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

Lead Author, Agency, and Contact Information:

- Missouri Department of Conservation (MDC)
  - Joe McMullen joe.mcmullen@mdc.mo.gov

Participating Agencies:

- Kansas Department of Wildlife and Parks (KDWP)
  - Chris Steffen chris.steffen@ks.gov
  - Liam Odell liam.odell@ks.gov
- Missouri Department of Conservation (MDC)
  - Kasey Whitman kasey.whiteman@mdc.mo.gov
  - Adam McDaniel adam.mcdaniel@mdc.mo.gov

Statement of Need: Populations of invasive carp (silver carp, bighead carp, black carp, and grass carp) have rapidly expanded throughout the Mississippi River basin. Management and control of invasive carp is necessary to reduce their impact on native species, the ecosystem, and the economy. In response to these threats, many states throughout the Mississippi and Great Lakes basins are working to find effective strategies to manage existing populations and to control the expansion of invasive carp into adjacent aquatic systems. Appropriations for the Department of Interior indicate that 'while the Committees (House Subcommittee on Interior, environment, and Related Agencies and the Senate Subcommittee on Interior, Environment, and Related Agencies) recognize the importance of studying and understanding invasive carp patterns, the Service is encouraged to take action on a strategy that increases the focus on biomass removal and restricts carp progression by coordinating with other Federal partners on constructing invasive carp barriers'. These projects are focused on the priorities identified by Congress, namely biomass removal and barrier construction.

Projects:

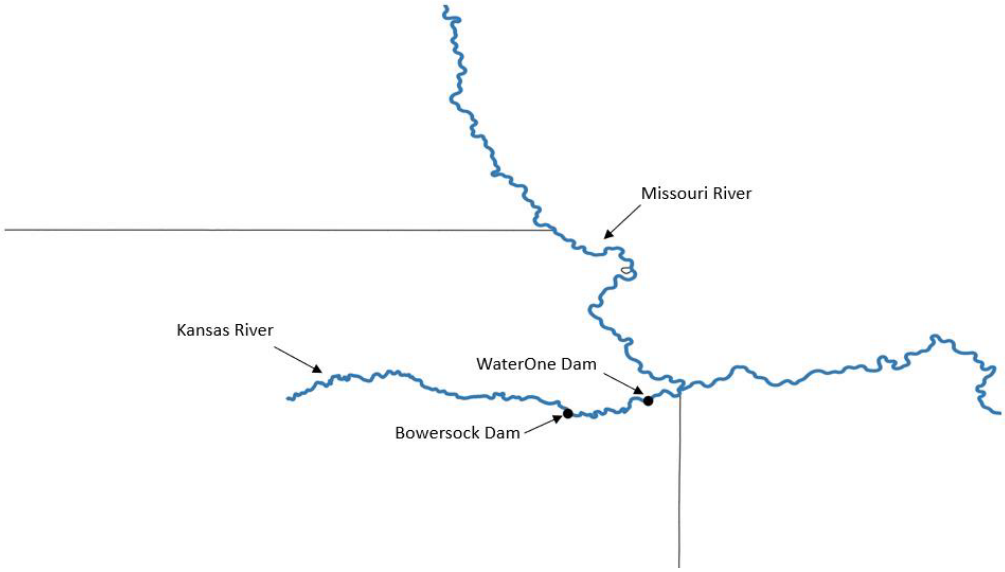
1) Kansas River Invasive Carp Removal (Appendix 1)
2) Lamine River Invasive Carp Removal (Appendix 2)

Appendix 1: Kansas River Invasive Carp Removal

Lead Author, Agency, and Contact Information: Kansas Department of Wildlife and Parks (KDWP), Chris Steffen (chris.steffen@ks.gov), Liam Odell (liam.odell@ks.gov)

Participating Agencies: NA

Location of Activities: Kansas River downstream of Bowersock Dam



Statement of Need:

Introduced invasive carps (bighead carp, black carp, grass carp, and silver carp) have become established in many portions of the Mississippi River Basin (Jennings 1998; Kolar et al. 2005). The feeding habits and population densities of invasive carps cause significant ecological harm where populations become established (Schrank et al. 2003; Irons et al. 2007; Sampson et al. 2009; Solomon et al. 2015; Phelps et al. 2017). The resulting diminished opportunity for fishing (recreational and commercial), boating, and other wildlife-associated recreation causes significant negative economic impact.

Kansas River

The Kansas River drains approximately the north half of the state of Kansas, a portion of south-central Nebraska, and flows East to its confluence with the Missouri River at Kansas City, Kansas. The Kansas River is one of only three publicly accessible navigable waterways in the state of Kansas and, along with several large reservoirs located in the basin, is highly utilized for outdoor recreation such as fishing, boating, nature watching, etc. Bighead carp were first document in the Kansas River in 1987 and silver carp in 1991. Anecdotally, invasive carp populations remained relatively low until 2011 when many young of the year invasive carp were observed. Since that time, invasive carps, primarily silver carp, have remained abundant.

The Bowersock Dam at RKM 84 in Lawrence, Kansas serves as a critical point in the control and management of invasive carp in the Kansas River system. Only six (6) bighead carp have been documented upstream of this structure. These six bighead carp were previously assumed to have passed over Bowersock Dam during an extreme flood event of 120,000 cfs in 1993. However,

the recently completed, USFWS funded, "Bowersock Dam Invasive Carp Acoustic Deterrent System Feasibility Study" leads us to believe that invasive carp may be able to pass over the Bowersock Dam at lower flows, possibly as low as 24,762 cfs. Regardless of the uncertainties of what flows are needed for fish passage at Bowersock Dam, KDWP continues to monitor and sample for invasive carp upstream of the structure and there has been no evidence found to suspect that there is a breeding population of invasive carp upstream of Bowersock Dam.

In addition to the Bowersock Dam at RKM 84, the WaterOne Weir at RKM 24 in Edwardsville, Kansas serves as an additional obstacle to fish movement in the Kansas River basin. Data from a KDWP-funded study in 2018-2019 found that the demographics data for silver carp in the section of the Kansas River between the Bowersock Dam and WaterOne Weir are significantly different than those of fish in the lowest portion of the Kansas River (invasive carp in the lowest portion can freely migrate to and from the Missouri River). Additionally, using otolith microchemistry, it was found that about 70% of the silver carp in the section of the Kansas River between these Bowersock Dam and WaterOne Weir were found to be resident fish (i.e. the fish had not spent time in water with different chemistry). In addition, very few juvenile invasive carp have been encountered in the Kansas River upstream of the WaterOne Weir. These facts lead KDWP to believe that invasive carp removal efforts downstream of the Bowersock Dam are a pragmatic management strategy that has the potential to reduce the population of invasive carp in this system and protect upstream waters.

Removing invasive carp downstream from the Bowersock Dam is intended to reduce the number of silver carp and bighead carp that may attempt to pass over the dam during high flow events and subsequently decrease the potential for these species to establish a breeding population upstream of the structure. Protecting the upper Kansas River basin from invasive carp invasion is KDWP's highest invasive carp related priority in the Missouri basin and KDWP has been conducting invasive carp removal in this area since 2021; this project builds on those previous efforts. In addition to removal efforts, KDWP is pursuing design and installation of an a deterrent system at Bowersock Dam as an integrative management strategy to protect upstream waters from invasive carp.

KDWP intends to meet the objective of invasive carp population reduction downstream of Bowersock Dam by using funds to employ and equip agency staff to remove invasive carp.

Project Objectives:

1. Remove invasive carp downstream of Bowersock Dam to protect upstream waters.

Project Highlights:

- 9,820 kg of invasive carp were removed from the Kansas River between Bowersock Dam and WaterOne Weir.
- Initiated first removal efforts downstream of the WaterOne Weir.
- Completed acquisition of an electrified dozer trawl to increase efficiency of carp removal efforts.
- Demographic data from invasive carp in the removal area continues to shift towards larger size structure, differing from control locations.

Methods:

Objective 1

KDWP conducted agency removal efforts in 2024 using gill nets, traditional or multi-boat electrofishing, and electrified dozer trawling. Removal efforts were focused on using gill nets in "whip sets" (spiral formation) [Figure 1]. Only floating style nets were used in 2024, but a variety of depths were used depending on location of set and river conditions. Mesh sizes were consistently 4" or 3 ¼". [4" or 3-1/4" mesh, 12' hobbled to 10' or 18' hobbled to 16' deep or 22' hobbled to 20', and 200-300 yards long]. Electrofishing was conducted typically using 45hz pulsed dc. Multiple boat standard electrofishing or "raptor pack" methods were used in 2024. Newly acquired electrified dozer trawl removal was also conducted in 2024.

In addition to regular removal efforts, KDWP continued to collect 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 4/4/24-4/17/24 using standard electrofishing as the collection method. KDWP sampled 100 random fish from each location.

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. Due to invasive carp suppression being a new activity in Kansas, KDWP conducted a multitude 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:

Objective 1

A total of 9,869 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 2024. Of the 9,820 kg of removed carp, 3,454 kg were via electrofishing, 4,173 kg via gill nets and 2,241 kg via the electrified dozer trawl [Figure 2]. It is important to note the electrified dozer trawl was acquired towards the end of 2024. Multi-boat electrofishing was a productive tool for KDWP in 2024. During a multi-boat electrofishing event, 770 kg of invasive carp were removed. KDWP had the most success in the spring and fall of 2024, like in 2023 [Figure 3]. The most captured bycatch species were smallmouth buffalo [Figure 4], captured at a 1:4 ratio to silver carp, a notable decrease compared to 2023. Additional important notes from 2024 were KDWP replacing the carp removal technician position and the start of the Neosho River-Grand Lake system bighead carp telemetry project.

In 2024, KDWP conducted demographic comparisons on invasive carp from three different locations [Figure 5] to evaluate differences between a treatment population of invasive carp (Kansas River above WaterOne Weir) and two control populations (Kansas River below

WaterOne Weir and Missouri River at Atchison, KS). The 2023 comparison revealed the size structure of the treatment population had shifted to slightly larger than the control populations. KDWP conducted the same evaluation in 2024 [Figures 6, 8, and 10]. Differences between the treatment location in 2023 and 2024 were also evaluated [Figures 7, 9, and 11]. The silver carp from the treatment location reach longer lengths at a higher frequency than the two control populations [Figure 6]. Similarly, silver carp from 2024 achieved longer lengths at a higher frequency than silver carp from 2023 [Figure 7]. The continued increase in lengths of silver carp suggests our removal efforts are having an impact on growth of silver carp in the treatment population above WaterOne Weir. Silver carp from the treatment population have achieved faster growth rates to larger sizes than the two control populations [Figure 8]. Notable differences in growth are harder to detect in the treatment population between 2023 and 2024, but the 2024 population seems to reach maturity at longer lengths suggesting a less dense population than in 2023 [Figure 9]. Continuing to run this evaluation on silver carp removed from above the WaterOne Weir throughout the project will present better details with more time. Silver carp from the treatment population are significantly longer and weigh drastically more than the two treatment populations [Figure 10]. The same observation can be made for silver carp collected from the treatment population in 2024 vs. 2023 [Figure 11]. The investigations conducted between the three locations and between 2023 and 2024 suggest the KDWP removal effort seems to be influencing the body condition of the silver carp where heavy removal occurs.

Recommendation:

- KDWP recommends continuing invasive carp removal efforts above the WaterOne Weir and continuing to expand removals below the WaterOne Weir in the Kansas River also. Developing a formal evaluation will be a necessary step to assess and quantify the effects of the removal efforts. Additionally, further in house monitoring and evaluation will help to gauge the effectiveness of invasive carp suppression in the Kansas River. KDWP will continue to seek out new ways to measure removal success and develop new effective methods of capture/removal for invasive carp.

