Project Title: Control and containment of invasive carp in the Missouri River Basin

Geographic Location:

1. Kansas River from WaterOne Dam (Edwardsville, KS, RKM 24) to Bowersock Dam (Lawrence, KS, RKM 60).

2. Lower Missouri River, from river mile 550 to river mile 200. Mid-sized Missouri River tributaries including Lamine River, Platte River, Nodaway River, and Grand River. Waterbodies including Big Lake.

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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 (Schrank 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 such as pound nets (Collins et al. 2015), drift nets (Roth 2018) and hydroacoustics (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:

1. Remove invasive carp from the Kansas River to reduce the number of fish that may attempt to pass over the dam during a high flow event, decreasing the potential for a breeding population to establish upstream of the dam.

2. 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.

Project Highlights:

- **Objective 1:**
    - Removal of 10,460kg of invasive carp from the Kansas River between Bowersock Dam and WaterOne Weir by a contracted fisher and two newly hired invasive carp focused KDWP employees.
    - Many methods and gears were experimented with and caught fish; KDWP continues to seek information, learn additional methods, and acquire additional gears to optimize invasive carp removal.

  - Demographic data collected from invasive carp captured in 2022 differs from invasive carp captured in 2018-2019.

- **Objective 2:**
  - In September 2022, the MDC working in conjunction with the USFWS - Columbia piloted an intensive short-term invasive carp removal on the lower Grand River in northwest Missouri.
  - Block nets were utilized to provide a closed population, with daily hydroacoustic surveys used to quantify invasive carp abundance.
  - Boat electrofishing, paupier, dozer trawl and gill nets were utilized to remove invasive carp over the five-day removal effort.
  - Grand River removal efforts resulted in 6,663 silver carp, 52 bighead carp, and 178 grass carp weighing 11,294 kilograms (24,900 lbs.) being removed from approximately 6 miles of the lower Grand River. No black carp were sampled.
  - Hydroacoustic data analyzed using Leslie depletion models indicate an initial population estimate of 8,736 (+/-3,430) silver carp and an overall mortality rate of 0.62.

Methods:

- **Objective 1:** KDWP consulted with other states conducting contract invasive carp removal to inform implementation of contract removal in Kansas. Using that information, KDWP contracted with a trusted and experienced Kansas contract fisher, JD Bell, to conduct invasive carp removal in the Kansas River from March – June 2022. JD Bell utilized gill nets [3-1/4" mesh and 4" mesh nets of various heights, lengths, and set types], hoop nets [4', 7', and 8' configurations], and acoustic herding equipment.

  KDWP staff conducted limited agency removal efforts from July – August 2022 using traditional boat electrofishing. In September 2022, KDWP hired two new staff members dedicated to invasive carp management in Kansas. To better understand invasive carp capture methods, the new employees trained with staff from Arkansas Game and Fish Commission and Kentucky Department of Fish and Wildlife. The new KDWP invasive carp employees conducted additional invasive carp removal activities in the Kansas River from October – December of 2022. Based on their training activities with other state agencies, these efforts focused on using "whip set" (spiral formation) gill net sets [3-1/4" mesh, 8' height hobbled to 6', and 200-300yds long] and boat electrofishing [45hz pulsed dc].

  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 and our

contracted fisher conducted a lot of experimentation with gear types, deployment techniques and locations, set length, etc. Because of this wide variation, calculation of CPUE and direct comparisons of techniques are not possible; results are simply reported as total catch (in kg) per month by gear type.

- **Objective 2:** The lower Grand River in northwest Missouri was considered a suitable location for a rapid invasive carp removal due to the density and size structure of silver carp collected from population demographics work and local habitat characteristics. There is also a Missouri Department of Conservation boat access with ample parking located in Brunswick, MO on the lower Grand River 3.6 river kilometers upstream from the confluence with the Missouri River. The lower portion of the Grand River provides shallow areas to utilize block nets effectively and provide a closed population. This area also contains deep pools with low water velocities that tend to congregate invasive carp and provide water depths to effectively utilize the electrified paupier trawl. The sample area designated for the removal was between block nets deployed at river kilometer 1.1 and 10.8 on the Grand River.

  Block nets measuring 106.7 meters in length and 7.6 to 13.7 meters deep rigged with 25.4 and 50.8 mm bar mesh was deployed at river kilometer 1.1 to block the downstream portion and river kilometer 10.8 to provide the upstream barrier and close the population inside to immigration and emigration. Block nets were deployed with extra weights connected to the lead line every 3 to 6 meters in areas preselected for ideal bathymetry characteristics to ensure contact with the river bottom. Block nets were fixed with 20 kN carabiners to a 12.7mm AmSteel line stretched across the channel and pulled tight with electric winches to raise the block nets approximately 4.5m or more above the water's surface. The block nets elevated above the surface of the water prevented escapement of silver carp jumping over the nets, which is common with silver carp when nets simply float on the surface.

  Once the experimental population was closed using block nets, a hydroacoustic assessment surveys was conducted by USFWS to develop an initial relative abundance estimate. Surveys consisted of one downstream and one upstream transect. Transects were conducted along the thalweg of the removal area between the block nets. Hydroacoustic assessment surveys were conducted daily throughout the removal effort, and were conducted pre- and post-removal to quantify changes of silver carp relative abundnace. Transects were later divided into 0.8 km replicates throughout the removal area to calculate daily mean relative abundance and standard error. Daily silver carp relative abundance was later paired with daily cumulative catch of silver carp to fit a Leslie depletion model. In summary, depletion models predict how large the total harvest would have to be in order to drive relative abundance to zero. This estimate corresponds

to the initial unfished population size. Depletion models were fit using daily cumulative silver carp catch and daily relative abundance results from hydroacoustics and all removal gears except gillnets. Fishing mortality of the removal effort was calculated by dividing the total cumulative catch by the initial population size from the depletion model.

