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2022 Asian Carp Sampling in UMR and MO River Basins

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Project Highlights:

Component 1. Invasive carp movement and habitat use in the Missouri River Basin

We deployed twenty-eight acoustic receivers throughout the Little Sioux River Basin in Spring 2022 to track the movements of Silver and Bighead Carp. We tagged 67 Silver Carp and 14 Bighead Carp within the Little Sioux River and four of its tributaries during May 2022. We originally anticipated tagging an additional 40 fish during Fall 2022; however, low water levels throughout the Little Sioux River Basin required us to remove several receivers this Fall and consequently, we postponed tagging efforts until Spring 2023. We completed our last receiver downloads in mid-November. As of October 31st, 2022, movement of Silver and Bighead Carp was highest and they were most abundant in tributaries of the Little Sioux River during June coinciding with increased Little Sioux River discharge. Of the 23 fish (14 Bighead and 9 Silver Carp) tagged in Milford Creek, 22 have been detected at least once near the electric barrier and 8 individuals (5 Bighead and 3 Silver Carp) have moved back to the Little Sioux River. Besides one spike in discharge in mid-July that initiated some movements, detections of invasive carp throughout the study area were minimal starting in late-July, and this trend extended through October 31st when discharge and water levels were low.

We also installed a video surveillance system at the electric barrier on Milford Creek in June 2022 and spent summer 2022 experimenting with various camera angles and recording settings to develop a protocol to record and monitor the number of fish present and their behaviors at the barrier. We will use camera recordings along with a suite of environmental (temperature and discharge), spatial (barrier proximity and electrode proximity), and temporal (time of day, moon phase, and season) factors to evaluate factors related with barrier challenges and efficiency. The drought during summer 2022 limited our ability to quantify barrier effectiveness. When water was flowing over the barrier we observed invasive carp present at the barrier, but never crossing on top of the barrier into the electric field. The barrier wall ultimately blocked any upstream movement of fish during the periods of low water. We also did not detect passage of any acoustically tagged invasive carp past the barrier during 2022. We will continue to monitor the number of fish and their behaviors at the electric barrier in 2023.

Component 2: Reproduction and recruitment of Asian Carp in Missouri River tributaries

We collected 420 ichthyoplankton samples across 13 sites on the Big Sioux, Little Sioux, Floyd, and Boyer rivers between April 27th – August 5th, 2022. Our ichthyoplankton sampling successfully detected a large spawning event of invasive carp in the Big Sioux River on the Iowa/South Dakota border, where we captured approximately 4,500 invasive carp larvae and 300 eggs over 3 ichthyoplankton tows on June 15th, 2022, near Akron, Iowa. These larval invasive carp densities (~6,300 larvae/100 m^3) are substantially higher than larval densities reported in other areas, including the Illinois River. We have not yet identified invasive carp larvae at the other two sites or other dates on the Big Sioux River or on the Little Sioux, Floyd, or Boyer rivers during 2022, but are still processing some samples in the laboratory. In addition to invasive carp, we developed a spawning phenology of native fishes throughout these four rivers. Most native larvae belonged to family *Cyprinidae*, followed by *Catostomidae*, and *Percidae*.

Invasive carp have become established in the Missouri River basin within Iowa. However, juvenile invasive carp are rarely detected in the basin, and it is unknown if there is an impediment to recruitment within these systems or if current sampling extents and methodologies have not been effective at detecting them. Between May – October 2022, we sampled 36 2nd – 5th order stream sites using backpack electrofishing and seining in 12 HUC8 watersheds in the Missouri River basin. We captured 36,403 individuals of 43 species but did not collect juvenile invasive carp. We did capture seven adult Silver Carp, two adult Silver x Bighead Carp hybrids, and eight adult Grass Carp. We also sampled eight off-channel habitats along the Missouri River proper using backpack electrofishing, seine nets, clover-leaf minnow traps, and mini-fyke nets. We collected 33 species in off-channel habitats, including seven juvenile Silver Carp (mean TL = 70 ± 12 mm SE) at three off-channel sites (a side-channel within Lower Hamburg Bend Conservation Area in Atkinson County, MO, a backwater in Big Bear Park in Thurston County, NE, and a backwater in Schilling Lake Wildlife Management Area in Cass County, NE) during October. We collected juvenile Silver Carp in water <0.5 m with silty-sand substrates, little to no velocity, and little macrophytes, woody debris, and canopy cover. We will repeat these sampling efforts during 2023 to be better able to elucidate the drivers of juvenile invasive carp recruitment and identify key habitats for management.

Component 3: Upper Mississippi River Basin invasive carp reproduction

We collected 21 ichthyoplankton samples in pools 14-16 of the Upper Mississippi River approximately every 7 days between 3 May and 28 June 2022 (189 samples total in 2022). Egg densities (all fish taxa) across sampling sites peaked during June 2nd whereas densities of age-0 fishes (yolk-sac larvae, mesolarvae, and juveniles) were highest during June 23rd and 28th. We did not collect age-0 invasive carp in pools 14-16 during 2022. Instead, *Cyprinidae*, *Catostomidae*, *Clupeidae*, and *Centrarchidae* represented the most abundant families and peak densities occurred during May 19th (*Catostomidae*), June 23rd (*Cyprinidae* and *Centrarchidae*), and June 28th (*Clupeidae*). Consequently, pool 16 appears to be the furthest upstream invasive carp are currently able to reproduce. Chlorophyll *a* concentrations (µg/L) were highest within the Rock and Wapsipinicon rivers and lowest at most of the Mississippi River sites and variable among channel habitats.

Component 4. Upper Mississippi River Basin invasive carp movement

We acoustically tagged 77 Silver Carp in Des Moines River during fall 2021. Despite significant effort, we were only able to tag 9 Silver Carp in the Cedar River and were not able to capture any invasive carp in the Iowa River during fall 2021. We resumed sampling during spring 2022 and tagged an additional 24 Silver Carp in the Cedar River and 33 in the Iowa River prior to mid-May when we expected individuals from the UMR to migrate upstream. We also tagged an additional 60 Silver Carp among these three rivers during fall 2022. Receivers in the Des Moines River were most recently downloaded in August/September 2022 and receivers in the Cedar and Iowa rivers are being downloaded in November 2022. Silver Carp tagged in the Des Moines River had varying movement tendencies between tagging locations. The cohort tagged below Red Rock Dam generally appear to be residents while the cohort tagged below Ottumwa Dam exhibited more partially migratory behavior. We observed four Silver Carp downstream transitions through Ottumwa Dam and one of those individuals appears to have successfully passed back upstream. Of the cohort tagged below Ottumwa Dam, 14 individuals have moved downstream to the mouth of the Des Moines River at some point and 11 of 14 migrated back upstream. Of those eleven upstream migrants, four have moved downstream to the mouth of the Des Moines River a second time. We will continue to tag fish and monitor movement patters to assess residency and migration behaviors in relation to variation in environmental conditions (e.g., discharge).

Introduction

Ecological communities worldwide are becoming more uniform through the introduction and subsequent establishment of non-native species into novel areas through anthropogenic activities (Rahel 2002). Intentional introductions commonly occur to provide societal benefits such as food, recreation, and biological control (Pimentel et al. 2000) while advancements in transportation and worldwide commerce have increased unintentional introductions (Rahel 2002). A single non-native species can alter ecosystem structure and function and have costly economic consequences (Macisaac 1996, Pimentel et al. 2005, Weber and Brown 2009), but in the United States, approximately 50,000 non-native species introductions have occurred with varying success and impacts (Pimentel et al. 2005, Sagoff 2005). Economic losses due to non-native introductions are estimated at US$120 billion a year; however, actual costs are likely much higher because monetary costs associated from species extinctions, loss of ecosystem services, and aesthetic values are not easily assessed (Pimentel et al. 2005). Likewise, ecological costs may be much greater than economic costs but are difficult to quantify and assess because of lag times between invasion and empirically confirmed impacts to the environment (Gido and Brown 1999, Stohlgren and Schnase 2006).

Rivers naturally provide an invasion highway for invasive fishes to expand. Modifications to rivers for navigation have further facilitated spread by connecting previously separate waterways, facilitating inter-basin movement and the spread of invaders into additional novel habitats (Leuven et al. 2009). For example, the Mississippi River Basin (MRB) covers approximately 40% of the lower 48 U.S. states with thousands of river miles (USACE 2011). At least 83 non-native fishes have become established in the MRB as a result of dispersal from other basins or by direct introduction from anthropogenic activities (Rasmussen 2002). Two of the more recent and widely recognized invaders to the MRB are Silver Carp (*Hypophthalmichthys molotrix*) and Bighead Carp (*H. nobilis*; collectively referred to as invasive carp). Invasive carp have become abundant and threaten the integrity of the MRB and any connected aquatic ecosystems (Irons et al. 2009). Invasive carp were imported during the 1970s into the United States for food consumption and biological control in aquaculture facilities (Freeze and Henderson 1982). In the 1970s, individuals thought to have escaped during flooding events were observed in several rivers within Arkansas. Due to their high reproductive capabilities and long-distance migrations (DeGrandchamp et al. 2008), invasive carp quickly became established and now inhabit more than 20 states throughout the Mississippi, Missouri, Ohio, and Illinois river basins (Kolar et al. 2007, Baerwaldt et al. 2013, Deters et al. 2013). By the mid-1980s, invasive carp were caught in the pooled sections of the Upper Mississippi River Basin (UMRB; Kolar et al. 2007) with the first observations of invasive carp in Iowa occurring in 1986 when Silver Carp were captured in the UMRB below lock and dam 19 (LD19) near Keokuk (Irons et al. 2009). A year later, bighead carp were captured near the mouth of Yellow Springs Creek north of Burlington, IA (Irons et al. 2009). Since the initial observations in Iowa, invasive carp adults have been sighted in several additional UMRB tributaries in Iowa such as the Des Moines, Skunk, Iowa, and Cedar rivers (Bruce 1990, United Press International 2011, Irons 2012, Camacho 2016, Sullivan 2016). In the Missouri River Basin (MORB), invasive carp have been recorded as far north Gavin's Point Dam, SD and in tributaries such as the James River in Stutsman County, North Dakota (United States Geological Survey 2022). The first invasive carp was collected from the Missouri River in Iowa in 1995 (Pherigo 2017). Populations were well established in Iowa's border waters by 2008 and have since been sampled in tributaries of the Missouri River including the Little Sioux, Big Sioux, Ocheyeden, and Platte Rivers, among others (Irons et al. 2012; Pherigo 2017; USGS 2022).

Currently, invasive carp have colonized the entire Missouri River and its tributaries in western Iowa upstream to Gavin's Point Dam near Yankton, SD. Alternatively, southeastern Iowa represents the leading edge of invasive carp expansion in the UMRB. Substantially higher adult catch rates of both Silver and Bighead Carp occur below LD19 than above, suggesting this structure and other lock and dams on the Mississippi River may serve as a partial migration barriers (Wilcox et al. 2004). For example, the UMRB water level is regulated at each dam in order to maintain a navigation channel by reducing or eliminating the amount of water discharged, leaving passage through the locks as the only means of fish movement during low river discharge periods. However, dam gates are lifted during higher discharge events that facilitate fish passage (Garvey et al. 2010). It is also during these high discharge events that invasive carp exhibit some of their highest movement rates among pools, especially during annual spring runoff and associated peak discharge events when temperatures are below or within the spawning optimum, suggesting movement may be associated with spawning migration behavior (Jennings 1988, Peters et al. 2006, DeGrandchamp et al. 2008). Furthermore, invasive carp can quickly make long distance migrations (DeGrandchamp et al. 2008), indicating that these fish are capable of dispersal into new locations.

The rapid spread of invasive carp throughout the US is largely due to the ability of adults to make long distance movements. Understanding invasive carp movements in relation to environmental conditions and barriers (e.g., locks and dams, lowhead dams, electric barriers, etc) can provide insights into population structure (e.g., discrete populations vs one large intermixing population) and identify locations where deterrence technologies, concentrated removal efforts, etc. can be used for containment and control. Silver and Bighead Carp movements into tributaries including the Des Moines, Iowa, and Little Sioux rivers has been observed; however, the seasonal and spatial extent that invasive carp use these tributaries is still unknown. Invasive carps are captured in tributaries throughout the year but in varying abundances (Sullivan et al. 2017), suggesting a portion of the population may be residents while others may be migrants. In the Des Moines River, individuals are observed throughout the year directly below Red Rock Dam (rkm 224) and Ottumwa Dam (rkm 148). Red Rock Dam is an effective barrier to fish movements upstream while Ottumwa Dam is believed to be an effective barrier to upstream movements under low water and normal conditions but passible during high water conditions. There are no barriers below Ottumwa Dam that would limit downstream movement in the Des Moines. Other interior rivers in Iowa are unimpounded that could allow invasive carp to move further upstream and provide access to more habitats, but they are also smaller and may not be suitable for carp year-round. For example, invasive carp are abundant in the Little Sioux River that has allowed them to invade smaller streams and lentic systems. However, the movement dynamics of invasive carp in these small systems is poorly understood. Variation in movement across systems as well as within a system temporally in relation to environmental conditions (e.g., discharge) have metapopulation dynamic implications. Metapopulations may allow for persistence in areas or times of limited or no recruitment due to the high dispersal/contribution from recruiting populations (Dauphinais et al. 2018, Sorensen and Bajer 2020). Identification of local populations or subpopulations may allow insight for local control efforts and improve the overall multi-jurisdictional management required for invasive carp.

Although adult invasive carp may move long distances and can navigate some barriers, habitats in invaded areas may be unsuitable for reproduction, resulting in population sinks. Invasive carp are highly fecund (up to 3.5 million eggs per female; Garvey et al. 2006) and have short gestation periods (Chapman and George 2011). Thus, only a few adult individuals may be needed to quickly establish an abundant population (Crawley et al. 1986). Despite adult invasive carp being detected above LD19 up to St. Paul, MN, USA, their populations have remained low, suggesting reproduction may be limited in these reaches. Pooled sections associated with lock and dams exhibit reservoir-like characteristics that are more lentic in nature resulting in lower invasive carp reproduction than in unregulated sections where lock and dams are absent (Lohmeyer and Garvey 2009). In contrast, established invasive carp populations in tributary systems, such as the Illinois River, can have high recruitment and adult populations have increased exponentially in abundance within a decade (Sass et al. 2010). Yet, invasive carp abundance in Iowa tributaries appear lower compared to the Illinois River and much less is known regarding invasive carp reproduction ecology within these systems, despite its importance as a mechanism regulating adult population abundance.

Successful invasive carp spawning depends on adults finding suitable habitat of sustained, high flow or increasing discharge when water temperatures are between 17 and 30°C (Kolar et al. 2007). Continuous river flow of at least 25 km may be necessary to suspend the semi-buoyant eggs for a 24 h period or until larvae successfully hatch (Krykhtin and Gorbach 1981, George and Chapman 2013, Murphy and Jackson 2013). In most areas of the UMRB, reaches between dams with sufficient sustained velocities of 0.3 to 3.0 m/s and turbulence to keep eggs in suspension do not exist or are poorly suited for egg survival (Lohmeyer and Garvey 2009). However, age-0 invasive carp have been documented in tributaries such as the Cache River (a tributary to the Ohio River; Burr et al. 1996) and the Illinois River (a tributary to the Mississippi River; DeGrandchamp et al. 2007). Additionally, tributaries are associated with invasive carp spawning activity in their native range in the Yangtze River (Yi et al. 1988) and in varying capacities in the Missouri River (Schrank et al. 2001) and Illinois River (DeGrandchamp et al. 2007) where they are introduced. Successful reproduction of invasive carp in Iowa tributaries (Camacho et al. 2021) could provide sources of recruitment for pooled sections of the UMRB and other areas of poor reproduction. Similarly, tributaries in western Iowa could also represent recruitment sources for the Missouri River. However, these systems are smaller, have lower discharge, and are more degraded compared to UMRB tributaries in eastern Iowa and it is unknown if these systems are suitable for invasive carp reproduction. Evaluating factors affecting reproduction and recruitment in tributaries of the Mississippi and Missouri river in association with annual variation in environmental conditions is needed to better understand invasive carp population dynamics in these systems and potentially develop management strategies for these invasive fishes.

Project Objectives:

Component 1: Invasive carp movement and habitat use in the Missouri River Basin

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

   a. Determine if Silver Carp and Bighead Carp have extended presence in tributaries and directional movement into and out of Missouri River tributaries.
   b. Evaluate the effects of environmental factors (e.g., season, temperature, discharge) on Silver Carp and Bighead Carp residency and movement behaviors in select Missouri River tributaries.

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

Component 2: Missouri River Basin invasive carp reproduction

2.1) Assess timing and magnitude of invasive carp reproduction in the Little Sioux River using larval densities.

2.2) Assess detection probabilities and spatial distribution of juvenile invasive carp throughout Missouri River tributaries in Iowa.

Component 3: Upper Mississippi River Basin invasive carp reproduction

3.1) Delineate the leading edge of invasive carp reproduction across pools 14-16 of the Upper Mississippi River.

Component 4: Upper Mississippi River Basin invasive carp movement

4.1) Analyze Silver Carp residency patterns and their metapopulation implications within tributaries of the Upper Mississippi River
   a. Identify individual-based movement patterns (e.g., residents vs. migrants)
   b. Analyze population structure within the study area
   c. Identify trends in spatial and temporal use of tributaries

Methods

<u>Component 1.1:</u> Evaluate invasive carp residence time and movement behaviors in the Little Sioux River and its tributaries in association with season, environmental conditions, and barriers.

We deployed an array of twenty-eight 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 conduct routine receiver maintenance at approximately 3-6 month time intervals to ensure receivers are 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 that were 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 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 May 2022 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=21 and V16-4x, n=40, VEMCO Inc., Halifax, Nova Scotia, Canada) provide presence/absence data at receiver locations. We also implanted V16A-6x (n=10) and V16T-4x (n=10) 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 tagged 67 Silver Carp (Male n=51, Female n=16) and 14 Bigheaded Carp (Male n=5, Female n=9) during May 2022. We tagged a majority of Silver Carp near (<5 rkm) the confluence of the Ocheyedan River (n=5, [TL: 621-800mm, mean TL = 677mm]), Lost Island Outlet (n=17, [TL: 466-826 mm, mean TL = 639 mm]), and Milford Creek (n=16, [TL: 542-750 mm, mean TL = 659 mm]). We tagged 14 Bighead Carp (TL: 522-758 mm, mean TL = 663 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 in May 2022. Finally, we tagged 20 (TL: 531-809 mm, mean TL = 655 mm) additional Silver Carp further downstream between Cherokee, IA, and Correctionville, IA. Acoustic receiver and fish tag data is archived and shared with partners throughout the Midwest via FishTracks (https://umesc-gisdb03.er.usgs.gov/Fishtracks) operated and maintained by USGS.

Component 1.2: Assess fish behaviors in association with an electric barrier at the outflow of the Iowa Great Lakes.

Invasive carp are well established throughout the Missouri River and its tributaries. Flooding in 2012 allowed invasive carps to move upstream in the Little Sioux River and 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 quickly 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. 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 7.6 cm (3”), which typically occurs in the spring when invasive carp 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 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 (Jonathan Meerbeek, Iowa DNR, personal communication); thus, upstream fish passage through the barrier may also be possible.

Several 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 likely hold the most 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.

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

After the initial setup, we programmed the camera to record videos during randomly selected 15-minute intervals from each hour of the day that were saved to a hard drive on site. From these videos, we will categorize fish behaviors as avoidance (slow approach and retreat away from the base of the electrical barrier), erratic (deviation from normal swimming behavior including rapid bursts of movement), challenging (persistent attempt to swim upstream over the barrier but is unsuccessful), inhibition (swimming inhibited due to involuntary contraction and relaxation of the muscles), galvanotaxis (actively swimming toward anode due to electrical field), motionless (temporarily stunned or involuntary relaxation of muscle due to shock from barrier), tetany (severe involuntary muscle contraction, open mouth, lack of operculum movement; death), and advanced (stunned but made a successful attempt and crossed the barrier; Ostrand et al. 2009). In addition, we will document the number of Silver Carp jumps, number of fishes present, and the total amount of time each fish spends actively trying to challenge the barrier.

We recorded voltage in the electric field on and adjacent to the barrier via an oscilloscope in May 2022. We will periodically measure barrier voltage when water inundates the barrier to document any change in the electrical output. Likewise, we will periodically measure water velocity across the top of the barrier to document water flow under various conditions to develop a relationship between water depth and velocity. Finally, we are collecting water temperature data every 15 minutes below the barrier via a HOBO data logger.

Component 2.1: Assess timing and magnitude of invasive carp reproduction in the Little Sioux River using larval densities.

We sampled ichthyoplankton at four sites along the Little Sioux River and nine additional sites across the Big Sioux River, Floyd River, and Boyer Rivers for a total of thirteen sites (Table 3; Figure 4). We selected sites to cover the upper, middle, and lower thirds of each river, except for the Little Sioux, which is longer and was divided into quarters. We separated all sites by at least 60 river kilometers to decrease the probability of resampling a single spawning event farther downstream. We collected three replicate ichthyoplankton samples at each site every ten days from April 27th until August 5th, 2022. Each sampling session lasted two consecutive days. We collected larval fishes with a conical ichthyoplankton net (0.5-m mouth diameter, 500-µm mesh) anchored to a bridge and held stationary in the current for approximately 4 minutes. Nets were aligned parallel to shore and facing upstream to capture drifting eggs and larvae. We only sampled the thalweg to accommodate low water levels and standardize sampling across the varied sizes of study rivers (wetted widths of sampling sites varied from 78.9 meters to 6.7 meters). A General Oceanics flowmeter was attached to the mouth of the net to record the water volume sampled (m^3) in each tow. We measured air temperature, water temperature, conductivity, and pH at each site with a dual temperature/conductivity YSI probe and a Hach HQ40D pH meter. We used the nearest upstream USGS or NOAA stream gauge to obtain daily river discharge. Twice in August we towed the net manually against the current when river discharge was too low to properly engage the flowmeter, once at the FLD-UPR site on August 5th, 2022 and once at the LSR-UPR site on August 4th, 2022. Furthermore, we did not sample the FLD-MID site on August 5th, 2022, as the thalweg depth was less than 0.5 of the net's diameter. After each tow, we rinsed net contents into the cod end, filtered it through a 500- µm sieve, and preserved the sample content in 95% ethanol.

In the lab, at least two individuals separated eggs and larval fishes from debris and stored them in glass scintillation vials for identification. After sorting, we categorized age-0 fishes as yolk-sac (presence of a yolk), larvae (yolk was completely resorbed), or juveniles (full set of developed fins). We classified embryos still encased in the egg membrane as eggs. In addition to larval stage classification, we identified all fishes to family or genus (when possible) using morphological landmarks such as yolk-sac characteristics, gut length, and myomere counts (Auer 1982; Lenat and Resh 2001). Finally, we classified invasive carp larvae as bigheaded carps (*Hypophthalmichthys molitrix* and *H. nobilis*), Grass Carp (*Ctenopharyngodon idella*), or Common Carp (*Cyprinus carpio*), following metrics provided by Chapman and George (2011) and Chapman (2006).

<u>Component 2.2:</u> Assess detection probabilities and spatial distribution of juvenile invasive carp throughout Missouri River tributaries in Iowa.

We sampled fish assemblages at 36 stream sites across twelve HUC8 watersheds in the Missouri drainage from May – October 2022 (Figure 5). We selected sites ranging from 2nd – 5th order tributaries using a Generalized Random Tessellation Stratified (GRTS) sampling design (Stevens and Olsen 2004). Along with these randomly selected stream sites, we selected and sampled eight backwaters/side-channels along the Missouri River proper. In streams, we used both backpack electrofishing and seining to compare catches and assemblages between gears. We delineated each stream site (40 times the mean wetted width) and divided it into three equally spaced reaches separated by 50 m. We then divided reaches into two smaller sub-reaches, one for an electrofishing survey and the other for a seine haul.

Prior to fish sampling, we measured water temperature, dissolved oxygen, turbidity, pH, and conductivity using a Hach HQ40d multimeter and Hach 2100p turbidimeter. We conducted backpack electrofishing within each reach following methods similar to that of the Iowa Department of Natural Resources (2015). We used single backpack electrofishers for streams <5 m wide and two backpack electrofishers for streams >5 m. We aimed to achieve 2-5 amps of output and settings were set at 15% duty cycle at 60Hz with a voltage range of 150-250 volts, depending on conductivity and fish taxis effect (Bonar et al. 2009). We electrofished in an upstream direction ending at a block net or natural barrier. We captured stunned fishes with dip nets and placed them directly into buckets and/or live wells until the sample was completed. After the sample, we recorded effort in seconds, identified fish to species and enumerated them, and if caught, we recorded lengths and weights of invasive carp and preserved them in ethanol. After fishes were processed, we released them downstream of the electrofishing reach to avoid recapture. Following electrofishing, we conducted a seine haul (bag seine, 11 m x 1.8 m, 4.7 mm mesh) where we pulled the seine at the same speed or faster than the current in a downstream direction for 30 m to a block net or natural barrier. Once the haul was completed, we processed fishes in the same fashion as the electrofishing survey. We completed this process three times at each site for a total of three electrofishing replicates and three seine haul replicates.

In addition to sampling streams, we also sampled backwater/side channels to the Missouri River and its tributaries, as backwater areas may serve as nursery areas for juvenile invasive carp (Kolar et al. 2007). We sampled backwaters using similar methods as stream sites; however, we sampled with five replicates of each gear instead of three and we standardized backpack surveys to 30 m sections along the bank. Within each of the five reaches we also deployed one mini-fyke net (2' x 4' box, 21' lead, ¼" delta mesh) and one clover leaf trap (28" x 15," ¼" mesh) to further compare juvenile invasive carp sampling efficiency of multiple gears.

We measured physical stream habitat after fish sampling to avoid disturbance. We divided the length of each reach into four equally sized transects, for a total of twelve transects, and measured habitat parameters at the midpoint of each transect (Iowa Department of Natural Resources 2015). We measured wetted width to the nearest 0.1 m and depth, velocity, and substrate type at 10, 25, 50, 75, and 90% of the wetted width at each transect. We measured current velocity with a Marsh-McBirney velocity meter at 60% of the depth in locations less than 0.75 m and averaged between two measurements at 20 and 80% of the depths in locations greater than 0.75 m (Sindt et al. 2012). We measured instream fish cover (filamentous algae, aquatic macrophytes, woody debris/small brush, overhanging banks/vegetation, under-cut banks, boulders, artificial structure, and deep pool presence) 5 m upstream and downstream of each transect midpoint. We measured in-stream fish cover on a scale of 0 – 4 with 0 being absent, 1 being sparse (<10%), 2 being moderate (10-40%), 3 being heavy (40-75%), and 4 being very heavy (>75%) and we estimated percent bare stream bank (nearest 5%) on either side of the stream, and canopy cover in three directions using a spherical densiometer (Iowa Department of Natural Resources 2015).

