

Project Title: Control and Containment of Invasive Carp in the Missouri River Basin**Geographic Location:**

- Kansas River from rkm 0 (confluence with the Missouri River) to rkm 60 (Bowersock Dam; Lawrence, KS).
- Grand River from rkm 0 (confluence with the Missouri River) to rkm 12.2 (Brunswick, MO), and from RKM 24.1 to RKM 28.9 (Bosworth, MO).

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Statement of Need:

Invasive species have been a major cause of decline in native fish abundance and biodiversity and have undesirable economic impacts. Invasive carp (including silver carp, bighead carp, grass carp, and black carp) have successfully invaded watersheds in the United States and have a high probability of causing negative ecological and economic effects. Several studies reported diet overlap or competition between invasive carp and native species such as Bigmouth Buffalo, Paddlefish, Freshwater Drum, catfishes, and redhorse suckers (Schrack et al. 2003, Nico et al. 2005, and Sampson et al. 2009). Such effects have occurred in some areas of the Mississippi River Basin where invasive carp populations have become established. Irons et al. (2007) reported that bigmouth buffalo and gizzard shad condition has declined since the establishment of invasive carp. The impacts of these four species in the Missouri River basin are largely unknown, however basin-scale management of invasive carp species may be important in the recovery of native fish communities. Bighead and silver carp are well established in the Missouri River Basin where natural resource managers are concerned that these species are causing extensive and irreversible changes to the aquatic environment.

Research has shown that bighead and silver carp populations could potentially be recruitment overfished. One study estimated that harvesting 25 percent of silver carp greater than 300-mm total-length would lead to reduced abundances in the Missouri River (Seibert et al. 2015). Still other studies estimate exploitation rates of 30% (Tripp and Phelps 2018) to 40% (ACRCC 2019) would lead to a reduction of invasive carp populations. Tsehaye et al. (2013) estimated exploitation rates exceeding 70% in the Illinois River would be required to collapse the population. What remains unanswered is the amount of fishing effort required to reach a targeted exploitation rate (i.e., μ of 0.25) and if the minimum amount of effort needed to collapse the population is feasible.

Some previous sampling efforts for invasive carp have occurred in the Missouri River Basin. Since 2014, the U.S. Fish and Wildlife Service has conducted focused surveys of invasive carp in the Missouri River Basin and performed gear evaluations on novel active gears like the electrified paupier and dozer trawls (Hammen et al. 2019). In 2018 state and federal agencies conducted an invasive carp removal study in Creve Coeur Lake, a Missouri River floodplain lake near St. Louis, MO. Researchers in other portions of the Mississippi River Basin have evaluated passive gears (pound nets (Collins et al. 2015) and drift nets (Roth 2018)) and utilized hydroacoustics to assess the efficacy of removals (MacNamara et al. 2016). These evaluations show varying effectiveness depending on the body of water and invasive carp life stage targeted. Still, most commercial fishers and state agencies rely on standard commercial gears for sampling efforts.

Efforts outlined herein will not only utilize management approaches to reduce invasive carp populations, but also provide insight for future efforts aimed at reducing invasive carp populations. Effective and efficient methods of containing (i.e., preventing range expansion) and controlling (e.g., mass harvest) invasive carps are needed to prevent/minimize further impacts.

Project Objectives:

KDWP

- Remove invasive carp from the Kansas River below Bowersock Dam to provide a buffer against range expansion should dam be inundated during a high flow event.

MDC

- Compare the catchability of different size classes of bighead carp and silver carp among multiple removal methods in the mainstem Missouri River, mid-sized tributaries, and floodplain waterbodies. Estimate the amount of fishing effort required to achieve targeted exploitation rates among top-performing removal techniques. Assess the feasibility of a fishery-induced collapse of bighead carp and silver carp.

- Determine the amount of fishing effort required to achieve targeted exploitation rates among top-performing removal techniques in an open system.
- Remove a minimum of 15,000 pounds of invasive carp per week from the Grand River during two separate removal efforts.
- Quantify change in density of Silver Carp utilizing hydroacoustic surveys conducted by U.S. Fish and Wildlife Service.
- Quantify individual fisheries gear contributions to invasive carp removal.
- Assess the feasibility of various removal techniques in an open system.

Project Highlights:*KDWP*

- Agency personnel removed 11,679 kg of invasive carps from the Kansas River downstream of Bowersock Dam.
- KDWP personnel experimented with new net types, acoustic herding, and electrofishing techniques to optimize removal methods.
- Silver carp collected from the removal location are larger and have faster growth than silver carp collected from unfished areas of the Kansas and Missouri Rivers.

MDC

- In September 2023, MDC staff, working in conjunction with USFWS - Columbia and KDWP conducted an intensive short-term invasive carp removal on the lower Grand River in northwest Missouri.
- Daily hydroacoustic surveys were used to quantify invasive carp densities.
- Four gear types, including boat electrofishing, electrified paupier trawl, electrified dozer trawl and gill nets, were utilized to remove invasive carp over the course of the two four-day sampling periods.
- Grand River removal efforts resulted in 10,843 Silver Carp, 32 Bighead Carp, and 244 Grass Carp for a total of 17,554 kilograms (38,700 lbs.) of invasive carp removed from the lower Grand River. No Black Carp were sampled.
- Intensive rapid removals over the last two years on the Grand River have resulted in 17,506 Silver Carp and 63,600 lbs. of invasive carp harvested.
- Hydroacoustic data indicated Silver Carp densities were lower in 2023 compared to 2022 and densities decreased throughout each sampling period.

Agency: Kansas Department of Wildlife and Parks (KDWP)

Methods:

KDWP conducted agency removal efforts in 2023 using traditional boat electrofishing and gill nets. Removal efforts were focused on using gill nets in “whip sets” (spiral formation) (Figure 1). Two different net types (floating and sinking) were used in 2023. Both types of nets had the same configurations [3-1/4” mesh, 8’ height hobbled to 6’, and 200-300yds long]. Electrofishing was conducted using 45hz pulsed dc.

In addition to regular removal efforts, KDWP collected silver carp demographic data from two additional locations (Kansas River below WaterOne Weir and Missouri River at Atchison, KS) to compare to carp from the Kansas River above WaterOne weir. Sampling occurred from 6/12/2023-6/16/2023 using electrofishing as the collection method. KDWP collected silver carp using >550 mm – <850mm size bins with increments of 50mm.

Because the Kansas River is generally shallower and more braided than other locations in the Mississippi River basin where commercial and state agency carp suppression efforts have occurred and invasive carp suppression is a new activity in Kansas, KDWP conducted a lot of experimentation with gear types, deployment techniques and locations, set length, etc. Because of this wide variation, calculation of CPUE is not possible.

Results and Discussion:

A total of 11,769 kg of invasive carps were removed from the Kansas River between the Bowersock Dam and WaterOne Weir. KDWP was responsible for 100% of the removal in 2023. Of the 11,769 kg of removed carp, 8,440 kg were via gill nets and 3,329 kg were from electrofishing.

KDWP deployed two different types of gill nets (floating and sinking) in 2023. The sinking nets accounted for 4,919 kg and the floating nets caught 3,521 kg of the total 8,440 kg removed using gill nets (Table 1). KDWP had the most success with removal in the early spring and late fall of 2023, particularly the months of February and November (Figure 2). By far, the most frequently captured bycatch species was smallmouth buffalo, which was captured at a ratio of 3:1 invasive carp to buffalo, respectively. The next highest bycatch species were river carpsucker and blue catfish (Table 2). Bycatch mortality was recorded along with species count. Due to the short time nets are set and careful handling of native species, there was >99% survival rate for bycatch. KDWP also kept track of locations where removal occurred most frequently (Figure 3) to increase efficiency of locating invasive carp.