Figure 1: *Visual representation of a spiral whip set*

Tables and Figures:

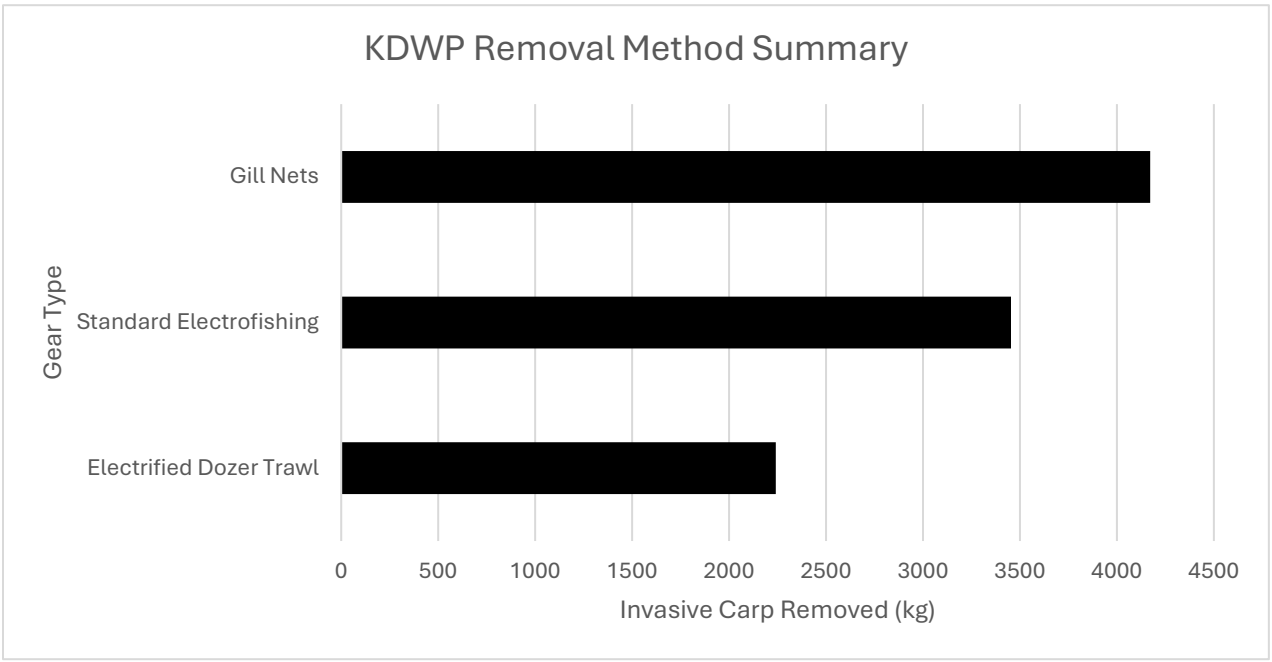


Figure 2: *Summary of invasive carp removed (kg) by gear type.*

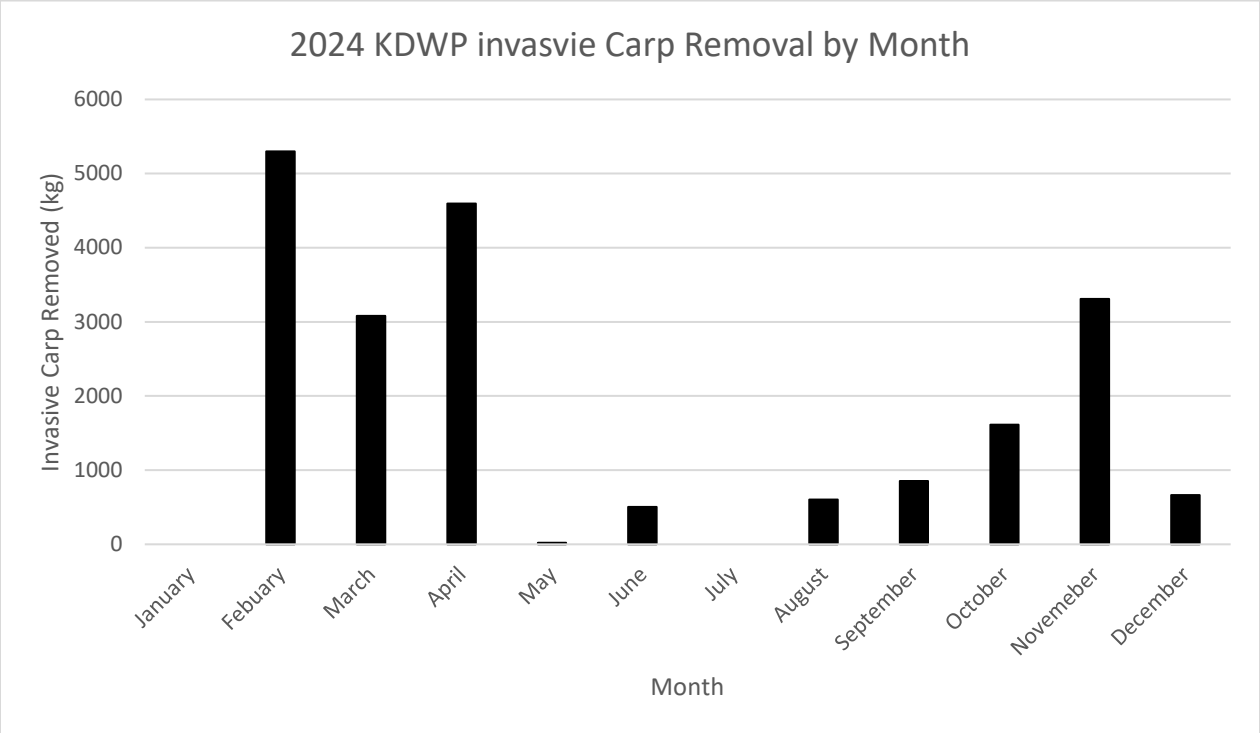


Figure 3: *Histogram of invasive carp removed (kg) per month.*

Species	Count
Smallmouth Buffalo	490
Gizzard Shad	81
River Carpsucker	67
Freshwater Drum	36
Bigmouth Buffalo	22
Longnose & Shortnose Gar	21
Blue and Flathead Catfish	17
Common Carp	14
Shovelnose Sturgeon	9
Goldeye	8
Blue Sucker	7
White Bass	6
White & Black Crappie	4

Figure 4: *Summary of species and count bycatch data for 2024.*

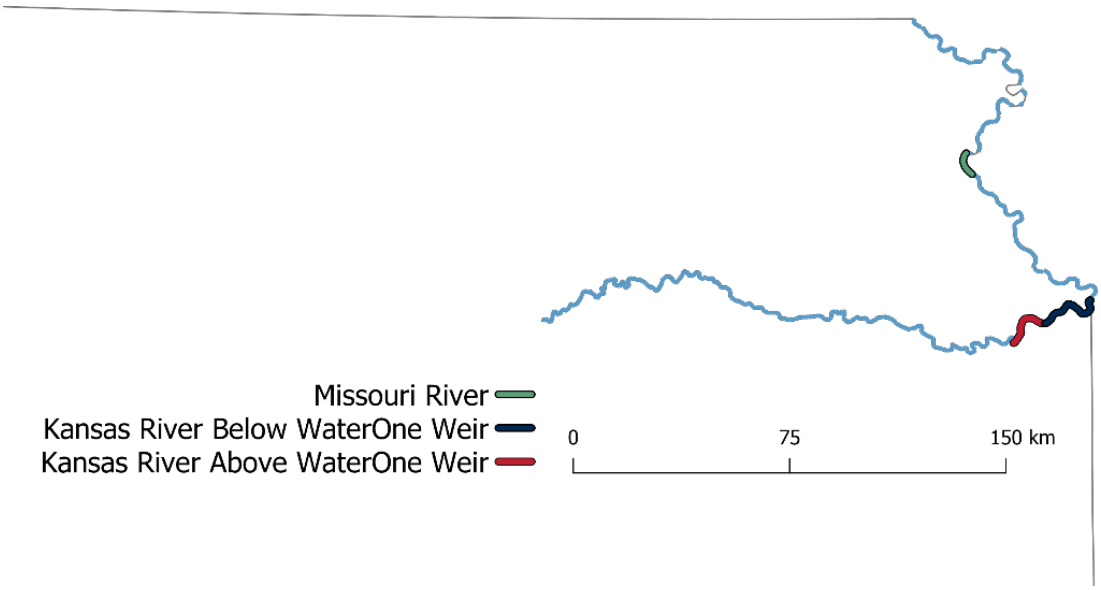


Figure 5: *Locations KDWP used for demographic comparisons between treatment populations and control populations.*

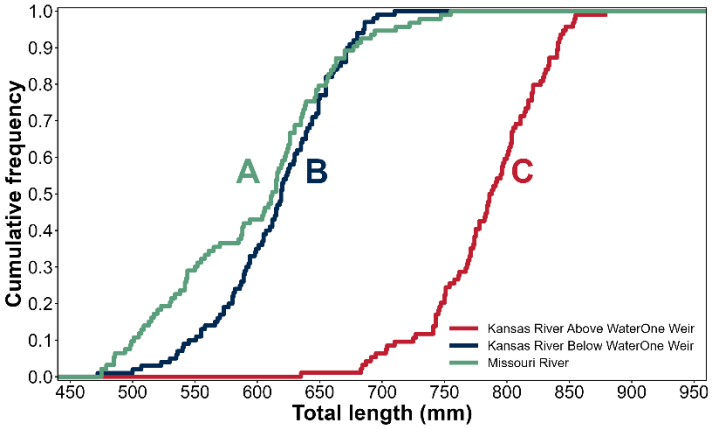


Figure 6: *Length frequency/distribution for silver carp between Kansas River above WaterOne Weir (treatment population) vs Kansas River below WaterOne Wier and Missouri River at Atchison, KS (control populations).*

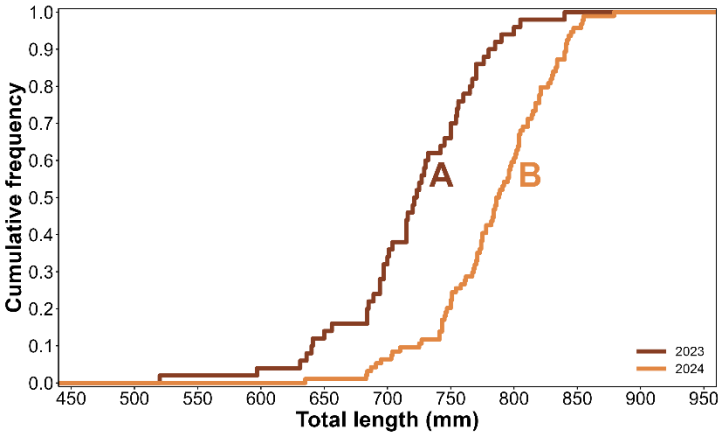


Figure 7: *Length frequency/distribution for silver carp from the Kansas River above WaterOne Weir (control location) between 2023 and 2024.*

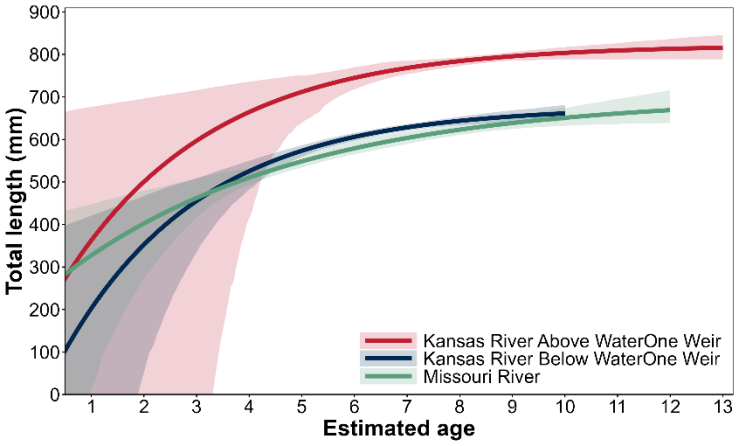


Figure 8: *Age and growth for silver carp between Kansas River above WaterOne Weir (treatment population) vs Kansas River below WaterOne Wier and Missouri River at Atchison, KS (control populations).*

