaluate the extent of invasive carp spawning activity in the Ohio River above Markland L&D, West Virginia University and WVDNR conducted ichthyoplankton tows at sampling sites within the R.C. Byrd (N = 3), Greenup (N = 1) Meldahl (N = 2), and Markland (N = 2) pools. Each sampling site was visited approximately three times from May 22 to August 2, 2023. During each visit, four tows were conducted: three within the Ohio River proper, and one within the tributary or at the intake structure if the site was a previous EA Engineering larval sampling site. In addition, WVU conducted three ichthyoplankton tows at six stratified random main channel sites within both Markland and Meldahl pools, sampling each site three times throughout the same timeframe.

To further identify specific tributaries and areas of the Ohio River in which invasive carp spawning occurs, ichthyoplankton tows were conducted at tributaries within J.T. Myers (N=1), Newburgh (N = 2), Cannelton (N = 2), and McAlpine (N = 2) pools twice each from June 20 to July 6, 2023, during ideal spawning conditions (water temperatures between 64 to 80°F with moderate to high water 2-3 days after peak flow event). Additionally, tows were conducted on two occasions within the drain of Hovey Lake to determine presence and size of post-gas-bladder-inflation larvae. Lastly, the mainstem Ohio River was sampled in two to three locations within each the J.T. Myers, Newburgh, Cannelton, and McAlpine pools from June 20 to July 6, 2023. Three tows were conducted at each sampling site.

For all tows, a conical ichthyoplankton net (0.5 m, 500 µm mesh) was deployed from the bow of the boat. The boat was motored in reverse, pulling the ichthyoplankton net upstream for three minutes. The water volume sampled was recorded using a General Oceanics Flowmeter fitted to the ichthyoplankton net; depth (m) and water temperature (°C) were recorded using a boat-mounted depth sounder. All contents in the ichthyoplankton net were rinsed into a 500 µm sieve and preserved using 95% non-denatured ethanol (at an estimated ratio of nine parts ethanol to one-part sample volume) for physical identification in the lab. Suspect *Hypophthalmichthys* eggs and larvae were morphometrically identified (process outlined below) and a subsample were sent to Whitney Genetics Laboratory for genetic confirmation. For specific details on genetic identification results and methods employed by the Whitney Genetics Laboratory, refer to Appendix A.

Larval fish were initially sorted into non-invasive carp and potential invasive carp (suspicious) species using morphometric parameters provided by Auer (1982). Furthermore, early developmental characteristics outlined by Yi et al. (1998) and Chapman (2006) were utilized to physically identify suspect *Hypophthalmichthys* larvae, advanced eggs, and eggs from each sample (Figure 1). Invasive carp larvae were identified by the presence of an eye spot, and suspect *Hypophthalmichthys* were differentiated from Grass Carp (*Ctenopharyngodon idella*) and Black Carp (*Mylopharyngodon piceus*) using myomere counts. *Hypophthalmichthys* larvae have 38 to 39 myomeres, whereas Grass Carp larvae range from 43 to 45 myomeres and Black Carp have 40 and 41 myomeres. Suspect *Hypophthalmichthys* eggs were identified based on general size and presence of a large perivitelline membrane (5 to 6 mm in diameter). Suspect *Hypophthalmichthys* 'advanced eggs' were defined as the beginning of a yolk-sack larvae still contained within the perivitelline membrane. In most cases, suspicious eggs and larvae may not have every morphometric characteristic of invasive carp, however, due to their collection locations, several may have been vouchered and sent to Whitney Genetics Lab for genetic confirmation of species.

Surface trawl:
Targeted YOY invasive carp sampling using surface trawls took place in tributaries and embayments of the Ohio River from J.T. Myers Pool to Racine Pool. Due to YOY Silver and Bighead Carp being found in Markland Pool in 2022, crews put significantly more effort into sampling upstream tributaries in 2023.

Because several new crews began assisting with targeted surface trawling efforts, a collaborative training/demonstration event took place in Markland Pool on July 27th and 28th, 2023, to get familiar with trawling techniques and standardize gears as much as possible.

The surface trawl measured 3.7 m wide, 0.6 m tall, and 5.5 m deep with 31.8 mm bar (number 12) netting. An additional layer of 4.8 mm mesh (35-pound delta) bag was attached externally to improve capture of small fishes. Additional foam floats were added to the top line of the trawl to provide extra buoyancy. Otter boards were 30.5 cm tall, 61.0 cm long, and each had a 12.7 cm diameter, 27.9 cm long "buoy style" PVC float attached to the top of the board allowing them to float. The trawl was deployed off the bow of the boat and attached with 24.4 m ropes. The boat was motored at 1.6 to 3.2 km per hour in reverse for five minutes before retrieving the net. In some locations it was not possible to complete five minutes of trawling, in which case sample time was documented. At the biologist's discretion, additional trawls were conducted at sites where either coverage was limited, or juvenile invasive carp were suspected. All invasive carp were identified to genus, measured to total length, and weighed.

Black Carp YOY Sampling:
KDFWR conducted targeted sampling for YOY Black Carp in the lower Ohio River from the confluence with the Mississippi River to above Smithland lock and dam. Sampling locations were chosen based on the hydrologic similarity to the location where YOY Black Carp were collected previously in Kentucky. Sampling effort did not exceed 30 days. Areas were sampled with beach seine and backpack electrofishing as accessible. If juveniles were collected; length and weight were recorded, and the specimens were preserved for additional analysis as needed. Most sites were sampled using a backpack electrofisher (Smith-Root LR-24) for variable durations depending on amount of habitat available to sample. Seining with 20' x 5' and 15' x 5' (1/8" mesh) seines was done at six sites, but proved to be difficult because of the deep, soft mud substrate.

Wabash River ichthyoplankton:
Eastern Illinois University (EIU) sampled ichthyoplankton in the Wabash River mainstem and four of its tributaries to monitor invasive carp (*Hypophthalmichthys* spp.) reproduction. EIU used a bow-mounted ichthyoplankton push net (Wildco), 0.5 meters in diameter, 2.5 meters in length, and 500 µm mesh. The tributaries sampled include the Vermilion, White, Embarras, Little Wabash rivers. At each tributary nine push net samples were collected: three within the tributary, three in the Wabash River above the tributary, and three in the Wabash River below the tributary. Each triplicate of samples consisted of a left bank, middle, and right bank sample to cover multiple areas across the channel. Each push net sample lasted five minutes and the volume of water filtered was estimated by a General Oceanics flow meter to achieve a target sample volume of 50 cubic meters. The contents of the net were emptied into a sample container and preserved with 95% non-denatured ethanol for identification in the lab. Invasive carp eggs and larvae were identified using meristic and morphometric features. A subsample of invasive carp eggs and larvae are in the process of genetic confirmation. A handheld YSI multiparameter meter was used to record temperature (°C). River discharge data (m3/s) from gauges nearest to sampling locations were obtained from United States Geological Survey.

Hovey Lake recruitment:
Hovey Lake is a known nursery area within the lower Ohio River, with YOY finding their way into the lake nearly every year. Excluding flood events, all water passing into and out of Hovey Lake must funnel through three culvert pipes at a control structure across Bayou Drain. Blocker boards can be installed within the culvert pipes during certain times of year to control the amount of water entering or leaving the lake. This control structure is operated by the Hovey Lake Fish and Wildlife property staff to manage the lake level primarily for waterfowl hunting opportunities. Multiple gears were used within Bayou Drain on both the river side and lake side of the control structure to evaluate the timing of YOY passage from the Ohio River into Hovey Lake.

Sampling for larval invasive carp was conducted using a conical ichthyoplankton net (0.5m, 500 µm mesh) deployed from the front of the boat. The boat was motored in reverse, pulling the ichthyoplankton net for three minutes (approximately 180 meters). This was repeated three times per side of the control structure. The water volume sampled was recorded using a General Oceanics Flowmeter fitted to the ichthyoplankton net; water temperature (°C) was recorded using a boat-mounted depth sounder. All contents in the ichthyoplankton net were rinsed into a 500 µm sieve and preserved using 95% non-denatured ethanol (at an estimated ratio of nine parts ethanol to one-part sample volume) for physical identification in the lab. Suspect and suspicious *Hypophthalmichthys* larvae were sorted from all other native fish larvae and were counted and measured. A subset of some of the earliest suspect *Hypophthalmichthys* were sent to Whitney Genetics Lab for genetic confirmation of species.

A modified, rigid-frame surface trawl (herein called a beam trawl) was developed specifically for sampling in Bayou Drain with a small jon boat. Due to accessibility issues, a small jon boat was the only option for sampling the lake side of Bayou Drain. The standard 3.7 m wide surface trawl with otter boards that is used for other Ohio River YOY sampling was too large and produced too much drag to be able to effectively pull it with a small jon boat. The beam trawl consisted of a wooden frame measuring1.83 m wide and 0.61 m tall, with a 3.66 m long bag of 4.8 mm mesh (35-pound delta). Additional weight was added to the bottom of the frame to properly orient the trawl such that it floated upright in the water and just below the surface when towed. The trawl was deployed off the bow of the boat and attached with 20 m tow ropes. The boat was motored at 1.6 to 2.6 km per hour in reverse for the duration of the trawl before retrieving the net. A total of 14 minutes of trawling covering approximately 730 m was conducted on each side of the control structure each day. Individual tows lasted 3.5 to 5 minutes depending on obstacles in the water. After each tow, fish were sorted and YOY invasive carp were counted and measured.

Quadrafoil light traps were also deployed at Bayou Drain to passively sample for *Hypophthalmichthys* overnight. The light traps measured 30 cm diameter, 25 cm tall, with four entry slits of 5 mm (https://www.forestry-suppliers.com/p/78000/88740/watermark-quadrafoil-larval-fish-light-trap). A green Cyalume chemical lightstick (https://getcyalume.com/product/6-inch-green-snaplight-9-08076/) was placed in each trap and then traps were deployed to float below the water surface. Three to six traps were deployed on each side of the control structure – this number fluctuated depending on the amount of macroinvertebrate bycatch collected on previous sampling trips. Upon retrieval, all specimens concentrate in the bottom collection basin, water is drained through 250-micron mesh, and contents of the trap are rinsed into jars and preserved in 95% non-denatured ethanol.

In April, USGS installed a stream gage within Bayou Drain that monitors stream stage and velocity to compute streamflow in Bayou Drain. The gage is still being calibrated, but will be a valuable tool for assessing the exact flow conditions that allow invasive carp passage into Hovey Lake.

Microchemistry:
Water samples were taken from the Ohio River in J.T. Myers (N = 2), Newburgh (N = 3), Cannelton (N = 3), McAlpine (N = 3), and Markland pools (N = 3) during July and August, 2023. Additionally, three samples were collected from the Great Miami River (Markland Pool) throughout the same time period. Water samples were collected using a syringe filtration (0.45 µm pore size) technique and analyzed for Sr, Ba, and Ca concentrations.

Results:

Ichthyoplankton tows:
A combined total of 133 ichthyoplankton tows were conducted within the R.C. Byrd (N = 41), Greenup (N = 8), Meldahl (N = 42), and Markland (N = 42) pools (Table 1; Figure 2). Within those pools, 4 suspicious larvae were identified (one from Markland Pool, two from Meldahl, and 1 from R.C. Byrd) and sent to WGL for genetic confirmation. Two suspicious larvae were genetically confirmed shiner species, and two were Freshwater Drum. Likewise, a total of 25 suspicious eggs were sorted from tow samples and sent off to Whitney Genetics Lab for species confirmation. Twenty two of the 25 samples returned genetic results, none of which were invasive carp. Suspicious eggs were genetically confirmed as Freshwater Drum (n = 13), Shiner species (n = 4), Herring species (n = 4), and Silver Chub (n = 1). Most of the suspicious eggs from the upper pools varied in size and were typically much smaller than *Hypophthalmichthys* eggs; many lacked a large perivitelline membrane.

A total of 54 ichthyoplankton tows were conducted within the mainstem Ohio River in the J.T. Myers (N = 12), Newburgh (N = 12), Cannelton (N = 18), and McAlpine (N = 12) pools (Table 2). Zero *Hypophthalmichthys* eggs or larvae were collected in the Ohio River proper. Four suspicious larvae were collected in Newburgh Pool at RM 772.8 near Yankeetown, IN; These were genetically confirmed shiner species. In Cannelton Pool, ten suspicious larvae and two eggs were identified in samples collected from RM 662.9 near Leavenworth, IN; seven larvae and two eggs were submitted to Whitney Genetics Lab. Of these, the two eggs were Grass Carp, while the larvae were genetically confirmed as two Grass Carp, two Freshwater Drum, one herring species, and one chub species. No suspect eggs or larvae were collected from the mainstem McAlpine Pool samples.

An additional 48 ichthyoplankton tows were conducted in select tributaries of the lower Ohio River (Table 2; Figure 2). Three *Hypophthalmichthys* larvae were collected in tributaries of J.T. Myers Pool, one in Green River and two in Bayou Drain of Hovey Lake. Three additional Newburgh Pool tributary larvae were send for genetic confirmation and were determined to be Freshwater Drum and shiner species. No suspect invasive carp eggs or larvae were found in Newburgh or Cannelton Pool tributaries. Two suspicious larvae were pulled from Harrods Creek in McAlpine Pool, but were both genetically identified as shiner species.

Surface trawl:
Among project partners, surface trawling effort consisted of 162 tows totaling 13.2 hours of sampling. The majority of effort was expended in tributaries of Markland (4.7 hrs), Cannelton (3.2 hrs), and Meldahl (2.4 hrs) pools, followed by J.T. Myers (1.4 hrs), R.C. Byrd (1.0 hrs), Greenup (0.9 hrs), and Racine (0.3 hrs) pools (Figure 3). Only one YOY Silver Carp measuring 46 mm was captured in Hovey Lake's Bayou Drain in J.T. Myers Pool (not including data summarized in the *Hovey Lake recruitment* subsection). Despite extensive sampling efforts, zero YOY invasive carp were captured via surface trawls in Ohio River tributaries upstream of J.T. Myers Pool in 2023.

Black Carp YOY Sampling:
KDFWR sampled for YOY invasive carp at 24 sites along the lower Ohio River, 9 sites along the Mississippi River, 11 sites along the lower Tennessee River and 11 sites along the lower Cumberland River (Table 3; Figure 4). Five sites sampled had YOY invasive carp and one of those sites had one YOY invasive Black Carp. All specimens were fixed in formalin and identification was verified in the laboratory. The YOY Grass Carp and Black Carp were identified by removing pharyngeal teeth and comparing their morphology (Figure 5).

Wabash River ichthyoplankton:
EIU collected a total of 111 ichthyoplankton samples from May 25th to August 9th, 2023, across five sampling dates. Samples were taken from each tributary and corresponding main-stem Wabash River sites up to five times throughout the season, depending on access. An additional 15 samples were collected in the Embarras River near Charleston, IL, but results are not reported here as no visually identified invasive carp larvae or eggs were captured at these sites. The Vermilion River was inaccessible for the duration of the season and samples from the adjacent main stem Wabash River were taken on one occasion (June 6th). After the August 9th sampling event, water levels remained too low for the rest of the season to sample any sites.

In total, 2,621 larvae and 599 eggs were visually identified as invasive carp (Table 4). Additionally, 1,212 eggs had similar morphometry to invasive carp eggs but were smaller in diameter than average and were designated as 'potential eggs' (Table 4). A sub-sample of all eggs and larvae collected throughout the season are awaiting genetic confirmation.

Larvae were found in all the tributaries except for the Embarrass River tributary site. The Little Wabash River and adjacent mainstem Wabash River sites produced the greatest density of invasive carp larvae throughout the sampling season (Table 4). Peaks in larval density generally coincided with rapid rises in discharge in the tributary site and/or adjacent mainstem Wabash River sites (Figure 6). For example, on July 5th, peaks in larval abundance were observed in the mainstem Wabash River sampling location following a rapid river rise at New Harmony days prior (Figure 6). This contrasted with results from August 9th where only the Little Wabash River had a significant rise, resulting in relatively high density of larvae within the tributary, and the mainstem site below the tributary. Similar patterns were observed in the White River sites, just with relatively lower density levels to the Little Wabash sites (Figure 7). However, larvae were collected on June 7th from the Wabash River above the White River confluence that did not correspond to river rises in either the tributary, or mainstem Wabash River.

All sites except for the Embarras River tributary had visually identified *Hypophthalmichthys* eggs found in the samples. The eggs that were found in the Wabash River near the Embarras River tributary site are awaiting genetic confirmation as they were not clearly identifiable. The mainstem Wabash River near the Vermilion River had the highest density of eggs for a sampling event, followed by the White River and adjacent mainstem sites. The mainstem Wabash River sites near the Embarrass River also produced significant numbers of eggs, whereas the within-tributary sites produced very few. Final egg totals are subject to change as we complete genetic confirmation, thus results presented here represent a conservative estimate of invasive carp egg production for 2023.

Hovey Lake recruitment:
Bayou Drain of Hovey Lake was sampled on both sides of the water control structure from May 15th to June 23rd, 2023, via ichthyoplankton netting, surface trawling, and passive light traps. Ichthyoplankton netting effort consisted of 138 tows; 57 on the lake side of the control structure, 65 on the river side, and an additional 16 collections at the outflow of the control structure when water velocity was high enough to suspend the net. A total of 46 *Hypophthalmichthys* larvae were collected via ichthyoplankton nets. An additional 28 suspicious larvae were sent to WGL to genetically confirm species, however, none were determined to be invasive carp. The suspicious larvae were confirmed to be Orangespotted Sunfish, Common Carp, White Crappie, Freshwater Drum, Gizzard Shad, and shiner and buffalo species. Invasive carp larvae were first detected in ichthyoplankton nets on the river side of the control structure on May 25th, and on June 1st on the lake side of the structure. Ichthyoplankton nets captured invasive carp larvae from May 25th to June 8th, when densities ranged from 0.097 to 0.574 individuals/10 m^3, peaking on May 26th.

A total of 106 light traps were deployed over 11 sampling days. Traps were set 30 minutes before sundown and soaked overnight for approximately 14 hours. Light traps first collected *Hypophthalmichthys* larvae on May 19th on the river side of the control structure, yet didn't collect them on the lake side until June 13th. From May 19th to June 6th, the river side of the control structure had the highest catch rates, ranging from 1.67 to 15.83 invasive carp/trap night. From June 13th to June 23, the lake side of the control structure had higher light trap catches than the river side, which ranged from 0.33 to 3.25 invasive carp/trap night. Invasive carp ranging from 9 to 42 mm were captured via light traps (Figure 7).
Beam trawls efforts consisted of 141 tows, including 66 on the river side of the control structure and 72 tows on the lake side. Beam trawls first detected invasive carp on the river side of the control structure on May 31st, and later collected them on the lake side of the structure on June 5th. YOY Silver Carp catch rates were typically higher on the river side of the control structure, peaking at 9.7 fish/minute on June 8th. Silver carp captured via beam trawl ranged in size from 13 to 46 mm (Figure 8).

Collectively, gears captured more YOY invasive carp on the river side of the control structure (Figure 9). Fish showing up on the lake side of the control structure appeared to coincide with water levels equalizing, as highlighted by provisional data collected at the USGS stream gage station installed in Bayou Drain (Figure 10).

Microchemistry:
Mainstem Ohio River water samples were processed to further refine Sr:Ca signatures within the basin. Any sample with Sr:Ca value of less than 1334 µmol/mol can be definitively classified as tributary origin, while any samples with a value greater than 1438 µmol/mol can be classified as definitive Ohio River origin. Since 2021, 710 Silver Carp otoliths have been analyzed, the majority of which were collected in Cannelton and McAlpine pools. Tributary origin comprises 86.4% (n = 614) of Silver Carp otoliths sampled, while 11.0% (n = 78) originated in the Ohio River proper. To date, six Silver Carp have exhibited extremely high Sr:Ca core signatures, suggesting they may have originated much further upstream in the Ohio River Basin than the currently known recruitment front.

Discussion:

Results of the eighth year of the Abundance and Distribution of Invasive Carp Early Life Stages in the Ohio River project offer the most up to date information on the extent of invasive carp spawning and recruitment in the Ohio River. Collective efforts of ichthyoplankton tows, targeted surface trawls, and electrofishing directly addressed Basin Framework Strategy 2.8 by improving capabilities to detect early stages of invasion and spawning populations of invasive carp. This project continues to provide data to describe our current understanding of the distribution of invasive carp recruitment for the Water Resources Reform and Development Act (WRRDA) reporting. Moreover, knowledge acquired from this project directly informs planning efforts for future invasive carp deterrent, control, and other management strategies.

Excluding the Wabash River, invasive carp reproduction appeared to be very limited in 2023. The only significant river rise on the Ohio River throughout spring and summer of 2023 occurred in early May when water temperatures were below 65 F. There was no other high water event throughout the remainder of the summer, which likely limited spawning. During the early May event, water temperature was around 62 F during the crest, which is near the minimum temperature for Silver Carp spawning activity. Regardless, there appeared to be a small amount of spawning occur as suggested by post gas-bladder inflation larvae showing up in Bayou Drain of Hovey Lake on May 19th. A minor bump in river levels in early July likely produced some spawning, as we captured one *Hypophthalmichthys* larvae in the Green River. However, many gravid female Silver Carp were captured during various sampling efforts throughout the majority of the summer, again suggesting unfavorable Ohio River spawning conditions through much of 2023.

Among the subsamples of eggs and larvae sent to Whitney Genetics Lab, most were not confirmed to be Silver and Bighead Carp. There were a couple Grass Carp, shiners, and chubs that field crews suspected were *Hypophthalmichthys* but genetics confirmed otherwise. We knew that not all eggs/larvae sent to Whitney Genetics Lab from 2023 had every characteristic of *Hypophthalmichthys* species, however due to the proximity of where some were collected, we wanted verification to be safe. Invasive carp larvae can be readily identified by trained biologist, however due to staff turnover and the number of suspicious yet non-invasive carp larvae in our samples, we recommend a refresher training course to help further refine staff's ability to morphometrically identify larval invasive carp species confidently. Eggs remain inherently more difficult to discern and will likely need continued species confirmation through genetic methods.

More surface trawling effort was expended in 2023 than any other sampling year dating back to 2019 when trawling became the primary method for YOY collections. The increase in trawling efforts was driven by the 2022 collection of YOY Silver and Bighead carps in Markland Pool of the Ohio River, and subsequent interest from project partners to begin sampling for them further upstream. Despite the efforts, zero YOY invasive carps were captured upstream of J.T. Myers Pool. Surprising, even after finding YOY *Hypophthalmichthys* in Cannelton Pool in 2021 and 2022, none were collected there in 2023, further supporting the notion of limited spawning and recruitment in the Ohio River.

Efforts in 2023 revealed the presence of YOY Black Carp at a single location out of 55 sites sampled along the lower Ohio, Mississippi, Tennessee, and Cumberland River. The location was along the Ohio River shoreline at river mile 920, directly upstream of the Cumberland River confluence of the Ohio River. This site is 27 miles upstream of Gar Creek, where the single YOY fish was collected in 2018, and 15 river miles upstream of the site that YOY Black Carp were collected in 2022 (Figure 4). The 2022 and 2023 sites have similar habitat characteristics; both are close to the main river channel, shallow (< 1 m), muddy backwaters that may be a nursery area at higher water levels but can become isolated during low river stage. This occurrence is further evidence of consistent, albeit low, Black Carp reproduction in the lower Ohio River drainage in Western Kentucky. No juvenile or adult Black Carp were captured or observed during sampling. Although currently available collection data indicates Black Carp are now established and reproducing in the lower Ohio River drainage, it suggests their dispersal into the area has been more recent and they are less common than Grass and Silver carps.

Observed results for 2023 Wabash River ichthyoplankton sampling demonstrate there are multiple areas where invasive carp successfully reproduce throughout the Wabash River Basin, particularly in the Little Wabash River and the adjacent mainstem of the Wabash River. Although fate of larvae and recruitment dynamics are unclear for this species, these results suggest the Wabash River could be a significant source of YOY to the greater Ohio River Basin. Additionally, we documented spawning events in the White River, including significant numbers of invasive carp eggs. This location has not been sampled in the past by EIU and could represent an additional source of YOY within the basin. We found 2023 to have lower levels of invasive carp reproduction in the Wabash River Basin relative to past studies by EIU, likely due to low-water levels for the majority of the sampling season. Through this study and additional adult sampling, it appeared that gravid females retained their eggs later into the season than typically observed until there were significant rises in discharge. Two main peaks in larval and egg abundance were observed on July 5th, and August 9th and coincided with the relatively few discharge rises in the mainstem Wabash and its tributaries. Overall results of our 2023 sampling season show the Wabash River Basin is a potential source of invasive carp propagule pressure to the Ohio River Basin, even in years of less suitable hydrological conditions for their spawning. Continued monitoring over multiple years and varying hydrological conditions will be particularly important in future efforts, as well as a more detailed comparison to trends observed throughout the Ohio River Basin.

Extensive sampling within Bayou Drain from mid-May through June gave us the first look into the conditions that allow successful invasive carp passage from the Ohio River into Hovey Lake. As expected, YOY were first identified on the river side of the water control structure. One week later, as the water velocity flowing out of the lake subsided, YOY were detected on the lake side of the control structure. The multi-gear approach appeared to work well for capturing various sizes of YOY invasive carp, from post gas-bladder inflation larvae (~9 mm) and larger. Light traps captured invasive carp a few days earlier than ichthyoplankton nets, and captured the widest size range of YOY carp, suggesting they would be a good tool for early detection efforts in other potential recruitment areas throughout the basin. Although the installed water velocity gage is not yet calibrated, and therefore its data is preliminary, visual observations suggest that carp passage into the lake is limited when high velocity water is flowing out of the lake through the water control structure. Another year of data collections is needed to confirm, but keeping YOY carp from entering Hovey Lake may be as simple as closely monitoring drain flows and installing blocker boards immediately when the lake and river water levels nearly equalize. Interestingly, although we captured YOY on the lake side of the control structure, multiple surface trawling attempts in Hovey Lake proper did not capture any. If Hovey Lake water levels drop quickly and stay low, exposed mud flats and beaver dams may act as secondary barriers, keeping YOY trapped in the drain and out of the lake proper. The apparent limited invasive carp reproduction in 2023 may have drastically lowered the amount of YOY attempting to traverse Bayou Drain, therefore results from a "normal" spawning year may provide better insight for the quantity of carp entering the lake.

Preliminary results from otolith microchemistry data suggest a small percentage of Silver Carp spawned much further upstream than previously thought. Individual fish data will be investigated to better understand what may be happening. Unfortunately equipment issues with the laser ablation system caused additional delays and no new otoliths were processed. Gathering additional otolith samples from upstream river reaches may help better understand potential recruitment sources of the upper Ohio River.

There has not been what we would consider a strong spawning event or year-class since this project was initiated in 2016, and 2023 had exceptionally low spawning activity. However, based on the presence of adult invasive carp as far upstream as R.C. Byrd Pool, the 2022 findings of YOY invasive carp in Markland Pool, a highly successful spawning event could quickly shift the current known extent of recruitment to pools farther upstream. Therefore, the spatial and temporal variation in invasive carp recruitment in the Ohio River emphasizes the need for continued long-term monitoring with this project as well as others within the basin. Efforts in this project provide valuable insight into factors promoting the reproduction and recruitment of invasive carp, and ultimately range expansion. Results support several Basin Framework and National Plan strategies and will be used by biologists to mitigate the spread of these invasive fishes.

Recommendations:

We recommend continued work towards a uniform ichthyoplankton sampling design throughout the Ohio River. In addition to informing the partnership of the extent of spawning, these data will continue to help locate specific tributaries or locations important for invasive carp reproduction. Having comparable data within the Ohio River, and among other sub-basins, will allow managers to prioritize control efforts. In addition, we recommend beginning to use ichthyoplankton tows as a tool to measure more than just presence/absence – quantifying density of invasive carp eggs and larvae will help evaluate changes in spawning success over time.

Based on genetically confirmed results from the past four years, physical morphometrics can be successful in identifying *Hypophthalmichthys* advanced eggs and larvae from other native fish species. However, a few native fish and Grass Carp stumped us this year. The identification of eggs is more difficult and should still be verified via genetic analysis. The use of a measuring device on a microscope to determine if the perivitelline membrane is 5 to 6 mm will help in sorting between non-invasive carp and invasive carp-type eggs. There were many 'suspicious' eggs and larvae submitted to the genetics lab again this year that weren't in fact invasive carp, but rather, buffalos, shiners, Freshwater Drum, and other species. Because of this, along with staff turnover, we recommend field staff involved in the physical identification of *Hypophthalmichthys* larvae and eggs be trained or take a refresher course on larval fish identification. We recommend the continued use of morphometric methodologies being paired with genetic confirmation of a subsample of specimens to accurately discern between invasive carp and native fish eggs and larvae.

KDFWR recommends continuing to develop and geographically expand invasive carp YOY surveys in the lower Ohio River Basin with an emphasis on searching for YOY Black Carp. Continued effort is planned for 2024. With regards to YOY Silver and Bighead carp sampling, we recommend continuing targeted sampling in Markland Pool and areas further upstream. Both KDFWR, WVU, and USFWS are now outfitted with surface trawls which will be used to greatly expand YOY sampling further upstream in 2024.

INDNR recommends conducting another season of intensive sampling on both sides of the Hovey Lake water control structure in the spring of 2024 using the multi-gear approach. Seasonal variation may change the timing and quantity of YOY invasive carp attempting to enter the lake. As soon as the new USGS stream flow and velocity gage is calibrated, we recommend monitoring water conditions remotely in the future to help inform when to shut off water flow between the Ohio River and Hovey Lake.

Acknowledgements:

We would like to thank Zeb Woiak, Aaron Johnson, and staff at the USFWS Whitney Genetics Laboratory for their help processing egg and larval samples for this project.

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Table 1. Summary of ichthyoplankton tows collected by West Virginia University and West Virginia DNR. Sampling took place between May 22 and August 2, 2023. An asterisk (*) denotes genetically confirmed *Hypophthalmichthys* samples, or the lack thereof, analyzed by Whitney Genetics Lab.

Sampling Information				Samples to WGL (N)		*Hypophthalmichthys* (N)		
Pool	**Location**	**Transect Type**	**Tows (N)**	**Eggs**	**Larvae**	**Eggs**	**Advanced Eggs**	**Larvae**
Markland	RM 528	Ohio River	3	0	0	0	0	0
Markland	RM 514	Ohio River	3	0	0	0	0	0
Markland	RM 496.7 (near Hogan's Cr.)	Ohio River	9	0	0	0	0	0
Markland	Hogan's Creek	Tributary	3	0	0	0	0	0
Markland	RM 484	Ohio River	3	3	0	0*	0	0
Markland	RM 473	Ohio River	3	0	0	0	0	0
Markland	RM 463.5 (near Little Miami R.)	Ohio River	9	3	1	0*	0	0*
Markland	Little Miami	Tributary	3	0	0	0	0	0
Markland	RM 452	Ohio River	3	3	0	0*	0	0
Markland	RM 449	Ohio River	3	3	0	0*	0	0
Medahl	RM 429	Ohio River	3	0	0	0	0	0
Medahl	RM 405	Ohio River	3	2	1	0*	0	0*
Medahl	RM 404.7 (near J.M. Stuart)	Ohio River	9	0	0	0	0	0
Medahl	J.M. Stuart Plant	At structure	3	0	0	0	0	0
Medahl	RM 396	Ohio River	3	0	0	0	0	0
Medahl	RM 373	Ohio River	3	4	1	0*	0	0*
Medahl	RM 356.4 (near Sciota R.)	Ohio River	9	3	0	0*	0	0
Medahl	Sciota River	Tributary	3	0	0	0	0	0
Medahl	RM 355	Ohio River	3	2	0	0*	0	0
Medahl	RM 344	Ohio River	3	0	0	0	0	0
Greenup	RM 305.2 (near Guyandotte R.)	Ohio River	6	0	0	0	0	0
Greenup	Guyandotte River	Tributary	2	0	0	0	0	0
R.C. Byrd	Raccoon Creek	Tributary	12	0	1	0	0	0*
R.C. Byrd	RM 265.1 (near Kanawha R.)	Ohio River	9	2	0	0*	0	0
R.C. Byrd	Kanawha River	Tributary	20	0	0	0	0	0

Table 2. Summary of ichthyoplankton tows collected by the Kentucky Department of Fish and Wildlife Resources and Indiana Department of Natural Resources. Sampling took place between June 13 and July 6, 2023. An asterisk (*) denotes genetically confirmed *Hypophthalmichthys* samples, or the lack thereof, analyzed by Whitney Genetics Lab.

Sampling Information				Samples to WGL (N)		*Hypophthalmichthys* (N)		
Pool	**Location**	**Transect Type**	**Tows (N)**	**Eggs**	**Larvae**	**Eggs**	**Advanced Eggs**	**Larvae**
J.T. Myers	RM 840.6 (near Hovey Lake)	Ohio River	6	0	0	0	0	0
J.T. Myers	Hovey Lake Drain	Tributary	6	0	0	0	0	2
J.T. Myers	RM 784.0 (near Green R.)	Ohio River	6	0	0	0	0	0
J.T. Myers	Green River	Tributary	6	0	4	0	0	1*
Newburgh	RM 772.8 (near Little Pigeon Cr.)	Ohio River	6	0	3	0	0	0*
Newburgh	Little Pigeon Creek	Tributary	6	0	0	0	0	0
Newburgh	RM 731.3 (near Anderson R.)	Ohio River	6	0	0	0	0	0
Newburgh	Anderson River	Tributary	6	0	0	0	0	0
Cannelton	RM 718.7 (near Deer Cr.)	Ohio River	6	0	0	0	0	0
Cannelton	Deer Creek	Tributary	6	0	0	0	0	0
Cannelton	RM 662.9 (near Blue R.)	Ohio River	6	2	7	0*	0	0*
Cannelton	Blue River	Tributary	6	0	0	0	0	0
Cannelton	RM 608.5 (near New Albany)	Ohio River	6	0	0	0	0	0
McAlpine	RM 595.8 (near Harrods Cr.)	Ohio River	6	0	0	0	0	0
McAlpine	Harrods Creek	Tributary	6	0	2	0	0	0*
McAlpine	RM 545.8 (near Kentucky R.)	Ohio River	6	0	0	0	0	0
McAlpine	Kentucky River	Tributary	6	0	0	0	0	0

Table 3. Summary of YOY invasive carp captures in Western Kentucky during 2022 and 2023.

