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ANNUAL PERFORMANCE REPORT

for

Invasive Carp Research and Monitoring

Project Leaders: *Jeffrey Herod, Josh Tompkins*

Project Biologists: *Tyler Befus, Matthew Dollenbacher, Chris Hickey, Maris Weihe*

Project Technicians: *Clayton Adams, Chris Bowers, Logan Clark, Justin Lambert*

Kentucky Department of Fish and Wildlife Resources

Fisheries Division

Table of Contents

Aquatic Invasive Species Murray Branch: Josh Tompkins, Tyler Befus, Matthew Dollenbacher, Clayton Adams, Justin Lambert

Tennessee/Cumberland River Basin Invasive Carp Partnership

Evaluation & Removal of Invasive Carp in the Tennessee & Cumberland Basins 1

Early Detection of Invasive Carp Reproduction and Population Expansion in the Tennessee and Cumberland Rivers 41

Monitoring Invasive Carp Impacts on Native Fish Communities 47

Deterrent Strategy Planning for Invasive Carp in The Ohio River Basin 69

Aquatic Invasive Species Frankfort Branch: Jeffrey Herod, Chris Hickey, Maris Weihe, Chris Bowers, Logan Clark

Ohio River Basin Invasive Carp Partnership

Early Detection and Evaluation of Invasive Carp Removal in the Ohio River 83

Abundance and Distribution of Early Life Stages of Invasive Carp in the Ohio River 157

Quantifying Lock and Dam Passage, Habitat Use, and Survival Rates of Invasive Carps in the Ohio River Basin 191

Control and Containment of Invasive Carp in the Ohio River 239

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

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

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

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

Project Objectives:

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

Project Highlights:

KDFWR

- Commercial fishers removed over 15.8 million pounds of invasive carp statewide and 14.3 million pounds of invasive carp through the Invasive Carp Harvest Program in 2024. CPUE (fish/yard) was highest in 4” bar mesh gill nets.
- KDFWR staff conducted 135 ride-alongs with commercial fishers in the invasive carp harvest program, to monitor catch rates and collect other data. Of the 107-entanglement gear ride-alongs, 20 ended with no nets being set.
- Commercial fishers enrolled in the subsidy contract fishing program received $1,019,768.16 for invasive carp harvested from Barkley and Kentucky reservoirs.

- KDFWR continued a MOU with two fishers to test invasive carp experimental gears in Kentucky waters. During 2024, the fishers harvested approximately 87,976 lbs. of invasive carp from Kentucky and Barkley Reservoirs, 50,006 lbs. from the Green River, 1,078,107 lbs. from the Ohio River, 403,211 lbs. from the Mississippi River, 55,635 lbs. from the Kentucky tailwater, and 2,236,555 lbs. in Barkley tailwater.
- KDFWR received five reports of black carp in the Ohio River during 2024.

Methods:

KDFWR

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

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

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

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

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

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

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

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

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

KDFWR continues to offer contract fishing in Barkley and Kentucky Reservoirs to ensure commercial fishing effort targeting invasive carp remains robust, to meet agency management objectives. Commercial fishers must apply for the contract program and once approved, will receive a designated price per pound for invasive carp harvested from Barkley or Kentucky Reservoirs. The Invasive Carp Harvest Program is one of two programs Kentucky has implemented to increase commercial removal of invasive carp in the reservoirs.

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

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

Objective 5. 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 & B)

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

Paupier

U.S. Fish and Wildlife Service sampled Kentucky Reservoir with their electrified Paupier net boat during the fall of 2024. Lengths and weights were collected for all species until up to 30 individuals per species and then counted. If a transect concluded with a species count over ~500, they were subsampled and counted by weight. The electrified Paupier sampling observed a silver carp CPUE (fish/hr) of 13.9 in Big Bear embayment, which was a significant decrease from previous years (Table 6). Paupier data suggests a significant decline in CPUE of silver carp from Kentucky reservoir from 2019 through 2024. (Appendix B, Figure 2.). This trend data continues to support the hypothesis that the silver carp population in Kentucky reservoir is declining. Data from the Paupier sampling, compared to gill netting, theoretically creates less sampling bias and therefore a better fitting regression line when looking at Log10 transformed lengths and weights for silver carp; Kentucky Reservoir R^2=0.82 whereas Barkley reservoir R^2=0.69 (Figure 7 & 8).

Invasive Carp Harvest Program

Length and weight data was collected on 1999 silver carp harvested by commercial fishers in 2024 with 1711 of these fish being harvested from Kentucky and Barkley Reservoirs. Lengths ranged from 23.7 – 43.3 inches with an average of 31.8 inches, and weights ranged from 2.7–27.2 lbs. with an average of 13.2 lbs. for the ICHP program overall (Table 2). The average weight of fish caught in Kentucky and Barkley Reservoirs, when calculated separately from the overall ICHP program was found to be 14.3 lbs. which indicates overall condition is improved in fish living in the Kentucky and Barkley Reservoirs versus the Ohio, Tennessee, Cumberland, Mississippi, and Green River systems. If this metric is used in correlation with the total pounds of silver carp harvested by commercial fishers through the ICHP in 2024, that would produce a rough estimate of 993,140 individual silver carp being removed from Kentucky waters through the ICHP in 2024 (14,201,895 lbs.; Table 1). During ride-alongs, commercial fishers were observed using gill nets with a range of bar mesh sizes to target invasive carp (3.5” – 4.5” bar mesh; Table 3, Figure 12). Catch per unit effort of gill nets used to harvest silver carp were highest in gill nets with a bar mesh size of 4” (0.49 fish/yard), followed by 3.5” bar mesh which had a CPUE of 0.27 fish/yard. This showed a change from previous years towards a preference of larger gill net mesh sizes by the fishers. The data collected shows an increase from the previous three years (2020-2023) when the highest CPUE was in 3.5" and 3.75" bar mesh nets. The change in the size mesh size commercial fishers were using in Barkley and Kentucky Reservoirs, is likely due to an increase in the relative weight of the 2015 cohort of silver carp.

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

Barkley and Kentucky Reservoir Population Dynamics

A length-frequency histogram was created for silver carp harvested from Barkley and Kentucky Reservoirs from all harvest methods in 2024. Data suggested the 800 mm size class of silver carp were dominant in both systems (Figures 1 & 2).

Age and Growth

Otoliths were collected from silver carp in Barkley and Kentucky Reservoirs in the fall of 2024 for aging. Barkley ages ranged from 4 to 8 years old, with age 6 being the most abundant. Kentucky ages ranged from 4 to 9 years old, with age 8 being the most abundant, (Figures 3 & 4). Data suggests a strong presence of three cohorts of silver carp behind the 2015 cohort (9-year-old fish). Since no age-0 silver carp have been collected in either reservoir since 2015, logically these fish continue to immigrate into the reservoirs through the lock systems.

Mortality

Catch-curve regressions were developed for the 2015 cohort of silver carp by reservoir. This cohort of silver carp is the only documented cohort known to occupy the lakes at age 0. Data for age frequencies were ln(x+1) transformed to compensate for heteroscedasticity. A Chapman-Robson analysis was performed to estimate annual mortality (Â) and instantaneous mortality (Z). Annual mortality for silver carp from Kentucky Reservoir was estimated at 50% and instantaneous mortality was estimated at 0.70 (N=245, $F_{1,2}$=28.18.40, P=0.003, R^2=0.85; Figure 5). Annual mortality for silver carp from Barkley Reservoir was estimated at 42% and instantaneous mortality was estimated at 0.55 (N= 279, $F_{1,2}$=30.96, P=0.003, R^2=0.86; Figure 6). Estimates of annual mortality in 2024 increased from the vales reported in 2023 in Kentucky Reservoir but decreased in Barkley Reservoir from 2023. This is attributed to the wider time series of data for this cohort informing better model predictions.

Condition

Linear regressions were constructed to describe the log10 length-log10 weight relationship for silver carp in Barkley and Kentucky Reservoirs. The length-weight equation for Kentucky was estimated at Log10(weight(g)) = 3.2598Log10(length(mm)) –5.7117(Figure 7). The length-weight equation for Barkley was estimated at Log10(weight(g)) = 2.7669Log10(length(mm)) – 4.2531 (Figure 8).

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

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

No results to report.

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

<u>Incentivized Invasive Carp 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 2024, contractors received $1,019,768.16 for invasive carp harvested from Barkley and Kentucky Reservoirs. This equates to over 10 million pounds of invasive carp harvested through the contract program in 2024, the largest harvest to date. Refinements to the program were made in 2021 which removed the varying pay out based on size of fish harvested. As of January 2025, the program now pays contractors $0.10 / lb. for invasive carp harvested from Kentucky waters of the reservoirs regardless of the size of those fish.

<u>Invasive Carp Harvest Program Monitoring</u>

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

Since 2013, commercial fishers in Kentucky have harvested a total of 74,986,008 lbs. (Figure 14.) of invasive carp, the majority was harvested through the ICHP (Table 1), however there is a portion of commercial harvest that occurs in the Ohio River Contract Fishing program and via regular commercial fishing outside the ICHP. Total harvest would be higher if grass carp were included for all years, however commercial fishing reports prior to 2020 did not delineate grass carp from common carp. Most invasive carp harvested in Kentucky are from Barkley Reservoir

(Table 1). Commercial fishers typically prefer fishing Barkley Reservoir over Kentucky Reservoir as it is shallower, has more habitat to corral fish, less recreational traffic, and the fishers believe the silver carp are larger. From 2020 to 2023 there was a decrease in number of individual commercial fishers in Barkley Reservoir, but 2024 saw an increase in participation by fishers to levels seen in previous years. Overall, an increase in harvest was observed from 2023 to 2024, and from 2023 to 2024 there was an increase of almost 900 trips made on Barkley Reservoir as well as an increase in over 800,000 lbs. of carp removed over 2023's harvest. The amount of harvest of invasive carp from Kentucky Reservoir increased by approximately 40,000 lbs. from 2023 to 2024 and the number of individual fishers and trips increased from 2023 to 2024 (Table 1). The number of commercial fishers in Kentucky and associated trips under the ICHP program has varied annually. Factors affecting the increased efficiency are likely a combination of the 2015 cohort strength and improved commercial practices. Commercial fishers' adaptation in net sizes during the past several years helped facilitate the 2024 harvest as well as improvements to equipment such as boats, trucks, net rollers, cranes, and electronics.

Invasive carp harvest data was summarized by month from January 2020 to December 2024 (Figures 9 & 10). The highest number of commercial fishing trips recorded in a single month was 379 in October 2024; in 2021, number of trips was more standard across the months, whereas 2022 saw a lot of seasonal differences which has been mirrored in 2023. In 2024, it was observed that there was an increase in number of trips every month compared to 2023 except for January and December which saw only a slight decrease from 2023 (Figure 9). Average total pounds of silver carp harvested per trip decreased from 2023 and ranged from 2,925-5,760 pounds per month in 2024 (Figure 10).

Commercial harvest rates also vary among fishers. The most successful fishers understand silver carp behavior better, and they use higher quality gear with larger boats that have higher weight capacities. In 2024, the average number of pounds harvested per trip was calculated for all ICHP fishers (N=40), and average pounds of silver carp harvested varied from 256.6 lbs./trip to 8,488 lbs./trip. Interestingly, not all fishers with high catch rates fished frequently (Figure 11). The number of trips a commercial fishers took in 2024 varied from 1 to 223, with an average of 66 trips. This only included the number of trips where harvest occurred. In 2024, 52% of the requests to fish ended with fish harvested. Some fishers call in for whole weeks at a time, but may not go out every day, some cancelations were due to weather or equipment being down, other times, a fisher may go out to gill net, scan around and not find a school of fish big enough to set their net on.

Ride-Alongs

KDFWR conducted 135 ride-alongs with 19 unique commercial fishers utilizing the ICHP January through December 2024. Of those 135 ride-alongs, 107 were with fishers implementing entanglement gears. During entanglement ride-alongs 71,763 yards of gill net were fished and 373,768 lbs. of invasive carp were harvested (Table 4, Figure 13). Most ride-alongs were on Barkley Reservoir (N=79), while Kentucky Reservoir only had 21 ride alongs, which was representative of fishers' efforts divided between the two reservoirs. Commercial fishers using gill nets, set nets primarily along secondary channels, on flats on the main lake, and in embayments. In previous years, the northern end of Barkley Reservoir received the most fishing pressure. However, in 2021 through 2024, fishing pressure observed through ride-alongs was more evenly distributed throughout Barkley and Kentucky Reservoirs (Figure 13). The mean effort per trip (yards of net fished) increased in 2024 (751 yds/trip) compared to 2023, which is reflective of the changing strategies that commercial fishers were employing to catch silver carp (active setting vs. dead setting nets) (Table 4). Effort was more comparable with observed efforts in 2020, 2021, and 2022. Average total weight of silver carp harvested per trip during ride-alongs in 2024 (4,452 lbs.), slightly lower than 2023 (Table 5). On multiple trips, KDFWR staff observed, a commercial fisher scan with side scan technology and not set a net because they couldn't find a big enough school of invasive carp. This occurred on three occasions during 2021, six times during 2022, nine times during 2023, and twenty times in 2024. KDFWR has begun to monitor zero net set trips and search time as a fisheries dependent trend to inform invasive carp stock assessments.

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

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

KDFWR staff continued to monitor seining practices under the current experimental gears program to determine efficacy in Kentucky waterways for removal of invasive carp and to determine the lasting impact on non-target fish species. Robbins Construction LTD harvested approximately 87,652 lbs. of invasive carp from Barkley Reservoir in 2024 with a daily average of 17,530 lbs./day which was consistent with his daily average in 2023 of 17,825 lbs./day. Additionally, Robbins harvested 2,236,555 lbs. (39,237 lbs./day) of silver carp from the Cumberland River and 55,635 lbs. of silver carp from the Tennessee River. Sport fish bycatch and other fish species, that were not harvested, were observed to have an 100% survival rate at the time of release. While outside the scope of this report, it is worth noting that Robbins Construction LTD also harvested 1,076,327 lbs. (33,635 lbs./day) of silver carp from the Ohio

River, 371,413 lbs. (37,141 lbs./day) from the Mississippi River, and 50,006 lbs. (12,501 lbs./day) from the Green River in 2024 through the program. Robbins' seining in Kentucky waters yielded him a total of 3,877,588 lbs. of silver carp, averaging 34,315 lbs. of silver carp per day in 2024.

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

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

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

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:

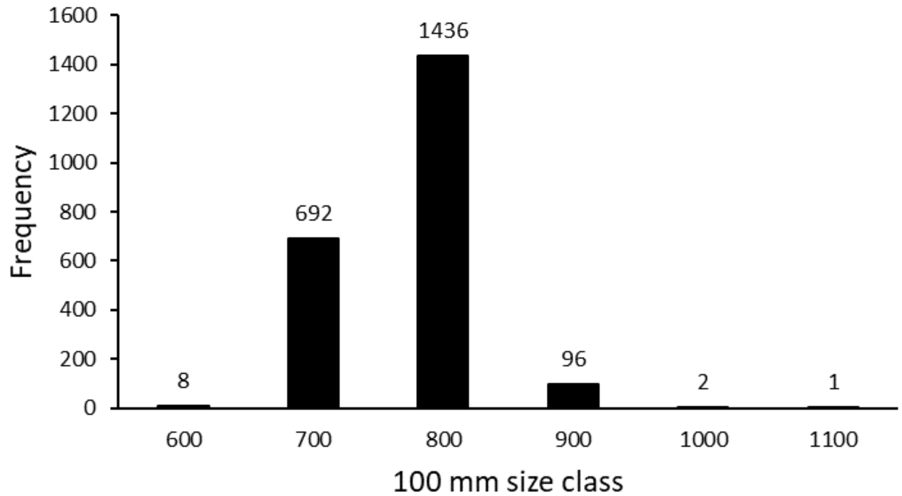

Figure 1. Length-frequency distribution of silver carp collected from Barkley Reservoir, from all methods in 2024 (N=2235).

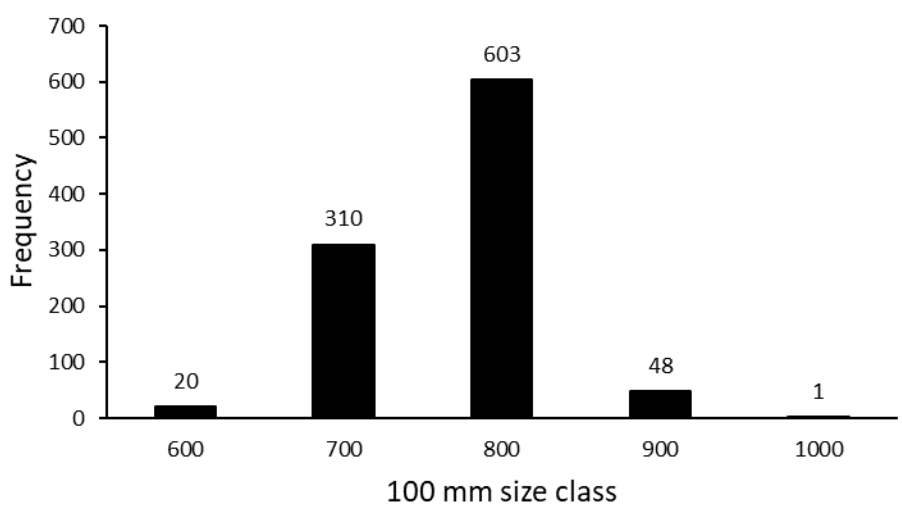

Figure 2. Length-frequency distribution of silver carp collected from Kentucky Reservoir, from all methods in 2024 (N=982).

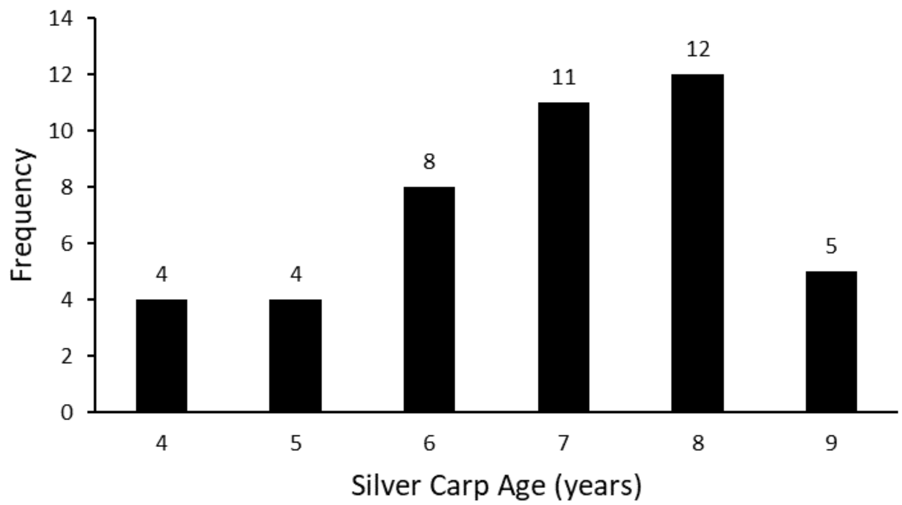

Figure 3. Age-frequency distribution for silver carp collected from Kentucky Reservoir in 2024 (N=44)

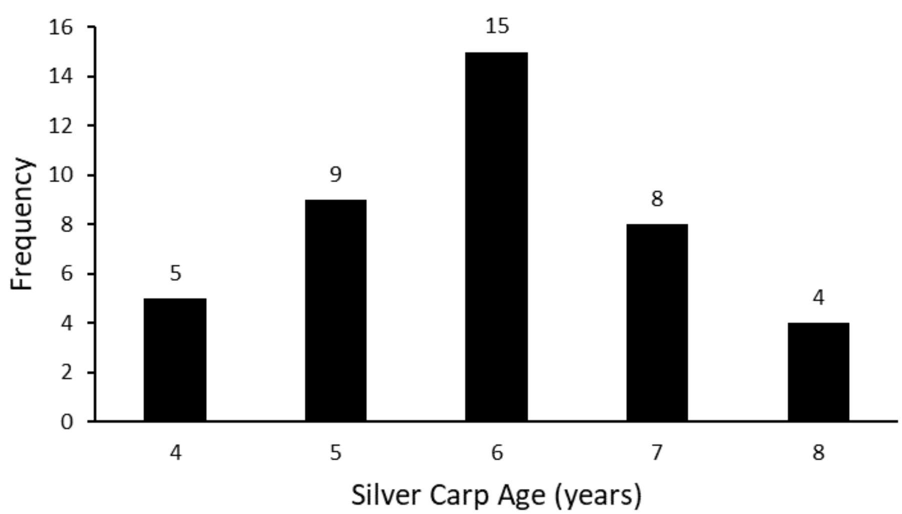

Figure 4. Age-frequency distribution for silver carp collected from Barkley Reservoir, in 2024 (N=41).

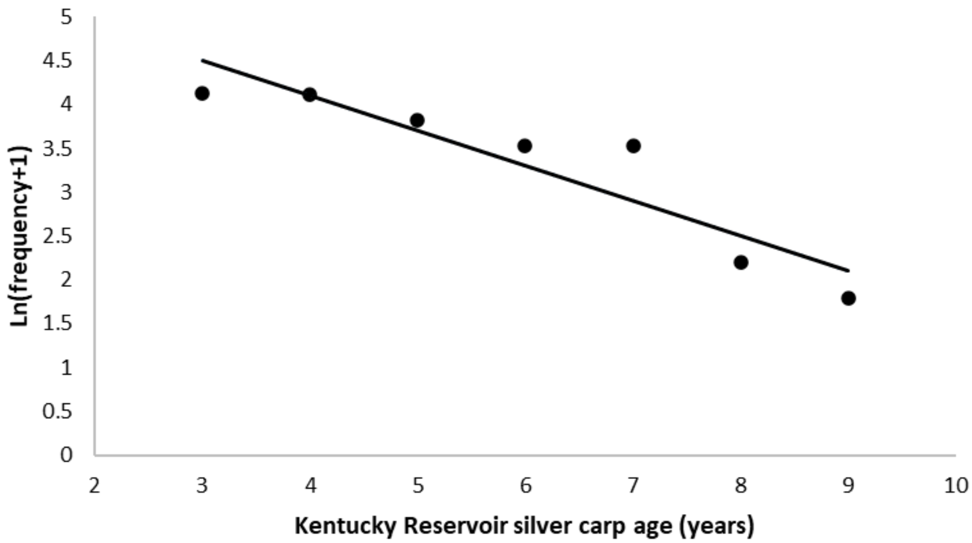

Figure 5. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Kentucky Reservoir in 2024 (N=245, F1,2=28.18, P=0.003, R2=0.85).

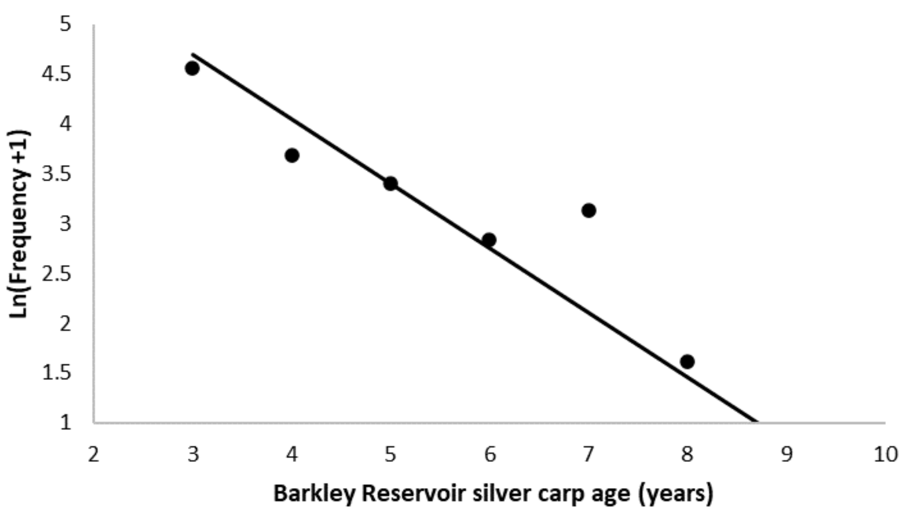

Figure 6. Catch-curve regression estimating mortality of the 2015 cohort of silver carp in Barkley Reservoir in 2024 (N=279, F1,2=30.96, P=0.003, R2= 0.86).

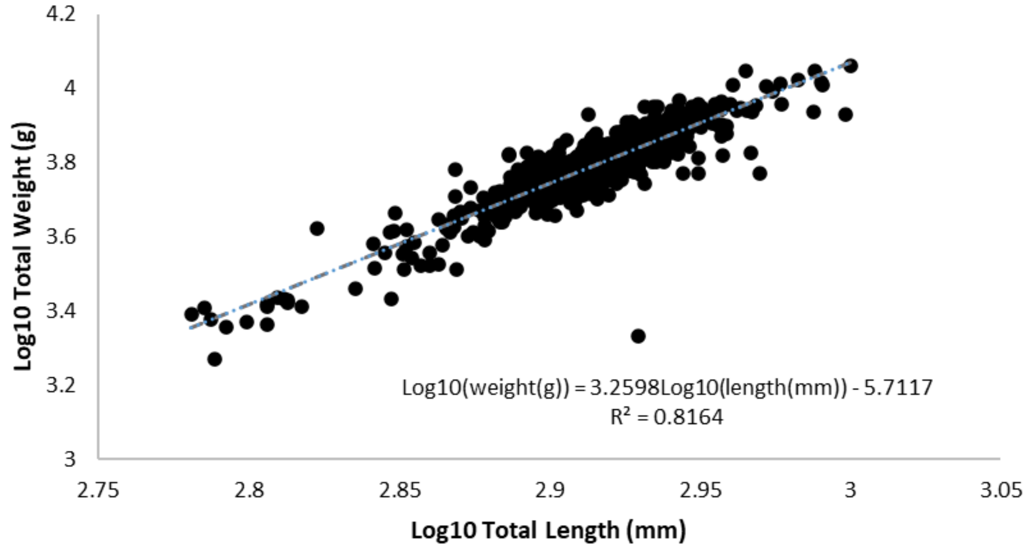

Figure 7. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Kentucky Reservoir in 2024 with a regression line describing the relationship between lengths and weights (N=580).

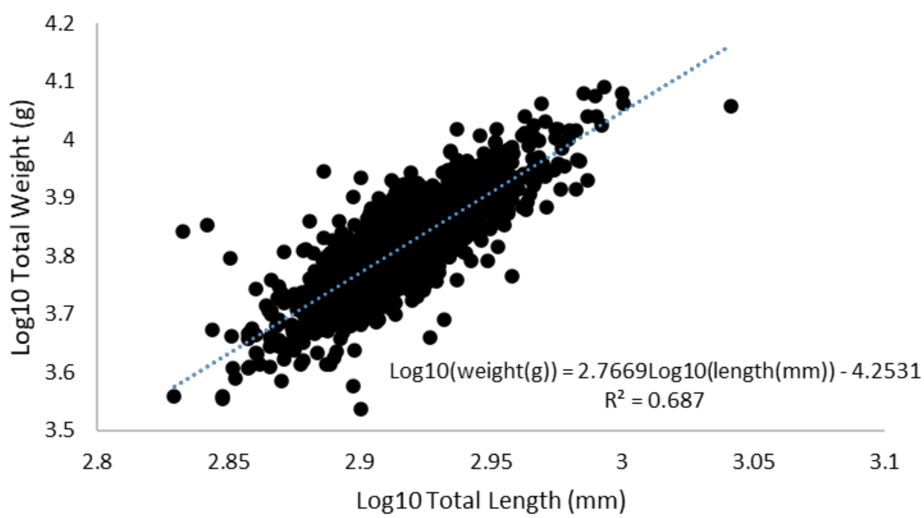

Figure 8. A scatterplot of Log10 transformed lengths and weights for silver carp harvested from Barkley Reservoir in 2024 with a regression line describing the relationship between lengths and weights (N=1572).

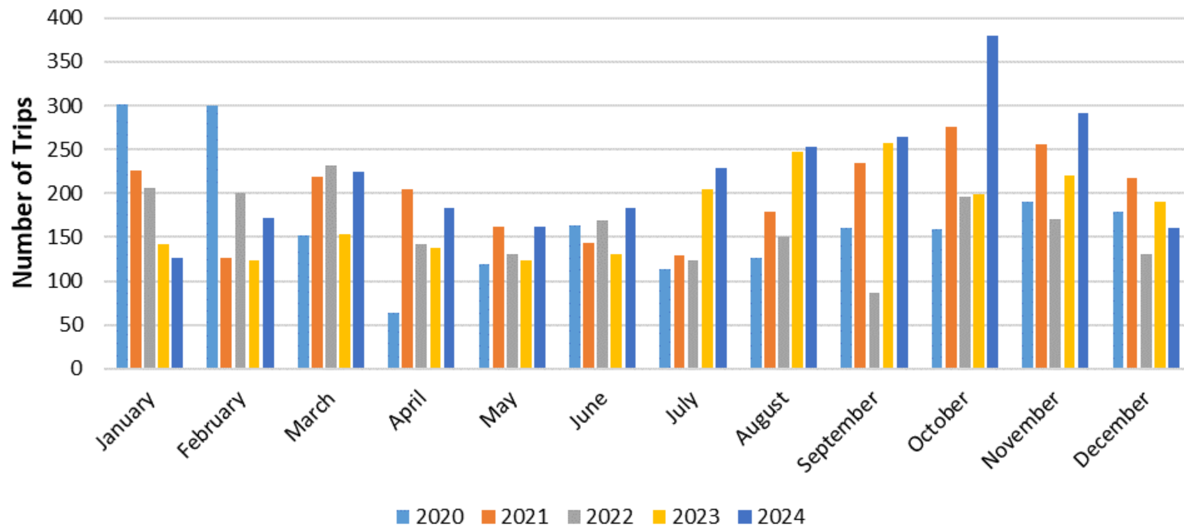

Figure 9. Number of fishing trips made monthly by commercial fishers fishing under the Invasive Carp Harvest Program from January 2020 - December 2024.

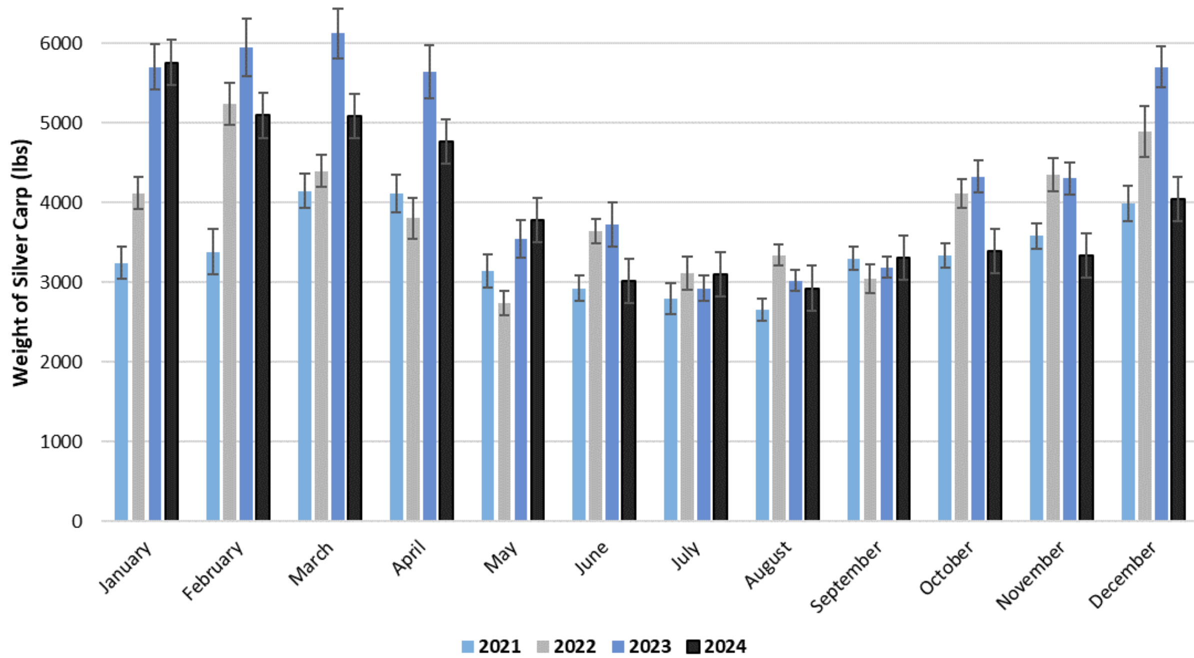

Figure 10. Monthly average total weight (lbs.) of silver carp harvested per trip by commercial fishers fishing under the Invasive Carp Harvest Program January 2021 - December 2024. Error bars represent standard error values.

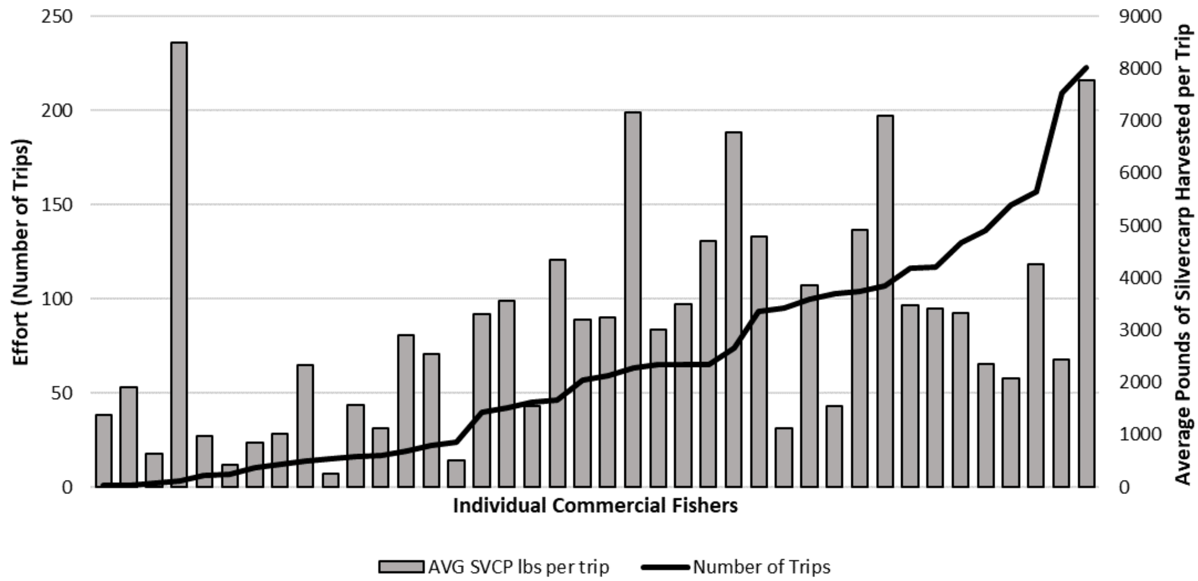

Figure 11. Average weight harvested per trip by individual commercial fishers compared to the number of trips that ended in harvest taken by those fishers under the Invasive Carp Harvest Program in 2024.

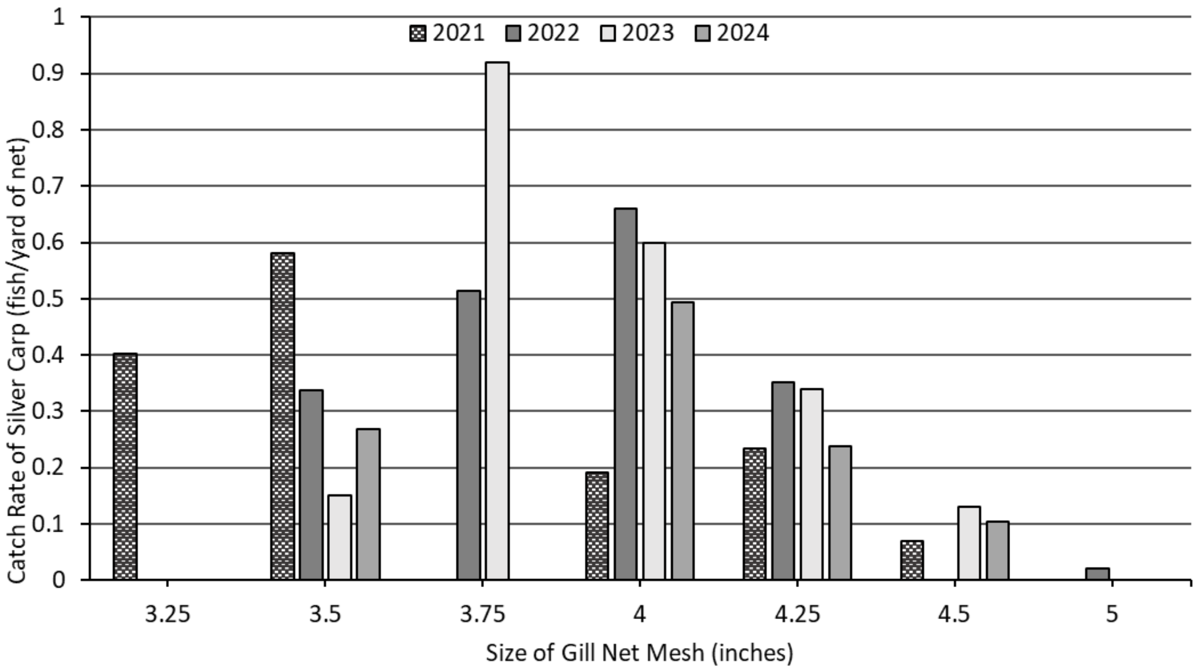

Figure 12. Catch rates (number of fish / yards of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Invasive Carp Harvest Program from 2021 through 2024.

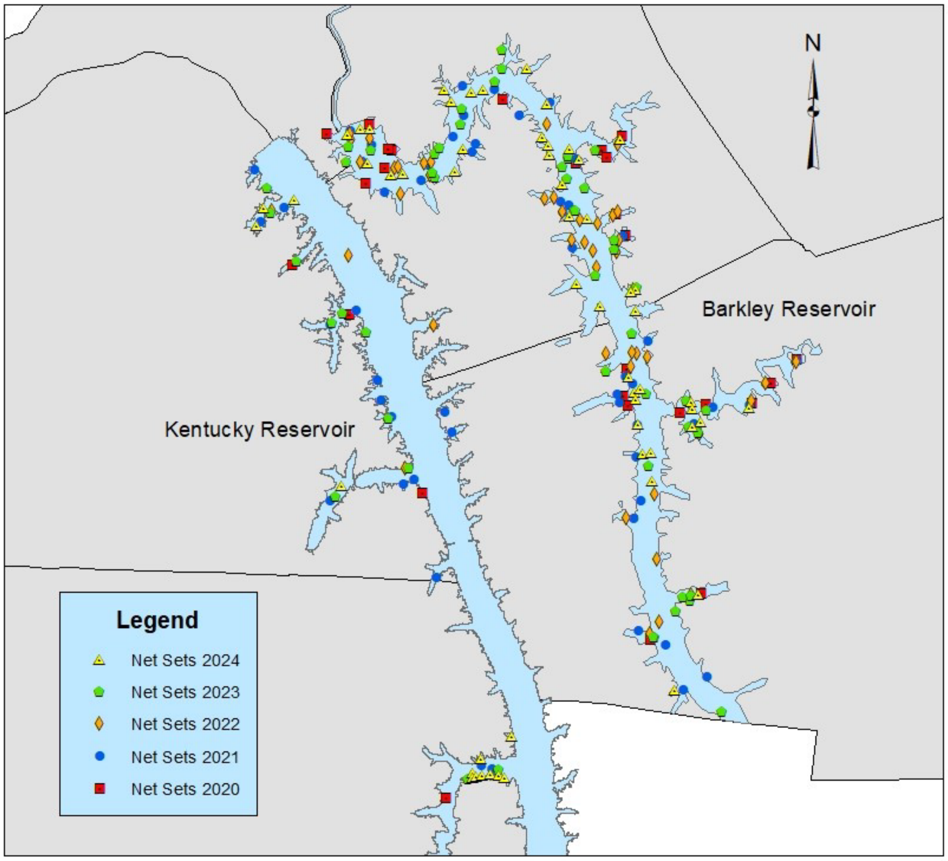

Figure 13. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff from 2020 through 2024.

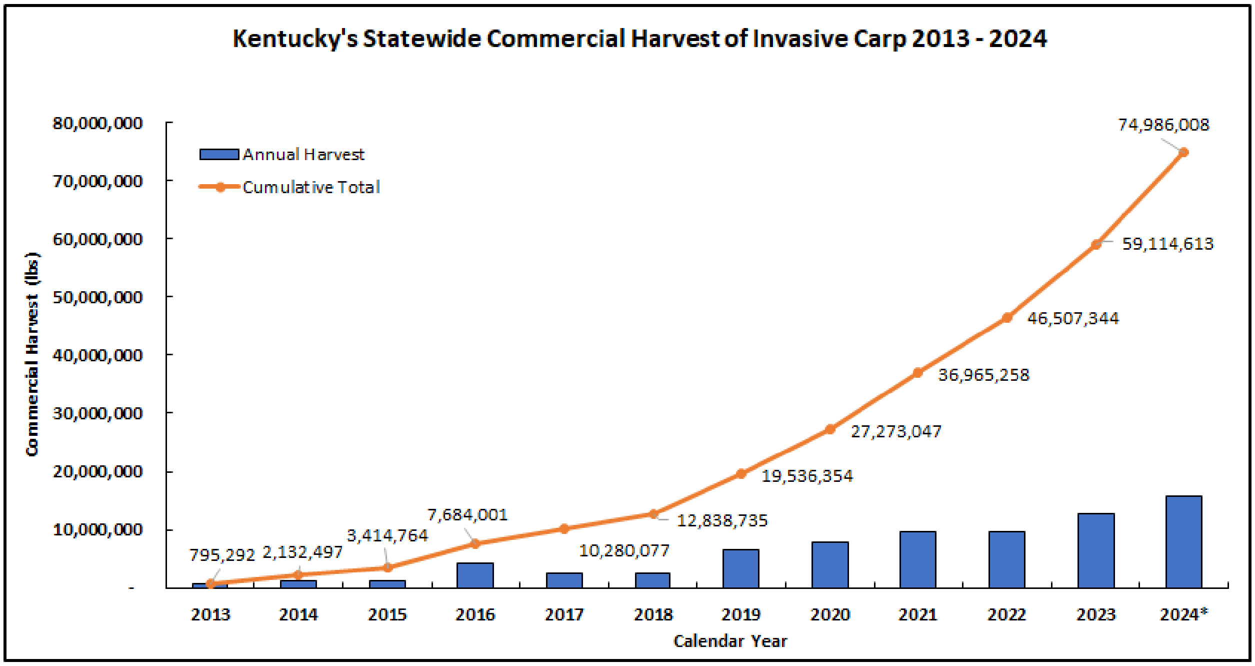

Figure 14. Kentucky's statewide reported commercial harvest of invasive carp in all programs from 2013-2024.

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

Water Body	Year	Number of Days/Trips	Number of fishers	Weight silver carp harvested (lbs)	Weight bighead carp harvested (lbs)	Weight grass carp harvested (lbs)
Barkley Reservoir	2020	1,431	43	4,700,149	28,714	61,487
	2021	1,707	32	5,918,405	18,669	43,213
	2022	1,510	30	6,120,640	24,762	37,664
	2023	1,725	31	7,914,777	20,024	59,284
	2024	2,626	38	8,686,362	16,683	54,358
Kentucky Reservoir	2020	426	27	1,601,822	4,196	40,882
	2021	587	28	2,154,845	4,227	27,514
	2022	309	20	1,184,756	3,074	8,666
	2023	338	25	1,174,586	3,953	3,773
	2024	487	28	1,213,612	12,065	4,132
Ohio River	2020	151	13	137,754	7,402	6,402
	2021	56	7	60,741	1,286	3,028
	2022	124	11	274,235	5,117	8,872
	2023	57	9	143,580	90	9,810
	2024	192	6	117,219		
Statewide *	2020	2,052	48	6,471,718	43,931	111,190
	2021	2,373	38	8,148,093	24,699	74,430
	2022	1,951	39	7,582,713	33,123	55,805
	2023	2,131	35	9,250,292	25,001	72,967
	2024	2,629	40	14,201,895	34,094	87,644

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

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

Year	Number Sampled	Average total length (inches)	Average weight (lbs)	S. E.
2020	595	28.0	8.5	0.11
2021	949	27.9	8.9	0.07
2022	1041	29.9	10.9	0.09
2023	1040	31.4	13.0	0.08
2024	1999	31.8	13.2	0.08

Table 3. Number of bighead carp, grass carp, and silver carp captured by gill-net mesh size as observed during KDFWR ride-alongs with commercial fishers participating in the Invasive Carp Harvest Program 2020 - 2024. (CPUE = catch per unit effort)

Year	Net Bar Mesh Size (inches)	Effort (linear yards of net)	Number of Silver carp	Silver carp CPUE (fish/yard)	Number of Bighead carp	Number of Grass carp
2020	3	100	18	0.18		
	3.25	3,933	1,968	0.50	2	17
	3.5	21,692	14,792	0.68	33	169
	4	533	38	0.07		
	4.25	2,100	319	0.15	6	
	4.5	1,583	104	0.07	5	
	5	267	9	0.03	4	
2021	3.25	2,117	851	0.40		6
	3.5	35,093	20,416	0.58	73	134
	4	2,583	494	0.19	17	3
	4.25	1,100	258	0.23	17	
	4.5	1,450	102	0.07	4	
2022	3.5	11,000	3,699	0.34	10	11
	3.75	17,292	8,812	0.51	22	12
	4	5,033	3,136	0.62	32	4
	4.25	56,667	2,784	0.05	39	
	5	667	10	0.01		
2023	3.5	1,200	174	0.15		
	3.75	2,767	2,547	0.92	5	3
	4	28,193	16,843	0.60	74	46
	4.25	2,983	1,003	0.34	3	2
	4.5	2,133	273	0.13	4	
2024	3.5	400	107	0.27		
	4	27,367	13,527	0.49	39	26
	4.25	36,097	8,614	0.24	65	28
	4.5	6,567	679	0.10	15	8

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

Year	Effort *	Mean effort per trip	S. E.	Number of ride alongs	Number of fishers	Total WT of bighead carp harvested (lbs)	Total WT of silver carp harvested (lbs)	Total WT of grass carp harvested (lbs)
2020	30,208	1,007	58.0	30	16	1,226	143,257	1,372
2021	42,193	728	53.0	58	18	1,780	198,249	1,130
2022	39,658	778	55.9	51	16	2,227	203,994	297
2023	34,010	654	40.6	61	18	2,064	273,994	600
2024	71,763	751	38.3	107	19	3,190	369,561	1017

*effort is calculated in yards of gillnet fished.

Table 5. Comparison of the average weight harvested per trip of silver carp, bighead carp and grass carp during KDFWR ride-alongs, and through commercial fishers reports for the Invasive Carp Harvest Program in 2016 - 2024. (S.E. = standard error)

Year		Silver Carp	S. E.	Bighead Carp	S. E.	Grass Carp	S. E.
2020	Ride Alongs	4,775	677.5	41	14.8	46	15.5
	Commercial Fisher Reports	3,186	62.4	22	1.8	55	3.0
2021	Ride Alongs	3,389	353.2	31	9.4	20	4.0
	Commercial Fisher Reports	3,434	56.9	10	1.2	31	1.9
2022	Ride Alongs	3,731	365.5	147	64.6	28	9.2
	Commercial Fisher Reports	3,889	63.9	137	17.2	122	13.5
2023	Ride Alongs	4,492	441.7	10	4.7	34	17.0
	Commercial Fisher Reports	4,641	93.7	10	2.7	33	6.0
2024	Ride Alongs	4,452	425.4	114	26.2	54	13.3
	Commercial Fisher Reports	3,810	61.2	214	21.6	351	56.9

Table 6. Paupier net effort and catch rates from sampling conducted in Big Bear embayment of Kentucky Reservoir in 2024. (S.E. = Standard error)

Date (Month-Year)	Net Hours	Number of Silver carp captured	Mean Silver carp CPUE (fish/hr)	S.E.	Number of Grass carp captured	Number of Bighead carp captured
Nov-16	9.12	1,406	168.9	23.0	3	
Oct-17	2.12	516	229.2	40.3		2
Oct-18	4.72	1496	308.3	61	1	2
Oct-19		442	~260	~60	1	
Oct-22	1.28	105	105.9	33.2		
Nov-23	0.66	24	36	9.07		
Nov-24	1.67	22	13.2	14.3		1

Appendix B:

Project Title: Kentucky Lake Silver Carp Assessment

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

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

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

Statement of Need:

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

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

To supplement ongoing invasive carp demographic sampling, Columbia Fish and Wildlife Conservation Office implemented sampling in Kentucky Lake embayments using the electrified paupier trawl (hereafter, "paupier"), starting in fall of 2019 (Towne et al. 2022). Fall sampling with the paupier has now occurred in 2019 and 2022 – 2024, with COVID-19 and personnel constraints precluding sampling in 2020 and 2021. Based on partner input, the objective of this study was to provide catch rates, size distribution, and body condition of Silver Carp in Kentucky Lake using the paupier.

Project Objectives:

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

Project Highlights

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

Methods:

Site Selection

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

Field Collection

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

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

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

Data Analysis

Catch per unit effort (CPUE), body condition, and size structure was summarized among all the embayments sampled within a year. The CPUE for Silver Carp was calculated as number of fish at or above stock size (250 mm: Phelps and Willis 2013) per hour. Relative standard error (RSE) of CPUE was calculated to estimate precision of catches, with a target RSE of ≤ 25 (Dumont and Schlechte 2004). To compare body condition, relative weight was calculated using the observed weight and the standard weight equation specific to Silver Carp (Lamer 2015). The relative weight equation was developed using a 50th percentile approach (Wege and Anderson 1978; Lamer 2015), which defines a Silver Carp in average condition as having a relative weight of 100. A Kruskal-Wallis test (Nelson 2023) was used to compare the relative weight among years. If the model was significant, a Dunn's Test (Dinno 2024) was completed to determine which year comparisons were statistically different. Non-parametric tests were used due to data non-normality. All statistical analyses, summaries, and figures were performed or produced in R (R 4.4.2; R Core Team 2024).

Results and Discussion

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

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

Invasive species demographic rates can alter in response to changes in densities either by natural or human intervention. With the removal of Silver Carp in a quantity large enough to impact the population, trends in data would be expected, such as a decline in relative abundance, increase of relative weight, and increase in growth. Despite differences in power that could be affecting catch (Table 1), the paupier data potentially show an aging, declining Silver Carp population found within the embayments as shown in the catch and lengths. However, other population dynamic components such as mortality and migration need to be considered when interpreting observed population declines. Fishing mortality due to removal efforts in conjunction with natural fish mortality, immigration, or emigration would have an impact on the Silver Carp population in Kentucky Lake. Further research into these components, particularly immigration and emigration, within the Tennessee River system and its connection to the Cumberland River basin are needed to better understand data trends (MICRA 2022b; Umland et al. 2024). Maintaining high exploitation through the incentivized harvest programs is necessary. Furthermore, modeling efforts, as being done by state and federal partners, should continue to be conducted using fisheries dependent and fisheries independent data to better understand what levels of exploitation are needed to exert population level effects to further reduce the impacts of Silver Carp on the ecosystem, economy, and recreation of Kentucky Lake.

Table and Figures

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

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

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

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

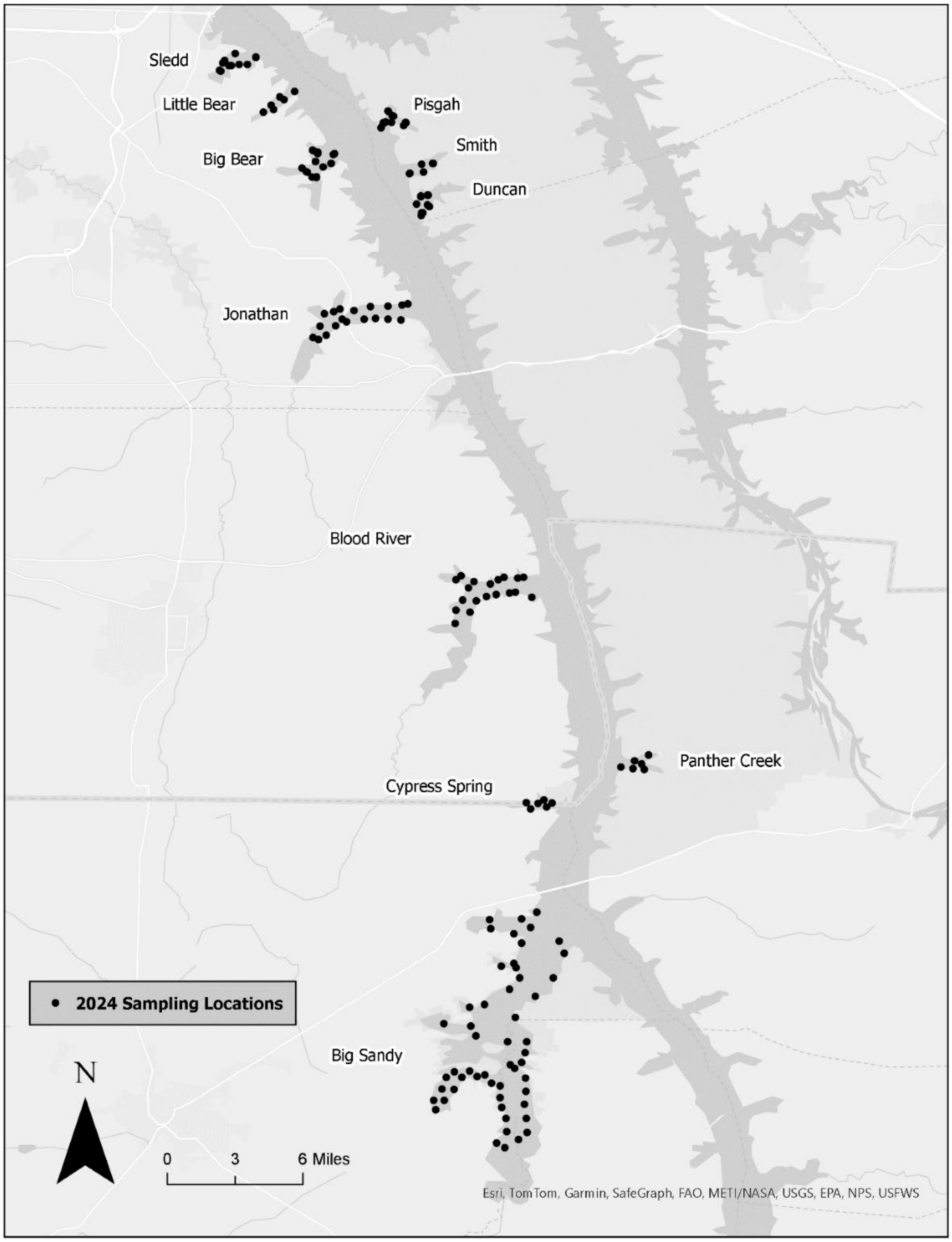

Figure 1: Map of electrified paupier trawl sampling locations in 2024.

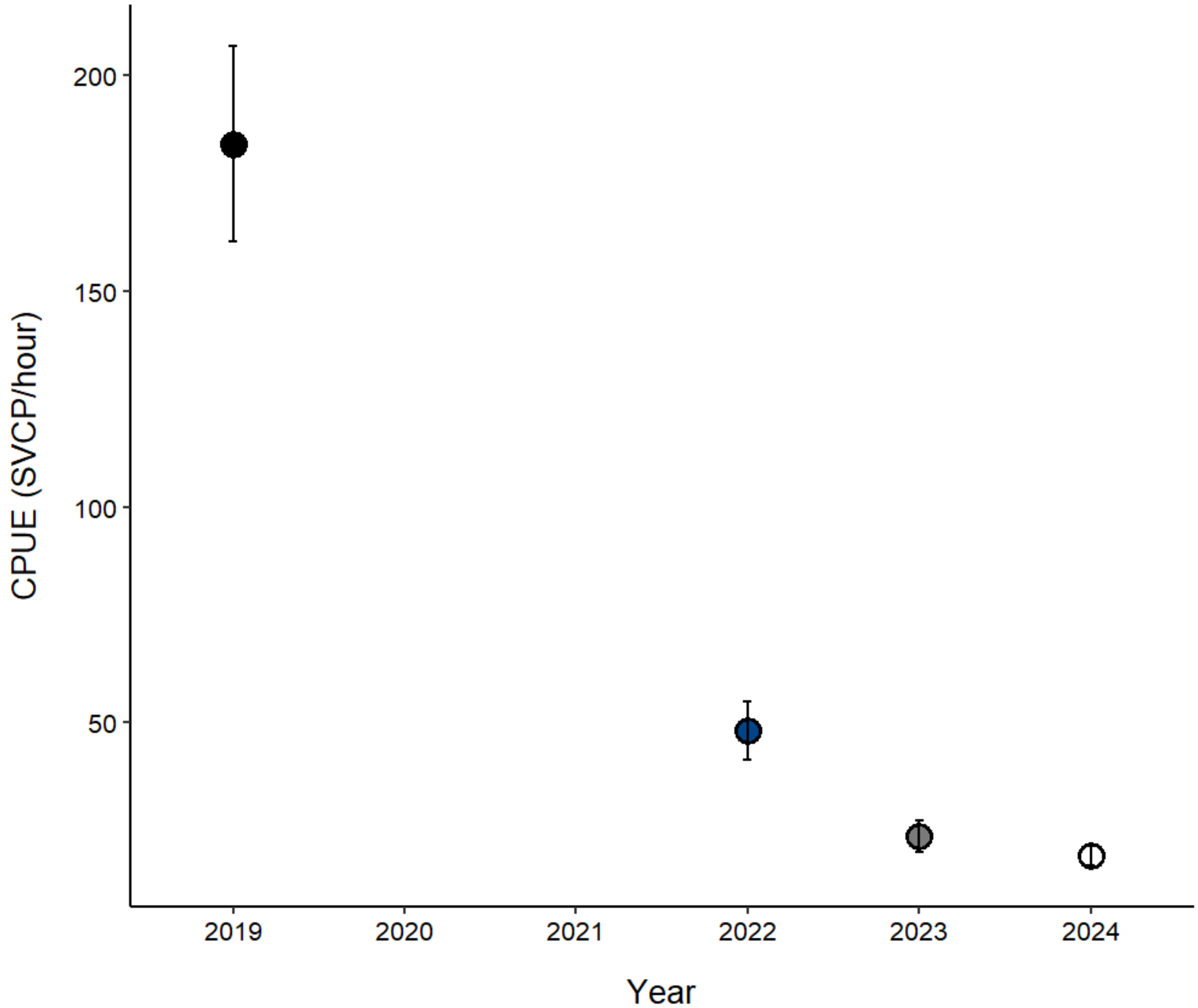

Figure 2: Kentucky Lake catch per unit effort (CPUE) of Silver Carp (SVCP) by year. Error bars represent one standard error.

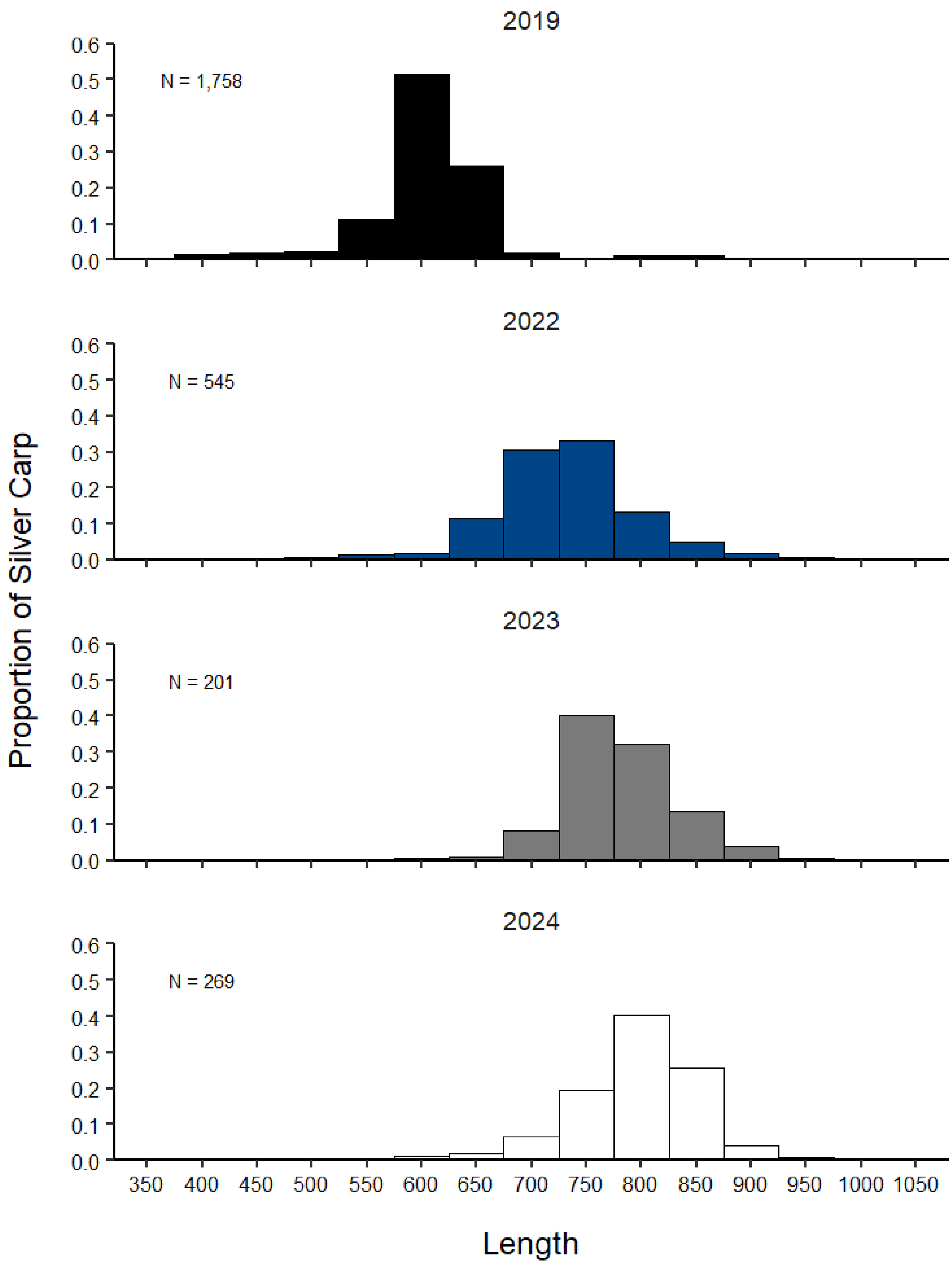

Figure 3: Relative length frequency of Silver Carp collected with the paupier in Kentucky Lake in 2024. The number of Silver Carp per 50 mm length bin collected by each year is included for each respective graph.

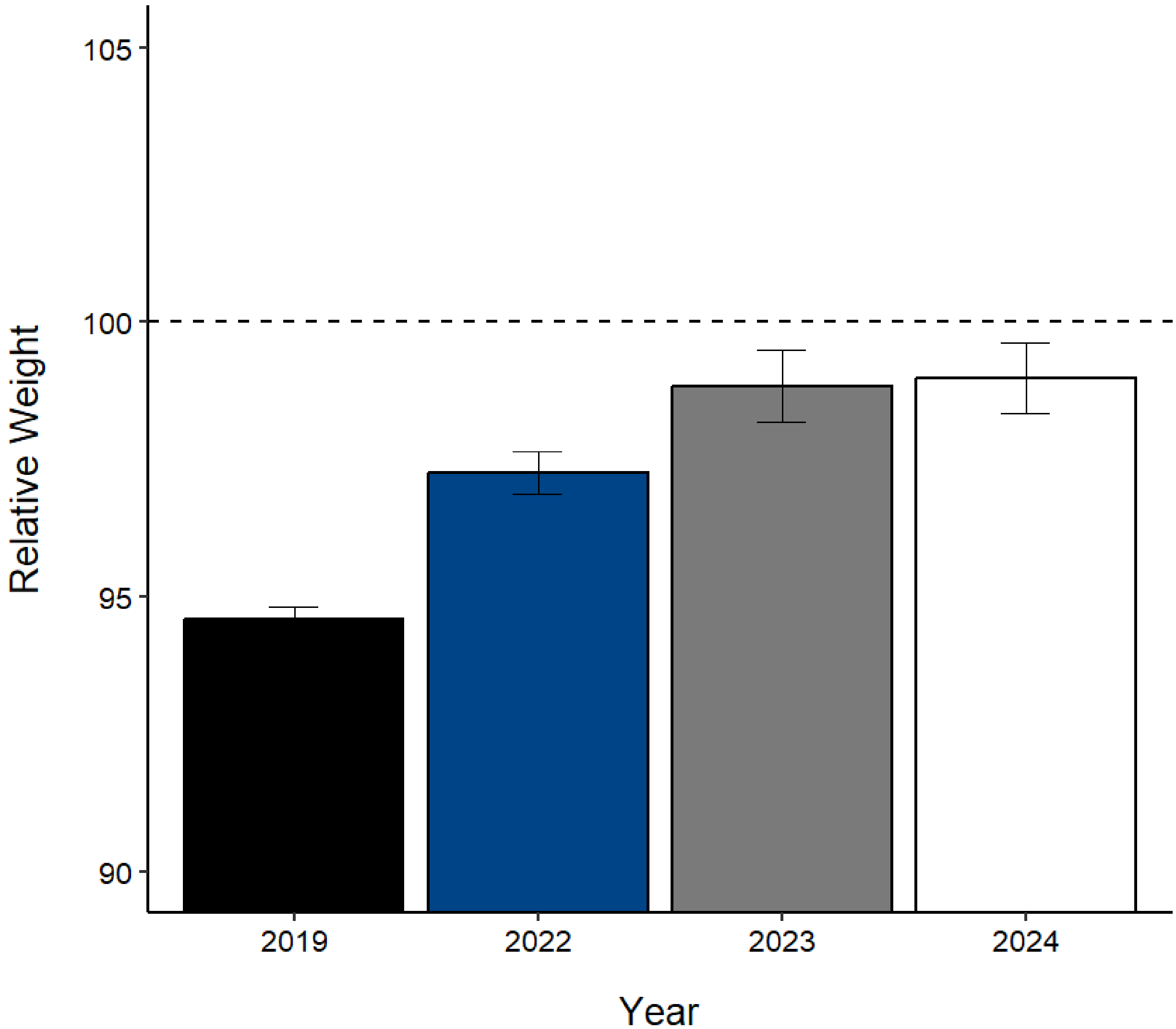

Figure 4: Relative weight for Silver Carp (SVCP) by year for Kentucky Lake. Bars represent one standard error and the dashed horizontal line indicates an "average" body condition based on the standard weight equation (Lamer 2015).

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Appendix BA.

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

Fish Species	Big Bear	Big Sandy	Blood River	Cypress Spring	Duncan	Jonathan
Bighead Carp	1	3	0	0	0	1
Black Buffalo	3	0	0	0	0	0
Bluegill	21	61	15	8	4	41
Bigmouth Buffalo	1	7	1	0	0	0
Channel Catfish	2	81	3	0	0	30
Freshwater Drum	2	15	0	1	0	6
Gizzard Shad	5,291	14,918	2,167	1,222	409	3,613
Largemouth Bass	12	6	8	1	1	5
Redear Sunfish	3	7	1	0	0	14
River Carpsucker	1	0	0	0	0	0
Sauger	3	2	1	0	2	0
Skipjack Herring	13	8	6	0	5	6
Smallmouth Buffalo	1	43	7	3	0	22
Smallmouth Bass	1	0	2	0	0	0
Spotted Sucker	29	48	41	18	0	33
Spotted Gar	1	15	5	0	0	6
Silver Carp	22	76	30	15	10	35
Thredfin Shad	75	5,987	245	33	119	153
White Bass	5	17	3	5	6	6
White Crappie	10	55	17	4	0	34
Yellow Bass	18	37	22	1	3	30
Black Crappie	0	2	0	0	0	0
Emerald Shiner	0	2	1	0	0	0

Golden Shiner	0	5	0	1	0	1
Longnose Gar	0	5	0	2	0	3
Paddlefish	0	1	0	0	0	0
Shortnose Gar	0	14	2	0	0	1
Unidentified Cyprinid	0	8	0	0	0	0
Unidentified Moxostoma	0	2	0	0	0	0
Unidentified Morone	0	1	0	0	0	0
Longear Sunfish	0	0	1	0	0	0
Grass Carp	0	0	0	0	1	0
Shorthead Redhorse	0	0	0	0	1	0
Warmouth	0	0	0	0	0	1
Striped Bass	0	0	0	0	0	0
Total	**5,515**	**21,426**	**2,578**	**1,314**	**561**	**4,041**

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

Fish Species	**Little Bear**	**Panther Creek**	**Pisgah**	**Sledd**	**Smith**
Bighead Carp	0	0	0	0	0
Black Buffalo	0	0	0	0	0
Bluegill	1	1	12	7	4
Bigmouth Buffalo	0	1	2	0	0
Channel Catfish	0	0	0	2	0
Freshwater Drum	0	2	2	0	0
Gizzard Shad	1,140	1,394	2,084	3,129	749
Largemouth Bass	1	3	3	6	1
Redear Sunfish	0	1	2	0	0

River Carpsucker	0	0	1	0	0
Sauger	0	0	0	0	0
Skipjack Herring	1	0	5	6	0
Smallmouth Buffalo	1	1	4	3	0
Smallmouth Bass	0	1	4	0	2
Spotted Sucker	0	1	20	5	6
Spotted Gar	0	0	1	0	0
Silver Carp	25	16	19	14	10
Thredfin Shad	35	14	49	110	57
White Bass	4	6	19	3	9
White Crappie	0	0	0	2	0
Yellow Bass	1	6	10	6	3
Black Crappie	0	0	0	0	0
Emerald Shiner	1	0	0	0	0
Golden Shiner	0	0	0	0	0
Longnose Gar	1	1	1	0	0
Paddlefish	0	0	0	0	0
Shortnose Gar	1	1	0	0	0
Unidentified Cyprinid	0	0	0	0	0
Unidentified Moxostoma	0	0	0	0	0
Unidentified Morone	0	0	0	0	0
Longear Sunfish	0	0	1	1	2
Grass Carp	0	0	0	0	0
Shorthead Redhorse	0	0	1	0	2
Warmouth	0	0	0	0	0
Striped Bass	0	0	3	0	0
Total	**1,212**	**1,449**	**2,243**	**3,294**	**845**

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

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

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

Participating Agencies: TWRA, Tennessee Technological University (TTU), Kentucky Department of Fish and Wildlife Resources (KDFWR), Alabama Department of Conservation and Natural Resources (ADCNR), and Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP)

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 2024.
- Catch rates of adult silver carp during paupier sampling in 2024 on Kentucky Reservoir were the lowest recorded since surveys began.
- One adult black carp was sampled via hoop nets in the lower Cumberland River in 2024
- YOY black carp were captured at two locations along the lower Mississippi River in 2024

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 eight embayments over the course of six 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 nine 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.

<u>Electrofishing</u>

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 2024. 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 3,569 total fish caught and 7.2% of those were gizzard shad over 180mm, which is a decrease from 2023(57%). Sampling on Barkley Reservoir resulted in 3823 total fish caught, out of which 10.3% were gizzard shad over 180mm, which is a reduction compared to 2023(72%). 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 3 fish/hr in Barkley Reservoir (Appendix B. Table 2)

<u>Paupier</u>

Sampling with USFWS collected a total of 20,289 fish with the electrified paupier net boat over six nights spent on Kentucky Reservoir. This sampling was targeting 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 (13.9 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 3 sites along the lower Ohio River, 12 sites along the Mississippi River, and no sites along the lower Tennessee and Cumberland Rivers (Table 4). We sampled YOY black carp in two locations along the Mississippi River at mile markers 934 and 922 (Figure 1). The first site 4 YOY black carp were collected, ranging from 25-29 mm in length. The second site 173 black carp were collected, ranging from 24-71 mm. Both sites were adjacent backwaters to the mainstem of the Mississippi River, less than one meter deep with sandy/muddy substrate. The first site was directly connected to the river, while the second site was isolated because of low water levels.

