2019

INTERIM SUMMARY REPORT

Asian Carp Monitoring and Response Plan

Asian Carp Regional Coordinating Committee

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

United States Coast Guard
U.S. Department of Homeland Security

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EXECUTIVE SUMMARY

This Asian Carp Interim Summary Report (ISR) was prepared by the Monitoring and Response Workgroup (MRWG) and released by the Asian Carp Regional Coordinating Committee (ACRCC). It is intended to act as an update to previous ISRs and present the most up-to-date results and analysis for a host of projects dedicated to preventing Asian carp from establishing populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Specifically, this document is a compilation of the results of 25 projects, each of which plays an important role in preventing the expansion of the range of Asian carp, and in furthering the understanding of Asian carp location, population dynamics, behavior, and the efficacy of control and capture methods. Each individual summary report outlines the results of work that took place in 2019 and provides recommendations for next steps for each project.

This ISR builds upon prior plans developed annually since 2011. This 2019 ISR serves as a record of activities and accomplishments by MRWG agencies during 2019. A companion document, the 2020 Asian Carp Monitoring and Response Plan (MRP), has also been completed by the MRWG. The 2020 MRP presents each project's plans for activities to be completed in 2020. The MRP is intended to function as a living document and will be updated at least annually. In conjunction, the 2020 MRP and 2019 ISR present a comprehensive accounting of the projects being conducted to prevent the establishment of Asian carp in the CAWS and Lake Michigan. Through the synthesis of these documents, the reader can obtain a thorough understanding of the most recent project results and findings, as well as how these findings will be used to guide project activities in the future.

The term "Asian carp" generally refers to four species of carp native to central and eastern Asia that were introduced to the waters of the United States and have become highly invasive. The four species generally referred to with the "Asian carp" moniker are Bighead Carp (*Hypophthalmicthys nobilis*), Silver Carp (*Hypophthalmicthys molitrix*), Grass Carp (*Ctenopharyngodon idella*), and Black Carp (*Mylopharyngodon piceus*). For the purpose of this ISR, the term 'Asian carp' refers to Bighead Carp and Silver Carp, exclusive of other Asian carp species such as Grass Carp and Black Carp. Where individual projects address Grass Carp and Black Carp, they will be referenced specifically by name, and without using the generic 'Asian carp' moniker.

All ISRs to date, including the 2019 ISR, have benefitted from the review of technical experts and MRWG members, including, but not limited to, Great Lakes states' natural resource agencies and non-governmental organizations. Contributions to this document have been made by various state and federal agencies.

As in the past, all projects discussed in this document have been selected and tailored to further the MRWG overall goal and strategic objectives.

Overall goal: Prevent Asian carp from establishing self-sustaining populations in the CAWS and Lake Michigan.

The five strategic objectives selected to accomplish the overall goal are:

1) Determination of the distribution and abundance of any Asian carp in the CAWS, and use this information to inform response and removal actions;
2) Removal of any Asian carp found in the CAWS to the maximum extent practicable;
3) Identification, assessment, and reaction to any vulnerability in the current system of barriers to prevent Asian carp from moving into the CAWS;
4) Determination of the leading edge of major Asian carp populations in the Illinois River and the reproductive successes of those populations; and
5) Improvement of the understanding of factors behind the likelihood that Asian carp could become established in the Great Lakes.

In keeping with the overall goal and strategic objectives, the 2019 results for 25 projects are included in this ISR. These summary reports document the purpose, objectives, and methods for each individual project, in addition to providing an analysis of results and recommendations for future actions. The projects are grouped into three general categories:

1) **Detection:** Determine the distribution and abundance of Asian carp to guide response and control actions.
2) **Manage and Control:** Prevent upstream passage of Asian carp towards Lake Michigan via use of barriers, mass removal, and understanding best methods for preventing passage.
3) **Response:** Establish comprehensive procedures for responding to changes in Asian carp population status, test these procedures through exercises, and implement if necessary.

A summary of the highlights of each project is presented below, intended to provide a brief snapshot of project accomplishments during 2019.

DETECTION PROJECTS

***Seasonal Intensive Monitoring (SIM) in the CAWS* –** This project focuses on conducting two high-intensity monitoring events for Asian carp in the CAWS above the Electric Dispersal Barrier System (EDBS). Monitoring is conducted in the spring and fall, in areas with historic detections of Asian carp or Asian carp eDNA.

- Completed two 2-week SIM events with conventional gears in the CAWS upstream of the EDBS in 2019.
- No Silver Carp or Bighead Carp were captured or observed in 2019. From 2011-2016 and 2018-2019, no Bighead Carp or Silver Carp have been captured or observed. One Bighead Carp was captured in Lake Calumet in 2010, and one Silver Carp was captured in the Little Calumet River in 2017.

- In 2019, an estimated 2,693 person-hours were spent completing 103 hours of electrofishing, setting 128.1 kilometers (km) (79.6 miles) of gill net, and 2.9 km (1.8 miles) of commercial seine.
- Across all locations and gears, 27,326 fish were sampled representing 53 species and 3 hybrid groups in 2019.
- Since 2010, an estimated 31,927 person-hours have been spent to complete 1,293.2 hours of electrofishing and set 1075.0 km (668.0 miles) of gill/trammel net, 16.3 km (10.1 miles) of commercial seine, and 114.2 net nights of tandem trap nets, hoop nets, fyke nets, and pound nets.
- From 2010-2019, a total of 471,730 fish representing 86 species and seven hybrid groups were sampled, including 2,842 Banded Killifish (state threatened species).
- Since 2010, 124,698 young-of-year (YOY) Gizzard Shad were examined and found no YOY Asian carp were found.
- Since 2010, 16 non-native species have been captured accounting for 15 percent of the total number of fish caught and 19 percent of the total species.
- Recommend continued use of SIM in the CAWS upstream of the EDBS for localized detection and removal of Asian carp.

Strategy for Environmental Deoxyribonucleic Acid (eDNA) Sampling in the CAWS – This project continues eDNA monitoring in strategic locations in the CAWS that will be used to provide information on the location of Asian carp.

- Two planned eDNA sampling events took place in the CAWS at targeted off-channel locations in 2019, resulting in 364 samples collected the week of April 8 and 376 samples the week of October 7.
- Results: In April, four samples were positive for Asian carp DNA in Lake Calumet: one sample positive for only Silver Carp DNA, one sample positive for only Bighead Carp DNA, and two samples positive for DNA of both species. In early October, 49 samples were positive for Asian carp DNA in the South Branch of the Chicago River: 22 samples positive for only Silver Carp DNA and 27 samples positive for DNA of both species.
- Additional sampling was conducted the week of October 28 in response to the unusually high number of positive samples from the initial October event. This resulted in a similar number of positive detections for Asian carp DNA.

Telemetry – This project uses ultrasonically tagged Asian carp and surrogate species to assess if fish are able to challenge and/or penetrate the EDBS or pass through navigation locks.

- To date, the U.S. Army Corps of Engineers (USACE) has acquired 33.5 million detections from 686 tagged fish.
- No live tagged fish have crossed the EDBS in the upstream direction.
- A high percentage of tagged surrogate fish in the Lower Lockport Pool continue to be detected near the EDBS.

- There were seven upstream and 11 downstream passages of Common Carp between the Brandon Road and Lockport pools.
- Asian carp continue to be detected throughout the Dresden Island Pool with the majority of detections occurring near the Harborside Marina and Dresden Island Lock.
- Up to 70 percent of the transmitters within Dresden Island Pool were detected near Harborside Marina at the Kankakee River confluence. This location registered approximately 81 percent of all the detections in the pool for the year.

Real-Time Telemetry in Support of Management – This project uses real-time acoustic telemetry receivers for detecting Asian carp and surrogate fish, deployed at strategic locations in the upper Illinois Waterway (IWW). Location information of tagged bigheaded carp (Silver Carp and Bighead Carp) from real-time detections are available online to biologists directing day-to-day fish removal efforts, and as email alerts to managers responsible for executing monitoring and contingency actions.

- Deployed, maintained, and range-tested nine real-time receivers in the upper IWW system in 2019.
- Maintained a system to alert key MRWG personnel of detections of bigheaded carp in areas of concern.
- Initiated analyses of receiver detections and catch data from contract fish removal efforts to determine the potential usefulness of real-time receivers to inform decisions on those efforts.

USGS Illinois River Catch Database and Visualization – This project incorporates all data from removal and monitoring efforts into a centralized database. This centralized database facilitates data standardization, accessibility, sharing, and analysis to aid in Asian carp removal efforts, evaluations of management actions, and population modeling.

- Implemented automated quality control checks during the data upload process into the database to ensure data consistency.
- Coded development of an analytical tool to visualize the spatial and temporal patterns of catch data.
- Initial development of an online, interactive mapping tool as a centralized access point for existing Asian carp-related data layers

Monitoring of Fish Abundance and Spatial Distribution near the EDBS and in Lockport, Brandon Road, and Dresden Island Pools – This project uses numerous monitoring tools to assess fish populations near the EDBS in an attempt to identify seasonal and temporal trends for fish abundance near the barrier.

- Fish abundances both within and directly downstream of the EDBS were similar across the majority of the 2019 hydroacustic survey.

- Fish abundances within the EDBS were low with an annual mean of 1.8 large fish targets detected per survey (min = 0, max = 8 individual large fish targets).
- Surveys with fish abundances greater than two individuals, within the EDBS, were observed during only four surveys: June 24 (six individuals), August 27 (five individuals), November 1 (five individuals), and November 15 (eight individuals).
- Fish abundances directly downstream of the EDBS were releativly low with an annual mean of 3.6 large fish targets detected per survey (min = 0, max = 13 individual large fish targets).
- Fish density was greater in Dresden Island Pool during the summer surveys relative to the densities in Brandon Road and Lockport pools. The greatest fish density was observed during the August survey of Dresden Island Pool. The lowest fish density was observed in during the September survey of Dresden Island Pool. Overall fish density was similar among the three pool during the fall surveys.

Distribution and Movement of Small Silver Carp and Bighead Carp in the IWW – The purpose of this project is to establish where young Asian carp (YOY to age 2) occur in the IWW through intensive, directed sampling with gears that target these specific life stages.

- Total efforts for monitoring included:
  - 140 crew weeks effort during multi-agency monitoring of the Illinois River for informed decision making (collaborative efforts) sampling Peoria Pool to Lockport Pool.
  - 6 crew weeks targeted supplemental sampling Peoria Pool to Dresden Island Pool
- A total of 101 Silver Carp less than 153 millimeters (mm) Total Length (TL) were captured in Peoria Pool, with the furthest upstream at Hennepin, Illinois (River Mile 207.8, 88 miles from EDBS) during the 2019 field season. No Silver Carp less than 153mm were captured upstream of Starved Rock Lock and Dam.

Larval Fish Monitoring in the IWW – This project focuses on sampling larval Asian carp and Asian carp eggs. It provides crucial information on the location of breeding populations, the conditions that trigger spawning, and current population fronts.