2022	# of Sites Sampled	Sites with YOY Invasive Carp	Sites with YOY Black Carp
Ohio River	21	2	1
Mississippi River			
Tennessee River	2		
Cumberland River			
Total	23	2	1
2023	**# of Sites Sampled**	**Sites with YOY Invasive Carp**	**Sites with YOY Black Carp**
Ohio River	24	3	1
Mississippi River	9	2	
Tennessee River	11		
Cumberland River	11		
Total	55	5	1

Table 4. Sampling location, transect location, number of push net samples, number of invasive carp larvae collected, number of invasive carp eggs collected, and number of potential invasive carp eggs collected in the Wabash River Basin in 2023.

Sampling Location	Transect Location	Push Net (N)	Larvae (N)	Eggs (N)	Potential Eggs (N)
Vermilion	Wabash Upstream	3	1	115	385
Vermilion	Wabash Downstream	3	0	100	295
White	Wabash Upstream	15	7	90	0
White	Wabash Downstream	12	4	118	4
White	Tributary	15	5	65	89
Embarras	Wabash Upstream	12	69	70	55
Embarras	Wabash Downstream	12	7	30	47
Embarras	Tributary	12	0	0	47
Little Wabash	Wabash Upstream	9	503	6	0
Little Wabash	Wabash Downstream	9	1329	3	30
Little Wabash	Tributary	9	696	2	315
Totals		**111**	**2621**	**599**	**1212**

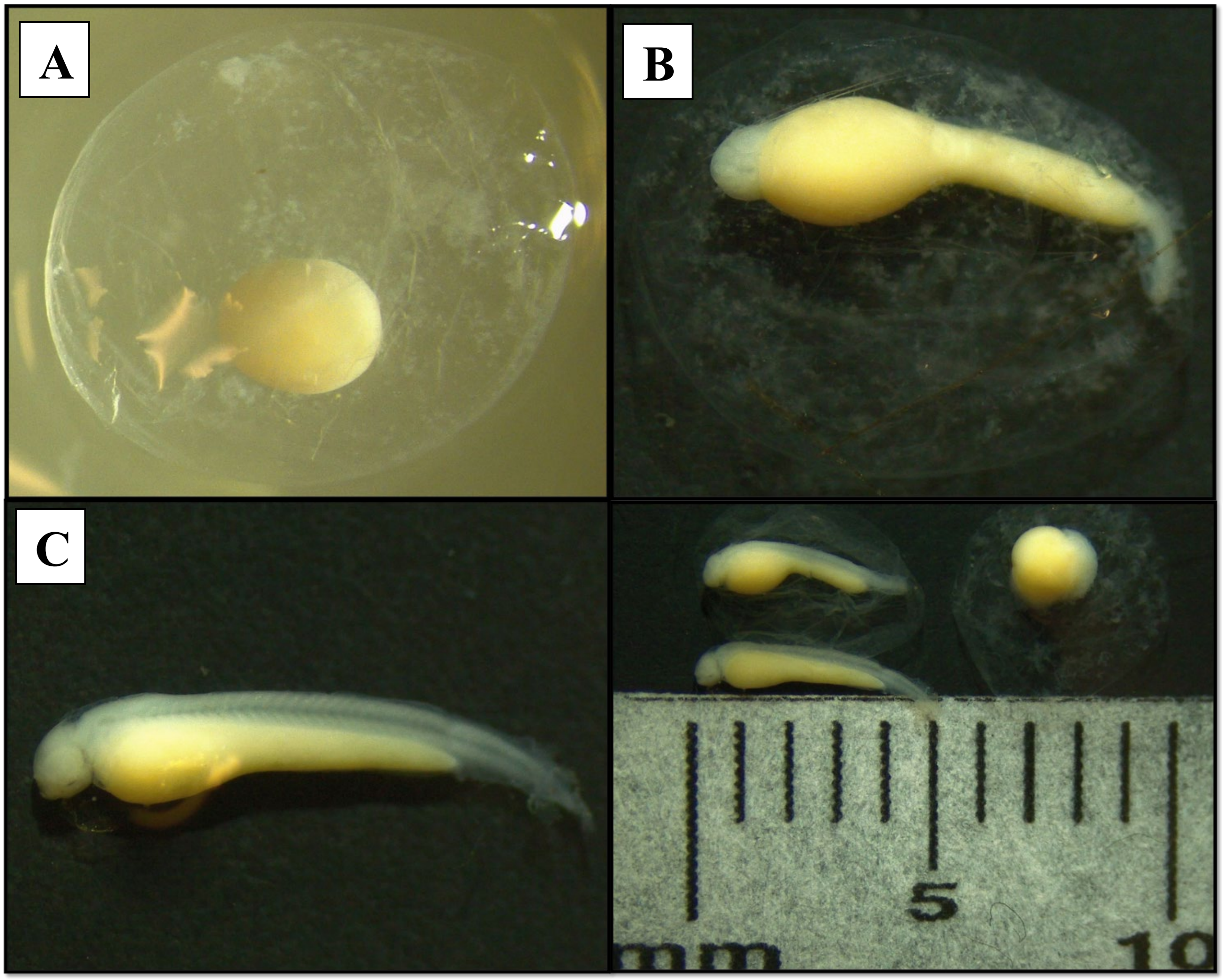

Figure 1. Developmental life stages of *Hypophthalmichthys* spp. with size comparisons. For the purposes of this report, pictures A, B, and C demonstrates specimens categorized as “eggs”, “advanced eggs”, and “larvae”, respectively.

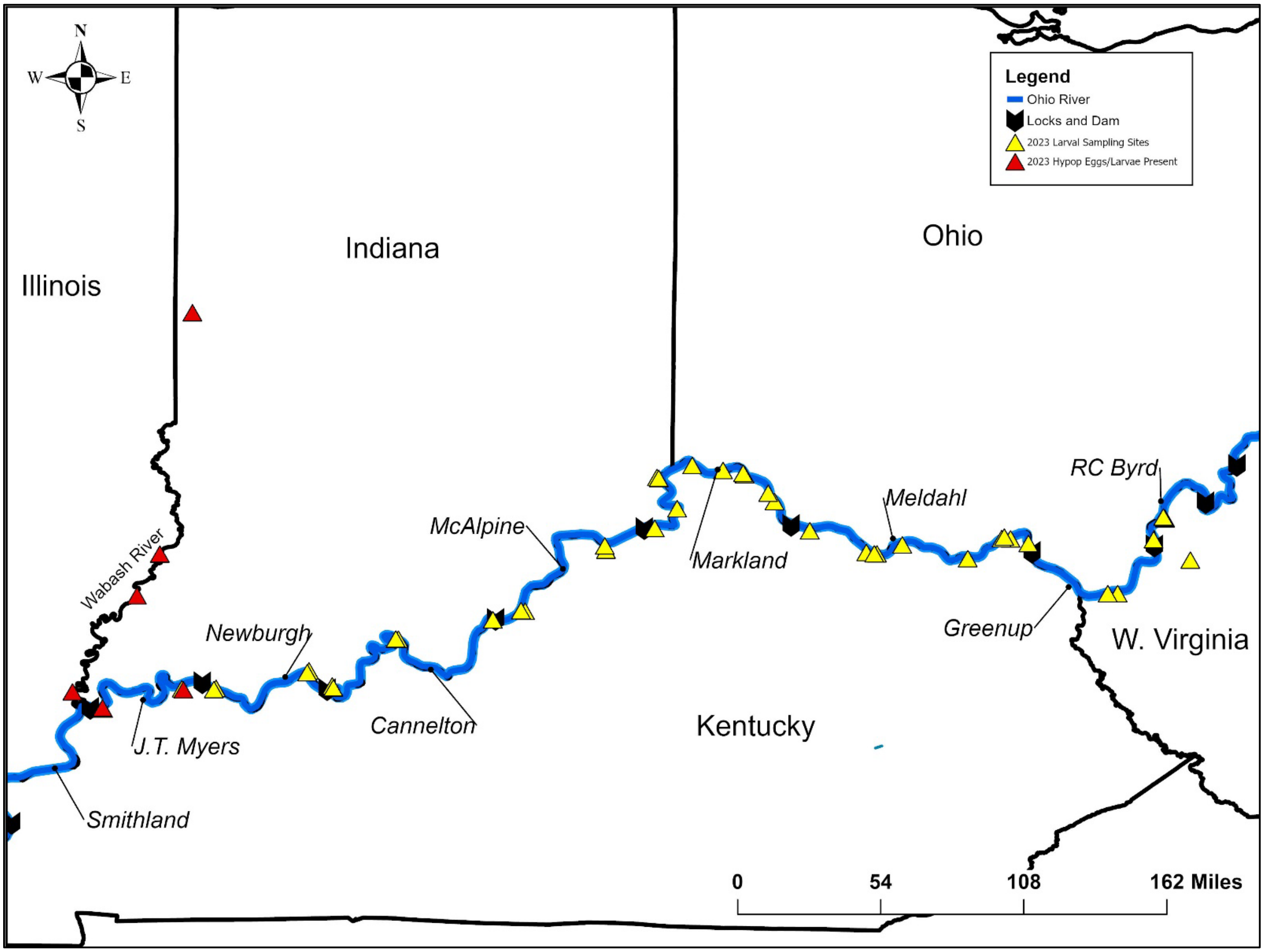

Figure 2. Map of 2023 study area of larval sampling sites. Black icons denote a locks and dam, yellow triangles indicate larval sampling sites, red triangles indicate locations where confirmed *Hypophthalmichthys* eggs, embryos, or larvae were collected.

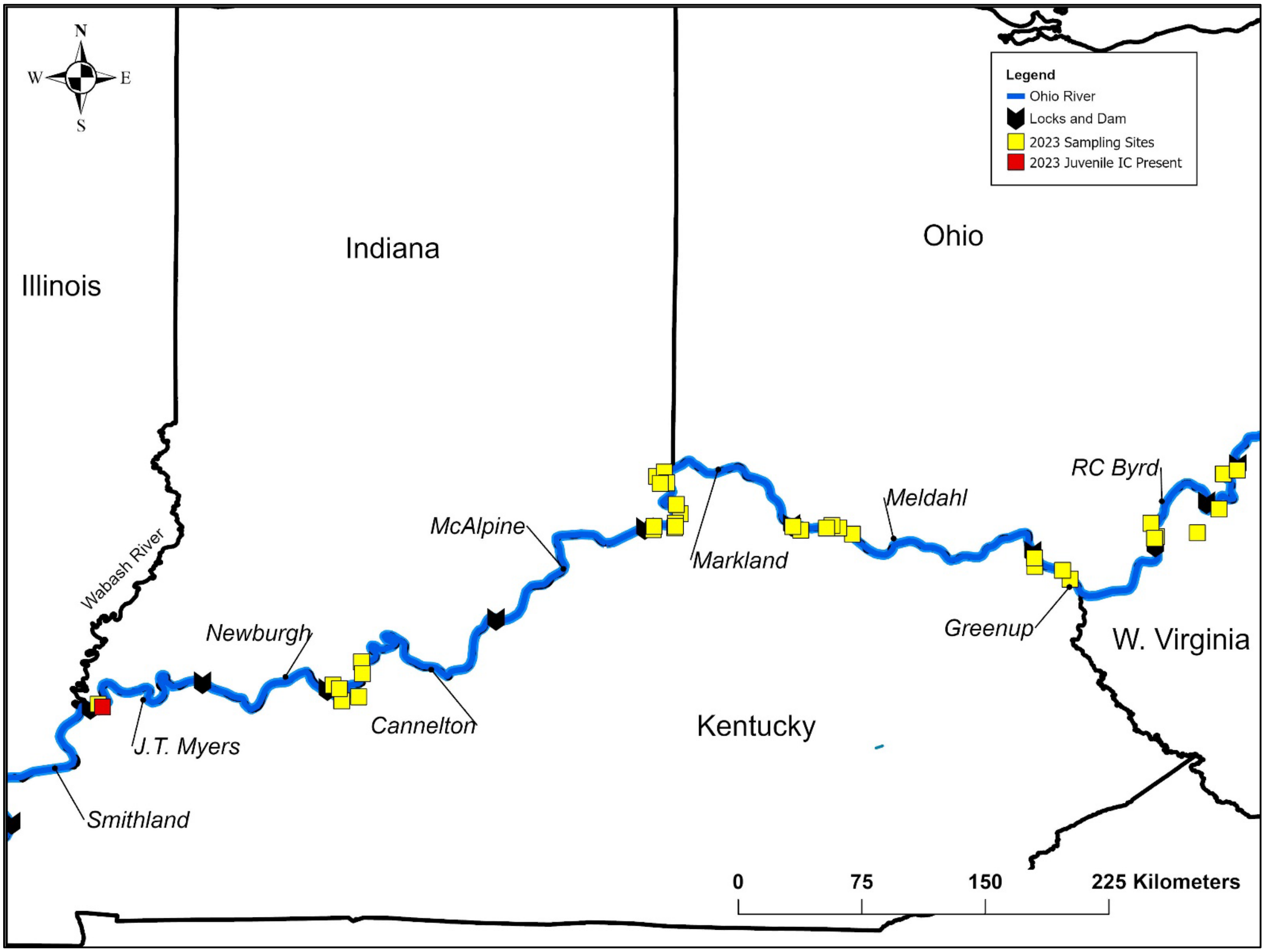

Figure 3. Map of 2023 study area of targeted juvenile sampling sites. Black icons denote a locks and dam, yellow squares indicate targeted sampling sites, red squares indicate locations where YOY or juvenile *Hypophthalmichthys* were collected.

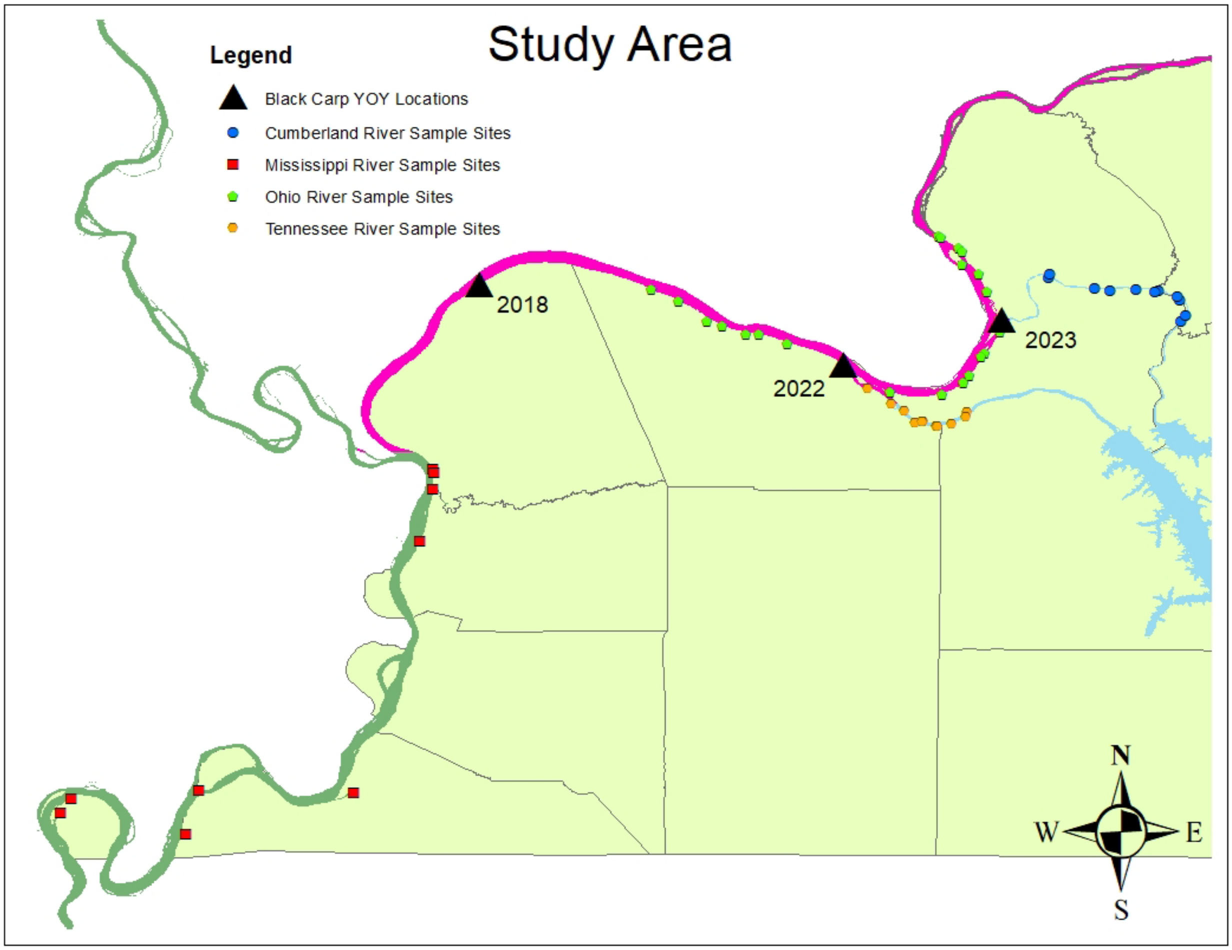

Figure 4. Site localities sampled in the lower Ohio River for YOY invasive carps during 2023, as well as locations of YOY Black Carp captures in 2018, 2022, and 2023.

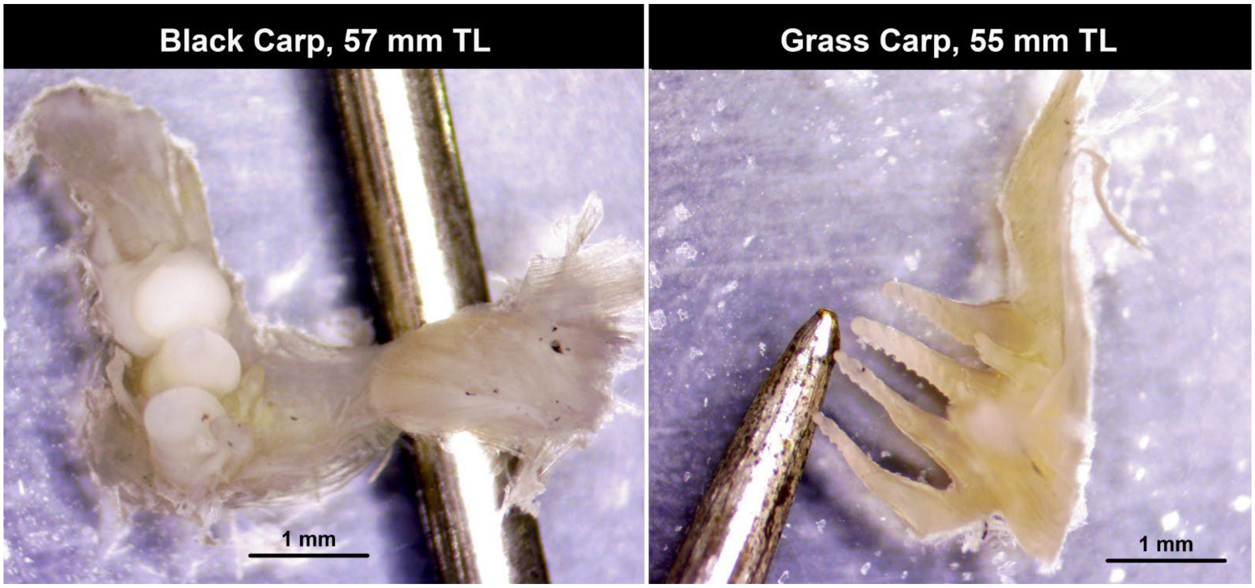

Figure 5. Comparison of pharyngeal tooth morphology between YOY Black and Grass carps of approximately the same size. Shown for each species is the dissected right pharyngeal arch. Black Carp has single row of 4 molar-like teeth (3 are visible). Grass Carp has two rows of slender, grooved teeth: 4 on inner row (visible) and 2 on outer row (obscured).

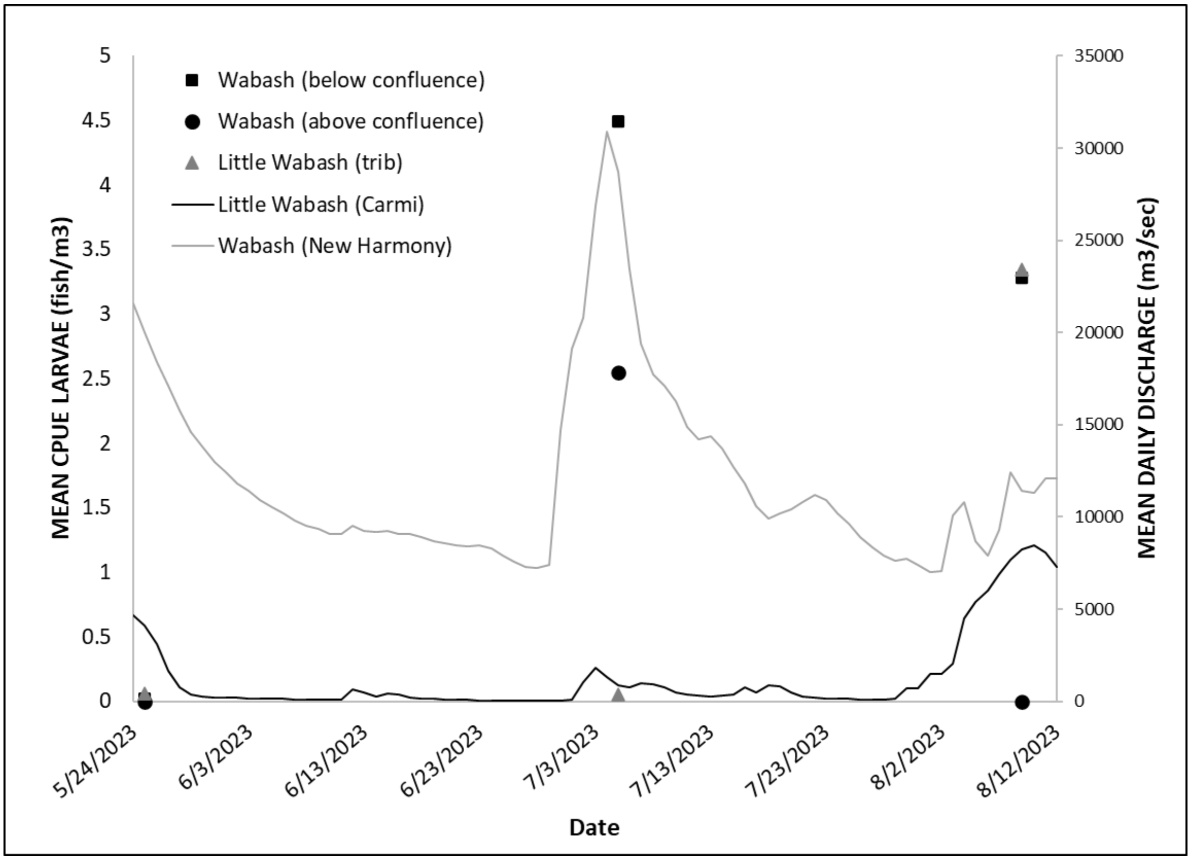

Figure 6. Catch per unit effort (fish/m^3 H2O filtered) of invasive carp larvae collected in the Little Wabash River (tributary site, grey triangles), and the Wabash River above (black circles) and below (black squares) the confluence of the tributary from May 25th to August 9th, 2023. Mean daily discharge (m^3/sec) is shown on secondary y-axis for the Little Wabash at Carmi (black line), and Wabash River at New Harmony (grey line).

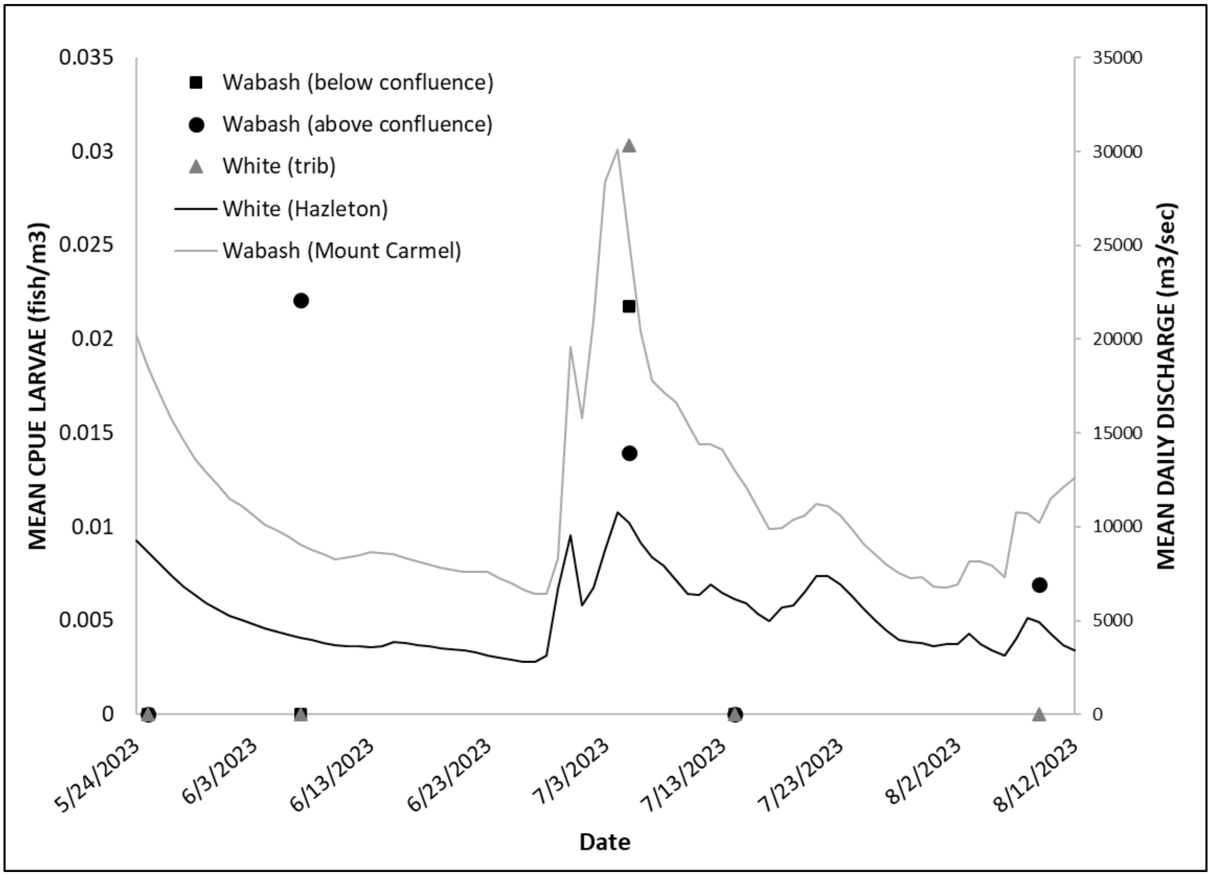

Figure 7. Catch per unit effort (fish/m^3 H_2O filtered) of invasive carp larvae collected in the White River (tributary site, grey triangles), and the Wabash River above (black circles) and below (black squares) the confluence of the tributary from May 25th to August 9th, 2023. Mean daily discharge (m^3/sec) is shown on secondary y-axis for the White River at Hazleton (black line), and Wabash River at Mount Carmel (grey line).

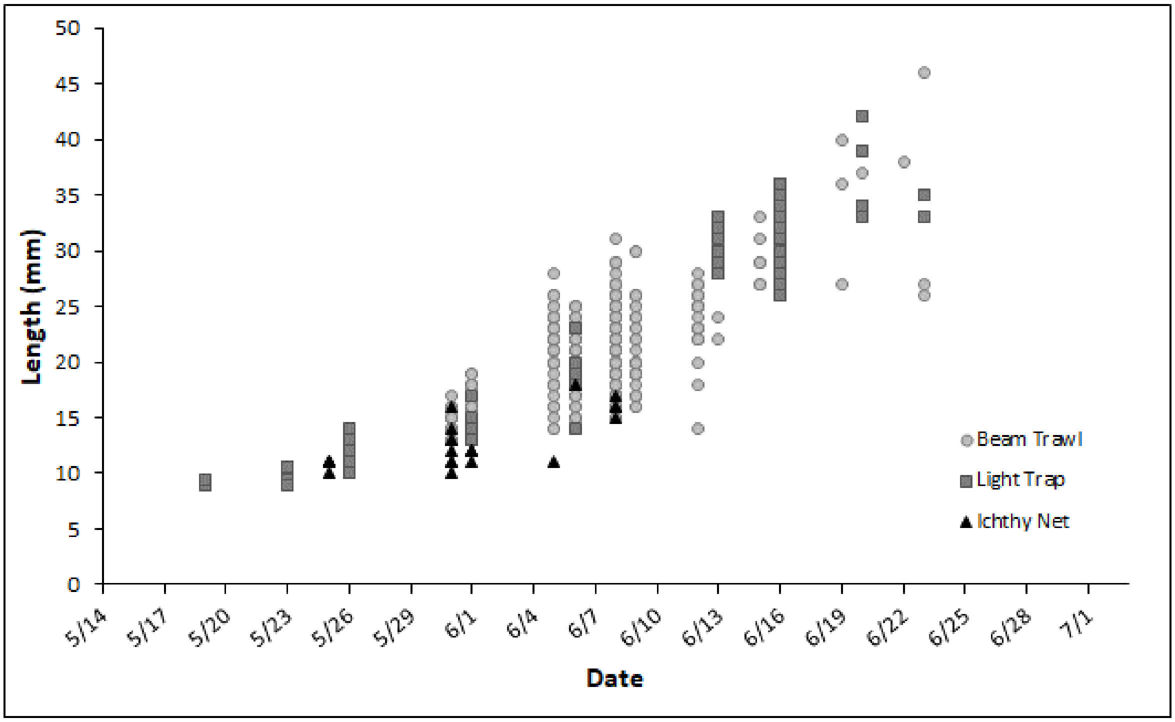

Figure 8. Length (mm) of YOY invasive carp captured within Bayou Drain of Hovey Lake during spring sampling efforts using beam trawls (circles), light traps (squares), and ichthyoplankton nets (triangles).

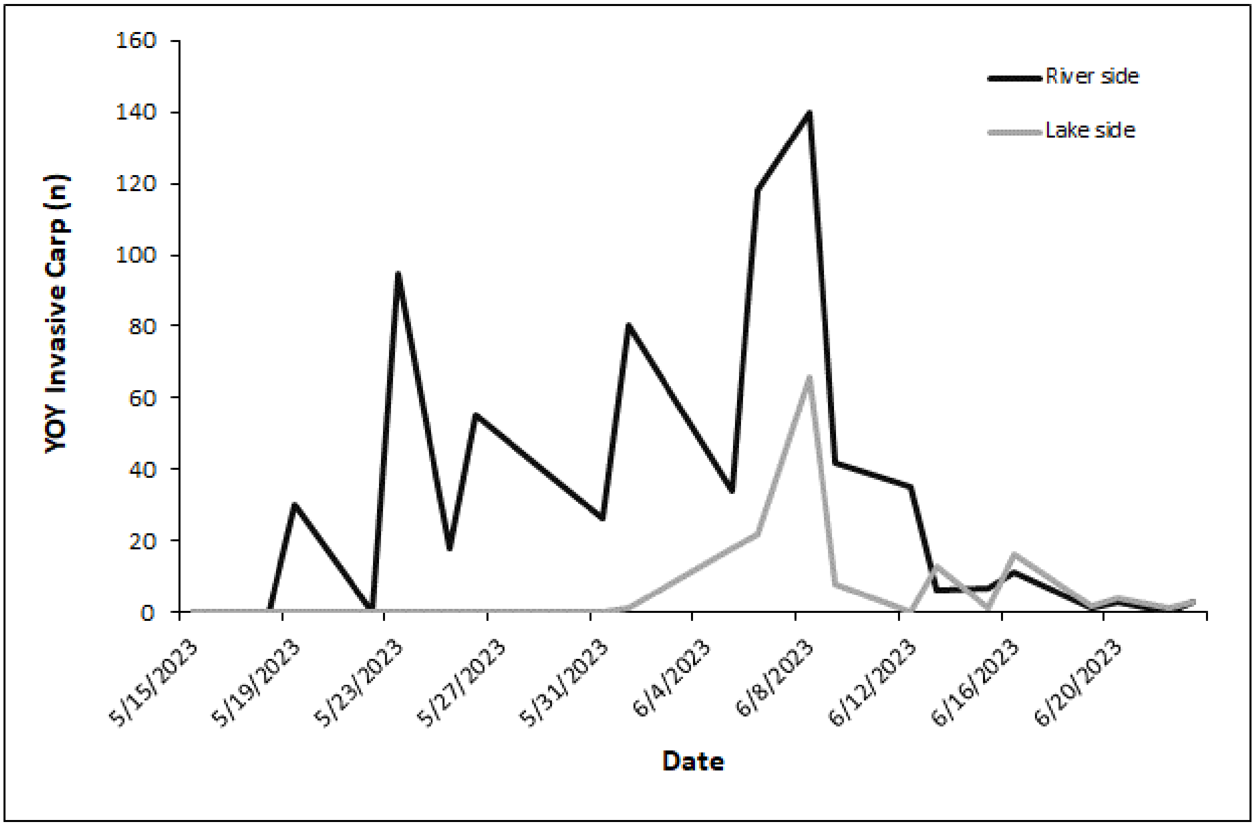

Figure 9. Number of YOY invasive carp captured within Bayou Drain of Hovey Lake during spring sampling efforts. Black line indicates the number captured on the river side of the control structure, while the grey line indicates the number captured on the lake side of the control structure.