Component 3.1: Delineate the leading edge of invasive carp reproduction across pools 14-16 of the Upper Mississippi River.

To assess invasive carp reproduction along the Upper Mississippi River invasion front, we collected chlorophyll *a*, fish eggs, and age-0 fishes at seven locations (Figure 6) approximately every seven days depending upon river conditions from early May until early July 2022. Sampling sites are abbreviated to distinguish tributary sites from sites within the Mississippi River upstream and downstream from the tributary site (Table 4). We sampled sestonic chlorophyll *a* in conjunction with each tow for eggs/age-0 fish by filtering 100 mL of water through a GF/F Whatman© glass fiber filter (47-µm porosity) that we placed on ice in the field and frozen in the laboratory. We extracted chlorophyll *a* with 90% acetone and quantified using an Aquafluor Handheld Fluorometer (Turner Designs) to obtain chlorophyll *a* concentrations (µg/L). We conducted ichthyoplankton tows (0.5 m diameter net, 500 µm mesh) at the surface at a constant boat speed relative to the shoreline up to four minutes depending on debris load. We attached a General Oceanics flowmeter (Model 2030R) in the mouth of the net to estimate volume (m^3) of water filtered during each tow. We conducted three tows at each site parallel to river flow: the first tow was in the main thalweg for drifting eggs and larvae (<24 hours post fertilization), the second tow occurred near channel borders where water velocity is moving downstream slower than the thalweg, and the third was in an adjacent backwater area for mobile larvae and juveniles (>24 hours post fertilization). After each tow, we rinsed ichthyoplankton net contents toward the cod end, placed in sample jars, and preserved in 95% ethanol.

In the laboratory, we separated eggs and fishes (yolk-sac larvae, mesolarvae, and juveniles) from debris. We subsampled larvae within a sample using a Fulsom Plankton Splitter when samples contained ≥1,000 age-0 fish (n=1 of 189 samples), so that at least 25% (minimum 250 fish) were identified. We identified all fishes to the lowest possible taxonomic level using morphometric and meristic characteristics described in literature (Auer 1982). Invasive carp larvae are difficult to distinguish among species and were identified to genus using meristic and morphometric characteristics (Chapman 2006; Chapman and George 2011). We first categorized fishes as yolk-sac larvae, larvae, or juveniles based on fin development and complete absorption of the yolk-sac. Fish recognized as having a full complement of fins are categorized as juvenile fish. Data and figures presented here includes all age-0 fishes without distinguishing ontogenetic categories.

Component 4.1: Analyze Silver Carp residency patterns and their metapopulation implications within tributaries of the Upper Mississippi River

We deployed an array of twenty-nine VEMCO VR2W and VR2Tx acoustic receivers throughout the Des Moines (N=14), Cedar (N = 7), and Iowa (N = 8) rivers to enhance detection coverage throughout these systems (Table 5; Figure 7). We hung receivers inside PVC conduit using stainless steel cable and mounted them to bridge pilings with the exceptions of a receiver in a Des Moines River backwater and a receiver in a Cedar River backwater that we deployed with a bottom set.

We initially tagged Silver Carp during fall 2021 and early spring 2022 when individuals from the UMR would not be migrating upstream for spawning. We collected Silver Carp using boat electrofishing (DC, 15 amps, 150V, 40 pulses per second) focusing on woody habitat, riffles, and shade. We implanted 142 Silver Carp with acoustic transmitters (VEMCO V13-1x, V16-4x, V16A-6x, or V16T-4x, Vemco Inc., Halifax, Nova Scotia, Canada) during Fall 2021 and Spring 2022: 38 (14 Males and 24 Females [TL: 680-821 mm; mean TL = 733 mm]) in the Des Moines River below Red Rock Dam, 39 (25 Males and 14 Females [TL: 630-889 mm; mean TL = 719 mm]) in the Des Moines River near Cliffland, IA, 33 (16 Males and 17 Females [TL: 736-995 mm; mean TL = 860 mm) in the Cedar River, and 32 (14 Males and 18 Females [TL: 766-912 mm; mean TL = 842 mm) in the Iowa River (Table 6). We tagged an additional 60 Silver Carp during fall 2022: 15 (7 Males and 8 Females [TL: 684-855 mm; mean TL = 751 mm) in the Des Moines River below Red Rock Dam, 15 (6 Males and 9 Females [TL: 615-831 mm; mean TL = 714 mm]) in the Des Moines River near Cliffland, IA, 15 (7 Males and 8 Females [TL: 784-1049 mm; mean TL = 924 mm]) in the Cedar River, and 15 (5 Males and 10 Females [TL: 753-905 mm; mean TL = 853 mm]) in the Iowa River (Table 6). We identified fish sex by a combination of visual inspection during surgical procedures and the presence/absence of a rough patch on the pectoral fins (Wolf et al. 2018). Acoustic receiver and fish tag data is archived and shared with partners throughout the Midwest via FishTracks (https://umesc-gisdb03.er.usgs.gov/Fishtracks) operated and maintained by USGS.

To determine general, broad movements of Silver Carp, we calculated maximum displacement values for individual Silver Carp and estimated mean values based on tagging location. Maximum displacement value represents the distance (km) between most upstream and downstream detections. We then classified individuals as migrants or residents based on thresholds used in previous studies (Prechtel et al. 2018) as well as frequency distributions of maximum displacement values at each study site (Figure 8). Currently, we have classified individuals with a maximum displacement value less than 25 kilometers as residents, individuals with displacement values greater than 100 km as migrants, and individuals with displacement values between those thresholds as intermediate.

We also assessed the frequency of transitions between the DSMR and UMR to provide insights on population structure/connectivity of individuals located above Ottumwa Dam, below Ottumwa Dam, and in the UMR. We noted observations of both upstream and downstream passage through Ottumwa Dam. We also assessed water temperature and discharge from nearby USGS gauging stations (De Cicco et al. 2022) as well as HOBO temperature loggers (HOBO 64K Pendant data loggers; Onset Computer Corp., Bourne, Massachusetts) attached to the receivers to understand Silver Carp movements in relation to environmental conditions.

Results and Discussion:

<u>Component 1.1:</u> Evaluate invasive carp residence time and movement behaviors in the Little Sioux River and its tributaries in association with season, environmental conditions, and barriers.

We downloaded all 28 acoustic receivers located throughout the study area at least once between early-August and mid-November. Due to low water levels during late July and much of Fall 2022, multiple bridge receivers were not in service. In addition, multiple bottom set receivers were covered in sediment over unknown time periods during Summer 2022 but were checked at approximately one-month time intervals to uncover from sediment if needed.

Cumulatively, we have acquired 139,944 invasive carp detections on the three receivers located within Milford Creek between May 4th and November 14th, 2022. Most of these detections (139,748) were recorded by the acoustic receiver 250 m downstream of the electric fish barrier. Of the 23 fish (9 Silver Carp and 14 Bighead Carp) tagged in Milford Creek, all but 1 Silver Carp has been detected near the barrier. The number of fishes detected near the barrier decreased significantly from May 4th to November 14th, while detections of unique individuals at the middle and confluence receiver locations increased during June and July (Figure 9). No acoustically tagged invasive carp have been detected in the Iowa Great Lakes.

Since early May, 5 Bighead Carp and 3 Silver Carp moved from Milford Creek to the Little Sioux River. One of the 5 Bighead Carp that left Milford Creek was detected in the West Fork Little Sioux River, Ocheyedan River, and Lost Island Outlet all within a 3-day period. After its last detection in Milford Creek on July 8th, this individual was detected a total of 50 times across 14 different receivers, and traveled approximately 545 km before its last detection at our Missouri River receiver located approximately 35 km downstream of the Little Sioux River confluence on July 24th (Bighead Carp 1, Figure 10). Of the 58 Silver Carp tagged in the Little Sioux River, none have been detected in Milford Creek. However, there have been multiple Silver and Bighead Carp detected moving into the West Fork Little Sioux River, Ocheyedan River, and Lost Island Outlet. The number of unique individuals detected per month appeared to be highest in these tributaries during June, followed by July (Figure 11) that corresponded with periods of increased discharge in the Little Sioux River (Figure 12) and increased water levels in tributaries (Figure 13). However, due to acoustic receivers being covered in sediment within Lost Island Outlet and the Ocheyedan River during multiple unknown time periods throughout Summer 2022, the number of individuals detected in these systems may have been underestimated. Multiple gaps in detections that we observed may also imply some individuals are still present within these systems and would could explain why they have not been detected anywhere in the Little Sioux River since those occasions. Finally, of the 81 fish tagged from May 4th - 18th (Silver Carp and Bighead Carp combined), we have not detected 5 Silver Carp anywhere in the acoustic receiver array.

Disregarding the 8 fish that moved from Milford Creek to the Little Sioux River, the remaining 15 appear to be highly resident and have shown very little signs of movement from their initial tagging location near the electric fish barrier. Total fish detections near the barrier dropped significantly during late-July through mid-November that coincided with declining water levels. However, large numbers of fish (primarily Bighead and Silver Carp) were observed in person on multiple occasions throughout Summer 2022 approximately 300 meters downstream of the electric fish barrier (~75 meters downstream of nearest acoustic receiver). Optimal 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 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 that were initially tagged in this area were detected, but the determination of mortalities was inconclusive (Table 2).

To evaluate Silver and Bighead Carp movements in the Little Sioux River and its tributaries, we classified movement events as either upstream or downstream. Directional movements were considered as sequential detections of an individual on a series of receivers that followed a unidirectional pattern. Fish we tagged on May 18th did not have as many days to move as other individuals, so movements in May were not directly compared to the other months. Since a large majority of our receivers were downloaded in the first and second week of November, detection data was only analyzed through October 31st.

Monthly movements of Silver and Bighead Carp appeared to be correlated with Little Sioux River discharge. High rainfall during June initiated both upstream and downstream movements of various magnitudes for both species. We observed Silver Carp movements were more frequent and larger during June that coincided with an extended period of high discharge in the Little Sioux River. Thirty-three of 67 Silver Carp exhibited at least 1 upstream movement (mean: 47.0 km ± 8.12 SE) and 30 individuals had 1 or more downstream movements during June (mean: 51.0 km ± 8.18 SE). In July, average Silver Carp upstream (mean = 20.6 km ± 8.38 SE) and downstream (mean = 21.2 km ± 6.38 SE) movements were smaller. Movement appeared to be very limited between August and October; only two upstream movements were observed between two individuals during August (mean = 33.75 km ± 7.35 SE) that coincided with a slight increase in Little Sioux River discharge. Across all months, the furthest downstream Silver Carp movement (225 km) exceeded the furthest upstream movement (205 km; Figure 14). Throughout much of August and all of September and October, there were no detections of Silver Carp that suggested any type of movement event.

Bighead Carp generally showed less signs of movement than Silver Carp where only 6 of 14 fish had a movement event from June 1st to October 31st. Only one individual had an upstream movement event during June (3.5 km), while 3 individuals had downstream movements (mean = 38.8 km ± 19.78). Comparatively, Bighead Carp downstream movements (mean = 130.72 km ± 68.14 SE) were more frequent and larger than upstream movements (mean = 37.3 km ± 27.63 SE) during July. The furthest upstream Bighead Carp movement was 92 km and occurred in the beginning of July, while the largest downstream movement spanned from 3 km upstream into the West Fork Little Sioux River, to 35 km downstream of the Little Sioux River/Missouri River confluence (~395 km) during mid-late July. Similar to what was observed in Silver Carp, Bighead carp movement from August – October was very limited. In fact, we did not observe a single movement event from the end of July until our most recent data download in November. As of October 31st, 3 Silver Carp and 1 Bighead Carp have been detected at the receiver near the Little Sioux River mouth (Figure 10). Since their last detection at this receiver, we have only detected the Bighead Carp once in our array. We detected this individual in the Missouri River ~35 km downstream of the Little Sioux River confluence 4 days after its last detection in the Little Sioux River. Of the 3 Silver Carp that were last detected near the Little Sioux River mouth in mid-June and mid-July, none have been detected again within our array. However, 1 individual was detected on September 4th ~40 km upstream into the Platte River, ~160 km from the mouth of the Little Sioux River, representing a total minimum movement of 253 km from its tagging location near Correctionville, IA.

Low water levels exhibited throughout much of the Little Sioux River Basin in late-July and subsequent months could potentially explain why movement was limited during this period. Drought-like conditions have persisted through August, September, and October 2022 across much of the Little Sioux River Basin, likely limiting movements during this time. Future detection data will allow us to assess how invasive carp movement can be affected by environmental conditions and the potential reduction in habitat connectivity among different systems on a seasonal basis. Additional years of data under variable river discharge patterns will provide insights into how movements vary interannually based on wet versus dry years.

Component 1.2: Assess fish behaviors in association with an electric barrier at the outflow of the Iowa Great Lakes.

During summer 2022, we experimented with a number of different camera configurations to assess options for evaluating fish behaviors at the Lower Gar electric barrier. Initial video analysis revealed our ability to see and identify fishes decreased with increasing distance from the camera. Similarly, we found the infrared light emitted by the LED lights on the camera at night were only illuminating a small section of our viewing frame. Therefore, we repositioned the camera to focus on visible fish movements on the north end of the barrier (Figure 15). After the installation of the surveillance camera, there were 60 days (06/14/2022 - 08/12/2022) when the barrier was active and water was flowing. Of the 60 days of flow, we captured 32 days (7/12/2022 – 8/12/2022) of viable videos. There has been no flow over the barrier between August and November 2022. On the day's videos were viable, we did not observe any fishes trying to cross the barrier. Instead, we observed fishes downstream attempting to challenge the barrier. We will continue to monitor fish activity and their behaviors at the barrier when water levels increase. We have also been working on study logistics to assess barrier effectiveness more thoroughly once flows over the barrier resume.

Field measurements of voltage variation between electrodes resulted in strengths of 4.2 V/cm between electrodes one and two, 5.0 V/cm between electrodes two and three, 5.3 V/cm between electrodes three and four, 5.2 V/cm between electrodes four and five, 5.0 V/cm between electrodes five and six, 5.6 V/cm between electrodes six and seven, and 4.6 V/cm between electrodes seven and eight. Stray voltage 1 m below electrode one had a strength of 0.86 V/cm, while stray voltage 1 m above electrode eight had a strength of 0.6 V/cm (Figure 16).

Component 2.1: Assess timing and magnitude of invasive carp reproduction in the Little Sioux River using larval densities

We conducted 426 larval tows across 13 sites on four rivers (Big Sioux, Little Sioux, Floyd, Boyer) during summer 2022 to assess invasive carp reproduction throughout western

Iowa (Figure 4). To date, we have processed 4,988 larvae and 356 eggs from our samples with an additional 39 samples awaiting processing in the lab as of December 2022. We detected eggs and larvae at all sites, though not on all dates. Egg densities ranged from 0 to 220 eggs/100 m^3 while larval densities in individual tows ranged from 0 to 6,280 fish/100 m^3. The highest density of age-0 fishes in a single tow (6,280 fish/100 m^3) was recorded at the BSR-MID site on June 15th, 2022. In addition, this was the only sampling event where we captured age-0 invasive carp (approximately 4,500 yolk-sac and larval individuals). Of the carp identified thus far, 51.3% are genus *Hypophthalmichthys* (960 individuals) and 25.2% are *Ctenopharyngodon* (471 individuals). An additional 441 larvae could not be positively identified down to genus and are assigned broadly to "invasive carp".

All Bigheaded Carp larvae collected in the Big Sioux River ranged in age from approximately 3 days to less than 12 hours post-fertilization (Chapman and George 2011) that were likely spawned during a significant rise in flow from May 31st to June 1st (188 m^3/sec) and from June 13th to June 16th, 2022 (137 m^3/sec; Figure 17). Eggs and larvae were captured on the ascending arm of the hydrograph during this smaller, secondary peak in discharge. Water temperatures between May 31st and June 15th across the Big Sioux River sample sites increased by an average of 7.0°C to 23.6°C, 23.3°C, and 24.9°C at the upper, middle, and lower sites, respectively. We hypothesize this major temperature increase acted synergistically with elevated flows to initiate invasive carp reproduction.

The highest native fish larval density was 97.3 fish/100 m^3. Native taxa consisted overwhelmingly of *Cyprinidae* (253), followed by families *Catostomidae* (primarily genera *Ictiobus* and *Carpiodes*; 44), *Percidae* (42), *Centrarchidae* (genus *Pomoxis*; 2), and *Hiodontidae* (1). Native densities across all rivers but the Big Sioux peaked in mid to late June (Figure 18, 19). Native larval and yolk-sac fishes were captured at water temperatures between 12.7 and 31.0°C and discharges between <1 and 150 m^3/sec. Furthermore, conductivity ranged from 448 to 1,149 µS and pH varied from 7.89 to 9.84 during sessions when age-0 fishes were detected, indicating the tolerance of many native taxa to a wide range of environmental conditions. Larval fish taxonomic makeup and diversity tended to be homogenous between rivers. However, preliminary regression analyses suggest that family *Cyprinidae* is significantly associated with sites FLD-LWR and LSR-LWR, *Catostomidae* is associated with BSR-MID and BYR-MID, and

Percidae is associated weakly with BYR-UPR and LSR-UPR, suggesting potential differences in assemblages within rivers. *Cyprinidae*, *Percidae*, and *Catostomidae* were detected in all rivers; *Hiodontidae* was only captured in the Big Sioux and *Centrarchidae* was only captured in the Floyd and Little Sioux rivers. We only detected three families in the Boyer River compared to four families in the Big Sioux, Floyd, and Little Sioux rivers (Figures 18, 19).

Late June, July, and August 2022 were characterized by high water temperatures and low water levels in the four river basins sampled. Drought conditions were likely unfavorable for invasive carp spawning and may have restricted the spawning activities of native taxa as well. The Big Sioux River is the largest (by width and volume) of the four rivers sampled and remains less channelized compared to the Little Sioux, Boyer, and Floyd Rivers. Though still impacted by the drought, the Big Sioux River consistently maintained the highest discharge of all four rivers during 2022 (Figure 20). It is therefore unsurprising we documented invasive carp reproduction in the Big Sioux River but not the other three, especially given the previous detection of young-of-the-year invasive carp in the lower Big Sioux (Hayer et al. 2014). Continued ichthyoplankton sampling in 2023 will further shed light on the extent of invasive carp reproduction in these river systems under various environmental conditions.

<u>Component 2.2:</u> Assess detection probabilities and spatial distribution of juvenile invasive carp throughout Missouri River tributaries in Iowa

We sampled fish communities at 36 river sites throughout western Iowa during 2022 to assess potential recruitment sources for invasive carp. We collected 36,403 individuals of 44 species during river sampling but did not detect juvenile invasive carp. We also sampled 8 off-channel sites along the Missouri proper where we detected juvenile invasive carp at three of these sites – a side-channel within Lower Hamburg Bend Conservation Area in Atkinson County, MO, a backwater in Big Bear Park in Thurston County, NE, and a backwater in Schilling Lake Wildlife Management Area in Cass County, NE during October. Among the three sites, we only collected seven juvenile Silver Carp (mean total length of 70 ± 12 mm SE). We collected five Silver Carp in two seine hauls while we collected one individual with backpack electrofishing and one in a mini-fyke net. We found all seven individuals in similar habitats where substrate was silty sand, depth was $\leq$ 0.5 m, there was little to no flow, little macrophytes and woody debris, and no canopy cover. We collected all juvenile Silver Carp within samples that had moderate to high abundances of Gizzard Shad (*Dorosoma cepedianum*). Our captures of juvenile Silver Carp only in backwaters and side channel habitats of the Missouri River and not in the tributaries is consistent with the hypothesis that invasive carp may preferentially use main river off-channel habitats for nursery areas (Kolar et al. 2007). However, habitat may have been limited in tributaries as water levels have been lower than average this year, especially July – October. We captured all juveniles late in the field season, suggesting that sampling late-summer through early-autumn may increase captures; however, we also only sampled off-channel habitats of the Missouri River later in the field season. We hope with continued sampling efforts focusing on larger tributaries and off-channel habitats of the Missouri River, we will be better able to elucidate sources and drivers of invasive carp recruitment and identify key habitats for management.

In addition to juvenile invasive carp, we collected adult Silver Carp in the Little Rock River and the Tyson Bend backwater (IA). We also observed but were unable to capture adult Silver Carp at one site in the Boyer River, one site in the Big Sioux River, and the Decatur Bend backwater (IA), Louisville Bend backwater (IA), and Big Bear Park backwater (NE). We also caught adult Grass Carp in three rivers, including one site in Turkey Creek, one site in Wolf Creek Ditch, and one site in the Floyd River.

Component 3.1: Delineate the leading edge of invasive carp reproduction across pools 14-16 of the Upper Mississippi River.

Chlorophyll a — Chlorophyll *a* concentrations within the Rock and Wapsipinicon rivers were consistently higher than within the Mississippi River throughout 2022, with some of the highest concentrations being the thalweg (54.86 µg/L ± 3.28 SE) and channel border (53.87 µg/L ± 4.00 SE) of the Rock River mouth (Figure 21). Backwater sites tend to have higher chlorophyll *a* concentrations than both channel border and thalweg sites (Figure 21). While chlorophyll *a* concentrations within tributaries may be more dependent on the local watershed, chlorophyll *a* within the main-stem UMR is likely the cumulative result of tributary contributions as well as its own productivity. Sites directly downstream of tributaries (UMR-DNW channel border and

UMR-DNR channel border) tend to have increased chlorophyll *a* concentrations, likely a result of tributary contributions.

Eggs and Age-0 Fishes — We completed a total of 189 ichthyoplankton tows (9 sessions, 7 sites tows, and three habitats equating to 21 tows per session) in the UMR basin during 2022. We collected eggs during every sampling session for a total of 1,087 eggs in 2022. We collected the largest number of eggs June 2nd (46.9 eggs/100 m^3 ± 21.2 SE; Figure 22). We captured eggs at all sites and habitats except for the channel border and thalweg habitats of the Wapsipinicon River mouth (Figure 23). We completed 135 tows in the Mississippi River that collected 988 eggs and an additional 54 tows within tributary mouths that captured 99 eggs (Rock = 98 eggs and Wapsipinicon = 1 egg). Egg density appeared highest in Pool 14 (UMR-UPW) and Pool 15 (UMR-P15) and lowest within the mouth of the Wapsipinicon River and Pool 16 (UMR-UPR and UMR-DNR; Figure 24). Across all tributary sites and habitats, the highest egg density (19.3 eggs/100 m^3 ± 5.9 SE) was within the thalweg of the Rock River while the highest overall egg density was within the thalweg habitat of UMR-DNW of the Mississippi River (441.7 eggs/100 m^3 ± 47.5 SE; Figure 23).

In addition to eggs, we captured 15,548 age-0 fishes in 2022. We observed the highest densities of age-0 fishes June 23rd (237.0 eggs/100 m^3 ± 169.2 SE) and June 28th (239.3 eggs/100 m^3 ± 156.4 SE), two sessions immediately following the main peak in egg density (Figure 22). We observed the lowest density of age-0 fishes (0.13 eggs/100 m^3 ± 0.24 SE) on May 3rd, the first sampling session (Figure 22).

We captured age-0 fishes from every river in 2022. We captured most age-0 fishes either upstream (5,595 fish) or downstream (6,176 fish) of tributaries compared to within tributary mouths (209 fish; Figure 24), suggesting reproduction of most fishes was occurring within the Mississippi River. Age-0 fish densities varied among upstream, downstream, and tributary sites. Age-0 fish densities were numerically higher downstream than upstream of the Wapsipinicon, but higher upstream than downstream on the Rock River (Figure 24). Across sites, age-0 fish densities tended to be highest within the thalweg compared to backwater and channel border habitats (Figure 23).

Ichthyoplankton from 2022 have been identified to family except for invasive carp that were identified to genus. *Cyprinidae* were the most abundant age-0 fishes collected followed by *Catostomidae*, *Clupeidae,* and *Centrarchidae* (Figure 25). Other taxa present but at lower densities include *Cyprinus carpio, Sciaenidae*, *Percidae*, *Moronidae*, *Lepisosteidae*, and *Atherinopsidae* (Figure 25). Age-0 fish densities peaked during May 19th for *Catostomidae* (87.9 fish/100 m^3 ± 51.1 SE), June 23rd for *Cyprinidae* (229.4 fish/100 m^3 ± 67.7 SE) and *Centrarchidae* (5.9 fish/100 m^3 ± 3.8 SE), and June 28th for *Clupeidae* (30.5 fish/100 m^3 ± 29.1 SE; Figure 25).

<u>Component 4.1:</u> Analyze Silver Carp residency patterns and their metapopulation implications within tributaries of the Upper Mississippi River

We are using acoustic telemetry to assess residency and metapopulation dynamics of Silver Carp in UMR tributaries. We are downloading receivers in the Cedar and Iowa rivers in fall 2022 and will analyze data in the following months. We downloaded receivers in the Des Moines River during August and September 2022 except for a backwater receiver that was not accessible due to low water conditions. Here, we present preliminary observations below based on individuals tagged in the Des Moines River during fall 2021.

Of the Silver Carp we tagged below Red Rock Dam during fall 2021, 24 individuals were classified as resident, 3 individuals were classified as migrant, and 10 individuals were classified as intermediate (Figure 8). One individual has not yet been detected. The longest confirmed maximum displacement was approximately 220 km. However, we had a Silver Carp (765 mm TL) at the mouth of the Des Moines River on May 19, 2022 that was detected a single time in the UMR at L&D 26 near Alton, IL (~460 km) on June 18, 2022 by the Missouri Department of Conservation, but we have not received additional detections to verify the movement of this fish. Of the 39 Silver Carp we tagged below Ottumwa Dam, we classified 11 individuals as residents, 15 individuals as migrants, and 13 individuals as intermediate (Figure 8). The longest confirmed maximum displacement of individuals tagged below Ottumwa Dam was approximately 150 km; however, a Silver Carp (781 mm TL) was detected twelve times at a receiver in the Illinois River near Peoria, IL (~615 km) by the USFWS-Wilmington. We hope to obtain detections between the mouth of the Des Moines River and where it was detected near Peoria, IL to help confirm this movement.

Four Silver Carp tagged below Red Rock Dam transitioned downstream and successfully passed through Ottumwa Dam between October 2021 and August 2022 (Figure 26). One of those individuals (A69-1602-49718) appears to have successfully transitioned back upstream through Ottumwa Dam and two individuals have continued downstream to the mouth of the Des Moines River. We have not observed any individuals tagged below Ottumwa Dam transitioning upstream through Ottumwa Dam. Fourteen individuals we tagged below Ottumwa Dam have transitioned downstream to the mouth of the Des Moines River during this period. Of those fourteen, eleven have since migrated back upstream to their tagging location while four of eleven have migrated back downstream to the mouth of the Des Moines River a second time, showcasing highly mobile behavior (Figure 27).