Invasive carp were captured utilizing the electrified paupier and dozer trawls, gill nets, and boat electrofishing. The paupier conducted 5 to 7 minute transects in the main channel focusing in areas with dense schools or aggregations. Two tender boats and one sorting boat accompanied the paupier to process catch. The dozer trawl conducted transects in habitats outside of the paupier sampling area but, later in the removal week, worked in conjunction with the paupier to improve fishing efficacy. Daily pedal time and number of runs were recorded for both electrified trawls. Gill nets measuring 61, 91, 107 and 122 meters in length and 3.7, 4.9 and 7.3m in depth containing mesh sizes including 63.5, 76.2, 89, 101.6 and 127mm were deployed in areas with dense aggregations, deep pools or areas to block invasive carp from seeking refuge. 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, brushpiles). Electrofishing boxes were set to 60 pps and 40 Hz and enough volts to achieve 20 amps or more. Two to three electrofishing boats worked in unison to sample target areas and maximize catch. Boat electrofishing was not implemented until day 2 of the event to alleviate day 1 logistics and personnel.

All invasive carp captured were counted and identified to species, and all invasive carp (silver, bighead, grass and black carp) were 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.

Hydroacoustics is not a stand-alone gear and must be paired with species length frequency data to separate the overall fish community size distribution into species-specific distributions. Thus, 25% of paupier, dozer trawl, and boat electrofishing runs were subsampled for fish demographic data. All fish were identified to species, and lengths were collected for all individuals >250mm. These data were used to characterize bycatch and paired with hydroacoustics data during the species apportionment process. Native species were either released outside the block nets or at capture site.

Invasive carp catch per unit effort was calculated as fish per hour for paupier, dozer trawl and boat electrofishing. Silver carp length groups were tested for normality ($P<0.05$). If treatment groups passed the normality test, a one-way analysis of variance (ANOVA)

was conducted and multiple pairwise comparisons were made using the Holm-Sidak method. When treatment groups failed normality test, analysis used a Kruskal-Wallis one way analysis of variance on ranks and when a significant difference in treatment groups was detected further analysis and multiple pairwise comparisons were made using Dunn's method. Analysis was conducted using SigmaPlot 14.5 by SYSTAT.

Results and Discussion:

- **Objective 1:** A total of 10,460 kg of invasive carp were removed from the Kansas River between the Bowersock Dam and WaterOne Weir (Figures 1 & 2); 8,294 kg were removed by a contracted fisher and 2,166 kg by KDWP staff (Table 1). Of the 8,294 kg of invasive carp removed by the commercial fisher, 978 kg were removed using 3-1/4" gill nets, 3,709 kg using 4" gill nets, 2,222 kg using 4' hoop nets, and 1,385 using 7-8' hoop nets. Of the 2,166 kg of invasive carp removed by KDWP, 876 kg were removed using whip-set 3-1/2" gill nets and 1,290 kg using boat electrofishing. Locations of KDWP gill net sets are displayed in Figure 2. Electrofishing had limited effectiveness when water temperatures dropped below approximately 5º C.

  Comparisons of Kansas River silver carp demographic data from 2018-2019 (before removal efforts) and 2022 (during and after removal efforts) reveal that there are some differences (Figures 3, 4, and 5). Silver carp in 2018-2019 averaged 682mm in length and 3,240 g in weight while in 2022 silver carp averaged 704 length and 4,056 g in weight (Figures 3 and 4). Additionally, there is a statistically significant difference in the length-weight relationship of silver carp captured in 2018-2019 in comparison to 2022 (Figure 5). Silver carp captured in 2022 are heavier at smaller sizes than silver carp captured in 2018-2019 (Figure 5). We have insufficient information to conclude if removal efforts alone are responsible for these changes, however, these are the type of changes that would be expected if silver carp growth in this section of the Kansas River was limited due to density-dependent factors prior to initiation of removal efforts. KDWP intends to continue removal efforts and monitoring changes in population demographics to further evaluate the impacts and effectiveness of invasive carp suppression.

- **Objective 2:** Grand River invasive carp removal was conducted September 12th through the 16th, 2022. Five days of removal efforts totaled 9.6 hours of fishing time for paupier runs, 11.5 hours with dozer trawl, 30.4 boat electrofishing hours, and 33 gill net deployments. Total catch amounted to 6,663 silver carp, 52 bighead carp, and 178 grass carp weighing in at 11,294 kilograms (approximately 24,900 lbs.) being removed from approximately 9.6 kilometers of the lower Grand River.

  Invasive carp catch rates generally declined for most gears between day 1 and day 4. Block nets were removed prior to capture gears deployment on day 5, resulting in an

increase in catch rates from immigration outside the main sample area (Figure 6). 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 339mm captured with the paupier to 880mm captured with the dozer trawl. Mean lengths ranged from 500mm with boat electrofishing to 613mm 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 7). 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 silver carp, contributing 38% of the total silver carp catch and 77% of grass Carp collected. Paupier collected 86% of bighead carp harvested (Figure 8). Gill nets only contributed 2% of silver carp, 8% of bighead carp and 6% of grass carp collected. Silver carp relative abundance ranged from 346.47 fish per hour on day 1 with the Paupier to 48.17 fish per hour on day 4 with boat electrofishing (Table 2). Relative abundance estimates on day 5 were excluded from analysis for boat electrofishing, paupier and dozer trawl due to block nets being removed on day 5 prior to sampling. However, hydroacoustic surveys were conducted prior to block net removal on day 5.

Leslie depletion models (i.e., simple linear regressions) were fit using daily data from four gear types (Table 2). High coefficients of determination indicated that relative abundance for each gear type was strongly related to cumulative catch. However, whereas hydroacoustics-based relative abundance was significantly related to cumulative catch, this was not true for the other gear types (Figure 9). This finding is likely related to smaller sample sizes used for the paupier and dozer ($N = 4$) and electrofishing ($N = 3$). Initial silver carp population size and removal mortality rate were derived using depletion results. Mortality rates were calculated as the ratio between cumulative silver carp catch and the initial silver carp population size. For example, the cumulative catch on day 5 was 5,456 silver carp and the hydroacoustics initial population size estimate was 8,736 silver carp (Table 2). This corresponds to a mortality rate of 0.62 (Table 3).