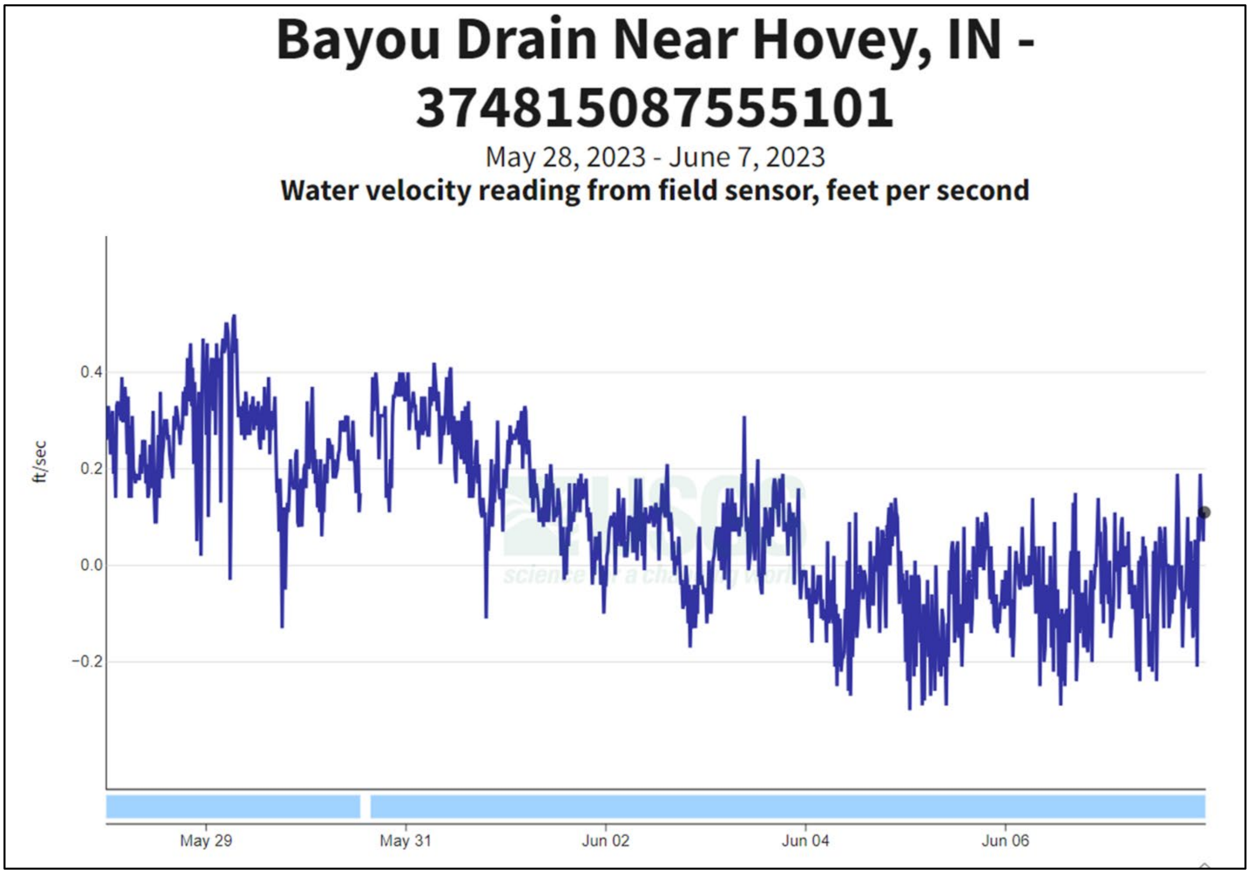

Figure 10. Water velocity readings from the monitoring gage installed within Bayou Drain of Hovey Lake near the water control structure during the week when lake and river levels began to equalize. Positive values indicate water flowing out of Hovey Lake into the Ohio River, while negative values indicate reverse flow into the lake. Note that data are still provisional and subject to change as calibrations are made. Debris near the control structure appears to be impacting the quality of data being collected.

WGL Report: March 27, 2024

Genetic Identification Via Sanger Sequencing

Indiana Department of Natural Resources
By: Zeb Woiak & Aaron Johnson

Samples (n=88) were received by the Whitney Genetics Lab from the Indiana Department of Natural Resources. Samples were kept in a -20°C freezer until they were processed by WGL lab staff.

Methods

We used our laboratory's standardized methods for Sanger sequencing. Samples were extracted using a modified version of the IBI Scientific gMAX extraction kit with a lyse and spin column (Qiagen) and a final elution volume of 200µL. For DNA extraction procedures and all further analyses, clean laboratory practices and appropriate anti-contamination precautions were used.

Samples were sequenced at the cytochrome c oxidase I gene (COI), which is commonly referred to as the 'barcode gene' and has been widely sequenced specifically for the purpose of species-level identification. This gene was amplified with a cocktail of four primers (VF2_+1, FishF2_+1, R1d_+1, FISHR2_+1) that are universal to most fish species (Ivanova et al. 2007; Ward et al. 2005). Amplification was accomplished with the Platinum™ Green Hot Start PCR mix (Invitrogen™ Life Technologies, Carlsbad, CA) in 25 µl reactions, using primers references above modified with M13 tags to streamline sequencing work. PCR products were cleaned with ExoSAP-IT® PCR Product Cleanup (Affymetrix, Santa Clara, CA). All PCR products were cycle sequenced in 1/16th BigDye Terminator v1.1 (Life Technologies, Carlsbad, CA) 20 µL reactions using both the forward and reverse primers.

Clean-up of the sequences before analysis was done with BigDye Xterminator kits (Life Technologies) to remove unincorporated bases. Sequence data were collected on an Applied Biosystems 3500XL Genetic Analyzer (Life Technologies). Sequences for each sample were trimmed, manually edited, and de novo assembled using the default Geneious assembler software. If a sample had one forward or reverse sequence that was low quality or failed, the other sequence was carried forward for all further analyses. Sequences were then compared to sequence data using the Basic Local Alignment Search Tool (BLAST) for all sequences in NCBI GenBank.

Results

Of the 88 samples 83 amplified (Table 1) and 33 could only be identified to genus. We sequenced both forward and reverse directions for 75 of the samples and used the assembled sequences for the final analysis. Six samples were successfully amplified but only matched ~94% to reference sequences in GenBank. These samples are marked with an asterisk because we do not have confidence in any species assignments that are less than 98% identical. Control samples were as expected. Sample failure may be due to low quality DNA or a failure in the sample processing. Final species assignments are in the attached table (Table 1). In the attached spreadsheet there are two tabs (1) Final Species Assignment and (2) Top 5 Blast Results. As mentioned above, some samples have final species assignments that are only assigned to a genus (e.g., *Notropis* spp.), but there is only a single species listed in their top 5 blast results. This is a result of a lack of genetic diversity between closely related species at the locus we analyzed.

FASTA sequences can be sent in a file which may be opened using Microsoft Notepad, if needed. Please let me know if you have any questions or concerns.

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Ward RD, R Hanner, PDN Hebert. 2009. The campaign to DNA barcode all fishes, FISH-BOL. Journal of Fish Biology 74:329–356.

WGL Report: March 27, 2023

Table 1. Species assignment based on sequence data from cytochrome c oxidase I (COI) mitochondrial locus. Results were derived using the Basic Local Alignment Search Tool and NCBI GenBank. Table values for samples that failed to sequence were populated with "*No Data*".
* Denotes samples with less than a 98% match to any reference sequence from NCBI GenBank.

IDNR Sample #	Final Species Assignment
1	*Notropis* spp.
2	*Notropis* spp.
3	*Notropis* spp.
4	*Aplodinotus grunniens*
5	*Aplodinotus grunniens*
6	*Notropis* spp.
7	*Notropis* spp.
8	*Hypophthalmichthys molitrix*
9	*Ctenopharyngodon idella*
10	*Ctenopharyngodon idella*
11	*No Data*
12	*No Data*
13	*Notropis* spp.
14	*Notropis* spp.
15	Pomoxis annularis
16	*Cyprinus carpio*
17	*Cyprinus carpio*
18	*Lepomis humilis*
19	*Lepomis humilis*
20	*Lepomis humilis*
21	*Lepomis humilis*
22	*Aplodinotus grunniens*
23	*Cyprinus carpio*
24	*Lepomis humilis*
25	*Lepomis humilis*
26	*Cyprinus carpio*
27	*Lepomis humilis*
28	*Lepomis humilis*
29	*Ictiobus* spp.
30	*Ictiobus* spp.
31	*Ictiobus* spp.
32	*Ictiobus* spp.
33	*Ictiobus* spp.
34	*Ictiobus* spp.
35	Hypophthalmichthys molitrix
36	Hypophthalmichthys molitrix
37	Hypophthalmichthys molitrix
38	Hypophthalmichthys molitrix
39	Hypophthalmichthys molitrix
40	Hypophthalmichthys molitrix

41	Hypophthalmichthys molitrix
42	Hypophthalmichthys molitrix
43	*Notropis* spp.
44	*Notropis* spp.
45	*Notropis* spp.
46	*Notropis* spp.
47	*Hypophthalmichthys molitrix*
48	*Ictiobus* spp.
49	*Notropis* spp.
50	Ictiobus spp.
51	*Notropis* spp.
52	*Ictiobus* spp.
53	*Lepomis humilis*
54	*Dorosoma cepedianum*
55	*Lepomis humilis*
56*	*Alosa* spp.
57	*Ctenopharyngodon idella*
58*	*Macrhybopsis* spp.
59	*Ctenopharyngodon idella*
60	*Aplodinotus grunniens*
61	*Notropis* spp.
62	*Aplodinotus grunniens*
63	*Aplodinotus grunniens*
64	Macrhybopsis storeriana
65	*Aplodinotus grunniens*
66	*Aplodinotus grunniens*
67*	*Alosa* spp.
68*	*Alosa* spp.
69	*No Data*
70	*Notropis spp.*
71	*Notropis spp.*
72*	*Alosa* spp.
73	*Notropis* spp.
74	*Aplodinotus grunniens*
75	*No Data*
76	*No Data*
77	*Aplodinotus grunniens*
78	*Aplodinotus grunniens*
79	*Aplodinotus grunniens*
80	*Aplodinotus grunniens*
81	*Aplodinotus grunniens*
82	*Aplodinotus grunniens*
83	*Aplodinotus grunniens*
84	*Notropis* spp.
85	*Aplodinotus grunniens*
86*	*Alosa* spp.
87	*Aplodinotus grunniens*
88	*Aplodinotus grunniens*

Project Title: Quantifying lock and dam passage, habitat use, and survival rates of invasive carps in the Ohio River Basin

Geographic Location: The Ohio River basin from Olmsted Pool (RM 964.4) to Willow Island Locks and Dam (RM 161.7), including tributaries. The Wabash River from Terre Haute, IN downstream to the confluence with the Ohio River. White River from Indianapolis, IN downstream to the confluence with the Wabash River.

Lead Agency: U.S. Fish and Wildlife Service **(**USFWS)

Participating Agencies: Southern Illinois University (SIU), Eastern Illinois University (EIU), Indiana Department of Natural Resources (INDNR), Illinois Department of Natural Resources (ILDNR), Kentucky Department of Fish and Wildlife Resources (KDFWR), Ohio Division of Wildlife (ODOW), West Virginia Division of Natural Resources (WVDNR), Ecosystem Connections Institute (ECI)

Statement of Need: Silver and Bighead Carp (*Hypophthalmichthys molitrix* and *H. nobilis*, respectively), herein referred to as "invasive carps", are invasive fishes within the Mississippi River Basin. Since they were first detected within the Mississippi River Basin in the early 1980's (Freeze and Henderson 1982; Jennings 1988; Robison and Buchanan 1988; Burr et al. 1996), the range of invasive carps has expanded to include much of the mainstem of the Mississippi River as well as other large rivers within the Mississippi River Basin (e.g., the Ohio, Missouri, and Illinois rivers) (Burr et al. 1996; Garvey et al. 2006; Camacho et al. 2020; Schaick et al. 2020). This rapid expansion throughout the Mississippi River Basin is likely due, at least in part, to rapid population growth resulting from high individual growth rates, short generation times, high fecundity, a protracted spawning period, and long-distance dispersal capabilities (Garvey et al. 2006; Peters et al. 2006; DeGrandchamp et al. 2008; Lenaerts et al. 2021).

Invasive carp populations are established throughout the lower and middle reaches of the mainstem Ohio River as well as many of its tributaries and successful reproduction is suspected as far upstream as Louisville, Kentucky. The establishment of these populations and the potential for invasive carp populations to expand their range into the upper Ohio River has led to concern among natural resource managers that invasive carps might gain access to the Great Lakes Basin through tributaries of the Ohio River. If invasive carps were to gain entry to the Great Lakes, they could cause substantial ecological and economic damage by disrupting food webs (Sass et al. 2014; Collins and Wahl 2017) and commercial and recreational fisheries (Pimentel et al. 2000, 2005). Because of the ability of invasive carps to cause extensive economic and ecological damage, limiting the expansion of invasive carp populations into novel habitats is of the utmost concern.

To prevent the spread of invasive carps into the upper portions of the Ohio River basin and potentially into the Great Lakes, we must understand their propensity for upstream movement, habitat use, and the probability of among-pool transitions. These monitoring efforts will reveal the timing and conditions most likely associated with pool transitions and entry into novel habitats. Additionally, mass movements to "preferred" habitats may reveal the timing and locations of spawning aggregations. Knowledge of these movements will be used to create management strategies designed to limit population expansion and inform management actions such as mass removal efforts.

Project Objectives:

1) Understand tributary use by invasive carps and the role of tributaries as potential sources for recruitment and routes of invasion into adjacent basins.
2) Delineate the upstream population distribution of invasive carps.
3) Quantify passage of invasive carps through Ohio River locks and dams.
4) Quantify movement patterns of invasive carps within the Wabash River basin including assessing movement between the Wabash and Ohio rivers (i.e., the contribution of Wabash River populations to those of the Ohio River) and between the White and Wabash rivers.
5) Inform invasive carp removal efforts by quantifying fine-scale habitat use and how habitat use changes through time in the Wabash and White rivers.

Project Highlights:

- Eighty-three Silver Carps were tagged during 2023 in Markland and Meldahl pools.
- During the course of this study, ~85% of Silver Carps have inhabited tributaries compared with ~53% of Silver Carps detected in mainstem habitats.
- Tributaries of high occupancy (≥25% of Silver Carps detected in a pool detected within that tributary) were identified for each pool.
- Monthly survival probability of Silver Carps during June 2013 – July 2023 was estimated between 0.96 and 1.
- Estimated mean pool-to-pool transition probabilities were generally low (< 0.2) for Silver Carps, suggesting that most of these fish remain within the pool in which they were tagged.
- Silver Carps in the Wabash River appear to select for outside bend habitats as well as logjams and areas of rip rap.

Methods:

Ohio River

Acoustic telemetry was used to determine the probabilities of survival, detection, lock and dam passage, and movement between tributary and mainstem habitats of invasive carps in the lower to middle Ohio River (Olmsted to R.C. Byrd pools but primarily focused from J.T. Myers to R.C. Byrd pools). To do this, the locations of individual invasive carps tagged with VEMCO, Model V16 acoustic tags were recorded using a stationary array of VR2 receivers. Receivers were placed either within the mainstem Ohio River, the lower reaches of select tributaries, or lock and dam (L&D) structures. Within some tributaries, a pair of receivers was deployed, one near the mouth of the tributary and the second further upstream. This arrangement of receivers allows for the interpretation of upstream and downstream movement of tagged carps and improves our ability to assess tributary use as well as the timing of entry into and exit from tributaries throughout the year. For L&Ds, at least four VR2 receivers were deployed at each L&D to record pool-to-pool transitions through the lock chambers with the exception of Markland and R.C. Byrd L&Ds. During 2023, three receivers were deployed at Markland L&D, one at the downstream approach and two in the lock chamber. For R.C. Byrd L&D one receiver was deployed at the upstream approach and two were deployed in the lock chamber. For all other L&Ds, two receivers were placed within the lock chamber and at least one receiver was placed on each of the downstream and upstream approach walls. These receivers provide consistent spatial coverage across L&Ds to ensure detection capabilities are similar at each location and increase confidence in interpretation of detection data.

Acoustic Receiver Array: During August 2022 – July 2023, the receiver array extended from river mile 937.0 in Olmsted Pool, ~20 miles downstream of the Smithland L&D, upstream to Willow Island Pool (river mile 159.3) (Figure 1). During non-winter months, detection data were downloaded from receivers monthly or as often as possible.

Acoustic Transmitter Tagging: Adult invasive carps were collected via boat electrofishing. Efforts were concentrated in areas where invasive carps are known to congregate such as side channels, backwaters, and tributaries. Fish were measured for total length (mm) and weight (g), and visually or manually sexed (if possible). Following these measurements, an acoustic transmitter (Vemco, Model V16-6H; 69 kHz) was implanted into the peritoneal cavity via a ~3 cm incision in the ventral musculature. The incision was closed with two or three sutures. The V16-6H transmitters provide individual identification and are nominally programmed to transmit a signal every 40 seconds yielding an expected battery life of ~1,460 days (4 years). Fish implanted with acoustic transmitters were also tagged externally using a lock-on tag inserted posterior to the dorsal fin (Floy Tag & Manufacturing, Inc. FT-4 Lock-on tag with clear over-tubing).

Active Tracking: To supplement detections from the acoustic receiver array, active tracking took place in select areas of the Ohio River. A VR100 omnidirectional hydrophone was used to detect fish during these sampling trips.

Tributary Use: To assess tributary use by Silver Carps (Bighead Carps were omitted due to a paucity of data), the proportion of detected Silver Carp in each habitat was determined by dividing the number of individual Silver Carps in each habitat by the total number of detected individuals June 2013 – July 2023. Additionally, to determine if specific tributaries may be of increased importance to Silver Carps, the number of individual Silver Carp detected in a tributary was divided by the total number of Silver Carps detected in that pool. Lastly, the time spent between transitions from tributary to mainstem habitat and vice versa was determined for each species as the mean number of days between detections in these two habitat types.

Pool-to-Pool Transition Analysis: To determine the probabilities of transitions among pools, survival, and detection of Silver Carps in the Ohio and Wabash rivers, a Multi-state with Live Recaptures analysis was conducted in Program Mark (Cooch and White 2008) using the RMark package (Laake 2013) in R version 4.1.2 (R Core Team 2021). In this analysis, the Wabash River and each navigation pool of the Ohio River are considered "states". Because environmental data (e.g., temperature and gage height) were included in this analysis and were collected from January 2014 to July 2023, detection data prior to January 2014 were omitted. Encounter histories were constructed for each individual by determining the pool of the last detection for each month (January 2014 – July 2023). Because tagging took place at various times throughout the duration of the study period and the expected battery life of the acoustic transmitters is ~4 years, not all individuals have a complete encounter history (maximum of 115 possible time periods).

Encounter histories of tagged carps that were harvested during the study period were right-censored. This process removes these individuals from the estimation procedures for the times following harvest. Additionally, transition probabilities were estimated only for adjacent pools because there were very few detected movements among non-adjacent pools. Transitions among non-adjacent pools were fixed to 0. Due to the small number of fish tagged (n = 46) and tags currently active in the Ohio River (n = 2), Bighead Carps were not included in these analyses.

To examine the effects of environmental conditions on the survival, detection, and movement of Silver Carps in the Ohio River, daily water temperature, discharge, and gage height data were collected from U.S. Geological Survey gage stations from Olmsted to R.C. Byrd pools as well as the Wabash River (Table 1). Data were collected for January 1, 2014 – July 31, 2022. Because the focus of this analysis was on pool-to-pool transitions, only data from mainstem gage stations were used. Although three variables were examined [i.e., temperature (°C), discharge (ft^3 sec^{-1}), and gage height (ft)], only eight gage stations collected discharge data and collections were inconsistent temporally resulting in many gaps in these time series. Because discharge is also highly variable among gage stations, it was omitted from this analysis. Temperature data were only collected at four gage stations in the sampling area but were consistent among these gage stations. An overall mean monthly temperature was, therefore, calculated for the mainstem Ohio and Wabash rivers using data from these gage stations. In contrast, all selected gage stations collected gage height data (ft) during the study period allowing pool-specific monthly mean gage height data to be calculated. To do this, gage heights were first converted to meters then the monthly mean gage height was calculated using all gages within a pool. Because monthly mean gage heights were highly variable among pools, these values were standardized within each pool by subtracting the mean and dividing by the standard deviation. Standardizing these data effectively places gage heights for all pools on the same scale, making comparisons more meaningful. After calculating standardized monthly mean gage heights, the time series for J.T. Myers, and R.C. Byrd pools were still incomplete. The methods used to complete the time series varied for each of the pool as a result of where in the time series gaps occurred and each pool's location in the river. For R.C. Byrd Pool (the farthest upstream pool for which data were collected), there were no gage height data collected during April 2017. To complete this time series, linear interpolation was conducted between March and May 2017. For J.T. Myers Pool, there were no gage height data from January – September 2014. Because this is the beginning of the time series, temporal interpolation within J.T. Myers Pool was not possible. Data from the pools directly upstream and downstream (Newburgh and Smithland pools, respectively) of J.T. Myers Pool were, therefore, used to spatially interpolate the missing data for each month using linear interpolation.

These time series of temperature and gage height as well as the encounter histories of individual Silver Carps were used to inform transition, survival, and detection estimates in multi-state models. Potential model structures included spatially and temporally invariant parameters, parameters that varied temporally (by month or season) and/or spatially (by pool), and parameters that varied with environmental conditions (e.g., mean temperature and standardized mean gage height). In addition, additive and interactive effects of covariates were considered. Due to the large number of potential model structures, a hierarchical model selection approach was used (Doherty et al. 2012). In this approach, detection and transition probabilities were held constant while the effects of month, season, mean temperature, and pool on survival probability were evaluated (Table 2). After determining the best supported structure for survival probability, it was retained while evaluating the effects of month, season, standardized mean gage height, pool, the number of receivers per pool and the number of receivers per river mile in each pool on detection probabilities (Table 3). Lastly, the best supported structures for survival and detection probabilities were held constant while evaluating the effects of month, season, standardized mean gage height, and pool as well as a linear and quadratic effect of temperature on transition probabilities (Table 4). Models were compared using Akaike's information criterion corrected for small sample size (AIC_c; Burnham and Anderson 2002) to find the most parsimonious model. Akaike weights (W_i) were also calculated to examine uncertainty in model selection (Burnham and Anderson 2002).

Wabash River

Acoustic Receiver Array: Thirty-five VR2 receivers have been deployed since 2022 throughout the Wabash River from the confluence with the Ohio River to 214 river miles upstream (near Terre Haute, Indiana) and within the White River, from its confluence with the Wabash River to 50 miles upstream (Figure 2). Receiver deployments followed the methods described above and receivers were retrieved and were downloaded monthly when river conditions allowed. As in 2022, extended periods of low water during 2023 prevented portions of the receiver array from being retrieved, especially during autumn (Figure 3).

Acoustic Transmitter Tagging: Tagging of invasive carps in the Wabash River follows the methods for the Ohio River, above. A total of 537 Silver Carps have been tagged since 2021 at multiple locations in the Wabash River, with 207 tagged in spring and fall 2023 (Table 5).

Interbasin and Intrabasin Movement:

Within the Mississippi River and its tributaries, target-removal by professional fishers has shown temporary success in decreasing local densities (MacNamara et al. 2016). This harvest-control method relies on the assumption that silver carp aggregate within the river. However, two distinct movement strategies have been found in silver carp in a free-flowing system (Prechtel et al. 2018; Coulter et al. 2022), creating the need to evaluate the movement patterns of silver carp in other rivers to effectively manage their populations. Objectives were: (1) Uncover if intraspecific variation in dispersal exists among silver carp the lower Wabash River; (2) Observe if distance traveled differs across seasons. (3) Determine the level of betweenness among individuals.

Fine-Scale Habitat Selection: Fine-scale habitat selection by tagged adult Silver Carps was assessed throughout the Wabash and White Rivers from 2021-2023. Monthly active tracking events occurred throughout the 305 rkm from Terre Haute, IN to the confluence of the Ohio River and the lower 105 rkm of the White River from Maysville, IN to its confluence with the Wabash in Mt. Carmel, IL. During active tracking, the boat was maneuvered downstream while towing an omnidirectional hydrophone (Vemco VH165). Once a transmitter was detected, the fish's position was triangulated by using a submersible directional hydrophone (Vemco VH110). Habitat characteristics including macrohabitat type (channel border open, inside river bend, outside river bend) and microhabitat type (log jam, rip-rap, run, thalweg) were recorded at each fish's location.

To assess selection, available habitat within the study area was quantified using a randomized sampling regime. The study area was split into three sections: Upper Wabash, Lower Wabash and White River. The Wabash was separated at Mt. Carmel, Illinois where the confluence with the White River nearly doubles total discharge. In each of the three sections, random sites were generated based on the total length of the section. Sites spanned 1 km in length with enough sites in each section to cover roughly 5% of the total length. Availability of macro and microhabitats were estimated in each site and averaged across sections to give the proportion of available habitat for each section. Manly log-likelihood chi-squared tests (Manly et al. 2002) were used to determine if fish used habitats in different proportions than their availability, indicating selection. Manly selection ratios (Manly et al. 2002) were calculated to determine the direction and strength of selection patterns both within the entire study reach and individual river sections.

Invasive carp movement and distribution following dam removal

In November 2021, two dams were removed from the Eel River at river kilometer (RKM) 2. The largest of these two dams was 435-feet long and 9-feet tall and served as a barrier to invasive carp movement further up the Eel River. Removal of these dams created a novel opportunity to better understand invasive carp establishment in newly accessible habitat and evaluate the ecological risk of invasive carp occupancy in comparison to the ecological lift of new native species establishing in the Eel River basin.

Twenty-two sample sites were established to verify presence or absence of invasive carp species and to score each site using the Index of Biotic Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) (Figure 4). An eDNA sample was collected at each of these 22 sites to validate presence or absence of invasive carp. Fish movement in the mainstem Eel River was tracked using a network of six antenna arrays installed from RKM 56 to RKM 121 that can detect Passive Integrated Transponder (PIT) tags and eight VR2TW and VR2Tx receivers installed from RKM 2 to RKM 121 that can detect acoustic tags. Active tracking of fish implanted with acoustic tags was conducted the entire length of the Eel River (RKM 121 to RKM 0).

Fish movement in the upper Wabash River, Tippecanoe River, Mississinewa River, and Salamonie River was tracked using a network of 12 VR2Tx receivers for detection of acoustic tags. Receivers in the Wabash River were installed upstream and downstream of the confluence of each of the four tributaries in May 2022. The remaining four receivers were installed in the mainstem channel of each tributary upstream of the confluence with the Wabash River. For this report, data was collected from May 2022 through 21 December 2023 but all 12 receivers remain operational.

Tags detected from the network of VR2Tx receivers were cross referenced with a database of known deployed tags in the Wabash River. When possible, fish species, gender, length at time of tagging, and weight at time of tagging, and tagging date were also included in the cross-referenced information. When unknown tags were detected in the upper Wabash River basin, project partners (and potentially Innovasea) were contacted to identify the source of tag. If the source of an unknown tag could not be identified, it was removed from further analysis since the species, gender, length, and weight were unknown.

Telemetry data was analyzed in the statistical software R, using the riverdist package. The riverdist package utilizes a river network line shapefile and GPS referenced detections to calculate the distance a fish traveled between detection dates and times.

Agency-Specific Accomplishments

Kentucky Department of Fish & Wildlife Resources (KDFWR)

During 2023, KDFWR maintained and regularly offloaded all tributary and mainstem receivers located in the Cannelton (from the Salt River to McAlpine L&D), McAlpine, and Markland (from Markland L&D to Cincinnati) pools. KDFWR also assisted other project partners with offloading receivers located in the most downstream pools (Olmsted, Smithland and JT Meyers) of the array. KDFWR met with USFWS and INDNR staff to identify new receiver sites in the lower Cannelton Pool that will be used to monitor invasive carp movements in response to contract fishing efforts and other environmental conditions. KDFWR staff also assisted USFWS with the tagging of additional invasive carp in the Meldahl Pool to replace several expired transmitters. KDFWR continued serving as the project's data manager by gathering receiver offloads from all other project partners and importing them into a SQL database, which also contains up-to-date records on tagged carp, receiver locations, and harvested tag reports. In 2023, KDFWR also compiled and integrated the Wabash River telemetry data that SIU staff have been collecting since 2021. Lastly, KDFWR created and maintained secondary databases with environmental data and daily receiver histories that are required by the telemetry project's modelling and analysis efforts.

Indiana Department of Natural Resources (INDNR)

INDNR deployed 8 additional VR2 receivers in the mainstem Ohio River and tributaries of Cannelton Pool to assist USFWS and KDFWR in evaluating fine-scale Silver Carp movements in response to contract fishing pressure. INDNR conducted a tagging event on the upper Wabash River, tagging an additional 72 Silver Carp. INDNR assisted USFWS in tagging fish in Markland Pool, spending a total of 14 hours electrofishing and tagging six invasive carp. Data from receivers in J.T. Myers and Newburgh pools were downloaded regularly by INDNR and sent to KDFWR for processing. INDNR maintained and downloaded the receivers station at J.T. Myers, Newburgh, and Cannelton lock and dams. Cannelton Pool receivers were downloaded by INDNR for the first six months in 2023 before being handed off to USFWS. INDNR subcontracted with ECI to complete work in the upper Wabash River to evaluate movements of invasive carps in response to a dam removal.

Ohio Division of Wildlife (ODOW)

ODOW maintained and offloaded data from mainstem and tributary receivers in the Markland (from Cincinnati to Meldahl L&D), Meldahl, and Greenup pools as well as those located at the Meldahl and Greenup L&Ds during 2023. All data were made available to KDFWR for processing.

West Virginia Division of Natural Resources (WVDNR)

WVDNR maintained and offloaded data from mainstem and tributary receivers in the R.C. Byrd Pool, including the portion of the Kanawha River within the pool. HOBO temperature loggers were deployed on four receivers within the pool in locations where tagged fish are frequently detected. The added array in the R.C. Byrd pool has informed WVDNR in targeted removal efforts (specifically the Kanawha river locations) where populations are less dense by providing additional detail on specific movement patterns, environmental cues to movement and additional locations where tagged fish frequent. All data was sent to KDFWR for processing and reporting.

US Fish and Wildlife (USFWS)

During 2023, USFWS, Carterville FWCO (with assistance from state and federal partners, tagged a total of 83 Silver Carps in Markland (n = 53) and Meldahl (n = 30) pools following the methods above. The Carterville FWCO also used the data collected by state agencies and processed by KDFWR to parameterize multistate models to better understand pool-to-pool transition probabilities for Silver Carps. These data were also used to understand tributary use of Silver and Bighead Carps (see methods above for details). Additionally, the USFWS Ohio River Substation (Lower Great Lakes FWCO) continued maintenance of 24 VR2 receivers (including replacement of 18 older VR2W with VR2Tx receivers) in R.C. Byrd, Racine, Belleville, and Willow Island pools took over the maintenance of the VR2 array on the Ohio River L&Ds during late fall 2022.

Illinois Department of Natural Resources, Southern Illinois University (ILDNR, SIU)

Southern Illinois University maintained thirty-five VR2 acoustic telemetry receivers throughout the Wabash River from the confluence with the Ohio River to 214 river miles upstream (near Terre Haute, Indiana) and within the White River, from its confluence with the Wabash River to 50 miles upstream. Receivers were retrieved and detections downloaded monthly when river conditions allowed. A new receiver stand was designed to improve retrieval of receivers in the rivers. Tagging of 207 invasive carps occurred in the Wabash River during May and September 2023. An analysis of the movement of silver carp from the Wabash River into the Ohio River during 2021 throughout 2023 suggested that only about 6% of Wabash River silver carp moved into the Ohio River.

Illinois Department of Natural Resources, Eastern Illinois University (ILDNR, EIU)

Eastern Illinois University conducted active tracking of acoustically tagged Silver Carps throughout the Wabash River during 2023 to identify patterns in fine-scale habitat use. Active tracking occurred monthly during daytime, with some additional nighttime active tracking taking place on select occasions to understand diurnal trends in fine-scale habitat use. Habitat characteristics were recorded at each fish's location, including macrohabitat type (river channel border, inside river bend, outside river bend) and microhabitat type (log jam, rip-rap, river run, thalweg). Additional microhabitat measurements, including substrate type, dissolved oxygen concentration, water velocity, water temperature, and water clarity were also measured at each fish's location. An analysis of fine-scale habitat use by silver carp showed that log jams were selected by this species and should be targeted for harvest removal.

Results and Discussion:

Ohio River

Acoustic Receiver Array: During 2023, 174 receivers were deployed from Olmsted Pool to Willow Island L&D. Of these, 43 were deployed at L&Ds, 40 at mainstem sites, and 91 at tributary sites (Figure 1, Table 6).

Fish Tagging Efforts: As of July 2023, 1556 invasive carps (1510 Silver and 46 Bighead) from J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, Meldahl, and R. C. Byrd pools have been surgically implanted with acoustic transmitters (Table 10). Of the 1556 tagged carps, 34 Silver Carps have been harvested during the study (June 2013 – July 2023). During 2023, 31 invasive carps (30 Silver and 1

Bighead) had tags that were expected to expire (Table 7). To replace these tags and meet the needs of partner agencies, 83 Silver Carps were tagged in Markland (n = 53) and Meldahl (n = 30) pools. No Bighead Carps were tagged during 2023 due to a lack of availability.

Fish Detections: There were 1052 active tags deployed in invasive carps (1050 Silver and 2 Bighead) in the Ohio River during 2023, 543 (52%) of which were detected (539 Silver and 4 Bighead). Active tags included those expected to be active during 2023 (n = 1052) as well as those expected to expire prior to 2023 that were detected during 2023 (n = 65).

Fish Movement: Throughout the study area, the net movement (i.e., the difference between the most upstream and most downstream detections for an individual) ranged from 0.0 km to 379.8 km for Silver Carps and from 0.0 km to 130.8 km for Bighead Carps during August 2022 – July 2023. The longest net movement by a Silver Carp was completed by a male fish travelling from McAlpine Pool to the Hovey Lake area of J.T. Myers Pool during August – September 2022. In contrast, the longest net movement by a Bighead Carp during August 2022 – July 2023 was completed by a male fish that moved within Meldahl Pool. Long-distance movements are relatively rare for Silver Carp; ~71% of Silver Carp had a maximum distance travelled of < 30 km during August 2022 – July 2023. In contrast, 40% of Bighead Carp had a maximum distance travelled of < 30 km, however, given the small sample size (n = 5), these data should be interpreted cautiously. Additionally, although detections of invasive carps above Greenup L&D were rare (~0.1% of total detections), during 2023, the most upstream detections for both Silver and Bighead carps occurred in R.C. Byrd Pool at river miles 251.3 and 265.2, respectively.

