

2018 Annual Interim Report on the Collaborative Strategy for Deterrent Barrier Research, Design, Implementation and Assessment to Minimize the Spread of Asian Carps in the Upper Mississippi River

Geographic Location: Upper Mississippi River, Pools 14-19

Participating Agencies: Western Illinois University (WIU), United States Fish and Wildlife Services (USFWS), United States Geological Survey-Upper Midwest Environmental Sciences Center (USGS-UMESC), Illinois Department of Natural Resources (ILDNR), Missouri Department of Conservation (MDC), Minnesota Department of Natural Resources (MNDNR)

Statement of Need:

Bighead carp and silver carp (Asian carp) populations are increasing in abundance and expanding their upstream range in the Upper Mississippi River (UMR). Lock and Dam (LD) 19 is a major pinch point for Asian carp expansion, restricting all passage to the lock chamber. Fish that achieve upstream passage at this point, later experience major impediments to passage at LD 14 and 15, which are infrequently at open river conditions. These major pinch points make excellent candidates for fish deterrent technologies that aim to impede further Asian carp establishment upstream. Prior to deterrent establishment, it is critical to evaluate its effects on native fish species and their passage. Paddlefish were chosen as a representative native species due to their robust size, habitat overlap with Asian carp, and their ability to traverse dams and move long distances. The established and extensive network of acoustic receivers (VR2W) on the UMR provides an excellent resource for evaluating paddlefish and Asian carp movements. Through our close partnerships with state and federal collaborators (USFWS, USGS-UMESC, ILDNR, MDC, and MNDNR), the infrastructure is established to evaluate paddlefish passage using the VR2W network. Biologists from WIU will manually track using VR100 receivers to supplement information regarding paddlefish and Asian carp habitat use and overlap. Obtaining pre-deterrent data on native and invasive species movement, passage efficiency, and habitat use will inform the partnership on the effects fish deterrents could affect the rate of native fish passage in the future.

Project Objectives:

The primary purpose of this research is to provide preliminary data that details paddlefish habitat use and passage over major pinch points in the UMR as well as assess habitat relationships between invasive Asian carp species and native migratory species. This project will serve as a future reference to evaluate the effect deterrents have on native fish passage.

The primary objectives are:

- (1) Acoustically tag and monitor 121 paddlefish in the summer of 2018, in conjunction with previously tagged Asian carp species, to assess the frequency and timing of fish passage at Lock and Dams 14 through 19.
- (2) Quantify paddlefish habitat use and selectivity in Pools 14 through 19 and determine the magnitude of habitat overlap with Asian carp species.

Project Highlights:

- 107 paddlefish were detected between manual and stationary receivers. 42 successful passages over dams occurred among 14 individuals.
- Paddlefish have demonstrated the ability to pass through LD 14 and 15 in a downstream and upstream direction (5 passages over LD 15 and 3 passages over LD 14). No detections have been observed over LD 19, although paddlefish have been observed above the LD 19 spillway.
- Highest number of paddlefish detections were observed in areas that had low water velocity, indicating a preferred for areas such as backwater habitat and areas with structures such as wing dams, closing dams, and above/below navigational dams.

Methods:

Fish Collection

From 5 June 2018 to 2 July 2018, 119 paddlefish were collected and surgically implanted with acoustic transmitters from Pools 14 (N=58) and 16 (N=60) in the UMR (Fig. 1A). Two paddlefish were surgically implanted with acoustic transmitters in September 2017 in Pool 16 as a pilot study. In total, 121 paddlefish were used to monitor habitat use and movement in Pools 14-19. All paddlefish were netted as bycatch with 5” mesh gill nets from contracted removal efforts. Paddlefish with the most vigor in the gill nets were chosen for surgery to optimize maximum recovery and survival potential. Netting occurred between 08:00 to 15:00. Paddlefish were captured from areas within each pool that were historically identified as being inhabited by paddlefish. Transmitters were surgically implanted into the peritoneal cavity and sutured closed by a series of internal and external square knot sutures (Schramm and Black 1984). The tag weight did not exceed 2% of the fish weight (Winters 1983).