- 476 ichthyoplankton samples were collected from seven sites from the Brandon Road to LaGrange navigation pools of the IWW during April – October 2019, collecting over 80,000 larval fish; including 3,595 Asian carp larvae; plus 1,430 Asian carp eggs. Asian carp eggs or larvae were present during late May through June, and a late spawning event was observed at the beginning of October. Asian carp reproduction occurred during periods of rising water levels when the temperature was above 18°C. Asian carp eggs and larvae were only collected in the LaGrange and Peoria pools during 2019.
- 345 ichthyoplankton samples were collected from tributary rivers (Kankakee, Fox, Mackinaw, Spoon, and Sangamon rivers) during 2019. No Asian carp eggs or larvae were

collected in the Kankakee or Fox rivers, but larvae were observed in all other tributaries and eggs were collected in the Spoon and Sangamon rivers. Asian carp eggs and larvae were present in tributaries during late June and early July, and were associated with increases in water levels once temperatures were above 18°C.

- Modeling efforts examining the influence of adult spawning stock density and environmental factors on Asian carp reproductive output found that a model with potential spawner density, cumulative degree days by the end of June, and May-June flow rate was most strongly supported by the observed data. Asian carp egg production was found to be highest during years with warmer spring to early-summer water temperatures and higher flow rates and increased nonlinearly with adult density.

***Monitoring Bigheaded Carp Movement and Density in the Illinois River* –** Bigheaded carp spatial distributions vary both seasonally and annually; therefore, quantifying how spatial distributions change through time will help direct contracted harvest efforts to high-density locations in order to maximize removal efficiency. Density hotspots, though, shift throughout the year and vary among years. Thus, assessments of bigheaded carp spatial distributions in Dresden Island and Marseilles pools will allow contracted removal to maintain high harvest rates.

Monitoring of bigheaded carp densities via hydroacoustic sampling throughout the Illinois River (Alton to Dresden Island pools) by Southern Illinois University (SIU) has been ongoing since 2012 and is a useful metric to evaluate long-term changes in bigheaded carp abundance. Broad-scale density estimates also help inform management actions in the upper river near the invasion front.

- Repeated hydroacoustic surveys in Dresden Island and Marseilles pools identified areas of high bigheaded carp density and how these locations change through time. These data helped direct contracted removal efforts throughout 2019.
- Fall 2019 bigheaded carp densities in Starved Rock, Marseilles, and Dresden Island pools were the lowest or as low as any densities observed in those pools since monitoring began in 2012. River discharge during sampling dates in the upper river pools were similar to previous years.
- Mean observed bigheaded carp densities in Dresden Island Pool during October of 2019 was 96.7 percent lower than the mean observed density in 2012.
- Bigheaded carp densities in Alton and Peoria pools during fall 2019 were lower than previous monitoring years which coincided with flooding and historically high river discharge during the time of sampling. Low observed densities may have been caused by fishes moving out of high-flow main channel areas and into shallow, low-flow habitats that were not sampled.
- Upstream passages by bigheaded carp at dams of greatest concern in the upper Illinois River continue to be limited, with one upstream passage occurring at Dresden Island Lock and Dam, two at Marseilles Lock and Dam, and four at Starved Rock Lock and

Dam. These results are based solely on SIU's telemetry data, so data combined across agencies could produce additional passage events.

- Tentative results from surrogate fish work indicate that microhabitat selection is different between Common Carp and Silver Carp, but broader habitat use (e.g., main channel versus side channel) may be similar. Initial results also suggest the ranges occupied by Silver Carp are larger than ranges used by Common Carp. Eight to 34 percent of fish sampled upstream of Brandon Road Lock and Dam, depending on taxa, exhibited fin ray strontium:calcium ratio (Sr:Ca) suggesting prior residency in the Illinois or Kankakee rivers, and therefore upstream passage through Brandon Road Lock and Dam.

Habitat Use and Movement of Juvenile Silver Carp in the Illinois River – Laboratory tests have indicated the EDBS is sufficient for stopping large-bodied fish passage but tests on small Bighead Carp (51-76mm total length) have indicated that the operational capabilities of the EDBS may be insufficient to block passage of small-bodied fishes. Acoustic and radio telemetry provide a means to directly evaluate habitat use and movement patterns of young life-stage Silver Carp and their risk of breaching the EDBS. Additionally, information on juvenile Silver Carp habitat preferences can be exploited by monitoring agencies to improve both the effectiveness and efficiency of juvenile Silver Carp early detection monitoring.

- In total, 190 juvenile Silver Carp have been tagged with internally implanted radio or acoustic transmitters. Annual tagging totals included:
    - 72 fish in 2017
    - 81 fish in 2018
    - 37 fish in 2019
- On average, residence times by macro-habitat type for telemetered juvenile Silver Carp were:
    - 2017:150.6 hours in backwaters, 43.2 hours in marinas, 38.1 hours in main channels, 104.4 hours in side channels
    - 2018: 97.6 hours in backwaters, 104.5 hours in marinas, 4.4 hours in main channels, 0.2 hours in side channels. Side channels were lacking spatial/temporal coverage due to lost receivers.
    - 2019: data download and analyses pending

Des Plaines River Monitoring – In 2019, sampling was conducted in the upper Des Plaines River from E Romeo Rd (Romeoville, Illinois) to Columbia Woods (Willow Springs, Illinois; Figure 1). Sampling was performed using pulsed-DC boat electrofishing and short term (1 – 2 hours) surface to bottom gill net sets. No Bighead Carp or Silver Carp have been captured or observed through all years of sampling (2011-2018).

- Collected 12,776 fish representing 67 species and 3 hybrid groups from 2011 – 2019 via electrofishing (73 hours) and gill netting (153 sets; 23,684 yards [21,656.7 m]).
- No Bighead Carp or Silver Carp have been captured or observed through all years of sampling.

- Ten Grass Carp have been collected since 2011. No Grass Carp were collected in 2019.
- Three overtopping events since 2011 have resulted in several improvements to the barrier fence. No overtopping events occurred in 2019.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring – This project focuses on sampling and removing Asian carp from urban fishing ponds in the Chicago area, to prevent the potential incidental or intentional transport of fish from these ponds to the CAWS or Lake Michigan.

- 34 Bighead Carp have been removed from five Chicago area ponds using electrofishing and trammel/gill nets since 2011; three of which are on display at the Shedd Aquarium in Chicago.
- Eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have also been removed from Chicago area ponds since 2008.
- One Bighead Carp was incidentally caught by a fisherman in a Chicago area pond in 2016.
- 18 of the 21 Illinois Department of Natural Resources (IDNR) Chicago Urban Fishing Program ponds have been sampled with nets and electrofishing.
- All eight Chicago area fishing ponds with positive Asian Carp eDNA detections have been sampled with electrofishing and trammel/gill nets.

Multiple Agency Monitoring of the Illinois River for Decision Making – This project uses standardized methodology to monitor Bighead Carp, Black Carp, Grass Carp, and Silver Carp populations in pools below the EDBS. This monitoring is necessary to understand their upstream progression and minimize the risk of establishment above the EDBS. Extensive monitoring also provides managers the ability to evaluate the impacts of management actions (e.g., contracted removal) and collect data to assist other projects (e.g., Spatially Explicit Asian Carp population [SEACarP] model). Data collected from a standardized multiple gear sampling approach have been used to create accurate and comparable relative abundance estimates of specific species and detect the presence of previously unrecorded invasive species.

- In 2019, an estimated 11,815.5 person-hours were expended sampling fixed and random sites downstream the Electric Dispersal Barrier system including 187.75 hours of electrofishing, 1177.3 hoop netting net nights, 475.8 minnow fyke netting net nights, and 113.1 fyke netting net nights.
- A total of 150,171 fish representing 108 species and 16 hybrid groups were captured in 2019.
- No Asian carp (large or small) were captured in Lockport or Brandon Road pools in 2019.

- The leading edge of the Bighead Carp and Silver Carp populations remained around river mile 281 (north of I-55 Bridge within the Dresden Island Pool near the Rock Run Rookery) in 2019.
- No small Silver Carp or Bighead Carp (less than 6 inches/152.4 mm) were captured in pools up river of Peoria Pool (river mile 201; about 130 miles from Lake Michigan) in 2019.
- Data from projects outside of the MRWG MRP were incorporated to create a comprehensive synthesis of each Asian carp species' status across the entire Illinois River Waterway below the EDBS in 2019.

MANAGE AND CONTROL PROJECTS

USGS Telemetry Database and Analyses in Support of SEACarP – This project focuses on the development and administration of a common standardized telemetry database and estimating movement probabilities and associated uncertainty needed for the SEACarP model. The telemetry database (FishTracks) facilitates standardization, archiving, sharing, quality assurance, visualization and analysis of the telemetry data needed for management.

- Developed a standard operating procedure for data collection, formatting, and upload requirements.
- Implemented an online upload tool to streamline the data upload process and automate quality control checks to ensure data consistency.
- Developed program to summarize millions of telemetry data records into consolidated datasets for optimizing telemetry receiver placement throughout the network of receivers.

USGS Geospatial Support for Unified Fishing Method – This project provides support during the implementation of the Unified Fishing Method. This fishing method requires spatial and temporal coordination among multiple agencies' personnel and contracted fishermen in a unified manner at scales ranging from individual backwaters to entire navigation pools. Better understanding the spatial and temporal aspects of these fishing techniques in relation to movements of fish and catch events during a Unified Fishing Method can improve the efficiency and effectiveness of the implementation of this mass harvest method.

- Equipment requirements (i.e., GPS units), deployment techniques (e.g., best placement for ensuring proper data collection), and a methodology for collecting time-stamped GPS tracking and activity data from boats and gear deployments during Unified Fishing Method events has been developed. This methodology was utilized during the Dresden Island Pool fall of 2019 Unified Fishing Method event, implementing improvements to data collection issues that were revealed from gaps in data collection during the Dresden Island Pool fall of 2018 event.
- Geospatial data collected during the Dresden Island Pool fall of 2018 Unified Fishing Method event were post-processed into visualizations of the coordinated effort and used to reduce the time required to clear the same area during subsequent events (e.g., covering Dresden Island Pool with four days of coordinated fishing effort instead of five

days). Data from the fall of 2019 event is being processed and visualizations are being refined to incorporate telemetry data to display fish movement relative to boat activities and gear deployments.

Contracted Commercial Fishing Below the EDBS – This project uses contracted commercial fishers to reduce Asian carp (Bighead Carp, Black Carp, Grass Carp and Silver Carp) abundance and monitor for changes in range in the Des Plaines River and upper Illinois River, downstream of the EDBS. By decreasing Asian carp abundance, we anticipate reduced migration pressure towards the EDBS, lessening the chances of Asian carp gaining access to upstream waters in the CAWS and Lake Michigan.

- Since 2010, contracted commercial fishers' effort in the upper IWW below the EDBS includes 3,892 miles (6,264 km) of gill/trammel net, 19 miles (31 km) of commercial seine, 239 Great Lakes pound net nights, and 4,369 hoop net nights.
- In total, 97,849 Bighead Carp; 997,732 Silver Carp; and 9,373 Grass Carp were removed by contracted fishers from 2010-2019. The total estimated weight of Asian carp removed is 4,528.6 tons (9,057,200 lbs.).
- No Asian carp have been collected in Lockport or Brandon Road pools since the inception of this project in 2010.
- The leading edge of the Asian carp population remains near Rock Run Rookery in Dresden Island Pool (approximate river mile 281; 46 miles from Lake Michigan). No appreciable change has been found in the leading edge over the past 10 years.
- Since 2010, this program has been successful at managing the Asian carp population in the upper Illinois River. Continued implementation of this project will provide the most current data on Asian carp populations at their leading edge and reduce pressure on the EDBS.

