ASIAN CARP TELEMETRY MONITORING IN POOLS 5A-20 IN THE UPPER MISSISSIPPI RIVER 2017

Geographic Location:
The USFWS/USGS telemetry receivers span from Pool 5a downstream to Pool 20 on the Upper Mississippi River.

Lead Agencies: USFWS LaCrosse Fish and Wildlife Conservation Office and USGS Upper Midwest Environmental Sciences Center

Participating Agencies:
Minnesota Department of Natural Resources
Missouri Department of Conservation
Southern Illinois University
U.S. Army Corps of Engineers
U.S. Coast Guard
U.S. Geological Survey – Upper Midwest Environmental Sciences Center (USGS)
Western Illinois University

Statement of Need:
Populations of Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*H. nobilis*) as well as Hybrids (*H. molitrix x nobilis*) between these species, are advancing in the Upper Mississippi River (UMR) basin (Conover et al. 2007; Chapman and Hoff 2011; O'Connell et al. 2011). Three zones of relative abundance of Asian carp have been identified in the UMR, a robust core population (established) below L&D 19, a transitional zone of moderately dense populations with potential reproduction from L&D19 to L&D 15, and a zone where individual captures of some adults have been recorded above L&D15 (USFWS 2016). This project spans all three management zones to help understand movement and habitat use within and among pools across these zones.

Project Objectives:

1) Utilize real-time mobile tracking and passive receivers to understand Asian carp movement patterns and identify environmental variables that influence those patterns.
2) Increase efficiency of removal efforts by locating congregations of Asian carp and sharing information with removal teams in a timely manner.
3) Understand movement of Asian carp through and around locks and dams to inform development and evaluation of potential deterrents.

Project Highlights:

- 363 Bighead, Silver, and Hybrid Carp have been tagged to date and 313 transmitters were active the entire year in 2017.
- By manual tracking fish tagged in Pool 17, a new congregation site was identified in Pool

16 (the most upstream targeted capture site to date).
    - To date, 82 Asian carp were tagged in Pool 16.
    - Guided by the telemetry data on tagged fish, the largest removal of Asian carp in Pool 16 occurred at this newly identified site in 2017 (80 fish).
- Monthly manual tracking provided 309 pinpointed locations and identified high-use areas in Pools 16 and 19 that aided removal efforts during 2017.
- Asian carp were detected in the Rock (n=49), Cedar (n=7), Iowa, (n=43), and Skunk (n=47) rivers when conditions were favorable for spawning.
- Over 800 passage events have been recorded indicating that Asian carp populations from Pool 10 to Pool 26 intermix at different rates especially during spawning and when main spillway dam gates are open. Greater than 50% of tagged Asian carp used multiple pools with a year.
- Telemetry data resulted in increased efficacy of removal efforts with 150,000 lbs of Asian carp being removed by netting from pools 16-20 in the last two years.
- In 2017, one female Silver Carp, which was tagged in Pool 19, was detected on a stationary receiver in Pool 10 >350 km upstream from where it was tagged. This suggests a small percentage of fish (<1%) move upstream as potential propagules for upstream populations.

Methods:

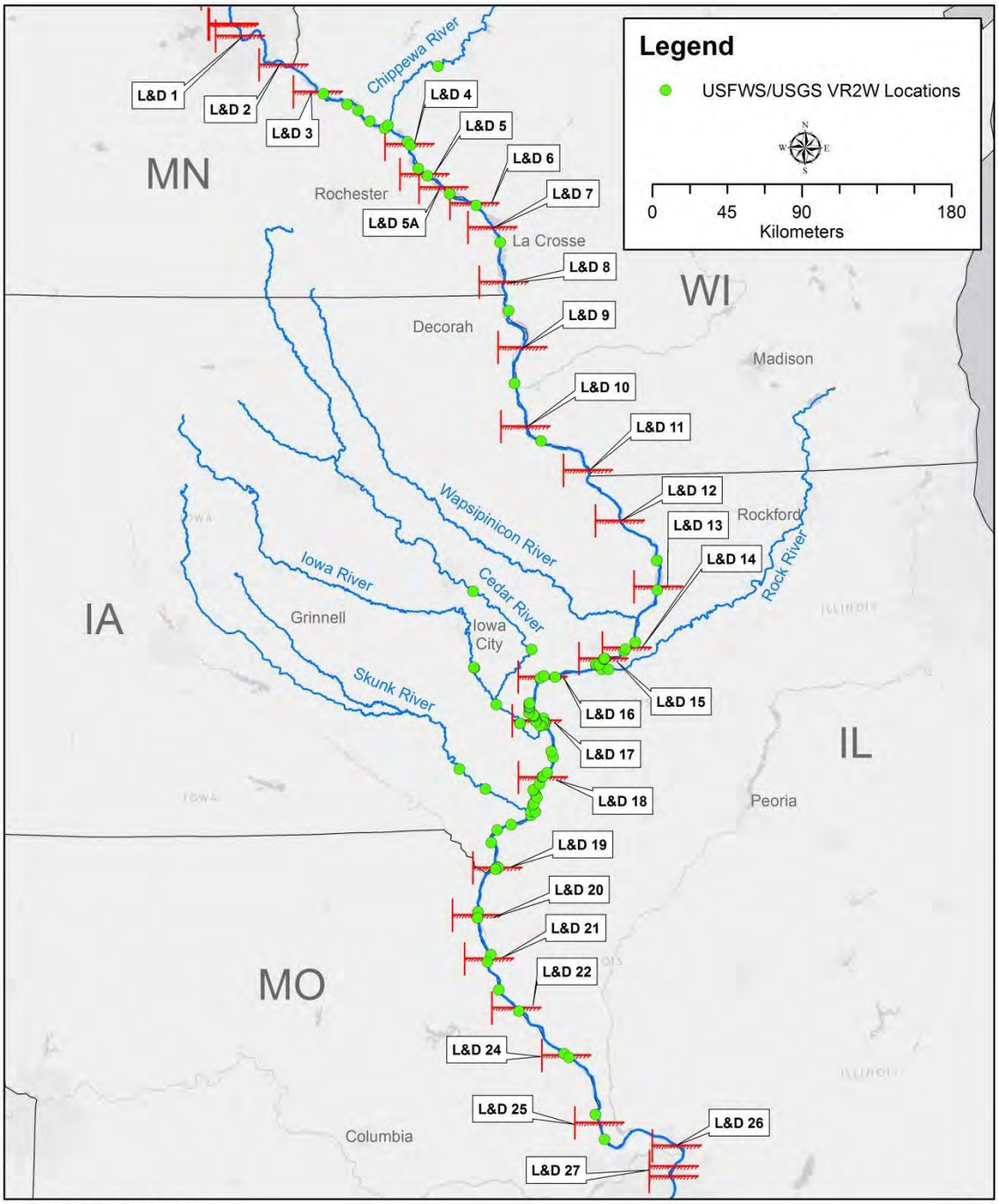
Acoustic Transmitter Tagging: Fish were collected from Pool 16 to Pool 19 using short-term gill net sets. Total length (mm), weight (g), and sex were recorded. Vemco Model V16-6H acoustic transmitters (69 kHz 16mm diameter, 96 mm length, 34g), programmed to transmit on a random delay from 30 to 90 seconds with a battery life of 2,538 days, were tested for recognition with a mobile receiver (VR-100-200) and surgically implanted according to procedures outlined by Summerfelt and Smith (1990). Target tag density was two fish per river mile for each pool. Acoustically tagged Asian carp were also fitted on the jaw with uniquely numbered orange Monel bands printed with contact information. These bands were primarily placed on the upper jaw but a few bands were placed on the lower jaw if necessary for an adequate fit. Post-surgery, each fish was held for observation until the fish recovered enough to maintain equilibrium and swim on its own. Fish were then released in close proximity to the capture location.

Acoustic Receiver Array: An array of stationary receivers (Vemco Model VR2W) was initially installed in the fall of 2013. In 2017, the total number of receivers deployed was increased to about 120, providing coverage from Pool 4 down to Pool 26. Receivers in pools 4 and 5 were maintained by MN DNR. In pool 14 through 19, the transitional population zone and/or the leading edge of the invasion (and where removal efforts are focused), receivers were installed with a higher density to better determine movements and distribution of the population (Figure 1). Receivers were also deployed in several tributaries, including the Rock (Pool 16), Iowa (Pool 18), Cedar (Pool 18), and Skunk (Pool 19) rivers to monitor movements in and out of tributaries and identify possible spawning events. The federal telemetry array bridges a gap between the Minnesota Department of Natural Resources array (Pool 1 to Pool 3) and the Missouri Department of Conservation array (Pool 19 to Caruthersville, MO) resulting in combined

telemetry coverage of about 1,600 river kilometers. Data from stationary receivers were downloaded monthly or seasonally which provided information on gross movements, movement patterns, possible spawning events, and habitat use to inform removal and potential deterrent placement.

Two 2-dimensional positioning arrays were placed on the downstream side of each lock approach at Lock 15 and 19 and were operational in 2017 (Figure 2 and 3). Two-dimensional arrays allow latitudinal and longitudinal positioning of fish detected in each lock approach. Receivers (Vemco Model VR2Tx) were placed in ladder recesses, allowing easy access and minimizing interference with lock navigation. Data will be analyzed to establish baseline information to evaluate possible future lock deterrents.

Mobile Tracking: Mobile tracking was used to locate fish within pools and to determine Asian carp movement patterns outside of stationary receiver coverage. In pools where acoustically tagged fish numbers were low, active tracking was used to locate areas where fish were present to increase the probability of capturing new fish to tag and to guide removal efforts. Fish were located with a mobile receiver and hydrophones (Vemco Model VR100-200 and Vemco Model VH110 and VH165). Location, depth, and habitat type were recorded at each site. Tracking in pools 16 and 19 was conducted on a monthly basis from April to October. Standardized point transects (e.g., points along a line), which were spaced 0.53 kilometers apart, were used to provide consistent tracking coverage throughout the sampling season.



