Project Title: Invasive carp movement and habitat use in the Missouri River Basin to inform containment and control management actions.

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Participating Agencies: Iowa Department of Natural Resources (IADNR) & Iowa State University (ISU), Missouri Department of Conservation (MDC), South Dakota Department of Game, Fish, and Parks (SDGFP) & University of South Dakota (USD), USFWS – Great Plains Fish & Wildlife Conservation Office (USFWS – GPFWCO)

Location of Activities: The study area includes Missouri River tributaries with direct connection to the Lower Missouri River and periphery streams within the states of South Dakota, Iowa, Kansas, and Missouri. The Lower Missouri River is the 1,305 river kilometers (rkm) of the mainstem Missouri River downstream of Gavins Point (the most downstream dam) to its confluence with the Mississippi River near St. Louis, MO.

South Dakota

- The James River joins the Missouri River approximately 18 rkm downstream of Gavins Point Dam and extends into South Dakota and North Dakota. The study area will focus on the lower 358 rkm of the James River upstream of the Missouri River confluence to Huron, South Dakota.
- The Vermillion River joins the Missouri River at approximately rkm 1,242 and extends into South Dakota. The study area will focus on the lower 192 rkm of the Vermillion River upstream to the East Vermillion Lake dam.
- The Big Sioux River joins the Missouri River at approximately rkm 1,181 and extends into Iowa and South Dakota. The study area will focus on the lower 255 rkm of the Big Sioux River upstream to the Sioux Falls in Sioux Falls, SD.

Iowa

- The Missouri River from rkm 1,183 upstream of Sioux City to rkm 885 downstream of Nebraska City. Major tributaries of the Missouri River in Iowa where invasive carp movements will be assessed include the Big and Little Sioux, Floyd, Boyer, and Nishnabotna rivers.
- The Little Sioux River joins the Missouri River at approximately rkm 1,077 and extends from Iowa into Minnesota. Milford Creek connects the Little Sioux River to the Iowa Great Lakes, which are comprised of seven different waterbodies that are extremely important recreationally and economically. Following flooding in 2012 that allowed invasive carps to invade the Iowa Great Lakes, the Iowa DNR, Minnesota DNR, and local partners installed an electric barrier at the outlet of Lower Gar Lake on Milford Creek.
- Sill #4 is a US Army Corps of Engineer structure located approximately 9 km upstream of the mouth of the Little Sioux River

Missouri

- The Kansas River joins the Missouri River at approximately rkm 591 and extends into Kansas. This study will focus on the area from the confluence with the Missouri River near Kansas City, MO, to Bowersock Dam near Lawrence, KS (rkm 60).

- The Grand River joins the Missouri River at approximately rkm 402 and extends north into Missouri with its headwaters in Iowa. This study will focus on the confluence with the Missouri River near Brunswick, MO.
- The Lamine River joins the Missouri River at approximately rkm 325 and extends south into Missouri. This study will focus on the confluence with the Missouri River near Booneville, MO.
- The Moreau River joins the Missouri River at approximately rkm 222 and extends south into Missouri. This study will focus on the confluence with the Missouri River near Jefferson City, MO.
- Creve Coeur Creek joins the Missouri River at approximately rkm 50 and provides access to Creve Coeur Park Lake, a high-use recreational area with a 320-acre oxbow lake in the Missouri River floodplain owned and maintained by St. Louis County Parks and Recreation Department. This study will focus on the 3.5 rkm from the confluence with the Missouri River to Creve Coeur Lake.

Statement of Need: Containment (Goal 2 in the National Plan and Goal 3 in the Missouri River Framework) prevents Invasive carp from expanding a known population confined to its current geospatial distribution. Invasive Carp are well established throughout the Missouri River and tributaries downstream of Gavins Point Dam. Knowing when and under what environmental conditions adult Bighead and Silver carp are moving into the tributaries will help inform when to monitor the population as well as implement management actions. Understanding the movement range of Bighead and Silver Carp in the Missouri River basin, the environmental conditions associated with movements, and the conditions associated with congregations at deterrent barriers currently present in the Missouri River Basin will allow for the identification of locations where deterrence technologies, concentrated removal efforts, physical barriers, or other emerging technologies can be utilized for containment and control. Identification and evaluation of containment opportunities can facilitate the implementation of deterrent and/or removal systems that may limit dispersal, reproduction, or recruitment of Invasive carp. A better understanding of the movement and behavior of Invasive carp in tributaries and in association with barriers as outlined in this proposal is critical to devising strategies for successful containment. As stated in National Plan Goal 6, scientifically valid research is necessary to provide accurate information for the effective management and control of Bighead and Silver carp. This research will be used to develop criteria for deterrent barriers, harvest regulations, or other management activities.

Invasive carp populations extend into the interior waters of Missouri River Basin states such as Minnesota via the Little Sioux River in northwestern Iowa and North Dakota via the James River. The Little Sioux and James rivers have barriers that act as deterrents under certain conditions. Flooding in 2012 allowed Invasive Carps to invade the Iowa Great Lakes that are comprised of seven different waterbodies that are extremely important recreationally and economically. The Iowa DNR, Minnesota DNR, and local partners responded to the invasion by installing an electric barrier on the outlet of Little Gar Lake, the most downstream lake in the Iowa Great Lakes chain with a 352 km^2 watershed that includes both Iowa and Minnesota. Additionally, the Little Sioux River originates in southwestern Minnesota and in December 2019, a Silver Carp was captured in the Ocheyedan River, about 100 yards from the Iowa border in southwestern Minnesota.

The electric barrier on the outlet of the Iowa Great Lakes is 49 m wide and 8 m long and consists of eight electrodes and seven pulsers that span the width of the outlet with a gradient of electrical intensity. The barrier is only activated when water on the barrier surpasses 3”, which typically occurs in the spring when Invasive Carps migrate upstream for spawning but can also occur periodically during the summer and fall, albeit less frequently. While the barrier has been in place since 2013, no evaluations have occurred to determine how effective it is at slowing or stopping upstream movements of Invasive Carp. Invasive Carp are frequently observed below the barrier and anecdotal evidence suggests that they may have passed the barrier during high water in 2018, as individuals are occasionally captured in the Iowa Great Lakes; however, it is unknown if these fish are new individuals that have recently passed the barrier or fish that were part of the initial invasion. Downstream movement of fishes past the barrier from the Iowa Great Lakes is commonly observed; thus, upstream fish passage through the barrier may also be possible.

A number of different Invasive Carp barrier evaluations have been conducted to date using a variety of different deterrents. However, most of these evaluations have occurred in laboratory settings due to the cost and regulations associated with installing barriers in natural environments. Electrical barriers hold promise for limiting or stopping the upstream movement of Invasive carp and the barrier currently in place on the Iowa Great Lakes is only one of a few systems available in the world that provides an opportunity to test its effectiveness under natural conditions. However, no evaluations of this barrier have been conducted to date and it is currently unknown how effective the barrier is at preventing upstream movement of fish. Additionally, no information is available regarding the seasonal presence of Invasive Carp at the barrier or the source of these fish (e.g., Little Sioux River residents or migrants from the Missouri River). Further, the timing and frequency of Invasive Carp movements further upstream into Minnesota is unknown but could provide information about invasion phenology. Thus, more information regarding tributary movements of Invasive Carp and potential effectiveness of electric barriers at minimizing or stopping their upstream movements is needed.

Project Objectives:

1. Determine Silver Carp and Bighead Carp residence time and movement in the Missouri River and its tributaries in association with season, environmental conditions, and barriers to inform containment and control management actions.

   1.1. Determine if Silver Carp and Bighead Carp have extended presence in tributaries and directional movement into and out of Missouri River tributaries.

   1.2. Evaluate environmental factors (e.g., season, temperature, discharge) for Silver Carp and Bighead Carp movements in select Missouri River tributaries.

   1.3. Assess fish behaviors in association with an electric barrier at the outflow of the Iowa Great Lakes, a concrete spillway at Creve Coeur Lake, and dams on the Kansas River (WaterOne Dam and Bowersock Dam), particularly how fish approach, challenge, and pass the barriers.

   1.4. Evaluate seasonal congregations of Silver Carp and Bighead Carp in Missouri River tributaries, particularly as they relate to fish barriers.

Project Highlights:

- Majority of invasive carp movement limited to tributary of tagging origin or within the Missouri River system, with only one invasive carp leaving the Missouri River system.
- Invasive carp that stayed within the Missouri River system traveled up to approximately 510 river miles from their tagging origin; one invasive carp each from the Moreau and Lamine Rivers traveled to Blair, NE.
- The single invasive carp that left the Missouri River system traveled approximately 291 river miles from Creve Coeur Creek to the lower Mississippi River at New Madrid, MO.
- Invasive carp in the Little Sioux were largely residents, although some individuals moved back to the Missouri River.
- Invasive carp made predictable exploratory movements into small tributaries, even during low water conditions, putting novel systems at invasion risk.
- Tagged Silver Carp in the James River were largely resident, and movements were linked to changes in the hydrograph.

Agency: Iowa Department of Natural Resources and Iowa State University

Methods:

Evaluate invasive carp residence time and movement behaviors in the Little Sioux River and its tributaries in association with season, environmental conditions, and barriers.

We deployed an array of 28 VEMCO acoustic receivers (VR2W, N=26; VRTx, N=2) in Spring 2022 within the Little Sioux River Basin, Missouri River, and Iowa Great Lakes using a combination of bridge mounted housings and bottom set stands (**Figure 1**). Bridge mounted receivers within the Little Sioux River (16), Ocheyedan River (1), West Fork Little Sioux River (1), and Missouri River (1) were deployed in PVC housings we attached to the downstream side of intersecting road bridges during Summer 2021. Acoustic receivers were suspended with 3 mm stainless steel cable inside the housing that allowed them to be fully submerged while being protected from floating debris in the river. Bottom set receivers were required in the West Fork Little Sioux River (1), Milford Creek (3), Ocheyedan River (1), and Lost Island Outlet (2) as there were no intersecting highway bridges at desired receiver locations (**Figure 2**). We conducted routine receiver maintenance at approximately 3-6 month time intervals to ensure receivers were functioning properly, download detection data, and install new batteries. We also deployed water temperature loggers (HOBO 64K Pendant data loggers; Onset Computer Corp., Bourne, Massachusetts) with each receiver programmed to record data at 1-hour intervals. To monitor water levels in the Little Sioux River, West Fork Little Sioux River, Milford Creek, Ocheyedan River, and Lost Island Outlet, we deployed five water level loggers (HOBO U20 Water Level Loggers; Onset Computer Corp., Bourne, Massachusetts) during June 2022 that record water pressure at 1-hour intervals for each system that can then be converted to water levels. We suspended loggers in PVC housing clamped to a 2.5 m T-post and pounded into the stream bed. We also deployed dissolved oxygen loggers (miniDOT Logger; Precision Measurement Engineering Inc, Vista, California) in all five systems and attached to the same PVC housings to monitor temporal fluctuations in DO (mg/l). DO loggers were programmed to record measurements at 10-minute intervals.

We conducted boat electrofishing (Smith Root Model VVP- 15b, pulsed DC 170-200 V, 8-10 amps) and seining (15.0 x 2m, 4mm mesh) during Spring 2022 and 2023 to capture Silver and Bighead Carp for acoustic tagging. We focused sampling efforts on the northern reaches of the Little Sioux River in the Iowa Great Lakes Region near the confluences (<5 rkm) of the West Fork Little Sioux River, Milford Creek, Ocheyedan River, and Lost Island Outlet. We seined within tributaries where boat travel was not feasible due to low water levels. Before each surgery, we measured fish for total length (mm) and weight (g) and identified sex using the presence of a rough patch on pectoral fin rays (present indicates male, absent indicates female; Wolf et al. 2018; Lederman et al. 2022) or by visually inspecting gonads during surgeries.

We implanted a number of different acoustic tags in invasive carp. The simplest transmitters (V13-1x, N=26 and V16-4x, N=53, VEMCO Inc., Halifax, Nova Scotia, Canada) provide presence/absence data at receiver locations. We also implanted V16A-6x (N=25) and V16T-4x (N=21) to transmit presence/absence data along with acceleration (V16A, m/s^2) and temperature (V16T, °C) data for each tag transmission detected by receivers. Across all tags, transmitter weight did not exceed 2% of fish wet weight. We have tagged 101 Silver Carp (Male N=69, Female N=32) and 24 Bigheaded Carp (male N=7, female N=17) from May 2022 – May 2023. We tagged a majority of Silver Carp near (<5 rkm) the confluence of the West Fork Little Sioux River (N=4, [TL: 635-814 mm, mean TL = 683 mm]), Milford Creek (N=26, [TL: 530-750 mm, mean TL= 633 mm]), Ocheyedan River (N=11, [TL: 555-800 mm, mean TL= 641 mm]), and Lost Island Outlet (N=17, [TL: 466-826 mm, mean TL = 639 mm]). We also implanted transmitters in 24 Bighead Carp (TL: 522-758 mm, mean TL = 672 mm) and nine Silver Carp (TL: 605-949 mm, mean TL = 704 mm) within Milford Creek approximately 300 m downstream of the electric fish barrier located at the outflow of Lower Gar Lake. Last, we tagged 35 Silver Carp (TL: 513-809 mm, mean TL = 626 mm) further downstream between Linn Grove, IA and Correctionville, IA.

Assess fish behaviors in association with an electric barrier at the outflow of the Iowa Great Lakes.

To assess number of fishes and fish behavior at the electric barrier, we installed an outdoor video surveillance camera (Sunba network PTZ) at the electric barrier during June 2022 (**Figure 3**). We mounted the camera to a fence pole directly above the barrier and positioned it for the best possible view of fish movements on top of and below the barrier. We added a polarized 49 mm lens coupled with a UV protective lens in front of the camera lens to reduce the reflective glare on the water's surface. Additionally, we cut down vegetation below the barrier to maintain an unimpeded view of fish movements.

After the initial setup, we programmed the camera in summer 2022 to record videos during randomly selected 15-minute intervals from each hour of the day that were saved to a hard drive on site. Due to drought that limited number of days with sufficient water levels observed in 2022, we programmed the camera in summer of 2023 to continuously record when water was flowing, and the barrier was active. From these videos, we planned to categorize fish behaviors as avoidance (slow approach and retreat away from the base of the electrical barrier), erratic (deviation from normal swimming behavior including rapid bursts of movement), challenging (persistent attempt to swim upstream over the barrier but is unsuccessful), inhibition (swimming inhibited due to involuntary contraction and relaxation of the muscles), galvanotaxis (actively swimming toward anode due to electrical field), motionless (temporarily stunned or involuntary relaxation of muscle due to shock from barrier), tetany (severe involuntary muscle contraction, open mouth, lack of operculum movement; death), and advanced (stunned but made a successful attempt and crossed the barrier). We also planned to document the number of Silver Carp jumps, number of fishes present, and the total amount of time each fish spends actively trying to challenge the barrier.

In addition to video monitoring on the north end of the barrier, we conducted a manipulative experiment in summer 2023 to assess differences in invasive carp behavioral responses to the electric barrier by testing the efficiency and effectiveness of different electrical settings. On the south end of the barrier, we constructed an enclosure (12 m long x 2.5 m wide) leading up to the top of the barrier by hammering round wooden fence posts into the creek bed to make the perimeter and wrapped the perimeter with 10.16 x 5.72 cm mesh safety fence and secured the fencing to the posts with zip ties and sealed the base of the enclosure to the creek bed with 15.24 cm landscape staples and metal T-posts (**Figure 4**). At the base of the enclosure, we sectioned off an area (1 m long x 2.5 m wide) using mesh safety fence. We continued the enclosure up on to the top of the barrier by laying cinder blocks down to create an impassable wall. Adjacent to the enclosure, we built an additional 2 m x 2 m holding pen 55 m downstream of the barrier along the north side of the creek to hold fish that were used for each trial (**Figure 4**).

To understand ways to improve the efficiency of the electric barrier, we tested the effectiveness of different standard pulse and gated burst waveforms that utilize the same power output while producing an overall field gradient of 5 V/in. We assessed the behavioral responses of invasive carp to the barrier based on different combinations of burst count, pulse frequency, pulse width, and burst spacings. Previous studies assessing standard pulse waveforms have suggested pulse frequency is a critical factor affecting injuries sustained by fish when using pulsed direct current, while high pulse widths have been associated with increased rates of corrosion on barrier electrodes. Conversely, gated burst waveforms may have operational advantages over standard pulse waveforms by reducing the possibility of fish injury while being more power conservative through the application of increased frequency pulses repeated in reduced frequency patterns (Beaumont et al. 2002). Therefore, we assessed one standard pulse waveform (2.5ms, 2Hz) and three different waveform combinations of burst count, pulse frequency, and pulse width [(5 x 0.5ms, 2Hz), (10 x 0.2ms, 2.5Hz), (5 x 0.2ms, 5Hz)] at two different burst spacings (15ms spacing, 30ms spacing) resulting in six gated burst waveforms (5 x 0.5ms (15ms spacing) 2Hz, 5 x 0.5ms (30ms spacing) 2Hz, 10 x 0.2ms (15ms spacing) 2.5Hz, 10 x 0.2ms (30ms spacing) 2.5Hz, 5 x 0.2ms (15ms spacing) 5Hz, 5 x 0.2ms (30ms spacing) 5Hz) for a total of 7 treatments and a control of the barrier turned off. We conducted 15 replicates of each treatment that were determined by a power analysis for a total of 120 trials using one Silver Carp or Bighead Carp per trial. Trials were conducted when water flowing over the barrier >38 mm were conducive for potential upstream movements. We conducted one replicate of each treatment setting in a random order (trial set) before moving on to the next set of replicates.

We captured up to eight Silver or Bighead Carp at a time downstream of the barrier using a seine net and placed them in a holding pen adjacent to the experimental enclosure. Before each trial, we measured fish before placing them into the sectioned off downstream end of the enclosure to acclimate for 15 minutes. During the acclimation period, we recorded water flow (m/s), depth (mm), conductivity (µS/cm), and temperature (°C). We also periodically measured barrier voltage via a voltage meter when water inundated the barrier to document any change in the electrical output during each treatment. After the 15-minute acclimation period, we used a dip net to transfer the fish into the main area of the enclosure where it had access to the barrier for a 15-minute experimental period. An observer used a 1.8 m tall ladder positioned 5.55 m away and 2.4 m above the enclosure to monitor movements during each trial. The observer recorded the total number of approaches and deflections, attempts to cross the barrier, the distance at which a fish swims on top of the barrier before being deflected back downstream, the total amount of time spent within the electric field on top of the barrier, and any of the known potential adverse behaviors (erratic, inhibition, galvanotaxis, motionless, tetany) described in detail above related to exposure to an electrical field. After the completion of each trial, fish were released back downstream.

Invasive carp and native species movement and passage in the Missouri River Basin.
We deployed six acoustic receivers (VR2W and NexTrak R1, 69 kHz, InnovaSea Systems Inc., Halifax, Nova Scotia, Canada) in the Little Sioux River, including two upriver and four downriver of Sill 4, in spring and summer 2024. We deployed five receivers as a bottom set with cage style frame cabled to ground anchors on the river bank while the confluence receiver is protected in a PVC housing attached to a bridge piling. We checked on receivers regularly following high water events to ensure they were not damaged or silted in.

We conducted modified boat electrofishing (Smith Root Model VVP- 15b, pulsed DC 170-200 V, 8-10 amps) downriver of Sill 4 in the Little Sioux River during May 2024 for Bigmouth Buffalo, Blue Sucker, Channel Catfish, Flathead Catfish, Grass Carp, Smallmouth Buffalo, and Silver Carp. Fish were measured to the nearest mm and weighted to the nearest gram. We identified Silver Carp sex by the presence or absence of nodules on the pectoral fin rays (Wolf et al. 2018) and all other species through visual inspection of gonads. Fish were surgically implanted with either a V13-1x or a V16-4x acoustic transmitter (InnovaSea Systems Inc., Halifax, Nova Scotia, Canada) depending on fish weight following the 2% rule.
We also collected invasive carp at six sites throughout the Iowa portion of the Missouri River in 2023 and 2024 (**Figure 5**). We tagged 130 Silver Carp in fall 2023 (TL 400-894, mean TL 647) and 119 Silver Carp (TL 429-930mm, mean TL 678 mm) and one Bighead Carp in fall 2024. Capture, biometric data collection, and tagging methods followed the methods described above.

Results and Discussion:
Evaluate invasive carp residence time and movement behaviors in the Little Sioux River and its tributaries in association with season, environmental conditions, and barriers.
We downloaded 27 of 28 acoustic receivers located throughout the study area at least twice between June and November 2022 – 2024. Our receiver located in the Missouri River downstream of the Little Sioux River confluence (Station Name: MOR - HW30 Missouri River) was removed in October 2023 due to low water levels and deployment of additional receivers by USGS throughout the Missouri River (A DeLonay, USGS, personal communication). Due to sedimentation in tributaries, multiple bottom set receivers were out of service for periods of time during summer 2022 and had to be checked on monthly. Additionally, low water levels during late summer and fall during both years caused multiple bridge-mounted receivers to be out of

water for various time periods and forced us to remove or convert them to bottom sets during Winter 2022 and 2023 to prevent ice damage. Receivers in the West Fork Little Sioux River, Ocheyedan River, and Lost Island Outlet were permanently removed in May 2024. Due to multiple invasive carp leaving the Little Sioux basin during summer 2022 and numerous mortality events that likely occurred during winter, only 9 individuals (11%) tagged and last detected in the Little Sioux Basin during 2022 were detected again in 2023. Therefore, an additional 44 fish (34 Silver Carp and 10 Bighead Carp) were tagged during Spring 2023. Of these individuals, five were not detected anywhere in our array during 2023-2024 (including active tracking efforts in a backwater near Linn Grove, IA). As of May 2024, 13 Silver Carp and 4 Bighead Carp appeared to be alive and in our array.

Cumulatively, we acquired 322,822 invasive carp detections (2022: 139,994 detections; 2023: 136,941 detections; 2024: 45,937 detections) on the three receivers within Milford Creek between May 2022 to May 2024. A majority of these detections (322,605) were recorded by the acoustic receiver 250 m downstream of the electric fish barrier. Of the 33 fish (9 Silver Carp and 24 Bighead Carp) tagged in Milford Creek, all but 1 Silver Carp were detected near the barrier. The number of fishes detected near the barrier was highest during April – June in 2022 and 2023, coinciding with increased water levels. The number of individuals detected at the middle and confluence receiver locations was also highest during these months, suggesting individuals were primarily entering and leaving Milford Creek under high-water conditions (**Figure 6**). From May 2022 to May 2024, 10 Bighead Carp and 3 Silver Carp moved from Milford Creek to the Little Sioux River. No acoustically tagged invasive carp have been detected in the Iowa Great Lakes.

Disregarding the 13 fish that moved from Milford Creek to the Little Sioux River, the remaining 22 appear to be either highly resident and have shown very little signs of movement from their initial tagging location near the electric fish barrier or have died/shed their transmitter. During 2022 and 2023, total fish detections near the barrier dropped significantly during late-July through mid-November when water levels were low. However, large numbers of fish (primarily Bighead and Silver Carp) were observed in person on multiple occasions throughout Summer 2022 and Summer 2023 approximately 300 m downstream of the electric fish barrier (~75 m downstream of the nearest acoustic receiver). Detection ranges of acoustic receivers in Milford Creek were < 50 meters (61% detection probability at 50 m) in June 2022 when water levels were relatively high, suggesting tagged fish in this area downstream of the receiver likely had lower detection probabilities. A portable hydrophone was used in this area during Summer 2022 to attempt to detect any Silver or Bighead Carp that may have been present and whether any mortalities had occurred. Five Bighead Carp and 2 Silver Carp initially tagged in this area were detected during this effort, but the determination of mortalities was inconclusive. In 2023 while conducting similar efforts, we found one transmitter implanted in a Bighead Carp during May 2023. However, whether the transmitter was shed from a live or dead fish is unknown; thus, we excluded this individual from our analyses.

Of the 92 Silver Carp tagged in the Little Sioux River, we only observed one entering Milford Creek. In contrast, we have observed numerous Silver and Bighead Carp entering the West Fork Little Sioux River, Ocheyedan River, and Lost Island Outlet. Individuals primarily entered tributaries during periods of warming water temperatures (> 10ºC and < 25ºC) and increased discharge events (> 25 m^3/s) in the Little Sioux River from April – July. However, the number of individuals that entered varied substantially by year and system (**Figure 7**). In general, the duration of residency events was short (< 3 days) and individuals exited tributaries under the same conditions as when they entered. We have also observed multiple large gaps in detections of individuals that were last detected in a tributary. This may imply those individuals remained in the tributary, but their fates are unknown.

To evaluate Silver and Bighead Carp movements in the Little Sioux River Basin, we classified movement events as either upstream or downstream. Directional movement events were considered as sequential detections of an individual on a series of receivers that followed a unidirectional pattern. Movement events were terminated after an individual went > 14 days without being detected or if they were detected at a receiver in the opposite direction that implied a change in movement direction and would subsequently initiate a new event. Movements that only occurred within tributaries were not included to account for bias created by receivers being spaced closer together and directional movements were classified into ~50 km distance bins (e.g., 10-50, 51-100, 101-150 km etc.). Last, we did not complete 2022 tagging until the end of May, so movements during this period should not be directly compared to other months in 2022, 2023, or 2024.

Overall, we primarily observed Silver and Bighead Carp movements during Spring and early Summer both years when discharge events exceeded 25 m^3/s and water temperatures were 10-25ºC. However, we did observe multiple individuals move during October 2023 when discharge surpassed ~15 m^3/s and water temperatures were ~10ºC (**Figure 8**). Across all years, we mainly observed Bighead Carp movements during May - July, but movements were infrequent and a large proportion of individuals showed few signs of movement from their original tagging location. Of the 14 individuals tagged in 2022, five had at least one movement event from May – November (mean upstream: 54.5 ± 37.5 SE; mean downstream: 138.1 km ± 52.3 SE), but only two survived and had movements during 2023 (upstream: 43.9 km, mean downstream: 137.6 km ± 52.6 SE). Of the 9 Bighead Carp tagged in 2023, only two individuals moved from May – October (mean upstream: 37.6 km ± 5.7 SE). Across both years, the furthest upstream movement in the Little Sioux Basin was 92 km (July 2022) and the largest downstream movement was ~395 km (July 2022), although this individual was also detected passing four receivers owned by the Missouri Department of Conservation (MDC) from September – November 2022 (first detected approximately 2 months later) in the Missouri, Mississippi, and Ohio Rivers. From its original tagging location (Milford Creek, IA), this individual had a displacement of ~1,700 km.

In 2022, Silver Carp movements were most frequent in June and July that coincided with an extended period of high discharge. Twenty-seven of 67 (40%) tagged Silver Carp exhibited at least one upstream movement (mean: 67.2 km ± 8.3 SE) and 33 (49%) individuals had one or more downstream movements (mean: 67.4 km ± 7.41 SE). Additionally, three individuals left the Little Sioux River during June - July, one of which was detected on a receiver owned by the University of Nebraska-Lincoln (UNL) within the Platte River, NE during September 2022 that was ~253 km from its original tagging location in Correctionville, IA. However, movement appeared limited starting in late July, and this extended throughout Winter 2022 when water levels were severely low across the Little Sioux River basin. Due to numerous mortality events that likely occurred during Winter, only three Silver Carp tagged in 2022 had movement events of various magnitudes that occurred from May-June 2023 (mean upstream: 90.4 km ± 38.4 SE; mean downstream: 148.5 km ± 81.8 SE). For individuals tagged in 2023, movement was similarly related to Little Sioux River discharge and temperature, but less frequent in comparison to individuals in 2022. In general, movements were primarily exhibited during April – June, but only 8 of 34 individuals exhibited at least one upstream movement (mean 62.1 km ± 23.5 SE) and 13 had one or more downstream movements (mean 77.3 km ± 15.0 SE; **Figure 9**). Seven individuals also had large downstream movements (mean: 217.0 km ± 28.1 SE) that were likely triggered by an increased discharge event and cooling water temperatures in the Little Sioux River. Five of seven Silver Carp were last detected near the Little Sioux River confluences, suggesting they left the systems during this period (**Figure 10**). Across both years, the largest upstream movement exhibited by a Silver Carp in the Little Sioux Basin was ~207 km (June 2022 and 2023) and the furthest downstream movement was ~328 km (October 2023).