Comparisons of demographic data between three different locations (Figure 4) revealed that there are some differences (Figure 5, Figure 6, and Figure 7) between the treatment location’s silver carp population (Kansas River above WaterOne Weir) and the control locations’ populations (Kansas River below WaterOne Weir and Missouri River at Atchison, KS). Fifty percent (50%) of sampled carp in the treatment population were >718 mm in length compared to

654mm (Kansas River below WaterOne Weir) and 624 mm (Missouri River) in the control population (Figure 7). Size structure of the treatment population is shifted toward larger fish than the two control populations. At 650 mm, the treatment population had an expected weight of 3,285 g. The control locations had lower expected weights, which were 3,043 g (Kansas River below WaterOne Weir) and 2,677 g (Missouri River) (Figure 6). Expected weight at length is slightly higher in the treatment population than the two control populations.

The maximum observed age in the treatment population was 11 years. Both control locations had a maximum age of 13 years. Median length at age-4 in the treatment population was 670 mm. The median length at age-4 in the control populations was 613 mm (Kansas River below WaterOne Weir) and 580 mm (Missouri River) (Figure 7). The treatment population demonstrated higher age at length and faster growth than the two control populations.

Overall, the silver carp collected from the treatment location are larger and have faster growth than the carp collected from the two control locations. The differences in demographics may be attributed to the KDWP removal program, however without historical data for comparison, it is unknown if the demographic differences are due to removal or other factors. KDWP intends to continue collecting data and making comparisons across the three locations to monitor for demographic changes that may be attributed to the removal effort and inform future invasive carp management decisions in the Kansas River.

Tables and Figures:

Table 1. Summary of catch data (kg per month) of invasive carp removed from Kansas River between Bowersock Dam and WaterOne Weir in 2023. [Return To Text](#)

Month	KDWP Removal Method			Total (kg)
	Sinking Gill Net (kg)	Floating Gill Net (kg)	Electrofishing (kg)	
January	1018	-	-	1018
February	2368	-	29	2397
March	303	-	1403	1705
April	519	-	490	1009
May	384	-	202	586
June	-	-	1206	1206
July	-	-	-	-
August	327	-	-	327
September	-	216	-	216
October	-	-	-	-
November	-	2522	-	2522
December	-	783	-	783
Total (kg)	4919	3521	3329	11769
Gill Net total = 8440kg				

Table 2. *Summary of species and count bycatch data for 2023.* [Return To Text](#)

Species	Count
Smallmouth Buffalo	709
River Carpsucker	119
Blue Catfish	97
Flathead Catfish	36
Common Carp	32
Bigmouth Buffalo	32
Blue Sucker	23
Longnose Gar	7
Channel Catfish	6
Freshwater Drum	5
Shovelnose Sturgeon	1

**Figure 1.** *Picture of gill net set in spiral whip set.* [Return To Text](#)

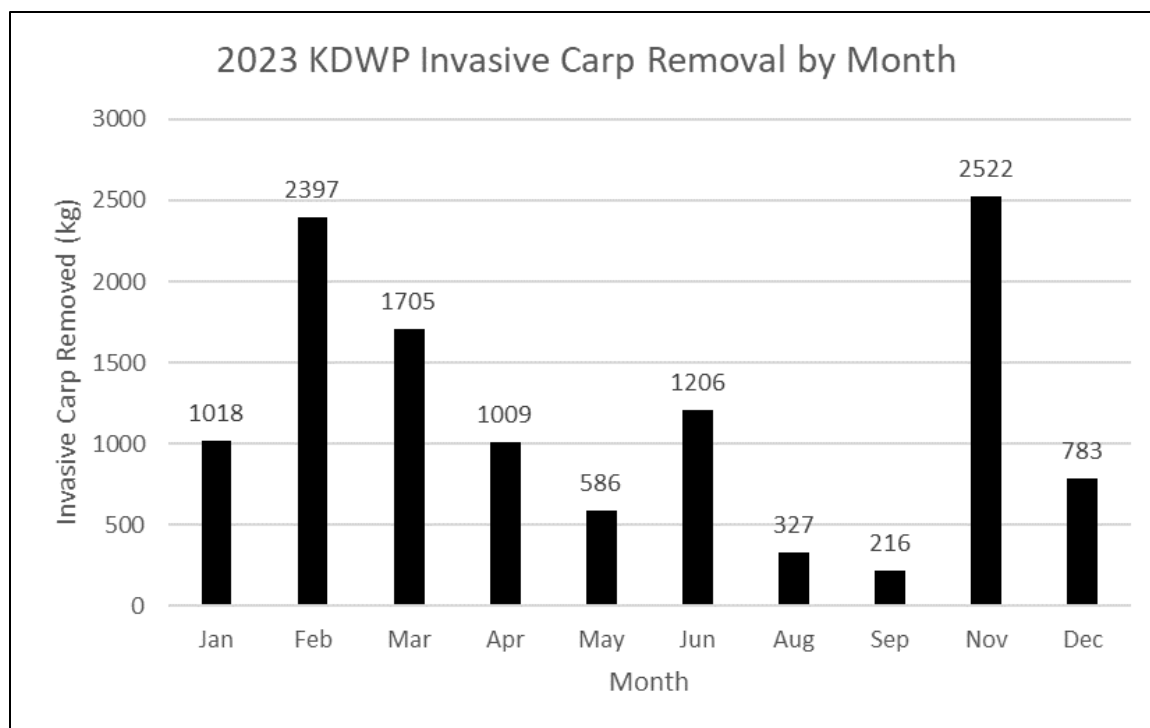


Figure 2. Invasive carp removed in kg per month. [Return To Text](#)