Map created by: Jeena Credico
Sources: USFWS, USGS, and Esri
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Figure 1. Locations of stationary receivers deployed by the USFWS/USGS (Green) in the Mississippi river basin during 2017.

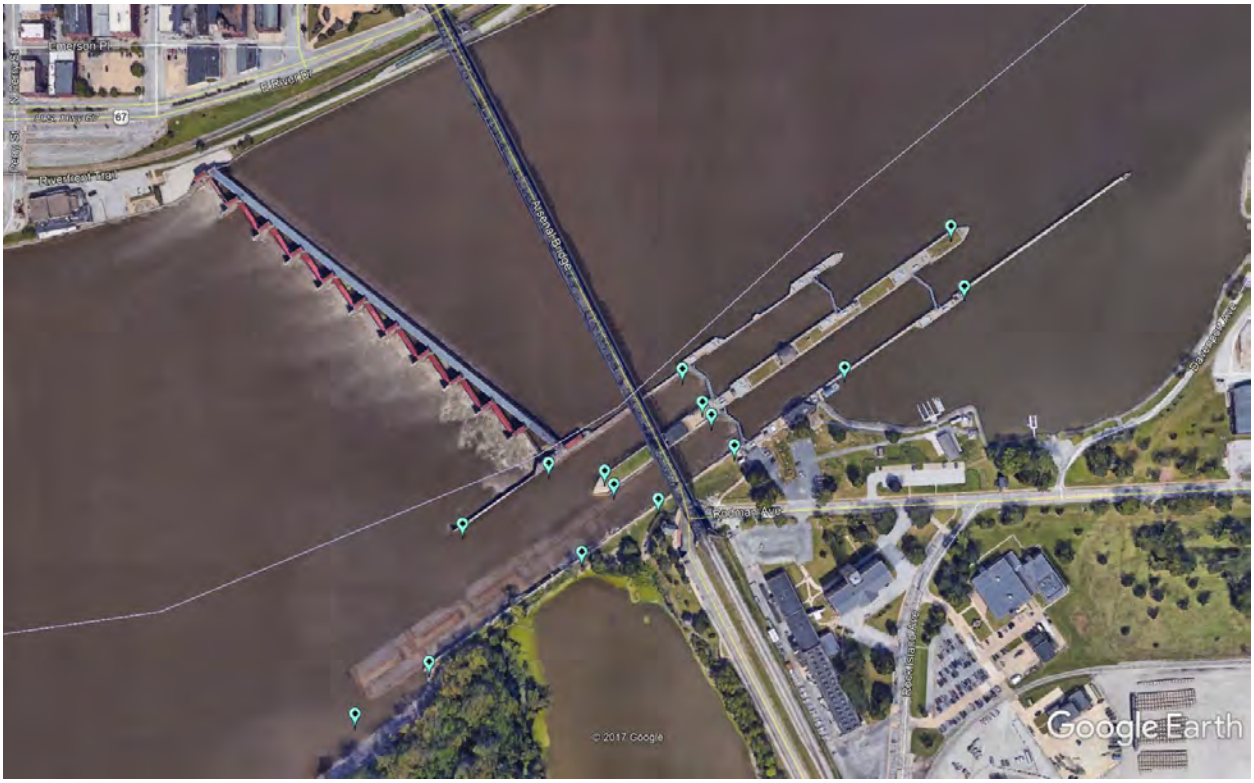

Figure 2. Locations of stationary receivers deployed by USFWS/USGS (Blue) to form a 2-dimensional positioning array located at Lock and Dam 15.

Figure 3. Locations of stationary receivers deployed by USFWS/USGS (Blue) to form a 2-dimensional positioning array located at Lock and Dam 19.

Results:

Acoustic Transmitter Tagging: An additional 38 Asian carp were acoustically tagged in 2017. This addition and the loss of older transmitters dying out resulted in a maximum of 313 active tags during 2017.

Acoustic Receiver Array: During 2017, 195 fish and 9.6 million detections were recorded on stationary receivers. The number of detections recorded during 2017 doubled the size of the database. Three tagged Asian carp were detected by the array above L&D 15. One male Bighead Carp tagged in Pool 16 in 2016, was detected upstream in Pool 15 during 2016. A female Bighead Carp also tagged in Pool 16 in 2016, was detected as far upstream as Pool 14 during 2017. One female Silver Carp tagged in Pool 19 in 2016, was detected as far upstream as Pool 10 during 2017. This fish was last detected back downstream in Pool 11 near Cassville, WI on June 15th, 2017. Ten fish were detected downstream of L&D 19 from Pool 20 downstream to Pool 25. A total of six Asian carp were detected in the Illinois River during 2017.

*Tributaries of the Mississippi above LD19*__ In 2017, Asian carp were located throughout the season in the Rock (Pool 16, n=49 fish), Skunk (Pool 19, n=47 fish), Iowa (Pool 18, n=43 fish),

and Cedar (Pool 18, n=7 fish) rivers. Detections in the tributaries occurred from March to November, but timing did vary for each tributary.