Overall, invasive carp movement within the Little Sioux River Basin appeared to be highly influenced by seasonal water levels and water temperatures during 2022, 2023, and 2024. Environmental conditions were similar among years: water levels were highest during Spring and early Summer but then remained low throughout late-Summer and Fall. Low numbers of detections during these time periods and thereafter suggest movement of invasive carp, and potentially their survival, may be strongly influenced by the harsh environmental conditions (e.g., low water levels and dissolved oxygen, high water temperatures, etc.) exhibited in these systems on a seasonal basis. However, when hydrological conditions are favorable for movement, individuals appear to be more likely to explore connected tributaries and are capable of traveling large distances in short time periods. Future detection data will allow us to assess how invasive carp movement can be affected by environmental conditions and the reduction in habitat connectivity between different systems on a seasonal basis. Additional data under variable river discharge patterns will provide insights into how movements vary interannually based on wet versus dry years.

Assess fish behaviors in association with an electric barrier at the outflow of the Iowa Great Lakes.

During summer 2022, we experimented with a number of different camera configurations to assess options for evaluating fish behaviors at the Lower Gar electric barrier. Initial video analysis revealed our ability to see and identify fishes decreased with increasing distance from the camera. Similarly, we found the infrared light emitted by the LED lights on the camera at night was only illuminating a small section of our viewing frame. Therefore, we repositioned the camera to focus on visible fish movements in an 8 x 15 m area on the north end of the barrier (**Figure 11)**. After the installation of the surveillance camera, there were 60 days (06/14/2022 - 08/12/2022) when the barrier was active and water was flowing. Of the 60 days of flow, we captured 32 days (7/12/2022 – 8/12/2022) of viable videos. There was no flow over the barrier between August and November 2022. On days with viable videos, we did not observe any fishes directly on top of the barrier attempting to cross but we did observe fishes downstream challenging the barrier. During summer 2023, we recorded 80 days (4/12/2023 – 6/30/2023) of videos when the barrier was active and water was flowing. We are working to analyze videos collected during summer 2023 for fish activity and behaviors.

In addition to video recordings, we conducted 120 experimental trials at the electric barrier from 5/12/2023 to 7/15/2023. Throughout our trials, we assessed the movements and behaviors of 75 Silver Carp, 39 Bighead Carp, and 6 hybrids under a variety of environmental conditions. Fluctuations in water temperature and conductivity ranged from 15.7°C to 28°C and 342 µS/cm to 440 µS/cm. In addition, we experienced diurnal fluctuations in water depth both on top of the barrier (38 mm - 120 mm) and adjacent to the barrier (346 mm - 757 mm) that contributed to variable flows ranging from 0.56 m/s to 0.90 m/s on top of the barrier throughout the study. Field voltage measurements between electrodes varied slightly between each active treatment. Voltage strengths ranged from 0.00 V/cm to 5.54 V/cm, with the highest voltage occurring between the edge of the barrier and the first ledge on the downstream end and between electrode eight and the edge of the barrier on the upstream end throughout all treatments (**Figure 12-13**).

In total, we observed 561 behaviors from 120 individuals ranging in size from 410 mm to 817 mm, including 251 attempts, 207 deflections, 27 erratic movements, 52 inhibitions, 22 motionless occurrences, and 2 galvanotaxis responses. No fish died near the barrier. Due to low water levels, no fish were observed crossing on to the top of the barrier into the main electric field. Instead, all behaviors were observed downstream of the barrier. We observed the most attempts from invasive carp trying to pass over the barrier wall into the electric fields during the 5 x 0.2ms (30ms spacing) 5Hz gated burst waveform that had the highest pulse frequency tested. Invasive carp deflected the most from the barrier during our only standard pulse 2.5ms, 2Hz waveform (**Figure 14**). In relation with attempts, we also observed the most additional adverse behaviors associated with exposure to an electrical field during the 5 x 0.2ms (30ms spacing) 5Hz gated burst waveform (**Figure 15**). We hypothesize that the 30ms spacing between bursts provided sufficient time for carp to attempt to pass, but the high 5Hz pulse frequency halted movement by causing the adverse effects as observed in previous studies.

Invasive carp and native species movement and passage in the Missouri River basin.
We downloaded the six receivers associated with Sill 4 at least twice between May and November 2024 for a total of 16 downloads. Only one upstream passage event occurred, despite high flows throughout a large part of the summer. One Silver Carp rapidly advanced from the confluence receiver to upstream of Sill 4 on August 5 during moderate flows of about 453 m^3/sec and a temperature of approximately 27°C and it remained upstream of Sill 4 through November (**Figure 21**). The first receiver upstream of Sill 4 malfunctioned from August through October and we are attempting to recover that data. Therefore, other fish may have also moved upstream past Sill 4 but have not yet been detected.

While native fishes did not move upstream of Sill 4, we obtained 315,000 downstream detections of these fishes (**Figure 16-23**). Channel Catfish, Grass Carp, and Bigmouth Buffalo appear to be more active with elevated discharge but other species, including Silver Carp, maintained activity during time periods with reduced discharge. Discharge also had varied effects on the river position of fish depending on species. Grass Carp, Bigmouth Buffalo, and Silver Carp were all detected further downriver at the confluence river during periods of low flow more frequently. Residency within the lower section of the Little Sioux may not be influenced by discharge and may be more associated with temporal variables. For instance, of 19 Bigmouth Buffalo tagged, 10 appear to have left the Little Sioux before or during the middle of June despite flows remaining above 110 m^3/sec through June (**Figure 16**).

Eight of 130 Silver Carp tagged in the Missouri River were detected in the Little Sioux River (**Figure 23**). The Missouri River Silver Carp were first detected in two distinct periods. The first four fish entered the week of June 24th when Missouri River discharge reached 4,445 m^3/sec and the Little Sioux River peaked at almost 1,780 m^3/sec. In contrast, the other four fish entered between August 18th and August 30th during declining discharges with flows from 14-28 m^3/sec, indicating Silver Carp are able to pass Sills 1-3 across a wide range of discharges.

Tables and Figures:

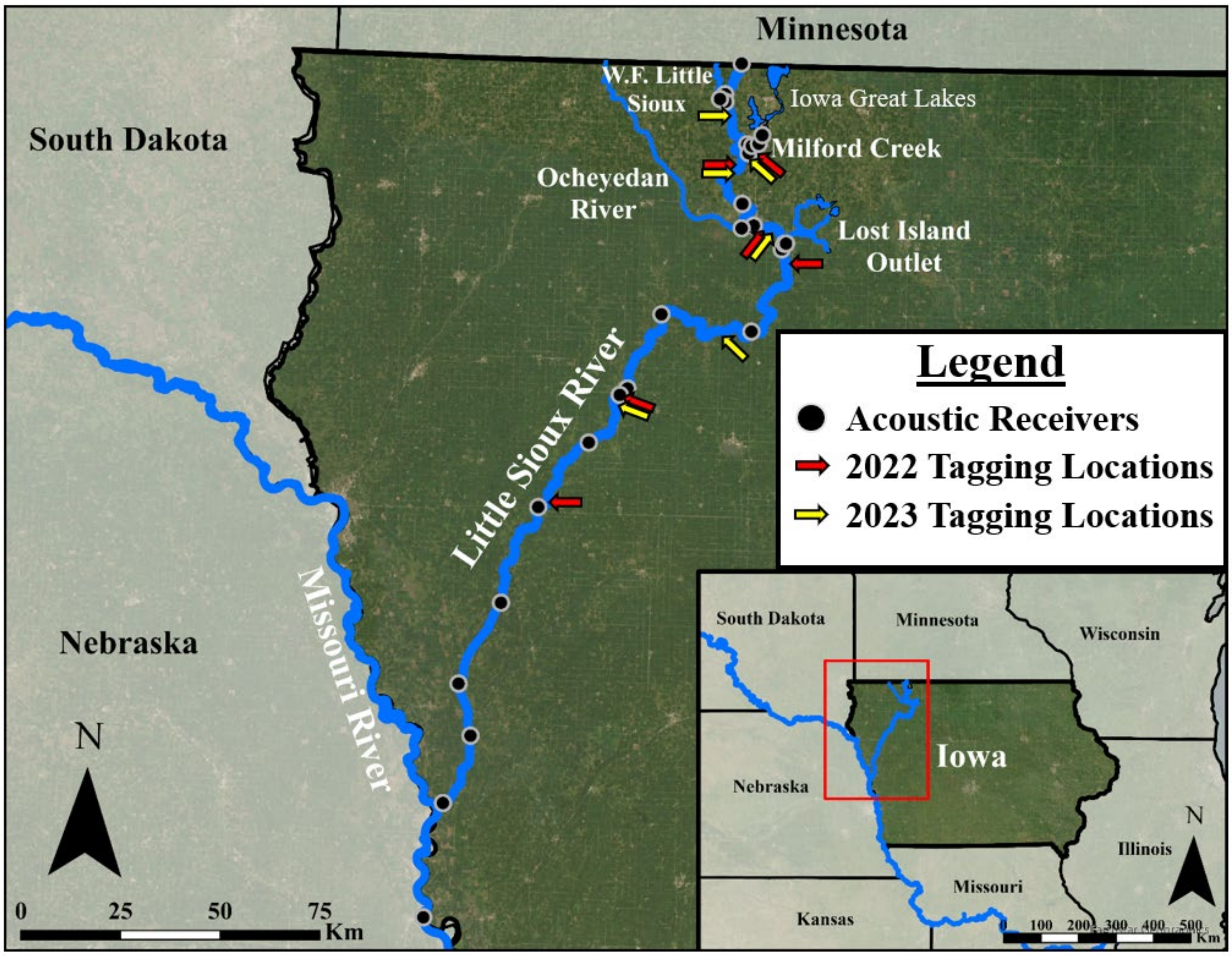


Figure 1. *Little Sioux River, four of its tributaries, and the Iowa Great Lakes in Northwest Iowa. Black dots indicate acoustic receiver locations in the Missouri River (1), Little Sioux River (16), West Fork Little Sioux River (2), Milford Creek (3), Ocheyedan River (2), and Lost Island Outlet (2). Two additional acoustic receivers were deployed in the Iowa Great Lakes upstream from the electric fish barrier that will help assess its efficacy in deterring invasive carps. We acoustically tagged invasive carp at eight sites between 2022-2023 (red and yellow arrows) in the Iowa Great Lakes Region and between Linn Grove, IA and Correctionville, IA.*

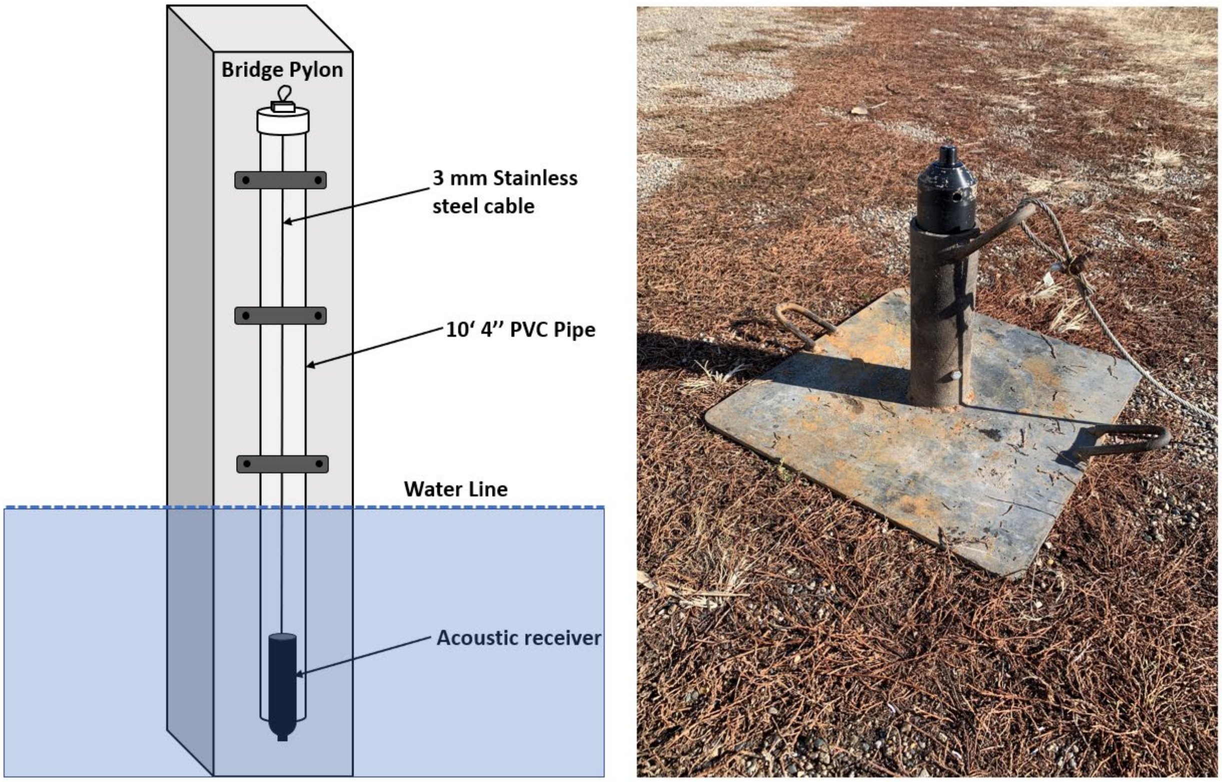


Figure 2. We deployed 19 acoustic receivers in PVC housings attached to the downstream side of intersecting highway bridges (left) and 9 bottom sets (right) throughout the study area (see **Figure 1** for receiver locations). Bridge mounted receivers were oriented in a downward position and were placed at various areas of the water column depending on each site whereas bottom set receivers were pointed in an upright position approximately 0.5 m above the stream/lake bed. Bottom set receivers were anchored to the nearest shoreline with 6.5 mm cable.

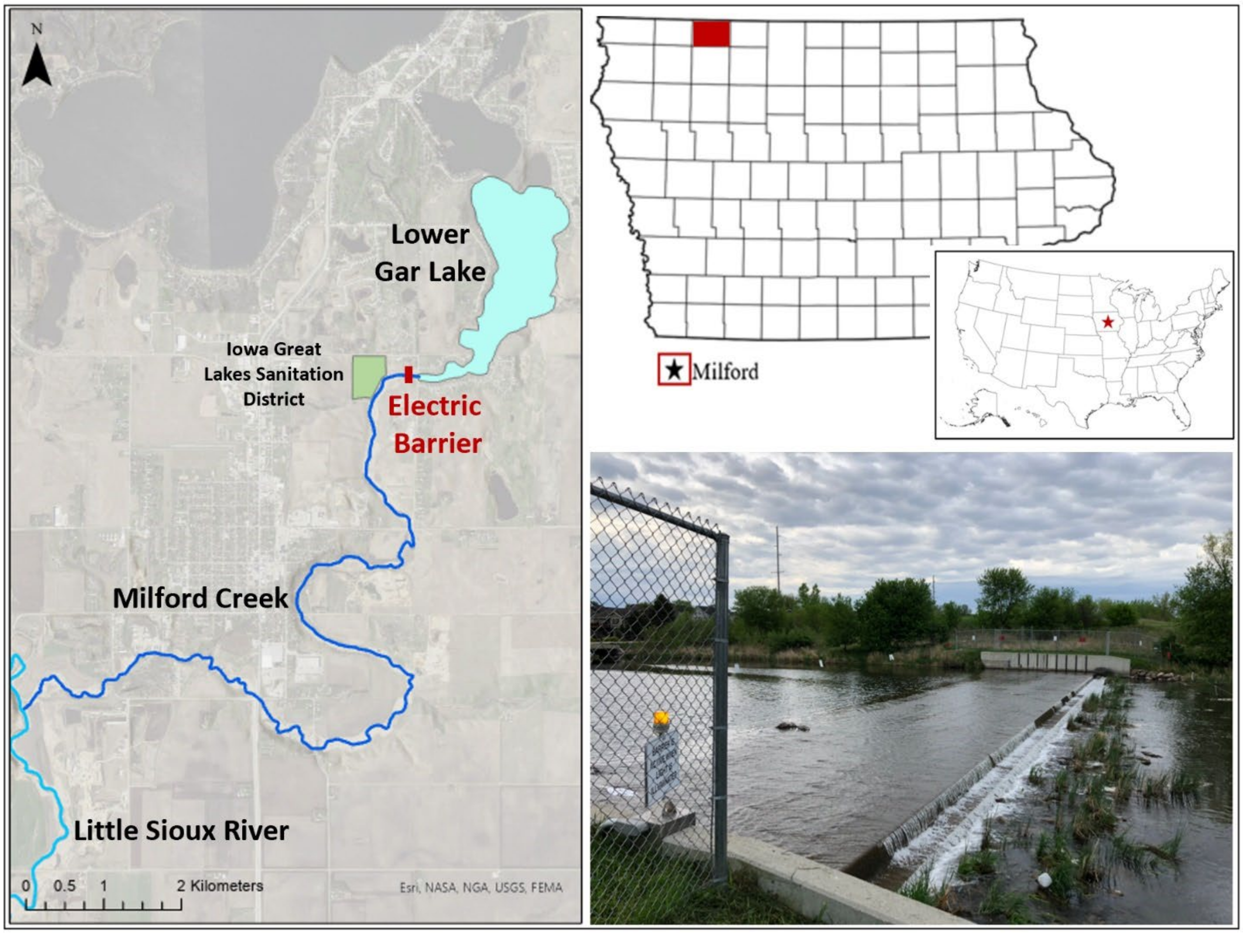


Figure 3. *Electric barrier in Milford Creek located in Milford Iowa, USA (43.340732, -95.132642). Aerial view shows proximity of electric barrier to Lower Gar Lake and the Iowa Great Lakes Sanitation District that sustains streamflow in Milford Creek.*

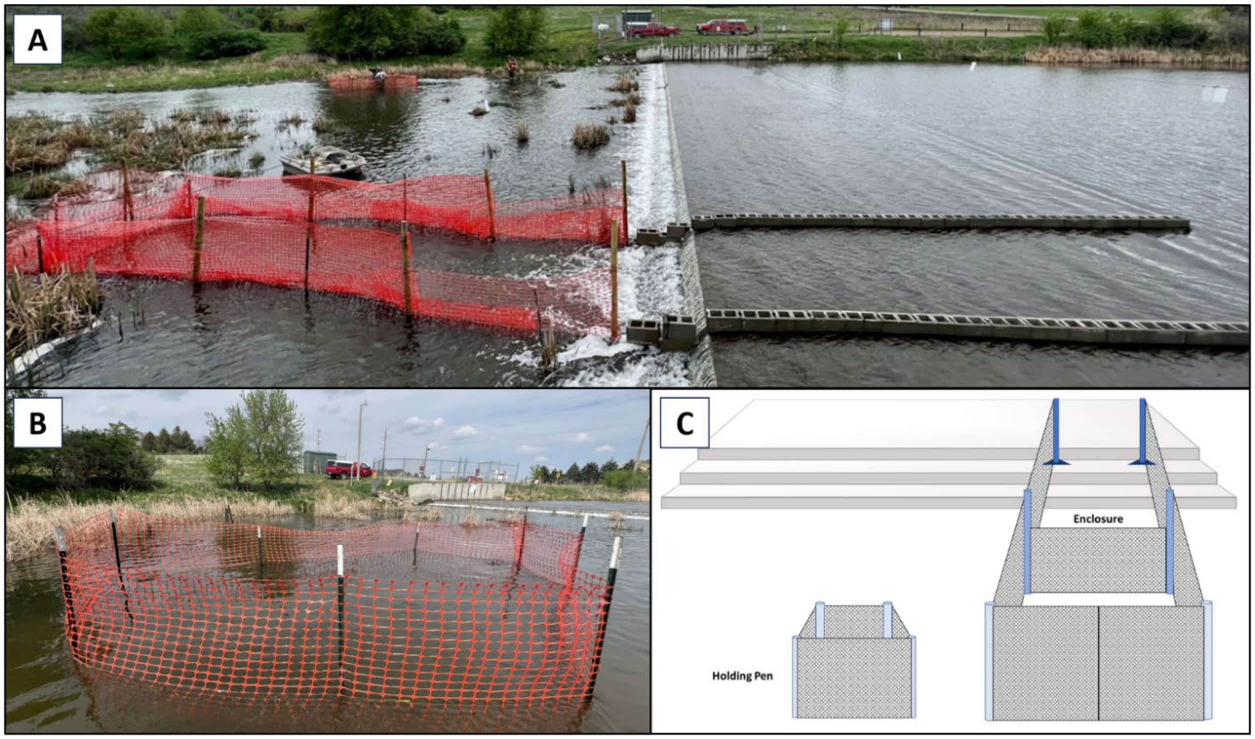


Figure 4. *(a) Fish enclosure constructed for experimental trials in summer 2023 with (b) holding pen positioned downstream of barrier away from stray voltage below barrier. (c) Conceptual design of fish enclosure showing acclimation enclosure at the base of the main enclosure.*

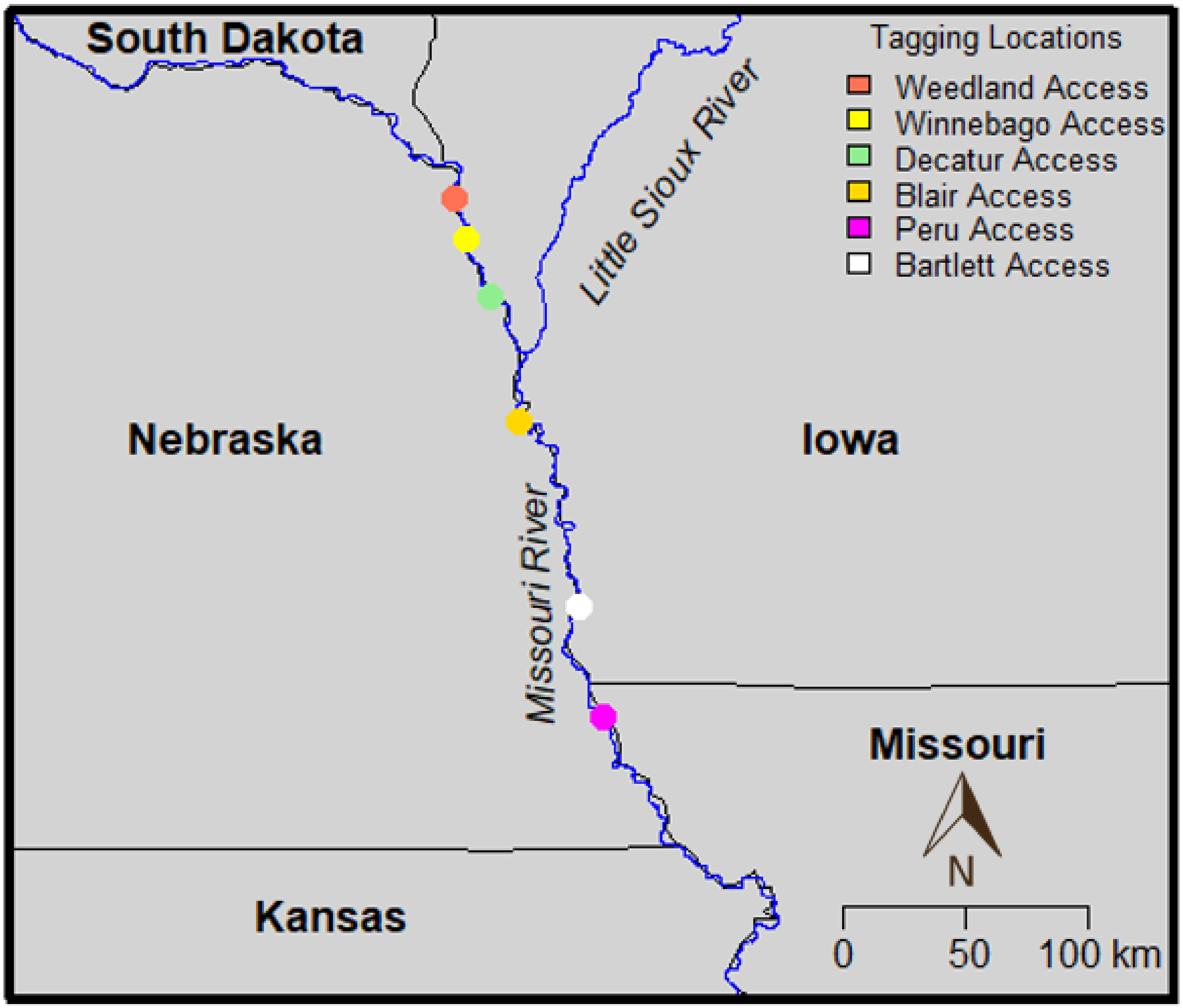


Figure 5. *Six locations throughout the Missouri River long the Iowa, USA border where we collected invasive carp and implanted them with acoustic transmitters during fall 2023 and 2024.*

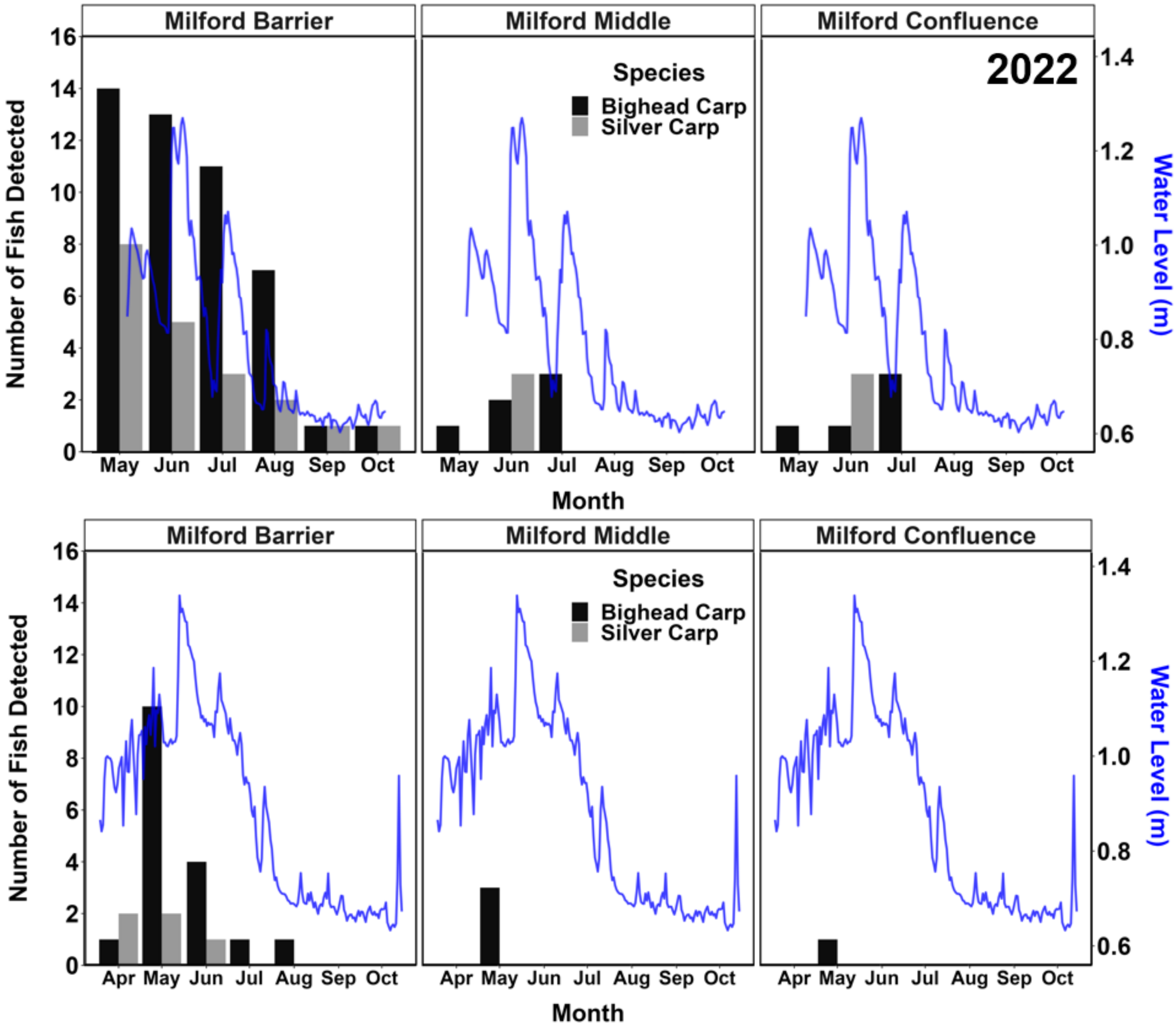


Figure 6. Number of Bighead Carp (black) and Silver Carp (grey) detected at the three receivers in Milford Creek from May - October 2022 (top figure) and March - October 2023 (bottom figure) in relation to water level (m; blue line). No individuals were detected during Winter of either year. Of the 24 Bighead Carp and 9 Silver Carp tagged in Milford Creek, only 1 Silver Carp has not been detected near the electric fish barrier. During May 2023, the large spike in the number of Bighead Carp detected near the barrier receiver was likely due to us tagging 10 individuals near this location on May 16th. As of May 2024, 13 individuals tagged in Milford Creek have been detected in the Little Sioux River.