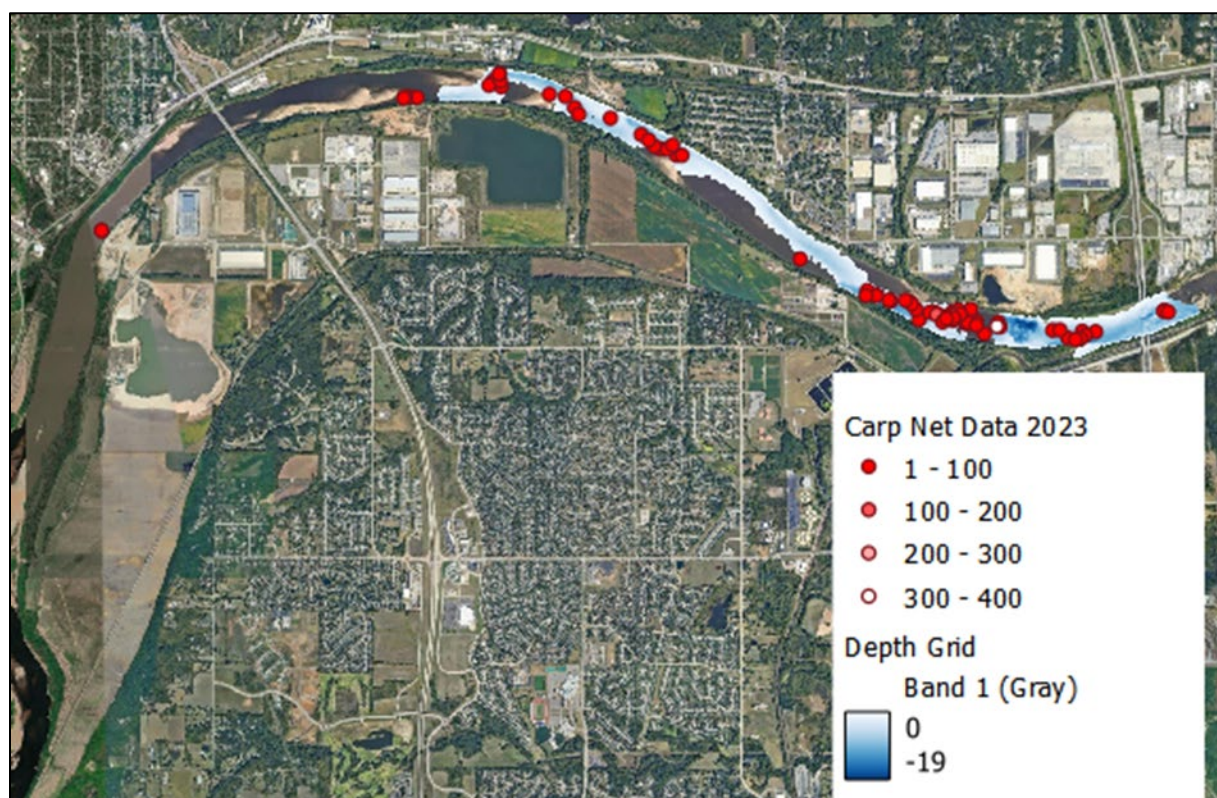


Figure 3. Heat map of KDWP invasive carp removal sites. [Return To Text](#)

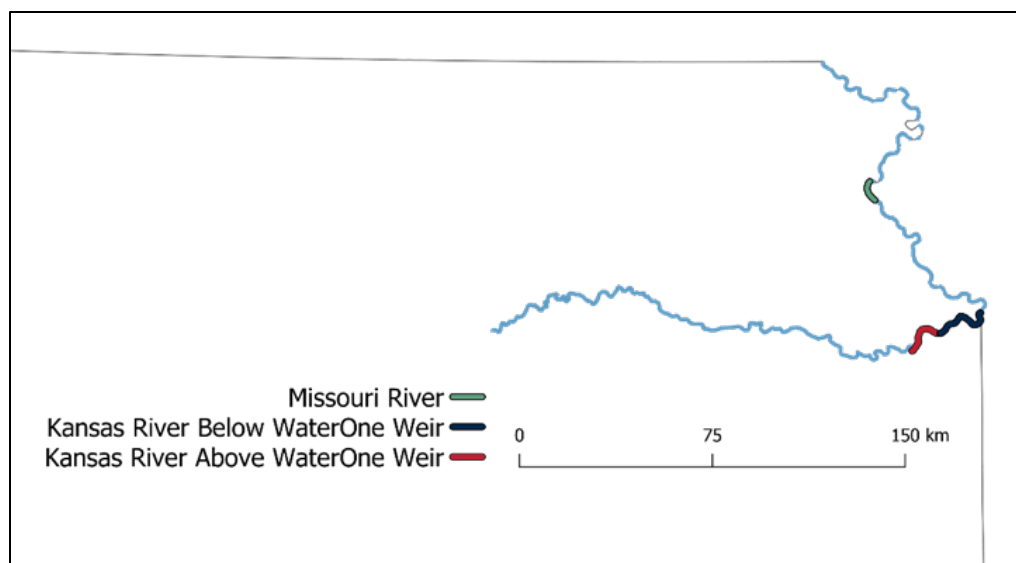


Figure 4. Locations KDWP used for demographic comparisons between removal (treatment) population and control populations. [Return To Text](#)

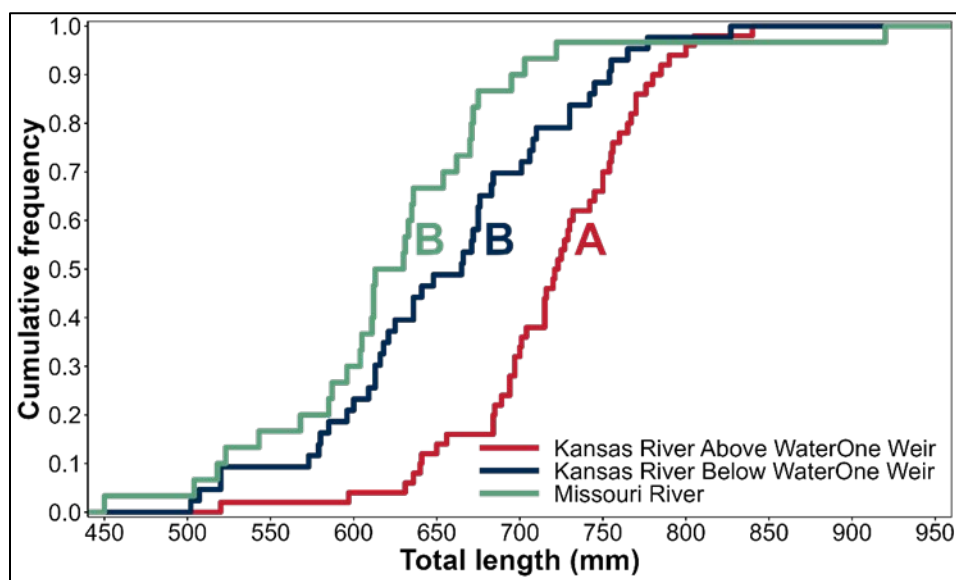


Figure 5. Comparison of length frequency/distribution between Kansas River above WaterOne Weir (treatment population) vs. Kansas River below WaterOne Weir and Missouri River at Atchison, KS (control populations). [Return To Text](#)

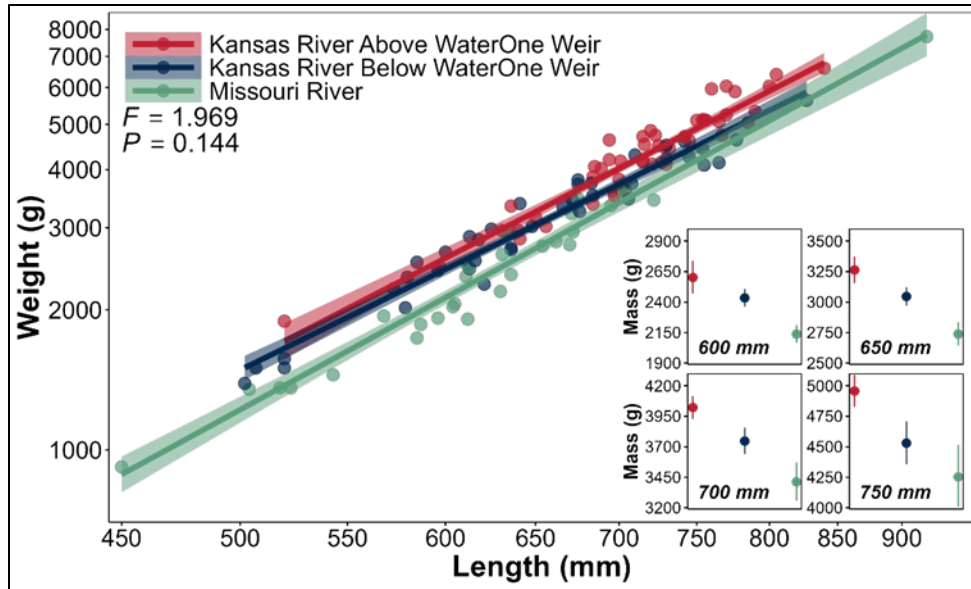


Figure 6. Comparison of expected weight at length between Kansas River above WaterOne Weir (treatment population) vs. Kansas River below WaterOne Weir and Missouri River at Atchison, KS (control populations). [Return To Text](#)