*Key Backwaters*__ Based on manual tracking and stationary receiver information from previous years, a total of ten backwaters were targeted for intense monitoring in Pools 16 through 19 to better understand environmental factors (e.g., flow, temperature, season, food resources, and oxygen) that influence Asian carp movements and aggregations in these areas to inform removal efforts (Figure 4-7). In total, 144 tagged Bighead Carp and Silver Carp were detected in these ten backwaters throughout the year (Figure 8) and nearly half (n=70) of these fish were detected in multiple backwaters.

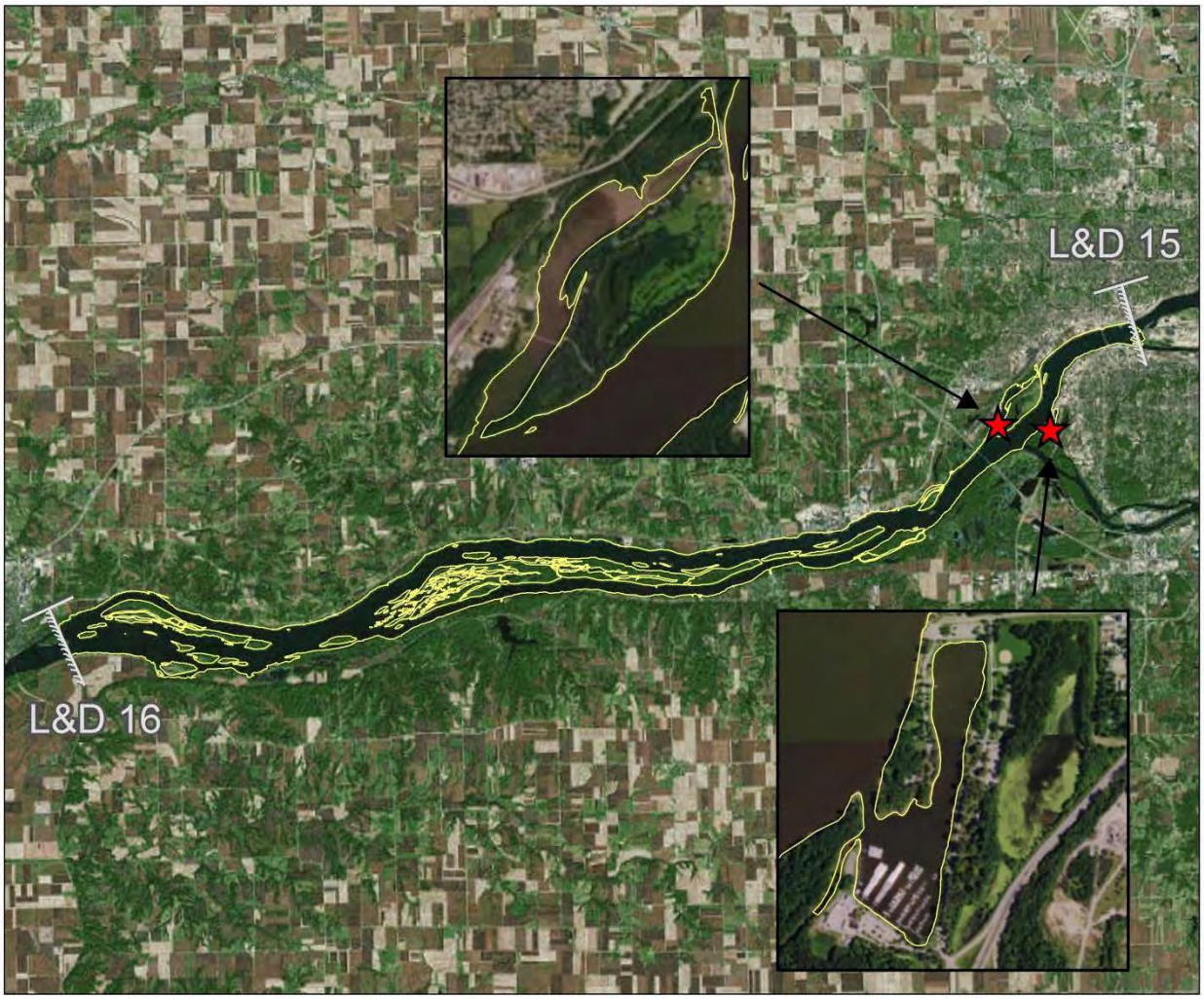

Figure 4. Two backwaters monitored by acoustic receivers in Pools 16 of the Mississippi River.