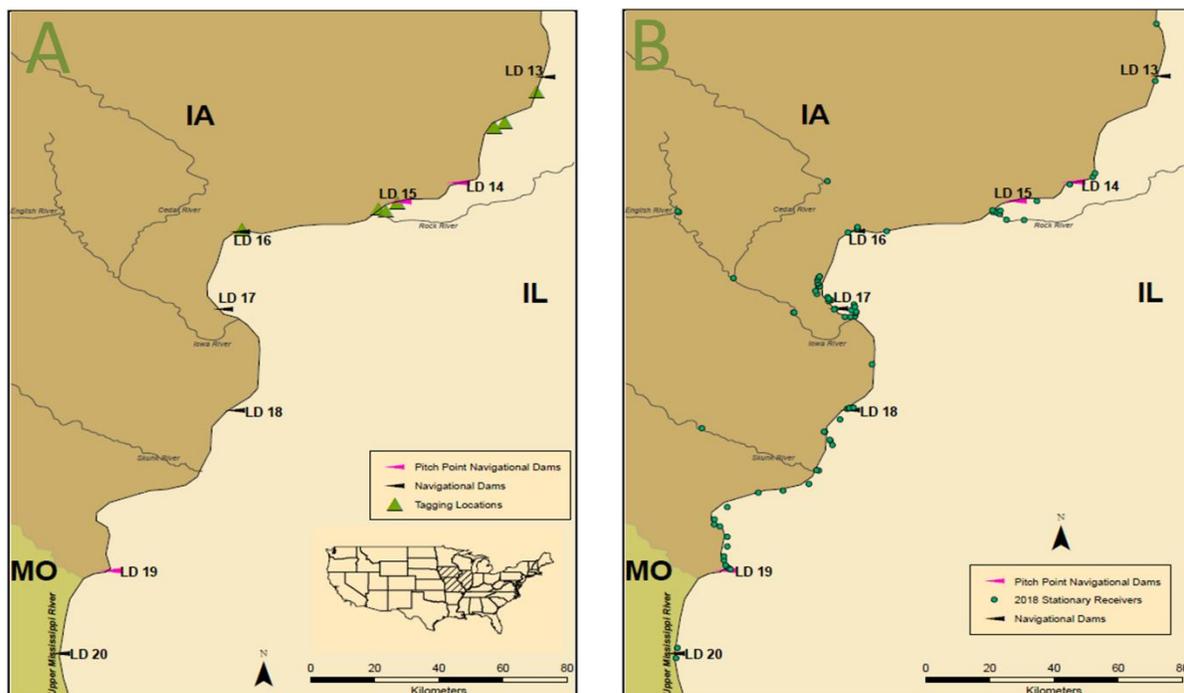


Figure 1. Locations of captured paddlefish (N=121) for acoustic telemetry study in the Upper Mississippi River (A). Locations of VR2W acoustic monitoring system

within study area ($N=81$). The number of receivers per pools are: Pool 13 (2), Pool 14 (3), Pool 15 (2), Pool 16 (2), Pool 17 (17), Pool 18 (20), Pool 19 (25), and Pool 20 (1).

Surgical Procedures

Collected fish were transferred to a 375 L holding tank. A flow-through system created by a large submersible pump and a water agitator were used to continually oxygenate the holding tank. Surgical instruments and the acoustic transmitter were placed in a sterilizing tray and saturated with 70% isopropyl alcohol. The transmitter and instruments were left to soak in the solution for at least 15 min to fully disinfect equipment. Due to the docile nature of paddlefish, anesthesia was not used prior to surgery. Individuals were weighed (kg) and measured eye-to-fork length (EFL; mm; Ruelle and Hudson 1977) with the ventral surface facing up. Paddlefish were then moved to a V shaped cradle, where the gills were ventilated with oxygenated water via a tube in the mouth from a submersible pump. With a scalpel (no. 2 scalpel handle, no. 11 scalpel blade, Swann-Morton), a 5-8 cm incision was made along the mid-ventral line, taking special care to avoid viscera penetration. Once the body cavity was exposed, a transmitter was inserted into the peritoneal cavity and positioned directly below the incision, avoiding excessive pressure to underlying tissues and organs. A continuous suture was used to close the incised peritoneum with the suture needle and absorbable suture material (polydioxanone, sterile, Ethicon Inc.). A single-instrument tie knot was used at the beginning and the end of the continuous suture. Five to ten, evenly spaced, simple interrupted sutures were used to close the incised skin with the suture needle and non-absorbable suture material (polypropylene, sterile, Ethicon Inc.). A single-instrument tie knot was used for each of the interrupted sutures. Both suture threads were at least 70 cm of size 3-0 (1 per fish). The average surgery time per fish was 7-8 min. After surgery, fish were transported to a recovery tank with a holding net (3m X 3m X 2m) until full recovery was observed. The criteria for full recovery was evaluated by regained equilibrium and reaction to external stimuli (Moore et al. 1990). At full recovery, fish were placed in holding nets and released back into the captured location.

Manual and Stationary tracking

Acoustic tags were set to transmit acoustic codes at 69 kHz at a random time interval between 30-90 s (Welch et al. 2009). All fish were surgically implanted with Vemco V16-6x transmitters (16mm, 10 years, Nova Scotia, Canada). The extended battery life allowed enough battery power to track paddlefish within the study period. Acoustically-tagged fish were manually tracked weekly along pre-determined grids that were spaced one-third of a mile apart within the study reach. Manual tracking aimed to evaluate all habitat types to determine habitat use and selectivity. Manual tracking for our study began on 12 Jun 2018. A VR100 receiver (Vemco, Nova Scotia, Canada) was used to track transmitters during 9 h shifts between 07:00 to 16:00. When positioned on a waypoint, the depth sounder was turned off to reduce acoustic interference. A Vemco VH165 omni-directional hydrophone (50-85 kHz; Nova Scotia, Canada) was submerged at each waypoint along the grid for 100 s to identify activated tags in the area. When a tag was identified, the omni-directional hydrophone was replaced with a Vemco VH110 directional hydrophone (50-84 kHz; Nova Scotia, Canada) mounted to PVC pipe. The directional hydrophone was slowly turned in a circular motion, watching for signal strength values. The maximum signal value indicated the bearing. The boat was moved in the direction of the bearing until the signal strength reached 70-80 decibels (dB) at a gain of 0 dB, indicating the boat was

positioned on top of the transmitter. Environmental water parameters such temperature (°C), water flow (ft/s), secchi (cm), specific conductivity ($\mu\text{S}/\text{m}$), coordinates (DD), and dissolved oxygen (ppm) were recorded at these points. Water quality and coordination information were recorded for each tag for precise habitat selectivity.