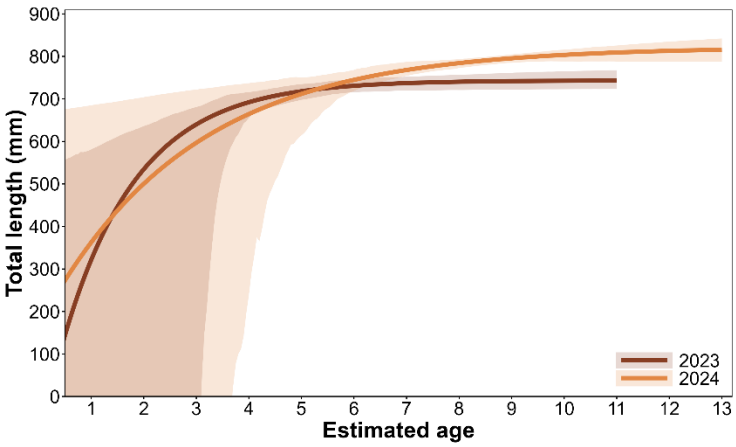


Figure 9: *Age and growth for silver carp from the Kansas River above WaterOne Weir (control location) between 2023 and 2024.*

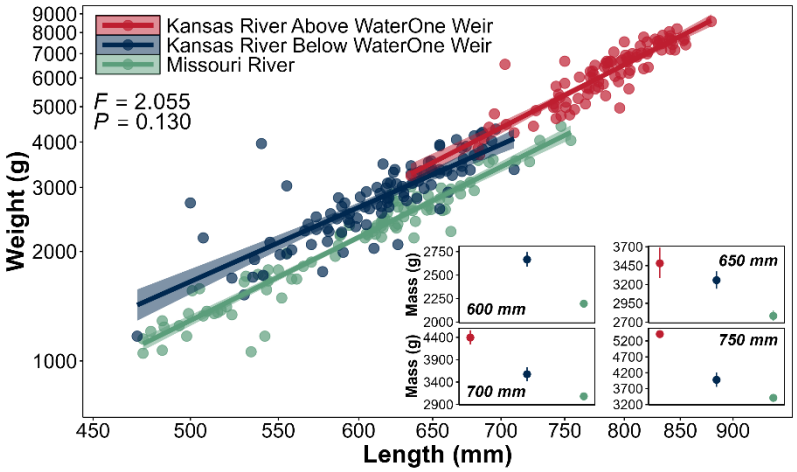


Figure 10: *Expected weight at length for silver carp between Kansas River above WaterOne Weir (treatment population) vs Kansas River below WaterOne Wier and Missouri River at Atchison, KS (control populations).*

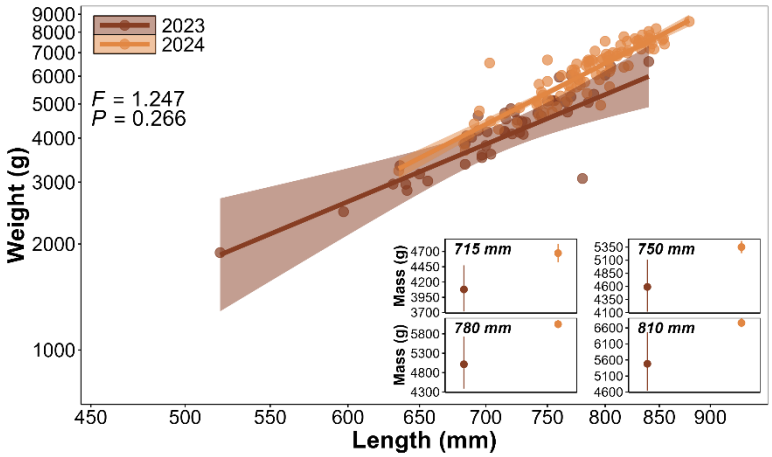


Figure 11: *Expected weight at length for silver carp from the Kansas River above WaterOne Weir (control location) between 2023 and 2024.*

References:

Irons, K. S., G. G. Sass, M. A. McClelland, and J. D. Stafford. 2007. Reduced condition factor of two native fish species coincident with invasion of non-native Asian carps in the Illinois River, U.S.A. Is this evidence for competition and reduced fitness? Journal of Fish Biology 71:258-273.

Jennings, D. P. 1988. Bighead carp (Hypophthalmichthys nobilis): a biological synopsis. U.S. Fish and Wildlife Service, Biological Report 88 (29), Washington, D.C.

Kolar, C. S., D. C. Chapman, W. R. Courtenay Jr., C. M. Housel, J. D. Williams, and D. P. Jennings. 2005. Asian carps of the genus Hypophthalmichthys (Pisces, Cyprinidae): a biological synopsis and environmental risk assessment. U.S. Fish and Wildlife Service, Washington, D.C.

Phelps, Q. E., S. J. Tripp, K. R. Bales, D. James, R. A. Hrabik, and D. P. Herzog. 2017. Incorporating basic and applied approaches to evaluate the effects of invasive Asian Carp on native fishes: A necessary first step for integrated pest management. PLoS One 12(9):e0184081.

Solomon, L. E., R. M. Pendleton, J. H. Chick, and A. F. Casper. 2015. Long-term changes in fish community structure in relation to the establishment of Asian carps in a large floodplain river. Biological Invasions 18:2883-2895.

Appendix 2: Lamine River Invasive Carp Removal

Lead Agency: Missouri Department of Conservation – Missouri River Field Station

Participating Agencies: U.S. Fish and Wildlife Service – Columbia Fish and Wildlife Conservation Office, Kansas Department of Wildlife and Parks, and the Quantitative Ecology and Conservation team at the Columbia Environmental Research Center, U.S. Geological Survey provided telemetry and modeling support.

Location of Activities: Lamine River from river kilometer 0 (confluence with the Missouri River) to river kilometer 18.

Project Highlights

- *In September 2024, the Missouri Department of Conservation working in conjunction with the U.S. Fish & Wildlife Service (USFWS) and Kansas Department of Wildlife and Parks conducted an intensive short-term Invasive Carp removal on the Lamine River in central Missouri.*

- *Hydroacoustic surveys were conducted by the USFWS pre- and post-removal each week to quantify invasive carp densities.*

- *Four gear types including standard boat electrofishing, the electrified paupier trawl, the electrified dozer trawl and gill nets were utilized to remove invasive carp over the course of the two four-day sampling periods.*

- *Removal efforts resulted in 8,962 Silver Carp, 53 Bighead Carp, and 191 Grass Carp weighing 19,686 kilograms (43,401 lbs.) being removed from the lower Lamine River. No Black carp were sampled.*

- *Hydroacoustic surveys indicated a 27.8% decline in Silver Carp densities measured immediately pre and one-week post-removal.*

- *Standard boat electrofishing sampling pre- and post- removal indicated Silver Carp relative abundance significantly decreased ($P<0.05$) with an overall 59% decrease in abundance.*

- *A "refuge area" concept was tested and indicated potential for future applications during removals.*

- *Data from telemetry stationary receiver arrays indicated Silver Carp mean dispersal rates during removals were two times greater compared to movement pre- and post-removal.*

- *Telemetry data indicates immigration rates increased one week following first week removal and emigration rates increased during fish kill event followed by high*

immigration rates immediately following removal during which time dissolved oxygen levels increased.

Introduction

Invasive species have been a major cause of deleterious impacts to native fish abundance, biodiversity, and economies. Invasive carp (including Silver, Bighead, Grass, and Black carp) have been successful invaders in the United States and have a high probability of causing negative ecological and economic effects. These four species may be impacting the food web and native fish community in the Missouri River Basin. Several studies have reported diet overlap or competition between invasive carp and native species such as Bigmouth Buffalo, Paddlefish, Freshwater Drum, catfishes, and redhorses (Schrank et al. 2003, Nico et al. 2005, and Sampson et al. 2009). Such effects have occurred in 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. Thus, extirpation of feral invasive carp populations is desired for many ecosystems.

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% 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. 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 trawl (hereafter called paupier) and electrified dozer trawl (hereafter called dozer trawl; Hammen et al. 2019). In 2018, state and federal agencies conducted an invasive carp removal study at 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) and drift nets (Roth 2018). These evaluations show varying effectiveness depending on the body of water and invasive carp life stage targeted. Still, most commercial fishermen and state agencies rely on standard commercial gears for sampling efforts.

The project outlined in this template will not only highlight management approaches to reduce invasive carp populations but also provide insight for removal efforts aimed to reduce invasive carp populations.

Objectives

Long Term Goal Statement:

- Develop an approach to effectively reduce invasive carp populations in the Missouri River and its tributaries.

Short Term Goal Statement:

- Compare the effectiveness of a multi-gear removal approach across a gradient of tributary characteristics and invasive carp densities.

Research objectives:

- Compare the performance (CPUE per gear, total fish/tons removed) of multi-gear removals in two MOR tributaries (the Grand and Lamine rivers) that differ with respect to watershed and invasive carp densities.
- Test the efficacy of creating a "refuge area" within the removal zone where fishing is not undertaken until the last day of the removal.
- Estimate exploitation using mark-recapture from t-bar tags.
- Quantify change in density of silver carp.
- Quantify individual gear's contribution to removal.
- Estimate the amount of fishing effort required to achieve targeted exploitation rates among top-performing removal techniques with an open system.
- Estimate Silver Carp movement, immigration and emigration rates during removal utilizing telemetry stationary receiver arrays.

Management objectives:

- Utilize a multi-gear removal to deplete carp by *no less than 25%* (the depletion affected in the Grand River in 2022 and 2023) within a in a spatially significant management zone of the Lamine River (another Missouri River tributary) with a higher CPUE than in previous years as measured by an *immediate pre and post assessment.*
- Obtain 15,000 lbs. of Carp minimum for processor each week.

Site

The Lamine River in central Missouri was targeted for a third rapid invasive carp removal due to the density and size structure of Silver Carp collected from population demographics work and local habitat characteristics. There are also two Missouri Department of Conservation boat accesses with ample parking on the lower Lamine River; DeBourgmont and Harriman Hill Access approximately 5.5 and 16.4 river kilometers upstream, respectively from the confluence with the Missouri River. The primary sample area designated for the removal was between river kilometer 18 and 0 at the confluence with the Missouri River. A "Refuge Area" was delineated at river kilometer 8.0 to 8.7 where no fishing would occur until the last day of each removal week.

Methods

Hydroacoustic assessment surveys were conducted by USFWS pre- and post- removal to estimate invasive carp densities. Surveys consisted of one downstream and one upstream transect from river kilometer 18 in the Lamine 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 kilometer moving in an upstream direction at 4.8 kph from the confluence of the Lamine and Missouri rivers until habitats were too shallow to sample. Standard boat electrofishing sampling was also conducted pre- and post-removal in the Lamine River. Ten random 5 minute runs were conducted at two sites; Site 01 rkm 0 to 9.9 and Site 02 rkm 10 to 18 pre-removal for population demographic study. Post-removal sampling included the same random sites sampled pre-removal.

Invasive carp were captured utilizing standard boat electrofishing, electrified paupier trawl, electrified dozer trawl and gill nets. The paupier conducted transects of varying duration in the main channel, focusing in areas with dense schools or aggregations. The dozer trawl conducted transects in habitats predominantly 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, 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 captured (Silver, Bighead, and Grass Carp) were counted, identified to species, and harvested regardless of size. Invasive carp were transferred to 1.3 cubic meter bulk bags with 1000 kg weight capacity. Bulk bags containing invasive carp were then offloaded at the DeBourgement boat ramp using a backhoe to lift bags from boats and transferred to shipping containers provided by FKF Commercial Fishers, LLC.

Twenty-five percent of fish collected from paupier, dozer trawl and gill nets were subsampled for fish length (all individuals >250mm) and fish were identified to species, and lengths recorded. These data were used to characterize bycatch, as well as assign species apportionment 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.

Abundance estimates from mark recapture data used Chapman’s Modification to account for a low number of recaptures.

$$\widehat{N} = \frac{(r+1)\cdot(n+1)}{m+1} - 1$$

r = total number of marked fish before removal

n = total number of fish removed

m = total number of marked fish removed

Acoustic telemetry was also utilized pre-, post- and during the removal to provide additional data of previously tagged Silver Carp in the Lamine River and Missouri River basin. Active telemetry sweeps of the lower 18 river kilometers were conducted in May, July, August and the first day of each removal week in addition to a post removal sweep in late October of 2024. Stationary telemetry receivers were deployed at rkm 0, 5.5, 8.5, 13.5, 15.5 and extensive arrays with multiple receivers were deployed at the Lamine River confluence with the Missouri River and the Blackwater River confluence with the Lamine River at rkm 15.5. Position data was generated for all tagged fish detected in the receiver array using Fathom Position software. Dispersal rates were calculated using the total dispersal distance per time period divided by the number of unique individuals detected moving during that same period.