Because there were relatively few detections of invasive carps in the pools upstream of Greenup L&D and below J.T. Myers L&D, further analysis of fish movement during August 2022 – July 2023 focused only on J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, and Meldahl pools. In these pools, net movements are typically shortest during January – March and peak during late spring and summer (May – July) regardless of species or pool (Figures 5 and 6). For Silver Carp, mean net movements in Markland and Meldahl pools are typically longer than those in lower pools.

Dam Passage: Throughout the duration of this study (June 2013 – July 2023), there have been 465 dam passage events (140 upstream and 325 downstream passages) (Figure 7). Dam passages were completed by 237 Silver Carps and 11 Bighead Carps. Of the upstream passages, 11 (7.9%) were completed by five Bighead Carps, with one fish accounting for three of those passages as it moved from Meldahl Pool to Racine Pool during May 2014 – August 2015. One-hundred twenty-nine upstream passages (92.1%) were completed by 94 Silver Carps. Sixteen downstream passages (4.9%) were completed by nine Bighead Carps, whereas 316 (95.1%) were completed by 211 Silver Carps. Additionally, in only 50 of the 465 dam passages (10.8%) was the fish detected within the lock chamber, suggesting a high prevalence of passages through the dam gates. Passages where fish were detected within the lock chamber occurred at R.C. Byrd, Greenup, Markland, Cannelton, Newburgh, and J.T. Myers L&Ds during 2017 (n = 2; 1 Bighead and 1 Silver Carp), 2019 (n = 1; Silver Carp), 2021 (n = 14; Silver Carp), 2022 (n = 25; Silver Carp), and 2023 (n = 8; Silver Carp). All but one confirmed lock chamber passage (at Greenup L&D during 2017) were in the downstream direction.

The current arrangement of VR2 receivers around most L&D structures in the study area and their year-round deployment suggests a high probability of detecting invasive carps transitioning among pools through lock chambers. However, if fish pass through the dam gates they likely will not be detected.

Tributary Use: Throughout the study period, ~85% of detected Silver Carps have been detected in tributaries of the Ohio River whereas, only ~53% of these fish have been detected in mainstem Ohio River habitats (Figure 8). In addition, when Silver Carps enter tributaries, they tend to spend more time (mean ± SE = 34.8 ± 1.1 days) there than in mainstem habitats (15.3 ± 0.7 days; Figure 9).

When examining specific tributaries that are commonly used within each pool, there is at least one tributary within each pool (J.T. Myers – Meldahl) that was visited by ≥25% of Silver Carps detected within that pool (Figure 10). In J.T. Myers, Cannelton, and Markland pools, only one tributary met this criterion in each pool, Eagle Creek (33%), the Salt River (59%), and Laughery Creek (79%). In each Newburgh and Meldahl pools, two tributaries were commonly inhabited by Silver Carps, Little Pigeon Creek (39%) and Borrow Pit 1 (26%) in Newburgh Pool and Ohio Brush Creek (78%) and the Scioto River (41%) in Meldahl Pool. Lastly, three tributaries were inhabited by ≥25% of Silver Carps detected in McAlpine Pool, Indian-Kentuck Creek (57%), the Little Kentucky River (47%), and the Kentucky River (73%; Figure 10). These data suggest that not only do tributaries provide important habitat for Silver Carps, but some tributaries may provide more suitable habitat than others be preferred over others and should, therefore, be more closely monitored to determine if these areas can be targeted for control efforts.

Pool-to-Pool Transition Results: For Silver Carps, AIC_c indicated that for each model parameter (S, p, and ψ) only one model structure was supported (Tables 2-4). Based on this hierarchical model selection process (ΔAIC_c and W_i), the final model included a survival probability (S) that varied with month, a detection probability (p) that varied with the additive effects of pool and the number of receivers, and transition probabilities (ψ) that varied with the additive effects of pool and month. The AIC weights of 1 for each part of the hierarchical model selection process indicate little to no uncertainty in model selection.

The mean probability of survival (S) of Silver Carps varied with month such that survival was highest during cooler months (Jan – April) and lowest during May and June (Figure 11). Estimated mean survival probability was, however, high (0.95 – 0.99) for all months.

Estimated mean detection probabilities (p) for Silver Carp were affected by the additive effect of pool and the number of receivers and ranged from 0.01 to 1.00. The probability of detection increases following a sigmoidal curve such that there is a rapid increase in detection probability from 0 to ~10 receivers after which the rate of increase in detection probability slows (Figure 12). Interestingly, detection probabilities in Greenup Pool remain low, despite this pool having a similar number of receivers than some more downstream pools and likely reflects the relative lack of tagged fish in this pool.

Model estimates of mean transition probabilities (ψ) varied with the additive effect of pool and month and indicate that Silver Carps are most likely to move from one pool to another in April and October and are least likely to move among pools in August (Table 11, Figure 13). This was also true for movements between the Wabash River and the Smithland Pool (Table 11). Interestingly, transition probabilities from the Wabash River to the Smithland Pool were consistently higher than those from the Smithland Pool to the Wabash River supporting the idea that the Wabash River Silver Carp population may act as a source population to the Ohio River. Furthermore, transition probabilities among pools were typically low (< 0.2) with some exceptions (e.g., Greenup to Meldahl and J.T. Myers to Smithland during April and October) indicating that the probability of Silver Carps remaining within a pool was typically high (>0.8).

Lastly, transition probabilities from upstream to downstream pools tend to higher than those from downstream to upstream pools regardless of month.

Wabash River

Fish Movement: The retriever array in the Wabash River was difficult to reach and download during 2023 due to prolonged periods of low water levels, where most receivers were either inaccessible by boat or buried under sand in the riverbed. Only two receivers were able to be retrieved and downloaded in 2023, although a crew (with shovels and a winch) will be deployed in early spring 2024 to locate and unbury receivers. To improve receiver retrievals in the future, SIU will be experimenting with different deployment designs that cater to the rapidly changing hydrology and riverbed of the Wabash River. The "Swiss Sled" prototype (Figure 14) has been designed to improve the ability to pull receivers from the riverbed using a onshore tether. The sled is sufficiently large and heavy to remain upright on the river bottom but contains holes that reduce weight and allow the sled to be pulled out of sand. This prototype will be tested in the Wabash River in spring 2024.

Interbasin and Intrabasin Movement: An analysis of available silver carp movement data collected during 2021 through 2023 in the Wabash River revealed that greater detections and higher average distance moved occurred in spring than other months (Figure 15). Consistent with other research on movement in the Wabash River, the majority of silver carp remained near the location of release although a few moved greater than 60 km (Figure 16). A network graph was used to visualize the connectivity among tagged individuals within the Wabash River (Figure 17). Nodes depict individual fish and lines connect fish that cross within 2 km of each other within a 24-hour period. In the Wabash River, connectivity degree ranged from 0 to 19 with most fish remaining between Vincennes, IN and Grayville, IL (approximately a 65 km range; Figure 17).

Between 2021 and 2023, 537 silver carp were tagged in the Wabash and White Rivers. Of these 537 fish, only 33 fish transitioned from the Wabash River system to the Ohio River (Table 9). On average it was 300 days from tagging in the Wabash River for an individual fish to be detected in the Ohio River. Fish tagged in the Mt. Carmel site were the most often detected in the Ohio River (15/33 detected fish), followed by those tagged in Hutsonville (7/33). Interestingly, while the New Harmony, Illinois site had the most intensive tagging (139 fish) and was the closest to the confluence of the Wabash and the Ohio River, only 5 fish tagged there were later detected in the Ohio River. Hazelton, Indiana was the only tagging site on the White River, and only 2 of the 55 fish tagged were detected in the Ohio River. No fish tagged in Merom, Indiana were detected in the Ohio River, likely because this site is relatively far from the confluence and had the fewest tagged fish (42). In the Ohio River, fish were most commonly detected at the Smithland lock and dam (15 unique fish), Brookport Bridge (8 unique fish) and the J.T. Meyers lock and dam (7 unique fish). This indicates that carp originating from the Wabash River tend to go downstream in the Ohio River, towards the Mississippi River (Figure 18).

Movement data are very limited at this juncture, but patterns of silver carp movement in the Wabash River appear to differ substantially from other highly studied rivers such as the Illinois River. In the Illinois River, patterns of movement are restricted, perhaps by structures such as locks and dams and limited suitable habitat. Analysis of the network movement of silver carp suggests that fish more freely move among receiver locations in the Wabash River. A converse explanation is that the rapidly changing flow and geomorphology of the Wabash River cause silver carp to move more frequently. Further analyses of these patterns will aid commercial harvest operations to more efficiently remove silver carp. The apparent lack of silver carp moving (only about 6%) from the Wabash River into the Ohio River mainstem is surprising. However, the mouth of the Wabash River feeding into the Ohio River is often blocked by aggradation of Ohio River bed material during periods of low flow, perhaps reducing the connectivity into the river, especially during years of low discharge such as 2022 through 2023. Identifying conditions (e.g., high flow) when populations in the Ohio and Wabash Rivers become connected may aid in identifying times to direct harvest near the confluence.

Fine-Scale Habitat Selection (Eastern Illinois University):

Silver Carps detected in the Wabash and White Rivers selected for both macro- ($\chi^2 = 376.72$, df = 216, $p < 0.05$) and micro-habitats ($\chi^2 = 442.78$, df = 336, $p < 0.05$) disproportionately to available habitat. Fish were not randomly distributed across habitats, but actively selected for specific habitat types. Throughout the entire study area, outside bends were positively selected while both channel border open and inside bends were slightly avoided (Figure 19). Outside bend areas are generally deeper than the other macro habitats, which likely contributes to individuals selecting for these areas. Logjam and rip-rap micro-habitats were selected for while run and thalweg areas were avoided (Figure 20). Micro-habitat selection patterns can likely be attributed to differences in flow across available habitats. Logjam and rip-rap areas generally have slower flow and provide a velocity refuge that allows silver carp to limit energetic output. Run and thalweg areas have much higher flow which requires individuals to constantly swim to maintain position.

Although habitat selection was apparent throughout the entire study area, longitudinal variation influenced how individuals used habitat in each river section. In the lower portion of the Wabash, Silver Carps selected for outside bends much more than any other macro-habitat type (Figure 21). This was not the case in the upper Wabash where there were no obvious patterns in macro-habitat selection. Additionally, individuals in the White River selected for channel border open areas and did not select for or avoided other habitat types (Figure 21). Compared to the other sections of the study area, the lower Wabash is much wider and dominated by sandy substrates so outside bends are likely the only deep areas available to silver carp. Micro-habitat use between sections was more similar with fish selecting for logjams across all sections (Figure 22). Run and thalweg habitats were generally avoided in in all sections, although in the lower Wabash, individuals slightly selected for thalweg habitats (Figure 22). Rip-rap areas had less clear patterns of habitat selection with high variability in the lower Wabash and slightly positive selection in the upper Wabash (Figure 22). Logjams seem to be universally selected for throughout the study area and may be useful areas to target for large-scale removals or commercial harvest. However, most habitat selection patterns are not uniform throughout the study area so, depending on where removal efforts occur, different habitats may need to be targeted to maximize harvest.

Invasive carp movement and distribution following dam removal

Results from the Eel River Basin in 2023 showed IBI scores ranged from “Poor” to “Very Good” in Eel River tributaries and “Fair” to “Exceptional” in the mainstem Eel River (Table 10). QHEI scores at the Eel River tributary sites were geographically clustered with the lowest scores occurring at headwater sample sites. It should be noted that IBI scores at these headwater sites were lower in 2023 than in 2022. These sites had accumulated high organic mucks in-channel between the two years.

Approximately fifteen Silver Carp were observed in the Eel River on 5 July 2023 at RKM 56 (Stockdale Dam). This is the first recorded instance of Silver Carp in the Eel River above RKM 2. Boat electrofishing resulted in three male Silver Carp being collected (Table 11). These three carp were tagged with a PIT Tag and acoustical transmitter and then released. One of the fish tagged at Stockdale Dam was detected going down the Eel River, into the Wabash River, and was last detected in the Wabash River, Upstream of the confluence with the Tippecanoe River. No new species were found in the Eel River in the 2023 sampling. However, it was documented that several new species have moved further up the river. For example, Freshwater Drum were found at RM 35 and Bluebreast Darter and Tippecanoe Darter were documented at RKM 16. Grass Carp were only found at Logansport, RKM 2. This was the most upstream extent of Grass Carp in 2022 as well.

Environmental DNA (eDNA) samples detected Grass Carp DNA in 100% of replicates at Logansport (RKM 2) and 33% of replicates at Adamsboro (RKM 12), Hoover (RKM 20), Mexico (RKM 30), and Collamer Dam (RKM 103) (Table 12). Grass Carp DNA was also detected in 33% of replicates at Paw Paw Creek Upper and 67% of replicates at Beargrass Creek Upper. Checking for Grass Carp will be a point of emphasis in 2024 given the impact Grass Carp could have on the rooted plants of the Eel River (e.g. Eelgrass (*Vallisneria americana*)).Silver Carp DNA was detected in 33% of replicates at Squirrel Creek Upper. Caution should be taken when reviewing eDNA results with low detection rates (e.g., 33%) since false positives are common at this detection rate. For example, 2023 was a dry year and Squirrel Creek Upper was dry through most of the summer, so it is likely that the detection of Silver Carp DNA at Squirrel Creek Upper was a false positive.

A total of 68 Silver Carp were detected and able to be cross-referenced with tagging information using the network of 12 receivers established throughout the Upper Wabash River Basin. Detected fish were tagged in seven separate tagging events (Table 13). Of note are Silver Carp that were tagged in the Cumberland River, near Chetham Dam but were then detected 862 River Kilometers (RKM) away from their tagging location on multiple different receivers in the upper Wabash River basin. There was also seven Silver Carp detected in the upper Wabash River basin that were tagged near Hutsonville, Illinois, 159 RKM downstream from the closest receiver used for this project.

It was found that Silver Carp movement was seasonally dependent with the most movement occurring in May, June, and July (Figure 23). Females had a higher average distance traveled than males in these three months. The Silver Carp that migrated from the Cumberland River were outliers in this analysis as they traveled over 5 times further than any other fish. The gender of the Cumberland River Silver Carp was not reported, and they were first detected in the upper Wabash River on 19 May 2022 and 31 May 2022. Additional years of data will allow a more powerful analysis on Silver Carp movement in small tributaries of the upper Wabash River, including the refinement of Eel River utilization after low head dam removal.

Recommendations:

Despite the expansion of the receiver array in Cannelton Pool to better understand tributary vs mainstem habitat use, there are still gaps in the receiver array that, if filled, could further improve our understanding of invasive carp movement and habitat use. For instance, receiver coverage in Smithland and Olmsted pools is poor with only two mainstem receivers near in the upper portion of Olmsted Pool and eight receivers at the locks and dams at the lower and upper ends of Smithland pool. Increasing receiver coverage in these pools would not only improve our understanding of movement and habitat use of invasive carps in the Ohio River, but would also inform movement between the Ohio River and three other large rivers with established invasive carp populations, the Wabash River (Smithland Pool) and the Tennessee and Cumberland Rivers (Olmsted Pool). Furthermore, deploying recievers at the downstream end of Olmsted Pool and in the open river between Olmsted Lock and Dam and the confluence of the Mississippi River would improve our understanding of movements between the Mississippi and Ohio rivers. Because all of these areas host large populations of invasive carps, understanding the movements of fish among these systems is critical to understanding source-sink dynamics and to effective management of these fishes. Specifically, understanding the movement of invasive carps between the Tennessee-Cumberland system and the Ohio River may elucidate movement patterns of invasive carps as they relate to deterrent technologies at Barkley Lock (e.g., do fish move away from the barrier at Barkley Lock and instead move upstream within the mainstem Ohio River?). In addition, broader spatial coverage in areas of low invasive carp density (i.e., upstream of Meldahl Pool) would help agencies understand the distribution of invasive carps in these areas and allocate removal efforts more efficiently. Accomplishing this may require the reallocation of some receivers in the upper pools to increase spatial coverage.

Although, current receiver deployments provide consistent year-round coverage of the lock chambers of all L&Ds between Smithland and Willow Island L&Ds, coverage near the gates of dams is lacking. Improving receiver coverage near dam gates could enhance our knowledge of pool-to-pool transitions (including the timing of these transitions as it relates to open-water conditions) as well as improve our ability to determine if L&D passages are primarily occurring through the lock chambers or through the dam gates. However, site selection near dam gates requires careful consideration because deploying stationary receivers in these areas is logistically challenging and raises concerns for the safety of agency personnel that would be tasked with downloading and maintaining the receivers.

There are currently 35 receivers deployed in the Wabash River. However, low waters and siltation has resulted in difficulties retrieving these receivers. These difficulties retrieving receivers mean that less information is being gathered in that system. Improving retrieval success is critical to understanding invasive carp movement within the Wabash River as well as among the Wabash and Ohio rivers. SIU is currently working to retrieve additional receivers and test different receiver deployments in the hopes of improving retrieval success.

In addition to adding receivers in specific areas to improve coverage, understanding the true coverage provided by those receivers currently deployed is critical to our understanding of fish movements and habitat use. The current combination of VR2W receivers and V16 transmitters used for invasive carp telemetry in the Ohio River ostensibly provides a detection range of 800 – 1200 m. Ambient conditions (e.g., turbidity, flow, receiver orientation) can, however, drastically affect detection ranges. It is, therefore, recommended that receivers be range-tested during a variety of conditions to determine reasonable expectations for the detection range of receivers in the Ohio River system.

Lastly, data management will continue to be vital as the telemetry program adds to the existing data set. Increases in the number of invasive carp detections are anticipated, especially within the lower pools of the Ohio River where the array and tagging efforts were expanded during 2021. Due to the expected increase in detections, front-end data management and data processing capability will become increasingly important to ensure that data are available for analysis in a timely manner. Furthermore, to accommodate the likely increase in time necessary to process and analyze these larger quantities of data, it is recommended that, as in 2022, each agency perform a download of all receivers in their areas of management and transfer the downloaded data to KDFWR by July 31 of each year. This will allow ample time for data processing, analysis, and reporting, and increase time for discussion of the results and potential improvements to analyses prior to reporting in March of the following year.

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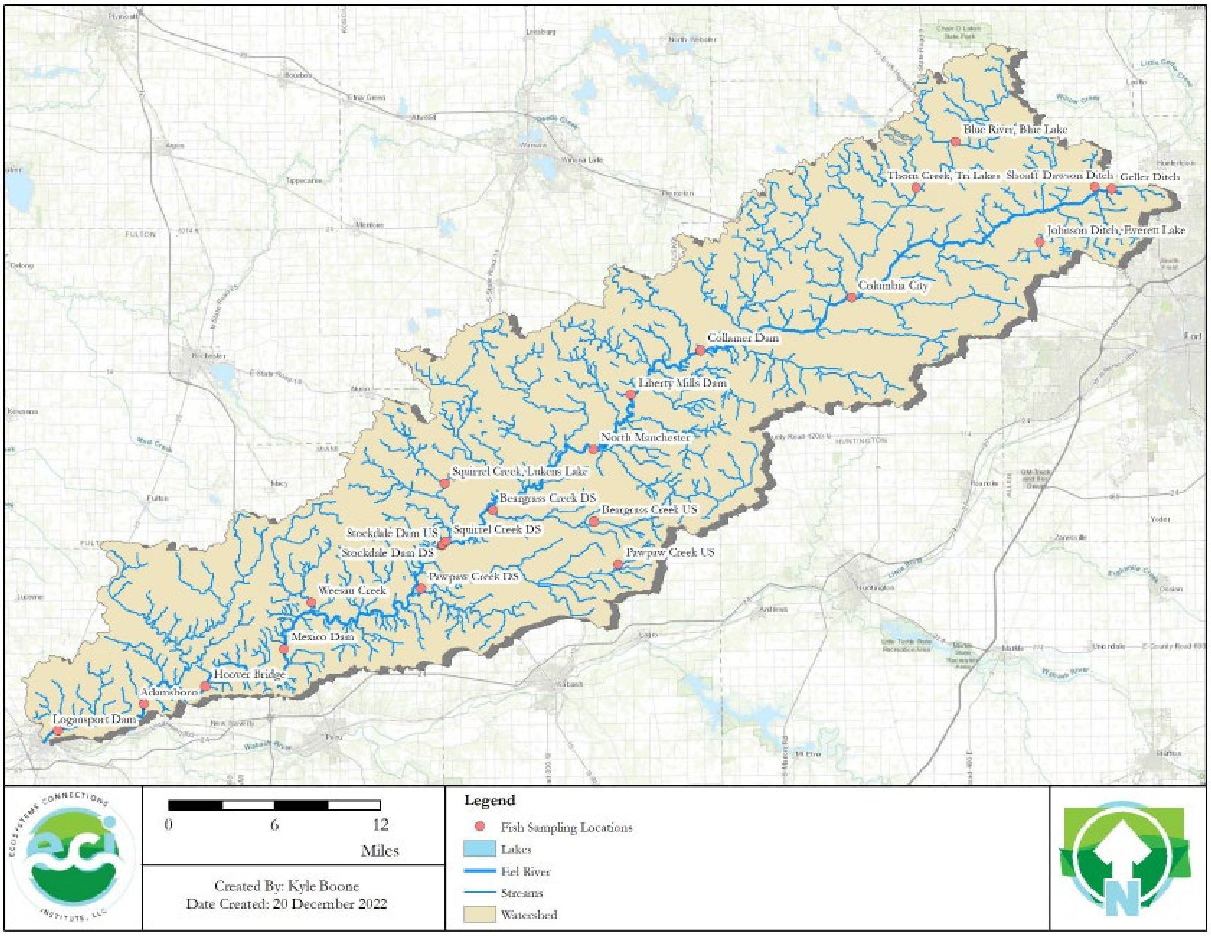


Figure 4. Locations of 22 fish sampling sites in the Eel River Watershed.

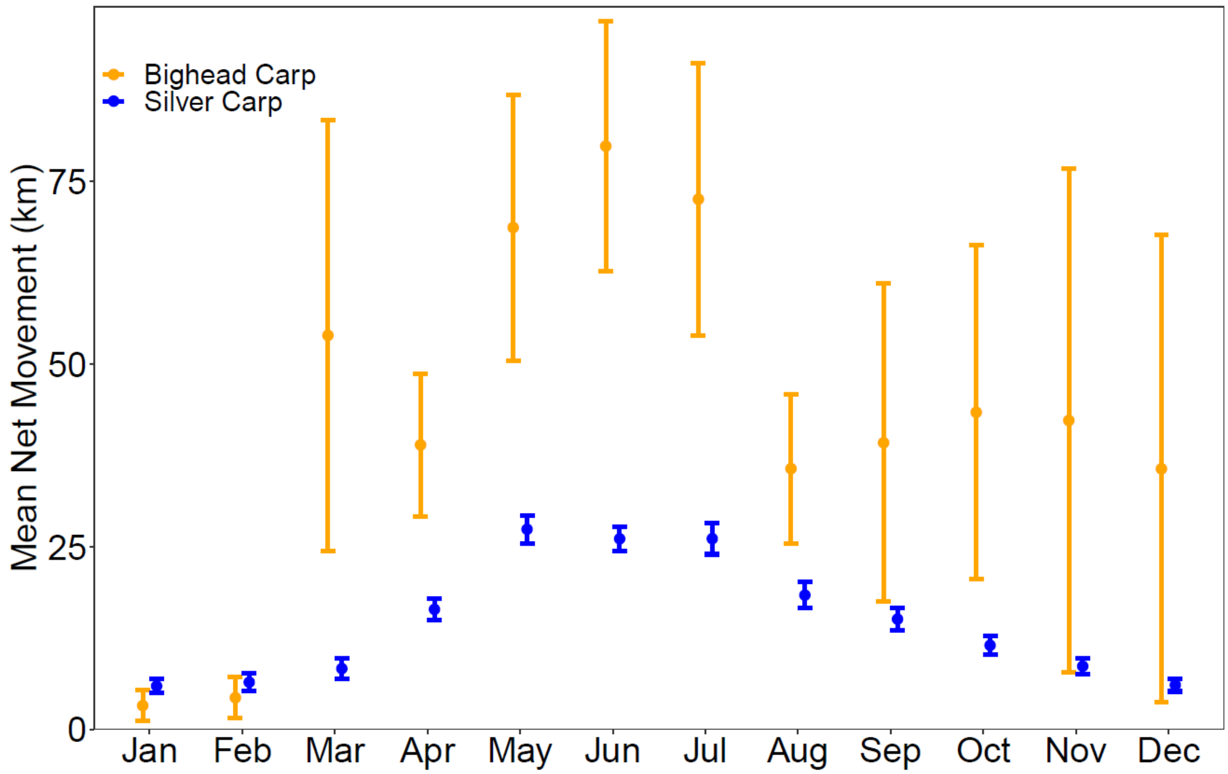


Figure 5. The mean monthly net movements (river kilometers) between the most upstream and downstream detections for tagged Silver Carp (blue) and Bighead Carp (orange) in J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, and Meldahl pools during June 2013 – July 2023. Error bars represent standard error. Only tagged carp detected ≥ 2 times during a month were included in the distance calculations.

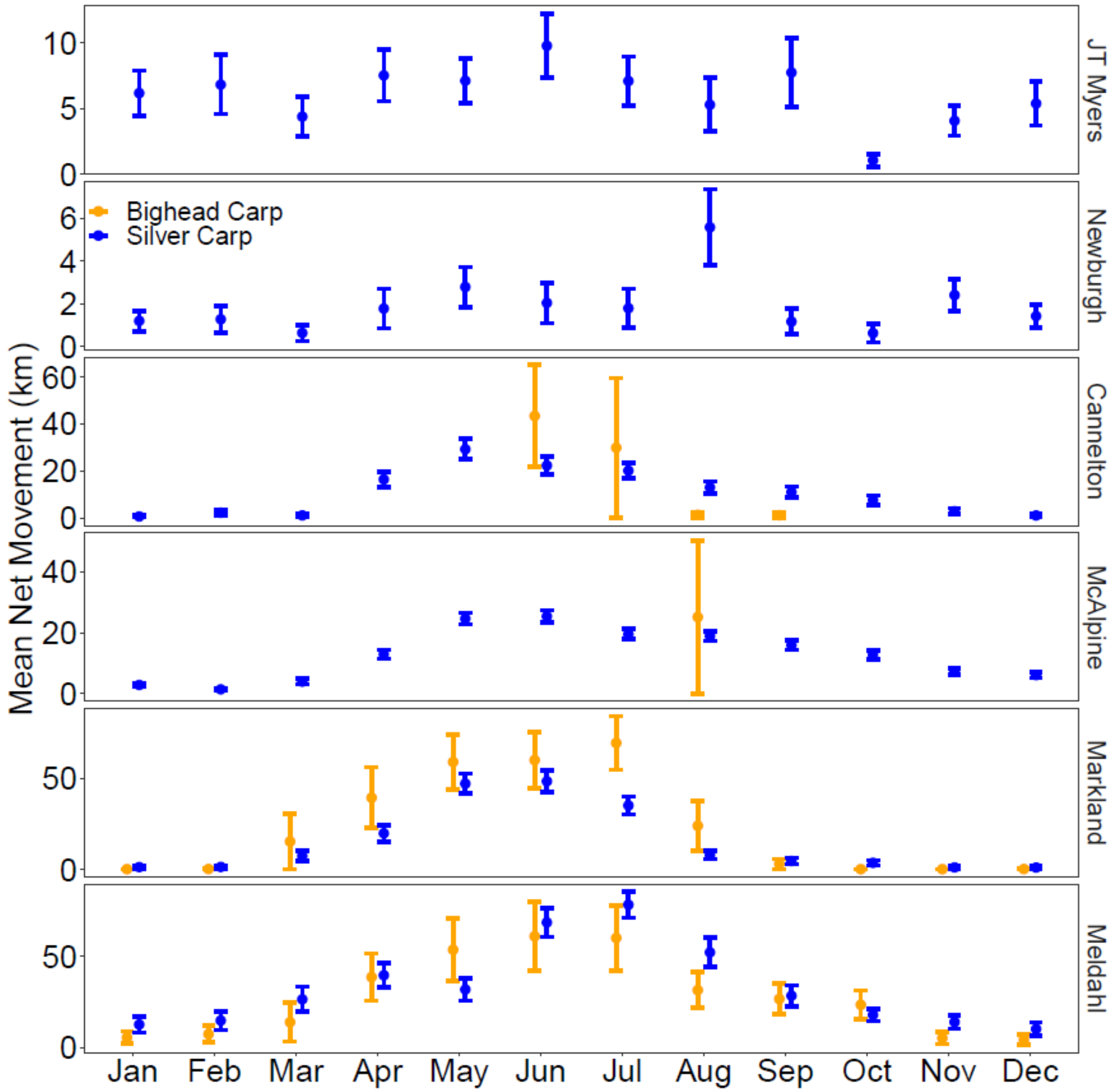


Figure 6. The mean monthly net movements (river kilometers) between the most upstream and downstream detections for tagged Silver Carp (blue) and Bighead Carp (orange) by pool in the six most active pools of the telemetry project (J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, and Meldahl pools) during June 2013 – July 2023. Error bars represent standard error. Only tagged carp detected ≥ 2 times within a single pool each month were included in the distance calculations.

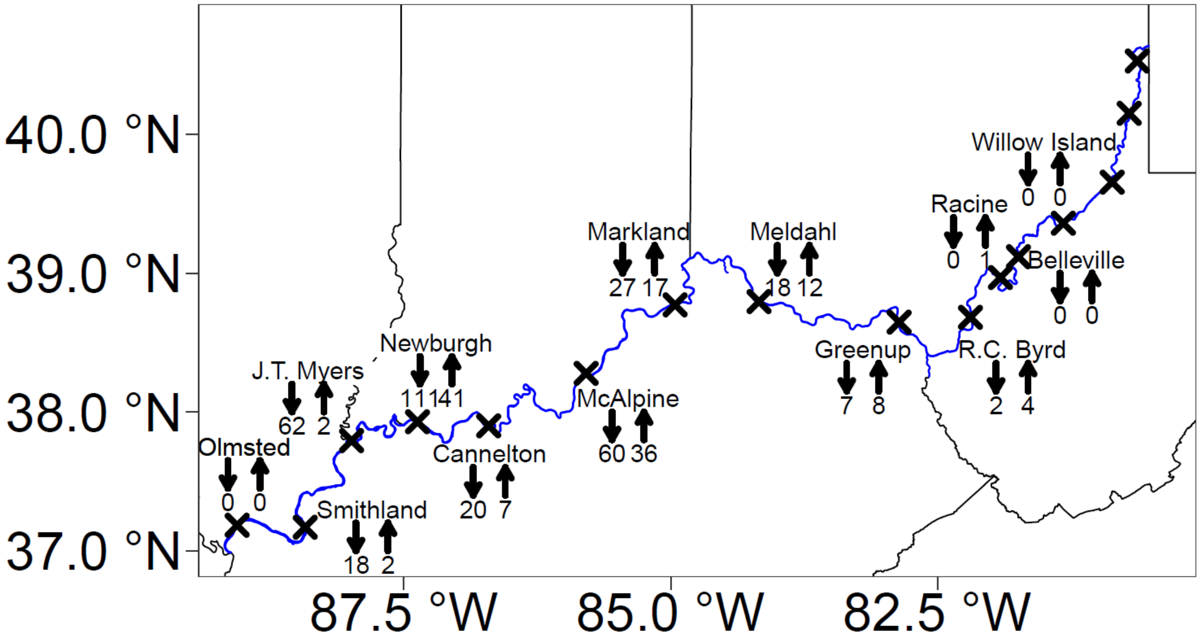


Figure 7. Total number of downstream (↓) and upstream (↑) lock and dam (L&D) passages by invasive carps during June 2013 – July 2022. Map shows passages from Olmsted L&D (river mile 964.4) near the confluence of the Ohio and Mississippi rivers to Willow Island L&D (river mile 161.7) which is the most upstream location at which acoustic receivers were deployed.

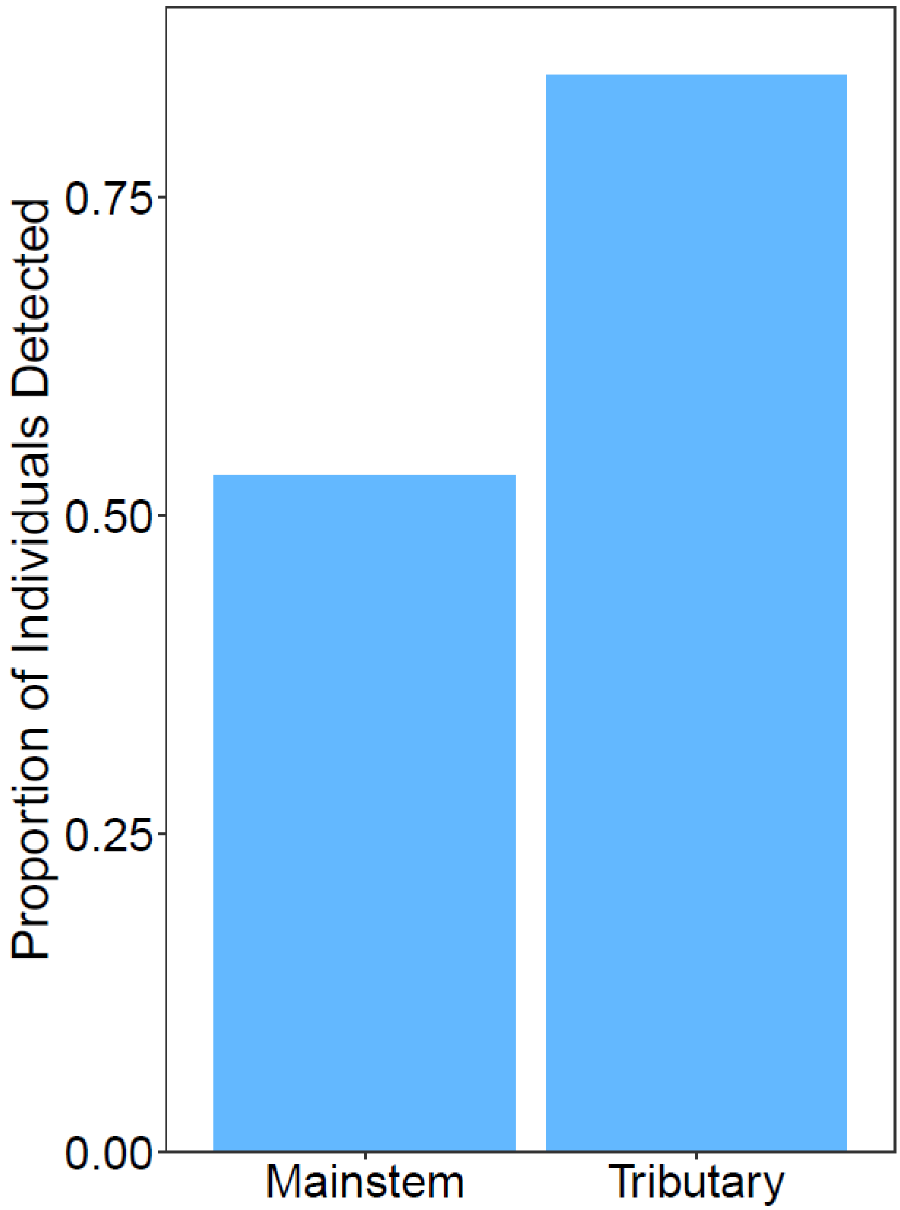


Figure 8. The proportion of individual Silver Carp detected in mainstem and tributary habitats during June 2013 – July 2023.