A stationary Vemco VR2W acoustic monitoring system (Nova Scotia, Canada) was used to detect fish movement and dam passage. An established and extensive VR2W network maintained by United States Fish and Wildlife Service (USFWS)-LaCrosse, United States Geological Survey-Upper Midwest Environmental Science Center (USGS-UMESC), Missouri Department of Conservation (MDC), and Minnesota Department of Natural Resources (MNDNR) allowed collaboration for standardized acoustic telemetry methods and to better quantify fish movement in the UMR (Fig. 1B).

Habitat Classification and Statistical Analysis

Areas that were occupied by detected paddlefish were categorized according to the Upper Mississippi River Long Term Resource Monitoring Program Procedures. The six strata classes are based on geomorphic and physical features that represent permanent features within the UMR system (Wilcox 1993; Ratcliff et al. 2014; Table 1). The strata are: main channel border-unstructured area (MCB-U), main channel border-wing dam (MCB-W), side channel border (SCB), backwater, contiguous-shoreline (BWC-S), impounded-shoreline (IMP-S), tributary (TRI), and tailwater zone (TWZ). Descriptions for these strata classes can be found in Ratcliff et al. (2014). Detection coordinates were inserted into ArcMap 10.6.1 (ESRI 2011, Redlands, CA) and strata type were determined by the position of coordinate points within pool.

Results and Discussion:

Of the 121 paddlefish acoustically-tagged, 88% of our paddlefish have been detected between manual and stationary receivers. 531,735 detections were recorded from stationary receivers and 261 detections were recorded from manual receivers between 22 Sept 2017 to 21 Dec 2018. Paddlefish have demonstrated the ability to transverse dam barriers, including passage at major pinch points, LD 14 and LD 15. We observed 3 passage events over LD 14, 5 passage events over LD 15, and 0 passages over LD 19. We observed 42 successful passages over dam barriers among 14 individuals. Of these passages, 29 were in a downstream direction and 13 were in an upstream direction. The average size for individuals that successfully transversed dam barriers was 722.4 mm and 6.5 kg. From 2018, we observed a few individuals demonstrate exaggerated movements in the UMR. We observed 1 individual move from Pool 14, down to Pool 17, and returned to Pool 14 between 18 July 2018 and 14 Sept 2018. We observed another individual make significant movements from Pool 16, to Pool 15, and then down to Pool 19 between 6 Jun 2018 to 20 Aug 2018. Although we have not observed any passages over LD 19, we have detected 1 individual directly above LD 19.

261 paddlefish detections have been recorded from our manual VR100 receivers. 113 of those detections were found in backwater habitat and 61 detections were found in channel borders. Paddlefish utilized backwater habitat primarily in the summer 2018 and shifted to channel border habitat in the fall 2018 (Fig. 2; Fig. 3). Backwater habitat was characterized as low velocity areas separated from the active main channel by an outlet. Channel border habitat

was characterized as areas along main navigational channels. Wing and closing dams are common in these channel border habitat areas which create low velocity barriers. 171 of 261 detections were found near dams or low velocity areas indicating a strong preference for these low velocity areas. As ice began to form in backwater areas, paddlefish moved to channel areas with wing dams or above spillways areas to seek low flow refuge.

Our future objectives for 2019 are to (1) continue collecting manual tracking data once the temperature increases and conditions permit and (2) analyze stationary receiver data between 17 Sept 2018 to 29 Jan 2019 to evaluate paddlefish movement and passage in the UMR.

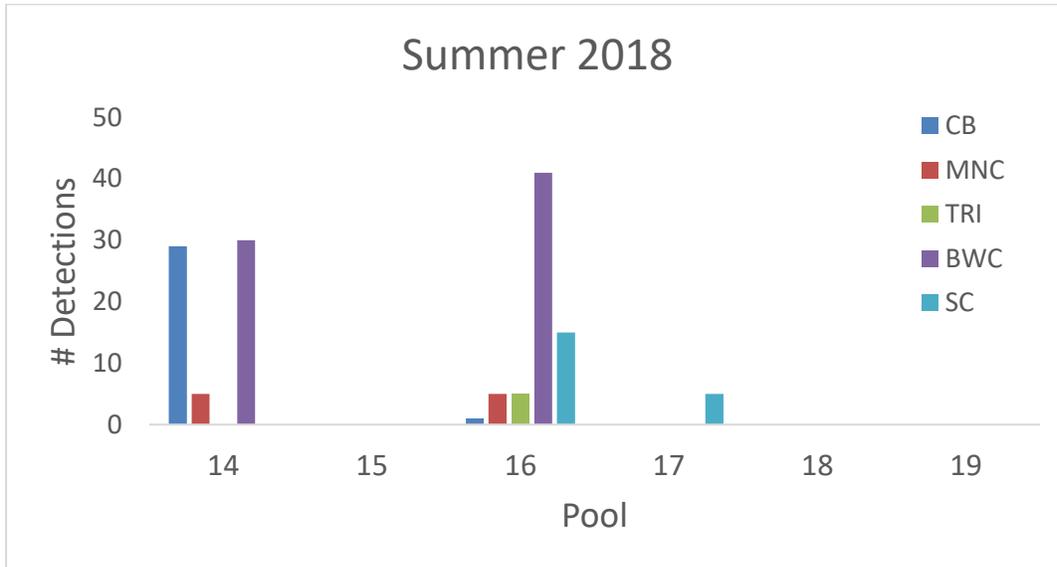


Figure 2. Summer (Jun—Aug) 2018 paddlefish habitat use in Pools 14-19 on the UMR from 05 Jun 2018 to 21 Dec 2018 from manual receiver detections.