Adult Black Carp:

KDFWR sampled, via hoop nets, for adult black carp in the lower Ohio and Cumberland Rivers. Sampling consisted of 81 net nights on the lower Ohio River and 62 net nights on the lower Cumberland River (Figure 2). One adult black carp (TL = 1187 mm, WT = 13.05 kg) was captured in the lower Cumberland River less than four kilometers from the confluence.

Appendix B – KDFWR Tables and Figures

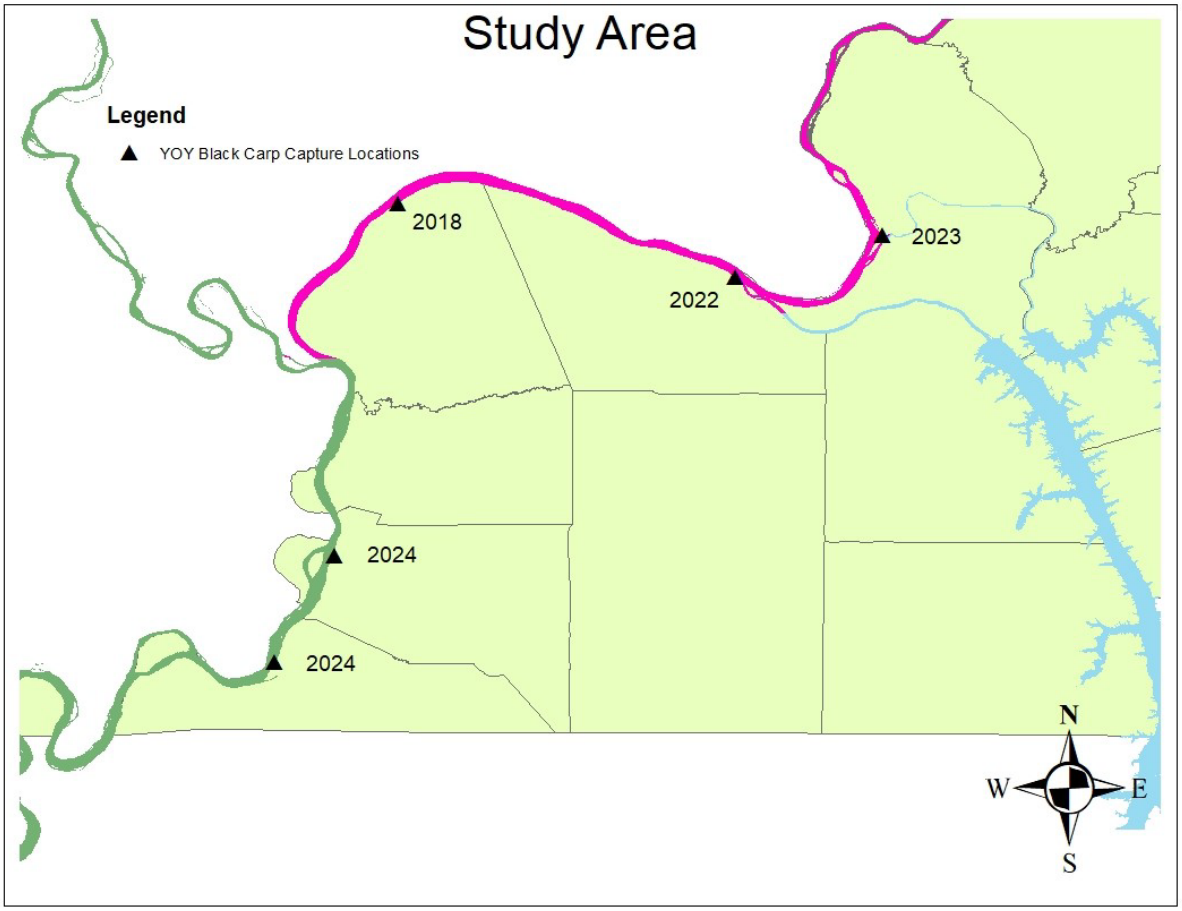

Figure 1. Capture locations of YOY invasive black carp along the lower Ohio and Mississippi Rivers in Western Kentucky.

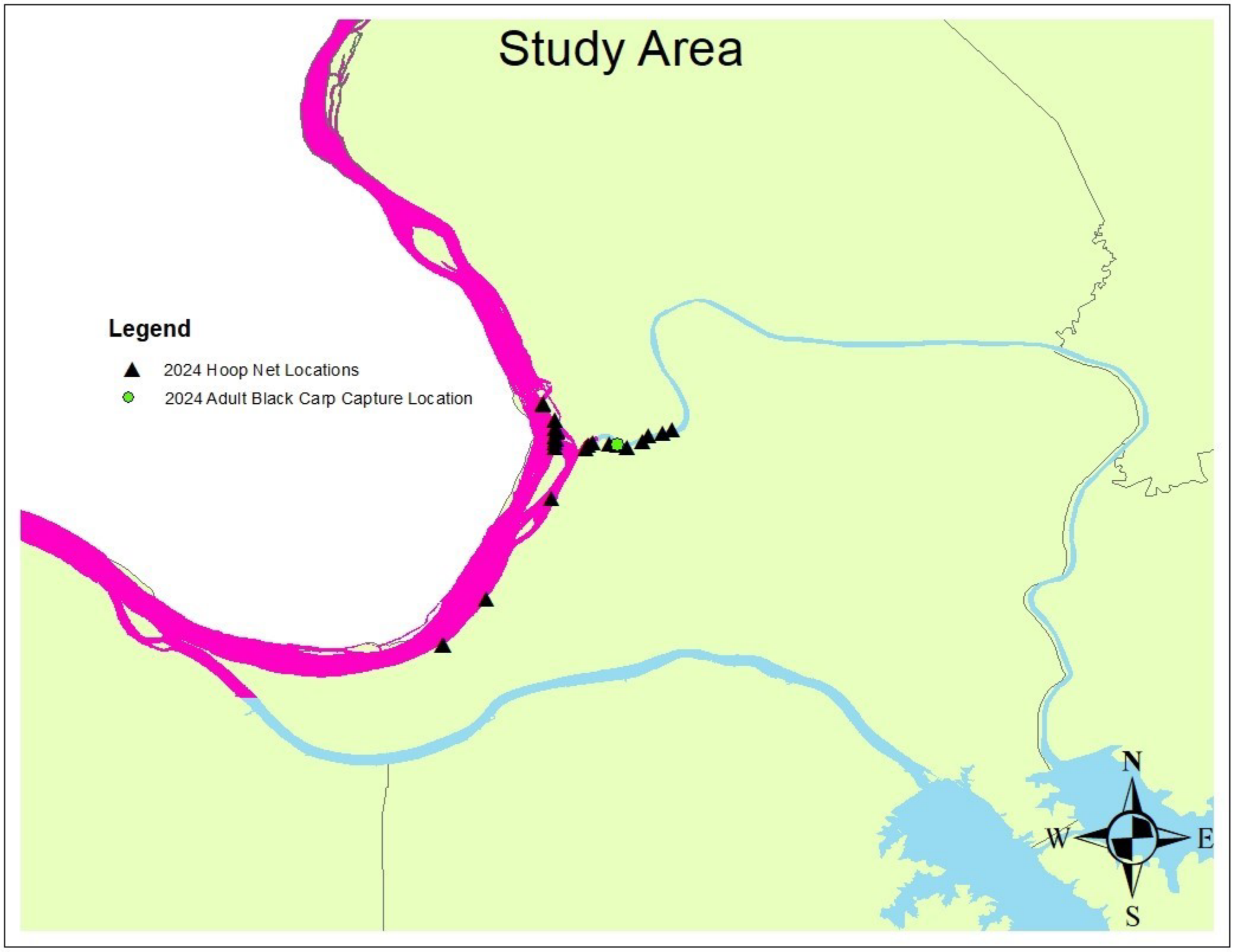

Figure 2. 2024 Sample Locations of Hoop Netting along the lower Ohio and Cumberland Rivers with the capture location.

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.
- KDFWR recommends expanding the hoop netting for adult black

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: N/A

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. In this project, the KDFWR will evaluate the response of native fishes, such as gizzard shad, buffalo, and paddlefish, which compete directly with bigheaded carp for zooplankton.

Project Objectives:

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

Project Highlights:

Methods:

Kentucky Department of Fish and Wildlife Resources

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

During field work when bigmouth buffalo and paddlefish are collected, total length and weight data were collected. Measurements were used for determining condition factors through relative weight analysis. Values will be monitored over time to determine if they will be useful to assess impacts that invasive carp may have on conditions of the native fishes. The species chosen for this assessment are often captured in gill nets and have been recognized as being vulnerable to competition for resources with invasive carp species (Irons et al. 2007, Schrank et al. 2003).

KDFWR conducted targeted sampling for 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.

Objective 1.1: Monitor bycatch of native fish species collected through invasive carp harvest programs

KDFWR continues to administer the Invasive Carp Harvest Program (ICHP) and content to develop and expand the Experimental Gears and Methods 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 collect this information during ride alongs with commercial fishers. These two data sets will be analyzed independently to determine if commercial fishing efforts are negatively impacting native fish species.

Objective 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. Additionally, KDFWR staff continues to collaborate with partners to investigate better analysis approach to understand community interactions in these areas.

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 (Wr) with harvest rates of invasive carps to evaluate trends.

In 2024, KDFWR conducted the creel survey on Barkley 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.

Results and Discussion:

Kentucky Department of Fish and Wildlife Resources (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 2024. 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 369 gizzard shad, 2,617 threadfin shad, and 99 skipjack herring were collected. On Barkley Reservoir 1,698 gizzard shad, 1,351 threadfin shad, and 14 skipjack herring were collected. CPUE for gizzard shad both over 180 mm and under 180 mm was greater in Barkley Reservoir compared to Kentucky Reservoir (Table 2). In 2024 we had reduced catch of gizzard shad on both reservoirs, but similar catches of threadfin shad compared to previous years (Table 3).

Paupier

Sampling with USFWS collected a total of 20,289 fish with the electrified Paupier net boat over four nights spent on Kentucky Reservoir. This sampling was targeting 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 (13.9 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 2024 was like 2023 in both reservoirs (Table 14). Paupier sampling produced higher CPUEs for gizzard shad and silver carp, but lower CPUEs for threadfin shad and skipjack herring (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 (Figure 2) resulted in the capture of 10,107 total fish comprised of 41 species during 4.5 hours of effort in 2024. Gizzard shad catch rates increased in 2023 compared to 2022 and 2021 (113 fish/hr compared to 47 and 44, Table 5). Threadfin shad catch rates decreased in 2023 but increased in 2024. Largemouth bass CPUE was the highest observed since 2020 and smallmouth bass CPUE returned to historical levels after 2023 which had the highest observed since 2015 at 43 per hour. Silver carp and grass carp CPUE remained similar in 2024 compared to 2022 and 2023 (Table 5).

Fall sampling in the Barkley Tailwater (Figure 2) resulted in the capture of 9,505 total fish comprised of 32 species over 3.0 hours of effort in 2024. Threadfin shad catch rates was the second highest seen since 2016 with a CPUE of 2690 fish/hr (Table 6). 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 2 fish/hr and 5 fish/hr, respectively (Table 6). Largemouth bass CPUE increased in 2024 while smallmouth bass CPUE decreased. Grass carp catch rates remained like historical values while silver carp catch rate increased from the previous year's low from 6 fish per hour to 16 (Table 6).

Relative weights (Wr) were calculated for selected species collected during fall sampling to monitor fish condition (Tables 7 & 8). 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 85, the same observed in 2020 (Table 7). Largemouth bass decreased slightly from 2022 and 2023 but remained within historical ranges. Smallmouth bass Wr increased slightly from 2023 but isn't as high as the three years before that (Table 7). 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 = 82) from 2023. Gizzard shad Wr decreased to the second lowest we have observed since 2020. Smallmouth and largemouth bass relative weights remain steady and within historical ranges (Table 8). 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 2023). White crappie exhibited a mean relative weight (103) that was higher than previous years while black crappie mean relative weight (91) dropped down slightly from previous years. Largemouth bass average *W*r dropped slightly from previous years at 93 and was lower than the preferred range of 95-105. 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 2023). Mean relative weights for both black and white crappie increased slightly from previous years having *W*r of 100 and 102, respectively. Mean *W*r value for largemouth bass in 2022 was 101 which is within the preferred values. 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.

Barkley Reservoir Creel

In 2024, survey results indicated that the number of trips and fishing pressure increased from 2021 back to historical values close to 2018 and 2016 creel data (Table 9). The catch rate for 2024 was the highest we have recorded in the last four Lake Barkley Creels at 581,131 total number of fish caught (Table 9). The methods of fishers remained similar previous surveys at 85% of anglers fishing from a boat and 10% fishing from the bank while only 4 % are fishing from a dock. Angling methods remain like historical values with about 95% of anglers still fishing or casting (Figure 1).

Part of Barkley 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 76.9 % of people answered "Yes" which has increased every year since asking the question. 92.7 % of people surveyed were aware that commercial harvest of invasive carp occurs on Lake Barkley which has also increased slightly every year since asking. Out of the 426 anglers surveyed, 296 or 69.5% of them felt that the abundance of invasive carp has decreased in the past two years (Appendix B).

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 2024, the total number of bycatches reported decreased and was the lowest recorded since 2020 (Table 10). 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 10). 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 2024 from 2023 reporting levels, however rates were within historic levels. Survival rates of sportfish (75.0%) and paddlefish (62.8%) decreased in comparison to previous years, and the survival rate of catfish (99.6%) and rough fish (98.1%) remained like previous years (Table 10).

Survival rates of all bycatches caught during ride-alongs in 2024 were documented by KDFWR observers and were analyzed independent of commercial fisher reporting (Table 11). During ride-alongs, the survival rate of sport fish as bycatch decreased from all previous years when data was collected (71.0%). Survival rates of catfish species observed as bycatch during ride-alongs was like previous years at 94.0%. Paddlefish survival rates observed during ride-alongs in 2024 were the lowest observed in the program history at 19.0% and the number of paddlefish captured during ride-alongs was the second highest observed in the program history. (Table 11).

A comparison for bycatch of paddlefish, catfish species, and sport fish species reported by commercial fishers through daily reports and information collected during ride-alongs shows a decrease since 2015 in number of sport fish captured per trip for most species (Table 12). We observed an increase in bycatch of catfish species in 2024. However, bycatch reported captured per trip for recreationally and commercially important species such as paddlefish and catfish spp.

were higher during ride-alongs than from fisheries dependent reports (Table 12). 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 (5.14% in 2024). 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 10).

Paddlefish survival was observed to be low in 2024 (19.0% during ride-alongs, 62.8% total ICHP) in relation to other species in the bycatch (Tables 10 & 11). 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 2024 was 3.27 hours and the two months with the coolest water temperatures 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 as seen from data from April through August of 2024 where survival rate decreases as soak time increases in conjunction with rising average water temperatures due to seasonality (Table 13). However, commercial fishers are more frequently using active methods for targeting invasive carp with gill nets and soak times of nets decreased overall in 2024. To increase the sample size, water temperature and soak times will continue to be recorded during ride-alongs in 2025.

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 in 2024. (S.E. = Standard error)

Date (Month-Year)	Net Hours	Number of Silver carp captured	Mean Silver carp CPUE (fish/hr)	S.E.	Number of Grass carp captured	Number of Bighead carp captured
Nov-16	9.12	1,406	168.9	23.0	3	
Oct-17	2.12	516	229.2	40.3		2
Oct-18	4.72	1496	308.3	61	1	2
Oct-19		442	~260	~60	1	
Oct-22	1.28	105	105.9	33.2		
Nov-23	0.66	24	36	9.07		
Nov-24	1.58	22	13.9	4.4		1

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 2024.

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Blood River	1.5	58	38	177	33	0
Jonathan	1.5	46	15	1152	4	0
Big Bear	1.5	17	11	211	10	1
Sledd Creek	1.5	52	9	205	19	1
*Kentucky Reservoir**	*6*	*43*	*18*	*436*	*17*	*1*

Location	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
Demumbers/Willow	1.5	42	79	316	1	5
Eddy Creek	1.5	101	118	91	1	2
Little river	1.5	83	245	213	2	5
Honker Bay	1.5	37	427	281	5	1
*Barkley Reservoir**	*6*	*66*	*217*	*225*	*2*	*3*

* Mean CPUE for each reservoir

Table 3. Comparison of average Catch Per Unit Efforts (CPUE, fish/hour) for Bakley & Kentucky reservoirs baitfish, with night-time electrofishing across years.

Year	Location	Water Temp.* (C)	Effort (hr)	CPUE GZSD >180 mm	CPUE GZSD <180 mm	CPUE TFSD	CPUE SKJH	CPUE Adult SVCP
2024	Barkley Reservoir	20.0	6	66	217	225	2	3
2023	Barkley Reservoir	18.4	6	107	619	125	5	8
2022	Barkley Reservoir	19.3	6	101	726	506	80	1
2024	Kentucky Reservoir	18.7	6	43	18	436	17	1
2023	Kentucky Reservoir	17.2	6	64	759	505	12	1
2022	Kentucky Reservoir	20.6	6	116	984	345	30	0

*Average water temperature recorded during week long sampling event

Table 4. Paupier Net and Night-time Electrofishing (EF) sampling CPUEs for Kentucky Reservoir in fall of 2024.

Location	**Effort (hr)**	**GZSD CPUE (fish/hr)**	**TFSD CPUE (fish/hr)**	**SKJH CPUE (fish/hr)**	**SVCP CPUE (fish/hr)**
KY Lake Mean EF *	6	61	436	17	1
*KY Lake Mean Pauiper **	*8.8*	*2129*	*96*	*5*	*19*
Big Bear EF	1.5	28	211	10	1
Big Bear Pauiper	*1.58*	*3174*	*45*	*8*	*13.9*
Sledd Creek EF	1.5	61	205	19	1
Sledd Creek Pauiper	*1*	*3303*	*110*	*6*	*16*

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

Table 5. Comparison of fall electrofishing CPUE for selected species collected in Kentucky Lake tailwaters in 2020 (effort = 2.75 hours), 2021 (effort = 3.75 hours), 2022 (effort = 4.5 hours), 2023 (effort = 4.5 hours), and 2024 (effort = 4.5 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Fall 2020		Fall 2021		Fall 2022		Fall 2023		Fall 2024	
	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	89	22.3	44	17.6	25	13.9	2	0.7	8	2.9
Gizzard shad	163	69.7	44	21.4	47	11.4	113	30.7	99	29.8
Threadfin shad	712	241.1	665	291.6	1860	795.2	330	138.7	1841	542.7
Grass carp	8	4.7	1	0.8	2	0.7	2	0.5	1	0.5
Silver carp	9	4.9	9	3.1	2	0.7	2	0.8	2	0.7
Smallmouth buffalo	2	0.8	4	1.3	5	1.2	2	0.7	1	0.5
Channel catfish					1	0.6	<1	0.4	<1	0.2
Flathead catfish	< 1	0.4	1	0.4	1	0.5	2	0.7		
White bass	5	2.5	3	1.8	1	0.7	5	1.3	2	0.6
Yellow bass	3	1.6	1	0.4	6	3.1	11	4.3	23	7.2
Bluegill	26	5.9	4	2.1	34	8.2	38	6.9	49	10.3
Longear sunfish	10	3.9	2	1.2	5	1.6	8	2.3	6	1.9
Redear sunfish	2	1.1	1	0.4	2	1.0	<1	0.3	<1	0.4
Smallmouth bass	10	2.8	6	2.6	15	4.1	43	6.7	19	5.6
Spotted bass					<1	1	2.63	1	2	1
Largemouth bass	15	3.6	5	1.7	13	3.2	19	2.7	20	7.2
Sauger			1	0.5	<1	0.2	1	0.3	1	0.5
Freshwater drum	11	2.8	5	1.4	15	12.5	12	9.4	3	1.0
Striped mullet	1	1.0	1	0.8	<1	0.6				

Table 6. Comparison of fall electrofishing CPUE for all species collected in Lake Barkley tailwaters in 2020 (effort = 2.75 hours), 2021 (effort = 3.0 hours), 2022 (effort = 3.0 hours), 2023 (effort = 3.0 hours), and 2024 (effort = 3.0 hours). (CPUE=catch per unit effort; S.E.=standard error)

Species	Fall 2020		Fall 2021		Fall 2022		Fall 2023		Fall 2024	
	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	41	10.8	28	10.9	17	7.3	11	3.6	7	2.5
Gizzard shad	189	49	8	5.0	38	14.5	113	34.6	276	57.8
Threadfin shad	1298	719	378	182.4	1263	352.9	2103	985.2	2690	944.0
Grass carp	3	1.22	3	0.7			1	0.4	2	1.0
Silver carp	23	6.58	24	6.4	11	2.5	6	2.1	16	4.2
Smallmouth buffalo	10	3.75	3	1.6	13	4.8	5	2.6	3	1.5
Channel catfish	1	0.49			<1	0.33			<1	0.3
Flathead catfish	4	1.57	2	1.2	4	1.3	1	0.4	<1	0.4
White bass	1	0.56	2	1.4	6	2.9	4	2.6	8	3.7
Yellow bass	3	1.24	2	1.0	<1	0.7	1	0.4	1	0.6
Bluegill	37	11.7	21	5.9	21	6.4	10	2.2	2	0.9
Longear sunfish	41	10.1	14	4.7	16	4.1	11	4.5	5	1.7
Redear sunfish	2	0.83	3	1.2	<1	0.3	1	0.4	1	0.8
Smallmouth bass	8	1.53	13	3.0	12	2.1	23	6.1	10	2.4
Spotted bass	1	1.09			<1	0.45	<1	0.28	<1	0.4
Largemouth bass	26	11	15	5.1	6	2.3	15	3.2	25	4.2
Freshwater drum	8	1.87	5	1.7	11	3.0	4	1.3	2	0.9

Table 7. Mean relative weight (Wr) and standard error for a subsample of fish collected during fall electrofishing at Kentucky Tailwaters in 2020 - 2024. (S.E. = standard error)

Species	2020			2021			2022			2023			2024		
	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	66	85	1.6	79	92	6.0	##	89	1.1	128	86	0.9	184	85	1.1
Yellow bass	4			3	88	8.6							52	88	2.1
White bass	9	95	5.1	8	86	5.9	2	88	4.4	3	91	4.2	5	85	2.8
Bluegill	41	93	8.3	11	97	4.0	28	86	4.6	14	86	6.9	46	92	2.5
Redear sunfish	4	85	5.3	2	104	4.2	6	102	23.6				3	97	17.4
Smallmouth bass	6	100	4.9	9	95	4.9	12	93	3.3	6	87	3.9	31	88	2.4
Spotted bass							1	84					7	109	4.7
Largemouth bass	26	113	8.4	17	87	4.9	33	105	2.7	12	111	10.3	66	101	1.9
Freshwater drum	29	91	3.3	18	90	5.6	25	92	2.4	1	89		12	95	4.6
Smallmouth buffalo	6	81	2.7	14	93	14.3							5	81	2.8
Silver carp	26	76	1.7	32	76	2.0							7	80	4.0

Table 8. Mean relative weight (Wr) and standard error for a subsample of fish collected during fall electrofishing at Barkley Tailwaters in 2020 - 2024. (S.E. = standard error)

Species	2020			2021			2022			2023			2024		
	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	53	96	4.2	20	73	3.1	82	89	1.5	171	88	1.7	206	82	0.7
Yellow bass	7	85	4.5	3	74	8.3							3	90	4.5
White bass	2	115	1.8	3	96	6.4	16	90	3.0	15	109	14.7	23	90	2.3
Bluegill	63	102	2.3	29	118	10.6	27	102	6.2	26	100	3.9	2	80	7.7
Redear sunfish	4	101	13.0	4	101	12.4	1	45		3	77	8.1	4	91	4.4
Smallmouth bass	11	93	2.5	7	81	4.4	15	95	2.8	43	93	2.0	26	94	2.7
Spotted bass	2	103	9.4				2	104.91	2.4	1	75.23		2	93	1.6
Largemouth bass	41	101	4.3	20	101	7.1	10	102	4.0	24	96	5.1	72	99	1.6
Freshwater drum	22	96	2.3	14	92	2.1	33	95	2.5	14	92	3.0	7	110	18.9
Smallmouth buffalo	27	81	1.4	9	78	2.6							6	79	3.3
Silver carp	64	77	1.2	70	78	1.3							49	75	1.1

Table 9. Lake Barkley creel survey fishing pressure and catch rates from 1985 through 2024.

YEAR	**Fishing Trips** # fishing trips	**Fishing Pressure** Total Angler Hours	**Average Trip Length** (hours)	**Catch Rates** Total #	**Catch Rates** Fish / Hour
1985	274,628	875,588	3.19	1,166,532	1.34
1986	226,577	828,487	3.66	1,312,183	1.57
1987	310,544	943,547	3.04	1,644,704	1.85
1991	131,458	413,727	3.15	681,891	1.65
1999	117,580	584,962	4.98	505,213	0.84
2005	192,799	765,331	3.97	1,197,613	1.56
2008	145,774	625,656	4.29	1,032,144	1.55
2012	229,892	958,964	4.17	1,510,876	1.43
2016	89,412	386,341	4.32	457,127	1.14
2018	94,732	408,414	4.31	364,496	0.92
2021	40,898	177,689	4.34	209,277	1.03
2024	61,266	303,721	4.96	581,131	1.91

Table 10. 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 Caught	Survival Rate %	Number Caught	% Survival Rate	Number Caught	Survival Rate %	Number Caught	Survival Rate %	number
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
2024	44	75.0	8,006	98.1	1045	99.6	95	62.8	9,190

*Sport fish are defined in 301 KAR 1:060

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

Table 11. Species composition, number of individuals captured, and survival rate of species observed in bycatch during KDFWR ride-alongs with commercial fishers fishing under the Invasive Carp Harvest Program in 2020 - 2024. Survival rate of fish is defined as fish that swim away after release.

		2020		2021		2022		2023		2024	
	Species	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate	Number captured	Survival rate
Sport Fish	White bass			2	100%	1	100%			4	75%
	Yellow bass			1	100%			3	100%	11	64%
	Striped bass	10	80%	1	100%	2	50%			7	43%
	Hybrid striped bass	2	100%	1	100%						
	Sauger	2	50%	3	100%	3	66%	1	100%	8	75%
	Largemouth bass	4	75%	9	100%	2	100%	1	<1%	4	100%
	Smallmouth bass							1	100%		
	Redear sunfish			1	100%	2	100%		100%	3	67%
	Black crappie	1	100%					1	100%		
	White crappie			1	100%			1	<1%	4	100%
	Total	19	81%	19	100%	10	83%	8	75%	41	71%
Catfish species	Blue catfish	32	100%	38	92%	62	97%	43	93%	174	91%
	Channel catfish	5	100%	16	96%	3	100%	11	100%	38	100%
	Flathead catfish	7	100%	26	100%	28	89%	8	100%	41	100%
	Total	44	100%	80	95%	93	95%	62	95%	253	94%
	Paddlefish	26	50%	16	69%	7	28%	17	47%	68	19%
Rough Fish*	Lake sturgeon			1	100%						
	Shovelnose sturgeon	3	100%								
	Skipjack herring	16	<1%	25	36%	29	52%	85	<1%	30	2%
	Smallmouth buffalo	103	100%	173	99%	236	99%	249	99%	236	97%
	Bigmouth buffalo	14	100%	12	75%	6	100%	16	100%	4	100%
	Black buffalo	1	100%					2	100%		
	Common carp	36	97%	17	100%	10	100%	21	100%	86	97%
	Gizzard shad	1	100%					1	100%		
	Freshwater drum	40	82%	54	94%	56	89%	50	76%	211	56%
	River carpsucker	41	100%	5	100%	2	100%			2	100%
	Spotted gar	1	100%	2	100%	1	100%	4	100%		
	Longnose gar	3	100%	3	100%	7	100%	3	33%	1	<1%
	Shortnose gar	5	100%	5	100%	1	100%	6	100%	5	80%
	Total	329	98%	299	92%	348	93%	437	71%	373	91%

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

Table 12. 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 2020-2024. (S.E. = standard error).

	2020				2021				2022				2023				2024			
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.	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	<0.01	<0.01	0.64	0.65
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	<0.01	<0.01	1.63	0.61
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	<0.01	<0.01	0.36	0.32
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	<0.01	<0.01	0.38	0.58
Catfish*	0.08	0.01			0.16	0.01			0.08	0.02			0.33	0.12			0.01	<0.01		
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	<0.01	<0.01	0.04	<0.01
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					0.06	0.48
Yellow bass	<0.01	<0.01			<0.01	<0.01	0.02	0.02					0.01	<0.01	0.05	0.04			0.1	0.63
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					0.04	<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			0.07	0.14
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			0.04	0.33
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					0.03	<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 13. 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 2020 - 2024.

Year	Month	No. paddlefish captured	% released alive	Mean water temp (˚F)	Mean soak time (hours)
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
2024	February	5	100%	49	7.75
	April	6	17%	65.5	12.67
	May	23	17%	73.7	7.72
	June	14	7%	80.5	8.75
	July	4	0%	85.7	8.81
	August	15	7%	83.7	10.68
	September	1	100%	77	3.27

Table 14. Relative weight (*Wr*) values of gizzard shad collected from boat electrofishing and paupier net sampling in Barkley and Kentucky reservoirs in fall of 2020-2024.

Kentucky Lake			
Year	No.	Wr	S.E.
2024	649	86	0.45
2023	546	84	0.36
2022	1527	91	0.3
2021	85	92	0.5
2020	95	92	0.8
Lake Barkley			
Year	No.	Wr	S.E.
2024	330	85	0.59
2023	392	86	0.32
2022	440	90	0.49
2021	34	90	1
2020	47	93	0.7

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

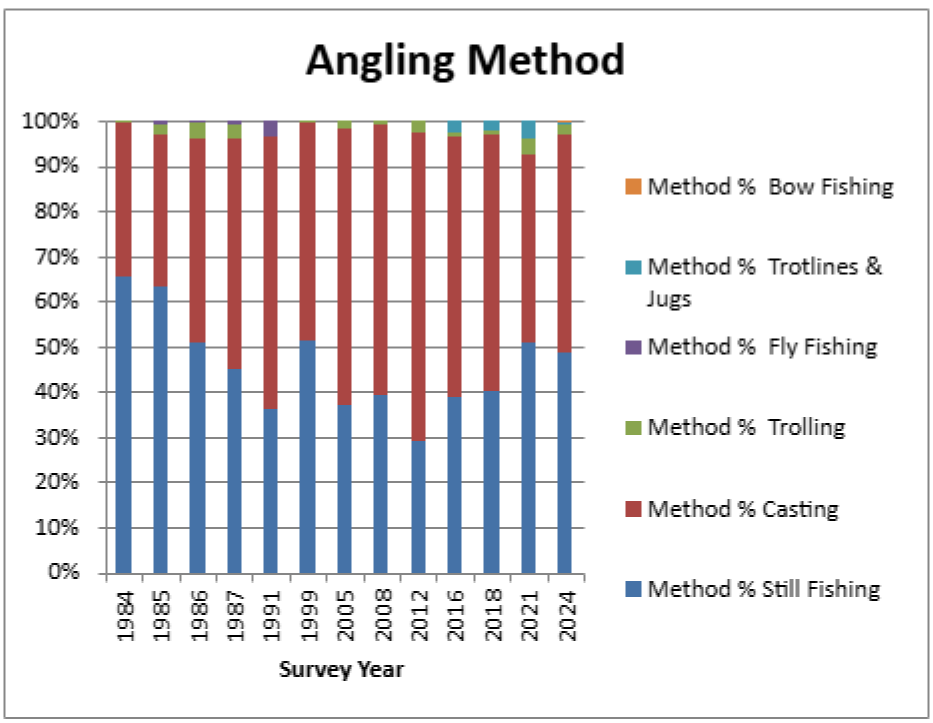


Figure 1. Angling method for fishing on Barkley Reservoir 1984-2024.

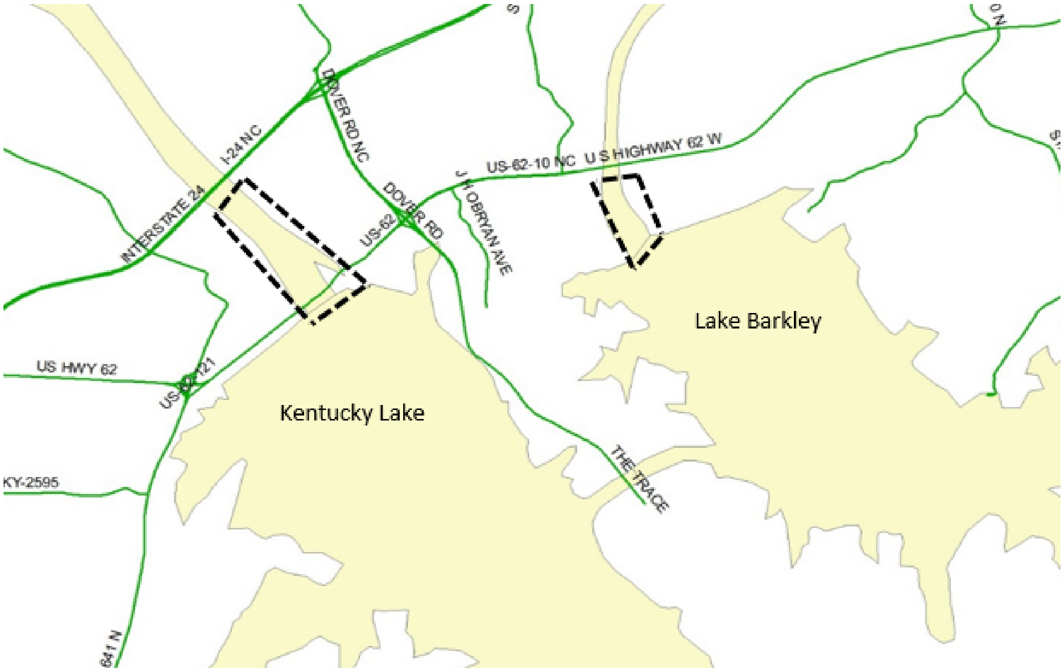
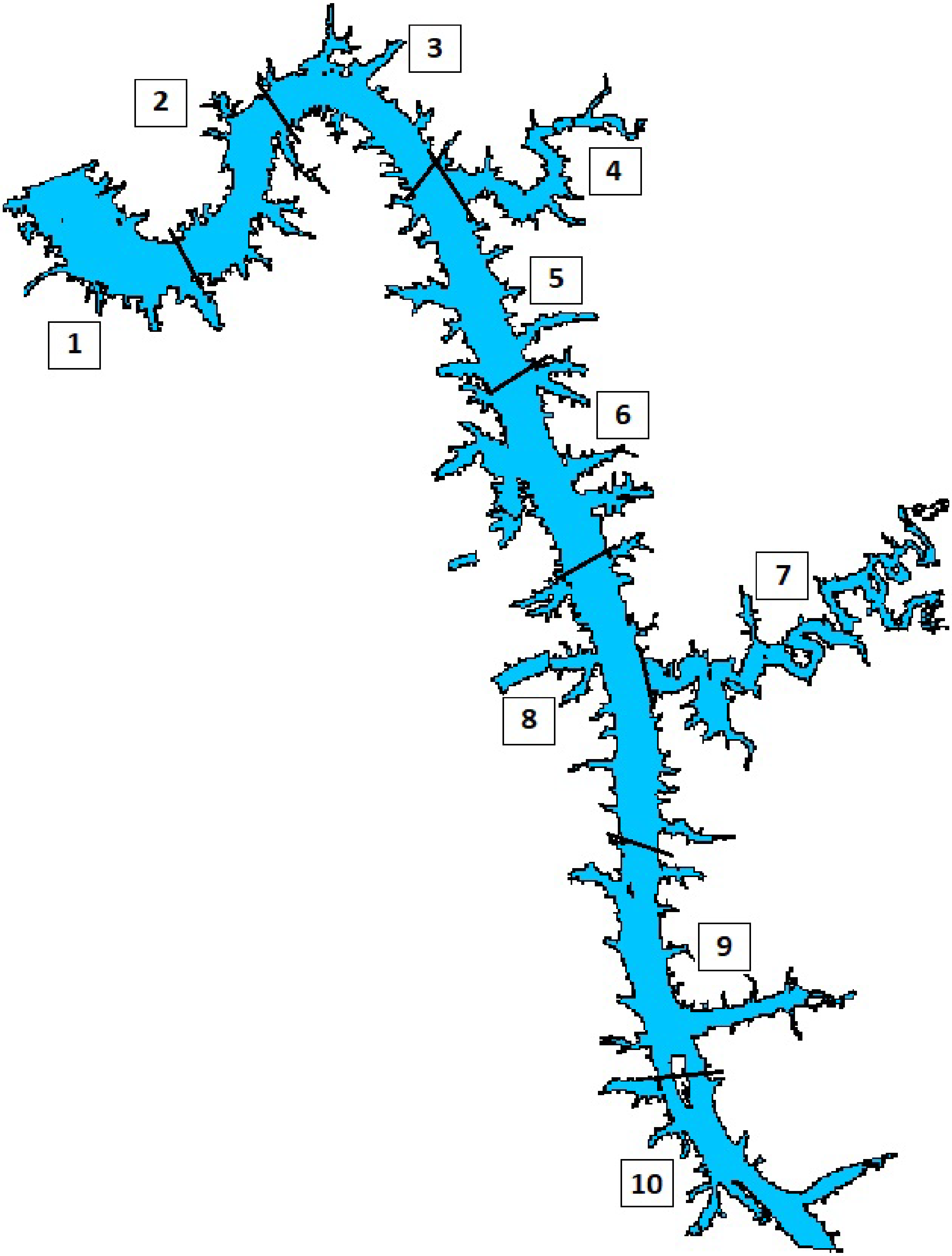


Figure 2. The tailwater electrofishing at Kentucky Tailwater extended from the dam downstream to the Interstate 24 bridge. The electrofishing at Barkley Tailwater extended from the dam downstream to the US Hwy 62 bridge. Sample areas are outlined by dashed line.



Appendix A. Lake Barkley Creel divided into ten areas.

Appendix B. Lake Barkley Angler Attitude Survey Results for 2024.

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

2. Name ________________________________ (**Optional**) Zip Code ______________________

3. On average, how many times do you fish Lake Barkley in a year? N=423

   First time here 5.0% 1-4 20.6% 5-10 13.0% More than 10 61.5%

4. Which species of fish do you fish for at Lake Barkley (**check all that applies**)? N= 426
   Redear 9.4% Bluegill 18.8% Black bass 63.4% Crappie 42.5% Catfish 30.3% White Bass 13.4% Yellow Bass 2.1% Carp 0.2% Sauger 0.2%

5. Which one species do you fish for most at Lake Barkley (**check only one**)? N=426
   Redear 1.2% Bluegill 2.8% Black bass 52.6% Crappie 25.8% Catfish 13.8% White Bass 3.8%

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 Lake Barkley? N=40
   Very satisfied 17.5% Somewhat satisfied 40.0% Neutral 25.0% Somewhat dissatisfied 12.5% Very dissatisfied 5.0%

   6a. If you responded with somewhat or very dissatisfied in question (6) – what is the single most important reason for your dissatisfaction? N=7
   Number of fish 85.7% Size of fish 14.3%

Bluegill Anglers

7. In general, what level of satisfaction or dissatisfaction do you have with the Bluegill fishing at Lake Barkley? N=80
   Very satisfied 35.0% Somewhat satisfied 30.0% Neutral 12.5% Somewhat dissatisfied 18.8% Very dissatisfied 3.8%

   7a. If you responded with somewhat or very dissatisfied in question (7) – what is the single most important reason for your dissatisfaction? N=18
   Number of fish 88.9% Size of fish 11.1%

Black Bass Anglers

8. In general, what level of satisfaction or dissatisfaction do you have with the black bass fishing at Lake Barkley? N=270
   Very satisfied 21.1% Somewhat satisfied 45.2% Neutral 15.9% Somewhat dissatisfied 12.6% Very dissatisfied 5.2%

   8a. If you responded with somewhat or very dissatisfied in question (8) – what is the single most important reason for your dissatisfaction? N=48
   Number of fish 75.0% Size of fish 10.4% Lake levels 4.2% Asian carp 6.3% Lack of Grass 2.1% Personal 2.1%

Crappie Anglers

9. In general, what level of satisfaction or dissatisfaction do you have with crappie fishing at Lake Barkley? N=181
   Very satisfied 27.6% Somewhat satisfied 35.9% Neutral 14.4% Somewhat dissatisfied 17.1% Very dissatisfied 5.0%

9a. If you responded with somewhat or very dissatisfied in question (9) – what is the single most important reason for your dissatisfaction? N=40
Number of fish 87.5% Size of fish 5.0% Asian carp 2.5% Can't catch them 2.5%
Personal 2.5%

Catfish Anglers

10. In general, what level of satisfaction or dissatisfaction do you have with the catfish fishing at Lake Barkley? N=128
Very satisfied 71.9% Somewhat satisfied 17.2% Neutral 6.3% Somewhat dissatisfied 3.1%
Very dissatisfied 1.6%

10a. If you responded with somewhat or very dissatisfied in question (10) – what is the single most important reason for your dissatisfaction? N=6
Number of fish 100.0%

White Bass Anglers

11. In general, what level of satisfaction or dissatisfaction do you have with the White Bass fishing at Lake Barkley? N=57
Very satisfied 68.4% Somewhat satisfied 19.3% Neutral 8.8% Somewhat dissatisfied 3.5% 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 100.0%

Crappie Anglers Only

12. When you fish for crappie at Lake Barkley, how often do you release keeper size fish (>10")? N=181
Always 6.1% Often 23.2% Sometimes 26.5% Rarely 22.1% Never 22.1%

12a. If you release them, what is the number one reason you release a keeper size crappie? N=142
Only caught a few 28.2% Release large females 8.5% Release large fish 11.3%
Too close to the size limit 10.6% Only keep larger fish 6.3% Only practice catch and release 18.3%
Only keep a few per trip 3.5% Looks unhealthy 1.4% Catch and release sometimes 0.7%
Catch them while fishing for bass 0.7% Freezer is already full 1.4%
Already have enough in the livewell 4.9% Don't want to deal with them 0.7%
Catch crappie in other states 0.7% Already have a limit 2.8%

Catfish Anglers Only

13. When you fish for catfish at Lake Barkley, which is more important to you: catching trophy fish or catching more keeper size fish to eat? N=128
Trophy fish 9.4% Catching keeper fish to eat 67.2% Both equally important 17.2% No opinion 6.3%

All Anglers

14. When you fish at Lake Barkley, do you use some form of real-time, forward-facing sonar like livescope or a similar system? N=424
Yes 41.0% No 59.0%

14a. If "Yes", how often do you use it while crappie fishing? N=173
Always 63.6% Often 15.6% Sometimes 13.3% Rarely 7.5% Never 0.0%

15. Are you satisfied with the current size and creel limits on all sport fish at Lake Barkley? N=423
Yes 89.8% No 10.2%

15a. If you responded "No" to Question 15, which species are you dissatisfied with and what size and creel limits would you prefer? N=43

LMB minimum size 12" 2.3% LMB minimum size 14" 7.0% LMB minimum size 18" 2.3%
LMB 15-18" slot 2.3% LMB 15-24" slot 2.3% 1 LMB over 18"/day 2.3%
1 LMB under 15"/day 2.3% LMB creel limit 3/day for a few years 2.3%
LMB creel limit 3/day 4.7% SMB minimum size 12" 2.3% SMB minimum size 14" 4.7% SMB minimum size 18" 4.7% SMB 15-18" slot 2.3%
SMB creel limit 3/day 4.7% SMB creel limit 3/day for a few years 2.3%
Crappie minimum size 10.5" 2.3% Crappie minimum size 11" 23.3% Crappie minimum size 12" 14.0%
Crappie slot limit under 10" 2.3% Crappie slot limit 14" 2.3% Crappie creel limit 15/day 23.3%
Crappie creel limit 10/day 9.3% Crappie creel limit 30/boat 2.3%
RES minimum size 8" 2.3% RES minimum size 10" 2.3% SAG minimum size 12" 2.3%
SAG No minimum size 2.3% White Bass creel limit 30/day 2.3%
BLG creel limit 25/day 2.3% No bass tournaments for a few years 2.3%
Crappie creel limit 10/day until post spawn 2.3%
Crappie guides unable to keep fish while guiding 2.3%

16. Have you participated in an organized fishing tournament on any body of water within the last 12 months? N=425 Yes 39.8% No 60.2%

16a. If "Yes", were any of the tournaments an alternative format (catch, photo, release; onboard weighing, etc) N=166 Yes 6.6% No 93.4%

16b. 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=169
Support 78.7% Oppose 6.5% No Opinion 14.8%

16c. Would you support or oppose a regulation requiring tournaments to report their fishing effort and catch to our department? N=169
Support 71.0% Oppose 12.4% No Opinion 16.6%

17. Based on your personal experience on the water, how do you feel the abundance of Asian carp has changed in Lake Barkley in the past two years? N=426
Increasing 8.0% Decreasing 69.5% No change 8.7% No opinion 13.8%

18. Are you aware that Asian carps are generally considered to be excellent fish to eat? N=425
Yes 76.9% No 23.1%

19. Are you aware that commercial harvest of Asian carps occurs on Lake Barkley? N=424
Yes 92.7% No 7.3%

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), 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 and Tennessee-Tombigbee waterway
    2. Specific to the Ohio River
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.

Project Highlights:

- KDFWR decommissioned the HTI telemetry array used during the testing period for the Bio-Acoustic Fish Fence.
- Upstream movements (i.e., Kentucky Reservoir to Pickwick Reservoir) slightly outnumber downstream movements (i.e., Pickwick Reservoir to Kentucky Reservoir) from 2017 to 2023, but in 2024, downstream movements outnumbered upstream movements.
- Bigheaded carp have been detected moving upstream into Pickwick Reservoir on the Tennessee River. No passages or detections of tagged fish have been observed upstream of Pickwick Reservoir at Wilson Dam or above in the Tennessee River.
- Majority of pool-to-pool movements by bigheaded carp took place between the Tennessee River and Cumberland River (Kentucky Reservoir <> Barkley Reservoir). Interconnectedness of populations through the Barkley Canal or Ohio River should be considered in management and control efforts.
- Downstream movements in 2024 peaked in the April-May timeframe, whereas upstream movements peaked later, in the May-August timeframe.

Agency: Kentucky Department of Fish and Wildlife Resources

Activities and Methods:

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

KDFWR participated in six, two-hour meetings virtual meetings and one-half day in person meeting for phase II of the structured decision-making process with collaborating partners to provide data and expert opinion about invasive carp population characteristic for deterrent scoping the in Tennessee, Cumberland and Tombigbee waterways.

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

KDFWR maintained and improved the telemetry array on a quarter cycle in the TNCR. A total

of 64 telemetry receivers were maintained in TNCR in 2024. KDFWR assisted the USGS with telemetry tagging of 130 silver carp in the TNCR.

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

KDFWR provided onsite support for the Bio-Acoustic Fish Fence (BAFF) in the downstream approach of Barkley lock chamber. This included decommissioning the HTI telemetry array, inventorying hardware and providing local support for shipping equipment back to Wisconsin.

Agency: Tennessee Wildlife Resource Agency

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

1.1: Specific to the Tennessee and Cumberland Rivers

TWRA staff participated in multiple meetings with partners to inform the US Army Corps of Engineers' process to implement a deterrent pilot program (WRDA 2020, Section 509, as amended). Staff worked with partners to provide priority locations for deterrent placement in the Tennessee, Cumberland, and Tenn-Tom systems.

Objective 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.

An acoustic telemetry receiver array has been established from Kentucky Dam upstream to Guntersville Dam on the Tennessee River and Barkley Dam to Old Hickory Dam on the Cumberland River (Figure 1). Receivers were either anchored in bottom sets, secured to barge mooring cells, or attached to lock walls to monitor bigheaded carp upstream and downstream movements through locks. Efforts to add to and update the receiver array and increase numbers of tagged bigheaded carp to bolster movement data were continued through 2024. Throughout previous years, data was offloaded from receivers, damaged receivers were replaced, and new batteries were installed as necessary. Receiver monitoring is a multi-state effort by KDFWR, TWRA, TTU, MDWFP, and ADCNR. From 2017-2024, tags were deployed annually in bigheaded carp in the Tennessee and Cumberland rivers (Table 1). Tagged bigheaded carp were captured using boat electrofishing during cool water periods to reduce stress and improve post-release survival.

All bigheaded carp tagged in the Tennessee and Cumberland rivers by numerous agencies exist in the analysis. During the study period, some Silver Carp were captured upstream of dams, tagged, and released downstream of the same dams (referred to as translocations). Translocated fish were evaluated separately in some analyses, as the translocation event may differently influence the behavior of the tagged Silver Carp. Data from receivers is filtered to remove possible false detections. If a tagged bigheaded carp was detected twice or more by receivers in a single pool or lock, the detection was considered valid. Multiple detections of a single tag could occur on one or multiple receivers. Single detections were considered false and removed from the analysis. Detections of tagged bigheaded carps at receivers placed in different pools were used to inform on pool-to-pool movements by individual bigheaded carp.

The detection ability of receivers was tested with tag drags. In tag drags, a special acoustic test tag is pulled roughly 1-m below a boat past a receiver to evaluate detection efficiency and range. The path of tag drags passes downstream, inter-lock, and upstream receivers. Tag drag paths were recorded on GPS to match receiver detections to test tag locations based on time stamps. The known location of the tag drag path enables the detection range of passed receivers to be evaluated. If a receiver detected the test tag in multiple areas surrounding a lock (i.e. upstream and inter-lock), detections by the receiver were considered unreliable and removed from analysis. Detections at multiple areas around locks by a single receiver could simulate movement by a stationary bigheaded carp. Tag drags thus assist in accurate detection data collection. Tag drags were attempted at least once per year to evaluate the receiver array through 2022. TTU was unable to perform a tag drag during 2023 and 2024.

Results and Discussion:

Objective 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.

Raw detections of bigheaded carp have generally increased from 2017 to 2024 in the Tennessee and Cumberland rivers (Table 2). No detections have yet occurred in Old Hickory, Wilson, Wheeler, or Guntersville reservoirs (Tables 2, 3). The number of unique individual bigheaded carp detected in most pools and locks has also generally increased (Table 3). New maxima in unique individuals detected occurred in 2024 for Barkley, Cheatham, Kentucky, and Pickwick reservoirs (Table 3). This increase in detections may result from increases in the numbers of bigheaded carp tagged over the years in these pools (Table 1). Unique individuals detected decreased in Barkley and Kentucky locks from 2022 to 2024 (Table 3).

Upstream pool-to-pool movements in 2017 to 2023 by individual bigheaded carps in the Tennessee and Cumberland rivers outnumbered downstream movements between pools (Table 4). However, there were more downstream movements in 2024 (Table 4). Movements between Kentucky and Barkley reservoirs (both directions) comprised most of the pool-to-pool movement (Table 4). Movement between Kentucky Reservoir on the Tennessee River and Barkley Reservoir on the Cumberland River may occur through the Barkley Canal or the Ohio River (requiring multiple dam passages). Given no detections of bigheaded carp occurred at Wilson, Wheeler, or Guntersville dams (Table 2), no passages were observed at or upstream of those dams. Overall, a more complete understanding of bigheaded carp ecology in the Tennessee and Cumberland rivers is essential. Consideration must be given to factors that may influence upstream passage by non-translocated bigheaded carp as well as factors affecting downstream passage. Interpopulation dynamics of bigheaded carp in Kentucky and Barkley reservoirs is crucial to understand for deterrent and removal efforts given the high degree of connection between the two systems.

As numbers of tagged bigheaded carps and detections have increased in recent years, temporal trends are more readily observed. Since 2018, most downstream movements occurred between March and May, while most upstream movements varied more between May and November (Figure 2). Peak 2024 movements downstream occurred in May in Barkley, Cheatham, and Pickwick reservoirs (Figure 3). Downstream movements in Kentucky Reservoir began to peak in April (Figure 3). Upstream movements in 2024 had lower peaks than downstream movements. Barkley Reservoir peaked in June, Cheatham Reservoir peaked in May, Kentucky Reservoir peaked in June and July, and Pickwick Reservoir peaked in August, with the lowest upstream movement of all pools (Figure 3). Canal movement from Kentucky to Barkley Reservoir peaked from April to May, whereas movement from Barkley to Kentucky Reservoir peaked in May (Figure 4).

Two new receivers were deployed in 2024. Forty-three receivers were offloaded at least one time in 2024. Four receivers were unrecovered in 2024. Two receivers were retrieved and removed from the Tennessee and Cumberland rivers due to receiver offload fails. Two of four receivers redeployed after recovery by the TWRA Dive Team, were not offloaded due to high water and unsafe conditions.

Plans for 2025 include adding more tags to bigheaded carp in the Tennessee and Cumberland rivers for monitoring and passage evaluation. This will allow a greater understanding of bigheaded carp ecology and behavior through the addition of more data. Active receivers will continue to be monitored throughout the upcoming year. Efforts to better understand temporal patterns (annual and diel) in movements and environmental impacts will continue in 2025. Continued telemetry efforts will further improve understanding of the bigheaded carp invasion in the Tennessee and Cumberland rivers.

Recommendation:

- Monitoring and testing of telemetry receivers should be continued to provide more reliable data for analysis of environmental conditions influencing lock-and-dam passage. Understanding of these conditions' influence will enable a better evaluation of deterrent strategies.
- Increased tagging of bigheaded carp is necessary to increase the sample size of tagged carp. Tagging should be spatially stratified to include bigheaded carp throughout the invaded range in the Tennessee and Cumberland rivers in the sample.
- Describe interpopulation dynamics (e.g., immigration and emigration) between bigheaded carp populations in Kentucky and Barkley reservoirs to determine importance of population isolation (e.g., will suppression of bigheaded carp in one reservoir led to source-sink population dynamics, or will ineffectively control methods in one reservoir negate effective management in the other).

Table 1. Number of bigheaded carp tagged with VEMCO acoustic transmitters in Tennessee River and Cumberland River pools from 2016 to 2023. Translocations (T) of bigheaded carps occurred in 2020, 2021, 2022, and 2023. "NA" indicates areas where tagging did not occur. "Kentucky*" and "Barkley*" indicates Kentucky Tailwater and Barkley Tailwater, respectively.

Pool	2016	2017	2018	2019	2020	2020 (T)	2021	2021 (T)	2022	2022 (T)	2023	2023 (T)	2024	2024 (T)
Kentucky	69	91	24	16	35	NA	179	NA	160	NA	100	50	67	NA
Kentucky*	NA	NA	NA	NA	9	91	120	38	150	NA	65	NA	NA	NA
Pickwick	NA	10	29	10	NA	NA	NA	NA	NA	NA	78	NA	100	NA
Barkley	NA	NA	NA	NA	NA	NA	80	NA	170	NA	104	50	64	NA
Barkley*	NA	20	41	152	151	NA	150	NA	135	NA	NA	NA	NA	NA
Cheatham	NA	NA	NA	NA	NA	NA	NA	NA	50	NA	56	NA	101	NA
Reelfoot	NA	NA	NA	NA	NA	NA	NA	NA	25	25	40	16	27	26

Table 2. Total number of detections of tagged bigheaded carp per pool/lock by year. "NA" indicates there were no receivers in place to detect movements.

	Year							
Pool	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Barkley	6,465	58,042	168,571	366,576	1,387,981	2,708,615	4,792,460	4,515,899
Barkley Lock	NA	1,384	6,782	21,888	40,214	49,245	40,293	84,920
Cheatham	NA	NA	NA	NA	85,561	1,710,757	1,794,437	2,105,688
Cheatham Lock	NA	NA	22	52	15,414	22,814	4,153	11,323
Kentucky	289,134	1,021,503	602,737	536,895	2,550,572	2,499,884	3,311,017	4,062,890
Kentucky Lock	NA	373	631	996	6,038	29,289	77,975	26,797
Old Hickory	NA	NA	0	0	0	0	0	0
Old Hickory Lock	NA	NA	0	0	0	0	0	0
Pickwick	8,877	136,052	93,496	68,329	71,368	199,296	602,779	284,262
Pickwick Lock	NA	323	2,669	2,535	47,591	122,596	37,081	34,346
Wilson	0	0	0	0	0	0	0	0
Wheeler	0	0	0	0	0	0	0	0
Guntersville	NA	NA	NA	0	0	0	0	0

Table 3. Total number of individual fish detected in each pool/lock by year. "NA indicates there were no receivers in place to detect movements.

Pool	Year							
	2017	2018	2019	2020	2021	2022	2023	2024
Barkley	5	28	48	45	174	433	444	624
Barkley Lock	NA	21	44	135	97	182	101	179
Cheatham	NA	NA	NA	NA	18	79	114	231
Cheatham Lock	NA	NA	1	2	47	73	61	94
Kentucky	24	78	99	77	241	393	429	582
Kentucky Lock	NA	7	7	31	41	63	37	62
Old Hickory	NA	NA	0	0	0	0	0	0
Old Hickory Lock	NA	NA	0	0	0	0	0	0
Pickwick	7	32	36	28	38	73	170	235
Pickwick Lock	NA	3	8	7	75	100	126	190
Wilson	0	0	0	0	0	0	0	0
Wheeler	NA	0	0	0	0	0	0	0
Guntersville	NA	NA	NA	NA	0	0	0	0

Table 4. Number of pool-to-pool movements (starting pool, ending pool, lock used) by tagged bigheaded carp by year. "NA" indicates no receivers were in place to detect movements.

			Year							
From	**To**	**Lock Used**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Barkley	Cheatham	Cheatham	NA	NA	0	0	18	19	2	13
Barkley	Cheatham	None	NA	NA	0	0	0	0	0	7
Barkley	Kentucky	None	3	14	23	18	53	200	163	303
Cheatham	Barkley	Cheatham	NA	0	0	0	0	0	0	4
Cheatham	Barkley	None	NA	0	0	0	0	8	1	42
Kentucky	Barkley	None	3	17	32	20	73	176	132	307
Kentucky	Pickwick	None	0	0	4	0	0	0	0	0
Kentucky	Pickwick	Pickwick	0	2	3	4	30	43	21	30
Pickwick	Kentucky	None	0	10	18	19	7	16	10	106
Pickwick	Kentucky	Pickwick	0	0	0	1	0	2	3	21

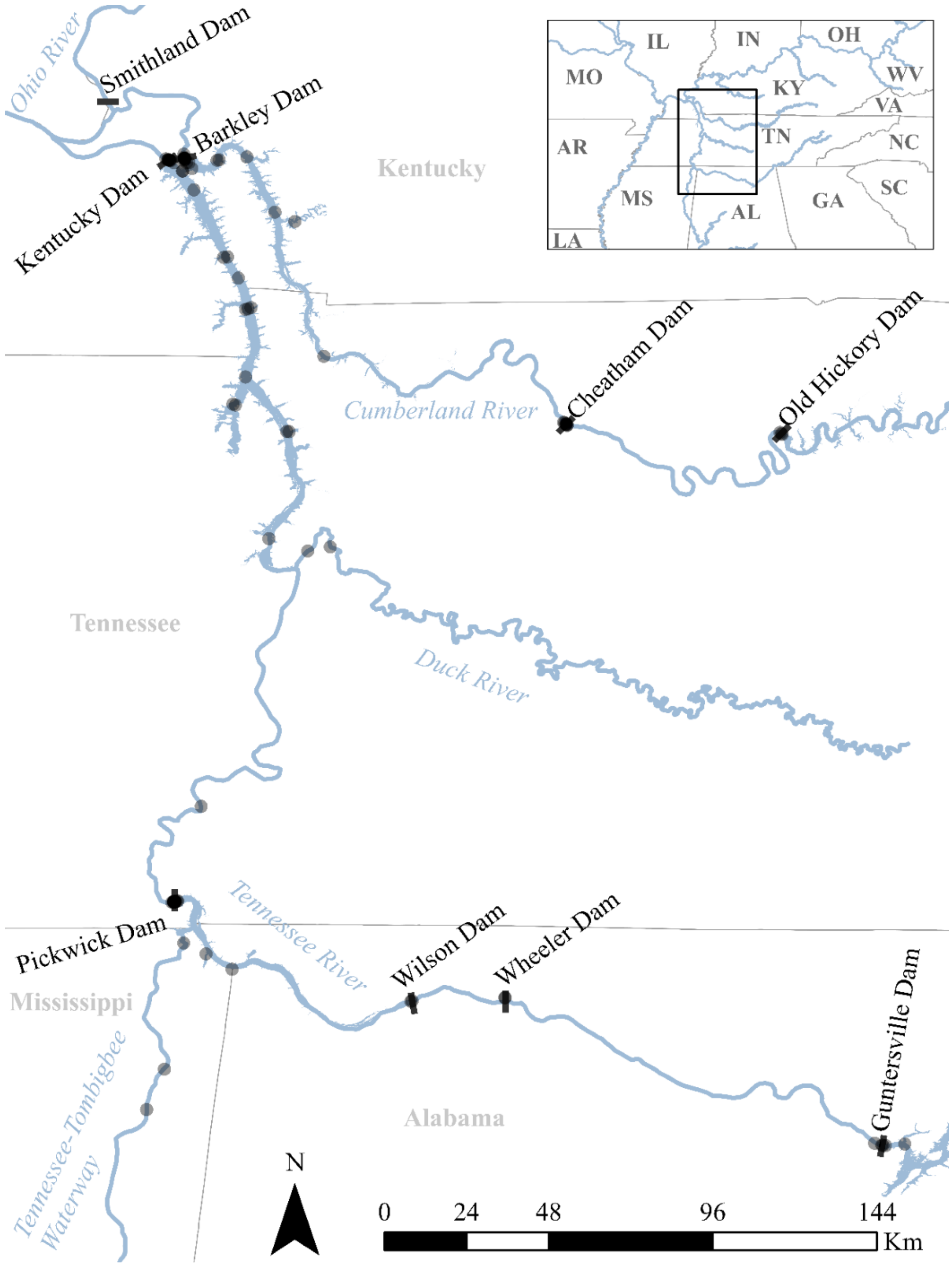


Figure 1. Map of receiver deployment locations (gray circles) in the Tennessee River and Cumberland River to monitor bigheaded carp pool-to-pool movements and upstream invasion.

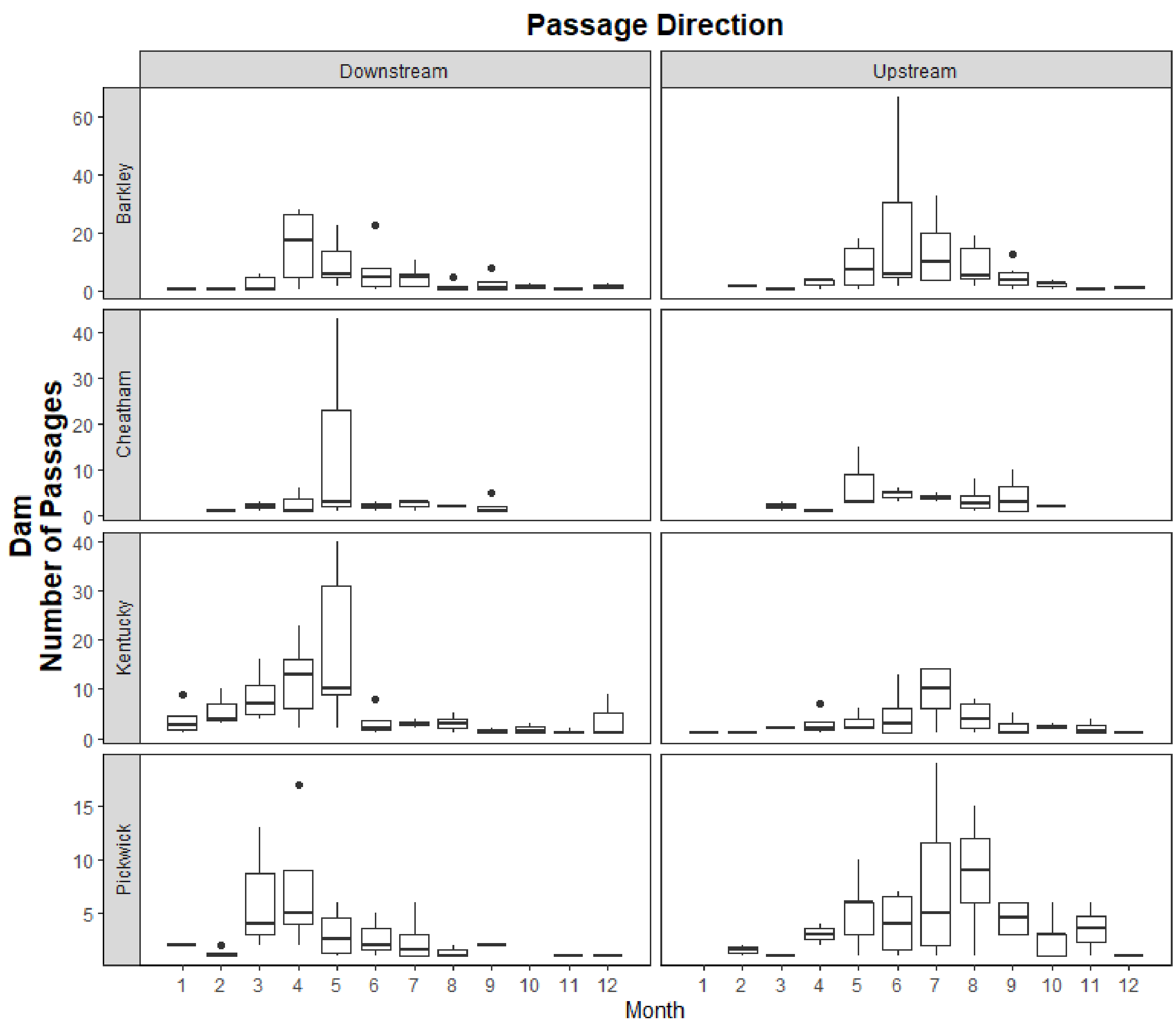


Figure 2. Yearly variability in the total number of silver carp passages by month for each dam with passage direction from 2018 to 2024. Y-axis scale varies for each dam. *Two outliers were removed (Dam = Pickwick, Year = 2024, Month = 5, Direction = Downstream, n = 138; Dam = Barkley, Year = 2024, Month = 5, Direction = Downstream, n = 96) to better illustrate the monthly distribution.

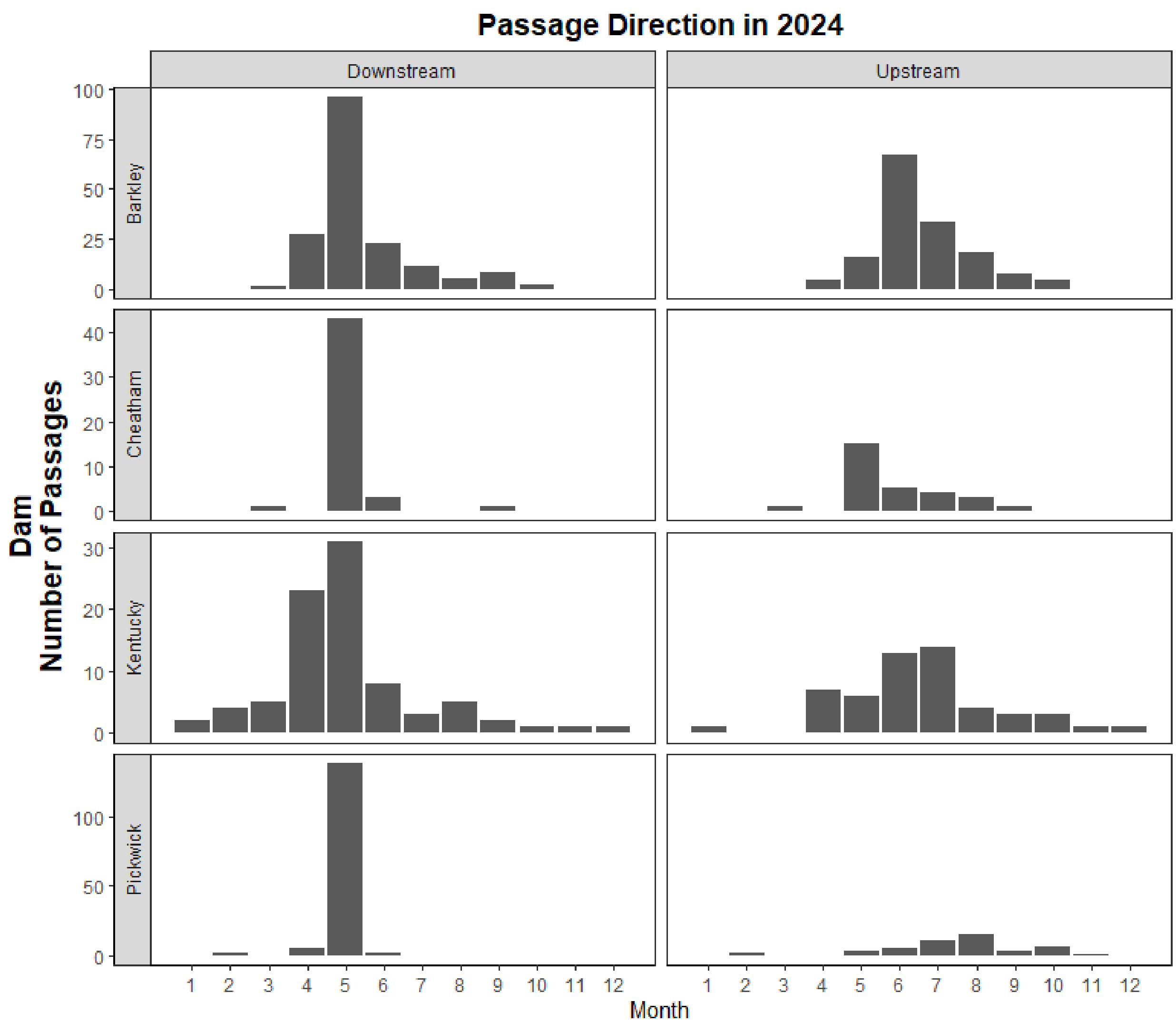


Figure 3. Total number of silver carp passages for each dam by month and passage direction for 2024. Y-axis scale varies for each dam.

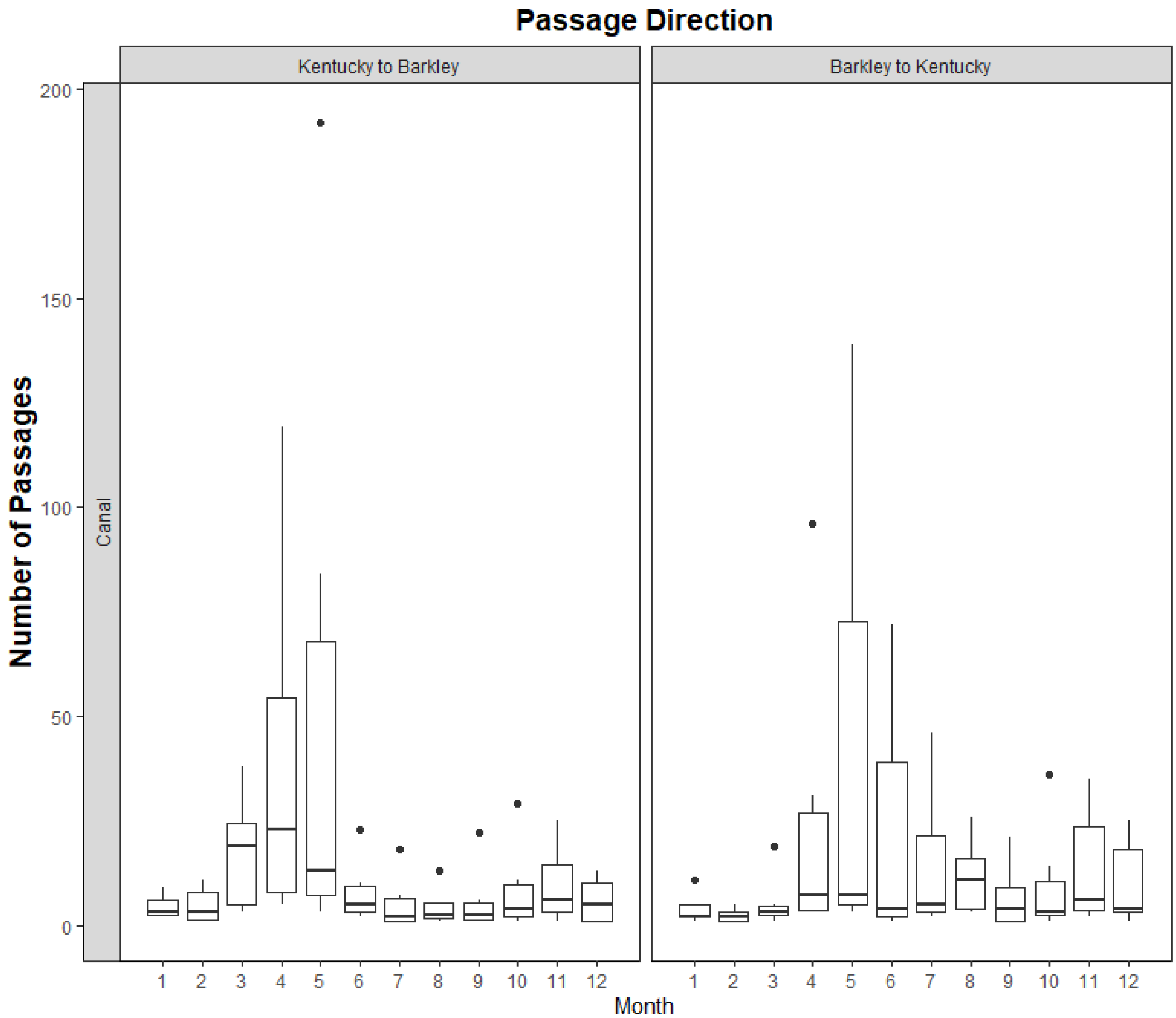


Figure 4. Yearly variability in the total number of silver carp passages through the Barkley Canal by month from 2018 to 2024.