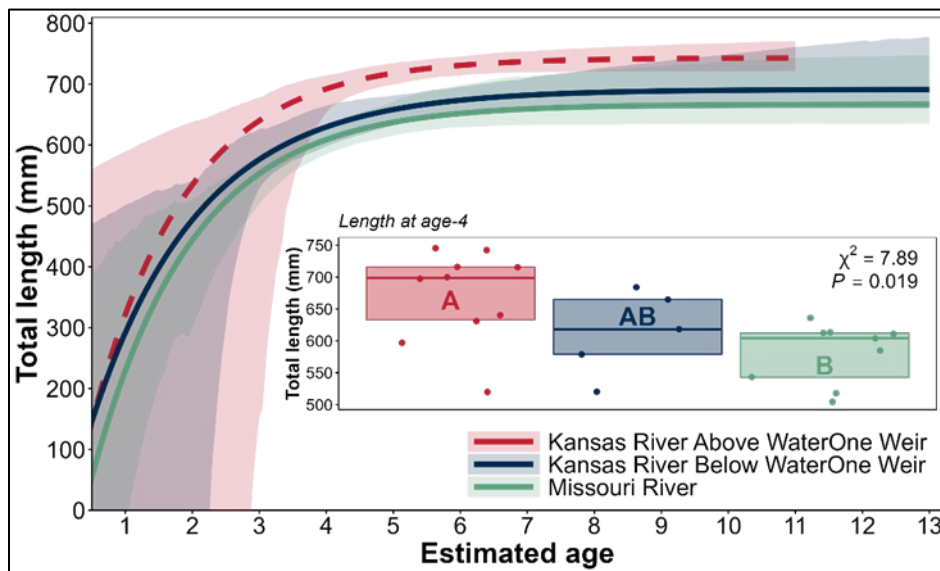


Figure 7. Comparison of age and growth between Kansas River above WaterOne Weir (treatment population) vs. Kansas River below WaterOne Weir and Missouri River at Atchison, KS (control populations). [Return To Text](#)

Agency: Missouri Department of Conservation (MDC)

Methods:

Hydroacoustic assessment surveys were conducted by USFWS pre-, daily, and post- removal to estimate invasive carp densities. Surveys consisted of one downstream and one upstream transect from rkm 12.2 in the Grand River to the confluence with the Missouri River. Dozer trawl standard sampling was conducted by USFWS pre- and post- removal with a five minute transect sampled every river kilometer moving in an upstream direction at 4.8 kph from the confluence of the Grand and Missouri rivers until habitats were too shallow to sample.

Invasive carp were captured utilizing the paupier, dozer trawl, gill nets, and boat electrofishing. The paupier conducted transects of varying duration in the main channel, focusing in areas with dense schools or aggregations. The paupier was accompanied by one tender boat to process catch. The dozer trawl conducted transects in habitats outside of the paupier sampling area, but also worked in conjunction with the paupier at times during the removal to maximize catch rates. Daily pedal time and number of runs were recorded for both electrified trawls. Gill nets measuring 91.4, 106.7 and 121.9 m in length and 4.9 and 7.3 m in depth containing mesh sizes of 63.5, 76.2, 89, and 101.6 mm were deployed with multiple nets. These nets were tied together with sinking nets, followed by a set of floating nets, and set in concentric circles in areas with dense aggregations of Silver Carp. Daily number of gill nets, length of nets, soak time, and mesh size were recorded. Boat electrofishing was utilized in areas difficult for other gears to sample (i.e., snags and brush piles) and along the riverbanks. Electrofishing boxes were set to 60 Hz and 40% duty cycle and enough volts to achieve 20 amps or more. Two to three electrofishing boats worked in unison to sample target areas and maximize catch.

All invasive carp (Silver, Bighead, Grass and Black carp) captured were counted, identified to species, and harvested, regardless of size. Invasive carp were transferred to 1.3 cubic meter bulk bags with 1,000 kg weight capacity. Bulk bags containing invasive carp were then offloaded at boat ramp using a backhoe to lift bags from boats and transferred to shipping containers provided by FKF Commercial Fisheries and Bait, LLC.

Twenty-five percent of paupier, dozer trawl, and boat electrofishing runs were subsampled for fish length data. All fish were identified to species, and lengths were collected for all individuals >250 mm. These data were used to characterize bycatch, as well as assign identities to fish detected during hydroacoustic surveys.

Invasive carp catch per unit effort was calculated as fish per hour for paupier, dozer trawl, and boat electrofishing. Gill net catch per unit effort was calculated as fish per 100 yards of net.

Results and Discussion:

Invasive carp removal was conducted 11-14 (week 1) and 25-28 (week 2) September 2023. Removal efforts totaled 16.0 hours of paupier sampling, 15.4 hours dozer trawl, 107.1 boat electrofishing hours and 34 gill net deployments. Total catch amounted to 10,843 Silver Carp, 32 Bighead Carp, and 244 Grass Carp for a total of 17,554 kilograms (38,700 lbs.) of invasive carp removed from the lower Grand River in 2023, including both sites.

Brunswick site catch rates in week 1 were variable by gear throughout the week due to a couple of factors. The weather and rain reduced sampling efforts on day 1, electrofishing boats sampled upstream of the main Brunswick removal area on day 3 and gill net catch increased throughout the week as technique was refined. Paupier catch rates ranged from 140 to 64 Silver Carp per hour and dozer trawl catch exhibited a decreasing trend throughout the week ranging from 109.6 to 35.7 Silver Carp per hour (Figure 8). Week 2 catch rates exhibited more of a decreasing trend throughout the week for dozer trawl, electrofishing boats and gill nets. Paupier started week 2 off strong with 170 Silver Carp per hour and ended the week with 120.8 Silver Carp per hour, with a decreasing trend in the middle of the week. This may have been a factor of other gears sampling being focused more upstream while paupier sampled in the lower portion with deeper and longer runs.

Bosworth site catch rates in week 1 exhibited a decreasing trend throughout the week ranging from 225 Silver Carp per hour on day 1 to 48.7 Silver Carp per hour on day 4 (Figure 9). Week 2 catch rates at Bosworth ranged from 74 to 32 Silver Carp per hour and sampling was concluded after the second day of week 2 due to low catch rates.

Silver Carp was the most abundant species encountered by all sampling gears and the most abundant invasive carp species harvested. Silver Carp lengths ranged from 440 mm captured with boat electrofishing to 964 mm captured in gill nets. Mean lengths ranged from 552 mm with boat electrofishing to 621 mm with gill nets. Median length of Silver Carp captured in gill nets were significantly different ($P < 0.001$) than paupier, dozer trawl and boat electrofishing (Figure 10). However, not all Silver Carp were measured, as only a subsample was measured for paupier, dozer trawl and boat electrofishing.

Boat electrofishing captured the highest number of each invasive carp species, contributing 62% of the total Silver Carp catch, 50% of Bighead Carp, and 84% of Grass Carp collected. However, that includes high Bosworth catches and six total boat electrofishers. Paupier collected 16% of the total Silver Carp harvested and 27% at the Brunswick site (Figure 10).