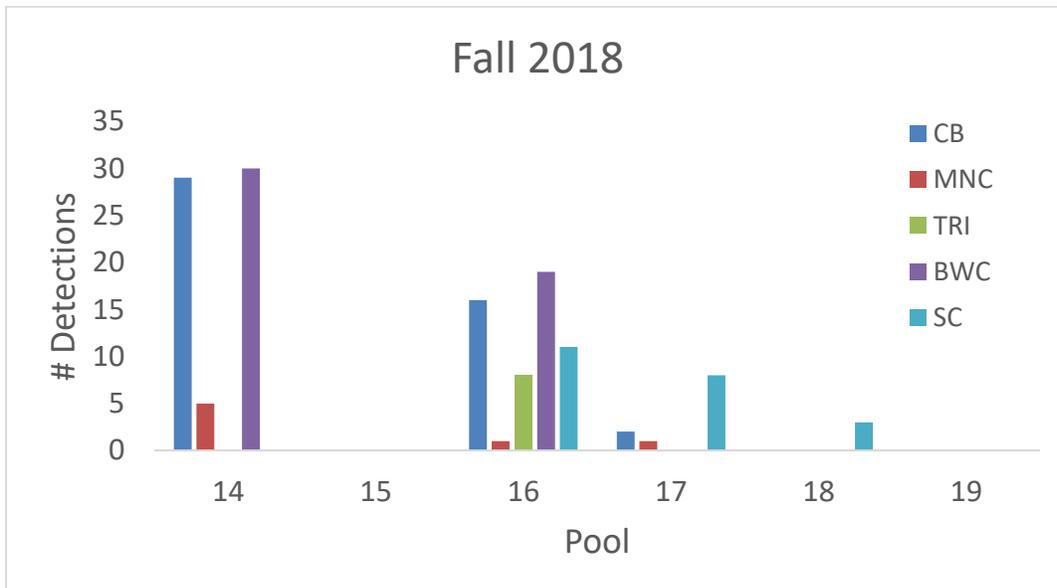


Figure 3. Fall (Sept—Dec) 2018 paddlefish habitat use in Pools 14-19 on the UMR from 05 Jun 2018 to 21 Dec 2018 from manual receiver detections.

Recommendation:

We have been actively tracking paddlefish and Asian carp for 7 months and have detected incredible dispersion from our tagged paddlefish. Evidence of paddlefish passage across LD 14 and 15 demonstrates the need for continued data collection prior to implantation of invasive species deterrents at these locations. Establishment of deterrents at pinch points on the UMR will need to rely on careful consideration of preliminary data collected from this project. As it stands, our strongest recommendation for deterrent implementation would be at LD 19, followed by LD 14 and LD 15, respectively.

We have observed paddlefish habitat overlap with invasive Asian carp species, indicating a preference for similar habitat qualities and potential interspecific competition for resources. It is our hope with permission from our partnership, that we can further investigate these potentially harmful interactions by accessing stationary receiver data to evaluate spatiotemporal overlap.

We suspect with continued tracking that we will observe additional dam passage events and a shift in habitat selectivity with seasonality. In January 2019, we resumed tracking until weather conditions prohibited us from accessing boat ramps safely. It is our intentions to continue tracking once water temperatures increase and boat ramps become more readily accessible.

Project Highlights:

Objective 4 - Quantify native and non-native fish passage at lock and dam 19, 15, and 14 as an assessment tool for the future testing of Asian carp deterrents.

MDC:

- Transmitters were implanted into an additional 44 Bighead Carp, 47 Silver Carp, and 41 Paddlefish below Lock and Dam 19. To date 465 native and invasive fish have been tagged and 407 were active during the year of 2018. The smaller transmitters put in Walleye, Sauger, and American Eel are expired and some of the Lake Sturgeon and Asian carp tagged in this area prior to the study have also expired.
- During the three years of the study (2016-2018), 90 individual fish (some of those with multiple entrances) were detected in the lock chamber (for a total of 167 entrances), and 22 of those fish were detected on the receiver upstream of the chamber for a total of 27 passage events.
- Of the 115 (46%) of Asian carp (Bighead, Silver, Hybrid Asian Carp, and Grass) that approached the lock chamber, 28 (14%) entered the lock chamber, and only 2 (1%) passed upstream into Pool 19.
- Only Bighead Carp, Grass Carp, Bigmouth Buffalo, Paddlefish, Flathead Catfish, and Walleye were detected and assumed to have passed upstream into Pool 19.
- Two of the Paddlefish passage events were downstream back into Pool 20.
- Although 29 of 53 Lake Sturgeon (55%) were detected in or approaching the lock chamber, none were detected moving into Pool 19.
- Four fish (2 Bigmouth Buffalo, 1 Paddlefish, and 1 Grass Carp) were detected passing through the lock chamber into Pool 19, but then returned to Pool 20 without being detected by any of the receivers on the dam above or below.