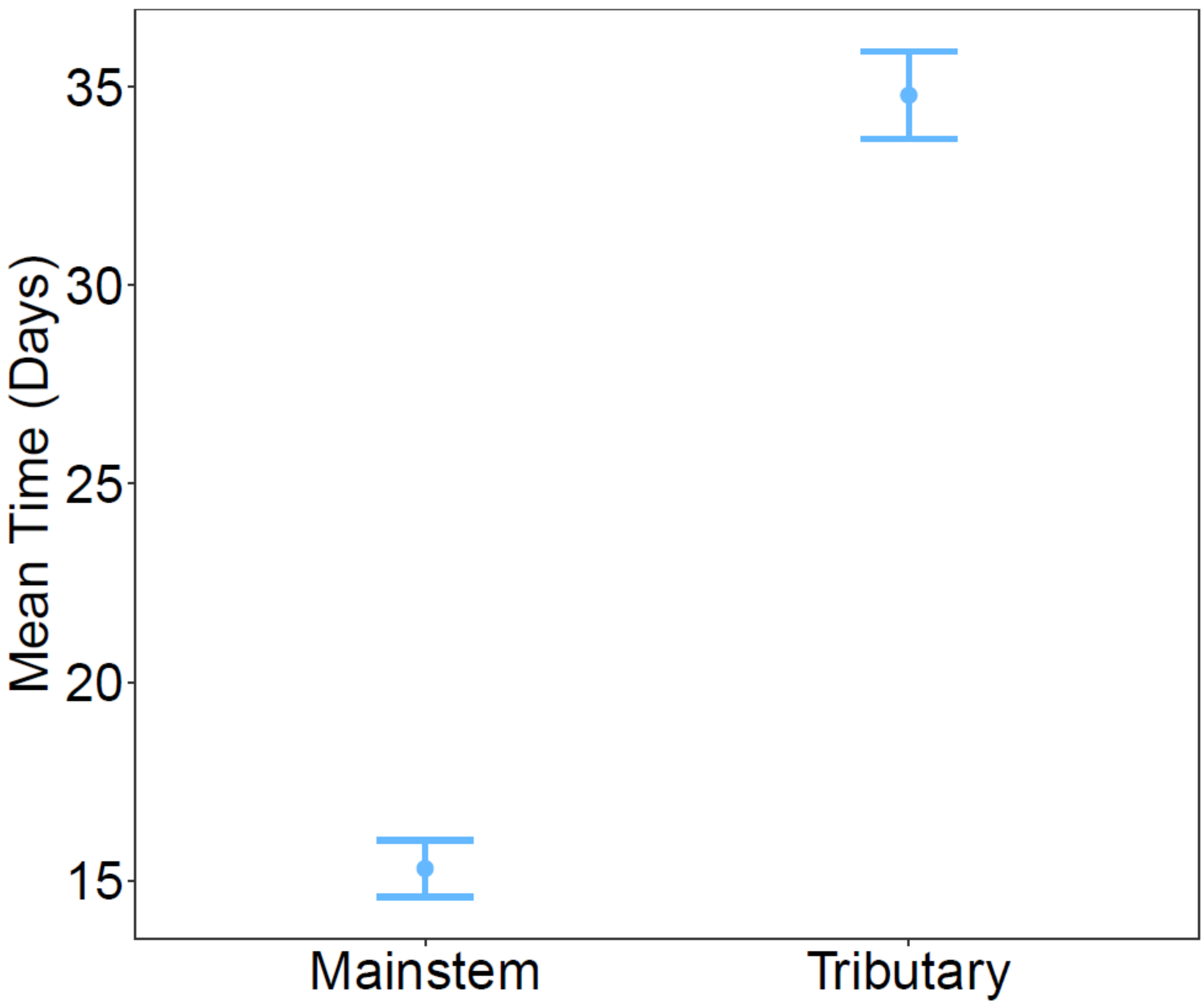


Figure 9. The mean time (days) spent in mainstem or tributary habitat for Silver Carps during June 2013 – July 2022. The number of days represents the time from the first detection of an individual in either the mainstem of the Ohio River or one of its tributaries to the first detection outside of that habitat.

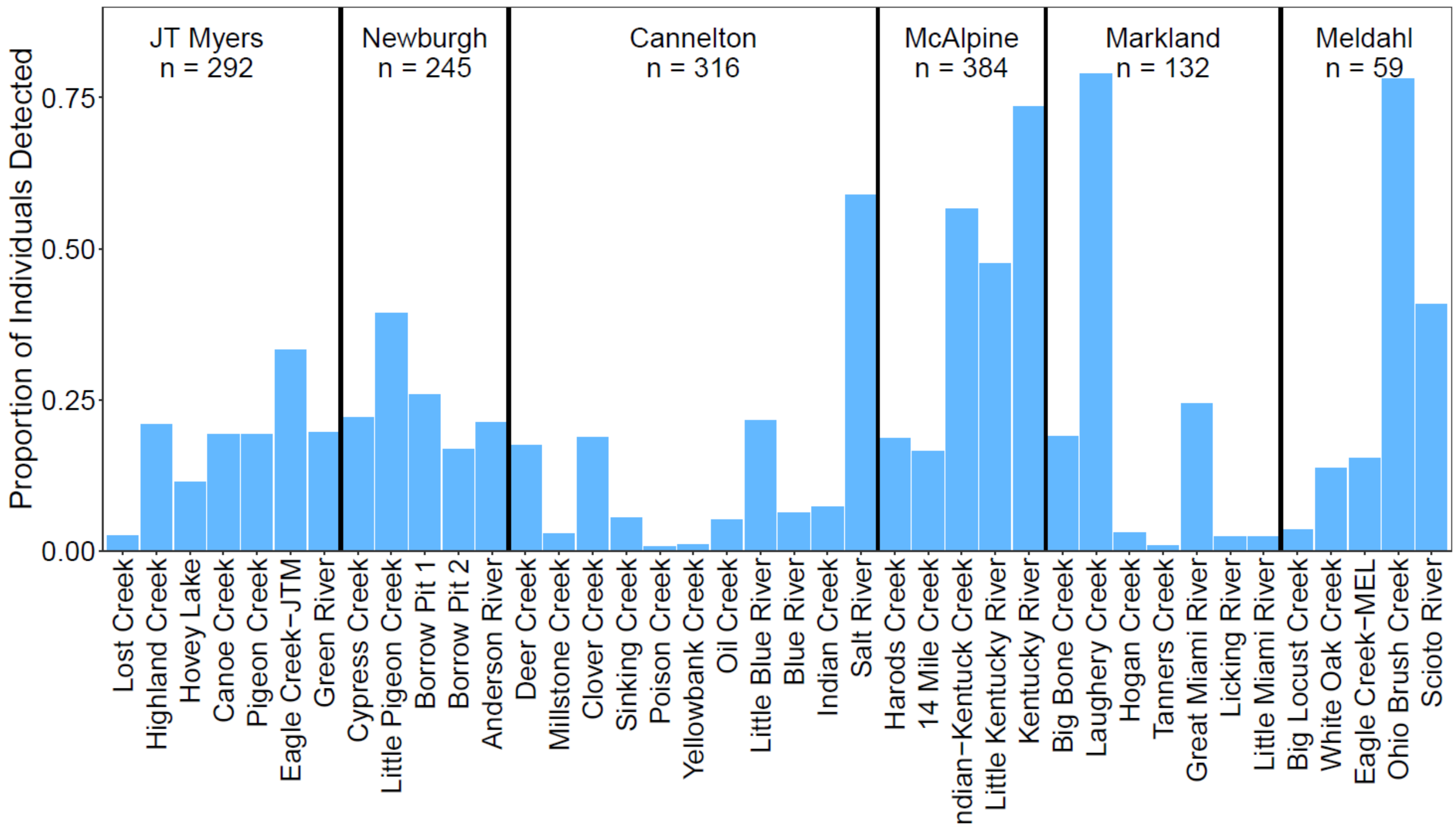


Figure 10. The proportion of individual Silver Carp in each pool that were detected in tributaries of those pools during June 2013 – July 2023. Numbers represent individual fish detected within that pool and the vertical lines are used to separate pools from most downstream to most upstream.

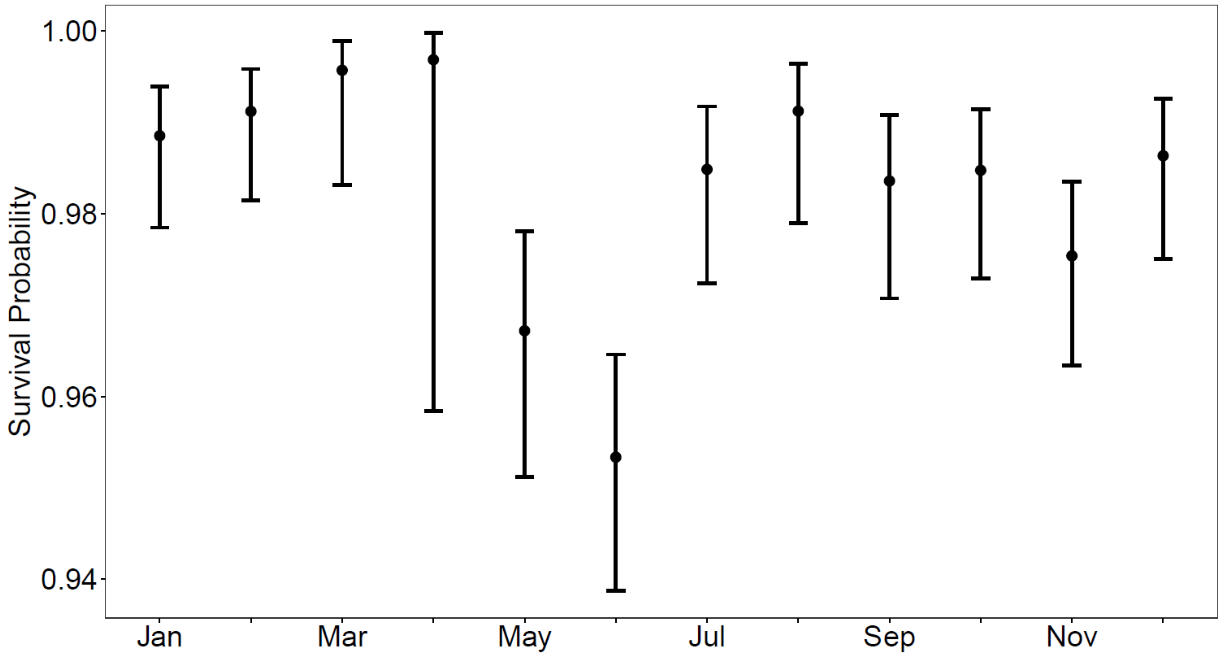


Figure 11. The effect of month probability of survival (S) of Silver Carps during January 2014 – July 2023. Plot shows mean probability of survival ± 95% confidence intervals for each month.

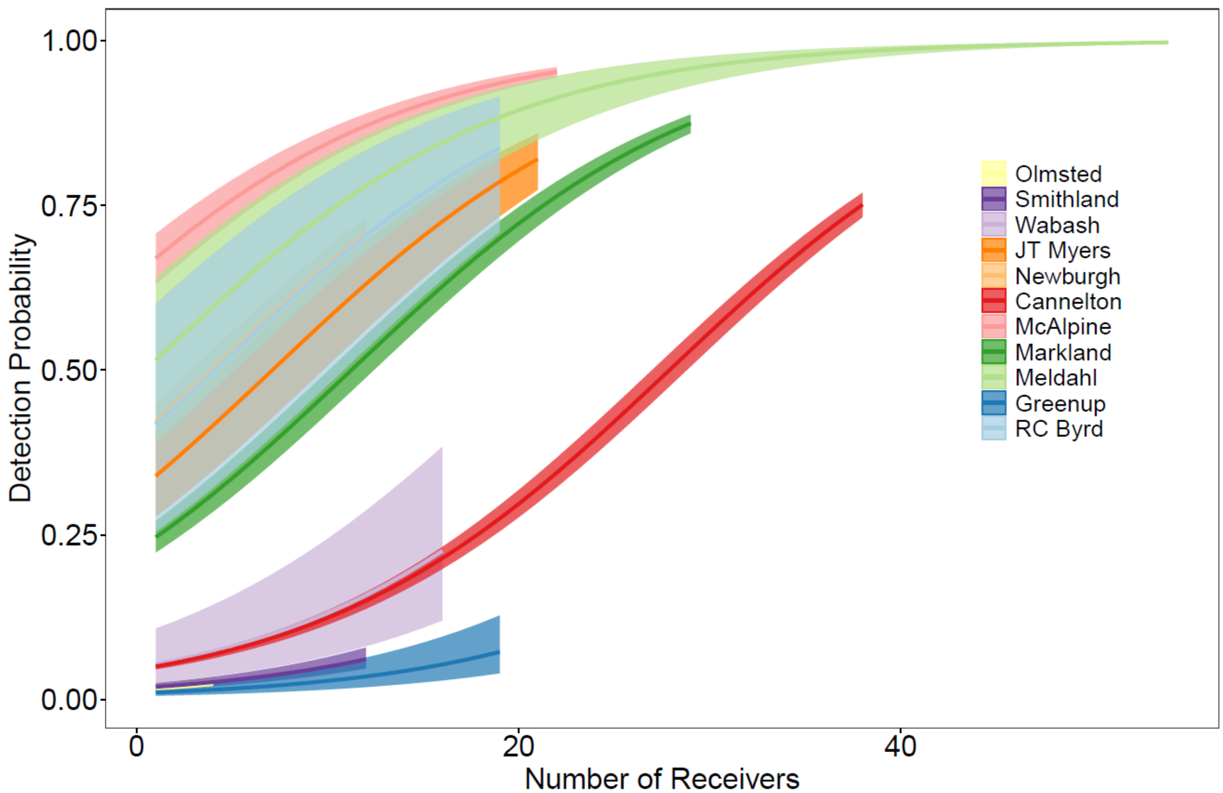


Figure 12. The effect of the number of receivers on the probability of detection (p) of Silver Carps in ten Ohio River pools and the Wabash River. The number of receivers ranged from 1 to 54 to reflect the number of receivers deployed in each pool during January 2014 – July 2023. The solid lines represent the mean probabilities of detection for each pool, whereas shaded areas represent the 95% confidence intervals surrounding those mean detection probabilities.

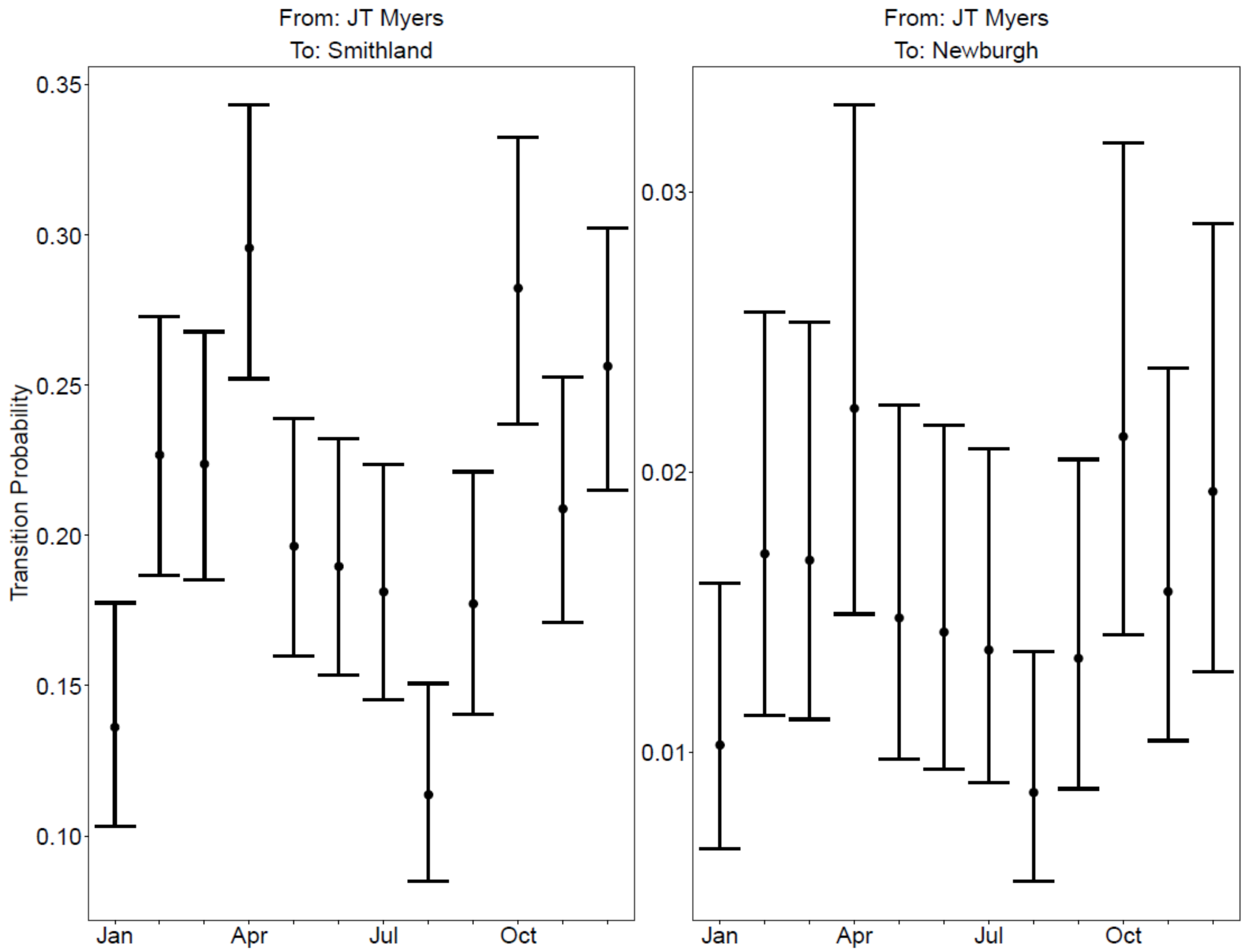


Figure 13. Monthly estimated transition probabilities (ψ) from J.T. Myers Pool downstream to Smithland Pool (left) and from J.T. Myers Pool upstream to Newburgh Pool (right). Plots for other pools are available from USFWS, CAR FWCO.

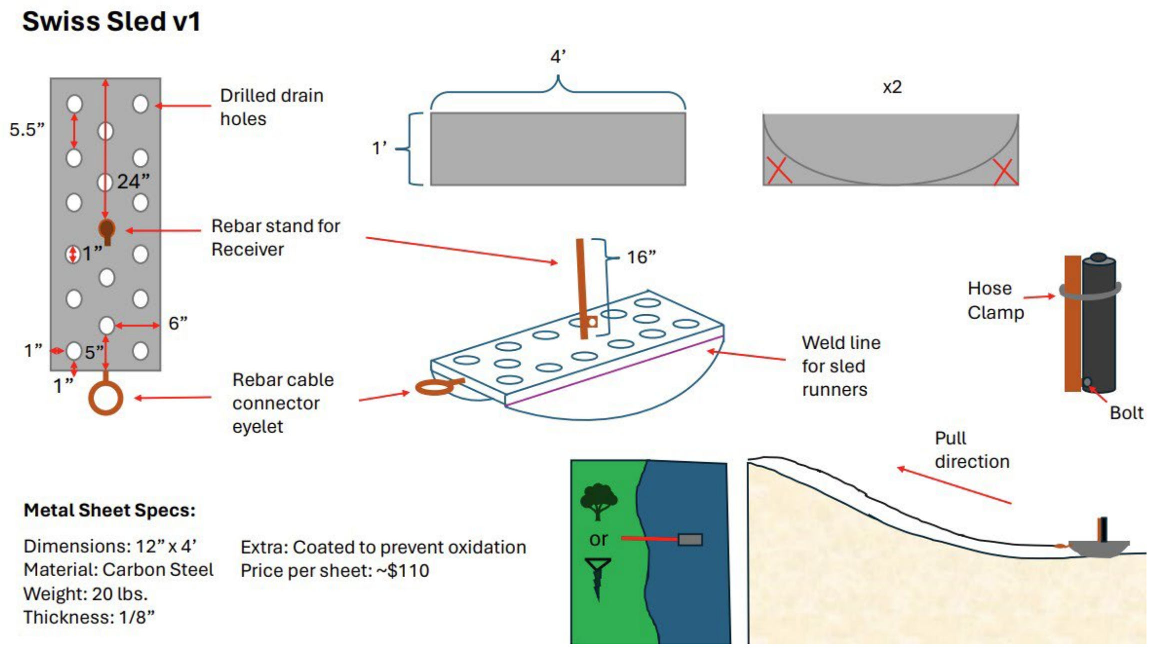


Figure 14. New "Swiss sled" design for deploying stationary VR receivers for fish acoustic telemetry in the Wabash and White Rivers. This prototype will be tested in the Wabash River to determine whether receivers can be better retrieved from the shifting sand bed of the river.

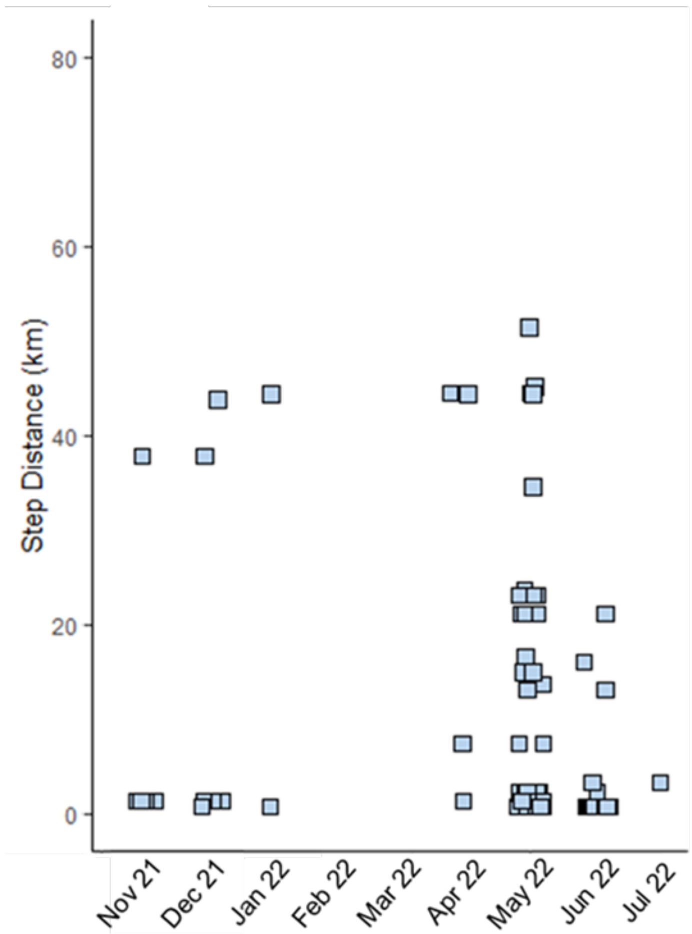


Figure 15. Net movement of silver carp in the Wabash River as a function of season and year as detected on the acoustic receiver network. Silver carp moved more during May 2022 perhaps as a function of elevated discharge and spawning.

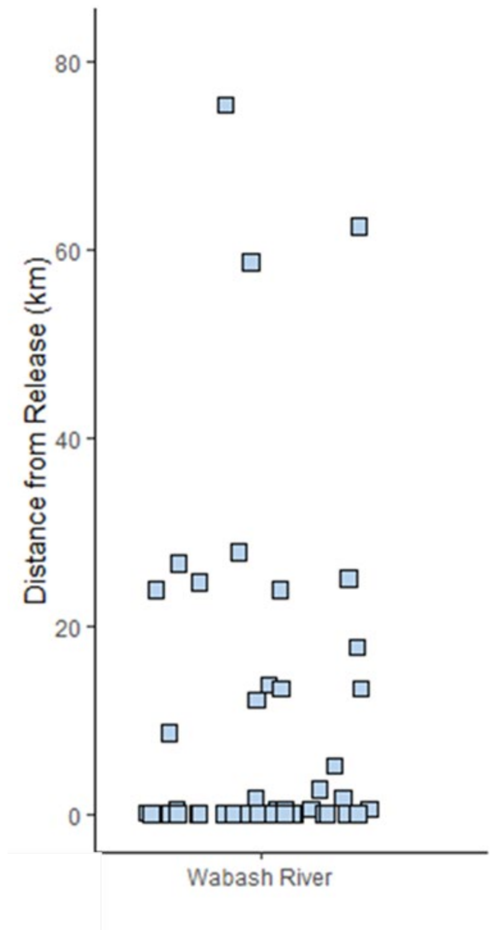


Figure 16. Farthest distance moved by silver carp as detected by the acoustic receiver array within the Wabash River during 2022 through 2023.

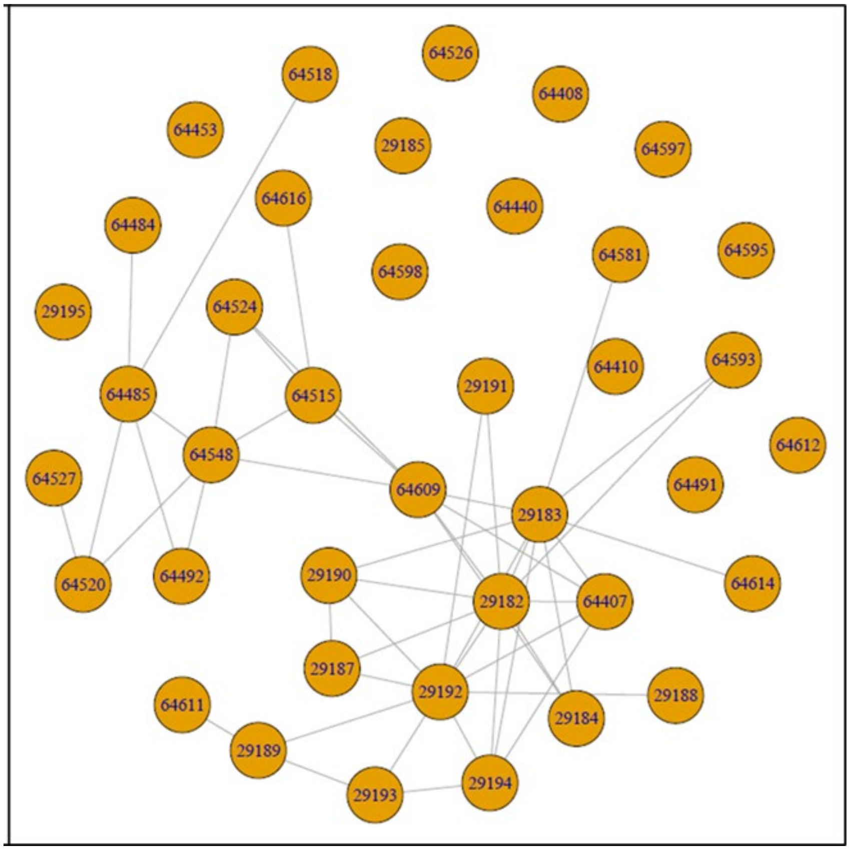


Figure 17. Network analysis of silver carp movement in the Wabash River. Each circle with number is an individually tagged silver carp. Proximity of silver carp movement to each other is depicted by connectors and proximity of circles. If all fish moved similarly, the nodes would be highly connected and circles clustered. An interpretation of this analysis is that silver carp move freely within the river, perhaps due to a lack of barriers.

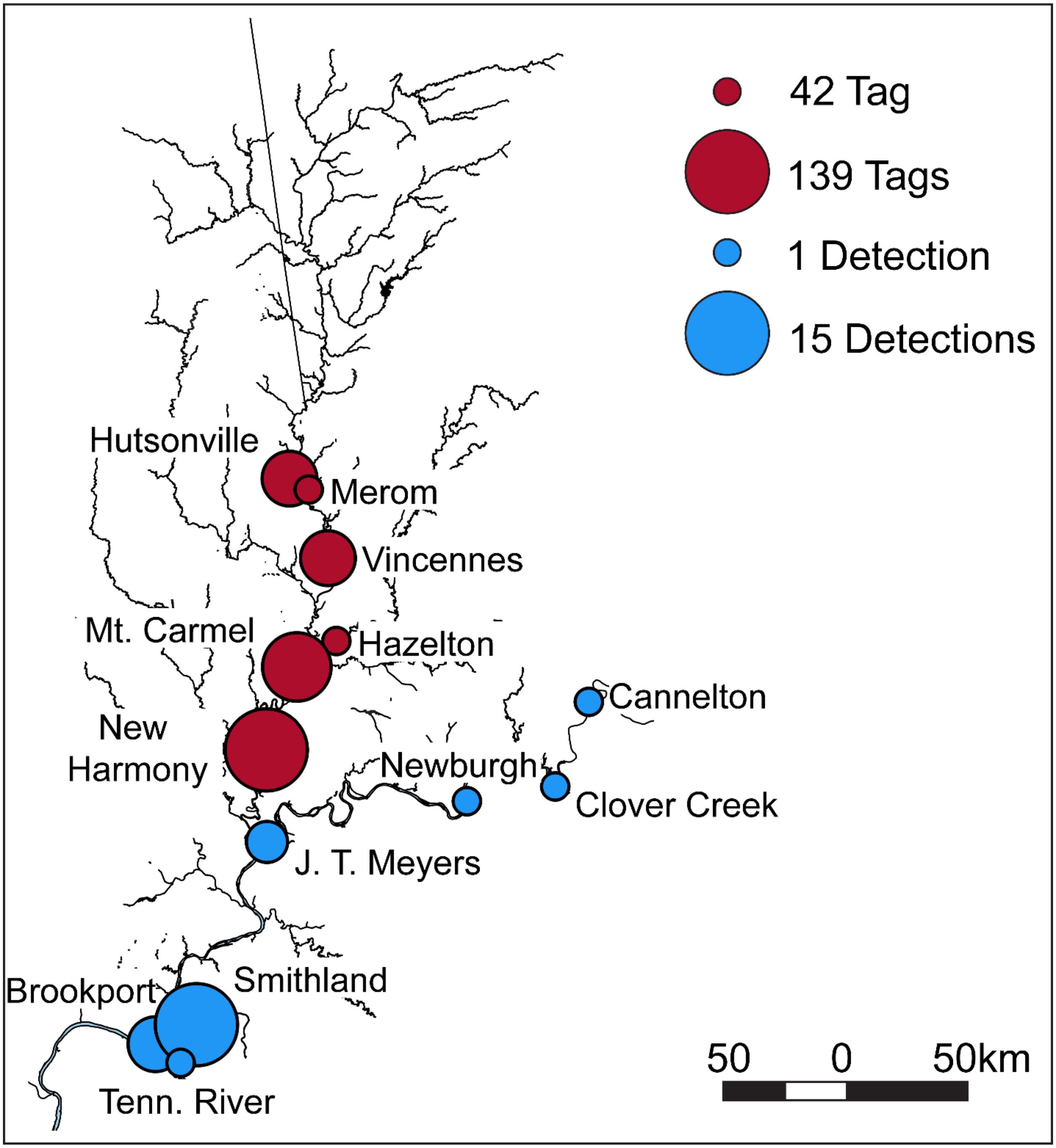


Figure 18: Map of tagging sites in the White and Wabash Rivers (Red) and receiver locations (blue) in the Ohio River from 2021-2023. For locations with multiple receivers (e.g. lock and dam structures) detections from all receivers were pooled, and the number of unique fish are reported.

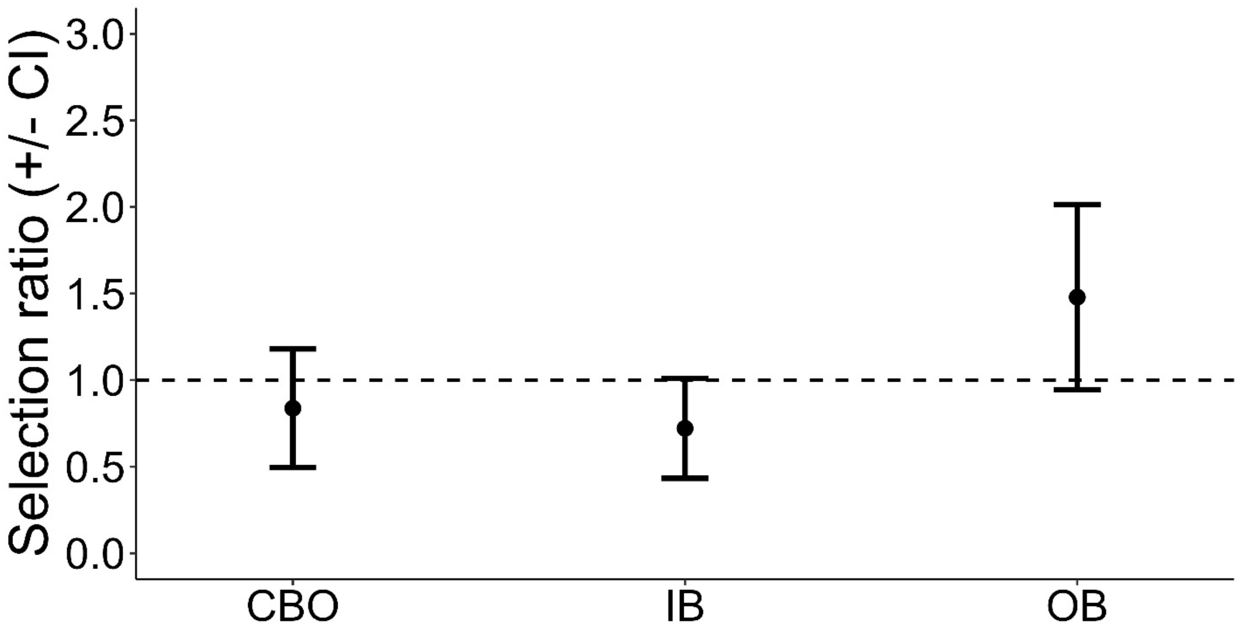


Figure 19. Selection ratios with 95% confidence intervals for macro-habitat [channel border open (CBO), inside bend (IB), and outside bend (OB)] in the Wabash and White rivers. Values greater than one indicate positive selection while values less than one indicate avoidance. These ratios were calculated using 305 detections of 108 unique individuals from 2021 to 2023.