Hydroacoustic surveys indicated overall Silver Carp densities in 2023 were lower than pre- and post-removal densities in 2022. Similar to 2022, Silver Carp densities in 2023 decreased daily throughout each removal period (Figure 11). After each removal week, there was a noticeable increase in density estimates.

Standard dozer trawl sampling pre- and post- removal indicated Silver Carp relative abundance decreased after removals in both 2022 and 2023. In 2022, catch rates decreased from 134 Silver Carp per hour to 69 Silver Carp per hour. In 2023, Silver Carp relative abundance was 114 Silver Carp per hour pre-removal, 23 Silver Carp per hour five days post removal and 44 Silver Carp per hour three weeks post removal (Figure 12).

Silver Carp daily catch rates in 2023 were lower for all gears compared to 2022 (Figure 13) except for gill nets, which is likely a factor of refining gill net techniques for capturing Silver Carp. Gill net catch per unit effort is difficult to compare to other gears especially electrofishing gears. The amount of effort at each deployment is high when utilizing five to six nets connected to circle large schools of Silver Carp and CPUE is calculated by 100 yards of net deployed. However, Figure 14 depicts the daily number of Silver Carp removed by gear and indicates gill nets in 2023 captured more Silver Carp than dozer trawl. Although, number of Silver Carp removed daily with all electrified gears was lower in 2023 than 2022 with the block nets (Figure 14). The daily total weight in pounds in 2023 was also lower in 2023 than 2022 at the primary Brunswick site (Figure 15). Ancillary invasive carp harvest at the Bosworth site increased daily totals and helped reach weekly goals of 15,000 lbs.

Overall, the Grand River invasive carp removal was a success and will provide valuable knowledge moving forward with invasive carp management. The goal of removing 15,000 lbs. of invasive carp each week was surpassed, which is a success. Intensive rapid removals over the last two years on the Grand River have resulted in 17,506 Silver Carp and 63,600 lbs. of invasive carp harvested.

There were similar decreases in hydroacoustic density estimates pre- and post-removal in 2022 (26.1%) and 2023 (27.3%), with similar numbers of fish removed in 2022 (6,663 Silver Carp) and 2023 (6,252 Silver Carp) from within hydroacoustic survey areas. This could suggest that one week (5 days) of a closed population removal had a similar effect on the local population as two weeks (total of 8 days) of open population removal efforts. However, it should be noted that relative abundance estimates indicated a lower population in 2023 that may have compounded this finding.

This event provided evidence that gill nets can be effective on Missouri River tributaries utilizing the described method. Two boats concurrently setting multiple nets tied together with sinking nets followed by floating nets set in concentric circles on top of schooling carp proved effective. In 2022, gill nets contributed to less than 1% of the Silver Carp harvested and in 2023 increased to 19% of the Silver Carp catch at Brunswick.

Multiple electrofishing boats working in unison proved effective once again in 2023. The boat electrofishers at the Bosworth site provided evidence that three electrofishing boats in smaller Missouri River tributaries such as those not accessible by the paupier or too many snags to use gill nets or dozer trawl, could exploit a high percentage of the invasive carp population in four days of effort. This technique also provides a sampling method for agencies lacking such gears as the paupier or dozer trawl and when removal locations are not conducive for paupier or dozer trawl sampling methodologies.

The lower Missouri River is channelized with rock structures and fast currents that present habitats where capturing invasive carp is difficult. Tributaries to the Missouri River are likely important habitat for invasive carp at multiple life stages and may be areas where invasive carp are susceptible to overfishing. The knowledge gained and estimates resulting from this removal

effort can aid biologists moving forward on future control and management actions of invasive carp in Missouri River tributaries.

Tables and Figures:

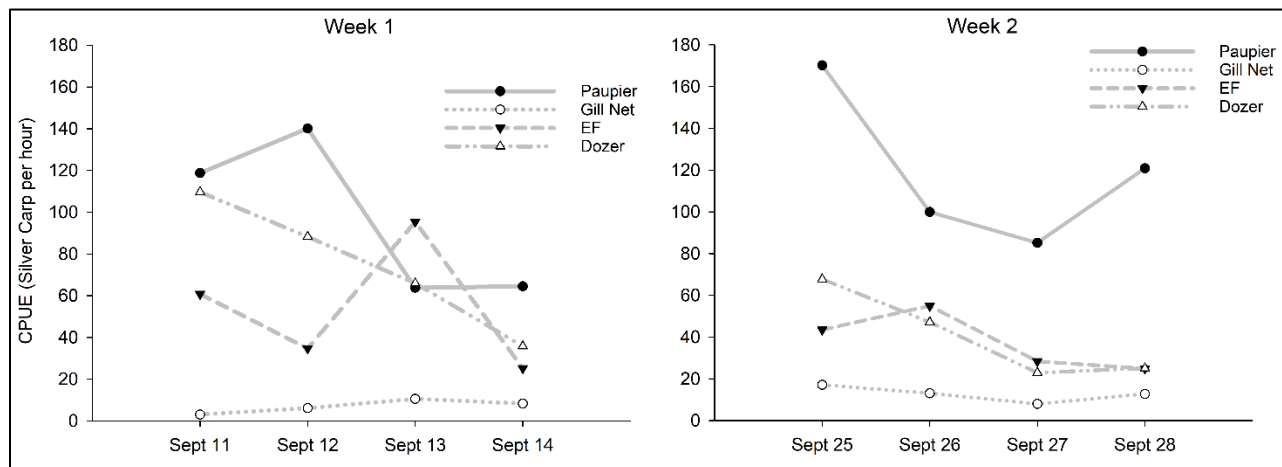


Figure 8. Silver Carp catch per unit effort (CPUE) by gear and day in 2023 at Brunswick Site on Grand River. CPUE was calculated as Silver Carp per hour for electrified gears and Silver Carp per 100 yards of net for gill nets. [Return To Text](#)