Methods:

Receiver Array: The collaborative stationary receiver array maintained by many state and federal agencies within the UMR was utilized to monitor fish movement around Lock and Dam 19, quantify passage events, and gain knowledge of pre-deterrent movement within Pool 20. The receivers within this array were deployed using many different methods such as, navigation buoys, bridge pier attachments, lock chamber wall attachment, bottom set stands, and along with barge-attached units to utilize a method of dynamic tracking by partnering with the commercial navigation industry (e.g., ADM). To more closely monitor the movement around Lock and Dam 19, one stationary receiver was placed on a navigation buoy approximately one mile downstream of the lock chamber approach. Two stationary receivers were placed above the lock chamber to work in correspondence with the lock chamber receiver to determine if a fish that enters the lock chamber exits above the dam for a successful passage event. The USFWS also placed a stationary receiver array inside the downstream approach to the lock chamber to further investigate passage. This array collects 2-dimensional data and uses Vemco Positioning System (VPS; accuracy of position of fish within 5 meters) to pinpoint fish approaching the lock chamber and determine how fish use the lock approach to inform deterrent placement and evaluate a deterrent should one be deployed in the future. Manual boat tracking (Vemco VR100) was also performed monthly to assess finer scale movement and habitat use within Pool 20.

Tagging: During 2018, transmitters were implanted into 44 Bighead carp, 47 Silver Carp, and 41 Paddlefish. Bringing the total number of fish tagged to 465 over the three-year study (Table 1). Asian carp and Lake Sturgeon were also tagged in 2012 in the same location, so

detections from these fish were also used in this study, but these transmitters are starting to expire and were not active during the entire 2018 season (Table 1). All fish were placed onto a clean surgery board where a low flow bilge pump circulated water over the gills. Incision site and all surgical tools were disinfected at the beginning and end of each surgery. The incision site was located ventral to the lateral line and anterior to the cloacal opening. A scalpel and hemostat were used to carefully make the incision to avoid damaging internal organs. Three or four Ethicon 3-0 monofilament sutures closed the incision site after the transmitter has been inserted into the abdominal cavity. After surgery fish were returned to the water where they were released upon regaining strength and orientation. The transmitters were all tested prior to implantation with a VR100 unit to ensure they had been activated. Acoustic signals began transmitting upon release of the specimen. The date, time, and location of release was recorded for each specimen.

Analysis: Stationary receivers were uploaded seasonally, and the detection data was analyzed to summarize movements and passage of the implanted fish over the four to five-year lifespan of the transmitter. This summary will be paired with the manual tracking data to generate finer scale habitat use and movements of fish within Pool 20. In order to investigate the potential overlap of native and invasive species habitat use, daily detections were represented as the GPS location and kernel density estimates were calculated for each group using PROC KDE state with Statistical Analysis System (SAS). This analysis allowed us to visualize location utilization for each of the groups (native and invasive). In order to quantify the overlap of areas used, we developed a grid system using the fishnet analysis in ArcMap and overlaid native and invasive fish detections. From this we determine the number of grids in which both native and invasive fish were utilizing each area. The number and date of passage events will be used to determine river conditions that yield high potential for passage.

Results

During the three-year period, a total of 90 individual fish (some of those with multiple entrances for a total of 167 entrances), have been detected on the VR2W in the lock chamber. Species detected in the lock chamber were; 1 American Eel, 5 Bighead Carp, 13 Bigmouth Buffalo, 1 Blue Sucker, 2 Channel Catfish, 4 Flathead Catfish, 5 Grass Carp, 16 Lake Sturgeon, 20 Paddlefish, 18 Silver Carp, and 5 Walleye (Table 1). Of these, 22 have been detected on the VR2W above the lock chamber. Species that have passed into pool 19 are as follows; 1 Bighead Carp, 9 Bigmouth Buffalo, 3 Walleye, 2 Flathead Catfish, 1 Grass Carp, and 6 Paddlefish (Table 1). Twenty-two of those fish detected in the lock chamber were detected on multiple receivers upstream of the chamber for a total of 27 passage events (Table 1). To look at this data another way we determined the percent of individuals within each species that approached the lock chamber and then the percent that successfully passed upstream into Pool 19 (Table 1). This demonstrated that while fewer individuals within each of the native species were implanted with transmitters, the native species (Bigmouth Buffalo, Paddlefish, Walleye, and Flathead Catfish) were more likely to approach the lock chamber, enter, and pass upstream. Despite the invasive species having many more individuals implanted and 115 (46%) approaching the lock chamber, only 2 (1%) of the invasive species successfully passed through Lock and Dam 19 into Pool 19 (Table 1). The Bighead Carp that successfully passed upstream into Pool 19 made 10 attempts or entered the lock chamber on 10 separate occasions before successfully passing upriver. The VR2W array below pool 20 detected 25 fish that have made long-range downstream movements. Native fish species that made downstream movements were Paddlefish, Lake Sturgeon, and Flathead Catfish. Each of the invasive species implanted were documented making downstream movements. For the native fish 2 Paddlefish and 4 Lake Sturgeon were documented moving

down into Pool 24, and one Paddlefish was documented moving down to Caruthersville, MO which is about 775 kilometers downstream. The invasive fish were also detected making some long-range movements downstream with Bighead, Silver, Grass, and hybrid Carp all being detected in Pool 24 (105 kilometers downstream). Bighead, Silver, and Grass Carp were also detected in the Kaskaskia River (190 kilometers downstream), Cape Girardeau, MO (500 kilometers downstream), the Ohio River at Cairo, IL (588 kilometers downstream), and Caruthersville, MO (775 kilometers downstream). The VR2W array above Pool 19 also detected some long-range upstream movements by natives. A Bigmouth Buffalo and Paddlefish were detected as far upstream as Pool 17 and a Walleye was detected in Pool 15.