Project 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 (RM 31.7), and Dashields (RM 13.3) pools of the Ohio River, in addition to the Wabash, Allegheny, and Monongahela rivers.

Lead agency: Kentucky Department of Fish and Wildlife Resources (KDFWR)

Participating Agencies: Illinois Department of Natural Resources (ILDNR), Indiana Department of Natural Resources (INDNR), Ohio State University (OSU), Pennsylvania Fish and Boat Commission (PFBC), Southern Illinois University (SIU), U.S. Fish and Wildlife Service (USFWS-Carterville FWCO and USFWS-Ohio River Substation FWCO), West Virginia Division of Natural Resources (WVDNR), 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 report contains information on efforts to collect these data while containment and control efforts are underway. Within the Ohio River Basin, this partnership works within and adjacent to an area called the "Intensive Management Zone" or IMZ. The IMZ is located within the Cannelton Pool where removal efforts are underway and future efforts are being planned. The Early Detection and Evaluation project is an effort to coordinate and report on efforts that assess management actions related to invasive carp removal, suppression, and containment.

The tasks outlined in this document would add a seventh 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 and eDNA. The primary goal of these projects is to provide an accurate status on the invasion front as well as provide a population trend assessment of Invasive Carp in areas experiencing active control and response/ removal efforts. In addition, fish community data and Invasive Carp abundance may aid in determining impacts of carp on native fish assemblages. These projects also inform strategies for Invasive Carp containment, gear effectiveness, early detection, and rapid response. Through the evaluation of multiple lines of evidence, 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 Carp within intensive management zone.
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, occupancy modeling, and power analysis) are in development to estimate abundance and inform decision making.
- Cannelton Pool had its second consecutive year of decreasing CPUE since peak catch rates for Silver Carp in 2022. McAlpine and Markland pools CPUE have been steadily increasing over the years. Changes in abundance indicate needs for further evaluation as large-scale harvest continues to take place in Cannelton and Newburgh pools.
- Research efforts resulted in a community size spectra manuscript published in Ecosphere (Novak et al. 2024, https://doi.org/10.1002/ecs2.70090) that compare CSS slopes over time in the Ohio and Illinois River. This builds from the Novak (2023) thesis, but with revised analyses using a new and cutting-edge Bayesian maximum likelihood estimator.
    - The impact of Invasive Carp on fish community size structure was estimated leading to identification of a 24% biomass threshold for negative Invasive Carp impacts (specifically, if carp exceed 24% of the biomass sampled in a standard electrofishing survey we expect to observe negative impacts, but below that threshold we expect minimal ecological impacts). Strong impacts were measured in the Illinois River post invasion, but not yet in the Ohio River.
- WVU and the U.S. Fish and Wildlife Service – Ohio River Substation and Carterville FWCOs have established an effective collaboration to evaluate the use of hydroacoustic data to assess fish community size structure (i.e. CSS). Preliminary findings suggest that for annual pool-specific community size spectra estimates side-looking hydroacoustics provide more precision (smaller confidence intervals) estimates than electrified dozer trawl derived data.

- A positive detection of Invasive Carp eDNA occurred in the Beverly Pool of the Muskingum River for a third consecutive year and in the Lowell Pool for a second consecutive year.
- Nine positive detections of Invasive Carp eDNA occurred in Mill Creek. This is also the second consecutive year with positive detections in Mill Creek.
- In Kentucky, Taylorsville and Cave Run lakes both had positive detections of Invasive Carp eDNA (n = 6 and n = 3, respectively) in the first year of sampling.
- No adult black carps were sampled via hoop nets in the lower Ohio River; however, one adult black carp was sampled in the lower Cumberland River less than 4 kilometers from the confluence.
- Five adult black carps were captured by commercial fishers in the lower Ohio River in 2024.
- Hydroacoustics surveys of the Wabash River showed that this technique is successfully tracking aggregations of bigheaded carp, as it does in the Illinois River. We have documented shifts in the distribution of densities and sizes of bigheaded carp showing that harvest indeed reduces local densities and causes Invasive Carp to reaggregate.
- Hydroacoustics demonstrates that densities of Silver Carp are higher in the upper Wabash River than the lower reaches. How this pattern is related to factors such as habitat availability, flow, and temperature is being explored.

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.

- *<u>Intensive Management Zone</u>*: The area where contract fishing is used to harvest Invasive Carp for the purpose of reducing propagule pressure.

<u>Objective 1:</u>
Spring Standardized Targeted Sampling (Cannelton – R.C. Byrd)
Targeted spring monitoring occurs annually, contributing to the historical dataset that tracks Invasive Carp relative abundance across an invasion gradient. During spring 2024 (22 April – 12 June; 6 May – 13 May), field crews from KDFWR, INDNR, and USFWS-Ohio River Substation FWCO conducted targeted sampling for Invasive Carp in five pools of the Ohio River. These included Cannelton Pool (RM 721) within the establishment front (i.e., intensive management zone), to R.C. Byrd Pool (RM 237) within the presence front (Figure 1). Fixed sampling sites within each pool were pulled from a stratified-random design process completed in 2015. 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 into categories. Sites were described as the mainstem river, island back-channels, tributaries/embayments, and dam tailwaters. Tributary sites were the most sampled, although the mainstem river was the most abundant habitat type in each pool. Mainstem river sites posed issues due to their size, depth and low-quality habitat. These characteristics created an area where it was 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 Carp. Relative abundance was inferred using catch per unit effort (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 December 2024. Field crews from four agencies (KDFWR, INDNR, WVDNR, and USFWS) targeted Invasive Carp using boat electrofishing and gill netting. Invasive Carp

were measured, weighed, observed/ notes taken for *DELTS* (i.e., deformities, fin erosion, lesions, tumors, and sores), and the pair of lapilli otoliths were removed. These data were used to determine length distributions, sex ratios, 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 and summarized within histograms. In addition to length frequency distributions being compared among pools, Invasive carp were assigned into proportional size distributions using methods described in Phelps et al. (2013) and Gabelhouse (1984). To further quantify and compare length frequency distributions across multiple Ohio River pools, data was applied to standard length categories developed for Invasive Carp and evaluated using traditional proportional size distribution (PSD).

Ages were estimated using the pair of lapilli otoliths collected in Cannelton and McAlpine (Cannelton: n = 304; McAlpine: n = 183). Otoliths were cleaned, encased in epoxy, and thin sectioned using agreed upon methods that were developed in 2021 during an Invasive Carp ORB workshop. Age distributions are described in terms of frequency of occurrence. 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:

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

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 December. Differences in body condition were compared between Cannelton, McAlpine, and Markland pools in 2024, and for Cannelton and McAlpine from 2015-2024.

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 sampled 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. Occupancy data was sent to WVU for analysis and recommendations for future sampling.

Sampling efforts in 2024 took place in Markland Pool of the Ohio River. Following previous sample design, Markland 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.

Objective 2:

Trends in Native Fish Communities

Native fish community sampling in 2024 took place at the tailwaters of Emsworth (Dashields Pool) lock and dam on the Ohio River, the tailwaters of Lock 9 (Pool 8) and Lock 2 (Emsworth Pool) on the Allegheny River, and the tailwater of Maxwell (Charleroi Pool) lock and dam on the Monongahela River. Five (5) 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, New Cumberland, and Dashields Pools of the Ohio River as well as the lower two miles of Little Beaver Creek using gill nets and night electrofishing. Electrofishing surveys in the Racine pool were conducted in November 2024 at the same fixed sites selected from a previous stratified-random design from 2022. Surveys consisted of 900 second timed transects during the daytime 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 2024 at the same fixed sites as in previous years. Gill net sets consisted of two (2) 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, 41 randomly selected sites in were sampled from September 16th through October 25th. 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 and data entry are 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 2024. In addition to the fish community monitoring noted above, the USFWS Ohio River Substation FWCO conducted fish community surveys in the spring (May/June) and again in the fall (September/October) in R.C. Byrd, Racine, Belleville (Muskingum River only), Willow Island, and the Kanawha River. A total of 170 surveys were conducted in 2024. Surveys consisted of 900 second timed transects during the daytime beginning at the marked coordinates and continued downstream in the mainstem river and large tributaries. Surveys of small tributaries and embayment's 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).

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. 2017, 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 2024, WVU researchers completed the third 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, (4) evaluate the sensitivity of CSS to use as an early warning indicator, and (5) investigate the application of side-looking hydroacoustic survey data for CSS. In the 2023 Annual Technical Report, we shared B. Novak's (2023) completed thesis which used a linear-regression method based on binned size class data to estimate annual pool-specific slopes. During 2024, we updated those analysis using a cutting-edge Bayesian maximum likelihood estimation approach (Wesner et al. 2024).

In collaboration with the U.S. Fish and Wildlife Service – Ohio River Substation and Carterville FWCOs we began evaluating the effectiveness of side-looking hydroacoustic survey data for community size spectra. The hydroacoustic data was produced by the Carterville FWCO (see methods for Objective #5 below). The refined hydroacoustic data derived from Objective #5 below were shared with the WVU team along with companion electrified dozer trawl data. For the preliminary analyses presented below we used the Edwards et al. (2017) maximum likelihood estimation (MLE) approach, which produces a lambda term which is the parameter that describes a truncated pareto distribution and is analogous to the traditional CSS slope from binned linear regression approaches. Edwards et al. (2017) and Pomeranz et al. (2023) found that MLE approach produces a more accurate and precise slope estimate. We used the MLE (non-Bayesian) approach to estimate the CSS slope for JT Myers and Newburgh pools from 2021 and McAlpine and Cannelton pools for 2022 for both the hydroacoustic and dozer trawl data sets. During 2025, the Carterville FWCO team will complete processing 2023 and 2024 data, which consists of four (4) additional pools. The WVU team will then refine analyses using the complete eight (8) pool (over 4 years) data sets first with the basic MLE approaches, then utilizing a variety of covariates with the newest Bayesian MLE approaches (Wesner et al. 2024).

<u>Objective 3:</u>

Monitoring Ahead of the Invasion Front

Targeted sampling for Invasive Carp was conducted in October 2024 in the Montgomery Pool and November 2024 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 near Phyllis Island and Georgetown Island.

Incidental sampling for Invasive 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 on Pool #2, Pool #6, and Pool #8 of the Allegheny River, the Dashields Pool of the Ohio River, and the Emsworth and Grays Landing Pools 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. Adult Sander species were targeted during these surveys and presence/absence of Invasive Carp species was recorded. Sampling in October occurred at four (4) fixed sites in Pool #4 of the Allegheny River, four (4) fixed sites in the Emsworth Pool, and five (5) fixed sites in the Charleroi Pool of the Monongahela River for a total effort of 6.97hrs. 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 Allegheny River in the Emsworth Pool and Pool #6, the Ohio River in the New Cumberland 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 (4) 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.

KDFWR conducted adult Black carp sampling on the lower Ohio River and the lower Tennessee/Cumberland River for four (4) weeks, in August and September 2025. This sampling was performed using baited five-foot hoop nets with seven (7) hoops, two-inch bar mesh, and two (2) finger throats. Site selection was stratified random and informed by historic commercial black carp harvest reporting. Environmental data was collected at each site including but not limited to temperature, dissolved oxygen, secchi, depth and discharge. All Invasive Carp were euthanized. Standard biological data was collected from the individual adult black carp collected.

To determine if Silver or Bighead Carps may be present in tributaries of the upper Ohio River, the USFWS – Ohio River Substation FWCO collected a total of 755 water samples from eight (8) tributaries of the upper Ohio River. During October 2024, the USFWS – Ohio River Substation FWCO sampled Raccoon Creek (Montgomery Pool), Beaver River (Montgomery Pool), and Little Beaver Creek (New Cumberland Pool). During November 2024, they sampled Sandy Creek, Mill Creek (Racine Pool) as well as Armour Creek, the Pocatalico River, and the Coal River (Winfield Pool of the Kanawha River). The USFWS – Carterville FWCO collected 320 water samples from the Muskingum River (Belleville Pool) during September and 300 water samples from both Taylorsville and Cave Run lakes during October 2024 (Table 3). All eDNA sampling followed the USFWS 2024 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.

Occupancy Analysis
Occupancy analyses and subsequent power analyses were run using existing adult Silver Carp data from 2015 – 2023. Surveys were conducted from February 15 – December 13, and survey dates varied from pool to pool and by year. Data was detection / non-detection of Silver Carp from Green River upstream to Willow Island. Not all 13 pools were sampled each year. Sites sampled within pools ranged from 3-69 (mean = 22, median = 22) and varied from pool to pool and by year. Each site was visited one to six (1-6) times annually. Boat electrofishing, electrified dozer trawl, and gill nets were the gear types employed. Data included surveys from both targeted and community sampling protocols.

The Bayesian occupancy model follows methods from Royle and Nichols (2003) to estimate a pool-level index of abundance that was allowed to vary over time. The model also estimates site-level occupancy probability which is influenced by pool-level abundance such that the more individuals there are in a pool, the more likely a site is to be occupied. Additionally, site-level occupancy probability is influenced by habitat type (i.e., main channel, side channel, backwater, and tributary). The model estimates detection probability conditional on a site being occupied. Detection probability is influenced by pool-level abundance such that the more individuals there are in a pool, the more likely an individual is to be detected at a site if they are there. Detection probability is also influenced by gear type (boat electrofishing, electrified dozer trawl, and gill nets), sampling type (targeted and community), and season (February 15 – August 14 and August 15 – December 13). Additionally, preliminary analyses showed a natural grouping of pools, so model estimates are given for three pool groups: Green River – Markland pools, Meldahl – RC Byrd pools, and Racine – Willow Island pools.

Power Analysis
A series of power analyses were run to determine optimal sampling effort needed to achieve a high level of carp detection (p = 0.8 – 0.95) based on different gear types, sampling strategies, sampling seasons, habitat types, and time spans. Model estimates for pool-level abundance, site-level occupancy, and detection probability were run over each combination of covariates for each of the three (3) pool groups and mean detection probabilities were calculated. This was simulated many times over a range of sample sizes (2-20 sites with three (3) surveys at each site).

Additionally, model estimates can be used to customize the power analysis to fit the needs of a specific sampling question, such as:

> "We know that carp are established in the main channel of a river, but very little is known about its tributaries. We want to be 95% confident that there are or are not carp at a tributary. How many samples do we need?"

A power analysis was run to determine the minimum number of targeted samples needed to achieve 95% detection probability in a tributary with unknown abundance, gear type, and sampling season.

<u>Objective 4:</u>
Spatial Distribution in the Wabash and White rivers
Mobile hydroacoustic sampling was conducted by Southern Illinois University (SIU) during spring and fall months of 2024 in the Wabash River between Terre Haute, IN and the confluence with the Ohio River (Figure 2). The sites sampled were as follows: Crawleyville (May 1, 2024), Dogtown Ferry (May 24, 2024), Fay's Landing (March 13, 2024; November 8, 2024), Hustonville (March 12, 2024; November 8, 2024), New Harmony (May 2, 2024), New Haven (April 25, 2024), St. Francisville (March 14, 2024; November 9, 2024); Terre Haute (March 11, 2024; November 7, 2024), and Vincennes (March 15, 2024; November 9, 2024). Sampling during summer and most of the fall was limited due to extremely low flow and discharge in the river (Table 4 and Figure 3). Hydroacoustic sampling consisted of two (2) 200-kHz split-beam BioSonics DTX transducers that were horizontally oriented toward the center of the river while sampling. Each survey was approximately 5 km long with multiple, non-overlapping, parallel passes covering the entire channel from bank to bank, and ensonified between 925,000 and 1,540, 000 cubic meters of water (Table 5). The fish community was also sampled in the same reaches of the Wabash River using daytime electrofishing to determine size-specific species proportional abundances that are needed for analyzing hydroacoustic data. Electrofishing transects consisted of 900 seconds of pedal time following standardized long-term monitoring protocols (McClelland et al 2012). Acoustic estimates from 2024 are being processed in Echoview and will be available by summer 2025. To date, SIU has been processing hydroacoustics data as per MacNamara et al 2016, where fish acoustic targets are

assigned as Bigheaded Carp or other species based on the relative proportion of the fish within each size class from the independent fisheries sampling. This is a simple approach that does not account for the variability within the fish assemblage estimates, especially for large fishes. SIU will work with USFWS – Carterville FWCO to explore the feasibility of the processing acoustics data using a Bayesian hierarchical approach as described below.

In March of 2023, a pilot project was conducted to assess the impact of targeted harvest removal of Invasive Carp in an oxbow of the Wabash River (Near Grayville, IL). Briefly, block nets separated the oxbow from the Wabash main channel throughout the harvest event. Hydroacoustic sampling by SIU was conducted prior to harvest/ sampling but after block nets were in place. This event proved the efficacy of hydroacoustics as a tool for the assessment of removal events, and in 2024 SIU is pursuing similar events. One was conducted in Bay Creek, a tributary of the Ohio River, in March 2025. SIU is discussing logistics of conducting similar pre/post scans in the White and Wabash rivers in conjunction with removals directed by INDNR. The end goal is twofold: first to use these controlled events to better understand carp behavior under removal stress, second to understand fishing mortality of carp, critical information for the assessment of removal success. Finally, in 2025 SIU is investigating alternate echo sounding equipment (e.g., Hummingbird or Lowrance), which may be more effective in shallow and constrained backwaters in which these removal experiments take place.

Objective 5:

Hydroacoustics Analysis

The USFWS – Carterville FWCO completed hydroacoustic sampling during September and October 2024 in J.T. Myers and McAlpine pools of the Ohio River. Hydroacoustic data collection followed methods described in the Large River Hydroacoustics Mobile Survey Standard Operating Procedure, Region 3 U.S. Fish and Wildlife Service. 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 downwards 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 > 0.5 mi in length, navigable tributaries (up to two miles from confluence), and backwaters because Invasive Carps often inhabit these areas. In the main channel, we selected 35% and 25% of available 0.5-mile sites for data collection using a random sampling approach for J.T. Myers and McAlpine pools, respectively (Johnson et al. in review). This resulted in 96.5 and 74 miles of main channel transects for J.T. Myers and McAlpine 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 U.S. Fish and Wildlife Service using Echoview Version 15.0. 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 250 mm fish during each survey and used that value as a TS threshold to remove fish less than 250 mm 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 mi) 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 ~4.8 km/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 250 mm 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 eight 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 no random effects; 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 median TS and credible intervals (CrI's) for each fish track. Median 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 fish track is a Silver Carp based on its TS (for details see DuFour et al. 2021). We then calculated the mean probability that fish tracks at a specific site were Silver Carp and used Monte Carlo simulations (n = 1000) to estimate the numbers of Silver Carp at each site. These abundances were converted to densities 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 median 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 500 and 900 mm 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).

To acquire mainstem Silver Carp abundance estimates for each pool, we used Monte Carlo simulations as outlined above to estimate mean densities for each 0.5 RM sampled using hydroacoustics. We then used inverse-distance weighting to interpolate densities for each RM at which hydroacoustic data collection did not occur. Inverse-distance weighting works by taking a weighted average of values from nearby sites where the values from sites closer to the unsampled area are assigned a greater weight. To convert hydroacoustic density estimates to abundance, we estimated the total volume for each 0.5 RM using USACE data (adjusted for gauge height) and multiplied density by volume for each 0.5 RM. We then summed the abundance estimate for each 0.5 RM to acquire a pool-wide, mainstem Silver Carp abundance estimate.

Results:

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

During spring 2024, KDFWR and INDNR contributed 47 hours of targeted boat electrofishing to collect a total of 231 Invasive Carp across the middle Ohio River. Of the three species caught, Silver Carp equated for 97.4% of catch, Grass Carp 2.17%, and Bighead carp 0.43% (Table 6). As in previous years, majority of Silver Carp were found in the 42 transects sampled within Cannelton Pool (N= 126). Although Cannelton had the highest CPUE among pools sampled in 2024 (3.1 fish/transect), abundance of Silver Carp continued to show a decreasing trend with a peak of 8.7 fish/transect in 2022 (Figure 8). While Cannelton CPUE decreased, an increase was observed in both McAlpine (1.76 fish/transect) and Markland (0.36 fish/transect) pools. Silver Carp captures have steadily increased in McAlpine (N= 80) and Markland (N=

18) pools (Figure 9). The average catch rates per pool for other Invasive Carp species (i.e., non-Silver Carp) remained negligible with 4 Grass Carp removed from Cannelton Pool, and 1 Bighead and 1 Grass Carp from Meldahl Pool.

Spring targeted boat electrofishing in the Greenup and R.C. Byrd pools by USFWS- Ohio River Substation resulted in zero (0) Invasive Carp over 20 survey sites and 5 hours of effort. Spring gill netting in these pools yielded four Silver Carp from 2250ft of net over 11 sites (Table 7). The most common bycatch species in these pools was Blue Catfish.

Assessing Invasive Carp Population Demographics
By the end of the reporting period, a total of three (3) Bighead Carp and five (5) Grass Carp had been captured during the 2024 sampling efforts in the middle Ohio River. Two (2) of the Bighead Carp were captured during fall electrofishing sampling efforts in McAlpine and Markland pools, and one (1) was captured in McAlpine during targeted spring monitoring. Data was included in the ongoing length-weight regression that is being constructed for Bighead Carp in the Ohio River (Figure 10). All five (5) Grass Carp captured in 2024 were via boat electrofishing during spring targeted monitoring efforts, with four (4) collected in Cannelton Pool and one (1) in Meldahl Pool. Total lengths ranged from 874 mm to 922 mm. Due to small sample sizes of both Bighead and Grass Carp collected in 2024, there will be no additional demographics provided for either species. A length-weight regression was constructed for Silver Carp in the Ohio River (Figure 11).

Length frequency distributions in 2024 revealed that only about 3% of Silver Carp were 600mm or less in total length, all of which were from Cannelton Pool (Figure 12). The mean length per pool was 774 mm in Cannelton, 878 mm in McAlpine, and 979mm in Markland Pool. This is a slight increase in average total length for McAlpine (797mm) and Markland pools (937mm) from the 2023 results, and a decrease in Cannelton Pool (770mm). All three (3) pools show relativity unimodal distribution trends, which is a new occurrence for Markland Pool having had a more scatter plot pattern in prior years. Traditional Proportional Stock Density (PSD) analysis was done. PSD calculations provided an index of size structure across the three (3) pools. Markland Pool size structure was dominated by large Silver Carp (PSD = 100; PSD-P = 100; PSD-M = 100; PSD-T = 86.57). McAlpine pool had smaller PSD values comparatively but was still primarily dominated by large Silver Carp (PSD = 100; PSD-P = 100; PSD-M = 99.5; PSD-T = 9.76). Cannelton Pool represented the smallest of the PSD values (PSD = 100; PSD-P = 97.59; PSD-M = 79.36; PSD-T = 0.27) across the three (3) pools (Table 8). Sex ratios in Cannelton and McAlpine pools remained similar to the 2023 results. Females were more abundant in both pools, representing 59% of the Silver Carp population in Cannelton and 55% in McAlpine. Males represented 41% of Silver Carp sampled in Cannelton Pool, and 45% in McAlpine (Figure 13).

Silver Carp from the Cannelton Pool in 2024 were estimated to be between 2 and 19 years old. Estimated ages of 5, 6, and 7-years were the most frequently sampled (54.0%), which is an increase in age class compared to the previous three years in Cannelton Pool. Silver Carp collected from the McAlpine Pool in 2024 exhibited a narrower age range of 4 to 13 years. The most frequently encountered age groups of Silver Carp from McAlpine Pool also fell within the 5, 6, 7-year range, equating for 80% of the 2024 sample (Figure 14). Markland Pool continues to represent a relatively small sample size with variable estimated age range, so ages were not summarized in this report.

Body condition of Silver Carp collected in Fall 2024 was determined using relative weight (W_r) equations generated from ten years of length-weight measurements (Figure 15). The mean W_r of Silver Carp collected from Cannelton in 2024 decreased to 105, and in McAlpine pool mean Wr increased to 114 (Figure 16). Markland Pool appears to have substantially higher average relative weights (130) than fish from the lower two (2) pools.

Development of an Effective Monitoring Program
Building on the previous project efforts in Cannelton Pool (2023), KDFWR moved sampling efforts upstream along the Ohio River in 2024. The occupancy project sampling design was implemented in Markland Pool, an area known to have a lower abundance of Silver Carp in comparison to the establishment front in Cannelton pool. Through June-July 2024, KDFWR sampled 39 electrofishing sites that were visited on three different occasions for a total of 117 sampling events.

Silver Carp were observed on at least one occasion at five (5) (12.8%) of the 39 site locations. Positive detections for Silver Carp were observed during 7.69% of the total sampling events. These data, along with all basin wide Silver Carp monitoring information, are being analyzed with occupancy models by WVU to provide further sampling recommendations for rapid detection and early response.

Native Fish Communities
Fish Community sampling in the and Racine Pool of the Ohio River was conducted by WVDNR in Oct-Nov 2024 and consisted of 4.25hrs of effort. Electrofishing surveys yielded data from 40 fish species (Table 9). Gizzard Shad and Freshwater Drum constituted the bulk of collected fishes comprising approximately 47% and 9% of the total catch between all pools, respectively. Bluegill and Hybrid Striped Bass 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. Additional methods to utilize these data are being investigated. Seventeen gill net surveys (3,300ft of net) were conducted by WVDNR in the R.C. Byrd and Greenup pools in fall 2024. One Silver Carp and one Grass Carp were removed from the R.C. Byrd pool during fall gill netting. No other fish were captured (Table 10).

Tailwater fish community monitoring by the PFBC in the Emsworth Pool and Pool# 8 of the Allegheny River, the Emsworth Pool and Charleroi Pools of the Monongahela River, and the Dashields pool of the Ohio River was conducted in May 2024 and consisted of 1.67hrs of effort per pool using pulsed DC night electrofishing. Total number of species captured ranged from 31 to 41 at each of the four tailwaters sampled, with individual fish counts ranging from 783 to 1,791 fish captured at each of the tailwaters. Emerald Shiner, Mimic Shiner, Smallmouth Bass, and Walleye comprised approximately 52% of the total catch between all pools (Table 11). No Invasive Carp were captured during these surveys. Randomized pool wide fish community sampling took place in September and October 2024 on the New Cumberland and Dashields Pools of the Ohio River and associated navigable tributaries. A total of 41 sites were sampled using night electrofishing and gill nets. 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.

The USFWS- Ohio River Substation FWCO collected a total of 29,297 fish, 69 unique fish species, over a total effort of 42.48 hours. Emerald Shiner and Gizzard Shad where the bulk of the species sampled with approximately 49% and 14% of the total catch amongst all sampled locations, respectively. An average of 140 fish were collected per survey.

Laboratory identification and data summary was completed for randomized pool wide fish community sampling from 2023 during summer 2024. In summary, 66 sites in the Emsworth Pool of the Ohio, Allegheny, and Monongahela rivers (including lower Chartiers Creek) were sampled using gill nets and night electrofishing. A total of 130 fish representing 11 species were captured from the Emsworth pool. Smallmouth Buffalo and Common Carp were the two most abundant species captured and comprised 82% of the gill net sample. Night electrofishing was performed for a total of 16.5hrs and captured 14.967 fish in the Emsworth Pool Fifty-two different species were captured; however, the majority of the individuals sampled electrofishing were Emerald Shiners (58%; Table 12). 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 2024. Identification and analysis of fish collected are ongoing. 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 Pool in August 2024. No Invasive Carp species were collected. A total of 3,879 individuals of 22 different species were captured. Emerald Shiner, Spotfin Shiner, and Bluntnose Minnow comprised 42%, 22%, and 17% of the total catch, respectively (Table 13).

Using Community Size Spectra to Monitor the Impacts of Invasive Carp
Novak et al. (2024, https://doi.org/10.1002/ecs2.70090) utilized a Bayesian MLE approach to quantify food web scale impacts (i.e. changes to the CSS) in direct relation to increases in invasive carp biomass. We used broken-stick regression to identify a critical threshold of 24% invasive carp biomass mass (Figure 17), essentially if the biomass of invasive carp exceeds 24% of the total fish biomass collected during a standard community boat e-fishing survey we predict food web scale effects (shift in the community size distribution, community efficiency). This points to a direct management goal, or target of reducing invasive carp to below 24% total fish biomass to minimize food web impacts.

Our newest work, initiated during 2024, is testing the application of side-looking hydroacoustic data within a CSS framework. Our first step was methodological, to evaluate how fish orientation influenced CSS mean and confidence. Fish orientation effects the reflected target strength, where fish parallel to the hydroacoustic signal have the strongest target strength, that should align with their true size, as fish orientation moves from parallel to perpendicular target strength is weakened and estimated total length is smaller, potentially obscuring the actual size structure of the community. Preliminary findings, however, suggest that fish orientation has little to no influence on CSS, although including fish from 45 – 90 degrees does appear to add some uncertainty (larger error bars, Figure 18) that will require additional analysis.

Hydroacoustic slopes for individual pools ranged from -1.69 to -2.03 (Figure 19). In three of the four pools CSS derived from hydroacoustic data were steeper than electrified dozer trawl data and closer to the theoretical prediction of -2.0 (Figure 20). Hydroacoustic derived estimates of slope (lambda) also showed notably smaller 95% confidence intervals. Overall, the application of side-looking hydroacoustics for developing CSS is promising as a tool for monitoring invasive carp impacts.

Monitoring Ahead of the Invasion Front

Targeted gill net sampling for Invasive Carp by the PFBC in the New Cumberland and Montgomery pools of the Ohio River did not collect any Invasive Carp species. A total of 128 individuals representing 15 species were captured during targeted gill net sampling. Smallmouth Buffalo and Common Carp were the two (2) most common species captured and each comprised 34% and 31% 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, the PFBC tracks incidental captures of Invasive Carp through other various projects. Efforts in 2024 included targeted gamefish surveys for Sander spp in March and November at ten (10) tailwaters in the Allegheny, Monongahela, and Ohio Rivers and targeted surveys for black bass at 13 fixed sites in one (1) pool of the Allegheny River and two (2) pools of the Monongahela River in October 2024. No Invasive Carp species were captured or observed in any of the targeted gamefish surveys in March, April, October, or November 2024. Black carp was captured by KDFWR. KDFWR ran hoop nets searching for adult black carp for 81 net nights on the lower Ohio River and 62 net nights on the lower Cumberland River (Figure 21). Sampling was done where commercial fishers historically had caught adult black carp around Smithland, KY. This sampling collected 316 total fish comprised of 21 different species with silver carp being the most predominate species at 22% of the catch with a CPUE of 0.5 fish/net night. One (1) adult black carp (TL = 1187 mm, WT = 13.05 kg) was caught in the lower Cumberland River less than 4 kilometers from the confluence with the Ohio River. In addition to agency sampling, KDFWR received five (5) adult black carp (TL = 997-1350 mm) from commercial fishers that were caught in the lower Ohio River.

The USFWS- Ohio River Substation FWCO also preformed targeted gill net sampling for invasive carp in R.C. Byrd, Belleville, Willow Island, and the Kanawha River. A total of 22 gill net surveys were conducted in 2024 for a total effort 44 hours. There was a total of 11 species sampled during targeted gill net surveys which represented seven (7) unique species. The most common species was Black Buffalo which represented 27% of total catch. There was one (1) silver carp (Kanawha River), and one (1) bighead carp (RC Byrd Pool) that were captured and removed during gill net surveys in 2024.

eDNA samples taken from tributaries from the Ohio River Basin tested positive for Invasive Carp. Of the 1685 eDNA water samples collected in the Ohio River Basin, 24 samples tested positive for Invasive Carp eDNA. Eleven samples were positive for the Silver Carp marker, three (3) in Mill Creek, two (2) in the Lowell Pool and one (1) in the Beverly Pool of the

Muskingum River, three (3) in Taylorsville Lake, and two (2) in Cave Run Lake. Seven (7) samples were positive for the Bighead Carp marker, five (5) in Mill Creek, and two (2) in the Pocatalico River. Lastly, six (6) samples were positive for the non-specific Invasive Carp (either Bighead or Silver Carp) marker, three (3) in Taylorsville Lake and one (1) in each of Cave Run Lake, Mill Creek, and the Pocatalico River. This is the second consecutive year with a positive detection of Invasive Carp eDNA in the Lowell Pool of the Muskingum River and Mill Creek. This is also the third consecutive year of positive detections in the Beverly Pool of the Muskingum River. Since the first positive samples were detected in the Muskingum River during 2022, the number of samples collected that were positive for Invasive Carp eDNA has not increased above one (1) percent of reportable samples. Continued eDNA sampling of these sites will guide the future need to use traditional sampling gear to monitor the Invasive Carp invasion front. The increase in consecutive positive detections in Mill Creek from two (2) in spring 2023 to nine (9) in fall 2024 has led to Mill Creek being sampled with traditional sampling gear to monitor the Invasive Carp invasion front along with continued eDNA sampling.

Occupancy Analysis
Green River – Markland pools show a significant increase in relative abundance over time (Figure 22). Mehldahl – RC Byrd pools and Racine – Willow Island pools show nonsignificant increasing trends in relative abundance over time (Figure 22. Site-level occupancy probability shows higher site occupancy in tributaries relative to other habitat types (Figure 23). Detection probabilities are highest when using electrified dozer trawls, applying a targeted sampling protocol, and sampling in the latter half of the year (Figures 24-26).

Power Analysis
In Green River – Markland pools, sufficient detection probability (p = 0.8) can be obtained in less than 20 sites at three (3) surveys each when sampling in any of the four (4) habitat types (Figure 27), using any of the three (3) specified gear types (Figure 28), applying either targeted or community sampling protocol (Figure 29), or sampling in either season (Figure 30). In Meldahl – RC Byrd pools and Racine – Willow Island pools, sampling > 20 sites is necessary to achieve a sufficient detection probability (Figures 27-30).

Tributary Case Study: Since the mainstem river has established populations of Invasive Carp but the abundance is unknown in its tributaries, the more conservative Meldahl – RC Byrd pools abundance estimate was used to run the power analysis. The recommended number of sites to sample to achieve 95% detection based on sampling season, gear type, and number of surveys per site is given in Table 15. Based on the information given, recommended sampling effort ranges from 60 surveys (30 sites with two (2) surveys each) in the fall using a dozer trawl to 324 surveys (54 sites with 6 surveys each) in the spring using boat electrofishing (Table 15).

Spatial Distribution in the Wabash and White rivers
In the Wabash River, a total of the 5, 385 fishes of 50 species were sampled in 2023 by SIU, Eastern Illinois University, INDNR. Of these fishes, only 37 fish were bigheaded carp, suggesting that either Invasive Carp were rare in the river or that sampling with boat electrofishing was not efficient. In contrast, 210 and 133 bigheaded carp were sampled with

similar effort in 2021 and 2022, respectively. Average sizes of bigheaded carp were similar among 2021 samples through 2024 although young-of-year bigheaded carp were only present in 2021 samples (Figure 31).

Fish measurement data (length and weight) have not undergone Quality Assurance yet, so we cannot provide an estimate of carp biomass in the Wabash River for 2023. However, preliminary analyses reveal that the density of fish targets ranges from 0.086 fish/ 1000 m^3 of water in New Harmony, to 0.978 fish/ 1000 m^3 of water in Hutsonville. The density of fish increases the farther a site is from the confluence with the Ohio River, agreeing with past years surveys (Figure 32). Unfortunately, equipment failure prevented accurate GPS acquisition during our Terre Haute and Fay's Landing spring surveys, as well as Terre Haute and New Harmony's fall surveys, precluding analyses of fish target density. SIU is currently developing code to analyze these sites utilizing previous years GPS coordinates, which would provide an estimate of what the fish density could have been. Additionally, SIU is working with BioSonics to proactively prevent such equipment failures in the future. Finally, in 2025, SIU will compare the densities, size spectra, and riverine macrohabitat utilization between Silver Carp in the Wabash and Illinois rivers. These rivers, while both heavily invaded, have markedly different flow regimes and management practices, as the Illinois River is channelized for barge traffic while the Wabash is free flowing. Comparisons between these two (2) systems, both of which SIU has long-term echosounded data for, will clarify how Invasive Carp respond to different conditions. These findings will allow for better targeting of mitigation strategies across these two (2) basins.

Hydroacoustic data were successfully collected at all sites on the Wabash River in the spring 2024. IN the fall 2024, low water levels again restricted access to the Crawleyville and New Harmony. All 2025 hydroacoustic data have been uploaded into Echoview with bottom lines assigned to echograms. Data are in the process of being analyzed for density estimates of bigheaded carp and should be available by summer 2025.

Hydroacoustics Analysis
Community data comprised samples from 103 (J.T. Myers = 55, McAlpine = 48) electrofishing and 104 (J.T. Myers = 54, McAlpine = 50) dozer trawl sites. Boat electrofishing collected more total fish > 250 mm (n = 503) than dozer trawling (n = 155). A total of 65 Silver Carp were captured with more Silver Carp captured with boat electrofishing (54) than the dozer trawl (11).

Model results indicate the greatest mean Silver Carp densities occurred at RM 788 and the Nugent Sand Pits in J.T. Myers and McAlpine pools, respectively (for site-specific density estimates contact the USFWS – Carterville FWCO). Silver Carp densities were < 1 fish/1000m^3 at all sites and no apparent longitudinal trends exist within either pool (Figure 33). Habitat differences existed both within and among pools (Figure 34). In J.T. Myers Pool, main channel sites had the greatest mean density followed by side channels and tributaries whereas backwaters had the greatest mean density in McAlpine Pool followed by tributaries, side channels, and main channel sites. J.T. Myers had greater Silver Carp densities than McAlpine in main channel and side channel habitats whereas McAlpine had greater Silver Carp density estimates in tributary habitats. Estimates of main channel Silver Carp abundance indicate that, as expected, there were approximately eight (8) times as many Silver Carp occupying main channel habitats in J.T. Myers Pool (mean abundance = 30,437) than in McAlpine Pool (mean abundance = 3,789) during the survey period (Figure 35).

Discussion:

The Early Detection and Evaluation project has developed and tested several tools to evaluate harvest, investigated Invasive Carp negative impacts on faunal communities, detect invasive carp presence, and add tools to respond to early detections. This partnership continues to detect Invasive Carp beyond Cannelton Pool. Harvest efforts appear to be keeping Invasive Carp at levels below expected impact thresholds as measured by CSS, and differences in population level trends within the IMZ were observed (i.e., CPUE is decreasing, length frequencies are not biomodal, and relative weight is decreasing). Several areas sampled for Invasive Carp DNA show persistent detection and new areas were tested (e.g., Taylorsville and Cave Run Lake). Occupancy sampling and power analysis can inform sampling effort in conjunction with eDNA sampling (i.e., early detection and rapid response planning). Finally, this project is advancing the hydroacoustic tools which can measure abundance and map Invasive Carp movements in response to harvest.

This year marks a shift in Silver Carp abundance in Cannelton Pool. With another year of decreasing CPUE results since peak catch rates in 2022, evidence suggest that the intensive commercial harvest efforts in Cannelton may be impacting Silver Carp populations both downstream and upstream. Length frequency distributions provide an additional line of evidence to changes in populations. In 2023, Silver Carp populations shifted to favor unimodal length frequency distributions in Cannelton and McAlpine pools, indicating year-class strength that is also seen within 2024 results. This may be due to previously failed spawning events or failed recruitment. Populations of Silver Carp in Markland and McAlpine pools were dominated by large fish as seen through the use of PSD indices. To better quantify length frequency distributions in the Ohio River, size structure indices can be further implemented into analysis to make comparisons between pools. McAlpine and Markland pools continued to show a steady increase in catch rates of Silver Carp, suggesting that agency removal should shift efforts upstream. 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.

Through the collaboration of multiple projects, we can further enhance our ability to rapidly detect and evaluate Invasive Carp populations as seen in 2024. After a fourth year of occupancy sampling across the invasion gradient, data was analyzed and incorporated into occupancy models that provide sampling recommendations to achieve 95% confidence in detecting of Silver Carp.

Specifically, KDFWR has integrated eDNA sampling and power analysis to formulate an Early Detection and Rapid Response framework for Invasive Carp in reservoirs. The strategy uses the first reservoir, moving upstream from the Ohio River mainstem, as a sampling location within tributaries that have known Invasive Carp populations. These reservoirs are created by dams that are assumed to be physical barriers to Invasive Carp upstream migration, and that Invasive Carp cannot disperse upstream of the dam unless physically transported by people.

USFWS sampled two (2) Kentucky reservoirs using eDNA (e.g., Taylorsville and Cave Run lakes). Invasive Carp eDNA was detected but at non-population levels. If the number of and pattern of Invasive Carp eDNA indicated a higher presence, KDFWR would responds and that response would be informed by the power analysis which describes the number of sites to be sampled, and number of site visits needed.

Community Size Spectra
The slope of community size spectra developed from community boat e-fishing surveys are sensitive to invasive carp relative abundance and identified a critical threshold of 24% carp biomass in the Ohio and Illinois Rivers. For the time series investigated, pools in the Ohio River only exceeded this threshold in one instance, consistently, Johnston (2023 Master's Thesis) found no carp related changes to the zooplankton assemblage in the Ohio River, but in the Illinois where carp abundances exceeded 24% in most years, the depletion of zooplankton assemblage is well established (e.g. Sass et al. 2014). We do not know whether the ~24% biomass threshold is specific to these rivers or is more universal. Thus, to expand this research and apply it throughout the Mississippi River basin, next steps include consolidating fish community (and zooplankton) data across the basin.

Size-looking hydroacoustic data could further refine the CSS management tool. Hydroacoustic data can collect a larger less bias sample of fish body sizes, which in theory should produce a more accurate estimate of the CSS slope with smaller confidence intervals, i.e. more sensitive. Theoretic predictions for lambda (CSS slope) are -2.0, which has been supported by numerous empirical studies (e.g. White et al. 2007). Three of the four pools in the Ohio River showed lambda values near -2.0 consistent with expectations, Newburgh pool was the lone outlier, which may reflect a higher abundance of invasive carp, which increases the CSS slope (Novak et al. 2024). Hydroacoustic-derived CSS slopes were also consistently steeper than the electrified dozer trawl, likely due to the catch bias of the trawl toward smaller fish (less effective at catching larger fish). Newburgh pool was once again the exception, and this time, likely that the dozer trawl did not catch large invasive carp at a proportional rate. It should be clearly noted that these are all preliminary analyses, all subject to change once the remaining data is added (four (4) additional pools) and we will take a deeper dive into the trawl catches. The take-away message at this stage is however, that hydroacoustic CSS tentatively appears to be a viable means of evaluating food web size structure to measure invasive carp impacts.

White and Wabash Rivers
The Wabash River is a major tributary of the lower Ohio River and possibly a source of bigheaded carp recruits throughout the Ohio River basin. Hydroacoustic sampling provides a quantitative benchmark by which the contribution of bigheaded carp from the Wabash River to the Ohio River sub-basin can be assessed through time. In 2021 and 2022, hydroacoustic sampling in the Wabash River revealed that densities of bigheaded carp were higher upstream. Thus, it is important to incorporate the spatial extent of distributions of carps in the river to be able to assess changes in density through time, especially as a function of harvest as a control. These data can be used to help direct harvest to control carp densities most efficiently. The frequency of hydroacoustics sampling in 2023 was reduced due to extremely low water levels

during most of the summer and throughout the entire fall. Given these circumstances, we were still able to complete 11 sampling events and these data will be processed and available by summer 2024. SIU is currently working with USFWS – Carterville FWCO to use a Bayesian hierarchical analysis to bring density estimates in the Wabash River into parity with the remainder of the Ohio River basin. This approach will incorporate a new measure of variability associated with the independent fish community sampling into density estimates.
The hydroacoustics used to assess the efficacy of harvest showed that this technique is successfully tracking aggregations of bigheaded carp in the Wabash River, as it does in the Illinois River (MacNamara et al. 2016). Shifts in the distribution of densities and sizes of bigheaded carp (almost exclusively silver carp) showed that harvest indeed reduces local densities and causes carp to reaggregate, likely as an attempt to avoid capture. This approach can be used to determine the relationship between acoustics density estimates and the true population size within a locality and is being explored further in 2024.

Hydroacoustics
We found that both habitat and pool significantly affected mean Silver Carp densities. 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). Our results suggest that Silver Carp densities are greater in backwaters and tributaries than in either main channel or side channel habitats in McAlpine Pool. This finding agrees with previous literature (Pretchel et al. 2018) that Silver Carp densities increase in non-main channel habitats. In contrast, main channel habitats had greater densities than other habitats in J.T. Myers Pool. Similarly, Gillespie et al. (2017) found that Silver Carp may use main channel habitats more than other habitats in some Ohio River pools. 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).

We found that J.T. Myers Pool had greater mainstem Silver Carp abundance than McAlpine Pool. These differences are supported by previous literature describing Silver Carp density gradients within large rivers (Sullivan et al. 2021; Werner et al. 2022). Two (2) dams (Newburgh and Cannelton) exist between J.T. Myers and McAlpine pools creating barriers that slow the advancement of this invasive species. These abundance estimates are likely conservative for two reasons, 1) biased community sampling and 2) we do not estimate Silver Carp abundance in non-main channel habitats. We rarely encounter juvenile Silver Carp during boat electrofishing and dozer trawl sampling and adult Silver Carp have an exaggerated flight response to electrical stimuli, reducing the effectiveness of electrified gears as a capture method. These biases reduce encounters with Silver Carp, decreasing the estimated probability that a fish is a Silver Carp given its length, and ultimately decreasing density and abundance estimates. Because we use bathymetry data to estimate abundance from density, we are unable to estimate abundance in areas lacking bathymetry data (side channels, backwaters, and tributaries). For these reasons, the total amount of Silver Carp within each pool is likely much greater than our estimate. Future work to add bathymetry data for non-main channel habitats and a better understanding of Silver Carp catchability would greatly benefit our ability to estimate Silver Carp abundances with this approach.

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 a. 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 hydroaoustic 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 (unpublished data). 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 (i.e., < 250mm TL). The ability to infer the probability of a fish target being a Silver Carp for lengths 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.

We acknowledge that our main channel abundance estimates give a limited view of the Silver Carp population. However, it is a useful first step towards better understanding the Silver Carp population within surveyed Ohio River pools. Importantly, our abundance estimates do not include side channel, tributary, or backwater habitats because we do not have bathymetry for these habitats. These habitats often have increased densities of Silver Carp (DeGrandchamp et al. 2008; Gillespie et al. 2017; Pretchel et al. 2018). Abundance estimates for these non-main channel habitats are easily attainable once bathymetry data are collected in these habitats. Although our abundance estimates are limited to main channel habitats, these estimates provide tangible numbers to managers that seek to evaluate removal efforts and set removal goals. The ability to proactively set removal goals based on abundance estimates and removal targets allows mangers to allocate (or solicit) appropriate funds to achieve a desired result based on projected removal efforts rather than evaluating success after the fishing season ends.

Recommendations:

- As monitoring evidence suggests changes in relative abundance across the invasion gradient, agencies should focus removal efforts in areas upstream of the establishment zone. A steady increase in CPUE of Silver Carp in McAlpine and Markland pools over the years indicate a need to reevaluate where intensive management occurs. The partnership needs to discuss the relevance of the IMZ and develop a decision process to determine when/ if the IMZ should move either upstream or downstream,
- With the increasing Silver Carp abundance in Markland Pool, additional effort should be placed into gathering population demographic information each year. Reports moving forward should include sex ratios, age distributions, and further insight into Silver Carp populations in Markland Pool.
- Using electrified dozer trawls, applying a targeted sampling protocol, and sampling in the latter half of the year is recommended to increase detection probability of adult Silver Carp in the Ohio River Basin. Additionally, conducting less surveys at more sites relative to more surveys at less sites is recommended to increase detection probability.
- 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.
- Consolidate and combine fish community data sets across the basin to test the universality of the 24% threshold. If not universal then calculate system-specific thresholds to guide management. With regard to hydroacoustic, complete another round of analyses with the complete 2021-2024 data set (i.e., eight (8) pools) to more thoroughly evaluate accuracy and sensitivity.
- During 2025, the Carterville FWCO recommends continued sampling the Muskingum River and, at the request of KDFWR, recommends sampling Green River Lake and Rough River Lake, two (2) additional reservoirs of recreational importance to the state of Kentucky. The Lower Great Lakes FWCO recommends continued sampling the eight (8) tributaries of the upper Ohio River and adding the Little Kanawha River in the Belleville Pool.
- KDFWR will continue to sample for adult Black Carp. Since our sampling locations and efforts resulted in one adult black carp capture, effort will increase for next year. KDFWR selected locations based on commercial catches of adult black carp and locations we have captured YOY black carps. We will continue this method to expand the sample area for 2025.
- The new sampling design implemented in 2023, and analytical approach (2022) 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 and abundance 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.

- We recommend collecting bathymetry data within selected tributaries, side channels, and backwaters to facilitate the estimation of abundances within these habitats. This information would improve the overall pool-wide estimates of Silver Carp within Ohio River pools.

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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 = -5.37 + 3.13(Log10 Length_mm)	860	5208	ORB Technical Report 2024
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 = -4.61 + 2.88(Log10 Length_mm)	1075	5635	ORB Technical Report 2024
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.

Ohio River Basin eDNA Water Samples Collected Results

Site	Collected	Negative	Bighead	Silver	Bighead AND Silver	Bighead OR Silver	No Results	Field Blanks*
Sandy Creek, WV	90	90	0	0	0	0	0	10
Mill Creek, WV	135	126	5	3	0	1	0	15
Kanawha River Armour Creek, WV	90	90	0	0	0	0	0	10
Pocatalico River, WV	90	87	2	0	0	1	0	10
Coal River, WV	90	90	0	0	0	0	0	10
Little Beaver Creek, PA	90	90	0	0	0	0	0	10
Raccoon Creek, PA	90	90	0	0	0	0	0	10
Beaver River, PA	90	90	0	0	0	0	0	10
Muskingum River, OH								
Lowell Pool	160	158	0	2	0	0	0	16
Beverly Pool	80	79	0	1	0	0	0	8
Luke Chute Pool	80	80	0	0	0	0	0	8
Kentucky Lakes								
Taylorsville Lake, KY	300	294	0	3	0	3	0	30
Cave Run Lake, KY	300	297	0	2	0	1	0	30

Table 4. Ensonified water volume (1000m^3) from Spring 2023 hydroacoustic transects. This can be interpreted as a metric of sampling effort. GPS failure prevented accurate assessment of water volume at the Terre Haute and Fay's Landing sites.

Site (Date)	Water Volume (1000m^3)
Terre Haute (4-17-2023)	-
Hutsonville (4-18-2023)	1287.662
Vincennes (4-19-2023)	463.896
New Haven (4-26-2023)	493.676
Dogtown Ferry (4-27-2023)	647.989
St. Francisville (5-9-2023)	660.260
Fay's Landing (5-10-2023)	-
Crawleyville (5-9-2023)	924.631
New Harmony (5-12-2023)	1541.362

Table 5: Hydroacoustic estimates of the total number of fish targets and the density of fish targets per 1000m^3 of ensonified water. Lower and upper 95% confidence intervals of these estimates also provided. GPS failure prevented accurate estimation of fish targets at the Terre Haute and Fay's Landing sites.

Site (Date)		Fish Targets	Fish Target Lower 95% CI	Fish Target Upper 95% CI
Terre Haute	Total No.	-	-	-
(4-17-2023)	No./1000 m3	-	-	-
Hutsonville	Total No.	1259.085	666.753	1851.417
(4-18-2023)	No./1000 m3	0.978	0.518	1.438
Vincennes	Total No.	42.905	26.477	59.333
(4-19-2023)	No./1000 m3	0.092	0.057	0.128
New Haven	Total No.	15.126	3.548	26.704
(4-26-2023)	No./1000 m3	0.031	0.007	0.054
Dogtown Ferry	Total No.	126.072	8.238	243.906
(4-27-2023)	No./1000 m3	0.195	0.013	0.376
St. Francisville	Total No.	159.756	101.226	218.286
(5-9-2023)	No./1000 m3	0.242	0.153	0.331
Fay's Landing	Total No.	-	-	-
(5-10-2023)	No./1000 m3	-	-	-
Crawleyville	Total No.	322.722	115.905	529.539
(5-9-2023)	No./1000 m3	0.349	0.125	0.573
New Harmony	Total No.	132.694	27.210	238.178
(5-12-2023)	No./1000 m3	0.086	0.018	0.155

Table 6. Spring targeted sampling in 2024 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. The 95% confidence intervals are in brackets.

2024 Spring Boat Electrofishing							
	Ohio River Pools						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	All Pools
Sampling Dates	22 April – 12 June						
Effort (Hours)	10.50	11.50	12.50	12.50	0	5	52
# Transects	42	46	50	50	0	20	208
Invasive Carp Counts							
Bighead Carp	0	1	0	0	0	0	1
Grass Carp	4	0	0	1	0	0	5
Silver Carp	126	80	18	1	0	0	225
All Carp	130	81	18	2	0	0	231
CPUE (fish/transect)							
Bighead Carp	0.00	0.02 (0.0-0.06)	0.00	0.00	0.00	0.00	
Grass Carp	0.10 (0.01-0.19)	0.00	0.00	0.02 (0.00-0.06)	0.00	0.00	
Silver Carp	3.0 (1.56-4.44)	1.74 (0.64-2.84)	0.36 (0.09-0.63)	0.02 (0.00-0.06)	0.00	0.00	
All Inv. Carp	3.1	1.76	0.36	0.04	0.00	0.00	

Table 7. Total catch of targeted gill netting conducted in the R.C. Byrd pool of the Ohio River in 2023. Greenup was not sampled.

2023 Spring Gill Netting By-Catch			
	Ohio River Pool		
Species	Greenup	R.C. Byrd	Total
Bighead Carp	-	-	-
Silver Carp	-	4	4
Blue Catfish	-	2	2
Common Carp	-	1	1
Longnose Gar		1	1
Muskellunge		1	1

Table 8. Traditional proportional size distribution (Proportional Stock Density) indices for Silver Carp across three Ohio River pools (methods follow Gabelhouse (1984) and Phelps et al. (2013).

Total Length Categories				
Stock	**Quality**	**Preferred**	**Memorable**	**Trophy**
250mm	450mm	560mm	740mm	930mm
PSD= (# of Fish > Specified Length Category) / (# of Fish > Stock Length) x 100				
	Proportional Size Distribution			
Ohio River Pool	**PSD**	**PSD-P**	**PSD-M**	**PSD-T**
Cannelton	100	97.59	79.36	0.27
McAlpine	100	100	99.5	9.76
Markland	100	100	100	86.57

Table 9. 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 Racine Pool in 2024.

	Racine Pool			
	4.25hrs (18 Transects)			
Species	**N**	**Wr**	**%**	**Mean CPUE (95% CL)**
Banded Killifish	4	-	0	0.89 (1.01)
Black Crappie	3	125	0	0.67 (0.95)
Black Redhorse	1	-	0	0.22 (0.44)
Bluegill Sunfish	72	95	4	16.0 (8.24)
Bluntnose Minnow	31	-	2	6.89 (5.29)
Channel Catfish	4	90	0	0.89 (1.01)
Channel Shiner	23	-	1	5.11 (3.46)
Common Carp	17	96	1	3.78 (1.84)
Emerald Shiner	131	-	7	29.1 (18.3)
Flathead Catfish	6	101	0	1.33 (1.10)
Freshwater Drum	154	103	9	34.2 (17.4)
Gizzard Shad	840	97	47	186.7 (112.8)
Goldfish	2	-	0	0.44 (0.59)
Golden Redhorse	40	-	2	8.89 (6.36)
Highfin Carpsucker	6	-	0	1.33 (1.09)
Hybrid Striped Bass	94	101	5	20.9 (9.97)
Hybrid Sunfish	6	-	0	1.33 (1.27)
Largemouth Bass	20	107	1	4.44 (2.44)
Logperch	4	-	0	0.89 (1.01)
Orangespotted Sunfish	6	-	0	1.33 (1.79)
Pumpkinseed	13	89	1	2.89 (1.98)
Quillback Carpsucker	16	-	1	3.56 (3.79)
Redear Sunfish	3	90	0	0.67 (0.95)
River Carpsucker	9	95	1	2.0 (1.58)
River Redhorse	2	-	0	0.44 (0.87)
Sauger	58	91	3	12.89 (5.09)
Shortnose Darter	1	-	0	0.22 (0.43)
Silver Chub	4	-	0	0.89 (1.74)
Silver Redhorse	5	-	0	1.11 (1.06)
Skipjack Herring	30	-	2	6.67 (3.35)
Smallmouth Bass	24	-	1	5.33 (5.52)
Smallmouth Buffalo	88	87	5	19.56 (7.91)
Smallmouth Redhorse	20	-	1	4.44 (3.29)
Spotfin Shiner	4	-	0	0.089 (0.79)
Spotted Bass	35	105	2	7.78 (3.0)
Spotted Sucker	10	-	1	2.22 (1.92)

Threadfin Shad	1	-	0	0.22 (0.43)
Walleye	1	-	0	0.22 (0.43)
White Bass	1	-	0	0.22 (0.43)
White Crappie	2	99	0	0.44 (0.59)

Table 10. 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)	1650	1650
Number of Sites	9	8
Species		
Bighead Carp	0	-
Grass Carp	1	-
Silver Carp	1	-

Table 11. 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 2024. (A=Allegheny, M=Monongahela, O=Ohio)

Species Captured	Pool 8 (A)	Emsworth (A)	Charleroi (M)	Dashields (O)	Total	Percent
Banded Darter	1				1	0.02%
Black Crappie	1	2		1	4	0.08%
Black Redhorse	111	2	6	12	131	2.66%
Bluegill	37	16	151	21	225	4.58%
Bluntnose Minnow			15	7	22	0.45%
Brook Silverside	1		4		5	0.10%
Brown Trout	1				1	0.02%
Channel Catfish	6	2	6	4	18	0.37%
Channel Darter	5	2	3		10	0.20%
Channel Shiner	107	84	49	564	804	16.35%
Common Carp		3		2	5	0.10%
Common Shiner	2				2	0.04%
Emerald Shiner	33	142	55	667	897	18.25%
Fantail Darter			1		1	0.02%
Flathead Catfish	2	4	4	2	12	0.24%
Freshwater Drum	3	14	17	8	42	0.85%
Gizzard Shad		4	2	6	12	0.24%
Golden Redhorse	241	41	76	12	370	7.53%
Golden Shiner				1	1	0.02%
Green Sunfish	1		16	2	19	0.39%
Greenside Darter	7		12		19	0.39%
Johnny Darter			5		5	0.10%
Largemouth Bass			8	1	9	0.18%
Lepomis hybrids	1		1		2	0.04%

Logperch	10	28	49	10	97	1.97%
Longear Sunfish			1		1	0.02%
Longhead Darter	20	2		2	24	0.49%
Longnose Gar	22	56	42	5	125	2.54%
Mimic Shiner	45	26	43	138	252	5.13%
Mooneye	7				7	0.14%
Muskellunge		1	2		3	0.06%
Northern Hog Sucker	42	2	4	3	51	1.04%
Ohio Lamprey				1	1	0.02%
Pumpkinseed	1		8		9	0.18%
Quillback	12	13	8	1	34	0.69%
Rainbow Darter	1				1	0.02%
Rainbow Trout	1				1	0.02%
River Carpsucker	2	1	1		4	0.08%
River Redhorse	32	3	2	4	41	0.83%
Rock Bass	82	41	67	46	236	4.80%
Rosyface Shiner	4				4	0.08%
Sand Shiner			1	1	2	0.04%
Sauger	1	39	14	82	136	2.77%
Silver Redhorse	41	45	28	19	133	2.71%
Smallmouth Bass	246	113	62	62	483	9.83%
Smallmouth Buffalo	2	18	1	5	26	0.53%
Smallmouth Redhorse	236	11	16	6	269	5.47%
Spotfin Shiner	15	4	37	50	106	2.16%
Spotted Bass		1	12		13	0.26%
Streamline Chub		1			1	0.02%
Walleye	104	62	18	44	228	4.64%
White Bass				1	1	0.02%

White Sucker			1	1	2	0.04%
Yellow Bullhead			1		1	0.02%
Yellow Perch	1		6		7	0.14%
Totals	1487	783	855	1791	4916	
Total Species	39	31	41	34	55	

Table 12. Total number of fish captured per pool by gear type in one pool of the Ohio River in September and October 2023. GN = Gill Net, NTEF = Night Electrofishing

Species Captured	Emsworth (GN)	Emsworth (NTEF)
Bigeye Chub		13
Black Buffalo	3	
Black Crappie		3
Black Redhorse		40
Bluebreast Darter		1
Blue Catfish		1
Bluegill		1518
Bluntnose Minnow		220
Brook Silverside		379
Channel Catfish	3	24
Channel Darter		9
Channel Shiner		335
Common Carp	18	30
Emerald Shiner		8636
Fantail Darter		1
Flathead Catfish	1	25
Freshwater Drum	4	56
Gizzard Shad		477
Golden Redhorse		130
Golden Shiner		1
Greenside Darter		2
Green Sunfish		17
Johnny Darter		3
Largemouth Bass		4
Lepomis hybrids		2
Logperch		178

Longhead Darter		62
Longnose Gar		23
Mimic Shiner		441
Muskellunge		1
Northern Hog Sucker		19
Pumpkinseed		60
Quillback	1	13
Rainbow Darter		1
River Carpsucker	4	17
River Redhorse		99
Rock Bass		297
Sand Shiner		14
Sauger		145
Silver Redhorse	5	64
Silver Shiner		2
Smallmouth Bass	1	963
Smallmouth Buffalo	89	94
Smallmouth Redhorse		78
Spotfin Shiner		100
Spotted Bass		88
Streamline Chub		15
Striped Bass - Hybrid	1	3
Walleye		236
White Bass		2
White Crappie		1
White Sucker		23
Yellow Perch		1
Totals	130	14967
Total Species	11	52

Table 13. Total number of fish captured and percent of total captured during annual beach seine surveys in the Montgomery Island Pool from 2024.

Species Captured	2024	Percent Abundance
Banded Darter	6	0.15%
Bluegill	12	0.31%
Bluntnose Minnow	653	16.83%
Brook Silverside	49	1.26%
Channel Shiner	107	2.76%
Eastern Sand Darter	84	2.17%
Emerald Shiner	1630	42.02%
Gizzard Shad	63	1.62%
Golden Shiner	2	0.05%
Greenside Darter	12	0.31%
Logperch	92	2.37%
Mimic Shiner	163	4.20%
Northern Hog Sucker	6	0.15%
Quillback	1	0.03%
River Redhorse	1	0.03%
Rosyface Shiner	38	0.98%
Sand Shiner	52	1.34%
Silverjaw Minnow	12	0.31%
Smallmouth Bass	4	0.10%
Spotfin Shiner	871	22.45%
Streamline Chub	20	0.52%
White Sucker	1	0.03%
Totals	3879	

Table 14. Number of sites (N) and average median and upper and lower 90% credible intervals (CrI) for Silver Carp density (SVC/1000m^3) for main channel (MC), side channel (SC), and tributary (TRIB), habitats within J.T. Myers and McAlpine pools.

Pool	Habitat	N	Average Median SVCP Density	Average Lower 90% CrI	Average Upper 90% CrI
J.T. Myers	MC	190	0.0346	0. 0339	0.0353
J.T. Myers	SC	48	0.0178	0. 0170	0.0186
J.T. Myers	Trib	6	0.0116	0.0102	0.0129
McAlpine	BW	3	0.0704	0.0697	0.0711
McAlpine	MC	148	0.0052	0.0049	0.0053
McAlpine	SC	8	0.0085	0.0078	0.0092
McAlpine	Trib	12	0.0368	0.0353	0.0384

Table 15. Recommended number of sites to sample to achieve 95% detection based on sampling season, gear type, and number of surveys per site in tributaries of a mainstem river with an established carp population when abundance is unknown in the tributaries.

	Targeted Fall DT	Targeted Spring DT	Targeted Fall EF	Targeted Spring EF
2 surveys each	30	80	44	148
3 surveys each	22	56	32	100
4 surveys each	18	44	26	76
5 surveys each	18	36	22	62
6 surveys each	16	32	20	54

Silver Carp Establishment in the middle Ohio

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.

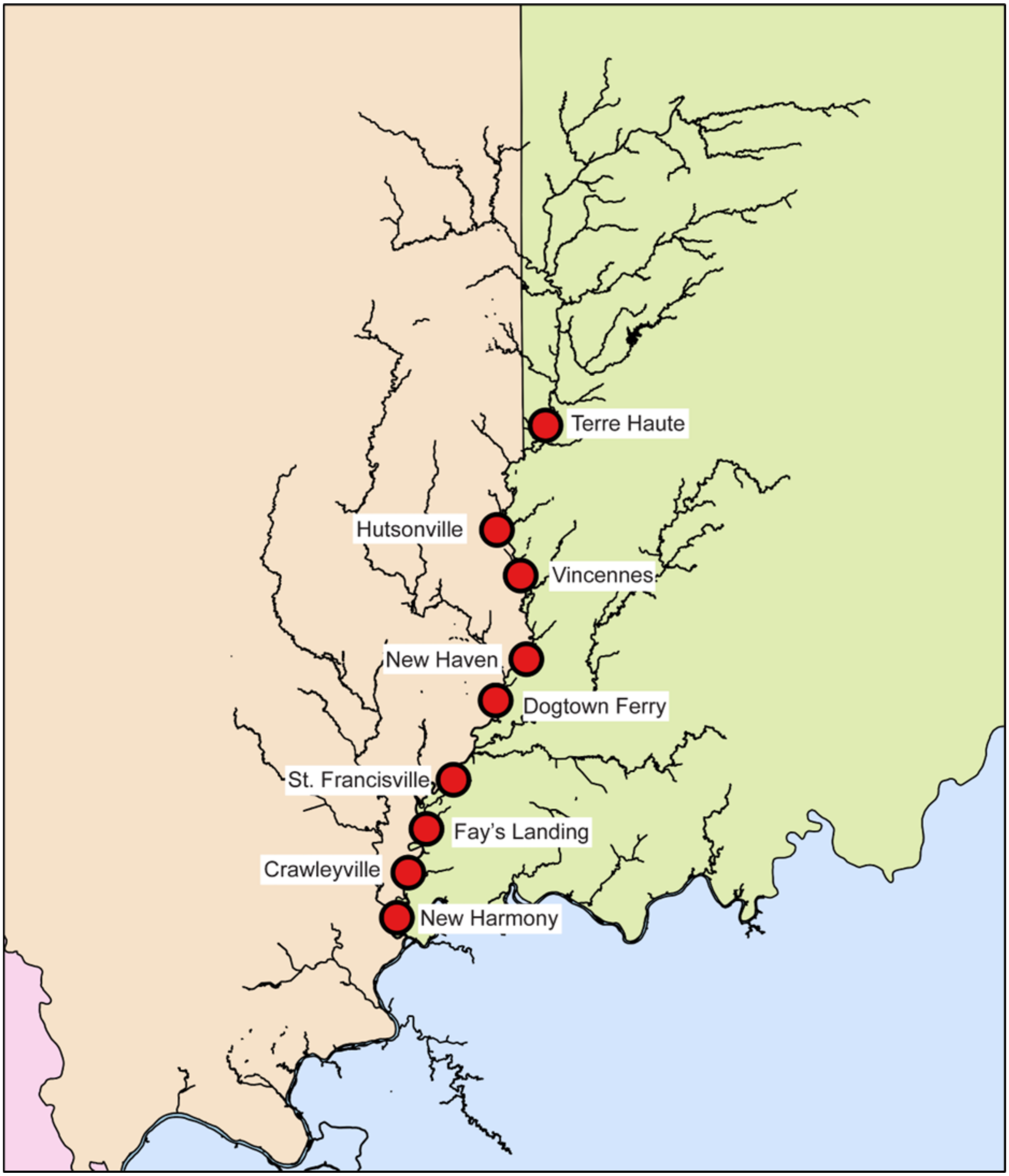


Figure 2. Map of hydroacoustic sample sites sampled in the River in 2023.

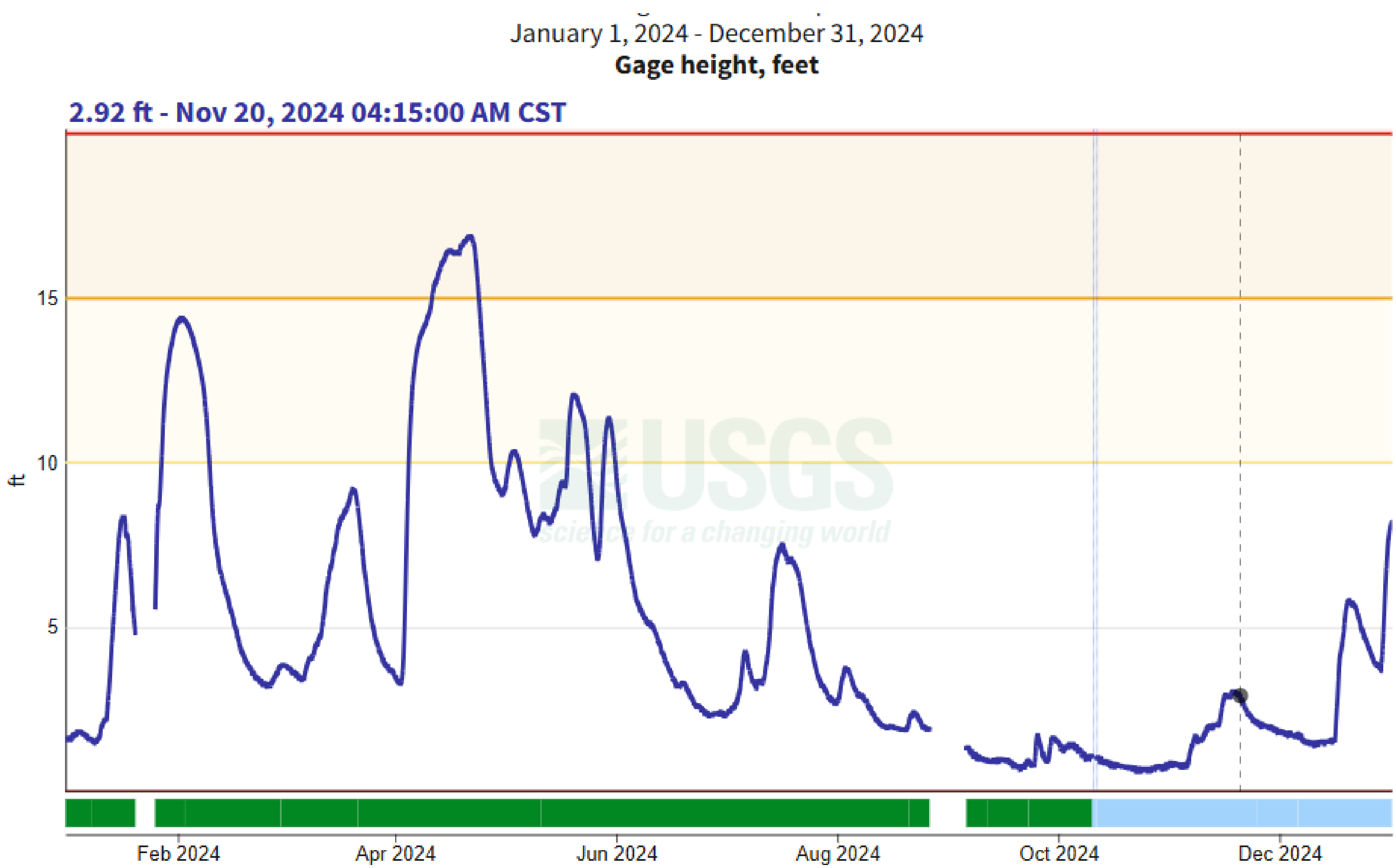


Figure 3. Gauge height at USGS Gauge 03378500 graph at New Harmony, IN on the Wabash River indicating low water in sumer and fall 2023 reducing the ability to reach hydroacoustice sample sites.

