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

Geographic Location: 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. Tributaries of interest include:

- 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.
- The Little Sioux River joins the Missouri River at approximately rkm 1,077 and extends into Iowa and Minnesota by way of the Iowa Great Lakes, which are comprised of seven different waterbodies that are extremely important recreationally and economically. This study will focus on the 415 rkm from the confluence with the Missouri River to the electric barrier on the outlet of the Iowa Great Lakes and upstream to the Iowa-Minnesota border. Following flooding in 2012 that allowed invasive carps to invade the Iowa Great Lakes, the Iowa DNR, Minnesota DNR, and local partners installed the electric barrier. In December 2019, a Silver Carp was captured in the Ocheyedan River, about 100 yards from the Iowa border in southwestern Minnesota.
- 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 the concrete spillway on the outlet of Creve Coeur Lake.

Lead Agency: South Dakota Department of Game, Fish and Parks (SDGFP), BJ Schall (benjamin.schall@state.sd.us)

Participating Agencies:

- Iowa Department of Natural Resources (IA DNR) & Iowa State University (ISU); Michael Weber
- Missouri Department of Conservation (MDC); Josh Abner
- South Dakota Department of Game, Fish, and Parks (SDGFP) & University of South Dakota (USD); Tanner Davis, Lindsey LaBrie
- USFWS – Gavins Point National Fish Hatchery (USFWS – Gavins Point NFH); Dan James

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.

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

Project Highlights:

We deployed 28 acoustic receivers throughout the Little Sioux River Basin in Spring 2022 to track the movements of Silver and Bighead Carp. Between May 2022 and May 2023, we tagged 101 Silver Carp and 24 Bighead Carp within the Little Sioux River and four of its tributaries. Our most recent receiver download was completed in mid-November 2023. As of November 15th, 2023, Silver and Bighead Carp were most abundant in tributaries of the Little Sioux River from May - June during both years. Of the 33 fish (24 Bighead and 9 Silver Carp) tagged in Milford Creek, 32 have been detected at least once near the electric barrier and 11 individuals (7 Bighead and 4 Silver Carp) moved back to the Little Sioux River. Overall, movement and detections of individuals during both years was primarily limited to Spring (April – May) and early Summer (June – July) during periods of elevated water levels. In 2022, we received minimal detections of individuals during the Fall and Winter months throughout the study area. However, we did observe 7 Silver Carp in October 2023 make large downstream movements (> 150 rkm) that coincided with an increased discharge event and dropping water temperatures in the Little Sioux River.

Methods:

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; Table 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 that we attached to the downstream side of intersecting highway 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 every desired receiver location (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 2.5m 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 (Table 2). Across all tags, transmitter weight did not exceed 2% of wet weight of fish (Winter 1996). 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]), 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.

Results and Discussion:

We downloaded 27 of our 28 acoustic receivers located throughout the study area at least twice between June and November during 2022 and 2023. Our receiver located in the Missouri River downstream of the Little Sioux River confluence (Station Name: MOR - HW30 Missouri River) was downloaded once a year, but was removed in October 2023 due to low water levels and deployment of additional receivers by USGS. 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. Due to multiple invasive carp leaving the Little Sioux Basin during Summer 2022 and numerous mortality events that likely occurred during Winter, only 9 of the individuals that were tagged and last seen 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 to supplement our data. Of these individuals, five have not been detected anywhere in our array during 2023 (including active tracking efforts in backwater near Linn Grove, IA).

Cumulatively, we acquired 276,885 invasive carp detections (2022: 139,994 detections; 2023: 136,941 detections) on the three receivers located within Milford Creek between May 2022 to November 2023. A majority of these detections (276,682) 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 has been detected near the barrier. Number of fishes detected near the barrier was highest during April – June both years coinciding with increased water levels. The number of individuals detected at the middle and confluence receiver locations were also highest during these months, suggesting individuals were primarily

entering and leaving Milford Creek under high-water conditions (Figure 3). Since May 2022 to November 2023, 8 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 11 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 meters downstream of the electric fish barrier (~75 meters downstream of 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 that was implanted in a Bighead Carp during May 2023. However, the reasoning behind this is unknown (shed transmitter or mortality), and the individual was excluded from all of our analyses.

Of the 92 Silver Carp tagged in the Little Sioux River, only one has been observed 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. For both years, individuals primarily entered tributaries during periods of warming water temperatures (> 10 ºC 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 4). In general, the duration of residency events was short (< 2 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 are still present within each particular system, 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 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 or 2023.

Overall, we primarily observed Silver and Bighead Carp movements during Spring and early Summer months 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 5). Across both 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 from 2023, only two individuals showed evidence of movement 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). However, the Bighead Carp with the latter movement was detected on 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 tagged Silver Carp exhibited at least one upstream movement (mean: 67.2 km ± 8.3 SE) and 33 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 in 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 7). 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 the seven Silver Carp were last detected near the Little Sioux River confluences, suggesting they left the systems during this period (Figure 8). 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 and 2023. 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 suggests movement of invasive carp and potentially their survival may be strongly influenced by the harsh environmental conditions 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.

Tables and Figures:

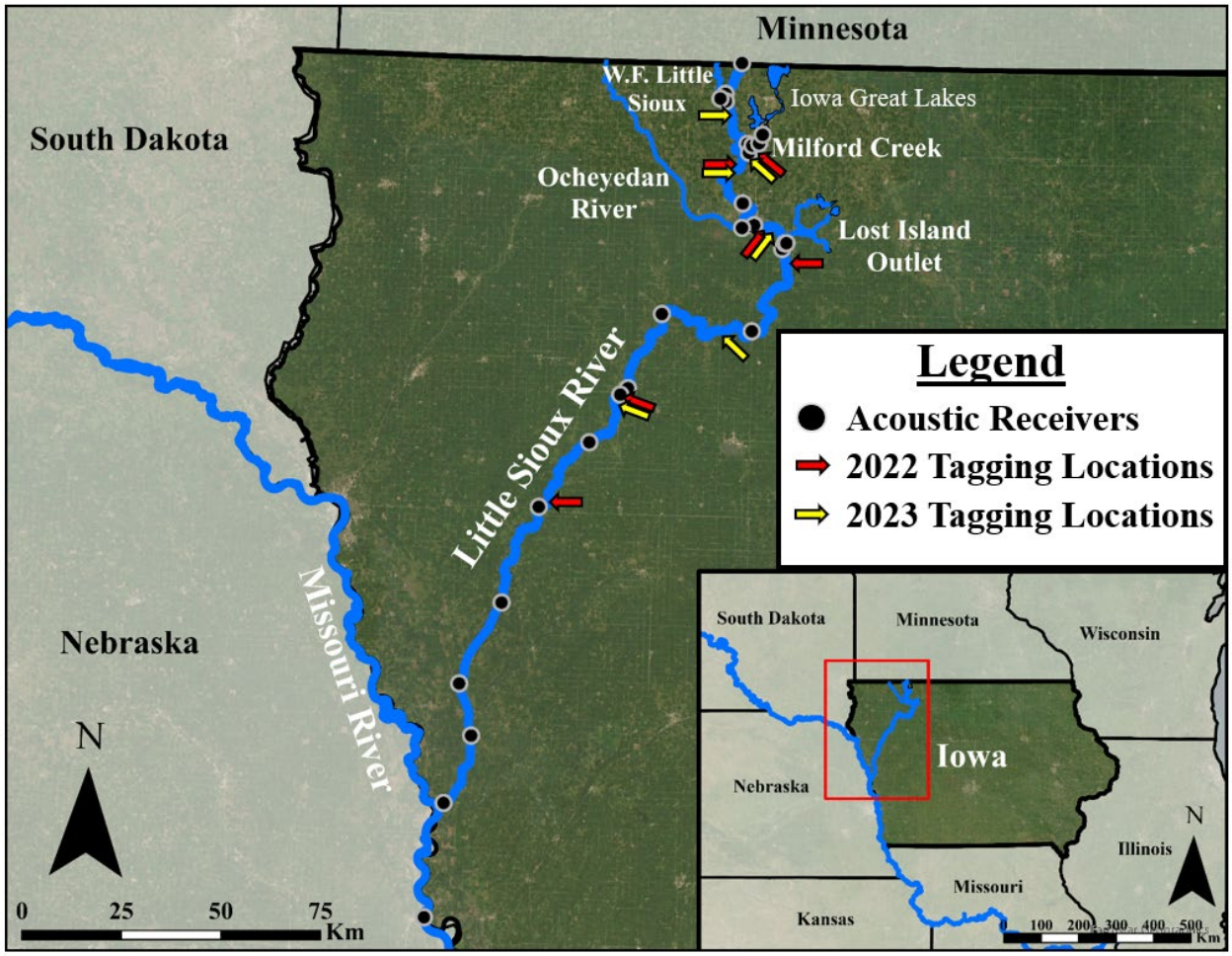

Figure 1. Little Sioux River, four of its tributaries, and the Iowa Great Lakes in Northwest Iowa. Black dots indicate acoustic receiver locations in the Missouri River (1), Little Sioux River (16), West Fork Little Sioux River (2), Milford Creek (3), Ocheyedan River (2), and Lost Island Outlet (2). 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.

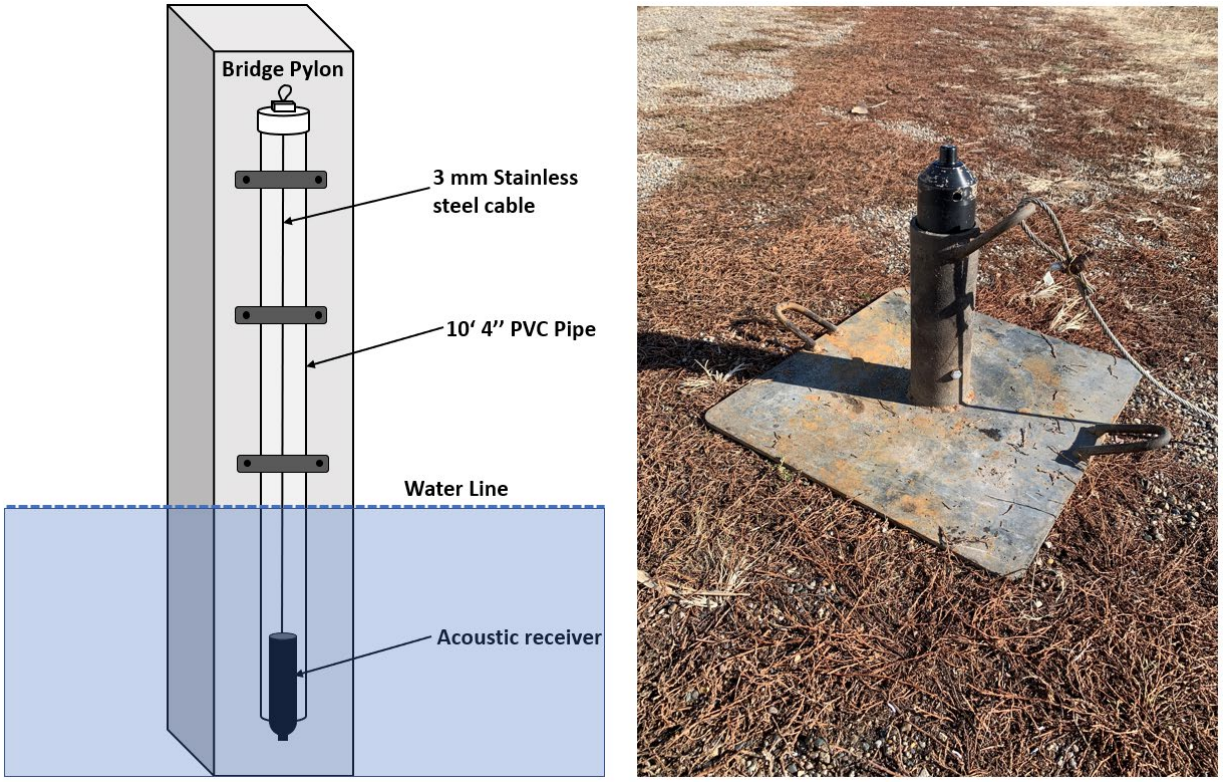

Figure 2: We deployed 19 acoustic receivers in PVC housings attached to the downstream side of intersecting highway bridges (left) and 9 bottom sets (right) throughout the study area (see Table 1, Figure 1 for receiver locations). Bridge mounted receivers were oriented in a downward position and were 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.

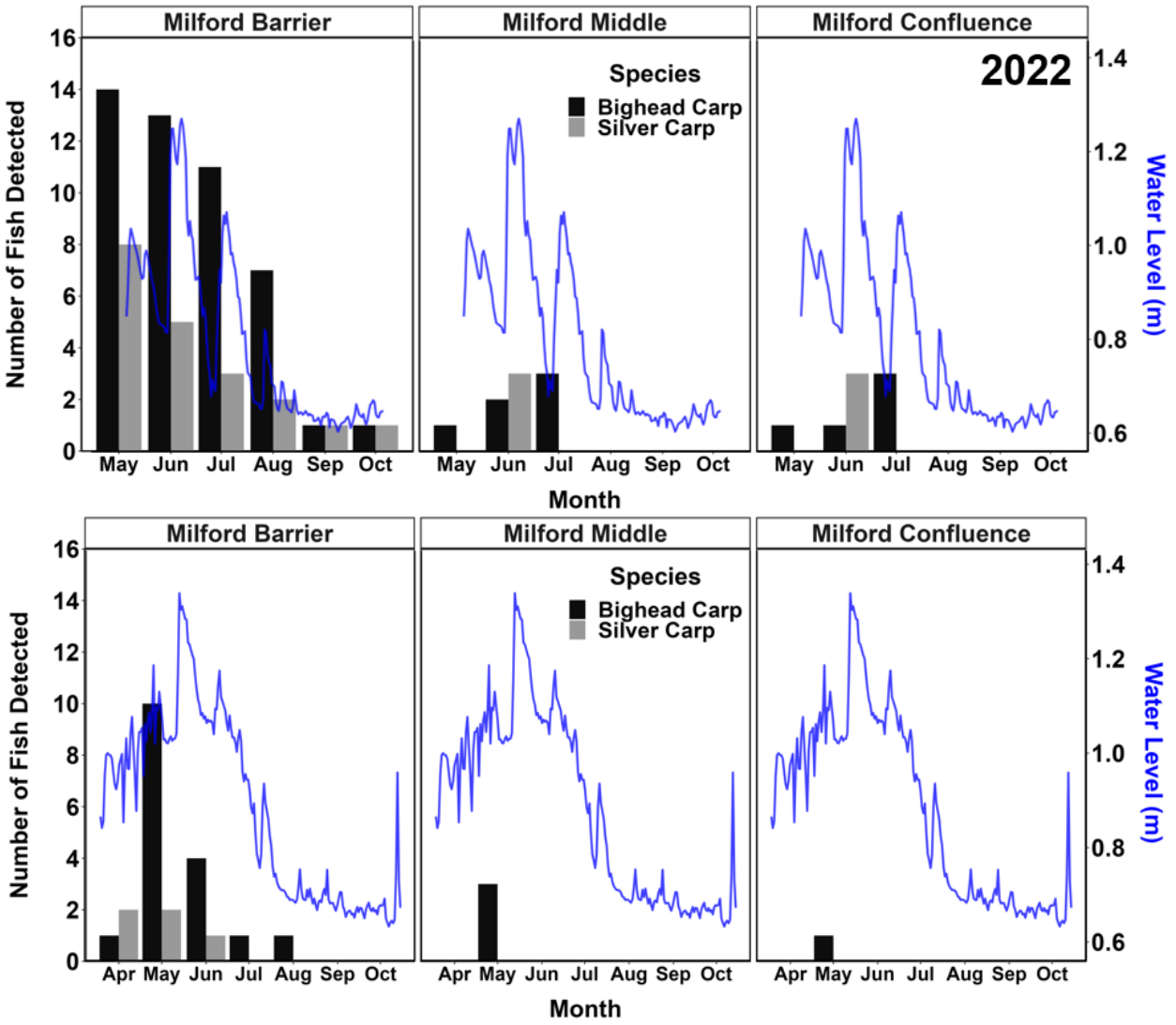

Figure 3: Number of Bighead Carp (black) and Silver Carp (grey) detected at the three receivers in Milford Creek from May - October 2022 (top figure) and March - October 2023 (bottom figure) in relation to water level (m; blue line). No individuals were detected during Winter of either year. Of the 24 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. In total, 11 individuals tagged in Milford Creek have been detected in the Little Sioux River.