Asian Carp Population Modeling to Support an Adaptive Management Framework – This project involves the creation and refining/updating of the SEACarP model. This model is used to predict Asian carp population density and movement amongst pools in the Illinois River. The model can be used to simulate different management and control actions to assist managers in prioritizing these actions.

- Updated demographic parameters for Silver Carp and Bighead Carp across the Illinois River as well as some pools in the Upper Mississippi and Ohio rivers including an additional 13,000 fish from 2018 and 2019 (Erickson et al. *in review*.; code available at https://github.com/rerickson-usgs/CarpLifeHistoryModels); defining demographic rates in additional locations improves estimates of Illinois River demographics and also provides information on potential source populations that will hopefully be incorporated into the SEACarP model in the future.
- Conducted sensitivity analysis, which is included in this report.
- Continued development of SEACarP by putting code into an R package.
- Worked closely with MRWG technical workgroups to prioritize future data collections and research using the SEACarP model assumptions and limitations as a decision support

tool. These efforts ensure that field-related efforts are coordinated to achieve management goals and provide maximum ability to test assumptions, alleviate limitations, and increase our general understanding of Asian carp population dynamics.

Asian Carp Population Modeling to Support an Adaptive Management Framework – U.S. Geological Survey (USGS) Support – This project includes USGS activities to support the SEACarP model. These activities include refining demographic data included in the model and supporting model development and refinement.

Telemetry Support for the SEACarP Model – This project supports the SEACarP model by providing additional monitoring of Asian carp via telemetry. Movement is the backbone of the SEACarP model and is the primary source of information about how researchers expect the population to respond to management strategies. Therefore, the model functions as an important tool that can be used by fisheries managers to inform harvest and control of adult Asian carp (Silver Carp and Bighead Carp) in the IWW. Because harvest effects such as changes in fish density and size distributions are likely impact movement and will thus influence our ability to predict population responses, continued monitoring of Asian carp movement in the IWW is necessary. This research provides an improved understanding of Asian carp movement in the IWW and its effects on population dynamics.

- 161 adult Silver Carp were captured in Peoria Pool and implanted with Vemco V5 acoustic transmitters.
- Data from the five 69 kHz acoustic receivers was collected, processed, and provided to the Telemetry Work Group.

Asian Carp Demographics – This project focuses on building a more robust understanding of Asian carp population demographics throughout the Illinois River, including establishing/refining consensus metrics for identification, sexing, and age determination of Asian carp.

- Collected a comprehensive Silver Carp dataset using fish captured from six pools of the Illinois River. Data collections included: length, age, maturity, sex, and relative abundance.
- Deployed a time efficient standardized sampling method using electrified dozer trawl to collect demographic data.
- Project data can be used to measure population responses to changes in management strategies.

Evaluation of a Modular Electric Barrier – This project focuses on testing and evaluating the use of a modular, transportable electric barrier to prevent the passage of Asian carp. Electric barriers have been used to impede or direct the movements of fishes for many years. However, almost all electric barriers used by fisheries agencies are constructed at fixed locations and are therefore stationary. Stationary electrical barriers currently serve as a line of defense in blocking the expansion of Asian carp into the Laurentian Great Lakes. Although useful for specific control purposes, such designs lack spatial flexibility and thus the capacity for adaptive management applications. Modular electric barriers may provide managers with the option to deploy control measures in a variety of locations to achieve various management objectives.

- A modular electric deterrent barrier system has been procured by the Illinois Natural History Survey (INHS). Because this barrier system is modular, it can be transported and deployed at a variety of locations. This system consists of a series of pulsers, generators, and winch-housed electrode cables that can be scaled to produce an electric field capable of deterring fishes across a range of waterbody conductivities and channel dimensions.
- Pond trials demonstrated that detection rates of Silver Carp and Bighead Carp in the vicinity of the electric barrier could be reduced by greater than 99 percent when the barrier is in operation, with most positive detections associated with fish mortality. However, detection rates of fishes were also found to be inversely related to barrier power output, suggesting that operating the barrier at lower power settings is not advisable and that any factor that could affect the strength of the electric field (changes in conductivity, boat entrainment, etc.) could provide opportunities for fish passage.
- Field deployments that were planned for 2019 were disrupted by record flooding along the Illinois River and the subsequent damage to roads and levees. Additional plans for field deployments at locations that will likely be less prone to disruption by flooding are being made for 2020.

Alternate Pathway Surveillance in Illinois – Law Enforcement – The IDNR Invasive Species Unit (ISU) was created in 2012 as a special law enforcement component to the overall Asian carp project.

- An out-of-state pond stocking company investigated by the ISU was criminally charged and pled guilty to unlawfully importing Viral Hemorrhagic Septicemia (VHS) susceptible species into Illinois without permits. The court ordered restitution to the Department in the amount of $11,494.00. The investigation revealed the company imported, sold, and stocked live gizzard shad, fathead minnows, bluegill, red ear sunfish, and largemouth bass without a non-resident aquatic life dealer’s license and often without VHS import permits.
- A total of 39 businesses within the Great Lakes region selling live Red Swamp Crayfish on the Internet and shipping them to customers through mail delivery services were identified and sent official notification letters containing jurisdictional regulations and agency aquatic invasive species (AIS) personnel contact information. The effort signified a proactive approach to protecting resources while simultaneously providing those within the industry easy access to regulatory information and personnel. News of the initiative reached the highest levels of state government and will serve as a model for limiting the spread of additional species in the future.

Asian Carp Enhanced Contract Removal Program – This project focuses on enhancing Asian carp removal in strategic locations, as determined by modeling efforts, including the SEACarP model. The project provides an economic incentive to commercial fisherman that remove Asian carp from targeted locations. Removal efforts currently focus on Peoria Pool.

- More than 518,000 pounds have been removed under this program. Removal from the lower Illinois River has been recommended and to that end Peoria Pool has been targeted to begin these efforts.
- Nineteen contracts were entered into with Illinois-licensed commercial fishers targeting the Peoria Pool.
- Processed more than $51,000 in payments to fisherman.
- Issued Request for Proposal for Branding & Marketing Strategy Development and Implementation.

***Barrier Maintenance Fish Suppression* –** This project provides a fish suppression plan to support USACE during maintenance operations at the EDBS. The plan includes sampling to detect Asian carp downstream of the barriers prior to turning off power, surveillance of the barrier zone with hydroacoustics, side-scan sonar, and DIDSON sonar during maintenance operations, and operations to clear fish from between barriers using mechanical or chemical means.

- The MRWG agency representatives met and discussed the risk level of Asian carp presence at the EDBS at each primary barrier loss of power to water.
- Five 15-minute electrofishing run were completed between Barriers 2A and 2B to supplement existing data in support of the MRWG clearing decision.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on a bi-weekly basis, both below and within the EDBS indicating fish over 300mm, but in low abundance.
- An acoustic deterrent system was installed approximately a 0.75 miles downstream of the EDBS between November 19, 2018 and April 3, 2019 in support of annual maintenance operations.
- **No Asian carp were captured or observed during fish suppression operations**

RESPONSE PROJECTS

***Contingency Response Plan Actions* –** Regularly-scheduled eDNA sampling in the CAWS yielded a high number of samples positive for Asian carp DNA near Bubbly Creek in October 2019. Out of the abundance of caution, IDNR led the ACRCC agencies in an intensive two-week sampling of the waters surrounding the eDNA detections in Bubbly Creek.

- A two-week, multiagency response utilized the Incident Command System with guidelines set forth in the 2019 MRP Upper Illinois River Contingency Response Plan (CRP).
- Dissolved oxygen levels were extremely low during sampling within the area where positive detections were located.
- No Bighead Carp or Silver Carp were captured or observed during the response.

INTRODUCTION

The 2019 Interim Summary Report (ISR) presents a comprehensive accounting of project results from activities completed by the Asian carp Monitoring and Response Workgroup (MRWG) in 2019. These projects have been carefully selected and tailored to contribute to the overall goal of preventing Asian carp from establishing self-sustaining populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Efforts to prevent the spread of Asian carp to the Great Lakes have been underway for over nine years. Over the course of this time, goals, objectives, and strategic approaches have been refined to focus on five key objectives:

1) Determination of the distribution and abundance of any Asian carp in the CAWS, and use this information to inform response removal actions;
2) Removal of any Asian carp found in the CAWS to the maximum extent practicable;
3) Identification, assessment, and reaction to any vulnerability in the current system of barriers to prevent Asian carp from moving into the CAWS;
4) Determination of the leading edge of major Asian carp populations in the Illinois River and the reproductive successes of those populations; and
5) Improvement of the understanding of factors behind the likelihood that Asian carp could become established in the Great Lakes.

The projects presented in this document represent the results of efforts undertaken during 2019 to further the implementation of each of these objectives.

BACKGROUND

The term "Asian carp" generally refers to four species of carp native to central and eastern Asia that were introduced to the waters of the United States and have become highly invasive. The four species generally referred to with the "Asian carp" moniker are Bighead Carp (*Hypophthalmicthys nobilis*), Silver Carp (*Hypophthalmicthys molitrix*), Grass Carp (*Ctenopharyngodon idella*), and Black Carp (*Mylopharyngodon piceus*). In this document, the term "Asian carp" refers only to Bighead Carp and Silver Carp, except where otherwise specifically noted.

Asian carp are native to central and eastern Asia, with wide distribution throughout eastern China. They typically live in river systems, and in their native habitats have predators and competitors that are well adapted to compete with Asian carp for food sources, thus limiting their population growth. In the early 1970s, Asian carp were intentionally imported to the US for use in aquaculture and wastewater treatment detention ponds. In these settings, Asian carp were used to control the growth of weeds and algae and pests. Flooding events allowed for the passage of Asian carp from isolated detention ponds to natural river systems. By 1980, Asian carp had been captured by fishermen in river systems in states including Arkansas, Louisiana, and Kentucky.

Flooding events during the 1980s and 1990s allowed Asian carp to greatly expand their range in natural river systems. Asian carp are currently wide spread in the Mississippi River basin, including the Ohio River, Missouri River, and Illinois River. Areas with large populations of Asian carp have seen an upheaval of native ecosystem structure and function. Asian carp are voracious consumers of phytoplankton, zooplankton, and macroinvertebrates. They grow quickly and are highly adapted for feeding on these organisms, allowing them to outcompete native species, and quickly grow too large for most native predators to prey upon. As a result, their populations have exploded in the Mississippi River basin.

The expansion of Asian carp populations throughout the central U.S. has had enormous impacts on local ecosystems and economies. Where Asian carp are present, the native ecosystems have been altered, resulting in changes to the populations and community structure of aquatic organisms. The trademark leaping behavior of silver carp when startled has also impacted recreational activities where they are populous, presenting a new danger to people on the water. Current academic studies estimate that the economic impact of Asian carp is in the range of billions of dollars per year. A central focus of governmental agencies is preventing the spread of Asian carp to the Great Lakes. Ecological and economic models forecast that the introduction of Asian carp to the Great Lakes could have enormous impacts.

In response to the threat posed to the Great Lakes by Asian carp, the Asian Carp Regional Coordinating Committee (ACRCC) and the Asian Carp MRWG present the following projects to further the understanding of Asian carp, improve methods for capturing Asian carp, and directly combat the expansion of Asian carp range.