A large movement event was observed between late October and early November 2021, with 13 of the 39 individuals tagged below Ottumwa Dam moving downstream to the mouth of the Des Moines River. The movement event coincided with a two week, ~350 m^3/s increase in discharge and water temperatures declining to approximately 10°C (Figure 28). Smaller upstream movement events were also observed during spring 2022 as both water temperature and discharge increased (Figure 29).

The maximum displacement analysis suggests a highly resident population of Silver Carp above Ottumwa Dam with most individuals displacing less than 25 km between October 2021 and August 2022 (Figure 8). Comparatively, individuals tagged below Ottumwa Dam appear to be more mobile, suggesting partially migratory behavior as observed in other systems (Prechtel et al. 2018; Coulter et al. 2022). It is important to note maximum displacement for all individuals detected at the mouth of the Des Moines River may be underestimated. We experienced gaps in detection histories after fish were detected at the mouth of the Des Moines River, suggesting individuals may have moved into the UMR and moved further throughout the UMR basin or beyond. We hope to obtain additional detections through the use of the USGS FishTracks database and communication with other agencies that will fill such gaps.

Differences in transition frequency were observed between Silver Carp tagged above Ottumwa Dam and those tagged below Ottumwa Dam. Transition observations suggest Silver Carp above Ottumwa Dam may be relatively independent from those below Ottumwa Dam during low water conditions. Movements of individuals above Ottumwa Dam have yet to be observed suggesting this population may be isolated while transitions of individuals tagged below Ottumwa Dam suggest more potential for metapopulation interactions. Observations suggest that the cohort tagged below Ottumwa Dam may be functioning as a subpopulation of a UMR metapopulation due to the frequent transitions individuals have made between the receiver at the mouth of the Des Moines River and more upstream receivers. Overall, some individuals remained in the upstream portions of the study stretch below Ottumwa Dam and above Ottumwa Dam throughout the entire study period thus far, suggesting a portion of the individuals throughout the Des Moines River may be residents. However, data collected to date has occurred during drought conditions. Additional years of data collection under various flow conditions will be insightful to evaluation how environmental conditions affect tributary movement dynamics.

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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 location.

Deployment Date	Most Recent Download	Removal Date	Anticipated Redeployment	Waterbody	Site Name	Receiver	Latitude	Longitude	Mount Type	# of Detections
5/9/2022	11/1/2022			Little Sioux River	LSR - HW69 Border Bridge	VR2W-137632	43.50078º	-95.20476º	BR	0
3/18/2022	11/8/2022	11/8/2022	Spring 2023	Little Sioux River	LSR - HW9 Bridge	VR2W-137283	43.43035º	-95.25355º	BR	20
5/5/2022	11/8/2022			West Fork Little Sioux River	WFLS - West Fork 160th Bridge	VR2W-137281	43.41947º	-95.2692º	BR, BT*	2
5/11/2022	11/14/2022			West Fork Little Sioux River	WFLS - West Fork Confluence	VR2W-137629	43.41391º	-95.25216º	BT	151
5/5/2022	11/1/2022			Little Sioux River	LSR - 225th Milford	VR2W-137645	43.31891º	-95.18127º	BR	20,613
5/4/2022	11/14/2022			Milford Creek	MFC - Milford Barrier	VR2W-137652	43.34039º	-95.13550º	BT	139,748
5/5/2022	11/14/2022			Milford Creek	MFC - Milford Mid	VR2W-137280	43.32077º	-95.14535º	BT	148
5/5/2022	11/14/2022			Milford Creek	MFC - Milford Confluence	VR2W-137650	43.31537º	-95.16617º	BT	48
5/6/2022	11/14/2022			Little Sioux River	LSR - A48 Milford	VR2W-137272	43.29883º	-95.17621º	BR	95,979
5/9/2022	11/1/2022			Little Sioux River	LSR - HW18N Spencer	VR2W-137630	43.18427º	-95.19138º	BR, BT*	27
3/18/2022	11/8/2022	11/8/2022	Spring 2023	Ocheyedan River	OCH - Ocheyedan 200th Bridge	VR2W-137637	43.12872º	-95.19146º	BR	0
5/5/2022	11/14/2022			Ocheyedan River	OCH - Ocheyedan Confluence	VR2W-137660	43.13557º	-95.15455º	BT	357
5/9/2022	11/14/2022			Lost Island Outlet	LIO - Lost Island Outlet #2	VR2W-137634	43.09687º	-95.05333º	BT	1,088
5/9/2022	11/14/2022	11/14/2022	Spring 2023	Lost Island Outlet	LIO - Lost Island Outlet Confluence	VR2W-137289	43.09640º	-95.05775º	BT	14,336
3/18/2022	11/8/2022	11/8/2022	Spring 2023	Little Sioux River	LSR - 390th Bridge	VR2W-137638	43.08360º	-95.06654º	BR	549
3/17/2022	11/8/2022	11/8/2022	Spring 2023	Little Sioux River	LSR - HW10 Sioux Rapids	VR2W-137282	42.89610º	-95.15342º	BR	158
3/17/2022	11/8/2022	11/8/2022	Spring 2023	Little Sioux River	LSR - HW10 Peterson	VR2W-137633	42.92970º	-95.43142º	BR	54
3/17/2022	11/8/2022	11/8/2022	Spring 2023	Little Sioux River	LSR - HW3 Cherokee	VR2W-137647	42.75986º	-95.52876º	BR	19
3/17/2022	11/8/2022	11/8/2022	Spring 2023	Little Sioux River	LSR - HW59 Cherokee	VR2W-137286	42.74499º	-95.55155º	BR	33
3/17/2022	11/8/2022	11/8/2022	Spring 2023	Little Sioux River	LSR - L51 Quimby	VR2W-137644	42.63529º	-95.64207º	BR	32
3/17/2022	11/8/2022			Little Sioux River	LSR - L36 Correctionville	VR2W-137290	42.48583º	-95.79027º	BR, BT*	273
3/17/2022	11/15/2022			Little Sioux River	LSR - 310th Oto	VR2W-137664	42.26710º	-95.89392º	BR, BT*	3
3/17/2022	11/15/2022	11/15/2022		Little Sioux River	LSR - L14 NE Onawa	VR2W-137636	42.08154 º	-96.01423º	BR	10
3/17/2022	11/15/2022			Little Sioux River	LSR - E54 SE Onawa	VR2W-137631	41.96501º	-95.97260º	BR, BT*	21

3/17/2022	6/9/2022	Little Sioux River	LSR - K45 LS Confluence	VR2W-137635	41.81053º	-96.04860º	BR	29
11/22/2021	11/15/2022	Missouri River	MOR - HW30 MO River	VR2W-137666	41.55105º	-96.09553º	BR	1
5/16/2022	9/20/2022	Lower Gar Lake	IGL - 18	VR2Tx-487217	43.35534º	-95.12280º	BT	0
4/27/2022	9/20/2022	Lower Gar Lake	IGL - 19	VR2Tx-487221	43.34258º	-95.12399º	BT	0

*Denotes receiver that that was converted from Bridge Mount (BR) to Bottom Set (BT) prior to Winter 2022 due to low water levels

Notes: A total of 10 receivers had to be temporarily removed prior to Winter 2022 due to low water levels, but will be redeployed in Spring 2023. All detections reported were from Iowa State University tags only.

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

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
A69-9007-10918	V16A	Silver Carp	M	654	3.32	Milford Creek	Electric Barrier	5/4/2022	8/28/2022	MFC - Milford Barrier	17,768	Alive
A69-9007-10920	V16A	Silver Carp	F	826	5.35	Milford Creek	Electric Barrier	5/4/2022	6/11/2022	OCH - Ocheyedan Confluence	2,924	Unknown
A69-9007-10924	V16A	Silver Carp	M	622	2.80	Milford Creek	Electric Barrier	5/4/2022	6/21/2022	MFC - Milford Confluence	4,177	Unknown
A69-9007-10922	V16A	Silver Carp	F	635	3.03	Milford Creek	Electric Barrier	5/4/2022	5/20/2022	MFC - Milford Barrier	937	Dead
A69-9007-10917	V16A	Silver Carp	M	706	3.92	Milford Creek	Electric Barrier	5/4/2022	9/3/2022	MFC - Milford Barrier	8,852	Alive
A69-9007-10919	V16A	Silver Carp	M	605	2.21	Milford Creek	Electric Barrier	5/4/2022	5/14/2022	MFC - Milford Barrier	2,277	Dead
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
A69-9007-10925	V16T	Silver Carp	M	660	3.16	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	4,780	Alive
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	3.95	Little Sioux River	A48 Bridge	5/6/2022	7/12/2022	LSR - 390th Bridge	12	Alive
A69-9007-10928	V16T	Silver Carp	M	626	3.55	Little Sioux River	A48 Bridge	5/6/2022	11/12/2022	LSR - A48 Milford	55,567	Alive
A69-9007-10931	V16T	Silver Carp	M	620	2.79	Little Sioux River	A48 Bridge	5/6/2022	6/18/2022	LSR - HW10 Sioux Rapids	5,227	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	8,265	Unknown
A69-9007-10929	V16T	Silver Carp	M	672	3.24	Little Sioux River	A48 Bridge	5/6/2022	7/15/2022	LSR - A48 Milford	32	Alive
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	Alive
A69-9007-10927	V16T	Silver Carp	F	542	1.86	Little Sioux River	A48 Bridge	5/6/2022	8/4/2022	LSR - A48 Milford	13,522	Alive
A69-9007-10923	V16A	Silver Carp	F	750	5.20	Little Sioux River	A48 Bridge	5/6/2022	5/11/2022	LIO - Lost Island Outlet Confluence	15	Unknown
A69-9007-10930	V16T	Silver Carp	M	658	3.21	Little Sioux River	A48 Bridge	5/6/2022	6/10/2022	LSR - HW10 Sioux Rapids	47	Unknown
A69-9007-10933	V16T	Silver Carp	F	621	2.92	Little Sioux River	A48 Bridge	5/6/2022	NA	NA	0	Unknown
A69-1604-29697	V16	Silver Carp	M	628	3.02	Little Sioux River	A48 Bridge	5/6/2022	7/19/2022	WFLS - West Fork Confluence	118	Alive
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	Unknown
A69-1604-29703	V16	Silver Carp	F	668	3.75	Little Sioux River	A48 Bridge	5/6/2022	7/19/2022	LSR - A48 Milford	640	Alive
A69-1604-29705	V16	Silver Carp	M	711	4.02	Little Sioux River	A48 Bridge	5/6/2022	7/26/2022	LSR - A48 Milford	33,268	Dead
A69-1604-29708	V16	Silver Carp	M	690	3.91	Little Sioux River	A48 Bridge	5/6/2022	7/14/2022	OCH - Ocheyedan Confluence	108	Alive
A69-1604-29696	V16	Bighead Carp	F	660	2.59	Milford Creek	Electric Barrier	5/9/2022	8/20/2022	MFC - Milford Barrier	7,021	Alive
A69-1604-29699	V16	Bighead Carp	M	629	2.78	Milford Creek	Electric Barrier	5/9/2022	8/1/2022	MFC - Milford Barrier	4,318	Alive

A69-1604-29710	V16	Bighead Carp	F	758	3.76	Milford Creek	Electric Barrier	5/9/2022	7/4/2022	MFC - Milford Barrier	2,169	Alive
A69-1604-29707	V16	Bighead Carp	F	631	2.58	Milford Creek	Electric Barrier	5/9/2022	8/21/2022	MFC - Milford Barrier	9,464	Alive
A69-1604-29704	V16	Bighead Carp	M	610	2.01	Milford Creek	Electric Barrier	5/9/2022	7/17/2022	OCH - Ocheyedan Confluence	4,096	Alive
A69-1604-29695	V16	Bighead Carp	F	731	3.76	Milford Creek	Electric Barrier	5/9/2022	8/8/2022	MFC - Milford Barrier	8,156	Alive
A69-1604-29701	V16	Bighead Carp	F	695	3.70	Milford Creek	Electric Barrier	5/9/2022	7/24/2022	MOR - HW30 MO River	6,644	Alive
A69-1604-29691	V16	Bighead Carp	F	688	3.63	Milford Creek	Electric Barrier	5/9/2022	7/11/2022	LSR - HW10 Sioux Rapids	6,018	Alive
A69-1604-29702	V16	Bighead Carp	F	671	3.16	Milford Creek	Electric Barrier	5/9/2022	8/28/2022	MFC - Milford Barrier	12,965	Alive
A69-1604-29698	V16	Bighead Carp	M	522	2.47	Milford Creek	Electric Barrier	5/9/2022	11/1/2022	MFC - Milford Barrier	17,853	Alive
A69-1604-29706	V16	Bighead Carp	F	727	3.71	Milford Creek	Electric Barrier	5/9/2022	8/10/2022	MFC - Milford Barrier	8,891	Alive
A69-1604-29709	V16	Bighead Carp	F	685	3.64	Milford Creek	Electric Barrier	5/9/2022	6/6/2022	LSR - HW10 Sioux Rapids	270	Unknown
A69-1604-29711	V16	Bighead Carp	M	671	3.33	Milford Creek	Electric Barrier	5/9/2022	6/27/2022	MFC - Milford Barrier	7,088	Unknown
A69-1604-29712	V16	Bighead Carp	M	613	2.68	Milford Creek	Electric Barrier	5/9/2022	7/12/2022	LSR - 390th Bridge	2,683	Alive
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	Alive
A69-1604-29692	V16	Silver Carp	M	629	2.56	Little Sioux River	Dickens, IA	5/10/2022	6/12/2022	LSR - 390th Bridge	11	Unknown
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	Unknown
A69-1604-29694	V16	Silver Carp	M	675	3.38	Little Sioux River	Dickens, IA	5/10/2022	7/21/2022	LSR - HW18N Spencer	1,538	Alive
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	Unknown
A69-1604-29730	V16	Silver Carp	M	761	4.36	Little Sioux River	Dickens, IA	5/10/2022	NA	NA	0	Unknown
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	Alive
A69-1604-29750	V13	Silver Carp	M	517	1.45	Little Sioux River	Dickens, IA	5/10/2022	NA	NA	0	Unknown
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	Unknown
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	Unknown
A69-1604-29725	V16	Silver Carp	M	656	3.45	Little Sioux River	Dickens, IA	5/10/2022	7/12/2022	LSR - 390th Bridge	20	Alive
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	Unknown
A69-1604-29743	V13	Silver Carp	M	466	1.03	Little Sioux River	Dickens, IA	5/10/2022	NA	NA	0	Unknown
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	Unknown
A69-1604-29723	V16	Silver Carp	M	624	2.59	Little Sioux River	Dickens, IA	5/10/2022	6/26/2022	LSR - HW10 Sioux Rapids	37	Unknown
A69-1604-29722	V16	Silver Carp	M	608	2.44	Little Sioux River	Dickens, IA	5/10/2022	6/17/2022	LSR - HW10 Sioux Rapids	9	Unknown
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	Unknown
A69-1602-49651	V13	Silver Carp	M	654	2.82	Little Sioux River	Spencer, IA	5/16/2022	6/10/2022	LSR - 390th Bridge	124	Unknown
A69-1604-29719	V16	Silver Carp	M	649	3.26	Little Sioux River	Spencer, IA	5/16/2022	8/10/2022	LIO - Lost Island Outlet Confluence	13,178	Alive

A69-1604-29720	V16	Silver Carp	F	661	3.69	Little Sioux River	Spencer, IA	5/16/2022	6/12/2022	LSR - 390th Bridge	26	Unknown
A69-1604-29718	V16	Silver Carp	F	800	6.09	Little Sioux River	Spencer, IA	5/16/2022	6/8/2022	LSR - HW18N Spencer	4	Unknown
A69-1604-29717	V16	Silver Carp	M	621	2.74	Little Sioux River	Spencer, IA	5/17/2022	6/18/2022	LSR - 390th Bridge	44	Unknown
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	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	Alive
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	Unknown
A69-1604-29714	V16	Silver Carp	M	695	2.55	Little Sioux River	Cherokee, IA	5/17/2022	6/13/2022	LSR - K45 LS Confluence	20	Alive
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	Alive
A69-1604-29731	V13	Silver Carp	M	674	3.50	Little Sioux River	Cherokee, IA	5/17/2022	7/11/2022	LSR - HW10 Sioux Rapids	12	Alive
A69-1604-29732	V13	Silver Carp	M	680	3.43	Little Sioux River	Cherokee, IA	5/17/2022	7/11/2022	LSR - 390th Bridge	53	Alive
A69-1604-29733	V13	Silver Carp	M	639	2.74	Little Sioux River	Cherokee, IA	5/17/2022	NA	NA	0	Unknown
A69-1604-29734	V13	Silver Carp	M	669	2.93	Little Sioux River	Cherokee, IA	5/17/2022	6/12/2022	HW10 - Peterson	7	Unknown
A69-1604-29735	V13	Silver Carp	M	609	2.44	Little Sioux River	Cherokee, IA	5/17/2022	5/19/2022	LSR - L51 Quimby	1	Unknown
A69-1604-29736	V13	Silver Carp	F	682	4.08	Little Sioux River	Cherokee, IA	5/17/2022	6/14/2022	LSR - HW59 Cherokee	13	Unknown
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	Unknown
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	Alive
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	Unknown
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	Alive
A69-1604-29741	V13	Silver Carp	M	638	2.90	Little Sioux River	Correctionville, IA	5/18/2022	6/11/2022	LSR - 390th Bridge	9	Unknown
A69-1604-29742	V13	Silver Carp	F	675	3.61	Little Sioux River	Correctionville, IA	5/18/2022	9/4/2022	Platte River, NE	261	Alive
A69-1604-29746	V13	Silver Carp	M	611	2.30	Little Sioux River	Correctionville, IA	5/18/2022	5/19/2022	LSR - L36 Correctionville	3	Unknown
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	Unknown
A69-1604-29748	V13	Silver Carp	F	674	3.29	Little Sioux River	Correctionville, IA	5/18/2022	7/13/2022	LSR - K45 LS Confluence	25	Alive

Notes: For fish fate, only individuals that have been detected since July 1st were listed as “Alive”. Fish listed with “Unknown” fates either haven’t been detected at all anywhere in our acoustic array, or their last detections were prior to July 1st. Fish that were assigned “Dead” fates were decided on a case by case basis and were comprised of individuals with continuous detections at a single receiver over long time periods, or fish that were tagged in Milford Creek and haven’t been detected since multiple days following their tagging date.

Table 3. The abbreviation of each Missouri River Basin ichthyoplankton sampling site, its associated river segment, and its latitude and longitude in Figure 4.

Site Code	**Site**	**Latitude**	**Longitude**
BSR-UPR	Big Sioux River upper	43.281397°	-96.578365°
BSR-MID	Big Sioux River middle	42.837555°	-96.561898°
BSR-LWR	Big Sioux River lower	42.626361°	-96.515384°
FLD-UPR	Floyd River upper	43.141773°	-95.887772°
FLD-MID	Floyd River middle	42.866099°	-96.109066°
FLD-LWR	Floyd River lower	42.519176°	-96.377367°
LSR-UPR	Little Sioux River upper	43.298773°	-95.176106°
LSR-UMD	Little Sioux River upper-mid	42.914653°	-95.339554°
LSR-LMD	Little Sioux River lower-mid	42.575503°	-95.726297°
LSR-LWR	Little Sioux River lower	42.081474°	-96.014105°
BYR-UPR	Boyer River upper	42.400283°	-95.156743°
BYR-MID	Boyer River middle	42.065665°	-95.344350°
BYR-LWR	Boyer River lower	41.678513°	-95.748249°

Table 4. Upper Mississippi River Basin ichthyoplankton sampling site codes, river segment, and their associated latitude and longitude. See Figure 6 for sampling locations

Site Code	Site	Latitude	Longitude
UMR-UPW	Upper Mississippi River, Upstream of the Wapsipinicon River	41.752314	-90.309389
UMR-DNW	Upper Mississippi River, Downstream of the Wapsipinicon River	41.707567	-90.312956
WAP-MTH	Mouth of the Wapsipinicon River	41.738189	-90.332128
UMR-P15	Upper Mississippi River, Pool 15	41.544278	-90.437725
UMR-UPR	Upper Mississippi River, Upstream of the Rock River	41.508328	-90.598497
UMR-DNR	Upper Mississippi River, Downstream of the Rock River	41.460333	-90.663444
ROC-MTH	Mouth of the Rock River	41.471378	-90.594483

Table 5. Deployment and maintenance information for acoustic receivers located throughout the Des Moines, Iowa, and Cedar rivers. See Figure 7 for visual reference of acoustic receiver locations.

Deployment Date	Most Recent Download	Removal Date	Redeployment Date	Waterbody	Site Name	Receiver	Latitude	Longitude	Mount Type	# of Detections
2016	8/18/2022			Des Moines River	DSMR - T17 Red Rock	VR2W-128912*	41.34358°	-92.94246°	BR	108,219
11/1/2021	6/8/2022			Des Moines River	DSMR - HWY 92 Gravel Pit	VR2W-137265	41.31558°	-92.88381°	BT	228,356
7/15/2021	8/18/2022			Des Moines River	DSMR - Abandoned Pier Tracy	VR2W-137270	41.28190°	-92.86005°	BR	431
7/15/2021	8/18/2022			Des Moines River	DSMR - Galeston Ave Eveland Access	VR2W-137285	41.23695°	-92.73666°	BR	19
7/14/2021	8/18/2022			Des Moines River	DSMR - HWY 137 Eddyville	VR2W-137284	41.14895°	-92.63613°	BR	7
7/14/2021	8/18/2022			Des Moines River	DSMR - H21 @ Chillicothe	VR2W-137268	41.09163°	-92.52643°	BR	3
7/8/2021	8/18/2022			Des Moines River	DSMR - Wapello Street Ottumwa	VR2W-137278	41.01829°	-92.41935°	BR	643
2016	8/31/2022			Des Moines River	DSMR - HWY 34 Ottumwa	VR2W-128910*	41.00063°	-92.40088°	BR	2,295
7/8/2021	8/19/2022			Des Moines River	DSMR - Cliffland Access	VR2W-137275	40.95719°	-92.34035°	BR	423,327
7/12/2021	8/31/2022			Des Moines River	DSMR - Eldon Old Bridge	VR2W-137267	40.91577°	-92.22595°	BR	48
7/29/2021	9/1/2022			Des Moines River	DSMR - HWY 98 Douds	VR2W-137271	40.83603°	-92.08887°	BR	2,268
7/29/2021	9/1/2022			Des Moines River	DSMR - Lark Avenue Kilbourn	VR2W-137291	40.80020°	-91.97039°	BR	2,456
8/18/2021	9/1/2022			Des Moines River	DSMR - J40 @ Bentonsport	VR2W-137266	40.72648°	-91.86294°	BR	1,415
11/9/2021	9/1/2022			Des Moines River	DSMR - W40 Bonaparte	VR2W-137277	40.69662°	-91.80324°	BR	1
11/9/2021	9/8/2022			Des Moines River	DSMR - HWY 2 Farmington	VR2W-137274	40.64027°	-91.74563°	BR	330
11/9/2021	9/8/2022			Des Moines River	DSMR - St. Francisville	VR2W-137276	40.46161°	-91.56723°	BR	639
2016	9/8/2022			Des Moines River	DSMR - HWY 136 Keokuk	VR2W-128911*	40.38550°	-91.43666°	BR	2005
6/2/2022	10/20/2022			Iowa River	IAR - U of Iowa Walking Bridge	VR2W-137641	41.66783°	-91.53646°	BR	0
9/24/2021	9/27/2022			Iowa River	IAR - HWY 6 Sturgis Ferry IC	VR2W-123288	41.64650°	-91.53643°	BR	10,643
9/24/2021	11/7/2022			Iowa River	IAR - HWY 22 River Junction	VR2Tx-487013	41.49611°	-91.51096°	BR	12,377
4/1/2022	10/25/2022			Iowa River	IAR - Johnson Louisa County Line Rd	VR2W-137288	41.42383°	-91.47886°	BR	36
9/28/2021	10/13/2022	10/13/2022	Spring 2023	Iowa River	IAR - HWY 70 Columbus Junction	VR2W-137521	41.29180°	-91.36000°	BR	104
9/28/2021	10/20/2022			Iowa River	IAR - HWY 92 Columbus Junction	VR2W-125130	41.27892°	-91.34340°	BR	28
9/28/2021	10/13/2022			Iowa River	IAR - HWY 99 Wapello	VR2W-123259	41.18014°	-91.18249°	BR	1,829
9/28/2021	10/25/2022			Iowa River	IAR - HWY 99 Oakville	VR2W-137528	41.10207°	-91.06315°	BR	66

10/19/2021	10/4/2022			Cedar River	CER - Edgewood Rd Cedar Rapids	VR2Tx-487218 , VR2W-137655	42.01145°	-91.70499°	BR	0
7/12/2022	9/29/2022			Cedar River	CER - Prairie Park Fishery Backwater	VR2Tx-486235	41.95471°	-91.63801°	BT	112,543
9/23/2021				Cedar River	CER - HWY 30 above Palisades State Park	VR2W-137525	41.92609°	-91.55064°	BR	-
9/23/2021	9/29/2021			Cedar River	CER - HWY 1 below Palisades State Park	VR2W-123265	41.88273°	-91.46506°	BR	465
10/19/2021	11/7/2022	11/7/2022	Spring 2023	Cedar River	CER - F28 Cedar Bluff	VR2Tx-487209 , VR2W-137287	41.78766°	-91.31321°	BR	34
9/24/2021	10/13/2022	10/13/2022	10/20/2022	Cedar River	CER - HWY 6 Moscow	VR2W-137523	41.56715°	-91.10775°	BR	35
9/28/2021	10/13/2022			Cedar River	CER - G28 Conesville	VR2W-123299	41.40941°	-91.29007°	BR	9

*denotes receivers owned by Missouri Department of Conservation (MDOC)

Notes: We replaced VR2Tx receivers at sites CER – Edgewood Rd Cedar Rapids and CER – F28 Cedar Bluff with VR2W receivers during Fall 2022. We were unable to access receivers at sites DSMR – HWY 92 Gravel Pit and CER – HWY 30 above Palisades State Park due to low water conditions during Fall 2022. Latitude and Longitude coordinates are in NAD83. All detections reported were from Iowa State University tags only.

Table 6. Tagging and encounter information for Silver Carp tagged in the Des Moines, Iowa, and Cedar rivers.