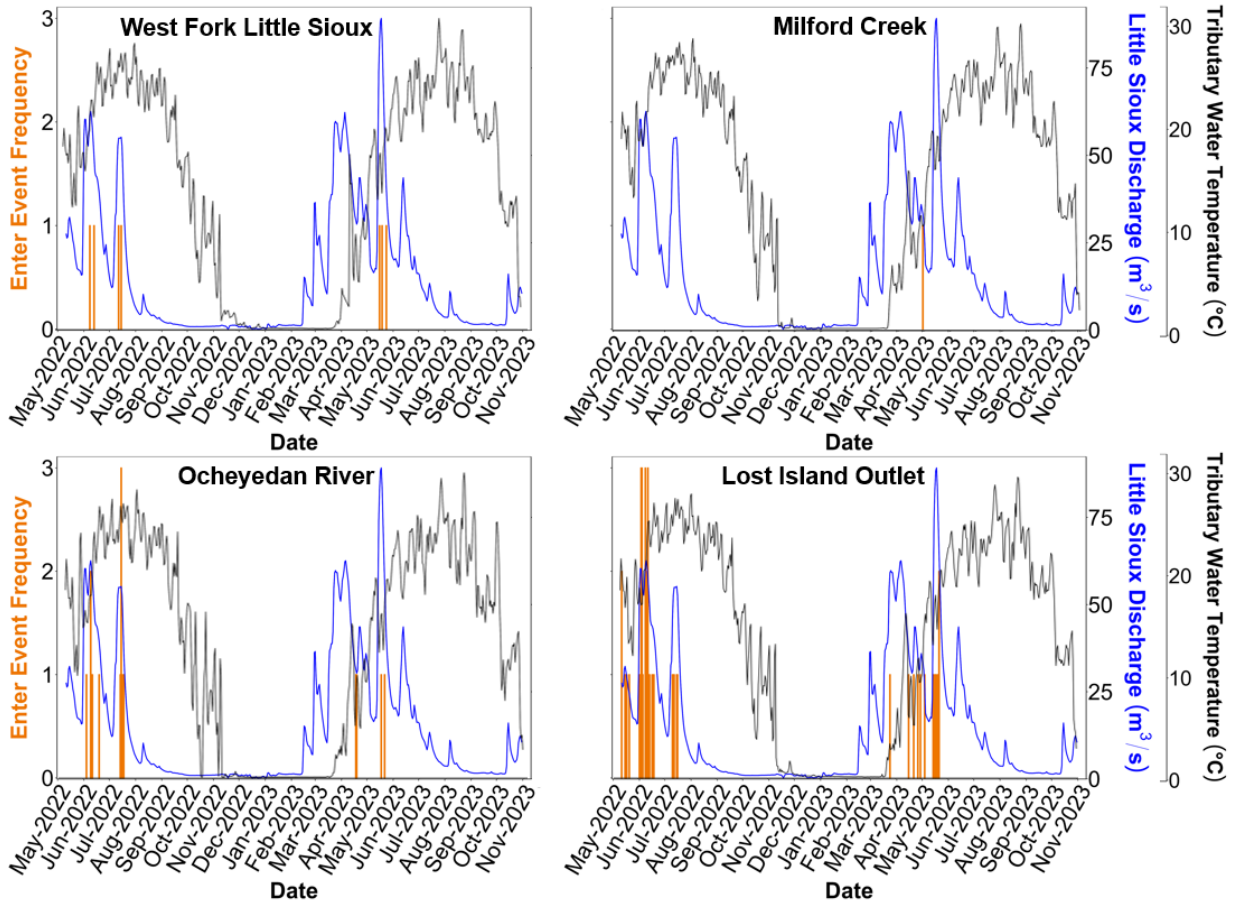

Figure 4: Tributary enter-events (orange bars) of invasive carp into the West Fork Little Sioux River, Milford Creek, Ocheyedan River and Lost Island Outlet from May 2022 to November 2023. Enter events were primarily observed during high discharge events in the Little Sioux River (m^3/s; blue line) when tributary water temperatures (ºC; black line) were 10-25ºC.

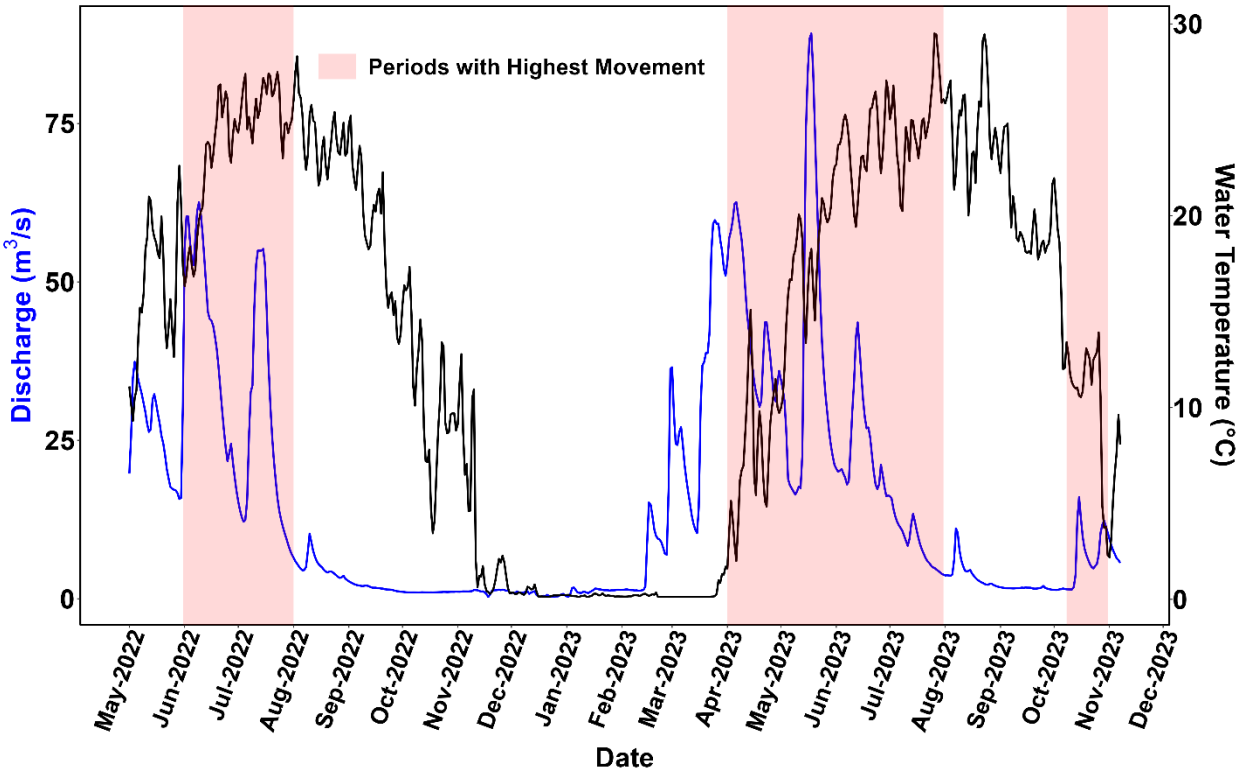

Figure 5: Hydrograph of Little Sioux River from May 2022 to November 2023 at USGS gauging station near Linn Grove, IA (Station ID: 06605850, rkm 220) from the first day invasive carp were tagged in 2022 to the first day receivers were downloaded in November 2023. Invasive carp movements were most apparent 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.

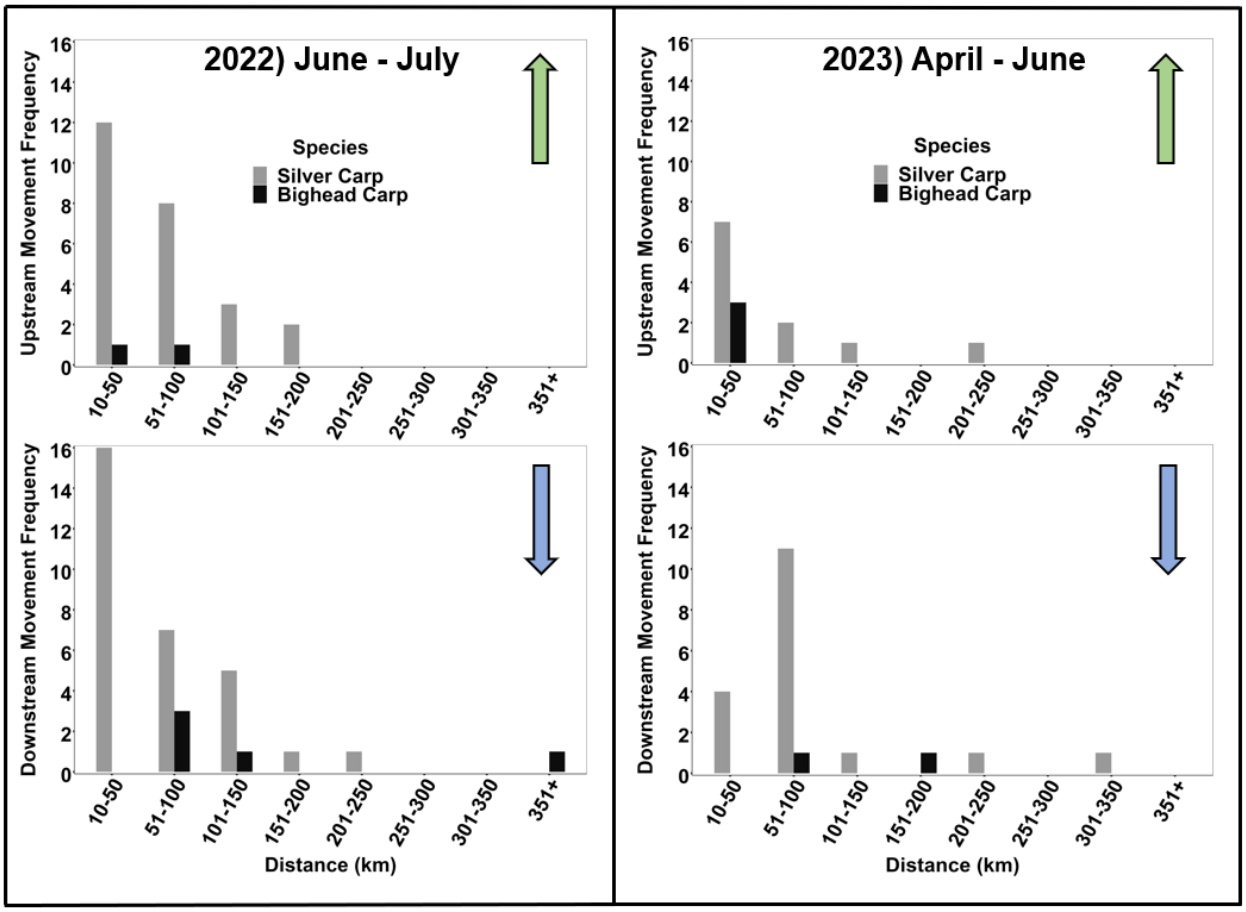

Figure 6: Directional movement event frequencies of Silver Carp (grey bars) and Bighead Carp (black bars) during most active periods in 2022 (left panel) and 2023 (right panel). Note the number of individuals tagged per species and year was not evenly distributed and frequency of movement events were cumulative across all individuals.

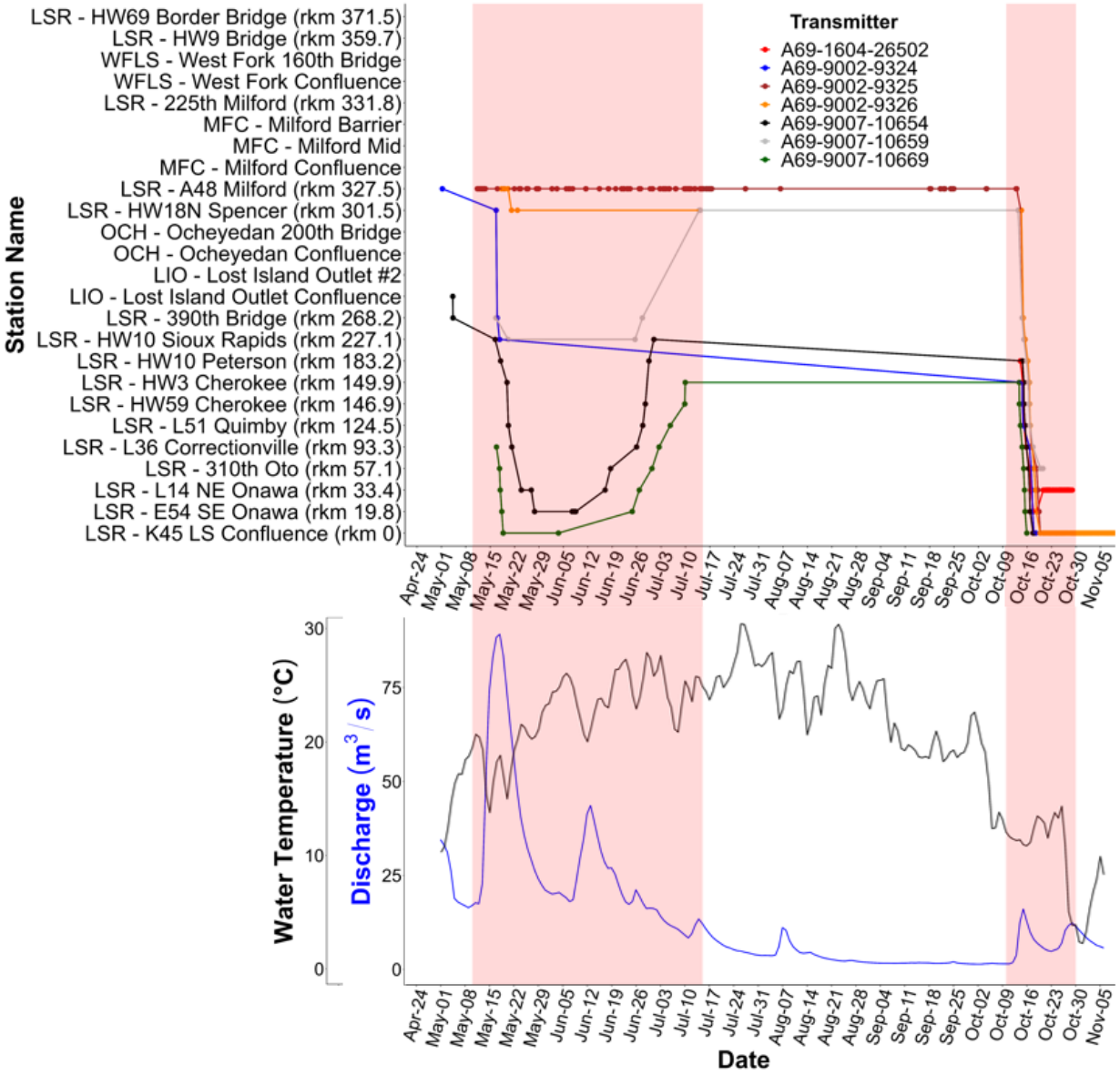

Figure 7: Abacus plot (top panel) showing seven Silver Carp that exhibited Spring, Summer, and Fall movements during 2023 in relation to Little Sioux River discharge and temperature (bottom panel). Spring and Summer movements were primarily observed when discharge (m^3/s; blue line) was > 25 m^3/s and 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.

Deployment Date	Most Recent Download	Removal Date 2022	Redeployment Date 2023	Removal Date 2023	Waterbody	Site Name	Receiver	Latitude	Longitude	Mount Type	# of Detections
5/9/2022	11/8/2023				Little Sioux River	LSR - HW69 Border Bridge	VR2W-137632	43.50078º	-95.2048º	BR, BT*	6
3/18/2022	11/8/2023	11/8/2022	4/12/2023	11/8/2023	Little Sioux River	LSR - HW9 Bridge	VR2W-137283	43.43035º	-95.2536º	BR	269
5/5/2022	11/8/2023			11/8/2023	West Fork Little Sioux River	WFLS - West Fork 160th Bridge	VR2W-137281	43.41947º	-95.2692º	BR, BT*	4
5/11/2022	11/8/2023				West Fork Little Sioux River	WFLS - West Fork Confluence	VR2W-137629	43.41391º	-95.2522º	BT	3,332
5/5/2022	11/7/2023				Little Sioux River	LSR - 225th Milford	VR2W-137645	43.31891º	-95.1813º	BR, BT*	22,855
5/4/2022	11/7/2023				Milford Creek	MFC - Milford Barrier	VR2W-137652	43.34039º	-95.1355º	BT	276,682
5/5/2022	11/7/2023				Milford Creek	MFC - Milford Mid	VR2W-137280	43.32077º	-95.1454º	BT	154
5/5/2022	11/7/2023				Milford Creek	MFC - Milford Confluence	VR2W-137650	43.31537º	-95.1662º	BT	49
5/6/2022	11/7/2023				Little Sioux River	LSR - A48 Milford	VR2W-137272	43.29883º	-95.1762º	BR	154,856
5/9/2022	11/7/2023			11/7/2023	Little Sioux River	LSR - HW18N Spencer	VR2W-137630	43.18427º	-95.1914º	BR, BT*	115
3/18/2022	11/7/2023	11/8/2022	3/31/2023	11/7/2023	Ocheyedan River	OCH - Ocheyedan 200th Bridge	VR2W-137637	43.12872º	-95.1915º	BR	0
5/5/2022	11/7/2023				Ocheyedan River	OCH - Ocheyedan Confluence	VR2W-137660	43.13557º	-95.1546º	BT	430
5/9/2022	11/8/2023				Lost Island Outlet	LIO - Lost Island Outlet #2	VR2W-137634	43.09687º	-95.0533º	BT	1406
5/9/2022	11/8/2023	11/14/2022	3/31/2023	11/8/2023	Lost Island Outlet	LIO - Lost Island Outlet Confluence	VR2W-137289	43.09640º	-95.0578º	BT	29,720
3/18/2022	11/7/2023	11/8/2022	3/24/2023	11/7/2023	Little Sioux River	LSR - 390th Bridge	VR2W-137638	43.08360º	-95.0665º	BR	910
3/17/2022	11/7/2023	11/8/2022	3/24/2023		Little Sioux River	LSR - HW10 Sioux Rapids	VR2W-137282	42.89610º	-95.1534º	BR	272
3/17/2022	11/8/2023	11/8/2022	3/24/2023	11/8/2023	Little Sioux River	LSR - HW10 Peterson	VR2W-137633	42.92970º	-95.4314º	BR	89
3/17/2022	11/8/2023	11/8/2022	3/14/2023		Little Sioux River	LSR - HW3 Cherokee	VR2W-137647	42.75986º	-95.5288º	BR	34
3/17/2022	11/8/2023	11/8/2022	3/14/2023	11/8/2023	Little Sioux River	LSR - HW59 Cherokee	VR2W-137286	42.74499º	-95.5516º	BR	58
3/17/2022	11/15/2023	11/8/2022	3/14/2023		Little Sioux River	LSR - L51 Quimby	VR2W-137644	42.63529º	-95.6421º	BR	51
3/17/2022	11/15/2023				Little Sioux River	LSR - L36 Correctionville	VR2W-137290	42.48583º	-95.7903º	BR, BT*	304
3/17/2022	11/15/2023				Little Sioux River	LSR - 310th Oto	VR2W-137664	42.26710º	-95.8939º	BR, BT*	31
3/17/2022	11/15/2023	11/15/2022	3/15/2023		Little Sioux River	LSR - L14 NE Onawa	VR2W-137636	42.08154º	-96.0142º	BR	282
3/17/2022	11/15/2023				Little Sioux River	LSR - E54 SE Onawa	VR2W-137631	41.96501º	-95.9726º	BR, BT*	285
3/17/2022	11/15/2023				Little Sioux River	LSR - K45 LS Confluence	VR2W-137635	41.81053º	-96.0486º	BR	5752
11/22/2021	10/6/2023			10/6/2023	Missouri River	MOR - HW30 MO River	VR2W-137666	41.55105º	-96.0955º	BR	1
5/16/2022	5/22/2023				Lower Gar Lake	IGL - 18	VR2Tx-487217	43.35534º	-95.1228º	BT	0

4/27/2022	5/22/2023	Lower Gar Lake	IGL - 19	VR2Tx-487221	43.34258º	-95.1240º	BT	0

*Denotes receiver that was converted from Bridge Mount (BR) to Bottom Set (BT) prior to Winter 2022 or 2023
Notes: A total of 10 receivers had to be temporarily had to be removed prior to Winter 2022 due to low water levels. Prior to Winter 2023, 8 receivers were temporarily removed for similar reasons. All detections reported were from Iowa State University transmitters only.