PROJECT LOCATIONS

In an effort to more clearly depict the geospatial scale and focus of the projects included in the MRP, the MRWG has prepared a project location cross-walk. This cross-walk is intended to be used as a tool to allow readers to quickly understand where a specific project focuses its efforts, and also to quickly discern all projects that are operating in a specific portion of the Illinois Waterway. The project cross-walk tool includes links to specific project ISRs for readers using a digital version of the ISR, and page numbers for readers using a physical version. In that sense, it can also function as an additional table of contents for the document. The project cross-walk tool is presented below.

Project	Illinois River Pool (Upstream > Downstream)									Primary Purpose	Page Number
	CAWS	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	LaGrange	Alton		
Seasonal Intensive Monitoring in the CAWS											
Strategy for eDNA Sampling in the CAWS											
eDNA Detection Response - Bubbly Creek											
Telemetry Interim Summary Report											
USGS Illinois River Catch Database and Visualization											
USGS Telemetry Database and Analyses in Support of SEAcarP											
Barrier Maintenance Fish Suppression										Management and Control	204
Monitoring Fish Abundance and Spatial Distribution Near the Electric Dispersal Barrier and in Lockport, Brandon Road, and Dresden Island Pools											
Contracted Commercial Fishing Below the Electric Dispersal Barrier											
USGS Real-Time Telemetry in Support of Management											
Distribution and Movement of Small Silver Carp and Bighead Carp in the Illinois Waterway											
Multiple Agency Monitoring of the Illinois River for Decision Making											
Larval Fish Monitoring in the Illinois Waterway											
Using Zooplankton to Measure Ecosystem Responses to Asian Carp Barrier Defense and Removal in the Illinois River (Appendix A)											
Monitoring Bigheaded Carp Movement and Density in the Illinois River											

Project	Illinois River Pool (Upstream > Downstream)									Primary Purpose	Page Number
	CAWS	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	LaGrange	Alton		
USGS Geospatial Support for Unified Fishing Method				↔						Management and Control	145
Asian Carp Population Modeling to Support an Adaptive Management Framework				↔	↔	↔	↔	↔	↔	Management and Control	165
Asian Carp Population Modeling to Support an Adaptive Management Framework - USGS Support				↔	↔	↔	↔	↔	↔	Management and Control	175
Asian Carp Demographics				↔	↔	↔	↔	↔	↔	Management and Control	185
Habitat Use and Movement of Juvenile Silver Carp in the Illinois River							↔			Detection	100
Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEAcarP)							↔			Management and Control	177
Asian Carp Enhanced Contract Removal Program							↔			Management and Control	203
Des Plaines River and Overflow Monitoring										Detection	107
Evaluation of a Modular Electric Deterrent Barrier										Management and Control	195
Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring										Detection	113
Alternative Pathway Surveillance in Illinois – Law Enforcement										Management and Control	200

DETECTION PROJECTS

Seasonal Intensive Monitoring in the CAWS

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Participating Agencies: Illinois Department of Natural Resources (lead); Illinois Natural History Survey, US Fish and Wildlife Service, US Army Corps of Engineers, and Southern Illinois University (field support); US Coast Guard (waterway closures when needed), US Geological Survey (flow monitoring when needed); Metropolitan Water Reclamation District of Greater Chicago (waterway flow management and access); and US Environmental Protection Agency and Great Lakes Fishery Commission (project support).

Pools Involved: Chicago Area Waterway System (CAWS)

Introduction and Need:

Detections of Asian carp (Silver Carp and Bighead Carp) eDNA upstream of the Electric Dispersal Barrier in 2009 initiated the development of a monitoring plan that utilized boat electrofishing and contracted commercial fishers to sample for Asian carp at five fixed sites upstream of the barrier. Random area sampling began in 2012 in order to increase the chance of detecting Asian carp in the CAWS beyond the designated fixed sites. Extensive sampling performed upstream of the Electric Dispersal Barrier from 2010 through 2013 (682 hours of electrofishing, 445.8 km (277 mi) of gill/trammel net, 2.2 km (1.4 mi) of commercial seine hauls) resulted in only one Bighead Carp being collected in Lake Calumet in 2010. Therefore, fixed site and random area sampling effort was reduced upstream of the barrier to two Seasonal Intensive Monitoring (SIM) events from 2014-2019. Following effort reduction, one Silver Carp been collected in the Little Calumet River in 2017, resulting in a rapid, interagency contingency response effort. The reduction of effort upstream of the Electric Dispersal Barrier System will allow for increased monitoring efforts downstream of the barrier. The increase in sampling downstream of the Electric Dispersal Barrier will focus sampling effort on the leading edge (Dresden Island Pool) of the Asian carp population, which will serve to reduce their numbers in that area, reducing the risk of individuals moving upstream towards the Electric Dispersal Barrier System and Lake Michigan by way of the CAWS. Results from SIM upstream of the Electric Dispersal Barrier will contribute to our understanding of Asian carp abundance in the CAWS and guide conventional gear or rapid response actions designed to remove Asian carp from areas where they have been captured or observed.

Objectives:

(1) Determine Asian carp population abundance through intense targeted sampling efforts at locations deemed likely to hold fish.

(2) Remove Asian carp from the CAWS upstream of the Electric Dispersal Barrier when warranted.

Project Highlights:

- Completed two 2-week SIM events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier in 2019.
- No Silver Carp or Bighead Carp were captured or observed in 2019. From 2011-2016 and 2018-2019, no Bighead Carp or Silver Carp have been captured or observed. One Bighead Carp was captured in Lake Calumet in 2010, and one Silver Carp was captured in the Little Calumet River in 2017.
- In 2019, an estimated 2,693 person-hours were spent completing 103 hours of electrofishing, setting 128.1 km (79.6 mi) of gill net, and 2.9 km (1.8 mi) of commercial seine.
- Across all locations and gears, 27,326 fish were sampled representing 53 species and 3 hybrid groups in 2019.
- Since 2010, an estimated 31,927 person-hours have been spent to complete 1,293.2 hours of electrofishing and set 1075.0 km (668.0 mi) of gill/trammel net, 16.3 km (10.1 mi) of commercial seine, and 114.2 net nights of tandem trap nets, hoop nets, fyke nets, and pound nets.
- From 2010-2019, a total of 471,730 fish representing 86 species and seven hybrid groups were sampled, including 2,842 Banded Killifish (state threatened species).
- Since 2010, 124,698 young-of-year (YOY) Gizzard Shad were examined and found no YOY Asian carp were found.
- Since 2010, 16 non-native species have been captured accounting for 15% of the total number of fish caught and 19% of the total species.
- Recommend continued use of SIM in the CAWS upstream of the Electric Dispersal Barrier for localized detection and removal of Asian carp.

Methods:

Pulsed DC-electrofishing, gill and trammel nets, deep water gill nets, fyke nets, commercial seine, and pound nets were used to monitor for Asian carp in the CAWS upstream of the Electric Dispersal Barrier System (Figure 1). Gill and trammel nets were 3 m (10 ft) deep x 91.4 m (300 ft) long in bar mesh sizes ranging from 88.9-108 mm (3.5-4.25 in). Deep water gill nets were 9.1 m (30 ft) deep x 91.4 m (300 ft) long with bar mesh sizes ranging from 69.9-88.9 mm (2.75-3.5 in). The commercial seine was 9.1 m (30 ft) deep x 731.5 m (2400 ft) long and had a cod end made of 50.8 mm (2.0 in) bar mesh netting. Pound nets had a single 100.0 m (328.0 ft.) by 3.0 m (9.8 ft.) lead and two adjustable length wings 3.0 m (9.8 ft.) in depth, and a mesh cab, or catch area, 6.1 m long by 3.0 m wide by 3.0 m deep (19.6 x 9.8 x 9.8 ft.) square made from webbing.

The cab had two, 3.0 m (9.8 ft.) long by 2.5 cm (1.0 in.) diameter steel pipes sewn to the bottom of the horizontal panels of the cab serving as weights and one 3.0 m (9.8 ft.) long by 7.6 cm (3.0 in.) diameter capped polyvinyl chloride pipe stitched to the top of the rear horizontal cab panel serving as a float. Fyke nets had a single 15.2 m (50.0 ft.) long by 1.4 m (4.5 ft.) deep lead. The frame of the net was constructed of two, 1.2 m (4.0 ft.) by 1.8 m (5.0 ft.) rectangular bars made of 8 mm (0.3 in.) black oil temper spring steel. Inner wings (vertical wall throats) of the frame extended from outer corners of the front rectangle to the middle of the rear rectangle. A 76.0 mm (3.0 in.) vertical gap existed on either side of lead between the wings and lead at middle of rear rectangle. A 1.2 m (4.0 ft.) webbing covered gap connected the cab and frame together. The cab was constructed of six, 0.9 m (3.0 ft.) diameter spring steel hoops spaced 61 cm (24 in.) apart from each other. Cab and frame together were 6.0 m (20.0 ft.) in total length.

Intensive electrofishing and netting took place at five fixed site areas and four random site sampling areas. Random sites were generated with GIS software from shape files of designated random site areas. For a more detailed description of fixed and random sampling areas, see the 2019 Monitoring and Response Plan.

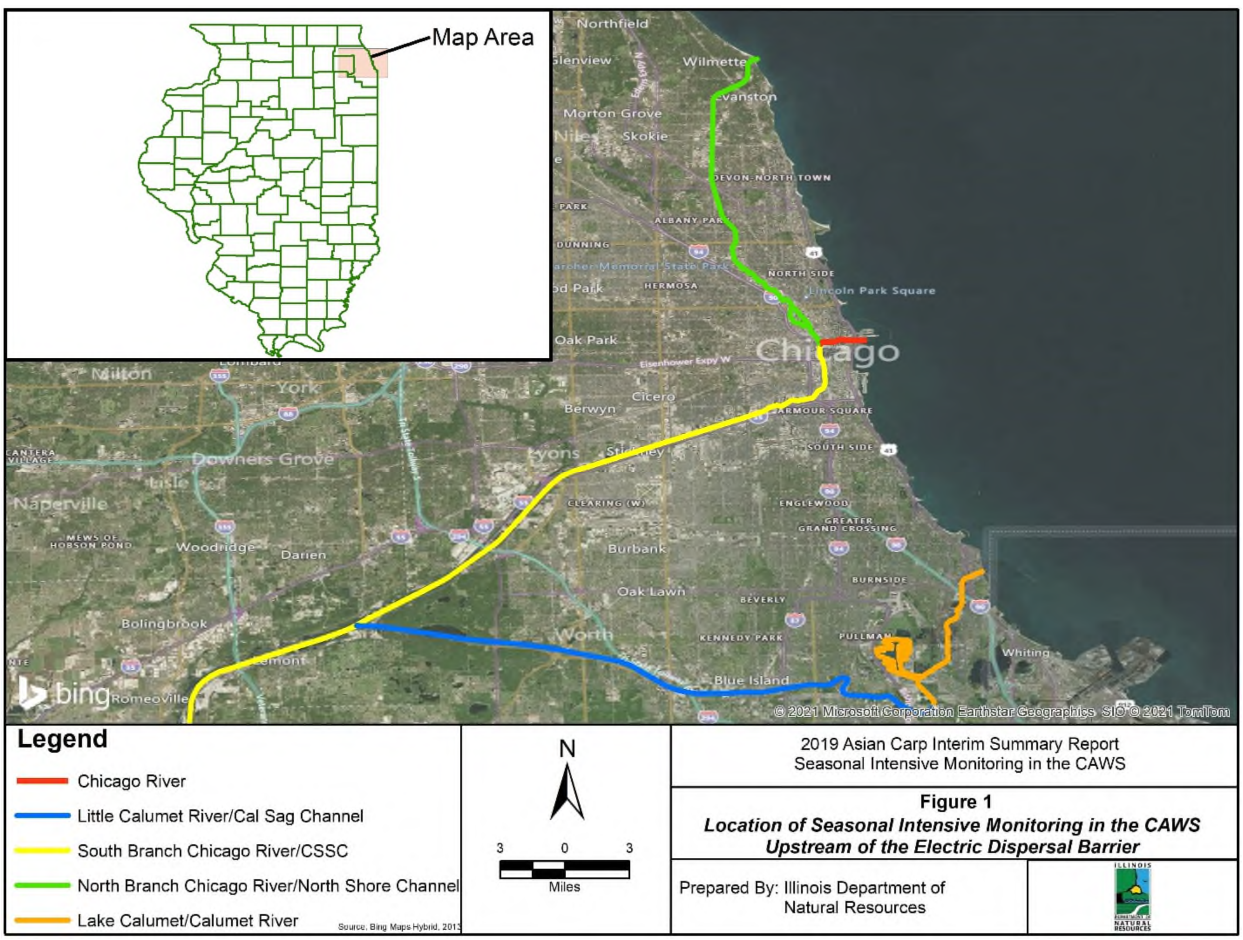

Figure 1. *Location of SIM in the CAWS upstream of the Electric Dispersal Barrier.*