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
A69-1602-49669	V13	Silver Carp	F	695	3.14	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/22/2022	DSMR - T17 Red Rock	759	Unknown
A69-1602-49670	V13	Silver Carp	F	706	3.71	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/15/2022	DSMR - T17 Red Rock	1	Unknown
A69-1602-49671	V13	Silver Carp	F	703	3.76	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/7/2022	DSMR - Abandoned Pier near Tracy	67	Unknown
A69-1602-49672	V13	Silver Carp	M	710	3.6	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	NA	NA	0	Dead
A69-1602-49703	V16	Silver Carp	F	735	4.52	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/7/2022	DSMR - Galeston Ave Eveland Access	23	Unknown
A69-1602-49704	V16	Silver Carp	F	712	3.82	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/7/2022	DSMR - HWY 92 Gravel Pit	1,933	Unknown
A69-1602-49705	V16	Silver Carp	F	721	4.34	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	10/19/2021	DSMR - T17 Red Rock	2	Unknown
A69-1602-49706	V16	Silver Carp	F	760	4.74	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/10/2022	DSMR - T17 Red Rock	11	Unknown
A69-1602-49707	V16	Silver Carp	F	720	3.89	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/7/2022	DSMR - Wapello Street Ottumwa	258	Unknown
A69-1602-49708	V16	Silver Carp	F	759	4.82	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/14/2022	DSMR - T17 Red Rock	20	Unknown
A69-1602-49709	V16	Silver Carp	F	821	7.03	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/15/2022	DSMR - T17 Red Rock	16	Unknown
A69-1602-49710	V16	Silver Carp	F	725	4.64	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	9/1/2022	DSMR - J40 @ Bentonsport	1,061	Alive
A69-1602-49711	V16	Silver Carp	F	760	4.63	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/7/2022	DSMR - Galeston Ave Eveland Access	9,169	Unknown
A69-1602-49712	V16	Silver Carp	M	698	3.68	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/25/2022	DSMR - T17 Red Rock	562	Unknown
A69-1602-49713	V16	Silver Carp	M	742	5.07	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/6/2022	DSMR - HWY 137 Eddyville	2,125	Unknown
A69-1602-49714	V16	Silver Carp	M	706	3.46	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/15/2022	DSMR - T17 Red Rock	957	Unknown
A69-1602-49715	V16	Silver Carp	M	749	4.57	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/3/2022	DSMR - HWY 137 Eddyville	1,448	Unknown
A69-1602-49716	V16	Silver Carp	M	756	4.83	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	8/18/2022	DSMR - T17 Red Rock	63,190	Alive
A69-1602-49717	V16	Silver Carp	M	725	4.13	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	8/12/2022	DSMR - T17 Red Rock	202,251	Alive
A69-9001-1671	V16	Silver Carp	F	764	5.22	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	10/16/2021	DSMR - T17 Red Rock	21	Unknown
A69-9001-1674	V16	Silver Carp	F	757	4.27	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	2/12/2022	DSMR - Galeston Ave Eveland Access	18,703	Unknown
A69-9002-4686	V16T	Silver Carp	F	765	5.16	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/18/2022	UMR - LD 26 Alton, IL	43	Unknown
A69-9002-4687	V16T	Silver Carp	F	720	3.99	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	10/17/2021	DSMR - T17 Red Rock	2	Unknown
A69-9002-4688	V16T	Silver Carp	F	714	3.77	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/14/2022	DSMR - T17 Red Rock	18	Unknown
A69-9002-4693	V16T	Silver Carp	F	698	3.59	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/11/2022	DSMR - T17 Red Rock	50	Unknown
A69-9004-14228	V16A	Silver Carp	F	735	4.29	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/12/2022	DSMR - T17 Red Rock	21	Unknown

A69-9004-14250	V16A	Silver Carp	M	768	4.97	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/19/2022	DSMR - T17 Red Rock	13,085	Unknown
A69-9004-14251	V16A	Silver Carp	F	790	7.08	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/14/2022	DSMR - T17 Red Rock	452	Unknown
A69-9004-14252	V16A	Silver Carp	F	771	5.77	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/7/2022	DSMR - T17 Red Rock	1	Unknown
A69-9004-14253	V16A	Silver Carp	F	769	6.68	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	2/23/2022	DSMR - Galeston Ave Eveland Access	519	Unknown
A69-9004-14254	V16A	Silver Carp	F	741	5.02	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/22/2022	DSMR - T17 Red Rock	5,255	Unknown
A69-9004-14255	V16A	Silver Carp	F	707	4.53	Des Moines River	Howell Station below Red Rock Dam	10/12/2021	6/13/2022	DSMR - T17 Red Rock	17	Unknown
A69-1602-49662	V13	Silver Carp	M	641	2.78	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	31,950	Alive
A69-1602-49663	V13	Silver Carp	F	658	3.31	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	41,858	Alive
A69-1602-49664	V13	Silver Carp	M	770	5.17	Des Moines River	Cliffland Access	10/20/2021	9/1/2022	DSMR - Lark Avenue Kilbourn	5,139	Alive
A69-1602-49665	V13	Silver Carp	M	669	3.32	Des Moines River	Cliffland Access	10/20/2021	7/23/2022	DSMR - Lark Avenue Kilbourn	999	Alive
A69-1602-49666	V13	Silver Carp	M	705	3.94	Des Moines River	Cliffland Access	10/20/2021	8/18/2022	DSMR - Cliffland Access	15,185	Alive
A69-1602-49667	V13	Silver Carp	M	709	3.59	Des Moines River	Cliffland Access	10/20/2021	7/18/2022	DSMR - HWY 34 Ottumwa	25,078	Alive
A69-1602-49668	V13	Silver Carp	M	675	3.52	Des Moines River	Cliffland Access	10/20/2021	7/19/2022	DSMR - Cliffland Access	208	Alive
A69-9001-1651	V16	Silver Carp	M	686	3.53	Des Moines River	Cliffland Access	10/20/2021	10/28/2021	DSMR - HWY 98 Douds	160	Unknown
A69-9001-1652	V16	Silver Carp	M	710	3.94	Des Moines River	Cliffland Access	10/20/2021	10/26/2021	DSMR - J40 @ Bentonsport	101	Unknown
A69-9001-1653	V16	Silver Carp	M	667	3.25	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	21,736	Alive
A69-9001-1654	V16	Silver Carp	F	841	6.57	Des Moines River	Cliffland Access	10/20/2021	11/1/2021	DSMR - Cliffland Access	25	Unknown
A69-9001-1655	V16	Silver Carp	F	772	4.94	Des Moines River	Cliffland Access	10/20/2021	7/22/2022	DSMR - Lark Avenue Kilbourn	1,193	Alive
A69-9001-1656	V16	Silver Carp	M	692	3.82	Des Moines River	Cliffland Access	10/20/2021	7/19/2022	DSMR - HWY 136 Keokuk	2,290	Alive
A69-9001-1657	V16	Silver Carp	F	676	3.77	Des Moines River	Cliffland Access	10/20/2021	8/31/2022	DSMR - HWY 98 Douds	15,133	Alive
A69-9001-1658	V16	Silver Carp	F	761	5.44	Des Moines River	Cliffland Access	10/20/2021	9/1/2022	DSMR - Lark Avenue Kilbourn	3,191	Alive
A69-9001-1659	V16	Silver Carp	F	660	3.11	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	28,068	Alive
A69-9001-1660	V16	Silver Carp	M	673	3.26	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	1,565	Alive
A69-9001-1661	V16	Silver Carp	M	699	4.11	Des Moines River	Cliffland Access	10/20/2021	8/18/2022	DSMR - Cliffland Access	463	Alive
A69-9001-1662	V16	Silver Carp	F	781	5.73	Des Moines River	Cliffland Access	10/20/2021	6/14/2022	Illinois River near Peoria, IL	290	Unknown
A69-9001-1663	V16	Silver Carp	M	653	3.13	Des Moines River	Cliffland Access	10/20/2021	8/21/2022	DSMR - HWY 98 Douds	10,262	Alive
A69-9001-1664	V16	Silver Carp	M	675	3.38	Des Moines River	Cliffland Access	10/20/2021	8/11/2022	DSMR - Cliffland Access	1,064	Alive
A69-9001-1665	V16	Silver Carp	F	776	5.18	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	24,310	Alive
A69-9001-1666	V16	Silver Carp	M	861	6.82	Des Moines River	Cliffland Access	10/20/2021	7/29/2022	DSMR - HWY 136 Keokuk	546	Alive

A69-9001-1667	V16	Silver Carp	M	715	4.41	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	849	Alive
A69-9001-1668	V16	Silver Carp	M	831	6.48	Des Moines River	Cliffland Access	10/20/2021	7/19/2022	DSMR - Lark Avenue Kilbourn	297	Alive
A69-9001-1672	V16	Silver Carp	M	692	3.73	Des Moines River	Cliffland Access	10/20/2021	9/6/2022	DSMR - HWY 136 Keokuk	1,181	Alive
A69-9001-1673	V16	Silver Carp	M	889	7.32	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	6,008	Alive
A69-9002-4689	V16T	Silver Carp	M	705	3.87	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	1,649	Alive
A69-9002-4690	V16T	Silver Carp	M	692	3.67	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	2,007	Alive
A69-9002-4691	V16T	Silver Carp	F	630	3.06	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	22,179	Alive
A69-9002-4692	V16T	Silver Carp	F	707	3.89	Des Moines River	Cliffland Access	10/20/2021	7/31/2022	DSMR - J40 @ Bentonsport	12,940	Alive
A69-9004-14238	V16A	Silver Carp	F	709	4.12	Des Moines River	Cliffland Access	10/20/2021	7/29/2022	DSMR - HWY 136 Keokuk	1,703	Alive
A69-9004-14239	V16A	Silver Carp	F	819	6.56	Des Moines River	Cliffland Access	10/20/2021	9/1/2022	DSMR - HWY 136 Keokuk	319	Alive
A69-9004-14240	V16A	Silver Carp	F	734	4.59	Des Moines River	Cliffland Access	10/20/2021	5/18/2022	DSMR - Cliffland Access	38,931	Unknown
A69-9004-14241	V16A	Silver Carp	M	730	4.5	Des Moines River	Cliffland Access	10/20/2021	8/1/2022	DSMR - HWY 98 Douds	16,179	Alive
A69-9004-14242	V16A	Silver Carp	F	722	4.23	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	51,463	Dead
A69-9004-14243	V16A	Silver Carp	M	715	4.29	Des Moines River	Cliffland Access	10/20/2021	7/19/2022	DSMR - HWY 136 Keokuk	2,229	Alive
A69-9004-14244	V16A	Silver Carp	M	631	3.14	Des Moines River	Cliffland Access	10/20/2021	8/19/2022	DSMR - Cliffland Access	12,586	Alive
A69-9004-14245	V16A	Silver Carp	M	700	3.84	Des Moines River	Cliffland Access	10/20/2021	5/18/2022	DSMR - Cliffland Access	41,040	Unknown
A69-1602-49673	V13	Silver Carp	M	731	NA	Des Moines River	Howell Station below Red Rock Dam	10/21/2021	6/7/2022	DSMR - T17 Red Rock	179	Unknown
A69-1602-49674	V13	Silver Carp	M	712	NA	Des Moines River	Howell Station below Red Rock Dam	10/21/2021	4/22/2022	DSMR - T17 Red Rock	3,145	Unknown
A69-1602-49718	V16	Silver Carp	M	719	NA	Des Moines River	Howell Station below Red Rock Dam	10/21/2021	6/6/2022	DSMR - HWY 92 Gravel Pit	940	Alive
A69-1602-49719	V16	Silver Carp	M	680	NA	Des Moines River	Howell Station below Red Rock Dam	10/21/2021	6/16/2022	DSMR - HWY 98 Douds	167	Alive
A69-1602-49720	V16	Silver Carp	M	700	NA	Des Moines River	Howell Station below Red Rock Dam	10/21/2021	6/15/2022	DSMR - T17 Red Rock	3,411	Alive
A69-9004-14226	V16A	Silver Carp	M	720	NA	Des Moines River	Howell Station below Red Rock Dam	10/21/2021	7/31/2022	DSMR - T17 Red Rock	8,812	Alive
A69-9004-14233	V16A	Silver Carp	F	940	NA	Cedar River	Prairie Park Fishery Backwater	11/9/2021	9/29/2022	CER - Prairie Park Fishery Backwater	76,598	Alive
A69-9004-14235	V16A	Silver Carp	M	839	NA	Cedar River	Prairie Park Fishery Backwater	11/9/2021	NA	NA	0	Unknown
A69-9004-14237	V16A	Silver Carp	M	736	NA	Cedar River	Prairie Park Fishery Backwater	11/9/2021	NA	NA	0	Unknown
A69-9004-14230	V16A	Silver Carp	F	898	NA	Cedar River	Prairie Park Fishery Backwater	11/15/2021	NA	NA	0	Unknown
A69-9004-14232	V16A	Silver Carp	M	857	NA	Cedar River	Prairie Park Fishery Backwater	11/15/2021	9/25/2022	CER - Prairie Park Fishery Backwater	134	Alive
A69-9004-14234	V16A	Silver Carp	F	888	NA	Cedar River	Prairie Park Fishery Backwater	11/15/2021	4/3/2022	CER - F28 Cedar Bluff	2	Unknown
A69-9004-14236	V16A	Silver Carp	M	889	NA	Cedar River	Prairie Park Fishery Backwater	11/15/2021	NA	NA	0	Unknown

A69-9001-1670	V16	Silver Carp	M	823	6.45	Cedar River	Prairie Park Fishery Backwater	11/17/2021	NA	NA	0	Unknown
A69-9001-1675	V16	Silver Carp	F	963	11.1	Cedar River	Prairie Park Fishery Backwater	11/17/2021	9/29/2022	CER - Prairie Park Fishery Backwater	35,770	Alive
A69-9001-1676	V16	Silver Carp	F	897	10.5	Cedar River	Rochester	4/15/2022	9/3/2022	IAR - HWY 99 Oakville	16	Alive
A69-9001-1680	V16	Silver Carp	F	882	9.8	Iowa River	Columbus Junction	4/21/2022	6/19/2022	CER - HWY 1 below Palisades State Park	47	Unknown
A69-9004-14229	V16A	Silver Carp	M	766	5.64	Iowa River	River Junction	4/21/2022	11/5/2022	IAR - HWY 22 River Junction	20	Alive
A69-1602-49687	V16	Silver Carp	F	809	7.23	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	7/1/2022	IAR - HWY 6 Sturgis Ferry IC	14	Alive
A69-1602-49690	V16	Silver Carp	F	912	9.33	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	6/24/2022	IAR - Johnson Louisa County Line Rd	1	Unknown
A69-9001-1679	V16	Silver Carp	M	835	6.79	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	NA	NA	0	Unknown
A69-9004-14227	V16A	Silver Carp	M	819	6.92	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	7/19/2022	IAR - HWY 99 Oakville	164	Alive
A69-9004-14231	V16A	Silver Carp	F	881	8.13	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	5/7/2022	IAR - HWY 6 Sturgis Ferry IC	1	Unknown
A69-9004-14246	V16A	Silver Carp	F	894	9.37	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	6/19/2022	IAR - HWY 6 Sturgis Ferry IC	19	Unknown
A69-9004-14247	V16A	Silver Carp	M	788	6.45	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	7/4/2022	IAR - HWY 6 Sturgis Ferry IC	37	Alive
A69-9004-14248	V16A	Silver Carp	F	801	6.94	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	6/26/2022	IAR - HWY 6 Sturgis Ferry IC	24	Unknown
A69-9004-14249	V16A	Silver Carp	M	820	5.72	Iowa River	Iowa City- Sturgis Ferry Park	4/25/2022	5/14/2022	IAR - HWY 6 Sturgis Ferry IC	30	Unknown
A69-1602-49685	V16	Silver Carp	F	843	8.05	Iowa River	River Junction	4/27/2022	6/6/2022	IAR - HWY 22 River Junction	44	Unknown
A69-1602-49686	V16	Silver Carp	M	824	5.92	Iowa River	River Junction	4/27/2022	6/3/2022	IAR - HWY 22 River Junction	11	Unknown
A69-1602-49688	V16	Silver Carp	F	905	10.66	Iowa River	Iowa City- Sturgis Ferry Park	4/27/2022	7/8/2022	IAR - HWY 6 Sturgis Ferry IC	214	Alive
A69-1602-49689	V16	Silver Carp	M	804	6.22	Iowa River	River Junction	4/27/2022	7/30/2022	IAR - Johnson Louisa County Line Rd	8	Alive
A69-1602-49691	V16	Silver Carp	F	819	6.95	Iowa River	Iowa City- Sturgis Ferry Park	4/27/2022	9/11/2022	IAR - HWY 6 Sturgis Ferry IC	9,642	Alive
A69-1602-49692	V16	Silver Carp	F	853	8.82	Iowa River	Iowa City- Sturgis Ferry Park	4/27/2022	11/5/2022	IAR - HWY 22 River Junction	113	Alive
A69-1602-49693	V16	Silver Carp	F	867	8.64	Iowa River	Iowa City- Sturgis Ferry Park	4/27/2022	10/21/2022	IAR - HWY 99 Oakville	1,649	Alive
A69-1602-49696	V16	Silver Carp	M	849	7.06	Iowa River	Iowa City- Sturgis Ferry Park	4/27/2022	5/21/2022	IAR - HWY 6 Sturgis Ferry IC	8	Unknown
A69-1602-49694	V16	Silver Carp	F	912	8.94	Iowa River	Iowa City- Sturgis Ferry Park	4/29/2022	5/19/2022	IAR - HWY 22 River Junction	1	Unknown
A69-1602-49695	V16	Silver Carp	F	869	9.2	Iowa River	Iowa City- Sturgis Ferry Park	4/29/2022	9/3/2022	CER - F28 Cedar Bluff	28	Alive
A69-1602-49697	V16	Silver Carp	M	770	5.42	Iowa River	Hills	4/29/2022	NA	NA	0	Unknown
A69-1602-49700	V16	Silver Carp	F	866	8.83	Iowa River	Hills	4/29/2022	11/5/2022	IAR - HWY 22 River Junction	12,289	Alive
A69-1602-49724	V16	Silver Carp	F	859	8.3	Cedar River	Palisades State Park	5/2/2022	6/12/2022	CER - HWY 1 below Palisades State Park	48	Unknown
A69-1602-49727	V16	Silver Carp	M	860	6.7	Cedar River	Palisades State Park	5/2/2022	6/19/2022	CER - HWY 1 below Palisades State Park	51	Unknown
A69-1602-49728	V16	Silver Carp	M	815	6.4	Cedar River	Palisades State Park	5/2/2022	9/2/2022	IAR - HWY 99 Oakville	5	Alive

A69-1602-49729	V16	Silver Carp	F	887	8.54	Cedar River	Palisades State Park	5/2/2022	9/2/2022	IAR - HWY 99 Wapello	22	Alive
A69-1602-49730	V16	Silver Carp	F	868	9.02	Cedar River	Palisades State Park	5/2/2022	9/2/2022	IAR - HWY 99 Oakville	35	Alive
A69-1602-49731	V16	Silver Carp	M	805	5.72	Cedar River	Palisades State Park	5/2/2022	5/16/2022	CER - HWY 1 below Palisades State Park	6	Unknown
A69-1602-49732	V16	Silver Carp	M	799	5.91	Cedar River	Palisades State Park	5/2/2022	8/28/2022	IAR - HWY 99 Oakville	21	Alive
A69-1602-49733	V16	Silver Carp	M	771	5.16	Cedar River	Palisades State Park	5/2/2022	8/30/2022	IAR - HWY 99 Oakville	206	Alive
A69-1602-49734	V16	Silver Carp	F	995	14.42	Cedar River	Palisades State Park	5/2/2022	8/10/2022	IAR - HWY 99 Wapello	21	Alive
A69-9001-1669	V16	Silver Carp	F	840	8.57	Cedar River	Palisades State Park	5/2/2022	9/3/2022	IAR - HWY 99 Oakville	11	Alive
A69-9001-1677	V16	Silver Carp	M	824	3.43	Cedar River	Palisades State Park	5/2/2022	NA	NA	0	Unknown
A69-9001-1678	V16	Silver Carp	M	873	8.27	Cedar River	Palisades State Park	5/2/2022	6/18/2022	CER - HWY 1 below Palisades State Park	15	Unknown
A69-1602-49650	V13	Silver Carp	M	833	6.72	Iowa River	Hills	5/4/2022	7/23/2022	IAR - HWY 6 Sturgis Ferry IC	80	Alive
A69-1602-49653	V13	Silver Carp	M	780	5.18	Iowa River	Hills	5/4/2022	8/10/2022	IAR - HWY 99 Oakville	29	Alive
A69-1602-49698	V16	Silver Carp	F	855	8.83	Iowa River	Hills	5/4/2022	7/9/2022	IAR - HWY 99 Oakville	9	Alive
A69-1602-49699	V16	Silver Carp	F	881	8.8	Iowa River	Iowa City- Sturgis Ferry Park	5/4/2022	7/3/2022	IAR - HWY 6 Sturgis Ferry IC	352	Alive
A69-1602-49701	V16	Silver Carp	M	790	5.28	Iowa River	Iowa City- Sturgis Ferry Park	5/4/2022	6/11/2022	IAR - HWY 6 Sturgis Ferry IC	4	Unknown
A69-1602-49702	V16	Silver Carp	M	839	6.53	Iowa River	Iowa City- Sturgis Ferry Park	5/4/2022	7/9/2022	IAR - HWY 6 Sturgis Ferry IC	6	Alive
A69-1602-49725	V16	Silver Carp	F	879	9.22	Cedar River	Palisades State Park	5/9/2022	9/3/2022	IAR - HWY 99 Oakville	90	Alive
A69-1602-49726	V16	Silver Carp	F	855	8.04	Cedar River	Palisades State Park	5/9/2022	8/10/2022	UMR - Pool 17 Coolegar Slough	189	Alive
A69-1602-49654	V13	Silver Carp	F	855	8.53	Cedar River	Palisades State Park	5/10/2022	9/3/2022	IAR - HWY 99 Oakville	41	Alive
A69-1602-49655	V13	Silver Carp	M	791	5.43	Cedar River	Palisades State Park	5/10/2022	7/18/2022	IAR - HWY 92 Columbus Junction	9	Alive
A69-1602-49656	V13	Silver Carp	M	854	7.74	Cedar River	Palisades State Park	5/10/2022	9/3/2022	IAR - HWY 99 Oakville	20	Alive
A69-1602-49657	V13	Silver Carp	M	829	6.14	Cedar River	Palisades State Park	5/10/2022	9/24/2022	CER - HWY 1 below Palisades State Park	54	Alive
A69-1602-49721	V16	Silver Carp	F	881	8.85	Cedar River	Palisades State Park	5/10/2022	5/27/2022	CER - HWY 6 Moscow	6	Unknown
A69-1602-49722	V16	Silver Carp	F	889	10.63	Cedar River	Palisades State Park	5/10/2022	7/3/2022	IAR - HWY 99 Oakville	27	Alive
A69-1602-49723	V16	Silver Carp	F	875	9.46	Cedar River	Palisades State Park	5/10/2022	6/22/2022	IAR - HWY 92 Columbus Junction	37	Unknown
A69-1602-49652	V13	Silver Carp	M	854	6.96	Iowa River	Hills	5/13/2022	7/9/2022	IAR - HWY 99 Oakville	6	Alive
A69-1602-49658	V13	Silver Carp	M	847	7.14	Cedar River	Palisades State Park	5/13/2022	7/19/2022	IAR - HWY 99 Oakville	5	Alive
A69-1602-49659	V13	Silver Carp	F	911	9.85	Cedar River	Palisades State Park	5/13/2022	7/4/2022	IAR - HWY 99 Oakville	11	Alive
A69-1602-49660	V13	Silver Carp	F	880	9.62	Iowa River	Iowa City- Sturgis Ferry Park	5/13/2022	7/9/2022	IAR - HWY 6 Sturgis Ferry IC	6	Alive
A69-1602-49661	V13	Silver Carp	F	829	7.69	Iowa River	Iowa City- Sturgis Ferry Park	5/13/2022	6/3/2022	IAR - HWY 6 Sturgis Ferry IC	2	Unknown

A69-1604-26493	V16	Silver Carp	F	834	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-1604-26494	V16	Silver Carp	F	905	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-1604-26495	V16	Silver Carp	F	893	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10636	V16T	Silver Carp	F	893	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10637	V16T	Silver Carp	F	876	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10638	V16T	Silver Carp	F	875	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10639	V16T	Silver Carp	F	895	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10640	V16T	Silver Carp	M	802	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10641	V16T	Silver Carp	M	800	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10689	V16A	Silver Carp	F	855	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10690	V16A	Silver Carp	F	880	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10691	V16A	Silver Carp	F	870	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10692	V16A	Silver Carp	M	785	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10693	V16A	Silver Carp	M	872	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10694	V16A	Silver Carp	M	753	NA	Iowa River	Iowa City- Sturgis Ferry Park	9/27/2022	NA	NA	0	Alive
A69-9007-10662	V16T	Silver Carp	M	869	7.53	Cedar River	Prairie Park Fishery Backwater	9/29/2022	NA	NA	0	Alive
A69-9007-10663	V16T	Silver Carp	M	846	7.07	Cedar River	Prairie Park Fishery Backwater	9/29/2022	NA	NA	0	Alive
A69-9007-10664	V16T	Silver Carp	F	931	14.46	Cedar River	Prairie Park Fishery Backwater	9/29/2022	NA	NA	0	Alive
A69-9007-10677	V16A	Silver Carp	F	954	14.31	Cedar River	Cedar Bluff	9/29/2022	10/26/2022	CER - F28 Cedar Bluff	4	Alive
A69-9007-10678	V16A	Silver Carp	M	859	7.82	Cedar River	Prairie Park Fishery Backwater	9/29/2022	9/29/2022	CER - Prairie Park Fishery Backwater	15	Alive
A69-9007-10679	V16A	Silver Carp	M	900	8.65	Cedar River	Prairie Park Fishery Backwater	9/29/2022	9/29/2022	CER - Prairie Park Fishery Backwater	18	Alive
A69-9007-10680	V16A	Silver Carp	M	990	11.1	Cedar River	Prairie Park Fishery Backwater	9/29/2022	9/29/2022	CER - Prairie Park Fishery Backwater	4	Alive
A69-9007-10681	V16A	Silver Carp	F	1049	15	Cedar River	Prairie Park Fishery Backwater	9/29/2022	9/29/2022	CER - Prairie Park Fishery Backwater	4	Alive
A69-9007-10682	V16A	Silver Carp	F	892	11.93	Cedar River	Prairie Park Fishery Backwater	9/29/2022	NA	NA	0	Alive
A69-1604-26490	V16	Silver Carp	F	962	11.54	Cedar River	Prairie Park Fishery Backwater	10/4/2022	NA	NA	0	Alive
A69-1604-26491	V16	Silver Carp	M	784	6.05	Cedar River	Prairie Park Fishery Backwater	10/4/2022	NA	NA	0	Alive
A69-1604-26492	V16	Silver Carp	F	992	14.34	Cedar River	Prairie Park Fishery Backwater	10/4/2022	NA	NA	0	Alive
A69-9007-10665	V16T	Silver Carp	F	970	13.14	Cedar River	Prairie Park Fishery Backwater	10/4/2022	NA	NA	0	Alive
A69-9007-10666	V16T	Silver Carp	F	970	11.06	Cedar River	Prairie Park Fishery Backwater	10/4/2022	NA	NA	0	Alive

A69-9007-10667	V16T	Silver Carp	F	927	10.73	Cedar River	Prairie Park Fishery Backwater	10/4/2022	NA	NA	0	Alive
A69-1604-26499	V16	Silver Carp	F	709	4.3	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-1604-26500	V16	Silver Carp	F	760	5.69	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-1604-26501	V16	Silver Carp	F	831	7.54	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10648	V16T	Silver Carp	F	710	4.52	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10649	V16T	Silver Carp	F	715	4.75	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10650	V16T	Silver Carp	M	690	3.9	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10651	V16T	Silver Carp	F	779	6.32	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10652	V16T	Silver Carp	M	679	3.95	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10653	V16T	Silver Carp	M	615	2.56	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10683	V16A	Silver Carp	F	655	3.24	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10684	V16A	Silver Carp	F	695	3.85	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10685	V16A	Silver Carp	M	621	3	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10686	V16A	Silver Carp	F	780	6.78	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10687	V16A	Silver Carp	M	745	4.66	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-9007-10688	V16A	Silver Carp	M	730	4.96	Des Moines River	Cliffland Access	10/6/2022	NA	NA	0	Alive
A69-1604-26496	V16	Silver Carp	F	792	5.9	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-1604-26497	V16	Silver Carp	F	855	7.12	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-1604-26498	V16	Silver Carp	M	769	5.02	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10642	V16T	Silver Carp	F	724	4.06	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10643	V16T	Silver Carp	F	755	5.45	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10644	V16T	Silver Carp	F	749	4.51	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10645	V16T	Silver Carp	M	684	3.99	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10646	V16T	Silver Carp	M	746	4.5	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10647	V16T	Silver Carp	M	758	4.38	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10671	V16A	Silver Carp	F	748	4.35	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10672	V16A	Silver Carp	F	743	4.7	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10673	V16A	Silver Carp	F	750	4.34	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10674	V16A	Silver Carp	M	751	4.75	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive

A69-9007-10675	V16A	Silver Carp	M	762	5.05	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive
A69-9007-10676	V16A	Silver Carp	M	684	3.2	Des Moines River	Howell Station below Red Rock Dam	10/11/2022	NA	NA	0	Alive

Notes: We determined fate by classifying individuals that have not been detected since July 1, 2022 as “Unknown” and individuals that have been detected since July 1, 2022 as “Alive”. Individuals with zero detections that we reasonably believe should have been detected at this point in time were classified as “Dead”. Individuals with a large number of detections at a single location were examined and fate was determined on a case by case basis. All individuals tagged during Fall 2022 were classified as “Alive”.