Post removal hydroacoustic surveys indicated invasive carp populations repopulated removal area 5 to 7 days following the rapid removal. However, densities were below levels measured prior to the removal (Figure 10).

Overall, Grand River invasive carp removal was a success and provided valuable knowledge moving forward in the struggle with invasive carp. The goal of removing 15,000 lbs of invasive carp was met and almost doubled, which was a success. Hydroacoustic surveys proved beneficial in providing valuable data toward population size, mortality rates and post-removal immigration abundance. Hydroacoustic data

indicated an overall silver carp mortality rate of 0.62, which suggests exploitation rates of 25% of fish 300mm and over could be met with the same amount of effort in two to three days for a rapid removal. However, rates at which silver carp repopulate sampled areas might suggest multiple weeks or removal occasions be required to achieve long-term reductions in silver carp.

The success of multiple electrofishing boats working together was rather eye-opening. This method proved effective in that silver carp jumping away from the electric field of one boat would jump into the electric field of another boat and more often exhibit enough taxis to be netted. It 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. Multiple boat electrofishers could be utilized in tributaries throughout the Missouri River basin and other basins affected by invasive carp.

Silver carp relative abundance estimates decreased from day 1 through day 4. On day 5, the dozer trawl and electrofishing boats sampled new habitats outside the initial block netted area and catch rates for both gears increased. Consequently, that data could not be used for the depletion models. The depletion models for those capture gears would have benefitted from additional data. If sampling efforts were recorded before the block net removal on day 5, observed p-values would be potentially significant. Although, the overall total weight of invasive carp removed probably would not be as high if block nets were not removed prior to sampling on the last day.

The lower Missouri River is channelized with rock structures and fast currents that present difficult habitats to capture invasive carp. Tributaries to the Missouri River are likely important habitats for invasive carp at multiple life stages and potential areas where invasive carp are susceptible to overfishing.

Paddlefish and buffalofish were common bycatch in removal efforts. Future efforts will need to take into consideration efforts not to impact those populations.

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:

- **Objective 1:**

Table 1. *Summary of catch data (kg per month) of invasive carp removed from Kansas River between Bowersock Dam and WaterOne Weir in 2022.*

	Contract fisher gears				KDWP gears	
Month	3-1/4" gill net	4" gill net	4' hoop net	7'-8' hoop net	3-1/2" gill net	boat electrofishing
January	-	-	-	-	-	-
February	-	-	-	-	-	-
March	978	823	227	-	-	-
April	-	1,616	-	118	-	-
May	-	363	666	537	-	-
June	-	907	1,329	730	-	-
July	-	-	-	-	-	-
August	-	-	-	-	79	538
September	-	-	-	-	-	-
October	-	-	-	-	160	534
November	-	-	-	-	347	218
December	-	-	-	-	290	-
2022 Total	978	3,709	2,222	1,385	876	1,290
	Contract fisher total = 8,294 kg				**KDWP total = 2,166 kg**	
	Total invasive carp removed = 10,460 kg					