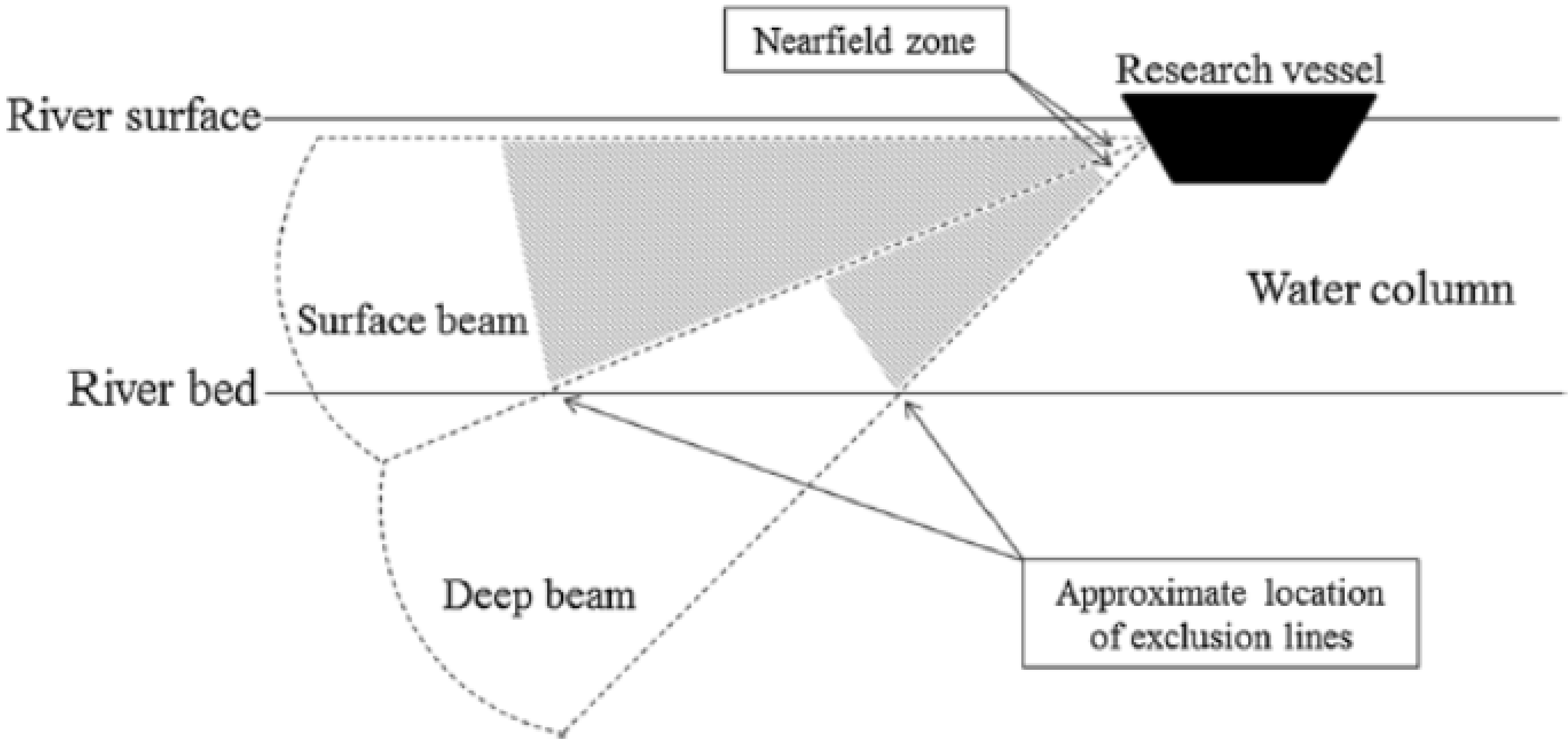


Figure 4. Depiction of hydroacoustic beams with transducers offset to maximize water column coverage for two split-beam echosounders.

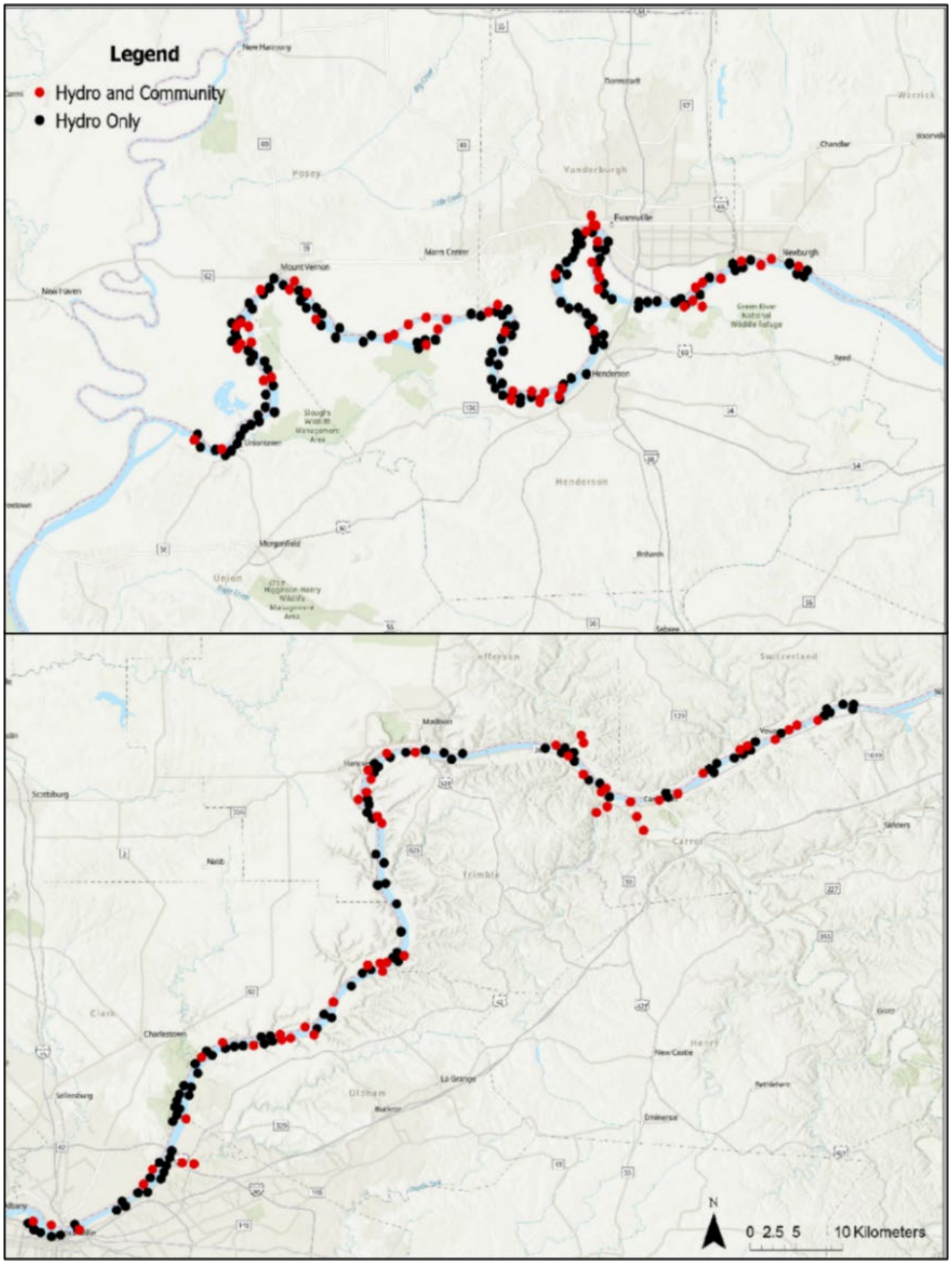


Figure 5. Map of dozer trawl (red) and boat electrofishing (blue) sites in Cannelton and Newburgh pools during October 2023. Community data were used to apportion hydroacoustic targets to species. Black lines across the river indicate dam locations.

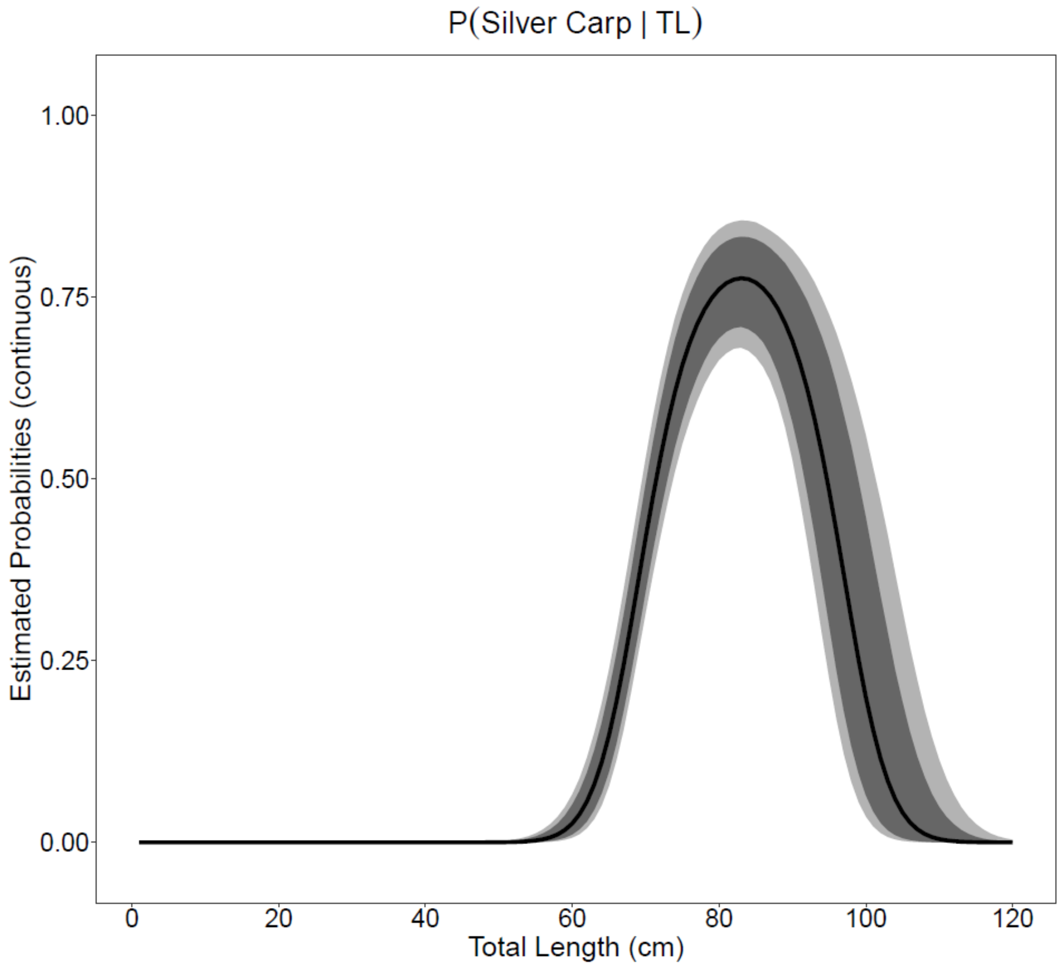


Figure 6. Estimated probability of a fish being a Silver Carp given its total length. The dark line is the median probability, and the gray-shaded areas represent the 90% (light) and 75% (dark) credible intervals, respectively.

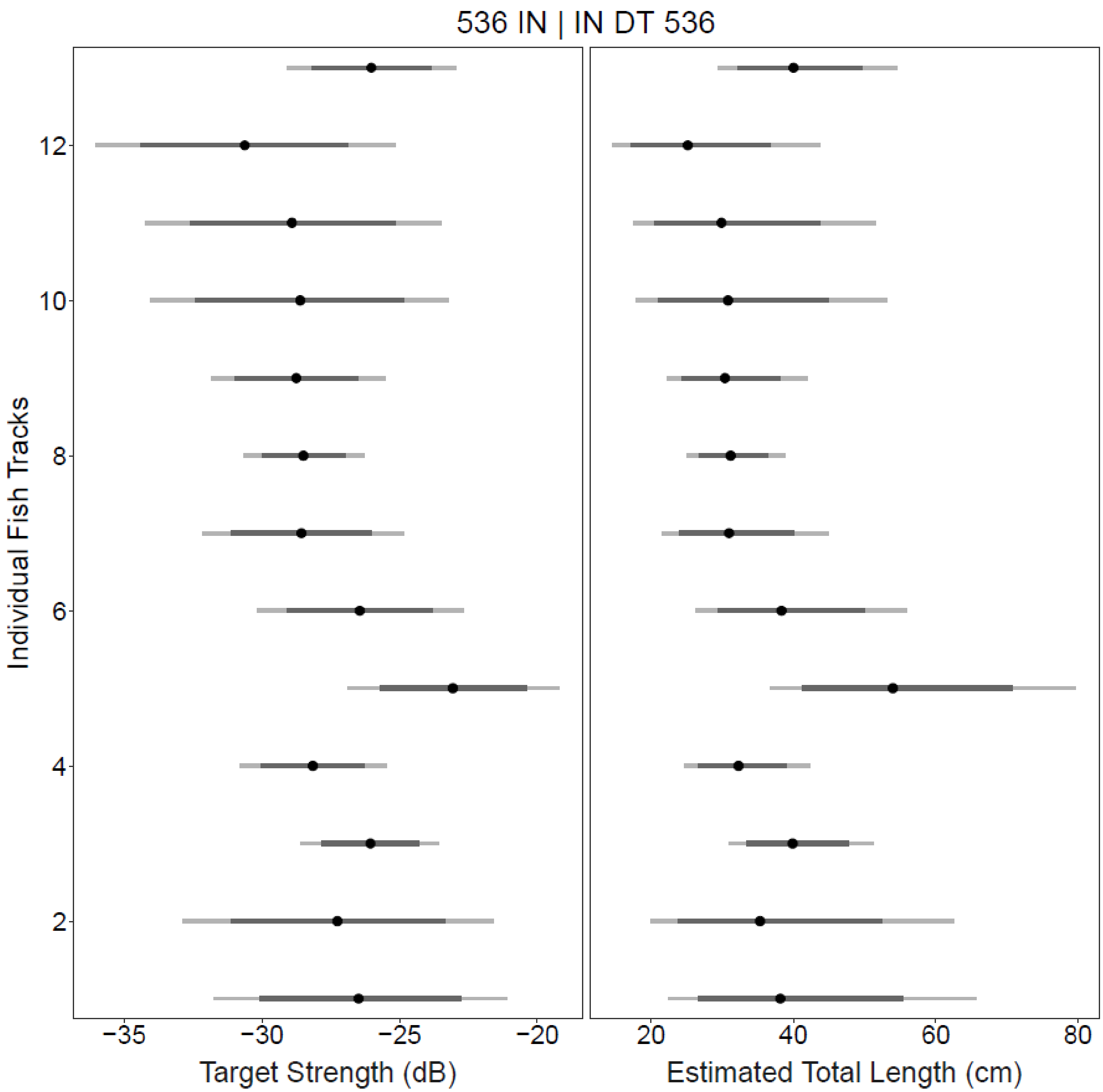


Figure 7. Estimated median TS (dB; left) and TL (cm; right) for all fish tracks at RM 536 for the downstream, thalweg-facing transect. Black dots represent the estimated median TS and TL. Dark and light gray lines represent 75% and 90% credible intervals, respectively.

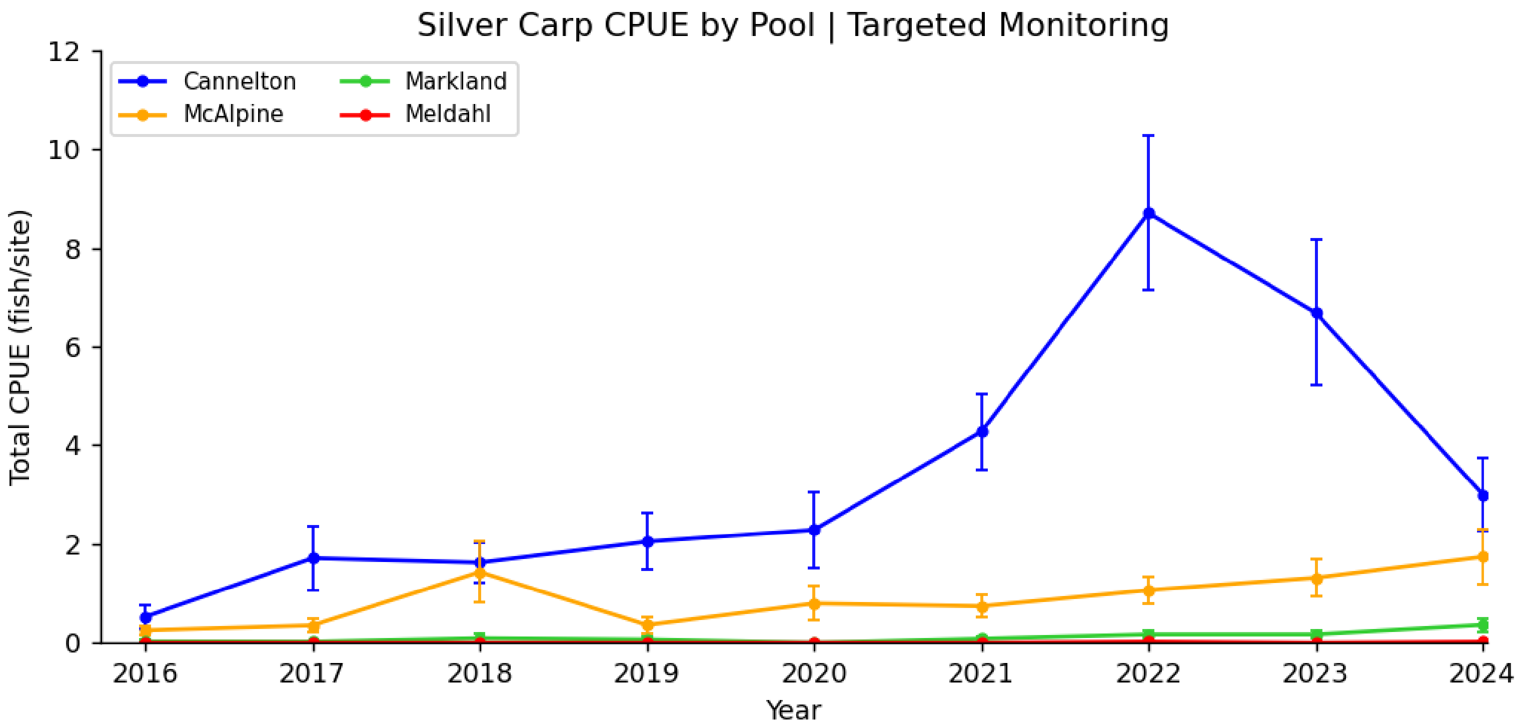


Figure 8. Spring Standardized Targeted Sampling in Cannelton -Meldahl pools showing Catch-Per-Unit-Effort (CPUE) during 2016-2024.

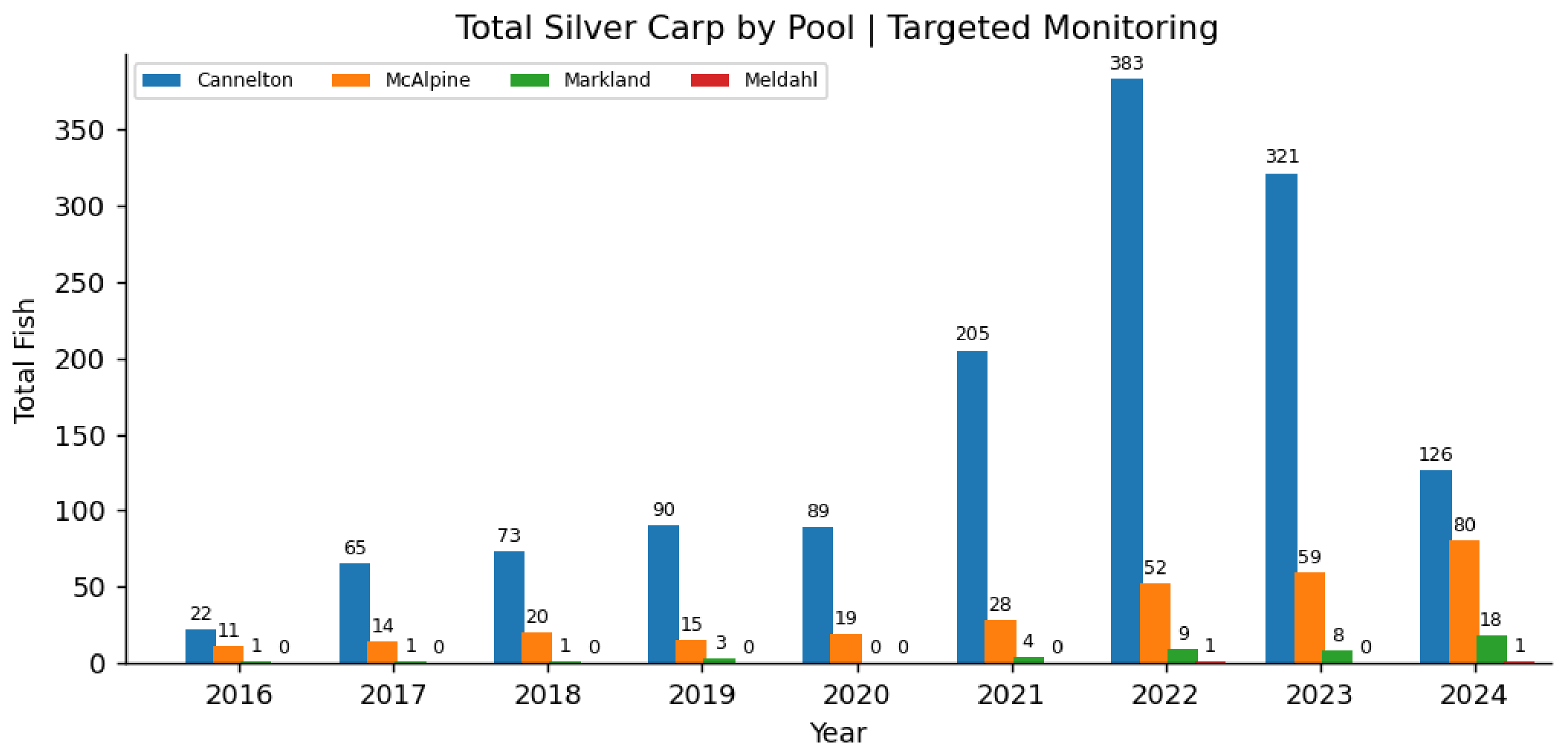


Figure 9. Spring Standardized Targeted Sampling in Cannelton -Meldahl pools showing total Silver Carp during 2016-2024.

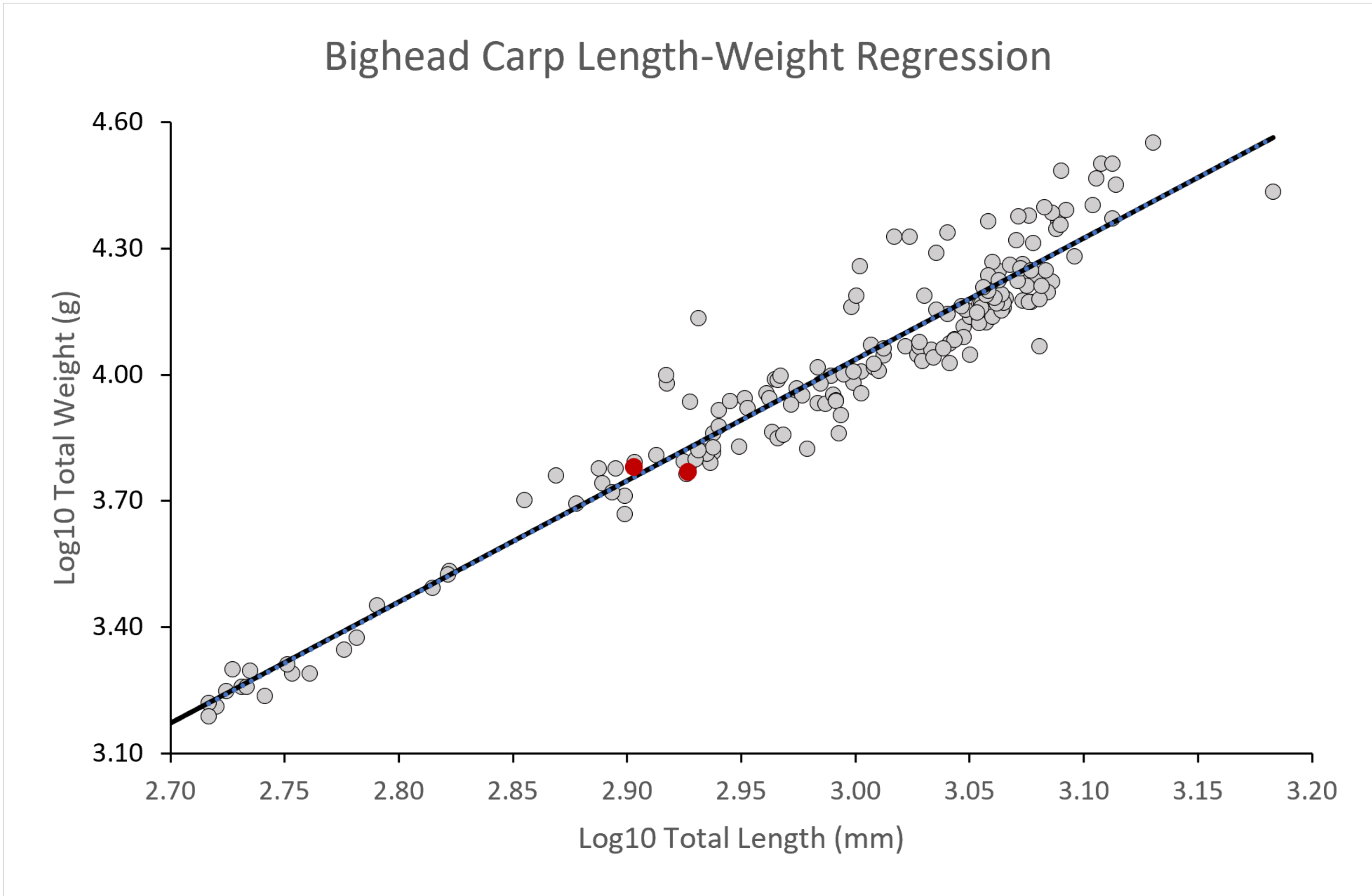


Figure 10. Bighead Carp Length-Weight regression in the Ohio River.

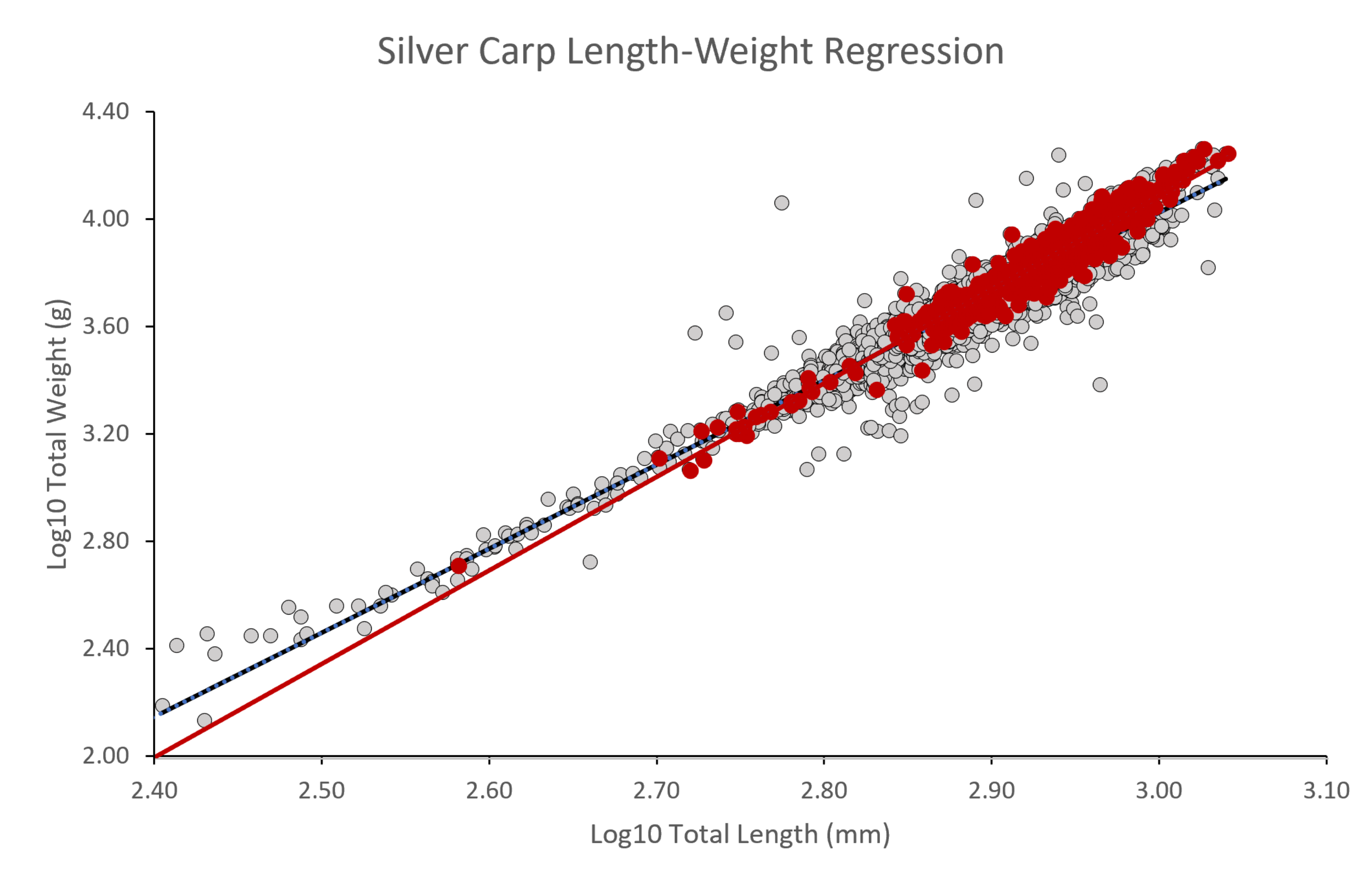


Figure 11. Silver Carp Length-Weight regression in the Ohio River.

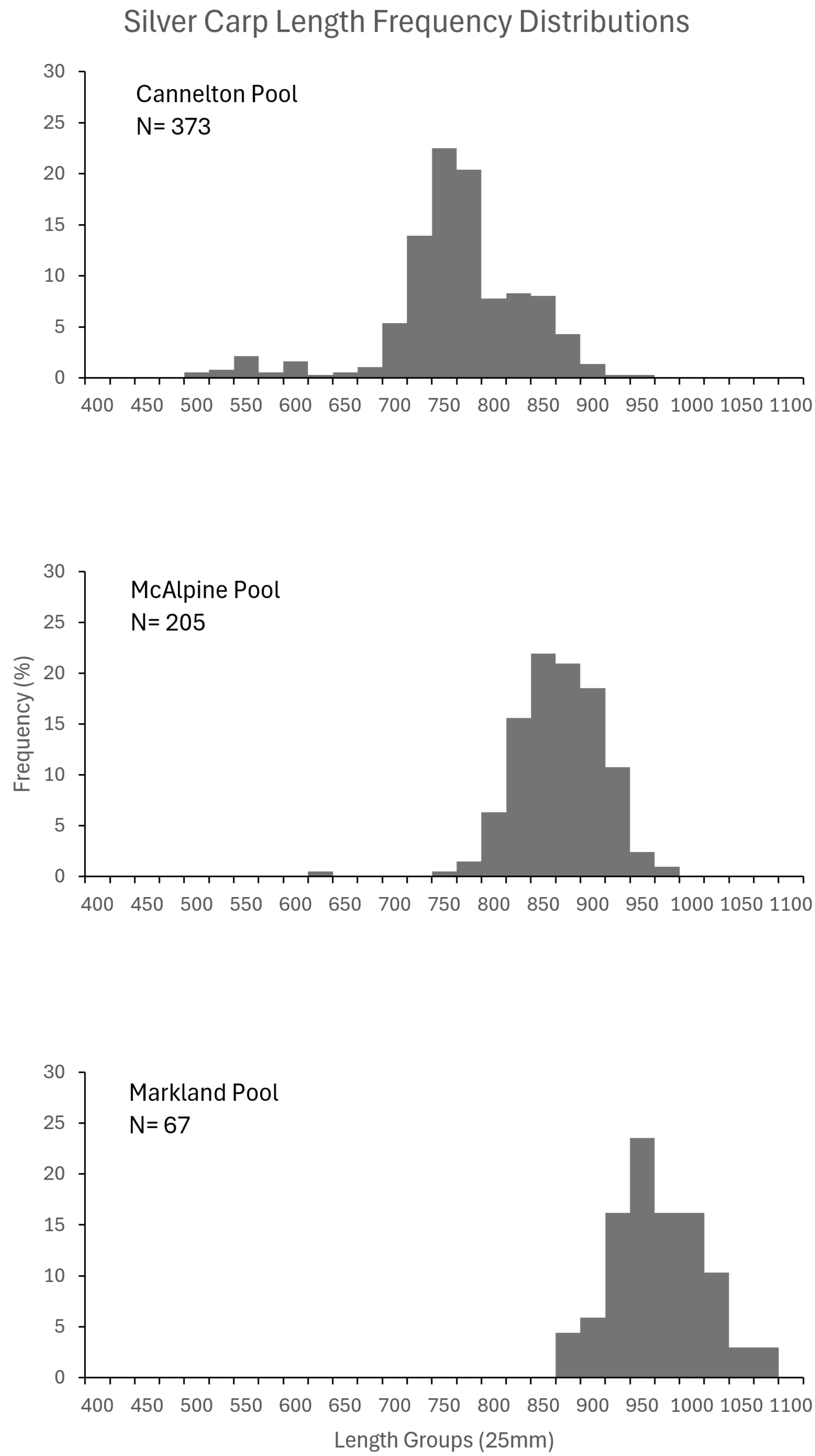
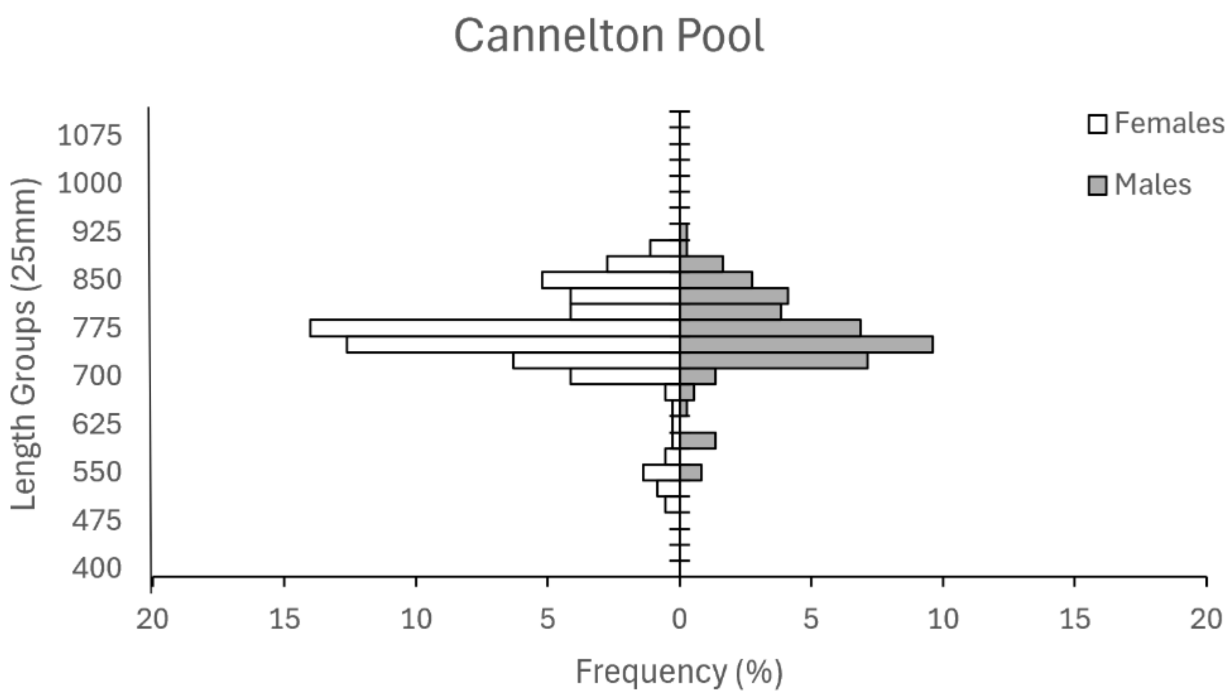


Figure 12. Silver Carp Length Frequencies from Cannelton, McAlpine, and Markland pools.



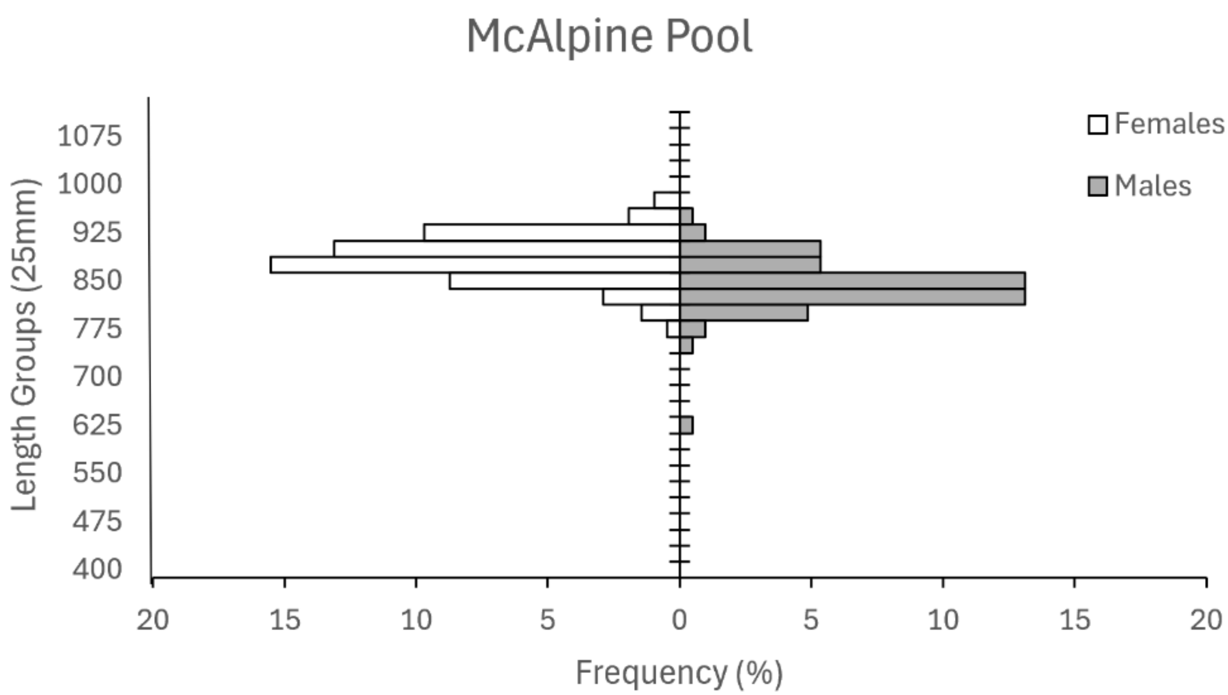


Figure 13. Silver Carp Length Frequencies by Male and Female in the Cannelton and McAlpine pools.

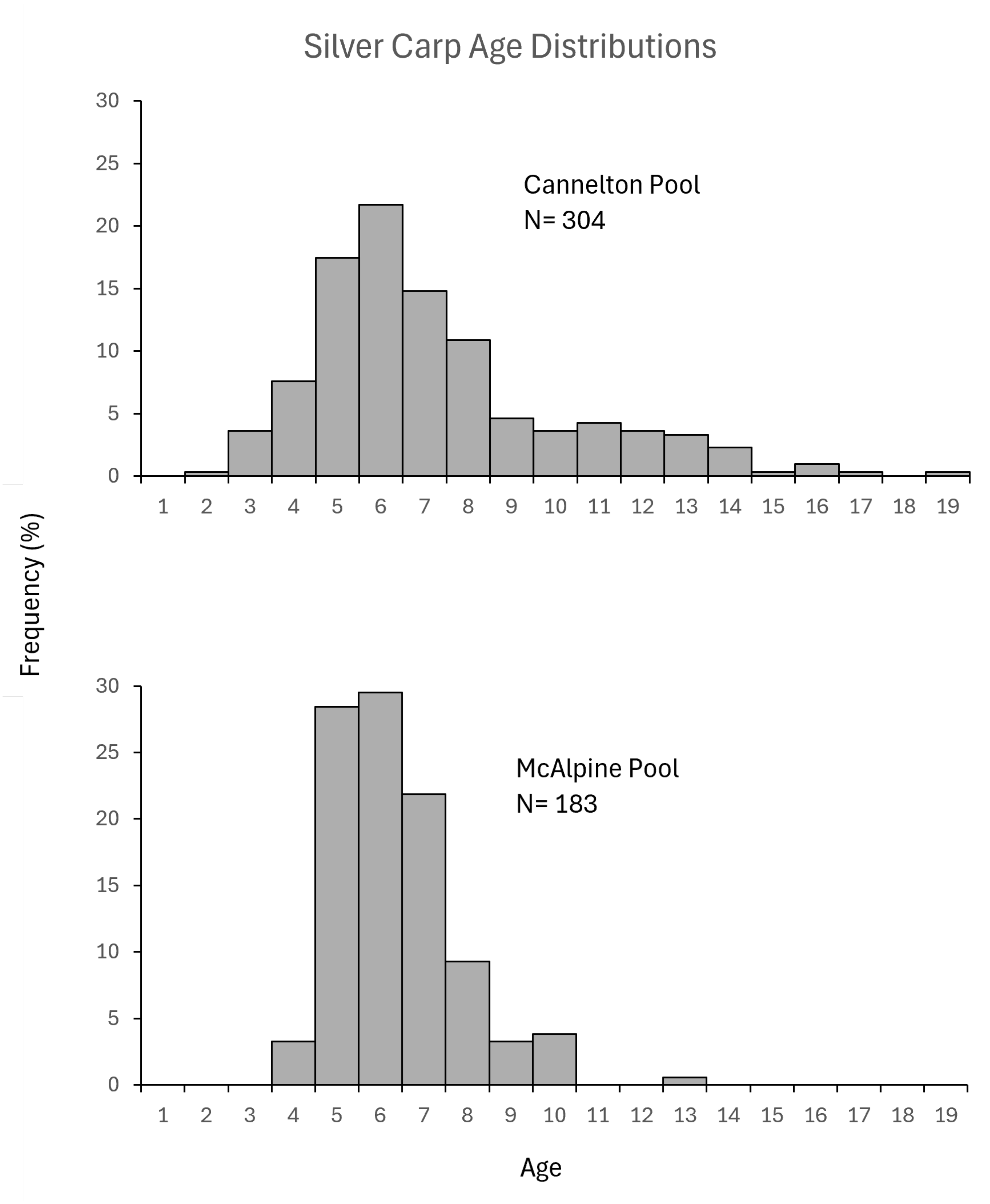


Figure 14. Silver Carp Age Distribution in Cannelton and McAlpine pools.

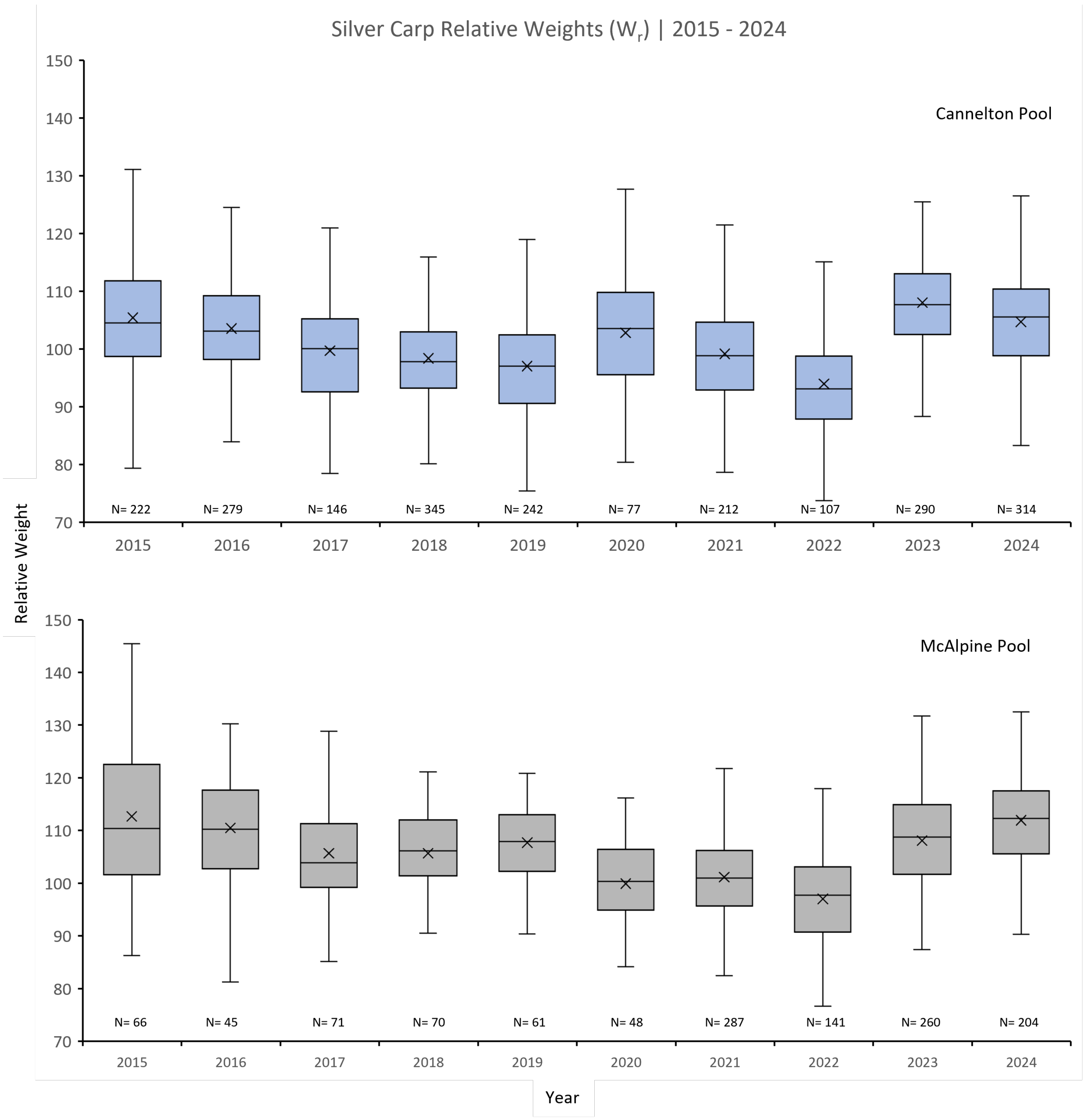


Figure 15. Silver Carp Relative Weights collected between 2015 - 2024.

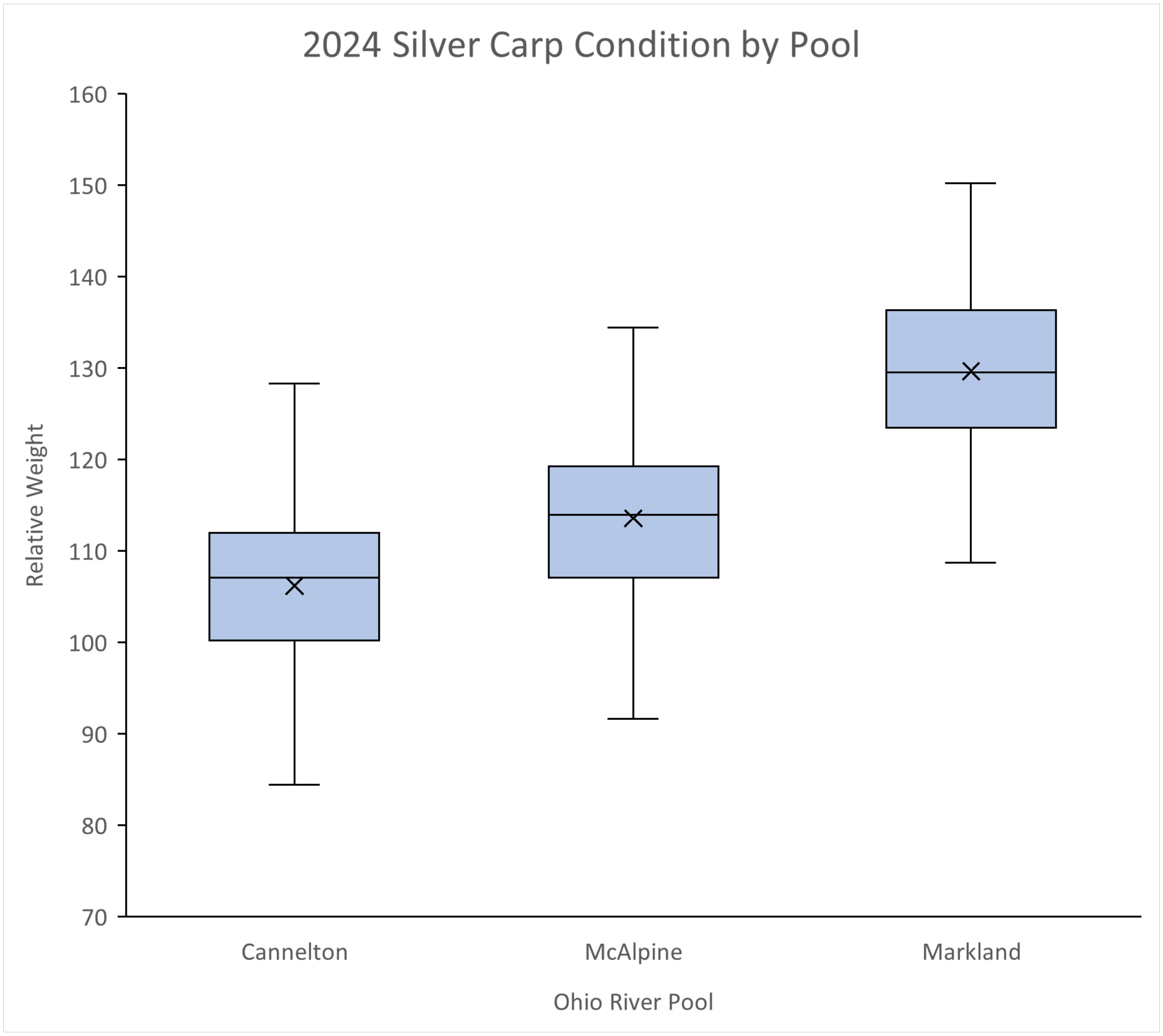


Figure 16. Silver Carp Relative Weights compared among Cannelton, McAlpine, and Markland pools.

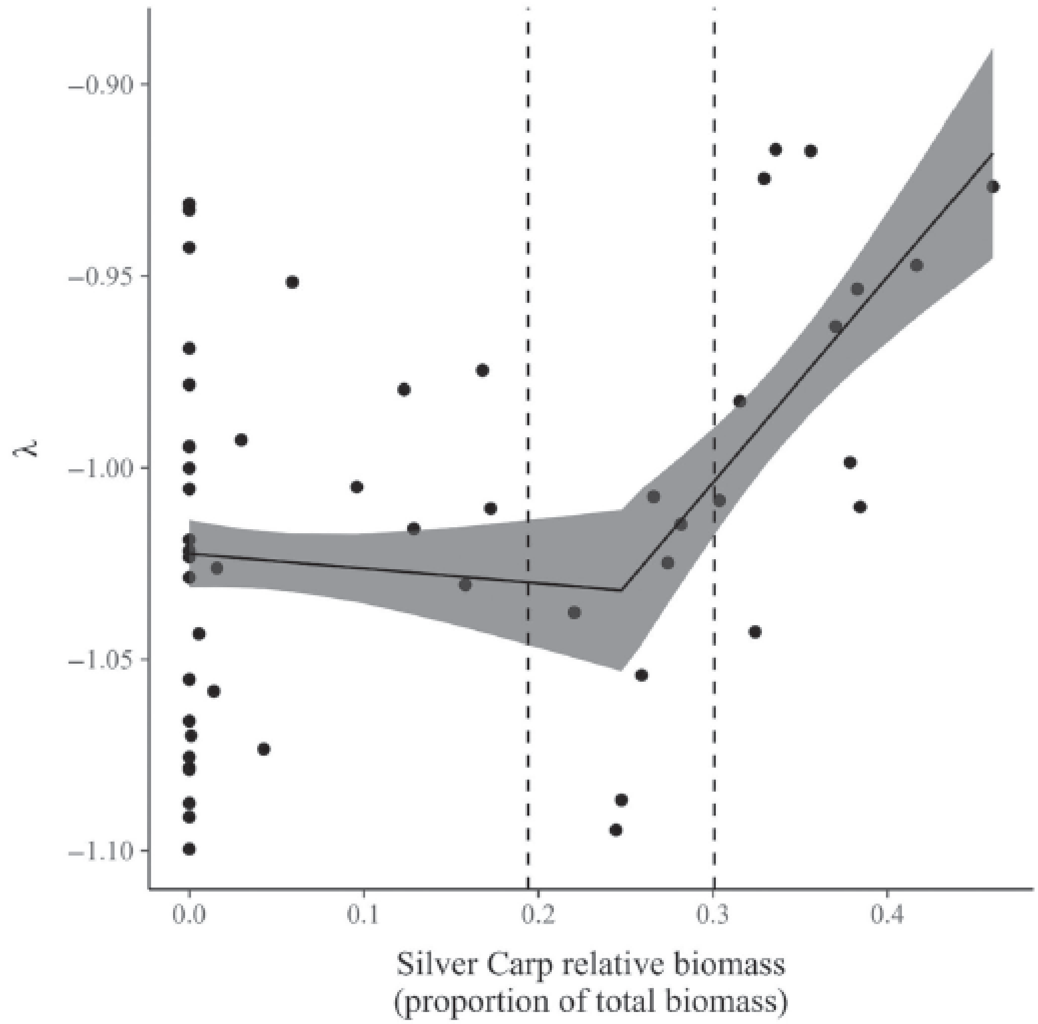


Figure 17. Broken stick regression from Novak et al. (2024, PDF as appendix). Lambda on the y-axis represents the CSS slope. A threshold exists between 0.2 and 0.3, at precisely 0.24 (24%) invasive carp biomass of standard community boat e-fishing. Below this threshold there are minimal food web impacts, but beyond this threshold we see rapidly increasing effects on food web efficiency (represented by lambda).

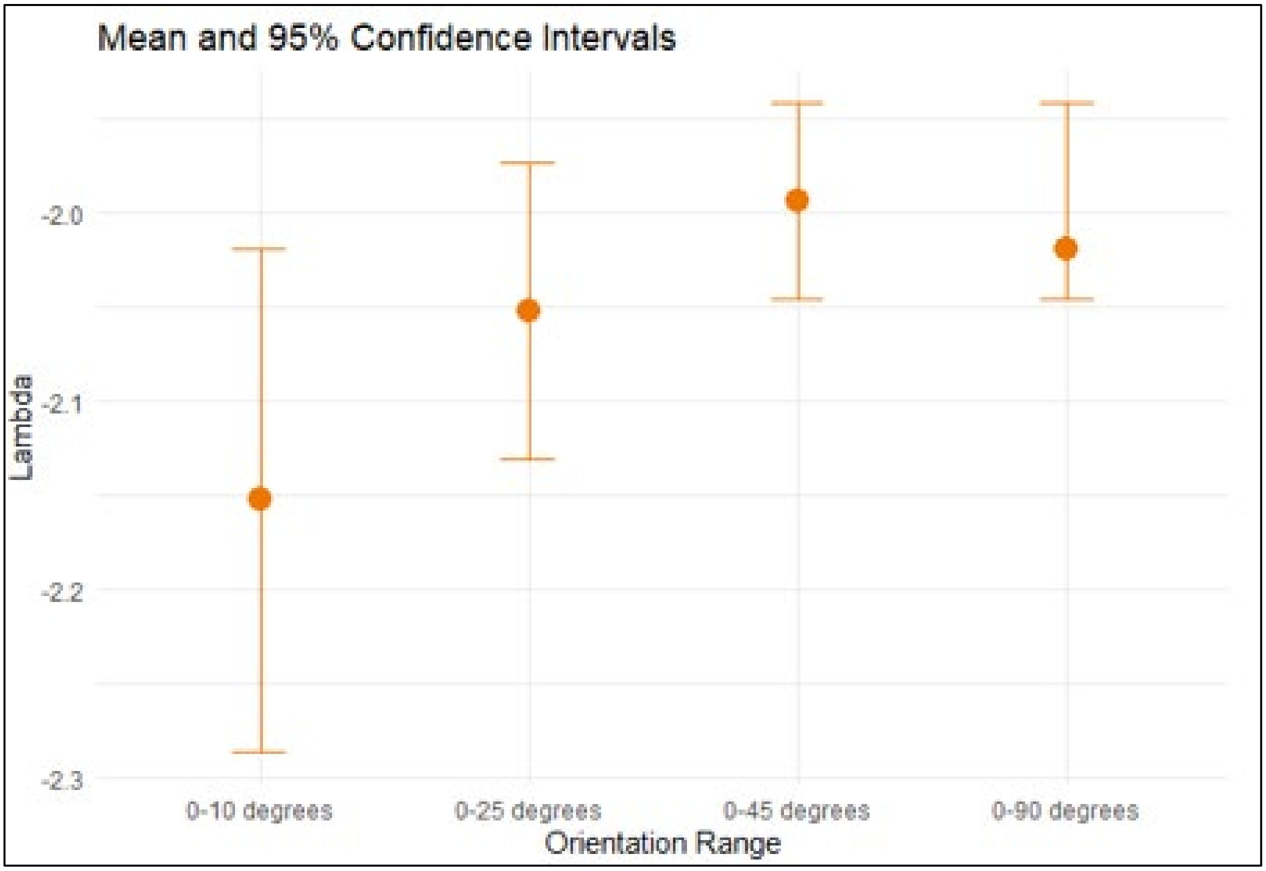


Figure 18. Effect of fish orientation on the CSS slope (lambda) estimate.

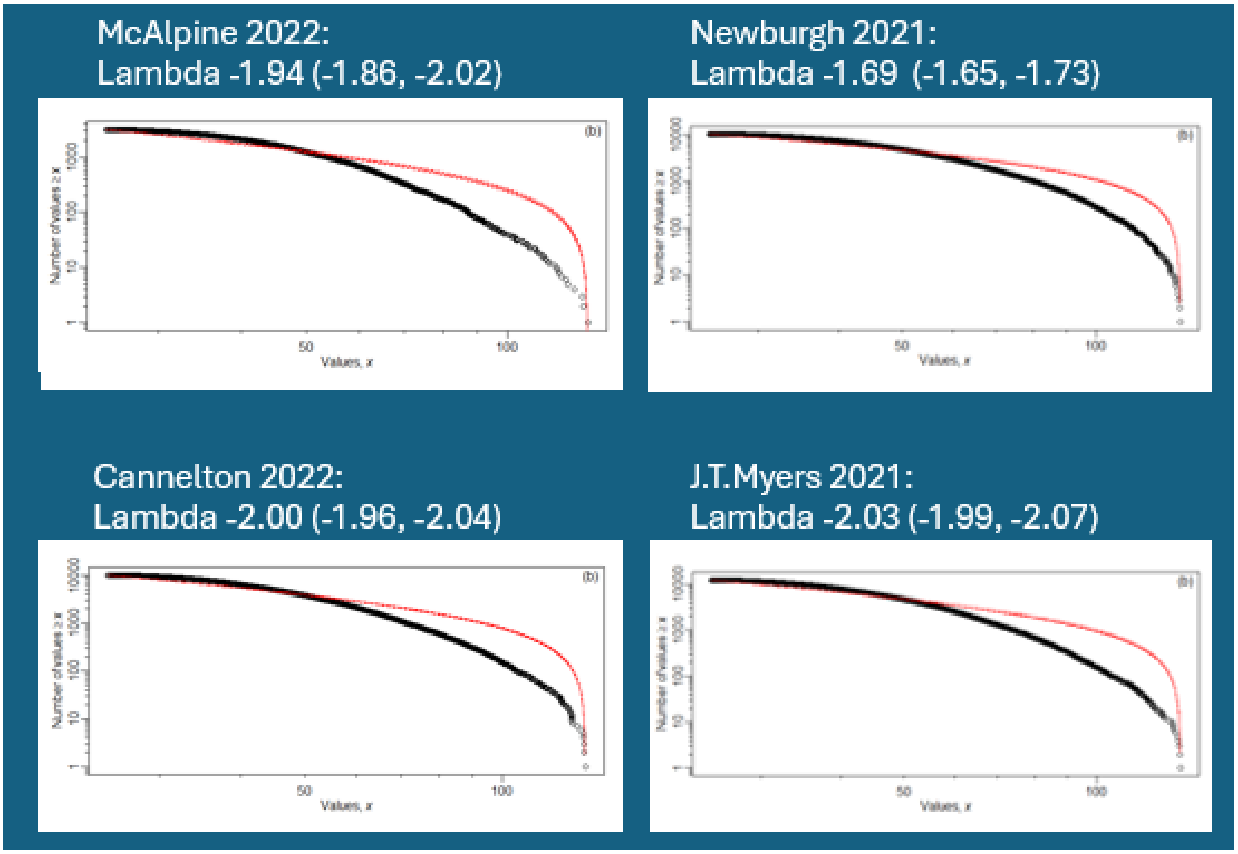


Figure 19. Preliminary comparison of CSS Slopes (lambda) across pools and years in the Ohio River.

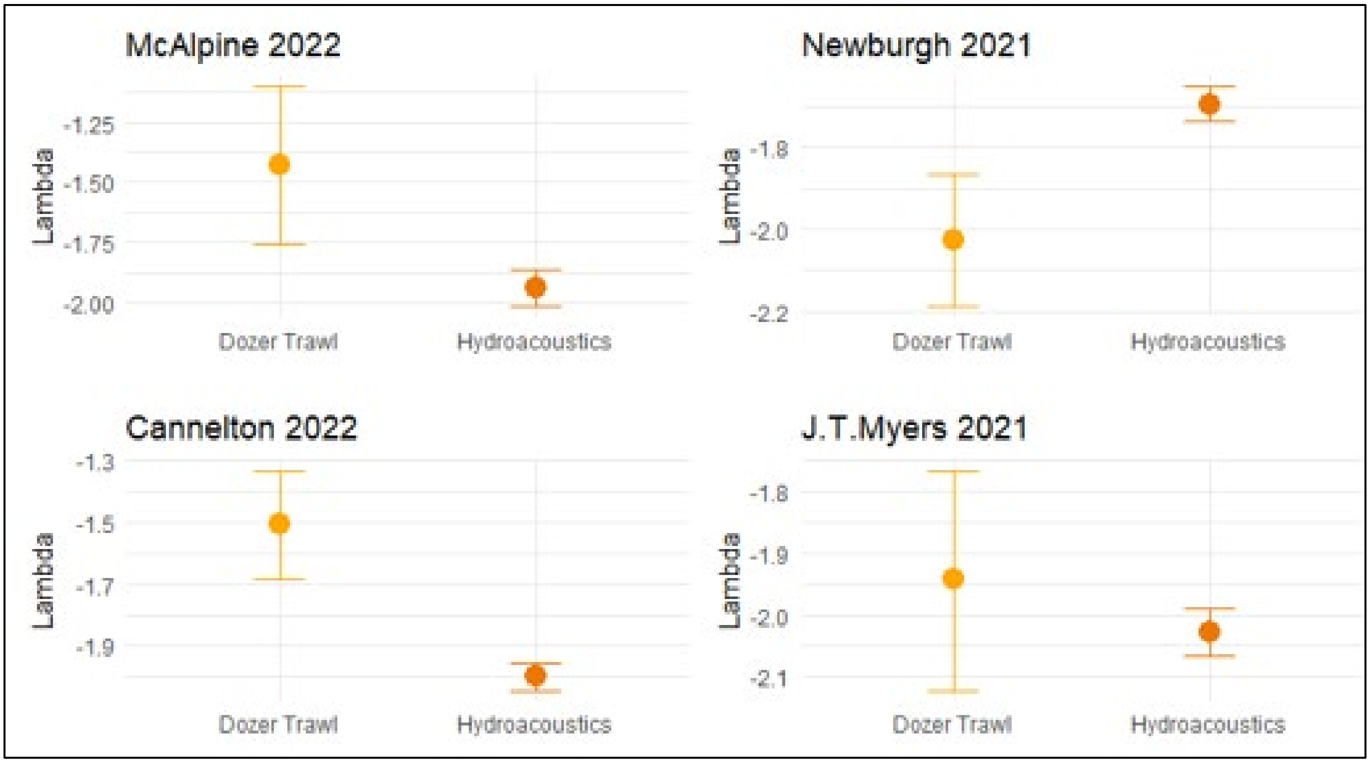


Figure 20. Comparison of CSS slope (lambda) and 95% confidence intervals between size-looking hydroacoustic CSS and electrified dozer trawl CSS.

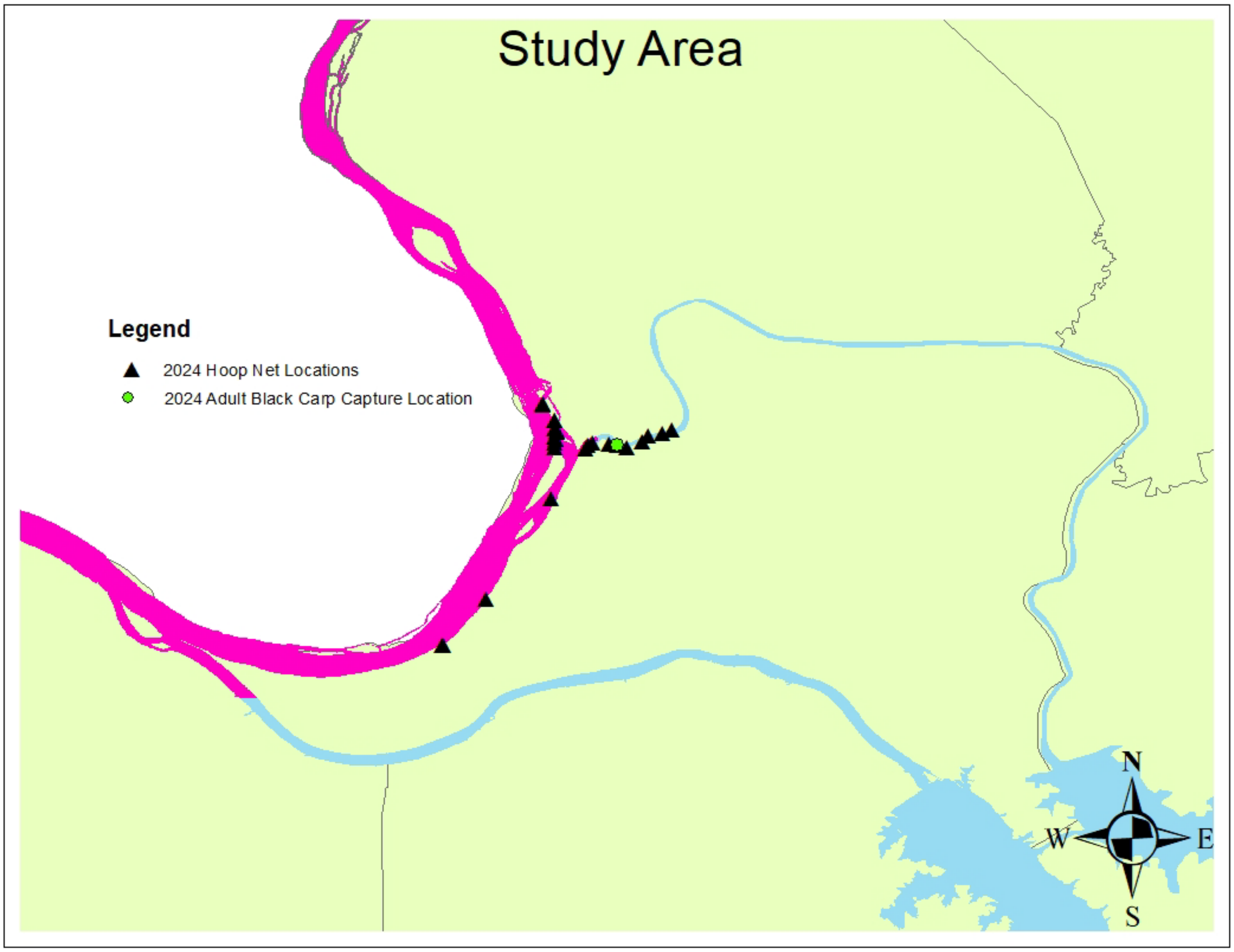


Figure 21. Between 18-19. 2024 Sample Locations of Hoop Netting along the lower Ohio and Cumberland Rivers with the capture location.

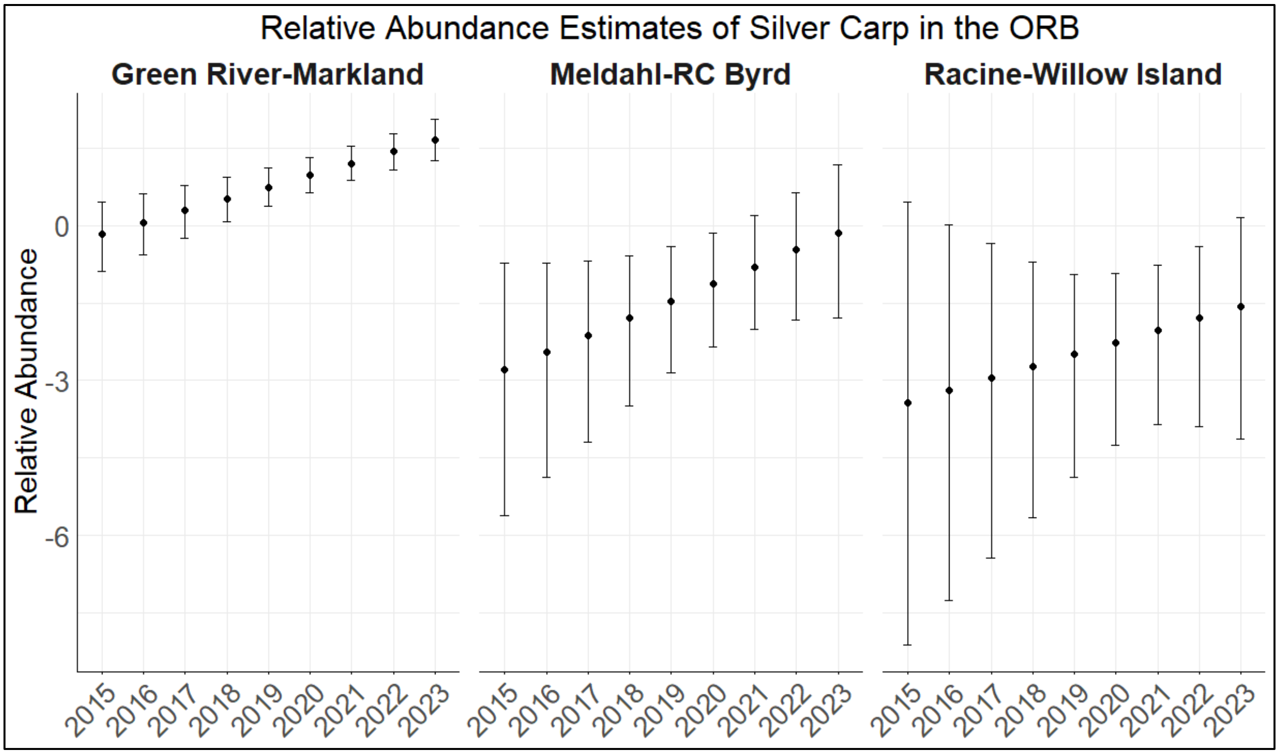


Figure 22. Relative abundance estimates of Silver Carp in grouped pools of the Ohio River Basin used in Occupancy Analysis.