Decontamination Protocol: Consistent with findings from the 2013 ECALS, the potential for Asian carp genetic material in eDNA samples exists as the result of residual material on sampling equipment (boats, netting gear, etc.). In response to these findings, the MRWG developed a Hazard Analysis and Critical Control Points (HACCP) plan to address the transport of eDNA and unwanted aquatic nuisance species. The decontamination protocol included the use of hot water pressure washing and chlorine washing (10% solution) of boats and potentially contaminated equipment for all agency boats participating in the SIM (*see* Monitoring and Response Plan for Asian Carp in the Upper Illinois River and Chicago Area Waterway System (MRP), Best Management Practices to Prevent the Spread of Aquatic Nuisance Species during Asian Carp Monitoring an Response Field Activities). Additionally, all nets used are site-specific to the CAWS and are only used for monitoring efforts upstream of the Electric Dispersal Barrier.

Electrofishing Protocol – Each boat used pulsed DC-electrofishing at fixed and random sites with two dip-netters to collect stunned fish. The location of each electrofishing transect was identified with GPS coordinates. Electrofishing runs began at each coordinate and continued for 15 minutes in a downstream direction in the main channels (including following the shoreline into off-channel areas) or in a counter-clockwise direction in Lake Calumet. Adult Common Carp were counted without capture and all other fish were netted and placed in a holding tank, identified and counted, and returned live to the water. Due to similarities in appearance and habitat use young-of-year (YOY) Gizzard Shad < 152.4 mm (6 in) long were examined closely for the presence of YOY Asian carp and enumerated.

Netting Protocol – Contracted commercial fishers set gill/trammel nets at fixed and random sites. Sets were of short duration and include driving fish into the nets with noise (e.g., plungers on the water surface, pounding on boat hulls, or revving trimmed up motors) to increase detection probability (Butler et al. 2018). In Lake Calumet, a 731.5 m (2400 ft) commercial seine was also used. Nets were attended at all times. Locations for each net set were located and identified with GPS coordinates. Captured fish were identified to species, enumerated, and released. Pound nets and fyke nets were set by agency biologists and checked once every 2 net nights.

Results and Discussion:

SIM took place during the weeks of June 3rd, June 10th, September 9th and September 16th in 2019. As established in the 2014 MRP, sampling for Bighead Carp and Silver Carp eDNA preceded SIM (*see* Strategy for eDNA Monitoring in the CAWS interim summary). To continually focus monitoring effort on the leading edge of the Asian carp population below the Electric Dispersal Barrier, the same reduced sampling effort protocols established in 2014 upstream of the barrier (CAWS) were followed in 2019 (Figure 2). Effort in 2019 was 103 hours of electrofishing (412 transects) requiring an estimated 1,118 person-hours, 128.1 km (79.6 mi) of gill netting (711 sets) utilizing an estimated 1,440 person hours, and 2.9 km (1.8 mi) of commercial seine with an estimated 135 person hours (Table 1). Fyke nets were not deployed in

2019 due to a high water levels and observed native species mortality in 2018. Fyke net use should be evaluated based on conditions in the future. Pound nets and trammel nets were similarly not deployed in 2019.

Across all locations and gears, 27,326 fish representing 53 species and three hybrid groups were sampled in 2019 (Table 2). Gizzard Shad and Common Carp were the predominant species, comprising 51% of all fish sampled. Nine non-native species were sampled, which included Common Carp and hybrids, Round Goby, Alewife, Goldfish, White Perch, Oriental Weatherfish, Grass Carp, Chinook Salmon, and Coho Salmon. Non-native species made up 17% of the total species collected and 18% of the total fish by count in 2019. All species collected in 2019 had been detected in prior years, except for a single Tadpole Madtom, which was collected for the first time in 2019. Two hundred and twenty-one (221) Banded Killifish, a state threatened species, were collected and returned to the water alive. In addition, 2,166 young of the year (YOY) Gizzard Shad were examined and none found to be YOY Asian carp. No Bighead or Silver Carp were captured or observed.

Since 2010, an estimated 31,927 person-hours were expended monitoring fixed and random sites upstream of the Electric Dispersal Barrier. Total effort was 1,293.2 hours of electrofishing (5,156 transects), 1,075.0 km (668.0 mi) of gill/trammel net (5,862 sets), 16.3 km (10.1 mi) of commercial seine hauls and 114.2 net nights of hoop, pound and fyke nets from 2010-2019 (Table 3). The use of hoop nets was suspended after 2013 due to low gear efficiency. A total of 471,730 fish representing 86 species and 7 hybrid groups have been sampled since 2010 (Table 3). Gizzard Shad, Common Carp, Bluegill, Largemouth Bass, Bluntnose Minnow, and Pumpkinseed were the predominant species sampled, accounting for 74% of all fish collected. Since 2010, 16 non-native species have been caught, which include Common Carp and hybrids, Alewife, Goldfish, White Perch, Round Goby, Oriental Weatherfish, Chinook Salmon, Threadfin Shad, Rainbow Trout, Grass Carp, Brown Trout, Coho Salmon, Tilapia, Rainbow Smelt, Silver Arrowana and Threespine Stickleback. Non-native species constitute 15% of the total number of fish caught and 19% of the total species. Banded Killifish, a state threatened species, has been routinely collected during monitoring effort in the CAWS. To date, 2,842 Banded Killifish have been sampled at fixed and random sites upstream of the Electric Dispersal Barrier. No Bighead Carp or Silver Carp were captured or observed in the CAWS upstream of the Electric Dispersal Barrier from 2011-2016 and 2018-2019. One (1) Bighead Carp was caught in a trammel net in Lake Calumet in 2010, and one (1) Silver Carp was captured in a trammel net in the Little Calumet River on June 22nd, 2017. Furthermore, 124,698 YOY Gizzard Shad have been examined since 2010 with no YOY Asian carp being identified.

Recommendation:

We recommend continued use of SIM upstream of the Electric Dispersal Barrier. SIM with conventional gears represents the best available tool for localized detection and removal of Asian carp to prevent them from becoming established in the CAWS or Lake Michigan. Furthermore, we recommend continued assessment of experimental gears during SIM as an alternative means for capturing Asian carp.

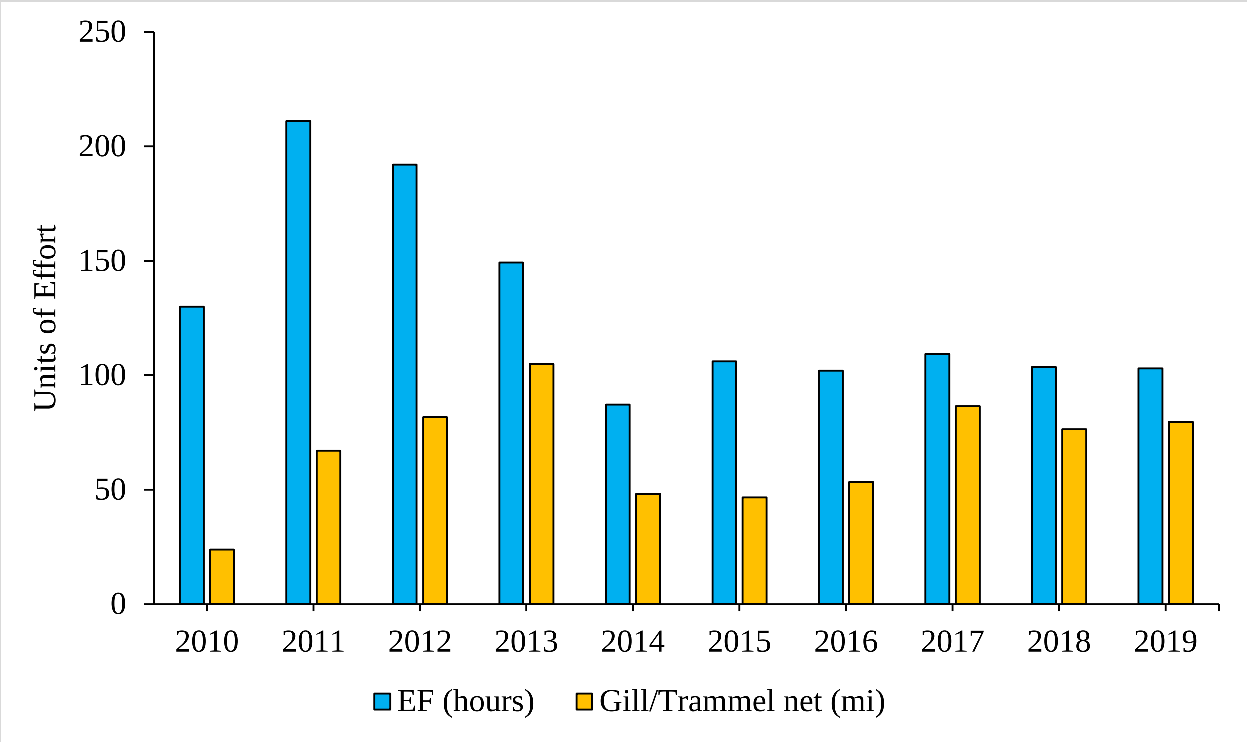

Figure 2. *Total electrofishing and trammel/gill netting effort at fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier System, 2010-2019.*

Seasonal Intensive Monitoring in the CAWS

Table 1. *Summary of effort and catch data for Seasonal Intensive Monitoring in the CAWS upstream of the Electric Dispersal Barrier System, 2019.*