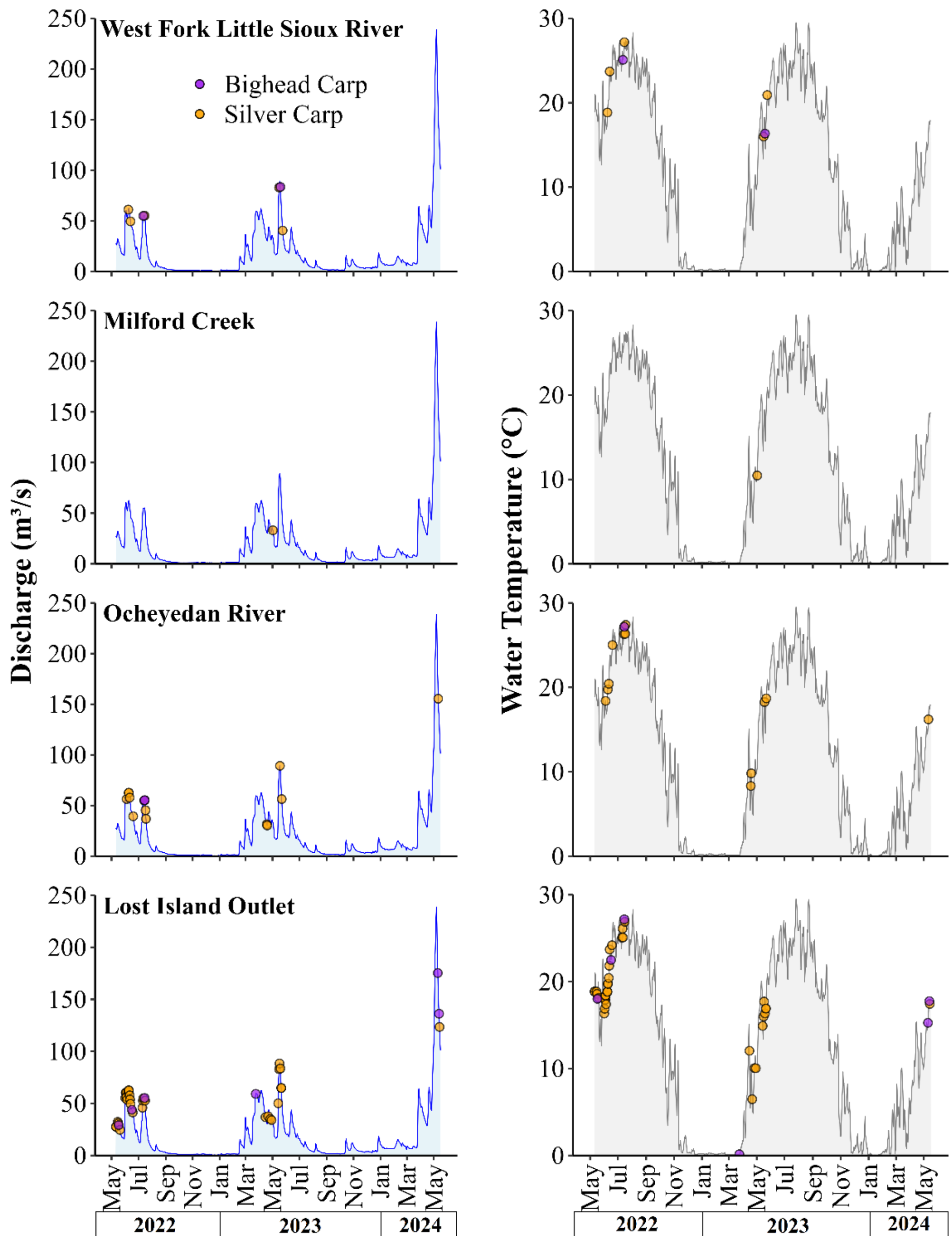


Figure 7. *Tributary enter events for Bighead Carp (purple circles) and Silver Carp (orange circles) in the West Fork Little Sioux River (WFLS), Milford Creek (MFC), Ocheyedan River (OCH), and Lost Island Outlet (LIO) in relation to Little Sioux River discharge (m^3/s; blue line) and water temperature (°C, grey line) from spring 2022-2024.*

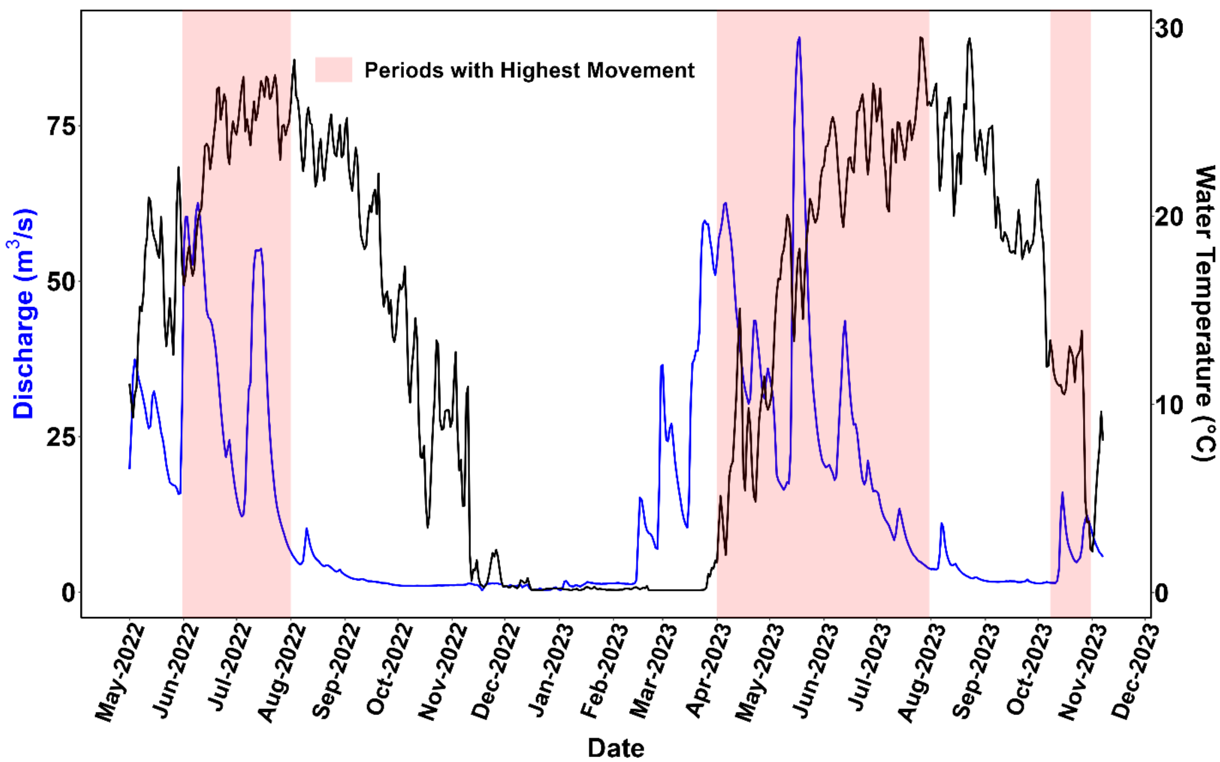


Figure 8. Hydrograph of Little Sioux River from May 2022 to November 2023 at USGS gauging station near Linn Grove, IA (Station ID: 06605850, rkm 220) from the first day invasive carp were tagged in 2022 to the first day receivers were downloaded in November 2023. Invasive carp movements were most apparent from June – July in 2022 and from April – June in 2023 when discharge (m^3/s; blue line) was > 25 m^3/s and water temperatures (ºC; black line) were 10-25 ºC. Silver Carp were also observed moving downstream during October 2023 during an increase in discharge and cooling water temperatures.

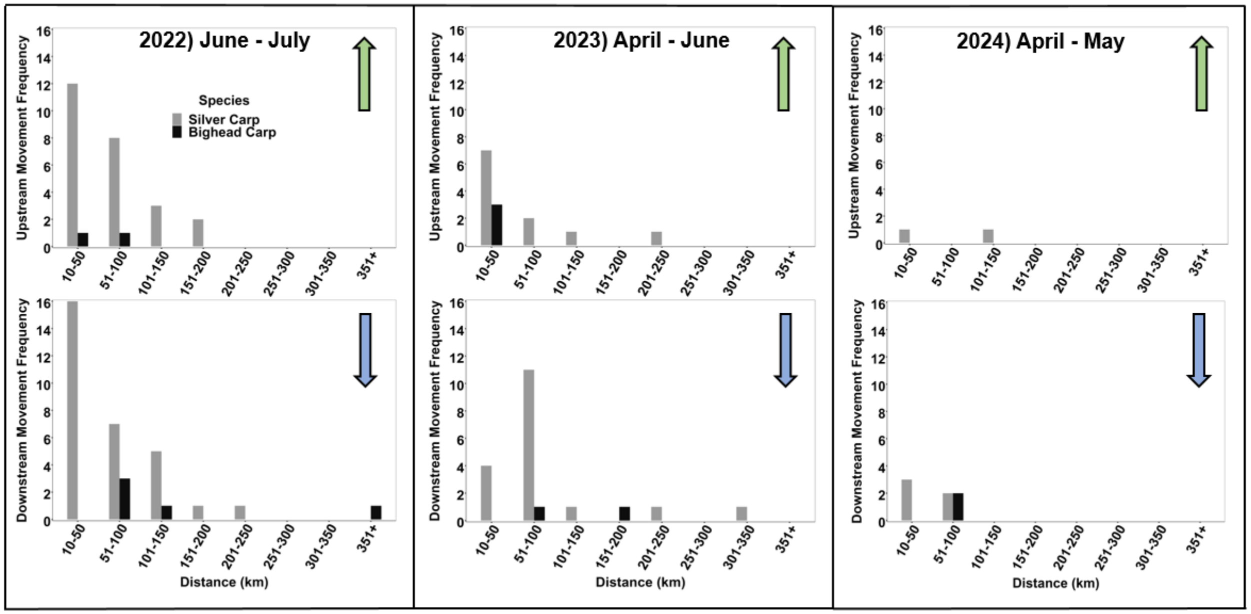


Figure 9. Directional movement event frequencies of Silver Carp (grey bars) and Bighead Carp (black bars) during most active periods in 2022 (left panel) and 2023 (right panel). Note the number of individuals tagged per species and year was not evenly distributed and frequency of movement events were cumulative across all individuals.

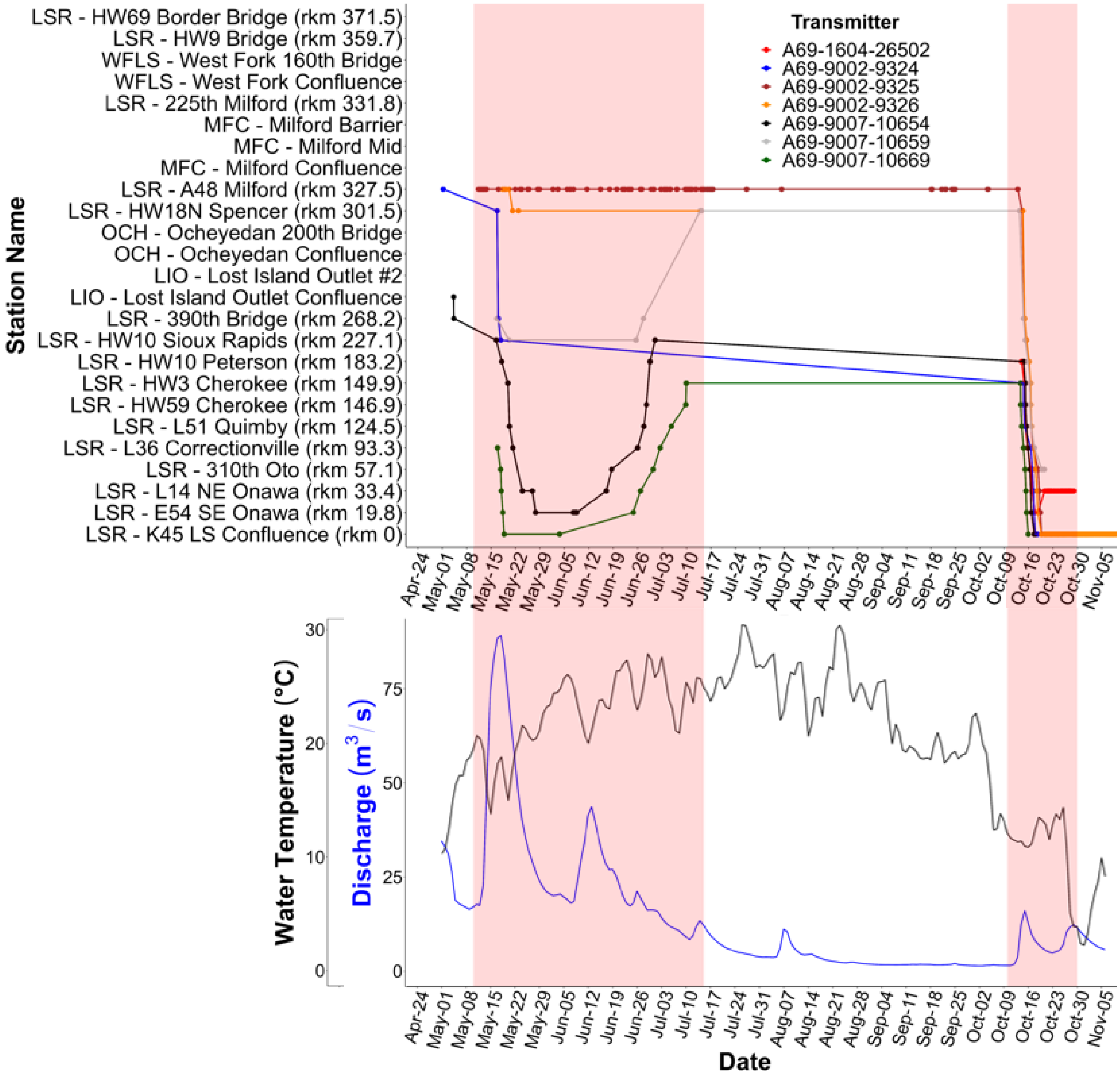


Figure 10. *Abacus plot (top panel) showing seven Silver Carp that exhibited Spring, Summer, and Fall movements during 2023 in relation to Little Sioux River discharge and temperature (bottom panel). Spring and Summer movements were primarily observed when discharge (m^3/s; blue line) was > 25 m^3/s and when water temperatures (ºC; black line) ranged from 10-25°C. Fall movements occurred when discharge rates were ~15 m^3/s and water temperatures were ~10°C.*

Figure 11. *Outdoor video surveillance camera (Sunba network PTZ) installed directly above the barrier on June 14th 2022. The camera is positioned to allow for the best possible view of fish movements on the north side of the barrier. Shown, is the viewing area (8 x 15 m) used during this study.*

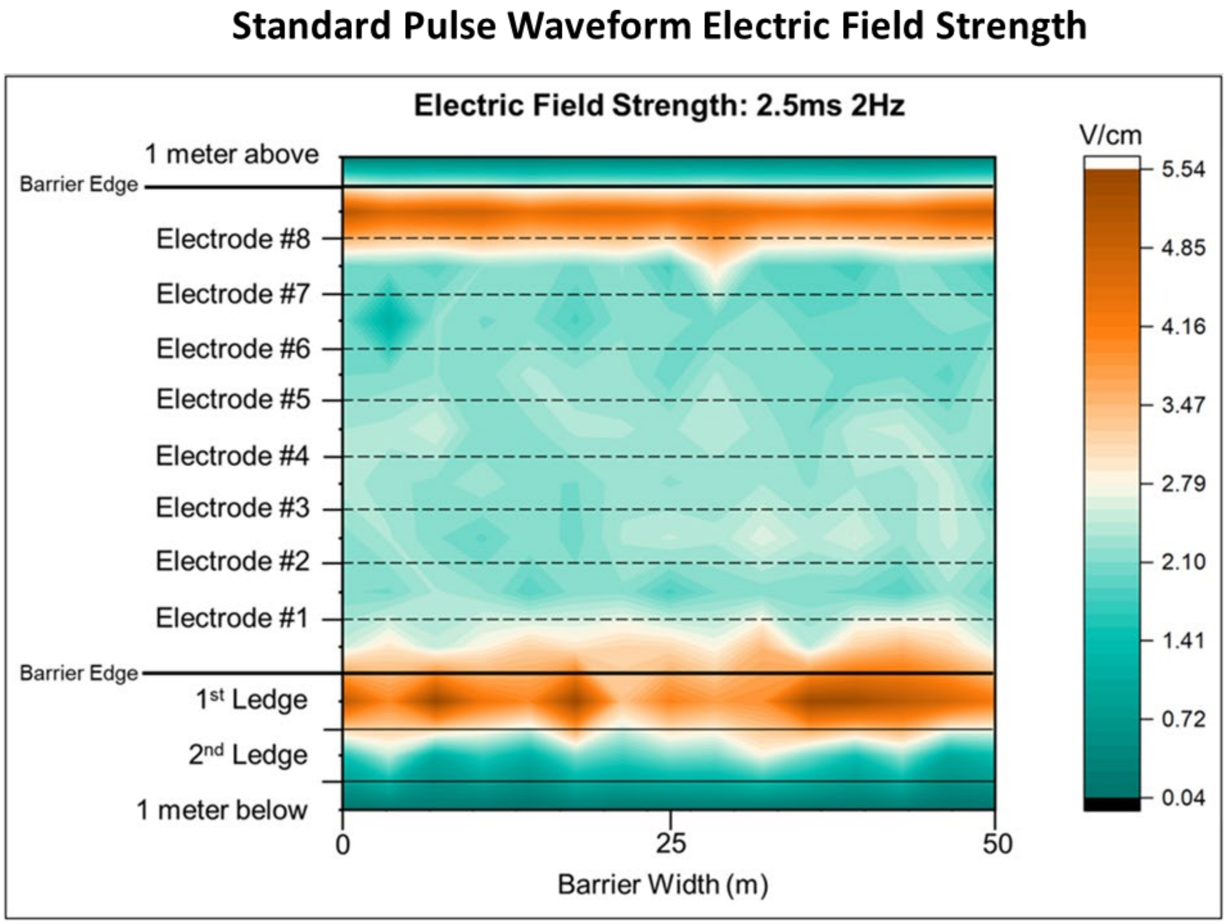


Figure 12. *Field gradient of voltage between electrodes and stray voltage above and below the barrier during the 2.5ms, 2Hz standard pulse waveform.*

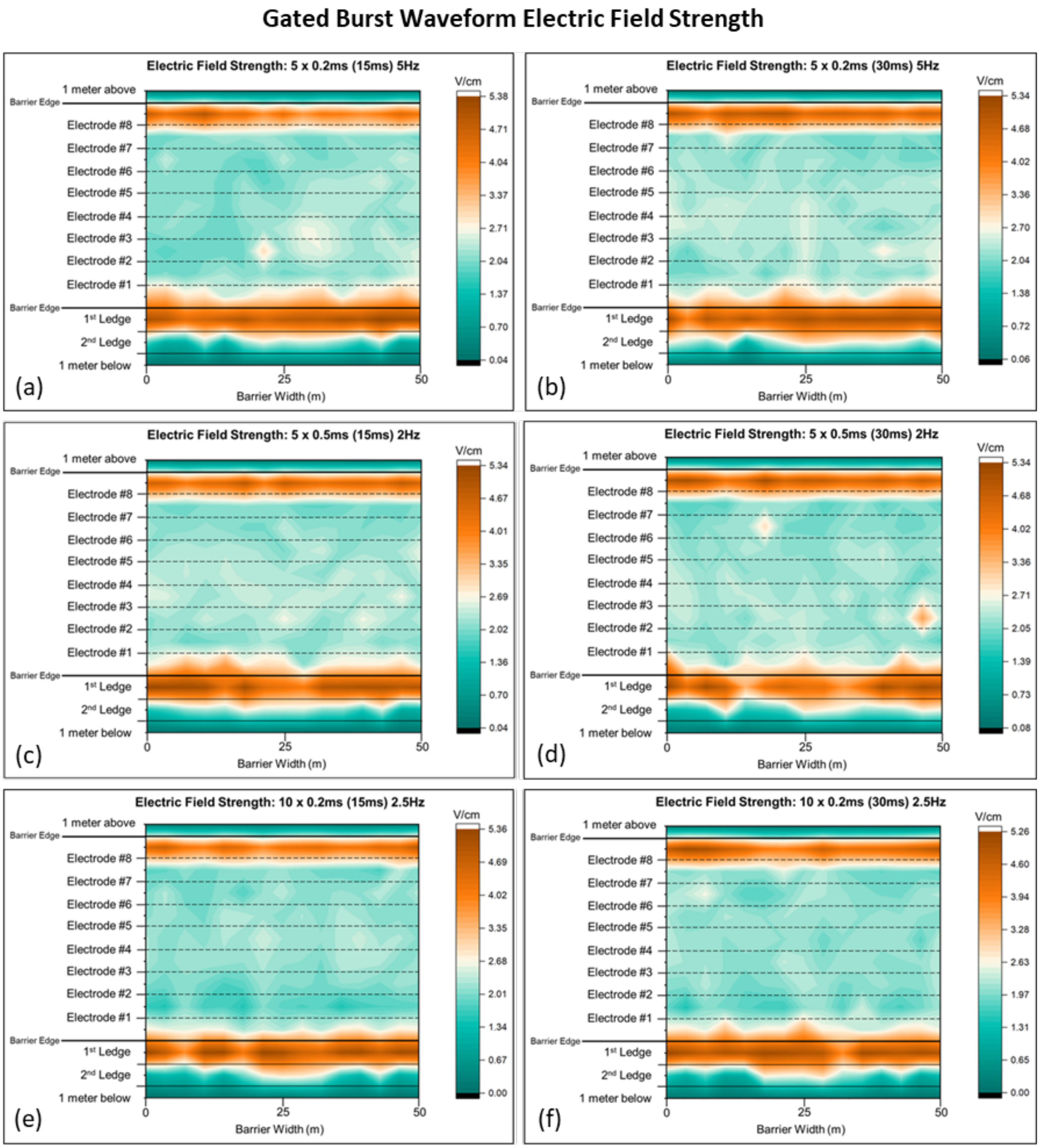


Figure 13. *Field gradient of voltage between electrodes and stray voltage above and below the barrier during gated burst waveforms (a) 5 x 0.2ms (15ms) 5Hz, (b) 5 x 0.2ms (30ms) 5Hz , (c) 5 x 0.5ms (15ms) 2Hz, (d) 5 x 0.5ms (30ms) 2Hz, (e) 10 x 0.2ms (15ms) 2.5Hz, (f) 10 x 0.2ms (30ms) 2.5Hz*

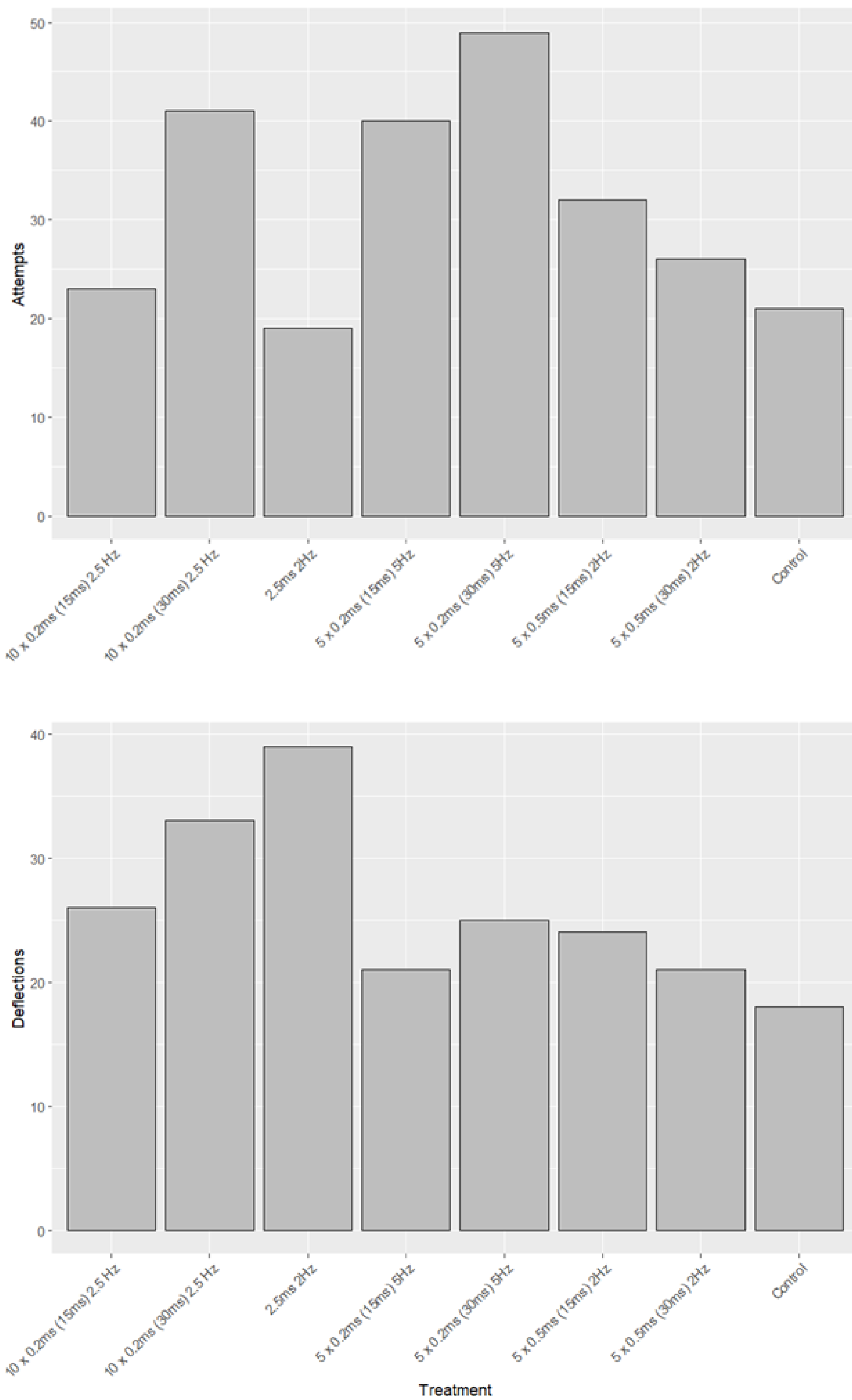


Figure 14. *Total attempts (top panel) and deflections (bottom panel) observed during each treatment throughout all experimental trials from May 12th to July 15th 2023.*