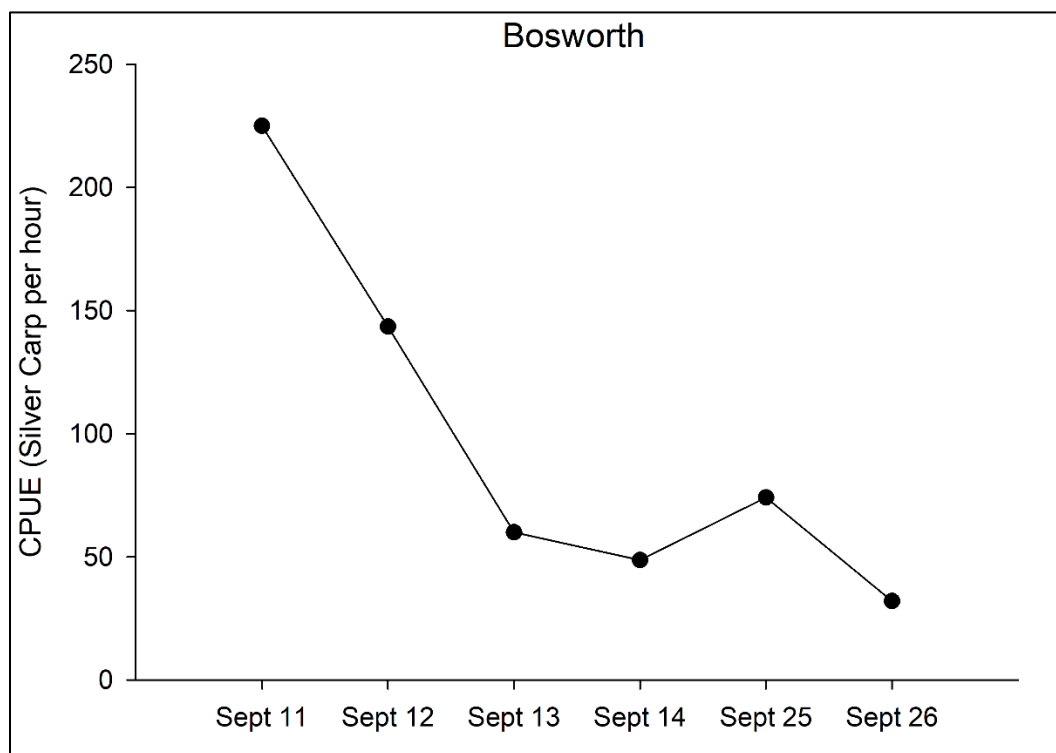


Figure 9. Boat Electrofishing Silver Carp catch per unit effort (CPUE) at Bosworth Site on Grand River. CPUE was calculated as Silver Carp per hour. [Return To Text](#)

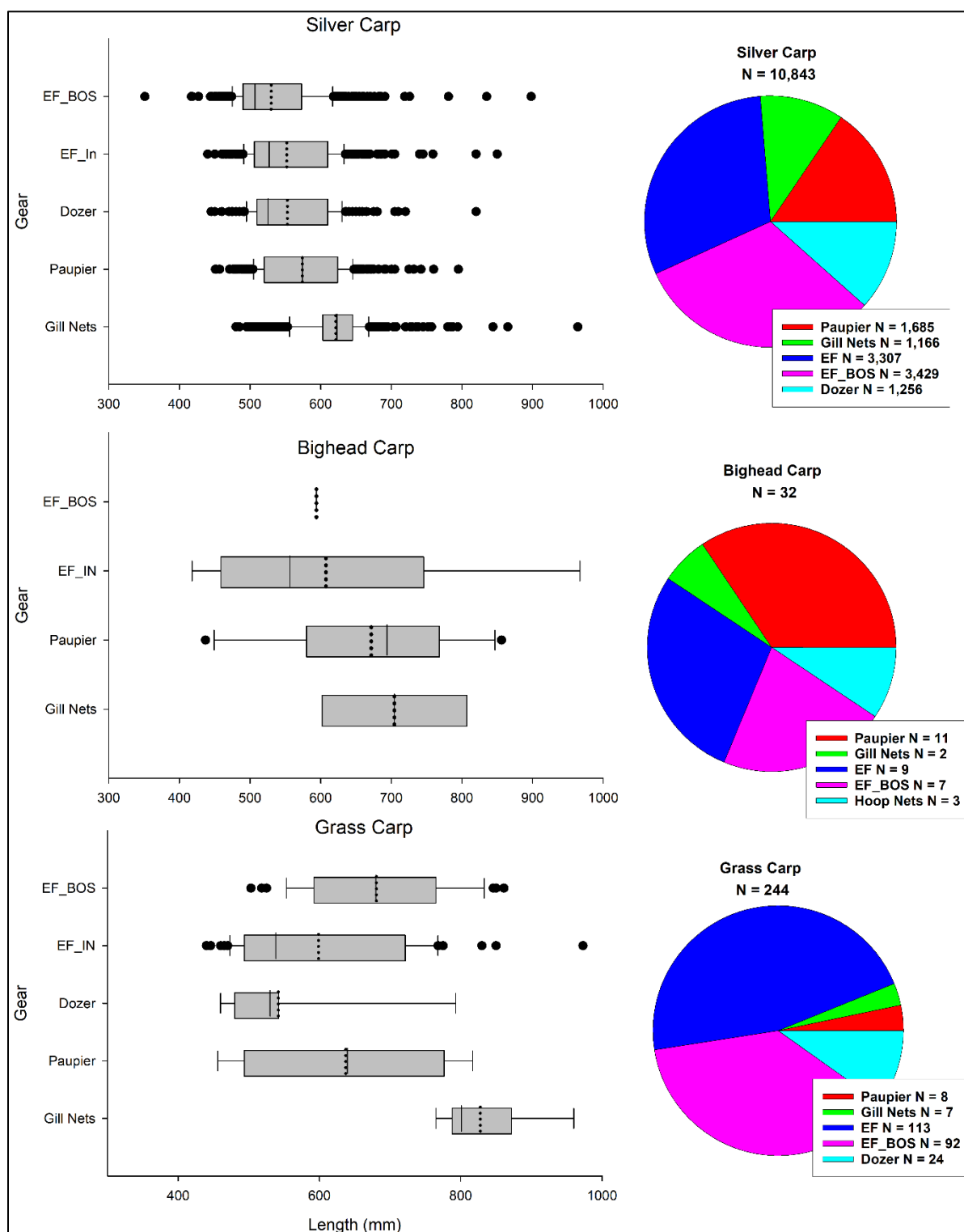


Figure 10. (left side) *a.* Box plots of invasive carp lengths by gear. Boxes represent the upper and lower quartiles, solid line represents the median, dotted line represents the mean, whiskers represent the 10th and 90th percentiles and black circles indicate outliers. (right side) *b.* Percent of total catch of invasive carp by gear. [Return To Text](#)