Types of Effort	Lake Calumet/ Calumet River	Little Calumet River/Cal Sag	S. Branch Chi. River/CSSC	Chicago River	N. Branch Chi. River/ N. Shore	Total
Electrofishing Effort						
Estimated person-hours	368	180	240	45	285	1,118
Samples (transects)	163	68	82	3	96	412
Electrofishing hours	40.8	17.0	20.5	0.8	24.0	103
Electrofishing Catch						
All fish (*N*)	7,491	2,766	2,992	319	4,679	18,247
Species (*N*)	35	36	30	5	33	139
Hybrids (*N*)	0	0	0	1	1	2
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	183.8	162.7	146.0	425.3	195.0	177.2
Netting Effort						
Estimated person-hours	540	405	248	23	225	1,441
Samples (net sets)	259	184	149	1	118	711
Miles of net	29.5	20.9	17.0	0.1	12.2	79.7
Netting Catch						
All fish (*N*)	733	310	470	2	107	1,622
Species (*N*)	17	8	3	2	3	33
Hybrids (*N*)	0	1	1	0	1	3
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/100 yds of net)	1.0	0.5	1.3	1.8	0.6	5.2
Seine Effort						
Estimated person-hours	135	-	-	-	-	135
Samples (seine hauls)	4	-	-	-	-	4
Miles of seine	1.8	-	-	-	-	1.8
Seine Catch						
All fish (*N*)	7,457	-	-	-	-	7,457
Species (*N*)	16	-	-	-	-	16
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	1864.3	-	-	-	-	1,864.3

Seasonal Intensive Monitoring in the CAWS

Table 2. *Total number of fish captured with electrofishing (EF), trammel/gill nets (Nets), and commercial seine (Seine) in the CAWS upstream of the Electric Dispersal Barrier during Seasonal Intensive Monitoring, 2019.*

Species	Chicago River		CSSC-South Branch		Lake Calumet-Cal River		Little Cal-Cal Sag			N Branch-N Shore		All Sites
	Electrofishing	Nets	Electrofishing	Nets	Electrofishing	Nets	Seine	Electrofishing	Nets	Electrofishing	Nets	All Gears
Alewife*	0	0	4	0	740	0	0	4	0	62	0	810
Banded Killifish	0	0	42	0	82	0	0	56	0	41	0	221
Bigmouth Buffalo	0	0	0	0	0	32	17	0	0	0	0	49
Black Buffalo	0	0	0	0	0	55	45	0	12	0	0	112
Black Bullhead	0	0	3	0	274	0	0	12	0	13	0	302
Black Crappie	0	0	9	0	14	0	40	1	0	21	0	85
Blackstripe Topminnow	0	0	14	0	0	0	0	0	0	31	0	45
Bluegill	41	0	91	0	828	0	0	58	1	553	0	1,572
Bluntnose Minnow	0	0	158	0	125	0	0	81	0	192	0	556
Bowfin	0	0	0	0	47	0	2	3	0	2	0	54
Brook Silverside	0	0	0	0	2	0	0	2	0	0	0	4
Brown Bullhead	0	0	0	0	1	0	0	1	0	0	0	2
Bullhead Minnow	0	0	4	0	0	0	0	22	0	6	0	32
Carp x Goldfish hybrid*	0	0	0	1	0	0	0	0	2	0	1	4
Central Mudminnow	0	0	0	0	0	0	0	2	0	0	0	2
Channel Catfish	0	0	24	8	15	25	253	29	7	33	3	397
Chinook Salmon*	0	0	0	0	2	2	0	0	0	0	0	4
Coho Salmon*	0	0	0	0	8	0	0	0	0	0	0	8
Common Carp*	12	1	729	459	786	175	13	776	257	547	101	3,856
Creek Chub	0	0	0	0	0	0	0	5	0	0	0	5
Emerald Shiner	0	0	54	0	40	0	0	62	0	70	0	226
Fathead Minnow	0	0	1	0	4	0	0	6	0	3	0	14
Flathead Catfish	0	0	0	0	0	12	0	0	0	0	0	12
Freshwater Drum	0	1	2	2	21	287	1,338	19	26	0	0	1,696
Gizzard Shad	230	0	612	0	166	4	5,658	352	1	860	2	7,885
Gizzard Shad < 6 in	27	0	664	0	258	0	0	558	0	659	0	2,166
Golden Redhorse	0	0	0	0	1	0	0	0	0	0	0	1
Golden Shiner	0	0	83	0	109	0	0	35	0	230	0	457
Goldfish*	0	0	20	0	5	0	0	28	2	32	0	87
Grass Carp*	0	0	0	0	2	3	0	0	0	0	0	5
Green Sunfish	0	0	21	0	25	0	0	22	0	23	0	91
Hybrid Sunfish	0	0	0	0	0	0	0	0	0	2	0	2
Largemouth Bass	3	0	210	0	1,336	1	13	287	0	346	0	2,196
Northern Pike	0	0	0	0	4	1	1	0	0	2	0	8
Orangespotted Sunfish	0	0	0	0	0	0	0	2	0	0	0	2
Oriental Weatherfish*	0	0	6	0	0	0	0	0	0	5	0	11
Pumpkinseed	0	0	155	0	929	0	1	251	0	36	0	1,372
Quillback	0	0	0	0	9	1	0	0	0	0	0	10
River Carpsucker	0	0	0	0	0	1	3	0	0	1	0	5
River Shiner	0	0	1	0	0	0	0	0	0	1	0	2
Rock Bass	0	0	0	0	452	0	0	4	0	15	0	471
Round Goby*	0	0	4	0	47	0	0	11	0	8	0	70
Sand Shiner	0	0	1	0	0	0	0	0	0	1	0	2
Smallmouth Bass	5	0	0	0	404	0	5	5	0	0	0	419
Smallmouth Buffalo	0	0	0	0	236	130	56	1	2	0	0	425
Spotfin Shiner	0	0	4	0	0	0	0	0	0	46	0	50
Spottail Shiner	0	0	6	0	0	0	0	5	0	8	0	19
Striped Bass x White Bass	1	0	0	0	0	0	0	0	0	0	0	1
Tadpole madtom	0	0	1	0	0	0	0	0	0	0	0	1
Unidentified Centrarchidae	0	0	0	0	3	0	0	0	0	0	0	3
Unidentified Cyprinidae	0	0	0	0	0	0	0	0	0	1	0	1
Unidentified Moronidae	0	0	0	0	5	0	0	0	0	0	0	5
Walleye	0	0	0	0	0	1	0	0	0	0	0	1
White Bass	0	0	2	0	18	1	9	15	0	1	0	46
White Crappie	0	0	0	0	0	0	0	3	0	3	0	6
White Perch*	0	0	1	0	9	0	0	5	0	0	0	15
White Sucker	0	0	19	0	10	2	0	3	0	790	0	824
Yellow Bass	0	0	0	0	0	0	0	4	0	0	0	4
Yellow Bullhead	0	0	47	0	100	0	0	26	0	30	0	203
Yellow Perch	0	0	0	0	374	0	3	10	0	5	0	392
Total Fish	319	2	2,992	470	7,491	733	7,457	2,766	310	4,679	107	27,326
Species (N)	5	2	30	3	35	17	16	36	8	33	3	53
Hybrids (N)	1	0	0	1	0	0	0	0	1	1	1	3

*: non-native species

Seasonal Intensive Monitoring in the CAWS

Table 3. *Summary of effort and catch data for all fixed and random site monitoring in the CAWS upstream of the Electric Dispersal Barrier, 2010-2019.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	**Total**
Electrofishing Effort											
Estimated person-hours	1,280	2,180	4,330	1,528	945	990	990	990	990	1,118	**15,341**
Samples (transects)	519	844	765	588	348	422	407	437	414	412	**5,156**
EF (hrs)	130.0	211.0	192.0	149.3	87.1	106.0	102.0	109.0	103.5	103.0	**1292.9**
Electrofishing Catch											
All fish (*N*)	33,688	52,385	97,510	45,443	24,492	28,549	22,557	26,198	26,944	18,247	**376,013**
Species (*N*)	51	58	59	56	56	61	59	58	60	48	**84**
Hybrids (*N*)	3	3	3	2	2	2	2	2	2	2	**7**
Bighead Carp (*N*)	0	0	0	0	0	0	0	0	0	0	**0**
Silver Carp (*N*)	0	0	0	0	0	0	0	0	0	0	**0**
CPUE (fish/hr)	259.1	248.3	507.9	304.4	281.2	269.3	221.1	239.7	260.3	177.2	**290.8**
Gill/Trammel Netting Effort											
Estimated person-hours	885	1,725	3,188	1,932	1,125	1,125	1,125	1,485	1,148	1,440	**15,178**
Samples (net sets)	208	389	699	959	440	445	498	803	710	711	**5,862**
Miles of net	23.8	67.0	81.7	104.9	48.2	46.6	53.3	86.5	76.6	79.7	**668.3**
Netting Catch											
All fish (*N*)	2,439	4,923	3,060	4,195	1,461	1,062	1,283	1,917	1,174	1,622	**23,136**
Species (*N*)	17	20	20	30	18	13	18	14	23	19	**40**
Hybrids (*N*)	1	1	1	1	1	1	1	1	1	1	**2**
Bighead Carp (*N*)	1	0	0	0	0	0	0	0	0	0	**1**
Silver Carp (*N*)	0	0	0	0	0	0	0	1	0	0	**1**
CPUE (fish/100 yds of net)	5.8	4.2	2.1	2.3	1.7	1.3	1.4	1.3	0.9	1.2	**2.0**
Seine Effort											
Estimated person-hours	-	-	-	135	135	135	135	135	135	135	**945**
Samples (seine hauls)	-	-	-	3	2	3	3	4	3	4	**22**
Miles of seine	-	-	-	1.4	0.9	1.4	1.4	1.8	1.4	1.8	**10.1**
Seine Catch											
All fish (*N*)	-	-	-	7,577	1,725	5,989	3,765	2,763	3,110	7,457	**32,386**
Species (*N*)	-	-	-	15	11	14	15	10	10	16	**27**
Hybrids (*N*)	-	-	-	1	0	0	0	0	0	0	**1**
Bighead Carp (*N*)	-	-	-	0	0	0	0	0	0	0	**0**
Silver Carp (*N*)	-	-	-	0	0	0	0	0	0	0	**0**
CPUE (fish/seine haul)	-	-	-	2,525.7	862.5	1,996.3	1,255.0	690.8	1,036.7	1,864.3	**1,472.1**
Hoop/Trap Net/Tandem Trap Net											
Estimated person-hours	-	-	-	-	-	30	28	135	135	-	**328**
Samples (sets)	-	-	-	11	-	4	3	8	7	-	**33**
Net-days	-	-	-	25.2	-	16	12	52.1	43	-	**148.3**
Catch											
All fish (*N*)	-	-	-	93	-	172	102	294	693	-	**1,354**
Species (*N*)	-	-	-	17	-	17	15	17	19	-	**34**
Hybrids (*N*)	-	-	-	0	-	0	-	1	1	-	**2**
Bighead Carp (*N*)	-	-	-	0	-	0	-	0	0	-	**0**
Silver Carp (*N*)	-	-	-	0	-	0	-	0	0	-	**0**
CPUE (fish/net-day)	-	-	-	3.7	-	10.75	8.5	5.6	16.1	-	**9.1**
Pound Net Effort											
Estimated person-hours	-	-	-	-	-	-	-	135	-	-	**135**
Net-days	-	-	-	-	-	-	-	8.9	-	-	**8.9**
Pound Net catch											
All fish (*N*)	-	-	-	-	-	-	-	646	-	-	**646**
Species (*N*)	-	-	-	-	-	-	-	15	-	-	**15**
Hybrids (*N*)	-	-	-	-	-	-	-	0	-	-	**0**
Bighead Carp (*N*)	-	-	-	-	-	-	-	0	-	-	**0**
Silver Carp (*N*)	-	-	-	-	-	-	-	0	-	-	**0**
CPUE (fish/net-day)	-	-	-	-	-	-	-	72.6	-	-	**72.6**

Strategy for eDNA Sampling in the CAWS

Jenna Merry
U.S. Fish and Wildlife Service, La Crosse FWCO

Participating Agencies: U.S. Fish and Wildlife Service

Pools Involved: CAWS

Introduction and Need:
Monitoring with multiple gears in the CAWS has been essential to determine the effectiveness of efforts to prevent self-sustaining populations of Asian carp from establishing in the Great Lakes. Environmental DNA (eDNA) sampling has been conducted annually, as a surveillance tool to monitor for genetic presence of Bighead Carp and Silver Carp in the Chicago Area Waterway System (CAWS) and maintain vigilance above the Electric Dispersal Barrier since 2009. Beginning in 2013, eDNA results no longer automatically trigger any kind of response action through the Monitoring and Response Plan. Since the implementation of dedicated sampling gears for all efforts above the Electric Dispersal Barrier, and the application of refined DNA markers during sample processing, a low, base-line level of Asian carp DNA signal has been consistently detected in the CAWS and attributed to a combination of vectors. This consistent level of minimal or zero positive eDNA detections annually, along with limited captures of live Asian carp by traditional sampling gears above the Elecric Dispersal Barrier, supports the assumption that there is not a self-sustaining, reproductive Asian carp population above the barrier.