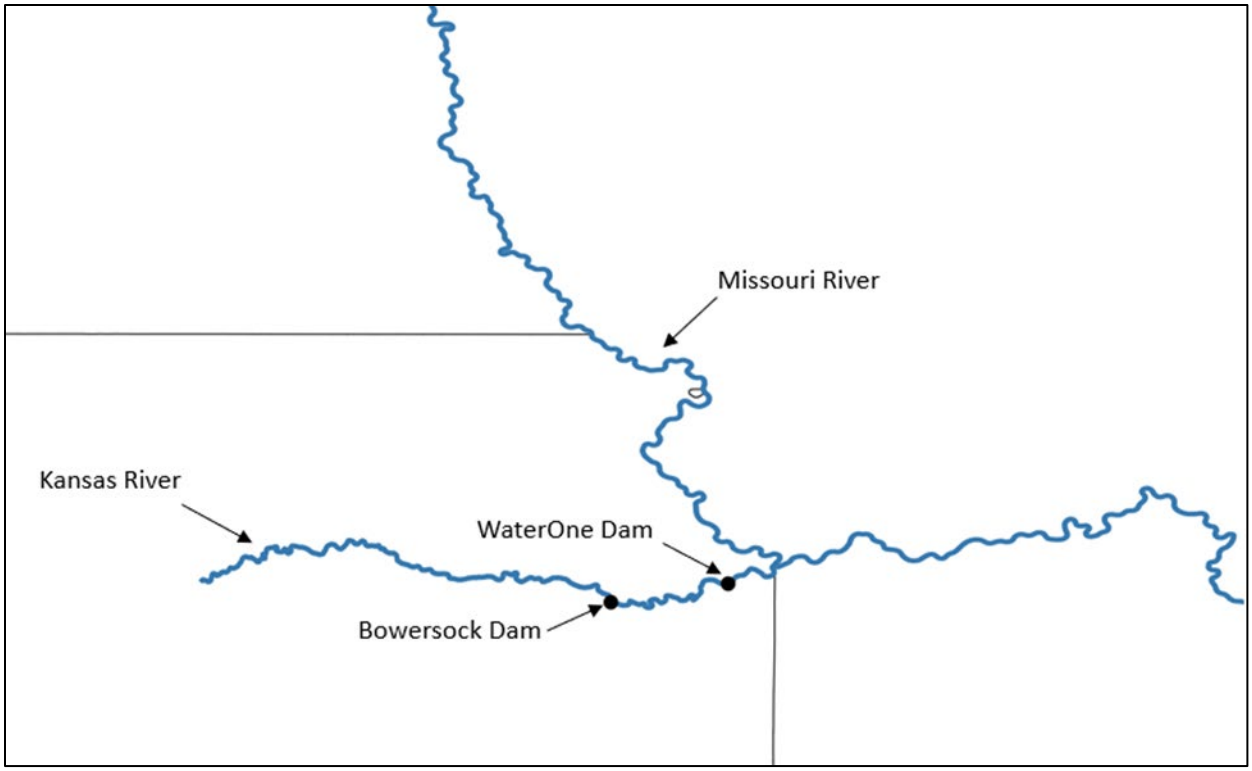

Figure 2. *Map of Kansas River project area.*

Figure 2. *Heat map of Kansas River invasive carp removal sites.*

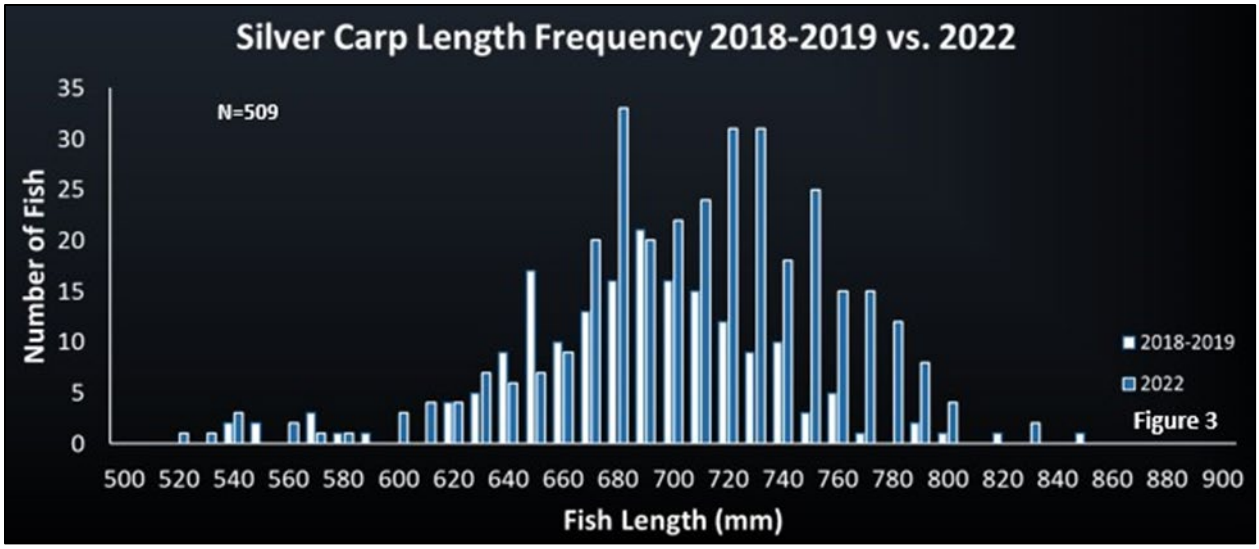

Figure 3. *Length frequency of invasive carp captured from the Kansas River in 2018-2019 (white bars) and invasive carp captured in 2022 (blue bars).*

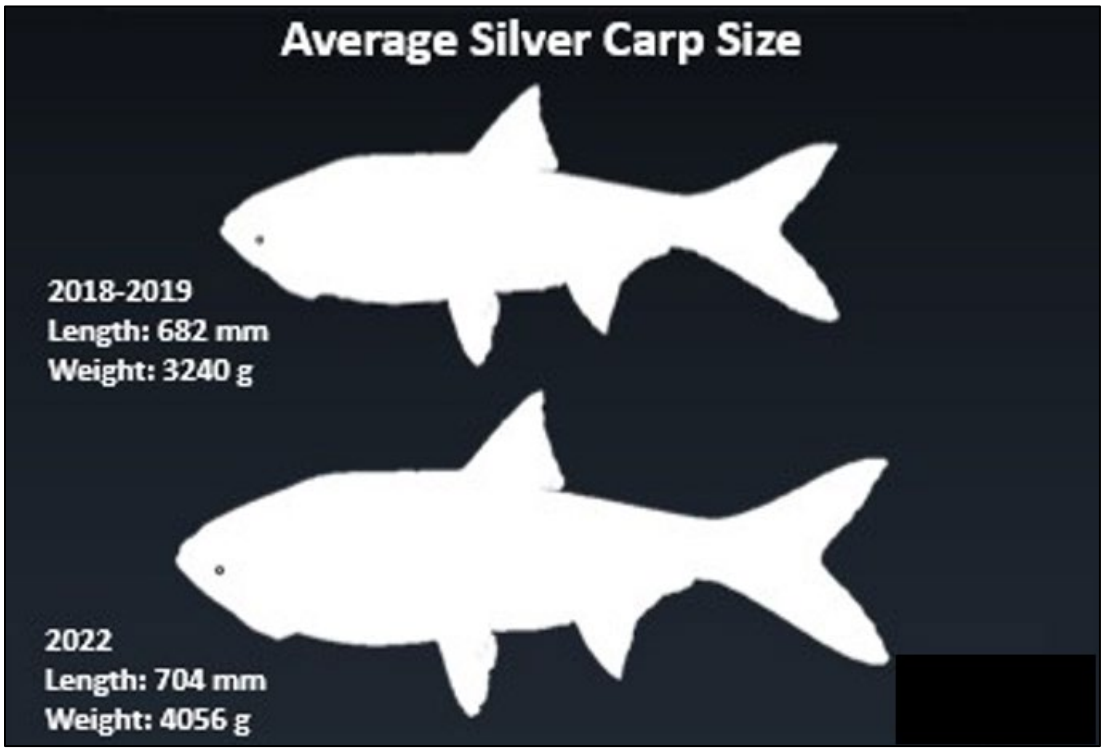

Figure 4. *Average weight of silver carp captured from the Kansas River in 2018-2019 (top) and 2022 (bottom).*