Table 1: Deployment and maintenance information for acoustic receivers located throughout the Little Sioux River Basin. See Figure 1 for visual reference of acoustic receiver locations.

Transmitter ID	Tag Type	Species	Sex	Length (mm)	Weight (kg)	Tagging Waterbody	Tagging Location	Tagging Date	Last Encounter Date	Last Encounter Location	Total Number of Detections	Fate
A69-9007-10699	V16A	Silver Carp	F	814	6.79	Little Sioux River	West Fork WMA	4/12/2023	6/20/2023	WFLS - West Fork Confluence	3155	Unknown
A69-9007-10700	V16A	Silver Carp	M	635	2.85	Little Sioux River	West Fork WMA	4/12/2023	6/12/2023	LSR - 225th Milford	271	Unknown
A69-9007-10701	V16A	Silver Carp	M	637	2.82	Little Sioux River	West Fork WMA	4/14/2023	5/25/2023	WFLS - West Fork Confluence	19	Unknown
A69-9007-10702	V16A	Silver Carp	M	649	3.48	Little Sioux River	West Fork WMA	4/14/2023	5/16/2023	LSR - 225th Milford	1	Unknown
A69-9007-10925	V16T	Silver Carp	M	660	3.15	Milford Creek	Electric Barrier	5/4/2022	6/24/2022	OCH - Ocheyedan Confluence	192	Unknown
A69-9007-10934	V16T	Silver Carp	M	680	3.40	Milford Creek	Electric Barrier	5/4/2022	7/16/2022	MFC - Milford Barrier	4780	Dead
A69-9007-10917	V16A	Silver Carp	M	706	3.92	Milford Creek	Electric Barrier	5/4/2022	5/23/2023	MFC - Milford Barrier	13358	Unknown
A69-9007-10918	V16A	Silver Carp	M	654	3.32	Milford Creek	Electric Barrier	5/4/2022	4/14/2023	MFC - Milford Barrier	17777	Unknown
A69-9007-10919	V16A	Silver Carp	M	605	2.20	Milford Creek	Electric Barrier	5/4/2022	5/14/2022	MFC - Milford Barrier	2277	Dead
A69-9007-10920	V16A	Silver Carp	F	826	5.35	Milford Creek	Electric Barrier	5/4/2022	6/11/2022	OCH - Ocheyedan Confluence	2924	Unknown
A69-9007-10921	V16A	Silver Carp	F	949	10.35	Milford Creek	Electric Barrier	5/4/2022	5/7/2022	MFC - Milford Barrier	835	Dead
A69-9007-10922	V16A	Silver Carp	F	635	3.02	Milford Creek	Electric Barrier	5/4/2022	5/20/2022	MFC - Milford Barrier	937	Dead
A69-9007-10924	V16A	Silver Carp	M	622	2.80	Milford Creek	Electric Barrier	5/4/2022	6/21/2022	MFC - Milford Confluence	4177	Dead
A69-1604-29691	V16	Bighead Carp	F	688	3.62	Milford Creek	Electric Barrier	5/9/2022	7/11/2022	LSR - HW10 Sioux Rapids	6018	Dead
A69-1604-29695	V16	Bighead Carp	F	731	3.75	Milford Creek	Electric Barrier	5/9/2022	5/29/2023	MFC - Milford Barrier	14282	Dead
A69-1604-29696	V16	Bighead Carp	F	660	2.58	Milford Creek	Electric Barrier	5/9/2022	8/20/2022	MFC - Milford Barrier	7033	Dead
A69-1604-29698	V16	Bighead Carp	M	522	2.46	Milford Creek	Electric Barrier	5/9/2022	8/4/2023	MFC - Milford Barrier	47979	Dead
A69-1604-29699	V16	Bighead Carp	M	629	2.77	Milford Creek	Electric Barrier	5/9/2022	8/1/2022	MFC - Milford Barrier	4318	Dead
A69-1604-29701	V16	Bighead Carp	F	695	3.70	Milford Creek	Electric Barrier	5/9/2022	7/24/2022	Ohio River Confluence	6644	Unknown
A69-1604-29702	V16	Bighead Carp	F	671	3.15	Milford Creek	Electric Barrier	5/9/2022	6/7/2023	MFC - Milford Barrier	23500	Dead
A69-1604-29704	V16	Bighead Carp	M	610	2.00	Milford Creek	Electric Barrier	5/9/2022	5/29/2023	LSR - HW10 Sioux Rapids	4407	Alive
A69-1604-29706	V16	Bighead Carp	F	727	3.70	Milford Creek	Electric Barrier	5/9/2022	7/20/2023	MFC - Milford Barrier	43053	Dead
A69-1604-29707	V16	Bighead Carp	F	631	2.58	Milford Creek	Electric Barrier	5/9/2022	6/19/2023	LSR - HW3 Cherokee	21238	Alive

A69-1604-29709	V16	Bighead Carp	F	685	3.63	Milford Creek	Electric Barrier	5/9/2022	8/30/2023	Linn Grove, IA Backwater	270	Alive
A69-1604-29710	V16	Bighead Carp	F	758	3.75	Milford Creek	Electric Barrier	5/9/2022	7/4/2022	MFC - Milford Barrier	2169	Dead
A69-1604-29711	V16	Bighead Carp	M	671	3.33	Milford Creek	Electric Barrier	5/9/2022	6/27/2022	MFC - Milford Barrier	7088	Dead
A69-1604-29712	V16	Bighead Carp	M	613	2.67	Milford Creek	Electric Barrier	5/9/2022	5/19/2023	LSR - 390th Bridge	3150	Unknown
A69-1604-26505	V16	Bighead Carp	F	687	4.73	Milford Creek	Electric Barrier	5/16/2023	6/1/2023	MFC - Milford Barrier	2040	Unknown
A69-1604-26506	V16	Bighead Carp	M	660	3.07	Milford Creek	Electric Barrier	5/16/2023	5/17/2023	MFC - Milford Barrier	163	Unknown
A69-1604-26507	V16	Bighead Carp	F	740	4.19	Milford Creek	Electric Barrier	5/16/2023	5/19/2023	LSR - HW69 Border Bridge	102	Unknown
A69-1604-26508	V16	Bighead Carp	M	694	3.76	Milford Creek	Electric Barrier	5/16/2023	8/6/2023	MFC - Milford Barrier	27896	Dead
A69-1604-26509	V16	Bighead Carp	F	626	2.81	Milford Creek	Electric Barrier	5/16/2023	5/17/2023	MFC - Milford Barrier	53	Unknown
A69-1604-26511	V16	Bighead Carp	F	706	4.95	Milford Creek	Electric Barrier	5/16/2023	5/17/2023	MFC - Milford Barrier	81	Unknown
A69-1604-26512	V16	Bighead Carp	F	688	4.58	Milford Creek	Electric Barrier	5/16/2023	6/14/2023	MFC - Milford Barrier	6412	Unknown
A69-1604-26513	V16	Bighead Carp	F	689	3.33	Milford Creek	Electric Barrier	5/16/2023	5/19/2023	WFLS - West Fork 160th Bridge	121	Unknown
A69-1604-26514	V16	Bighead Carp	F	676	3.88	Milford Creek	Electric Barrier	5/16/2023	6/24/2023	MFC - Milford Barrier	2481	Unknown
A69-1604-29697	V16	Silver Carp	M	628	3.01	Little Sioux River	A48 Bridge	5/6/2022	7/19/2022	WFLS - West Fork Confluence	118	Dead
A69-1604-29700	V16	Silver Carp	M	626	2.93	Little Sioux River	A48 Bridge	5/6/2022	5/10/2022	LSR - A48 Milford	1	Dead
A69-1604-29703	V16	Silver Carp	F	668	3.74	Little Sioux River	A48 Bridge	5/6/2022	7/5/2023	LSR - HW10 Peterson	640	Unknown
A69-1604-29705	V16	Silver Carp	M	711	4.02	Little Sioux River	A48 Bridge	5/6/2022	7/6/2023	LSR - A48 Milford	64291	Dead
A69-1604-29708	V16	Silver Carp	M	690	3.90	Little Sioux River	A48 Bridge	5/6/2022	6/13/2023	LSR - HW18N Spencer	644	Unknown
A69-9007-10923	V16A	Silver Carp	F	750	5.19	Little Sioux River	A48 Bridge	5/6/2022	5/11/2022	LIO - Lost Island Outlet Confluence	15	Unknown
A69-9007-10926	V16T	Silver Carp	M	705	3.38	Little Sioux River	A48 Bridge	5/6/2022	6/22/2022	WFLS - West Fork Confluence	8265	Unknown
A69-9007-10927	V16T	Silver Carp	F	542	1.85	Little Sioux River	A48 Bridge	5/6/2022	8/4/2022	LSR - A48 Milford	13522	Dead
A69-9007-10929	V16T	Silver Carp	M	672	3.23	Little Sioux River	A48 Bridge	5/6/2022	5/22/2023	LSR - HW18 Spencer	48	Unknown
A69-9007-10930	V16T	Silver Carp	M	658	3.20	Little Sioux River	A48 Bridge	5/6/2022	6/10/2022	LSR - HW10 Sioux Rapids	47	Dead
A69-9007-10932	V16T	Silver Carp	M	680	3.95	Little Sioux River	A48 Bridge	5/6/2022	8/10/2022	LSR - 390th Bridge	345	Dead
A69-9007-10933	V16T	Silver Carp	F	621	2.92	Little Sioux River	A48 Bridge	5/6/2022	NA	NA	NA	Dead
A69-9007-10915	V16A	Silver Carp	F	676	3.63	Little Sioux River	A48 Bridge	5/6/2022	6/2/2022	LSR - HW10 Sioux Rapids	60	Unknown
A69-9007-10916	V16A	Silver Carp	M	670	3.94	Little Sioux River	A48 Bridge	5/6/2022	7/12/2022	LSR - LSR 390th Bridge	12	Dead
A69-9007-10928	V16T	Silver Carp	M	626	3.55	Little Sioux River	A48 Bridge	5/6/2022	12/28/2023	LSR - A48 Milford	58240	Dead
A69-9007-10931	V16T	Silver Carp	M	620	2.78	Little Sioux River	A48 Bridge	5/6/2022	6/18/2022	LSR - HW10 Sioux Rapids	5227	Dead

A69-9002-9325	V16A	Silver Carp	F	578	2.29	Little Sioux River	A48 Bridge	4/24/2023	10/19/2023	LSR - K45 LS Confluence	3867	Unknown
A69-9002-9326	V16A	Silver Carp	F	589	2.49	Little Sioux River	A48 Bridge	4/24/2023	11/15/2023	LSR - K45 LS Confluence	5637	Unknown
A69-9007-10656	V16T	Silver Carp	M	654	3.26	Little Sioux River	A48 Bridge	4/24/2023	4/29/2023	LSR - 390th Bridge	6	Unknown
A69-9007-10657	V16T	Silver Carp	F	626	3.01	Little Sioux River	A48 Bridge	4/24/2023	NA	NA	NA	Dead
A69-9007-10658	V16T	Silver Carp	M	533	1.52	Little Sioux River	A48 Bridge	4/24/2023	5/18/2023	LSR - 390th Bridge	67	Unknown
A69-9007-10659	V16T	Silver Carp	M	696	4.18	Little Sioux River	A48 Bridge	4/24/2023	10/20/2023	LSR - 310th Oto	78	Unknown
A69-9007-10670	V16A	Silver Carp	F	568	2.12	Little Sioux River	A48 Bridge	4/24/2023	5/30/2023	LSR - 390th Bridge	362	Unknown
A69-9002-9323	V16A	Silver Carp	F	609	2.89	Little Sioux River	A48 Bridge	4/24/2023	10/12/2023	LSR - A48 Milford	20685	Alive
A69-9002-9324	V16A	Silver Carp	F	556	1.87	Little Sioux River	A48 Bridge	4/24/2023	10/18/2023	LSR - K45 LS Confluence	71	Unknown
A69-9007-10655	V16T	Silver Carp	F	530	1.74	Little Sioux River	A48 Bridge	4/24/2023	6/7/2023	MFC - Milford Barrier	437	Unknown
A69-1602-49651	V13	Silver Carp	M	654	2.81	Little Sioux River	Spencer, IA	5/16/2022	6/10/2022	LSR - 390th Bridge	124	Dead
A69-1604-29718	V16	Silver Carp	F	800	6.08	Little Sioux River	Spencer, IA	5/16/2022	6/8/2022	LSR - HW18N Spencer	4	Dead
A69-1604-29719	V16	Silver Carp	M	649	3.26	Little Sioux River	Spencer, IA	5/16/2022	5/11/2023	LIO - Lost Island Outlet Confluence	28117	Dead
A69-1604-29720	V16	Silver Carp	F	661	3.68	Little Sioux River	Spencer, IA	5/16/2022	6/12/2022	LSR - 390th Bridge	26	Dead
A69-1604-29717	V16	Silver Carp	M	621	2.73	Little Sioux River	Spencer, IA	5/17/2022	6/18/2022	LSR - 390th Bridge	44	Dead
A69-9007-10696	V16A	Silver Carp	M	678	3.49	Little Sioux River	Spencer, IA	4/12/2023	4/15/2023	LSR - HW18N Spencer	21	Unknown
A69-9007-10698	V16A	Silver Carp	M	649	3.28	Little Sioux River	Spencer, IA	4/12/2023	6/15/2023	LSR - K45 LS Confluence	26	Unknown
A69-9007-10668	V16A	Silver Carp	M	642	2.90	Little Sioux River	Spencer, IA	4/14/2023	4/26/2023	LSR - HW10 Sioux Rapids	138	Unknown
A69-9007-10654	V16T	Silver Carp	M	555	1.80	Little Sioux River	Spencer, IA	4/17/2023	10/17/2023	LSR - K45 LS Confluence	268	Unknown
A69-9007-10695	V16A	Silver Carp	M	583	2.04	Little Sioux River	Spencer, IA	4/17/2023	5/3/2023	LSR - HW10 Sioux Rapids	8	Unknown
A69-9007-10660	V16T	Silver Carp	M	560	1.85	Little Sioux River	Spencer, IA	5/3/2023	6/8/2023	LSR - HW10 Sioux Rapids	16	Unknown
A69-1604-29692	V16	Silver Carp	M	629	2.55	Little Sioux River	Dickens, IA	5/10/2022	6/12/2022	LSR - 390th Bridge	11	Dead
A69-1604-29693	V16	Silver Carp	F	681	3.63	Little Sioux River	Dickens, IA	5/10/2022	5/20/2022	LSR - 390th Bridge	234	Dead
A69-1604-29694	V16	Silver Carp	M	675	3.37	Little Sioux River	Dickens, IA	5/10/2022	7/21/2022	LSR - HW18N Spencer	1538	Dead
A69-1604-29721	V16	Silver Carp	F	636	2.86	Little Sioux River	Dickens, IA	5/10/2022	6/17/2022	LSR - 390th Bridge	25	Dead
A69-1604-29722	V16	Silver Carp	M	608	2.43	Little Sioux River	Dickens, IA	5/10/2022	6/17/2022	LSR - HW10 Sioux Rapids	9	Dead
A69-1604-29723	V16	Silver Carp	M	624	2.58	Little Sioux River	Dickens, IA	5/10/2022	6/26/2022	LSR - HW10 Sioux Rapids	37	Dead
A69-1604-29724	V16	Silver Carp	M	670	3.27	Little Sioux River	Dickens, IA	5/10/2022	6/18/2022	LSR - HW10 Sioux Rapids	4	Dead
A69-1604-29725	V16	Silver Carp	M	656	3.44	Little Sioux River	Dickens, IA	5/10/2022	7/12/2022	LSR - 390th Bridge	20	Dead