Results

Lamine River Removal

The Lamine River Invasive Carp Removal was conducted September 9th through the 12th and 23rd through 26th in 2024. Removal efforts totaled 16.9 hours for paupier runs, 21.9 hours with dozer trawl, 58.8 boat electrofishing hours and 34 gill net deployments (18,200 yards of net). Total catch amounted to 8,962 Silver Carp, 53 Bighead Carp, and 191 Grass Carp weighing 19,686 kilograms (43,401 lbs) being removed from the lower Lamine River.

Gill net and boat electrofishing efforts between mid-July through mid-August in the lower 18 river kilometers of the Lamine River (Figure 1) implanted a total of 1,858 Silver Carp with floy tags and released near point of capture. The first week of removal efforts resulted in 13 Silver Carp with floy tags recaptured and harvested, however fishing the second week only resulted in 2 Silver Carp recaptures.

Catch rates in week 1 were variable daily by gear throughout the week. Day 1 catch rates were high for most gears with paupier at 185 Silver Carp per hour, dozer trawl at 128 Silver Carp per hour and electrofishing boats at 81 Silver Carp per hour (Figure 3). Day 2 catch rates decreased for most electrified sampling gears with the exception of gill nets which increased. Day 3 catch rates increased for dozer trawl and boat electrofishing whereas paupier was similar to day 2 and gill net catch decreased. Day 4 the “refuge area” was sampled by all fish capture gears mid-day. Catch rates in the refuge area for paupier and gill nets increased more than two-fold compared to samples outside the refuge area that day (Figure 4). However, dozer trawl catch only increased slightly in the refuge area and electrofishing boats did not separate data collected in the refuge area.

The efficacy of the refuge area was evaluated using hydroacoustics-based density estimates. In addition to the refuge section, another 4 buffer sections (2 downstream and 2 upstream) were scanned (Figure 6). Densities in the refuge area and adjoining reference sections were monitored across four dates during which they received different harvest treatments (i.e., fished, unfished). More specifically, fish were harvested throughout the removal area including the buffer sections whereas no fishing activity was conducted in the refuge section until September 12th. Results were used to characterize how densities within the unfished refuge section responded to removals relative to fished reference sections. Densities in sections upstream and downstream of the refuge decreased dramatically from the pre scan whereas the refuge's density increased 32 % (Figure 6).

Week 2 catch rates were much more variable than week one due to a precipitation event that reduced fishing time for electrified gears on day 5 and then caused a fish kill on days six and seven from low dissolved oxygen. This low dissolved oxygen water originated in the Blackwater River, a tributary to the Lamine at river kilometer 15.9, and continued to slowly transport low dissolved oxygen water downstream through the Lamine throughout the week. Day 6 water with low dissolved oxygen had descended from river kilometer 15.9 downstream to river kilometer 4.0. However, this congregated fish from rkm 3.5 to the confluence and paupier and gill nets were able to exploit congregated fish with high catch rates in that lower section of the Lamine. Day 7 catch rates declined for paupier and gill nets as low oxygenated water had dispersed throughout the Lamine below the Blackwater but dozer trawl and electrofishing boats were able to sample above the Blackwater confluence with slightly higher catch rates than day 6. Catch rates by day 8 were low for all gears as dissolved oxygen levels began to increase throughout the Lamine but fish densities remained low and catch above the Blackwater confluence decreased.

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 422 mm captured with dozer trawl to 901 mm captured in gill nets. Mean lengths ranged from 587 mm with dozer trawl to 597 mm with gill nets. Mean length of Silver Carp captured in gill nets were significantly different ($P < 0.05$) than dozer trawl and boat electrofishing (Figure 5a). However, not all Silver Carp were measured, as subsampling techniques were used for all gears. Bighead Carp lengths ranged from 539 mm captured with boat electrofishing to 857 mm captured in gill nets. Mean lengths of Bighead Carp ranged from 699 mm captured with paupier to 748 mm collected in gill nets. Grass Carp lengths ranged from 605 mm collected with boat electrofishing to 916 mm captured with gill nets. Mean length of Grass Carp ranged from 677 mm with dozer trawl to 763 mm captured in gill nets.

Boat electrofishing captured the highest number of Silver Carp and Grass Carp, contributing 39% of the total Silver Carp catch and 62% of Grass Carp collected. Dozer trawl collected 25% of the Silver Carp followed by paupier at 20% and gill nets at 15%. Gill nets collected the highest number of Bighead Carp accounting for 53% of the total Bighead Carp catch (Figure 5b).

Hydroacoustic surveys indicated a 65.8% decrease in Silver Carp densities immediately after the first week of removal effort, with the population increasing approximately 15% after a week without fishing pressure (Figure 7). The immediate post second week survey showed a further

38% decline, rebounding within a week after all removal activity to an overall 27.8% density difference when compared to the pre-removal survey.

Standard boat electrofishing sampling pre- and post- removal indicated Silver Carp relative abundance significantly decreased ($P<0.05$) following the Lamine River removal (Figure 8). Lamine River Site 01 (0-rkm 9.9) indicated a 50% decrease in abundance and Site 02 (rkm 10 - 20) resulted in a 70% decrease. Overall, there was a 59% decrease in Silver Carp abundance with boat electrofishing post-removal.

Active telemetry sweeps in the Lamine detected 36 individual Silver Carp (Figure 10) comprising 23 females and 12 males identified at time of tagging. All were previously tagged in the Lamine in 2021 apart from two fish; one male from the Grand River and another male that was tagged in the Moreau, a small Missouri River tributary near Jefferson City, MO.

Stationary telemetry receivers detected 26 individual Silver Carp. No tagged Silver Carp were detected moving upstream of the upstream array or entering the Blackwater River. Daily detections of individual fish moving between the confluence and the receiver above DeBourgmont access at rkm 5.5 increased during removal periods (Figure 12 and 13). Similarly, mean dispersal distance was more than double during removal periods (Figure 14) and lowest during the fish kill period as most fish made only move to the confluence to avoid low dissolved oxygen levels. Prior to removals there was little difference in daily immigration and emigration rates with slightly higher emigration rates. There was no difference in daily immigration and emigration rates during the first week removal until day 3 in which immigration rates increased (Figure 15) which happens to coincide with increased catch rates with fish capture gears (Figure 3). Between removal periods it takes seven days until immigration rates increase with fish returning. The second removal period including the fish kill event emigration rates increased daily until day 4 which is when dissolved oxygen levels started to increase throughout the Lamine. Emigration rates also increased immediately following the second removal period (Figure 15).

Discussion

Overall, the Lamine River invasive carp removal was successful 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 and removal techniques that were successful in the Grand River proved effective in the Lamine River. Intensive rapid removals over the last three years on the Grand and Lamine River have resulted in 26,468 Silver Carp and 107,001 lbs of invasive carp harvested.

Mark-recapture efforts did not produce results intended from floy tagging Silver Carp prior to removal efforts. Chapman's Modification equation estimated 1,010,017 Silver Carp in the lower Lamine River which we believe to be highly overestimated when compared to previous estimates on the Grand River. Tag loss likely influenced this over inflated estimate. Fin clipping could have provided an estimate of tag loss and provided a marking option that would not be lost

although increased handling time of fish. Two separate trips were made with two gill net boats and eight trips with two electrofishing boats to tag 1,885 Silver Carp prior to removal efforts. In the future, these efforts may be better focused on fish removal.

Multiple electrofishing boats working in unison proved effective once again in 2024. 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. Although, all four gears work well to fish a wide range of habitats in mid-sized rivers.

Telemetry data from stationary receiver arrays and active tracking provided valuable insights into Silver Carp movement and behavior during and following removals. No Silver Carp were detected moving upstream of the Blackwater or into the Blackwater. However, increased movement to the confluence and the receiver at rkm 5.5 during removal efforts could indicate a preference for the deeper lower sections of the Lamine at times when fishing pressure is present. Telemetry data, hydroacoustic surveys and standard boat electrofishing pre- and post-removal combine to provide better understanding changes in Silver Carp densities and after-action evaluations.

Overall, three years of concentrated removal efforts in two tributaries with different characteristics produced similar Silver Carp population depletion and refill rates (measured by post removal surveys to determine how many fish moved back into the system) suggesting we are approaching a capabilities ceiling with the methods currently deployed and that explorations of new methods such as the refuge area will be critical to continuing forward progress. Removal areas may also need to be expanded to include fishing areas with high abundance on the Missouri River near tributary confluences to slow re-fill rates.

The lower Missouri River is channelized with rock structures and fast currents that present difficult habitats to capturing invasive carp. Tributaries to the Missouri River are likely important habitat for invasive carp at multiple life stages and probably 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.

Recommendations

For 2025 and beyond, removal techniques developed at the Grand and Lamine Rivers should be applied to new locations to test transferability across the landscape. Logistically, an open-system removal was less resource-intense 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. Hydroacoustic surveys, standard dozer trawl sampling and/or standard boat electrofishing pre- and post-removals should be conducted to measure abundance even if reductions are only temporary.

To continue forward progress, new goals and benchmarks for success should be established and planning should include the application of new fishing techniques. The three-boat electrofishing technique should be tested at a small tributary habitat such as the Platte River in Missouri. An evaluation of the applicability of commercial fishing crews should also occur to work towards a sustainable depletion model that can be applied across a larger geographical scale. New capture gears should be considered as well to further exploit the fish congregations noted on sonar imaging occurring beyond the reach of our gears. Specifically, deep habitats (>20 ft) provide refuge for invasive carp from many of our gears. Concurrently, the effectiveness of commercial fishing crews should be evaluated within the Missouri River basin to determine if they could be a cost-effective solution or addition to agency crews.

Literature Cited

Asian Carp Regional Coordinating Committee (ACRCC). 2019. 2019 Asian carp action Plan. Asiancarp.us

Broaddus, D.W., Bonjour, S.M., and Acre, M.R., 2025. Position Data for fish in the Lamine River Mouth, Missouri, USA from September to October 2024: U.S. Geological Survey data release, **https://doi.org/10.5066/P14QZAJF**.

Collins, S.F., S.E. Butler, M.J. Diana, and D.H. Wahl. 2015. Catch rates and cost effectiveness of entrapment gears for Asian carp: a comparison of pound nets, hoop nets and fyke nets in backwater lakes of the Illinois River. North American Journal of Fisheries Management 35: 1219-1225.

Hammen, J.J., E. Pherigo, W. Doyle, J. Finley, K. Drews, and J.M. Goeckler. 2019. A comparison between conventional boat electrofishing and the electrified dozer trawl for capturing silver carp in tributaries of the Missouri River, MO. North American Journal of Fisheries Management 39(3): 582-588.

Irons, K.S., G.G. Sass, M.A. McClelland, and J.S. Stafford. 2007. Reduced condition factor of two native fish species coincident with invasions of non-native Asian carps in the Illinois River, U.S.A. Is this evidence for competition and reduced fitness? Journal of Fish Biology 71:258-273.

Nico, L.G., J.D. Williams, and H.L. Jelks. 2005. Black carp: biological synopsis and risk assessment of an introduced fish. American Fisheries Society, Special Publication 32. Bethesda, Maryland.

Roth, D.R. 2018. Bighead carp reproduction in large tributaries with evaluation of sampling gear performance. Master's Theses. 4432 Eastern Illinois University.

Sampson, S.J., J.H. Chick, and M.A. Pegg. 2009. Dietary overlap among two Asian carp and three native fishes in backwater lakes on the Illinois and Mississippi Rivers. Biological Invasions.

Schrank, S.J., C.S. Guy, and J.F. Fairchild. 2003. Competitive interactions between age-0 bighead carp and paddlefish. Transactions of the American Fisheries Society 132: 1222-1228.

Seibert, J.R., Q.E. Phelps, K.L. Yallaly, S. Tripp, L. Solomon, T. Stefanavage, D.P. Herzog, and M. Taylor. 2015. Use of exploitation simulation models for silver carp (*Hypophthalmichthys molitrix*) populations in several Midwestern U.S. rivers. Management of Biological Invasions 6(3) 295-302.

Tripp, S. and Q.E. Phelps. 2018. Asian carp expansion in the Mississippi River: focusing on the leading edge of the invasion front. Acta Hydrobiologica Sinica 42(6): 1075-1080.