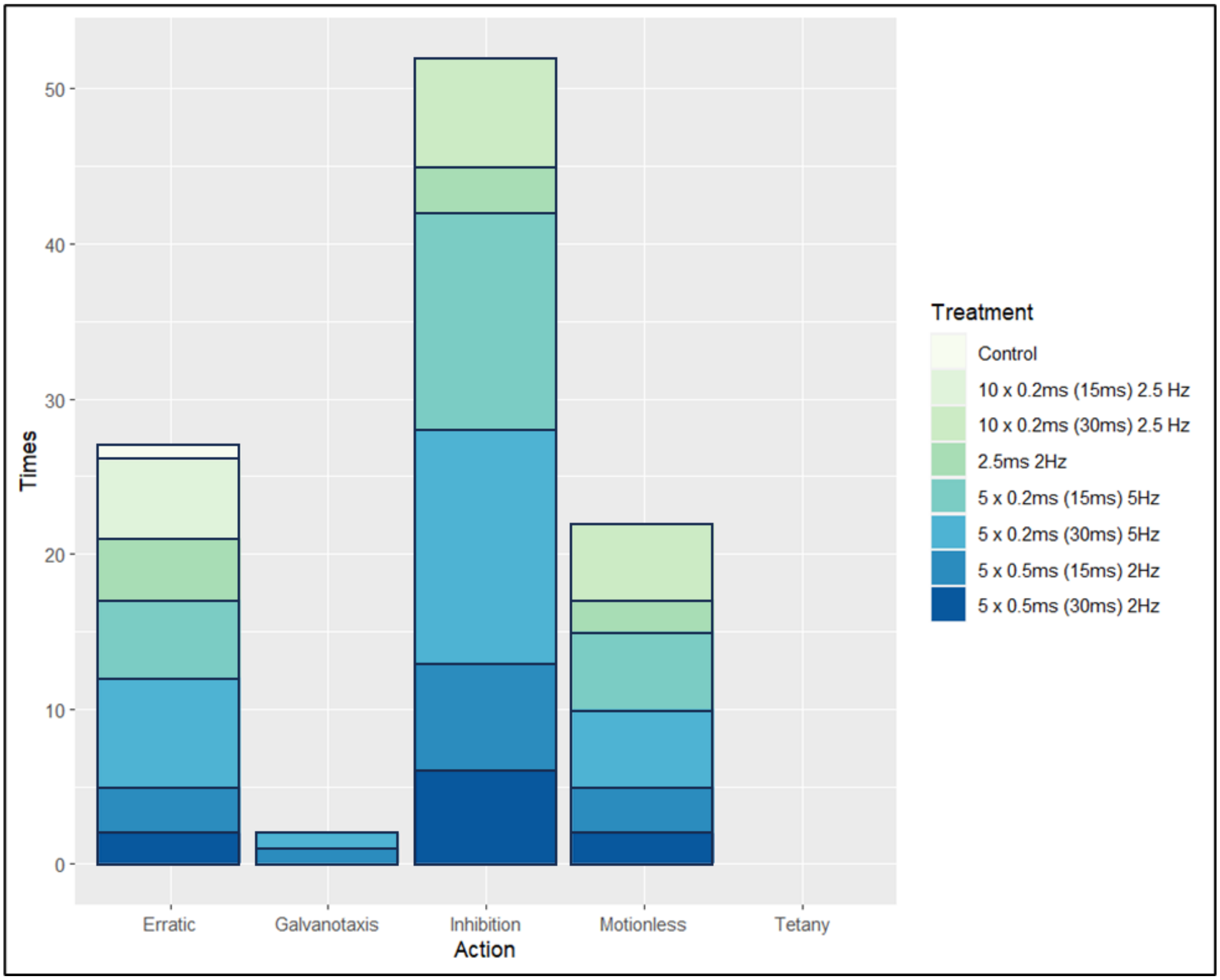


Figure 15. *Invasive carp behaviors observed during each treatment throughout all experimental trials from May 12th to July 15th 2023. Erratic (deviation from normal swimming behavior including rapid bursts of movement), galvanotaxis (actively swimming toward anode due to electrical field), inhibition (swimming inhibited due to involuntary contraction and relaxation of the muscles), motionless (temporarily stunned or involuntary relaxation of muscle due to shock from barrier), tetany (severe involuntary muscle contraction, open mouth, lack of operculum movement; death).*

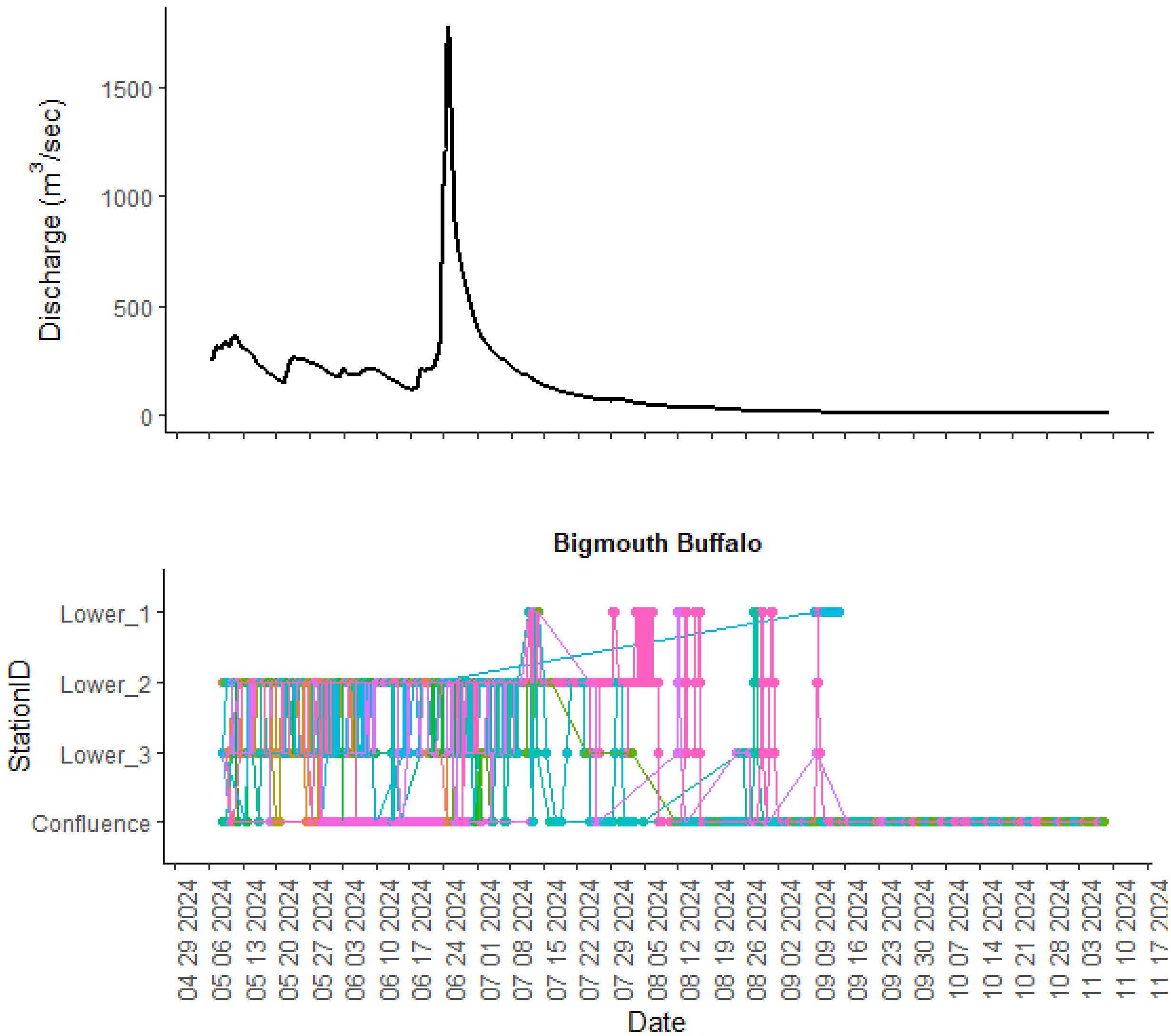


Figure 16. *Weekly Bigmouth Buffalo movements (bottom panel) relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

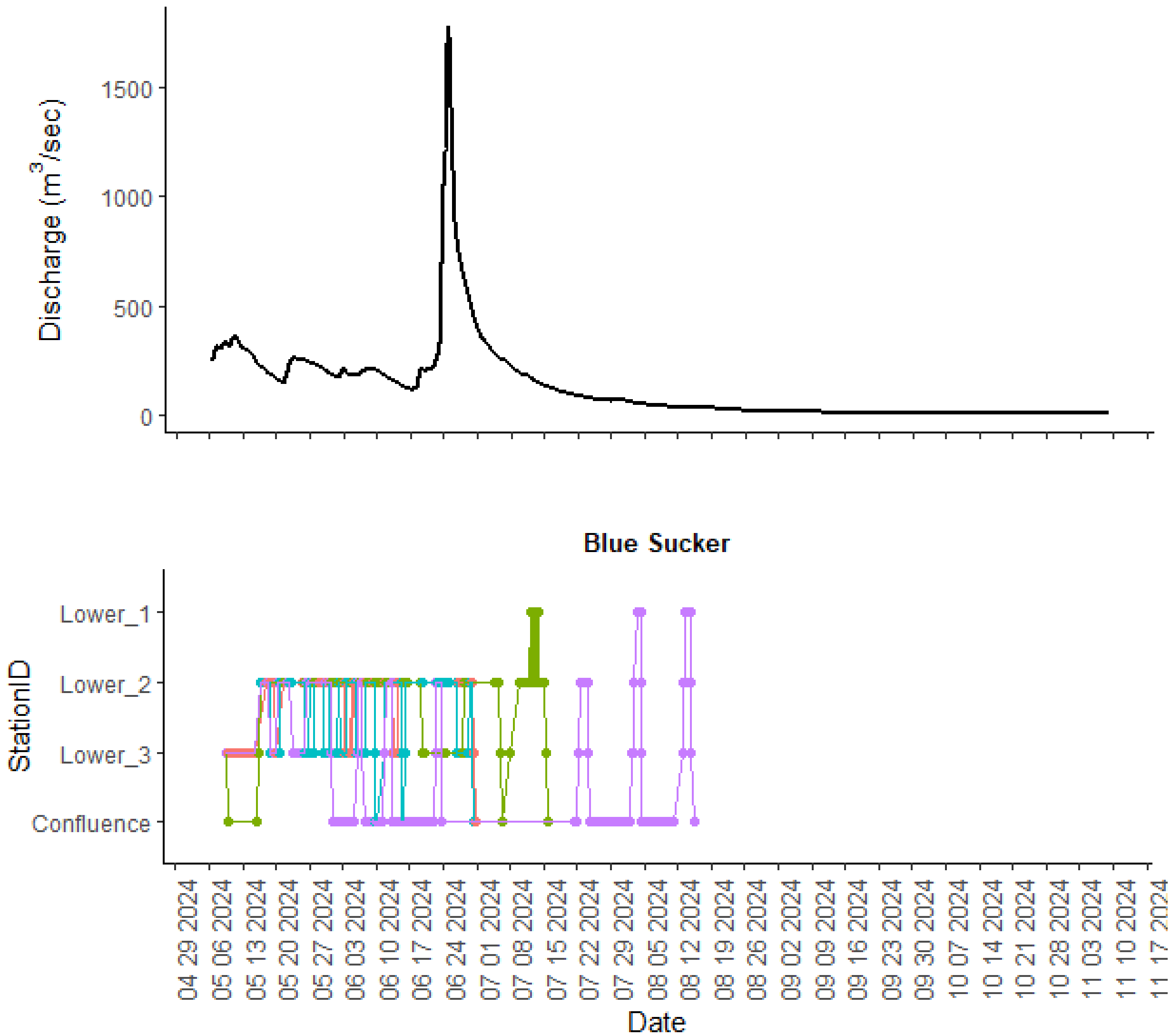


Figure 17. *Weekly Blue Sucker movements (bottom panel) relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

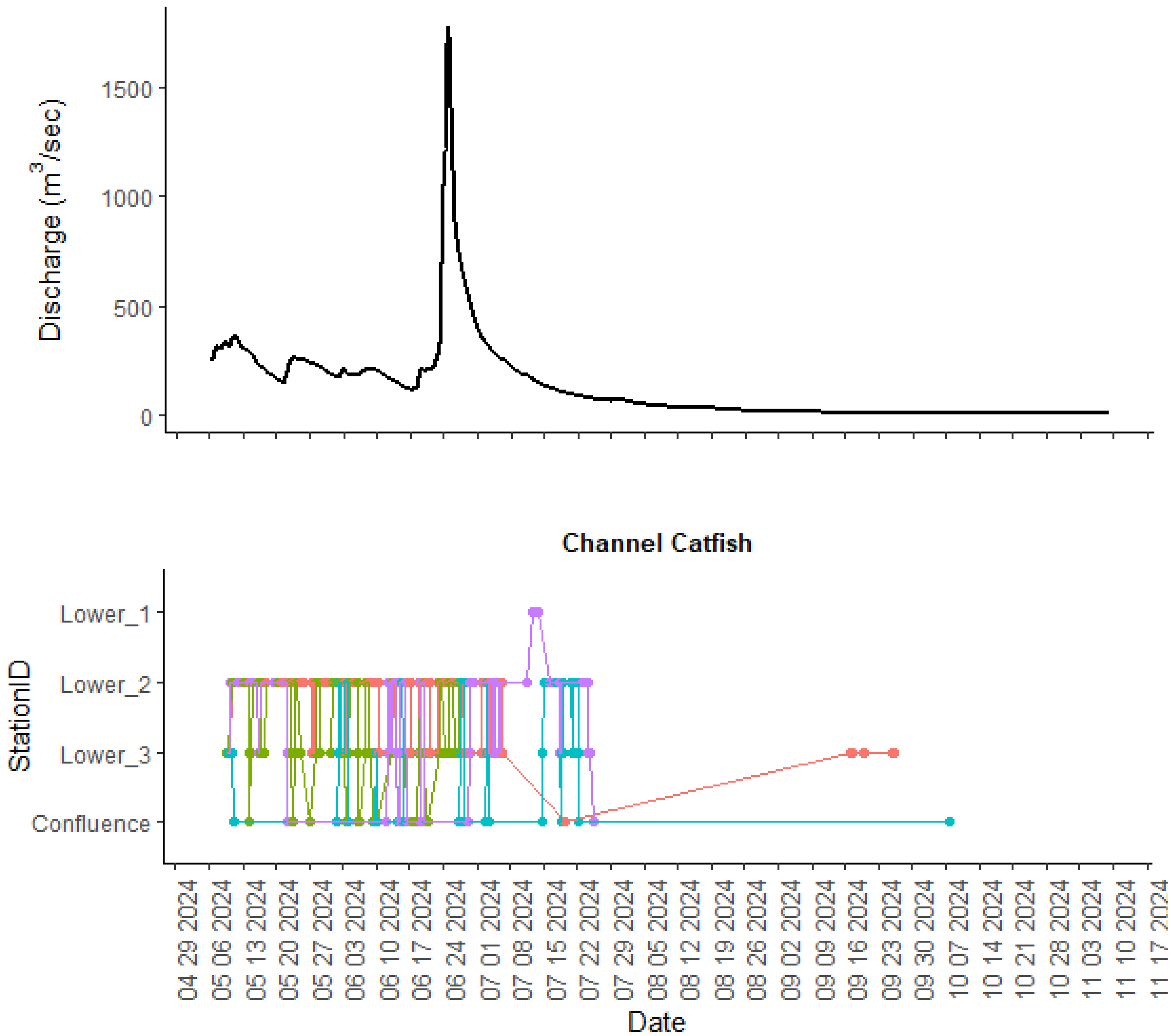


Figure 18. *Weekly Channel Catfish movements (bottom panel) relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

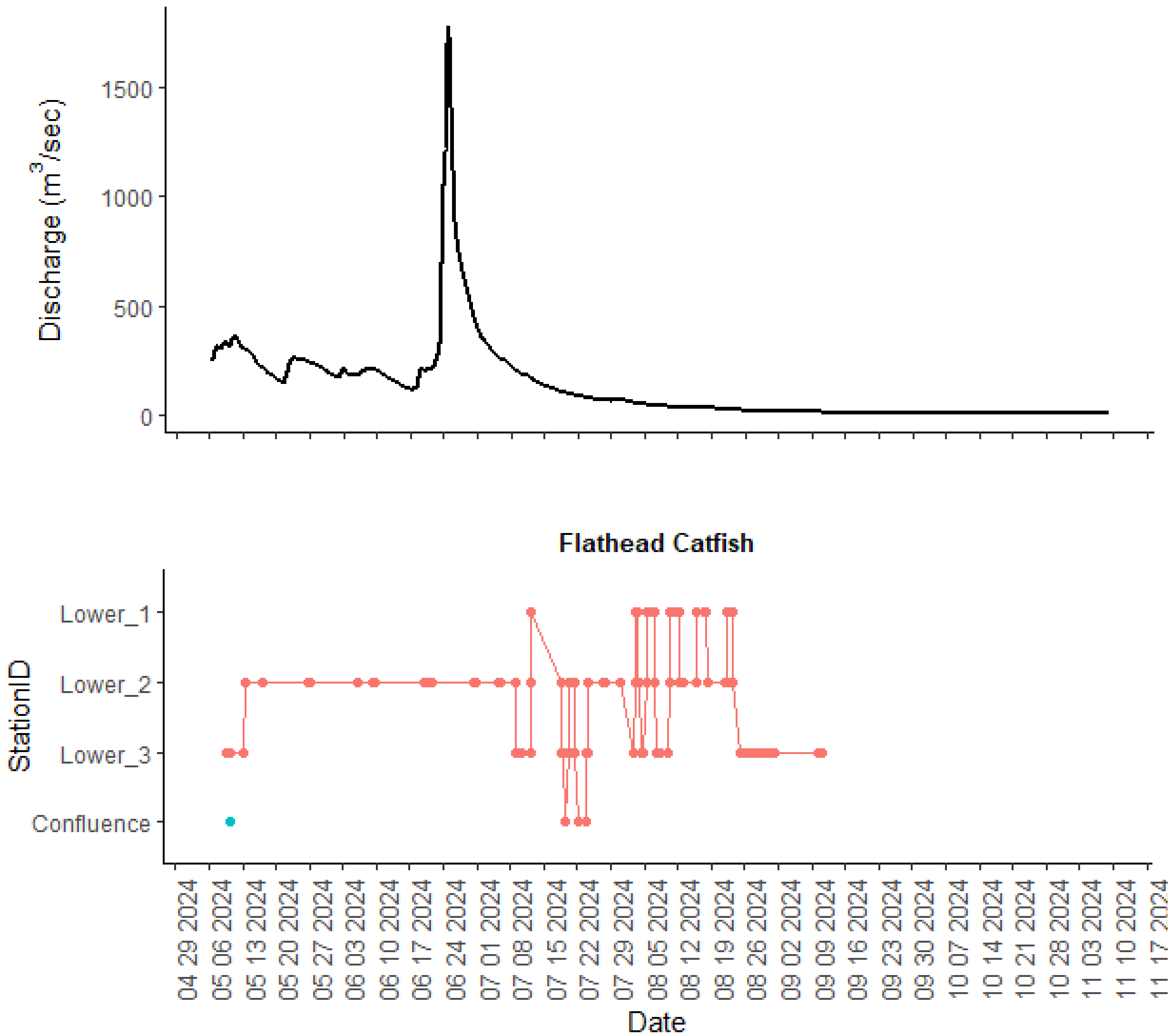


Figure 19. *Weekly Flathead Catfish movements (bottom panel) relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

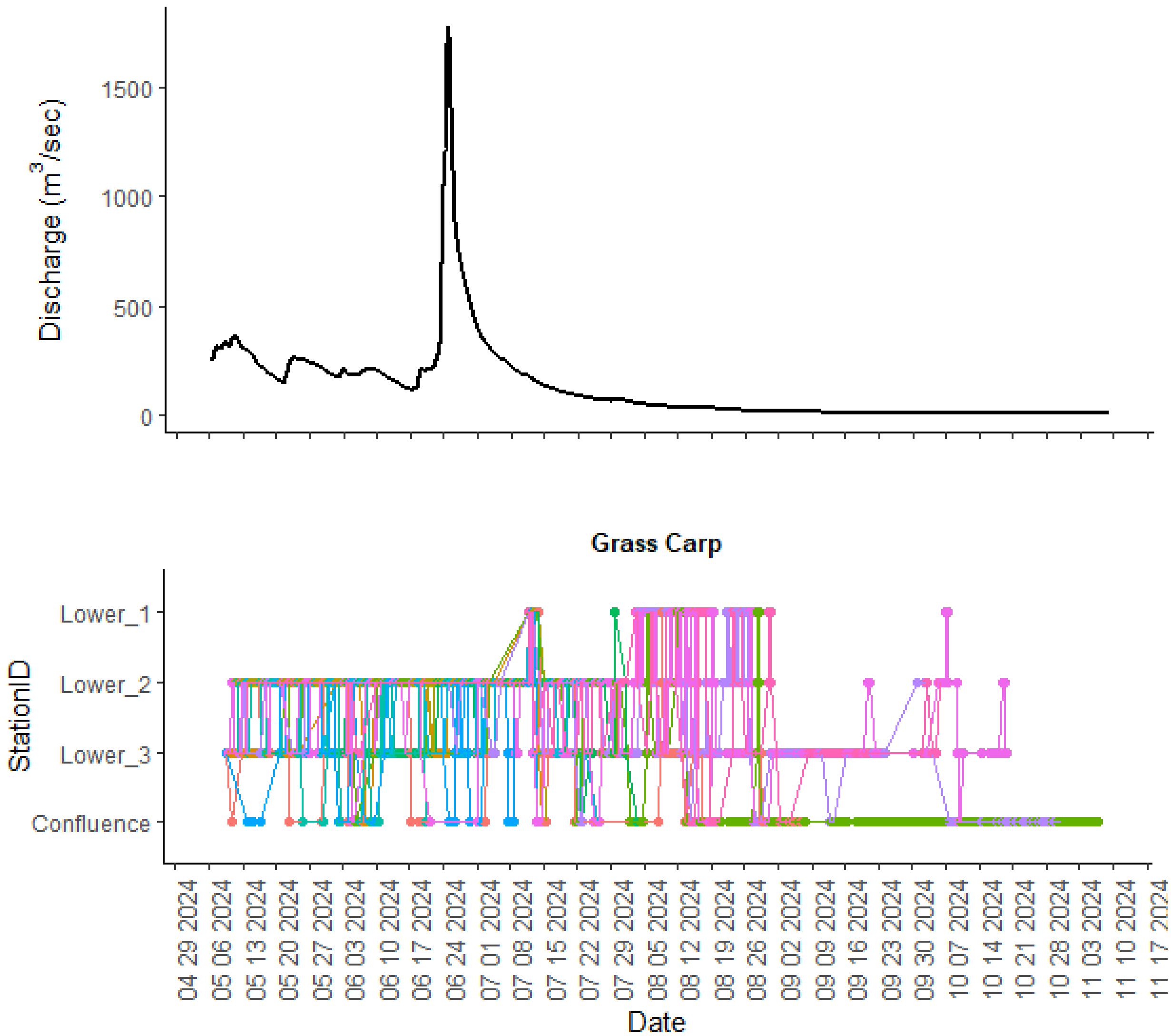


Figure 20. *Weekly Grass Carp movements (bottom panel) relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

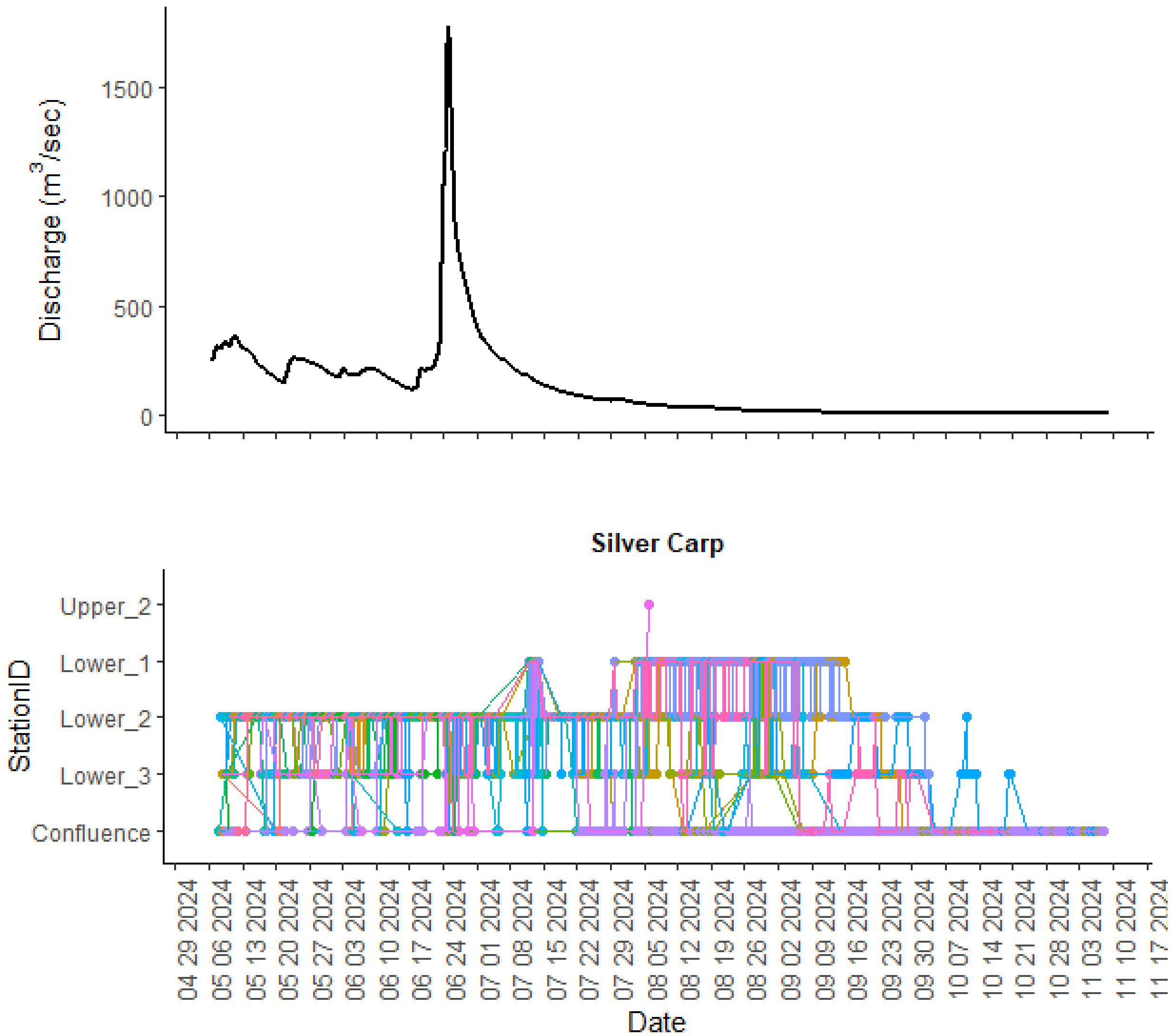


Figure 21. *Weekly Silver Carp movements (bottom panel) relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Upper_2" is upstream of Sill 4, "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