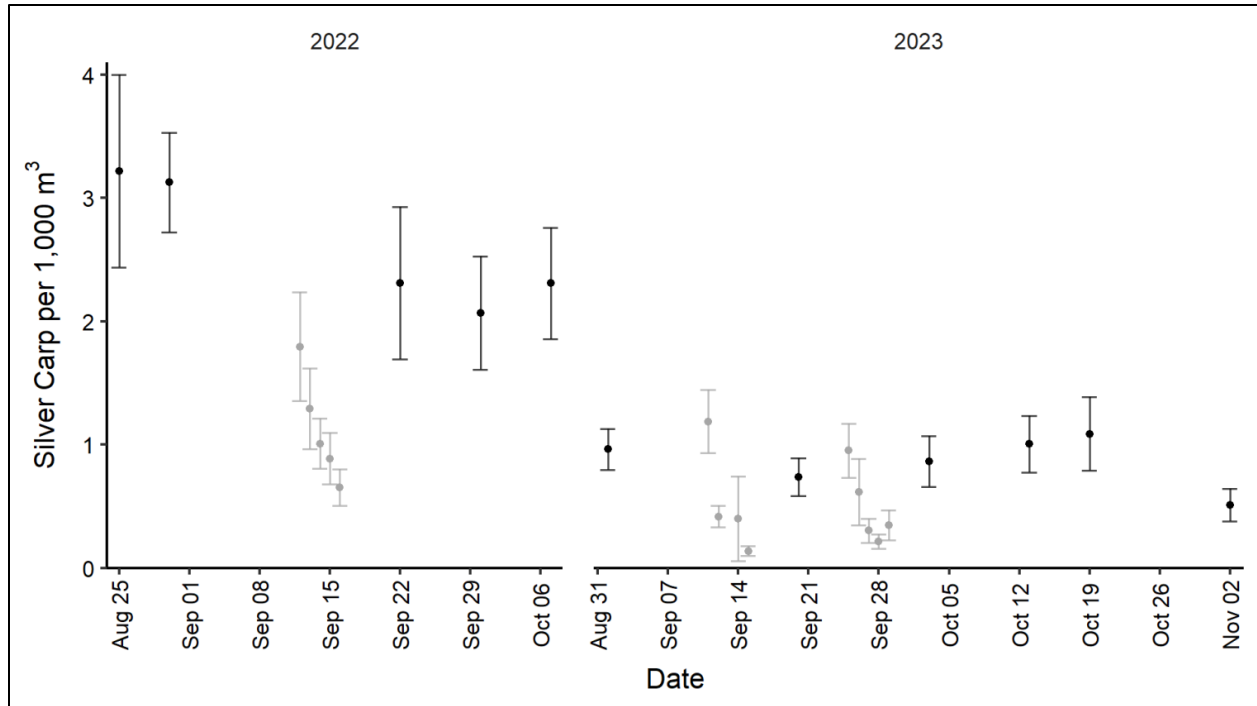


Figure 11. Time series depicting Silver Carp relative abundance estimated using hydroacoustics in 2022 and 2023. Black symbols indicate pre- and post- estimates, while gray symbols indicate daily abundance on removal days. [Return To Text](#)

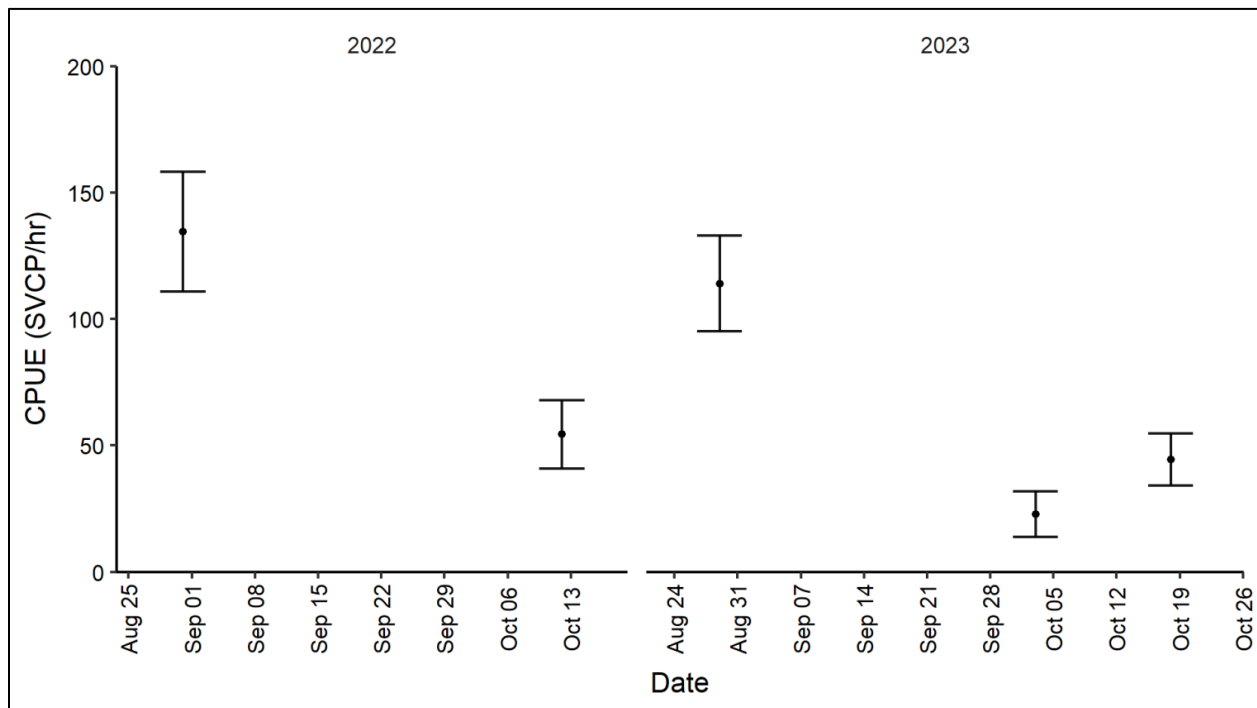


Figure 12. Silver Carp catch per unit effort using electrified dozer trawl pre- and post-removal. [Return To Text](#)

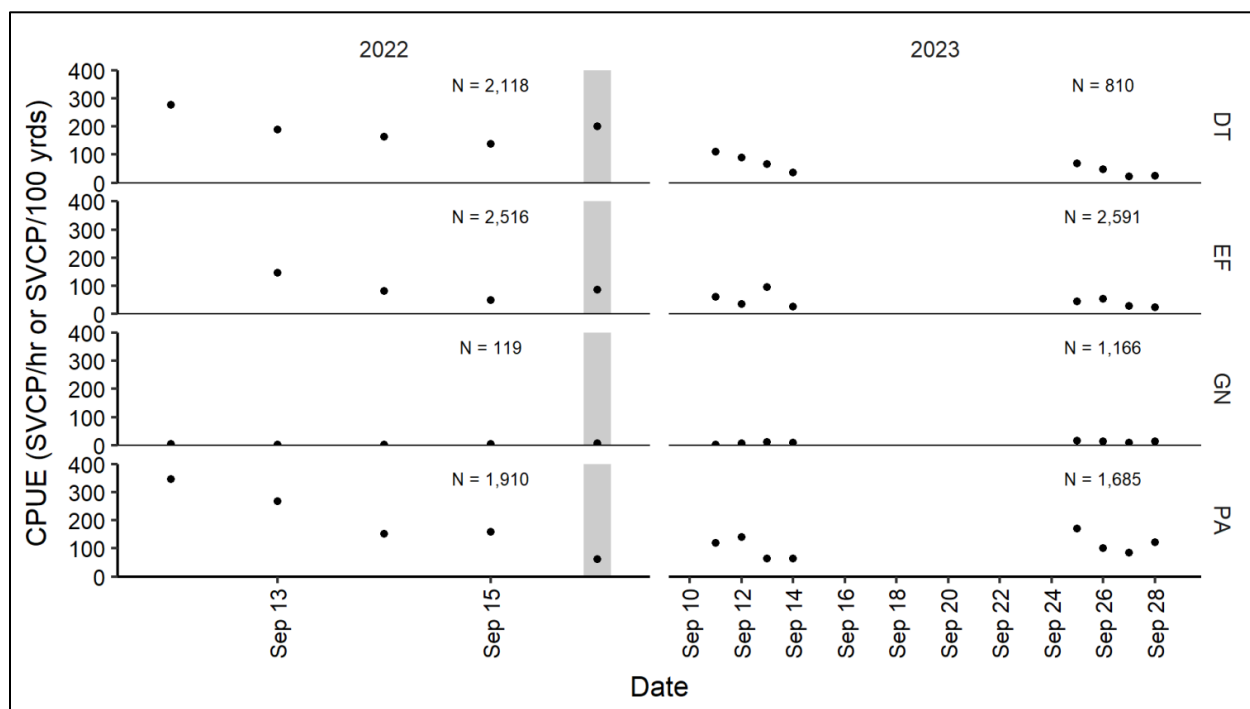


Figure 13. Silver Carp catch per unit effort by gear, day and year during Grand River removals. CPUE was calculated as Silver Carp per hour for electrified gears and Silver Carp per 100 yards of net for gill nets. Shaded portion on 2022 graph highlights catch after block nets were removed. [Return To Text](#)