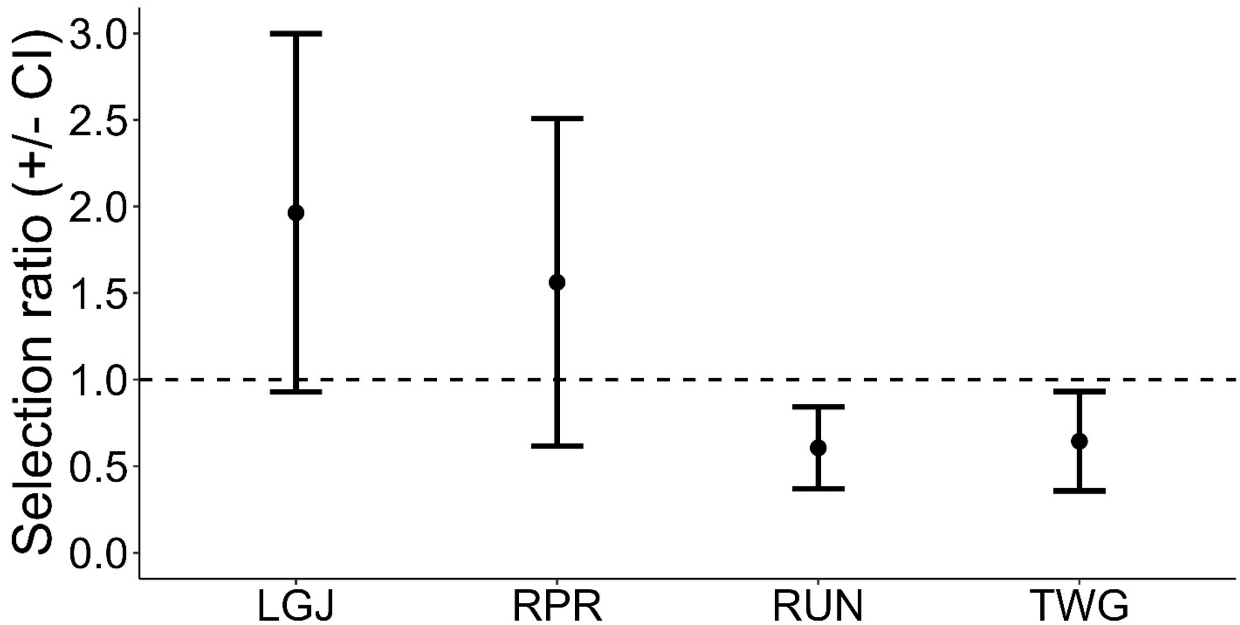


Figure 20. Selection ratios with 95% confidence intervals for micro-habitat [logjam (LGJ), rip-rap (RPR), run, and thalweg (TWG)] in the Wabash and White rivers. Values greater than one indicate positive selection while values less than one indicate avoidance. These ratios were calculated using 322 detections of 112 unique individuals from 2021 to 2023.

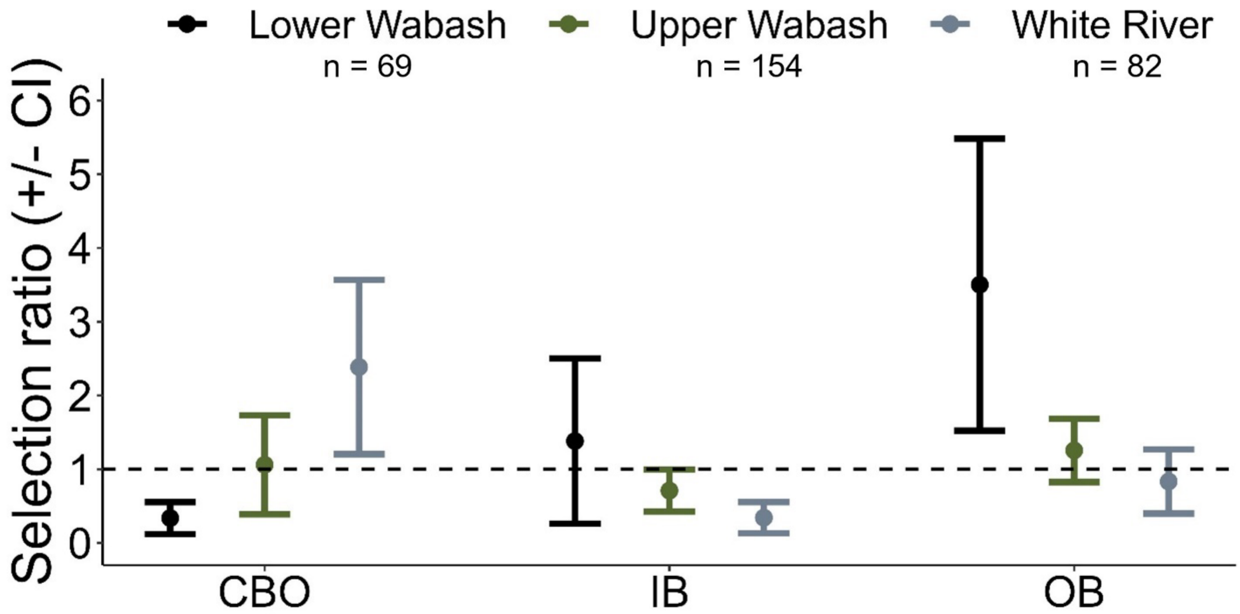


Figure 21. Selection ratios with 95% confidence intervals for macro-habitat [channel border open (CBO), inside bend (IB), and outside bend (OB)] within the Lower Wabash (Mt. Carmel, IL to Ohio River confluence), Upper Wabash (Terre Haute, IN to Mt. Carmel, IL) and White River (Maysville, IN to confluence with Wabash). Values greater than one indicated positive selection while values less than one indicate avoidance. These ratios were calculated using 305 detections of 108 unique individuals from 2021 to 2023.

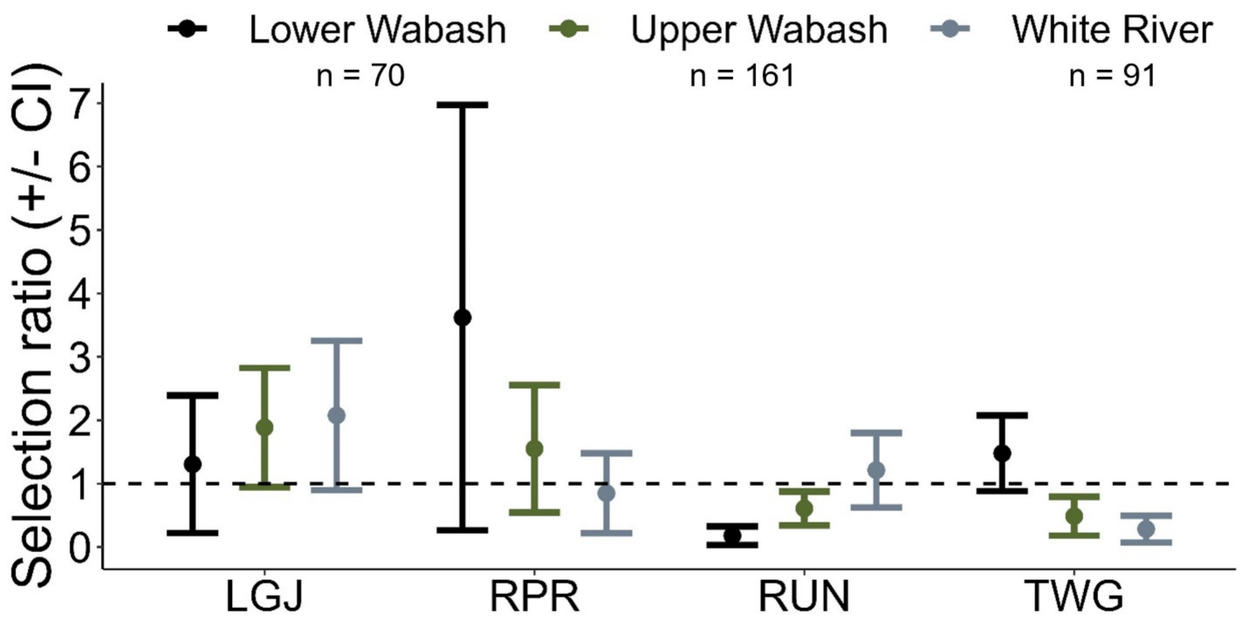


Figure 22. Selection ratios with 95% confidence intervals for micro-habitat [logjam (LGJ), rip-rap (RPR), run, and thalweg (TWG)] within the Lower Wabash (Mt. Carmel, IL to Ohio River confluence), Upper Wabash (Terre Haute, IN to Mt. Carmel, IL) and White River (Maysville, IN to confluence with Wabash). Values greater than one indicated positive selection while values less than one indicate aviodance. These ratios were calculated using 322 detections of 112 unique individuals from 2021 to 2023.

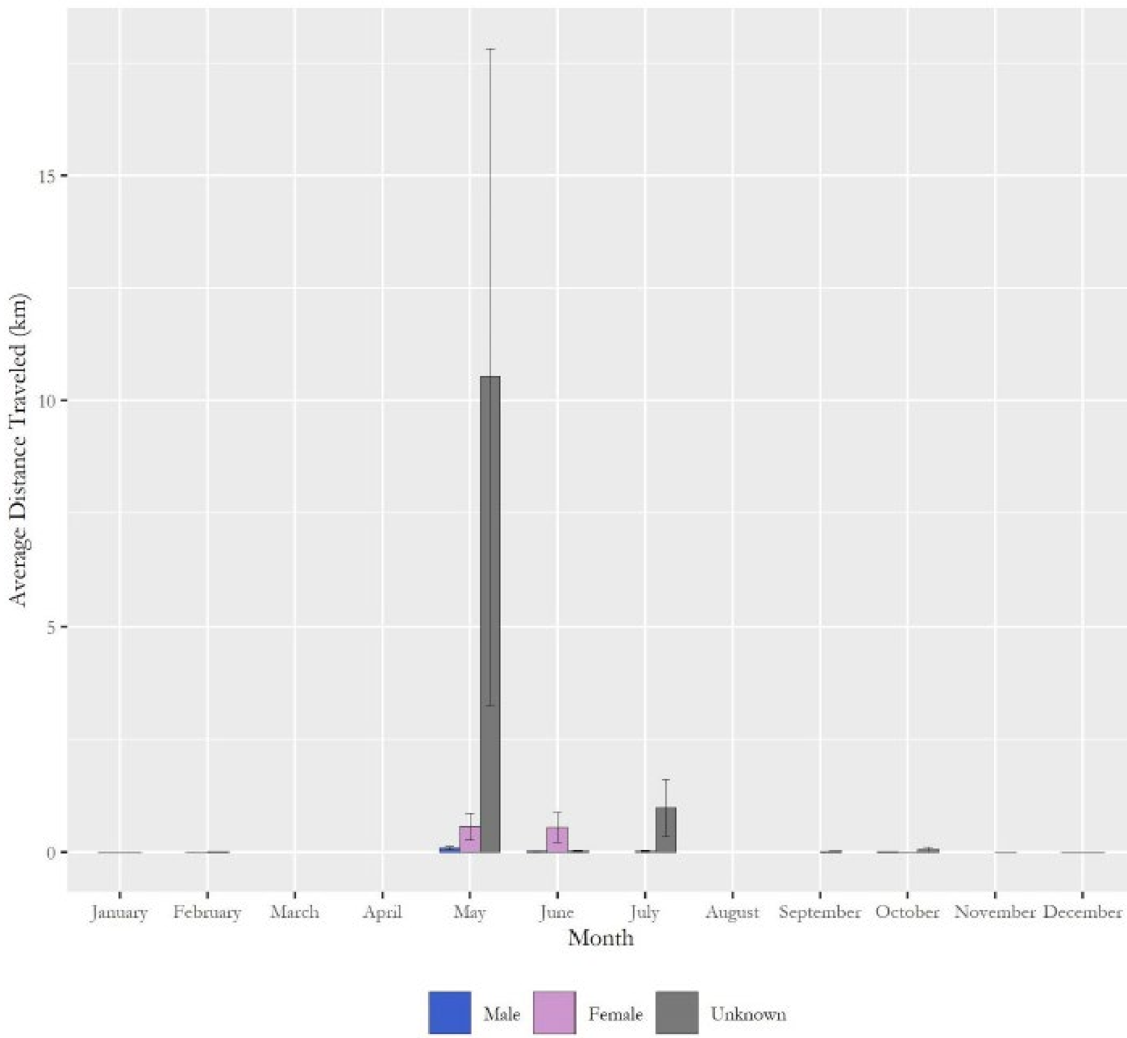


Figure 23. Average distance traveled per month for male, female, and fish where gender was unknown, for Silver Carp that were detected in the Upper Wabash River Basin network of acoustic receivers. A total of 68 Silver Carp were detected up to 21 December 2023. Months where no bars are showing indicate months where no movements were recorded for any fish. Error bars represent ± the standard error of the mean.

Table 1. The ID number, pool, and available data for US Geological Survey gage stations used in the pool-to-pool multistate model.

Gage ID	Pool	Gage Height	Temperature	Discharge
3399800	Olmsted	X		X
3611000	Olmsted	X		
3612600	Olmsted	X	X	X
3381700	Smithland	X		X
3384500	Smithland	X		
3377500	Wabash	X		X
3378500	Wabash	X	X	X
3304300	J.T. Myers	X		
3322000	J.T. Myers	X		
3322190	J.T. Myers	X		
3322420	J.T. Myers	X		
3303280	Newburgh	X	X	X
3294500	Cannelton	X		
3294600	Cannelton	X		
3292494	McAlpine	X		X
3293551	McAlpine	X		
3255000	Markland	X		
3217200	Meldahl	X		
3238000	Meldahl	X		
3206000	Greenup	X		
3216000	Greenup	X		
3216070	Greenup	X	X	X
3201500	R.C. Byrd	X		

Table 2. Model selection results for survival probability (*S*) of the multi-state with live recaptures model for Silver Carp pool-to-pool movements. The table shows the model structure, number of parameters in the model (npar), AIC_c, ΔAIC_c, and the AIC weight (W_i) for all model structures that converged for survival probability. The covariates affecting estimates of the survival probability are shown in parentheses and include temperature (temp), month, season, and pool. The "." notation indicates an invariant survival probability. The model structures for detection (*p*) and transition (ψ) probabilities were held constant and included only a pool effect for both parameters.

Model	**npar**	**AIC_c**	**ΔAIC_c**	**W_i**
S(month)p(pool)ψ(pool)	43	57457.89	0	1
S(season)p(pool)ψ(pool)	35	57495.89	38.0	0
S(.)p(pool)ψ(pool)	32	57529.52	71.63	0
S(temp)p(pool)ψ(pool)	33	57541.83	83.93	0

Table 3. Model selection results for detection probability (*p*) of the multi-state with live recaptures model for Silver Carp pool-to-pool movements. The table shows the model structure, number of parameters in the model (npar), AIC_c, ΔAIC_c, and the AIC weight (W_i) for all model structures for detection probability. The covariates affecting estimates of the detection probability are shown in parentheses and include the number of receivers (num_rec), the number of receivers per river mile (rprm), standardized gage height (std.height), month, season, and pool. The "." notation indicates an invariant detection probability. The model structures for survival (*S*) and transition (ψ) probabilities were held constant and included only a month effect for *S* (the best supported model structure) and a pool effect for ψ.

Model	npar	AIC_c	ΔAIC_c	W_i
$S(month)p(pool + num\_rec)\psi(pool)$	44	55261.9	0	1
$S(month)p(pool + rprm)\psi(pool)$	44	55295.56	33.66	0
$S(month)p(pool*season)\psi(pool)$	76	56951	1689.10	0
$S(month)p(pool* month)\psi(pool)$	164	57008.25	1746.35	0
$S(month)p(pool + month)\psi(pool)$	54	57033.66	1771.76	0
$S(month)p(pool + season)\psi(pool)$	46	57200.13	1938.23	0
$S(month)p(pool + std.height)\psi(pool)$	44	57240.63	1978.73	0
$S(month)p(pool)\psi(pool)$	43	57457.89	2195.99	0
$S(month)p(rprm)\psi(pool)$	34	57750.51	2488.61	0
$S(month)p(num\_rec)\psi(pool)$	34	58921.61	3659.71	0
$S(month)p(month)\psi(pool)$	44	61439.97	6178.07	0
$S(month)p(season)\psi(pool)$	36	61687.33	6425.43	0
$S(month)p(std.height)\psi(pool)$	34	61911.3	6649.39	0
$S(month)p(.)\psi(pool)$	33	62185.36	6923.46	0

Table 4. Model selection results for transition probabilities (ψ) of the multi-state with live recaptures model for Silver Carp pool-to-pool movements. The table shows the model structure, number of parameters in the model (npar), AIC_c, ΔAIC_c, and the AIC weight (W_i) for all model structures that converged for transition probabilities. The covariates affecting estimates of the transition probabilities are shown in parentheses and include standardized gage height (std.height), linear and quadratic effects of temperature (temp), month, season, and pool. The "." notation indicates an invariant transition probability. The model structures for survival (*S*) and detection (*p*) probabilities were held constant and included only a temperature effect for *S* and the additive effect of pool and receivers per river mile for *p*.

Model	npar	AIC_c	ΔAIC_c	W_i
$S(month)p(pool + num\_rec)\psi(pool + month)$	56	55144.77	0	1
$S(month)p(pool + num\_rec)\psi(pool + season)$	48	55219.49	74.72	0
$S(month)p(pool + num\_rec)\psi(pool + std.height)$	45	55245.95	101.18	0
$S(month)p(pool + num\_rec)\psi(pool + temp)$	45	55247.33	102.57	0
$S(month)p(pool + num\_rec)\psi(pool + temp + temp^2)$	45	55247.33	102.57	0
$S(month)p(pool + num\_rec)\psi(pool)$	44	55259.58	114.81	0
$S(month)p(pool + num\_rec)\psi(month)$	36	57275.96	2131.19	0
$S(month)p(pool + num\_rec)\psi(pool + std.height + temp + temp^2)$	46	58517.64	3372.87	0
$S(temp)p(pool + rprm)\psi(pool + std.height + temp)$	46	58519.85	3375.08	0

Table 5: Number of silver carp tagged at each location in the Wabash River system 2021-2023.

Tagging Location	No. Fish	Latitude	Longitude
Hazelton	55	38.49	-87.54
Hutsonville	98	39.11	-87.65
Merom	42	39.06	-87.57
Mt. Carmel	109	38.42	-87.74
New Harmony	139	38.13	-87.94
Vincennes	94	38.80	-87.53

Table 6. Number and distribution of VR2 receivers in the Ohio River during 2023. One-hundred sixty-two receivers were deployed from Olmsted pool, downstream of the Smithland lock and dam, to Willow Island lock and dam.

Ohio River Pool	Pool Length (km)	Lock and Dam Receivers (N)	Mainstem Receivers (N)	Tributary Receivers (N)	Total Receivers (N)
Olmsted	73.9	0	2	1	3
Smithland	116.7	7	0	2	9
J.T. Myers	112.5	4	1	14	19
Newburgh	89.1	4	0	8	12
Cannelton	183.3	1	10	34	45
McAlpine	121.2	3	3	5	11
Markland	153.3	0	2	6	8
Meldahl	153.2	7	9	8	24
Greenup	99.4	3	6	3	12
R.C. Byrd	67.1	4	5	8	16
Racine	54.1	4	1	2	7
Belleville	67.9	5	1	1	7
Willow Island	56.8	1	0	0	1
Total	1348.3	43	40	91	174

Table 7. The number of Silver and Bighead Carps tagged with acoustic transmitters by year and pool during June 2013 – December 2023. Numbers in parenthesis are fish with tags that have been reported as harvested before expected tag expiration and, therefore, are no longer active. Tags deployed for > 5 years are expected to be expired (inactive). Also included are species composition calculations for the tags expected to be active in each pool and the mean total length (mm) of all tagged fish by pool.

Year(s)	Status after 2023	Species	Ohio River Pool								Total
			J.T. Myers	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup	R.C. Byrd	
2013	Inactive	SVCP	-	-	-	-	-	6	-	-	6
		BHCP	-	-	-	-	-	13	-	-	13
2014	Inactive	SVCP	-	-	-	111	6	10	-	-	127
		BHCP	-	-	-	4	4	-	-	-	8
2015	Inactive	SVCP	-	-	-	23	3	5	-	-	30
		BHCP	-	-	-	1	1	5	-	-	7
2016	Inactive	SVCP	-	-	92	94	6	-	-	-	192
		BHCP	-	-	4	1	4	2	-	3	14
2017	Inactive	SVCP	-	-	90	-	12	3	-	-	105
		BHCP	-	-	-	-	2	-	-	-	2
2018	Inactive	SVCP	-	-	-	-	21	10	-	-	31
		BHCP	-	-	-	-	-	1	-	-	1
2019	Inactive	SVCP	-	-	-	30	-	-	-	-	30
		BHCP	-	-	-	1	-	-	-	-	1
2020	Active	SVCP	-	-	-	100 (1)	18	-	-	-	118
2021	Active	SVCP	226 (1)	230	92	97	3	-	-	-	648
2022	Active	SVCP	-	-	108 (1)	-	29	-	-	-	137
2023	Active	SVCP	-	-	-	-	53	30	-	-	83
2020-2023	Active	SVCP	225	230	199	197	103	30	-	-	985
2013-2019 (Including harvested)	Inactive	SVCP	1	-	182	259	48	34	-	-	524
		BHCP	-	-	4	6	11	21	-	3	45
		Overall	-	-	186	265	59	55	-	3	569

% Species Composition	Active	SVCP	22.9	23.4	20.0	23.4	10.5	3.0	0.0	0.0	100
Mean TL (mm)	Combined	SVCP	699.7	708.5	787.7	818.7	896.0	949.0	-	-	799.5
		BHCP	-	-	1139.8	1169.0	1175.1	1154.5	-	1210	1160.1

Table 8. Model-estimated mean (95% confidence intervals) pool-to-pool transition probabilities (ψ) of Silver Carps in the Ohio River derived from acoustic telemetry during January 2014 – July 2023. The highest-ranked model for Silver Carp included the additive effect of pool and month on transition probabilities. Black-shaded cells represent transitions among non-adjacent pools for which transition probabilities were not estimated. These transition probabilities were fixed to 0 and are, therefore, not reported in the table below. The probability of fish remaining within a pool is given in the gray shaded cells; upstream transition probabilities are to the right of gray-shaded cells and downstream transition probabilities are to the left of gray-shaded cells. No Silver Carps were detected above Racine Lock and Dam. Therefore, transition probabilities were not estimated for pools upstream of R.C. Byrd Pool. Shown here are the estimated transition probabilities during April and August, the months of the highest and lowest estimated pool-to-pool transition probabilities, respectively. Tables for other months are available from USFWS, CAR FWCO.

April

Departure Pool	Destination Pool										
	Olmsted	Smithland	Wabash	J.T. Myers	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup	R.C. Byrd
Olmsted	0.945	0.055 (0.026 - 0.113)									
Smithland	0.175 (0.124 - 0.242)	0.647	0.025 (0.014 - 0.047)	0.153 (0.121 - 0.191)							
Wabash		0.121 (0.037 - 0.329)	0.879								
J.T. Myers		0.296 (0.252 - 0.343)		0.682	0.022 (0.015 - 0.033)						
Newburgh				0.055 (0.043 -0.070)	0.941	0.004 (0.002 - 0.009)					
Cannelton					0.003 (0.002 - 0.004)	0.899	0.098 (0.085 - 0.112)				
McAlpine						0.162 (0.142 - 0.184)	0.835	0.003 (0.002 - 0.005)			
Markland							0.018	0.977	0.005		

							(0.012 -0.028)		(0.002 - 0.010)		
Meldahl								0.012 (0.006 - 0.025)	0.898	0.090 (0.065 - 0.122)	
Greenup									0.294 (0.217 - 0.384)	0.664	0.042 (0.019 -0.093)
R.C. Byrd										0.125 (0.051 - 0.277)	0.875
August											
Olmsted	0.983	0.017 (0.008 - 0.038)									
Smithland	0.070 (0.044 - 0.109)	0.860	0.010 (0.005 - 0.020)	0.061 (0.042 - 0.086)							
Wabash		0.040 (0.011 - 0.130)	0.960								
J.T. Myers		0.114 (0.085 - 0.151)		0.878	0.009 (0.005 -0.014)						
Newburgh				0.017 (0.012 - 0.024)	0.982	0.001 (0.000 - 0.003)					
Cannelton					0.001 (0.000 - 0.001)	0.968	0.031 (0.024 - 0.041)				
McAlpine						0.055 (0.042 - 0.071)	0.944	0.001 (0.001 - 0.002)			
Markland							0.005 (0.003 - 0.009)	0.993	0.001 (0.000 - 0.003)		
Meldahl								0.004 (0.002 - 0.008)	0.967	0.029 (0.020 - 0.043)	
Greenup									0.115	0.869	0.017

	[redacted]	(0.075 - 0.173)		(0.007 - 0.039)
R.C. Byrd	[redacted]	[redacted]	0.041 (0.015 - 0.105)	0.959

Table 9: Number of unique fish detected at each receiver location in the Ohio River 2021-2023. For locations with multiple receivers (e.g. lock and dam structures) detections from all receivers were pooled, and the number of unique fish are reported.

Receiver Location	No. Fish	Latitude	Longitude
Brookport	8	37.11	-88.63
Cannelton	2	38.12	-86.41
Clover Creek	1	37.84	-86.63
J.T. Meyers	7	37.80	-87.99
Newburgh	3	37.83	-87.04
Smithland	15	37.16	-88.43
Tennessee River	2	37.03	-88.53

Table 10. Index of Biotic Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) scores at 22 sites that were sampled in 2022 and 2023. An IBI score could not be calculated for Squirrel Creek Upper either year due to low catch rates of fish during electrofishing sampling.

System	Site	IBI Score 2022	IBI Score 2023	IBI Ranking 2023	QHEI Score 2022	QHEI Score 2023
Mainstem Eel River	Columbia City	40	42	Very Good	54	51.5
	Collamer	42	50	Exceptional	70.5	70
	Liberty Mills	48	38	Good	75	73.5
	North Manchester	44	46	Very Good	74	75.5
	Above Stockdale Dam	36	30	Fair	54	49.5
	Below Stockdale Dam	46	54	Exceptional	73	78.5
	Mexico	32	46	Very Good	76	69.75
	Hoover	48	44	Very Good	78	75
	Adamsboro	46	44	Very Good	75	73.25
	Logansport	44	44	Very Good	76	78
Tributaries	Geller Ditch	32	14	Poor	19	26.5
	Johnson Ditch	30	14	Poor	28	29.5
	Shoaff Ditch	30	24	Poor	35	32.5
	Thorn Creek	28	28	Fair	62	46
	Blue River	32	14	Poor	35.5	34

Beargrass Creek Upper	40	42	Very Good	64	47
Beargrass Creek Lower	46	24	Poor	78.5	71
Squirrel Creek Upper	NA	NA	NA	28	25
Squirrel Creek Lower	38	40	Good	65.5	65
Pawpaw Creek Upper	50	46	Very Good	42	46.5
Pawpaw Creek Lower	46	46	Very Good	79.5	76.5
Weesau Creek	46	44	Very Good	82	71

Table 11. Information and tag number for the three Silver Carp that were tagged at River Kilometer 56 of the Eel River on 5 July 2023. River discharge was 326 ft^3/s at the time of sampling.

Species	Date Tagged	Sex	Length (mm)	Weight (g)	Acoustic Tag Number	PIT Tag Number
Silver Carp	7/5/2023	Male	610	2502.5	A69-1602-23552	989001040400156
Silver Carp	7/5/2023	Male	630	2765	A69-1602-23553	989001040400151
Silver Carp	7/5/2023	Male	580	2800	A69-1602-23525	989001040400088

Table 12. Percent of replicates that were above detection limits at 24 sampled sites in the Eel River Watershed and Wabash River Watershed.

Site Type	Site Name	River Kilometer	Latitude	Longitude	Percent of Replicates that Detected DNA		
					Bighead Carp	Silver Carp	Grass Carp
Mainstem Eel River	Columbia City	121	41.118	-85.499	0	0	0
	Collamer	103	41.074	-85.664	0	0	33.33
	Liberty Mills	92	41.038	-85.739	0	0	0
	North Manchester	82	40.995	-85.781	0	0	0
	Above Stockdale Dam	59	40.914	-85.941	0	0	0
	Below Stockdale Dam	58	40.912	-85.951	0	0	0
	Mexico	30	40.818	-86.108	0	0	33.33
	Hoover	20	40.797	-86.198	0	0	33.33
	Adamsboro	12	40.783	-86.264	0	0	33.33
	Logansport	2	40.759	-86.364	0	0	100
Tributary of the Eel River	Thorn Creek		41.207	-85.429	0	0	0
	Blue River		41.245	-85.386	0	0	0
	Geller Ditch		41.206	-85.217	0	0	0
	Everett Lake Ditch		41.162	-85.296	0	0	0
	Shoaff Ditch		41.207	-85.235	0	0	0
	Pawpaw Creek Upper		40.898	-85.753	0	0	33.33
	Pawpaw Creek Lower		40.878	-85.966	0	0	0
	Squirrel Creek Upper		40.965	-85.940	33.33	0	0

	Squirrel Creek Lower		40.917	-85.939	0	0	0
	Beargrass Creek Upper		40.932	-85.779	0	0	66.67
	Beargrass Creek Lower		40.943	-85.890	0	0	0
	Wesau Creek		40.867	-86.086	0	0	0
Mainstem Wabash River	Wabash River Downstream Eel River	566	40.747	-86.407	0	0	0
	Wabash River Upstream Eel River	576	40.751	-86.301	66.67	100	100

Table 13. River name, site name, date of tagging, and number of individuals detected in the Upper Wabash River Basin network of receivers from the identified tagging event.

River Fish was Tagged In	Site Name	Date of Tagging	Number of Individual Detected from Tagging Event
Wabash River	Lafayette	4/1/2011	2
Cumberland River	Chetham Dam	3/2/2021	2
Eel River	Stockdale Dam	7/5/2022	1
Wabash River	Hutsonville	11/1/2021 and 4/18/2022	7
Wabash River	Lafayette	3/29/2023 and 3/30/2023	29
Wabash River	Omer Cole Ramp	8/2/2022 and 8/3/2022	20
Wabash River	Above Lafayette	9/14/2021 and 9/15/2021	7

FY23 Annual Report
Control and Containment of Invasive carp in the Ohio River

Geographic Location: Ohio River basin, extending from the Racine Lock and Dam (RM 237.5) to the Mississippi River (RM 0), including the Wabash River.

Participating Entities: Kentucky Department of Fish and Wildlife Resources (KDFWR), Illinois Department of Natural Resources (ILDNR), Indiana Department of Natural Resources (INDNR), and West Virginia Department of Natural Resources (WVDNR)

Introduction:

The complete eradication of an established invasive species is an extremely difficult task on its own, but it becomes virtually impossible to accomplish without causing collateral damage to native populations. Therefore, the best option for reducing the spread of an invasive species may include the combination of a strong prevention effort and a swift response to possible introductions. When as many as four different species of invasive carp (Silver, Bighead, Grass, and Black Carp) were introduced into a major US waterway, resource managers made numerous attempts to prevent them from expanding into other areas. Despite these efforts, the ranges of all four invasive carp species have steadily increased since their introduction (Kolar et al. 2005). Many of these populations have achieved densities that are high enough to negatively impact the native food web (Irons et al. 2007, Freedman et al. 2012) and disrupt human connections to these natural resources (i.e., fishing, boating, and navigation). With prevention and early response no longer an option for most of the lower Ohio River Basin, it has been determined that large-scale removal projects may be one of the few tools that managers can still utilize in their ongoing efforts to slow down the population's upstream expansion.

Agencies have implemented a suite of removal projects, supporting both incentivized commercial fishing, incentivized waterside pick up, and contract fishing in various areas of the lower Ohio River basin and tributaries. When consistent removal efforts are conducted in areas where the established population meets the invasion front, it has a high potential to decrease upstream immigration, lower pressure on existing barriers, and reduce carp densities at locations where there are species of conservation concern or valued sport fisheries. Cannelton Pool currently marks the establishment front for Silver Carp populations within the mainstem Ohio River. In addition, there are several locations above Cannelton Locks and Dam where Grass and bigheaded carps can be consistently targeted with sampling gear that is essential to large-scale removal efforts. The purpose of this project is to utilize basin-wide knowledge in the ongoing efforts to control and contain invasive carp populations that have become established within the Ohio River basin (ORB). Additionally, the data collected during the targeted removal are used to augment the other evaluation efforts that KDFWR conducts to determine the status of the invasive carp populations in different pools of the Ohio River. Further down river, incentivized commercial harvest and processor pick-up provide tools to utilize existing infrastructure to suppress populations and reduce numbers where these fish are at peak abundance.

Objectives:

1. Target and remove invasive carp to suppress populations and reduce propagule pressure in the Ohio River basin.
2. Implement a removal program using contracted fishers at intensive management zones to reduce invasive carp numbers across the Ohio River basin.

Project Highlights:

1. A total of 56.7 hours of electrofishing effort was used to remove approximately 3,678 kg (~8,108 lbs) of invasive carp from three different pools of the Ohio River in 2023.
2. A total of ~2.1 million pounds (928K kg) of invasive carp have been harvested by contract fishing efforts conducted between July 2019 and February 2024.
3. Contract fishing efforts continued to remove high numbers of invasive carps from the Cannelton Pool of the Ohio River without causing substantial impacts on native fish populations.
4. Incentivized commercial harvest resulted in the removal of 3,534,342 pounds of invasive carp in 2023.
5. Contract facilitation reimbursements to processors for waterside pickup supported the removal of 12,167,337 pounds of invasive carp in 2023.