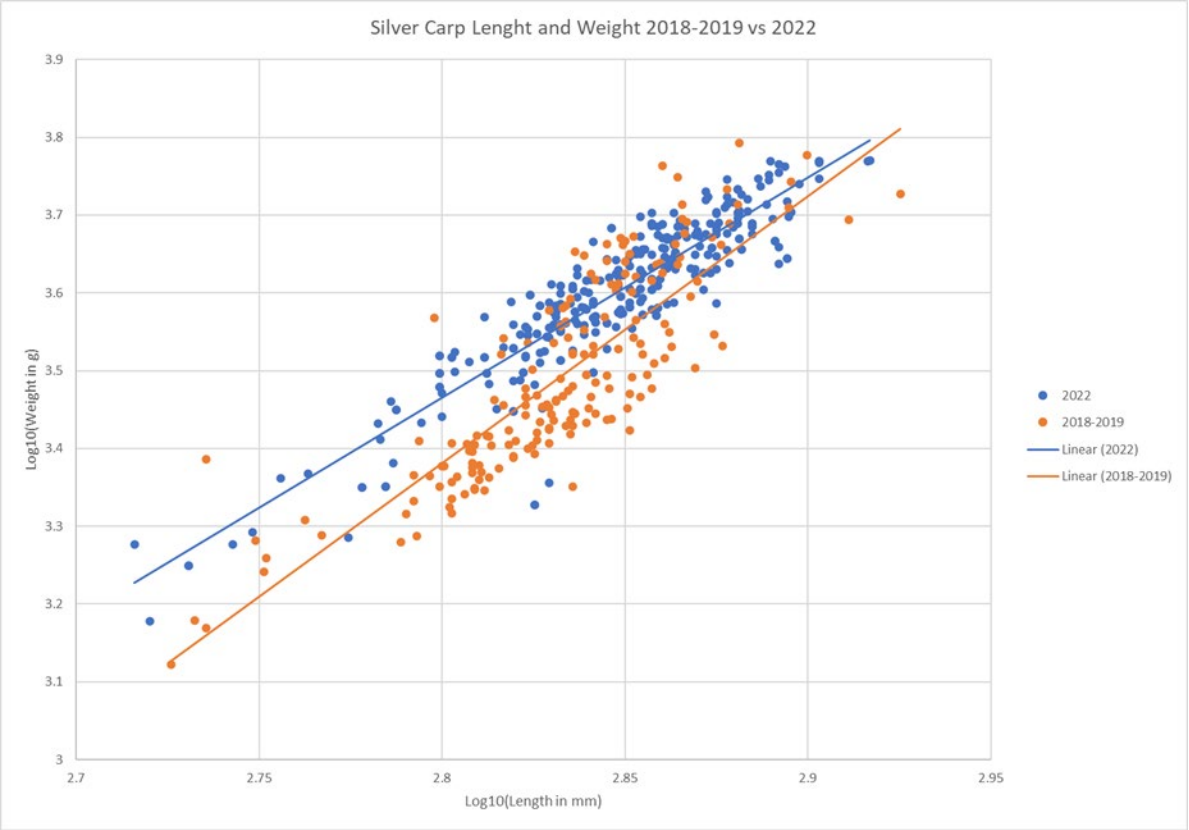

Figure 5. *Length-weight comparison of invasive carp captured from the Kansas River in 2018-2019 (red dots) and invasive carp captured in 2022 (blue dots).*

- **Objective 2:**

Table 2. *Daily silver carp catch, cumulative catch, and relative abundance data from the Grand River using four gear types (hydroacoustics, paupier, dozer, electrofishing). Hydroacoustics-based relative abundance data reflect the population prior to removal efforts on each day, whereas relative abundance estimates from the other gear types are based on the catch and effort collected over the course of each day. Dozer, paupier, and electrofishing data collected during day 5 were excluded from consideration because these data included fish harvested from outside the removal area. Lastly, electrofishing was not implemented during day 1.*

				CPUE			
Day of week	Day	Catch	Cumulative	Hydro (#/1,000 m^3)	DT (#/h)	PA (#/h)	EF (#/h)
Mon	1	1033	0	1.79	276.38	346.47	NA
Tue	2	1804	1033	1.29	189.69	266.41	146.08
Wed	3	1443	2837	1.01	162.71	151.17	82.39
Thu	4	1176	4280	0.89	138.14	159.64	48.17
Fri	5	1207	5456	0.65	NA	NA	NA

Table 3. *Initial silver carp population size and removal mortality rate from the Grand River derived using results from depletion models. Mortality rates were calculated as the ratio between cumulative silver carp catch and the initial silver carp population size. For example, the cumulative catch on day 5 was 5,456 silver carp and the hydroacoustics initial population size estimate was 8,736 silver carp (See Table 2). This corresponds to a mortality rate of 0.62.*

Gear	Initial Population (95% CI)	Mortality
Hydroacoustics	8736 (3,430)	0.62
Paupier	7,092 (6,321)	0.77
Dozer Trawl	8,653 (9,203)	0.63
Electrofishing	5,753 (4,563)	0.95