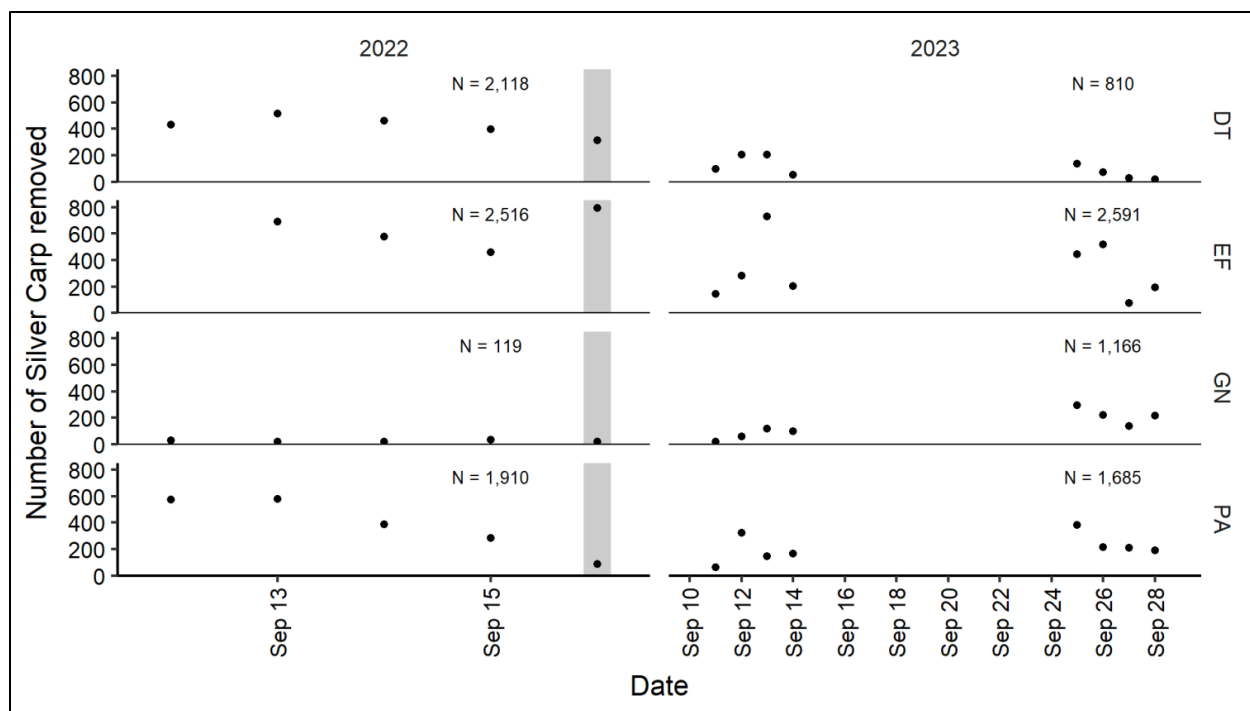


Figure 14. Number of Silver Carp removed by gear, day and year during Grand River removals. Shaded portion on 2022 graph highlights catch after block nets were removed. [Return To Text](#)

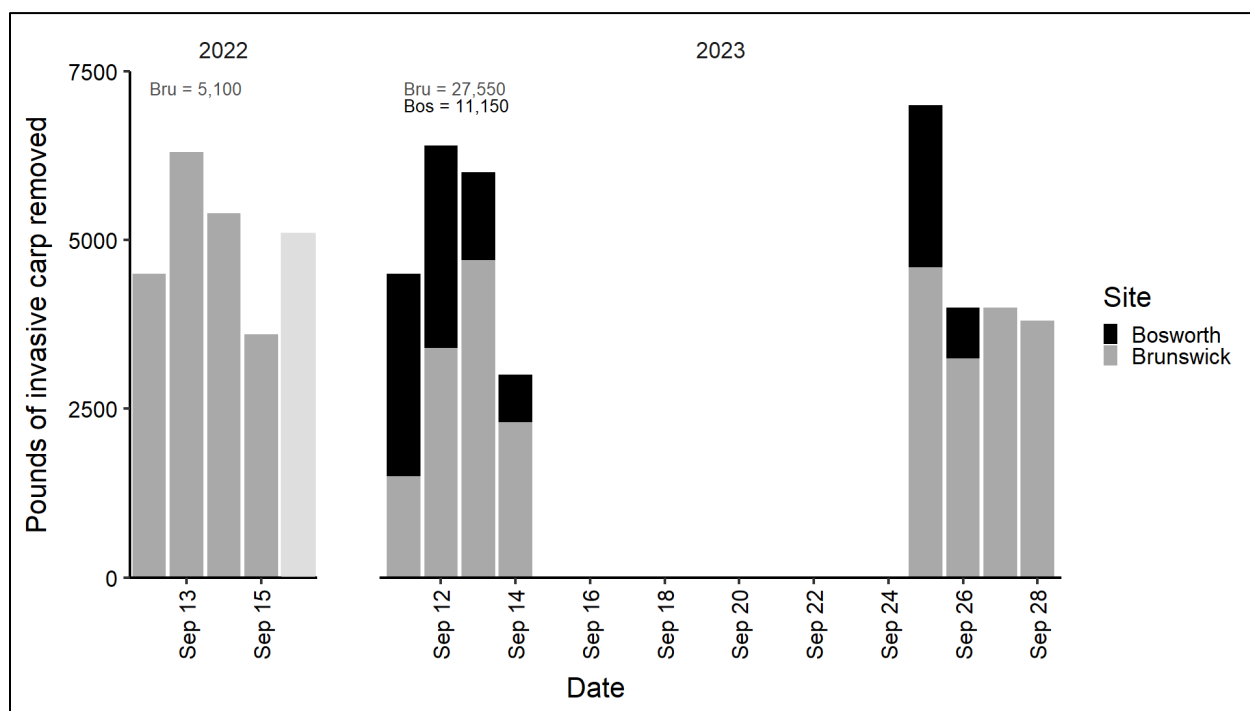


Figure 15. Pounds of invasive carp removed by day, year and site. Lighter shade bar on 2022 graph indicates pounds removed after block nets were removed. [Return To Text](#)

Recommendations:*KDWP*

- Continue invasive carp removal efforts in the Kansas River as there are demographic changes occurring in the silver carp population at this location that may be attributed to removal efforts.
- Continue monitoring changes in population demographics to further evaluate the impacts and effectiveness of invasive carp suppression.
- Experimentation and development of additional gears and techniques to maximize removal of invasive carps should be continued.
- Past invasive carp removal experiences are very valuable and can, should, and will be used to optimize the timing, location, methods, etc. of future removal efforts.

MDC

- For 2024 and beyond, removal techniques developed at the Grand River should be applied to new locations to test transferability across the landscape. Specifically, a two-week open system removal is recommended in another mid-size tributary such as the Lamine River using similar techniques. Logistically, an open-system removal was less resource-intensive and is likely more applicable across a broader range of tributaries. Furthermore, we have evidence that the open-system removal effort removed a comparable percentage of invasive carp relative to the closed-system removal. The three-boat electrofishing technique should be tested at a small tributary habitat such as the Platte River in Missouri.
- Commercial harvest of invasive carp should be explored in Missouri River tributaries. In 2024, a commercial harvest effort should be applied in a relatively similar location and season within the Grand River with pre- and post-removal hydroacoustic density estimates to compare commercial harvest results with agency harvest results.
- Telemetry data should be analyzed to better understand residency and impacts of removal efforts on invasive carp movement patterns in an open system.

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