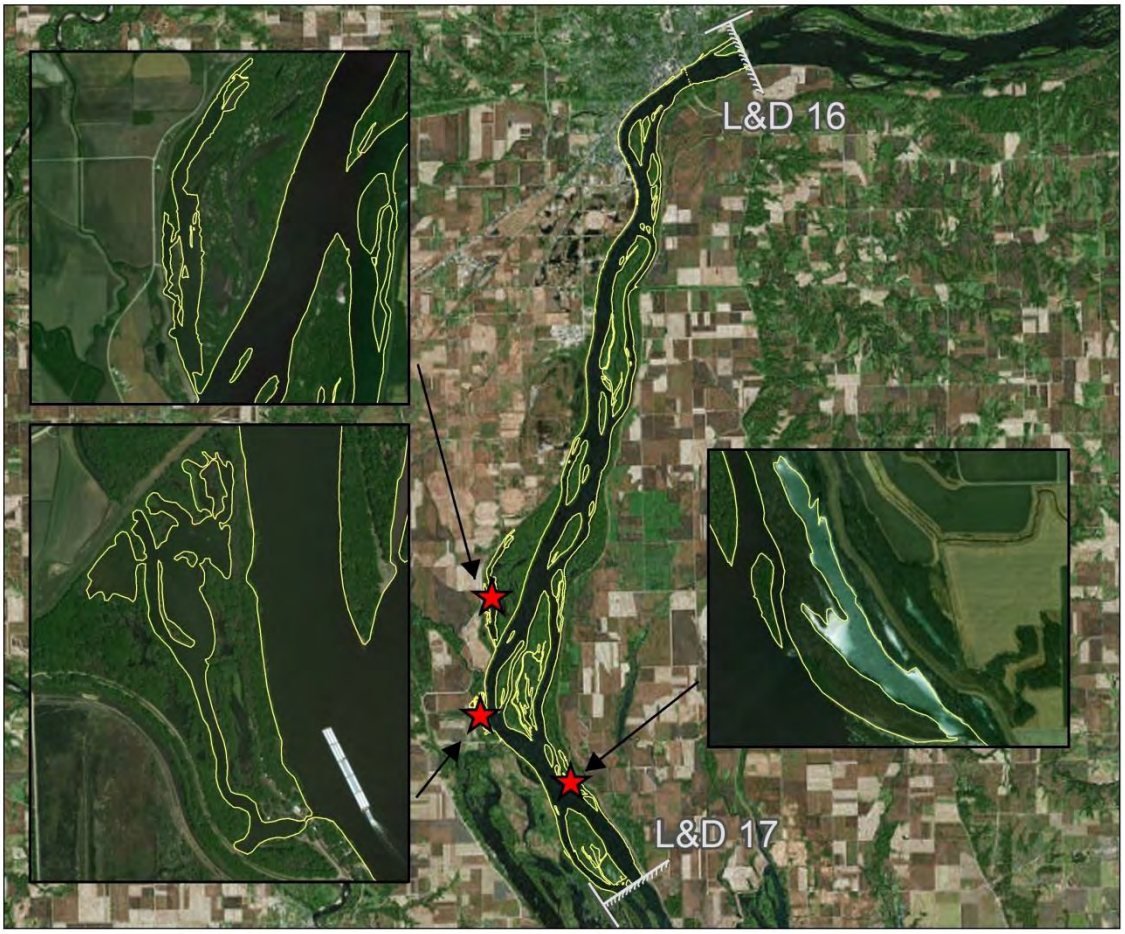

Figure 5. Three backwaters monitored by acoustic receivers in Pools 17 of the Mississippi River.

Figure 6. Two backwaters monitored by acoustic receivers in Pools 18 of the Mississippi River.