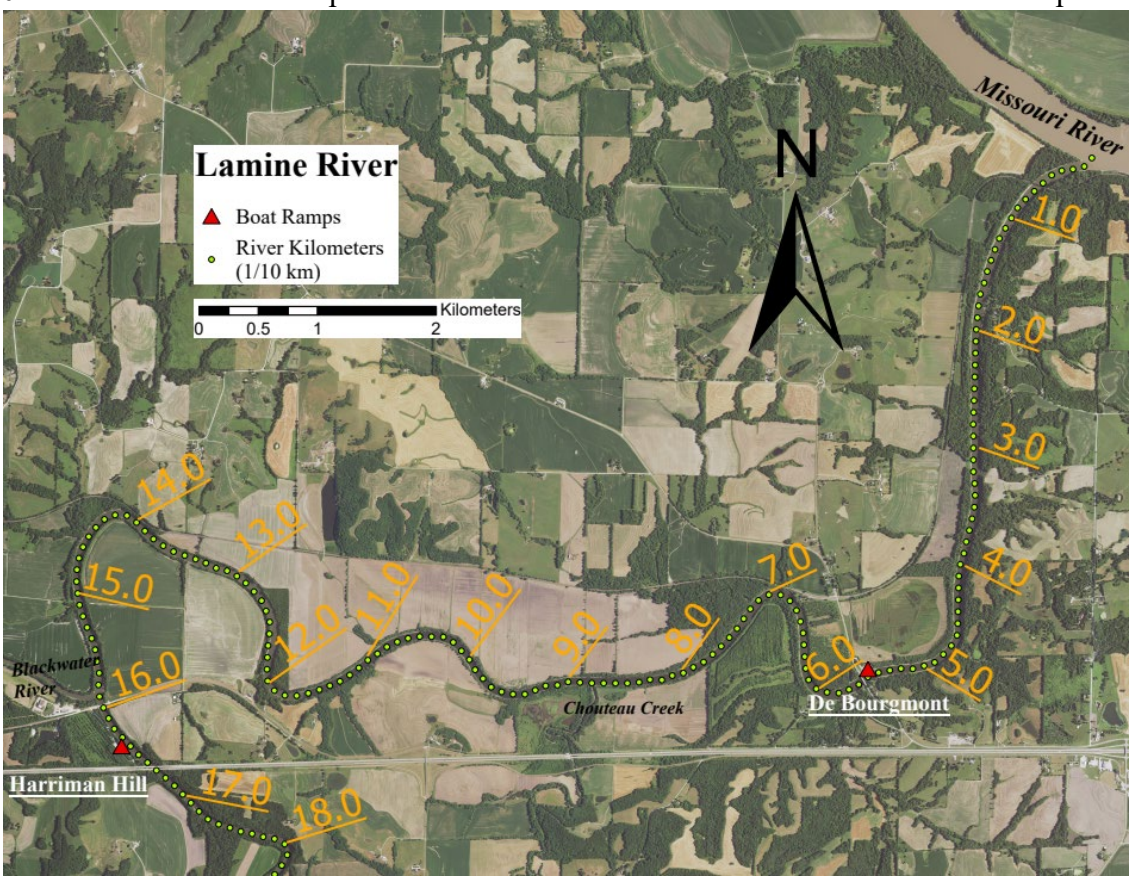


Figure 1. *Map of Lamine River and primary removal area in lower 18 river kilometers.*

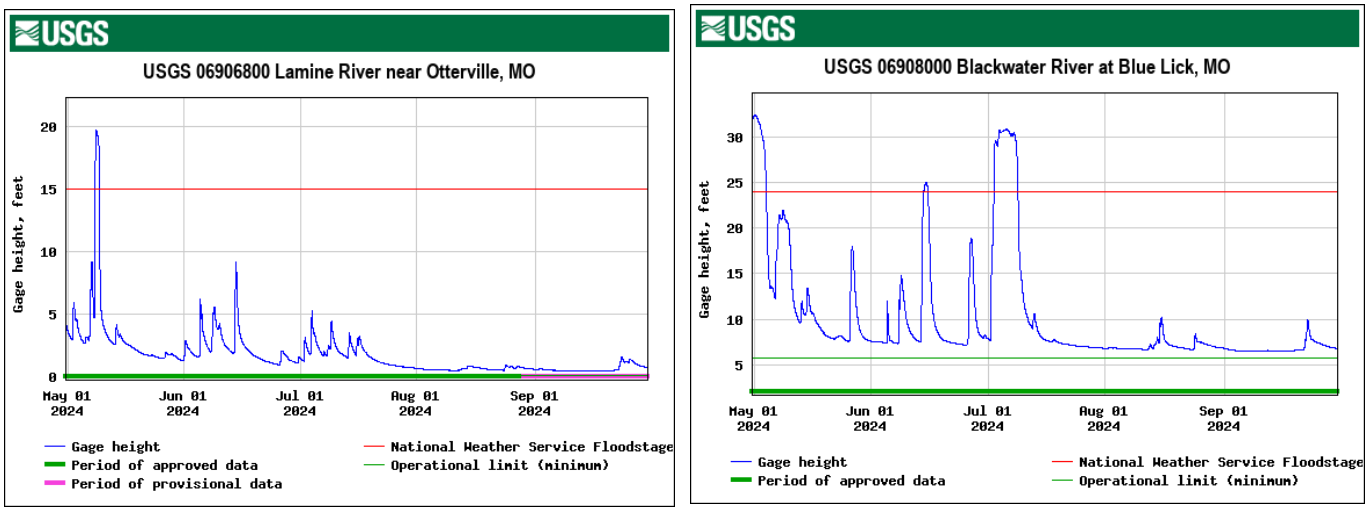


Figure 2. *Gage height on Lamine River (left panel) and Blackwater River (right panel) a tributary to the Lamine at rkm 15.9 from May 2024 through removal periods in September 2024.*

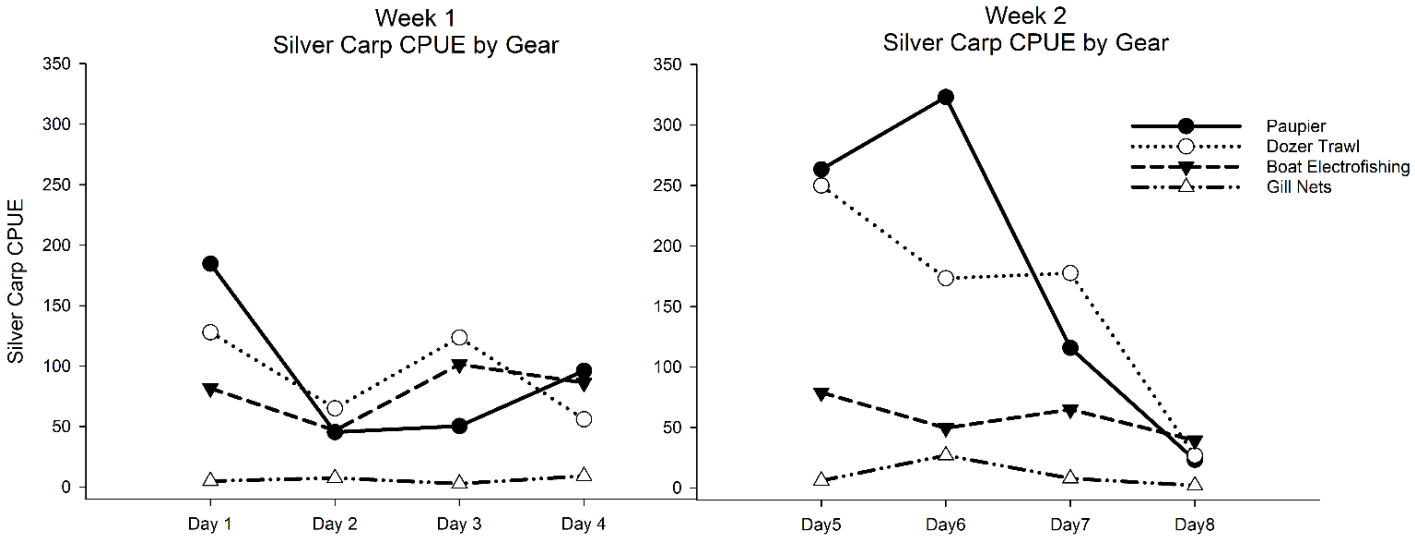


Figure 3. *Silver Carp catch per unit effort (CPUE) by gear and day in 2024 on Lamine River. CPUE was calculated as Silver Carp per hour for electrified gears and Silver Carp per 100 yards of net for gill nets.*

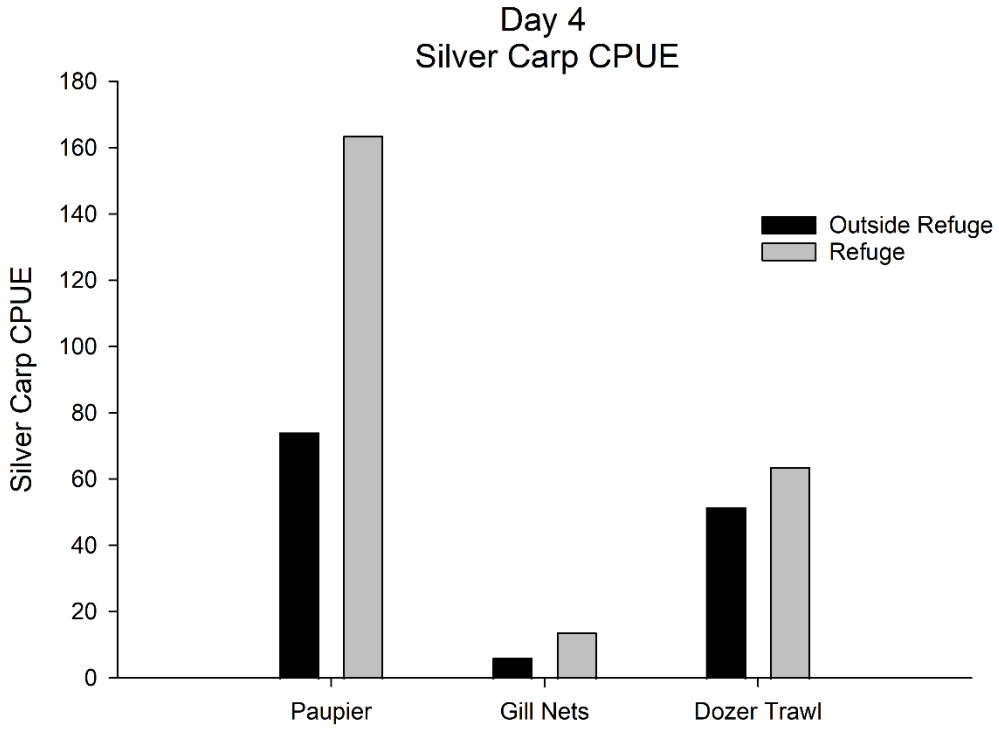


Figure 4. *Day 4 catch per unit effort inside refuge area (grey bars) and all other samples (black bars). CPUE was calculated as Silver Carp per 100 yards of net for gill nets and Silver Carp per hour for Paupier and Dozer Trawl.*