Objectives:
Sample for Bighead and Silver carp DNA in targeted areas of the CAWS to maintain vigilence and compliment other ongoing monitoring efforts above the Electric Dispersal Barrier.

Project Highlights:

- Two planned eDNA sampling events took place in the CAWS at targeted off-channel locations in 2019, resulting in 364 samples collected the week of April 8 and 376 samples the week of October 7.
- Results: In April, four samples were positive for Asian carp DNA in Lake Calumet: one sample positive for only Silver Carp DNA, one sample positive for only Bighead Carp DNA, and two samples positive for DNA of both species. In early October, 49 samples were positive for Asian carp DNA in the South Branch of the Chicago River: 22 samples positive for only Silver Carp DNA and 27 samples positive for DNA of both species.
- Additional sampling was conducted the week of October 28 in response to the unusually high number of positive samples from the initial October event. This resulted in a similar number of positive detections for Asian carp DNA.

Strategy for eDNA Sampling in the CAWS

Methods:

The CAWS was sampled for eDNA of Bighead Carp and Silver Carp in April and October 2019. The Metropolitan Wastwater Reclamation Disctict CSO events page was checked prior to sampling to verify that no Combined Sewer Overflow (CSO) events had occurred within or upstream of the target areas within 48 hours prior to sampling. April and October were targeted because water temperatures are cooler during these months, which slows DNA degradation. Additionally, Silver and Bighead carp in other systems are often in off-channel habitats during these times of the year rather than spread out among various habitats. Similar to previous years, sample collection and processing followed the Quality Assurance Project Plan (QAPP 2019) (http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf).

During the April and October sampling events in the CAWS, a USFWS crew collected samples (250 ml each) from targeted off-channel areas (Table 1). Specifically the Chicago Sanitary and Ship Canal (CSSC) and South Branch of the Chicago River sampling targeted six barge slips and the entirety of Bubbly Creek. The Little Calumet River sampling targeted the Marine Services Corporation marina. Lake Calumet sampling consisted of the entire lake basin. Samples were concentrated and preserved with 95% non-denatured ethanol until they were delivered to Whitney Genetics Lab for analysis. The state of Illinois was notified of results of these events following our Communication Protocol (QAPP 2019) after sample processing was complete. Results for these two events were posted online.

Additional samples were collected in late October in response to the results of the intitial October collection event. For this event, the number and location of samples collected in early October was repeated in areas of the CSSC and South Branch of the Chicago River. No additional sampling was conducted in the Little Calumet River and Lake Calumet.

Table 1. *Total number of samples collected in targeted areas of the Chicago Area Waterway System (CAWS) during April and October 2019.*

	Samples Collected		
Location	April	Early October	Late October
Chicago Sanitary Ship Canal	28 (31*)	28 (31*)	28 (31*)
S Branch Chicago River	116 (128*)	128 (141*)	128 (141*)
Little Calumet River	40 (44*)	40 (44*)	-
Lake Calumet	180 (198*)	180 (198*)	-
Total	364 (401*)	376 (414*)	156 (172*)

**Total collected inlcuding field blanks*

Strategy for eDNA Sampling in the CAWS

Results and Discussion:

Of the 364 eDNA samples (250 ml each) collected upstream of the Electric Dispersal Barrier in April, one sample was positive for only Silver Carp DNA, one sample was positive for only Bighead Carp DNA, and two samples were positive for both species (Figure 1). Of the 356 samples collected in early October, 22 samples were positive for only Silver Carp DNA and 27 samples were positive for both Silver and Bighead Carp DNA (Figure 2). All but one of the positive samples in early October occurred in Bubbly Creek. Of the 156 additional samples collected in late October in response to the high positivity of the early October event, 2 samples were positive for only Silver Carp DNA, 21 samples were positive for only Bighead Carp DNA, and 28 samples were positive for DNA of both species. All but five of these positive samples occurred in Bubbly Creek.

The results from the April sampling event, of four positive samples in Lake Calumet, were fairly similar to the baseline levels of Silver and Bighead carp DNA that have been observed over the past few years (https://www.fws.gov/midwest/fisheries/eDNA/Results-chicago-area.html). Since 2016, there has been one other positive sample collected near Lake Calumet and a handful of positives have occurred sporadically throughout the CAWS. Although the number of positives were few, having four positive samples concentrated in the lake is worth noting. However it is also worth noting that the total number of samples taken in the lake was also three times more than past events. While there is no way to confirm whether or not the positive samples were caused by a live fish, it is a possibility. It is also possible that a carcass or other Asian carp material was deposited in the area by a barge or piscivorous birds travelling from carp-infested waters. USFWS conducted 3.5 hours of follow up electrofishing sampling in Lake Calumet. No Silver or Bighead carp were captured or observed.

The eDNA sampling results in early October differed greatly from baseline levels of eDNA positive samples observed in the past. These results were especially unusual considering that the vast majority of positive samples occurred in Bubbly Creek, which has been sampled since 2017 and has not previously resulted in a single positive sample. The unusually high number of positive samples prompted a follow up eDNA collection event in late October and Illinois DNR coordinated an intense, multi-agency two week sampling response using gill netting and electrofishing gears. The follow-up round of eDNA sampling yielded a similarly large number of samples positive for Silver and Bighead carp DNA, however no Silver or Bighead carp were captured or observed during the two week response effort, nor were any Asian carp observed during either of the eDNA sampling events. Therefore, although it cannot be ruled out completely, it seems unlikely that the drastic increase in positivity was caused by a hoard of live Asian carp in the water. Additionally, Bubbly Creek is a degraded area with poor fish habitat and often experiences low dissolved oxygen. It is unlikely that the water quality in Bubbly Creek could support a large group of live Asian carp for an extended period necessary to cause such a highly positive signal. For comparison, there are areas of the Upper Mississippi River, that have resident and reproducing populations of adult Asian carp, in which eDNA sampling does not return the degree of positivity which occurred in Bubbly Creek. The Racine Avenue Pumping Station (RAPS) is a wastewater treatment facility located at the head of Bubbly Creek. That particular pumping station handles millions of gallons of wastewater each day from a drainage area that includes China Town and several markets that likely sell Asian carp fillets and parts. Occasionally during heavy rain events, the facility discharges untreated sewer water into Bubbly Creek. A RAPS discharge event occurred on 10/6/2019, approximately 48 hours before Bubbly Creek and the surrounding barge slips were sampled for eDNA on 10/8/2019. In late October, a RAPS release event occurred on 10/27/2019, a little more than 48 hours before that same area was sampled for eDNA on 10/30/2019. While USFWS was actively sampling Bubbly Creek on 10/30/19, another RAPS event occurred (http://geohub.mwrd.org/pages/cso).

Recommendation: The unusually high number of positive samples resulting from the two October eDNA collection events and their coincidence with the discharge of untreated sewer water, coupled with the lack of live Asian carp captures or observations during the intensive response effort, indicates that further investigation is warranted as to the potential connection between RAPS discharge events and positive eDNA detections in and around Bubbly Creek. USFWS has initiated discussion with RAPS representatives and hopes to design a sampling scheme to investigate this potential connection. In the meantime it is recommended that future eDNA sampling in the CAWS be distanced, both spatially and temporally, from CSO affected areas more than current protocol requires. Bubbly Creek has been sampled for Asian carp eDNA since 2017 with no positive detections until October 2019. In the past, there has been at least 8 days between a RAPS event and eDNA sample collection in Bubbly Creek whereas the October sampling events occurred within two days of RAPS events. In 2012, a storm sewer study was conducted as part of the eDNA Calibration Study (ECALS) in which ice water contaminated with Asian carp was dumped down a sewer and eDNA samples were collected at the outflow. Asian carp DNA was detected at the outflow immediately and one day after discharge, but was not detected one week later (ACRCC 2014). Additionally the ECALS probabilistic model showed that CSOs are probably the largest secondary contributor of eDNA to the CAWS (Schultz et al 2014). This suggests that, at minimum, future eDNA sampling in areas highly influenced by CSO activity should not be conducted within one week of discharge events, however further discussion should take place as to whether or not is it practical to continue sampling those areas.