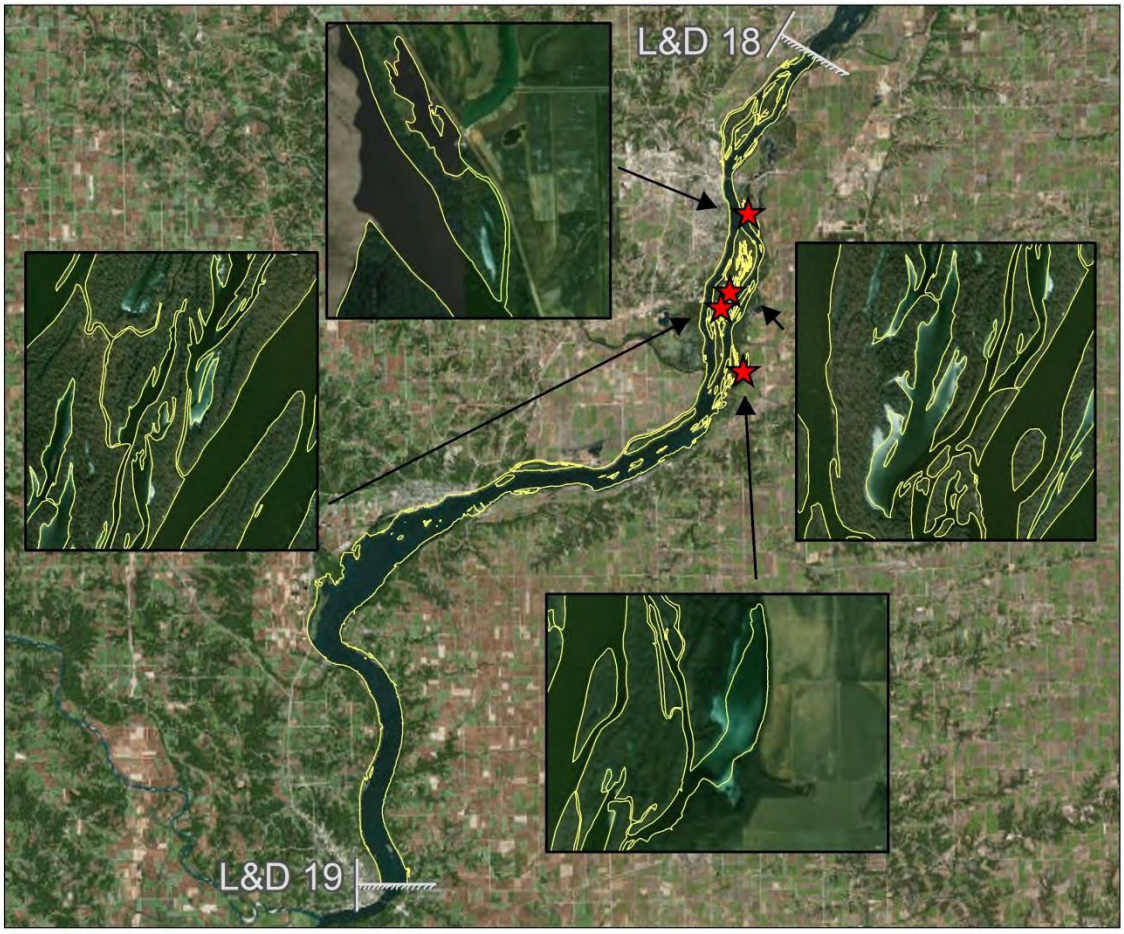

Figure 7. Four backwaters monitored by acoustic receivers in Pools 19 of the Mississippi River.

2-Dimensional Lock Approach Arrays: Lock approach array receivers were deployed from March to December during the 2017 field season. Very few fish were detected at Lock 15 (n=12). Species detected at Lock 15 included Bighead Carp, Silver Carp, and Walleye. However, quite a few fish (n=122 fish) of varying species (n=10) were detected at Lock 19. Two-dimensional positioning data will be analyzed in 2018 to establish baseline data.

Manual Tracking: Monthly manual tracking in pools 16 and 19 resulted in 309 pinpointed Bighead and Silver Carp locations in 2017 and aided in better defining high-use areas. The total number of manual tracking detections for all four pools since inception of the project in 2013 is 1,764. In 2017, 110 Bighead and Silver Carp were located in pools 16 (n=51) and 19 (n=62) and some individual fish were detected in both pools (n=3). Another 13 native fish, which were tagged by Western Illinois University and Missouri Department of Conservation, were located in Pools 16 and 19 by USFWS/USGS tracking efforts. A hotspot analysis will be conducted for all four pools comparing the difference in Bighead and Silver Carp locations for each year. The results of these analyses will be provided in a separate report or manuscript.

Manual tracking and stationary receiver data on Asian carp in 2017 likely contributed to the significant increase in fishing efficacy and efficiency in pools 16-19 as compared to 2016. As well, these data informed contracted fishing that resulted in the largest Asian carp catch in Pool 16, where Asian carp densities are relatively low and capture of Asian carp is more difficult. Specifically, an aggregation of Asian carp was detected using manual tracking and stationary receivers. This information was immediately relayed to Western Illinois University's contracted fishing crews and 100 Bighead and Silver Carp were removed, the largest Pool 16 Asian carp capture and removal to date.

Discussion

Migration Trends and Invasion Front: This study has compiled over 17.2 million detections, and only one Asian carp has been detected making a long (e.g., >350 kilometers) movement upstream into the lowest relative abundance management zone. To date, 0.8% (n=3) of the acoustically tagged fish have been detected above L&D 15. A Silver Carp tagged in Pool 19 has been detected the furthest upstream (Pool 10). Untagged Asian carp have occasionally been collected in upstream pools, mostly by commercial fisherman. This suggests that L&D 14 and 15 may be restricting movements upstream. Conversely, more (2.8%) Asian carp have been detected going downstream to Pool 26 and swimming up the Illinois River. Individual Asian carp used multiple pools (i.e., 16-19) throughout the year, suggesting that the fish in these pools are an intermixed population. Intermixing is particularly notable during the spawning season. The majority of intermixing has occurred between adjacent pools, but some has occurred between four or more pools in this reach. Upstream passage through dams has occurred at all locks and dams from Dam 10 down to Dam 26 with the majority of passages occurring from across dams 16-18. Notably, Bighead Carp and Silver Carp have moved downstream through L&D 19 and five of these fish have been detected moving back upstream through L&D 19.

Importance of Tributaries: Of the three tributaries above LD19 that were monitored and where Asian carp were detected, the Iowa River system has the longest reach (180+ kilometers) without an impassable barrier. Some studies suggest Asian carp require long passable river reaches for successful spawning (Kocovsky et al. 2012), suggesting that the Iowa River may be preferred by Asian carp for spawning over other tributaries that were monitored. Multiple peaks in the frequency-of-occurrence of Asian carp in the tributaries matched up with peaks in flow, and Asian carp egg and larval collections (M. Weber, Iowa State University, unpublished data). These data suggested that the Asian carp populations at this invasion front may spawn as many as five times in a given year if conditions are right. The greatest number of Asian carp detected in the tributaries was during the months of May and June indicating that this may be their primary spawning period. Staging of Asian carp prior to spawning in all three tributaries was primarily observed when water temperatures were >16°C.