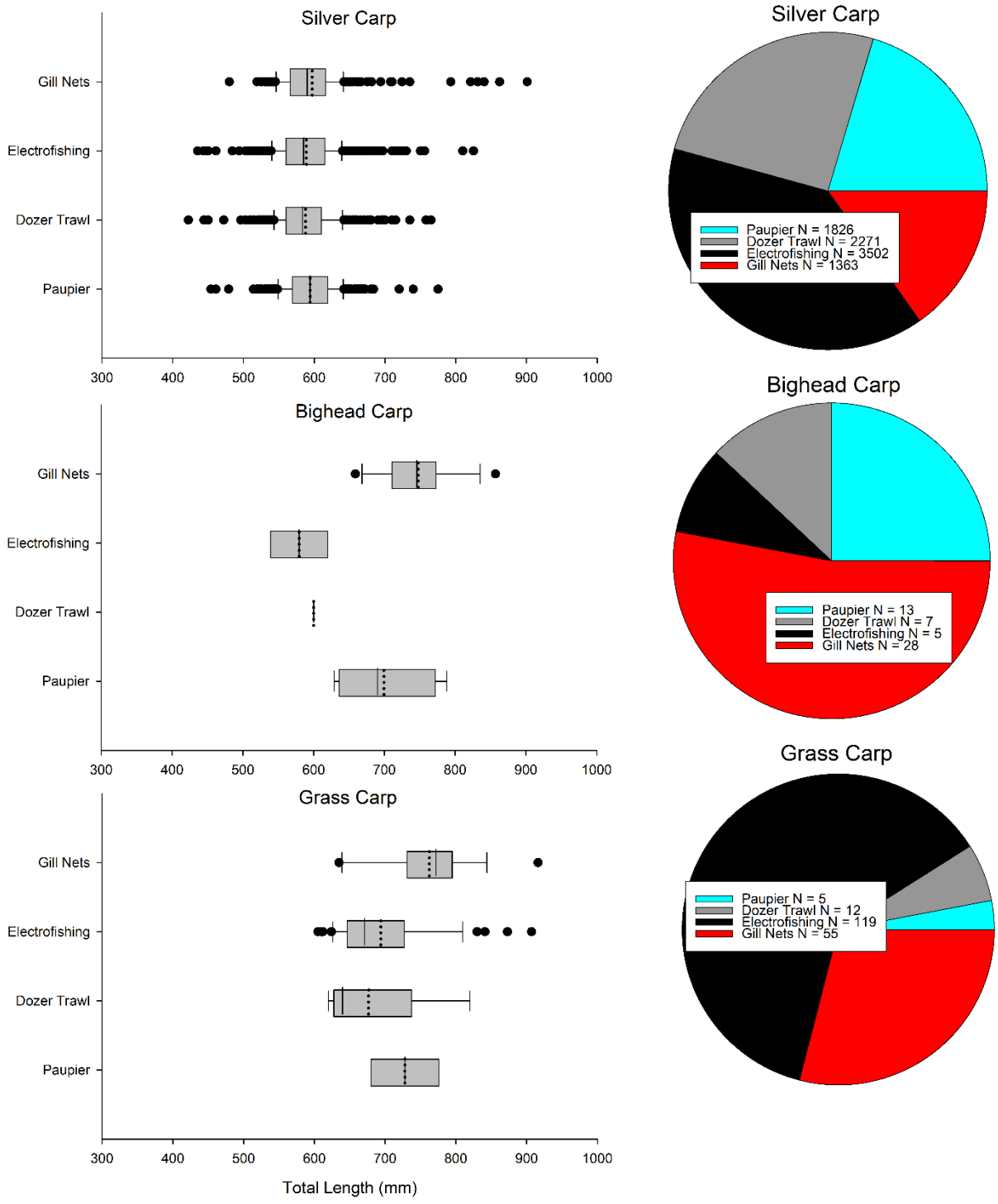
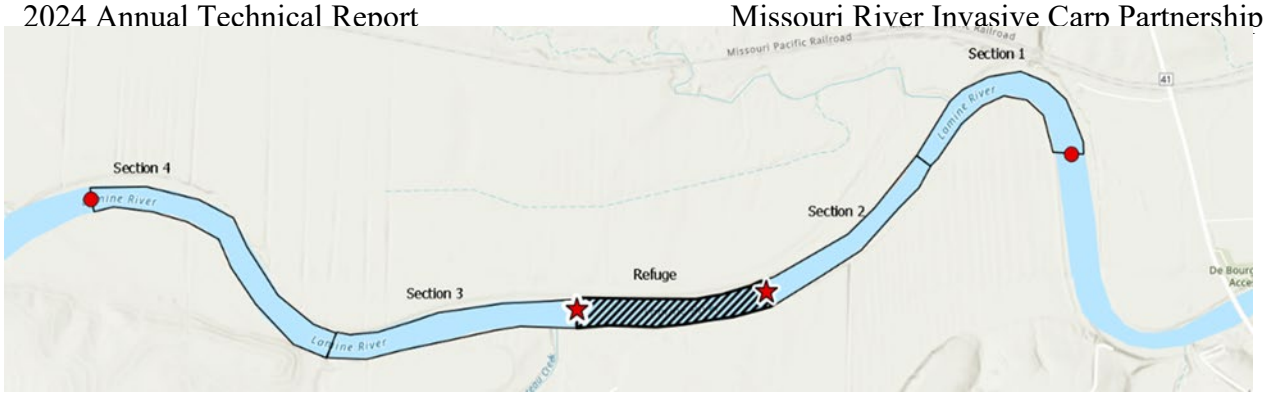


Figure 5. *(left side) a. Box plots of invasive carp lengths by gear. Boxes represent the upper and lower quartiles, solid line represents the median, dotted line represents the mean, whiskers represent the 10th and 90th percentiles and black circles indicate outliers. (Right side) b. Percent of total catch of invasive carp by gear.*



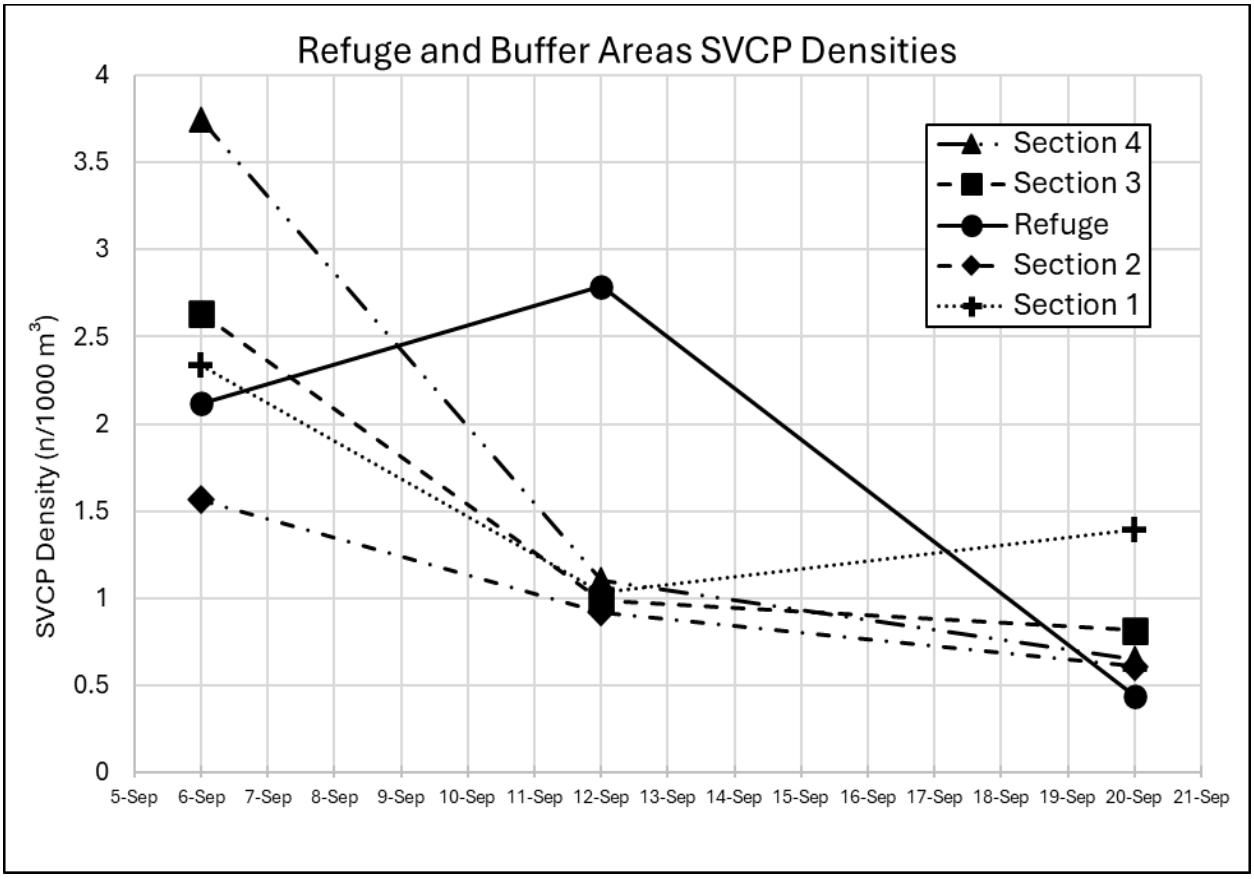


Figure 6. *Silver Carp densities estimated from Hydroacoustic scans for buffer and refuge sections for the pre and post removal. Map of refuge and section above graph.*

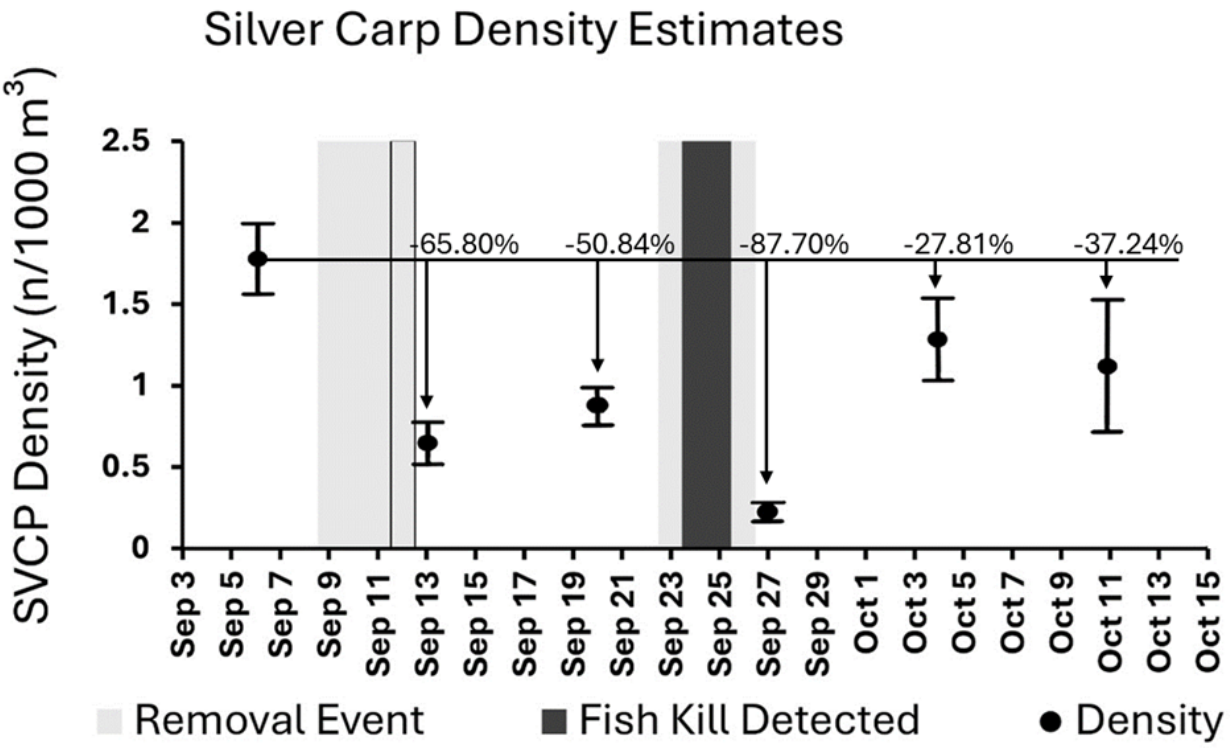


Figure 7. *Silver Carp density estimates derived from hydroacoustic surveys. Bars on the black dots represent (one standard error). Vertical bands represent removal days (grey), a fish kill event (black), and the refuge sampling event (grey with black outline).*