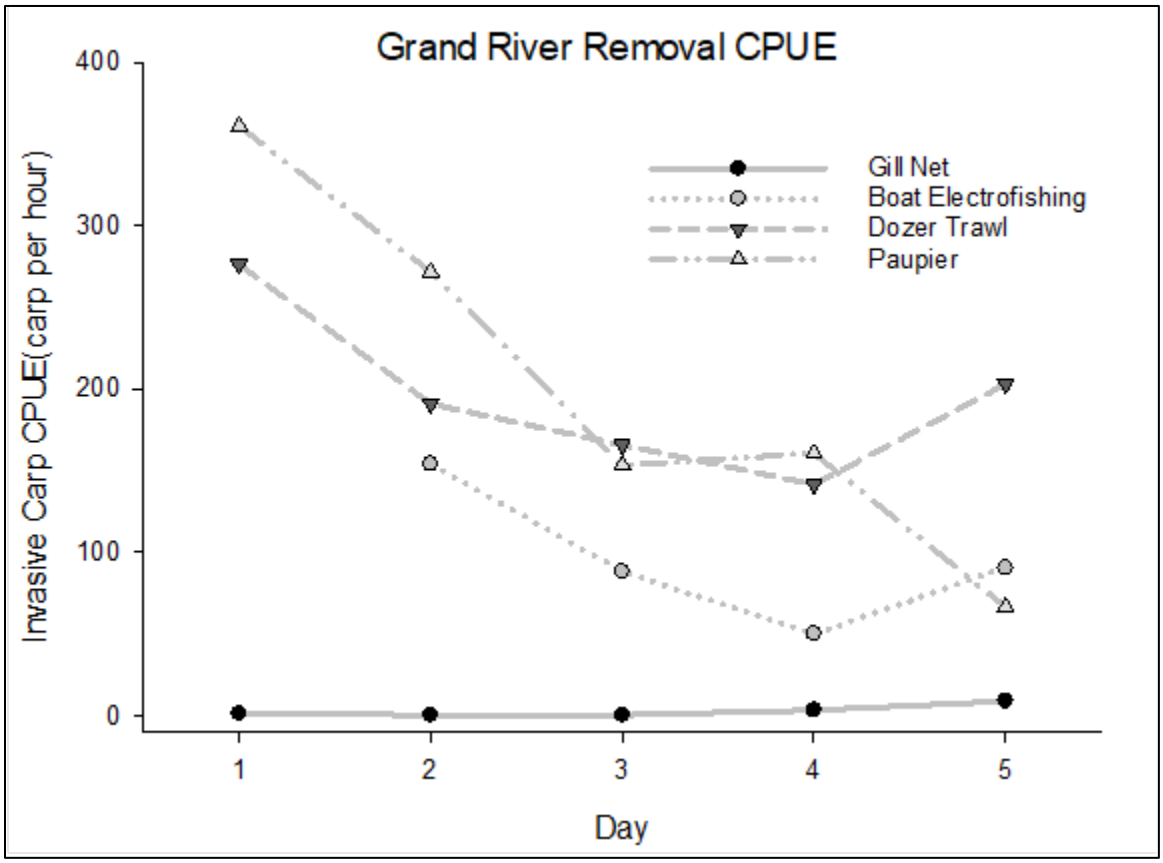

Figure 6. *Invasive carp catch per unit effort from the Grand River by day, for all gears.*

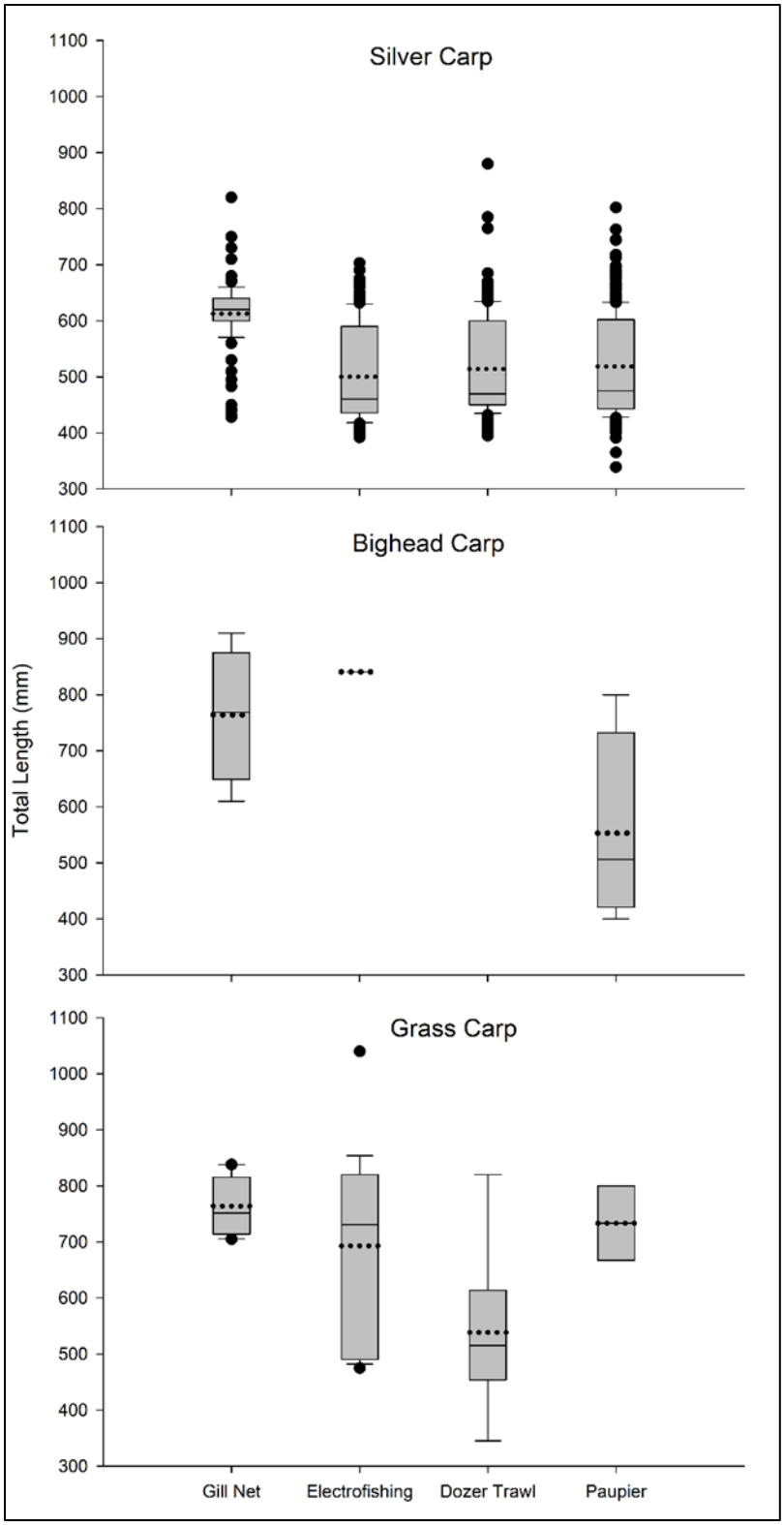

Figure 7. *Boxplots of invasive carp lengths from the Grand River by gear. Boxes represent the upper and lower quartiles, solid line represents the median, dotted line represents the mean, whiskers represent the 10th and 90th percentiles and black circles indicate outliers.*