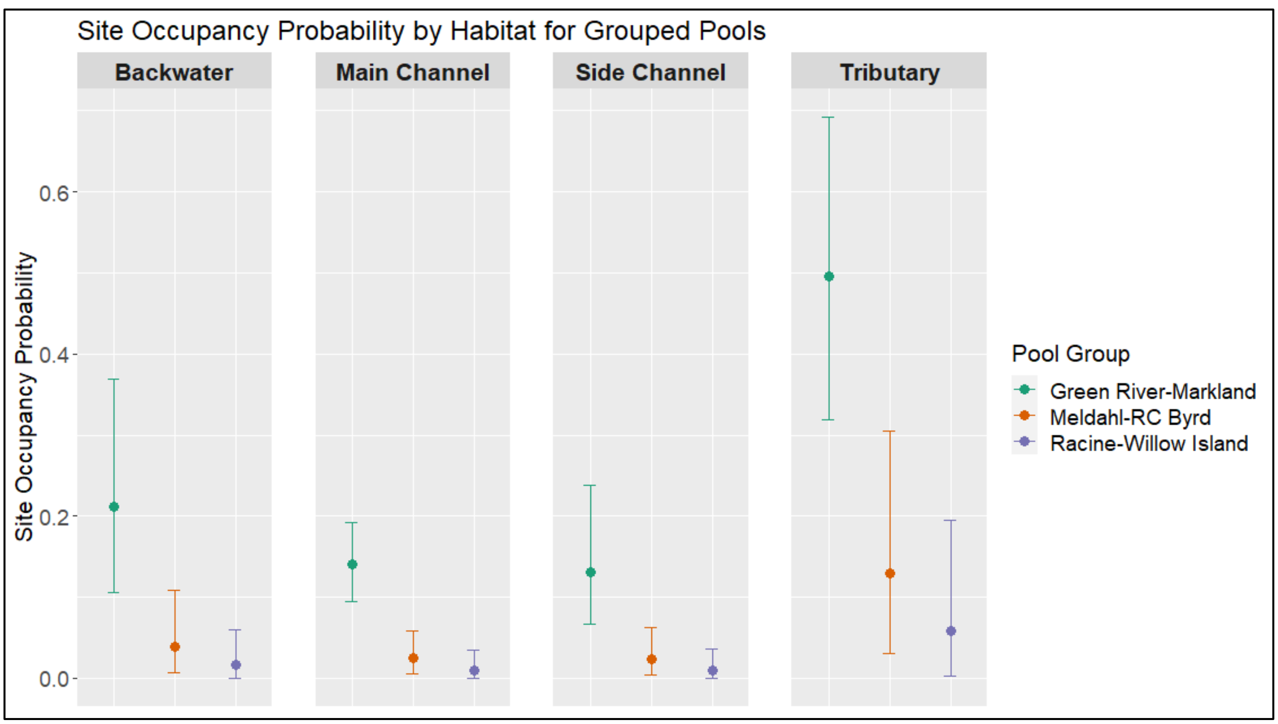


Figure 23. Site occupancy probability of Silver Carp in grouped pools of the Ohio River Basin by habitat type for Occupancy Analysis.

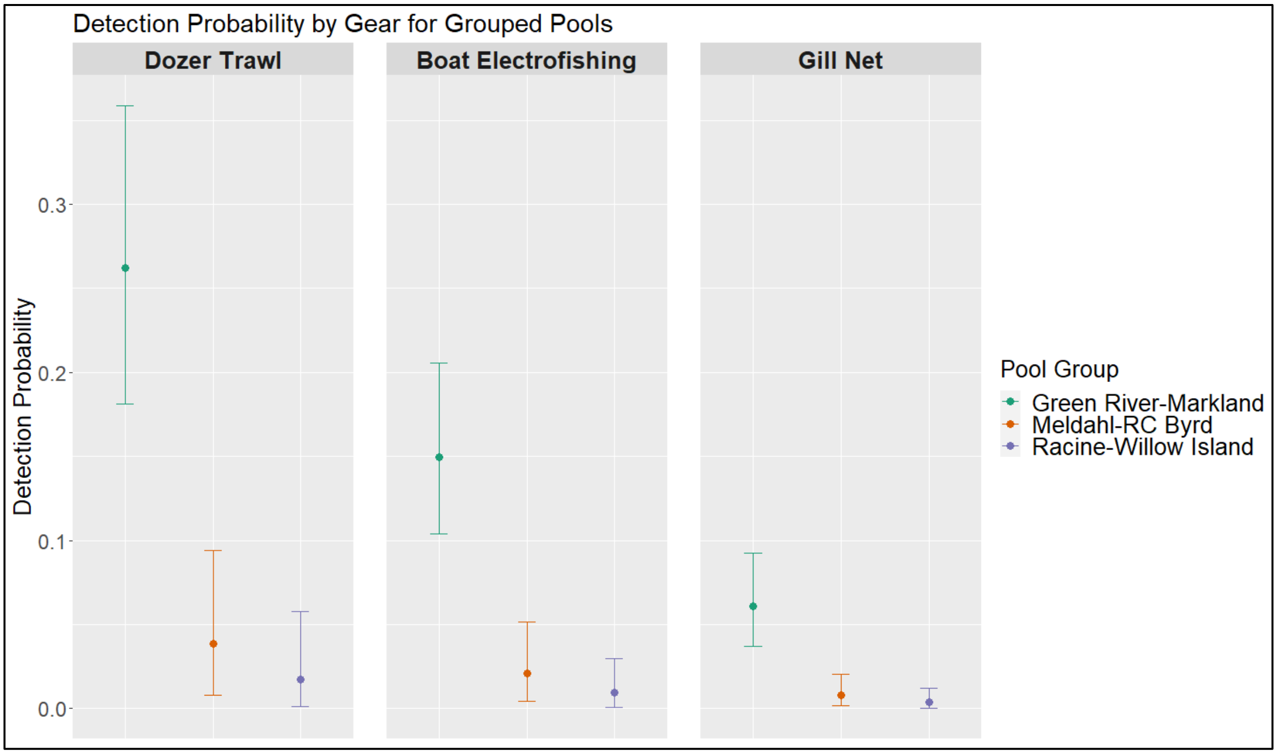


Figure 24. Detection probability of Silver Carp in grouped pools of the Ohio River Basin by gear type for Occupancy Analysis.

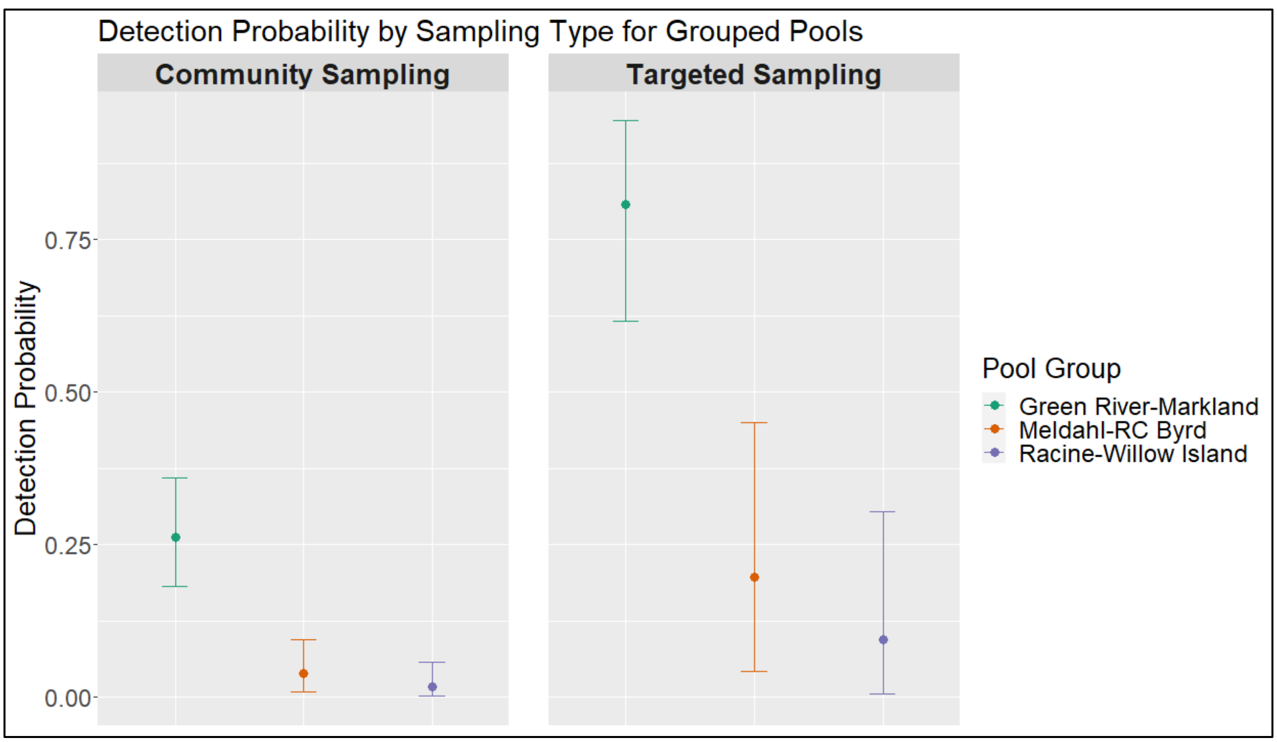


Figure 25. Detection probability of Silver Carp in grouped pools of the Ohio River Basin by sampling type for Occupancy Analysis.

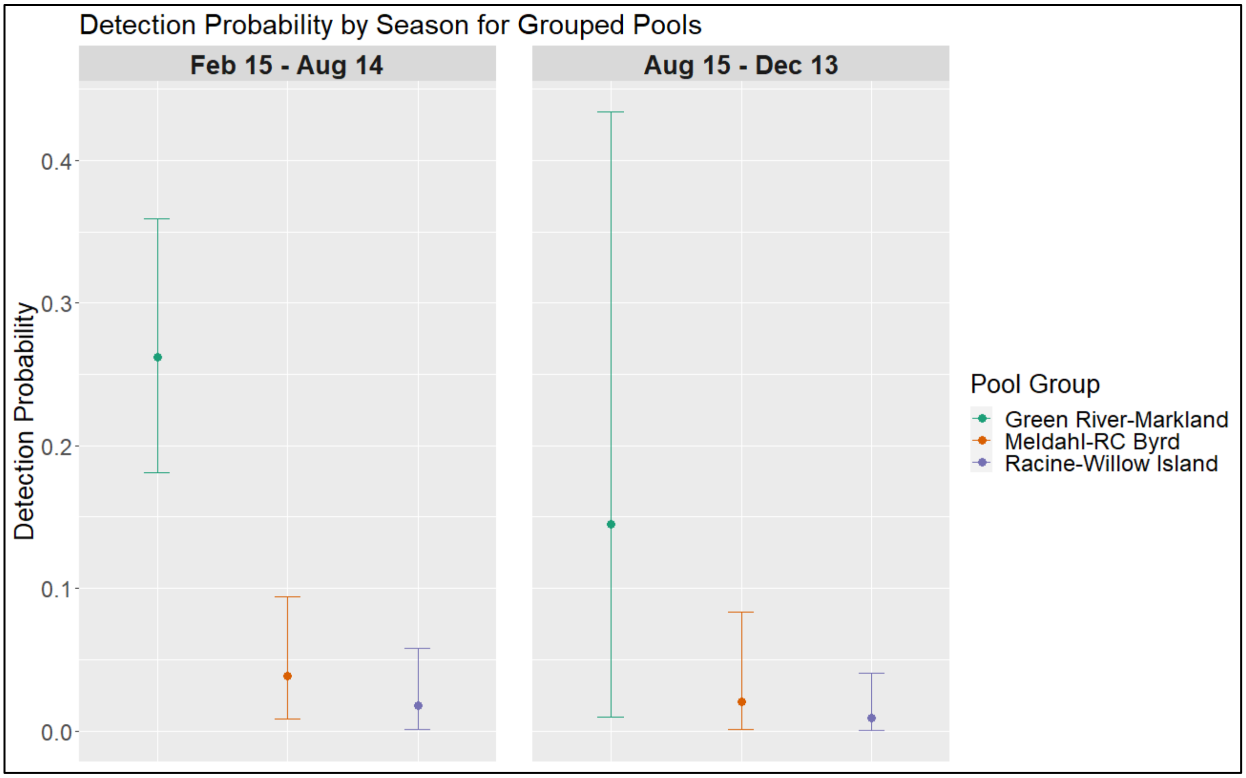


Figure 26. Detection probability of Silver Carp in grouped pools of the Ohio River Basin by season for Occupancy Analysis.

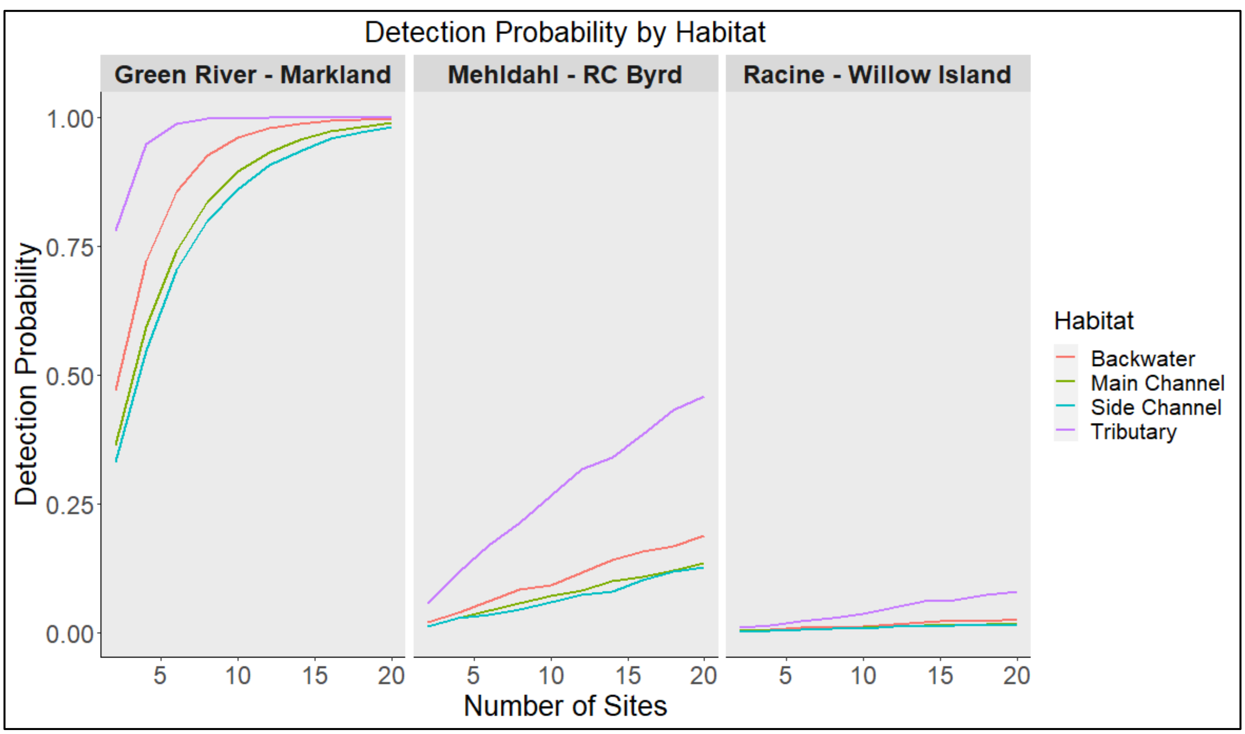


Figure 27. Relative power (Power Analysis) to detect Silver Carp in grouped pools in the Ohio River Basin by habitat type.

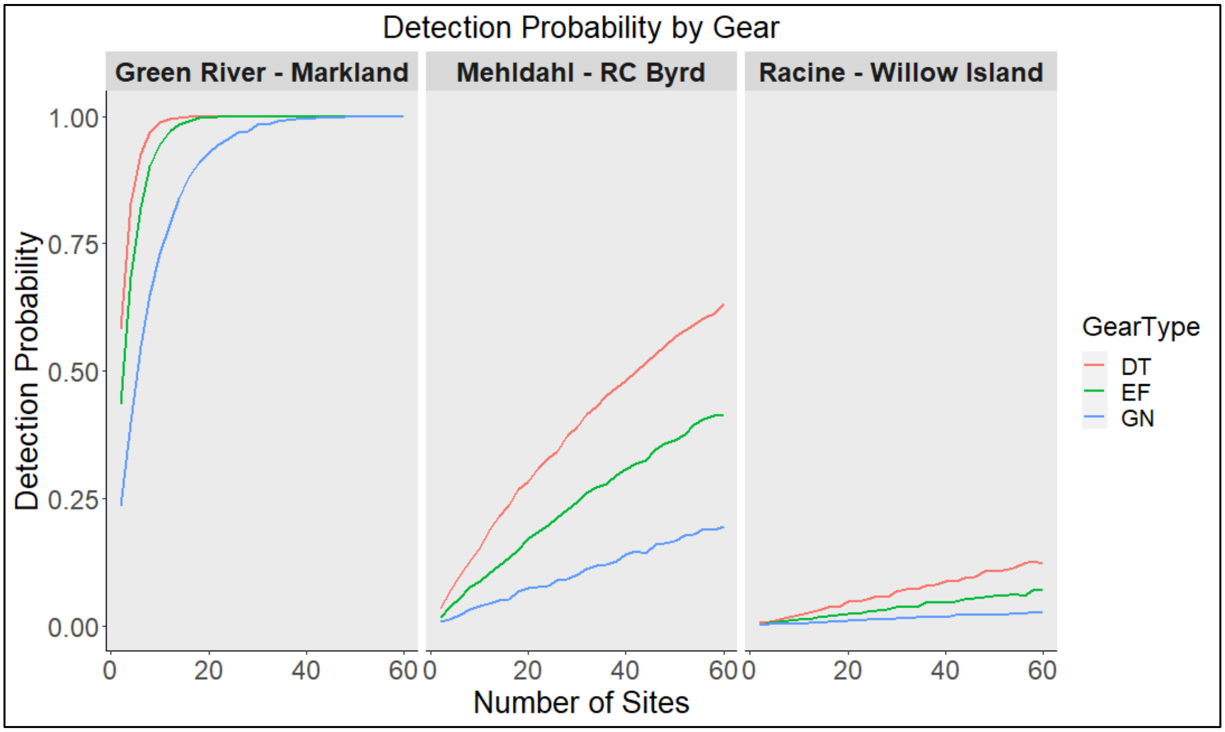


Figure28**.** Relative power (Power Analysis) to detect Silver Carp in grouped pools of the Ohio River Basin by gear type.

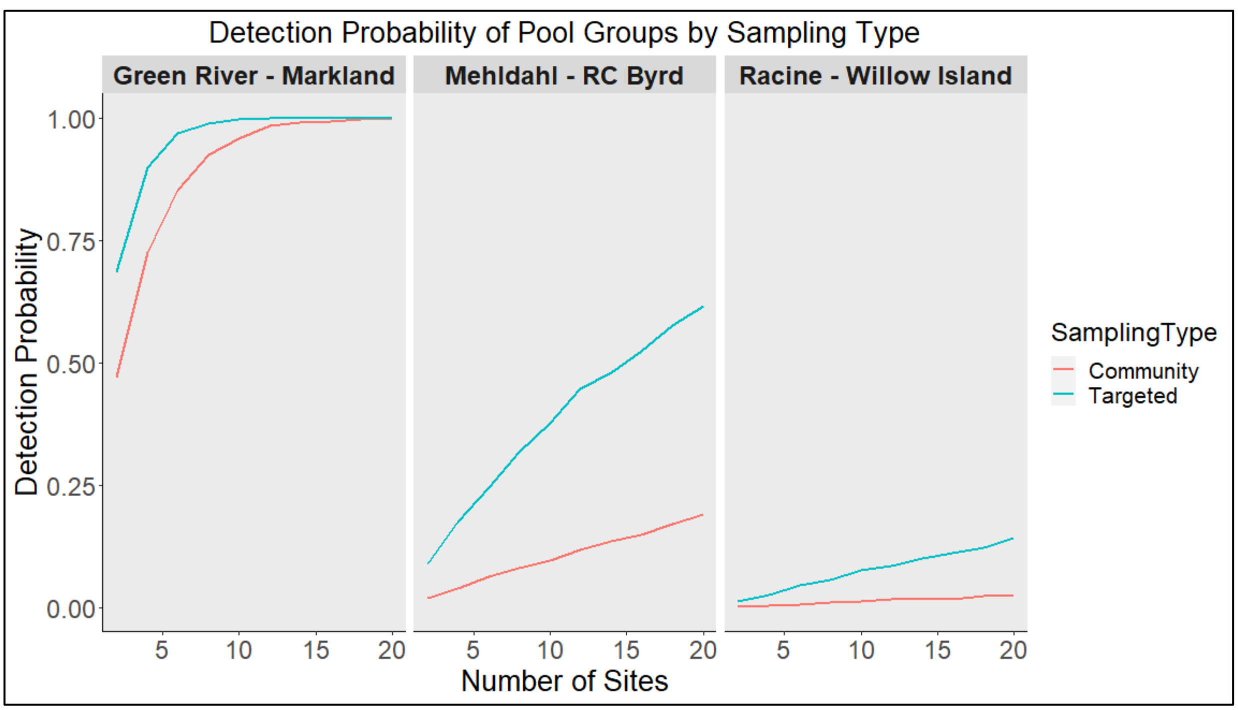


Figure 29. Relative power (Power Analysis) to detect Silver Carp in grouped pools of the Ohio River Basin by sampling type .

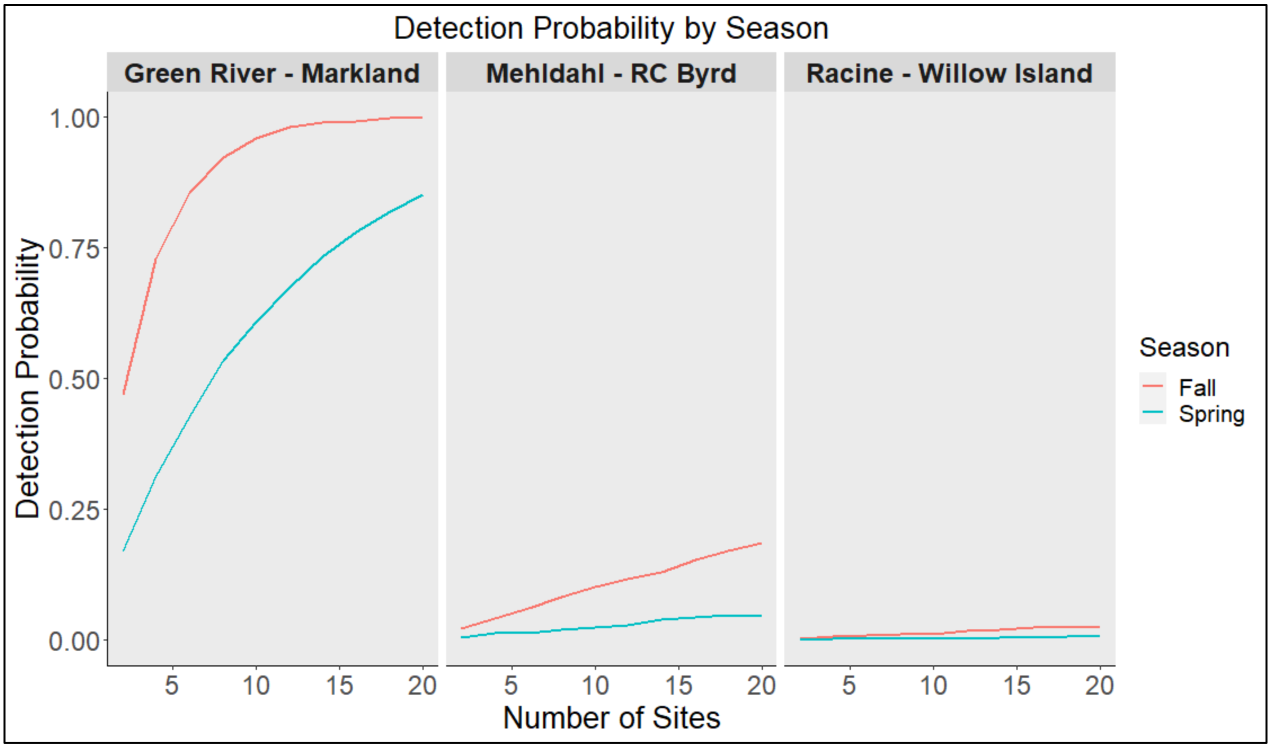


Figure 30. Relative power (Power Analysis) to detect Silver Carp in grouped pools of the Ohio River Basin by season.

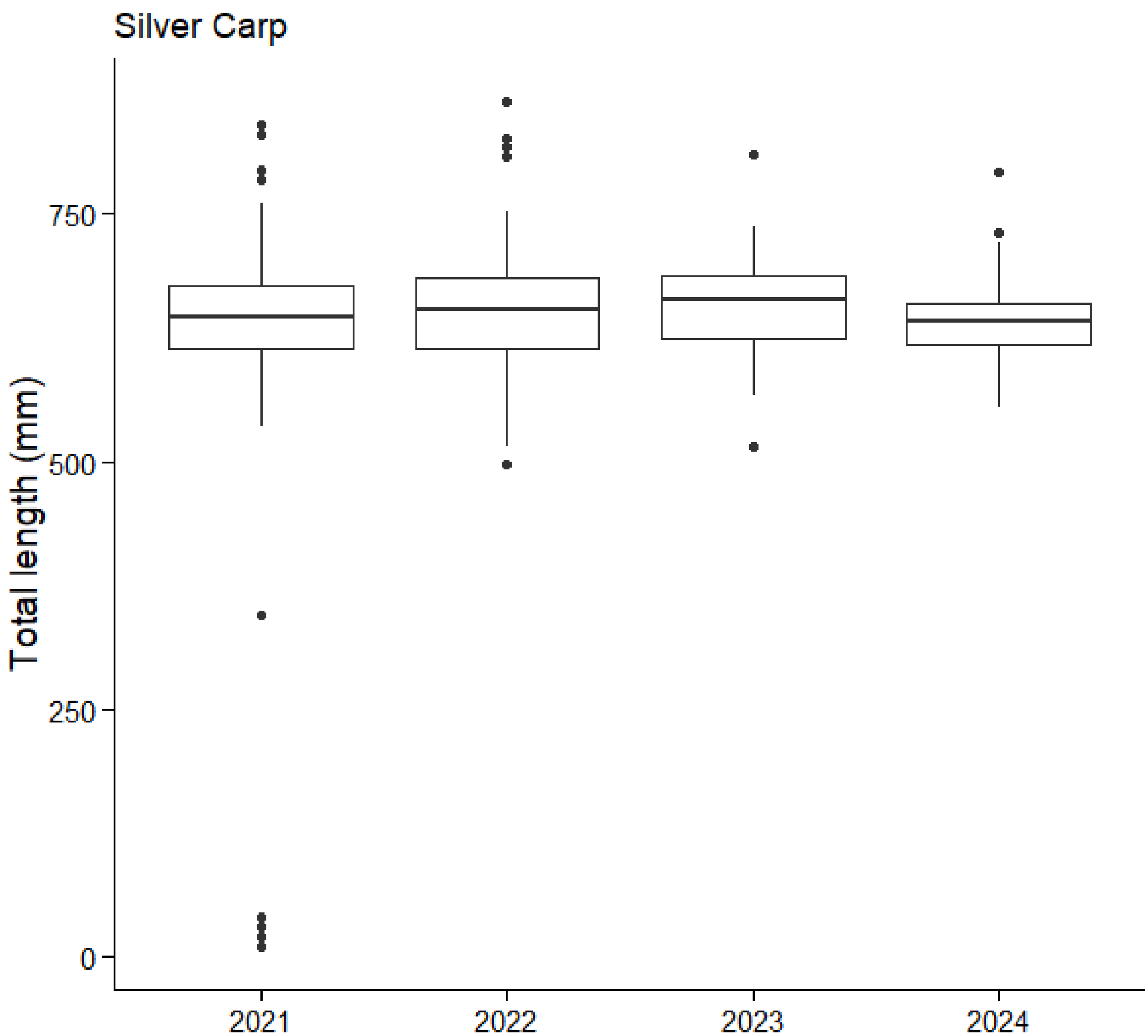


Figure 31. Boxplots of total lengths (mm) of silver carp sampled using electrofishing in the Wabash River during 2021 through 2024. Small fish, likely recruits were only sampled in 2021.

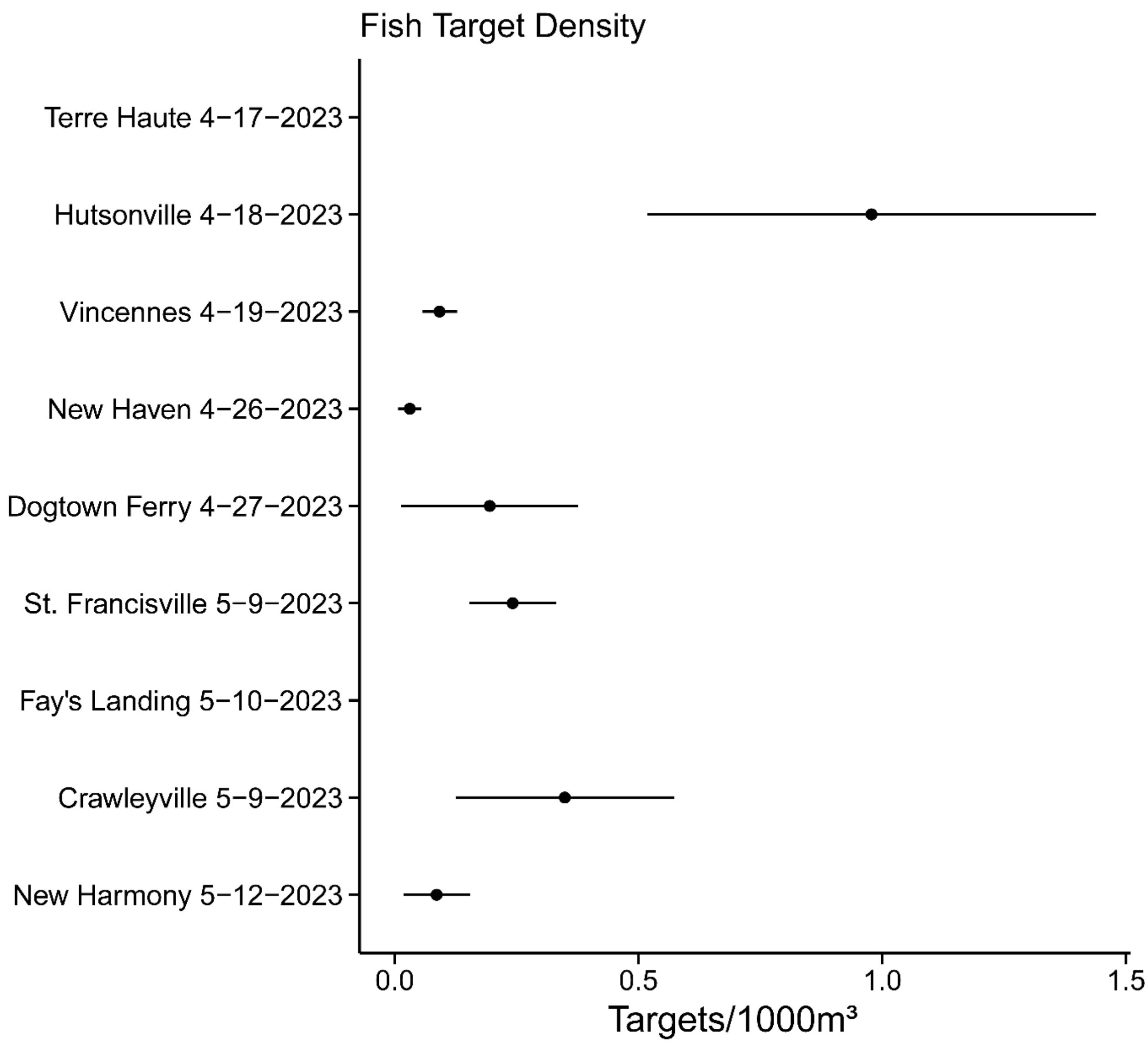


Figure 32. Estimated density of ensonified fish targets (targets per 1000m^3 of ensonified water) at each of SIU’s spring 2023 Wabash River hydroacoustic sites. Whiskers represent a 95% confidence interval around this estimate. GPS failure prevented accurate estimation of fish targets at the Terre Haute and Fay’s Landing sites.

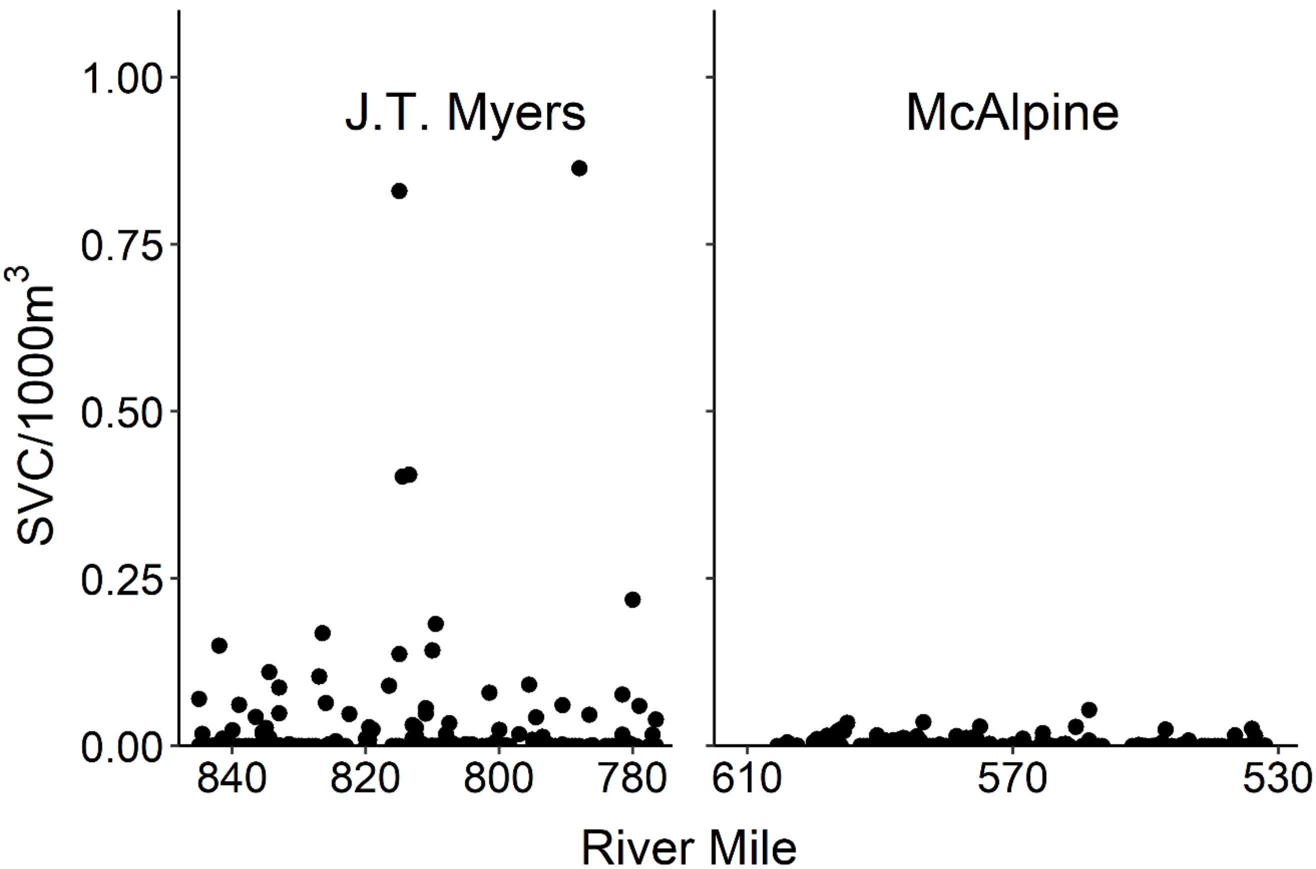


Figure 33 Hydroacoustically derived Silver Carp (SVC) density estimates by river mile for main channel sites in J.T. Myers and McAlpine pools during September and October 2024. River miles decrease from downstream to upstream within the Ohio River (left to right on x-axis).

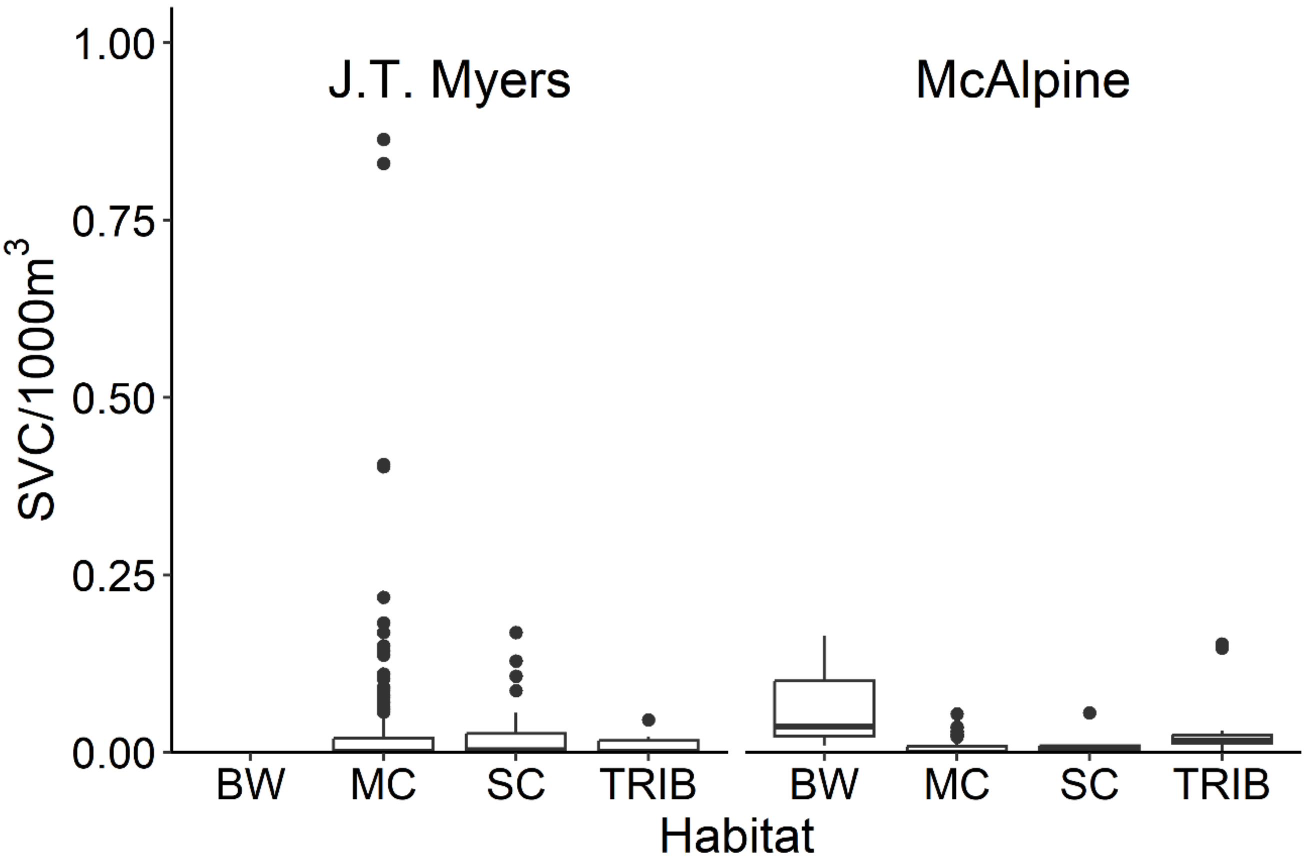


Figure 34. Box plots depicting the variability of hydroacoustically derived Silver Carp density estimates for backwater (BW), main channel (MC), side channel (SC), and tributary (TRIB) habitats in two Ohio River pools during fall 2024.

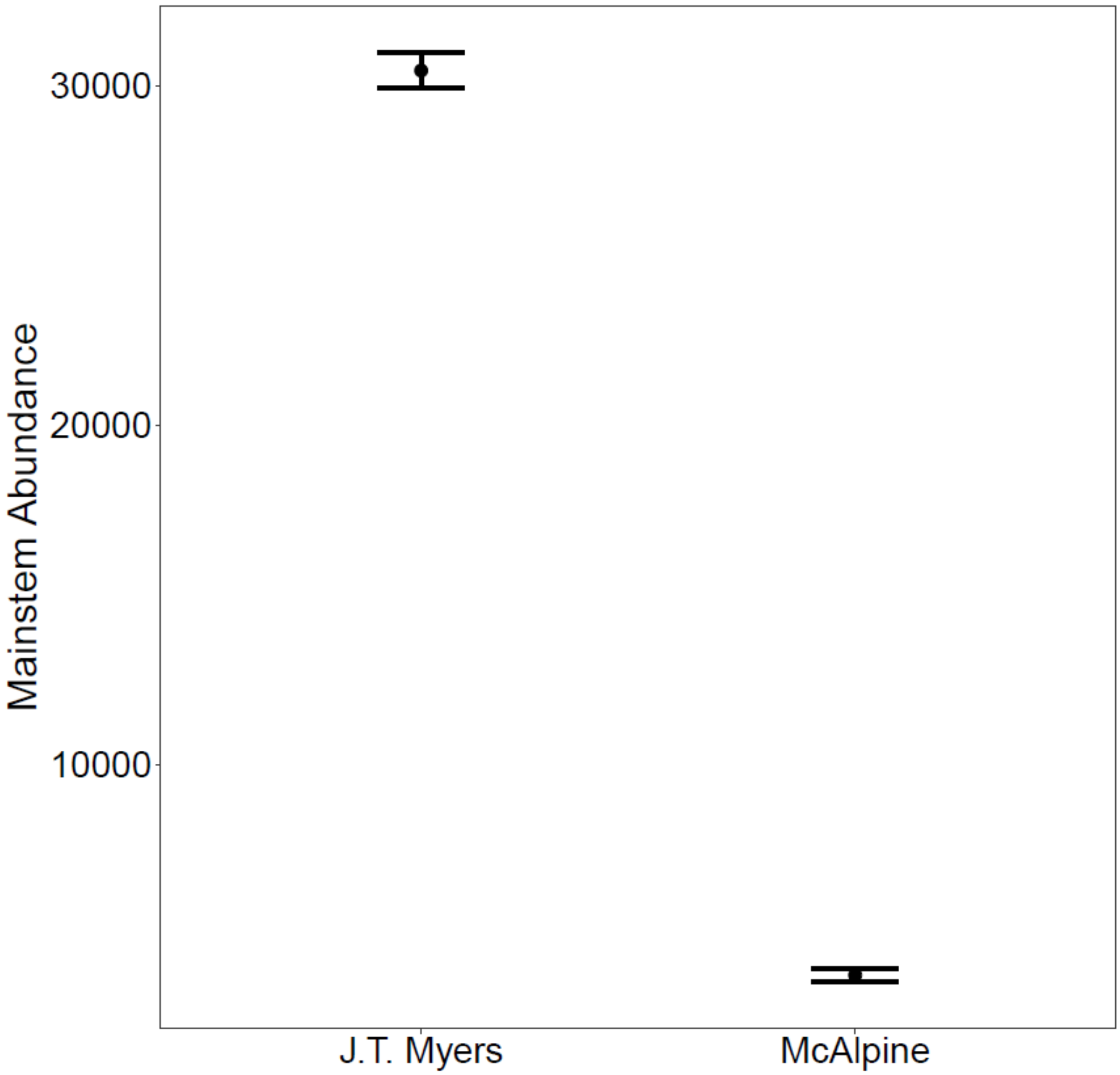


Figure. 35. Silver Carp mean abundance estimates with 95% confidence intervals for the main channel of two Ohio River pools during fall of 2024.

Project Title: Abundance and distribution of early life stages of invasive carp in the Ohio River: 2024 Technical Report

Lead Author, Agency, and Contact Information: Indiana Department of Natural Resources (INDNR), Craig Jansen (cjansen1@dnr.in.gov)

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

Location of Activities: Ohio River Basin

Statement of Need:

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

In order to limit the negative impacts of invasive carp populations and their further spread, efforts have increased to understand the distribution and abundance of invasive carp in the waters they currently inhabit. Previous sampling efforts on the Ohio River have documented adult invasive carp presence as far upstream as Robert C. Byrd Dam (R.C. Byrd) near Gallipolis Ferry, West Virginia. Densities of adult invasive carp are highest downstream of McAlpine Lock and Dam (Louisville, KY) and substantially decline farther upstream. In 2021, YOY were captured in Cannelton Pool (RM 691.5) and in 2022, they were captured even further upstream at RM 508.6 in Markland Pool. However, since 2016 the majority of Ohio River YOY have been consistently captured in J.T. Myers Pool.

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

To support both the national control plan (Conover et al. 2007) and the Ohio River Fish Management Team (ORFMT) Basin Framework objectives (ORFMT 2014), this project was initiated in 2016 to improve our ability to detect both 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). 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.

2024 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 basin in which spawning occurs.
3) Determine the extent, biological characteristics, and environmental requirements of invasive carp reproductions and recruitment locations in the Ohio River basin.
4) Evaluate the feasibility of drain structure modifications to limit invasive carp recruitment from Hovey Lake.
5) Determine genetic structure and relatedness of invasive carps in the Wabash and Ohio River basins to identify sources of propagule pressure and inform contract harvest at large scales.

Project Highlights:

- Ohio River invasive carp reproduction appeared to be limited for a second year in a row in 2024, as evident by low egg, larvae, and YOY captures throughout the field season.
- A total of 124 ichthyoplankton tows were conducted in the mainstem Ohio River from J.T. Myers Pool to R.C. Byrd Pool. Three morphometrically identified *Hypophthalmichthys* eggs and 60 larvae were collected, with the furthest upstream being documented at RM 608.5 near New Albany, IN.
- Suspicious eggs (n = 3) and larvae (n = 25) were collected from Markland, Meldahl, and Greenup Pools, which are pending genetic confirmation of species.
- An additional 59 ichthyoplankton tows were conducted at tributaries or power plants along the Ohio River. 1,295 *Hypophthalmichthys* larvae were captured, all but three came from Bayou Drain of Hovey Lake. One suspect *Hypophthalmichthys* eggs was collected from the Green River.
- Targeted surface trawling effort included 275 surface trawl tows, in addition to electrofishing and dozer trawling. Despite extensive efforts, YOY invasive carp were only collected in J.T. Myers Pool near Hovey Lake.
- Targeted YOY invasive carp sampling occurred at 3 sites along the lower Ohio River. Two sites out of 12 sampled along the lower Mississippi River had YOY Black Carp & YOY invasive carp were collected at all 3 sites along the lower Ohio River.
- Ichthyoplankton sampling in the Wabash River and its tributaries visually identified 32,734 invasive carp larvae and 7,749 eggs, producing some of the highest catch rates since 2016. Extensive elevated discharge levels in the Wabash River Basin in 2024 allowed invasive carps to spawn over a longer time period than previous sampling years.
- A larval Black Carp captured from the Wabash River in 2023 was genetically confirmed in 2024, becoming the furthest upstream Black Carp spawning record to date.
- Changes in operational timing of blocker board installation at the Hovey Lake drain water control structure appeared to limit passage of YOY invasive carp into the lake.

Methods:

For analysis purposes and for the remainder of this report, the phrase "bigheaded carps" will be referring to Silver and Bighead carps (*Hypophthalmichthys* spp.) only. YOY will be defined as fish less than 150 mm, and juvenile 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 sampling:
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 = 4), and Markland (N = 5) pools. Each sampling site was visited two times from May 15 to July 1, 2024. During each visit, three to four tows were conducted: three within the Ohio River proper, and one additional tow within the tributary or at the intake structure if the site was a previous EA Engineering larval sampling site. Larger tributary sites (Kanawha River and Raccoon Creek) had multiple tows conducted within the tributary during each sampling event.

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=2), Newburgh (N = 2), Cannelton (N = 2), and McAlpine (N = 2) pools twice each from May 13 to June 11, 2024, during ideal spawning conditions (water temperatures between 60 to 80°F with moderate to high water 2-3 days after peak flow event). Lastly, the mainstem Ohio River was sampled in conjunction with tributary sites within each the J.T. Myers, Newburgh, Cannelton, and McAlpine pools during the same timeframe. 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 the genetics lab at WVU for genetic confirmation.

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 some cases, eggs and/or larvae were labeled as "suspicious" if they exhibited some (but perhaps not all) morphometric characteristics of invasive carp. Out of caution due to the collection location of the suspicious specimens, they were pulled and sent to the genetics lab for genetic confirmation of species.

Targeted YOY Sampling:
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 and 2024.

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. The number of shad were counted for each tow and were used as a surrogate species to evaluate catch rates and net efficiencies. Shad density was calculated by dividing the number of shad per tow by water volume sampled per tow (net opening operating size multiplied by distance traveled).

In addition to surface trawls, pulsed-DC electrofishing (64 hz, 37% duty cycle) was conducted in various tributaries of the lower Ohio River pools. Experimental use of an electrified dozer trawl took place in the upper Ohio River. Processing of samples followed similar methodology as the surface trawl, where number of shad were counted for each tow to compare catch rate differences among gear types.

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 nine 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 twelve push net samples were collected: three within the tributary, three directly in the confluence mixing zone, 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 were submitted for genetic analysis and results are pending. A handheld YSI multiparameter meter was used to record temperature (°C). River discharge data (m^3/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 water 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 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 target goal 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.

In April 2023, USGS installed a stream gage within Bayou Drain that monitors stream stage and velocity to compute streamflow in Bayou Drain. Adjustments and calibrations were made throughout 2024, but the water flow near the control structure is challenging and gives variable results.

Genetic relatedness: The genetics component of this project has been delayed due to the EIU in-house genetics lab being no longer in operation. EIU was able to collaborate with an external lab (Dr. Devon Keeney at LeMoyne College) to process genetics samples for species identification and to investigate the genetic structure of invasive carp early life stages in the Wabash River Basin. To date, a subsample of larvae and eggs collected in 2024 have been sent to Dr. Keeney's lab for species identification; results are pending. Results will be shared with the Early Life Stages Workgroup and the rest of the Ohio River Basin collaborators when available.

Results and Discussion:

Ichthyoplankton sampling:
A combined total of 98 ichthyoplankton tows were conducted within the R.C. Byrd (N = 19), Greenup (N = 8), Meldahl (N = 36), and Markland (N = 35) pools (Table 1; Figure 2). Within those pools, 25 suspicious larvae were identified (16 from Markland Pool, 9 from Meldahl). Only three suspicious eggs were sorted from tow samples (one from Greenup pool and two from Markland). Suspicious eggs and larvae were collected between March 15th and June 12th, 2024. Markland and Melhdahl pools are the leading edge of the invasion, so we opted to be more liberal in retaining suspicious eggs and larvae for genetic confirmation.

A total of 46 ichthyoplankton tows were conducted within the mainstem Ohio River in the J.T. Myers (N = 6), Newburgh (N = 9), Cannelton (N = 18), and McAlpine (N = 13) pools (Table 2). Unless otherwise noted, all egg, advanced egg, and larvae counts listed herein are referring to morphometrically identified

Hypophthalmichthys species. Two advanced eggs and 11 larvae were collected from mainstem J.T. Myers Pool. One egg and nine larvae were identified from mainstem samples collected in Newburgh Pool. A total of 40 larvae were sampled in Cannelton Pool, with the furthest upstream being collected at river mile 608.5, near New Albany, IN. Zero *Hypophthalmichthys* eggs or larvae were collected from the Ohio River proper in McAlpine Pool. Among all mainstem ichthyoplankton sampling efforts (not including suspicious larvae from Markland and Meldahl pools), larvae density was highest in Cannelton Pool (1.60 larvae/100 m^3), followed by J.T Myers (1.25 larvae/100 m^3) and Newburgh pools (0.69 larvae/100 m^3) (Table 3).

An additional 39 ichthyoplankton tows were conducted in select tributaries of the lower Ohio River (Table 2; Figure 2). One egg and two larvae were captured within the Green River, along with an additional 1,292 larvae captured in Bayou Drain of Hovey Lake in J.T. Myers Pool (325.37 larvae/100 m^3). One larvae was captured in Anderson River of Newburgh Pool. No *Hypophthalmichthys* eggs or larvae were collected from Cannelton or McAlpine pool tributaries. Representative morphometrically identified specimens and suspect eggs/larvae from each sampling location were submitted to West Virginia University for genetic testing. Species confirmation is still pending, but will be shared with the partnership as soon as available.

Similar to 2023, Ohio River invasive carp reproduction appeared to be very limited in 2024. These results have the potential to change pending genetic confirmation results of several suspicious samples from Markland and Meldahl pools. In general, 2024 river conditions weren't conducive for large spawning events. Throughout much of May, the river experienced moderate flows and water temperatures above 60F. Beginning on June 10th, the Ohio River fell below 20ft (at the Newburgh L&D gage) and remained low until late-September. The lack of significant flow likely limited spawning. Also similar to last year, post gas-bladder inflation invasive carp larvae were collected from Bayou Drain of Hovey Lake indicating an early-May spawning event when water temperatures were between 60-65F. 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 2024.

Targeted YOY Sampling:
Among project partners, surface trawling effort consisted of 297 tows totaling 21.8 hours of sampling. The majority of effort was expended in tributaries of Cannelton (4.3 hrs), J.T. Myers (3.1 hrs), and Meldahl (3.1 hrs), followed by R.C. Byrd (2.5 hrs), Markland (2.3 hrs), Racine (2.1 hrs), Newburgh (2.1 hrs), Greenup (1.5 hrs), and McAlpine (0.5 hrs) pools (Figure 3). Only one YOY Silver Carp measuring 68 mm was captured in Hovey Lake in J.T. Myers Pool (not including data summarized in the *Hovey Lake recruitment* subsection) during 2024 surface trawling efforts. Despite extensive sampling, zero YOY invasive carp were captured via surface trawls in Ohio River tributaries upstream of J.T. Myers Pool in 2024.

Shad counts were used as a surrogate for evaluating catch efficiencies. Shad density per surface trawl varied widely within and among sampling sites. For example, 21 surface trawl transect within Hovey Lake across two days produced anywhere from 5 to 1,038 shad/100 m^3. Likewise, catch rates in multiple tributaries within Cannelton Pool varied from 0 to 200+ shad/100 m^3 (Table 4). Surprisingly, catch rates also varied quite substantially among agencies suggesting netting efficiency difference among crews (Table 5). One variable that appears to account for a portion of this difference is boat speed. The highest catch rates were when boats were operated at a speed of 1.7 to 2.3 mph (Figure 4). However, clumped distribution of species is always going to lead to high variability among shad (and invasive carp) densities.

Targeted electrofishing efforts in the lower Ohio River included 60 transects totaling 11.2 hours of sampling. This included 2.9 hours of effort in J.T. Myers Pool, 3.0 hours in Newburgh Pool, and 5.3 hours in Cannelton Pool. Twenty-three YOY Silver Carp, ranging in size from 28 to 40 mm, were collected from Bayou Drain of Hovey Lake in J.T. Myers Pool. Again, no YOY were captured in Newburgh or Cannelton Pools, however, 27 adult Silver Carp were also captured during electrofishing efforts. USFWS dozer trawl efforts included 98 transects, for a total of 8.0 hours of effort. Shad densities ranged from 0 to 271 shad/100

m^3, with an average density of 7 shad/100 m^3. The variability in catch rate was comparable to surface trawling efforts (Table 5), but the dozer trawl generally captured more shad per run. Due to higher catch rates and the reduced manpower needed to operate a dozer trawl setup, crews may start using it more often for targeted YOY sampling efforts.

A robust YOY sampling effort was again put forth in 2024. 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 or 2024, further supporting the notion of limited spawning and recruitment in the Ohio River.

Black Carp YOY Sampling:
KDFWR sampled for YOY invasive carp at 3 sites along the lower Ohio River, 12 sites along the Mississippi River, and no sites along the lower Tennessee and Cumberland Rivers (Table 6). We sampled YOY black carp in two locations along the Mississippi River (Figure 5). The first site we collected 4 YOY black carp ranging from 25-29 mm in length. The second site we collected 173 black carp ranging from 24-71 mm. Both sites were adjacent backwaters to the mainstem of the Mississippi River, less than one meter deep with sandy/muddy substrate. The first site was directly connected to the river, while the second site was isolated because of low water levels.

Efforts in 2024 revealed the presence of YOY Black Carp at two locations out of 15 sites sampled along the lower Ohio, Mississippi, Tennessee, and Cumberland River. The two capture locations along the lower Mississippi River were at mile markers 934 and 922. The 2024 sites have similar habitat characteristics to the previous years capture locations, but the site at mile marker 934 was more directly connected to the mainstem of the river, while the site at 922 was an isolated pool. Both are close to the main river channel, shallow (< 1 m), muddy and sandy 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 Mississippi River drainage in Western Kentucky.

Wabash River ichthyoplankton:
EIU collected a total of 307 ichthyoplankton samples from April 9th to July 24th, 2024, across 15 sampling dates. Samples were taken from each tributary and corresponding mainstem Wabash River sites up to five times throughout the season, depending on access. All tributaries except for the Vermilion River were sampled on 8 to 10 occasions depending on accessibility on given dates. The Vermilion River was sampled on three occasions and was inaccessible after May 29th. After July 24th most tributaries became inaccessible for the remainder of the season and previous efforts covered most of the elevated discharge events during peak spawning time frame for invasive carps.

In total, 32,734 larvae and 7,749 eggs were visually identified as invasive carp (Table 7). A sub-sample of all eggs and larvae collected throughout the season were submitted to Dr. Keeney's genetics lab at LeMoyne college and results are pending. Thus, the totals above are likely a slight overestimation of invasive carp eggs and larvae produced in the Wabash River Basin in 2024.

Invasive carp larvae were found in all tributaries with the greatest number in the Little Wabash River and adjacent mainstem site (n = 26,681, Table 7). As expected, peaks in larval density generally coincided with rapid rises in discharge in the tributary site and/or adjacent mainstem Wabash River sites (Figure 6). Elevated water levels during our first sampling event in April yielded zero invasive carp eggs and larvae as the water temperature had not reached the minimum threshold required for reproduction (~18° C) for these species. The lower Wabash River exhibited prolonged elevated water levels from late April through May that lead to greater production of larvae in the mainstem relative to the Little Wabash tributary over that time period. On May 30th invasive carp larval abundance peaked (mean = 79.2 fish/m^3), which was the greatest detection of larvae in across all sites over our sampling season. From early June to early July water levels dropped and sampling was not possible, but reproduction of invasive carps in the mainstem Wabash and Little Wabash Rivers was likely low or zero over this time period. From July 10th through the remainder of the sampling season water levels in the mainstem and the tributary rose and invasive carp larval abundance was detected at high levels once again, particularly in the mainstem. Water level patterns in the White River and the Wabash River at Mount Carmel were similar to patterns observed in the Little Wabash River. However, similar abundance of larvae was observed in White River and the mainstem Wabash River across most sampling dates (Figure 7). Overall abundance of larvae in the White River and adjacent mainstem was significantly lower than levels detected at the Little Wabash River site. The Embarras River exhibited moderate levels of larval invasive carp abundance with a total of 1,985 individuals over the entire sampling period. The Vermilion River had the lowest abundance of invasive carp larvae over the course of sampling with only 16 individuals collected.

All sites had visually identified invasive carp eggs found in the samples. In the previous sampling year, genetic analysis showed a large proportion of visually identified eggs came back as freshwater drum eggs. Thus, we used a larger size threshold to classify potential invasive carp eggs (~3mm or greater). Similar to larval results, our egg samples are still waiting for genetic confirmation and could be a greater estimate of actual invasive carp egg abundance. Contrasting our larval estimates, the White River produced the greatest amount of invasive carp eggs relative to all other tributary sites, and the mainstem Wabash River sites (Table 7). This is similar to 2023 results suggesting the lower White River is an important location for invasive carp spawning in the Wabash River Basin. The mainstem Wabash River near the Little Wabash confluence produced the second greatest abundance of invasive carp eggs, which is consistent with past collections as well (Table 7). The Vermilion and Embarras Rivers produced relatively few invasive carp eggs, which is consistent with the patterns of larvae observed across sampling sites in 2024 as well.

Due to logistical constraints EIU was unable to conduct a continuous sampling event of invasive carp ichthyoplankton across the duration of an entire spawn. We were overwhelmed with sample processing and identification of across all of our sites and underestimated how much effort this continuous sampling would take in the field and lab.

An additional analysis was conducted to guide future sampling efforts in a more targeted fashion. The goal of this analysis is to determine if targeted sampling can be implemented to reduce effort while maximizing catch. Scatter plots were used to visualize relationships between larval invasive carp densities and river hydrology (i.e. discharge and gauge height), using all data from 2016 to 2024. We have identified a minimum river discharge or gauge height level in each tributary to still be able to detect ~80% or more of invasive carp larvae when present, but reduce the amount of extraneous 'known zeros'. Our example provided here is for the Little Wabash River as it is frequently one of the invasive carp reproductive hot spots, but also is difficult to access and sample in low water. When plotted all together, there is a sharp drop off in CPUE of invasive carp larvae at a gauge height of 9 feet or less (Figure 8) or about 62 m^3/s in discharge (Figure 9). Of the 218 samples we have collected in the lower Little Wabash River, 50% have been collected at gauge heights below ~9 feet or 62 m^3/s. Of those 114 events below that water level, 88 (77%) have been zeros. In terms of total counts of larvae, 15,305 out of the 16,218 individuals (94%) collected at that site were at water levels greater than 9 feet. Therefore, we have determined this level as an appropriate minimum threshold for targeted sampling efforts at that site. We will use a similar data visualization process for each of our sampling locations to determine the most efficient sampling strategy.

The 2024 Wabash River sampling season showed reproduction of invasive carps was significantly greater than the previous two years, and one of the highest rates since EIU began sampling in 2016. Invasive carp successfully reproduce in multiple areas throughout the Wabash River Basin, particularly in the Little Wabash River, the adjacent mainstem near New Haven, IL, and the lower White River. In addition, a genetically confirmed Black Carp larvae was captured in 2023, the furthest upstream documentation of Black Carp spawning in the Ohio River basin. Those data were received after completion of the 2023 Early

Life Stages technical report and therefore were not included last year. For more specifics on that work, please see Appendix A.

These results continue to suggest the Wabash River basin is a significant source of propagule pressure of invasive carps to the greater Ohio River Basin. Similar to 2023 results, the lower White River had high abundance of invasive carp eggs, suggesting this area is an important spawning ground for these invasive fishes. These results are similar to previous work published by EIU that demonstrate larger tributaries with greater mean discharge throughout the spring and summer (e.g. Little Wabash and White Rivers) support significantly higher reproduction than smaller tributaries such as the Vermilion River (Schaick et al. 2020). Extensive elevated discharge levels in the Wabash River Basin in 2024 allowed invasive carps to spawn over a longer time period than previous sampling years. Additionally, the highest rates of reproduction were observed in many of our sites located in the lower half of the basin (e.g. downstream of Mount Carmel). Given these results it is important that control strategies such as commercial harvest focus on the Lower Wabash River Basin to reduce propagule pressure to the surrounding Ohio River Basin.

Hovey Lake recruitment:
Bayou Drain of Hovey Lake was sampled on both sides of the water control structure once a week from May 21st to June 27th, 2024, via ichthyoplankton netting and surface trawling. Ichthyoplankton netting effort consisted of 36 three-minute tows; 18 on each side of the control structure. A total of 1,424 post gas bladder inflation *Hypophthalmichthys* larvae were collected via ichthyoplankton nets. Two of the early captured (developmental stage: 40) were submitted to the WVU genetics lab for confirmation, but results are still pending. Invasive carp larvae were first detected in ichthyoplankton nets on the river side of the water control structure on May 21st, and were not captured on the lake side of the structure. Invasive carp larvae densities on the river side of the water control structure ranged from 1.23 to 151.47 individuals/100 m^3, peaking on June 6th and decreasing each following week.

Beam trawls efforts consisted of 39 tows, including 23 on the river side of the water control structure and 16 tows on the lake side. Shorter transects were conducted on the lake side due to downed trees blocking the way. Beam trawls first detected invasive carp on the river side of the control structure on May 30th, but did not collect any on the lake side of the structure. YOY Silver Carp catch rates peaked at 59.2 fish/100 m^3 on May 30th. Silver carp captured via beam trawl ranged in size from 13 to 36 mm.

Collectively, gears only captured YOY invasive carp on the river side of the control structure. This was expected, considering 2023 findings and changes in the water control structure operation. Property staff at the Hovey Lake Fish & Wildlife Area pulled the blocker boards from the structure on May 23rd to begin the lake drawdown process. On June 7th, staff reinstalled the blocker boards to hold the lake water level higher than in previous years, to prevent excessively low water in the lake during summer drought like what happened in 2023. Therefore, the blocker boards were reinstalled prior to when the lake and river levels equalized, when there was still significant flow coming through the water control structure. (Figure 10). This meant that invasive carp had no ideal opportunity to traverse the water control structure throughout the sampling window.

Despite not capturing any larvae or YOY invasive carp on the lake side of the control structure during our sampling window, a single 68 mm Silver Carp was collected via surface trawls in the lake proper on July 11th. Only one individual out of 21 surface trawl pulls indicate very low densities. Based on daily growth rates previously derived, this 68 mm Silver Carp was likely over 60 days old, suggesting an early-May hatch date. We are uncertain exactly how the fish was able to enter the lake. One possibility is the May 11th river crest provided enough backflow into the drain, pushing small larvae through tiny crevices around the blocker boards within the water control structure. Regardless, passage into the lake was minimal, thus Hovey Lake recruitment as well.

Excluding the Wabash River, there has not been what we would consider a strong Ohio River spawning event or year-class since this project was initiated in 2016. 2023 had exceptionally low spawning activity, and 2024 was low as well. 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.

Tables and Figures:

Table 1. Summary of ichthyoplankton tows collected by WVU and WVDNR. Sampling took place between May 15 and June 12, 2024.

				Suspicious eggs/larvae (n)		
Pool	**Location**	**Transect Type**	**Tows (N)**	*Eggs*	*Adv. Eggs*	*Larvae*
Markland	RM 496.7 (near Hogans Creek)	Ohio River	6	0	0	0
Markland	Hogans Creek	Tributary	2	0	0	10
Markland	RM 463.5 (near Little Miami)	Ohio River	6	0	0	4
Markland	Little Miami	Tributary	2	0	0	0
Markland	RM 515.0 (Markland Lower)	Ohio River	8	0	0	0
Markland	RM 495.8 (Markland Middle)	Ohio River	5	2	0	0
Markland	RM 449.0 (Markland Upper)	Ohio River	6	0	0	2
Meldahl	Big Three Mile	Tributary	1	0	0	0
Meldahl	RM 404.7 (near JM Stuart Plant)	Ohio River	6	0	0	0
Meldahl	JM Stuart Plant	Tributary	2	0	0	0
Meldahl	RM 429.9 (Meldahl Lower)	Ohio River	6	0	0	8
Meldahl	RM 387.8 (Meldahl Middle)	Ohio River	7	0	0	0
Meldahl	RM 362.1 (Meldahl Upper)	Ohio River	6	0	0	0
Meldahl	RM 356.4 (near Sciota River)	Ohio River	6	0	0	1
Meldahl	Sciota River	Tributary	2	0	0	0
Greenup	RM 305.2 (near Guyandotte)	Ohio River	6	1	0	0
Greenup	Guyandotte	Tributary	2	0	0	0
R.C. Byrd	Kanawha	Kanawha River	6	0	0	0
R.C. Byrd	RM 265.1 (near Point Pleasant)	Ohio River	6	0	0	0
R.C. Byrd	Point Pleasant	Tributary	1	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 May 13 and June 11, 2024.

Pool	Location	Transect Type	Tows (N)	Suspect Hypop. (n) *Eggs*	*Adv. Eggs*	*Larvae*
JT Myers	RM 840.6 (near Hovey Drain)	Ohio River	3	0	0	11
JT Myers	Hovey Lake Drain (RS)	Tributary	3	0	0	1,292
JT Myers	RM 784.0 (near Green River)	Ohio River	3	0	2	0
JT Myers	Green River	Tributary	3	1	0	2
Newburgh	RM 772.8 (near Little Pigeon)	Ohio River	3	1	0	1
Newburgh	Little Pigeon Creek	Tributary	3	0	0	0
Newburgh	RM 731.3 (near Anderson Rv)	Ohio River	6	0	0	8
Newburgh	Anderson River	Tributary	6	0	0	1
Cannelton	RM 718.7 (near Deer Creek)	Ohio River	6	0	0	27
Cannelton	Deer Creek	Tributary	6	0	0	0
Cannelton	RM 662.9 (near Blue River)	Ohio River	6	0	0	11
Cannelton	Blue River	Tributary	6	0	0	0
Cannelton	RM 608.5 (New Albany ramp)	Ohio River	6	0	0	2
McAlpine	RM 595.8 (near Harrods Creek)	Ohio River	7	0	0	0
McAlpine	Harrods Creek	Tributary	6	0	0	0
McAlpine	RM 545.8 (near Kentucky River)	Ohio River	6	0	0	0
McAlpine	Kentucky River	Tributary	6	0	0	0

Table 3. Summary of mainstem Ohio River icthyoplankton sampling efforts by pool and corresponding morphometrically identified *Hypophthalmichthys* egg, advanced egg, and larvae densities. Suspicious eggs/larvae were not included in these data.

Hypophthaylmichthys Density (n/100m^3)

		Eggs			**Adv. Eggs**			**Larvae**		
Pool	***Number of tows***	*Mean*	*Max*	*St. Dev.*	*Mean*	*Max*	*St. Dev.*	*Mean*	*Max*	*St. Dev.*
J.T. Myers	6	-	-	-	0.22	1.35	0.55	1.25	5.34	2.18
Newburgh	9	0.08	0.75	0.25	-	-	-	0.69	3.17	1.21
Cannelton	18	-	-	-	-	-	-	1.60	18.35	4.41
McAlpine	13	-	-	-	-	-	-	-	-	-
Markland	30	-	-	-	-	-	-	-	-	-
Meldahl	30	-	-	-	-	-	-	-	-	-
Greenup	6	-	-	-	-	-	-	-	-	-
R.C. Byrd	12	-	-	-	-	-	-	-	-	-

Table 4. Shad densities among sites sampled during targeted YOY surface trawling efforts, 2024.