A69-1604-29726	V16	Silver Carp	M	649	3.15	Little Sioux River	Dickens, IA	5/10/2022	6/18/2022	LSR - HW10 Sioux Rapids	9	Dead
A69-1604-29727	V16	Silver Carp	M	735	3.88	Little Sioux River	Dickens, IA	5/10/2022	5/21/2022	LSR - 390th Bridge	247	Dead
A69-1604-29728	V16	Silver Carp	M	650	2.92	Little Sioux River	Dickens, IA	5/10/2022	5/22/2022	LSR - HW10 Sioux Rapids	2	Dead
A69-1604-29729	V16	Silver Carp	M	826	5.78	Little Sioux River	Dickens, IA	5/10/2022	7/12/2022	LSR - 390th Bridge	28	Dead
A69-1604-29730	V16	Silver Carp	M	761	4.36	Little Sioux River	Dickens, IA	5/10/2022	NA	NA	NA	Dead
A69-1604-29743	V13	Silver Carp	M	466	1.03	Little Sioux River	Dickens, IA	5/10/2022	NA	NA	NA	Dead
A69-1604-29744	V13	Silver Carp	M	531	1.48	Little Sioux River	Dickens, IA	5/10/2022	6/22/2022	LSR - HW10 Sioux Rapids	8	Dead
A69-1604-29749	V13	Silver Carp	M	554	1.83	Little Sioux River	Dickens, IA	5/10/2022	7/5/2022	LSR - 390th Bridge	49	Dead
A69-1604-29750	V13	Silver Carp	M	517	1.44	Little Sioux River	Dickens, IA	5/10/2022	NA	NA	NA	Dead
A69-9007-10634	V16T	Silver Carp	F	513	1.73	Little Sioux River	Linn Grove, IA	5/9/2023	5/14/2023	LSR - HW10 Sioux Rapids	41	Unknown
A69-9007-10635	V16T	Silver Carp	F	565	2.26	Little Sioux River	Linn Grove, IA	5/9/2023	NA	NA	NA	Unknown
A69-9007-10661	V16T	Silver Carp	M	541	1.87	Little Sioux River	Linn Grove, IA	5/9/2023	NA	NA	NA	Unknown
A69-9007-10697	V16A	Silver Carp	M	572	2.04	Little Sioux River	Linn Grove, IA	5/9/2023	5/12/2023	LSR - HW10 Peterson	1	Alive
A69-1604-26502	V16	Silver Carp	F	579	2.36	Little Sioux River	Linn Grove, IA	5/10/2023	10/28/2023	LSR - L14 NE Onawa	261	Alive
A69-9007-10633	V16T	Silver Carp	M	541	1.68	Little Sioux River	Linn Grove, IA	5/10/2023	5/19/2023	LSR - HW10 Sioux Rapids	6	Unknown
A69-1604-26485	V13	Silver Carp	F	627	3.21	Little Sioux River	Linn Grove, IA	5/15/2023	6/21/2023	Linn Grove, IA Backwater	0*	Alive
A69-1604-26486	V13	Silver Carp	M	579	2.06	Little Sioux River	Linn Grove, IA	5/15/2023	NA	NA	NA	Unknown
A69-1604-26487	V13	Silver Carp	M	542	1.92	Little Sioux River	Linn Grove, IA	5/15/2023	8/30/2023	Linn Grove, IA Backwater	0*	Alive
A69-1604-26488	V13	Silver Carp	F	541	1.72	Little Sioux River	Linn Grove, IA	5/15/2023	6/21/2023	Linn Grove, IA Backwater	0*	Alive
A69-1604-26489	V13	Silver Carp	F	678	3.89	Little Sioux River	Linn Grove, IA	5/15/2023	8/30/2023	Linn Grove, IA Backwater	0*	Alive
A69-1604-26503	V16	Silver Carp	F	549	1.95	Little Sioux River	Linn Grove, IA	5/15/2023	8/30/2023	Linn Grove, IA Backwater	0*	Alive
A69-1604-26504	V16	Silver Carp	F	584	2.49	Little Sioux River	Linn Grove, IA	5/15/2023	NA	NA	NA	Unknown
A69-1604-29713	V16	Silver Carp	M	637	2.81	Little Sioux River	Cherokee, IA	5/17/2022	7/17/2022	OCH - Ocheyedan Confluence	38	Dead
A69-1604-29714	V16	Silver Carp	M	695	2.54	Little Sioux River	Cherokee, IA	5/17/2022	6/13/2022	LSR - K45 LS Confluence	20	Unknown
A69-1604-29715	V16	Silver Carp	M	704	3.39	Little Sioux River	Cherokee, IA	5/17/2022	7/22/2022	LSR - HW10 Peterson	8	Dead
A69-1604-29731	V13	Silver Carp	M	674	3.50	Little Sioux River	Cherokee, IA	5/17/2022	3/29/2023	LSR - HW10 Peterson	13	Alive
A69-1604-29732	V13	Silver Carp	M	680	3.42	Little Sioux River	Cherokee, IA	5/17/2022	7/11/2022	LSR - 390th Bridge	53	Dead
A69-1604-29733	V13	Silver Carp	M	639	2.74	Little Sioux River	Cherokee, IA	5/17/2022	NA	NA	NA	Dead
A69-1604-29734	V13	Silver Carp	M	669	2.93	Little Sioux River	Cherokee, IA	5/17/2022	6/12/2022	LSR - HW10 Peterson	7	Dead

A69-1604-29735	V13	Silver Carp	M	609	2.43	Little Sioux River	Cherokee, IA	5/17/2022	5/19/2022	LSR - L51 Quimby	1	Dead
A69-1604-29736	V13	Silver Carp	F	682	4.07	Little Sioux River	Cherokee, IA	5/17/2022	6/14/2022	LSR - HW59 Cherokee	13	Dead
A69-1604-29737	V13	Silver Carp	M	628	2.88	Little Sioux River	Cherokee, IA	5/17/2022	6/25/2022	LSR - L36 Correctionville	5	Dead
A69-1604-29738	V13	Silver Carp	M	618	2.52	Little Sioux River	Cherokee, IA	5/17/2022	7/8/2022	LSR - 390th Bridge	17	Dead
A69-1604-29739	V13	Silver Carp	M	677	3.38	Little Sioux River	Cherokee, IA	5/17/2022	6/13/2022	LSR - HW10 Peterson	5	Dead
A69-1604-29740	V13	Silver Carp	M	635	2.61	Little Sioux River	Cherokee, IA	5/17/2022	7/15/2022	LSR - HW10 Sioux Rapids	7	Dead
A69-1604-29745	V13	Silver Carp	F	531	1.72	Little Sioux River	Cherokee, IA	5/17/2022	5/19/2022	LSR - HW10 Peterson	2	Dead
A69-1604-29716	V16	Silver Carp	M	809	5.26	Little Sioux River	Cherokee, IA	5/17/2022	6/29/2022	LSR - HW10 Sioux Rapids	12	Dead
A69-9007-10669	V16A	Silver Carp	M	742	4.27	Little Sioux River	Cherokee, IA	4/18/2023	10/15/2023	LSR - K45 LS Confluence	58	Alive
A69-1604-29741	V13	Silver Carp	M	638	2.89	Little Sioux River	Correctionville, IA	5/18/2022	6/11/2022	LSR - 390th Bridge	9	Dead
A69-1604-29742	V13	Silver Carp	F	675	3.60	Little Sioux River	Correctionville, IA	5/18/2022	9/4/2022	Platte River, NE	261	Unknown
A69-1604-29746	V13	Silver Carp	M	611	2.29	Little Sioux River	Correctionville, IA	5/18/2022	5/19/2022	LSR - L36 Correctionville	3	Dead
A69-1604-29747	V13	Silver Carp	M	628	2.40	Little Sioux River	Correctionville, IA	5/18/2022	6/21/2022	LSR - L51 Quimby	4	Dead
A69-1604-29748	V13	Silver Carp	F	674	3.28	Little Sioux River	Correctionville, IA	5/18/2022	7/13/2022	LSR - K45 LS Confluence	25	Unknown

*Denotes individual was never detected on a passive receiver throughout our array, but was detected with active hydrophone during at least one of the two tracking occasions that took place in a backwater area of the Little Sioux River near Linn Grove, IA during Summer 2023

Notes: For fish fate, individuals that were detected since August 1st, 2023 were listed as "Alive". Fish listed with "Unknown" fates were either tagged in 2023 but never detected at all in our array, last detected prior to August 1st, 2023, or last detected at the furthest upstream/downstream edge of our acoustic array. Individuals were assigned "Dead" fates if they were never/last detected in 2022 and not again during 2023, appeared to have continuous detections at a single receiver over long time periods, or fish that were tagged in 2022 within Milford Creek that haven't been detected since multiple days following their tagging date.

Table 2. Tagging and encounter information for Silver and Bighead Carp tagged in the Little Sioux River Basin, Iowa.

References

Lederman, N. J., S. A. Love, R. L. Anderson, J. A. DeBoer, and J. T. Lamer. 2022. Using pectoral fin ridges to assign sex to Bighead Carp *Hypophthalmichthys nobilis*. North American Journal of Fisheries Management 42:1003-1010.

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Wolf, M. C., Q. E. Phelps, J. R. Seibert, and S. J. Tripp. 2018. A rapid assessment approach for evaluating Silver Carp gender. Acta Hydrobiologica Sinica 42:1081-1083.

Agency: Missouri Department of Conservation

Methods:

Eighty-three additional invasive silver carp were implanted with acoustic transmitters during winter 2023 (Table 1). Seventy-three of those were tagged in the Kansas River, while the remaining ten were tagged in the Grand River (Figure 1). One additional stationary telemetry receiver was added to the Missouri River system during 2023. This receiver was placed near the mouth of the Kansas River just upstream of Kaw Point access (Table 2). The 21 previously deployed telemetry receivers were downloaded and maintained quarterly throughout 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 original 237 invasive carp tagged, 121 were detected at least a single day during 2023. One hundred twenty of those carp were not detected outside the lower Missouri River system, while one carp (tagged in Creve Coeur Creek) traveled approximately 291.0 river miles downstream to the lower Mississippi River and was detected at New Madird, MO (Figure 2). Eighty-four 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. Five carp tagged in Creve Coeur Creek left that tributary and traveled approximately 4.0 to 171.5 river miles (total distance from tributary, not accounting for total distance actually traveled) from Creve Coeur Creek within the Missouri River (Figure 3). Twelve invasive carp tagged in the Moreau River left that tributary and traveled approximately 17.8 to 510.0 river miles from the Moreau River within the Missouri River (Table 3). Seventeen invasive carp tagged in the Lamine River left that tributary and traveled approximatley 7.1 to 447.0 river miles from the Lamine River within the Missouri River (Table 3). Two invasive carp tagged in the Grand River left that tributary and traveled approximately 55.1 to 145.6 river miles from the Grand River within the Missouri River (Table 3). The two invasive carp, one each from the Moreau and Lamine Rivers, that traveled approximatley 447.0 to 510.0 river miles, respectively, were detected near Blair, NE (Figure 4). Movement patterns should be assessed in depth to further assist with harvest efforts.

Tables and Figures:

Table 1. Data relevant to invasive carp tagging: date, location, latitude, longitude, length, sex, weight (grams), transmitter ID, and floy tag number. All fish tagged were silver carp.

Date	Location	Latitude	Longitude	Length	Sex	Weight	Transmitter ID	Floy Tag
11/27/2023	Kansas River	39.11204	-94.61529	655	M	2780	A69-1604-27488	ORFS44264
11/27/2023	Kansas River	39.11204	-94.61529	629	M	2860	A69-1604-27489	ORFS44270
11/27/2023	Kansas River	39.11204	-94.61529	671	M	3380	A69-1604-27490	ORFS44265
11/27/2023	Kansas River	39.11204	-94.61529	652	M	3420	A69-1604-27491	ORFS44271
11/27/2023	Kansas River	39.11204	-94.61529	696	M	3520	A69-1604-27492	ORFS44266
11/27/2023	Kansas River	39.11204	-94.61529	646	F	3180	A69-1604-27493	ORFS44272
11/27/2023	Kansas River	39.11204	-94.61529	674	F	2060	A69-1604-27494	ORFS44267
11/27/2023	Kansas River	39.11204	-94.61529	618	M	2720	A69-1604-27495	ORFS44273
11/27/2023	Kansas River	39.11204	-94.61529	620	M	2520	A69-1604-27496	ORFS44268

11/27/2023	Kansas River	39.11204	-94.61529	721	F	4180	A69-1604-27497	ORFS44274
11/27/2023	Kansas River	39.11204	-94.61529	631	M	2780	A69-1604-27498	ORFS44269
11/27/2023	Kansas River	39.11204	-94.61529	692	M	3560	A69-1604-27499	ORFS44275
11/27/2023	Kansas River	39.11204	-94.61529	665	F	3420	A69-1604-27500	ORFS44702
11/27/2023	Kansas River	39.11204	-94.61529	715	M	4280	A69-1604-27501	ORFS44703
11/27/2023	Kansas River	39.11204	-94.61529	614	F	2920	A69-1604-27502	ORFS44704
11/27/2023	Kansas River	39.11204	-94.61529	714	F	4000	A69-1604-27503	ORFS44705
11/27/2023	Kansas River	39.11204	-94.61529	633	M	2920	A69-1604-27504	ORFS44706
11/27/2023	Kansas River	39.11204	-94.61529	609	M	2680	A69-1604-27505	ORFS44707
11/27/2023	Kansas River	39.11204	-94.61529	615	M	2680	A69-1604-27506	ORFS44708
11/28/2023	Kansas River	39.09779	-94.61165	611	M	2300	A69-1604-27507	ORFS44709
11/28/2023	Kansas River	39.09779	-94.61165	571	M	2200	A69-1604-27508	ORFS44710
11/28/2023	Kansas River	39.09779	-94.61165	563	M	2000	A69-1604-27509	ORFS44711
11/28/2023	Kansas River	39.09779	-94.61165	634	M	2660	A69-1604-27510	ORFS44712
11/28/2023	Kansas River	39.09779	-94.61165	687	M	3480	A69-1604-27511	ORFS44713
11/28/2023	Kansas River	39.09779	-94.61165	617	M	2720	A69-1604-27512	ORFS44714
11/28/2023	Kansas River	39.09779	-94.61165	557	M	1840	A69-1604-27513	ORFS44715
11/28/2023	Kansas River	39.09779	-94.61165	605	F	2540	A69-1604-27514	ORFS44716
11/28/2023	Kansas River	39.09779	-94.61165	640	F	2800	A69-1604-27515	ORFS44717
11/28/2023	Kansas River	39.09779	-94.61165	631	F	2820	A69-1604-27516	ORFS44718
11/28/2023	Kansas River	39.09779	-94.61165	634	M	2660	A69-1604-27518	ORFS44719
11/28/2023	Kansas River	39.09779	-94.61165	643	M	3200	A69-1604-27519	ORFS44720
11/28/2023	Kansas River	39.09779	-94.61165	648	F	3020	A69-1604-27520	ORFS44721
11/28/2023	Kansas River	39.09779	-94.61165	662	F	3360	A69-1604-27522	ORFS44722
11/28/2023	Kansas River	39.09779	-94.61165	602	M	2380	A69-1604-27523	ORFS44723
11/28/2023	Kansas River	39.09779	-94.61165	655	M	3160	A69-1604-27524	ORFS44724
11/28/2023	Kansas River	39.09779	-94.61165	657	M	3020	A69-1604-27526	ORFS44725
11/28/2023	Kansas River	39.09779	-94.61165	671	M	3300	A69-1604-27527	ORFS44726
11/28/2023	Kansas River	39.09779	-94.61165	625	M	3180	A69-1604-27528	ORFS44727
11/28/2023	Kansas River	39.09779	-94.61165	631	F	3240	A69-1604-27530	ORFS44728
11/28/2023	Kansas River	39.09779	-94.61165	641	M	2880	A69-1604-27532	ORFS44729
11/28/2023	Kansas River	39.09779	-94.61165	623	M	2520	A69-1604-27533	ORFS44732
11/28/2023	Kansas River	39.09779	-94.61165	604	M	2480	A69-1604-27535	ORFS44733
11/28/2023	Kansas River	39.09779	-94.61165	549	M	1820	A69-1604-27537	ORFS44734
11/28/2023	Kansas River	39.09779	-94.61165	610	M	2820	A69-1604-27538	ORFS44735
11/28/2023	Kansas River	39.09779	-94.61165	603	M	2380	A69-1604-27540	ORFS44736
11/28/2023	Kansas River	39.09779	-94.61165	618	M	2860	A69-1604-27542	ORFS44737
11/28/2023	Kansas River	39.09779	-94.61165	649	M	3300	A69-1604-27543	ORFS44738
11/28/2023	Kansas River	39.09779	-94.61165	606	M	2320	A69-1604-27545	ORFS44739
11/28/2023	Kansas River	39.09779	-94.61165	616	M	2340	A69-1604-27517	ORFS44276
11/28/2023	Kansas River	39.09779	-94.61165	738	F	4360	A69-1604-27521	ORFS44277