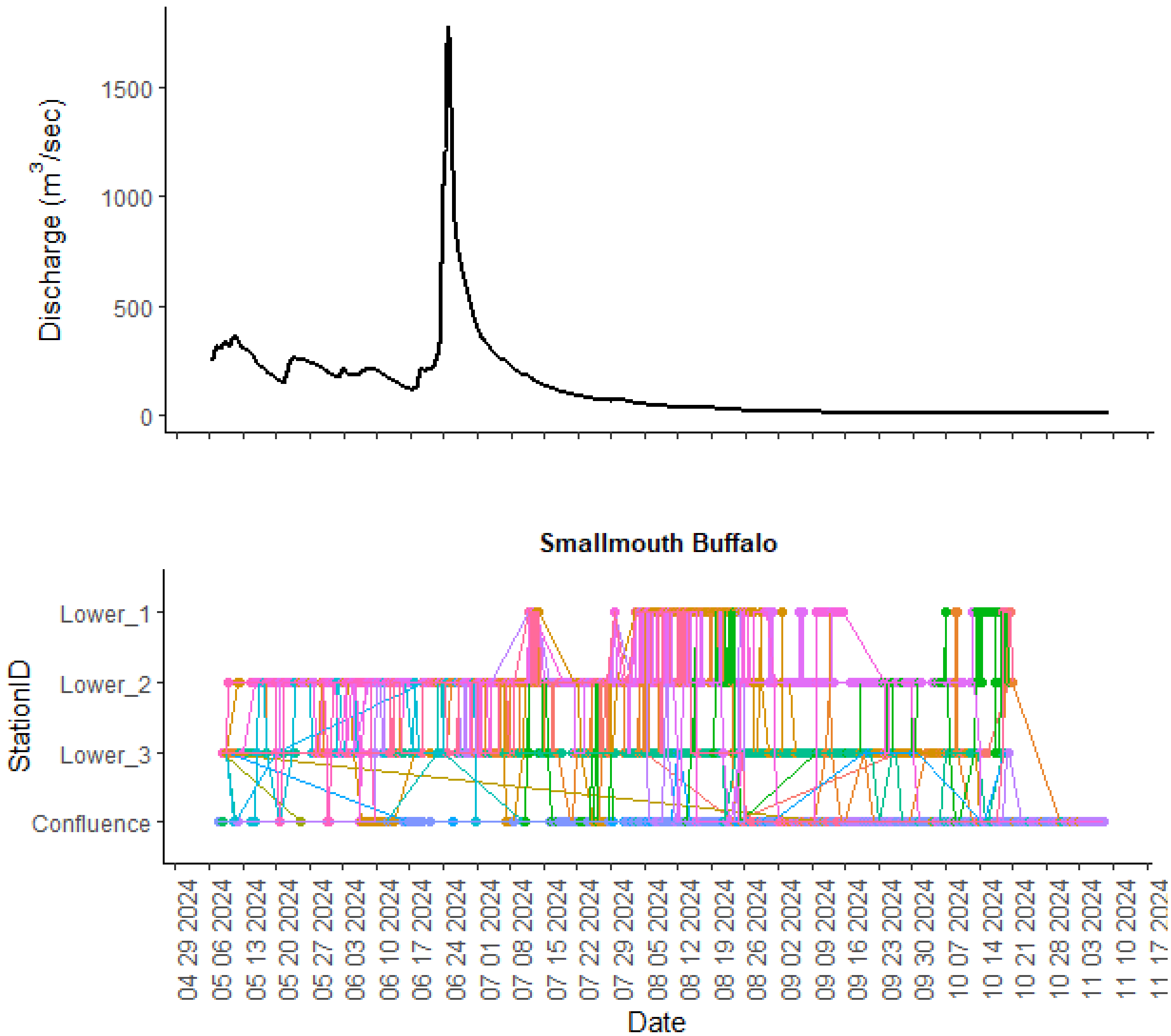


Figure 22. *Weekly Smallmouth Buffalo movements (bottom panel) relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

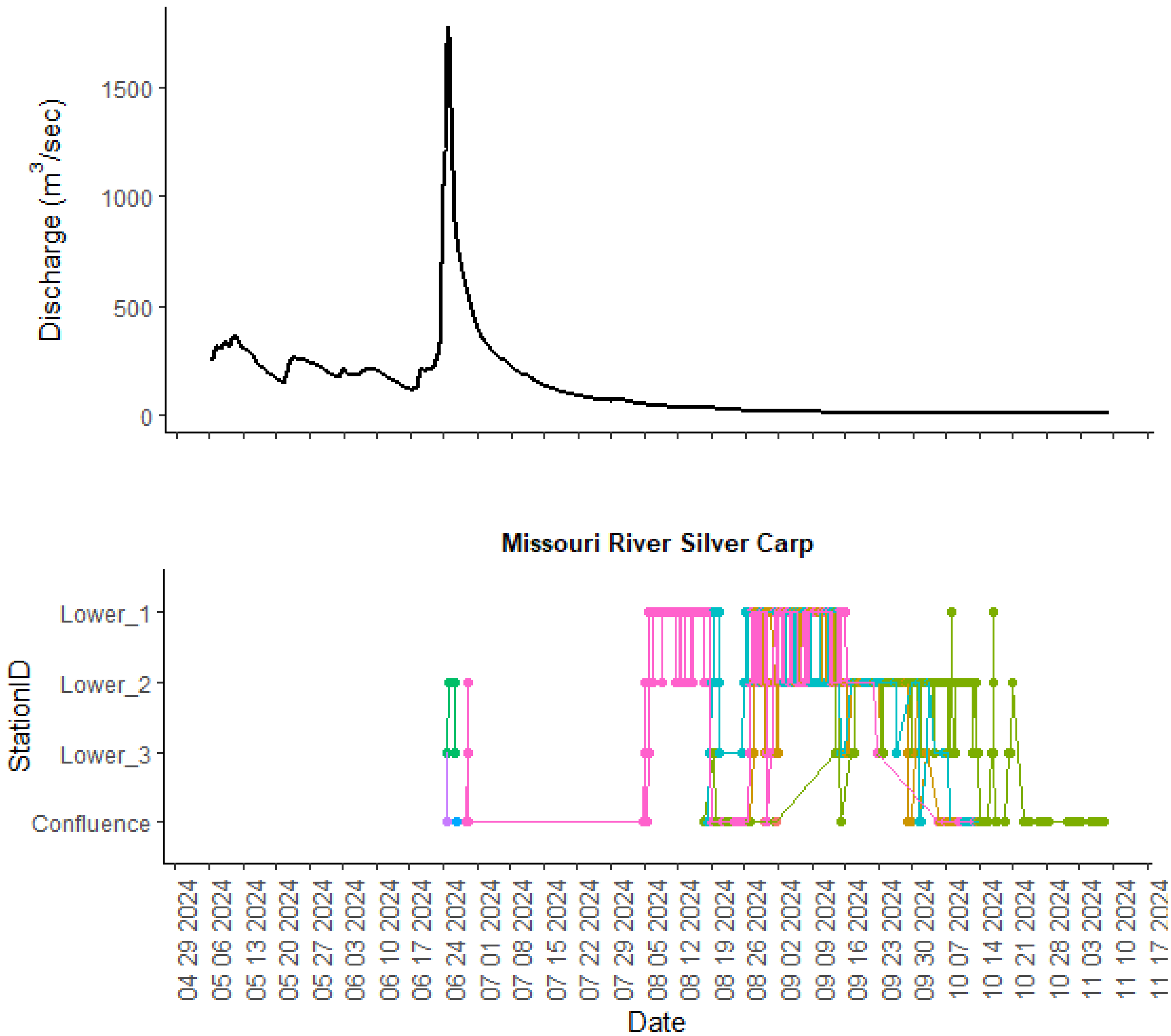


Figure 23. *Weekly movements of Silver Carp, tagged in the Missouri River, relative to discharge (m^3/sec; top panel) from April 29th, 2024 to November 10th, 2024. Station ID represents receiver locations where the individual was detected, where "Lower_1" is the closest receiver downstream of Sill 4 and the "Confluence" receiver is the furthest away. Each color represents a unique transmitter ID. Note that the Lower_1 receiver was not deployed until July 11th, 2024.*

Agency: Missouri Department of Conservation

Methods:
All telemetry receivers were downloaded and maintained quarterly throughout the year; data was shared with the appropriate partners annually or upon request.

Results and Discussion:
Invasive carp movement has been tracked on a broad scale. Of the 320 invasive carp tagged, 229 were detected at least a single day during 2024. 219 of those invasive carp were not detected outside the Missouri River system, while ten invasive carp traveled approximately 36.4 – 448.4 river miles from their original tagging locations. One invasive carp tagged in the Moreau River and two tagged in Creve Coeur Creek traveled 36.4 – 144.3 river miles and were detected in the MMR at Maple Island (Figure 24). One invasive carp tagged in Creve Coeur Creek traveled 38.5 river miles and was detected in lower pool 26 of the UMR (Figure 1). Three invasive carp tagged in Creve Coeur Creek traveled 115.9 river miles and were detected in the MMR at Chester, IL (Figure 1). One invasive carp tagged in the Grand River traveled 448.4 river miles and was detected in the Ohio River at Cairo, IL (Figure 25). One invasive carp tagged in Creve Coeur Creek traveled 263.9 river miles and was detected in the LMR at Seven Island (Figure 26). One invasive carp tagged in Creve Coeur Creek traveled 314.6 river miles and was detected in the Ohio River system at Barkley Dam (Figure 27). Fifty-three of those invasive carp were not detected outside of their respective tributaries, meaning they were only detected within the tributary that they were originally tagged in. Eight invasive carp tagged in Creve Coeur Creek traveled approximately 1.9 – 219.3 river miles (total distance from tributary, not accounting for total distance actually traveled) within the Missouri River system (Table 1). Fourty-two invasive carp tagged in the Moreau River traveled approximately 0.0 – 457.4 river miles within the Missouri River system (Table 1). Fourty-two invasive carp tagged in the Lamine River traveled approximatley 2.2 – 606.6 river miles within the Missouri River system (Table 1). Fifty-nine invasive carp tagged in the Grand River traveled approximately 1.8 – 526.9 river miles within the Missouri River system (Table 1). Sixty-eight invasive carp tagged in the Kansas River traveled approximately 0.5 – 432.0 river miles within the Missouri River system (Table 1).

Tables and Figures:
Table 1. Origin (CCC = Creve Coeur Creek, MR = Moreau River, LR = Lamine River, GR = Grand River, KR = Kansas River), transmitter ID, detected locations, distance from origin (DFO), and maximum distance traveled (MDT) for each invasive carp tagged in the lower Missouri River system.

Origin	Transmitter ID	Detected Locations	DFO	MDT
CC	A69-1602-48937	MOR RM2	28.9	28.9
CC	A69-1602-48938	MOR RM2 - St Charles	28.9	54.0
CC	A69-1602-48939	MOR RM2	28.9	28.9
CC	A69-1602-48946	Chester	115.9	115.9

CC	A69-1602-48947	Chester	115.9	115.9
CC	A69-1602-48948	7 Island Closer	263.9	263.9
CC	A69-1602-48954	Ohio Brookport - Barkley Dam	314.6	314.6
CC	A69-1602-48957	MOR RM2 - St Charles	28.9	54.0
CC	A69-1602-48961	MOR RM250 - Osage - MOR RM2	219.3	468.7
CC	A69-1602-48962	MOR RM2 - St Charles	28.9	54.0
CC	A69-1602-48968	Maple Island - MOR RM5	36.4	46.9
CC	A69-1602-48975	Creve Coeur Lake - Maple Island	36.4	40.3
CC	A69-1602-48979	Maple Island - L26	38.5	38.5
CC	A69-1602-48980	Creve Coeur Lake	1.9	1.9
CC	A69-1602-48981	MOR RM128.5 - MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM499 - MOR RM425 - MOR RM452 - Chester	468.3	1106.3
CC	A69-1602-48985	Creve Coeur Lake	1.9	1.9
MR	A69-1602-49117	Moreau Mouth - Moreau Upper (x11.5)	1.3	28.6
MR	A69-1602-49119	(Moreau Mouth - Moreau Upper (x14.5)) - (Osage - MOR RM128.5 (x1.5))	10.3	50.5
MR	A69-1602-49120	Moreau Mouth - Moreau Upper (x15)	1.3	37.7
MR	A69-1602-49121	Moreau Mouth - Moreau Upper (x5.5)	1.3	13.0
MR	A69-1602-49122	Moreau Mouth - Moreau Upper (x3.5)	1.3	7.8
MR	A69-1602-49123	(Moreau Mouth - Moreau Upper (x7.5)) - MOR RM131	7.8	26.0
MR	A69-1602-49126	Osage - Mari-Osa (x5.5)	18.4	99.8
MR	A69-1602-49127	Moreau Mouth - (Osage - Mari-Osa (x4.5))	18.4	81.8
MR	A69-1602-49128	Moreau Mouth - Moreau Upper (x9.5)	1.3	23.4
MR	A69-1602-49129	(Moreau Mouth - Moreau Upper (x2)) - Osage - (Moreau Upper - Moreau Mouth (x9))	9.3	47.2

MR	A69-1602-49130	(Moreau Mouth - Moreau Upper (x1.5)) - Osage - MOR RM250 - MOR RM398 - MOR RM452 - MOR RM499 - MOR RM529 - Platte - MOR RM499 - MOR RM249 - (Moreau Mouth - Moreau Upper (x1.5)) - (Osage - Mari-Osa (x3.5)) - MOR RM128.5 - Osage	457.4	1008.3
MR	A69-1602-49131	Moreau Mouth - Moreau Upper (x3.5)	1.3	7.8
MR	A69-1602-49132	Osage	9.3	9.3
MR	A69-1602-49133	Osage	9.3	9.3
MR	A69-1602-49134	Moreau Mouth - Moreau Upper (x6.5)	1.3	15.6
MR	A69-1602-49135	Osage - Boonville - Grand Mouth - MOR RM250 - MOR RM249 - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - Grand Mouth - (Osage - Mari-Osa (x1.5))	114.3	275.7
MR	A69-1602-49136	Moreau Mouth - Moreau Upper (x8.5)	1.3	20.8
MR	A69-1602-49137	(Grand Mouth - MOR RM249 (x1.5)) - Grand Upper - Grand Mouth - MOR RM250 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM477 - Nishnabotna - Grand Mouth - MOR RM250 - Grand Upper - Grand Mouth	404.7	707.9
MR	A69-1602-49139	Moreau Mouth - Moreau Upper (x3.5)	1.3	7.8
MR	A69-1602-49140	Moreau Mouth - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - MOR RM398 - MOR RM452 - MOR RM425 - Grand Mouth - MOR RM250 - Grand Upper - Grand Mouth - Boonville - Moreau Mouth	314.2	636.5
MR	A69-1602-49141	(Moreau Mouth - Moreau Upper (x1.5)) - Osage - Maple Island	144.3	148.3
MR	A69-1602-49143	Moreau Mouth - MOR RM129.5 - Osage - (Moreau Mouth - Moreau Upper (x9.5)) - Osage	9.3	52.7
MR	A69-1602-49144	Moreau Mouth - Moreau Upper (x6.5)	1.3	15.6
MR	A69-1602-49145	Moreau Mouth - Moreau Upper (x7.5)	1.3	18.2
MR	A69-1602-49146	Moreau Mouth - Moreau Upper (x7.5)	1.3	18.2
MR	A69-1602-49147	Moreau Mouth - Moreau Upper (x5.5)	1.3	13.0

MR	A69-1602-49150	Osage - (MOR RM129.5 - MOR RM128.5 (x1.5)) - Osage - MOR RM131 - MOR RM128.5	10.3	18.1
MR	A69-1602-49152	Osage - MOR RM128.5 - MOR RM131 - (Osage - Mari-Osa (x1.5))	18.4	33.8
MR	A69-1602-49153	Mari-Osa - Osage - Gasconade	35.2	53.9
MR	A69-1602-49156	Moreau Mouth - Moreau Upper (x8.5)	1.3	20.8
MR	A69-1602-49158	Osage - MOR RM129.5 (x1.5)	9.3	12.1
MR	A69-1602-49159	(Osage - MOR RM129.5 (x1.5)) - Moreau Mouth - (Osage - Mari-Osa (1.5)) - Moreau Mouth - (Osage - Mari-Osa (x4.5))	18.4	139.8
MR	A69-1602-49160	Moreau Mouth	0.0	0.0
MR	A69-1602-49161	(Osage - Mari-Osa (x1.5)) - Jefferson City	18.4	41.9
MR	A69-1602-49162	Moreau Mouth - Moreau Upper (x4.5)	1.3	10.4
MR	A69-1602-49163	Moreau Mouth - Moreau Upper	1.3	1.3
MR	A69-1602-49164	Moreau Mouth - (Osage - MOR RM131 (x1.5)) - Mari-Osa - Osage	18.4	30.4
MR	A69-1602-49165	(Osage - Mari-Osa (x3.5)) - Moreau Mouth	18.4	72.9
MR	A69-1602-49167	Moreau Mouth - Moreau Upper (x14.5)	1.3	36.4
MR	A69-1602-49168	(Osage - MOR RM129.5 (x1.5)) - (Mari-Osa - Osage (x3))	18.4	66.4
MR	A69-1602-49169	Moreau Mouth - Boonville - Lamine Mouth - (MOR RM250 - MOR RM249 (x2)) - (Grand Mouth - MOR RM249 (x1.5)) - (Lamine Upper - Lamine Mouth (x1.5)) - Moreau Mouth	112.3	244.0
MR	A69-1602-49171	Moreau Mouth - Moreau Upper (x6.5)	1.3	15.6
MR	A69-1602-49173	Moreau Mouth - Moreau Upper (x2.5)	1.3	5.2
LR	A69-1602-49055	(Lamine Upper - Lamine Mouth (x1.5)) - Lamine above DeBourgmont	4.2	10.8
LR	A69-1602-49056	(Lamine Upper - Lamine Mouth (x4.5)) - Lamine above DeBourgmont - Lamine Mouth	4.2	35.9
LR	A69-1602-49057	(Lamine Upper - Lamine Mouth (x2.5)) - MOR RM250 - Lamine Upper - (Grand Mouth - Grand Upper (x2.5)) - (MOR RM250 - Grand Mouth (x1.5)) - Lamine Upper - (Grand Mouth - Grand Upper (x2))	50.7	385.6

		- (MOR RM250 - Grand Mouth (x1.5)) - Lamine Mouth - Grand Upper - (Grand Mouth - MOR RM250 (x2))		
LR	A69-1602-49059	(Lamine Upper - Lamine Mouth (x4.5)) - Lamine above DeBourgmont - Lamine below Blackwater - Lamine above DeBourgmont	7.3	36.8
LR	A69-1602-49060	(Lamine Upper - Lamine Mouth (x2.5)) - Lamine above DeBourgmont	4.2	17.4
LR	A69-1602-49061	Lamine Mouth - MOR RM398 - (Lamine Upper - Lamine Mouth (x2.5))	196.6	408.6
LR	A69-1602-49062	Lamine Mouth - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - Lamine Mouth	50.7	100.3
LR	A69-1602-49063	(Lamine Upper - Lamine Mouth (x4)) - Boonville - Lamine Mouth	6.9	36.9
LR	A69-1602-49064	MOR RM641.5 - Platte - Nishnabotna - MOR RM452 - MOR RM368 - (Lamine Upper - Lamine Mouth (x1.5)) - Lamine above DeBourgmont	440.1	892.4
LR	A69-1602-49065	Kansas RM1 - MOR RM367 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM367 - Kansas RM1 - Below WaterOne - Lamine Upper - Lamine Mouth - MOR RM250 - MOR RM367 - Kansas RM1	250.6	696.7
LR	A69-1602-49066	MOR RM368 - (Lamine Upper - Boonville (x2)) - (Lamine Mouth - Lamine Upper (x1.5))	166.6	375.1
LR	A69-1602-49067	(Lamine Mouth - Lamine Upper (x2)) - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - MOR RM529 - Nishnabotna - MOR RM595 - MOR RM641.5	440.1	454.3
LR	A69-1602-49068	Lamine Upper - Lamine Mouth (x3)	2.2	18.7
LR	A69-1602-49069	Lamine Mouth - Lamine Upper - Boonville - Lamine Mouth	6.9	19.3
LR	A69-1602-49070	Lamine Upper - Lamine Mouth (x1.5)	2.2	8.8
LR	A69-1602-49071	MOR RM808 - (MOR RM787 - MOR RM776 (x1.5)) - MOR RM797 - James - MOR RM787 - MOR RM776 - Platte - (MOR RM595 - MOR RM594 (x1.5)) - MOR RM641.5 - MOR RM670 - MOR RM691 - MOR RM710	606.6	981.0
LR	A69-1602-49072	Lamine Upper - Boonville - (Lamine Mouth - Lamine Upper (x3)) - Lamine above DeBourgmont - Lamine Upper - Lamine Mouth - Lamine above DeBourgmont	6.9	46.2
LR	A69-1602-49074	(Lamine Mouth - Lamine Upper (x1.5)) - (Grand Mouth - Grand Upper (x1.5)) - Lamine Mouth -	50.7	206.1

		(Grand Mouth - Grand Upper (x1.5)) - Lamine Mouth		
LR	A69-1602-49075	Lamine Upper - Lamine Mouth (x4)	2.2	25.3
LR	A69-1602-49076	Lamine Upper - Lamine Mouth (x2)	2.2	12.1
LR	A69-1602-49077	MOR RM367 - Kansas RM1 - MOR RM368 - (MOR RM367 - Kansas RM1 (x1.5)) - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - MOR RM595 - Kansas RM1 - Below WaterOne - Lamine Upper - Lamine Mouth - MOR RM250 - MOR RM367 - Kansas RM1	393.6	985.7
LR	A69-1602-49081	(Kansas RM1 - Below WaterOne (x1.5)) - MOR RM367 - Kansas RM1 - Grand Mouth - Lamine Upper - Boonville	176.1	366.7
LR	A69-1602-49083	(Lamine Upper - Lamine Mouth (x5.5)) - (Lamine above DeBourgmont - Lamine below Blackwater (x2))	7.3	46.5
LR	A69-1602-49085	(Lamine Mouth - Lamine Upper (x1.5)) - MOR RM250 - MOR RM368 - MOR RM398 - MOR RM452 - Lamine Upper - Lamine Mouth	250.6	513.3
LR	A69-1602-49088	(Lamine Mouth - Lamine Upper (x2)) - MOR RM250	48.6	61.8
LR	A69-1602-49089	Boonville - Lamine Mouth - Lamine Upper	6.9	16.0
LR	A69-1602-49091	(Lamine Mouth - Lamine Upper (x2)) - (Grand Mouth - MOR RM250 (x1.5))	48.7	62.1
LR	A69-1602-49092	Nishnabotna	341.1	341.1
LR	A69-1602-49093	Lamine Mouth - MOR RM250 - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - (Lamine Upper - Lamine Mouth (x1.5)) - Lamine above Blackwater - Lamine below Blackwater - Lamine above DeBourgmont - Lamine Upper - Lamine Mouth	50.7	129.7
LR	A69-1602-49095	Lamine Mouth - (Grand Mouth - Grand Upper (x4.5)) - Lamine Mouth	50.7	112.3
LR	A69-1602-49096	(Lamine Upper - Lamine Mouth (x3.5)) - Lamine above DeBourgmont	4.2	24.0
LR	A69-1602-49097	Nishnabotna - Platte - Nishnabotna - (Lamine Upper - Lamine above DeBourgmont (x1.5)) - Lamine Mouth - (Lamine Upper - Lamine above DeBourgmont (x2.5)) - Lamine Mouth - Lamine Upper - (Lamine above DeBourgmont - Lamine below Blackwater (x3.5))	393.8	837.6

LR	A69-1602-49100	(Lamine Upper - Boonville (x1.5)) - Lamine Mouth - Lamine Upper	6.9	27.0
LR	A69-1602-49102	(Lamine Upper - Lamine Mouth (x2.5)) - Osage - MOR RM128.5	75.1	29.9
LR	A69-1602-49103	Lamine Mouth - Lamine Upper (x2.5)	2.2	14.3
LR	A69-1602-49104	MOR RM594 - MOR RM595 - (Lamine Mouth - Lamine Upper (x1.5))	393.6	792.7
LR	A69-1602-49105	Lamine Mouth - MOR RM398 - MOR RM425 - (Lamine Upper - Boonville - Lamine Mouth (x2))	223.6	482.5
LR	A69-1602-49106	(Lamine Upper - Lamine Mouth (x2.5)) - (Lamine above DeBourgmont - Lamine below Blackwater (x2.5)) - Lamine Upper - (Lamine above DeBourgmont - Lamine below Blackwater (x3))	7.3	49.3
LR	A69-1602-49108	Lamine Upper - Lamine Mouth (x1.5)	2.2	8.8
LR	A69-1602-49109	MOR RM250 - (MOR RM249 - Grand Mouth (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - MOR RM249 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - Grand Mouth - Grand Upper - MOR RM249 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - MOR RM368 - MOR RM398 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250 - (Lamine Upper - Lamine Mouth (x1.5)) - Lamine above DeBourgmont - Lamine Upper - Lamine Mouth - Lamine above DeBourgmont	196.6	448.2
LR	A69-1602-49112	(Lamine Upper - Lamine Mouth (x1.5)) - MOR RM249 - Lamine Upper - Lamine Mouth	47.6	111.7
LR	A69-1602-49113	(Lamine Upper - Lamine Mouth (x2.5)) - MOR RM250 - Lamine Upper - (Lamine Mouth - Boonville (x1.5))	48.6	131.9
GR	A69-1602-48989	(Grand Mouth - Grand Upper (x2.5)) - MOR RM249 - (Grand Upper - Grand Mouth (x2)) - (MOR RM250 - Grand Mouth (x3.5)) - (Grand Upper - Grand Mouth (x4)) - (MOR RM250 - MOR RM249 (x1.5)) - Grand Mouth - (MOR RM250 - Grand Upper (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - (Grand Mouth - Grand Upper (x5))	2.9	82.2
GR	A69-1602-48990	Grand Mouth - (Grand Upper - MOR RM249 (x1.5)) - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - Grand Mouth - MOR RM250 - MOR RM398 - MOR RM452 - MOR RM499 - (Grand Mouth -	250.9	545.2

		Grand Upper (x2.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x2.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - (Grand Upper - Grand Mouth (x2.5))		
GR	A69-1602-48993	Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x1.5))	1.9	26.8
GR	A69-1602-48994	(Grand Upper - Grand Mouth (x2)) - MOR RM249 - (Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Mouth (x1.5)) - (Grand Upper - Grand Mouth - MOR RM250 (x2)) - Grand Mouth - MOR RM250 - (Grand Upper - Grand Mouth (x2.5)) - MOR RM250 - Grand Upper - Grand Mouth - MOR RM250 - Grand Upper - Grand Mouth	2.9	41.8
GR	A69-1602-48995	Nishnabotna - Kansas RM1 - Grand Mouth - MOR RM250 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (MOR RM250 - Grand Mouth (x2)) - Grand Upper - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250	294.4	643.7
GR	A69-1602-48996	(Grand Mouth - Grand Upper (x1.5)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - MOR RM368 - (Kansas RM1 - Below WaterOne (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x1.5))	129.4	288.7
GR	A69-1602-48997	Grand Mouth - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x2.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - (Grand Upper - Grand Mouth (x4))	2.9	37.2
GR	A69-1602-48999	(Grand Upper - Grand Mouth (x3)) - MOR RM249 - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth -	2.9	42.0

		MOR RM250 (x2)) - Grand Upper - Grand Mouth - MOR RM250 - Grand Upper - Grand Mouth		
GR	A69-1602-49001	Grand Upper - (MOR RM250 - Grand Mouth (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (MOR RM250 - Grand Mouth (x2)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250 - MOR RM368 - MOR RM398 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x2))	149.9	334.0
GR	A69-1602-49003	(Grand Upper - Grand Mouth (x2)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - Grand Mouth - MOR RM250 - MOR RM398 - MOR RM452 - MOR RM499 - (Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Mouth - Grand Upper (x2)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x2)) - MOR RM250 - Grand Upper - Grand Mouth	250.9	548.0
GR	A69-1602-49005	(Grand Mouth - Grand Upper (x1.5)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x3.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2) - Grand Upper - Grand Mouth	2.9	58.6
GR	A69-1602-49007	Grand Upper - Grand Mouth - MOR RM250	1.9	2.3
GR	A69-1602-49008	(Kansas Mouth - Kansas RM1 (x3)) - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - Kansas RM1 - (Grand Mouth - Grand Upper (x2.5)) - (MOR RM250 - Grand Mouth (x3.5)) - (Grand Upper - Grand Mouth (x2)) - (MOR RM250 - Grand Upper (x2)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250 - (Grand Upper - Grand Mouth (x2))	250.9	550.4
GR	A69-1602-49009	Ohio Cairo	448.4	448.4
GR	A69-1602-49010	MOR RM249	2.9	2.9
GR	A69-1602-49011	(Grand Upper - Grand Mouth (x3)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5))	149.9	383.0