The Rock River has the shortest stretch (8 km) of unobstructed river relative to the other tributaries that were utilized by Asian carp. Short river reaches may not provide adequate drift time for egg survival to hatch time (Kocovsky et al. 2012) and therefore the Rock River may provide less favorable spawning conditions than the Iowa and Skunk rivers. However, the Rock River had the highest number of individual fish detected during 2017. Asian carp eggs produced here may survive to hatch if they stay suspended in the Mississippi River after drifting out of the Rock River.

The Skunk River had the second highest number of detected fish in 2017. The Skunk River does have a 60 km reach without a barrier which should provide adequate drift times needed for incubation (Koscovsky et al. 2012). The number of fish detected in the Skunk River in 2017 most likely increased from previous years because the density of tagged fish in the adjacent pool (19) was greatest in 2017. Fish were also detected congregating at the mouth of the Skunk River throughout the year.

Importance of Backwaters: Several seasonal high-use backwater areas were detected in Pool 16, 17, 18, and 19. Asian carp congregated in backwaters during certain times of the year and half of the Asian carp detected in backwaters used more than one backwater during the year. A large number of Asian carp staged in the backwaters during pre and post-spawn time periods. When not migrating or using the tributaries, Asian carp typically inhabited the high-use backwaters during the spring and summer.

Importance of 2-dimensional Lock Approach Arrays: Data were sent to Vemco for 2-dimensional positioning. Once the 2-D positioning is complete, data will be analyzed to understand how fish use the lock approaches in the absence of any deterrent or control methods. If a deterrent does go into place or a control method is implemented, these pre-data will be necessary to identify changes and determine effectiveness of management actions. Only a small number (n=12) of native fish and Asian carp were detected at Lock 15 in 2017. For a meaningful analysis to be completed, more detection data are needed. It is recommended that additional fish be tagged in Pool 16 to increase the probability of tagged fish entering the array at Lock 15. At the Lock 19 approach, a good variety and number of both native fish and Asian carp were detected. Completion of the 2-d positioning will indicate if more fish need to be tagged in Pool 20 to increase fish numbers using the Lock 19 approach area. Tagging fish with depth sensor transmitters would allow 3-dimensional positioning of the fish, providing critical information for deterrent design, placement, and application.

Implications for Management Efforts: Understanding what drives Asian carp to enter and leave these areas of congregation will be crucial to have successful targeted removals throughout the year. Also, understanding what gear and methods are most effective as river conditions and fish abundance change is critical for effective and efficient removal efforts. In the backwaters,

targeting Asian carp with gill nets and pound nets when they are moving into and out of each site (e.g., transitional periods) could increase capture and removal efficiency. Large seines may also be very effective, but may be difficult because of submerged trees at some sites. Boston Bay on Pool 18 could be targeted with gill nets or seine hauls in the bay, but only when water levels are such that fish cannot move into the flooded timber. Pound netting may also be particularly effective if fished when Asian carp enter or leave these areas.

A high percentage of tagged Asian carp congregated in the impounded areas above Dam 16, 17, and 18 just prior to and during winter. This provides an extended window to target Asian carp for removal. Each site has flowing water, but is still suitable for gill netting. If the relative use of these sites by tagged Asian carp is representative of the population, then removal efforts could target >50-90% of the population during these peak congregations in backwaters, tributaries, and impounded areas just above the dams. Asian carp removal efforts in these areas should give serious consideration to minimizing by-catch mortality as large numbers of Smallmouth Buffalo, Largemouth Buffalo, and Paddlefish also congregate there, particularly above the dams.

Table 1. Number of Silver, Bighead and Hybrid Carp tagged by individual pool and total number of active tags during 2017 in the Upper Mississippi River. Only 195 tags were detected.

	Pool					
Species	16	17	18	19	Total Tagged in 2017	Total Active
Bighead	6	-	6	-	12	117
Hybrid	2	-	-	-	2	18
Silver	15	-	9	-	24	178
Total	23	-	15	-	38	313