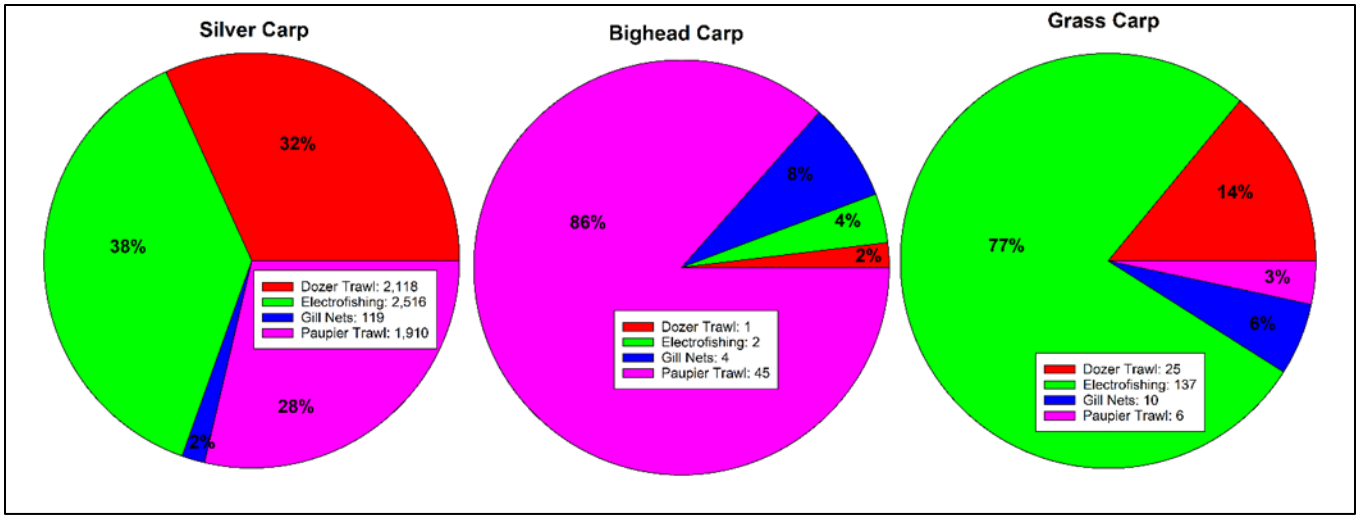

Figure 8. *Percent of total catch of each invasive carp species from the Grand River by gear type.*