Pool	Tributary/Embayment	Trawls (n)	Shad Density (n/100 m^3)		
			Min	*Max*	*Mean*
J.T. Myers	Canoe Creek	6	0.0	182.5	54.2
	Highland Creek	3	0.0	0.0	0.0
	Hovey Lake	21	5.0	1038.2	120.9
	Hovey Lake Drain	4	0.0	0.3	0.1
	Lost Creek	1	0.0	0.0	0.0
	Pigeon Creek	3	0.0	0.0	0.0
Newburgh	Anderson River	3	0.0	0.0	0.0
	Big Sandy Creek	2	0.0	0.0	0.0
	Blackford Creek	2	0.0	0.0	0.0
	Borrow Pit 1	5	0.0	0.0	0.0
	Borrow Pit 2	6	0.0	0.2	0.0
	Little Pigeon Creek	3	0.0	0.0	0.0
	Sandy Creek	1	0.7	0.7	0.7
	Van Buren Creek	1	0.0	0.0	0.0
	Cypress/Honey Creek	3	0.0	0.0	0.0
Cannelton	Blue River	3	0.0	0.0	0.0
	Clover Creek	8	0.4	9.9	3.1
	Deer Creek	7	0.0	235.8	36.1
	Little Blue River	4	0.0	0.0	0.0
	Millstone Creek	8	0.0	1.9	0.8
	Oil Creek	7	0.0	242.5	88.7
	Poison Creek	8	0.0	305.2	43.8
	Wolf Creek	3	0.0	0.3	0.2
	Yellowbank Creek	3	0.8	3.0	1.8
McAlpine	Admirals Anchor Marina	3	0.0	0.0	0.0
	Harrods Creek	3	0.0	0.0	0.0
	Nugent Sands Borrow Pit	3	0.0	0.0	0.0
	14 Mile Creek	3	0.0	0.0	0.0
Markland	Arnold Creek	3	0.7	1.7	1.2
	Big Bone Creek	3	0.0	0.4	0.2
	Bryant Creek	3	0.0	0.2	0.1
	Craigs Creek	3	0.2	2.5	1.1
	Grants Creek	3	0.4	1.0	0.7
	Gunpowder Creek	3	0.0	0.2	0.1
	Hogan Creek	3	0.0	0.2	0.1
	Tanners Creek	3	0.4	1.7	0.8
	Turtle Creek	3	0.0	0.5	0.2
Meldahl	Bracken Creek	6	0.0	7.2	1.5
	Bullskin Creek	4	0.0	0.0	0.0
	Locust Creek	6	0.0	0.5	0.2
	Red Oak Creek	6	0.0	0.1	0.0
	Snag Creek	3	0.0	0.1	0.0
	Straight Creek	6	0.0	0.0	0.0
	White Oak Creek	6	0.0	0.1	0.0
Greenup	Ginat Creek	4	0.0	0.0	0.0
	Ice Creek	4	0.0	0.0	0.0
	Little Sandy River	6	0.0	0.0	0.0
	Stroms Creek	4	0.0	0.0	0.0
R.C. Byrd	Chickamauga Creek	16	0.0	31.6	2.7
	Crab Creek	5	0.0	0.3	0.1
	Raccoon Creek	6	0.0	0.0	0.0
	Campaign Creek	9	0.0	1.3	0.2
	Ohio River	3	0.0	0.0	0.0
	Leading Creek	10	0.0	0.3	0.0
	Tenmile Creek	4	0.0	0.3	0.1
	Oldtown Creek	3	0.0	0.0	0.0
Racine	Mill Creek	3	0.0	0.2	0.1
	Sandy Creek	3	0.3	0.8	0.5
	Shade River	6	0.0	2.2	0.5
	Tombleson Run	4	0.0	0.6	0.1
	Little Mill Creek	15	0.0	9.7	0.9

Table 5. Differences in shad density calculations during targeted YOY sampling among various agencies, 2024. Samples collected in Hovey Lake proper are not included in these calculations.

			Shad Density (n/100 m^3)		
Agency	**Trawls (n)**	**Mean MPH**	*Min*	*Max*	*Mean*
INDNR	62	2.04	0.0	305.2	25.4
KDFWR	55	2.11	0.0	7.2	0.2
WVU	71	1.46	0.0	9.9	0.4
USFWS	87	1.53	0.0	31.6	0.8
USFWS - Dozer	98	1.85	0.0	270.6	7.2

Table 6. Summary of YOY invasive carp captures in Western Kentucky.

2022	Sites Sampled	Sites with YOY Invasive Carp	Sites with YOY Black Carp
Ohio River	21	2	1
Mississippi River			
Tennesse/Cumberland Rivers	2		
Total	23	2	1
2023	**Sites Sampled**	**Sites with YOY Invasive Carp**	**Sites with YOY Black Carp**
Ohio River	24	3	1
Mississippi River	9	2	
Tennesse/Cumberland Rivers	22		
Total	55	5	1
2024	**Sites Sampled**	**Sites with YOY Invasive Carp**	**Sites with YOY Black Carp**
Ohio River	3	3	
Mississippi River	12	8	2
Tennesse/Cumberland Rivers			
Total	15	11	2

Table 7. Sampling location, transect location (Wabash River upstream, Wabash River Downstream, Confluence, Within Tributary), number of push net samples, number of invasive carp larvae collected, mean larvae CPUE (fish/m^3), number of invasive carp eggs collected, egg CPUE (fish/m^3) collected in the Wabash River Basin in 2024. All samples are pending genetic testing and are subject to change.

Sampling Location	Transect Location	Push Net (N)	Larvae (N)	Larvae CPUE	Eggs (N)	Egg CPUE
Vermilion	Wabash Upstream	15	5	0.01	229	0.30
Vermilion	Wabash Downstream	15	6	0.01	252	0.38
Vermilion	Confluence	3	3	0.02	23	0.14
Vermilion	Tributary	9	2	0.00	15	0.04
White	Wabash Upstream	30	1,204	0.69	299	0.19
White	Wabash Downstream	30	1,473	0.84	1,322	0.87
White	Confluence	9	570	0.83	279	0.50
White	Tributary	30	805	0.47	2,488	1.46
Embarras	Wabash Upstream	21	646	0.53	74	0.06
Embarras	Wabash Downstream	24	1,195	0.97	72	0.06
Embarras	Confluence	8	98	0.29	20	0.05
Embarras	Tributary	24	46	0.04	1	0.00
Little Wabash	Wabash Upstream	27	5,165	3.86	1,371	0.72
Little Wabash	Wabash Downstream	27	5,751	3.88	922	0.52
Little Wabash	Confluence	8	2,384	4.64	334	0.67
Little Wabash	Tributary	27	13,381	9.23	48	0.04
Totals		**307**	**32,734**	**1.93**	**7,749**	**0.44**

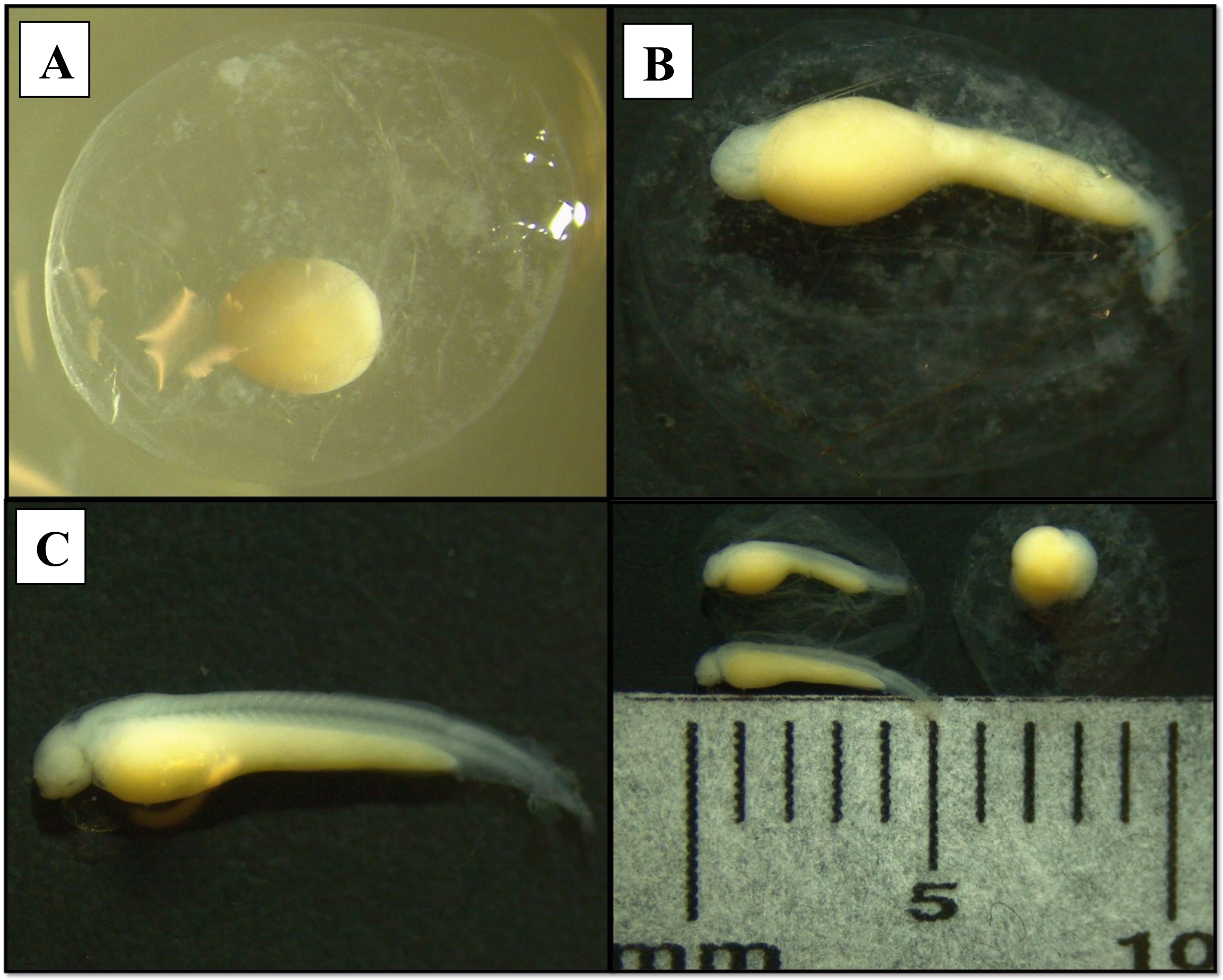


Figure 1. Developmental life stages of *Hypophthalmichthys* spp. with size comparisons. For the purposes of this report, pictures A, B, and C demonstrates specimens categorized as “eggs”, “advanced eggs”, and “larvae”, respectively.

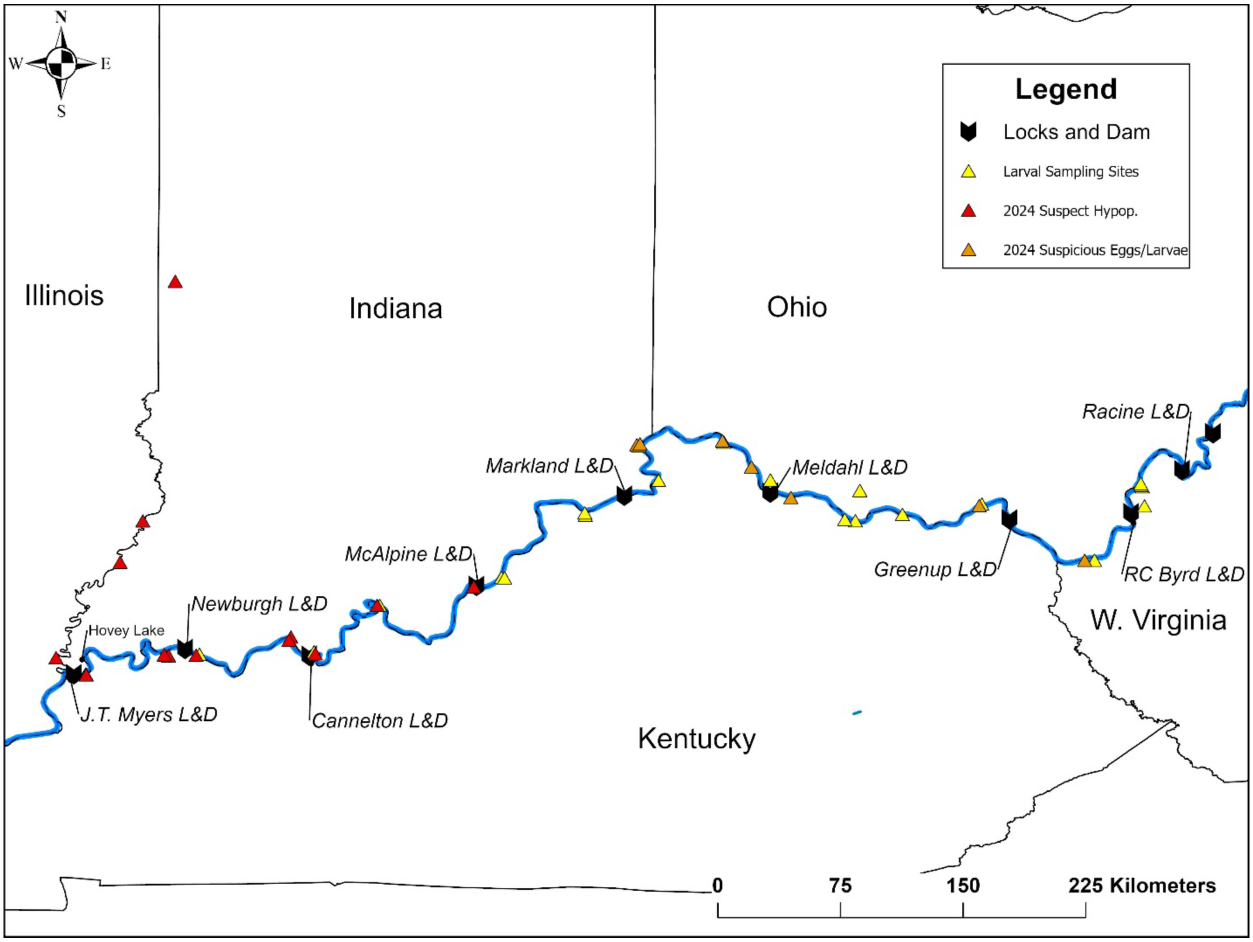


Figure 2. Map of 2024 study area of larval sampling sites. Black icons denote a lock and dam, yellow triangles indicate larval sampling sites, red triangles indicate locations where morphometrically identified *Hypophthalmichthys* eggs, embryos, or larvae were collected, and orange triangles indicate where suspicious eggs or larvae were collected.

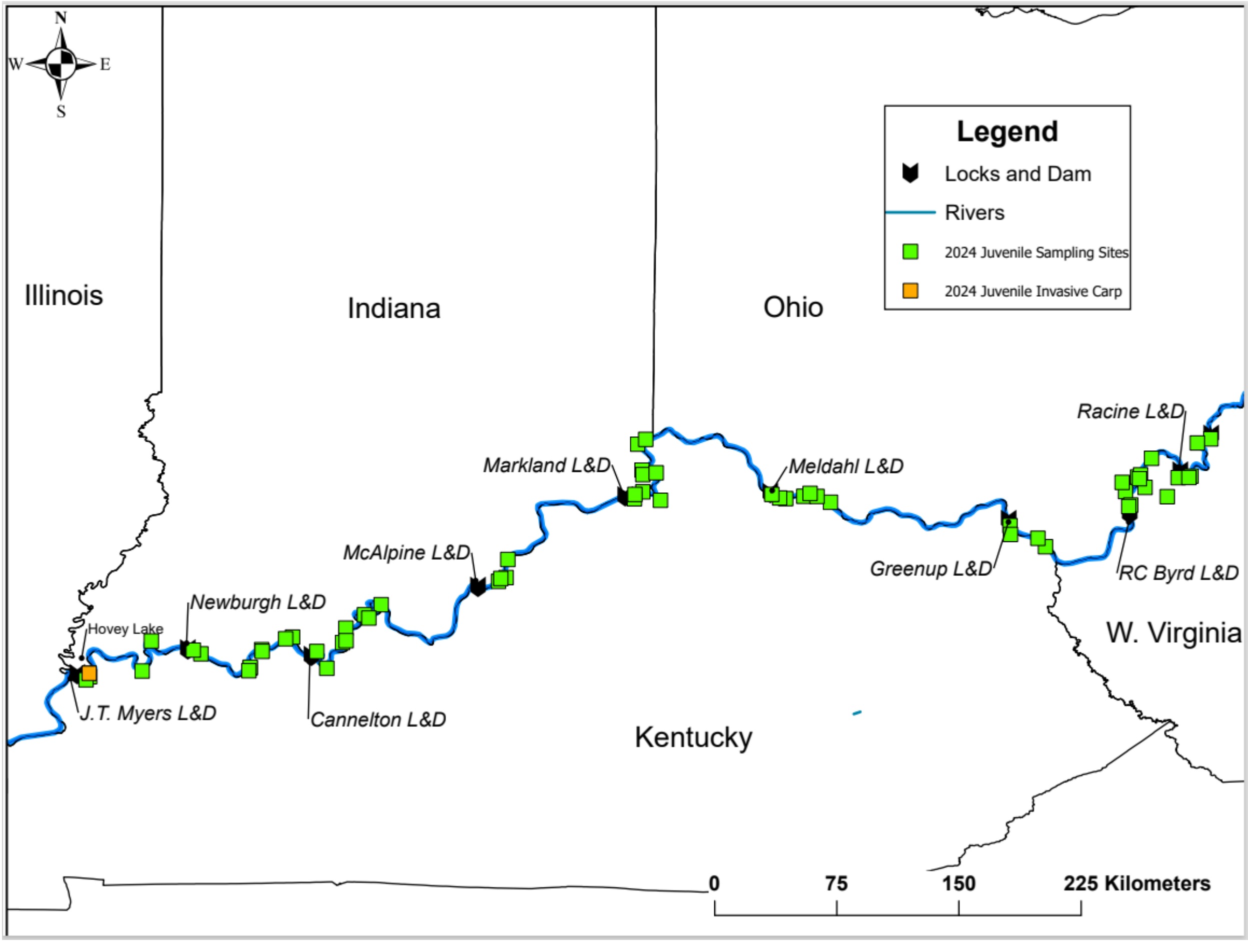


Figure 3. Map of 2024 targeted YOY sampling sites. Black icons denote a lock and dam, green squares indicate sampling sites, orange squares indicate locations where YOY *Hypophthalmichthys* were collected.

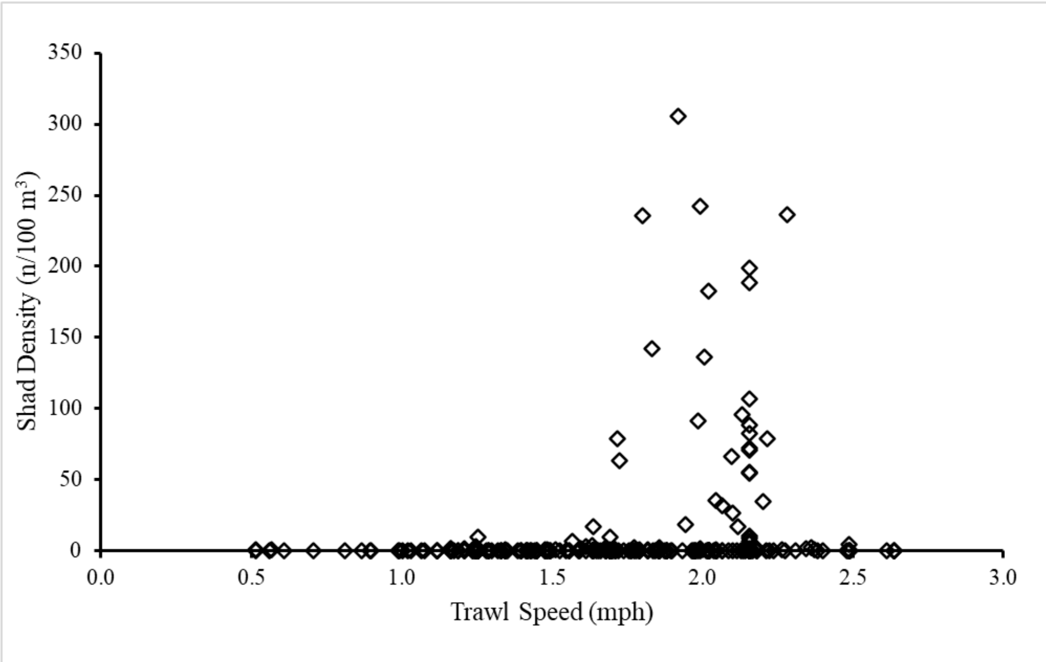


Figure 4. Shad density (n/100m^3) by trawling speed for agency surface trawling efforts in Ohio River tributaries, 2024. One surface trawl tow conducted at Hovey Lake is not displayed here due to being an extreme outlier; that tow had a speed of 2.0 MPH and a catch of 1,038 shad /100m^3.

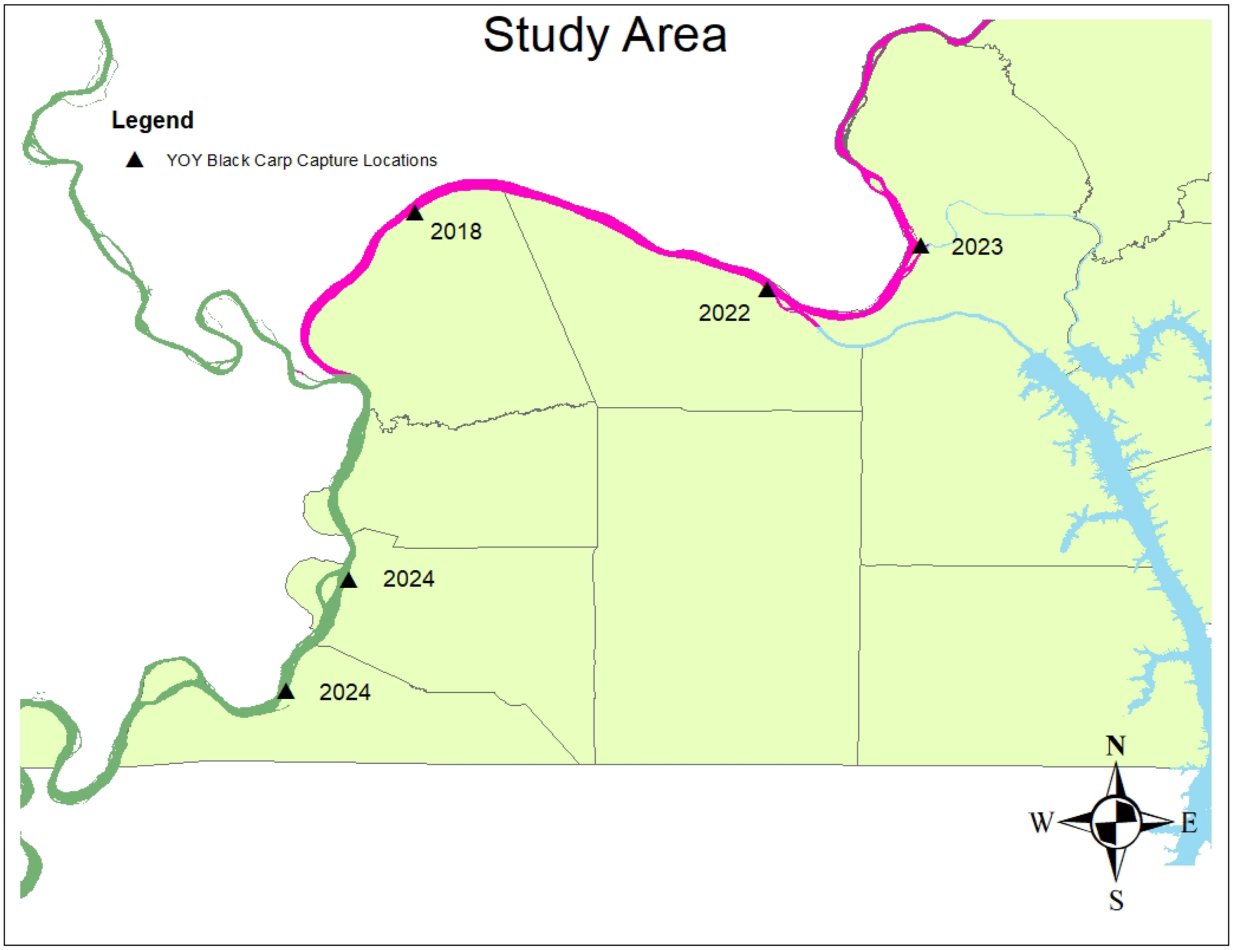


Figure 5. Capture locations of YOY invasive black carp along the lower Ohio and Mississippi Rivers in Western Kentucky.

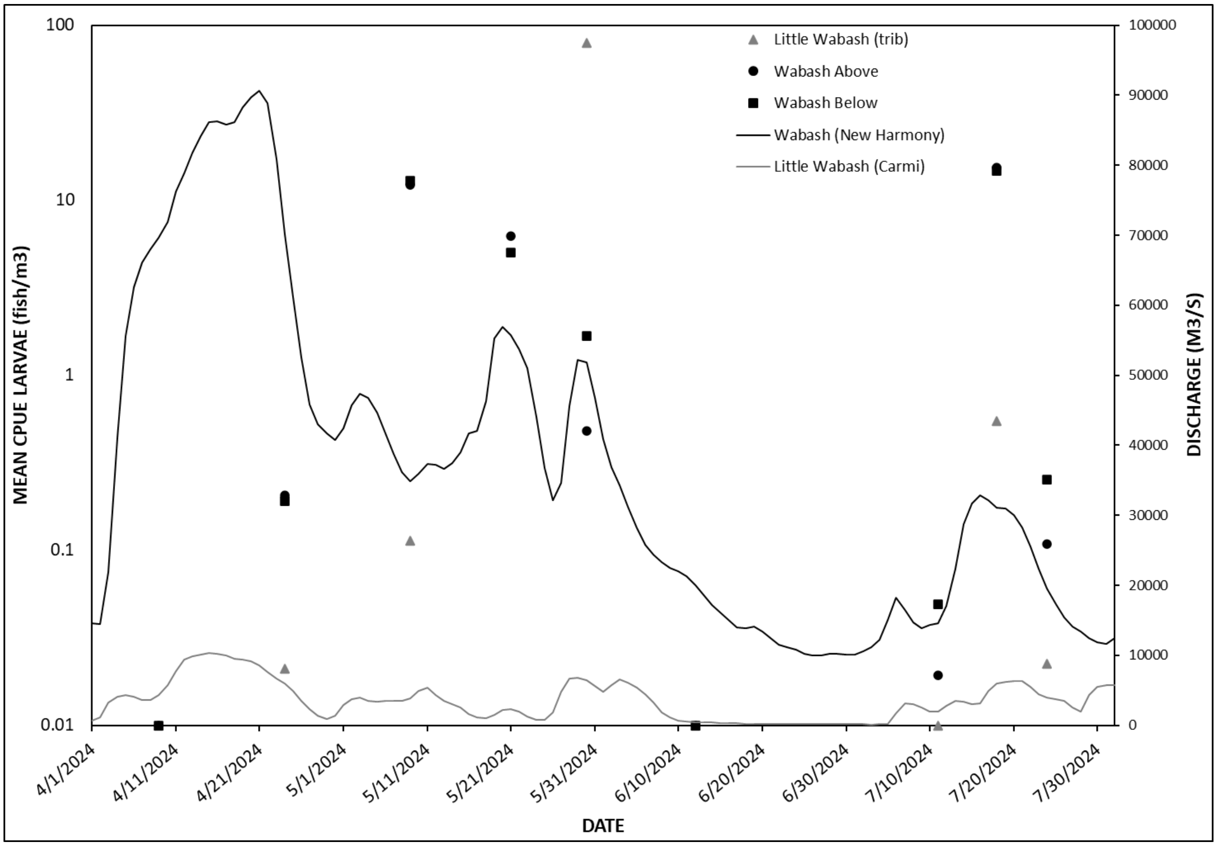


Figure 6. Catch per unit effort (fish/m^3 H2O filtered) of invasive carp larvae collected in the Little Wabash River (tributary site, grey triangles), and the Wabash River above (black circles) and below (black squares) the confluence of the tributary from April 9th – July 24th, 2024. Mean daily discharge (m^3/sec) is shown on secondary y-axis for the Little Wabash at Carmi (grey line), and Wabash River at New Harmony (black line). CPUE is plotted on a log scale and zeros are represented by CPUE = 0.01.

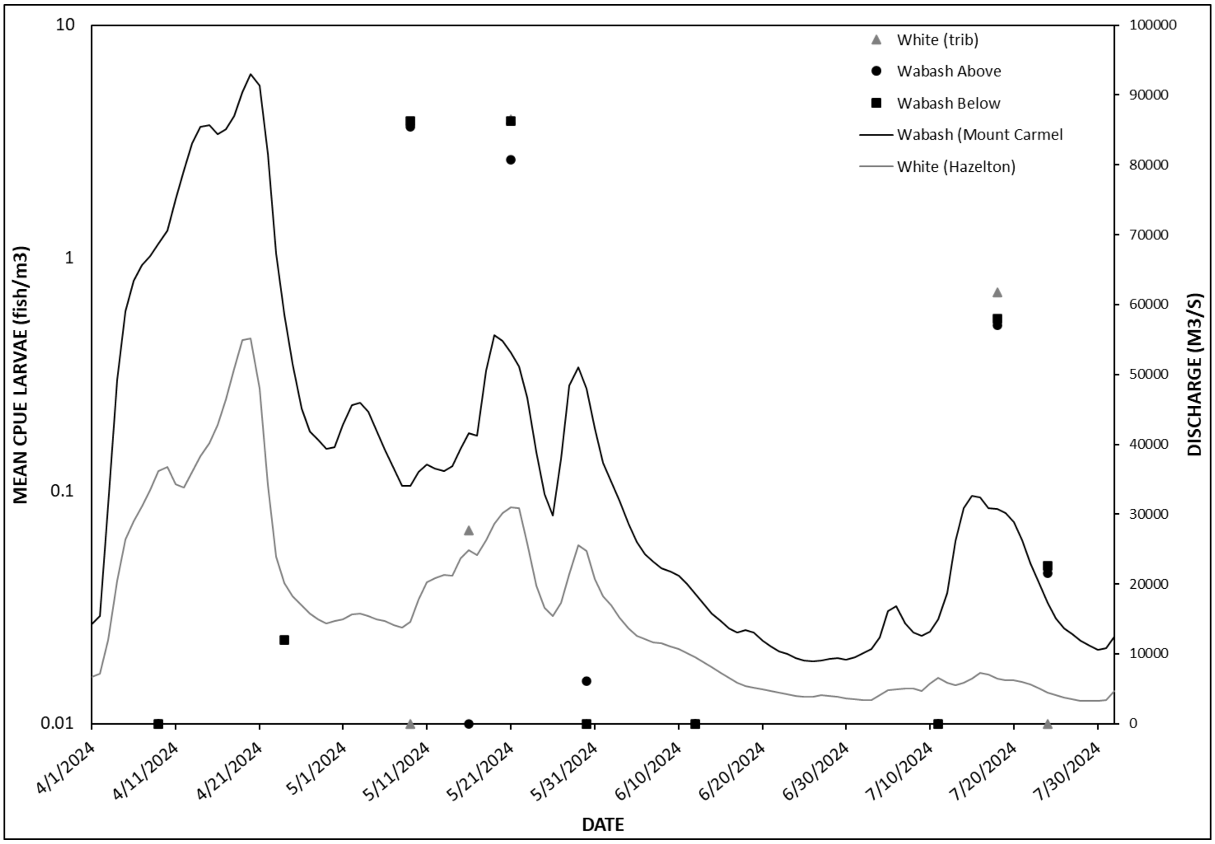


Figure 7. Catch per unit effort (fish/m^3 H2O filtered) of invasive carp larvae collected in the White River (tributary site, grey triangles), and the Wabash River above (black circles) and below (black squares) the confluence of the tributary from April 9th – July 24th, 2024. Mean daily discharge (m^3/sec) is shown on secondary y-axis for the White River at Hazelton (grey line), and Wabash River at Mount Carmel (black line). CPUE is plotted on a log scale and zeros are represented by CPUE = 0.01.

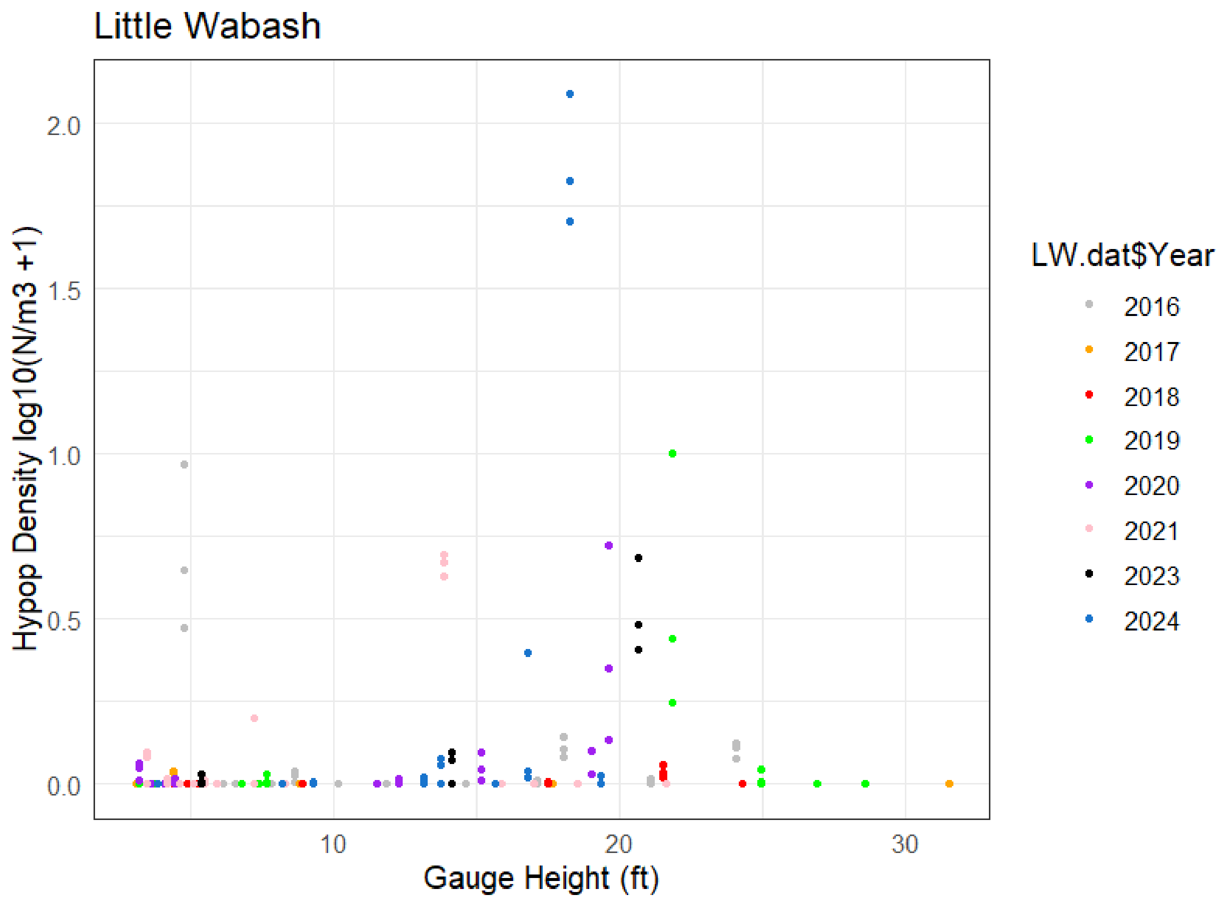


Figure 8. Scatterplot of log-transformed invasive carp density (Log (fish/m^3 + 1) on y-axis and gauge height (feet) on x-axis in collected in the lower Little Wabash River from 2016-2024. Guage data was obtained from the USGS gauging station located in Carmi, IL.

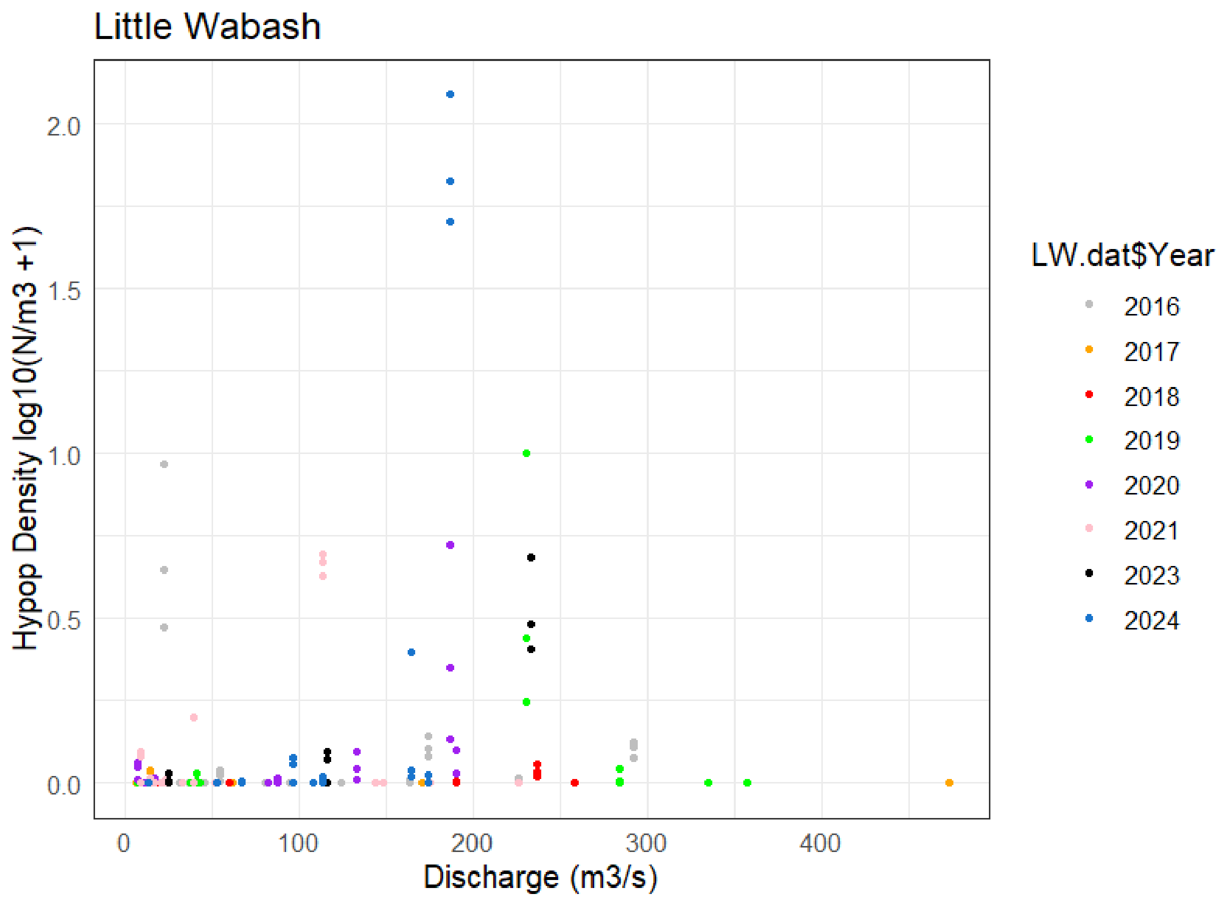


Figure 9. Scatterplot of log-transformed invasive carp density (Log (fish/m^3 + 1) on y-axis and discharge (m^3/s) on x-axis in collected in the lower Little Wabash River from 2016-2024. Guage data was obtained from the USGS gauging station located in Carmi, IL.

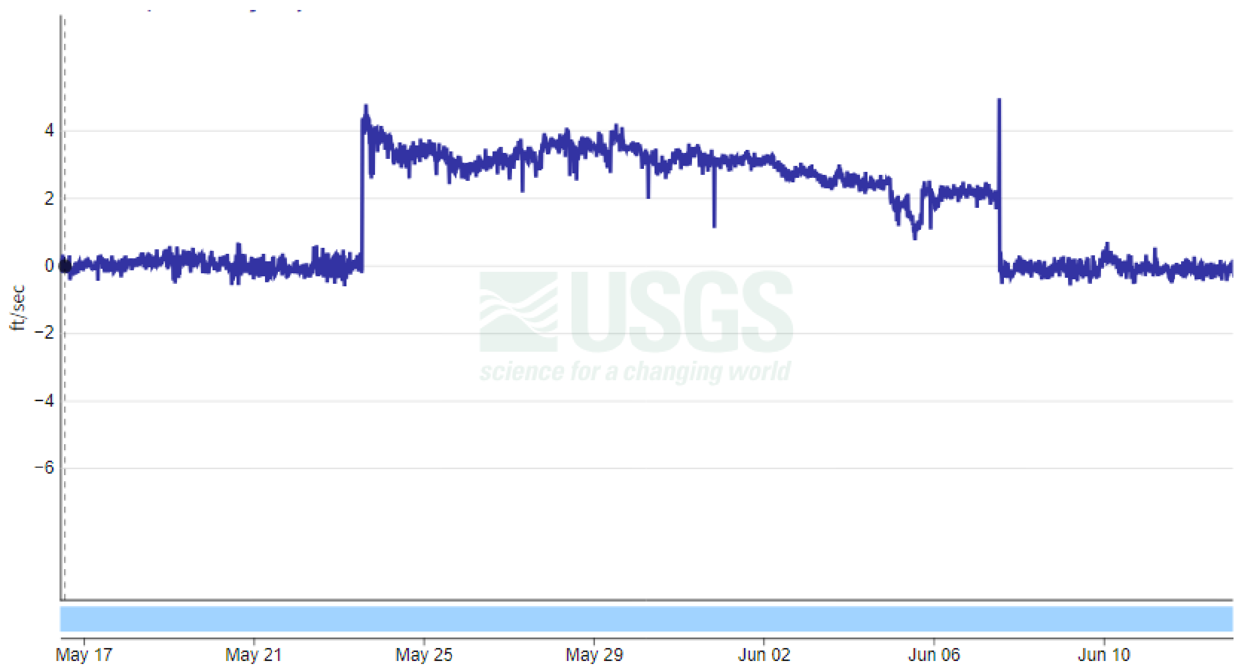


Figure 10. Water velocity (ft/sec) taken from field sensor in Bayou Drain of Hovey Lake. USGS gage station 374815087555101. Positive velocities indicate water flowing out of the lake towards the river, while negative velocities indicate water flowing into the lake.

Recommendations:

Results of the ninth 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.

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. As part of this standardization, we recommend transitioning ichthyoplankton sampling to 'push' setups, instead of towing in reverse off the bow of the boat, which introduces propwash. Paired sampling comparing push tows versus pulled ichthyoplankton nets show differences in catch rates, with push tows resulting in higher catch rates (Daniel Roth, EIU – Personal communication). Accurately quantifying density of invasive carp eggs and larvae will help evaluate changes in spawning success over time.

We recommend working towards a better process for getting genetic confirmation of ichthyoplankton samples. To reduce costs and steps in the process, we recommend getting genetic samples processed in house at West Virginia University. We also recommend setting an annual deadline for all project partners to have their respective ichthyoplankton samples sorted and suspect specimens sent to the genetics lab by November 1 following the field season to increase efficiency so results can be conclusively reported in the annual technical report. The larval fish identification workshop in 2024 was very helpful in getting staff comfortable identifying larvae, and we recommend holding similar workshops as needed in the future. 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 2025. With regards to YOY Silver and Bighead carp sampling, we recommend continuing targeted sampling in Markland Pool and areas further upstream. Having multiple agencies outfitted with surface trawls will be used to continue our expanded YOY sampling further upstream in 2025. However, we recommend continued standardization of methods, to ensure crews are collecting comparable data. In particular, ensuring the correct boat speed while surface trawling appears to have a large impact on catch rates. With electrified dozer trawl showing promise as another method to sample for YOY invasive carp, we recommend experimenting with it in higher density areas to evaluate differences in YOY catch rates between the dozer trawl and surface trawl.

INDNR recommends continuing to monitor Bayou Drain and Hovey Lake to determine if simple changes to the timing of installing blocker boards can significantly reduce invasive carp recruitment within the lake. Seasonal variation may change the timing and quantity of YOY invasive carp attempting to enter the lake, so some amount of annual monitoring should occur. INDNR biologists should work closely with Hovey Lake property staff to monitor water levels and attempt to close the water control structure inlet before lake levels equalize with river level in an attempt to keep YOY out.

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Appendix A: Eastern Illinois University Final Report – 2023 Field Season Findings.

07/31/2024
Final Report
Evaluating Reproduction of Invasive Carps in the Wabash River
Prepared by: Daniel Roth and Carley Capon, Eastern Illinois University

Introduction

Silver Carp *Hypophthalmichthys molitrix* and Bighead Carp *H. nobilis*, or invasive carps hereafter, are fishes that are native to China and that have spread exponentially throughout the Mississippi River basin and surrounding systems. Invasive carps possess several traits that make them successful invaders, including high fecundity (Garvey et al. 2006) and high dispersal rates (DeGrandchamp et al. 2008), and they pose risks to native fishes through competitive dietary overlap (Irons et al. 2007; Chick et al. 2020). Thus, extensive effort has been put forth to prevent the spread of invasive carps into new systems, however population dynamics in smaller tributary systems are often overlooked. Past research from EIU has shown invasive carp reproduction in the Wabash River is unique to that of the Illinois (Roth et al. 2020, Schaick et al. 2020) with greater magnitude and frequency of larval production. This is likely due to the free-flowing hydrology of the system that consistently produces flow and temperature regimes necessary for successful spawning and larval development. This suggests the Wabash River basin is a significant source of recruits to the Ohio River Basin and beyond.

Identification of invasive carps spawning locations through early life stage sampling has the ability to enhance management efforts, such as coordinating harvest to areas with potential to serve as population sources (Lohmeyer and Garvey 2009; Hintz et al. 2017). Most invasive carp studies have focused on adult demographics and population dynamics (Williamson and Garvey 2005; Stuck et al. 2015; Chick et al. 2020); however, identifying the spatial and temporal dynamics of invasive carp early life stages provides critical information on spawning activity and offers insight into factors influencing subsequent recruitment to the population. Reproduction of invasive carps and, in turn, larval fish density are variable among years and usually tied to interannual variability of hydrological and environmental factors (e.g., discharge and water temperature) in large rivers (DeGrandchamp et al. 2007).

Although invasive carps early life stage dynamics have been investigated in mainstem large rivers throughout the Midwest, relatively few have investigated multiple gear types in tributary habitats (DeGrandchamp et al. 2007; Coulter et al. 2013; Deters et al. 2013). Additionally, contracted commercial harvest of invasive carps is most effective when implemented in areas where reproduction is occurring (i.e., reduce propagule pressure) and at the leading edge of populations to reduce challenges to barriers and potential range expansion (MacNamara et al. 2016; Coulter et al. 2018). Thus, identifying the zones of reproduction in variety of habitats such as tributaries will better inform control efforts that are focused on these invasive fishes.

This project focused on larvae and egg monitoring in the Wabash River and tributaries to delineate the reproductive range of invasive carps within this system. Previous work has shown population control via contract fishing pressure is only successful if recruitment sources and the leading edge of invasion are identified and exploited simultaneously (Coulter et al. 2018).

Objectives:

1. Monitor reproduction of invasive carps in the Wabash River and its tributaries using early life stage sampling.
2. Assist in the development of a standardized ichthyoplankton sampling protocol for the Ohio River Basin invasive carp sub-basin partnership.

Methods

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 were identified using genetic analysis. A handheld YSI multiparameter meter was used to record temperature (°C). River discharge data (m^3/s) from gauges nearest to sampling locations were obtained from United States Geological Survey.

Results

Effort and Total Catch

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 mainstem 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 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 mainstem 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. Additionally, 1,212 eggs had similar morphometry to invasive carp eggs but were smaller in diameter than average and were designated as ‘potential eggs’. A sub-sample of all eggs and larvae collected throughout the season were identified using genetic techniques and updated totals are reflected in Table 1.

Larval Results

Invasive carp larvae were found in all the tributaries except for the Embarrass River tributary site, and Vermilion River tributary site (not sampled). After receiving genetics results, the majority of larvae identified as *Hypophthalmichthys* spp. were confirmed as that genus. A total of 944 larvae were genetically identified as Grass Carp, *Ctenopharyngodon Idella,* and thus were removed from totals in Table 1. Genetic analysis also detected one Black Carp larvae, *Mylopharyngodon piceus,* captured in the Wabash River near New Haven, IL. This fish was detected in a relatively large sample (n = 268), of which 27 larvae were sent in for genetic confirmation. Out of the subsample 14 individuals came back as

Grass Carp, 12 as Silver Carp, and one as Black Carp. Further screening of this sample using genetic techniques will be important to detect any further Black Carp reproduction near that location. The majority of Grass Carp larvae were collected in the Little Wabash River and adjacent mainstem, as well as the Wabash River mainstem near the Embarras River confluence. In all cases where Grass Carp were collected, *Hypophthalmichthys* spp. larvae were also collected simultaneously. The Little Wabash River and adjacent mainstem Wabash River sites produced the greatest density of invasive carp larvae throughout the sampling season (Table 1.) Peaks in larval density generally coincided with rapid rises in discharge in the tributary site and/or adjacent mainstem Wabash River sites (Figure 1.) 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 1.). 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 2.) 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.

Egg Results

All sites except for the Embarras River tributary had visually identified *Hypophthalmichthys* eggs found in the samples. After receiving genetic results, nearly all of the 1,212 suspected invasive carp eggs were identified as Freshwater Drum, *Aplodinotus grunniens.* These eggs were morphologically similar to invasive carp eggs but had diameters that were relatively smaller (~2-3mm) than typical invasive carp eggs. Three samples of suspected invasive carp eggs were confirmed as genus *Hypophthalmichthys* and were added to total invasive carp egg counts in Table 1. The remaining carp eggs that we confidently identified as invasive carp eggs visually were confirmed based on genetic subsamples. 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 (Table 1.).

Discussion

Our observed results for 2023 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 young-of-year 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 young-of-year within the basin. The detection of a Black Carp larvae in the lower Wabash River represents the furthest upstream location in the Ohio River basin where this species has been detected as young-of-year, but previous sampling has focused on juvenile detection (2023 Early Life Stages Technical Report). Low numbers of adult Black Carp have been detected near New Haven the Lower Wabash River, very close to the site where the single larva was collected (NAS Database, USGS). Further screening of our samples collected in 2023 and in the future will be important for further detection of Black Carp in 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. Our results showed invasive carp reproduction was higher in the Wabash River Basin compared to the rest of the Ohio River Basin sampled in 2023 (2023 Early Life Stages Technical Report). This could be due to precipitation and discharge patterns that were more suitable for invasive carp reproduction in the Wabash River relative to the Ohio River. This could also be due to the Wabash River's unique hydrology, with most of it being free flowing. The smaller watershed and flashiness of the river relative to the greater Ohio River basin likely allows for successful invasive carp in greater frequency and duration.

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 discharges 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.

Table 1. 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)
Vermilion	Wabash Upstream	3	1	321
Vermilion	Wabash Downstream	3	0	316
White	Wabash Upstream	15	7	87
White	Wabash Downstream	12	4	118
White	Tributary	15	3	65
Embarras	Wabash Upstream	12	42	70
Embarras	Wabash Downstream	12	3	30
Embarras	Tributary	12	0	0
Little Wabash	Wabash Upstream	9	292	6
Little Wabash	Wabash Downstream	9	807	3
Little Wabash	Tributary	9	512	2
Totals		**111**	**1671**	**1018**

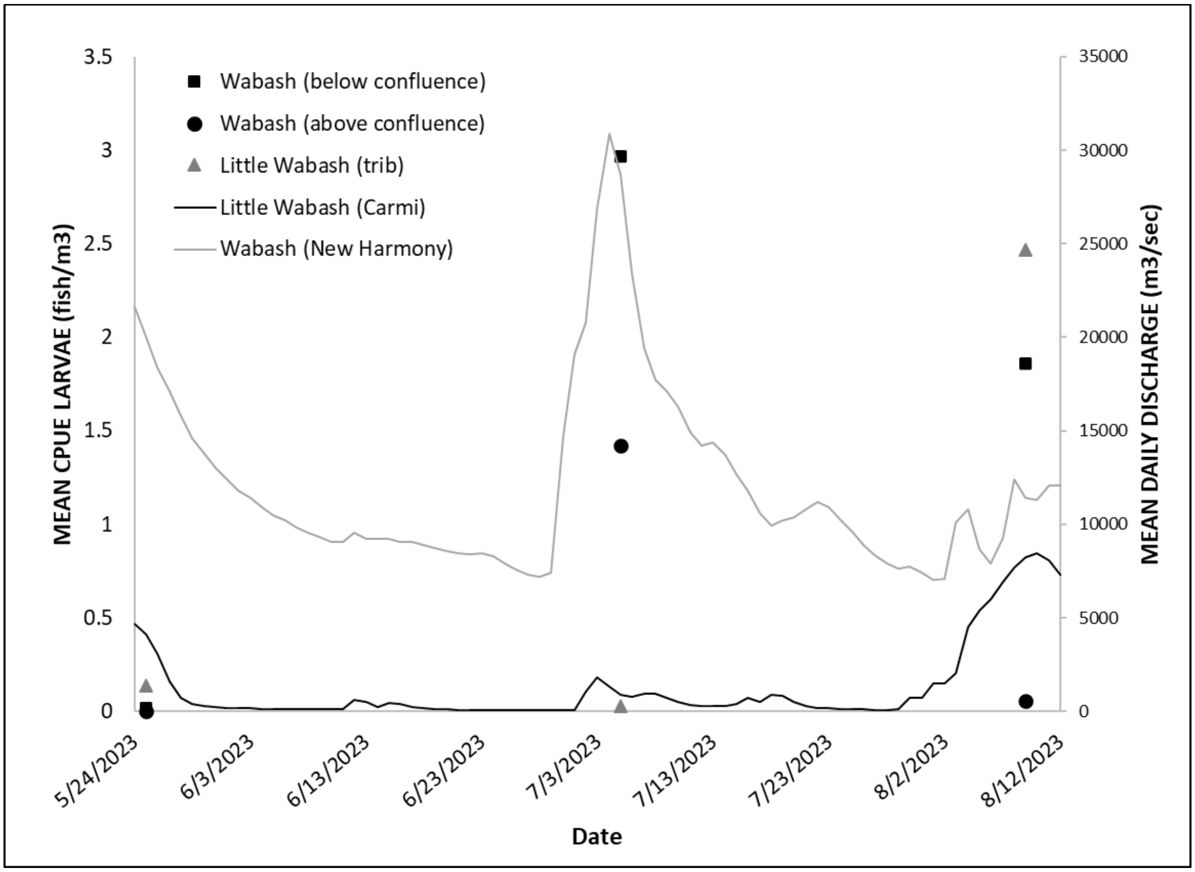

Figure 1. Catch per unit effort (fish/m^3 H2O filtered) of invasive carp larvae collected in the Little Wabash River (tributary site, grey triangles), and the Wabash River above (black circles) and below (black squares) the confluence of the tributary from May 25th to August 9th, 2023. Mean daily discharge (m^3/sec) is shown on secondary y-axis for the Little Wabash at Carmi (grey line), and Wabash River at New Harmony (black line).

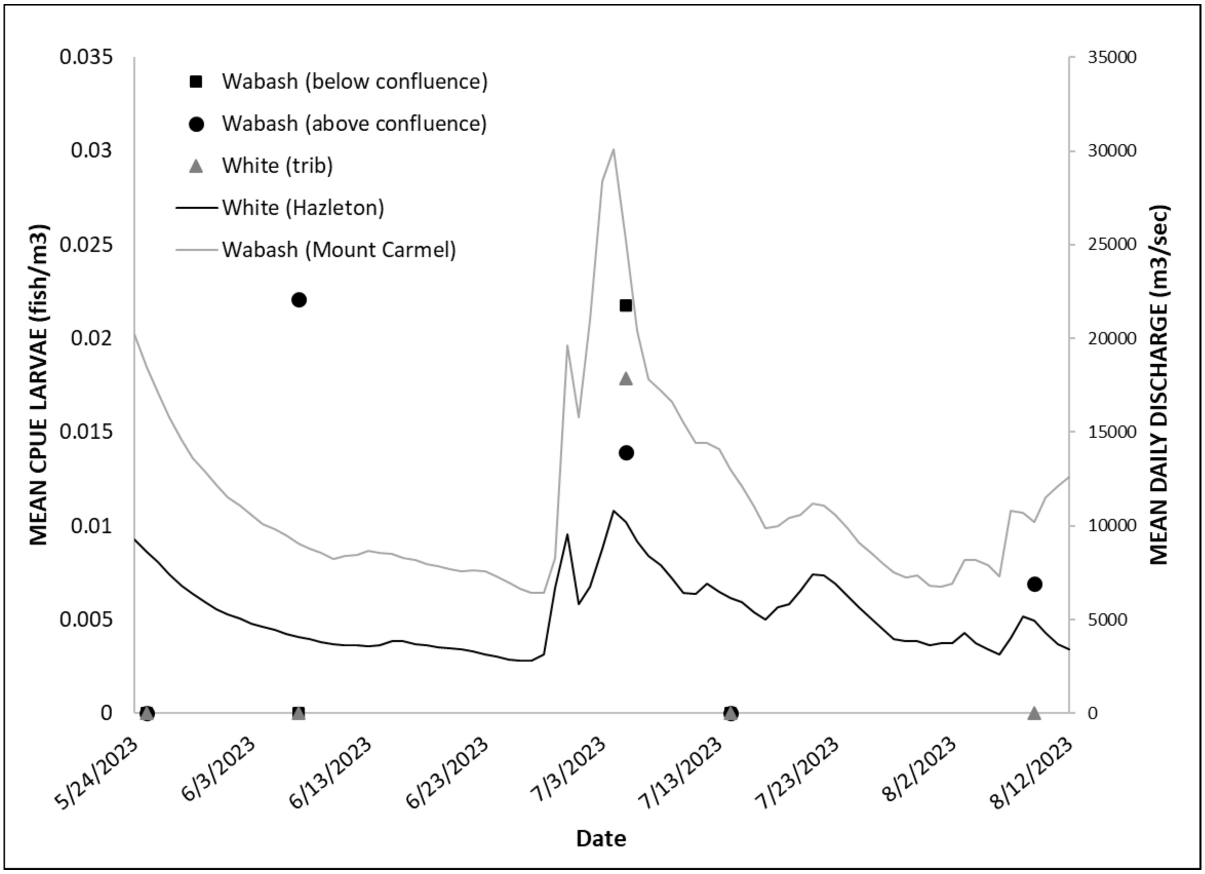

Figure 2. Catch per unit effort (fish/m^3 H_2O filtered) of invasive carp larvae collected in the White River (tributary site, grey triangles), and the Wabash River above (black circles) and below (black squares) the confluence of the tributary from May 25th to August 9th, 2023. Mean daily discharge (m^3/sec) is shown on secondary y-axis for the White River at Hazleton (grey line), and Wabash River at Mount Carmel (black line).

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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 Cincinnati, Ohio. 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) Quantify movement probabilities among navigation pools within the Ohio River, between the Wabash and Ohio rivers, and between the Wabash and White rivers.
2) Understand movements among tributary and mainstem habitats within the Ohio River basin in response to environmental conditions and commercial harvest.
3) 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:

- Five-hundred, seventy-two Silver Carps were tagged during 2024 in the mainstem Ohio River (n = 502; J.T. Myers – McAlpine pools) and the Wabash River (n = 70).
- During the course of this study, ~77% of Silver Carps have inhabited tributaries compared with ~55% of Silver Carps detected in mainstem habitats.
- Estimated mean monthly 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.
- Historical analysis of receiver data for tagged Silver Carps in the Wabash suggests that detection probability of tagged fish is > 80% with > 97% annual survival.
- Active tracking of Silver Carps in the Wabash River showed that habitat selection is not sex-specific indicating that targeted harvest will likely have similar effects on sex ratios.

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, multiple receivers were deployed from the mouth to several miles 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 2024, 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 chambers 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 2023 – July 2024, 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) and included receivers in portions of the Wabash, Tennessee, and Cumberland rivers (Figure 1). During non-winter months, detection data were downloaded from receivers bi-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).

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 2024, detection data prior to January 2014 were omitted. Encounter histories were constructed for each individual by determining the pool within which an individual was detected most during each month (January 2014 – July 2024). 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 127 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, therefore, fixed to 0. Due to the small number of fish tagged (n = 46) and tags currently active in the Ohio River (n = 1), Bighead Carps were not included in these analyses.

To examine the effects of environmental conditions on the survival, detection, and transition probabilities of Silver Carps in the Ohio River, daily water temperature 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, 2024. Because the focus of this analysis was on transitions among spatial states, only data from mainstem and Wabash River gage stations were used. Because gage data were not available for the Tennessee and Cumberland rivers, the gage data from Olmsted Pool were used for these areas. 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.

In addition, headwater and tailwater gage heights were provided by the U.S. Army Corps of Engineers to estimate the number of open river days at each Lock and Dam throughout the study period. Open river days were defined as those days that had a mean head height ≤1.5m (Fritts et al. 2024) To calculate mean head height, 30-60 min measurements of tailwater gage height were subtracted from headwater gage heights and used to calculate a daily mean head height. The number of days within each month for which mean head height was ≤1.5m were then summed to determine the number of open river days at each L&D.

These time series of temperature, gage height, and open river days as well as the encounter histories of individual Silver Carps were used to inform transition, survival, and detection probability 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, and mean temperature 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 median 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, standardized median gage height, monthly open river days, and pool on transition probabilities (Table 4). Models that did not converge are not presented in model selection tables. 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: During 2024, 18 receivers (Innovasea VR2Tx) were deployed in the Wabash River, and an additional two were deployed in the White River. These 20 receivers added to the existing network of 28 and 10 receivers in the Wabash and White Rivers, respectively (Figure 2). During 2024, only 7 receivers were recovered during July; the remainder were buried under the substrate or inaccessible to boats, despite changes to deployments by attaching them to river shoreline with cables. Low water during summer and fall 2024 made retrievals challenging.

Acoustic Transmitter Tagging: Tagging of invasive carps in the Wabash River follows the methods for the Ohio River, above. A total of 537 Silver Carp have been tagged since 2021 at multiple locations in the Wabash River. Tagging during 2024 was delayed by low water levels during spring and summer. EIU assisted in tagging efforts alongside SIU during fall 2024. Twenty tags were implanted in Silver Carp in Vincennes, IN on 11/18/24 and 50 tags were placed in Silver Carp in Terre Haute, IN on 11/19/24 for a total of 70 silver carp tagged in the Wabash River (Figure 3). An analysis of historical data from 2011-2018 for Silver Carp tagged in the Wabash River was conducted to determine the survival and detection probabilities. Detection and survival probabilities were determined using a longitudinal Cormack-Jolly-Seber model of acoustically tagged adult Silver Carp during 2011 through 2018 in both rivers, which is a unique approach only possible with long-term data from individual fishes.

Active Tracking for Habitat Use: Fine-scale habitat selection by tagged adult Silver Carps was assessed by EIU throughout the Wabash and White Rivers during 2021-2024. 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 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 macro-habitat type (channel border open, inside river bend, outside river bend) and micro-habitat type (log jam, rip-rap, run, thalweg) were recorded at each fish's location.

Beginning in May 2024, the invasive carp active tracking project was taken over by a new EIU graduate student. In the same month, macro-tracks were conducted on the Wabash and White rivers with one fish detected between the 40 combined river miles covered. During June 2024, an extended macro-track was conducted over 240 river miles, targeting the entire sampled reach of the Wabash River to determine the locations of tagged fish. Six individuals with tags belonging to SIUC were detected during this track, all located between Mt. Carmel, IL and New Harmony, IN. Micro-tracking was attempted at New Harmony during July 2024 but had to be cut short due to inclement weather. A macro-track of the upper reach of the White River was also attempted but also had to be cut short for the same reason, in addition to boat failure. During August another micro-track was conducted. It was determined that hour-to-hour assessment of movement between habitats (re-detection) is unfeasible due to logistical constraints (amount of distance that can be covered in the allotted time and variability in detection rates). Therefore, micro-track techniques will be refined to better assess fine-scale movements throughout the course of the day. Current plans for these refinements are to conduct future micro-track field tests that split reach runs into 3 time-of-day categories (morning, mid-day, evening), then re-tracked at each time category of the same day.

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). Water samples were collected at all 22 sites during May 2024 to determine the presence of invasive carp eDNA. Because movement data collected during 2023 suggested late summer movements of invasive carps in the mainstem of the Eel River, ten mainstem sites in the Eel River were resampled for the presence of invasive carp eDNA during August 2024. In addition, the movement of invasive carps in the mainstem Eel River was tracked using a network of six antenna arrays installed from RM 36.5 to RM 75 that can detect Passive Integrated Transponder (PIT) tags and eight VR2TW and VR2Tx receivers installed from RM 1 to RM 75 that can detect acoustic tags. Active tracking of fish implanted with acoustic tags was conducted the entire length of the Eel River (RM 75 to RM 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 during 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 were collected from May 2022 through 18 December 2024, but all 12 receivers remain operational.

Agency-Specific Accomplishments

Kentucky Department of Fish & Wildlife Resources (KDFWR)

During 2024, KDFWR maintained and offloaded 20+ tributary and mainstem receivers located in the upper Cannelton, McAlpine, and lower Markland pools. KDFWR also worked with other project partners to offload another 15+ receivers located in the furthest downstream pools

(Olmsted, Smithland and J.T. Myers) of the Ohio River. Field staff continued to assist the USFWS with tagging additional Silver Carp in the McAlpine and Cannelton pools to replace expired and/or harvested transmitters. KDFWR also established new stationary receiver sites (n = 7) in the upstream areas of the Kentucky (McAlpine Pool) and Salt (Cannelton Pool) rivers, which are located up to 60 miles above the existing sites near the mouths of each tributary. These new receivers will help determine if tagged carp have begun to occupy the upper reaches of tributaries that directly connect the Ohio River to valuable aquatic resources within Kentucky.

KDFWR continued to manage all data that project partners collected over the course of this reporting period. These efforts included the intensive processing of receiver data from 170+ sites in the Ohio River basin that was ultimately imported into the project's primary database (PostgreSQL), which consisted of more than 100M detection records through the end of 2024. KDFWR also maintained and updated multiple tables containing information on the project's tagged fish, stationary receiver sites, harvested tag reports and daily receiver histories. Additionally, KDFWR managed a second pgSQL database of environmental data that was collected from throughout the Ohio River Basin. Sources of this data included 60+ USGS gage stations and over a dozen temperature loggers that were deployed in conjunction with stationary receiver sites in the lower Cannelton Pool. Lastly, KDFWR compiled multiple data summaries and tables that were shared with all project partners and ultimately used to conduct most of the modelling/analysis efforts in this report.

Indiana Department of Natural Resources (INDNR)

INDNR subcontracted with ECI to complete work in the upper Wabash River evaluating movements of invasive carps in response to a dam removal. As part of this project, INDNR conducted a tagging event on the upper Wabash River during May 2024 and implanted 50 Silver Carp with acoustic transmitters. INDNR also regularly downloaded data from receivers in J.T. Myers and Newburgh pools including J.T. Myers, Newburgh, and Cannelton lock and dams. There data were sent to KDFWR for processing.

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 2024. 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. All data were sent to KDFWR for processing and reporting. To ensure that tagged fish were present in these areas and to determine the likelihood that translocated fish would move back upstream, WVDNR collaborated with USFWS-LGL FWCO to tag seven bigheaded carps in the old lock chambers of R.C. Byrd L&D and Raccoon Creek. Three of these fish were translocated downstream of R.C. Byrd L&D to examine dam passage by translocated fish.

U.S. Fish and Wildlife (USFWS)

During 2024, USFWS, Carterville FWCO (with assistance from state and federal partners, tagged a total of 502 Silver Carps in J.T. Myers (n = 100), Newburgh (n = 92), Cannelton (n = 200), and McAlpine (n = 110) 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 27 VR2Tx receivers (16 at locks and dams and 11 within either mainstem or tributary locations) in R.C. Byrd, Racine, Belleville, and Willow Island pools. The substation took over the maintenance of this portion of the Ohio River Basin VR2 array from WVDNR during late fall 2022.

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

Southern Illinois University maintained 40 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 70 invasive carps occurred in the Wabash River during November 2024.

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 2024 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 2024, 194 receivers were deployed from Olmsted Pool (including the lower Tennessee and Cumberland rivers and the Wabash River) to Willow Island L&D. Of these, 46 were deployed at L&Ds, 32 at mainstem sites, and 116 at tributary sites (Figure 1, Table 5).

Fish Tagging Efforts: As of July 2024, 2057 invasive carps (2011 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 6). Of the 2011 tagged carps, 45 Silver Carps have been harvested during the study (June 2013 – July 2024). One-hundred eighteen Silver Carps had tags that were expected to expire during 2024 (Table 6). To replace these tags and meet the needs of partner agencies, including expanding tagging in the lower Cannelton Pool to examine the effects of environmental conditions and commercial harvest on fish movements and residency, 502 Silver Carps were tagged in J.T. Myers (n = 100), Newburgh (n = 92), Cannelton (n = 200), and McAlpine (n = 110) pools. No Bighead Carps were tagged during 2024 due to a lack of availability.

Fish Detections: During 2024, there were 1521 tags deployed in invasive carps (1520 Silver Carps and 1 Bighead Carp) expected to be active in the Ohio River. Of these, 911 Silver Carps 543 (~60%) were detected. In addition, 58 invasive carps (54 Silver Carps and 4 Bighead Carps) whose tags were beyond their expected life were also detected on the Ohio River receiver array.

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 634.9 km for Silver Carps and from 0.0 km to 92.9 km for Bighead Carps during August 2023 – July 2024. The longest net movement by a Silver Carp was completed by a male fish travelling from McAlpine Pool to the Lower Tennessee River during August – December 2023. In contrast, the longest net movement by a Bighead Carp occurred during October 2023 – May 2024 and was completed by a male fish that moved within Meldahl Pool. Long-distance movements are relatively rare for Silver Carp; ~85% of Silver Carp had a maximum distance travelled of < 30 km during August 2023 – July 2024. In contrast, 60% 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.

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 June 2013 – July 2024 focused only on J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, and Meldahl pools. In these pools, net movements are typically shortest during December – March and peak during April – August regardless of species or pool (Figures 4 and 5). For Silver Carp, mean monthly net movements in Markland and Meldahl pools are typically longer than those in lower pools (Figure 5). In addition, a larger proportion of tagged Silver Carp had longer annual net movements in the upper pools examined (e.g., Markland and Meldahl pools) relative to the lower pools (e.g., J.T. Myers and Newburgh pools; Figure 6).

Dam Passage: Throughout the duration of this study (June 2013 – July 2024), there have been 1316 dam passage events (458 upstream and 858 downstream passages) (Figure 7). Dam passages were completed by 392 Silver Carps and 13 Bighead Carps. Of the upstream passages, 20 (4.4%) were completed by seven Bighead Carps. Four-hundred thirty-eight upstream passages (95.6%) were completed by 190 Silver Carps. Thirty downstream passages (3.5%) were completed by 11 Bighead Carps, whereas 828 (96.5%) were completed by 190 Silver Carps. Additionally, in only 324 of the 1316 dam passages (24.6%) was the fish detected within the lock chamber, suggesting a high prevalence of passages through the dam gates. Of these 324 dam passages, 250 were in the downstream direction, whereas 74 were in the upstream direction. Downstream passages through the lock chambers occurred at Greenup, McAlpine, Cannelton, Newburgh, J.T. Myers, Smithland, and Barkley (TNCR; Olmsted Pool) L&Ds during 2017-2024. Upstream passages through lock chambers occurred at R.C. Byrd, Greenup, Meldahl, Cannelton, Newburgh, J.T. Myers, Smithland and Barkley L&Ds. All dam passages through lock chambers occurred during 2017-2024.

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 are unlikely to be detected in the vicinity of the dam, making it more challenging to understand pool-to-pool movements.

Tributary Use: Throughout the study period, ~77% of detected Silver Carps have been detected in tributaries of the Ohio River whereas, only ~55% 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 = 38.6 ± 1.1 days) there than in mainstem habitats (14.1 ± 0.6 days; Figure 9).

With the exception of J.T. Myers Pool, there is at least one tributary within each pool examined (J.T. Myers – Meldahl) that was visited by ≥25% of Silver Carps detected within that pool (Figure 10). In Newburgh Pool, only one tributary met this criterion, Little Pigeon Creek (54%). In Meldahl Pool, two tributaries, Ohio Brush Creek (81%) and the Scioto River (35%) exceeded this 25% threshold. McAlpine and Markland pools each contained three tributaries that were inhabited by ≥25% of tagged Silver Carps, Indian-Kentuck Creek (50%), the Little Kentucky River (39%) and the Kentucky River (71%) in McAlpine Pool and Big Bone Creek (27%), Laughery Creek (75%), and Hogan Creek (39%) in Markland Pool. Lastly, there were five tributaries in Cannelton Pool that were inhabited by ≥25% of tagged Silver Carps, Deer Creek (32%), Sinking Creek (35%), Oil Creek (33%), the Little Blue River (26%), and the Salt River (36%; 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 (Dec – March) and lowest during April – June (Figure 11). Estimated mean survival probability was, however, high (0.96 – >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 typically 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 the Greenup Pool and the Wabash River remain low, despite these areas having a similar number of receivers than some other pools with high detection probabilities (Figure 13). These differences likely reflect either a small number of tagged fish (Greenup Pool) or poor receiver recovery rates (Wabash River). In addition, although most pools show changes in detection probabilities that are highly correlated with the number of receivers recovered, Meldahl Pool shows a consistently high detection probability despite a reduction in the number of receivers recovered (Figure 13). This result suggests that there are potential efficiencies to be gained with strategic receiver placement throughout the Ohio River Basin.