11/28/2023	Kansas River	39.09779	-94.61165	705	F	3340	A69-1604-27525	ORFS44278
11/28/2023	Kansas River	39.09779	-94.61165	615	M	2660	A69-1604-27529	ORFS44279
11/28/2023	Kansas River	39.09779	-94.61165	684	M	2940	A69-1604-27531	ORFS44280
11/28/2023	Kansas River	39.09779	-94.61165	646	M	2540	A69-1604-27534	ORFS44281
11/28/2023	Kansas River	39.09779	-94.61165	702	M	3580	A69-1604-27536	ORFS44282
11/28/2023	Kansas River	39.09779	-94.61165	662	F	3090	A69-1604-27539	ORFS44283
11/28/2023	Kansas River	39.09779	-94.61165	629	F	2560	A69-1604-27541	ORFS44284
11/28/2023	Kansas River	39.09779	-94.61165	633	M	2840	A69-1604-27544	ORFS44285
11/28/2023	Kansas River	39.04677	-94.80937	845	F	6740	A69-1604-27546	ORFS44740
11/28/2023	Kansas River	39.04677	-94.80937	848	F	8220	A69-1604-27548	ORFS44741
11/28/2023	Kansas River	39.04677	-94.80937	861	F	7540	A69-1604-27549	ORFS44742
11/28/2023	Kansas River	39.04677	-94.80937	854	F	7960	A69-1604-27551	ORFS44743
11/28/2023	Kansas River	39.04677	-94.80937	846	F	6520	A69-1604-27553	ORFS44744
11/28/2023	Kansas River	39.04677	-94.80937	770	M	5700	A69-1604-27554	ORFS44745
11/28/2023	Kansas River	39.04677	-94.80937	758	M	5720	A69-1604-27556	ORFS44746
11/28/2023	Kansas River	39.04677	-94.80937	842	F	8060	A69-1604-27557	ORFS44747
11/28/2023	Kansas River	39.04677	-94.80937	831	F	6920	A69-1604-27559	ORFS44748
11/28/2023	Kansas River	39.04677	-94.80937	835	F	5720	A69-1604-27547	ORFS44286
11/28/2023	Kansas River	39.04677	-94.80937	789	F	5300	A69-1604-27550	ORFS44287
11/28/2023	Kansas River	39.04677	-94.80937	787	F	5340	A69-1604-27552	ORFS44289
11/28/2023	Kansas River	39.04677	-94.80937	833	F	6720	A69-1604-27555	ORFS44290
11/28/2023	Kansas River	39.04677	-94.80937	826	F	6520	A69-1604-27558	ORFS44291
11/28/2023	Kansas River	39.04677	-94.80937	804	F	5980	A69-1604-27560	ORFS44292
11/29/2023	Kansas River	39.38575	-93.11136	530	M	1500	A69-1604-27561	ORFS44749
11/29/2023	Kansas River	39.38575	-93.11136	604	M	2400	A69-1604-27562	ORFS44750
11/29/2023	Kansas River	39.38575	-93.11136	627	M	2460	A69-1604-27563	ORFS44751
11/29/2023	Kansas River	39.38575	-93.11136	504	M	1460	A69-1604-27564	ORFS44752
11/29/2023	Kansas River	39.38575	-93.11136	549	M	1640	A69-1604-27565	ORFS44753
11/29/2023	Kansas River	39.38575	-93.11136	506	F	1400	A69-1604-27566	ORFS44754
11/29/2023	Kansas River	39.38575	-93.11136	631	M	3160	A69-1604-27567	ORFS44755
11/29/2023	Kansas River	39.38575	-93.11136	529	F	1400	A69-1604-27568	ORFS44756
11/29/2023	Kansas River	39.38575	-93.11136	549	M	1740	A69-1604-27569	ORFS44757
11/29/2023	Kansas River	39.38575	-93.11136	639	M	2840	A69-1604-27570	ORFS44758

Table 2. Site name, date of installation, and location (latitude and longitude) of the additional stationary telemetry receiver deployed in the Kansas River during winter 2023.

Site	Date	Latitude	Longitude
Kansas River Mouth	11/27/2023	39.11269	-94.61468

Table 3. Origin (CCC = Creve Coeur Creek, MR = Moreau River, LR = Lamine River, GR = Grand 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
CCC	A69-1602-48939	St Charles	4.0	4.0
CCC	A69-1602-48944	Lamine Mouth	171.5	171.5
CCC	A69-1602-48946	St Charles	4.0	4.0
CCC	A69-1602-48948	New Madrid (MO888.5)	291.0	291.0
CCC	A69-1602-48949	L&C Bridge	23.0	23.0
CCC	A69-1602-48961	Booneville - Lamine Mouth	171.5	171.5
MR	A69-1602-49117	Moreau Upper	1.8	1.8
MR	A69-1602-49120	Moreau Mouth - Moreau Upper	1.8	1.8
MR	A69-1602-49121	Moreau Upper	1.8	1.8
MR	A69-1602-49122	Moreau Upper	1.8	1.8
MR	A69-1602-49123	Moreau Upper	1.8	1.8
MR	A69-1602-49126	Osage River - Lamine Mouth - Booneville	64.2	105.7
MR	A69-1602-49129	Osage River - Moreau Upper	17.8	37.4
MR	A69-1602-49134	Moreau Upper	1.8	1.8
MR	A69-1602-49135	Booneville - Lamine Mouth - Grand Mouth - Lamine Mouth	111.7	159.2
MR	A69-1602-49137	Booneville - HWY 30 Blair, NE	510.0	510.0
MR	A69-1602-49139	Moreau Upper	1.8	1.8
MR	A69-1602-49144	Moreau Upper	1.8	1.8
MR	A69-1602-49145	Moreau Upper	1.8	1.8
MR	A69-1602-49146	Moreau Upper	1.8	1.8
MR	A69-1602-49147	Moreau Upper - Osage River	17.8	21.4
MR	A69-1602-49152	Osage River	17.8	17.8
MR	A69-1602-49153	Gasconade River	34.5	34.5
MR	A69-1602-49161	Osage River	17.8	17.8
MR	A69-1602-49163	Moreau Upper	1.8	1.8
MR	A69-1602-49164	Osage River	17.8	17.8
MR	A69-1602-49165	Osage River	17.8	17.8
MR	A69-1602-49167	Moreau Upper	1.8	1.8
MR	A69-1602-49169	Booneville - (Grand Mouth - Grand Upper (x1.5))	113.8	115.9
MR	A69-1602-49171	Moreau Upper	1.8	1.8
MR	A69-1602-49173	Osage River	17.8	17.8
LR	A69-1602-49055	Lamine Upper - Mouth (x2) - Booneville - Lamine Upper - Lamine Mouth	7.1	30.4
LR	A69-1602-49056	Lamine Upper - Lamine Mouth (x1.5)	2.1	8.7

LR	A69-1602-49057	Lamine Upper - Lamine Mouth - (Grand Mouth - Grand Upper (x2.5)) - Lamine Mouth - Lamine Upper	52.9	112.1
LR	A69-1602-49058	Lamine Upper - Lamine Mouth (x2.5)	2.1	15.3
LR	A69-1602-49059	Lamine Upper - Lamine Mouth (x4.5)	2.1	28.5
LR	A69-1602-49060	Lamine Upper - Lamine Mouth (x4.5)	2.1	28.5
LR	A69-1602-49061	Grand Mouth - (Lamine Mouth - Lamine Upper (x2))	52.9	106.1
LR	A69-1602-49062	Lamine Mouth	1.2	1.2
LR	A69-1602-49063	Lamine Upper - Lamine Mouth - Booneville - Lamine Mouth - Lamine Upper	7.1	20.5
LR	A69-1602-49064	Lamine Upper	2.1	2.1
LR	A69-1602-49065	Lamine Mouth - Lamine Upper (x2.5)	2.1	14.4
LR	A69-1602-49066	Lamine Upper - Lamine Mouth	2.1	5.4
LR	A69-1602-49067	Lamine Mouth - Lamine Upper (x1.5) - (Grand Mouth - Grand Upper (x2.5)) - (Lamine Mouth - Lamine Upper (x1.5))	52.9	117.4
LR	A69-1602-49068	Lamine Upper - Lamine Mouth - Booneville - Lamine Mouth - Lamine Upper	7.1	20.5
LR	A69-1602-49069	Lamine Mouth	1.2	1.2
LR	A69-1602-49070	Lamine Upper - Lamine Mouth (x2.5)	2.1	15.3
LR	A69-1602-49071	HWY 30 Blair, NE	447.0	447.0
LR	A69-1602-49072	Lamine Upper - Lamine Mouth (x3.5)	2.1	21.9
LR	A69-1602-49074	Lamine Mouth - Lamine Upper (x1.5)	2.1	7.8
LR	A69-1602-49075	Lamine Upper - Lamine Mouth (x4) - Booneville - (Lamine Mouth - Lamine Upper (x2))	7.1	46.9
LR	A69-1602-49076	Lamine Mouth - Lamine Upper (x5)	2.1	31.8
LR	A69-1602-49077	Lamine Mouth - Lamine Upper (x2)	2.1	12.0
LR	A69-1602-49081	Booneville - Lamine Mouth	7.1	13.0
LR	A69-1602-49083	Booneville - (Lamine Mouth - Lamine Upper (x2))	7.1	22.9
LR	A69-1602-49085	Lamine Mouth - Lamine Upper	2.1	4.5
LR	A69-1602-49088	Lamine Upper - Lamine Mouth (x2) - Booneville - Lamine Mouth	7.1	23.8
LR	A69-1602-49089	Lamine Mouth - Lamine Upper (x2)	2.1	12.0
LR	A69-1602-49091	Lamine Upper - Grand Mouth - (Lamine Upper - Lamine Mouth (x1.5))	50.8	110.3
LR	A69-1602-49093	Lamine Upper - Lamine Mouth (x4) - Grand Mouth - (Lamine Upper - Lamine Mouth (x4))	50.8	146.6
LR	A69-1602-49095	Lamine Mouth - Lamine Upper	2.1	4.5
LR	A69-1602-49096	Lamine Upper - Lamine Mouth (x5.5)	2.1	35.1
LR	A69-1602-49097	Lamine Mouth	1.2	1.2
LR	A69-1602-49100	Lamine Mouth - Lamine Upper (x3) - (Grand Mouth - Grand Upper (x4.5)) - (Lamine Upper - Lamine Mouth (x1.5))	52.9	141.9
LR	A69-1602-49102	Booneville - (Lamine Mouth - Lamine Upper (x3.5)) - Booneville - (Lamine Mouth - Lamine Upper (x5)) - Booneville - (Lamine Mouth - Lamine Upper (x4))	7.1	362.1
LR	A69-1602-49103	Lamine Mouth - Lamine Upper (x4)	2.1	24.3

LR	A69-1602-49104	Lamine Upper - Lamine Mouth	2.1	5.4
LR	A69-1602-49105	Lamine Upper - Grand Mouth - Lamine Mouth - Booneville - Lamine Mouth	50.8	112.2
LR	A69-1602-49106	Lamine Mouth - Lamine Upper (x4)	2.1	24.3
LR	A69-1602-49109	Lamine Upper - Lamine Mouth	2.1	5.4
LR	A69-1602-49112	Lamine Upper - Lamine Mouth (x4)	2.1	25.2
LR	A69-1602-49113	Booneville - (Lamine Mouth - Lamine Upper (x1.5)) - Grand Mouth - (Lamine Mouth - Lamine Upper (x1.5)) - Booneville - (Lamine Mouth - Lamine Upper (x2))	50.8	142.9
GR	A69-1602-48989	Grand Mouth - Grand Upper (x10)	1.6	39.6
GR	A69-1602-48990	Grand Mouth - Grand Upper (x15)	1.6	59.6
GR	A69-1602-48993	Grand Mouth - Grand Upper (x3)	1.6	11.6
GR	A69-1602-48994	Grand Mouth - Grand Upper (x5)	1.6	19.6
GR	A69-1602-48995	Grand Mouth - Grand Upper (x2.5)	1.6	9.6
GR	A69-1602-48996	Grand Mouth - Grand Upper (x7)	1.6	27.6
GR	A69-1602-48997	Grand Mouth - Grand Upper (x3)	1.6	11.6
GR	A69-1602-48999	Grand Mouth - Grand Upper (x4.5)	1.6	17.6
GR	A69-1602-49000	Grand Mouth	1.6	1.6
GR	A69-1602-49001	Grand Mouth - Grand Upper (x7)	1.6	27.6
GR	A69-1602-49003	Grand Mouth - Grand Upper (x14)	1.6	55.6
GR	A69-1602-49005	Grand Mouth - Grand Upper (x13)	1.6	51.6
GR	A69-1602-49008	Grand Mouth	1.6	1.6
GR	A69-1602-49009	Gasconade River	145.6	145.6
GR	A69-1602-49010	Grand Mouth - Grand Upper (x5.5)	1.6	21.6
GR	A69-1602-49011	Grand Mouth - Grand Upper (x8)	1.6	31.6
GR	A69-1602-49012	Grand Mouth - Grand Upper (x6)	1.6	23.6
GR	A69-1602-49013	Grand Mouth - Grand Upper (x5)	1.6	19.6
GR	A69-1602-49014	Grand Mouth - Grand Upper (x6)	1.6	23.6
GR	A69-1602-49015	Grand Mouth - Grand Upper (x5)	1.6	19.6
GR	A69-1602-49017	Grand Mouth - Grand Upper (x5.5)	1.6	21.6
GR	A69-1602-49018	Grand Mouth - Grand Upper (x7)	1.6	27.6
GR	A69-1602-49020	Grand Mouth - Grand Upper (x2)	1.6	7.6
GR	A69-1602-49021	Grand Mouth - Grand Upper (x6)	1.6	23.6
GR	A69-1602-49022	Grand Mouth - Grand Upper (x14.5)	1.6	57.6
GR	A69-1602-49023	Grand Mouth - Grand Upper (x12)	1.6	47.6
GR	A69-1602-49024	Grand Mouth - Grand Upper (x16)	1.6	63.6
GR	A69-1602-49025	Grand Mouth - Grand Upper	1.6	3.6
GR	A69-1602-49027	Grand Mouth	1.6	1.6
GR	A69-1602-49030	Booneville - (Grand Mouth - Grand Upper (x7))	55.1	137.8
GR	A69-1602-49031	Grand Mouth - Grand Upper (x4)	1.6	15.6

GR	A69-1602-49032	Grand Mouth - Grand Upper (x2.5)	1.6	9.6
GR	A69-1602-49033	Grand Mouth - Grand Upper (x4.5)	1.6	17.6
GR	A69-1602-49034	Grand Mouth - Grand Upper (x9.5)	1.6	37.6
GR	A69-1602-49035	Grand Mouth - Grand Upper (x7)	1.6	27.6
GR	A69-1602-49036	Grand Mouth - Grand Upper (x9.5)	1.6	37.6
GR	A69-1602-49038	Grand Mouth - Grand Upper (x6)	1.6	23.6
GR	A69-1602-49039	Grand Mouth - Grand Upper (x2.5)	1.6	9.6
GR	A69-1602-49043	Grand Mouth - Grand Upper (x14)	1.6	55.6
GR	A69-1602-49044	Grand Mouth - Grand Upper (x12)	1.6	47.6
GR	A69-1602-49045	Grand Mouth - Grand Upper (x5.5)	1.6	21.6
GR	A69-1602-49046	Grand Mouth - Grand Upper (x7.5)	1.6	29.6
GR	A69-1602-49047	Grand Mouth - Grand Upper (x3.5)	1.6	13.6
GR	A69-1602-49048	Grand Mouth - Grand Upper (x6)	1.6	23.6
GR	A69-1602-49049	Grand Mouth - Grand Upper (x9)	1.6	35.6
GR	A69-1602-49051	Grand Mouth - Grand Upper (x8)	1.6	31.6
GR	A69-1602-49052	Grand Mouth - Grand Upper (x10)	1.6	39.6
GR	A69-1602-49053	Grand Mouth - Grand Upper (x9)	1.6	35.6
GR	A69-1602-49054	Grand Mouth - Grand Upper (x3)	1.6	11.6

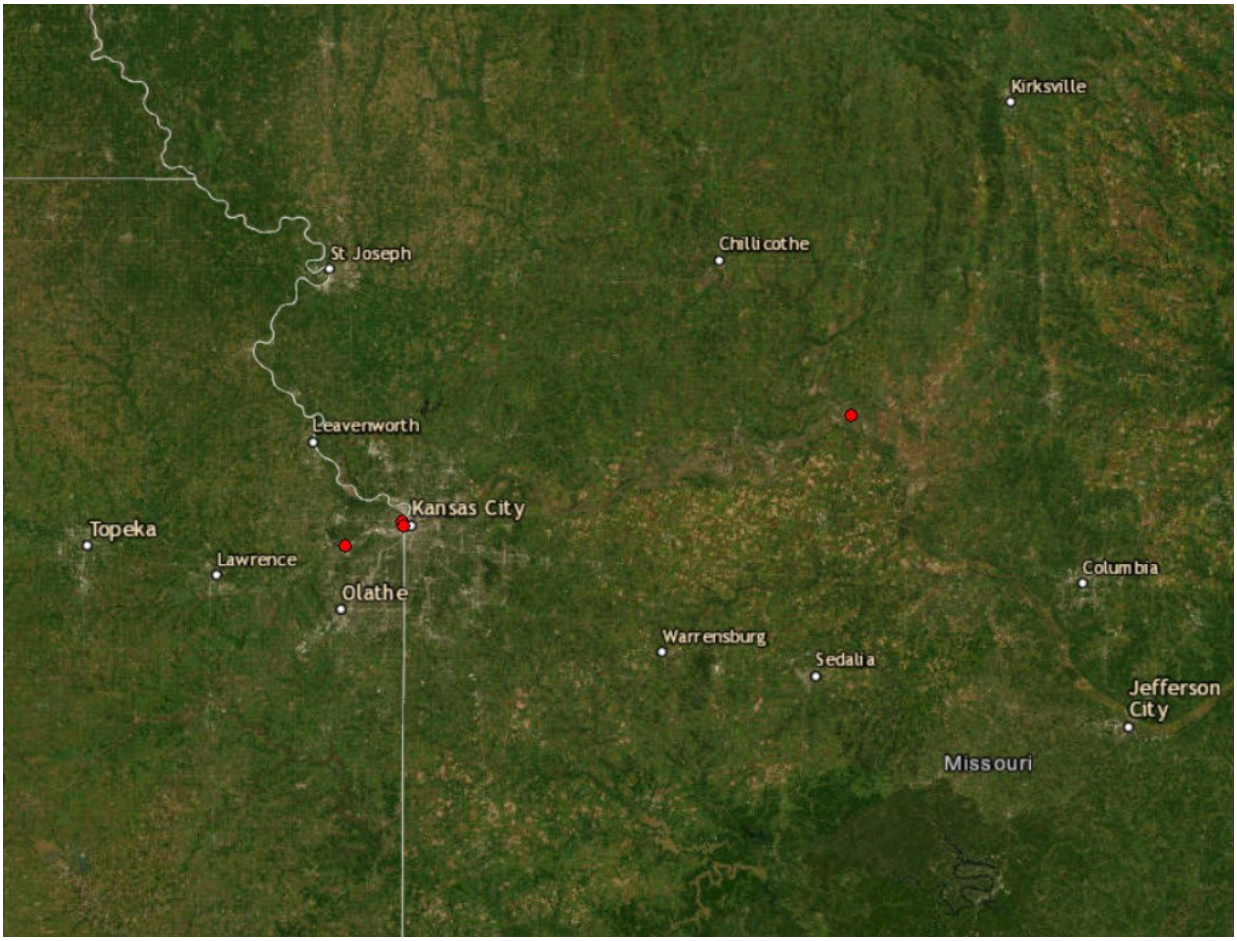

Figure 1. Locations (red dots) where invasive carp were implanted with acoustic transmitters during winter 2023 within the Missouri River system. Ten invasive carp were tagged in the Grand River (right dot) while 73 invasive carp were tagged in the Kansas River at Edwardsville (left dot) and Kaw Point (middle dots).