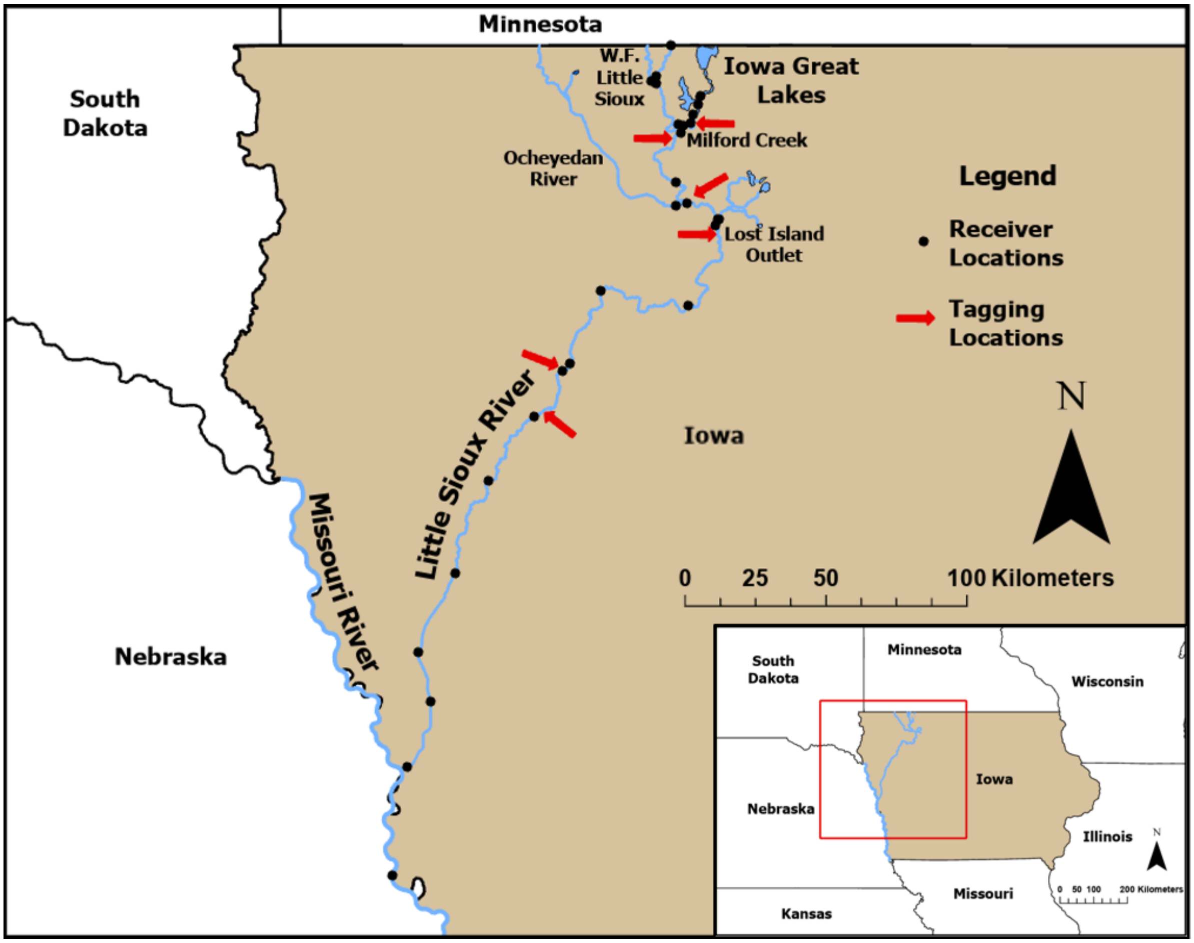

Figure 1. Little Sioux River, four of its tributaries, and the Iowa Great Lakes in Northwest Iowa. Black dots indicate acoustic receiver locations in the Missouri River (1), Little Sioux River (16), West Fork Little Sioux River (2), Milford Creek (3), Ocheyedan River (2), and Lost Island Outlet (2).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

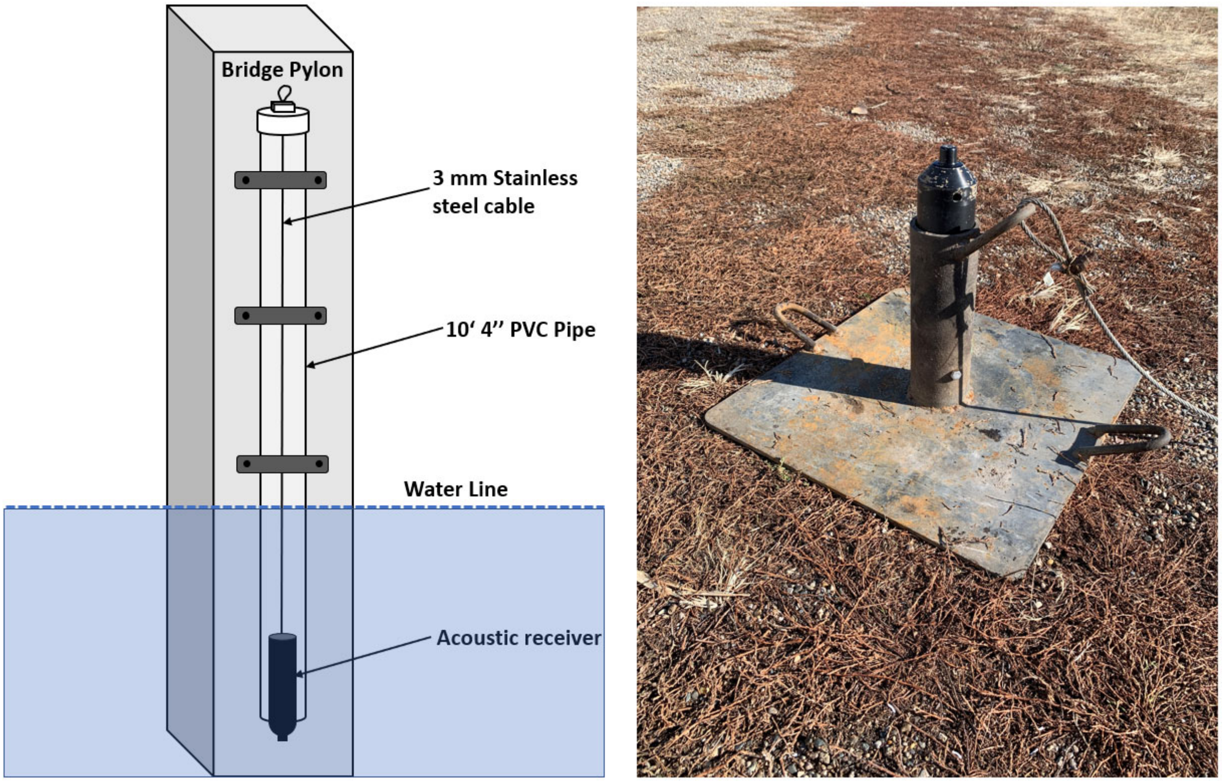

Figure 2. We deployed 19 acoustic receivers in PVC housings that were attached to the downstream side of intersecting highway bridges (left) and 9 bottom sets (right) throughout the study area (see Table 1, Figure 1 for receiver locations). Bridge mounted receivers were oriented in a downward position 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 receivers were anchored to the nearest shoreline with approximately 6.5 mm cable.

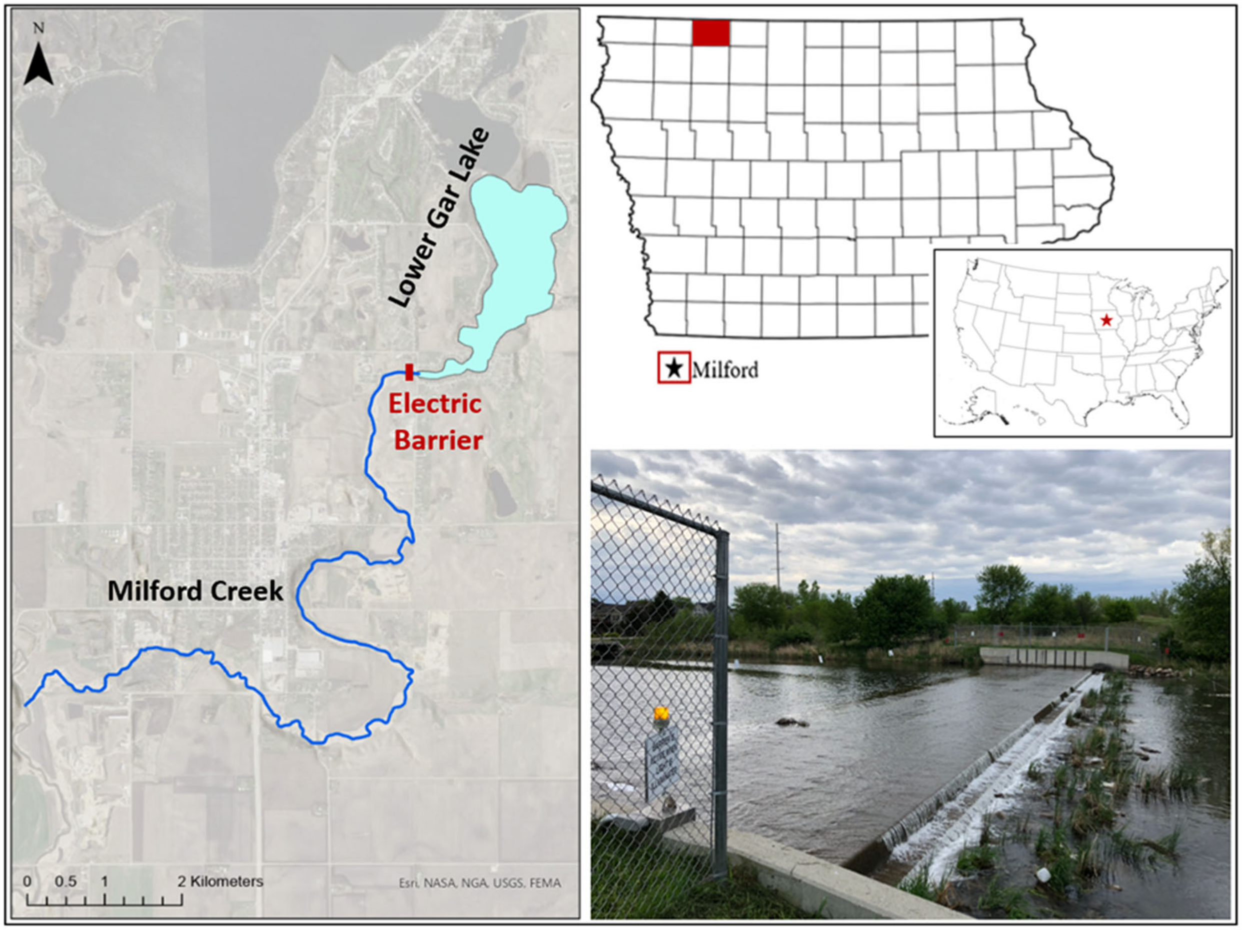

Figure 3. Electric barrier at the outlet of Lower Gar Lake and headwater of Milford Creek located in Milford Iowa, USA (43.340732, -95.132642).

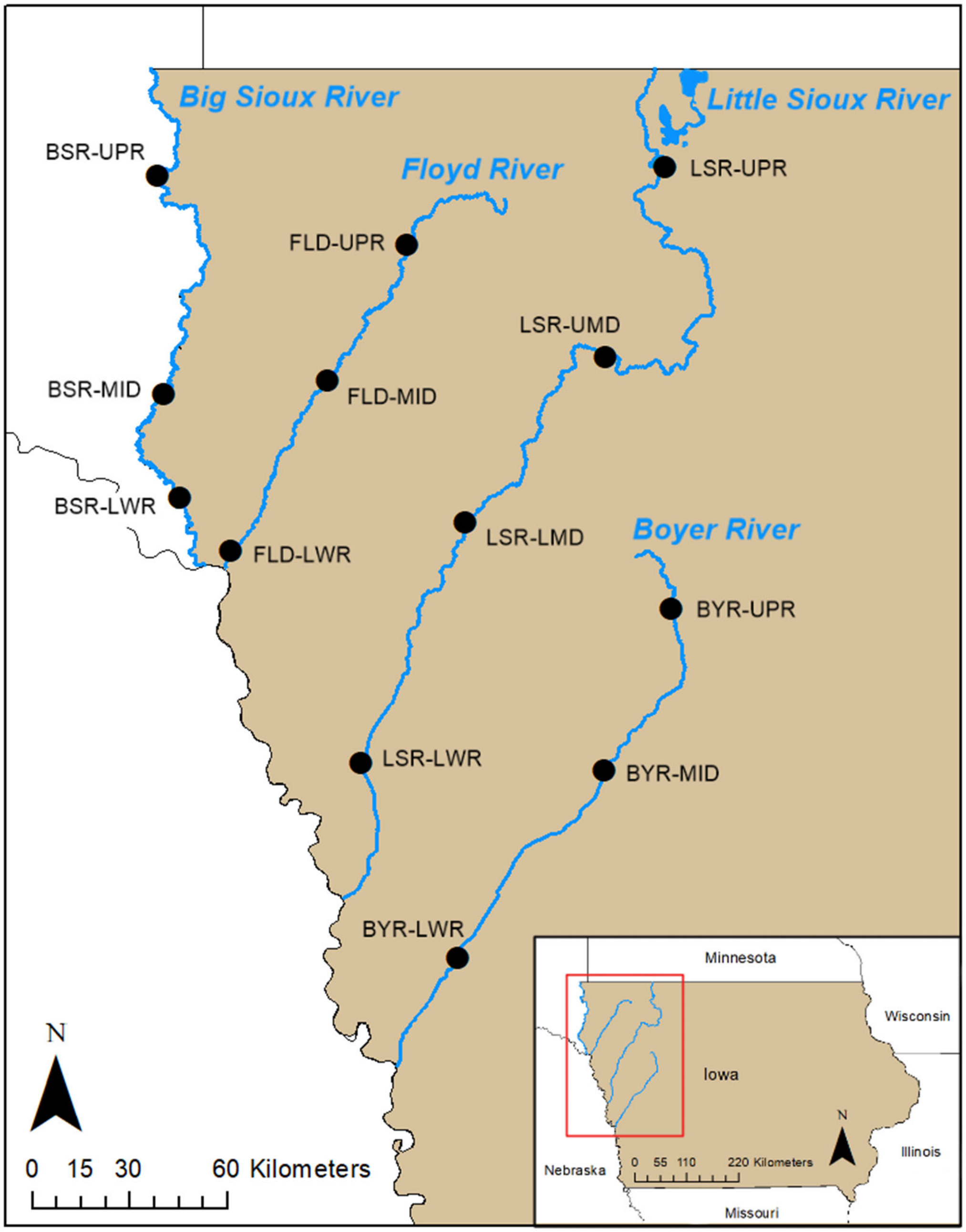

Figure 4. Locations of the thirteen sites on the Big Sioux, Floyd, Little Sioux, and Boyer Rivers in Northwestern Iowa where we sampled larval fishes during 2022. Sites were broadly selected to cover approximately equal sections of each river. See Table 3 for site abbreviation key and coordinates.

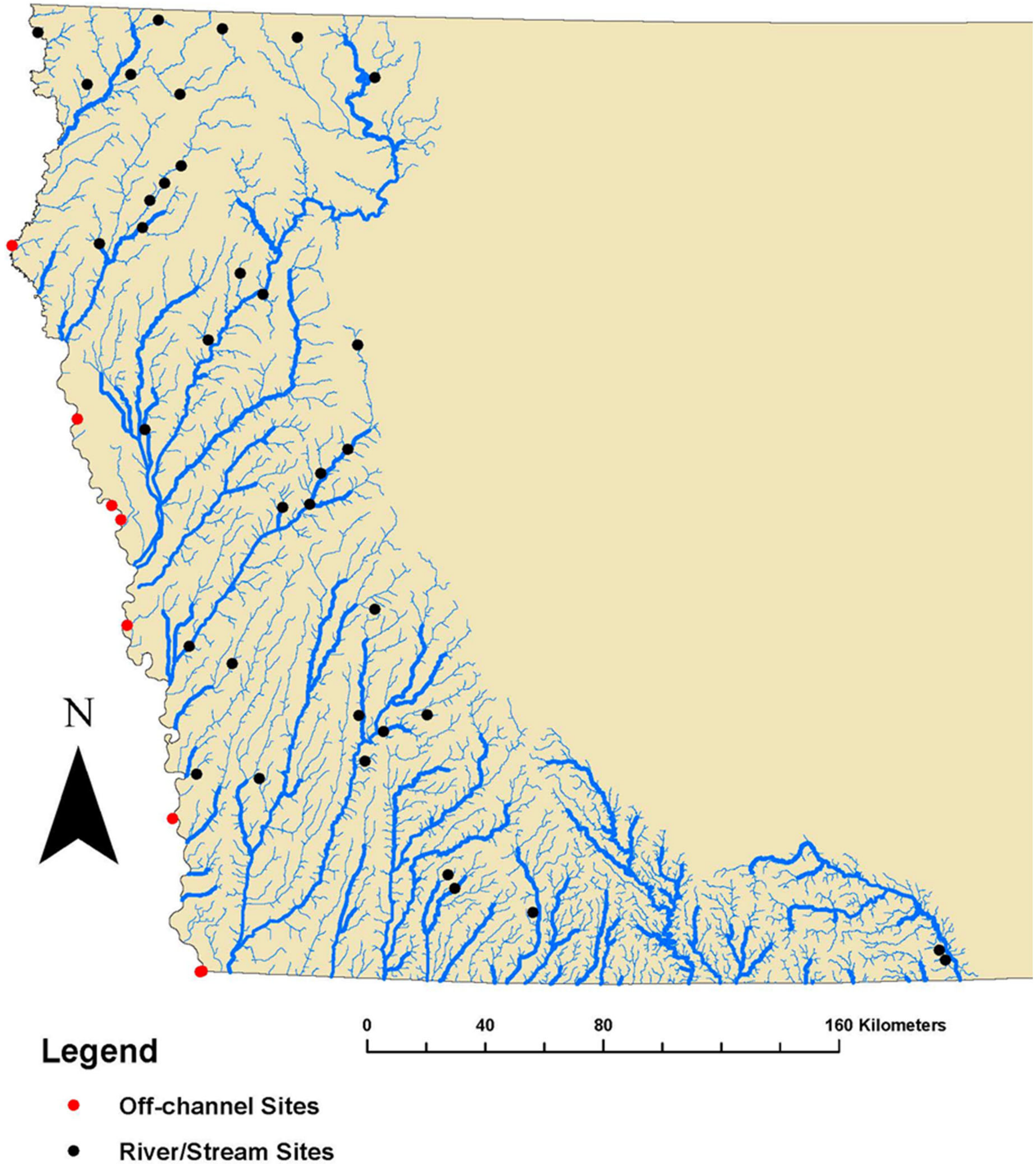

Figure 5. Locations of stream (n=36) and off-channel (n=8) sites in the Missouri River Basin where we sampled fish communities during 2022.

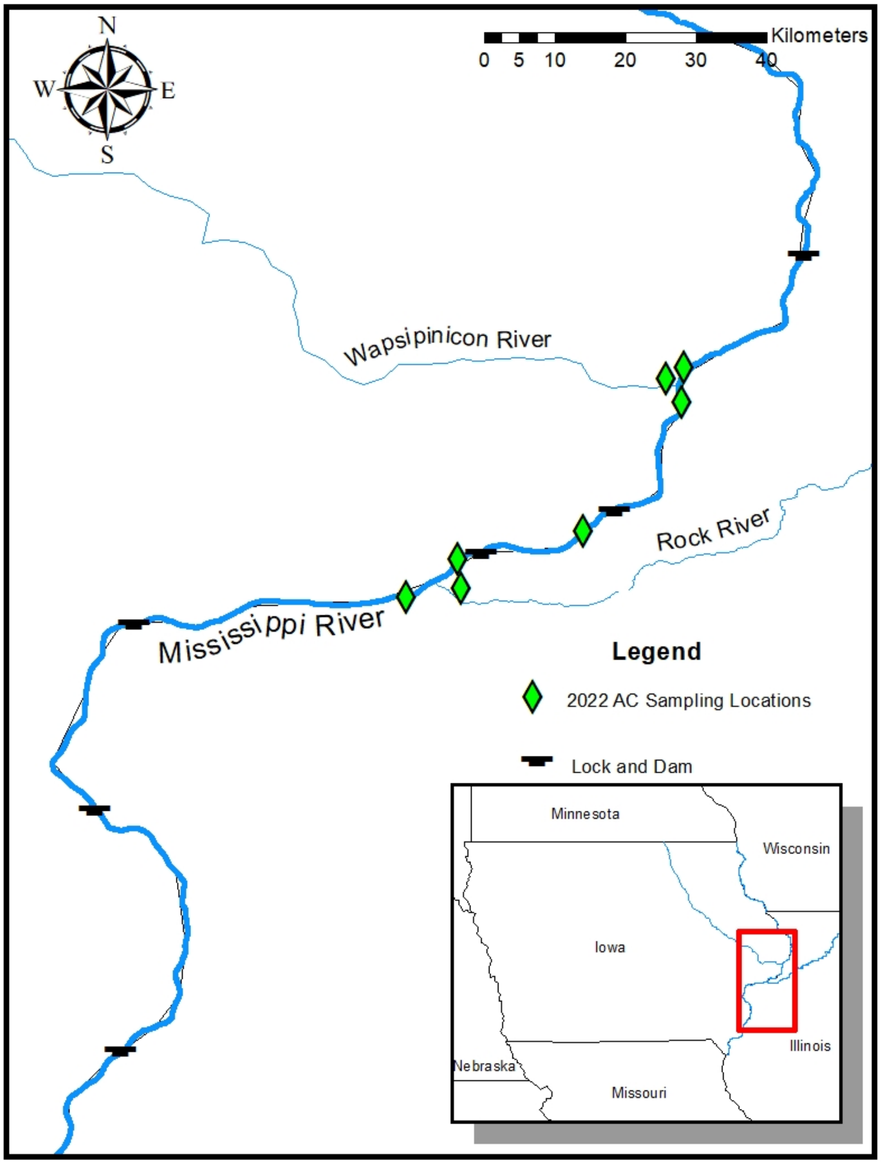

Figure 6. Location of ichthyoplankton sampling sites in pools 14-16 on the Upper Mississippi River on the southeast border of Iowa. The seven sampling sites where we collected chlorophyll *a*, fish eggs, and age-0 fishes during 2022 are indicated by green diamonds. Mississippi River lock and dams within the sampling reach are denoted by black lines. See Table 4 for site names and coordinates.