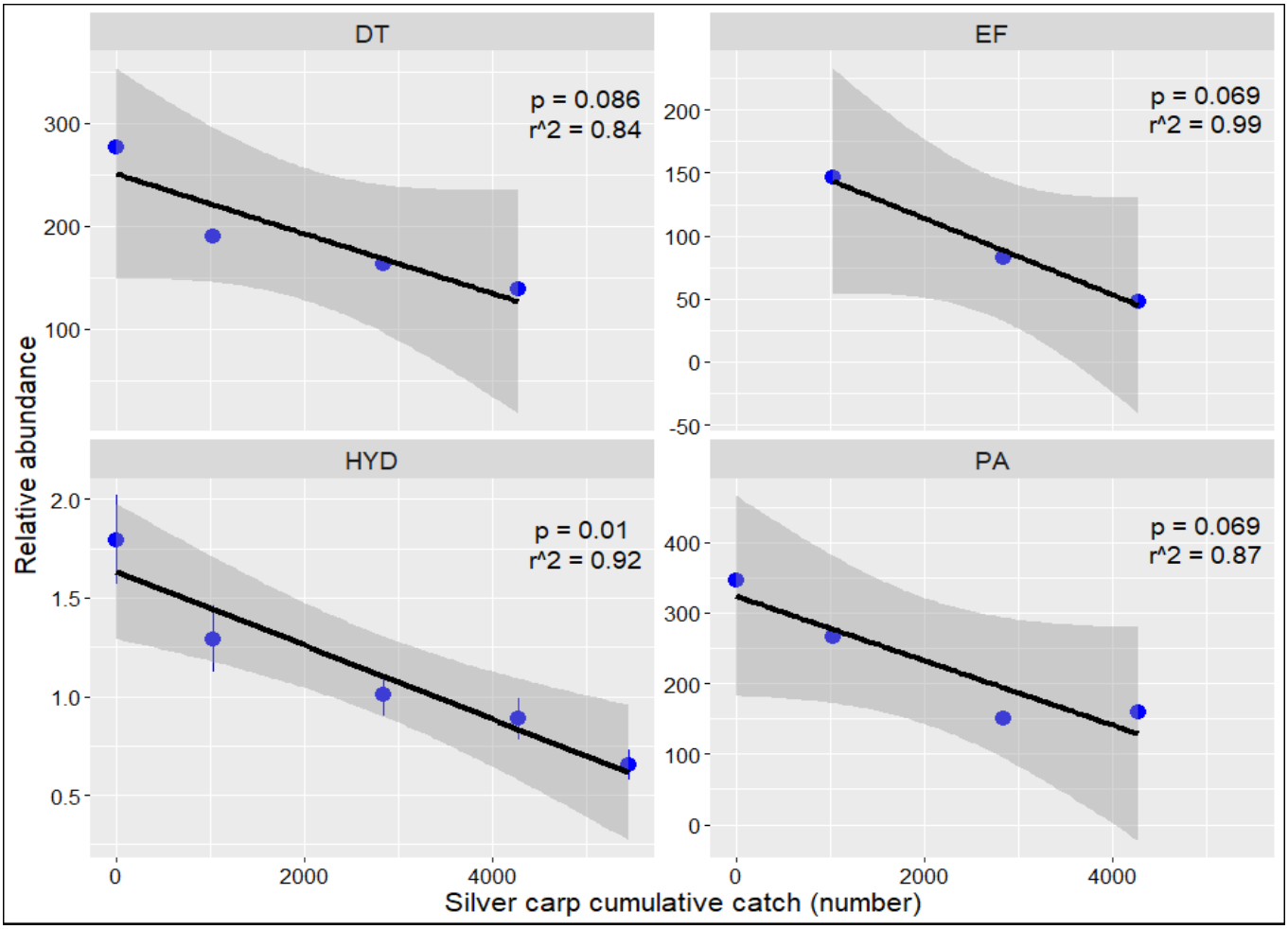

Figure 9. *Leslie depletion models (i.e., simple linear regressions) fit using daily silver carp catch data from the Grand River using four gear types (See table 1). The X-intercept represents the estimated initial silver carp population size. Note that the 0.8 km replicates were used to*

calculate daily mean relative abundance and SE for hydroacoustics data. Y-axis on hydroacoustic graph is scaled x1,000.

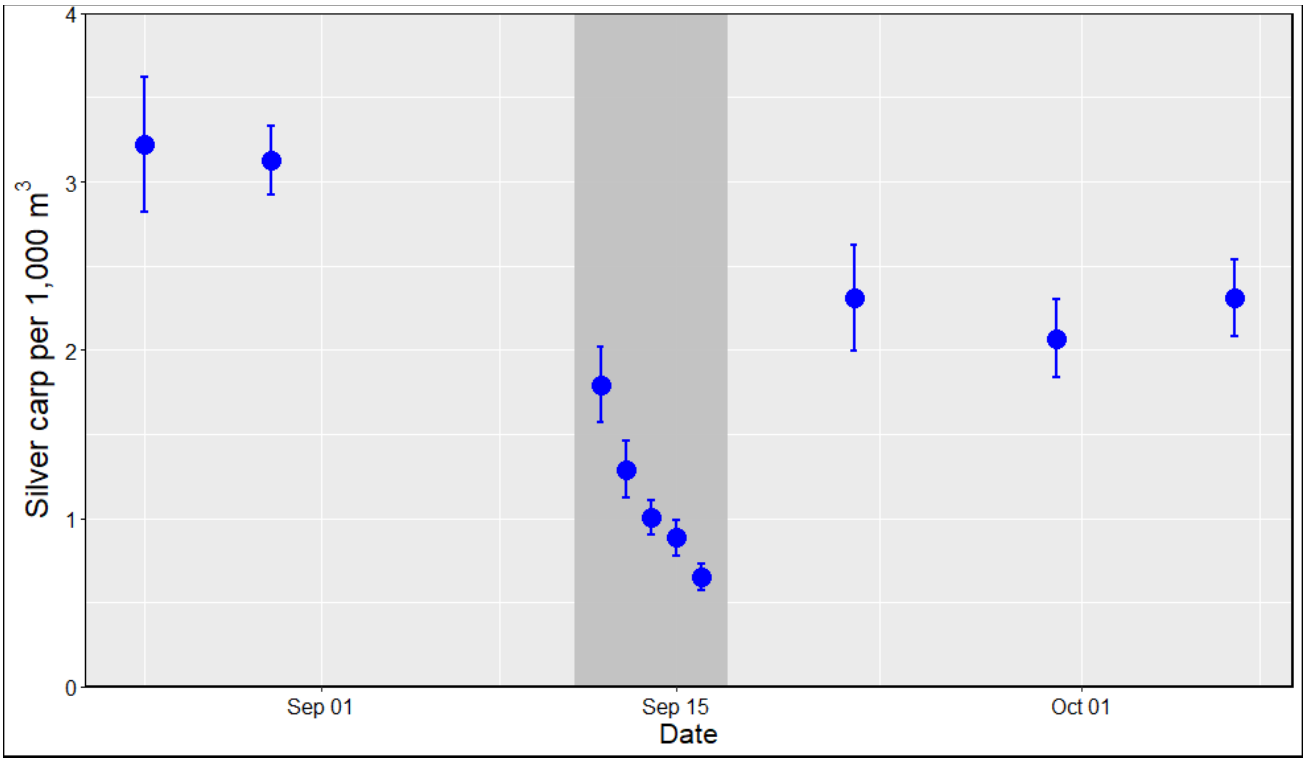

Figure 10. *Time series depicting silver carp relative abundance from the Grand River estimated using hydroacoustics. The shaded region corresponds to the removal period (12 – 16 September 2022) during which time the population was closed using block nets. Baseline pre-removal and post-removal results are for an open population (no block nets).*

Recommendation: One recommendation section for all collaborators. Questions to consider:

- **Objective 1:**
    - KDWP recommends continuing invasive carp removal efforts in the Kansas River and monitoring changes in population demographics to further evaluate the impacts and effectiveness of invasive carp suppression. KDWP also intends to seek and consider other metrics for evaluating invasive carp suppression efforts.
    - KDWP is using results and insights from this study to inform future management decisions.
    - Invasive carp suppression activities provide a fantastic, highly visible and engaging opportunity to raise public awareness of silver carp and their impacts as well as programs to manage them.

- **Objective 2:**

- MDC recommends continuing invasive carp removal efforts in the Grand River and other Missouri River tributaries. Invasive carp population demographics should also continue in Missouri River tributaries to evaluate and inform removal efforts.
- Hydroacoustic surveys conducted during removal efforts in addition to pre- and post-surveys can also provide valuable data to evaluate efforts.

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