Figure 2. Relative locations of an invasive silver carp tagged in Creve Coeur Creek (blue dot) that traveled approximately 291 river miles to the lower Mississippi River and was detected at New Madrid, MO (red dot).

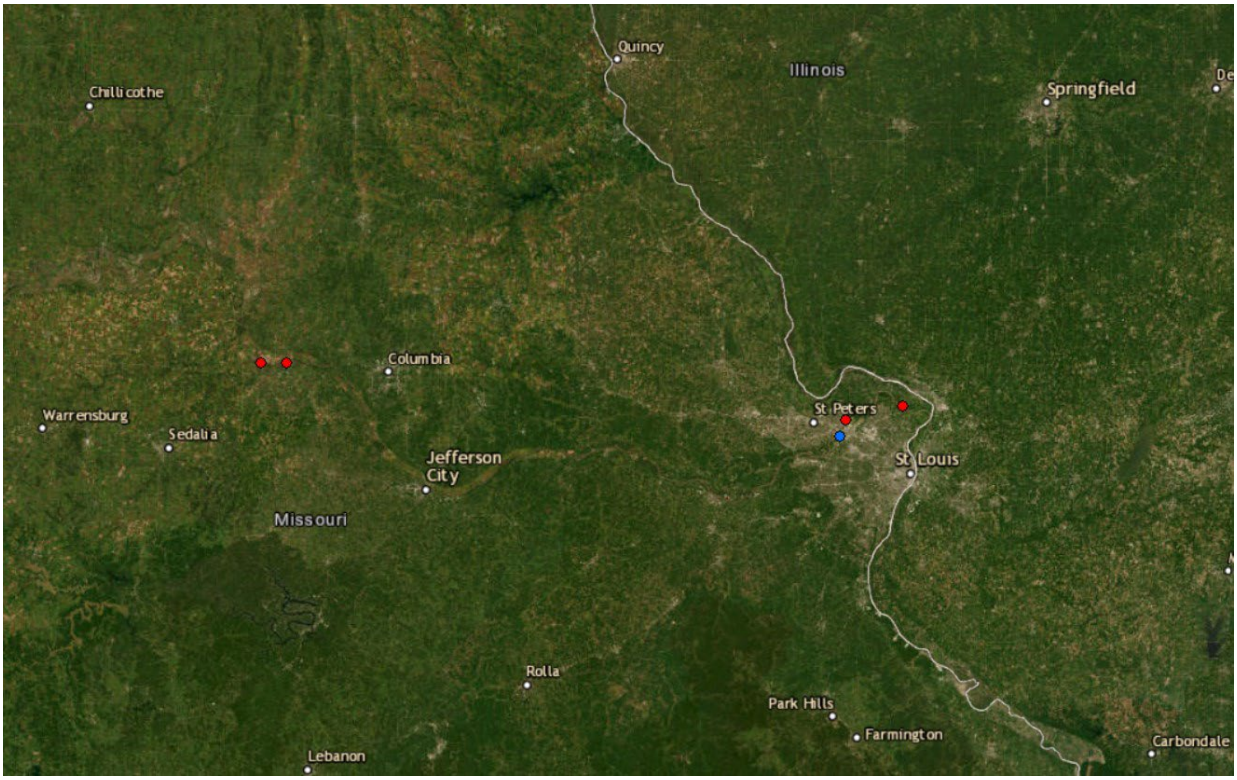

Figure 3. Relative locations of five invasive silver carp tagged in Creve Coeur Creek (blue dot) that traveled approximately 4.0 to 171.5 river miles within the Missouri River system and were detected at four locations (red dots): one at the Lewis and Clark bridge near West Alton, MO (first dot from right to left), two at St. Charles (second dot from right), one at Booneville (third dot from right), and one at the Lamine River (fourth dot from right).

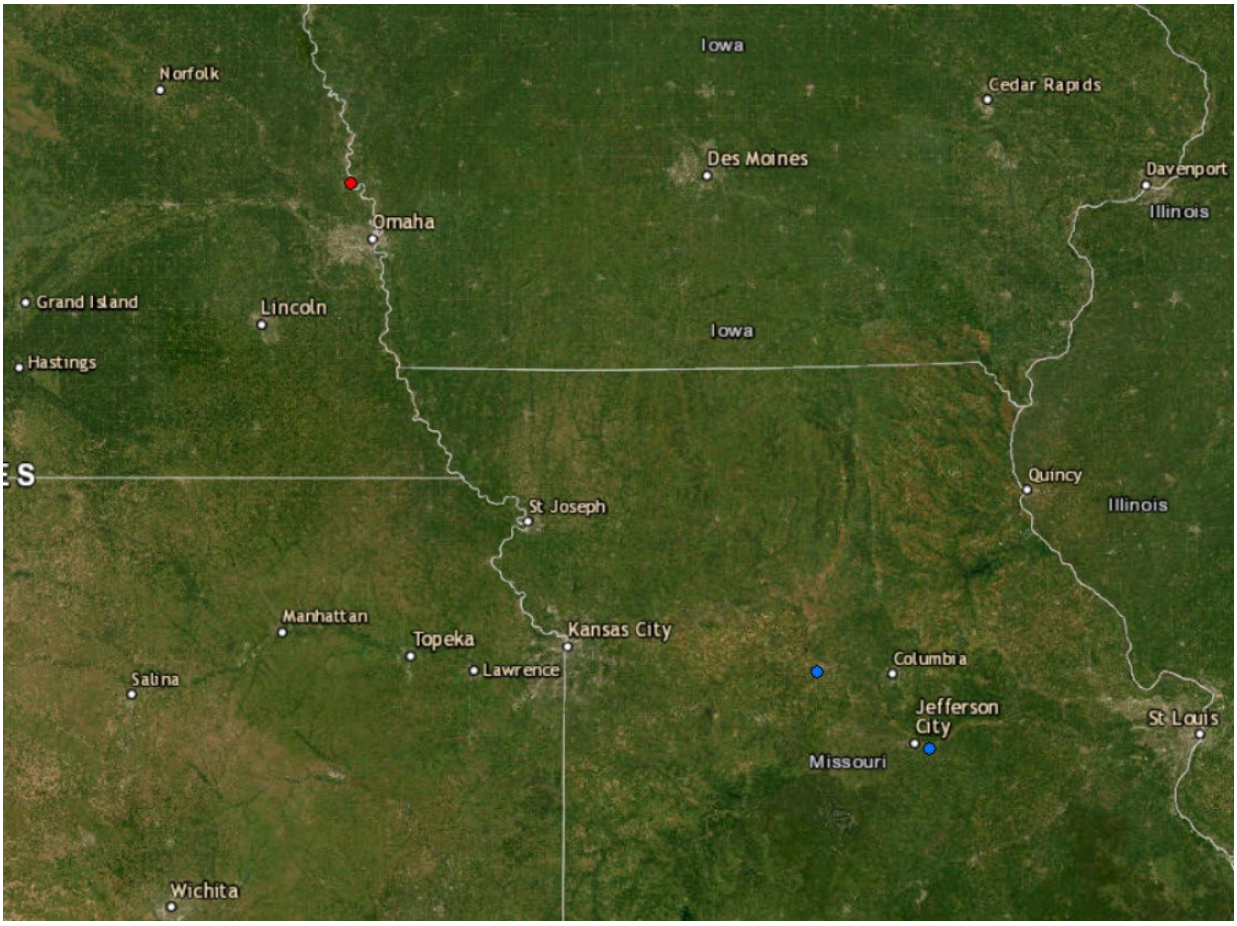

Figure 4. Relative locations of two invasive silver carp (blue dots) tagged in the Moreau and Lamine Rivers (one each) that were detected near Blair, NE (red dot) approximately 447.0 to 510.0 river miles from their respective tagging origins.

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

Methods:

Study Site

This study used passive telemetry to monitor large-scale movement patterns of Silver Carp in the James River, South Dakota. 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 (Muth & Schmulbach, 1984). It is highly sinuous, traveling a distance of 1,143 river kilometers (rkm), but only covering a straight distance of 400 km (Carreiro, 2000). The landscape is historically categorized by glaciated drift prairie, but municipalities and farmland are the contemporary predominant features on the landscape (Bartlett, 1984). There are at least 230 low-head dams on the James River (Shearer & 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

From June 7 to June 10, 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). Surgeries took an average of five minutes to complete. 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 (Figure 1).

An additional 50 V16 transmitters were implanted into Silver Carp from June 6 to June 8, 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). Tools were sterilized in a chlorhexidine solution. 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. Fish were monitored to ensure they were swimming upright in the live well before being released back into the James River near their capture locations. Initial movement data from these tagged individuals were not included in any analysis provided below.

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. 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 2). Discharge data were downloaded from USGS gage number 06478500 (Scotland, SD), using the *dataRetrieval* package (De Cicco & Hirsch, 2014) in Program R (version 4.1.1; R Core Team 2022).

Range Test of Tags and Receivers

We conducted a range test of our transmitters in mid to late summer 2022 to evaluate detection probabilities at various downstream distances from the receiver. We performed the range test using a V16 tag with the same specifications as our surgically implanted fish, except that the ping rate was set to 90 second intervals with no delay. We found that detection probability was almost 100% at 100 m downstream of the receiver. The downstream line-of-sight distance at each receiver on the James River was at least 100 m, and we are confident that any fish swimming near or past a receiver were detected (Carlson et al., 2023).

Data Analysis

We kept the first instance of detection for each fish at each receiver on each day that it was detected and filtered out any subsequent data from that day, unless the fish was detected on an additional receiver in the same day, in which case a datapoint was kept from the subsequent receiver following the same rule.

We used the *brms* package (Bürkner, 2017) in Program R (version 4.1.1; R Core Team 2022) to create models to predict whether daily mean discharge ("flow"), a change in discharge over 24 and/or 48 hours, average weekly temperature, average weekly DO, or a combination of these environmental factors best predicted Silver Carp movement in the James River. We fit a total of eighteen Bayesian linear models using different combinations of these variables. We estimated the probability of movement using a Bernoulli likelihood with a logit link using the following equation:

$$M \sim \text{Bernoulli}(p),$$
$$\text{logit}(p) = \alpha + \boldsymbol{\beta}X$$
$$\alpha \sim \text{Normal}(-1,1)$$
$$\boldsymbol{\beta}X \sim \text{Normal}(0,1)$$

where M indicates whether a fish moved (M=1) or not (M=0), p is the probability of movement versus non-movement, α is the intercept, **β**X is a linear equation representing up to five predictor variables from the six observed parameters (daily mean flow in cubic feet per second, change in discharge over 24h, change in discharge over 48h, weekly mean temp, weekly mean DO). All models were run with four chains and 2000 iterations. Then we chose the best fitting model using WAIC (Hooten & Hobbs, 2015) and visualized the posterior predictions using *ggplot* (Wickham et al., 2016). We ran a sensitivity analysis on the best fitting model to assess the

impact of the priors by doubling the standard deviation values to Normal (-1,2) for the intercept and Normal (0,2) for the beta values.

Results

There appeared to be little to no evidence of fallback occurrences from tagging (i.e., fish drifting downstream due to high flows or effects of complications from surgery), so we did not exclude any movement data from our analysis. High discharge within the James River from May through June of 2022 caused most of the tagged individuals to embark on a period with the highest proportion of observed movements during this peak in the hydrograph (Figure 3). Nine fish were not detected after the initial tagging date. These nine fish, therefore, had an "undetermined" fate and were left out of any analyses. Six fish were only detected at one receiver over multiple different dates (with net zero recorded movement). Total movement distance by all tagged individuals during the entire study period (June 2021 to October 2022) ranged from 0 to 1385 rkm (Figure 4) with a mean total movement distance (not including the nine fish with "undetermined" fate) of 365 rkm. The most upstream Silver Carp detection was at the receiver farthest upstream from the James-Missouri confluence near Huron, SD (rkm 354), while the most downstream detection was just outside of Blair, NE, in the Missouri River (236 rkm below the confluence). Only one of the tagged individuals was recorded swimming out of the James River, and all other individuals remained within the James River throughout the study period. The single individual that was detected swimming out of the James River and into the Missouri River ultimately swam back into the James River (Figure 5). During this study, daily mean flow ranged from 1.4 to 124.9 m^3/s, change in discharge over 24 hours ranged from -5.1 to 5.1 m^3/s, change in discharge over 48 hours ranged from -6.5 to 9.3 m^3/s , temperature ranged from 0 to 31°C, and dissolved oxygen ranged from 20 to 201% O_2.

The best model to predict Silver Carp movement included daily mean discharge, a change in discharge over 24h, mean weekly DO, and mean weekly temperature. According to this model, when mean daily discharge was low (1.4 m^3/s), there was a 54% probability that Silver Carp would move (95% CrI: 25 to 84%). The probability of movement increased as discharge increased, with a 64% probability (95% CrI: 40 to 85%) at 14.4 m^3/s, 89% probability (95% CrI: 61 to 99%) at 66.4 m^3/s, and 98% (95% CrI: 52 to 99%) at 124.9 m^3/s (Figure 6). Movement data also suggests that the tagged individuals were resident within the James River. Moreover, even when there was an instance of a single fish leaving the James River, after a short period of time it returned to almost the exact location that it had previously been occupying in the James River.

Based on our model, tagged Silver Carp within the James River remained mostly stationary until the mean daily discharge reached ~42 m^3/s. This provides a target range of discharge values during which population control efforts could be implemented. In the James River, if targeted removal were to be performed in areas with known Silver Carp congregations during times of low flow (i.e. flow < 42 m^3/s), it may be possible to maximize removal success while minimizing the labor and costs associated with removal efforts.