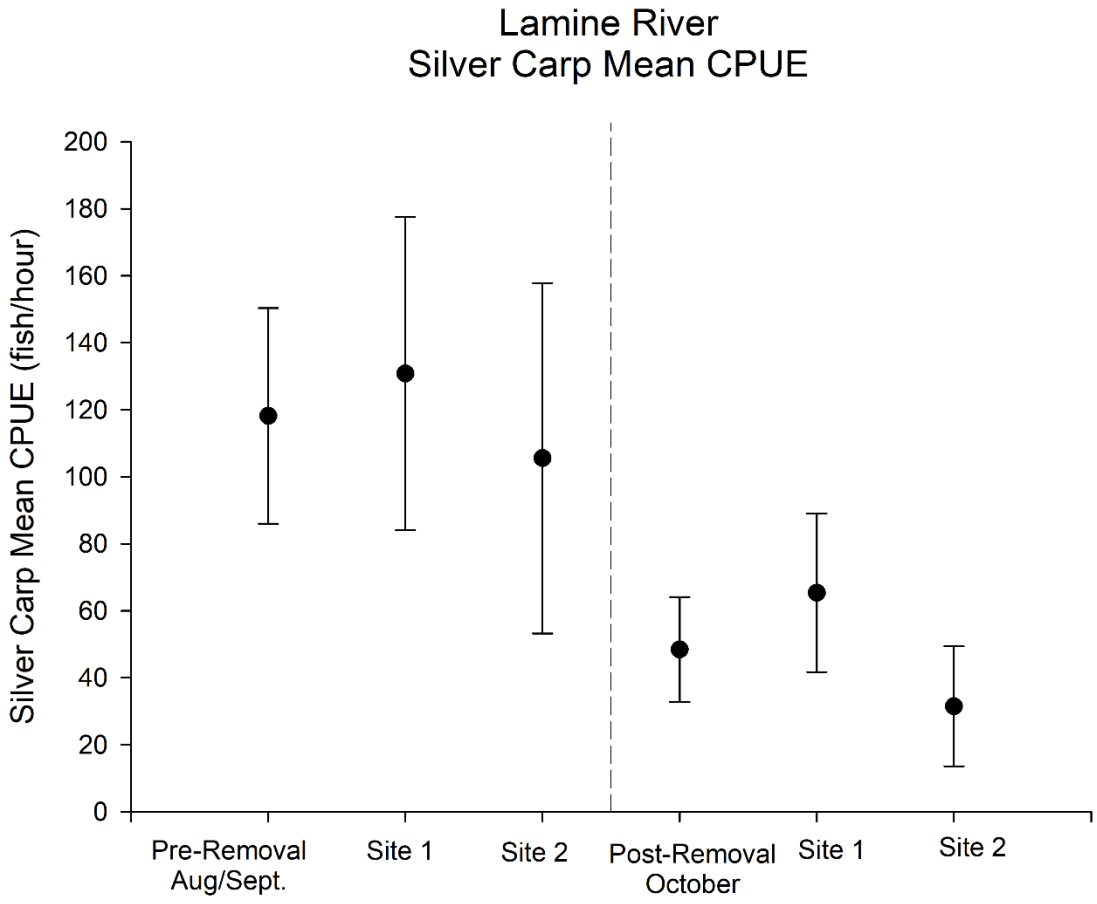


Figure 8. *Standard boat electrofishing Silver Carp catch per unit effort pre- and post-removal.*

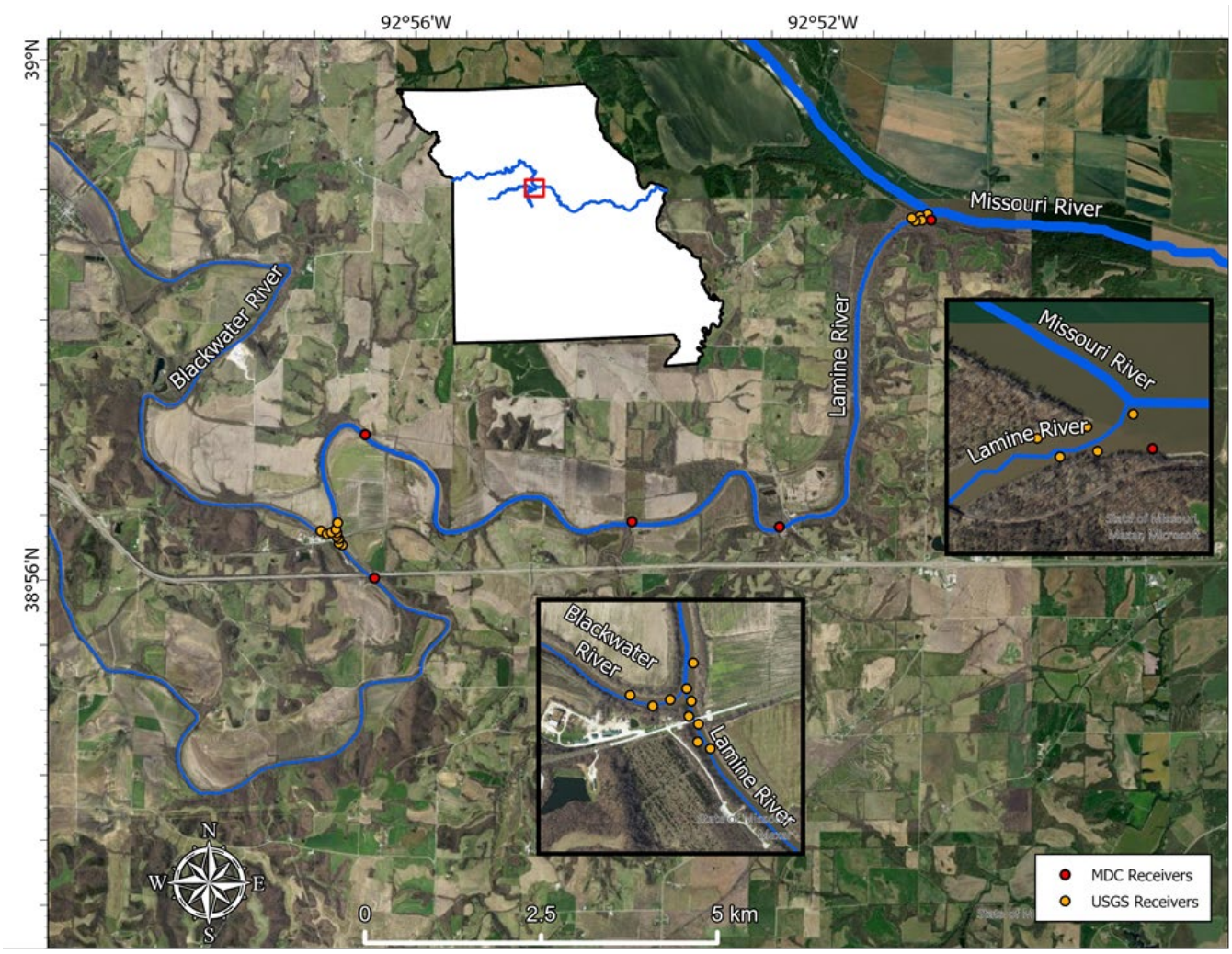


Figure 9. *Map of stationary telemetry receiver arrays and locations on Lamine River at confluence with Missouri River and Blackwater River confluence.*

Fish ID		Date							
Frequency	Tag #	5/15/2024	7/1/2024	8/28/2024	9/9/2024	9/23/2024	10/22/2024	Sex	Location Tagged
A69-1602	49070	1	1	1	1	1	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49069	1	1	1	1	1	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49111	1	1	1	1	1	1	M	LAMINE DEBOURGMORT ACCESS
A69-1604	27562	1	1	1	1	1	0	M	GRAND RIVER BRUNSWICK
A69-1602	49060	1	1	1	0	1	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49066	1	1	1	0	0	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49078	1	1	0	1	1	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49072	1	0	0	1	1	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49075	1	1	0	1	1	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49056	1	0	0	1	1	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49059	1	0	0	1	1	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49055	1	1	0	0	1	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49061	1	1	0	1	0	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49068	1	1	0	1	0	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49063	0	1	1	1	0	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49074	0	0	1	1	1	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49064	0	1	0	1	0	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49085	0	1	1	0	1	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49104	0	1	0	1	0	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49105	0	1	0	1	0	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49096	0	1	0	1	0	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49106	1	0	0	0	0	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49093	0	0	1	0	0	1	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49065	0	0	1	1	0	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49095	0	0	1	1	0	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49109	0	0	0	1	1	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49115	1	0	0	0	0	0	M	LAMINE DEBOURGMORT ACCESS
A69-1602	49116	1	0	0	0	0	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49108	0	1	0	0	0	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49113	0	1	0	0	0	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49169	0	1	0	0	0	0	M	MOREAU 50 ACCESS
A69-1602	49083	0	0	0	0	1	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49073	1	0	0	0	0	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49091	0	0	0	0	0	1	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49089	1	0	0	0	0	0	F	LAMINE DEBOURGMORT ACCESS
A69-1602	49097	0	0	0	0	0	1	F	LAMINE DEBOURGMORT ACCESS

Figure 10. *Silver Carp detections from active telemetry on Lamine River.*

Figure 11. *Map of all Silver Carp detections in Lamine River from active telemetry sweeps.*

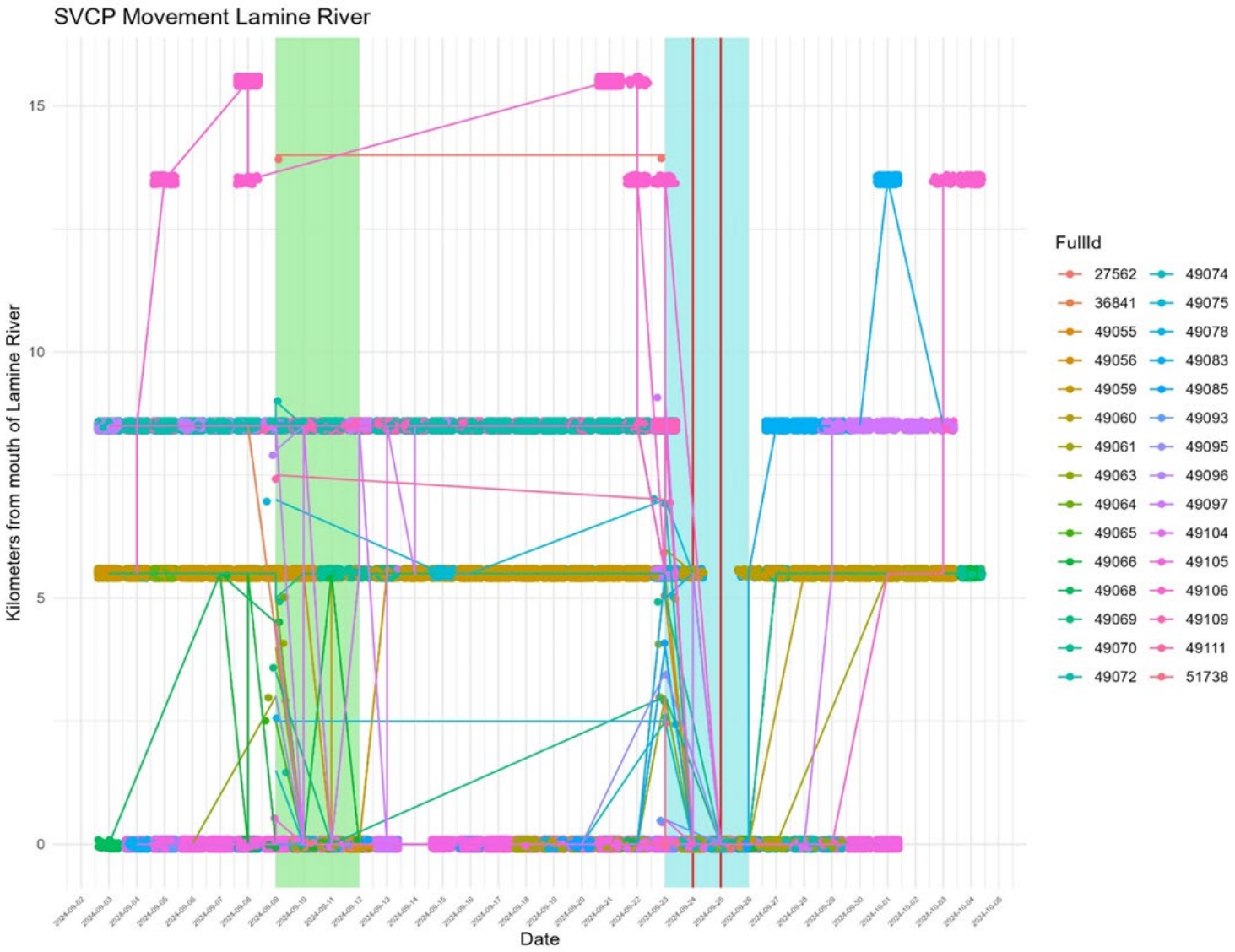


Figure 12. *Abacus plot of Silver Carp detections at stationary telemetry receivers by date. Vertical light green shaded portion is first week of removal and light blue is second week of removal. Vertical red lines represent timing of low oxygenated water moving through system.*