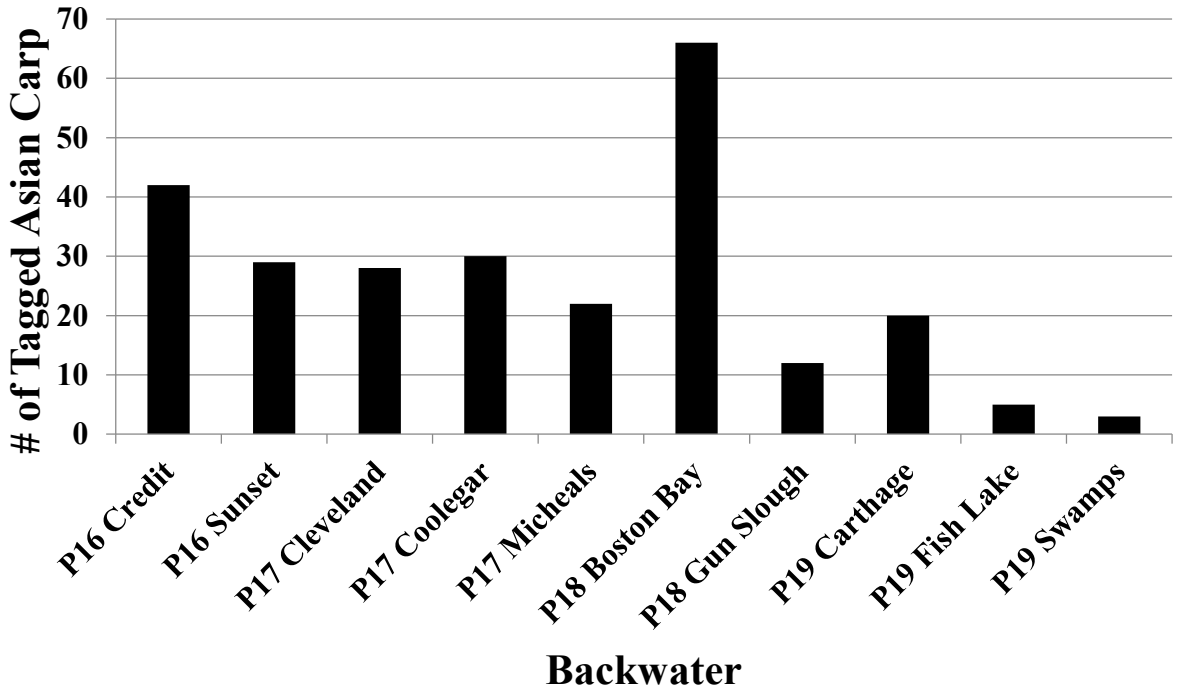

Figure 8. Number of tagged Bighead and Silver Carp (combined) detected in specific backwaters of pools 16 through 19 during 2017. Only 195 tags were detected. Some fish used multiple backwaters.

Recommendations:
Manual tracking data provides further evidence that Asian carp congregate in certain backwaters, above spillways, and in tributaries. These sites are temporally important habitat and can be targeted for Asian carp removal on the Upper Mississippi River. Use of Judas fish techniques (i.e., acoustically tagged Asian carp giving away the locations of many other non-tagged Asian carp) and gaining understanding of habitat selection by Asian carp will play a key role in monitoring and removal of Asian carp in pools where densities are low and where congregation sites are unknown. Two fish were detected by the stationary receiver array above Lock and Dam 15 during 2017 and were not detected moving back downstream of Lock and Dam 15, one as far upstream as Pool 10. A manual tracking effort was conducted in 2017 to locate these fish, but was unsuccessful. An attempt to locate them with stationary receivers and manual tracking will be repeated in early 2018 as they may direct us to new areas that Asian carp congregate in this low abundance zone.

Determining when and why Asian carp select sites is an integral part of effective management. Future work includes model development to predict movements, migrations, and habitat selection. Good models will enable managers to focus removal efforts in time and space and increase capture efficiency. Real-time receivers will also be deployed in 2018 as a primary method to inform removal efforts.

- Continue tagging in all pools to reach and maintain desired tag densities
- Increase density of remote receivers in present array and increase coverage in tributaries
- Place real-time receivers in key areas to further increase efficiency of removal efforts
- Increase density of receivers in pools 10-15 to better detect propagules into these pools
- Maintain 2-dimensional arrays around the lock approach of Locks 15 and 19 to continue collecting pre-deterrent fish use data
- Tag more fish in Pool 16 to increase detections in the lock approach at Lock 15
- Implement use of transmitters with depth sensors to obtain 3-dimensional positioning of fish in the lock approaches and chambers to facilitate the evaluation of deterrents.

References:

Chapman, D.C., and M.H. Hoff. 2011. Introduction *in* D.C. Chapman and M.H. Hoff, editors. Invasive Asian Carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland.

Conover, G., R. Simmonds, and M. Whalen., editors. 2007. Management and control plan for bighead, black, grass, and silver Carps in the United States. Asian Carp Working Group, Aquatic Nuisance Species Task Force, Washington, D.C. 190 pp.

Kocovsky, P. M., D. C. Chapman, and J. E. McKenna. 2012. Thermal and hydrologic suitability of Lake Erie and its major tributaries for spawning of Asian Carps. Journal of Great Lakes Research 38(1):159–166.

O'Connell, M.T., A.U. O'Connell, and V.A. Barko. 2011. Occurrence and Predicted Dispersal of bighead Carp ion the Mississippi River system: development of a heuristic tool. Pages 51-71 *in* D.C. Chapman and M.H. Hoff, editors. Invasive Asian Carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland.

Summerfelt, R.C., and L.S. Smith. 1990. Anesthesia, Surgery, and Related Techniques. Pages 213-272 *in* C.B. Schreck and P.B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

U.S. Fish and Wildlife Service. 2016. Annual Summary of Activities and Expenditures to Manage the Threat of Asian Carp in the Upper Mississippi and Ohio River Basins. Annual Report to Congress Pursuant to the Water Resources Reform and Development Act of 2014 (PL 113-121). Available: http://asianCarp.us/documents/WRRDA2016.pdf