Figures:

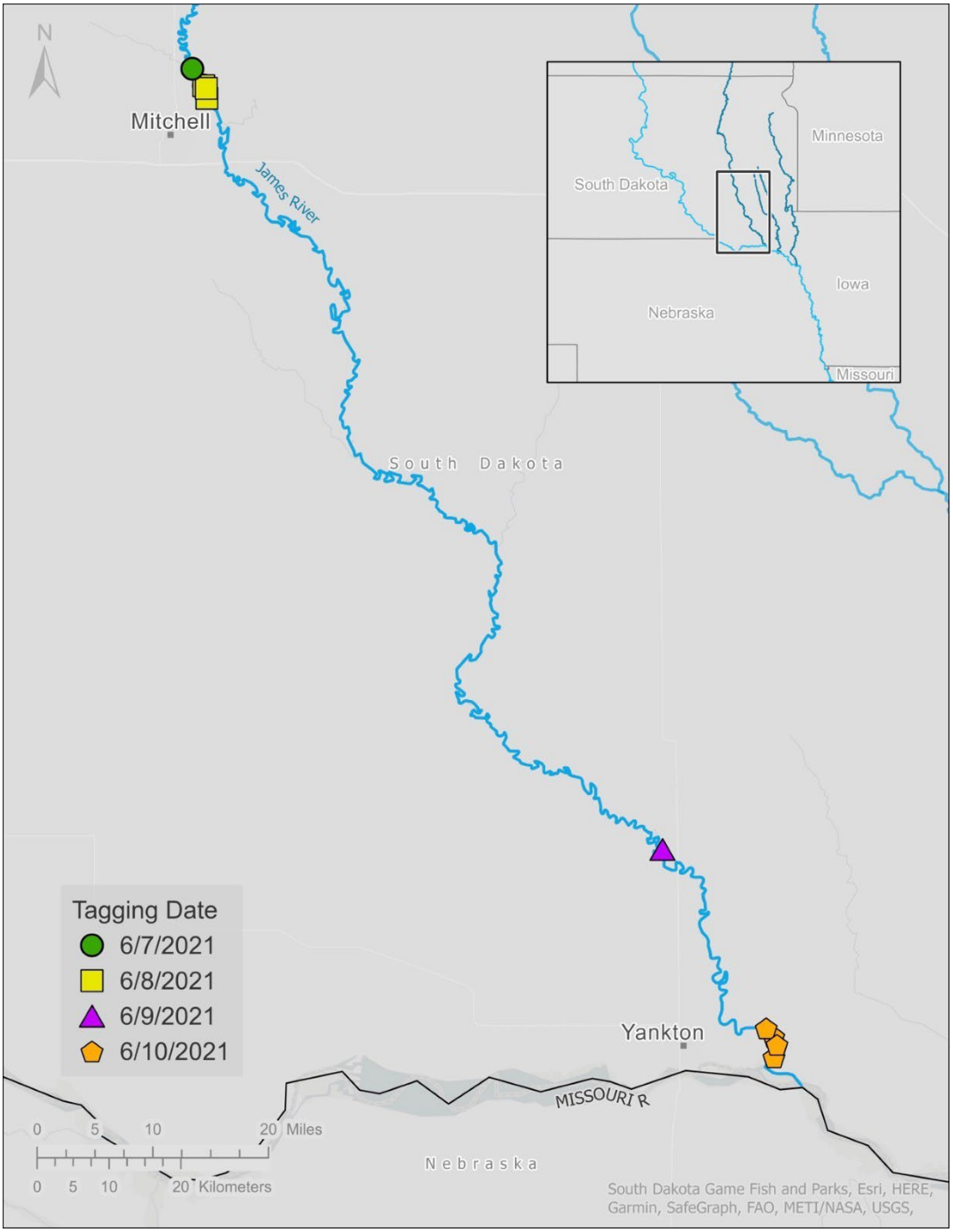

Figure 1. Silver Carp release points in the James River, SD, from June 7 through June 10, 2021, with a small inset map depicting the larger area for context.

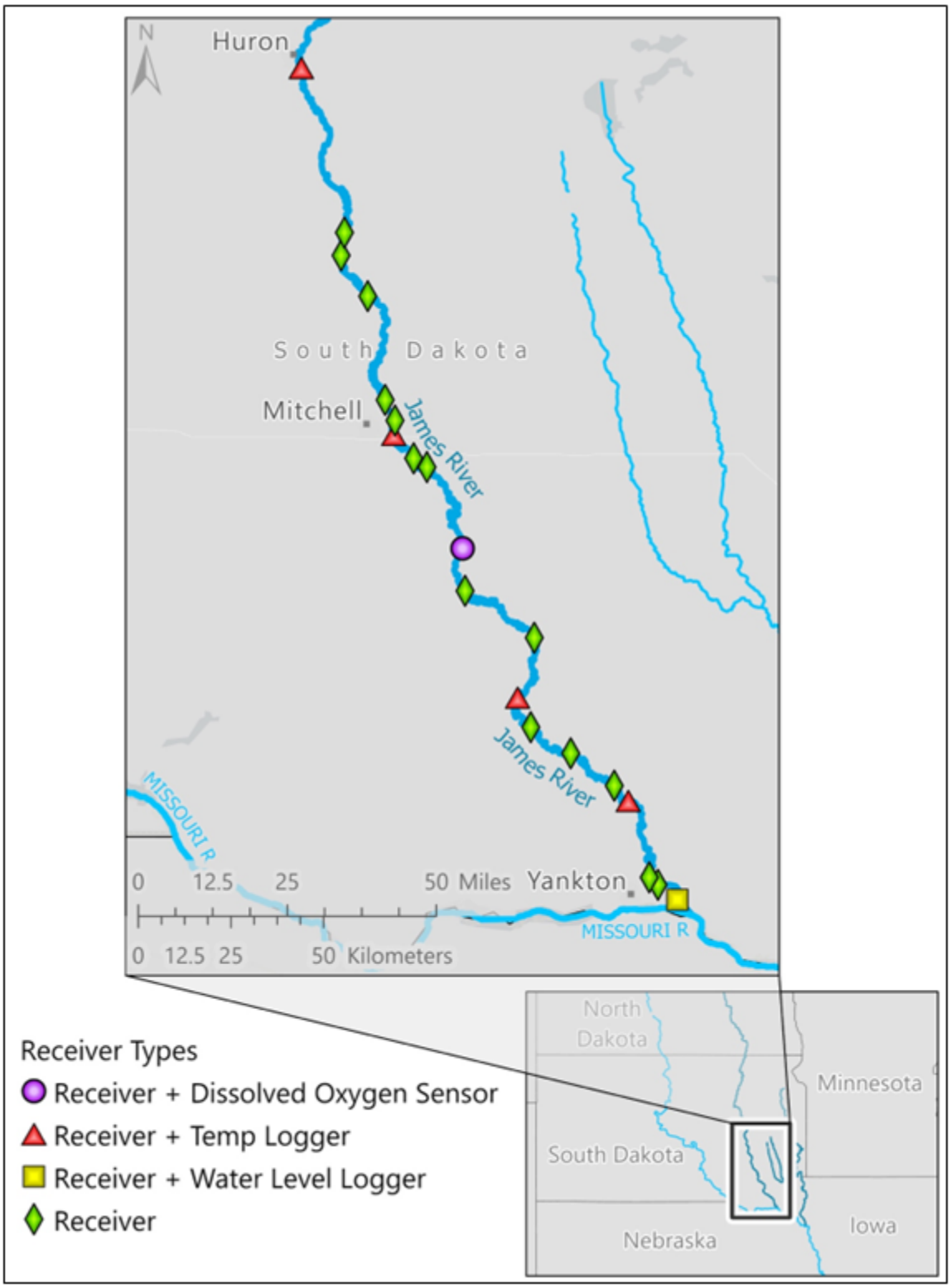

Figure 2. Map of receiver and environmental sensor locations in the James River, SD.

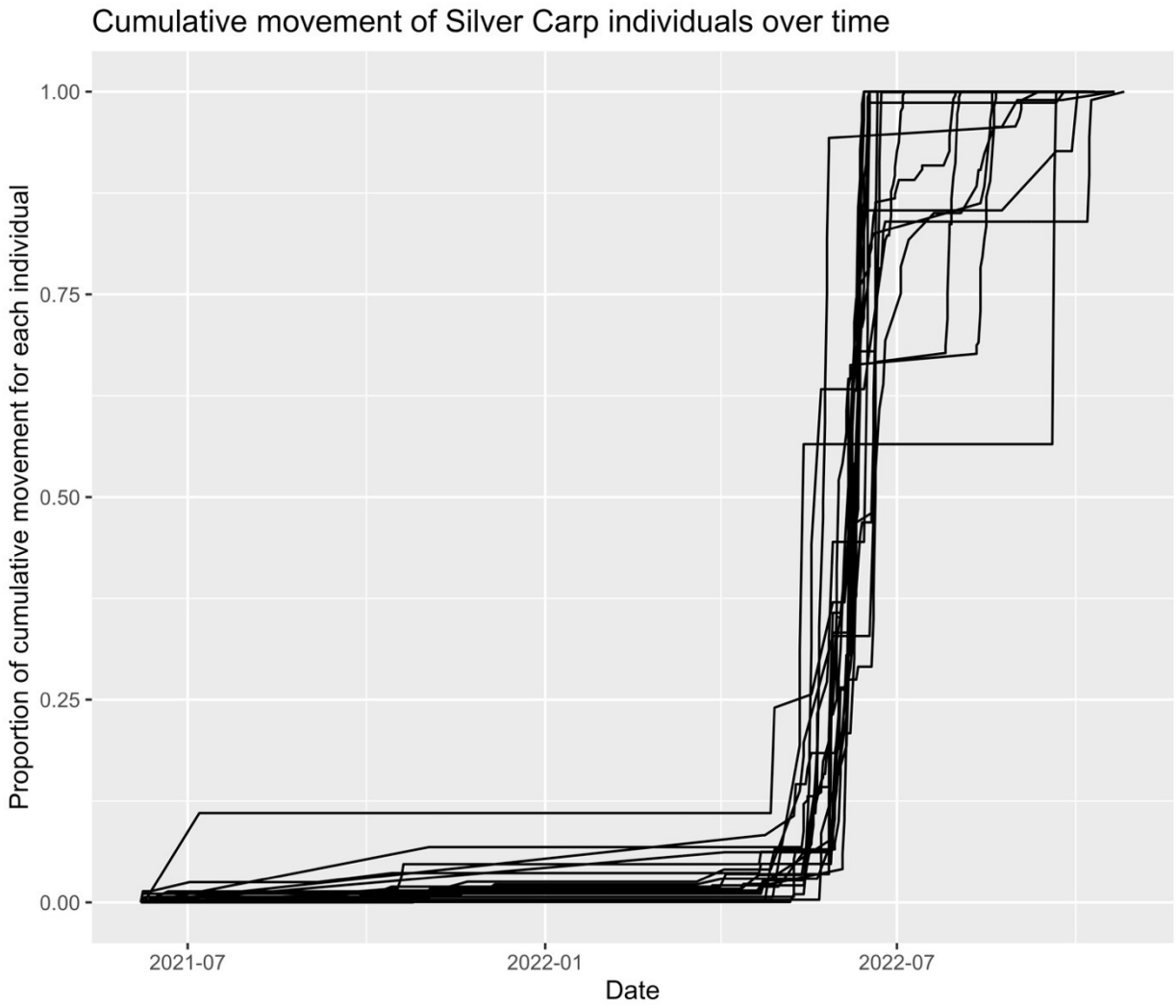

Figure 3. Cumulative movement over time for telemetered Silver Carp on a scale from 0 to 1 on the y-axis, with 0 representing no movement and 1 representing the cumulative total of each individual's movement.

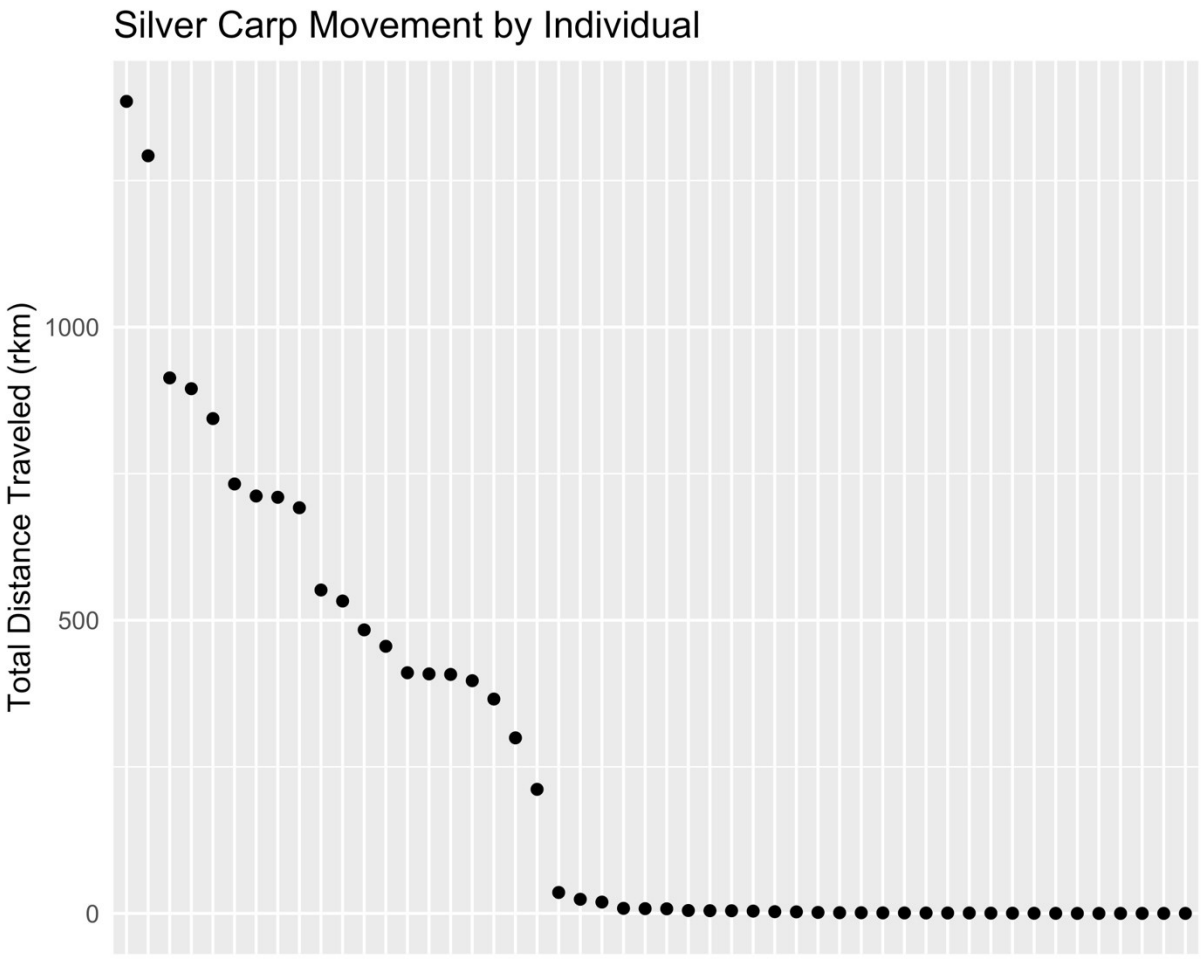

Figure 4. The total distances moved (in river kilometers) by telemetered Silver Carp in the James River, SD from June 24, 2021 to October, 24 2022. Each black dot represents one telemetered individual. The mean total distance moved was 256 rkm (range: 0 to 1385 rkm).

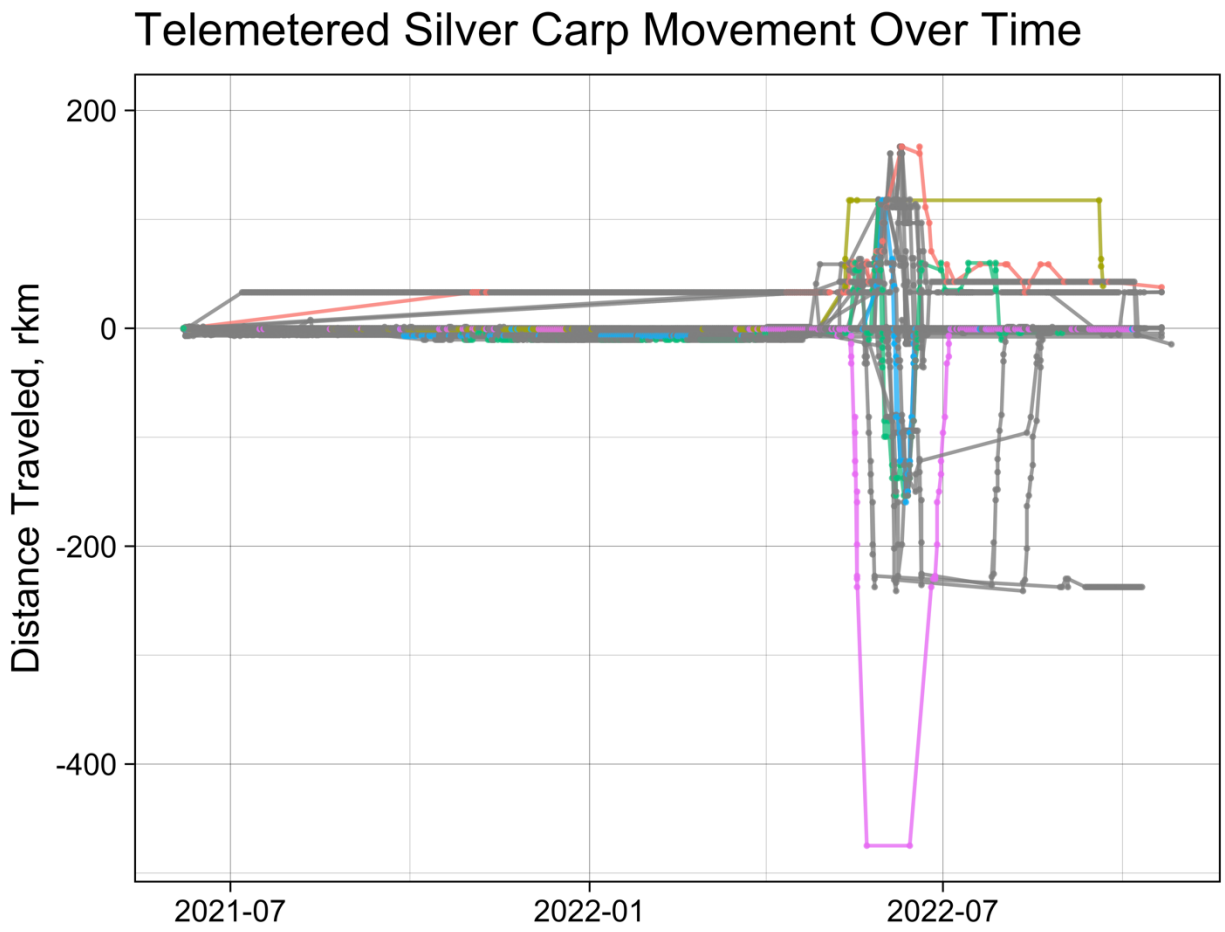

Figure 5. Movement data relative to the tagging location for Silver Carp in the James River, South Dakota. Zero on the y-axis represents the tagging location for each fish. Negative river kilometers on the y-axis represent downstream movement from the initial tagging location, and positive river kilometers represent upstream movement relative to the initial tagging location. A few individuals are colorized to show different variations in movement patterns.