When kernel density estimates were developed for the native and invasive species within Pool 20 using the manual tracking detections, it became evident that specific habitats were not being used such as wing dike or channel borders, it was more like the tailwater area or the mouth of the Des Moines River (Figure 1 and 2). While the core use areas are more spread out for native fish, with the natives also using areas below the mouth of the Des Moines River as well as the Mouth of the Des Moines and the tailwater area where invasives congregated (Figure 1 and 2). When we quantified the overlap of detections within the fishnet grid, 90% of the grids contained both native and invasive fish detections, so 90% of the areas used by native fishes were also being used by invasive carp.

To further investigate the passage events, the number of passage attempts and successful passage events for native and invasive species were plotted against the river stage based on the gauge for the Mississippi River at Keokuk, IA (Figure 3). Due to the low number of passages statistical analysis were not run of this data, but visual observation of the data show that the invasive fish passages occurred during June and August with a rise in river. The majority of the native fish passages occurred March through August but there were a few fall passages as well. Both the native and invasive species had fewer attempts and no passage events during the fall of 2017 and winter of 2018 when the river was lower for a prolonged period. When the USFWS approach data is processed we may be able to further investigate the passages and approaches to determine what factors maybe influencing the number of fish that approach and the number that successfully pass.

Table 1. Species detected downstream, within, and above Lock and Dam 19 with the percent of each species that approached the lock chamber and the percent that successfully passed through into Pool 19.

Species	Total Tagged	# Active in 2018	# of Tags Detected in Downstream Approach	Lock Chamber Detections		# Detected Above L&D 19		% Approached	% Passed
				# Tags	# Entrances	# Tags	# Passages		
Native									
American Eel	2	0	1	1	1	0	0	50	0
Sauger	3	0	2	0	0	0	0	67	0
Walleye	17	0	5	5	6	3	3	29	18
Blue Catfish	1	1	0	0	0	0	0	0	0
Channel Catfish	20	20	7	2	2	0	0	35	0
Flathead Catfish	25	25	7	4	5	2	2	28	8
Bigmouth Buffalo	24	24	18	13	36	9	12	75	38
Blue Sucker	23	23	6	1	1	0	0	26	0
Lake Sturgeon	53	33	29	16	29	0	0	55	0
Paddlefish	49	49	20	20	44	6	8	41	12
Non-Native									
Bighead Carp	93	87	35	5	15	1	1	38	1
Grass Carp	47	47	32	5	5	1	1	68	2
Hybrid Carp	3	3	1	0	0	0	0	33	0
Silver Carp	105	95	47	18	23	0	0	45	0
	465	407	210	90	167	22	27		