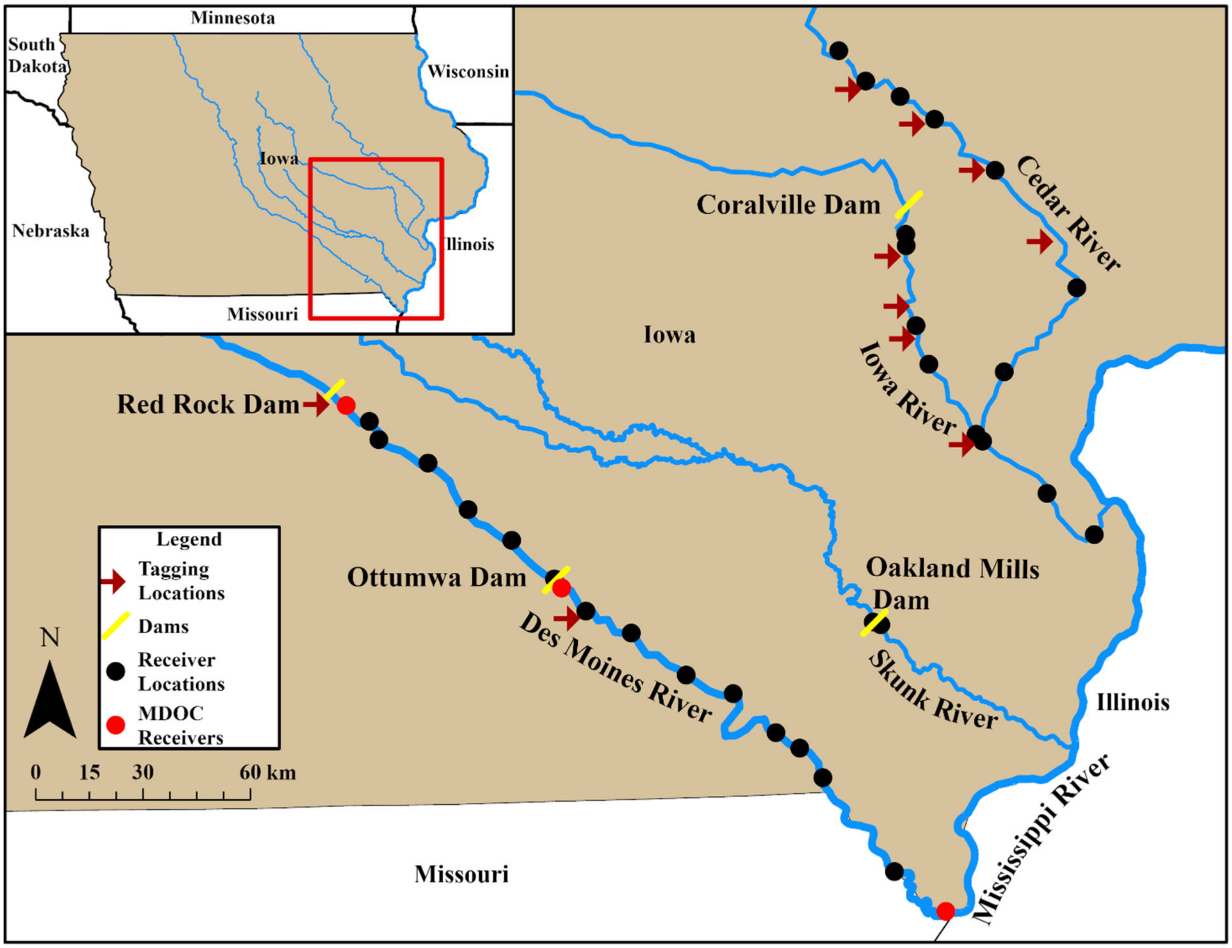

Figure 7. Upper Mississippi River and four of its tributaries (Des Moines, Skunk, Iowa, and Cedar rivers) in southeastern Iowa. Red arrows indicate Silver Carp tagging locations, black dots represent new receiver locations (see Table 5 for receiver location details), and red dots represent locations of preexisting Missouri Department of Conservation receivers. Yellow lines denote location of dams.

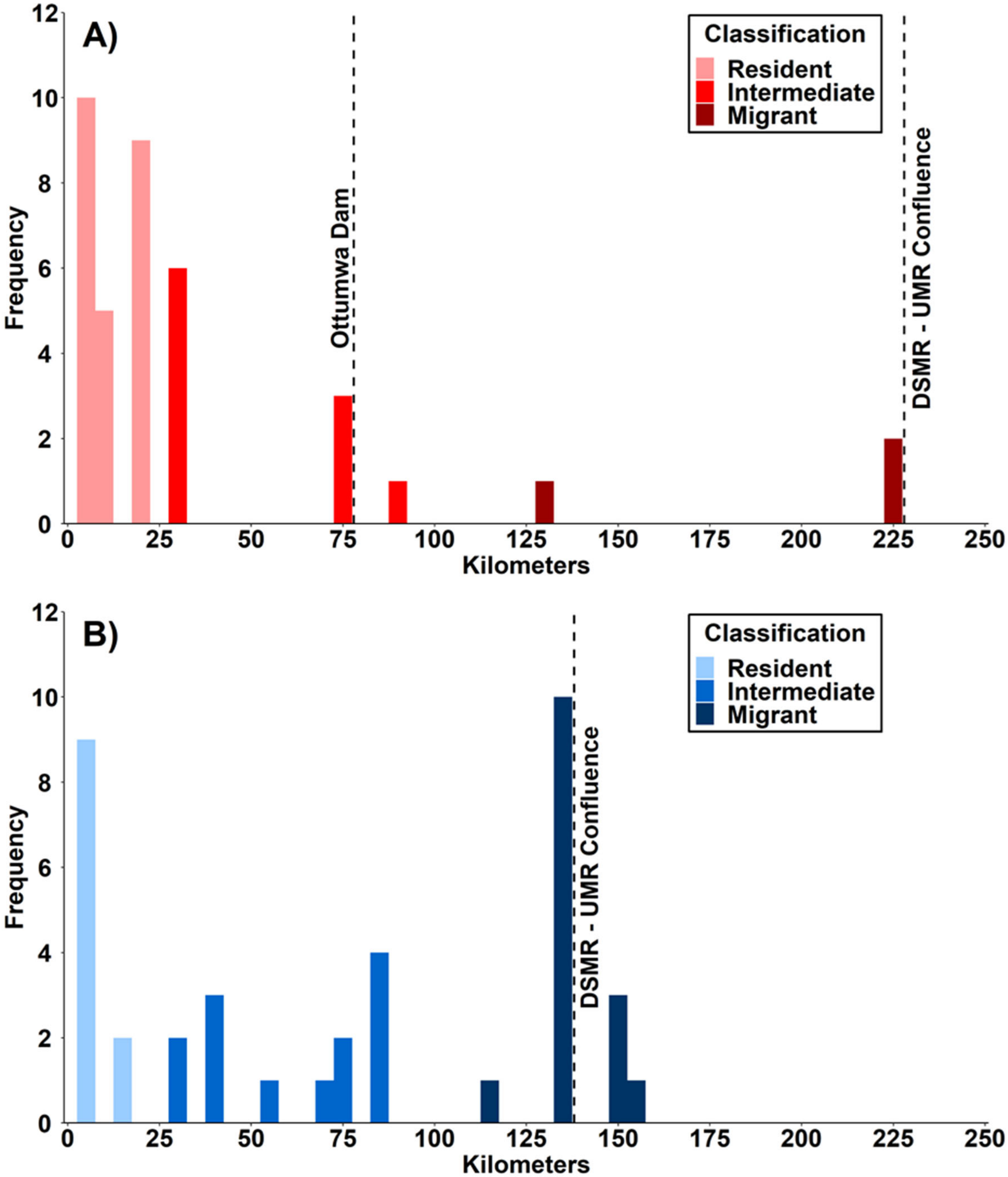

Figure 8. Movement-frequency of maximum displacement distances (kilometers) for A) Silver Carp tagged below Red Rock Dam and B) Silver Carp tagged below Ottumwa Dam. Note that Silver Carp we detected near the mouth of the Des Moines River (DSMR - HWY 136 Keokuk) could have moved further but we have not yet received detections from other agencies conducting acoustic telemetry in the basin.

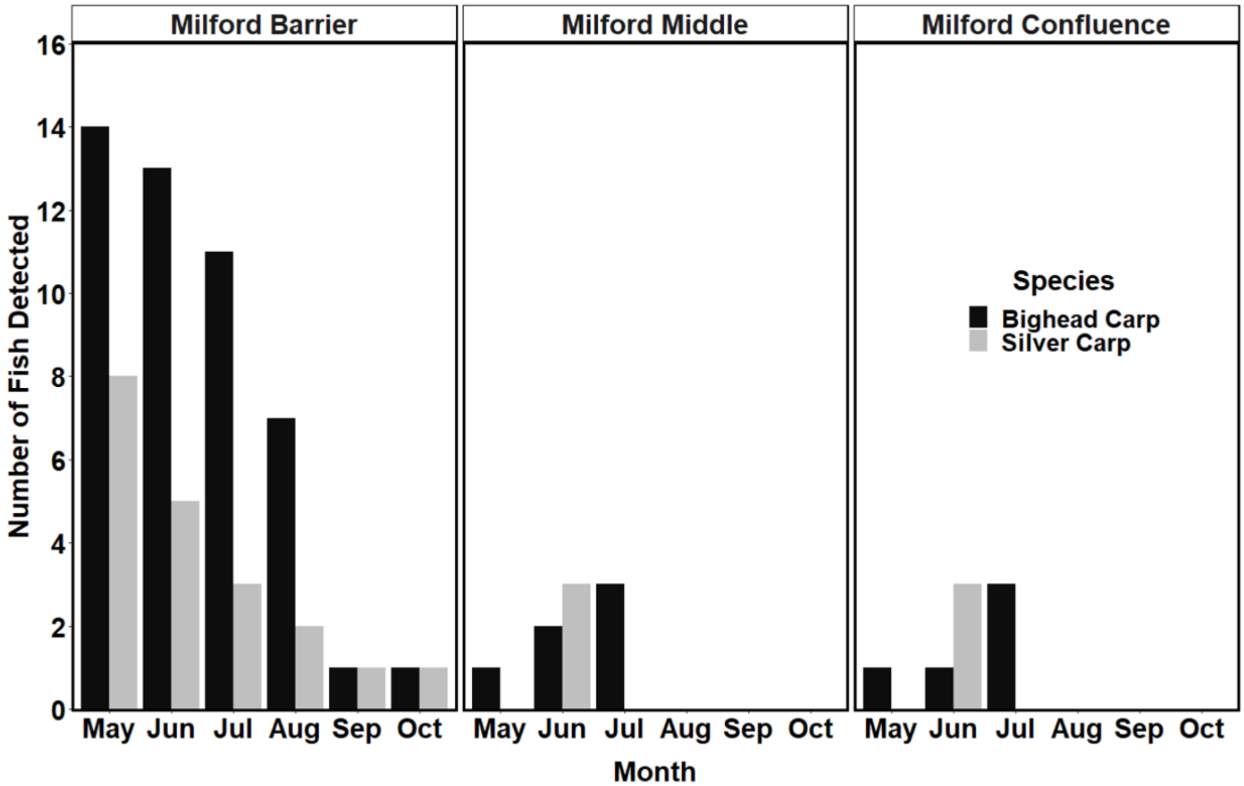

Figure 9. Number of Bighead Carp (black) and Silver Carp (grey) detected at the three receivers in Milford Creek from May-October 2022. Of the 14 Bighead Carp and 9 Silver Carp tagged in Milford Creek, only 1 Silver Carp has not been detected near the electric fish barrier (left panel). Fish detections at the middle receiver (middle panel) and confluence receiver (right panel) were highest in June and July, suggesting movements from Milford Creek to the Little Sioux River were most frequent during this time period. A total of 5 Bighead Carp and 3 Silver Carp that were tagged in Milford Creek have been detected in the Little Sioux River from May-October.

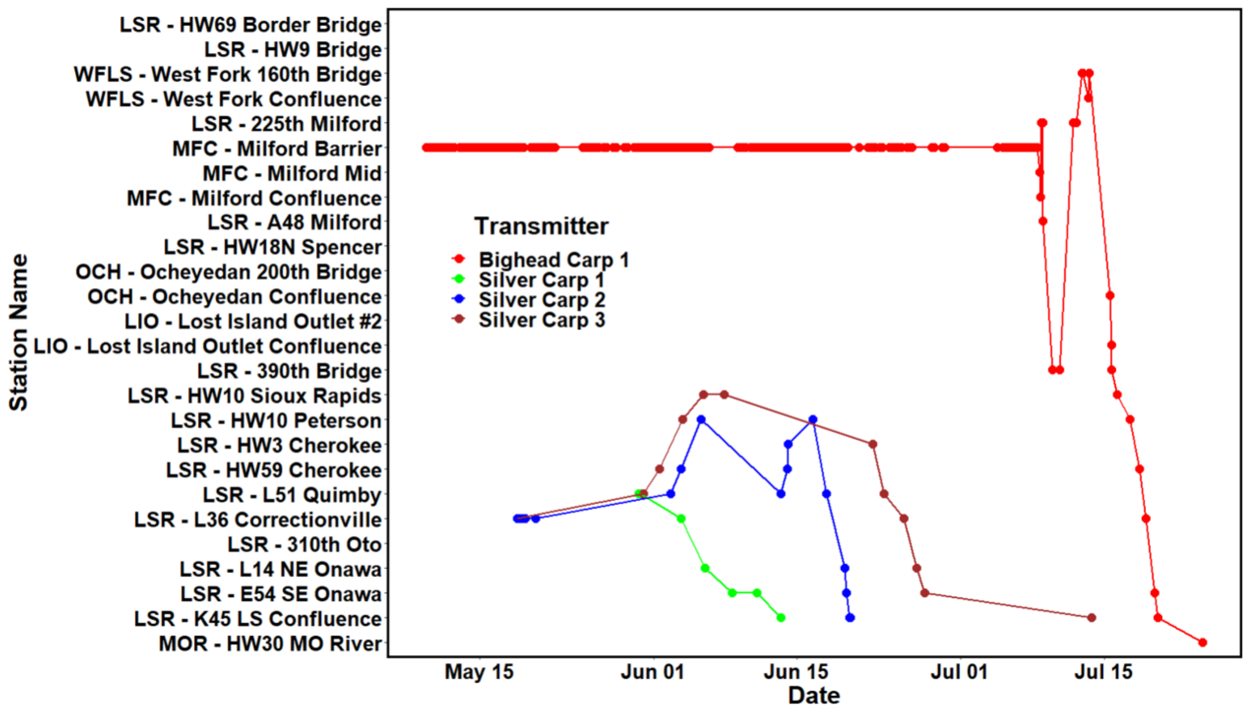

Figure 10. Abacus plot showing detection histories of 1 Bighead Carp (red) and 3 Silver Carp that have or likely have emigrated from the Little Sioux River between June 15th-July 24th, 2022. The Bighead Carp (red line) that was tagged on May 9 downstream of the electric fish barrier in Milford Creek traveled approximately 545 km before its last detection in the Missouri River, approximately 35 km downstream of the Little Sioux River confluence on July 24th. We tagged the 3 Silver Carp on May 17th-18th between Cherokee, IA and Correctionville, IA and were last detected during mid-June and mid-July near the Little Sioux River confluence with the Missouri River. Silver Carp 2 (blue line) was detected 40 km upstream into the Platte River, Nebraska on September 4th, ~255 km away from its tagging location four months prior.

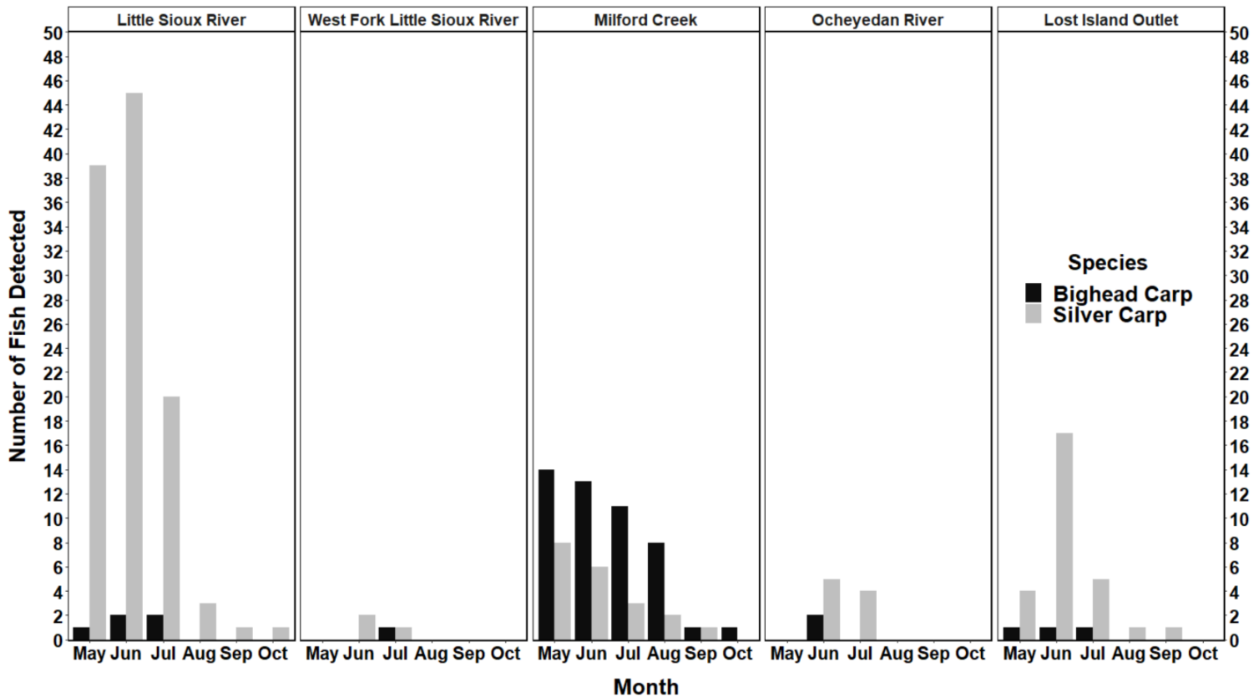

Figure 11. Number of Bighead Carp (black) and Silver Carp (grey) detected in the Little Sioux River, West Fork Little Sioux River, Milford Creek, Ocheyedan River, and Lost Island Outlet (left to right) from May-October. We captured and tagged invasive carp in Milford Creek (n=23) and the Little Sioux River near the confluence (<5 rkm) of Lost Island Outlet (n=17), Ocheyedan River (n=5), and Milford Creek (n=16). Twenty (n=20) additional invasive carp were tagged between Cherokee, IA and Correctionville, IA.

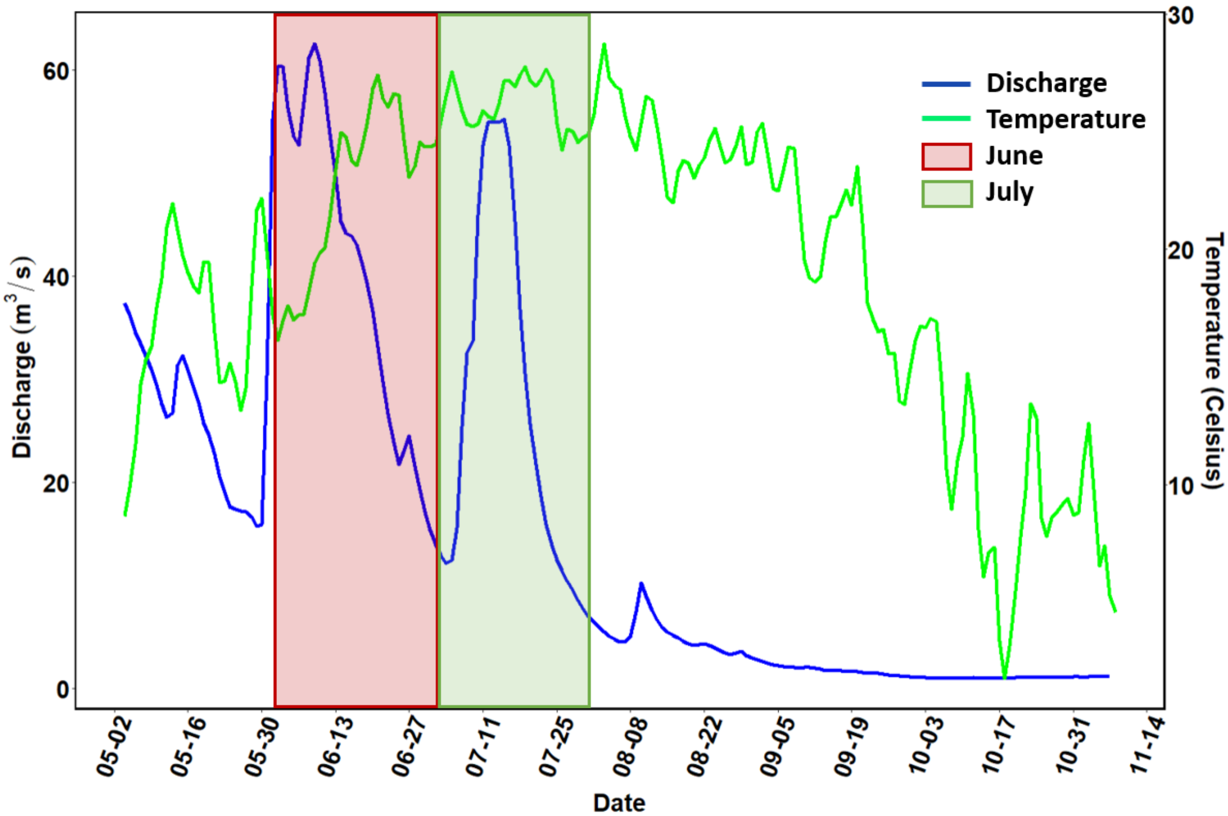

Figure 12. Hydrograph of Little Sioux River for 2022 from USGS gauging station near Linn Grove, IA (Station ID: 06605850, rkm 220) from the first day fish were tagged to the first day receivers were downloaded in November. Silver Carp movement events during June (red box) were generally more frequent and larger than movements in July (green box), whereas Bighead Carp movements were most frequent and larger in July. Discharge (m^3/s; blue line) reached its highest point during the month of June, followed by one spike that occurred in the middle of July.

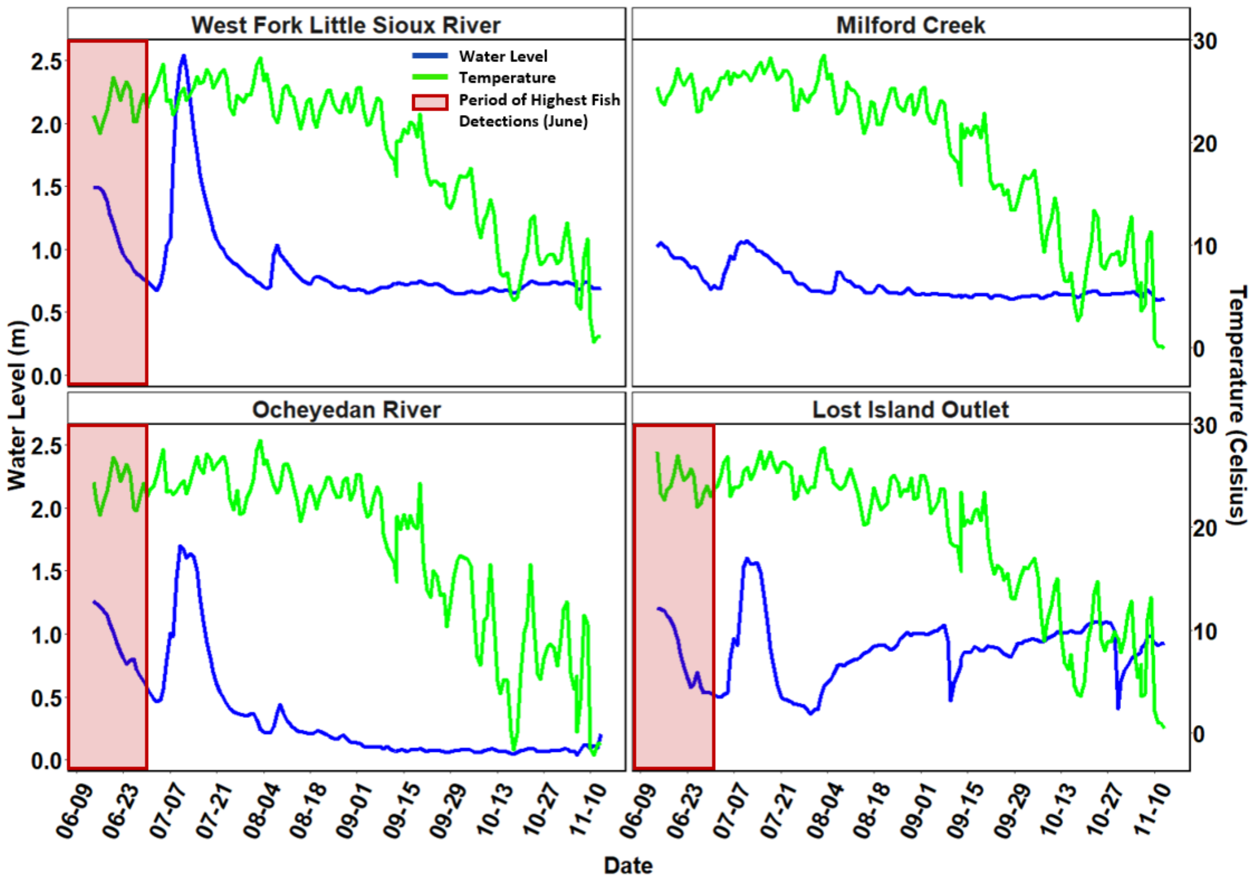

Figure 13. Water levels (m; blue line) and temperature (Celsius; green line) within the West Fork Little Sioux River, Milford Creek, Ocheyedan River, and Lost Island Outlet from mid-June through November 13th of 2022. We did not deploy water level loggers until June 13th, so water level data was not available prior to this date. Number of individuals that were tagged in the Little Sioux River and detected during June (red boxes) in the West Fork Little Sioux River (Bighead Carp: 0, Silver Carp: 2), Ocheyedan River (Bighead Carp: 2, Silver Carp: 5), and Lost Island Outlet (Bighead Carp: 1, Silver Carp: 17) were higher in comparison to all other months. To date, no Bighead or Silver Carp that were tagged in the Little Sioux River have been detected in Milford Creek.

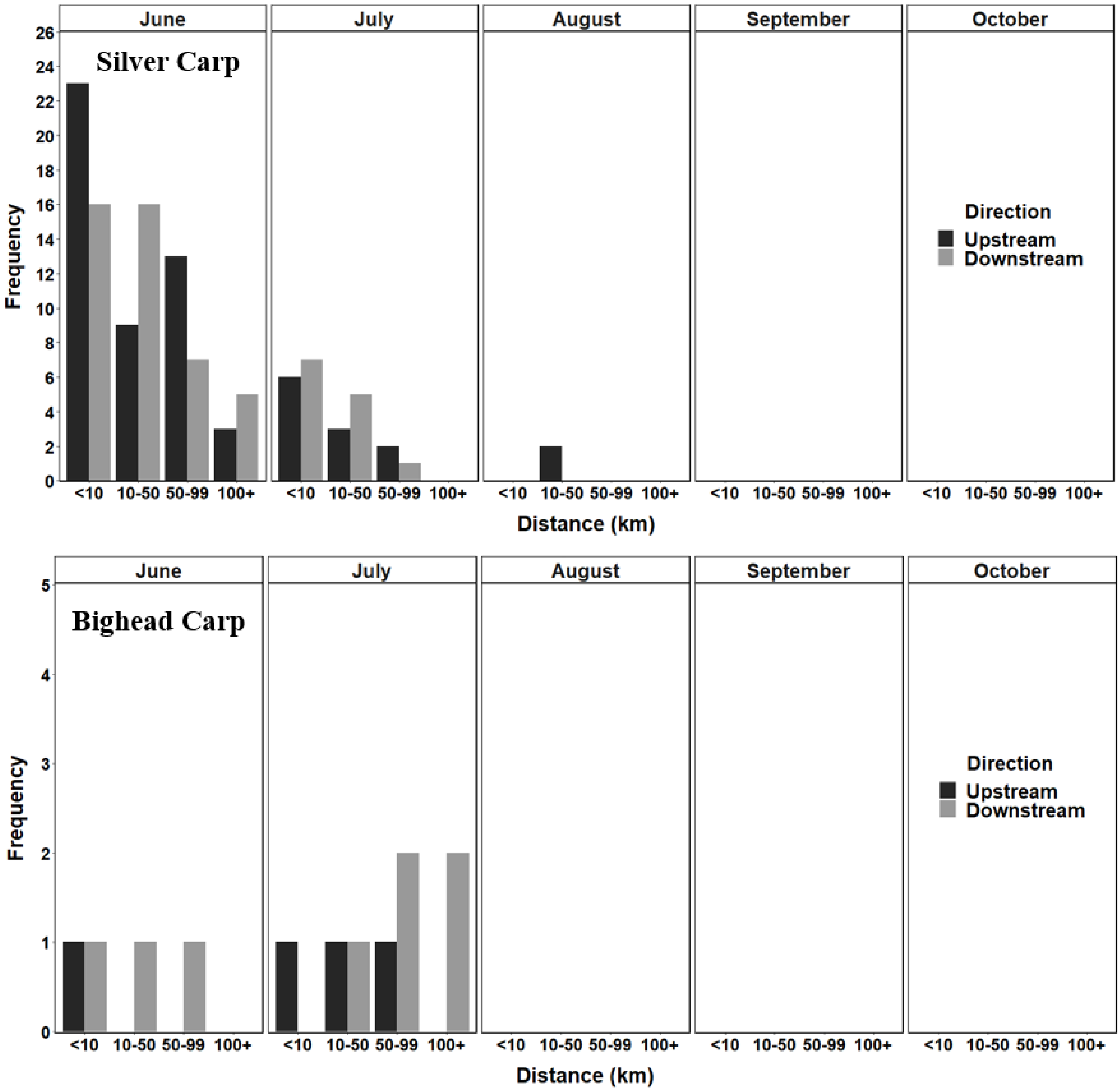

Figure 14. Directional movement event frequencies of Silver Carp (top figure) and Bighead Carp (bottom figure) from June 1st to October 31st. Note that number of individuals tagged per species was not evenly distributed (Silver Carp, n=67; Bighead Carp, n= 14), frequency of upstream/downstream movement events per month was cumulative across all individuals, and only the individuals that had at least one movement event were included in the analysis.