Agencies strongly agree that commercial removal, including contract fishing in the Cannelton Pool and the agency's additional upstream removal efforts should remain in place to continue reducing the densities of mature invasive carp that are capable of successful reproduction.

Methods:

Clarification of Terminology Referenced in This Document

With the current rate of invasive carp expansion and the massive effort to study and adaptively manage carp impacts across a broad range of Mississippi River sub-basins, it is important to clarify terminology used in technical documentation and annual reports. Therefore, a list of terms and their respective definitions used in this report are provided.

Bigheaded Carps – Silver (*Hypophthalmichthys molitrix*), Bighead (*Hypophthalmichthys nobilis*), and their hybrids.

Establishment Front – The furthest upriver range of invasive carp populations that demonstrates natural recruitment.

Invasion Front – The furthest upriver extent where reproduction has been observed (eggs, embryos, or larvae), but recruitment to young-of-year (YOY) fish has not been observed.

invasive carp – One of four species (i.e. Silver Carp, Bighead Carp, diploid Grass Carp, and Black Carp) that originated from the continent of Asia.

Presence Front – The furthest upstream extent where invasive carp occur, but reproduction is not evident.

Targeted Removal of Invasive Carp

In 2023, a small increase in the number of field staff and the assistance of other agencies have improved KDFWR's ability to conduct further invasive carp removal efforts in areas located upstream of the Cannelton Pool. During these targeted removal efforts, agency crews utilized pulsed DC electrofishing via a MLES control box (40% duty-cycle) that was typically set at a rate of 80 pulses per second (pps). In previous years, KDFWR would set gill nets near the downstream end of the sampling area to target any invasive carp that tried to evade the electrofishing boat. However, a reduction in available field crews during most of 2023 required KDFWR to continue using an electrofishing-only approach to complete its targeted removal efforts.

The 2023 removal efforts continued to be conducted entirely within tributaries and embayments of the Markland, McAlpine and Cannelton pools. Upon capture, all bycatch species were immediately identified and released. All invasive carp were inspected for tags, and if present, the id numbers were used to determine the status of the transmitter. A healthy tagged fish with an active transmitter presented the only conditions when an invasive carp would have been intentionally released back into the river. Any tagged fish with expired transmitters were ultimately removed for population control. Prior to being euthanized, the length, weight, sex, and presence/absence of a spawning patch were recorded for each invasive carp.

Similar to previous years, KDFWR utilized the 2023 removal efforts to collect aging structures from invasive carp that were captured from the Cannelton, McAlpine and Markland pools. During these situations, agency field staff would identify Silver Carp from specific size classes and then harvest otoliths that would later be processed and examined for the ongoing length-at-age analyses being conducted for the Early Detection and Evaluation Project.

Invasive Carp Contract Fishing Program

During the implementation of the invasive carp contract fishing program, there were changes to the timing of the year when fishing occurred, the number of fishers fishing/ week, access to Indiana waters, and program's administration. The Contract Fishing Program in the Ohio River officially began in July 2019. In 2023, KDFWR held contracts with ten contract fishers that allowed them to target invasive carp in the mainstem river, tributaries and embayments of the Cannelton and Newburgh pools. KDFWR also provided observers to accompany each program participant in order to record details about their fishing efforts (i.e., location, gear, etc) and their subsequent harvest of invasive carp. During these efforts, observers were required to obtain size and sex data from daily subsamples of 20 or more randomly selected Silver, Bighead and/or Grass carp. They were also responsible for identifying any bycatch that contract fishers picked up in their nets and then ultimately document any morbidity of these non-target species.

From late 2019 to early 2021, contract fishing efforts were spread throughout the entire year and any scheduling restrictions occurred only when required by program funding. In late 2021, KDFWR started altering the program's fishing schedule to shift more efforts to the cooler months that consistently produced higher harvest totals. After even more changes in 2022, the agency essentially created a contract fishing season by scheduling most of the program's efforts to occur within a 6-month period that began in October and then continued through March of the following year. This season primarily consists of peak harvest months that were identified during the first few years of the program.

These changes to the contract fishing program were implemented to increase harvest without creating a need for additional funding. The initial adjustments in 2021 involved a 2-month suspension of contract fishing efforts in August and September when high temperatures tend to reduce invasive carp harvest while increasing the mortality rates of any bycatch. For 2022, the agency initially planned to include an additional summer month to the program's suspension period (Jul – Sep). However, soon after the start of 2022, KDFWR had to deviate from this plan to accommodate the larger number of observers (n = 5) on their staff, which required the agency to schedule up to 2 additional fishermen each week. As a result, most dates on the schedule in Jan – Mar 2022 produced an average effort of ~5 "fishing days", which is equivalent to 1 program participants actively fishing for five full days. This unexpected surge in effort also increased program costs to the point that all FY2021 funds were spent by early May 2022, which ultimately caused all contract fishing to be suspended nearly two months sooner than expected.

Like 2021, the 2022 fishing efforts were to resume by early October when river conditions improve (i.e. lower water temperatures) and the next funding cycle is underway. However, delays in contract renewals and the hiring of new observers postponed the restart of the program until the last day of October 2022.

Once fishing efforts resumed, the invasive carp harvest numbers quickly returned to normal. Since then, key scheduling changes and further usage of group fishing techniques greatly increased harvest success.

In late November 2021, some program participants had the opportunity to fish for invasive carp within the McAlpine Pool, which is located directly upstream of Cannelton. These efforts were used to determine if McAlpine could benefit from contract fishing if there is ever a decision to expand the program beyond the Cannelton Pool. After just two days of fishing tributaries in McAlpine, the catch rates and numbers of harvested invasive carp were much lower than expected and contract fishers appeared to have difficulty finding areas that produced results comparable to those in Cannelton. Further expansion of the program's efforts also occurred in late 2023 when contract fishers began to target invasive carp in specific areas of the upper Newburgh Pool. Unlike the McAlpine Pool, the contract fishers' methods were successful at capturing invasive carp in these new areas, and the sites within the Newburgh Pool are likely to be targeted again during future years of the program.

Results:

Targeted Removal of Invasive Carp

Approximately 56.7 hours of boat electrofishing was conducted at a variety of tributary and mainstem sites located in three different pools (Cannelton, McAlpine and Markland) of the Ohio River. (Table 1). In 2023, KDFWR (with assistance from INDNR) used the combined efforts from all three pools to capture and removed a total 683 invasive carp, weighing 3,678 kg (8,108 lbs.). Like in previous years, most of the 2023 electrofishing efforts (53.1%) were conducted at sites in the McAlpine Pool, which resulted in the removal of 301 invasive carp weighing a total of ~1707.7 kg (3,764 lbs.). Bycatch of non-target species continue to be rarely encountered due to the selective nature of the electrofishing efforts. However, shad and alewife species were captured on occasion to verify that they were not juvenile (age-0 to age-1) invasive carp.

INDNR spent three days conducting targeted invasive carp removals in 2023. Removals took place in Little Pigeon Creek a tributary of the Ohio River located in Newburgh Pool (near Yankeetown, IN) and on the West Fork White River near Elnora, Indiana (Smithland Pool). A total of 13.8 hours were spent electrofishing for invasive carp, producing 1,885 Silver Carp, 1 Bighead Carp, and 64 Grass Carp. Approximately 6,055 kg (13,349 lbs) of invasive carp were removed through these agency removal efforts (Table 1). Combined with other project sampling efforts (targeted spring sampling, otolith collections, and fish community sampling) throughout 2023, INDNR crew removed 2,807 adult invasive carp for approximately 9,270 kg (20,437 lbs). INDNR helped ILDNR and SIU with community sampling for a removal event on a Grayville oxbow, spending 1 hour actively electrofishing. INDNR also assisted KDFWR with the contract fishing program on the Ohio River, providing ride-along observers when needed. Also, INDNR has been working to create a new permit allowing the use of gill nets and seines for harvesting invasive carp in otherwise closed waters. Draft language has been developed and the permit has been introduced into the first step of the rule-making process, however a timeline for when or if the permit will become effective remains unknown.

WVDNR conducted a total of four removal events yielding nine adult Bighead carp and four adult Silver carp from the R.C. Byrd Pool of the Ohio River. One solo removal event was conducted in Tenmile Creek of the Kanawha River (1 Silver carp) and three removal events were conducted in cooperation with the USFWS Ohio River sub-station staff in Raccoon Creek and the disused lock chambers of R.C. Byrd Dam from July-September 2023. A total effort of 685 meters (2250 ft) of gill nets were deployed for these efforts. Additionally, one adult Bighead and one adult Silver carp were caught and removed via gill nets set to collect Paddlefish in October of 2023.

Contract Fishing Program

At the beginning of 2023, KDFWR had enough observers on staff to regularly schedule up to 4 fishers a week. Program participants conducted an average of 56 fishing days per month during the first few months of 2023 (Jan – Mar) and ended this 3-month period with a total of 168 fishing days, which was comparable to the 156 days fished during this same time period in 2022 (Table 2). During these efforts in Jan – Mar 2023, contract fishers used 711 gill net sets (~ 325,100 net ft) to harvest a total of 54,700 carp that had a combined weight of more than 276,000 kg (~609,000 lb). Contract fishing efforts in Jan-Mar 2023 yielded the highest harvest totals than any 3-month period of the program, including the previous high of nearly 22,000 invasive carp that were captured and removed in Jan-Mar 2022. After the strong start to 2023, contract fishers continued to harvest high numbers of invasive carp in April and May (n = ~19,000 fish). By the time that contract fishing efforts were suspended for the summer months, a total of nearly 74,000 invasive carp weighing over 372,000 kg (~821,600 lb) had been harvested during the first five months of 2023.

Throughout 2023, program participants set an overall total of 1543 gill nets within both the Cannelton and Newburgh pools. In fact, by the end of 2023, sites within the Newburgh Pool were being regularly targeted by contract fishing efforts. This trend continued during the first two months of 2024, when nearly 33% of all gill nets had to be set at sites in the Newburgh Pool when Indiana tributaries were temporarily closed to contract fishing efforts.

During each year from 2019 to 2023, contract fishers have harvested three different species of invasive carp, which include Silver, Bighead and Grass carps. The most common by far, in terms of both numbers and weight, have been Silver Carp. In 2023, Silver Carp (n = 81,163) represented more than 98.7% of the harvested fish, while both Bighead (n = 496) and Grass (n = 531) carps combined to make up the other ~1.3% (Table 3). The species composition of all invasive carp caught in 2023 simply echoed an overall trend in the program's results where Silver Carp have made up 98.3% of all carp (n = 181,178) caught by contract fishers in the last 5+ years (Jul 2019 – Feb 2024).

After comparing the mean daily catch of invasive carp during peak months (Oct-Feb) of the past five contract fishing seasons (2019-2023), there was an initial decline in daily harvest rates during the first few years (Figure 1). However, this was not indicative of the program's performance as the overall harvest totals were increasing during this same time period. The disparity is related to the shift from year-round efforts in 2019-2020 to fishing that only occurred during peak months beginning in late 2021. In Oct 2021 – Feb 2022, program participants completed a total of ~225 fishing days, which was a sizable increase over the 120 fishing days from the same time period in 2019-2020. Contract fishers then completed ~220 fishing days in Oct 2022 through February 2023, but mean daily harvest actually increased substantially during this period, which included record numbers of invasive carp being harvested by contract fishers during Jan and Feb 2023. In contrast, a similar number of fishing days completed between Oct 2023 and February 2024 (n = 224) failed to match the record output of the previous 2022-2023 season, which is indicated by a decline in daily harvest rates during each of the 5 peak fishing months.

In 2023, the monthly comparisons of mean daily harvest indicated that contract fishers had their highest catch rates during the months of February (375 carp/day) and March (363 carp/day) (Figure 2). In contrast to 2022, the 2023 catch rates appear to be much more correlated with river levels, even though cooler water temperatures continue to have a large influence on harvest success. This can be misleading because high variability in daily harvest during these months can lead to lower rates even if contract fishers are still catching high numbers of invasive carp.

Gill nets continued to be the only gear used during the eight-month period that program participants were actively fishing in 2023. Netting effort often varies and can depend a lot on catch, but throughout 2023, contract fishers typically set out 600-750 meters (2000-2500 ft) of webbing per day. The Silver Carp catch ranged in total length from 100 mm to 1100 mm with most of the fish (~99%) measuring between 600 – 900 mm (Figure 3). Bighead and Grass carp were caught less frequently, but when harvested, most Bighead Carp (>85%) had total lengths of 750 to 1150 mm and nearly 88% of all Grass Carp measured between 750 - 1050 mm.

The bycatch from contract fishing efforts in 2023 was highest in January (31%) and June (32%) with other months showing that non-target species contributed between 9% and 27% of the total catch (Figure 4). All bycatch species were released immediately, and agency observers specifically documented any non-target fish that were either dead-on-arrival (DOA) or appeared to be moribund. Smallmouth and Bigmouth Buffalo (Ictiobus spp.) were the most common bycatch and contributed more than 81% of all non-target fish (n = ~15,520). Freshwater Drum (Aplodinotus), Catfish (Ictaluridae) and Paddlefish (Polyodon) were the next three most common types of bycatch found in the gill nets (Figure 5). In contrast to 2022, Ictiobids had only the 3rd highest morbidity rate among the common bycatch species in 2023 with 2.7% of the buffalo being DOA. Paddlefish (Polyodon) are considered to be highly vulnerable to nets, but they were only the fourth most commonly caught fish in 2023 contributing as little as 2.2% of all bycatch recorded by observers. However, it was determined that the Paddlefish (n = 416) pulled from contract fishing nets in 2023 also exhibited the highest morbidity rate (3.9%) of any other bycatch species.

ILDNR Contract Fishing

In February and March 2023, ILDNR contracted commercial fishers conducted a two-week removal effort in Bonpas Creek, a tributary of the Wabash River in Grayville, IL. During this effort 12,000 yards of gill and trammel net was deployed. In total, approximately 30,000 Silver carp and 2 Black carp were removed, with a total estimated weight of 112.5 tons (225,000 lbs.). Bycatch included 1550 Smallmouth Buffalo, 950 Bigmouth Buffalo, 450 Black Buffalo, 74 Freshwater Drum, 24 Channel Catfish, 22 Shovel-nose Sturgeon, 20 Largemouth Bass, 6 Blue Suckers, 5 Blue Catfish, and 3 Bowfin. All native species captured were released unharmed.

Hydroacoustic sampling results of the Grayvillle oxbow targeted harvest in March 2023 on the Wabash River.

Block nets separated the oxbow from the Wabash main channel throughout the harvest event. Only the southwest portion of the Grayville oxbow was targeted for removal and assessment. Hydroacoustic sampling by SIU was conducted prior to harvest/sampling but after block nets were in place. INDNR electrofished the adult fish community in the oxbow to inform hydroacoustic analyses. Gillnet harvest occurred for several days, followed by hydroacoustic sampling, and then removal of the block nets. Silver, common, and grass carp were harvested during the removal event and were therefore combined for hydroacoustic analyses and are referred to here as ‘invasive carp’.
Estimated invasive carp densities before harvest were highest near the center of the oxbow, slightly offshore (Figure 1). Spatial distributions of the entire adult fish community were relatively evenly distributed throughout the oxbow prior to harvest for all fish sizes (Figure 2). Harvest reduced invasive carp densities (Figure 3) and shifted their spatial distributions toward the eastern, nearshore area of the oxbow (Figure 1). Spatial distributions of the entire adult fish community were distributed toward the southern portion of the oxbow closest to the main channel following harvest, especially for medium to large size classes (Figure 2).

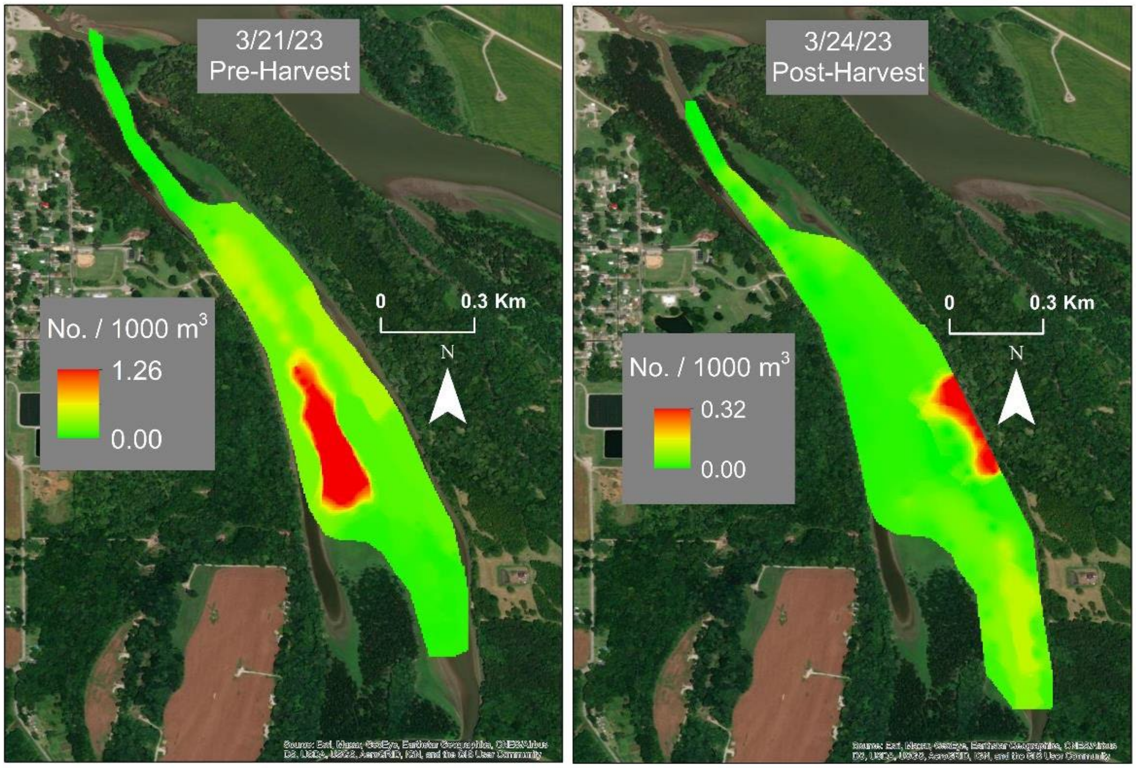


Figure 1. Spatial distributions of invasive carp before and after harvest in the Grayville oxbow of the Wabash River in March 2023. Note the lower density scale in the post-harvest panel.

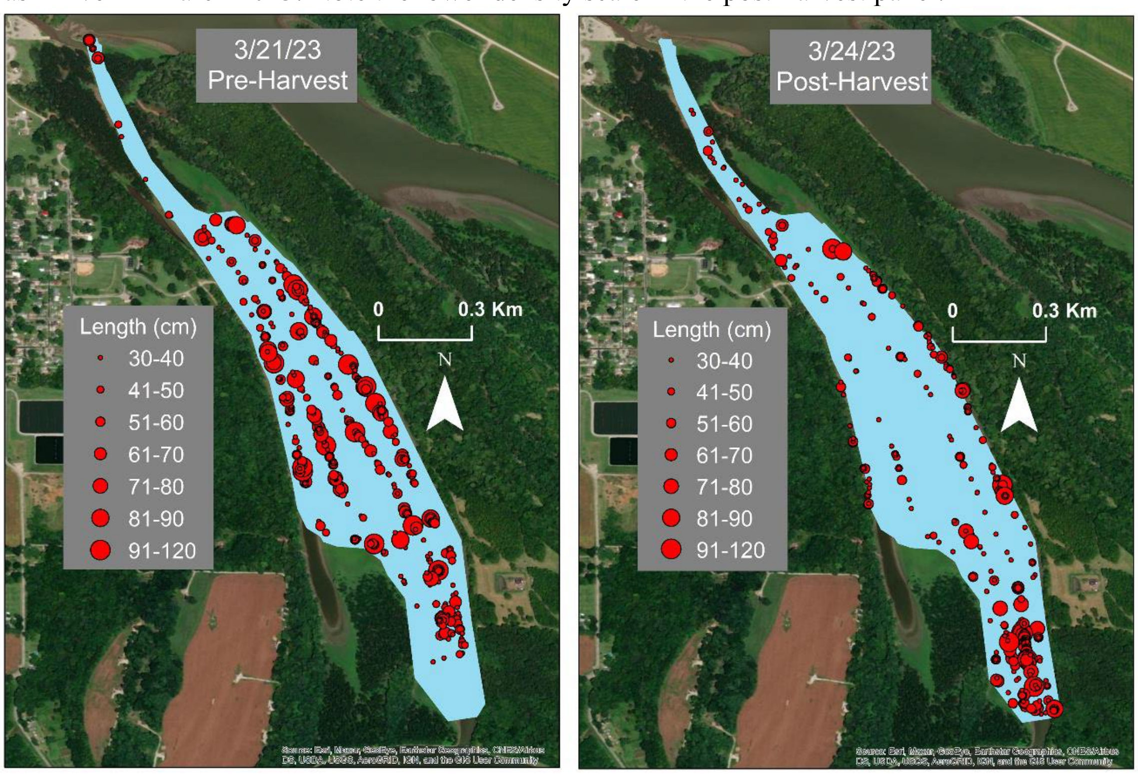


Figure 2. Spatial distributions and estimated sizes of the entire adult fish community sampled during hydroacoustic sampling pre- and post-harvest of invasive carp from the Grayville oxbow of the Wabash River in March 2023.

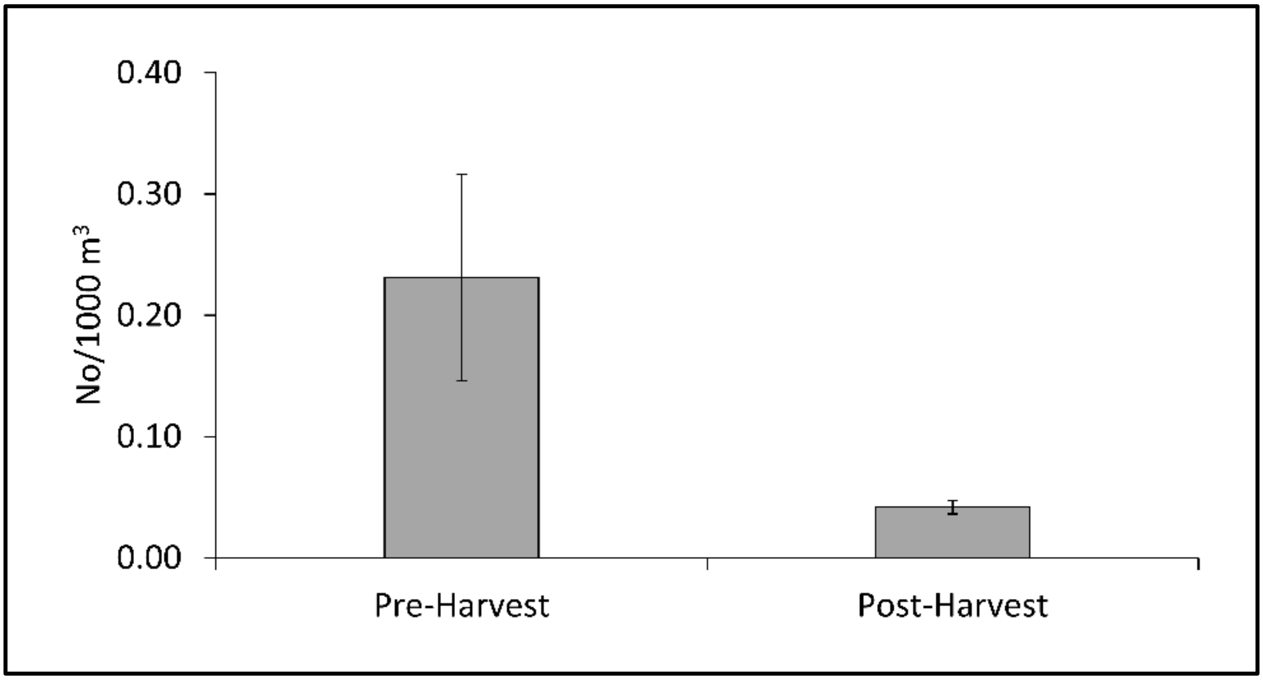
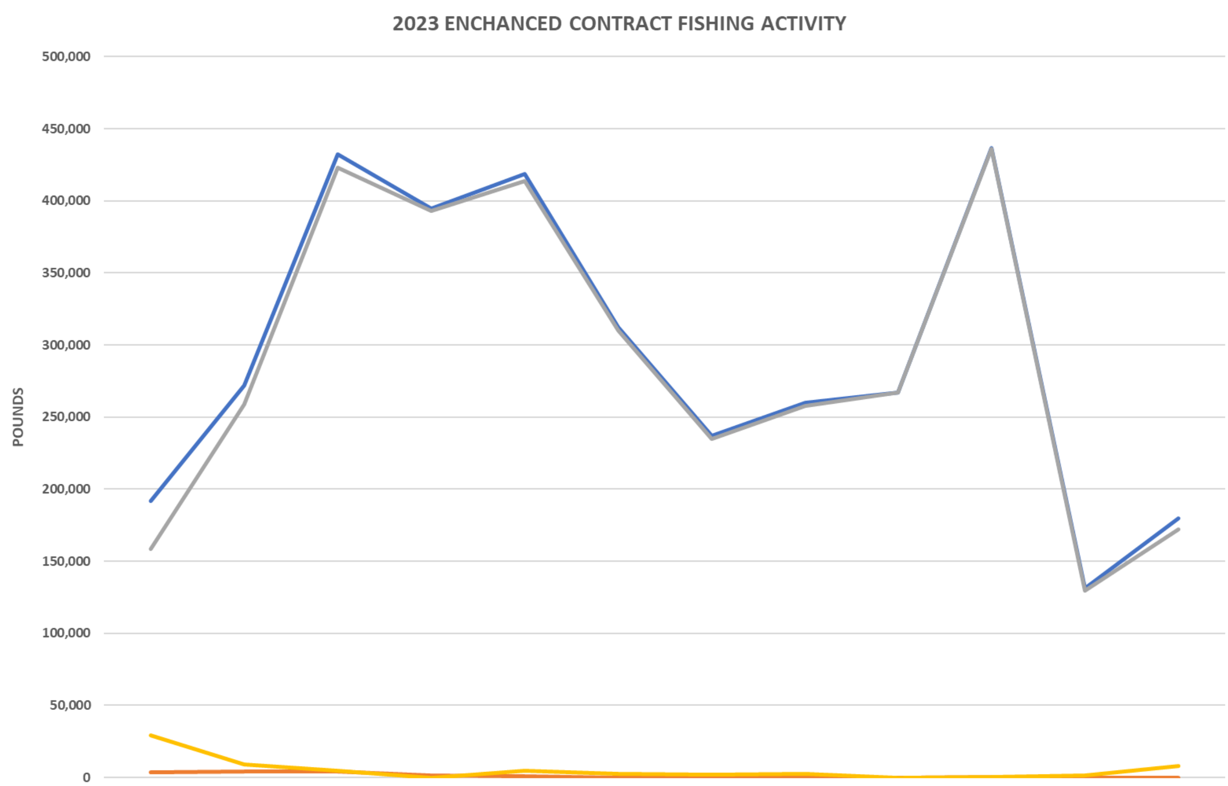


Figure 3. Mean (standard error) estimated invasive carp densities from hydroacoustic sampling conducted pre- and post-harvest of invasive carp from the Grayville oxbow of the Wabash River in March 2023.

Enhanced Contract Removal

Enhanced Contract Fishing was initiated in early 2022, offering contracts to licensed commercial fishers for compensation of $0.10 per pound for invasive carp removed from designated commercial waters and sold to a fish processor(s) or other buyer(s) for at least $0.07 per pound. The program used the same terms and maintains the designated waters of the previous program initiated in 2022. Designated waters includes the commercial waters of the following:
(1) the portion of the Wabash River from the Ohio River to the southernmost city limits of Lafayette, Indiana
(2) Skillet Fork River
(3) Little Wabash River
(4) Embarras River, except from Route 130 in Coles County upstream to the Harrison Street Bridge
(5) Lake Charleston
(6) Ohio River from McAlpine Dam to its confluence with the Mississippi River
(7) the tailwaters of Kentucky and Barkley Lakes
(8) Green River from the highway 259 bridge at Brownsville, Kentucky, downstream to the confluence with the Ohio River.

During 2023, ILDNR Enhanced Contract Removal Program had a total of 23 fishers under contract. With those 23 fishers, a total of 3,534,342 lbs of invasive carp were removed. Since the program's inception of March 2022, a total of 4,959,933 lbs have been removed from the designated waters of the Ohio River and its tributaries. Of that total amount, 98% of the invasive carp removed were Silver carp. February through May, and October were the months with the highest catch totals for 2023. Summer months of 2023 saw a dramatic decrease in the amount of invasive carp reported harvest (Figure 4).



	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23
Total Lbs.	191,613	272,169	432,469	394,544	418,971	312,485	236,870	260,035	267,302	436,799	131,068	180,018
Bighead	3,610	4,019	4,356	1,258	659	0	235	0	0	365	0	0
Silver	158,587	258,831	423,263	393,286	413,680	310,229	234,861	257,788	267,302	436,008	129,445	172,200
Grass	29,416	9,318	4,850	0	4,631	2,256	1,774	2,247	0	426	1,623	7,818

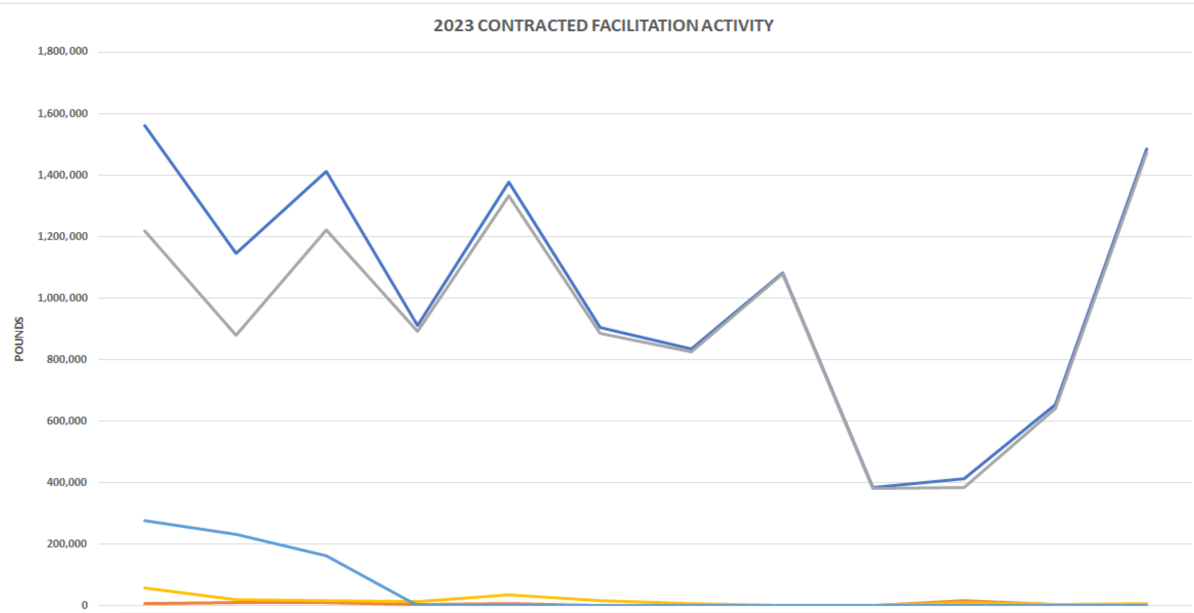
Figure 4. 2023 Enhanced Contract Removal per month

Contracted Facilitation

The Contracted Facilitation program also was initiated in early 2022 and offered contracts to fish processors and other buyers purchasing invasive carp from commercial fishers. Purchases must be made from either a facility or pick locations within 10 miles of designated waters. Compensation is $0.05 per pound for invasive carp removed from designated commercial waters and purchased for at least $0.07 per pound. This program facilitates practicable mechanisms for use of the harvested fish by private industry for a variety of purposes, including human consumption. The program in this proposal maintains similar terms and made the following changes to the designated waters. The designated waters from which fishers may remove invasive carp and where processors may pick up were expanded. New water bodies included LaGrange Pool on the Illinois River; Designated Waters – Designated waters include the commercial waters of the following:
(1) Peoria and LaGrange Pools of the Illinois River
(2) the portion of the Wabash River from the Ohio River to the southernmost city limits of Lafayette, Indiana
(3) Ohio River from McAlpine Dam to its confluence with the Mississippi River
(4) the tailwaters of Kentucky and Barkley Lakes
(5) Kentucky and Barkley Lakes in Kentucky

(6) Green River from the highway 259 bridge at Brownsville, Kentucky, downstream to the confluence with the Ohio River.
Additional Fishing Areas - Invasive carp caught in the following waters may also be picked up at one of the above designated water pick up locations: (1) Little Wabash River; (2) Skillet Fork River; (3) Embarras River, except from Route 130 in Coles County upstream to the Harrison Street Bridge; and (4) Lake Charleston.

The Contracted Facilitation Program had 7 processors under contract in 2023. Throughout 2023 a total of 12,167,337 lbs. were processed. Since the Program's inception of March 2022, a total of 21,008,353 lbs. have been processed. Silver carp make up 85% of the total number of invasive carp processed, with Bighead, Grass and undisclosed invasive carp combining to make the remaining 15%. Contracted facilitation had its highest month in January then fluctuating down as the year progressed. (Figure 5.)