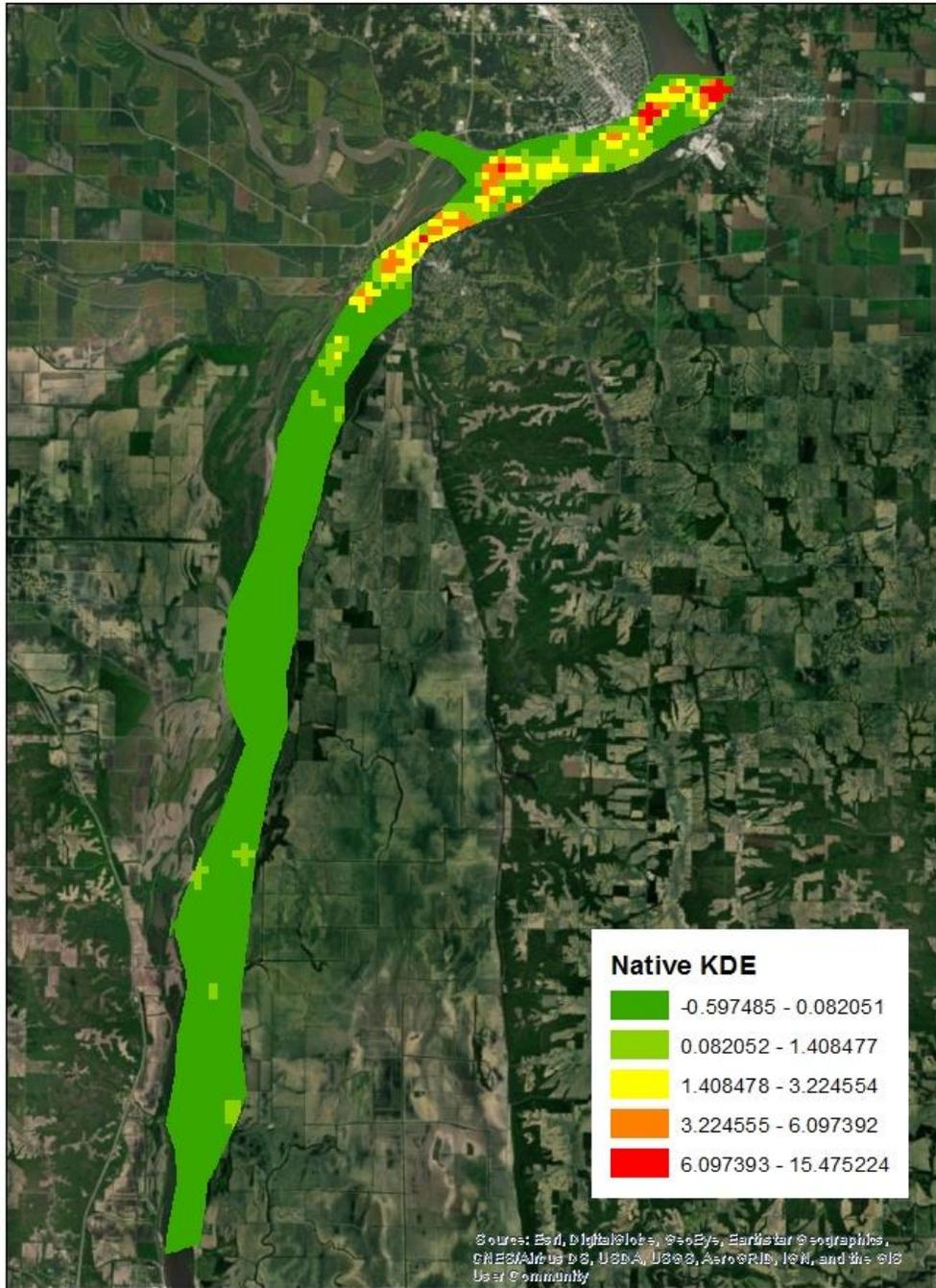


Figure 1. Kernel density estimates for native fish species in Pool 20.

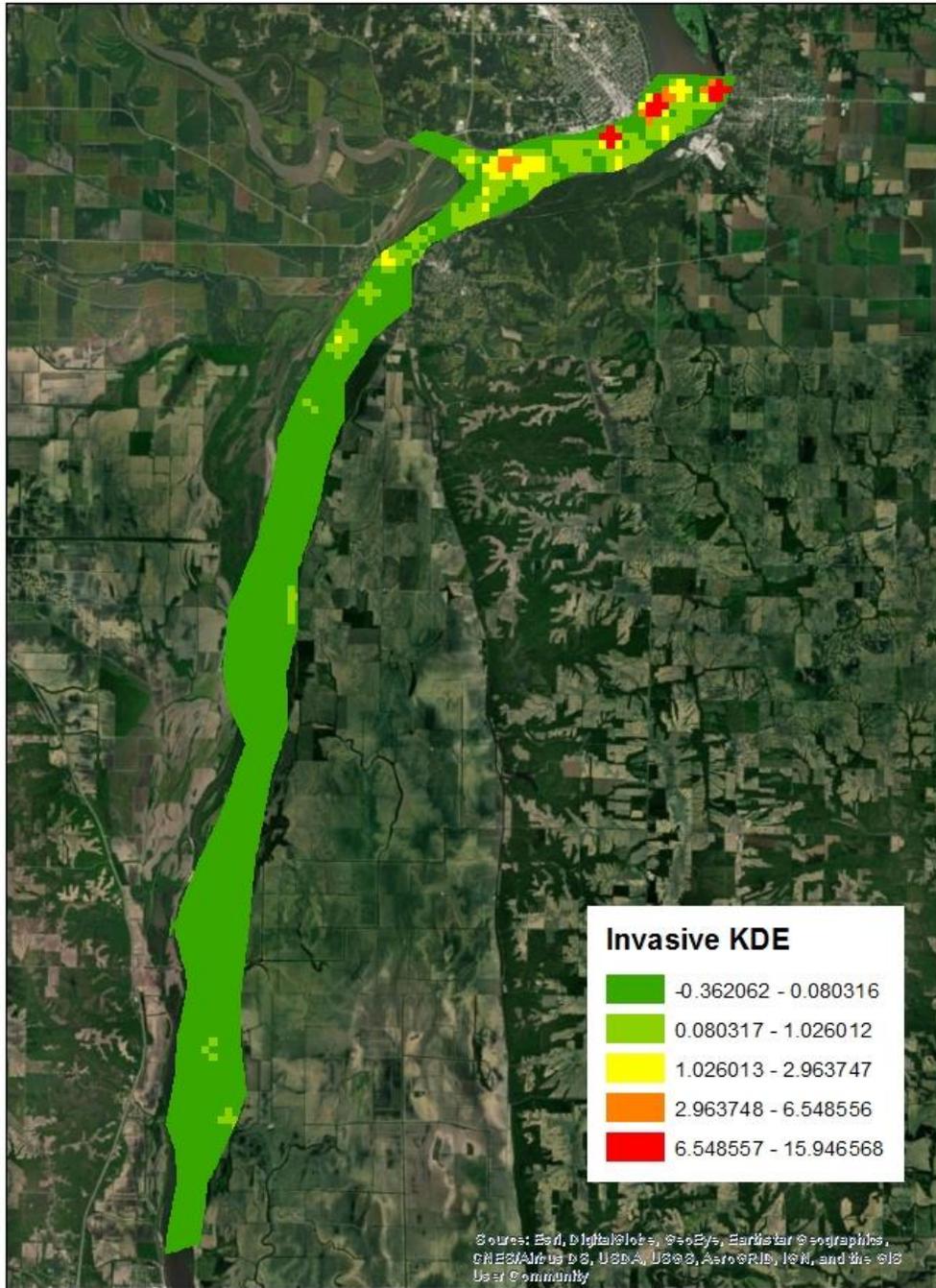


Figure 2. Kernel density estimates for invasive fish species in Pool 20.