		- (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250 - MOR RM368 - Kansas RM1 - Below WaterOne - MOR RM398 - Below WaterOne - Grand Mouth - MOR RM250 - (Grand Upper - Grand Mouth (x1.5)) - (MOR RM250 - Grand Upper (x2)) - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - Grand Mouth		
GR	A69-1602-49012	(Grand Mouth - Grand Upper (x1.5)) - MOR RM249 - (Grand Upper - Grand Mouth (x2.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Upper (x1.5)) - (Grand Mouth - Grand Upper (x3.5))	2.9	40.6
GR	A69-1602-49013	(Grand Upper - Grand Mouth (x2)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Mouth (x2)) - Grand Upper - Grand Mouth	1.9	48.2
GR	A69-1602-49014	(Grand Mouth - Grand Upper (x3.5)) - MOR RM249 - (Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Mouth (x1.5)) - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 - Grand Upper (x2)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x2)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth	2.9	83.0
GR	A69-1602-49015	(Grand Upper - Grand Mouth (x3)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth	2.9	24.8
GR	A69-1602-49017	MOR RM595 - Platte (x2.5)	347.1	347.7
GR	A69-1602-49018	(Grand Upper - Grand Mouth (x2)) - MOR RM249 - Grand Upper - Grand Mouth - (MOR RM250 - Grand Upper (x2)) - (Grand Mouth - Grand Upper (x2))	2.9	26.8
GR	A69-1602-49020	(Grand Upper - Grand Mouth (x3)) - MOR RM249 - (Grand Upper - Grand Mouth (x2)) - (MOR RM250 -	2.9	66.4

		Grand Mouth (x1.5)) - (Grand Upper - Grand Mouth (x3)) - MOR RM250 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x2)) - Grand Mouth - MOR RM250 - Grand Upper - Grand Mouth		
GR	A69-1602-49021	(Grand Mouth - Grand Upper (x1.5)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250	2.9	20.5
GR	A69-1602-49022	(Grand Mouth - Grand Upper (x1.5)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - Grand Mouth - MOR RM250 (x2)) - (Grand Mouth - MOR RM250 (x3.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - Grand Mouth (x1.5))	2.9	77.6
GR	A69-1602-49023	Grand Upper - (Grand Mouth - MOR RM249 (x2)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - MOR RM250 - MOR RM367 - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM477 - MOR RM499 - MOR RM452 - Kansas RM1 - Below WaterOne - Kansas RM1 - Grand Mouth - MOR RM250 - (Grand Upper - Grand Mouth (x1.5)) - MOR RM250	250.9	547.7
GR	A69-1602-49024	Grand Mouth - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - Grand Mouth (x3)) - (MOR RM250 - Grand Mouth (x4.5)) - (Grand Upper - Grand Mouth (x5)) - MOR RM 250 - (Grand Mouth - Grand Upper (x2.5)) - (MOR RM250 - Grand Mouth (x1.5)) - (Grand Upper - Grand Mouth (x4))	2.9	66.0
GR	A69-1602-49025	Grand Upper - Grand Mouth	1.8	2.2
GR	A69-1602-49027	(Grand Mouth - Grand Upper (x1.5)) - (MOR RM249 - Grand Mouth (x2)) - Grand Upper - (Grand Mouth -	55.2	130.2

		MOR RM250 (x3.5)) - Grand Upper - Grand Mouth - MOR RM250 - Boonville - (MOR RM250 - Grand Mouth (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5))		
GR	A69-1602-49029	Grand Mouth - Grand Upper (x1.5)	1.8	5.8
GR	A69-1602-49030	(Grand Mouth - MOR RM249 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5))	2.9	48.0
GR	A69-1602-49031	Grand Upper - (Grand Mouth - MOR RM249 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - Grand Upper - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - Grand Upper - (MOR RM250 - Grand Mouth (x1.5)) - Grand Upper	2.9	52.2
GR	A69-1602-49032	MOR RM452 - MOR RM499 - MOR RM529 - Platte - (Nishnabotna - MOR RM595 (x1.5)) - MOR RM529	347.1	468.3
GR	A69-1602-49033	Grand Mouth - MOR RM250 - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250	1.9	14.3
GR	A69-1602-49034	Grand Mouth - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - Grand Mouth - MOR RM250 - MOR RM398 - MOR RM452 - MOR RM398 - MOR RM452 - (Grand Mouth - Grand Upper (x2.5)) - (MOR RM250 - Grand Upper (x2)) - (Grand Mouth - Grand Upper (x1.5))	203.9	549.0
GR	A69-1602-49035	(Grand Mouth - MOR RM249 (x2.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - Grand Upper - Grand Mouth - MOR RM250 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM641.5 - MOR RM670 - MOR RM691 - (Grand Mouth - Grand Upper (x4.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Mouth (x2)) - Grand Upper - (Grand Mouth - MOR	442.9	930.9

		RM250 (x3.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x4.5)) - Grand Upper - Grand Mouth		
GR	A69-1602-49036	(Grand Mouth - Grand Upper (x2.5)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - Grand Mouth (x3.5)) - (MOR RM250 - Grand Mouth (x1.5)) - MOR RM398 - MOR RM452 - MOR RM477 - MOR RM499 - Nishnabotna - MOR RM641.5 - Little Sioux - MOR RM641.5 - MOR RM670 - MOR RM691 - MOR RM710 - MOR RM734 - MOR RM641.5 - MOR RM595 - Platte	485.9	724.0
GR	A69-1602-49038	(Grand Upper - Grand Mouth (x4.5)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - MOR RM250	2.9	37.1
GR	A69-1602-49039	Grand Mouth - MOR RM250 - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - (MOR RM250 - Grand Mouth (x2)) - Grand Upper - MOR RM250 - Grand Mouth - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x3))	1.9	28.1
GR	A69-1602-49043	(Grand Upper - Grand Mouth (x2)) - (MOR RM249 - Grand Mouth (x2)) - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - Grand Mouth (x3)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5))	2.9	37.8
GR	A69-1602-49044	Grand Mouth - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (MOR RM250 - Grand Mouth (x2)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - Grand Upper - (Grand Mouth - MOR RM250 (x2)) - (Grand Upper - Grand Mouth - MOR RM250 (x2)) - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (MOR RM250 - Grand Mouth (x2)) - (Grand Upper - Grand Mouth (x2))	2.9	71.2
GR	A69-1602-49045	(MOR RM250 - Grand Mouth (x2.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth -	1.9	41.2

		MOR RM250 (x2)) - (Grand Upper - Grand Mouth - MOR RM250 (x2)) - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x2.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x2.5))		
GR	A69-1602-49046	(Grand Mouth - MOR RM249 (x2)) - (Grand Upper - Grand Mouth (x6))	2.9	26.2
GR	A69-1602-49047	Grand Mouth - MOR RM250 - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x2)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5))	1.9	26.6
GR	A69-1602-49048	Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - MOR RM249 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - (Grand Mouth - Grand Upper (x2.5))	2.9	16.8
GR	A69-1602-49049	(Grand Upper - Grand Mouth (x3)) - (MOR RM250 - Grand Upper (x1.5)) - MOR RM398 - MOR RM368 - MOR RM367 - Grand Mouth - MOR RM250 - (Grand Upper - Grand Mouth (x3))	149.9	206.3
GR	A69-1602-49051	(Grand Upper - Grand Mouth (x2)) - MOR RM249 - Grand Upper - (Grand Mouth - MOR RM250 (x3)) - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - (Grand Mouth - Grand Upper (x1.5)) - MOR RM250 - Grand Upper - Grand Mouth	2.9	29.4
GR	A69-1602-49052	Grand Upper - (Grand Mouth - MOR RM249 (x1.5)) - Grand Upper - Grand Mouth - MOR RM249 - (Grand Upper - Grand Mouth (x3)) - Gasconade - (Moreau Mouth - Moreau Upper (x3.5))	148.3	329.5
GR	A69-1602-49053	(Grand Mouth - MOR RM249 (x1.5)) - (Grand Upper - Grand Mouth (x2)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - Grand Upper (x1.5))	2.9	24.4
GR	A69-1602-49054	Lamine Upper - Lamine Mouth (x1.5)	52.7	59.3
GR	A69-1604-27561	Grand Mouth - Lamine Mouth	49.4	49.4
GR	A69-1604-27562	Grand Mouth - Lamine Upper	52.7	52.7
GR	A69-1604-27563	(Grand Mouth - MOR RM249 (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x4.5)) - Grand Upper - Grand Mouth	2.9	12.8
GR	A69-1604-27564	(Grand Mouth - MOR RM250 (x1.5)) - Grand Upper - (MOR RM250 - Grand Mouth (x1.5))	1.9	6.3

GR	A69-1604-27565	(Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Mouth (x3.5)) - (Grand Upper - Grand Mouth (x4)) - MOR RM250 - Grand Mouth - (Grand Upper - MOR RM250 (x1.5)) - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - MOR RM250 (x1.5)) - Grand Mouth - (MOR RM250 - Grand Upper (x1.5)) - (Grand Mouth - MOR RM250 (x4.5)) - (Grand Upper - Grand Mouth (x2))	1.9	52.6
GR	A69-1604-27566	(Grand Mouth - Grand Upper (x1.5)) - MOR RM249 - (Grand Upper - Grand Mouth (x3)) - MOR RM250	2.9	20.1
GR	A69-1604-27567	(Grand Mouth - Grand Upper (x1.5)) - MOR RM249 - (MOR RM250 - Grand Mouth (x1.5)) - Grand Upper - (Grand Mouth - MOR RM250 (x1.5)) - (Grand Upper - Grand Mouth (x3)) - MOR RM250 - Grand Mouth - Grand Upper - MOR RM250	2.9	28.7
GR	A69-1604-27568	(Grand Mouth - MOR RM250 (x1.5)) - MOR RM249 - Grand Mouth	2.9	4.2
GR	A69-1604-27569	(Grand Mouth - Grand Upper (x1.5)) - MOR RM250	1.9	5.9
GR	A69-1604-27570	(Grand Mouth - Grand Upper (x1.5)) - (MOR RM250 - Grand Mouth (x2)) - (Grand Upper - Grand Mouth (x3)) - MOR RM250 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - MOR RM529 - Nishnabotna - MOR RM641.5 - MOR RM670 - MOR RM710 - MOR RM734 - Big Sioux - MOR RM735 - MOR RM752 - MOR RM775 - MOR RM595 - (Grand Mouth - Grand Upper (x4.5))	526.9	1086.4
KR	A69-1604-27488	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - (Platte - MOR RM595 (x2)) - MOR RM368 - Below WaterOne - MOR RM398 - MOR RM425	229.2	551.8
KR	A69-1604-27489	MOR RM367	2.0	2.0
KR	A69-1604-27490	MOR RM368 - MOR RM398 - MOR RM425 - (MOR RM452 - MOR RM499 (x1.5)) - MOR RM368 - Below WaterOne - Kansas RM1	133.0	283.5
KR	A69-1604-27491	MOR RM368 - Kansas RM1	2.0	3.5
KR	A69-1604-27492	Kansas Mouth	1.2	1.2
KR	A69-1604-27493	MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM477 - MOR RM499 - MOR RM641.5 - MOR RM595 - Platte - MOR RM452 - MOR RM425 - Kansas RM1	275.5	550.9
KR	A69-1604-27494	Kansas Mouth	1.2	1.2

KR	A69-1604-27495	(MOR RM368 - Kansas RM1 (x1.5)) - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM499 - (Kansas RM1 - MOR RM368 (x6.5))	133.0	286.5
KR	A69-1604-27496	Kansas Mouth	1.2	1.2
KR	A69-1604-27497	MOR RM368 - MOR RM425 - MOR RM452 - Platte - MOR RM595 - MOR RM452 - Kansas RM1 - (Below WaterOne - MOR RM368 (x1.5)) - Kansas RM1	229.2	496.9
KR	A69-1604-27498	Kansas RM1	0.5	0.5
KR	A69-1604-27499	Kansas Mouth	1.2	1.2
KR	A69-1604-27500	MOR RM367	2.0	2.0
KR	A69-1604-27501	MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM529 - Platte - MOR RM641.5 - MOR RM670 - MOR RM694 - MOR RM710 - (MOR RM734 - Big Sioux (x1.5)) - Platte - Below WaterOne - Kansas RM1 - MOR RM367	368.5	756.8
KR	A69-1604-27502	Kansas RM1	0.5	0.5
KR	A69-1604-27503	Kansas Mouth	1.2	1.2
KR	A69-1604-27504	MOR RM367 - (Kansas Mouth - Kansas RM1 (x2)) - MOR RM368 - MOR RM398 - MOR RM452 - Nishnabotna - MOR RM641.5 - MOR RM670 - Little Sioux - Platte - MOR RM595 - (Below WaterOne - MOR RM368 (x1.5)) - Kansas RM1	308.0	660.4
KR	A69-1604-27505	MOR RM367	2.0	2.0
KR	A69-1604-27506	MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - Kansas RM1 - Grand Mouth - MOR RM250 - Grand Upper - Grand Mouth - MOR RM250 - Kansas RM1	133.0	506.8
KR	A69-1604-27507	MOR RM367 - MOR RM368 - MOR RM398 - MOR RM452 - Below WaterOne - Kansas RM1 - Below WaterOne	86.0	199.5
KR	A69-1604-27508	Kansas Mouth	1.2	1.2
KR	A69-1604-27509	Below WaterOne - Kansas RM1 - MOR RM367 - MOR RM368 - MOR RM641.5 - MOR RM595 - MOR RM452 - Below WaterOne	275.5	577.5
KR	A69-1604-27510	MOR RM368 - (Kansas Mouth - Kansas RM1 (x3)) - (MOR RM367 - MOR RM368 (x1.5)) - Kansas RM1	229.0	470.1

		- MOR RM367 - MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM499 - MOR RM595 - Nishnabotna - Kansas RM1		
KR	A69-1604-27511	MOR RM367 - (Kansas Mouth - Kansas RM1 (x4)) - MOR RM368 - (Nishnabotna - MOR RM529 (x1.5)) - Below WaterOne - Kansas RM1	176.5	404.4
KR	A69-1604-27512	Below WaterOne - (Kansas RM1 - MOR RM367 (x2)) - MOR RM368 - MOR RM398 - MOR RM452 - (Kansas RM1 - Below WaterOne (x2)) - (Grand Mouth - Grand Upper (x1.5)) - Kansas RM1	86.0	469.7
KR	A69-1604-27513	Kansas Mouth	1.2	1.2
KR	A69-1604-27514	MOR RM368 - Kansas Mouth - (Kansas RM1 - Below WaterOne (x1.5)) - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM477 - MOR RM499 - Nishnabotna - Below WaterOne	176.5	382.5
KR	A69-1604-27515	MOR RM368 - MOR RM398 - (MOR RM452 - MOR RM565 (x1.5)) - MOR RM398	199.0	366.0
KR	A69-1604-27516	MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM477 - Platte - MOR RM595 - MOR RM398 - MOR RM368 - Kansas RM1	229.2	457.9
KR	A69-1604-27519	Kansas RM1	0.5	0.5
KR	A69-1604-27520	MOR RM367	2.0	2.0
KR	A69-1604-27521	MOR RM368 - (MOR RM398 - MOR RM425 (x1.5)) - MOR RM368	59.0	116.0
KR	A69-1604-27522	MOR RM367 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - Nishnabotna	176.5	177.5
KR	A69-1604-27523	MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM367 - Grand Mouth - Grand Upper - MOR RM249 - Boonville - Grand Mouth - MOR RM249 - MOR RM250 - (Grand Mouth - MOR RM249 (x8.5))	86.0	418.7
KR	A69-1604-27524	MOR RM368 - MOR RM398 - MOR RM452 - MOR RM477 - MOR RM499 - MOR RM529 - MOR RM452 - MOR RM499 - MOR RM477 - Grand Mouth - MOR RM250 - Kansas RM1	163.0	654.7
KR	A69-1604-27525	MOR RM368 - MOR RM398 - MOR RM452 - Platte - (Kansas RM1 - MOR RM367 (x5.5))	229.2	472.9
KR	A69-1604-27526	Below WaterOne - Kansas RM1 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM499 - (Platte - MOR RM595 (x5.5)) - MOR RM529 - MOR RM499 - MOR RM368 - Kansas RM1	229.2	475.3

KR	A69-1604-27527	MOR RM398 - MOR RM425 - (MOR RM452 - MOR RM499 (x1.5)) - MOR RM425 - Kansas RM1	133.0	265.5
KR	A69-1604-27528	MOR RM368 - MOR RM425 - MOR RM452 - MOR RM477 - Platte - MOR RM452 - MOR RM398 - Kansas RM1 - (Below WaterOne - MOR RM368 (x2.5)) - Kansas RM1	229.2	517.9
KR	A69-1604-27529	MOR RM368 - MOR RM452 - MOR RM499 - Nishnabotna - MOR RM477 - MOR RM499 - MOR RM425 - Kansas RM1	176.5	396.5
KR	A69-1604-27530	Below WaterOne - Kansas RM1 - MOR RM367 - MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM398 - MOR RM368 - Kansas RM1	86.0	189.5
KR	A69-1604-27532	MOR RM368 - MOR RM452 - Nishnabotna - Below WaterOne - MOR RM368 - Kansas RM1	176.5	373.5
KR	A69-1604-27533	MOR RM368 - MOR RM452 - MOR RM477 - MOR RM529 - Platte - MOR RM595 - MOR RM641.5 - Little Sioux - (MOR RM670 - MOR RM692 (x1.5)) - MOR RM641.5 - (Platte - MOR RM595 (x2)) - MOR RM398	326.0	610.7
KR	A69-1604-27535	Kansas RM1	0.5	0.5
KR	A69-1604-27536	MOR RM368 - MOR RM425 - MOR RM452 - MOR RM477 - MOR RM565 - Platte - MOR RM595 - Kansas RM1	229.2	457.9
KR	A69-1604-27537	MOR RM368 - MOR RM452 - MOR RM477 - (MOR RM499 - MOR RM529 (x1.5)) - MOR RM452 - MOR RM368	163.0	324.0
KR	A69-1604-27538	MOR RM368 - MOR RM398 - MOR RM452 - MOR RM477 - Platte - MOR RM595 - Kansas RM1	229.2	457.9
KR	A69-1604-27539	(MOR RM367 - Kansas RM1 (x1.5)) - MOR RM368 - Kansas RM1 - Below WaterOne	8.5	16.5
KR	A69-1604-27540	MOR RM367	2.0	2.0
KR	A69-1604-27541	MOR RM367 - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM452 - Platte - MOR RM595 - MOR RM641.5 - (Little Sioux - MOR RM670 (x1.5))	308.0	322.5
KR	A69-1604-27542	(MOR RM368 - MOR RM367 (x2.5)) - MOR RM398 - (Kansas RM1 - MOR RM368 (x1.5))	32.0	70.5
KR	A69-1604-27543	MOR RM368 - MOR RM398 - MOR RM452 - Platte - MOR RM398 - MOR RM368 - MOR RM367 - Kansas RM1	229.2	458.9
KR	A69-1604-27544	(Grand Mouth - MOR RM250 (x1.5)) - Boonville - Osage - MOR RM128.5	240.5	242.3

KR	A69-1604-27545	MOR RM368 - Kansas Mouth - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM425 - MOR RM452 - Platte - MOR RM641.5 - MOR RM670 - MOR RM692 - MOR RM710 - MOR RM735 - MOR RM752 - MOR RM776 - MOR RM787 - James - MOR RM797 - MOR RM787 - MOR RM776 - MOR RM752 - MOR RM735 - (Big Sioux - MOR RM734 (x1.5)) - MOR RM710 - MOR RM692 - MOR RM670 - MOR RM641.5 - (MOR RM368 - Kansas RM1 (x2))	432.0	871.9
KR	A69-1604-27547	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM452 - Nishnabotna - MOR RM641.5 - Little Sioux - Platte - Nishnabotna - MOR RM425 - Below WaterOne - Kansas RM1	322.5	650.3
KR	A69-1604-27548	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - Kansas RM1 - MOR RM367 - (MOR RM368 - Kansas RM1 (x3))	147.5	290.0
KR	A69-1604-27549	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM477 - Platte - MOR RM641.5 - MOR RM670 - MOR RM692 - MOR RM710 - MOR RM734 - MOR RM735 - MOR RM710 - MOR RM670 - MOR RM641.5 - Platte - Below WaterOne - (MOR RM368 - Kansas RM1 (x5))	383.5	785.8
KR	A69-1604-27550	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM398 - (MOR RM452 - MOR RM595 (x1.5)) - MOR RM368 - Below WaterOne	243.5	481.0
KR	A69-1604-27551	Below Bowersock - Above WaterOne	34.4	67.8
KR	A69-1604-27552	Above WaterOne	1.0	1.0
KR	A69-1604-27553	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM499 - Platte - MOR RM594 - MOR RM595 - MOR RM641.5 - MOR RM670 - MOR RM691 - MOR RM734 - Big Sioux - MOR RM670 - MOR RM641.5 - MOR RM452 - Kansas RM1	383.0	753.4
KR	A69-1604-27554	Below Bowersock - Below WaterOne - Kansas RM1 - MOR RM398 - MOR RM425 - MOR RM452 - MOR RM499 - Platte - MOR RM594 - MOR RM565 - Platte - (Kansas RM1 - MOR RM368 (x2.5)) - MOR RM367 - Kansas RM1 - MOR RM368	243.7	606.1
KR	A69-1604-27555	Below WaterOne - Kansas RM1 - MOR RM398 - MOR RM452 - MOR RM594	242.5	242.5

KR	A69-1604-27556	Above WaterOne	1.0	1.0
KR	A69-1604-27557	Above WaterOne	1.0	1.0
KR	A69-1604-27558	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM398 - MOR RM452 - MOR RM477 - Platte - Below WaterOne - Kansas RM1	243.7	490.4
KR	A69-1604-27559	Below Bowersock - Above WaterOne	34.4	67.8
KR	A69-1604-27560	Below WaterOne - Kansas RM1 - MOR RM368 - MOR RM452 - MOR RM499 - Platte - Below WaterOne	243.7	503.4

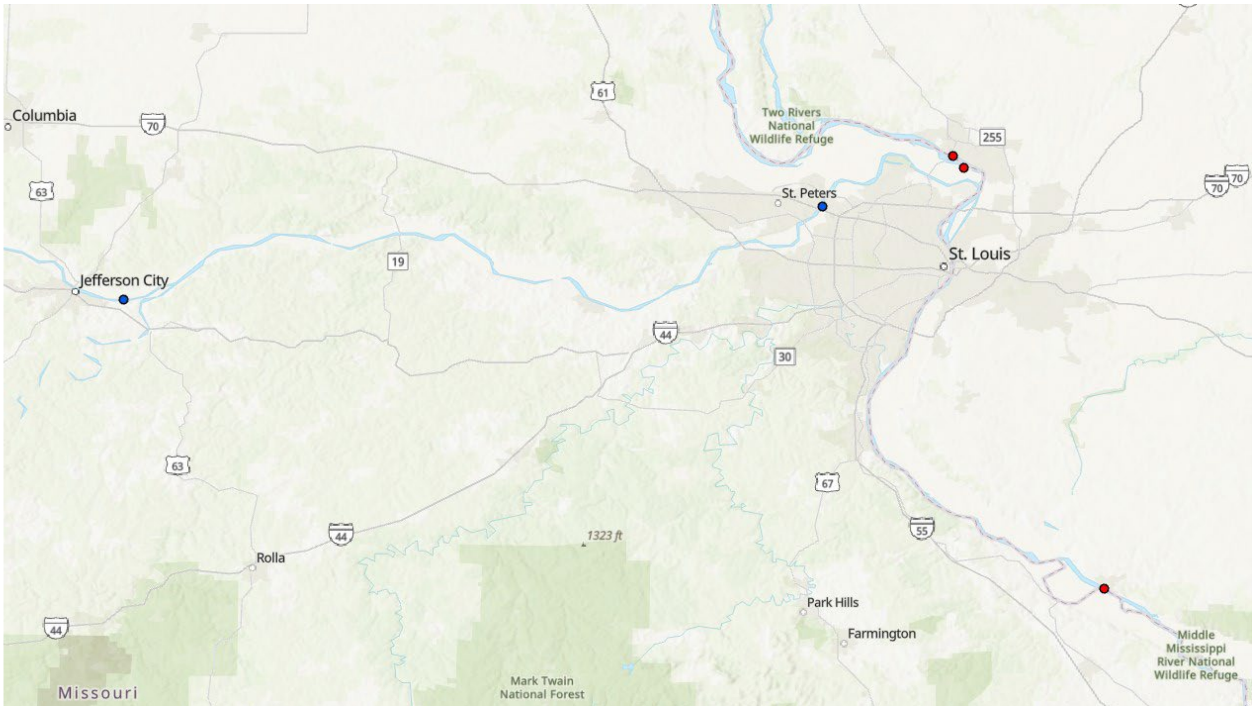


Figure 24. Relative locations of invasive Silver Carp (blue dots) tagged in the MOR (one from the Moreau River, six from Creve Coeur Creek) that made it to the MMR and were detected in lower pool 26 (upper red dot), Maple Island (middle red dot) and Chester, IL (lower red dot), approximately 36.4 to 144.3 river miles from the original tagging locations.

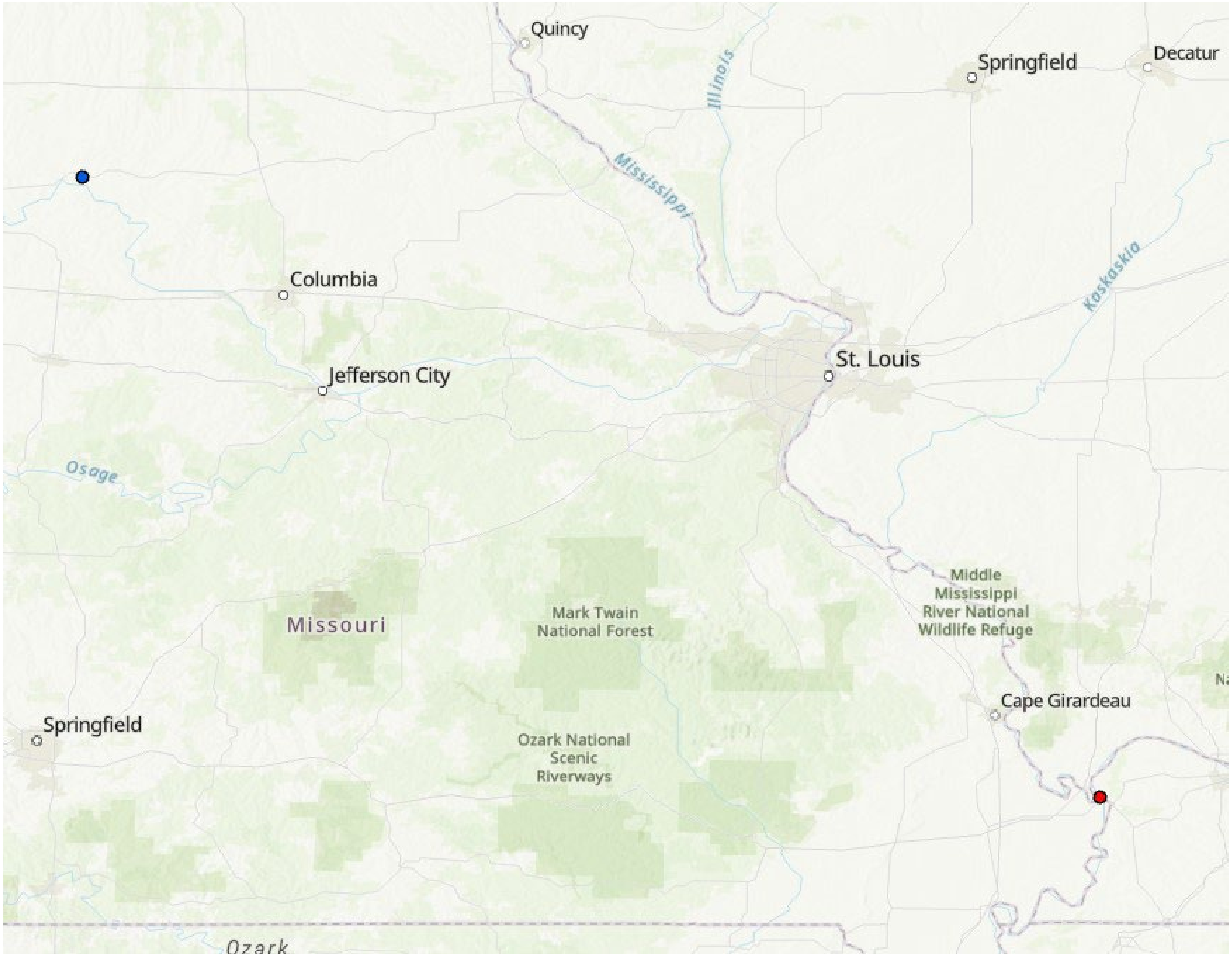


Figure 25. Relative locations of an invasive Silver Carp (blue dot) tagged in the MOR (Grand River) that made it to the Ohio River and was detected at Cairo, IL (red dot), approximately 448.4 river miles from the original tagging location.