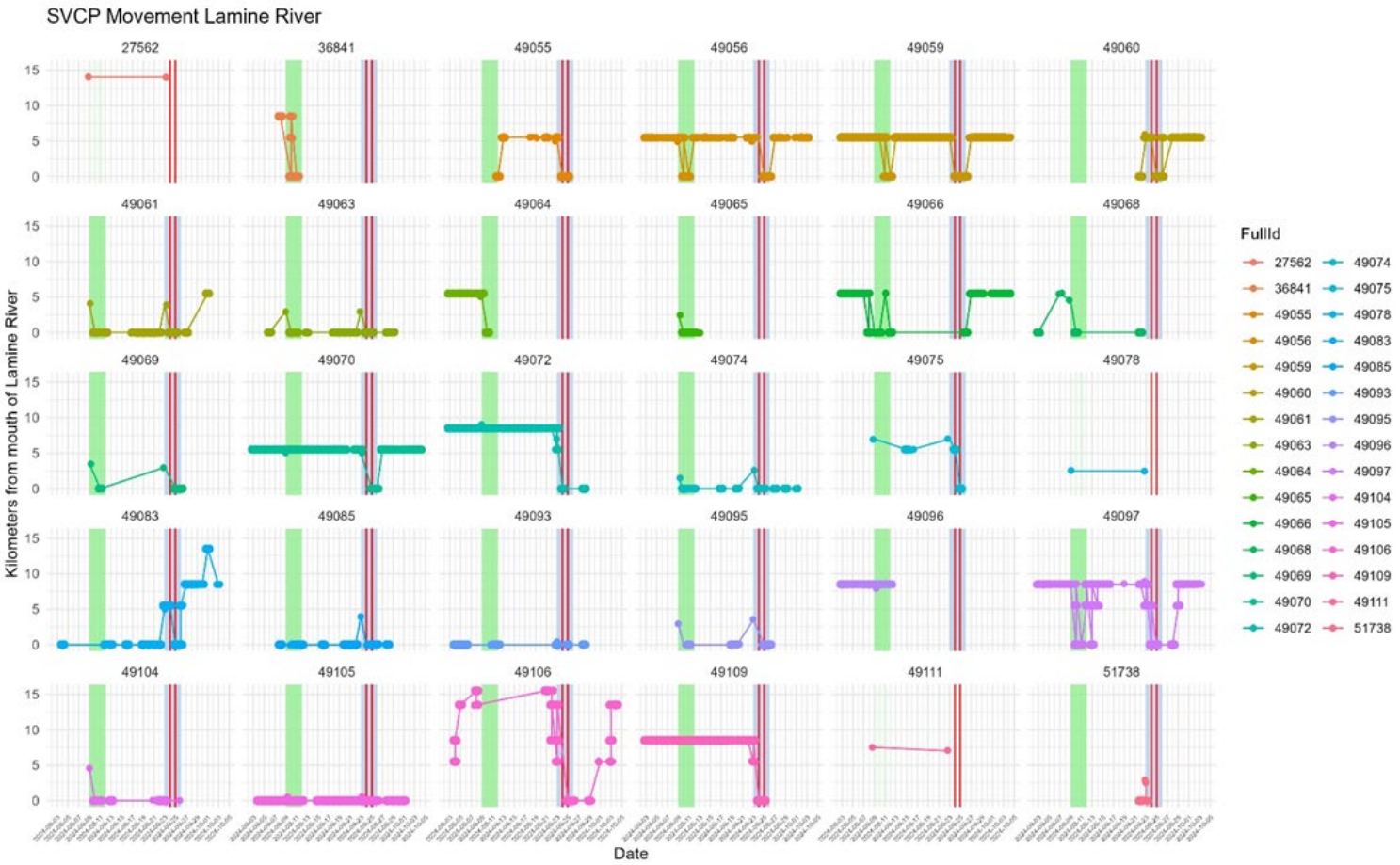


Figure 13. *Individual abacus plots for Silver Carp detections at stationary telemetry receivers by date. Vertical light green shaded portion is first week of removal and light blue is second week of removal. Vertical red lines represent timing of low oxygenated water moving through system.*

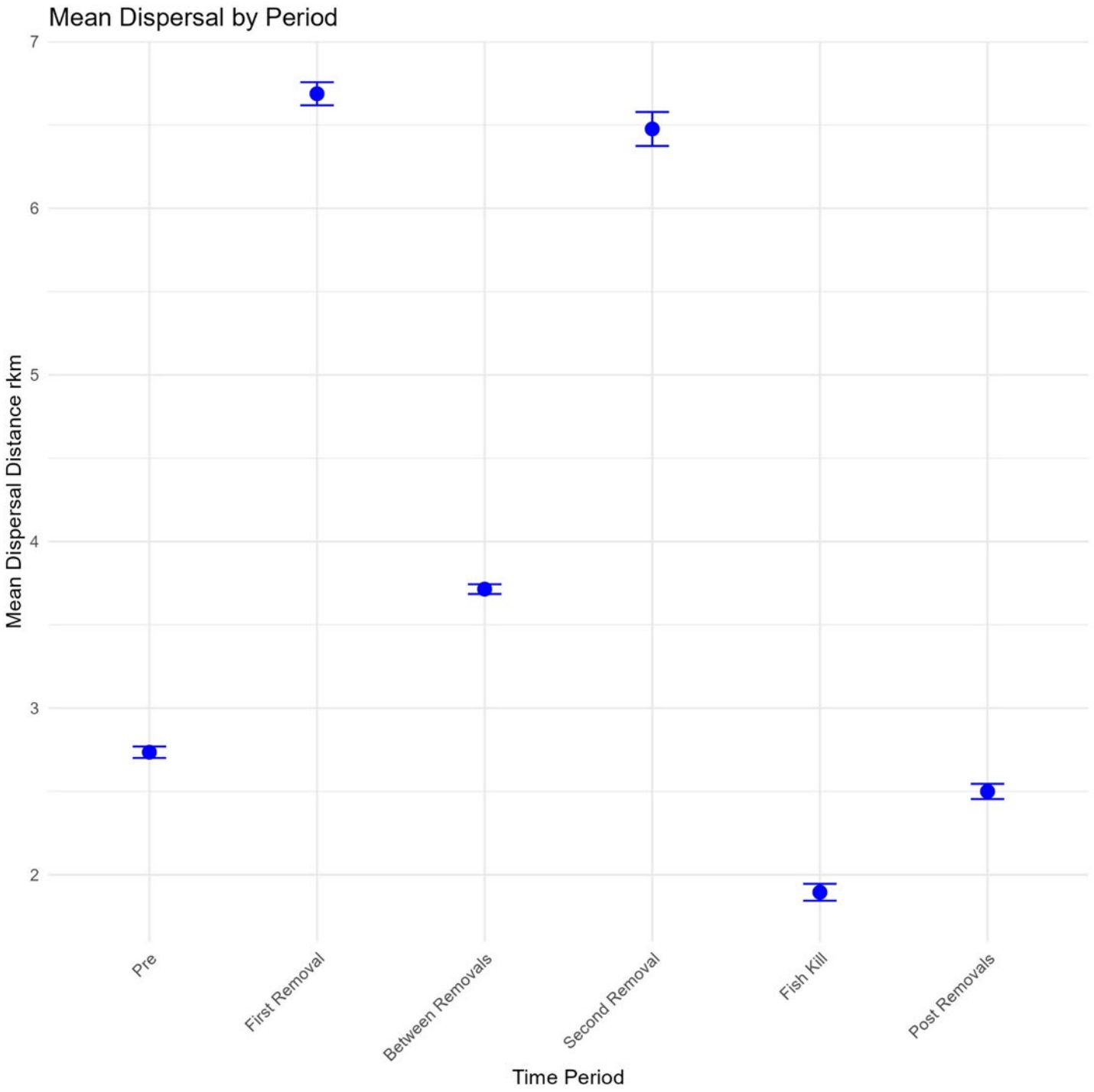


Figure 14. *Mean dispersal distance of Silver Carp by time periods.*

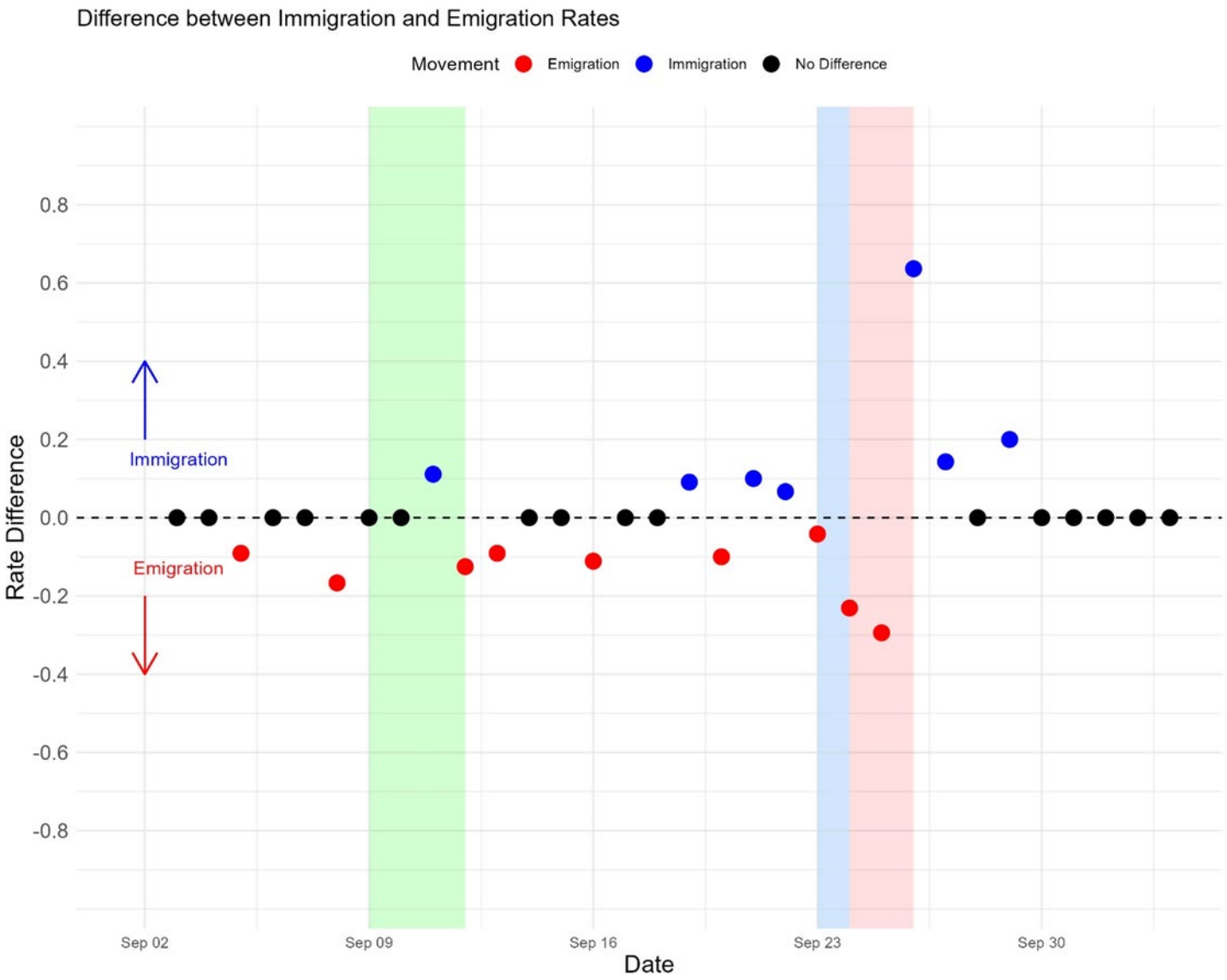


Figure 15. *Immigration and emigration rates of Silver Carp with telemetry tags in the Lamine River by date. Vertical light green shaded portion is first week of removal, light blue is second week of removal and light red portion represent timing of low oxygenated water moving through system.*