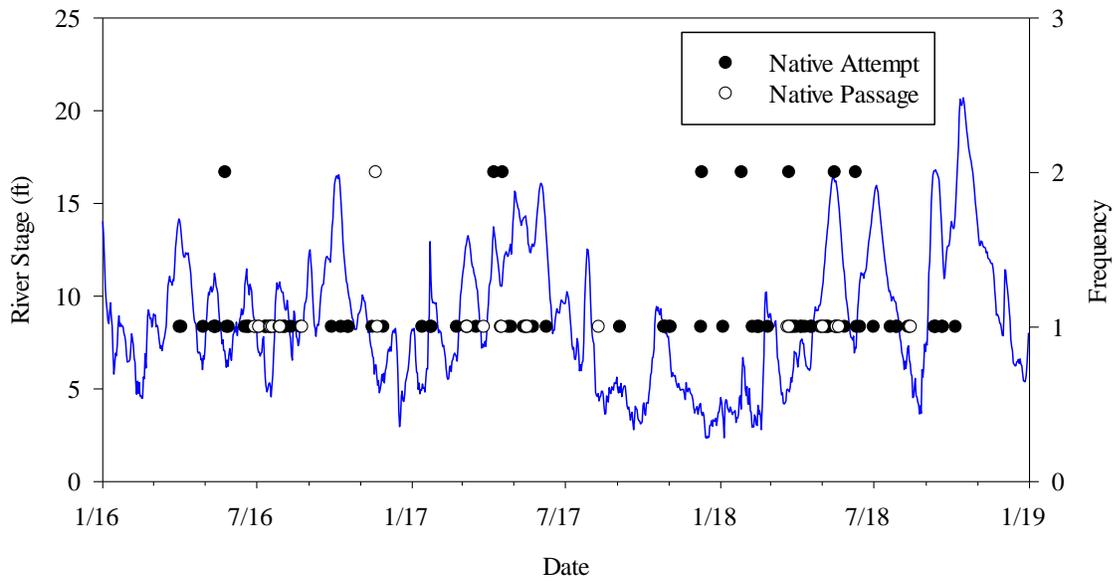
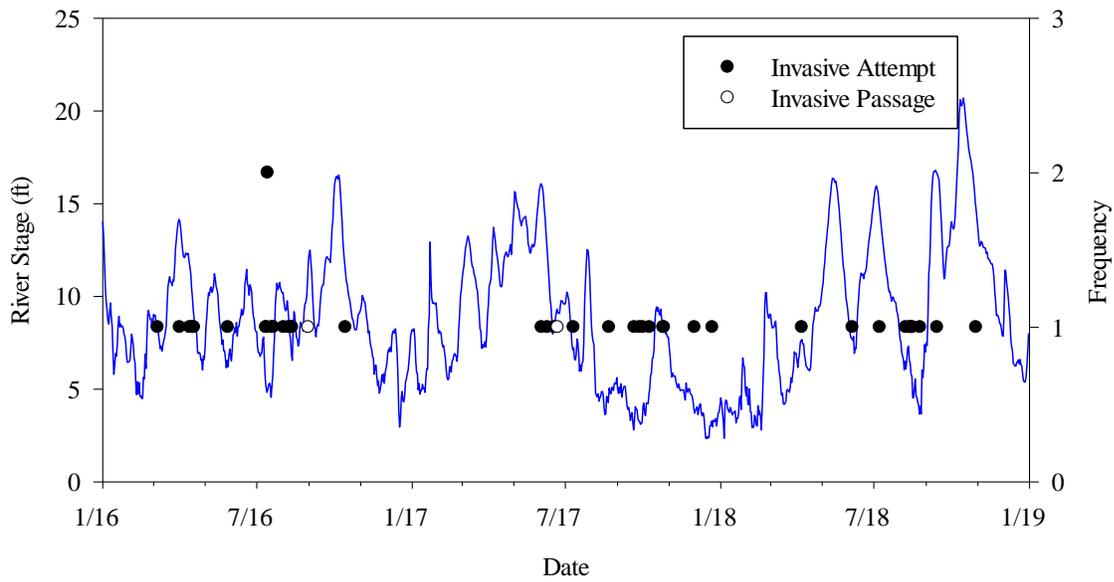


Figure 3. River stage at Keokuk, Iowa gauge associated with the dates of passage attempts and successful passage events. The top graph depicts invasive species attempts in black circles and invasive species passage in open circles and the bottom shows native species attempts (black) and passages (open).

USGS contribution to deterrent work at LD19 and LD15.

USGS, USFWS, Western Illinois University and Missouri Department of Conservation maintained two telemetry receiver arrays at Lock and Dam (L&D) 15 and L&D 19. Six receivers maintained by USGS were deployed at L&D 19, along with three receivers maintained by MDC. The telemetry array at L&D 15 consisted of 15 receivers dispersed in the area encompassing the approaches to both lock chambers as well as the area upstream of the lock chambers. The data from these telemetry arrays are being used to improve understanding of current passage rates of fish at these locations and to better understand factors that affect fish passage. Presentations of L&D 19 data were provided at the autumn meeting of the Upper Mississippi River Conservation Consortium (UMRCC) fisheries technical session, as well as to the Army Corps of Engineers and partners at L&D 19. Analysis of the first year of data from the telemetry array at L&D 19 will be completed in Spring 2019, and a manuscript will be submitted to Biological Invasions during Summer 2019.