Figure 15. Outdoor video surveillance camera (Sunba network PTZ) installed above the electric fish barrier at the outlet of Lower Gar Lake on June 14th, 2022. The camera is positioned to allow for the best possible view of fish movements on the north side of the barrier.

Field Strength Readings
(Readings are in Volts/Centimeter)

1 meter below #1	0.86
Electrode #1 to #2	4.2
Electrode #2 to #3	5.0
Electrode #3 to #4	5.3
Electrode #4 to #6	5.2
Electrode #5 to #6	5.0
Electrode #6 to #7	5.6
Electrode #7 to #8	4.6
1 meter above #8	0.6

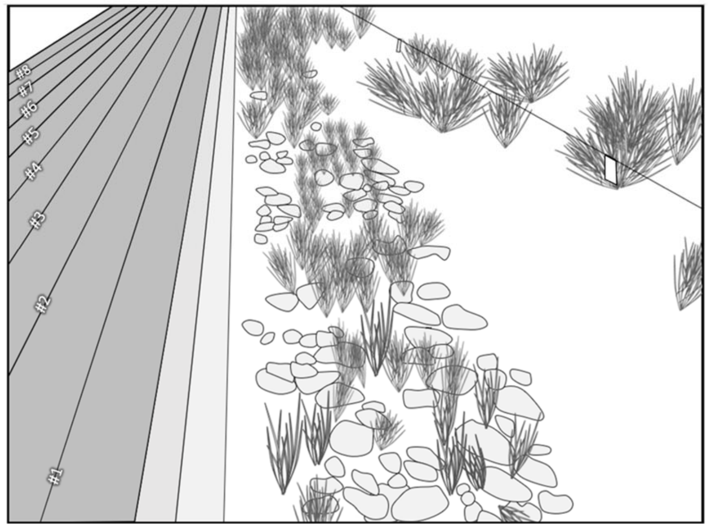

Figure 16. Field measurements collected by Smith-Root Inc. of voltage variation being emitted between electrodes on the electric barrier in Milford Creek Iowa, USA on May 4th, 2022. Stray voltage was also measured 1 meter above and below the barrier.

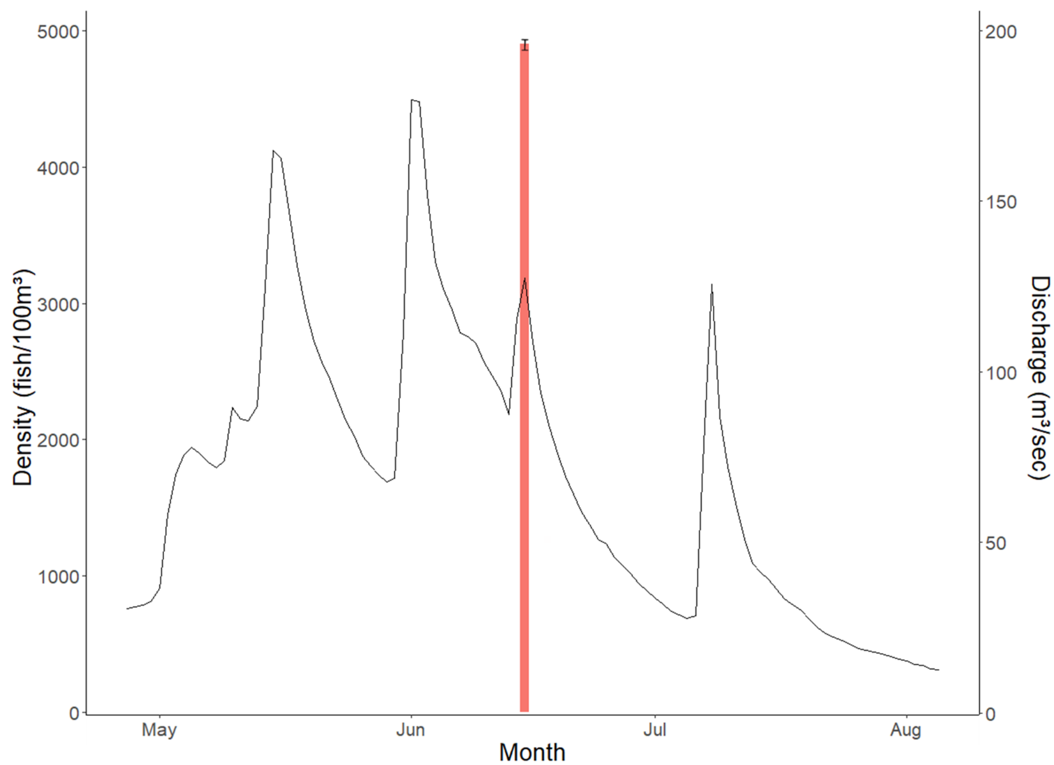

Figure 17. Larval and yolk-sac invasive carp densities (red bar; mean ± 95% CI) at the Big Sioux River middle site (BSR-MID) in relation to river discharge (m^3/sec).

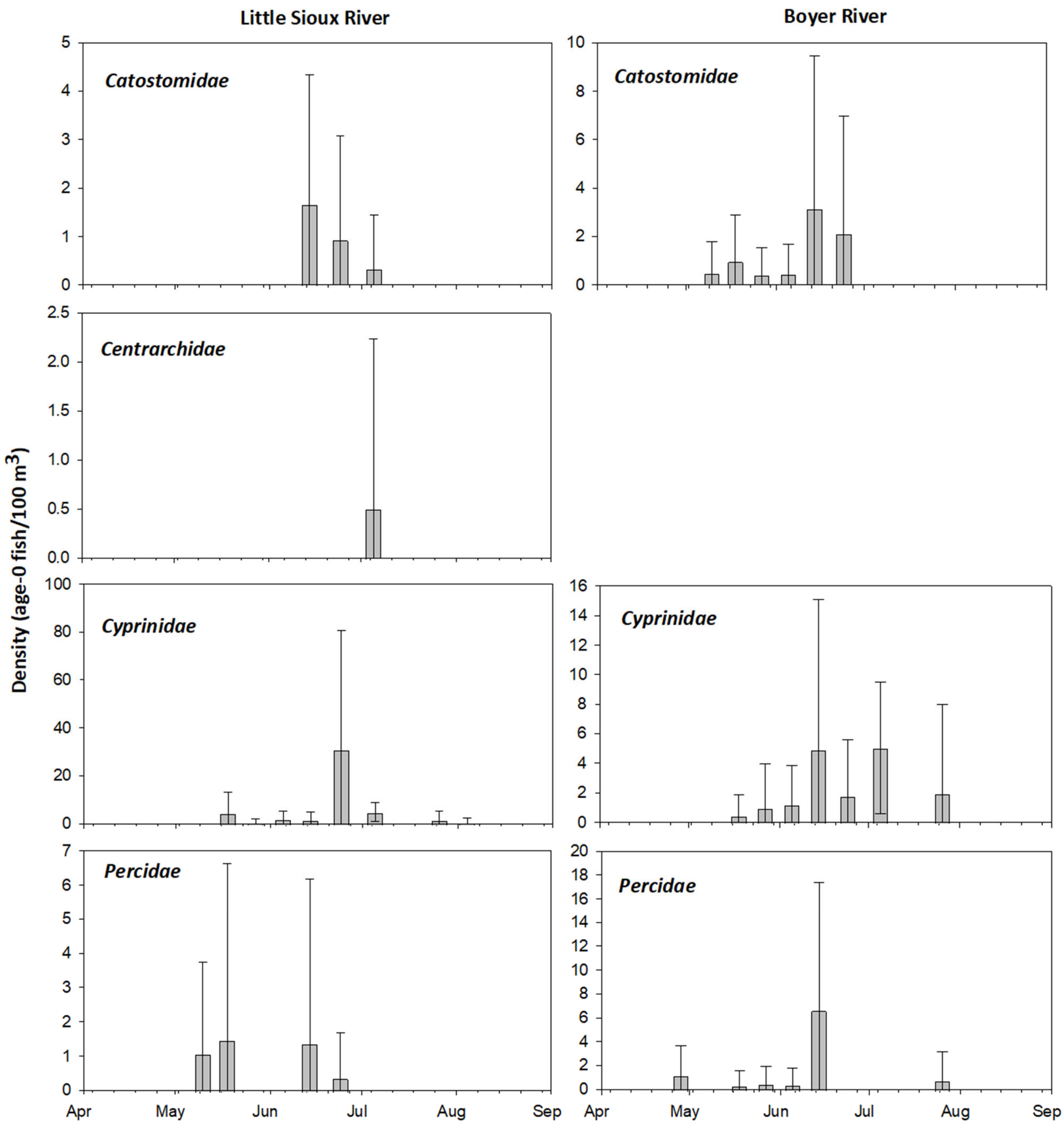

Figure 18. Density (mean ± 1 SE) of age-0 fishes from four families collected on the Little Sioux River (left) and Boyer River (right) from April 28th to August 5th, 2022. Note differences in y-axis scale among figure panels. No other taxa were detected on these rivers.

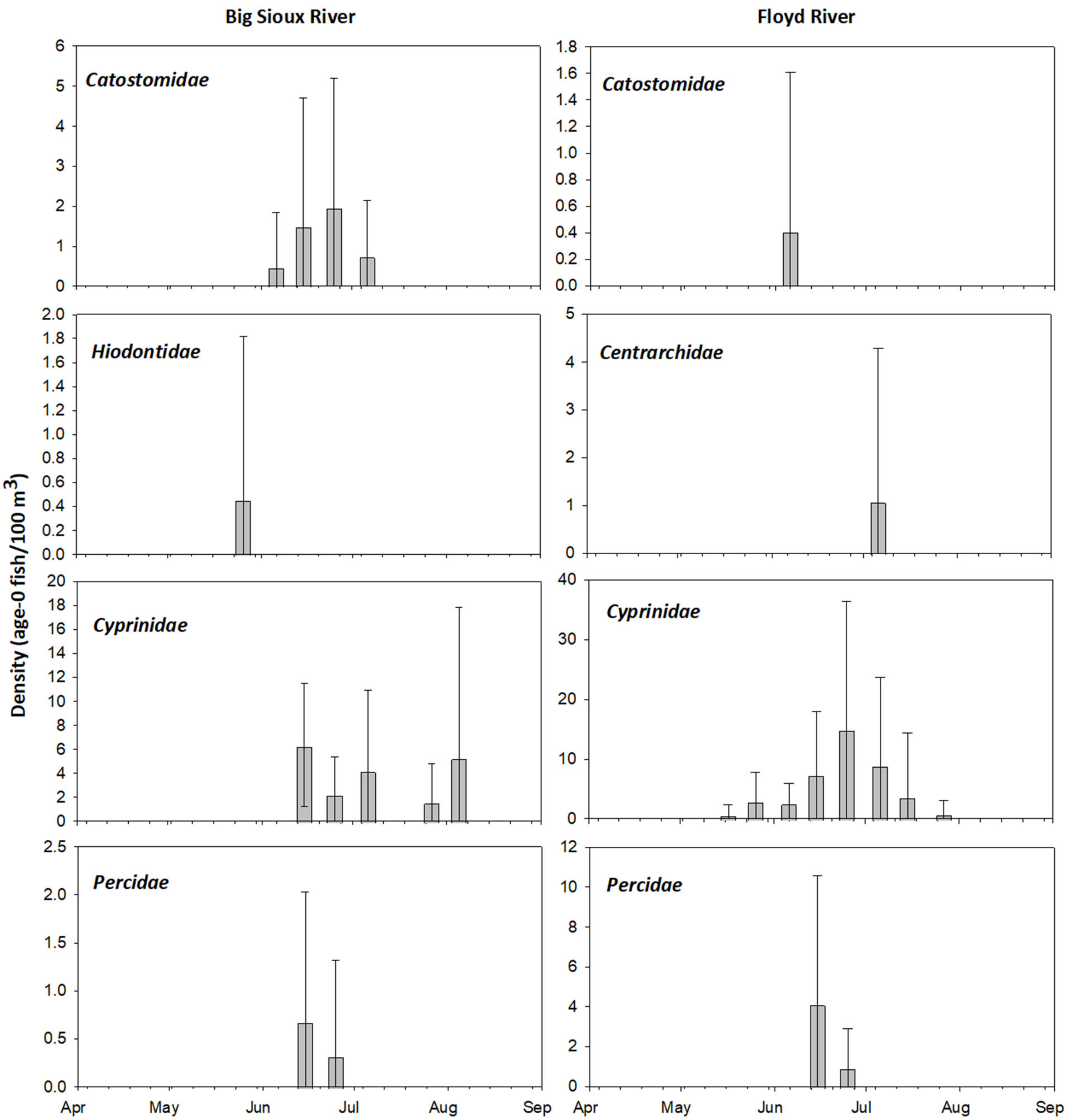

Figure 19. Density (mean ± 1 SE) of age-0 fishes from five families collected on the Big Sioux River (left) and Floyd River (right) from April 28th to August 5th, 2022. Note differences in y-axis scale among figure panels. No other taxa were detected on these rivers.

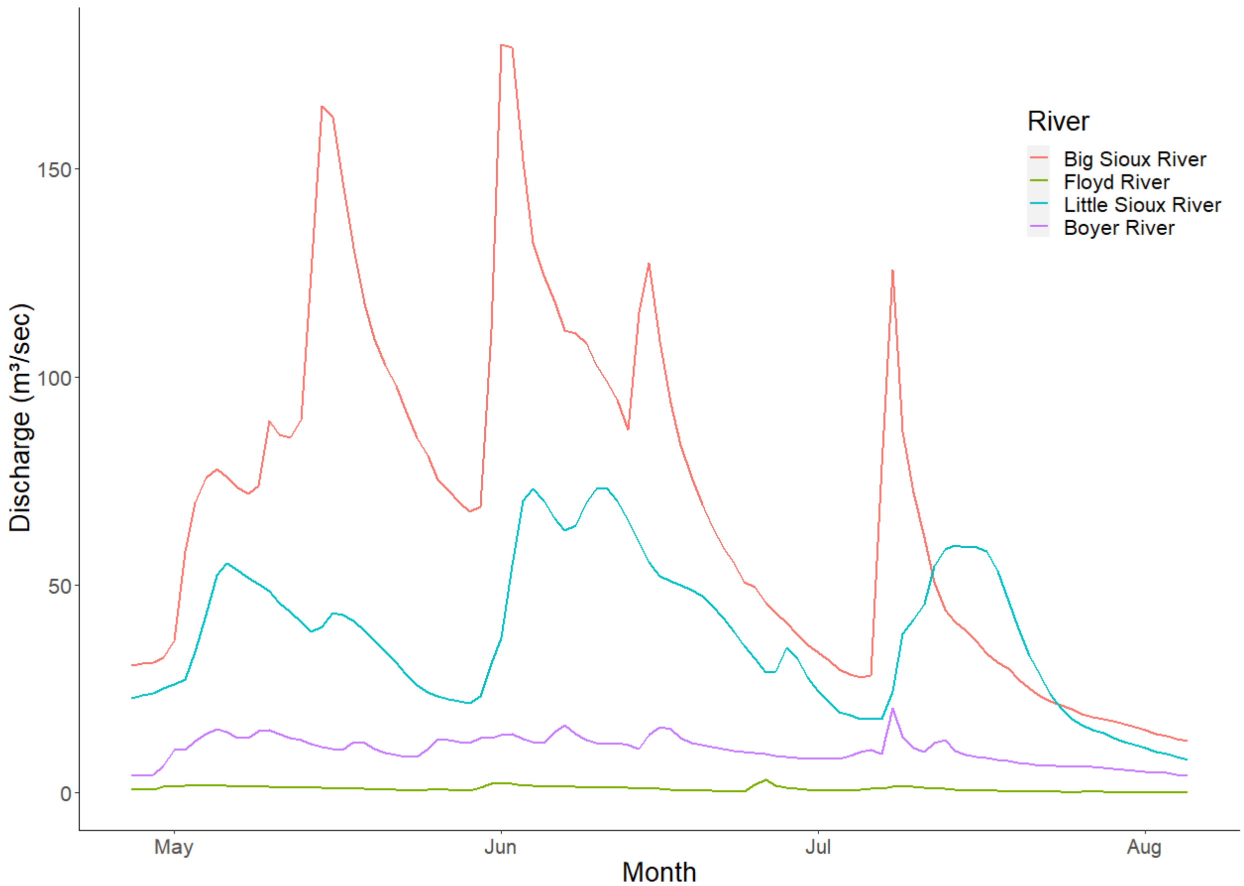

Figure 20. Discharge (m³/sec) of the Big Sioux, Floyd, Little Sioux, and Boyer River from April 28th to August 5th, 2022.

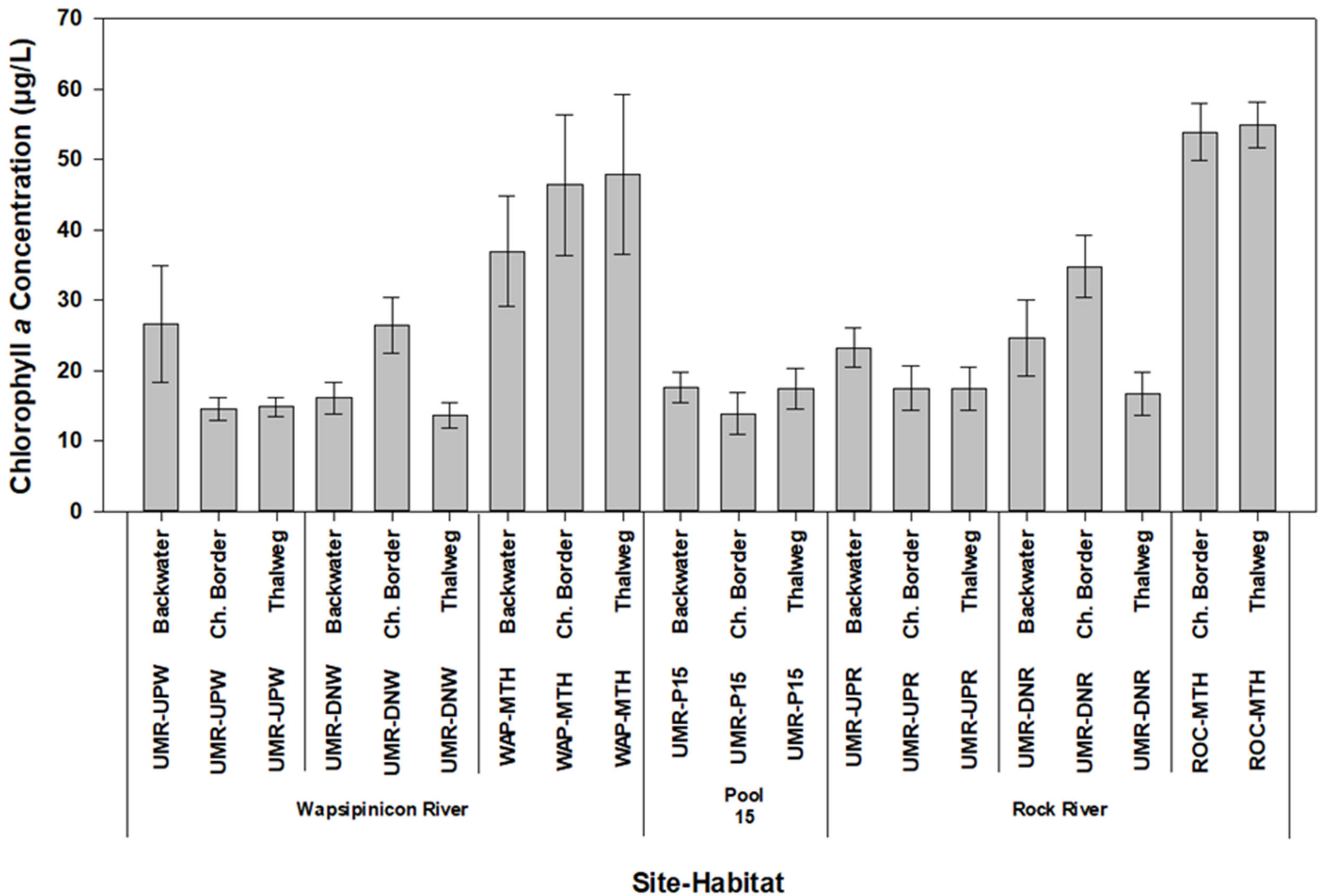

Figure 21. Chlorophyll a (mean ± SE) in backwater, channel boarder, and thalweg habitats at the mouths of the Wapsipinicon and Rock rivers and in pool 15 collected between May 3rd and June 28th, 2022.

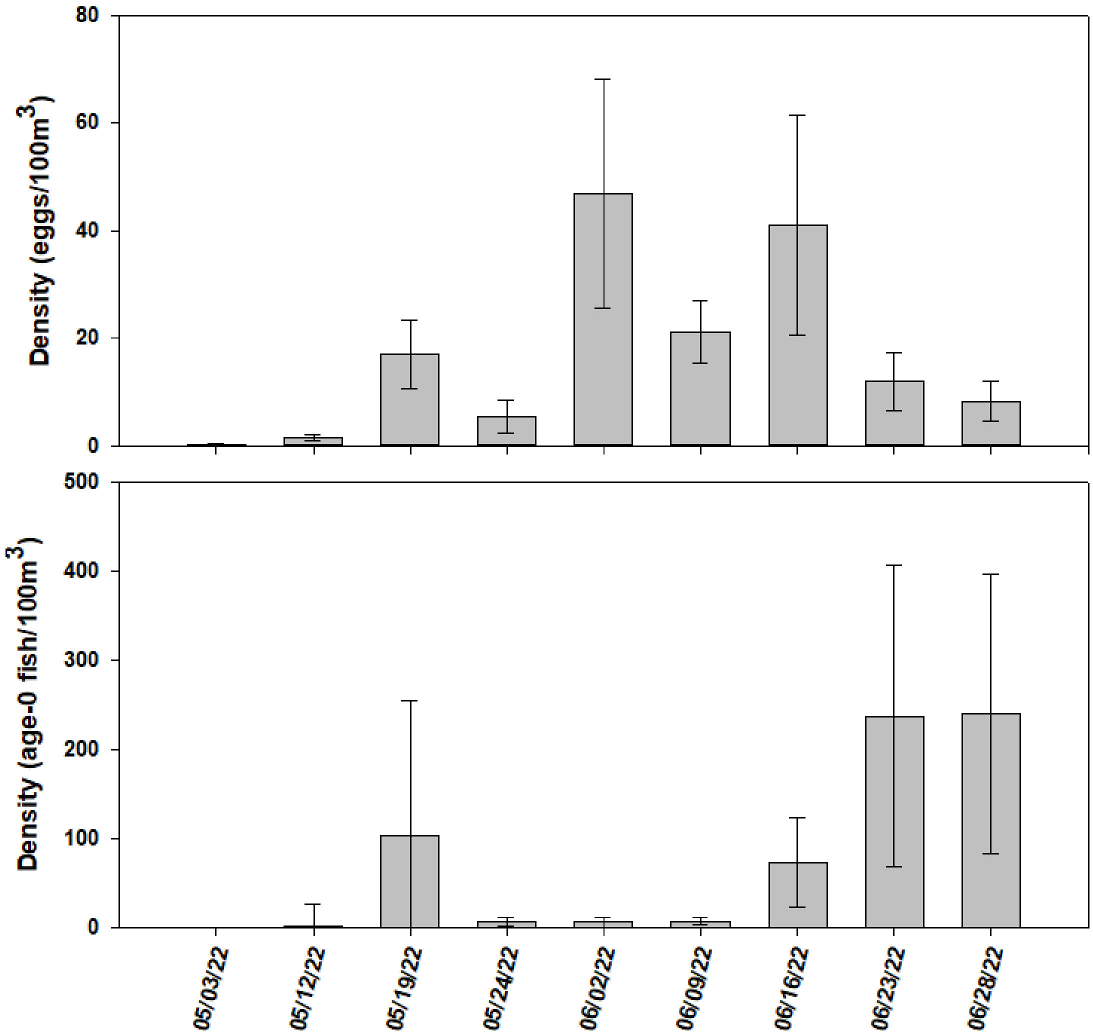

Figure 22. Density (mean ± 1 SE) of fish eggs (top) and age-0 fishes (yolk-sac, larvae, and juveniles; bottom) collected between May 3rd and July 28th, 2022 across all Upper Mississippi River tributary and mainstem sites described in Table 4.