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 (Figure 14). Interestingly, transition probabilities from the Wabash River to the Smithland Pool and from the TNCR to the Olmsted Pool were consistently higher than those from the mainstem Ohio River. Although these results support the idea that these tributaries may act as source populations to the Ohio River Silver Carp population, it is important to note that movements from the Ohio River to these tributaries may be underestimated because there has been no tagging effort in either Smithland or Olmsted pools.

Within the mainstem Ohio River, 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 tended to higher in the downstream direction than in the upstream direction (Figure 14).

Wabash River

Fish Movement: The 2024 receivers detected between 36 and 80 unique tagged carp and had a range of 788 to 13,922 detections per receiver (Table 7). The most unique fish were detected in the upper river near Darwin, IL, and the fewest unique fish were detected at St. Francisville. The total number of detections was highly variable across our receivers, but SIU has not yet filtered these detections to remove possible dead fish or expelled tags from the record. The Wabash and White Rivers have presented unique challenges to passive telemetry. Under normal conditions water levels fluctuate rapidly, and the river carries a high sediment load, as well as other hazards such as downed trees. In 2024 the Wabash and White Rivers experienced a record drought, dropping water levels and making the river inaccessible for much of the summer. For these reasons, recovery of receivers has been limited to when ramps and river channels are deep enough for boat access, and even then, it is only possible if the receiver anchors have not been buried by sand and/or logs.

In 2025, SIU will continue to modify the deployment of receivers to improve the recovery rate. These modifications include tree set deployment, where the free end of the cable is attached to a tree on the bank. Tree set deployment began in 2024 and has thus far improved our ability to relocate and recover receivers, with all recovered receivers being a tree set, and one additional tree set receiver was successfully recovered in February 2025 (data not included in this report). For 2025 deployments, SIU is fabricating a new anchor design based on the recommendations of colleagues at Kentucky Fish and Wildlife, which has had success in similarly flashy and silty rivers. Finally, SIU is requesting permission from Indiana Department of Transportation to mount a bridge set receiver on the New Harmony Bridge in New Harmony, Indiana. Bridge sets are highly recoverable (Carlson et al., 2023), and this will provide consistent coverage of this section of the Wabash River.

The historical analysis of survival and detection of silver carp is in press in *Management of Biological Invasions*. Proportion detection probability of individuals was consistently > 0.8 among years. Survivorship analysis translated to annual mortality (mean + 95% confidence interval) for the tagged Silver Carp in the Wabash River being 0.03±0.02 across all years. Tagging is a robust method for tracking the survival of silver carp in the Wabash River and should be sensitive to harvest removal efforts.

Fine-Scale Habitat Selection (Eastern Illinois University):

Data (2021-2024) were analyzed for habitat (macro and micro) usage by sex (131 F, 294 M). Because of the uneven sex distribution, female and male carp were first analyzed separately. For each sex, the number of individuals at each category for macro and micro habitats were divided by the total number of individuals of that sex and converted into a percentage (Table 8). By calculating a percentage, data were standardized to allow for direct comparisons between sexes and bar plots were used to visualize distribution of habitat categories (Figure 15). Macro-habitat distributions by sex were very similar across categories, where outside bends are utilized most heavily, followed by channel border open, then inside bend, with the fewest detections in tributaries. However, it is important to note that access to tributaries by boat is dependent on water level. Slight differences were observed across micro-habitats. Males seem to utilize logjams at a higher rate than females (40% and 28%, respectively) who select run (29% F, 22% M) or thalweg (22% F, 16% M) habitats more frequently than males. Both male and female silver carp utilized riprap at the same rate (21%). Overall similarity between sexes is consistent with the results found by Prechtel et al (2018) for reaches of the Wabash River upstream of our sample sites.

Logistic regression was used to determine probability of use for macro and micro habitats depending on 2 hydrological parameters: temperature and percent maximum discharge using data for all fish detected by EIU during 2021-2023. For each model, macro and micro habitat categories were analyzed as a function of each hydrological category independently. Models were combined into probability of use plots including all macro (Figure 16) and micro (SIU Figure 17) categories for each hydrological parameter. For temperature, the outside bend macro-habitat maintained the highest probability of use regardless of temperature, while channel border open macro-habitat use increased at higher temperatures and inside bend macro-habitat decreased at higher temperatures. With micro-habitats, logjams had the highest probability of use at low temperatures, however all categories approached similar use as temperature increased. At the highest temperatures, riprap becomes the most used micro-habitat by a small margin. For discharge, outside bend macro-habitat maintained the highest probability of use regardless of discharge, while inside bend macro-habitat maintained the lowest usage regardless of discharge. At lower discharge, probability of use for channel border open macro-habitat was marginally higher than the inside bend but decreased with increasing discharge to the same probability of use as inside bend macro-habitat. With micro-habitat use, all categories are similar at low discharge with thalweg and riprap micro-habitat being slightly higher, however these two categories decline to near zero at high discharge. Conversely, thalweg and run micro-habitat use probability increases at higher discharge. At high discharge, logjams show the highest probability of use. It is important to recognize the co-occurrence of these hydrological variables when predicting habitat use of silver carp in that cooler, swifter water and warmer, slower water are associated with temporal variation in the Wabash River. The preference for logjams and run habitat at low temperatures and high discharge may allow for predictability of movement during the spring, while the similarity in probability of micro-habitats in higher temperatures and lower discharge may cause decreased predictability of movement during the late summer and early fall. It is also notable that in low water, characteristic of the Wabash in the late summer and early fall, logjam micro-habitats, while preferred in the spring, are frequently dried up on the banks where they cannot be used as habitat structures. During this time, the best predictor of habitat selection by silver carp is macro-habitat, as models indicate the highest probability of use for outside bend macro-habitat regardless of temperature or discharge. The implications of these data are useful in efforts to improve the harvest of invasive silver carp by targeting areas likely to be inhabited in higher densities.

Predictability in habitat selection by silver carp, and potential variability in behavior by sex, is important to understanding their dynamics as invaders of riverine ecosystems. Further, it enhances our ability to orchestrate more effective targeted removal efforts. Active tracking of fine-scale habitat movement has allowed for the collection of data to support such efforts. Future endeavors by EIU aim to further refine predictability by time of day through micro-tracking efforts. Through this research, we seek to provide managers throughout the Ohio River basin with the information needed to maximize harvest of these deleterious fish.

Invasive carp movement and distribution following dam removal

Results from the Eel River Basin in 2024 showed IBI scores ranged from “Very Poor” to “Good” in Eel River tributaries and “Fair” to “Excellent” in the mainstem Eel River. The initial eDNA samples that were collected during late spring 2024 detected Grass Carp DNA in 33% of replicates at RM 1 (Logansport) of the Eel River. Silver Carp DNA was detected in 33% of replicates at RM 36.3 (Below Stockdale Dam) of the Eel River (Table 9). Supplemental eDNA sampling, collected during late summer 2024, found Grass Carp DNA in 33% of replicates at RM 1 (Logansport) of the Eel River (Table 10). No Silver Carp or Bighead Carp DNA was detected in the supplemental sampling. In addition, Grass Carp were captured at River Mile (RM) 7.4 and RM 1 (Logansport) of the Eel River. No Silver Carp or Bighead Carp were captured during electrofishing surveys in 2024.

A total of 94 Silver Carp were detected by acoustic receivers installed in the Wabash River, Tippecanoe River, Eel River, and Mississinewa River. No Silver Carp have been detected near the confluence of Salamonie River and Wabash River or in the Salamonie River mainstem to date. Fish detected were tagged during eleven separate tagging events including multiple Silver Carp tagged in the Cumberland River, near Cheatham Dam (Table 11). There were also 17 Silver Carp detected in the Upper Wabash River that were tagged in the Lower Wabash River near the towns of Hutsonville, Illinois, Merom, Indiana, and New Harmony, Indiana. The fish tagged at these locations were detected at the most downstream receiver in the array in the Wabash River downstream of the confluence with the Tippecanoe River.

There were a total of 12,536 detections of Silver Carp during 2022, 14,878 detections during 2023, and 12,496 detections during 2024. A single receiver installed in the Wabash River upstream of the confluence with the Eel River accounted for 46%, 62%, and 36% of detections in in 2022, 2023, and 2024, respectively with the majority of those detections occurring during fall and winter each year (Figure 18). Silver Carp movement in the Upper Wabash River Basin was found to be seasonally dependent with fish undertaking longer distance upstream migrations during spring and, to a lesser extent, the summer and shorter distance downstream migrations during fall and winter (Figure 19). A total of 31 Silver Carp were detected during 2022, 54 during 2023, and 66 during 2024. The receivers in the Wabash River upstream and downstream of the confluence with the Tippecanoe River and within the mainstem of the Tippecanoe River had the highest number of Silver Carp detected of any receivers during 2023 and 2024. This was especially pronounced during spring (Figure 20). Seasonal changes in the number of Silver Carp detected on the receiver array were not as pronounced further up the Upper Wabash River, but the receiver in the Wabash River downstream of the confluence with the Mississinewa River showed a similar trend as the receivers in and around the Tippecanoe River where the number of

Silver Carp detected was highest during spring and decreased in each subsequent season during 2024.

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 56 receivers deployed in the Wabash River. However, low waters and siltation has resulted in difficulties retrieving these receivers, especially in summer 2024. 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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Tables and Figures

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
03399800	Olmsted	X	
03611000	Olmsted	X	
03612600	Olmsted	X	X
03381700	Smithland	X	
03377500	Wabash	X	
03378500	Wabash	X	X
03304300	J.T. Myers	X	
03322000	J.T. Myers	X	
03322190	J.T. Myers	X	
03322420	J.T. Myers	X	
03303280	Newburgh	X	X
03294500	Cannelton	X	
03294600	Cannelton	X	
03292494	McAlpine	X	X
03293551	McAlpine	X	
03255000	Markland	X	
03217200	Meldahl	X	
03206000	Greenup	X	
03216000	Greenup	X	
03201500	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
$S(month)p(pool)\psi(pool)$	46	166678.8	0	1
$S(temp)p(pool)\psi(pool)$	36	166719.3	44.6	0
$S(.)p(pool)\psi(pool)$	35	166745.0	70.2	0
$S(season)p(pool)\psi(pool)$	38	166767.2	92.4	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), median standardized gage height (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)ψ(pool)	47	162221.6	0	1
S(month)p(rprm)ψ(pool)	36	164688.9	2467.3	0
*S(month)p(pool*month)ψ(pool)*	178	165214.4	2992.8	0
S(month)p(pool season)ψ(pool)*	82	165529.3	3307.7	0
S(month)p(pool + month)ψ(pool)	57	165560.6	3338.9	0
S(month)p(pool + season)ψ(pool)	49	165977.2	3755.6	0
S(month)p(num_rec)ψ(pool)	36	166388.8	4167.2	0
S(month)p(pool)ψ(pool)	46	166674.8	4453.2	0
S(month)p(pool + height)ψ(pool)	47	166676.8	4455.2	0
S(month)p(month)ψ(pool)	46	171886.7	9665.1	0
S(month)p(season)ψ(pool)	38	172225.2	10003.6	0
S(month)p(.)ψ(pool)	35	172864.2	10642.6	0
S(month)p(height)ψ(pool)	36	172866.3	10644.6	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 median standardized gage height (height), month, the number of open river days per month (ord), and pool. The model structures for survival (*S*) and detection (*p*) probabilities were held constant and included only a month effect for *S* and the additive effect of pool and number of receivers (num_rec) for *p*.

Model	npar	AIC_c	ΔAIC_c	W_i
$S(month)p(pool + num\_rec)\psi(pool + month)$	59	162156.8	0	1
$S(month)p(pool + num\_rec)\psi(pool + height)$	48	162188.8	32.0	0
$S(month)p(pool + num\_rec)\psi(pool + ord)$	48	162216.2	59.4	0
$S(temp)p(pool + rprm)\psi(pool)$	47	162221.6	64.8	0

Table 5. Number and distribution of VR2 receivers in the Ohio River and three major tributaries, the Wabash River and the Tennessee/Cumberland rivers (TNCR), during 2024. One-hundred ninety-four receivers were deployed from Olmsted pool, downstream of the Smithland lock and dam, to Willow Island lock and dam.

Ohio River Pool/River	Pool/River Length (km)	Lock and Dam Receivers (N)	Mainstem Receivers (N)	Tributary Receivers (N)	Total Receivers (N)
Olmsted	73.9	3	2	0	5
TNCR	222.2	5	0	7	12
Smithland	116.7	4	0	0	4
Wabash	344.5	0	0	20	20
J.T. Myers	112.5	4	1	15	20
Newburgh	89.2	4	0	8	12
Cannelton	183.4	1	9	28	38
McAlpine	121.2	3	1	7	11
Markland	153.4	3	2	8	13
Meldahl	153.3	3	7	6	16
Greenup	99.5	3	3	4	10
R.C. Byrd	67.1	4	5	9	18
Racine	54.1	5	0	2	7
Belleville	67.9	3	2	2	7
Willow Island	56.8	1	0	0	1
Total	NA	46	32	116	194

Table 6. The number of Silver and Bighead Carps tagged with acoustic transmitters by year and pool during June 2013 – December 2024. 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 > 4 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	Species	Ohio River Pool								Total
			J.T. Myers	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup	R.C. Byrd	
2013-2018	Inactive	SVCP	-	-	182 (10)	226 (5)	49 (1)	34	-	-	491
		BHCP	-	-	4	6	11	21	-	3	45
2019	Active	SVCP	-	-	-	30	-	-	-	-	30
		BHCP	-	-	-	1	-	-	-	-	1
2020	Active	SVCP	-	-	-	100	18	-	-	-	118
2021	Active	SVCP	226 (1)	230	92 (5)	97 (2)	3	-	-	-	648
2022	Active	SVCP	(2)	(1)	109 (5)	-	29	-	-	-	138
2023	Active	SVCP	-	-	(7)	-	54(1)	30	-	-	84
2024	Active	SVCP	100	92 (1)	200 (4)	110 (2)	-	(1)	-	-	502
2019-2024	Active	SVCP	326	322	401	337	104	30	-	-	1,520
		BHCP	-	-	-	1	-	-	-	-	1
2013-2018 (Including harvested)	Inactive	SVCP	-	-	182	226	49	34	-	-	491
		BHCP	-	-	4	6	11	21	-	3	45
		Overall	-	-	186	232	60	55	-	3	533
% Species Composition	Active	SVCP	21.4	21.2	26.4	22.2	6.8	2.0	0	0	100
		BHCP	-	-	-	0.1	-	-	-	-	-
Mean TL (mm)	Combined	SVCP	706.7	714.4	787.7	817.8	893.8	949.0	-	-	811.6
		BHCP	-	-	1139.8	1146.3	1175.1	1153.6	-	1210	1165.0

Table 7. Summary of detections from the seven successfully recovered receivers in 2024.

Receiver	Unique fish detected	Total number of unfiltered detections	Location
VR2Tx-486769	41	12069	Hutsonville
VR2Tx-486794	75	13922	Terre Haute
VR2Tx-490845	62	12181	Fay's Landing
VR2Tx-490849	80	12301	Darwin
VR2Tx-125867	43	2713	Mt. Carmel
VR2Tx-138898	46	12918	Mt. Carmel
VR2Tx-138912	36	788	St. Francisville

Table 8. Percentages of fish detections by sex for macro-habitat, micro-habitat, and their respective categories.

Variable	Category	Males	Females
Macro-habitat	Channel Border Open	30%	31%
	Inside Bend	22%	22%
	Outside Bend	43%	40%
	Tributary	5%	7%
Micro-habitat	Run	22%	29%
	Logjam	40%	28%
	Thalweg	16%	22%
	Riprap	21%	21%

Table 9. Percent of replicates that were above detection limits for Bighead Carp, Silver Carp, and Grass Carp DNA at 24 sampled sites in the Eel River and the Wabash River in the spring 2024 sampling.

					Percent of Replicates that Detected DNA		
Site Type	Site Name	River Mile	Latitude	Longitude	Bighead Carp	Silver Carp	Grass Carp
Mainstem Eel River	Columbia City	RM 75	41.118	-85.499	0	0	0
	Collamer	RM 63.7	41.074	-85.664	0	0	0
	Liberty Mills	RM 57.3	41.038	-85.739	0	0	0
	North Manchester	RM 50.9	40.995	-85.781	0	0	0
	Above Stockdale Dam	RM 36.8	40.914	-85.941	0	0	0
	Below Stockdale Dam	RM 36.3	40.912	-85.951	0	33	0
	Mexico	RM 18.7	40.818	-86.108	0	0	0
	Hoover	RM 12.3	40.797	-86.198	0	0	0
	Adamsboro	RM 7.4	40.783	-86.264	0	0	0
	Logansport	RM 1	40.759	-86.364	0	0	33
Tributary of the Eel River	Geller Ditch		41.207	-85.429	0	0	0
	Johnson Ditch		41.245	-85.386	0	0	0
	Shoaff Ditch		41.206	-85.217	0	0	0
	Thorn Creek		41.162	-85.296	0	0	0
	Blue River		41.207	-85.235	0	0	0
	Beargrass Creek Upper		40.898	-85.753	0	0	0
	Beargrass Creek Lower		40.878	-85.966	0	0	0
	Squirrel Creek Upper		40.965	-85.94	0	0	0
	Squirrel Creek Lower		40.917	-85.939	0	0	0
	Pawpaw Creek Upper		40.932	-85.779	0	0	0
	Pawpaw Creek Lower		40.943	-85.89	0	0	0
	Weesau Creek		40.867	-86.086	0	0	0
Mainstem Wabash River	Downstream of Eel River	RM 352	40.747	-86.411	0	0	0
	Upstream of Eel River	RM 358	40.75	-86.301	0	0	0

Table 10. Percent of replicates that were above detection limits for Bighead Carp, Silver Carp, and Grass Carp DNA at 11 sampled sites in the Eel River and the Wabash River in the late summer 2024 sampling.

					Percent of Replicates that Detected DNA		
Site Type	Site Name	River Mile	Latitude	Longitude	Bighead Carp	Silver Carp	Grass Carp
Mainstem Eel River	Columbia City	RM 75	41.118	-85.499	0	0	0
	Collamer	RM 63.7	41.074	-85.664	0	0	0
	Liberty Mills	RM 57.3	41.038	-85.739	0	0	0
	North Manchester	RM 50.9	40.995	-85.781	0	0	0
	Above Stockdale Dam	RM 36.8	40.914	-85.941	0	0	0
	Below Stockdale Dam	RM 36.3	40.912	-85.951	0	0	0
	Mexico	RM 18.7	40.818	-86.108	0	0	0
	Hoover	RM 12.3	40.797	-86.198	0	0	0
	Adamsboro	RM 7.4	40.783	-86.264	0	0	0
	Logansport	RM 1	40.759	-86.364	0	0	33
Wabash River	Upstream of Eel River	RM 358	40.75	-86.301	100	100	0

Table 11. 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 Individuals Detected from Tagging Event
Wabash River	Lafayette	4/1/2011	2
Cumberland River	Cheatham Dam	3/2/2021	2
Wabash River	Above Lafayette	9/14/2021 and 9/15 2021	7
Wabash River	Hutsonville	11/1/2021 and 4/18/2022	8
Wabash River	Omer Cole Ramp	8/2/2022 and 8/3/2022	23
Wabash River	Lafayette	3/29/2023 and 3/30 2023	34
Eel River	Stockdale Dam	7/5/2023	1
Wabash River	Merom	11/1/2023	6
Wabash River	New Harmony	11/3/2023	3
Wabash River	Lafayette	5/8/2024	8

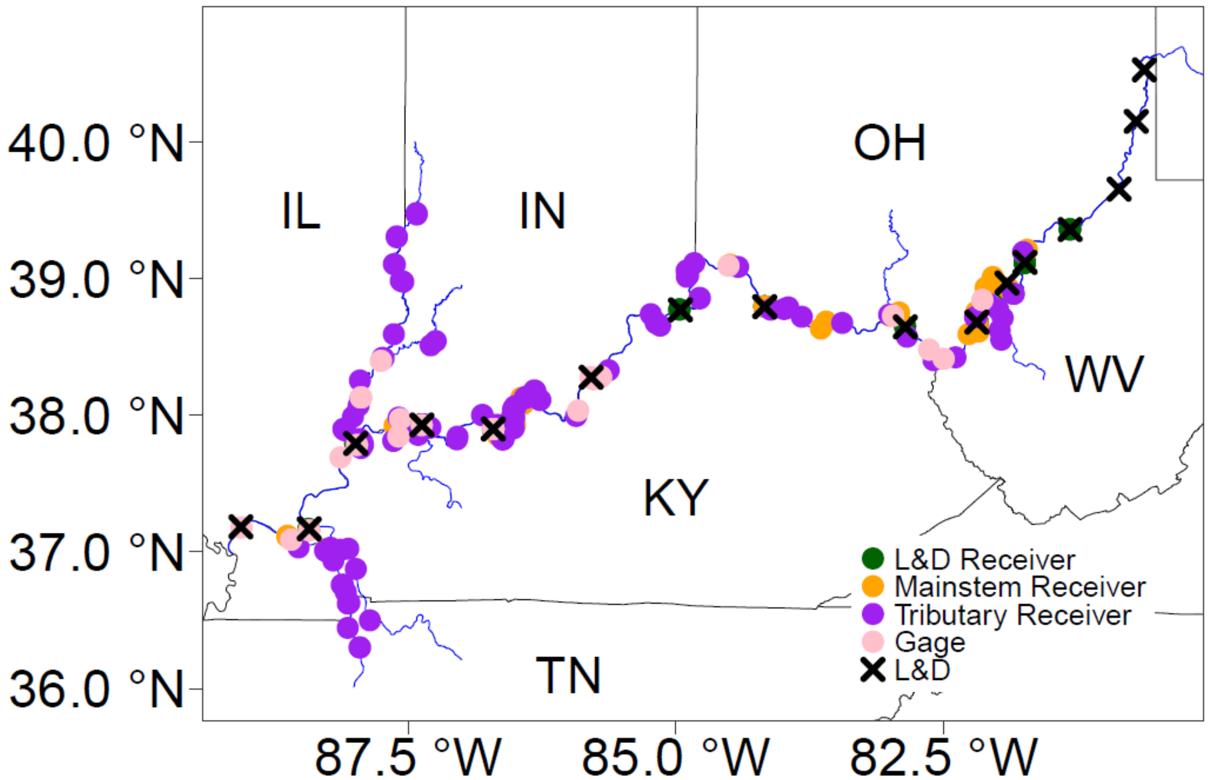

Figure 1. Locations of mainstem Ohio River Lock and Dam structures (L&D; black crosses), USGS gage stations (pink circles), and acoustic receivers deployed at L&D structures (green circles), in the mainstem (orange circles), and tributaries (purple circles) of the Ohio River during 2024. Map shows the Ohio River and some of its major tributaries (blue) from the confluence of the Ohio and Mississippi rivers in the west to the Pennsylvania border in the east. Receivers were deployed from Olmsted Pool, downstream of the Smithland L&D, to the Willow Island L&D. From west to east, the L&Ds are Olmsted, Smithland, J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, Meldahl, Greenup, R.C. Byrd, Racine, Belleville, Willow Island, Hannibal, Pike Island, and New Cumberland. Ohio River pools are named for the downstream L&D (e.g., Olmsted Pool begins at Olmsted L&D and ends at Smithland L&D).

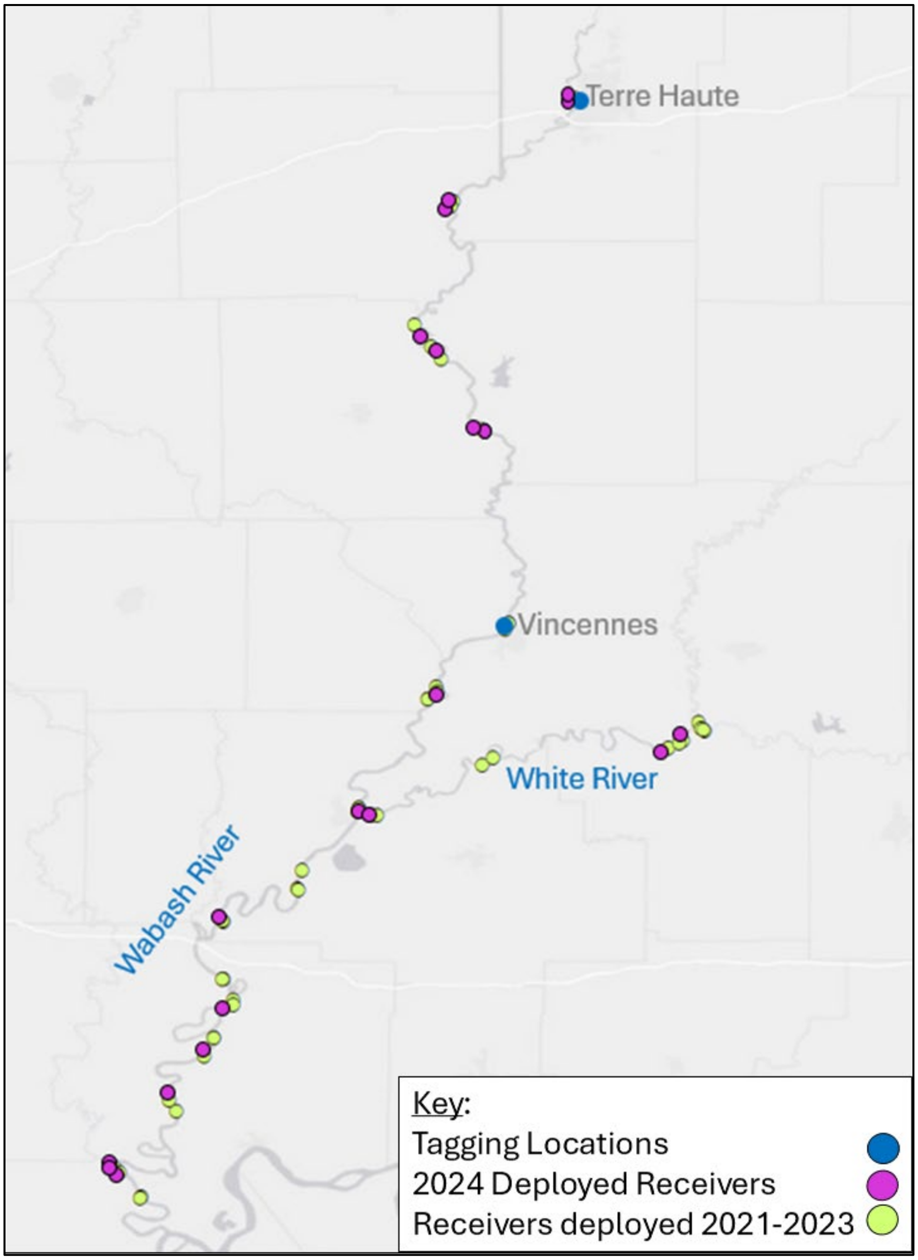

Figure 2. Map of tagging locations (blue), receivers newly deployed in 2024 (pink) and existing receivers (yellow).

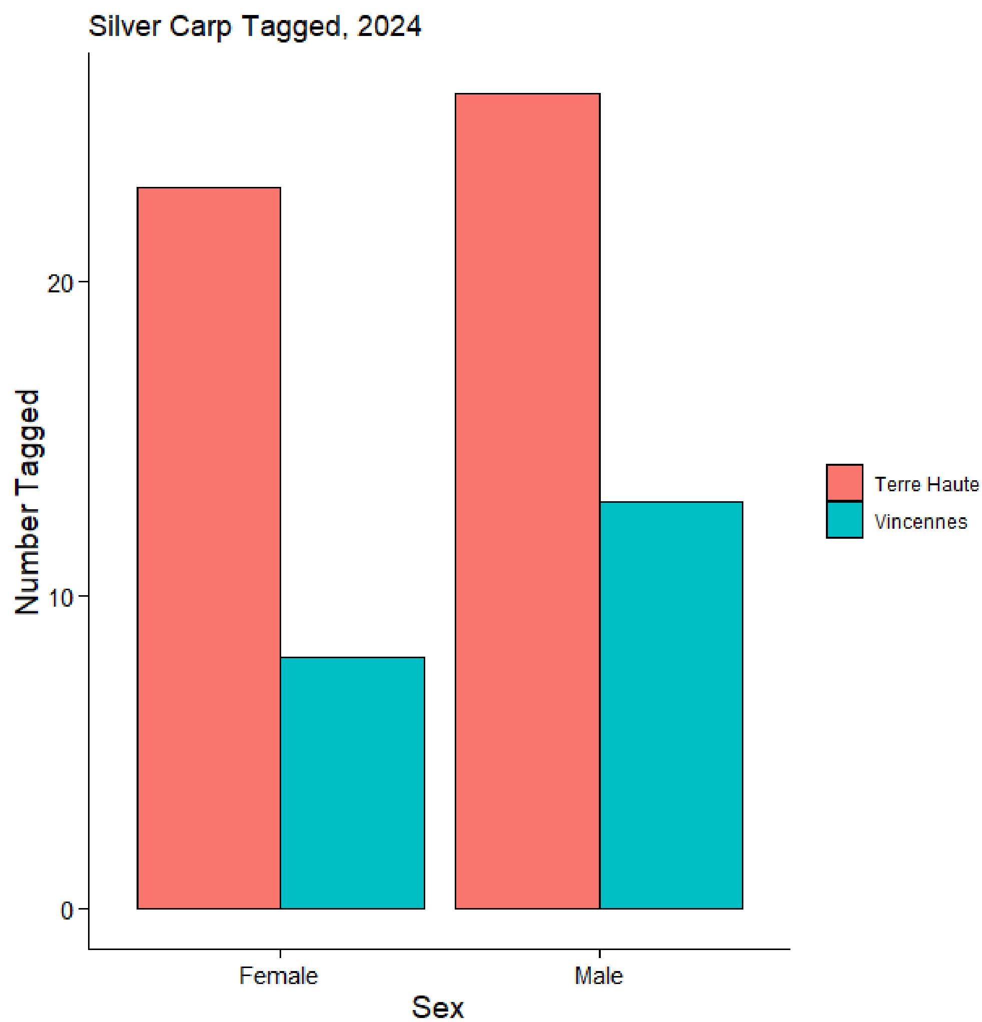

Figure 3. Sex and location breakdown of the 70 silver carp tagged in 2024.

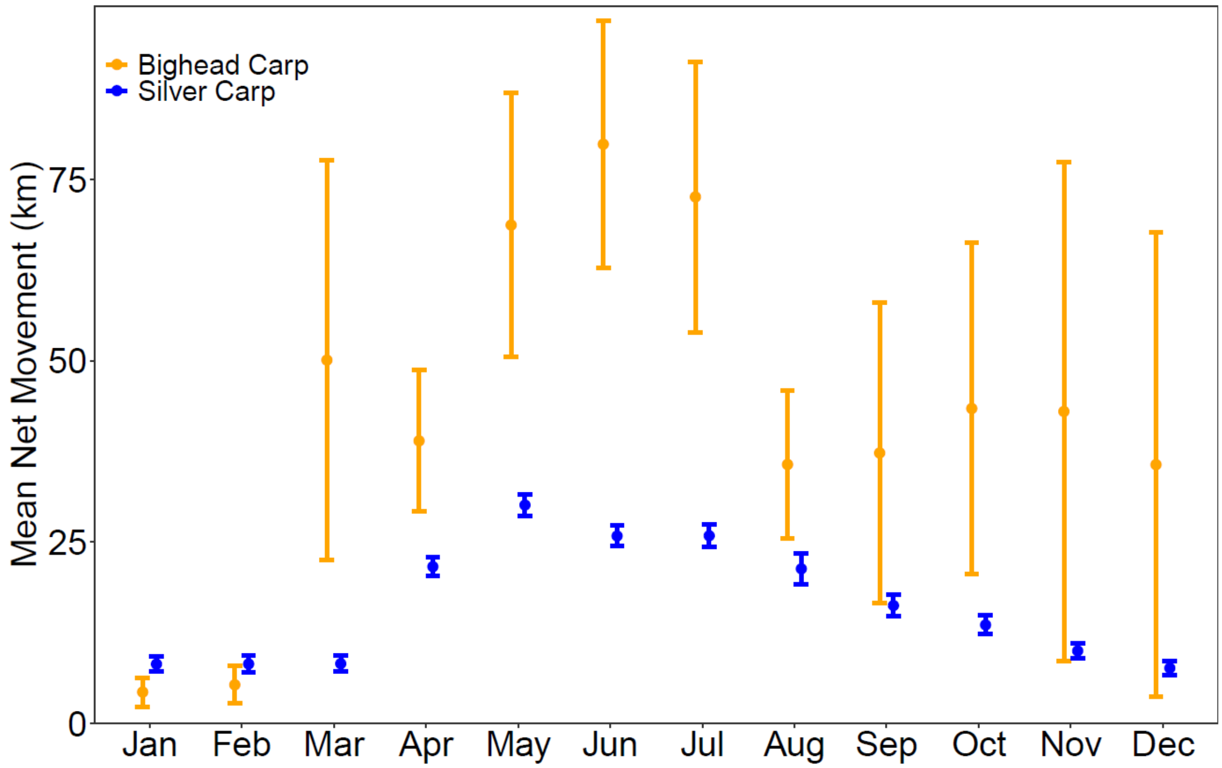

Figure 4. The mean monthly net movements (river kilometers) between the most upstream and downstream detections for tagged Silver Carp (blue) and Bighead Carp (orange) in J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, and Meldahl pools during June 2013 – July 2024. Error bars represent standard error. Only tagged carp detected ≥ 2 times during a month were included in the distance calculations.

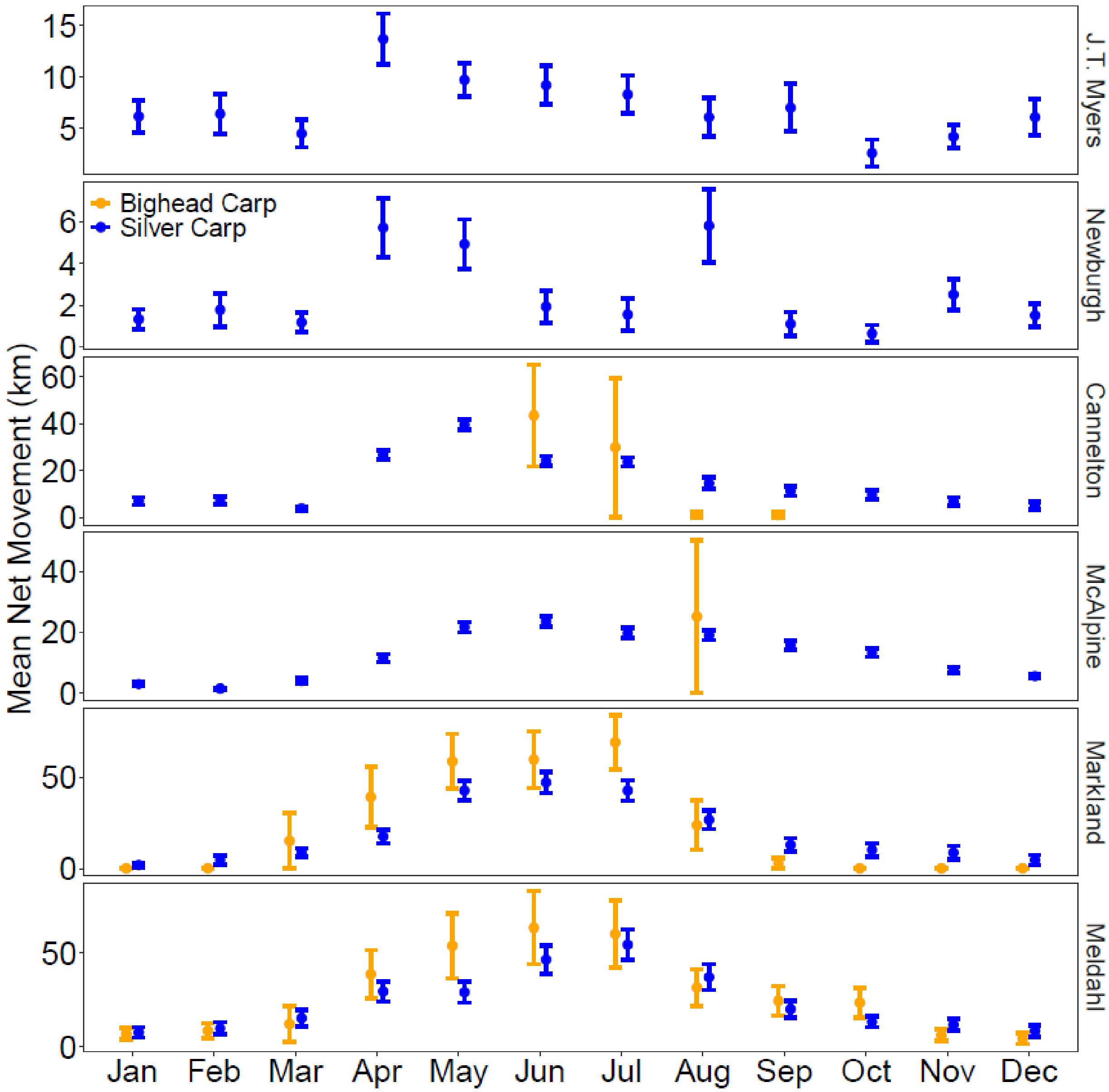

Figure 5. The mean monthly net movements (river kilometers) between the most upstream and downstream detections for tagged Silver Carp (blue) and Bighead Carp (orange) by pool in the six most active pools of the telemetry project (J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, and Meldahl pools) during June 2013 – July 2024. Error bars represent standard error. Only tagged carp detected ≥ 2 times within a single pool each month were included in the distance calculations.

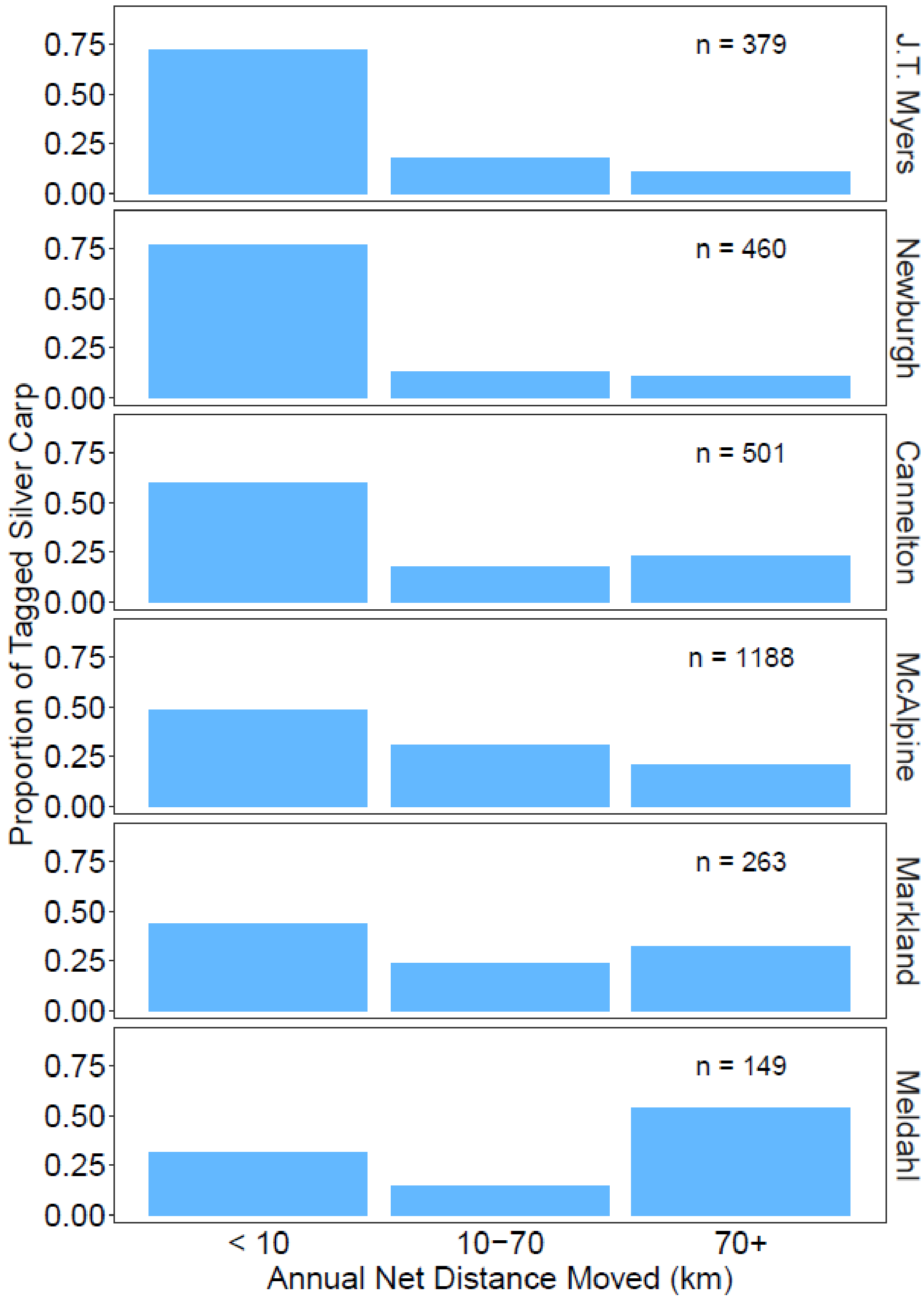

Figure 6. The proportion of tagged Silver Carp with annual net movements of < 10, 10-70, or 70+ km for each pool from J.T. Myers to Meldahl pools (top to bottom) during June 2013 – July 2024. The number of individuals included in this summarization is included in the top-right corner of each panel.

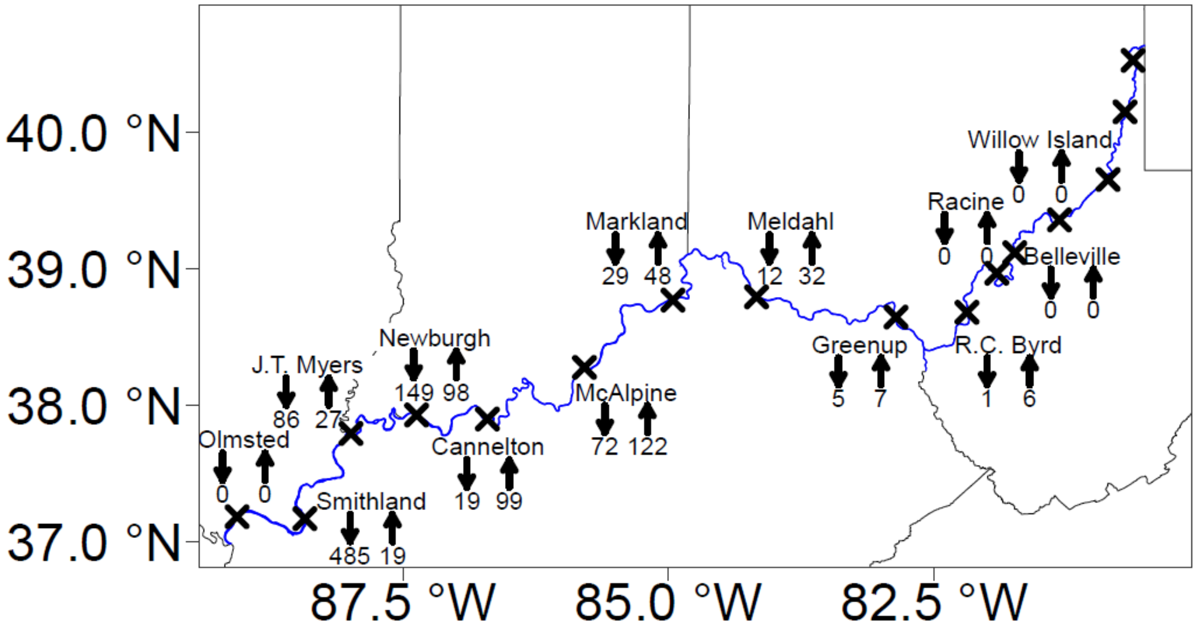

Figure 7. Total number of downstream (↓) and upstream (↑) lock and dam (L&D) passages by invasive carps during June 2013 – July 2024. Map shows passages from Olmsted L&D (river mile 964.4) near the confluence of the Ohio and Mississippi rivers to Willow Island L&D (river mile 161.7) which is the most upstream location at which acoustic receivers were deployed.

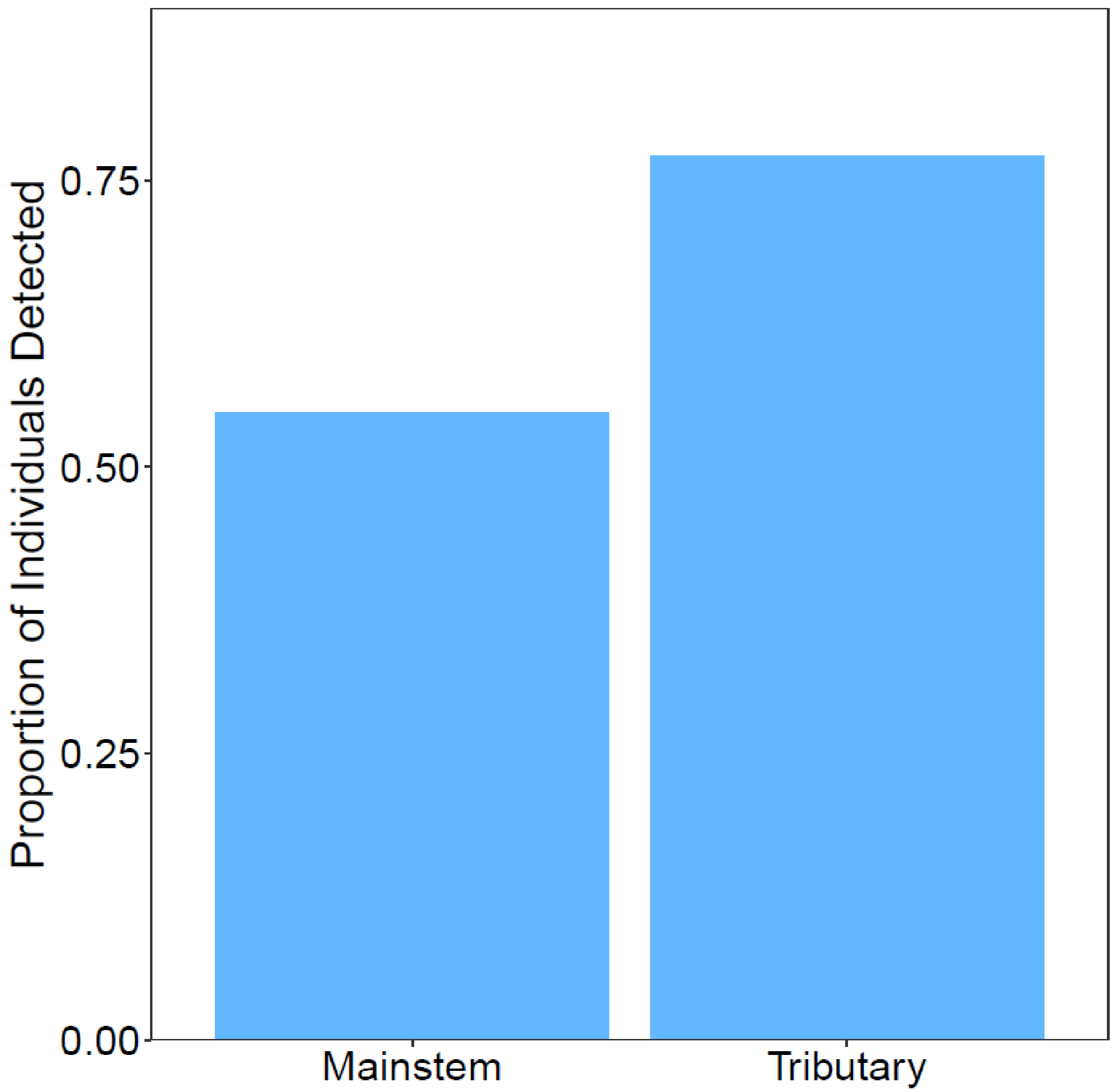

Figure 8. The proportion of individual Silver Carp detected in mainstem and tributary habitats during June 2013 – July 2024.

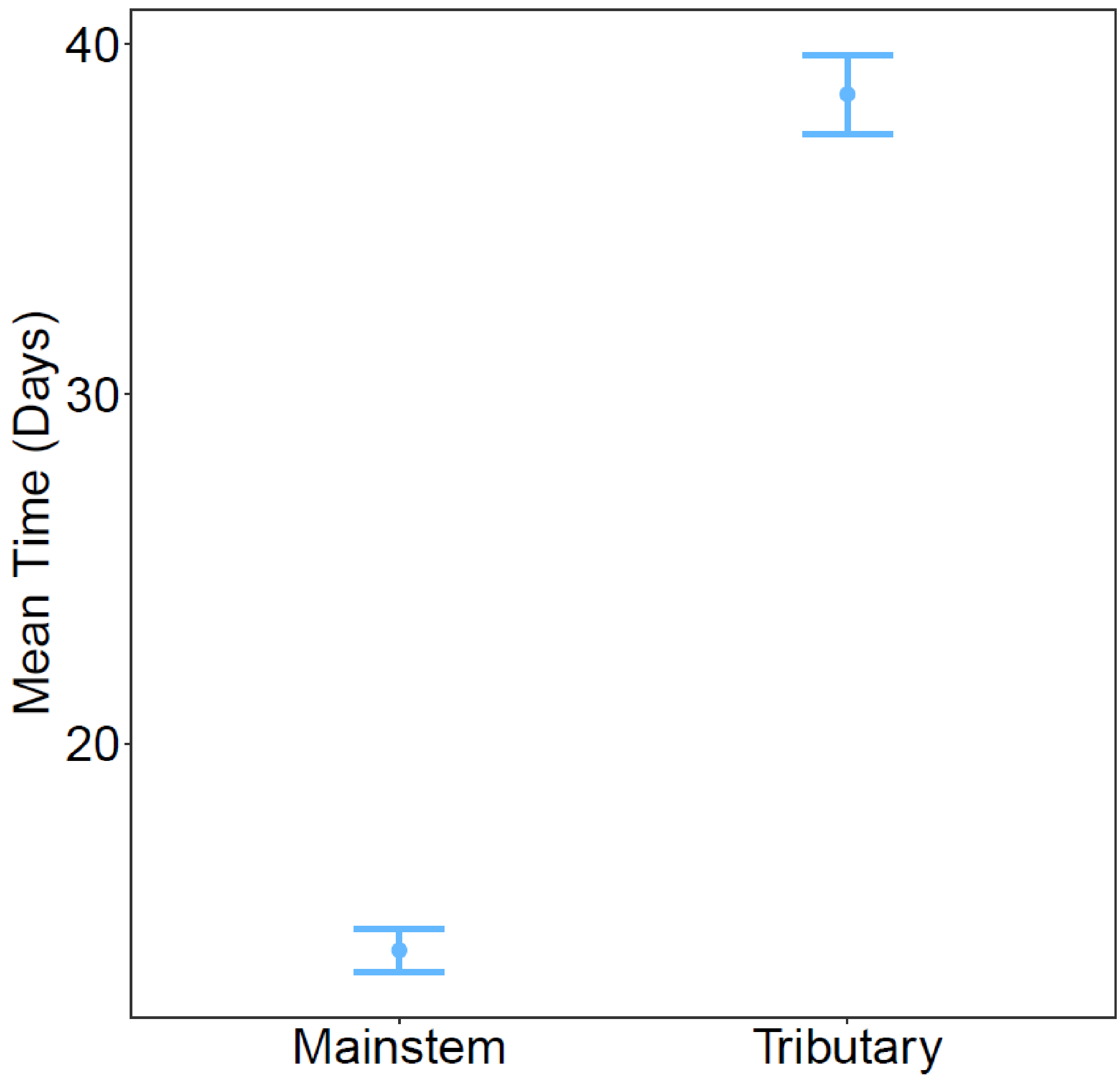

Figure 9. The mean time (days) spent in mainstem or tributary habitat for Silver Carps during June 2013 – July 2024. The number of days represents the time from the first detection of an individual in either the mainstem of the Ohio River or one of its tributaries to the first detection outside of that habitat.

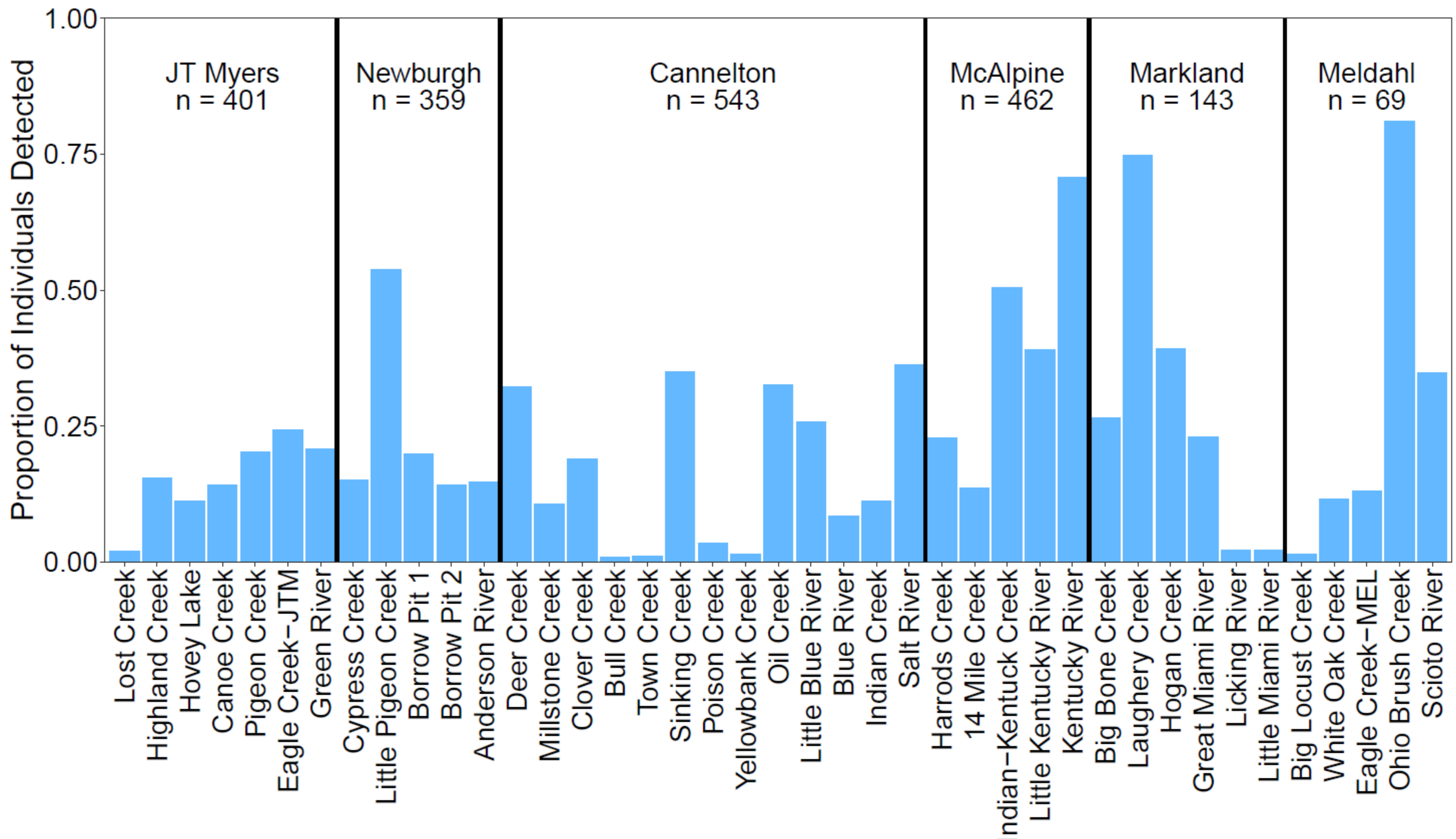

Figure 10. The proportion of individual Silver Carp in each pool that were detected in tributaries of those pools during June 2013 – July 2024. Numbers represent individual fish detected within that pool and the vertical lines are used to separate pools from most downstream to most upstream.

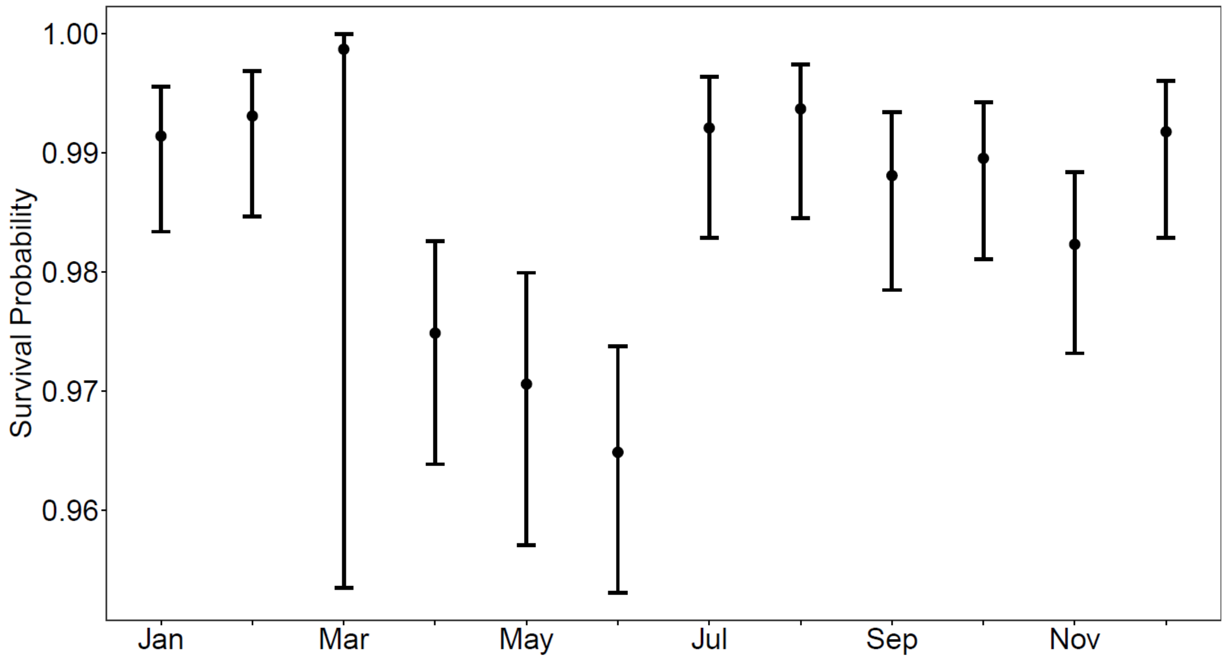

Figure 11. The effect of month on the probability of survival (S) of Silver Carps during January 2014 – July 2024. The plot shows the mean probability of survival ± 95% confidence intervals for each month.

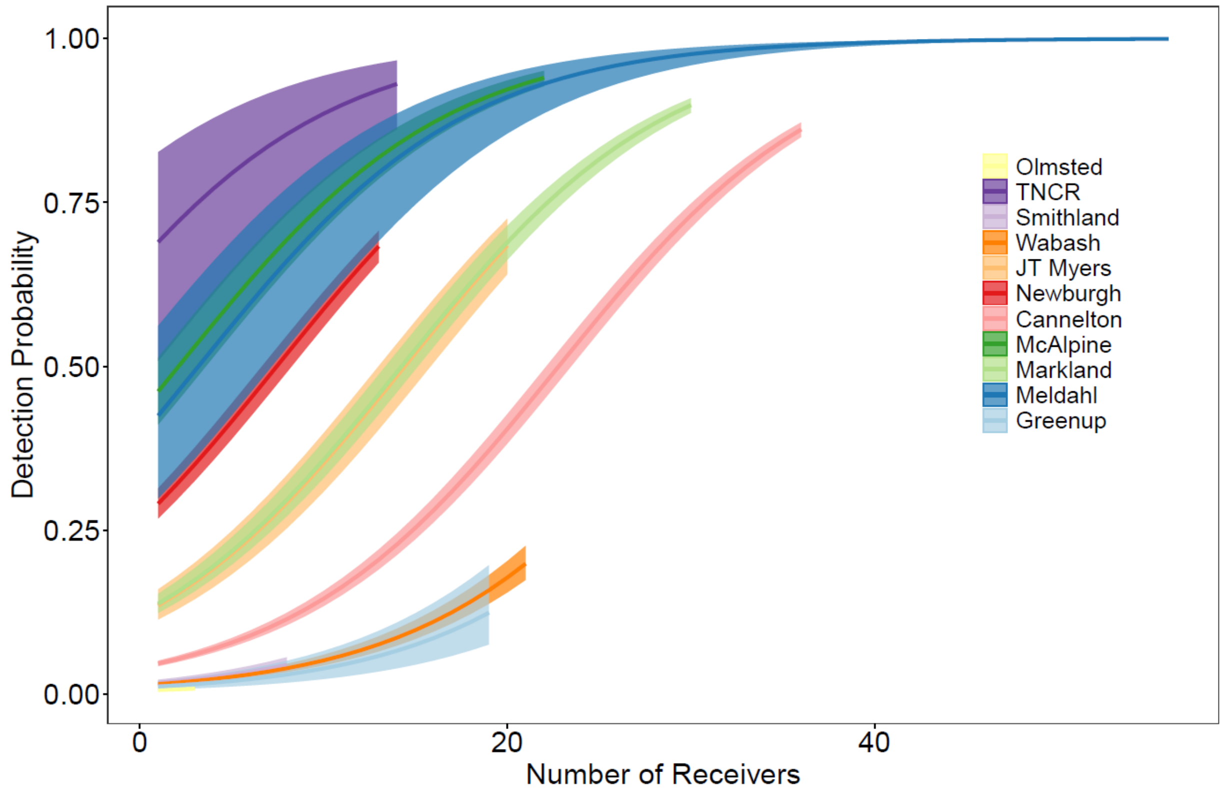

Figure 12. The effect of the number of receivers on the probability of detection (p) of Silver Carps in nine Ohio River pools, the Wabash River, and the Tennessee/Cumberland rivers (TNCR). The number of receivers ranged from 1 to 56 to reflect the number of receivers deployed in each pool during January 2014 – July 2024. 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.

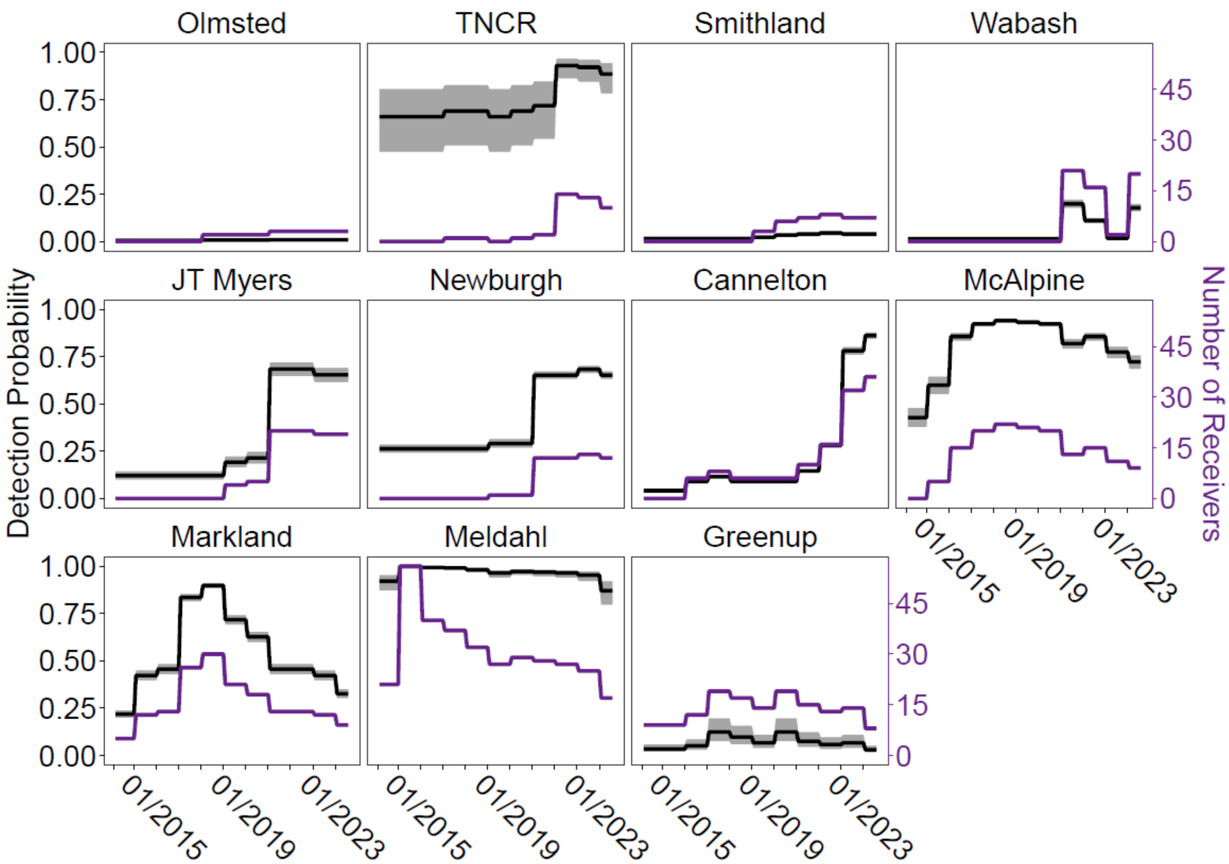

Figure 13. Mean and 95% confidence intervals of the detection probability of Silver Carp (black line and gray shaded area, respectively) and the number of receivers deployed (purple line) during January 2014 – July 2024 in each pool or river within the Ohio River Basin.

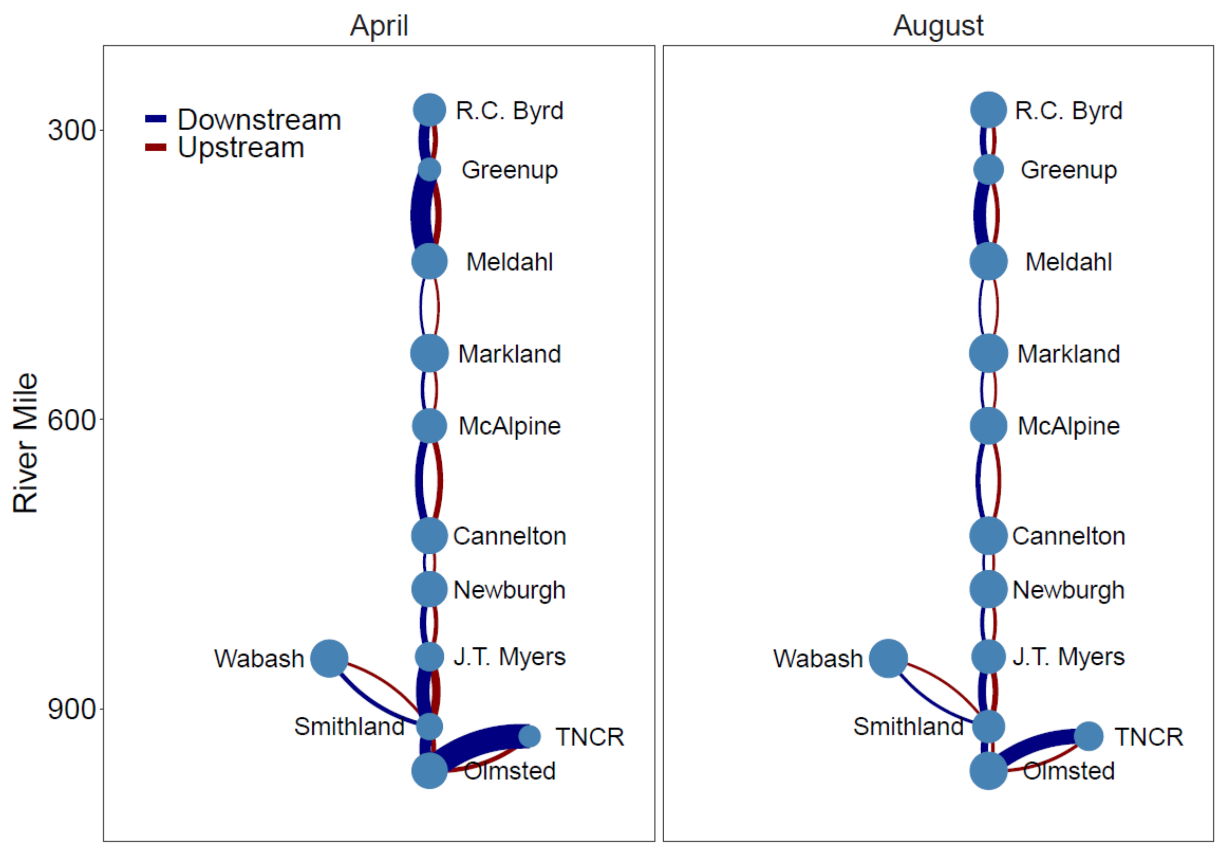

Figure 14. Mean estimated transition probabilities (ψ) among pools and river systems within the Ohio River Basin for April and August. Red lines indicate upstream transition probabilities, whereas blue lines denote downstream transition probabilities. Line thickness is proportional to the transition probability from one area to another. Blue points represent each pool or river and their size is proportional to the probability that Silver Carp remain within that pool during a month. Plots for other months are available from USFWS, CAR FWCO.

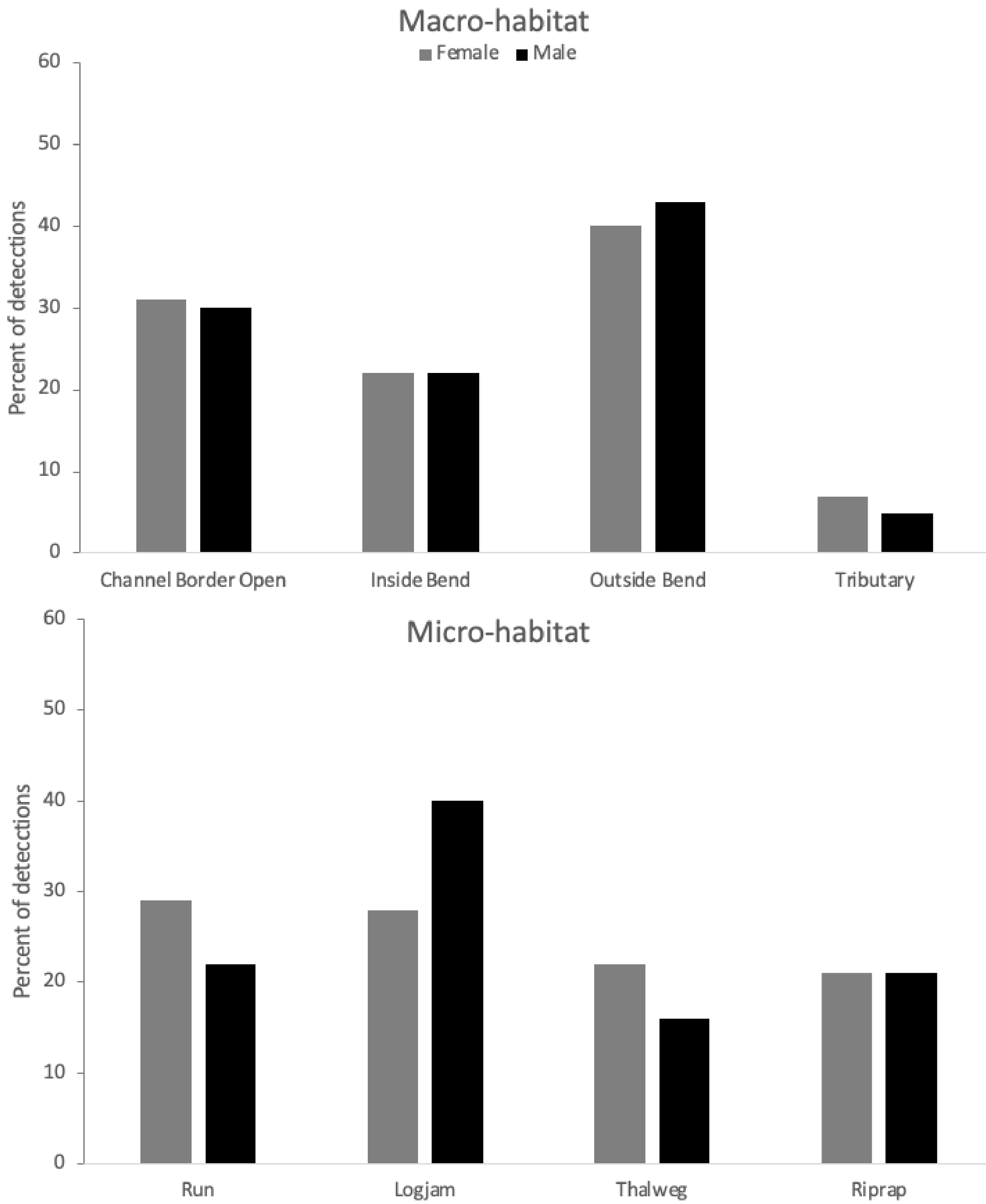

Figure 15. Percent distribution of macro-habitat (top) and micro-habitat (bottom) categories by sex (131 F, 294 M) from active tracking detections (2021-2024).