	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23
Total	1,560,516	1,145,815	1,412,613	910,392	1,378,554	905,100	834,219	1,083,888	384,201	413,116	654,292	1,484,632
Bighead	9,144	12,233	10,148	3,754	6,556	2,113	349	59	421	16,047	5,803	2,646
Silver	1,218,016	878,957	1,222,693	891,866	1,334,676	885,330	826,512	1,081,185	381,025	385,019	642,463	1,473,910
Grass	57,459	21,229	16,543	14,772	37,321	17,657	7,358	2,644	2,755	12,050	6,026	8,076
Not Disclosed	275,897	233,395	163,229	0	0	0	0	0	0	0	0	0

Figure 5. 2023 monthly processed totals for the Contracted Facilitation project

Discussion:
The locks and dam projects throughout the Ohio River are thought to provide some level of containment for the invasive carp species found within the mainstem river. Data acquired from several years of monitoring have demonstrated that average size and condition of Silver Carp increase as you move upstream, which is often accompanied by a transition to populations that consist of fewer, older fish. With it being a location where <400 mm carp are encountered each year, Cannelton continues to be one of the most upstream pools within the establishment zone. Because of this, its size and mounting evidence of successful reproduction as recently as 2021, the Cannelton Pool is still considered to be a high-priority location for any future efforts to control the invasive carp population.

In 2023, KDFWR contracted with ten program participants to provide the necessary fishing effort and as many as four observers were hired to record harvest success and any impacts of non-target species. Overall, fishers continued to be most successful when their efforts are focused within tributaries where decreased water depths allow the gill nets to catch invasive carp at higher rates. Because of past difficulties in capturing carp during warmer months, all fishing efforts were postponed from June through September of 2023, which was also expected to help reduce impacts on bycatch species. Any effect that this may have on morbidity rates will be examined more closely after collecting additional data from upcoming years where efforts are postponed during warmer months. Unlike a nearly 30-day delay experienced in 2022, the program resumed as planned on October 2nd, 2023, with participants immediately employing the same group fishing techniques that produced record harvests back in January, February and March of 2023. These techniques are considered to be an optimization of the program's fishing efforts as they require all participants to concentrate their nets in the same tributary.

Agency crews continue to provide regular recommendations based off previous years' experience and monitoring efforts. This includes information on where to target invasive carp and what gear specifications could be used to maximize fishing success; however, contract fishers have been routinely allowed to utilize gears that they felt would work best during each fishing event. Participants used gill nets with webbing constructed of 3.25 to 4.5 in bar-mesh throughout 2023, and this appeared to provide the best results when Silver Carp was the primary target. Earlier in the program, contract fishers started setting nets in specific locations with the purpose of closing off any routes that invasive carp could use to leave a tributary if/when they were able to avoid the initial capture efforts. This practice was intended to allow the contract fishers to repeatedly target an area until all invasive carp had been captured and removed. However, this would only produce the expected result if/when the appropriate amount of fishing pressure was applied directly upstream of these "block nets". This was a primary factor in KDFWR's decision to instruct multiple contract fishers to focus their efforts in the same tributary and/or embayment. These "group fishing" techniques were initially implemented during the second half of 2021 and appeared to result in immediate improvements. Higher harvest totals in 2022 and 2023 strongly support the continued use of group fishing, especially in areas with higher densities of invasive carp (i.e. Cannelton & Newburgh pools).

Similar to previous years, agency observers in 2023 continued to report that most bycatch was healthy at the time of release. After a temporary decline in 2022, Paddlefish captured by contract fishers once again exhibited the highest morbidity rates of all bycatch species, but it should be noted that fairly low numbers (n = ~400) of Paddlefish were caught in 2023. Ictiobids (i.e. Smallmouth Buffalo) were once again by far the most common bycatch in 2023, which was followed by Freshwater Drum and Catfish. Like in past years, most of these fish appeared to be unharmed, or only minimally injured, following their release. In addition to the shift to cooler water temperatures, the instances of low bycatch mortality were likely aided by the rapid setting and pulling of gill nets.

For agency removal efforts, electrofishing methods used in 2023 continued to produce the most success for the crews that were targeting lower density populations of invasive carp. When available, these efforts can be even more effective if side-scan technology is used to locate schools of Silver Carp that can be herded into gill nets using the electrofishing gear. However, capture success appears to be highly dependent on the experience of both the driver and the dipper. Targeting tributary waters gives removal crews an advantage because current sampling gears are often more effective in shallower water and the tributary banks help keep the invasive carp from scattering too far away from the electrofishing boats.

Pairing hydroacoustics with commercial fishing in descrete locations has the opportunity to demonstrate the extent of invasive carp population impacts in defined areas. Pre- and post hydroacoustic surveys within the Grayville oxbow demonstrate a propound reduction in large body fish returns. The corresponding pounds of fish removed by contract commercial fishers correlates with this finding.

In areas where invasive carp population densities are high, incentivizing removal by contract fishers is an economical strategy to reduce biomass, lessoning impacts on native fisheries and reducing propagule pressure upstream. Incentivized commercial harvest has steadily increased from 1.4 M pounds in 2022 to over 3.5 M pounds in 2023. The bulk of this harvest consist of Silver Carp. Most of the harvest occurred within the Ohio River (2 M pounds) with both the Wabash River and Kentucky and Barkley tailwaters with slightly over a half million pounds revmoved (.79 M and .69M).

The enhanced facilitation program provides a unique opportunity to facilitate commercial fishing efforts by incentivizing processors to pick up the fish near where the fishing occurs rather than requiring commercial fisher to haul fish hundreds of miles. The program incentivized removal of 12 M pounds of invasive carp in 2023. Most of the incentived removal occurred in Barkley Lake (3.7M and the Illinois River (3.8 M). The Ohio River followed with 1.8 M with the remainder occurring in Kentucky Lake, the Wabash River, KY and Barkley tailwaters and undisclosed.
This program facilitates practicable mechanisms for use of the harvested fish by private industry for a variety of purposes, including human consumption. This program also contributes to providing critical information on population densities of invasive carp over time in the Ohio River system to guide agency management efforts.

Recommendations:
It is imperative that fishing pressure is sustained and/or increased throughout the lower Ohio River to help protect and reduce migration of invasive carps further up the Ohio River. Incentivizing commercial harvest and paring that with incentivized processor pickup has increased efficiency and harvest in the lower portion of the Ohio River and other targeted waters. These programs provide a large amount of biomass removal for minimal investment and should remain in place. Contract fishing should continue to support population control efforts and should be closely monitored so that recommendations can be made to increase efficiency and successful harvest. Agency crews should continue to conduct removal efforts in lower density pools and internal waters to help reduce the numbers of all invasive carp species. Outreach and efforts to spur public and commercial interest within the ORB should continue as it is likely to become even more important to the long-term control of the current invasive carp populations. Further work in aiding facilitation of harvests to markets should continue in the future as it is expected to become even more difficult to convince commercial anglers to become long-term participants of the ongoing contract fishing program.

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Table 1. Results of electrofishing efforts that KDFWR and INDNR conducted in 2023 with the sole purpose of collecting and removing invasive carp from the middle Ohio River.

		Total Count (N)				Total Weight (kg)			
Ohio River Pool	EF Effort (hr)	Bighead Carp	Silver Carp	Grass Carp	Total Carp	Bighead Carp	Silver Carp	Grass Carp	All Carp
Smithland	9.8	1	1,732	63	1,796	2.5	5,234.9	237.2	5,474.6
Newburgh	4.0	0	153	1	154	0.0	576.8	3.7	580.5
Cannelton	3.9	0	90	1	91	0.0	366.1	6.7	372.8
McAlpine	30.1	0	301	0	301	0.0	1,707.7	0.0	1,707.7
Markland	14.5	7	27	0	34	17.7	274	0.0	292.5
All Pools	62.3	8	2,303	65	2,376	20.02	8,159.5	247.6	8,428.1

Table 2. A summary of the results obtained by program participants fishing from July 2019 to February 2024. A "fishing day" equals 1 crew fishing ~8 hr.

Year	Months	Fishing Effort			Total Carp Harvested	# Carp per Day	Total Harvest (kg)	Total Harvest (lb)	Mean Length & Weight			
		Days	Nets	Net Feet					TL (mm)	TW (kg)	TL (in)	TW (lb)
2019	JUL-SEP	26	191	87,615	2,640	101.5	15,261.6	33,646.0	843	5.78	33.2	12.74
	OCT-DEC	65	640	289,790	4,209	64.8	24,982.6	55,077.1	847	5.93	33.4	13.07
	TOTAL	91	831	377,405	6,849	75.3	40,244.1	88,723.1	846	5.87	33.3	12.94
2020	JAN-MAR	52	352	198,366	7,433	142.9	44,042.5	97,097.1	834	5.93	32.8	13.07
	APR-JUN	37	345	161,120	3,247	87.8	15,991.4	35,254.9	795	4.92	31.3	10.85
	JUL-SEP	28	318	118,775	1,371	49.0	6,375.2	14,055.0	772	4.65	30.4	10.25
	OCT-DEC	67	528	307,850	3,765	56.2	23,247.6	51,252.2	830	6.17	32.7	13.60
	TOTAL	184	1543	786,111	15,816	86.0	89,656.7	197,659.3	813	5.67	32.0	12.50
2021	JAN-MAR	67	474	251,400	8,429	125.8	51,142.9	112,750.7	842	6.07	33.1	13.38
	APR-JUN	40	243	189,520	3,115	77.9	15,855.3	34,955.0	814	5.09	32.1	11.22
	JUL-SEP	2	14	6,000	66	33.0	321.7	709.1	742	4.87	29.2	10.74
	OCT-DEC	97	562	289,875	8,060	83.1	39,882.4	87,925.7	786	4.95	31.0	10.91
	TOTAL	206	1293	736,795	19,670	95.5	107,202.2	236,340.4	813	5.45	32.0	12.02
2022	JAN-MAR	156	744	369,150	21,993	141.0	116,790.4	257,478.9	822	5.31	32.4	11.71
	APR-JUN	22	101	53,350	4,976	226.2	25,066.1	55,261.2	837	5.04	32.9	11.11
	JUL-SEP	0	0	0	--	--						
	OCT-DEC	84	433	235,360	13,431	159.9	68,093.3	150,119.9	805	5.07	31.7	11.18
	TOTAL	262	1278	657,860	40,400	154.2	209,949.8	462,860.0	818	5.20	32.2	11.46
2023	JAN-MAR	168	711	325,100	54,700	325.6	276,210.1	608,939.1	832	5.05	32.8	11.13
	APR-JUN	112	403	183,200	19,294	172.3	96,465.0	212,668.9	809	5.00	31.8	11.02
	JUL-SEP	0	0	0	--	--						
	OCT-DEC	114	429	287,213	8,196	71.9	35,957.6	79,273.0	774	4.39	30.5	9.68
	TOTAL	394	1543	795,513	82,190	208.6	408,632.7	900,881.0	813	4.97	32.0	10.96
2024	JAN-MAR	110	350	163,750	16,253	147.8	72,086.3	158,923.1	787	4.44	31.0	9.79
	TOTAL	110	350	163,750	16,253	147.8	72,086.3	158,923.1	787	4.44	31.0	9.79
	JAN-MAR	553	2,631	1,307,766	108,808	196.8	560,272.2	1,235,188.8	826	5.15	32.5	11.35

	APR-JUN	211	1,092	587,190	30,632	145.2	153,377.7	338,140.0	809	5.01	31.9	11.05
ALL YEARS	JUL-SEP	56	523	212,390	4,077	72.8	21,958.5	48,410.2	803	5.39	31.6	11.88
	OCT-DEC	427	2,592	1,410,088	37,661	88.2	192,163.5	423,647.9	808	5.10	31.8	11.24
	TOTAL	1247	6838	3,517,434	181,178	145.3	927,771.9	2,045,386.9	816	5.12	32.1	11.29

Table 3. Total counts and weights of the three Invasive carp species caught by contract fishers between 2019 and Feb 2024. All contract fishing efforts and results were recorded by agency observers.

Cannelton Pool (late 2019 – early 2024)

Year	Species	Total IC Caught	Harvest Weight (kg)	Harvest Weight (lb)
2019	BHC[A]	265	2,197.9	4,845.6
	GRC[B]	129	1,264.4	2,787.6
	SVC[C]	6,455	36,781.8	81,089.9
	ALL	6,849	40,244	88,723.1
2020	BHC	279	2,247.5	4,954.9
	GRC	235	1,975.7	4,355.7
	SVC	15,298	85,407.7	188,291.8
	ALL	15,812	89,630.9	197,602.3
2021	BHC	189	2,034.0	4,484.2
	GRC	208	1,564.5	3,449.2
	SVC	19,158	103,012.7	227,104.0
	ALL	19,555	106,611.2	235,037.4
2022	BHC	428	4,224.5	9,313.5
	GRC	298	2,234.7	4,926.7
	SVC	39,674	203,490.5	448,619.8
	ALL	40,400	209,949.8	462,860.0
2023	BHC	492	5,168.3	11,394.1
	GRC	507	4,020.3	8,863.2
	SVC	76,737	382,736.2	843,788.9
	ALL	77,736	391,924.7	864,046.1
2024	BHC	15	240.5	530
	GRC	60	591.9	1,305
	SVC	9,020	44,811.3	98,791.9
	ALL	9,095	45,643.6	100,626.9
All	BHC	1,668	16,112.7	35,522
	GRC	1,437	11,651.5	25,687
	SVC	166,342	856,240.1	1,887,686.2
	ALL	169,447	884,004.3	1,948,895.8

McAlpine Pool (2020 - 2021)

Year	Species	Total IC Caught	Harvest Weight (kg)	Harvest Weight (lb)
2020	BHC	0	0.0	0
	GRC	2	16.6	37
	SVC	2	9.2	20.3
	ALL	4	25.8	57.0
2021	BHC	0	0.0	0
	GRC	6	65.2	144
	SVC	109	525.9	1,159.4
	ALL	115	591.1	1,303.0
All	BHC	0	0.0	0
	GRC	8	81.8	180
	SVC	111	535.1	1,179.7
	ALL	119	616.9	1,360.0

Newburgh Pool (2023 - early 2024)

Year	Species	Total IC Caught	Harvest Weight (kg)	Harvest Weight (lb)
2023	BHC	4	46.4	102
	GRC	24	174.7	385
	SVC	4,426	16,486.9	36,347.4
	ALL	4,454	16,708.0	36,834.9
2024	BHC	8	89.7	198
	GRC	5	52.9	117
	SVC	7,145	26,300.1	57,981.8
	ALL	7,158	26,442.7	58,296.2
All	BHC	12	136.1	300
	GRC	29	227.6	502
	SVC	11,571	42,787.0	94,329.2
	ALL	11,612	43,150.7	95,131.1

All Pools Combined (late 2019 - early 2024)				
Year	Species	Total IC Caught	Harvest Weight (kg)	Harvest Weight (lb)
All Years	BHC	1,680	16,248.8	35,822.4
	GRC	1,474	11,961.0	26,369.4
	SVC	178,024	899,562.2	1,983,195.1
	ALL	181,178	927,771.9	2,045,386.9

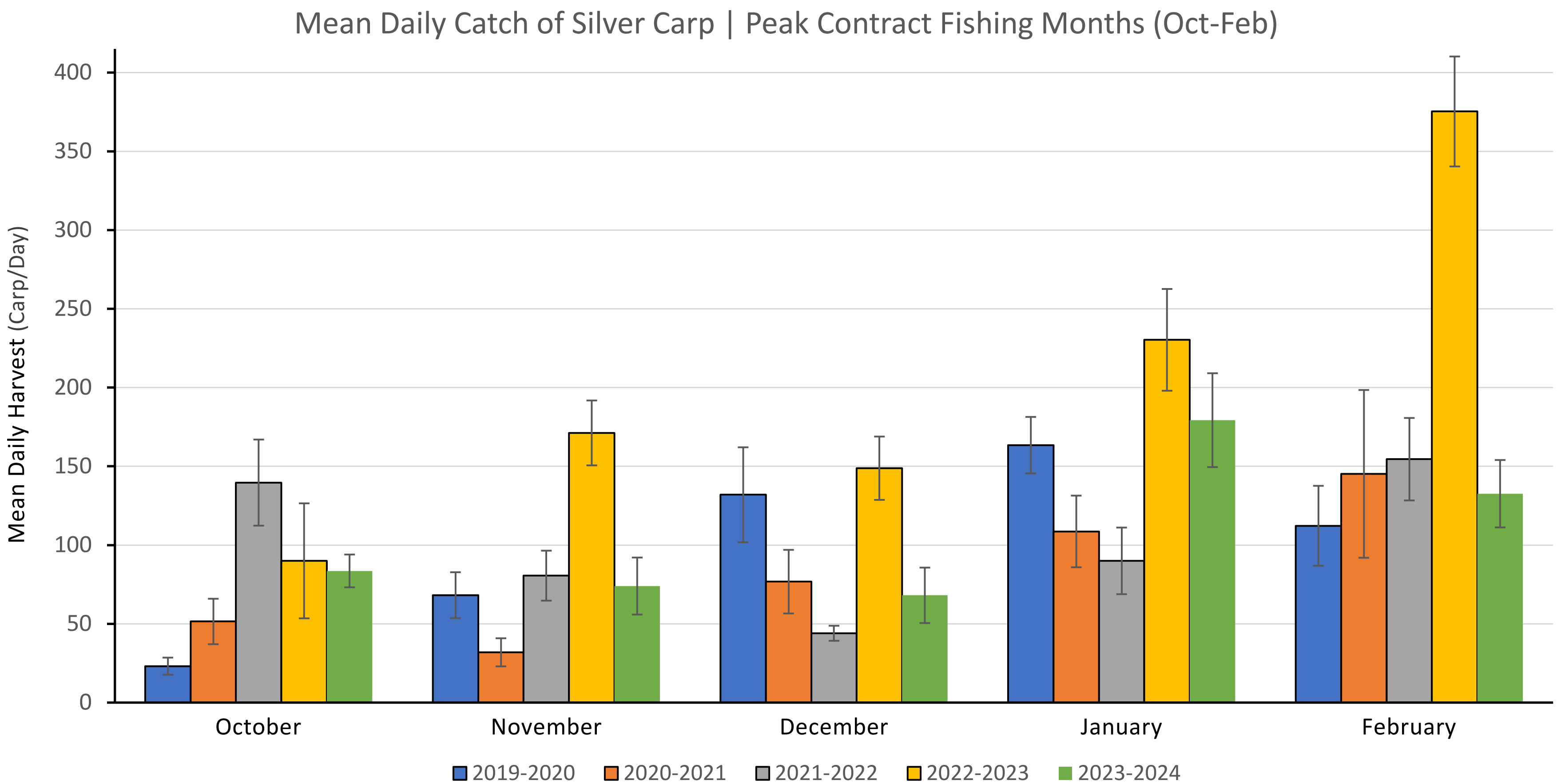

Figure 1. Graph illustrates the differences in average daily silver carp harvest for peak months of the past five contract fishing seasons. Error bars indicate SE.

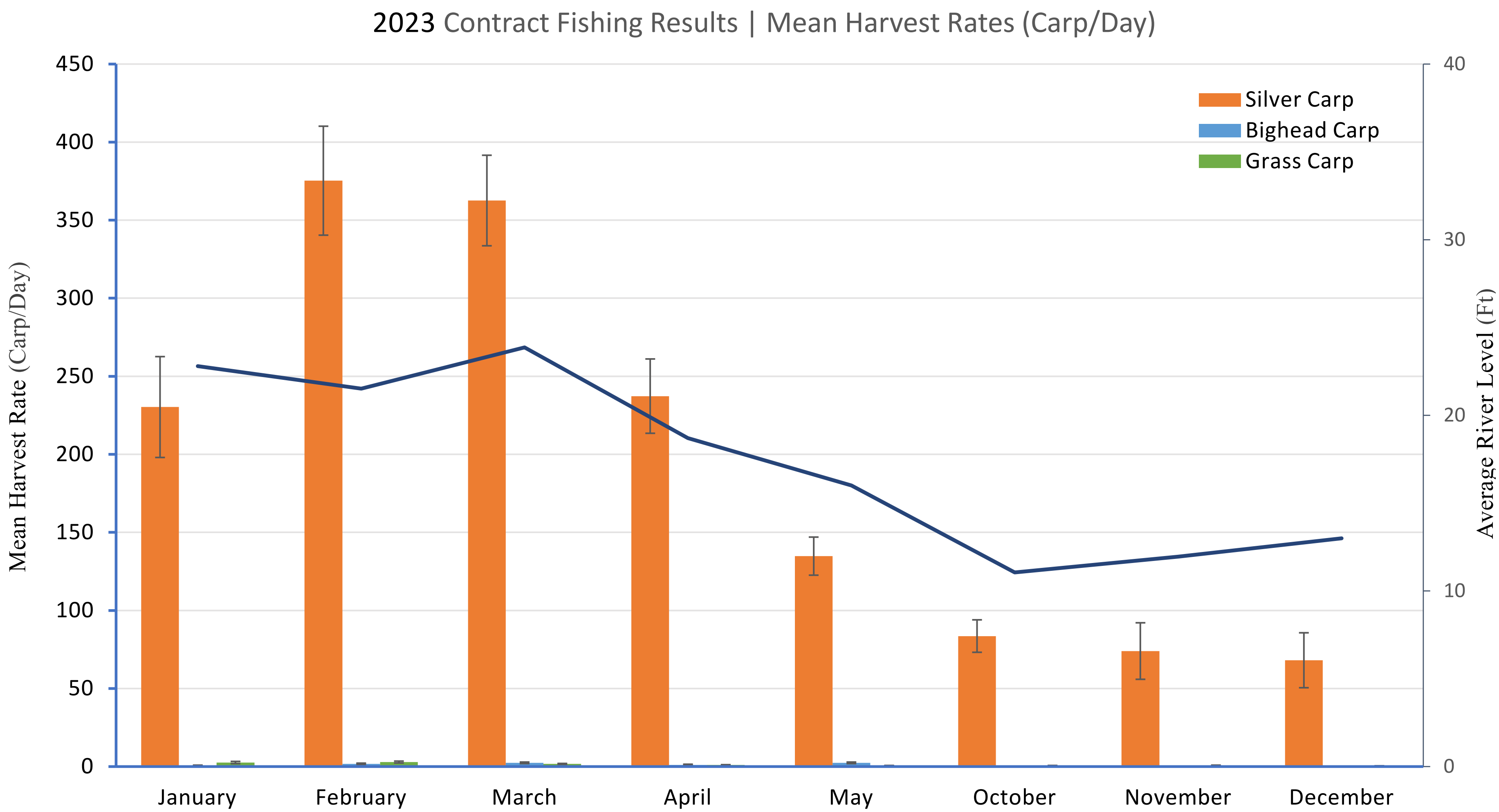

Figure 2. The average harvest rates (Fish/Day) in months between January and December 2023 that KDFWR employed contract fishermen to remove invasive carp. Error bars represented the standard error for daily catches. In addition, mean river level was calculated from data recorded by a USGS gage located at Cannelton Locks & Dam. Average daily landings in 2023 continued to be influenced by both temperature and river levels.

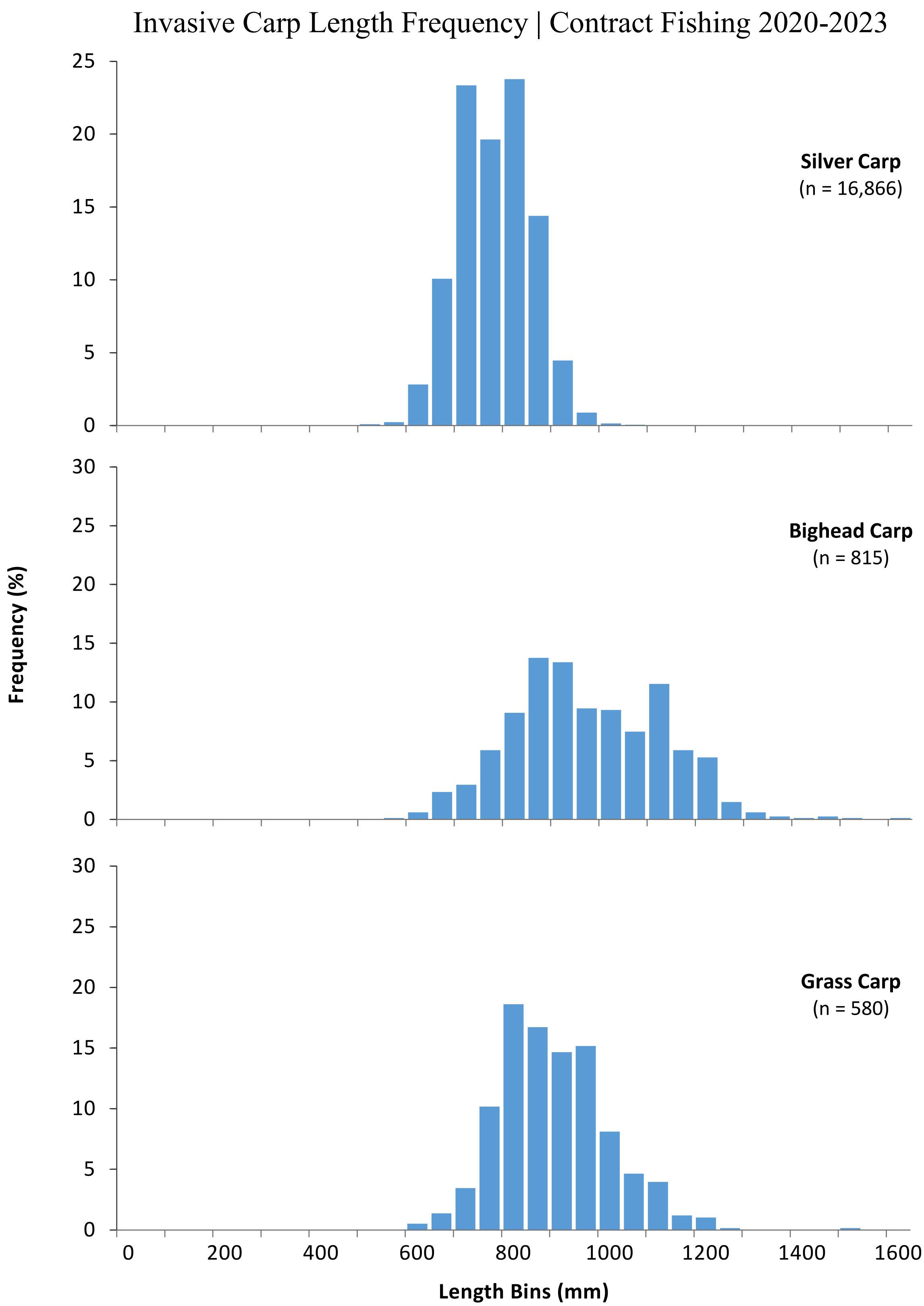

Figure 3. Length frequency distributions generated from subsamples of invasive carp that contract fishers caught and removed from the Cannelton Pool in 2020-2023.

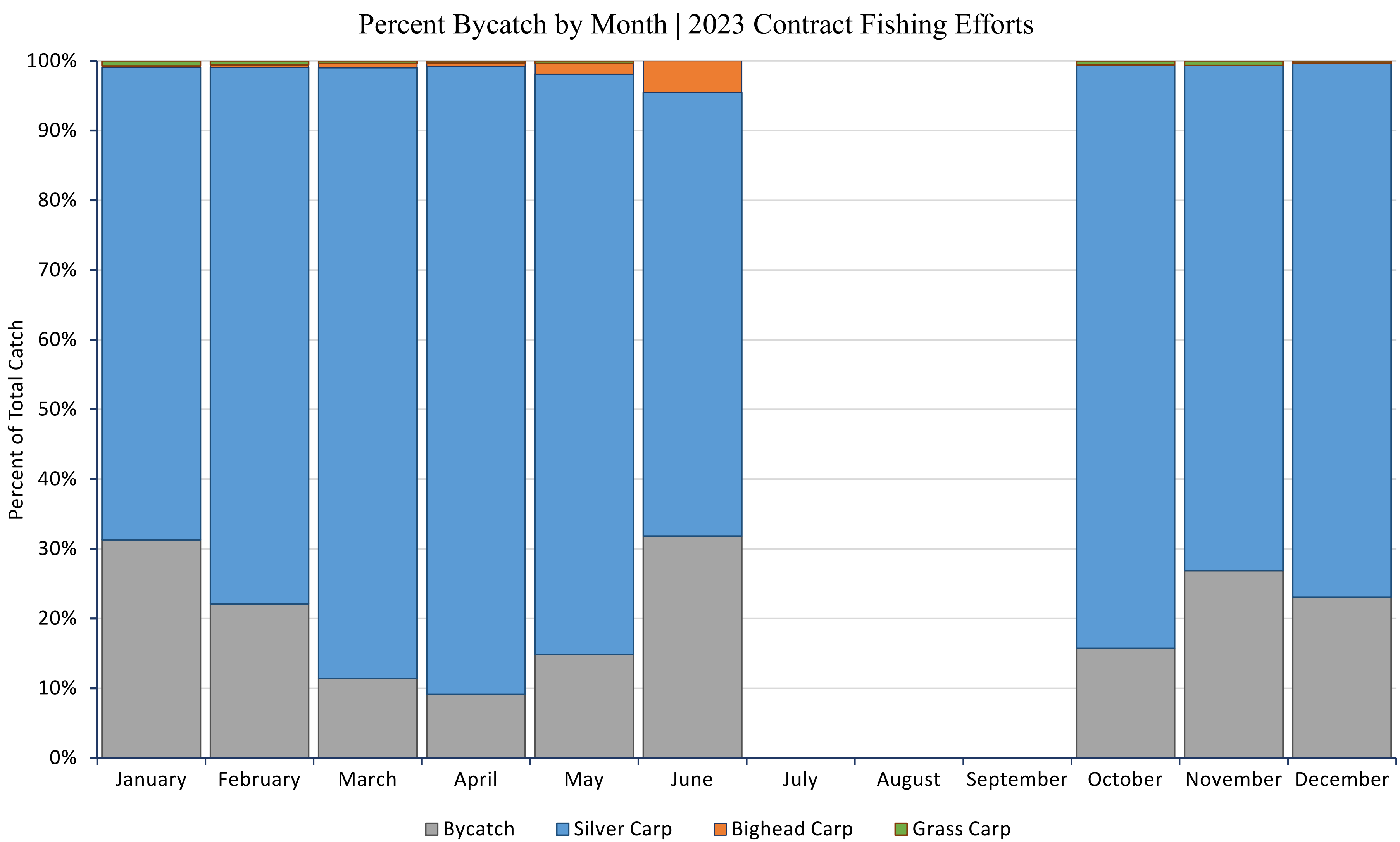

Figure 4. The monthly percent contribution of bycatch and the three invasive Carp species caught during the contract fishing efforts conducted in January through December 2023.

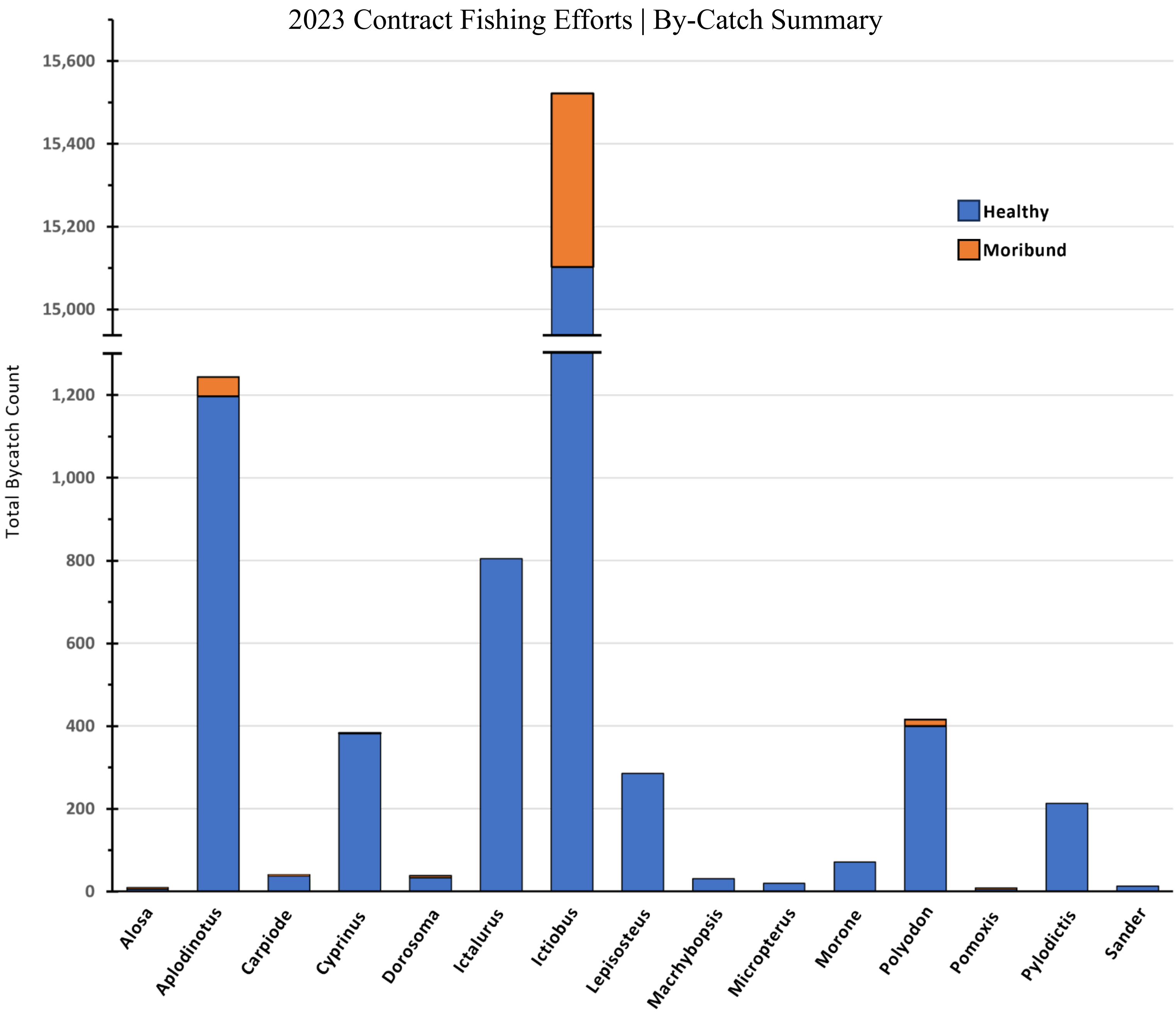

Figure 5. Total counts of all contract fishing bycatch recorded from January through December 2023. Color indicates the status of the fish after being removed from gill nets. Bycatch was considered moribund if it suffered significant damage or could not swim off following release. Healthy, or resilient, fish were those that quickly recovered and could swim away under their own power.