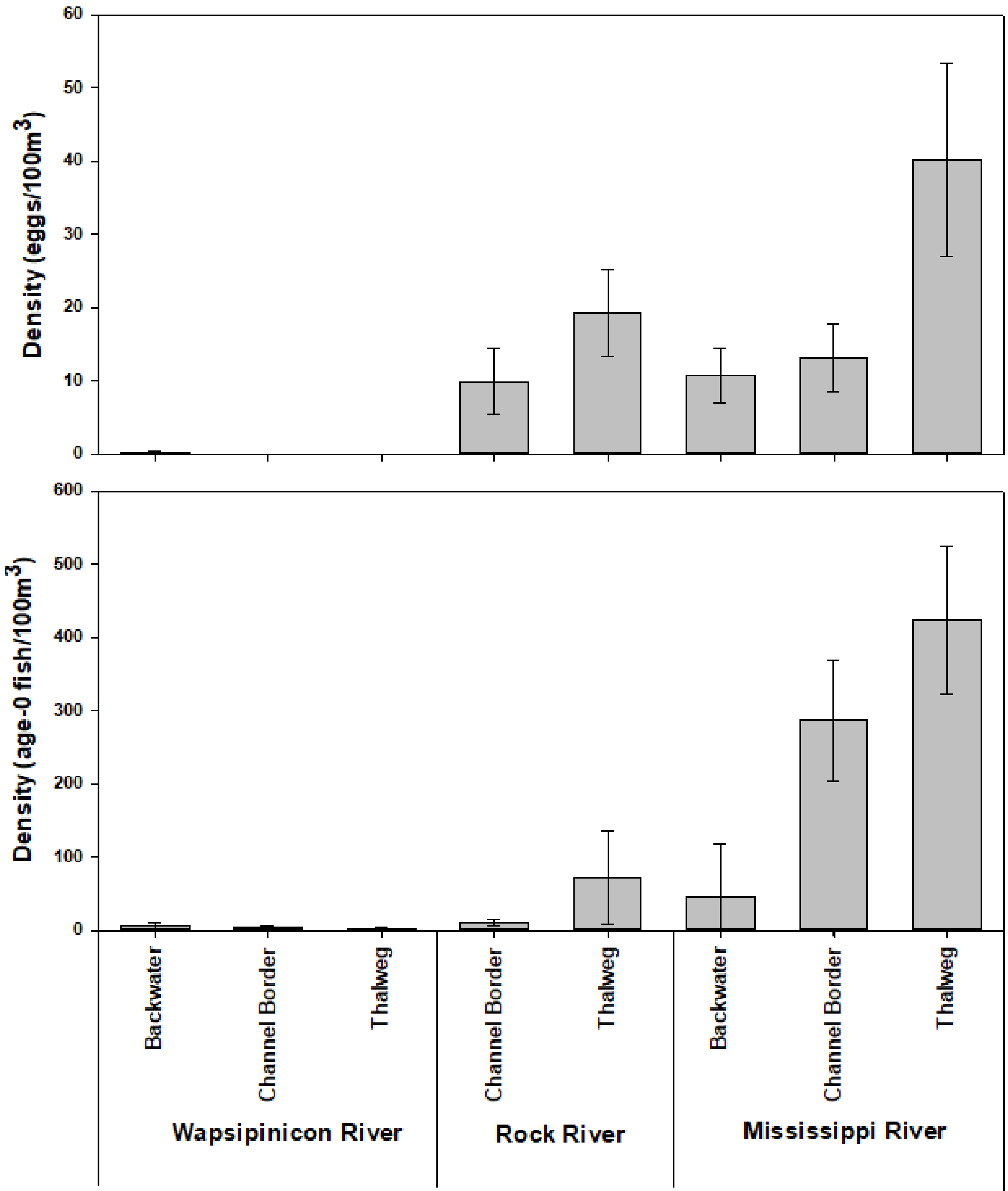

Figure 23. Density (mean ± 1 SE) of fish eggs (top) and age-0 fish (bottom) by habitat from the Wapsipinicon (WAP-MTH), Rock (ROC-MTH), and all sites sampled within the Mississippi river from the Mississippi River upstream of the Wapsipinicon River down to below the Rock River confluence during 2022. A list of sites can be found on Table 4.

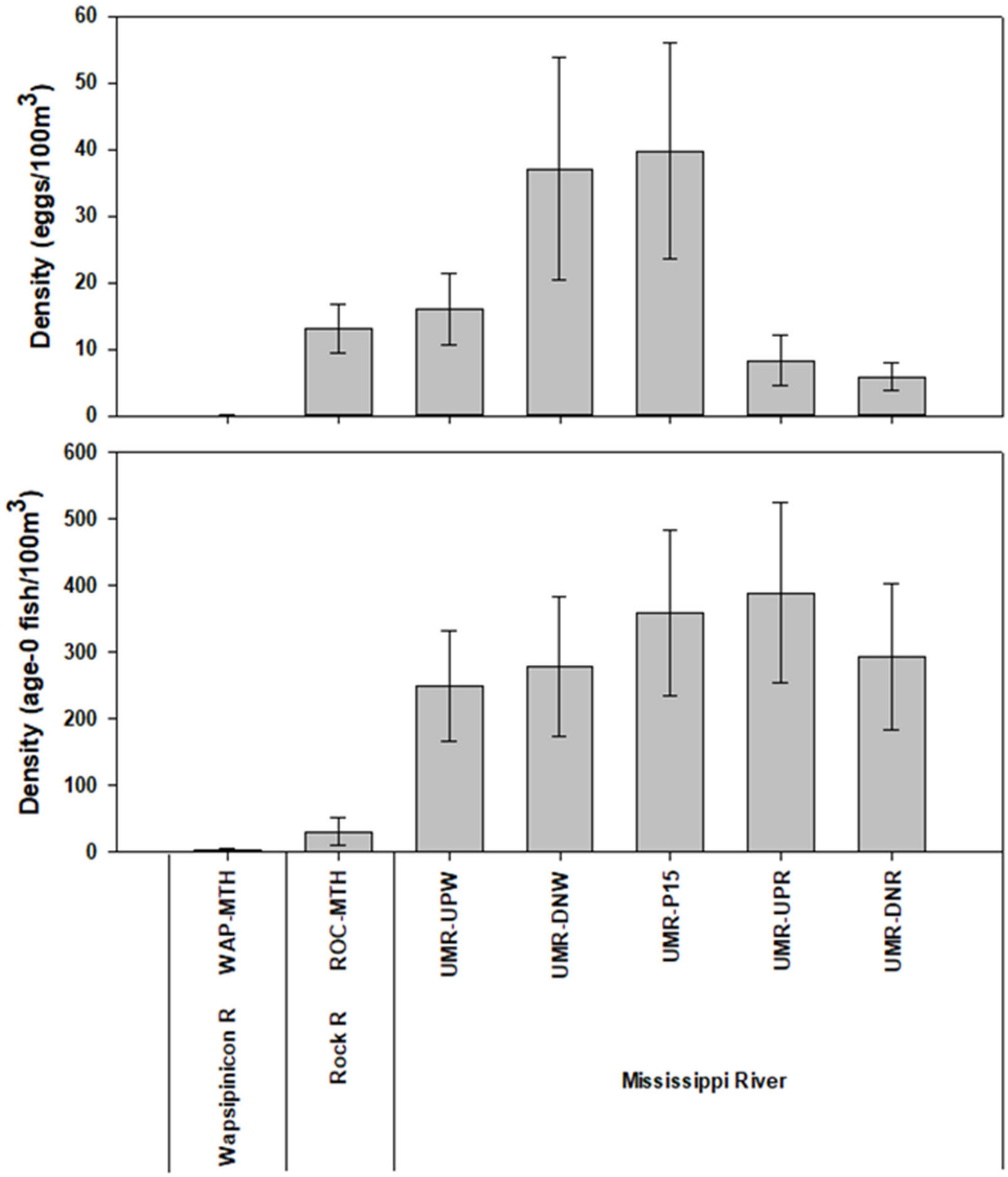

Figure 24. Density (mean ± 1 SE) of fish eggs (top) and age-0 fishes (bottom) collected across all dates from each site during 2022. Site codes are defined in Table 4.

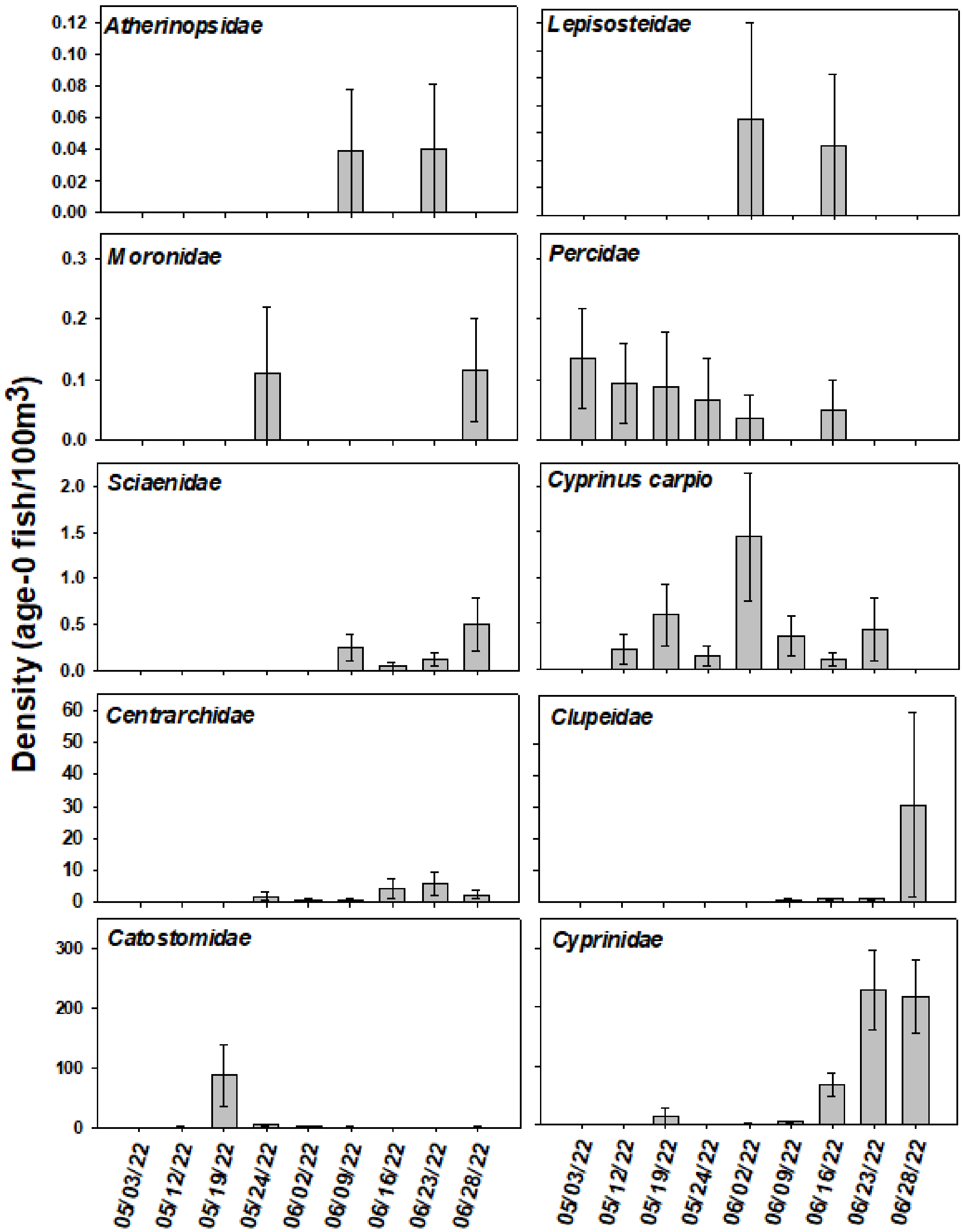

Figure 25. Density (mean ± 1 SE) of age-0 fishes by family collected during nine sampling sessions from May 3 through June 28, 2022. Note differences in y-axis scale among panels.

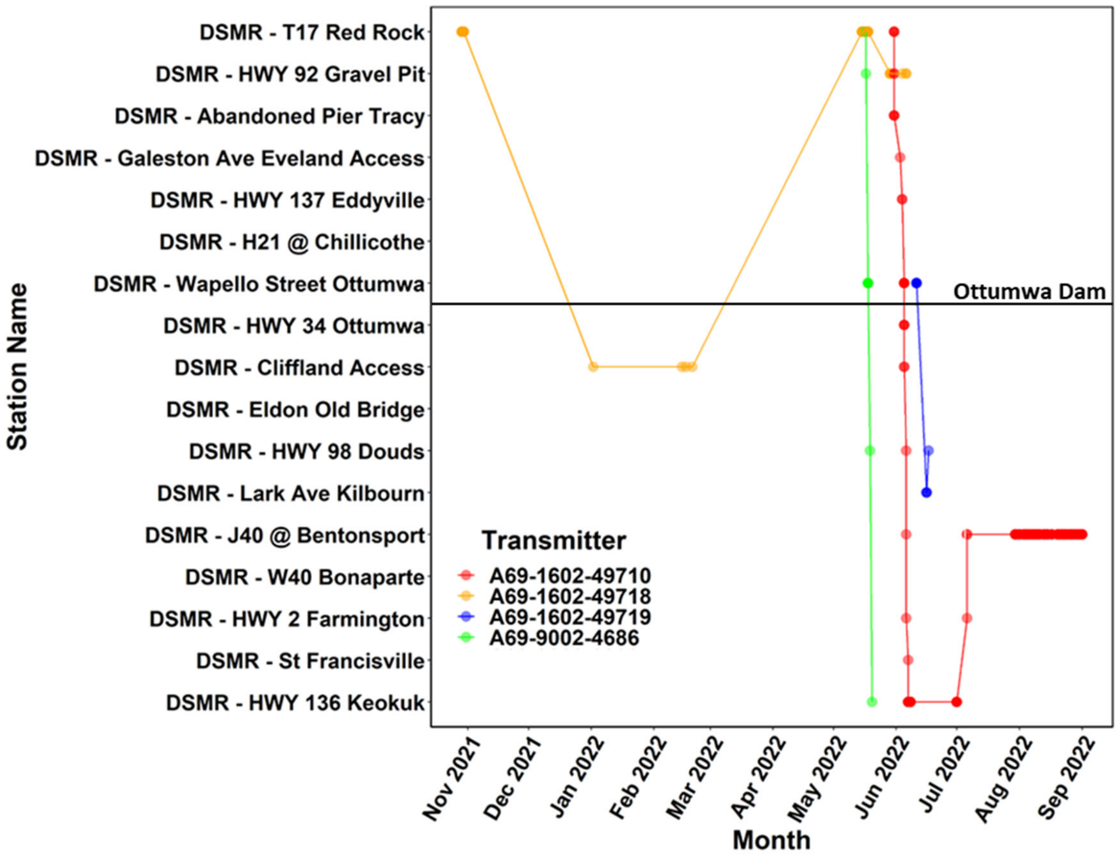

Figure 26. Abacus plot showing detection histories of the four Silver Carp that have transitioned downstream through Ottumwa Dam. Transmitter ID A69-1602-49718 (orange) successfully transitioned both downstream and upstream through Ottumwa Dam. Transmitter IDs A69-1602-49710 (red) and A69-9004-4686 (green) both transitioned downstream through Ottumwa Dam to the mouth of the Des Moines River.

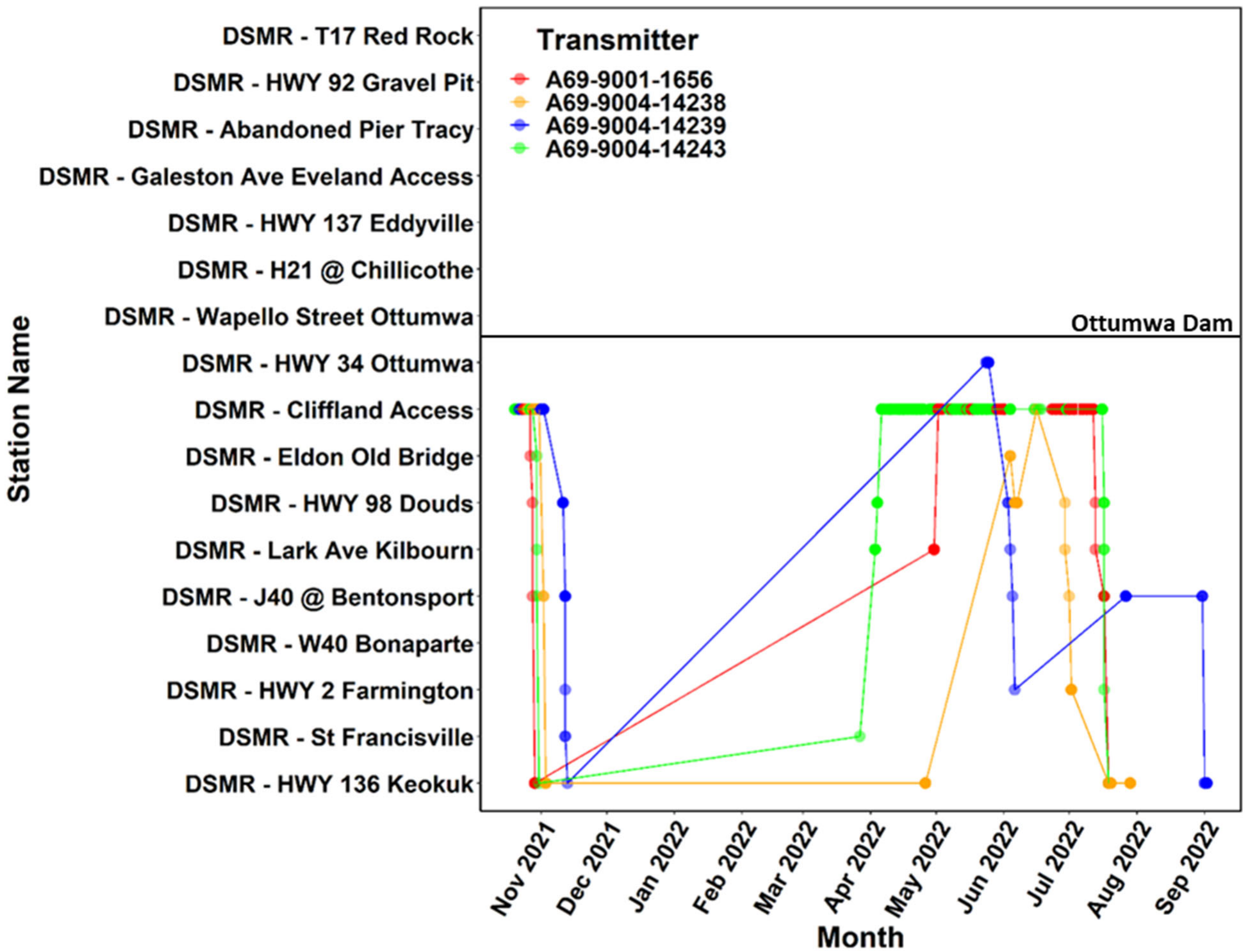

Figure 27. Abacus plot showing detections histories of four Silver Carp that have made multiple movements between receivers near Cliffland, IA and the last receiver near the mouth of the Des Moines River. Each movement from DSMR - Cliffland Access to DSMR - HWY 136 Keokuk is ~133 km. These four individuals migrated downstream, back upstream, and then back downstream between November 2021 and September 2022.

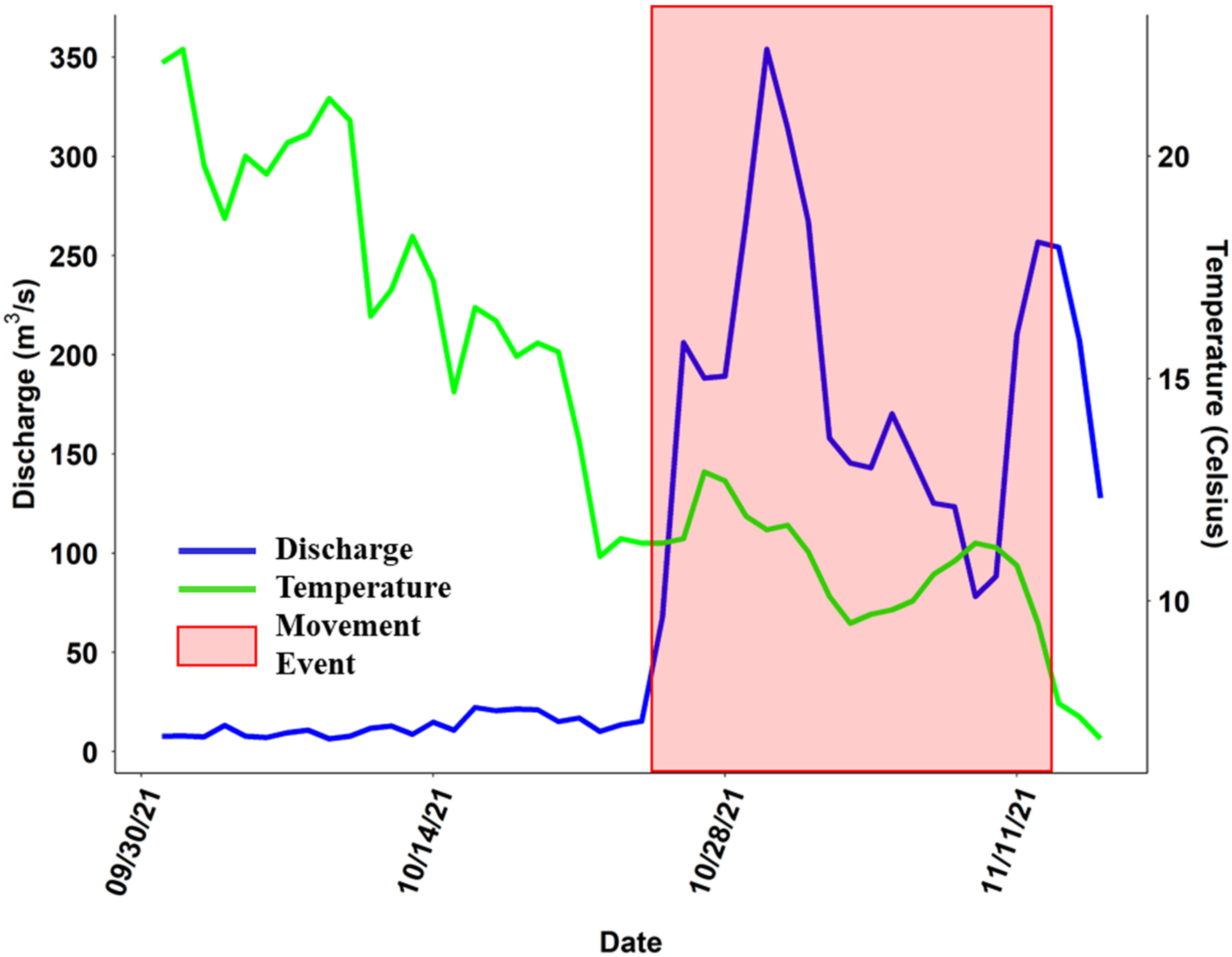

Figure 28. Discharge (m^3/s) and water temperature (Celsius) from the USGS gauging station at Ottumwa, IA (station number 05489500) between October 1, 2021 and November 15, 2021 (https://waterdata.usgs.gov). A downstream movement event where 13 of 39 Silver Carp tagged near Cliffland, IA moved downstream to the mouth of the Des Moines River during late October – early November 2021 (red) that coincided with increased discharge and decreasing water temperature.

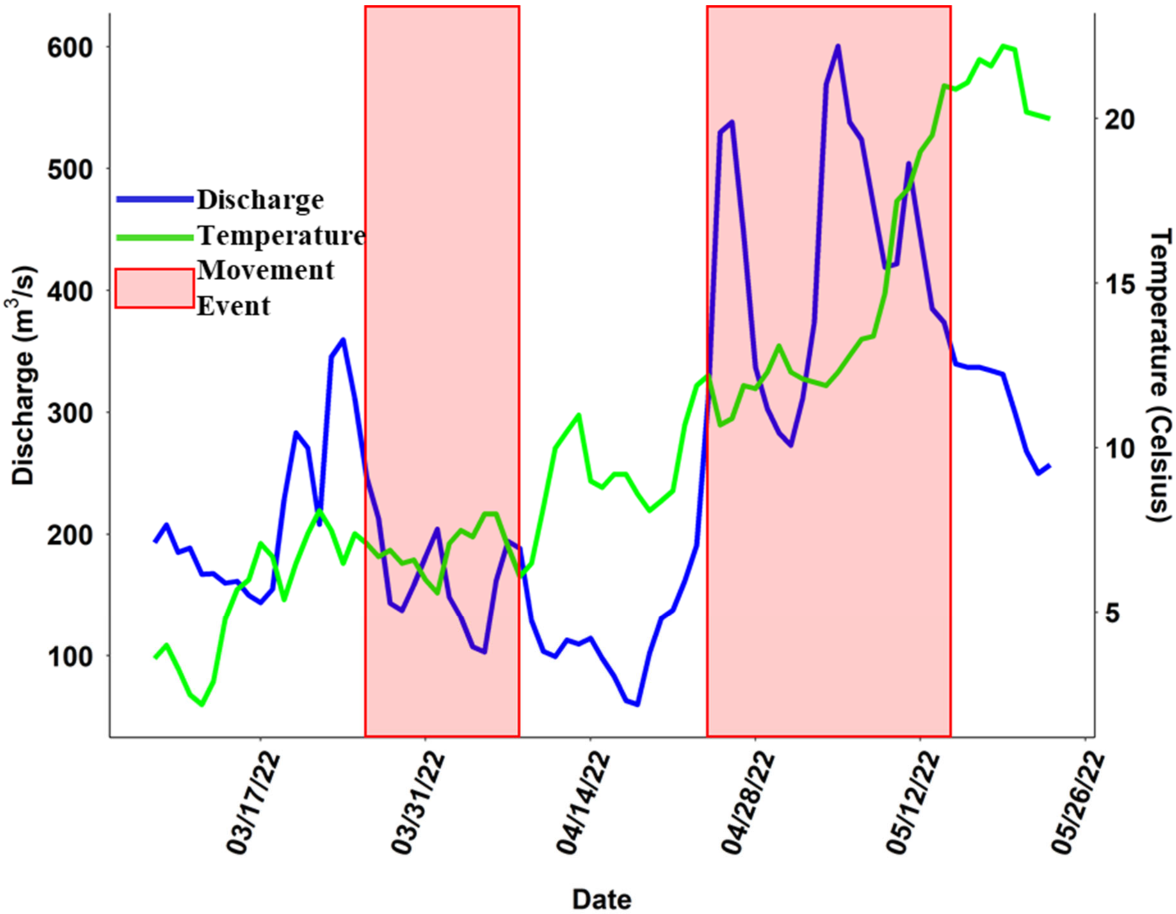

Figure 29. Discharge (m3/s) and water temperature (Celsius) from the USGS gauging station at Ottumwa, IA (station number 05489500) between March 17, 2022 and May 26, 2022 (https://waterdata.usgs.gov). Two upstream movement events where 4 Silver Carp moved upstream from the mouth of the Des Moines River to a receiver near Cliffland, IA during late March – early April 2022 (red) and where 6 Silver Carp moved upstream from the mouth of the Des Moines to a receiver near Cliffland, IA in late April – early May 2022 (red) that coincided with increased discharge and increasing water temperature.