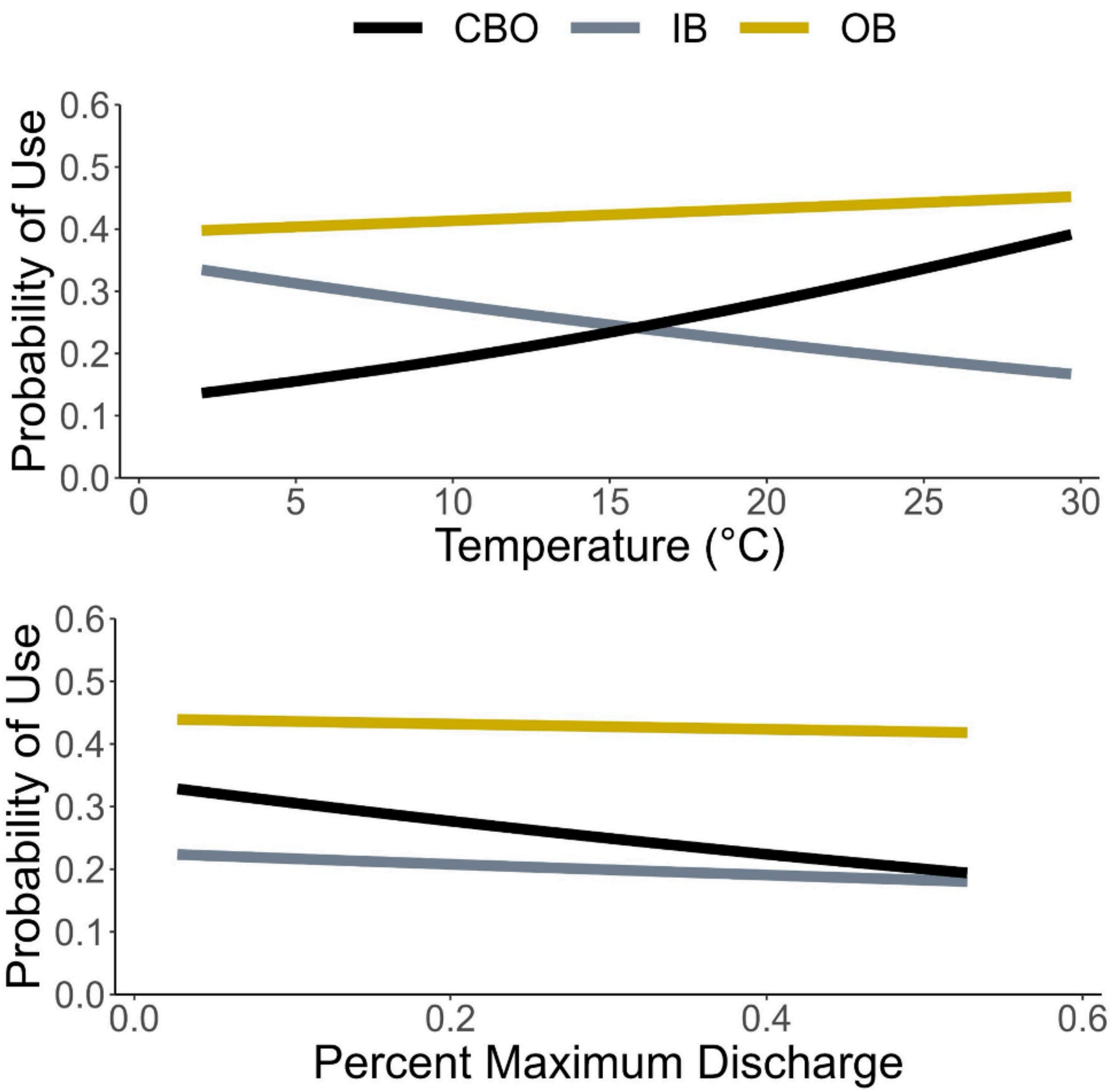

Figure 16. Probability of macro-habitat use logistic regression models based on river hydrological parameters (temperature and percent maximum discharge) for all tagged carp detected for the years 2021-2023. Macro-habitat categories include Channel Border Open (CBO), Inside Bend (IB), and Outside Bend (OB).

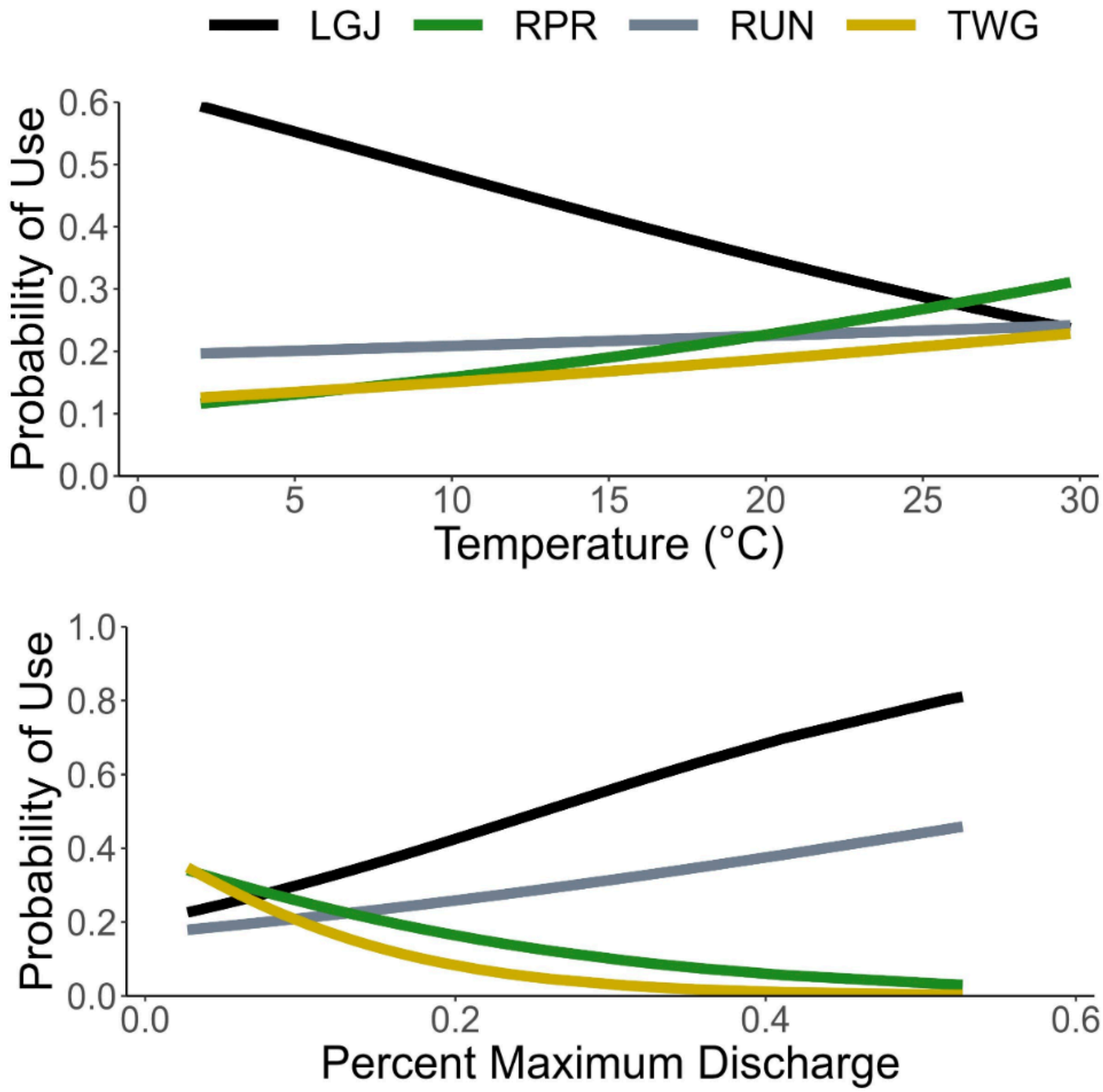

Figure 17. Probability of micro-habitat use logistic regression models based on river hydrological parameters (temperature and percent maximum discharge) for all tagged carp detected for the years 2021-2023. Macro-habitat categories include logjams (LGJ), riprap (RPR), run (RUN), and thalweg (TWG).

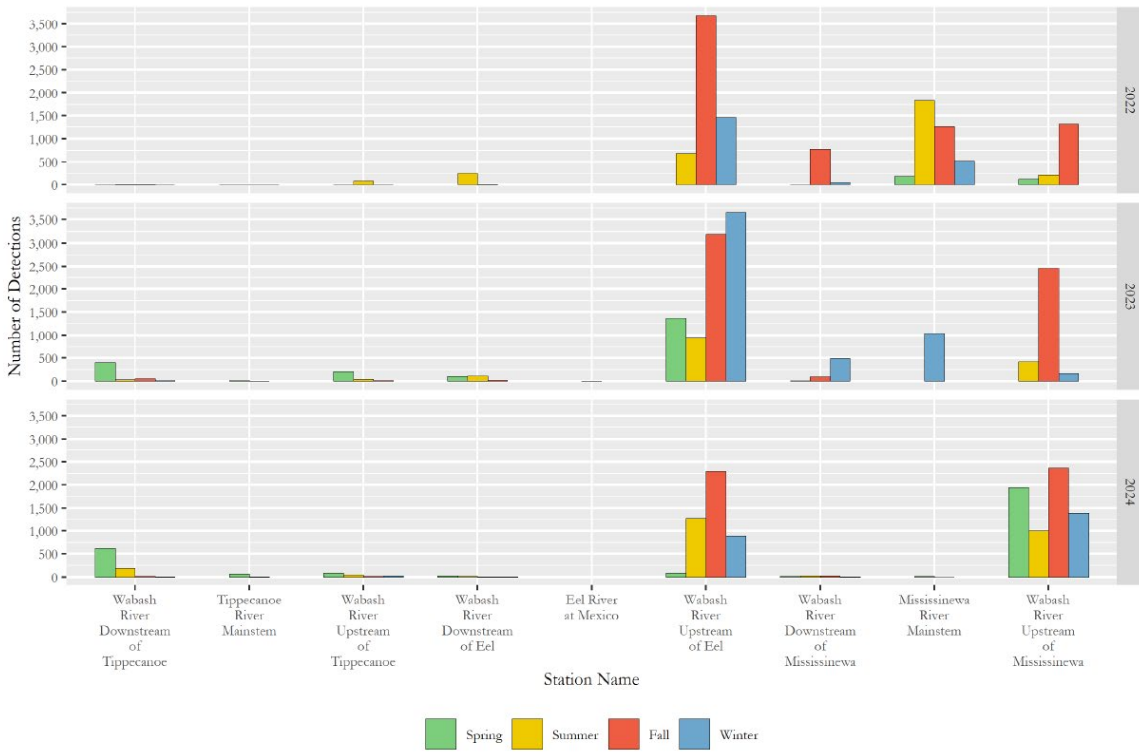

Figure 18. Number of detections of a tagged Silver Carp at each Innovasea acoustic receiver location per season in 2022, 2023, and 2024. No Silver Carp have been detected in the Salamonie River Mainstem or the receivers installed upstream and downstream of the confluence of the Salamonie River with the Wabash River. Season was determined using the meteorological definition of seasons. Receivers were installed in May 2022 and collected data until 18 December 2024 for this analysis.

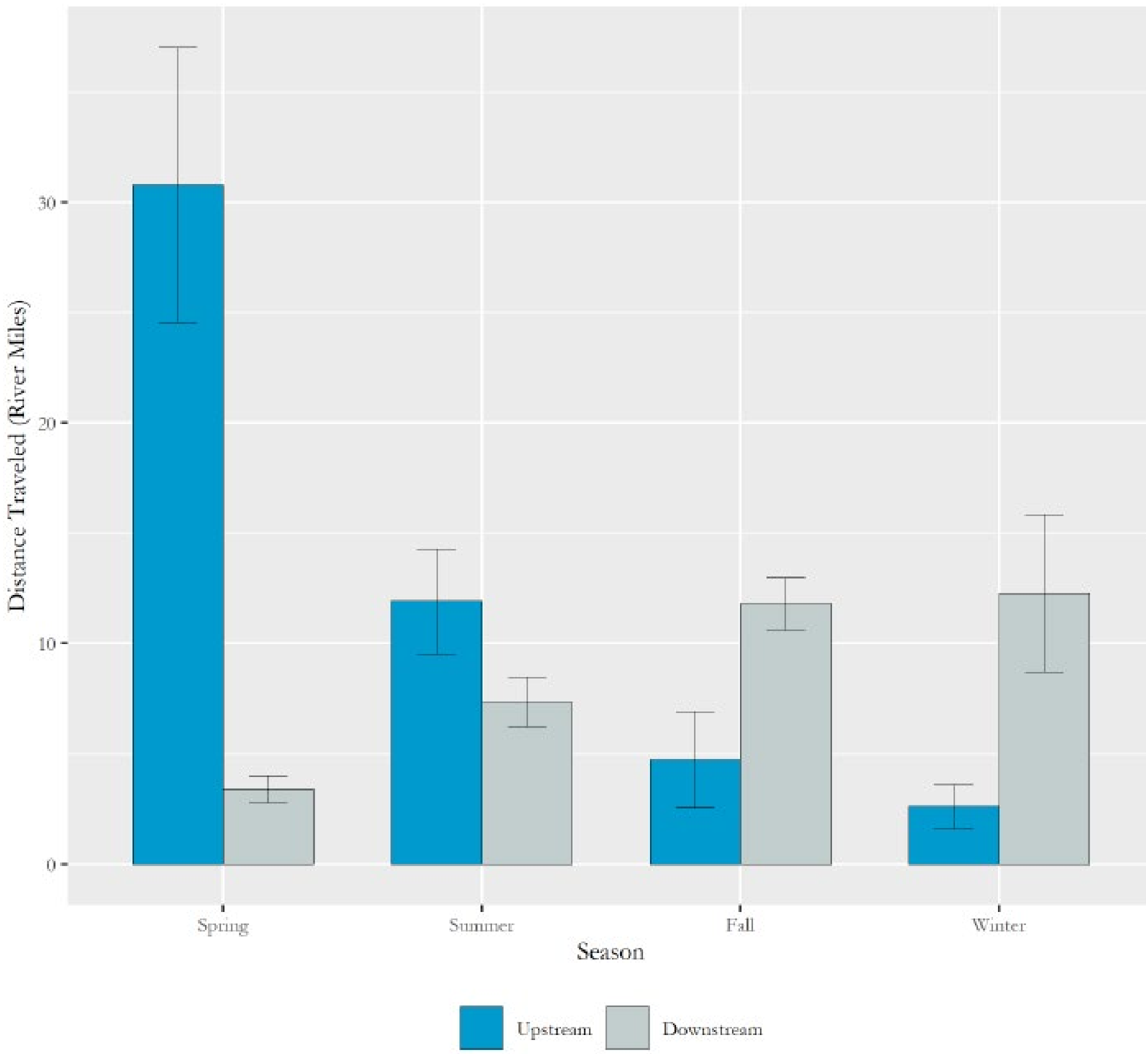

Figure 19. Average distance traveled per season and movement direction in river miles for Silver Carp detected using the network of Innovasea acoustic receivers installed in the Upper Wabash River Basin. Error bars represent ± the standard error from the mean. Season was determined using the meteorological definition of seasons. Receivers were installed in May 2022 and collected data until 18 December 2024 for this analysis.

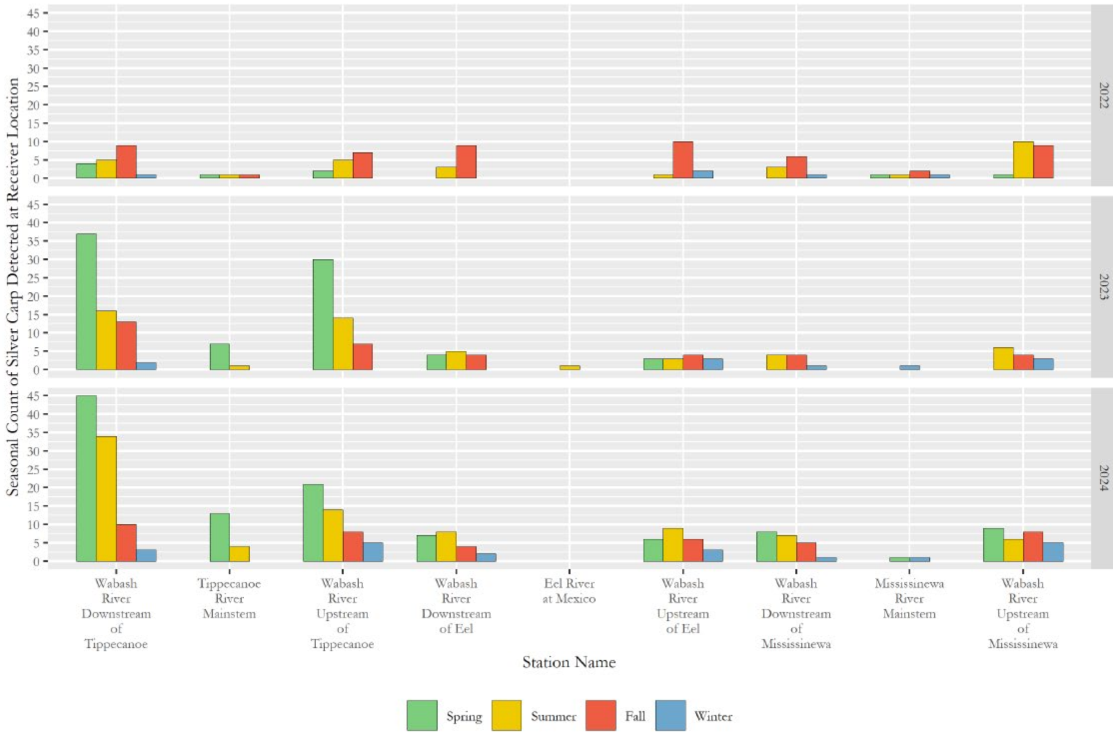

Figure 20. Number of Silver Carp detected at each Innovasea acoustic receiver location per season in 2022, 2023, and 2024. No Silver Carp have been detected in the Salamonie River Mainstem or the receivers installed upstream and downstream of the confluence of the Salamonie River with the Wabash River. Season was determined using the meteorological definition of seasons. Receivers were installed in May 2022 and collected data until 18 December 2024 for this analysis.

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 any possible introductions. After 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 still 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 (ORB), it has been determined that large-scale removal projects may be one of the few tools that managers can still utilize 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 been established within the ORB. Additionally, the data collected during the targeted removal are used to augment the ongoing evaluation efforts that KDFWR conducts to determine the status of invasive carp populations in other 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:

3. A total of 111.4 hours of electrofishing effort was used to remove approximately 7,478 kg (~16,486 lbs) of invasive carp from three different pools of the Ohio River in 2024.
4. A total of ~2.57 million pounds (1.16M kg) of invasive carp have been harvested by contract fishing efforts conducted between July 2019 and February 2025.
5. Contract fishing efforts continued to remove high numbers of invasive carps from the Cannelton Pool of the Ohio River without negatively impacting native fish populations.
6. Incentivized commercial harvest resulted in the removal of 5,184,018 pounds of invasive carp in 2024.
7. Contract facilitation reimbursements to processors for waterside pickup supported the removal of 12,795,333 pounds of invasive carp in 2024.
8. WVDNR staff conducted three independent removal surveys in Tenmile Creek (Kanawha R.) and Raccoon Creek removing one Bighead Carp.
9. Agency crews also coordinated with USFWS-LGL FWCO on two removal events in Raccoon Creek and one in the disused lock chambers of the R.C. Byrd L & D complex. Three adult Bighead Carp and two adult Silver Carp were caught and removed from this effort.

Management agencies strongly believe that contract fishing downstream of McAlpine Locks & Dam and additional upstream removal efforts by agency staff should continue in order to reduce the densities of the 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 have been provided below.

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 2024, KDFWR and INDNR combined for a total of over 110 hours of Invasive Carp removal efforts in the Cannelton, McAlpine and Markland pools of the Ohio River, which was nearly a 100% increase over the 57 hours completed in 2023. 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 used 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 2024 required KDFWR to continue using an electrofishing-only approach to complete its targeted removal efforts.

The 2024 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. Hence, any recaptured fish that contained an expired transmitter was also removed for population control. Prior to being euthanized, the total length, sex, and presence/absence of a spawning patch were recorded for each fish. Invasive Carp collected and removed during the first half of the year were not weighed in the field. Thus, weights for these fish were ultimately derived from pool-specific length-weight regressions that had to be compiled from historical data. However, KDFWR staff did record weights from Invasive Carp that were collected and removed during the fall (Sept – Dec), which was also required to complete relative weight calculations for the Early Detection and Evaluation Project (ED&D).

KDFWR continued to utilize the 2024 removal efforts to collect aging structures from invasive carp that were captured from the Cannelton, McAlpine and Markland pools. During such efforts, agency field staff identified Silver Carp from specific size classes and harvested otoliths to be processed and examined for the ongoing length-at-age analyses that was also being conducted for the Early Detection and Evaluation Project.

WVDNR staff conducted three independent removal surveys in Tenmile Creek (Kanawha R.) and Raccoon Creek during the reporting period (1,350ft. of net deployed). Gill nets (150ft, 5" mesh, 14ft-10ft) were set on opposite shores of the creek and allowed to soak for 2 hours or overnight. Agency crews also coordinated with USFWS-LGL FWCO on two removal events in Raccoon Creek and one in the disused lock chambers of the R.C. Byrd L & D complex. Seven nets were fished at Raccoon Creek during both events. Two nets were fished in each disused lock chamber overnight and were pulled the next morning.

Invasive Carp Contract Fishing Program

The KDFWR contract fishing program is constantly evolving and has undergone a number of minor changes since it officially began in July 2019. Some of these include the time of year that fishing occurred, the number of program participants out on the river each week and the amount of access that contract fishers had to waters outside of Kentucky (i.e. Indiana tributaries). All of these changes appeared to have some influence over the number of Invasive Carp being harvested from the Ohio River Basin. In 2024, KDFWR maintained contracts with six fishers that allowed them to target invasive carp in the mainstem river, tributaries and embayments of the Newburgh, Cannelton and McAlpine pools.

KDFWR also provided observers to accompany each program participant to record details about their fishing efforts (i.e., location, gear, etc) and the subsequent harvest of invasive carp. Throughout 2024, KDFWR observers continued to obtain total length (mm) and sex data from daily subsamples (n = 20) of each species of Invasive Carp (Silver, Bighead and Grass carp). During fall 2024, observers also began recording the weights (kg) of carp that had been selected for each subsample. Prior to these efforts, the weights of subsampled fish had been estimated using a predictive regression equation (pool-specific) that KDFWR biologists compiled from historical length-weight data for each species of Invasive Carp. And finally, KDFWR observers were responsible for identifying all bycatch that had been captured by the contract fishing gear to document the morbidity of non-target species.

In early 2024, there were administrative delays in the renewal of an exemption that allowed commercial fishing gear to be used within the borders of Indiana. This issue prevented program participants from being able to access Indiana tributaries and it essentially reduced the available contract fishing areas by more than 50%. By fall 2024, the contract fishers' access to all Indiana tributaries had been restored, but the program's schedule was adjusted once again to postpone contract fishing until mid-November. This decision was based on previous years of data that showed lower catch rates of Invasive Carp from October to December (i.e. 0 to only a few fish per day). The 2024 data ultimately supported this decision as lower numbers of carp were harvested prior to January 2025.

The Indiana Invasive Carp Harvest Permit Interim Rule was enacted in August 2024 authorizing the use of gill and seine nets for invasive carp harvest. The new permit enables KDFWR contract fishers to harvest invasive carp in Indiana waters and utilizes a new Indiana incentivized carp harvest program which launched around the same time. This new incentivized program was a pilot to evaluate if higher incentives would help increase harvest from the Wabash River basin. It paid fishers $0.12 per pound and processors $0.15 per pound to compensate for the lower condition of fish in that system.

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.

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.

During 2024, KDFWR also decided to conduct an exploratory analysis of both the agency removal data and the contract fishing results. The intent was to answer the question of whether these management tools were biased in their size selectivity and were there any lines of evidence that need further analysis (i.e., refer to the Early Detection and Evaluation Project). Silver Carp length data from each removal effort was compared and there appears to be no observable difference between the length frequency of contract fishing and that of KDFWR's agency removal efforts.

Results:

Targeted Removal of Invasive Carp

Approximately 111.4 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 2024, KDFWR (with assistance from INDNR) used the combined efforts from all three pools to capture and removed a total 1,144 Invasive Carp, weighing an estimated 7,475 kg (16,480 lbs.). Like in previous years, most of the 2024 electrofishing efforts (56.3%) were conducted at sites in the McAlpine Pool, which resulted in the removal of 681 Invasive Carp weighing an estimated total of 4,723 kg (~10,412 lbs.). Bycatch of non-target species continue to be rarely encountered due to the highly selective nature of the electrofishing efforts. However, shad and alewife species were intentionally captured on occasion to verify that they were not juvenile (age-0 to age-1) Invasive Carp.

WVDNR staff conducted three independent removal surveys in Tenmile Creek (Kanawha R.) and Raccoon Creek during the reporting period. One Bighead Carp was removed. Agency crews also coordinated with USFWS-LGL FWCO on two removal events in Raccoon Creek and one in the disused lock chambers of the R.C. Byrd L & D complex. Three adult Bighead Carp and two adult Silver Carp were caught and removed from this effort.

Contract Fishing Program

At the beginning of 2024, KDFWR had enough observers on staff to regularly schedule up to 4 fishers a week. Program participants conducted an average of 57 fishing days per month during the first few months of 2024 (Jan – Mar) and ended this 3-month period with a total of 172 fishing days, which was comparable to the 168 days fished during this same time in 2023 (Table 2). During these efforts in Jan – Mar 2024, contract fishers used 583 gill net sets (~ 278,000 net ft) to harvest a total of 24,747 carp that had an estimated weight of more than 112,400 kg (~248,000 lb.). Contract fishing efforts in Jan-Mar 2024 yielded substantially fewer numbers of harvested Invasive Carp when compared to same time span in 2023. However, it was not unexpected given the reduction in available fishing areas and the fact that the 54,700 carp harvested in Jan-Mar 2023 was the program's highest harvest total for any 3-month period. After an average start to 2024, contract fishers continued to harvest similar numbers of Invasive Carp in April – June (n = ~15,600 fish). By the time that contract fishing efforts were suspended for the summer months, a total of nearly 40,380 invasive carp weighing an estimated 179,401 kg (~395,512 lb.) had been harvested during the first 5+ months of 2024.

Throughout 2024, program participants set an overall total of 1217 gill nets within both the Cannelton and Newburgh pools. In fact, the reduced access to Indiana tributaries during the first half of 2024 meant that sites within the Newburgh Pool had to be more regularly targeted by program participants. This trend started to decline some during the last couple months of 2024 after Indiana tributaries were once again opened to the contract fishing efforts.

During each year from 2019 to 2024, 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 2024, Silver Carp (n = 46,346) represented more than 98.8% of the harvested fish, while both Bighead (n = 114) and Grass (n = 404) carps combined to make up the other ~1.2% (Table 3). The species composition of all invasive carp caught in 2024 continued to echo an overall trend in the program's results where Silver Carp make up 98.3% of all carp (n = 228,574) caught by contract fishers in the last 6+ years (Jul 2019 – Feb 2025).

After comparing the mean daily catch of Invasive Carp during peak months (Oct-Mar) of the last six fishing seasons (2019-2024), there continues to be evidence that the most productive period for contract fishing includes the first few months of each year (Figure 1). Fishing effort during this six-month season initially increased from around 130 total fishing days in the 2020-2021 season to 253 days during this same period in 2021-2022. Since then, the efforts conducted during this "peak" season has remained relatively stable with 252 and 286 fishing days completed during the 2022-2023 and 2023-2024 seasons, respectively. However, during this reporting period, KDFWR's decision to delay the start of contract fishing to November 2024 will likely drop the effort down to just over 200 total fishing days for the current season (Oct 2024-Mar 2025). A combination of factors, including favorable river conditions, continuous access to all fishing areas and a full staffing complement, allowed program participants to harvest Invasive Carp at a very high rate (200-350 fish/day) over the last three months of the 2022-2023 fishing season. Since then, the contract fishing program encountered some issues (i.e. low water levels, access restrictions), but fishers did manage to harvest Invasive Carp at favorable rates for ~100 fish/day. In fact, with some exceptions (i.e. Jan 2025), contract fishers have maintained average harvest rates of 100-150 carp/day during most months of the current reporting period (Jan 2024 - Feb 2025).

In 2024, the monthly comparisons of mean daily harvest indicated that contract fishers had their highest catch rates of Invasive Carp during the months of May (175 carp/day) and January (158 carp/day) (Figure 2). Like in previous years, the 2024 catch rates appear to increase when river levels rise and water temperatures drop. However, if river levels rise too high (i.e. April 2024), a reduction in useable access points can cause a general decline in the contract fishers' productivity, which is usually indicated by lower daily harvest rates. And finally, standard errors in the daily harvest results continue to stand out during those months (i.e. Nov - Dec 2024) when contract fishers experience the highest amount of variability in their catch rates.

Gill nets continued to be the primary gear used during the seven-month period that program participants were actively fishing in 2024. Netting effort does vary and can often depend on the current catch rates, but throughout 2024, contract fishers typically set out 600-700 meters (2000-2300 ft) of webbing per day. The Silver Carp catch ranged in total length from 450 mm to 1000 mm with most of the fish (98.5%) measuring between 650 – 900 mm (Figure 3). Bighead and Grass carp were caught less frequently, but when harvested, most Bighead Carp (~89%) had total lengths of 800 to 1200 mm and nearly 92% of all Grass Carp measured between 800 - 1100 mm.

The bycatch from contract fishing efforts in 2024 was highest in January (24%) and December (28%) with other months showing that non-target species contributed between 9% and 21% of the total catch (Figure 4). All bycatch species were released immediately, and KDFWR observers specifically documented any non-target fish that were either dead-on-arrival (DOA) or appeared to be moribund. Ictiobid species (i.e. Smallmouth, Bigmouth and Black buffalo) were the most common bycatch and contributed nearly 70% of all non-target fish (n = 6,585) (Table 4). Freshwater Drum (*Aplodinotus grunniens*), Catfish (*Ictaluridae* species) and Paddlefish (*Polyodon spathula*) were the next three most common types of bycatch captured in contract fishing nets. Even with the highest bycatch rates, the combined morbidity of the three Ictiobid species continued to be quite low at just over 3.7%. In fact, the only bycatch species in 2024 that exhibited a morbidity rate of 10% or more was the Logperch (~53%). However, despite its obvious sensitivity to the gear, very few Logperch were caught during this reporting period (n = 17) and it contributed to only 0.2% of the overall bycatch. KDFWR observers also continued to closely monitor the status of the Paddlefish (Polyodon spp), which is an important bycatch species that appears to be highly vulnerable to the contract fishing gear. Even though Paddlefish were the fourth most commonly caught bycatch (4.8%) in 2024, their morbidity rates were determined to be quite low (2.4%), especially when compared to the Ictiobids (3.7%), Longnose Gar (6.5%) and Freshwater Drum (6.8%).

To further understand the population structure of Silver Carp in Cannelton Pool, length frequency distributions from all agency removal data were overlaid with distributions generated from contract fishing subsample data from 2019 through 2024 (Figure 5). Distributions depict similar trends in length frequencies year to year, supporting that both forms of removal are effectively targeting the Silver Carp population in Cannelton Pool. Majority of fish captured, regardless of removal method, fall within the 600mm – 900mm size range.

The Indiana Invasive Carp Harvest Permit Interim Rule was enacted in August 2024 authorizing the use of gill and seine nets for invasive carp harvest. The initial phase was hampered by unfavorable fishing conditions, resulting in a total harvest of 101,988 pounds from August through December. KDFWR contract fishers contributed 38,667 pounds to this total from October through December, which is included in KDFWR's harvest data summarized below. The remaining 63,321 lbs. was harvested by fishers in the Wabash River who were enrolled in the incentivized program.

Enhanced Contract Removal

During 2024, ILDNR Enhanced Contract Removal Program had a total of 31 fishers under contract. With those 23 fishers, a total of 5,184,018 lbs of invasive carp were removed. Since the program's inception of March 2022, a total of 10,593,489 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 July, and September and October were the months with the highest catch totals for 2024. Winter months (November, December) of 2024 saw a dramatic decrease in the amount of invasive carp reported harvest (Figure 6). The bulk of the harvest in 2024 occurred in the main-stem Ohio River and the Tailwaters of Kentucky and Barkley Lakes. (Table 5)

Contracted Facilitation

The Contracted Facilitation Program had 7 processors under contract in 2024. Throughout 2024 a total of 12,795,333 lbs. were processed. Since the Program's inception of March 2022, a total of 37,272,149 lbs. have been processed. Silver carp make up 91% of the total number of invasive carp processed, with Bighead, Grass and undisclosed invasive carp combining to make the remaining 9%. Contracted facilitation had its highest months in March and October. (Figure 6.)

Discussion:
The USACE 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 regular evidence of successful reproduction, the Cannelton Pool is considered to be a high-priority location for any future efforts to control the invasive carp population.

In 2024, KDFWR contracted with six program participants to provide the necessary fishing effort and hired as many as four observers 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 October of 2024, which is also expected to have helped reduce impacts on bycatch species. Any effect this has on the morbidity rates of bycatch continues to be examined closely, especially as more data is collected during upcoming years. Unlike when the fishing resumed in early October 2023, the restart of the program in 2024 was intentionally delayed until mid-November to concentrate the contract fishing efforts to the most productive months of the year. Once efforts resumed on November 13, 2024, the program participants immediately began employing the same group fishing techniques that produced higher harvest rates in recent years. 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 continued to use gill nets with webbing constructed of 3.25 to 4.5 in bar-mesh throughout 2024, which 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 through 2024 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 2024 continued to report that most bycatch was healthy at the time of release. After having the highest morbidity rates in 2023, the Paddlefish captured and released by contract fishers in 2024 faired quite better, as there were as many as seven bycatch species with higher morbidity during this reporting period (Table 4). Ictiobids (i.e. Smallmouth Buffalo) were once again by far the most common bycatch in 2024, which was followed by Freshwater Drum and Catfish. Like in previous years, the overall morbidity rate of ~4.0% in 2024 means that most bycatch 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 continued practice of rapidly setting and pulling the gill nets.

For agency removal efforts, electrofishing methods used in 2024 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.

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 5 M pounds in 2024. The bulk of this harvest consist of Silver Carp. Most of the harvest occurred within the Kentucky and Barkley Lake tailwaters (2.4M) with another 2.3M pounds harvested from the Ohio River.

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 over 12 M pounds of invasive carp in 2024. Most of the incentivized removal occurred in Barkley Lake (4.1 M and the Illinois River (4.1 M). The Kentucky and Barkley Lake tailwaters followed 1.8 M) with another 1.6 M coming from the Ohio River.
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 Cannelton Pool to help protect and reduce migration of invasive carps further up the Ohio River. 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. Finally, KDFWR believes it is important to continue to measure a subsample of the harvested Invasive Carp removed by contract fishers. These data may be used to evaluate the length and weight of captured individuals and compare these data between removal and harvest gear types and locations.

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Table 1. Results of electrofishing efforts that KDFWR and INDNR conducted in 2024 with the primary objective of removing Invasive Carp from the middle Ohio River.

OHR Pool	Agency	Effort (hr.)	Total Count (N)				Total Weight (kg)			
			Bighead Carp	Silver Carp	Grass Carp	Total	Bighead Carp	Silver Carp	Grass Carp	Total
Cannelton	KDFWR	3.2	0	127	1	128	0	587.6	7.2	594.8
	INDNR	16.3	0	264	0	264	0	1409.6	0	1409.6
McAlpine	KDFWR	62.7	2	677	2	681	11.9	4700.3	11.2	4723.4
Markland	KDFWR	22.9	6	52	1	59	17.2	563.1	11.4	591.7
	INDNR	6.3	0	12	0	12	0	158.1	0	158.1
Combined	All	111.4	8	1132	4	1144	29.1	7418.7	29.8	7477.6

Table 2. Summary of results obtained by contract fishers between 2019 to February 2025. A "fishing day" equals 1 crew fishing ~8 hr.

Year	Months	Fishing Effort			Total Carp	# Carp	Total	Total	Mean Length & Weight			
		Days	Nets	Net Feet	Harvested	per Day	Harvest (kg)	Harvest (lb)	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
	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
	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	172	583	278,000	24,747	143.9	112,417.6	247,832.0	784	4.54	30.9	10.01
	Apr-Jun	124	417	201,130	15,634	126.1	66,983.4	147,674.7	782	4.28	30.8	9.45
	Oct-Dec	79	217	103,300	6,483	82.1	31,059.5	68,472.5	780	4.79	30.7	10.56
	Total	375	1217	582,430	46,864	125.0	210,460.5	463,979.2	782	4.49	30.8	9.90
2025	Jan-Mar	134	364	169,400	16,785	125.3	98,417.2	216,974.2	806	5.86	31.7	12.93
	Total	134	364	169,400	16,785	125.3	98,417.2	216,974.2	806	5.86	31.7	12.93
ALL YEARS	Jan-Mar	749	3228	1,591,416	134,087	179.0	699,020.6	1,541,072.0	820	5.21	32.3	11.49
	Apr-Jun	335	1509	788,320	46,266	138.1	220,361.2	485,814.7	807	4.76	31.8	10.50
	Jul-Sep	56	523	212,390	4,077	72.8	21,958.5	48,410.1	803	5.39	31.6	11.88
	Oct-Dec	506	2809	1,513,388	44,144	87.2	223,223.0	492,120.4	804	5.06	31.7	11.15
	Total	1646	8069	4,105,514	228,574	138.9	1,164,563.4	2,567,417.3	808	5.09	31.8	11.23

* Contract fishing was not conducted during summer months (Jul-Sep).

Table 3. A breakdown of total counts and weights of Invasive Carp harvested by contract fishers from 2019 to Feb 2025.

Cannelton Pool (2019 – early 2025)				
Year	Spp	Total IC Caught	Harvest Weight (kg)	Harvest Weight (lb)
2019	BHC	265	2,197.9	4,845.6
	GRC	129	1,264.4	2,787.6
	SVC	6,455	36,781.8	81,089.9
	ALL	6,849	40,244.0	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	92	1,283.7	2,830.1
	GRC	155	1,498.2	3,303.0
	SVC	20,831	108,223.5	238,587.4
	ALL	21,078	111,005.4	244,720.4
2025	BHC	95	1,338.6	2,951.0
	GRC	146	1,427.2	3,146.4
	SVC	14,770	83,148.5	183,314.4
	ALL	15,011	85,914.3	189,411.7
All	BHC	1,840	18,494.5	40,773.3
	GRC	1,678	13,985.0	30,831.7
	SVC	192,923	1,002,800.9	2,210,796.1
	ALL	196,441	1,035,280.4	2,282,401.2

Newburgh Pool (2023 - early 2025)				
Year	Spp	Total IC Caught	Harvest Weight (kg)	Harvest Weight (lb)
2023	BHC	4	46.4	102.0
	GRC	24	174.7	385.0
	SVC	4,426	16,486.9	36,347.4
	ALL	4,454	16,708.0	36,834.9
2024	BHC	22	302.7	667.4
	GRC	249	1,930.9	4,257.4
	SVC	25,515	97,221.5	214,334.1
	ALL	25,786	99,455.1	219,258.9
2025	BHC	1	13.7	30.2
	GRC	11	96.9	213.7
	SVC	320	1,301.6	2,869.7
	ALL	332	1,412.3	3,113.6
All	BHC	27	362.8	799.6
	GRC	284	2,202.5	4,856.1
	SVC	30,261	115,010.0	253,551.2
	ALL	30,572	117,575.4	259,206.9

McAlpine Pool (2020, 2021 & 2025)				
Year	Spp	Total IC Caught	Harvest Weight (kg)	Harvest Weight (lb)
2020	BHC	0	0.0	0.0
	GRC	2	16.6	37.0
	SVC	2	9.2	20.3
	ALL	4	25.8	57.0
2021	BHC	0	0.0	0.0
	GRC	6	65.2	144.0
	SVC	109	525.9	1,159.4
	ALL	115	591.1	1,303.0
2025	BHC	0	0.0	0.0
	GRC	0	0.0	0.0
	SVC	1,442	11,090.6	24,448.9
	ALL	1,442	11,090.6	24,448.9
All	BHC	0	0.0	0.0
	GRC	8	81.8	181.0
	SVC	1,553	11,625.7	25,628.6
	ALL	1,561	11,707.5	25,809.6

All Pools & Years Combined				
Years	Species	Total Catch	Harvest Weight (kg)	Harvest Weight (lb)
2019 - 2025	BHC	1,867	18,857.3	41,572.9
	GRC	1,970	16,269.3	35,868.8
	`SVC	224,737	1,129,436.6	2,489,975.9
	ALL	228,574	1,164,563.3	2,567,417.7

Table 4. Detailed summary of the bycatch species recorded during contract fishing efforts in January - December 2024. Healthy, or resilient, fish are those that recovered quickly and swam away under their own power, while moribund fish suffered significant damage and could not swim off after being released.

Bycatch Fish Spp. (Common Name)	Genus/Species	Resilient Count	Moribund Count	% Morbidity	Total Count	% of All Bycatch
Bigmouth Buffalo	*Ictiobus cyprinellus*	305	5	1.6	310	3.3
Black Buffalo	*Ictiobus niger*	103	9	8.0	112	1.2
Blue Catfish	*Ictalurus furcatus*	307	2	0.6	309	3.3
Bluegill/Redear	*Lepomis* spp	2	0	0.0	2	< 0.1
Bowfin	*Amia calva*	1	0	0.0	1	< 0.1
Channel Catfish	*Ictalurus punctatus*	52	0	0.0	52	0.6
Common Carp	*Cyprinus carpio*	250	4	1.6	254	2.7
Crappie species	*Pomoxis* spp	10	0	0.0	10	0.1
Flathead Catfish	*Pylodictis olivaris*	66	0	0.0	66	0.7
Freshwater Drum	*Aplodinotus grunniens*	936	68	6.8	1004	10.6
Gizzard Shad	*Dorosoma cepedianum*	69	3	4.2	72	0.8
Largemouth Bass	*Micropterus salmoides*	2	0	0.0	2	< 0.1
Logperch	*Percina caprodes*	8	9	52.9	17	0.2
Longnose Gar	*Lepisosteus osseus*	229	16	6.5	245	2.6
Mooneye	*Hiodon tergisus*	1	0	0.0	1	< 0.1
Paddlefish	*Polyodon spathula*	445	11	2.4	456	4.8
Quillback	*Carpiodes cyprinus*	9	0	0.0	9	0.1
River Carpsucker	*Carpiodes carpio*	18	0	0.0	18	0.2
Sauger/Saugeye	*Sander* spp	14	0	0.0	14	0.2
Shortnose Gar	*Lepisosteus platostomus*	17	0	0.0	17	0.2
Skipjack Herring	*Alosa chrysochloris*	13	1	7.1	14	0.1
Smallmouth Bass	*Micropterus dolomieu*	13	0	0.0	13	0.1
Smallmouth Buffalo	*Ictiobus bubalus*	5931	232	3.8	6163	65.3
Spotted Gar	*Lepisosteus oculatus*	63	0	0.0	63	0.7
Striped Bass	*Morone saxatilis*	192	20	9.4	212	2.2

Table 5. Enhanced contract fishing harvest totals by river reach.

TOTALS BY LOCATION							
Month	Total Lbs.	Catch Location *				
		Ohio River	Wabash River	Tailwaters (KY and Barkley Lakes)	MS River	Kaskaskia
2022 Totals	***1,425,591***	***114,594***	***1,310,997***			
Jan-23	**191,613**	116,847	74,766			
Feb-23	**272,169**	232,172	39,997			
Mar-23	**432,469**	298,485	133,984			
Apr-23	**394,544**	224,874	163,807	5,863		
May-23	**418,971**	125,785	293,186			
Jun-23	**312,485**	304,774	7,711			
Jul-23	**236,870**	192,665		44,205		
Aug-23	**260,035**	83,198		176,837		
Sep-23	**267,302**	88,084	2,849	176,369		
Oct-23	**436,799**	139,728	36,890	260,181		
Nov-23	**131,068**	86,449	17,667	26,952		
Dec-23	**180,018**	155,785	23,120	1,113		
2023 Totals	***3,534,342***	***2,048,845***	***793,977***	***691,520***	***0***	***0***
Jan-24	**349,222**	231,269	117,953	0	0	
Feb-24	**513,709**	479,228	7,922	0	26,558	
Mar-24	**588,277**	571,063	10,279	0	6,935	
Apr-24	**471,518**	357,815	32,052	62,158	19,493	
May-24	**519,997**	314,359	42,363	118,576	44,699	
Jun-24	**649,331**	140,065	0	485,109	24,157	
Jul-24	**550,236**	29,502	0	516,823	3,911	
Aug-24	**151,382**	68,097	0	81,495	1,790	
Sep-24	**461,775**	29,219	0	432,556	0	
Oct-24	**577,824**	35,225	0	542,599	0	
Nov-24	**204,039**	34,620	0	167,233	0	2,186
Dec-24	**146,708**	96,394	0	50,314	0	0
2024 Totals	***5,184,018***	***2,386,856***	***210,569***	***2,456,863***	***127,543***	***2,186***

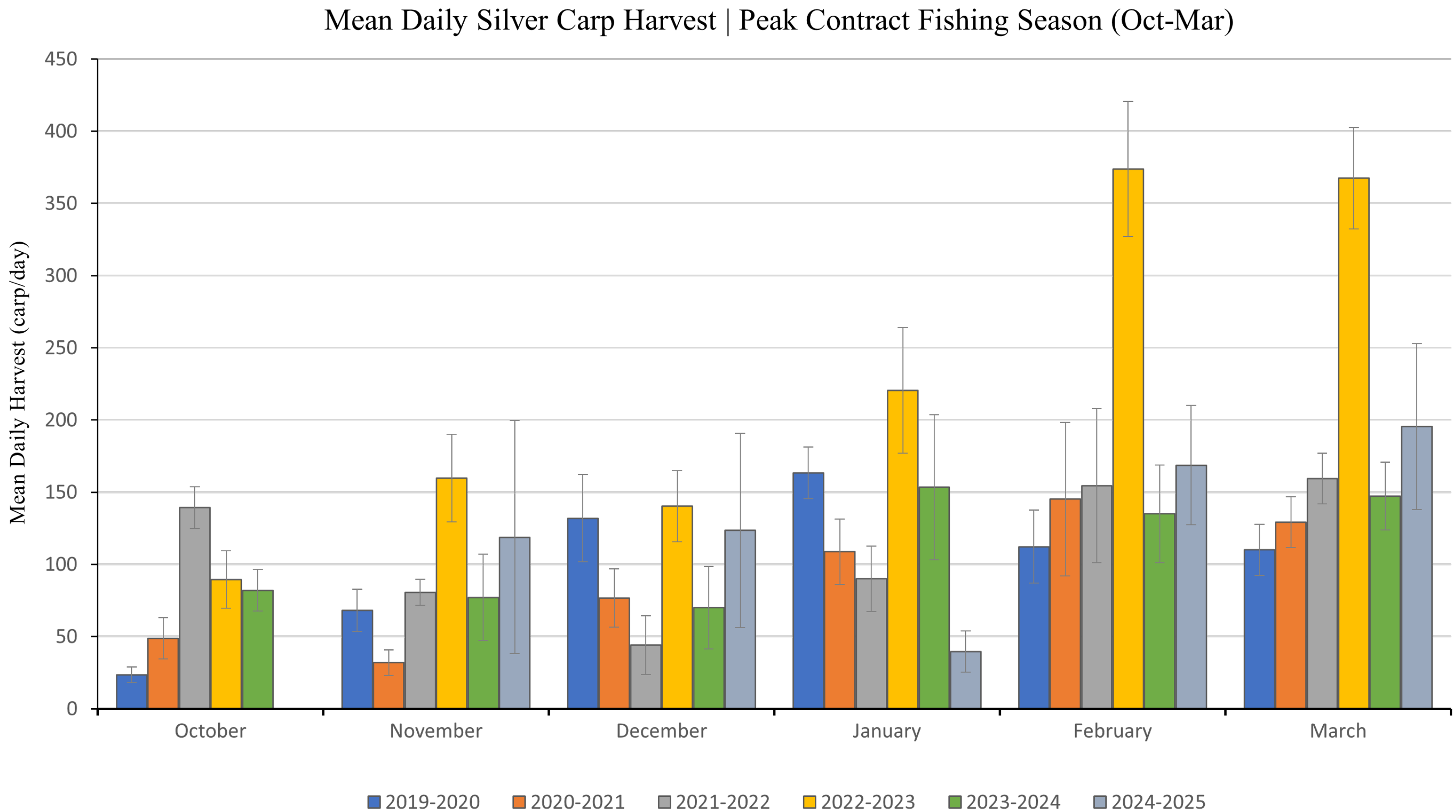


Figure 1. An illustration of the differences in mean Silver Carp harvest (total fish/day) for peak months over the past six fishing seasons. Error bars represent the standard error of the daily catch totals obtained from the contract fishers.

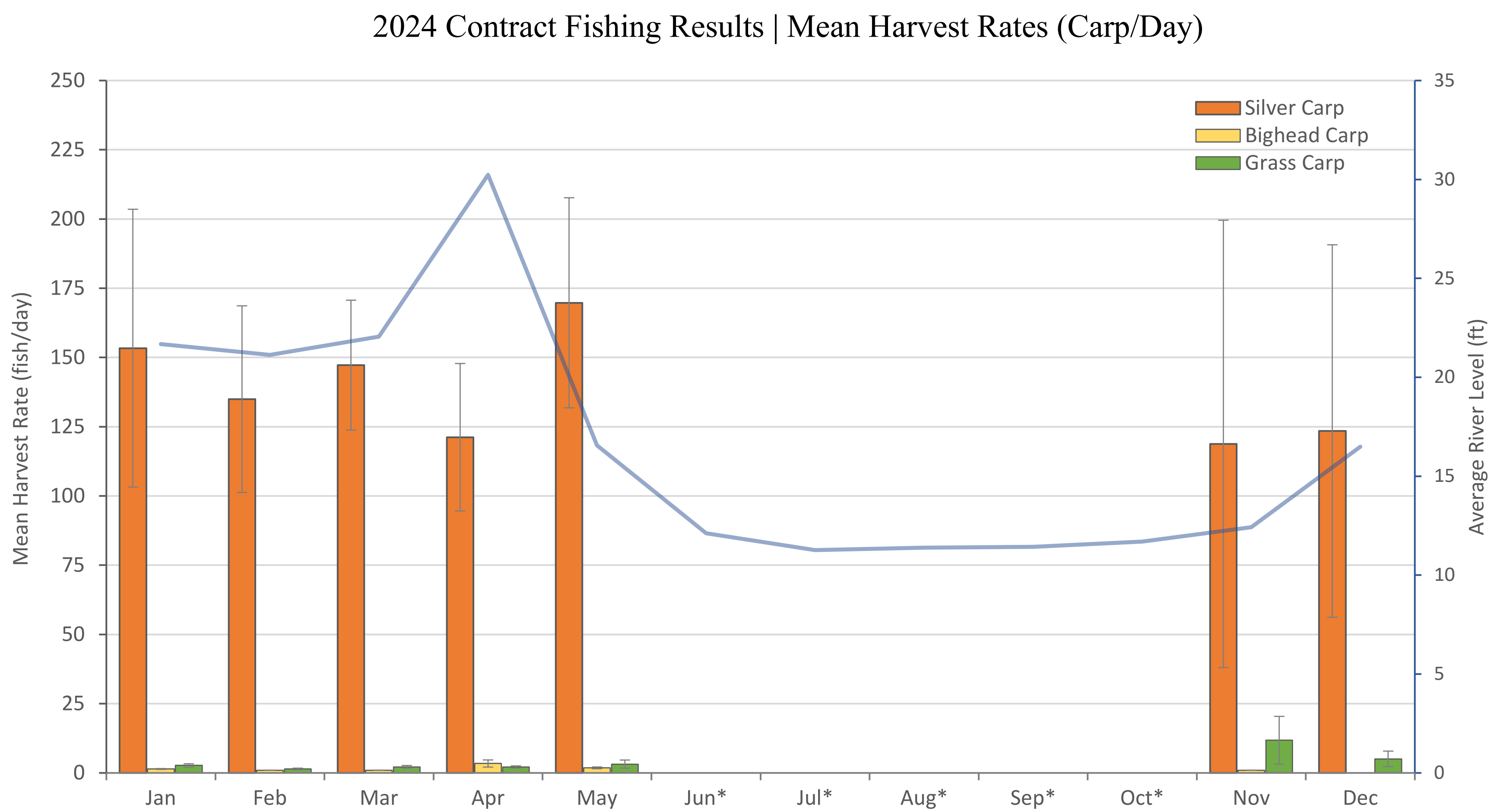


Figure 2. The average harvest rates (fish/day) in months between January and December 2024 that KDFWR employed contract fishermen to remove Invasive Carp. Error bars represented the standard error for daily catches. In addition, mean river level was calculated from data recorded by a USGS gage located at Cannelton Locks & Dam (blue line). Average daily landings in 2024 continued to be influenced by both temperature and river levels.

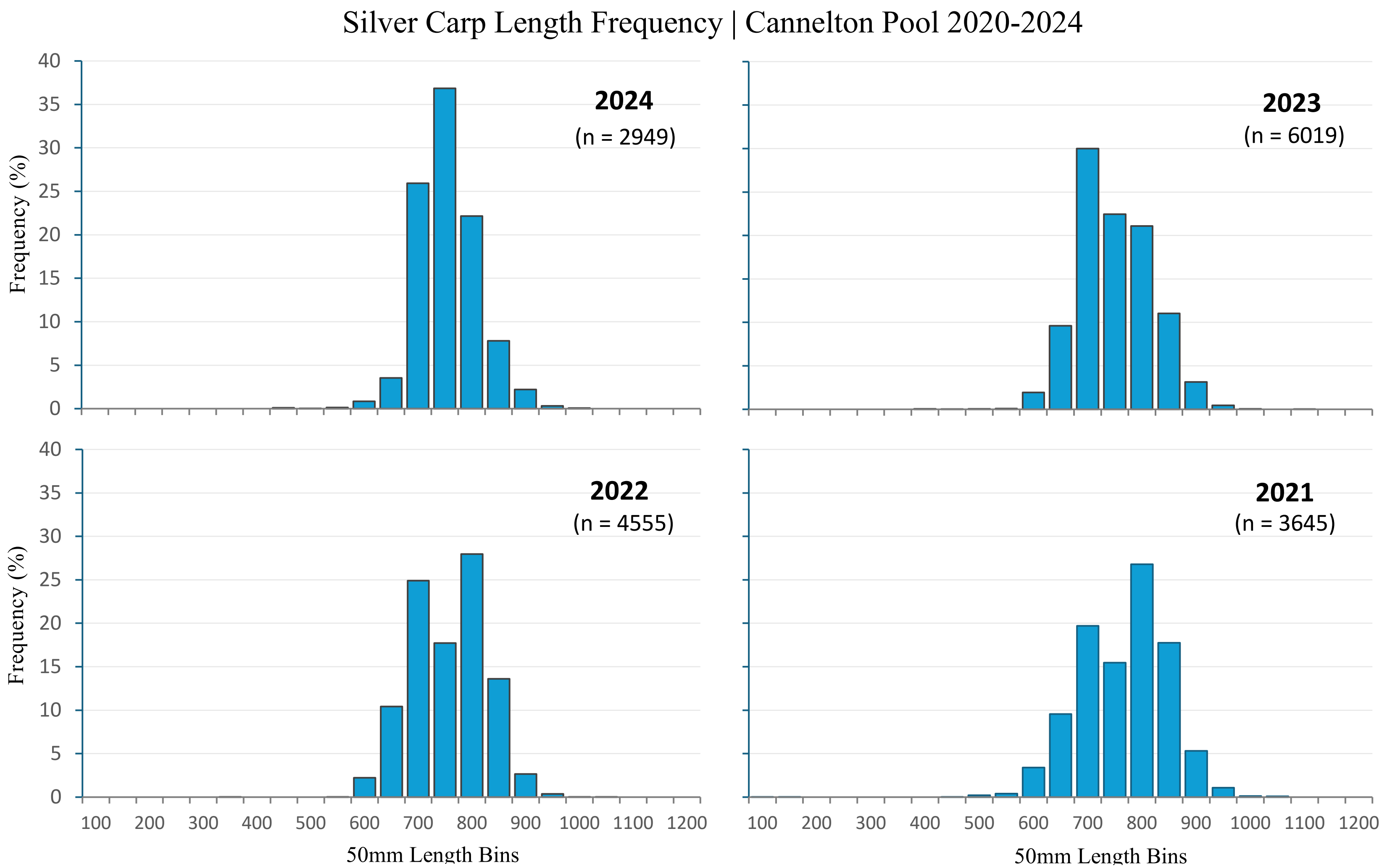


Figure 3. Length frequency distributions generated from subsamples of Silver Carp that contract fishers harvested from the Cannelton Pool in 2020-2024.

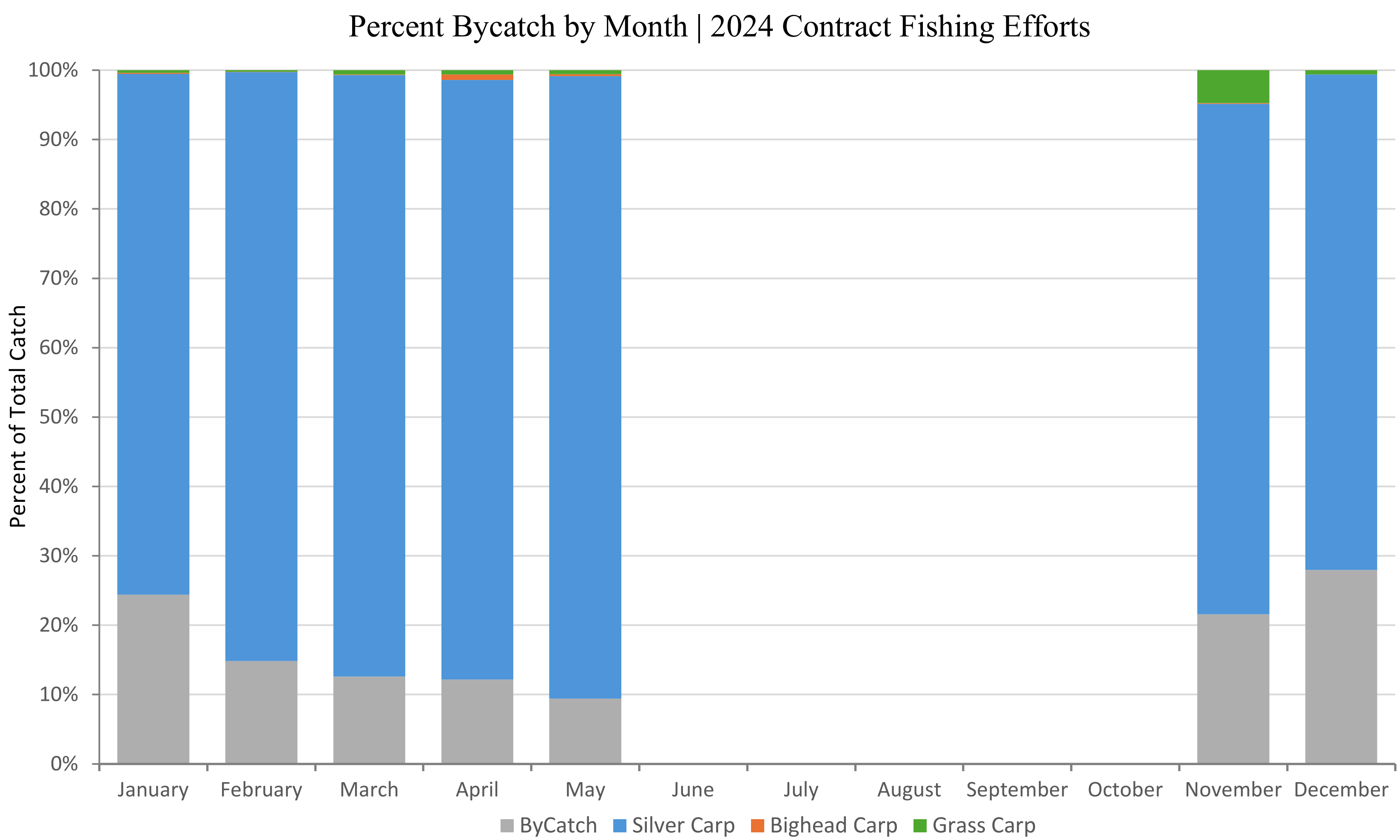


Figure 4. The monthly percent contribution of bycatch and three Invasive Carp species targeted by contract fishers from January to December 2024.

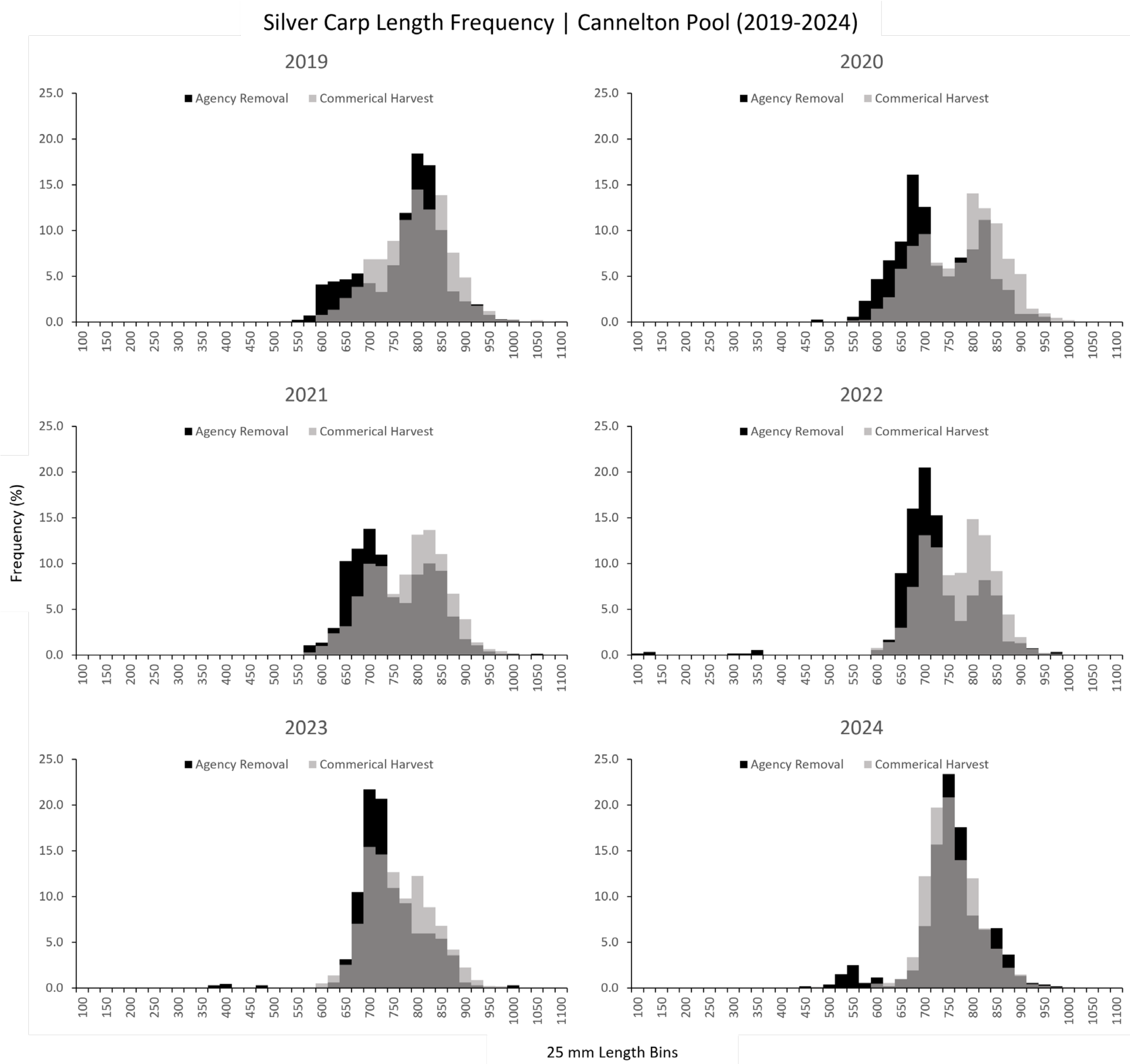
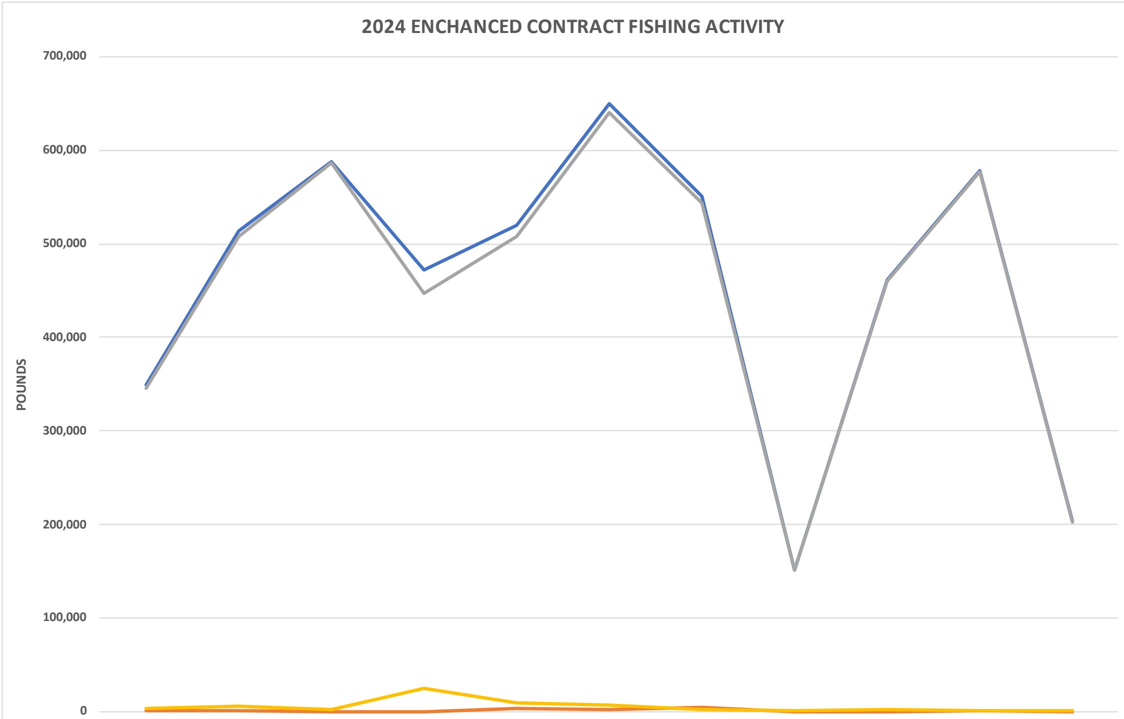
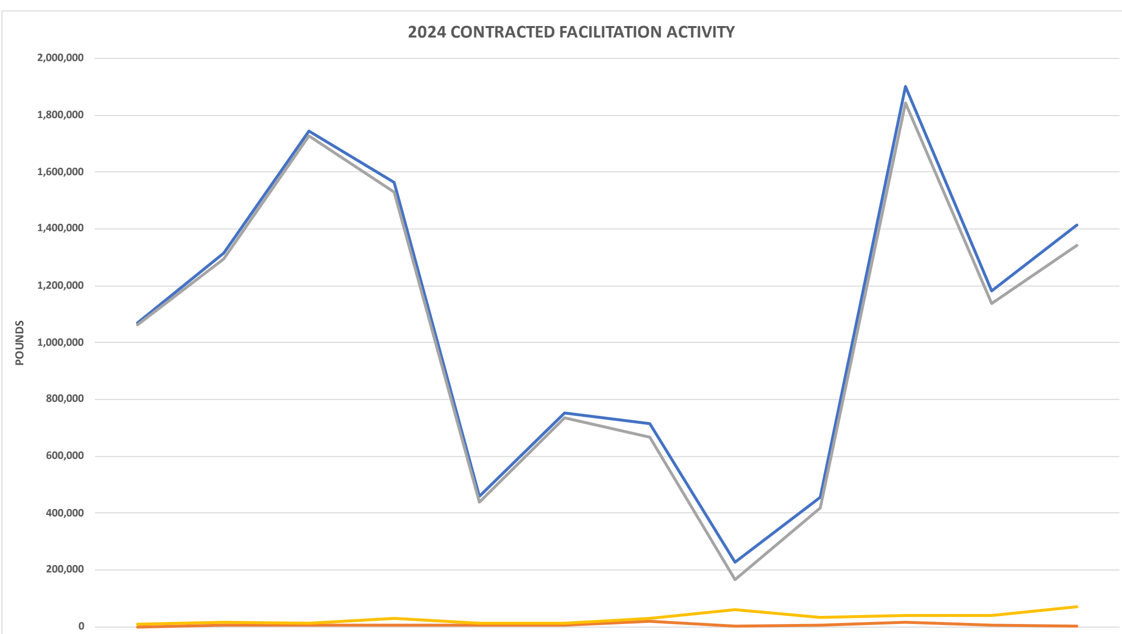


Figure 5. Length frequency distributions generated from agency removal data overlaid with length frequency distributions from contract fishing subsample data (2019-2024).



	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24
Total Lbs.	349,222	513,709	588,277	471,518	519,997	649,331	550,236	151,382	461,775	577,824	204,039
Bighead	142	881	109	0	2,864	1,834	4,577	0	0	496	0
Silver	345,636	507,385	586,342	446,409	507,650	640,541	543,237	150,683	459,899	576,526	202,860
Grass	3,444	5,443	1,827	25,109	9,483	6,956	2,422	699	1,876	802	1,179

Figure 6. 2024 Enhanced Contract Removal per month.



	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
Total	1,068,337	1,313,550	1,745,801	1,564,349	457,725	753,141	713,786	228,369	456,989	1,899,337	1,180,885	1,413,065
Bighead	229	4,385	6,045	5,302	6,554	4,253	18,960	2,265	4,549	16,621	5,512	844
Silver	1,060,802	1,294,074	1,728,748	1,529,011	438,041	735,768	666,332	166,184	418,317	1,842,755	1,137,084	1,342,558
Grass	7,306	15,091	11,008	30,036	13,130	13,120	28,494	59,920	34,123	39,961	38,289	69,663

Figure 7. 2024 monthly processed totals for the Contracted Facilitation project.