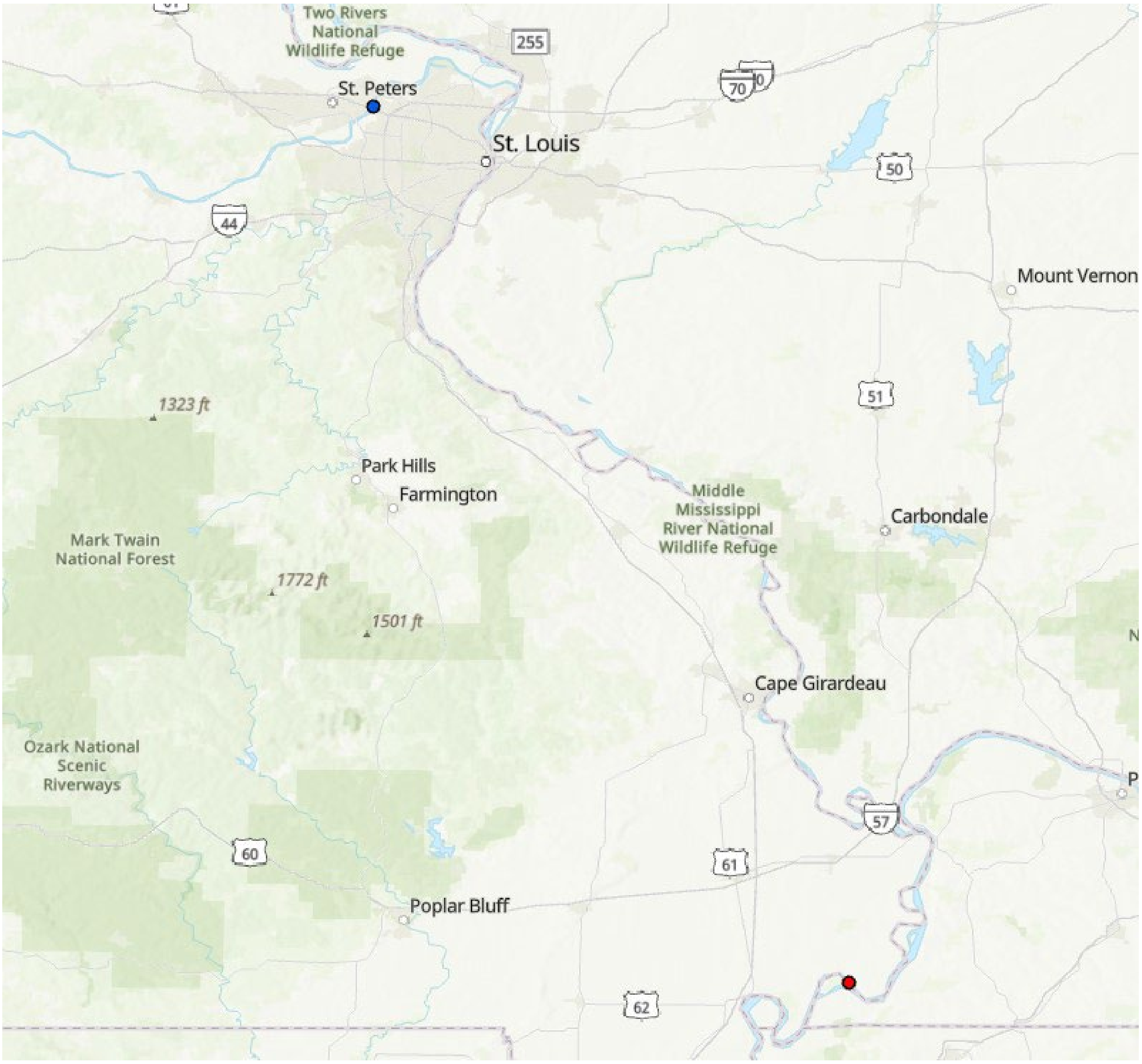


Figure 26. Relative locations of an invasive Silver Carp (blue dot) tagged in the MOR (Creve Coeur Creek) that made it to the LMR and was detected at Seven Island (red dot), approximately 263.9 river miles from the original tagging location.

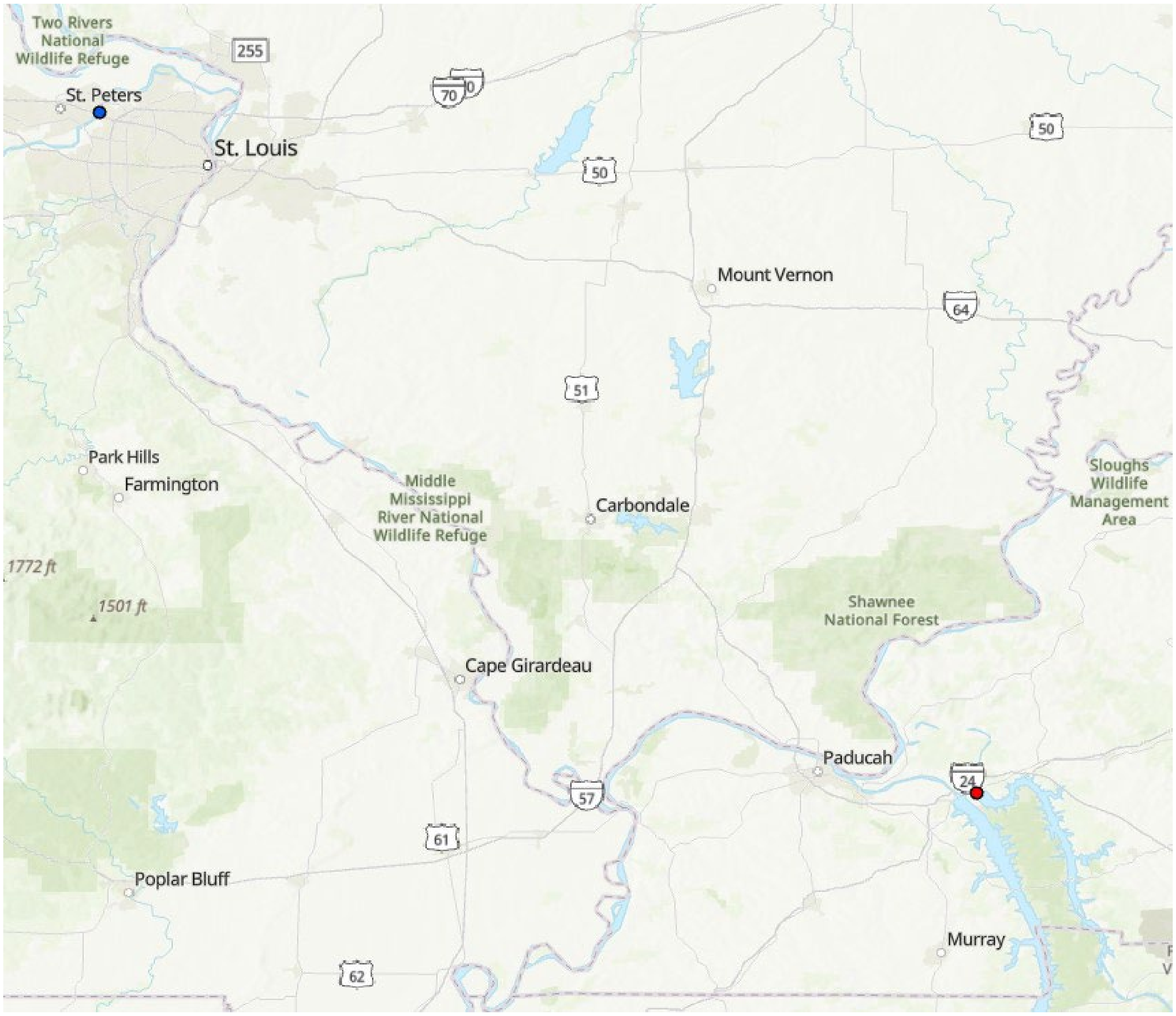


Figure 27. Relative locations of an invasive Silver Carp (blue dot) tagged in the MOR (Creve Coeur Creek) that made it to the Ohio River system and was detected at Barkley Dam (red dot), approximately 314.6 river miles from the original tagging location.

Agency: South Dakota Department of Game, Fish and Parks and South Dakota State University

Methods:

Study site

The James River begins in eastern North Dakota and flows south through the entirety of South Dakota to its confluence with the Missouri River. The James River is the largest tributary to the Missouri River between Gavins Point Dam near Yankton, South Dakota, and the confluence of the Platte and Missouri Rivers on the Nebraska-Missouri border. It is highly sinuous, traveling a distance of 1,202 river kilometers (rkm) but only drops 140 m in elevation (Owen et al. 1981; Benson 1983). The landscape is historically categorized by glaciated drift prairie, but municipalities and farmland are the contemporary predominant features on the landscape. There are at least 230 low-head dams on the James River (Shearer and Berry Jr 2003), which act as potential barriers to fish movement in times of low water but become submerged during high flow events and allow for fish passage (Carlson 2022).

Acoustic Tag Deployment

Passive telemetry has been used to monitor large-scale movement patterns of Silver Carp in the James River, South Dakota since 2021. In 2021, 50 Silver Carp were captured using boat electrofishing on a Smith-Root GPP 7.5 electrofishing boat (pulsed DC current; 120 Hz; 11-14 A; 170 V; 40-60% power) and implanted with an InnovaSea V16 transponding tag (model V16-4H; 69kHz; ping rate: 30 - 60 seconds; tag life: 1328 days; 16 mm diameter, 68 mm length, 24 g weight; henceforth: V16 tag) (Bedford, Nova Scotia, Canada). The total length (mm) and weight (g) of each individual was recorded upon capture. Each surgery was performed according to the University of South Dakota's Institutional Animal Care and Use Committee protocol (#10-08-20-23D). A 2-inch incision was made on the ventral side of the fish between the pelvic and pectoral fins, and an InnovaSea V16 tag was inserted into the body cavity. Sterile chromic catgut sutures were used to make 2-3 simple interrupted sutures. Tools were sterilized in a chlorhexidine solution. Mean wet weight was 3,019 g (range: 1,042 g to 5,454 g), and mean total length was 625 mm (range: 452 mm to 777 mm). Post-operation, the fish were monitored to ensure they were swimming upright in the livewell before being released back into the James River at a location no further than one rkm away from the original point of capture. An additional 50 V16 transmitters were implanted into Silver Carp from in 2023. Tagged fish in 2023 had a mean weight of 2,747 g (range: 1,343-4,950 g) and a mean TL of 619 mm (range: 490-731 mm). Between June 3 and June 10, 2024, 50 additional Silver Carp were tagged in the James River following the same protocols described above. Ten fish were tagged immediately downstream of the Olivet, SD boat ramp (rkm 105), 10 were tagged downstream of the Shramm access area boat ramp (rkm 40), and 30 were tagged in the first 9 km upstream of the Missouri River confluence. Mean total length was 605 mm (range: 445 mm to 728 mm), and mean weight was 2,439 g (range: 902 g to 4270 g).

Movement Data Collection

A total of 21 InnovaSea model Vr2Tx (n=5) and Vr2W (n=16) 69kHz receivers (InnovaSea, Bedford, Nova Scotia), spanned from rkm 1 to rkm 358 of the James River, SD (Figure 28). Receivers were mounted in one of two setup designs: pipe-mounted or frame-mounted as described in Carlson et al. (2023) and LaBrie (2023). Additional telemetry detections were collected from passive receivers deployed in the Missouri and Platte rivers and from active tracking events by collaborating agencies (i.e., USFWS, USGS, Nebraska Game and Parks Commission, etc.) throughout the course of this study. Data was offloaded from each receiver between two and four times during the duration of the study. To collect habitat data, four HOBO temperature loggers, one dissolved oxygen (DO) sensor, and one depth logger were placed intermittently along the telemetry network (Figure 28). Discharge data were downloaded from USGS gage number 06478500 (Scotland, SD), using the *dataRetrieval* package (De Cicco and Hirsch 2014) in Program R (version 4.1.1; R Core Team 2022).

Results and Discussion:
Results from data collected for fish tagged in 2021 are presented in LaBrie (2023). Estimated initial tag life for transmitters implanted in 2021 ended in January 2025, so final movements results from those tagged fish will be summarized following receiver downloads in summer 2025.

Major flooding occurred on the James River in 2024 following the release of fish following tagging (Figure 29). River discharge peaked at over 733 cms, which represents the 4th highest peak in discharge since 1998. As a result of the flood peaking, three receivers were displaced from the James River array. A frame-mounted receiver deployed in the middle of the river channel approximately 12 rkm upstream of the James-Missouri confluence was dislodged from its on-shore tether but was recovered ~1 km downstream. Two pipe-mounted receivers (40 rkm, 51 rkm) were dislodged from their bridge mounts and were lost.

To combat potential issues, all mounting equipment was replaced over a 1.5 month period in October and November 2024. We replaced all pipe-mounted infrastructure on bridges for 17 receivers and all cables on 4 frame-mounted receivers in the James River. As a result of the major renovations in mounting equipment, analysis of movement trends were delayed until 2025.

Tables and Figures:

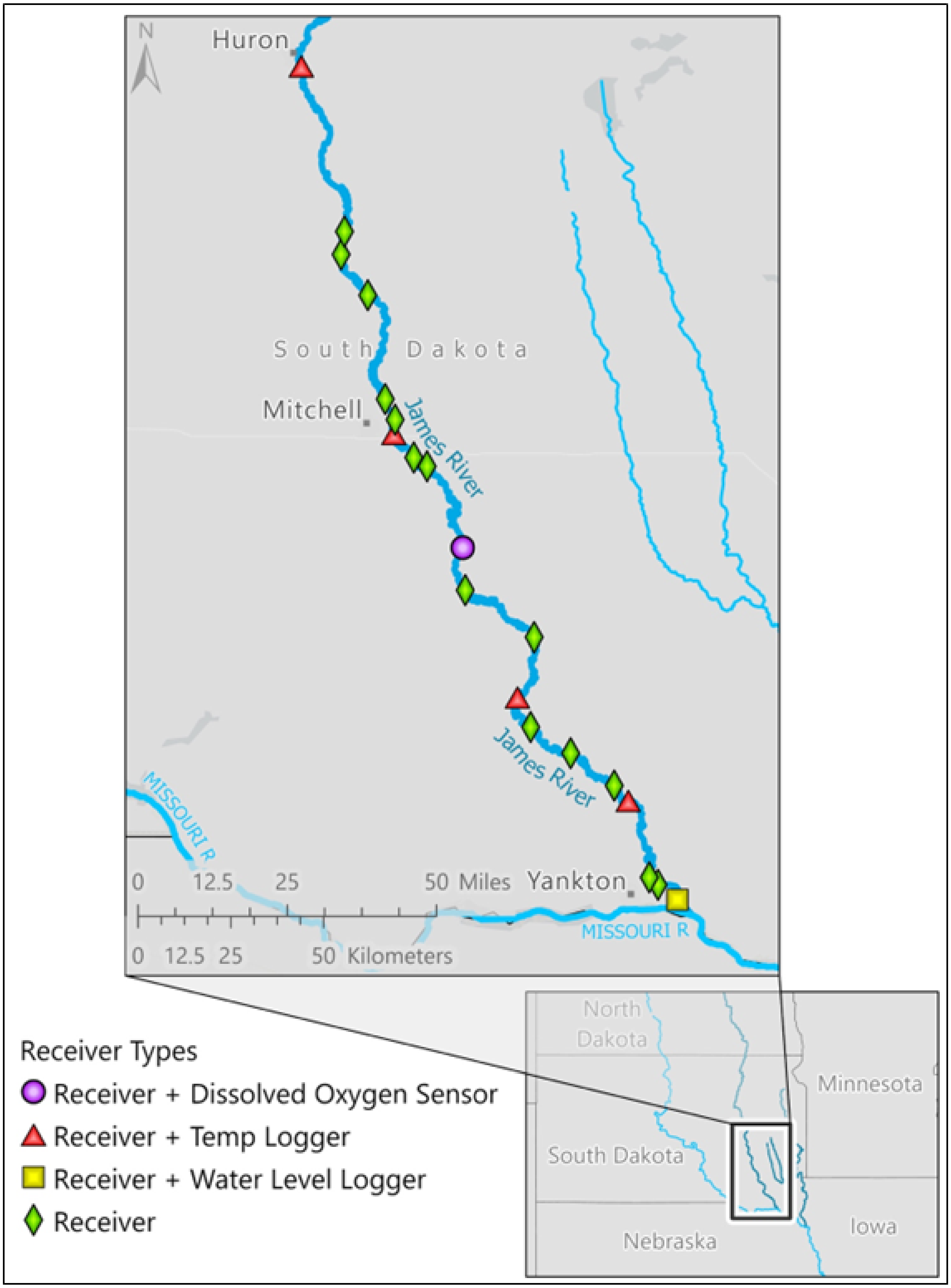


Figure 28. Map of receiver and environmental sensor locations in the James River, SD.

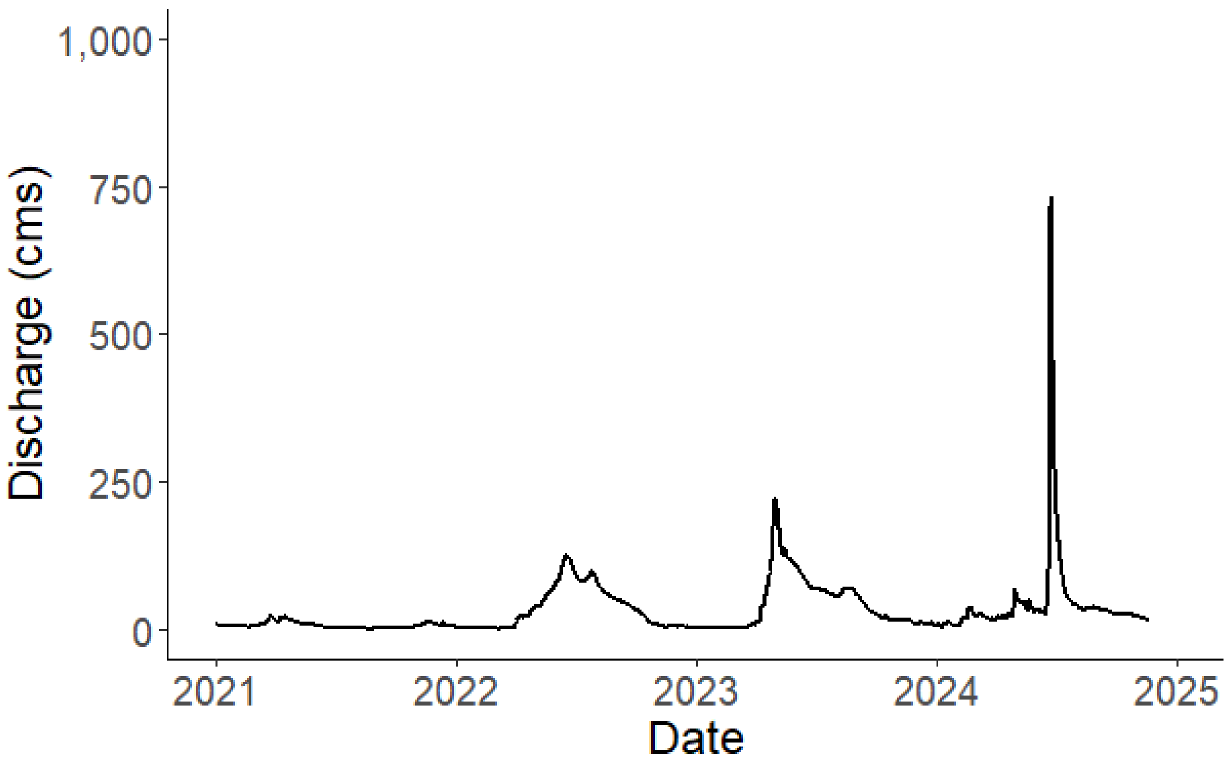


Figure 29. Discharge (cubic meters per second [cms]) at the USGS Scotland station (#06478000) on the James River, South Dakota from 2021 to 2024.

Agency: US Fish and Wildlife Service (USFWS)

Methods:

The Great Plains FWCO maintained a passive telemetry receiver array in the Big Sioux River, Vermillion River, and Split Rock Creek to monitor movement and distribution of tagged silver carp (Figure). The array consisted of 12 Innovasea VR2W acoustic receivers (n=6 Big Sioux River, n=5 Vermillion River, n=1 Split Rock Creek). Each receiver was fastened to a steel frame, placed on the bottom of the river, and attached to a secure object on shore (e.g., large tree) with ⅛-inch steel cable.

In the Big Sioux River system, receivers were placed starting at one river kilometer (RKM) upriver from its confluence with the Missouri River to 240 RKM from the confluence where sufficient water depth was available. One receiver was placed in Split Rock Creek, approximately one kilometer upstream of Big Sioux River-Split Rock Creek confluence (Big Sioux RKM 226) to monitor fish use of this tributary.

In the Vermillion River, receivers were placed starting at 1 RKM upriver from its confluence with the Missouri River to 84 RKM from the confluence where sufficient water depth was available.

In 2024, we monitored locations of 107 silver carp that were tagged in 2021 and 2022. Fish were caught using electrofishing methods beginning at the confluence of each river. Captured fish were held in a tank with a continuous flow of fresh river water. Each fish was anesthetized with Aqui-S 20E prior to surgery, weighed (g), measured for total length (mm), sexed, and implanted with acoustic transmitter tags (Innovasea model V16-4H; 69kHz, 16 mm diameter, 68 mm length, 24 g). A Floy T-bar anchor tag (Model FD-94; Floy Tag & Mfg. Inc.) with a unique identification code and contact information (CARP@FWS.GOV) was attached to each fish near its dorsal fin base. Following surgery, fish were placed into a tank with a continuous flow of fresh river water until the fish was recovered enough to maintain equilibrium and swim independently. Once recovered, each fish was released near its point of capture.

Receiver deployment began on April 09, 2024, and receivers were retrieved from the rivers by November 08, 2024 to avoid loss or damage to equipment during winter. Actual dates of receiver operation varied among rivers and locations due to extreme flooding events (Table 2

Silver carp detection data was summarized by month as:

1) Percent of individual fish detected daily (the percent of the total number of unique fish detected each day at all receivers that were detected at an individual receiver)
2) Percent daily detections (the percent of all daily tag detections from all receivers that were detected at an individual receiver)

These summaries allowed for monthly comparison of both the abundance of daily detections (percent of individual fish detected) and the frequency of daily detection occurrence (percent daily detections). Comparing these values identified if the number of detections at a receiver was due to site fidelity (tagged fish that remain near a receiver for long periods of time) or fish movement (a number of fish that pass by a receiver relatively quickly).

Results and Discussion:

Vermillion River Receivers

No data was recoverable from receivers located RKM-1 and RKM-2 from May through August due to receiver loss from a flood event. No tagged fish were detected at any location in August. All receivers were in service in September and October. Results are presented below as two time periods, based on receiver deployment status.

- May through July (Figure 31)
    - Tagged fish were detected at all receivers in service (RKMs 30, 61, 84; RKMs 1, 2 not in service).
    - The percent of individual fish detections and percent of monthly detections increased at RKM-30, RKM-61 and RKM-84 from May to June, suggesting an upstream movement pattern of tagged fish.
- September and October (Figure 32)
    - Tagged fish were only detected at receivers near the confluence (RKM-1; RKM-2)
        - Low discharge may have decreased available habitat in upstream reaches and hindered fish movement.

Big Sioux River Receivers

Receivers located at RKM-2, RKM-88, RKM-209, Split Rock Creek (SRC-1) and RKM-240 were operational from April through October. Detection data was unavailable for the RKM-1 receiver in July and August due to receiver loss from a flood event. No detections were observed at the RKM-240 receiver, and data from the RKM-61 receiver was omitted from analysis due to multiple time periods of unknown active status (flooding and vandalism). Results are presented below as three time periods, based on receiver deployment status.

- April through June (Figure 33)
    - In April and May, tagged fish were only detected at the 3 most downstream receivers (RKM-1, RKM-2, RKM-88).
    - The percent of individual fish detections and percent of monthly detections increased at RKM-88 from April to June, indicating upstream movement of tagged fish.
    - There were no major movements of tagged fish from the downstream group of receivers to the upstream group (RKM-209, SRC-1, RKM-240).
- July and August (Figure 34)
    - Tagged fish were detected at the farthest upstream location (SRC-1) over the entire study period during this time period.
    - From July to August there was a large increase in the percent of individual fish detections and percent of monthly detections at RKM-2, indicating movement of tagged fish to the confluence area.
- September and October (Figure 35)
    - All tag detections during this period were recorded in the most downstream group of receivers.
        - Minimal changes in the percent of individual fish detections and percent of monthly detections were observed.

RESULT HIGHLIGHTS

- A total of 459,236 silver carp detections were recorded.
- A total of 1,087 individual daily detections were observed.
  - Detections in 2024 were likely higher than in 2023 due to a longer duration of receiver deployment.
- There were consistencies in fish use patterns among the Vermillion and Big Sioux rivers, as fish use of areas near the Missouri River confluences was highest during the spring and fall, and there was some upstream movement during late spring-summer.
  - However, large-scale movements of tagged fish between the downstream (RKM-1, RKM-2, and RKM-88) and upstream (RKM-209, SRC-1, and RKM 240) groups of receivers in the Big Sioux River were not observed.
  - The high use of the confluence areas may be attributed to tagging site fidelity (all fish were tagged within five river kilometers of the confluence), fish movement patterns, or habitat availability.
- **Management Implications:** The near exclusive detection by confluence receivers in April, May, September, and October suggests that these locations and time periods may be ideal for targeted removal efforts in the future.

Tables and Figures:

Table 2. Passive receiver locations and dates of deployment and retrieval in the Big Sioux River, Vermillion River, and Split Rock Creek during 2024. *Denotes no tag detections in 2024.