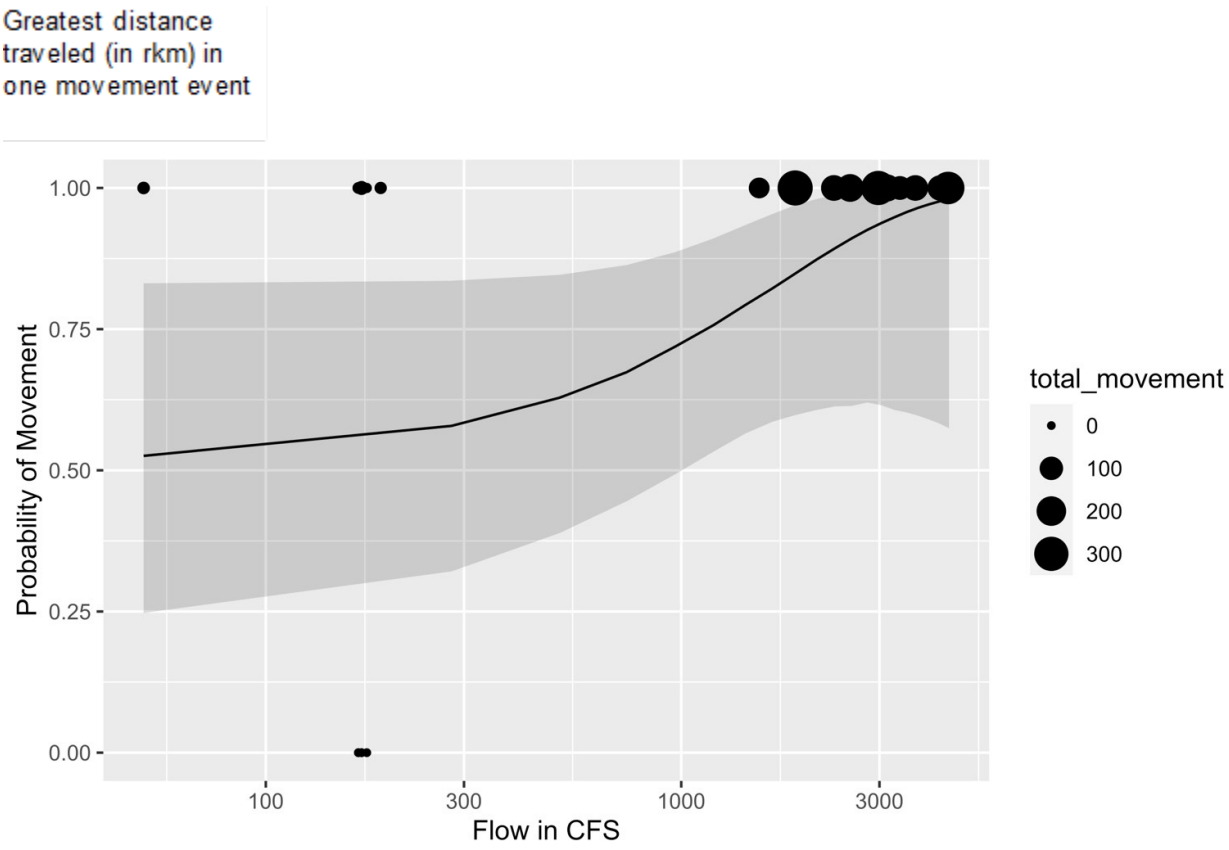

Figure 6. Posterior prediction intervals for the probability of movement as flow increases (all other model parameters were centered around the mean values). Dots represent each individual and are scaled to represent the greatest distance traveled in one movement event. Most individuals who moved during high flows also moved distances of over 200rkm in one movement event.

Agency: US Fish and Wildlife Service (USFWS)

Methods:
We developed a passive telemetry receiver array in the Big Sioux and Vermillion rivers to monitor movement and distribution of tagged silver carp (Figure 1). The array consisted of 8 Vemco VR2W acoustic receivers (n=5 Big Sioux River, n=3 Vermillion River). 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. A HOBO temperature logger was attached to the furthest upriver and downriver receiver frames to collect water temperature data for each river.

In the Big Sioux River, receivers were placed starting at 3.4 river kilometers upriver from its confluence with the Missouri River to 228.5 river kilometers from the confluence where sufficient water depth was available.

In the Vermillion River, receivers were placed starting at 7.8 river kilometers upriver from its confluence with the Missouri River to 154.3 river kilometers from the confluence where sufficient water depth was available.

In 2023, 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 (Vemco 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 and temperature logger deployment began on June 27, 2023, and receivers were retrieved from the rivers by October 18, 2023, to avoid loss or damage to equipment during winter. Actual dates of receiver operation varied among rivers and locations (Table 1).
Silver carp detection data was summarized as the number of unique individuals detected at each receiver per day.

Results and Discussion:
- A total of approximately 150,576 silver carp detections were recorded.
- A total of 199 individual daily detections were observed.
    - Daily detections in 2023 were likely lower than in 2022 and 2021 due to two differences in array deployment:
        - Receivers were more evenly distributed throughout both rivers to allow for detection of larger movement patterns. In previous years, tagged fish were

observed to congregate near the confluences; however, in 2023 fewer receivers were deployed in the immediate vicinity of the confluences.
    - In 2023, receivers were deployed later in the year and for a shorter duration.
- In the Big Sioux River, the number of silver carp detected was higher for receivers closer to the confluence than for receivers further upstream (Figure 2).
    - Zero silver carp were detected at the furthest upstream receivers (BSR 4 and BSR 5), so graphs from these receivers were omitted from Figure 2.
- In the Vermillion River, the number of tags detected at VER1 remained relatively constant (Figure 3).
    - Zero silver carp were detected in the furthest upstream receivers (VER 3 and VER 4), so graphs from these receivers were omitted from Figure 3.
- Despite below average discharge in both rivers, periods of elevated discharge did occur, and generally overlapped with an increased number of daily detections.
    - The highest number of daily detections at Big Sioux River receivers coincided with peak Big Sioux River discharge in early August 2023 (Figure 2).
    - The number of daily detections at VER1 in the Vermillion River increased immediately following an increase in discharge in early August 2023 (Figure 3).

Tables and Figures:

Table 1. Passive receiver locations and dates of deployment and retrieval in the Big Sioux and Vermillion rivers during 2023.

River	Site	Latitude (N)	Longitude (W)	River Kilometer	Date Deployed	Date Retrieved
Vermillion	VER 1	42.77295	-96.93013	7.8	06/27/23	10/18/24
Vermillion	VER 3	43.11169	-96.98073	85.5	06/27/23	10/18/24
Vermillion	VER 4	43.37292	-97.05428	154.3	06/27/23	10/18/24
Big Sioux	BSR 1	42.49949	-96.475598	3.4	07/06/23	10/19/24
Big Sioux	BSR 2	42.79237	-96.59446	68.4	07/06/23	10/19/24
Big Sioux	BSR 3	43.16995	-96.46949	147	07/06/23	10/19/24
Big Sioux	BSR 4	43.30639	-96.5268	183.1	07/06/23	10/19/24
Big Sioux	BSR 5	43.57339	-96.59996	228.5	07/06/23	10/19/24

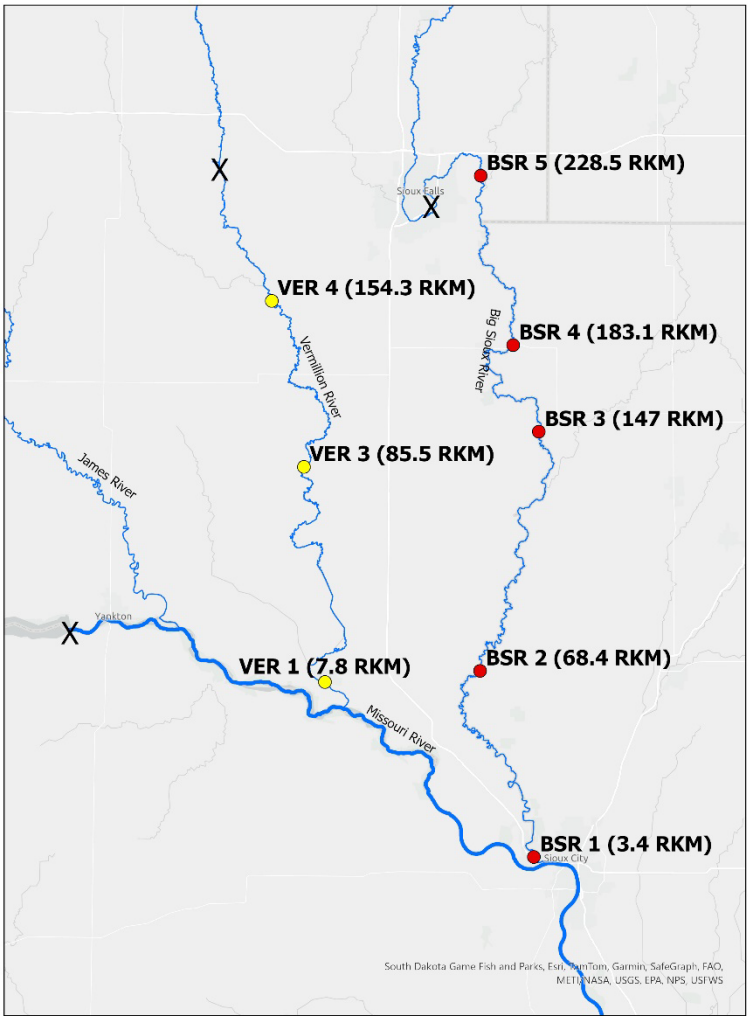

Figure 1. Location of passive receivers (yellow and red circles) and barriers to fish movement (black "X") in the Big Sioux and Vermillion rivers during 2023.

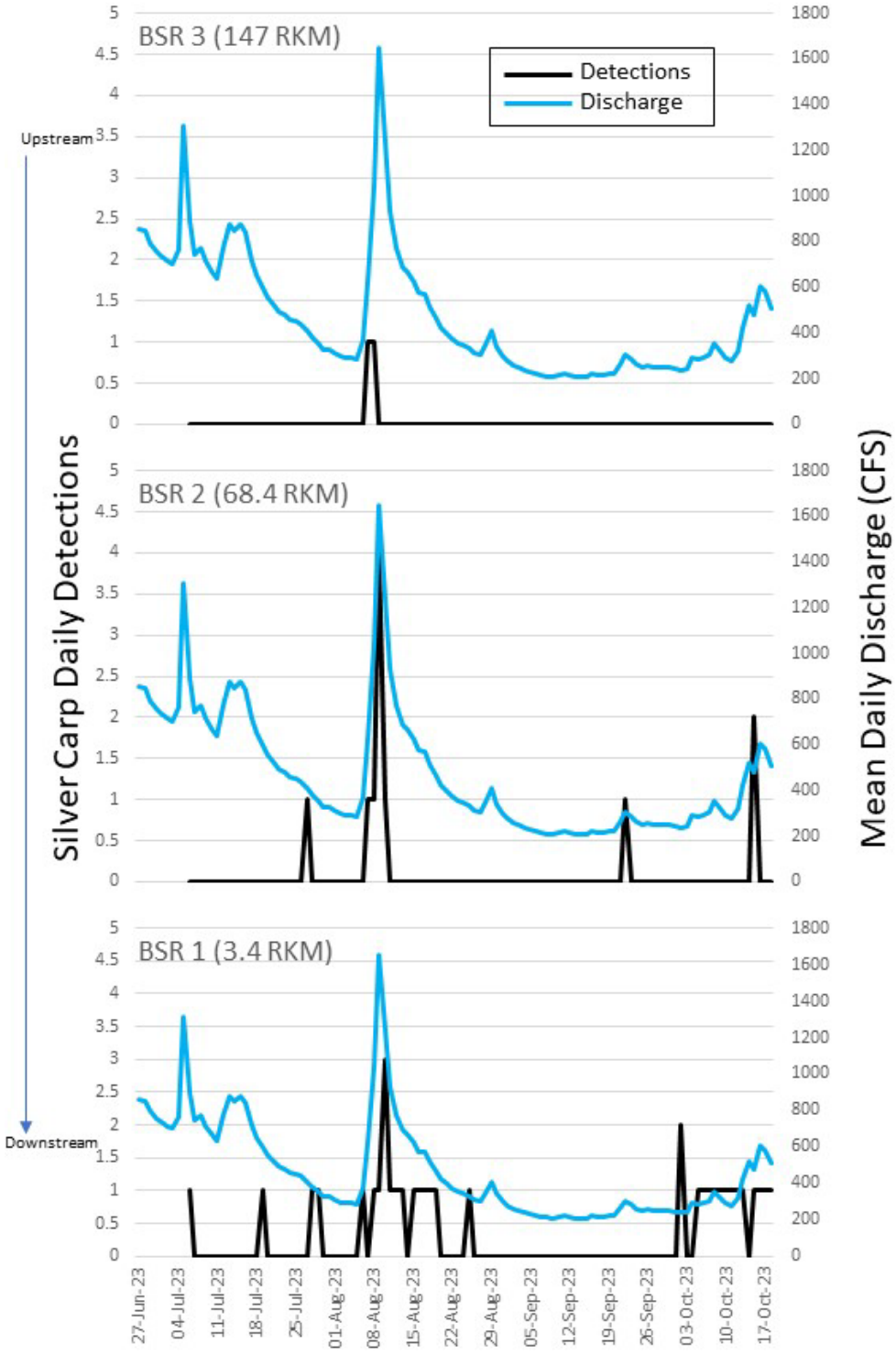

Figure 2. Number of daily detections of tagged silver carp by passive receivers and discharge (cubic feet per second; cfs) in the Big Sioux River at Sioux City, IA during 2023. Graphs arranged from upstream (top panel) to downstream (bottom panel).

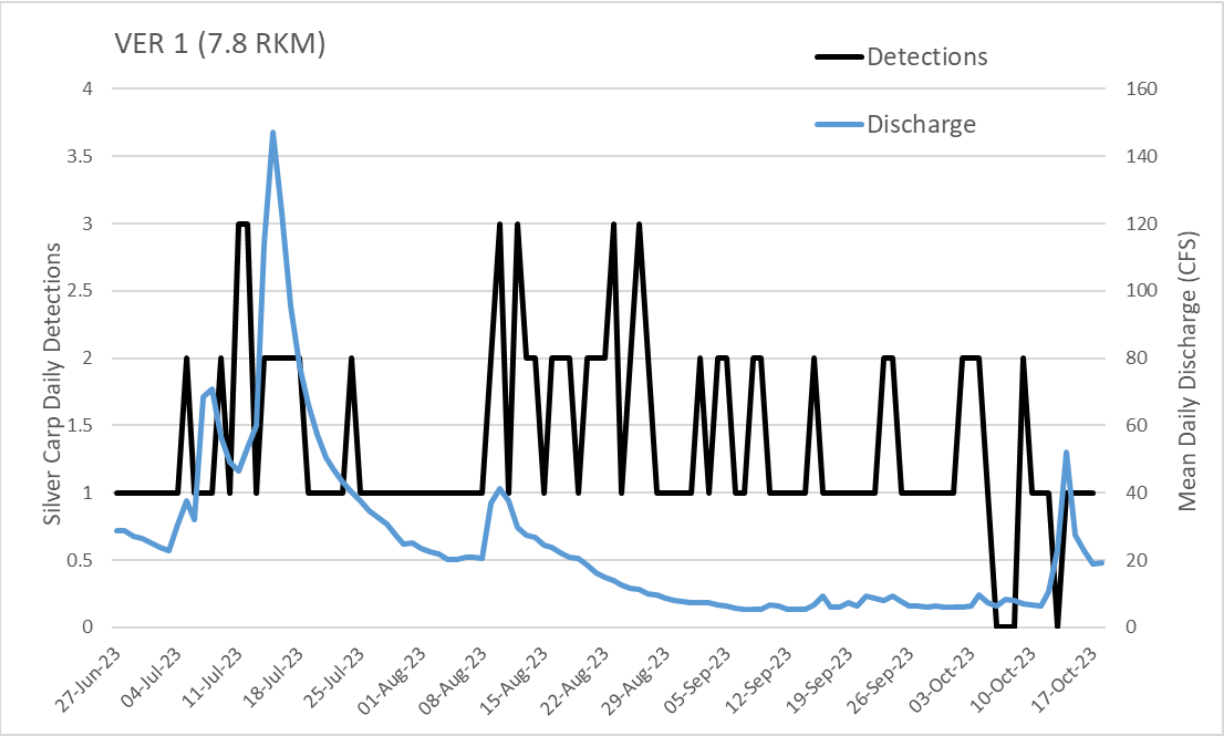

Figure 3. Number of daily detections of tagged silver carp by Vermillion receiver 1 and discharge (cubic feet per second; cfs) in the Vermillion River at Vermillion, SD during 2023.

Recommendations:

- 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.