River	Site	Latitude (N)	Longitude (W)	River Kilometer	Date Deployed	Date Retrieved
Vermillion	VER 1	42.73879	-96.88209	1	9/13/2024	11/08/2024
Vermillion	VER 2	42.74551	-96.87999	2	9/13/2024	11/08/2024
Vermillion	VER 3	42.90957	-96.91567	30	4/9/2024	10/29/2024
Vermillion	VER 4	43.02371	-96.96392	61	4/9/2024	10/29/2024
Vermillion	VER 5	43.11164	-96.98071	84	4/9/2024	10/29/2024
Big Sioux	BSR 1	42.49243	-96.45473	1	9/11/2024	11/08/2024
Big Sioux	BSR 2	42.49912	-96.47581	2	4/17/2024	11/08/2024
*Big Sioux	BSR 4	42.76056	-96.63086	61	9/11/2024	10/29/2024
Big Sioux	BSR 5	42.84993	-96.54423	88	4/17/2024	10/29/2024
Big Sioux	BSR 6	43.44853	-96.60227	209	4/17/2024	10/29/2024
*Big Sioux	BSR 7	43.59963	-96.65251	240	4/17/2024	10/29/2024
Split Rock Creek	SRC 1	43.54996	-96.59136	1	4/17/2024	10/29/2024

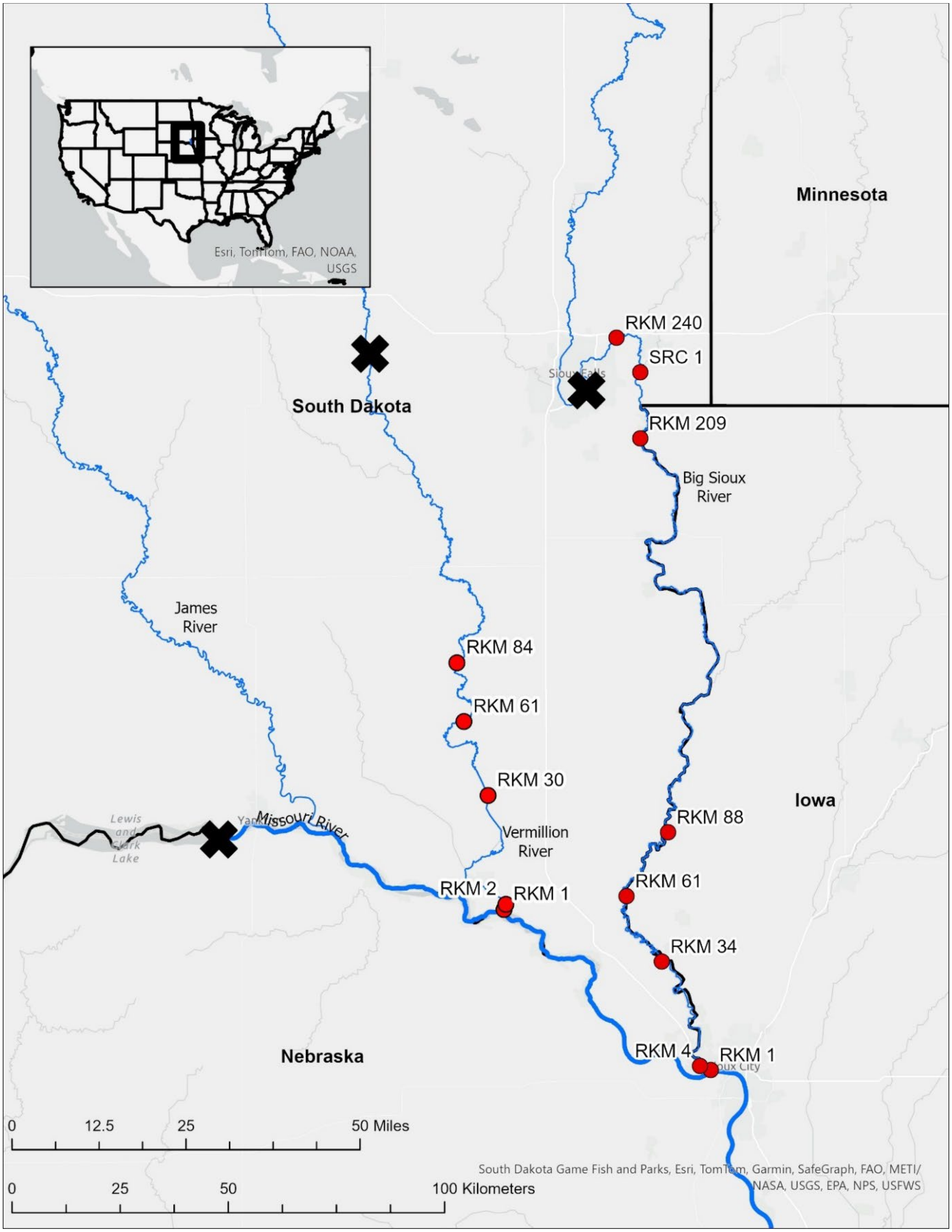
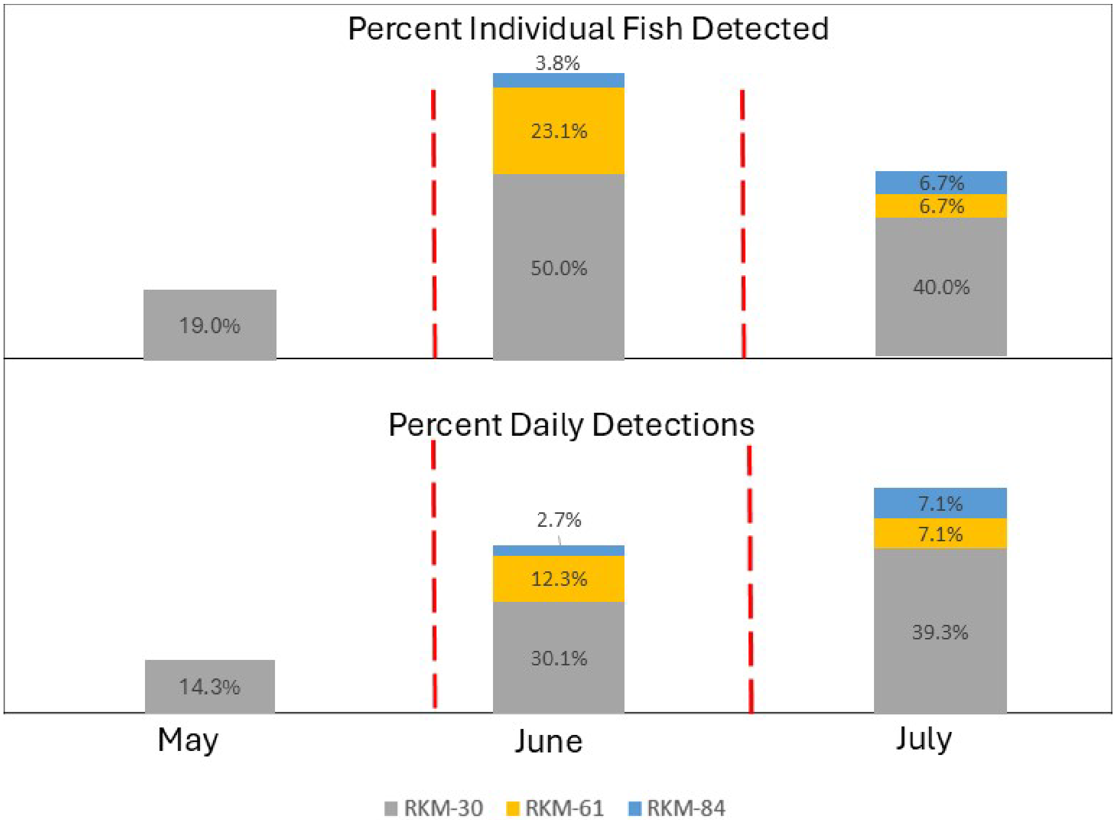


Figure 30. Location of passive receivers (red circles) and barriers to fish movement (black "X") in the Big Sioux River, Vermillion River, and Split Rock Creek during 2024.



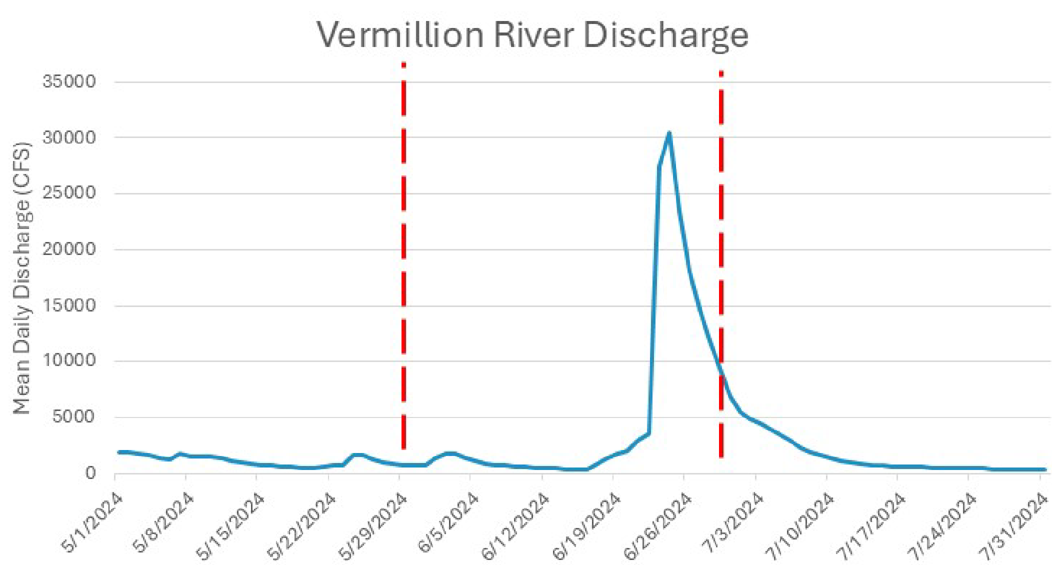
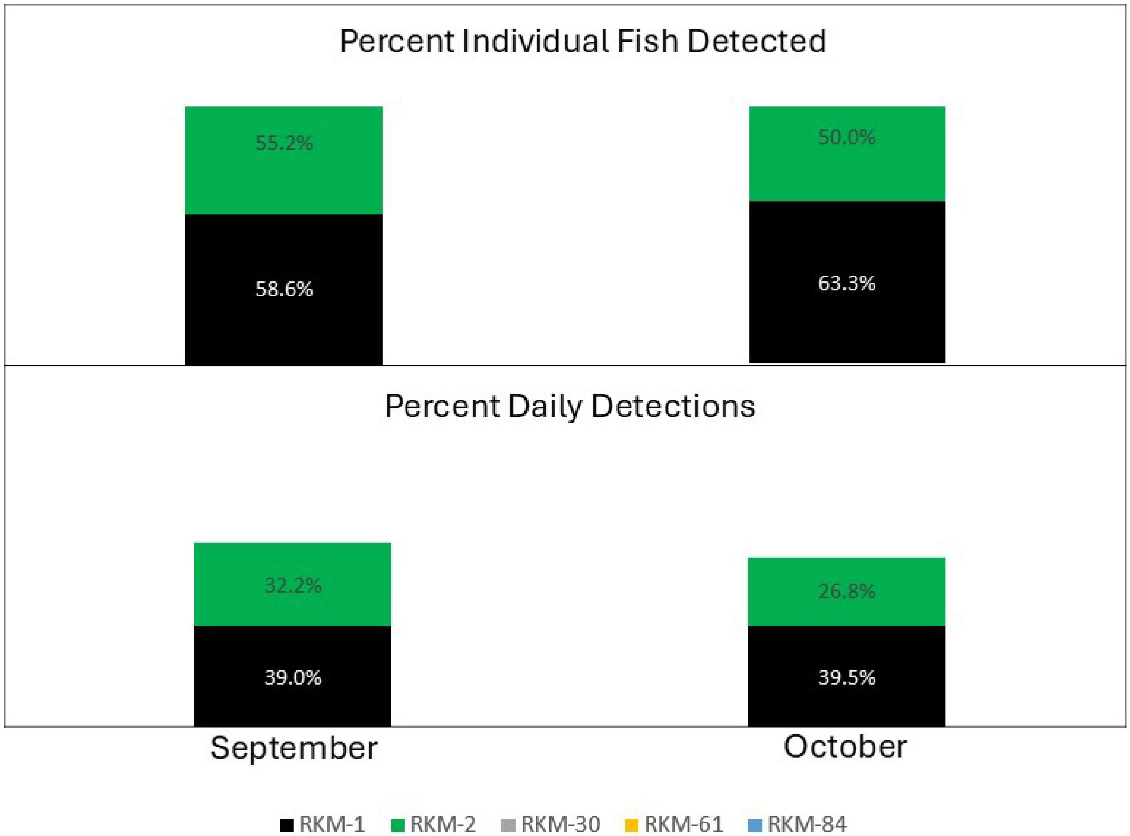


Figure 31. Monthly percent of individual fish (top) and percent of tag detections (middle) by receiver location (river kilometer; RKM) in the Vermillion River; and Vermillion River discharge (bottom) at Vermillion, SD, for May, June, and July 2024.



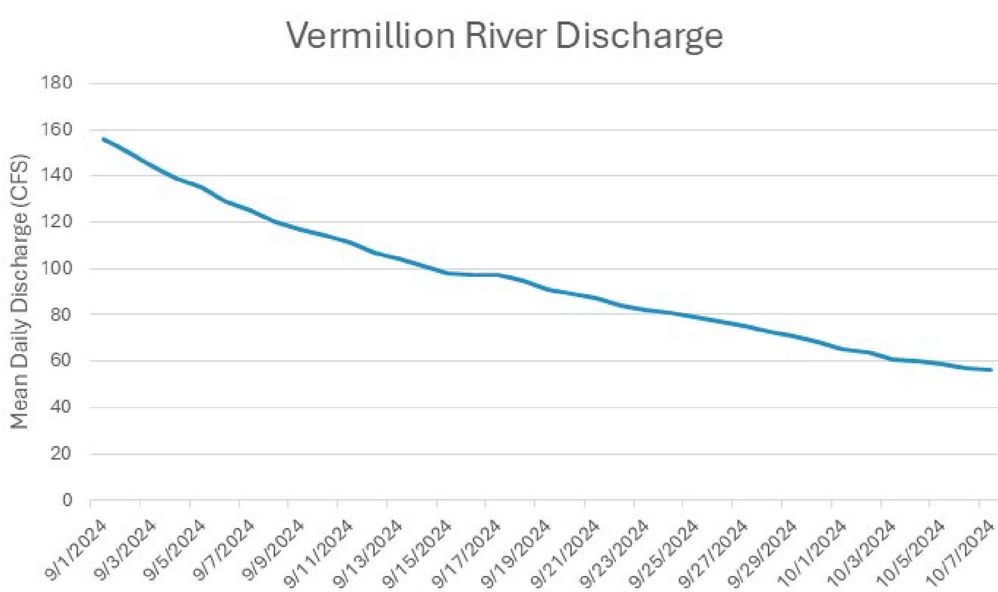


Figure 32. Monthly percent of individual fish (top) and percent of tag detections (middle) by receiver location (river kilometer; RKM) in the Vermillion River; and Vermillion River discharge (bottom) at Vermillion, SD, for September and October 2024 (Steam data unavailable after October 7, 2024).

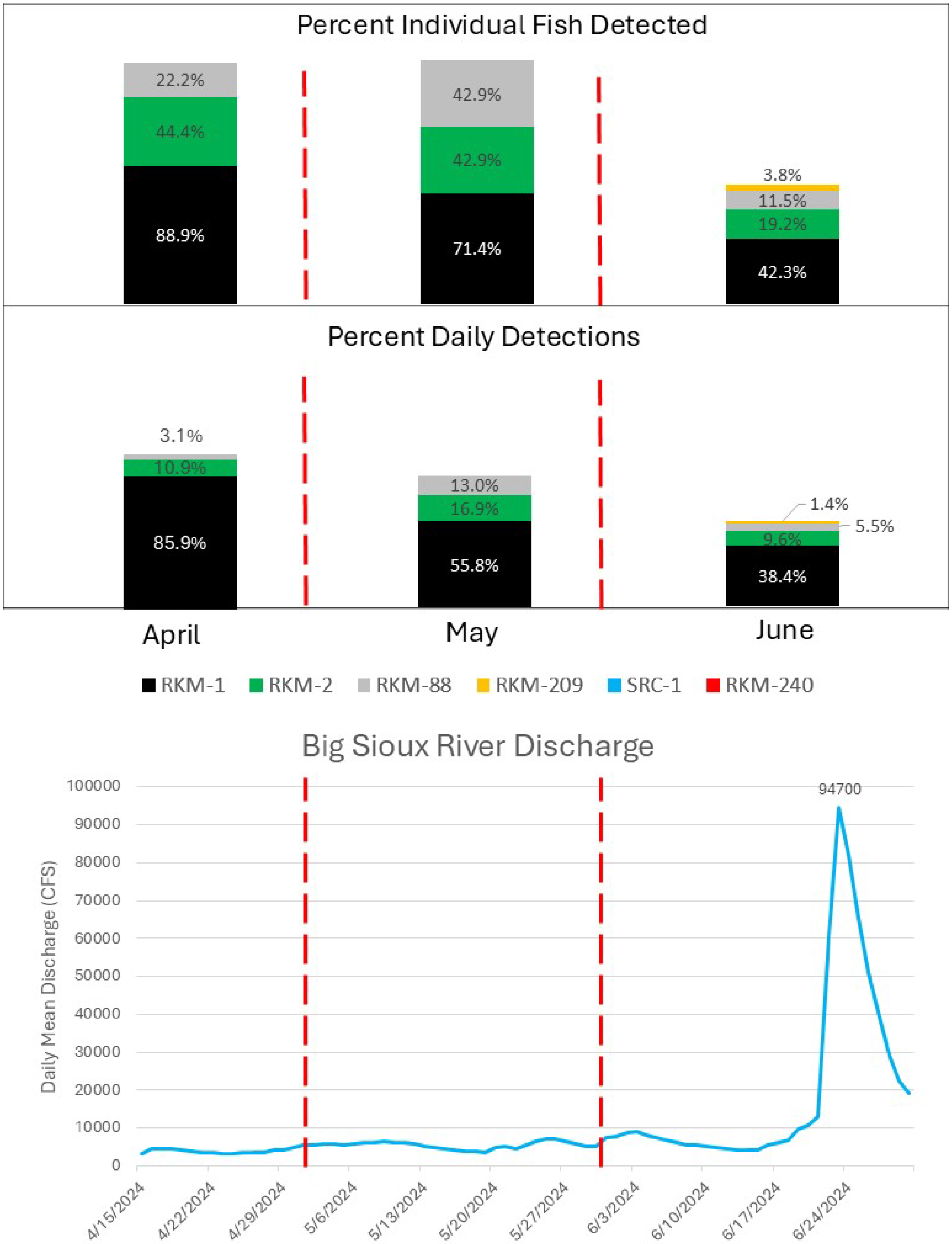


Figure 33. Monthly percent of individual fish (top) and percent of tag detections (middle) by receiver location (river kilometer; RKM) in the Big Sioux River and Split Rock Creek; and Big Sioux River discharge (bottom) at Sioux City, IA, for April, May and June 2024.

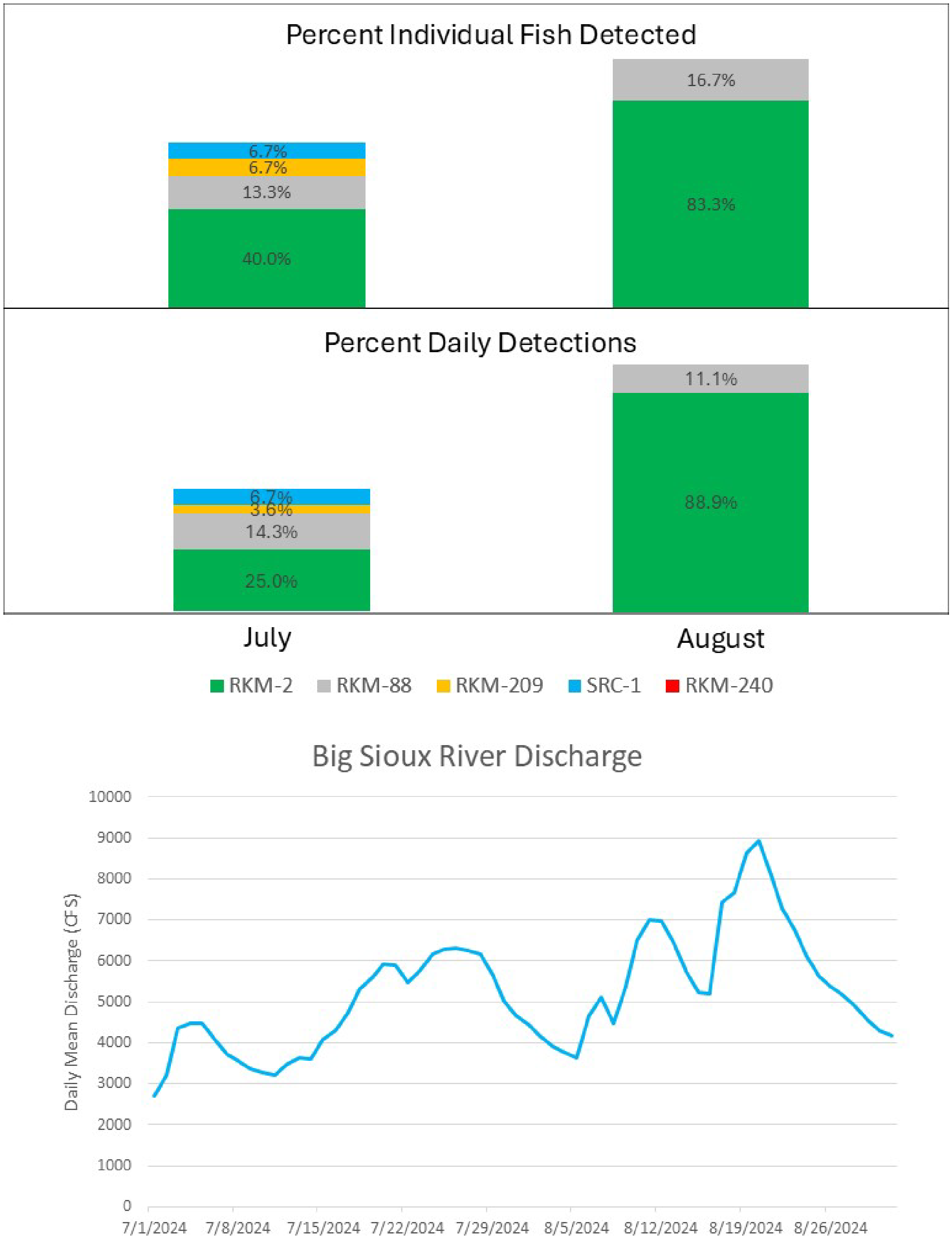
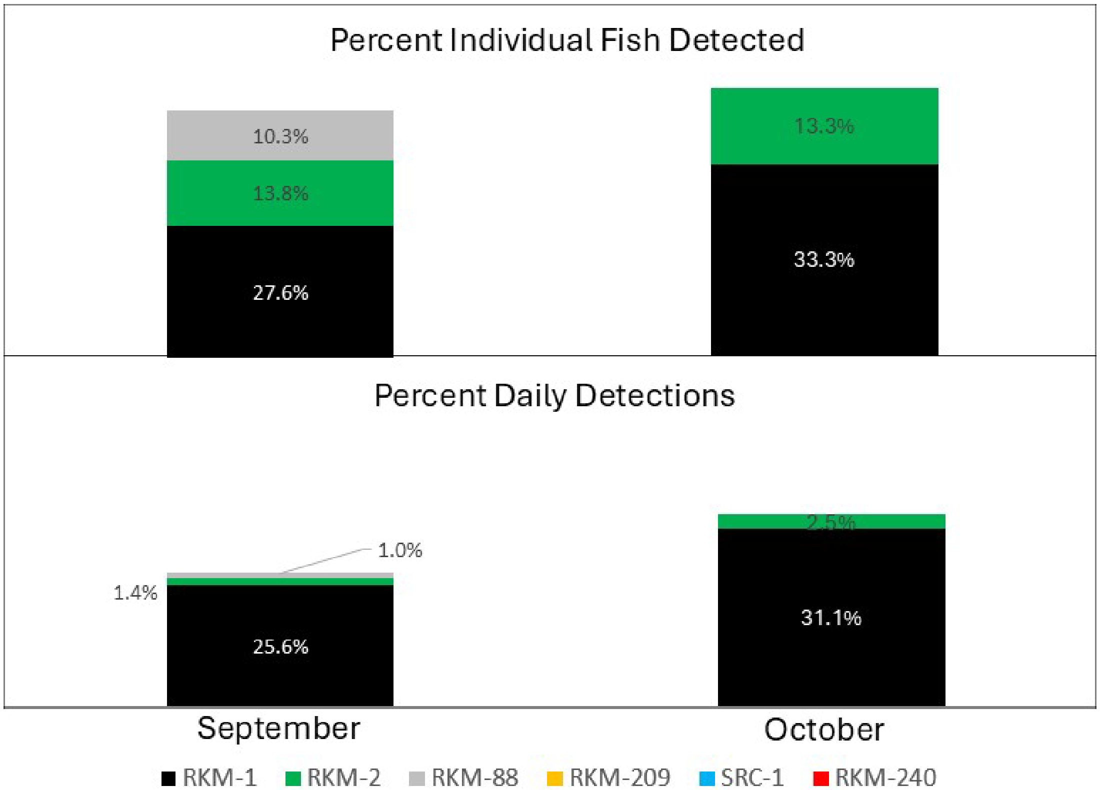


Figure 34. Monthly percent of individual fish (top) and percent of tag detections (middle) by receiver location (river kilometer; RKM) in the Big Sioux River and Split Rock Creek; and Big Sioux River discharge (bottom) at Sioux City, IA, for July and August 2024.



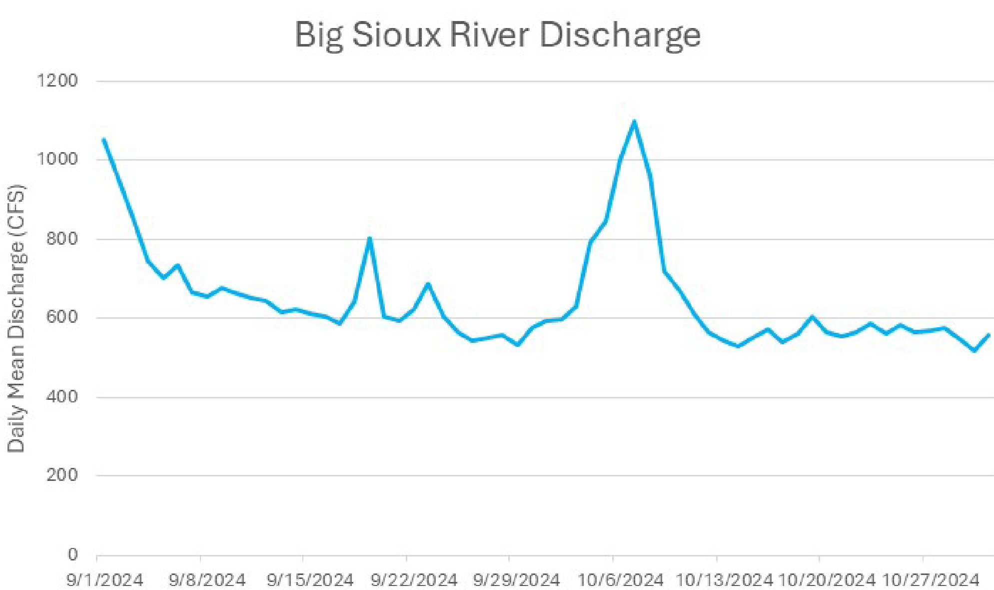


Figure 35. Monthly percent of individual fish (top) and percent of tag detections (middle) by receiver location (river kilometer; RKM) in the Big Sioux River and Split Rock Creek; and Big Sioux River discharge (bottom) at Sioux City, IA, for September and October 2024.

Recommendation:

- Because invasive carp in tributaries are largely residents, barriers and removal efforts could be valuable tools to control populations in these systems. However, tributaries are dynamic systems that are challenging to work in, making working in and managing these systems difficult.
- Monitoring invasive carp movement should continue until movement patterns are elucidated, at which time harvest should be the primary focus. Solidified movement patterns of invasive carp should allow for the most efficient harvest efforts to be carried out.
- Continued telemetry monitoring is recommended to encompass more river conditions and time periods.
- An expanded telemetry network would allow for more fine-scale movement pattern detections.
- Active tracking would allow for increased detections of individuals that are not located near a receiver.

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