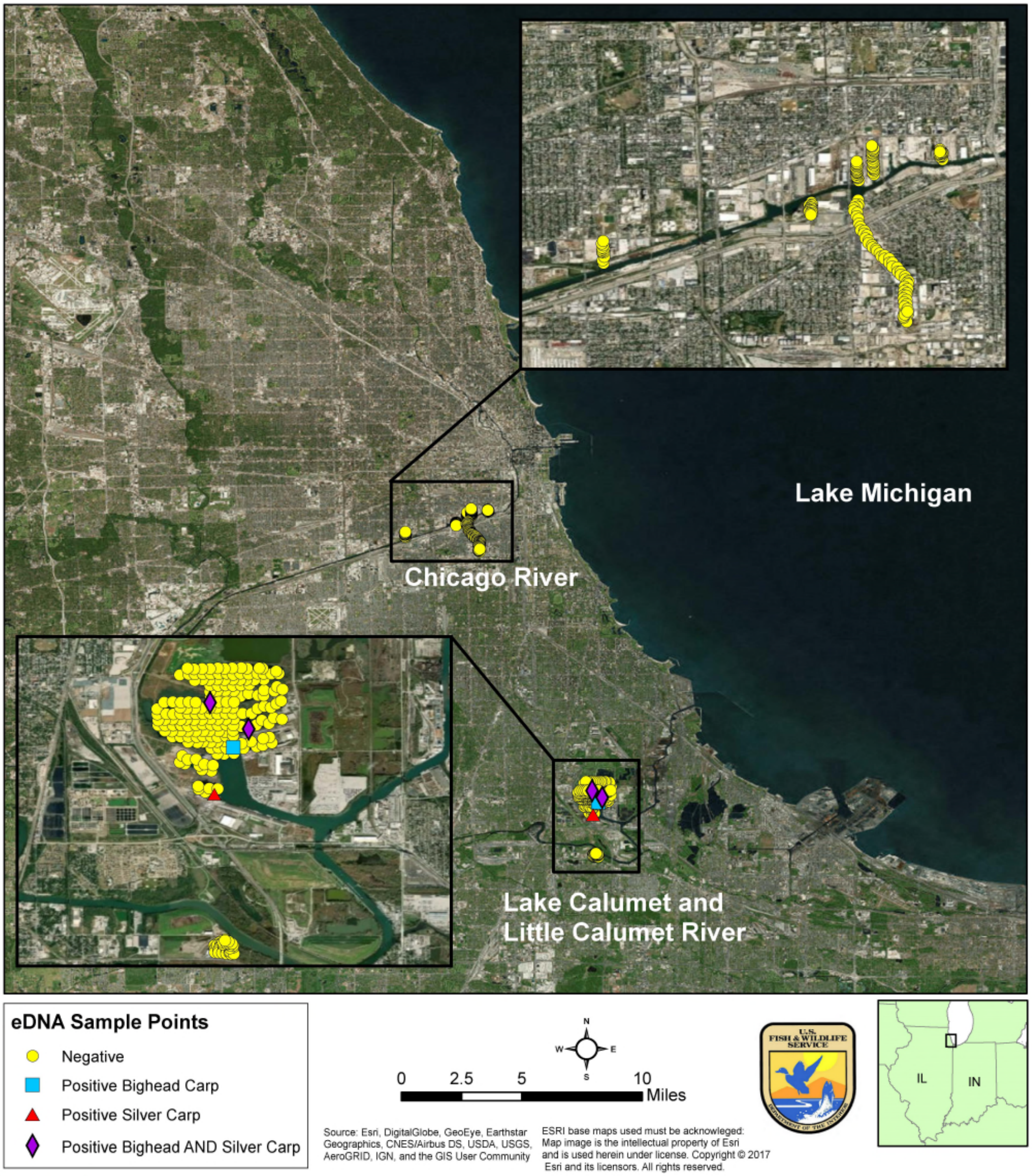

Figure 1. *Sample locations and DNA detection results for Asian Carp eDNA samples collected in the Chicago Area Waterway System (CAWS) in April 2019.*

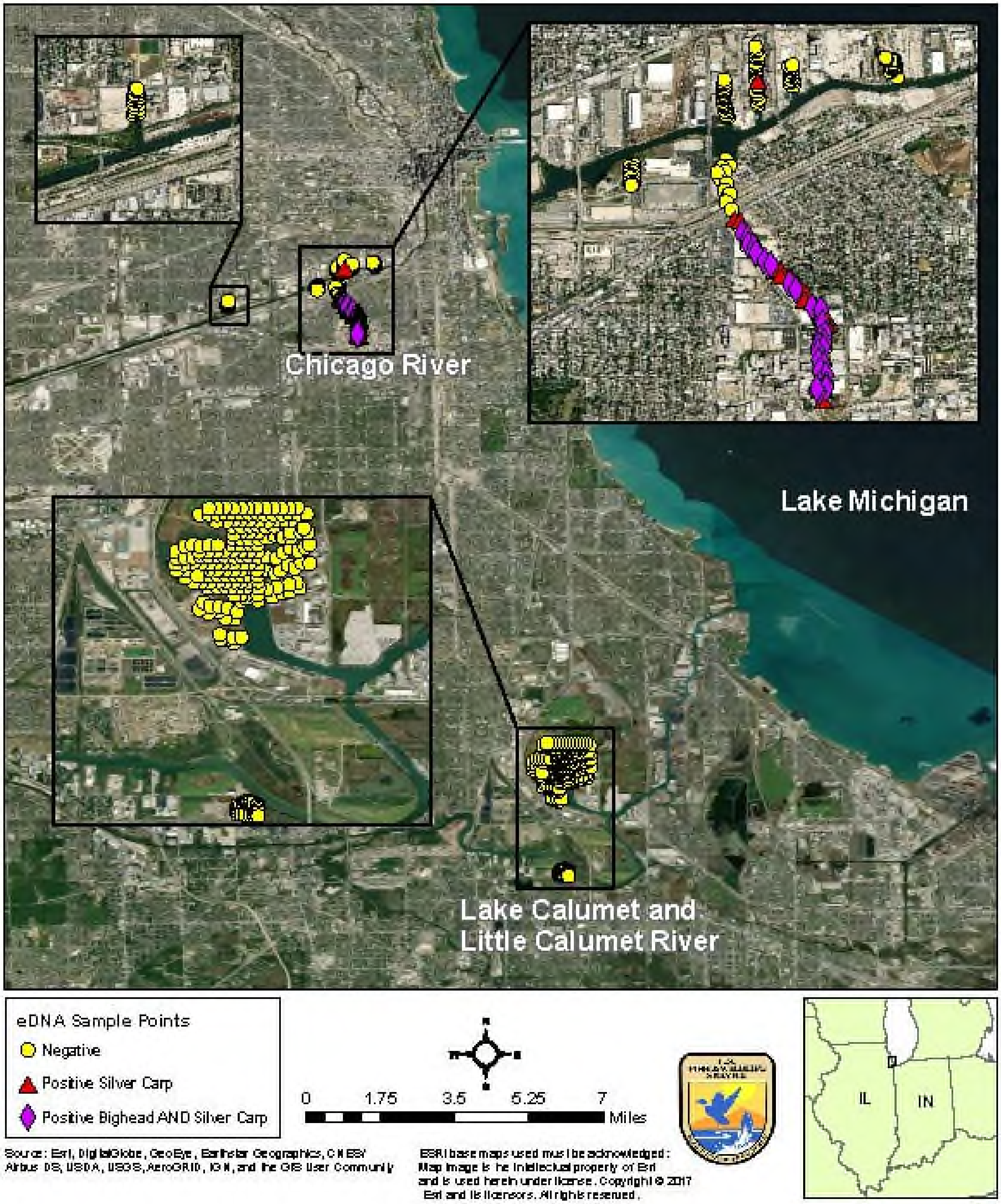

Figure 2. *Sample locations and DNA detection results for Asian carp eDNA samples collected in the Chicago Area Waterway System (CAWS) in early October 2019.*

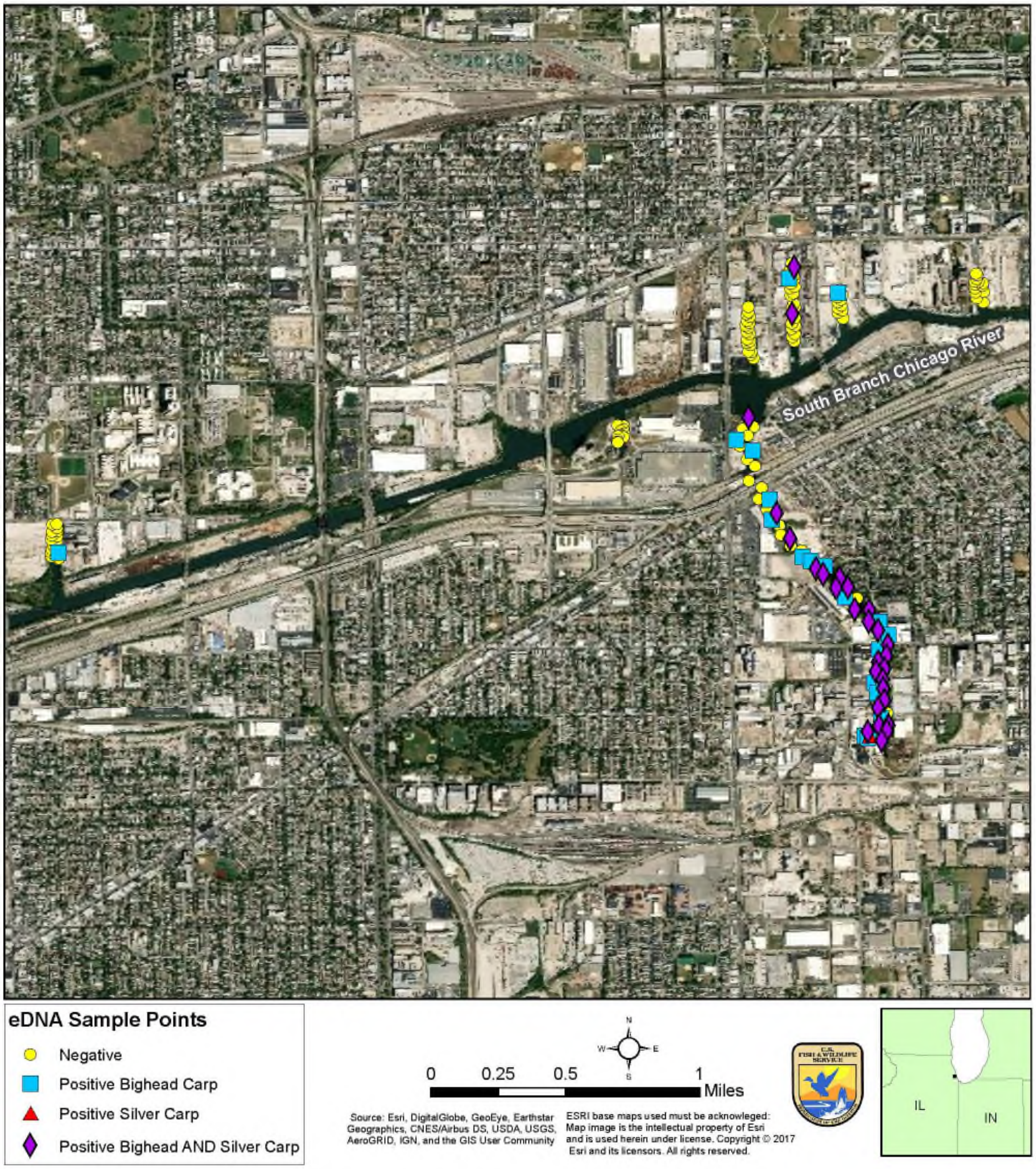

Figure 3. *Sample locations and DNA detection results for Asian carp eDNA samples collected in the Chicago Area Waterway System (CAWS) in late October 2019 as a follow up to sampling conducted in early October 2019.*

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Telemetry Interim Summary Report

John Belcik, Nicholas Barkowski, (US Army Corps of Engineers – Chicago District)

Participating Agencies: US Army Corps of Engineers (USACE; lead), US Fish and Wildlife Service (USFWS), Southern Illinois University at Carbondale (SIUC), Illinois Department of Natural Resources (ILDNR), US Geologic Survey (USGS) and Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) (field and project support).

Pools Involved: Lockport, Brandon Road, and Dresden Island

Introduction and Need:

Acoustic telemetry has been identified within the Asian Carp Regional Coordinating Committee (ACRCC) Control Strategy Framework as one of the primary tools to assess the efficacy of the Electric Dispersal Barrier system (EDBS). The following report summarizes methods and results from implementing a network of acoustic receivers supplemented by mobile surveillance to track the movement of Bighead Carp, *Hypopthalmichthys nobilis*, and Silver Carp, *H. molitrix*, in the Dresden Island Pool and associated surrogate fish species (locally available non-Asian carp fish species which most similarly mimic body shape and movement patterns) in the area around the EDBS in the Upper Illinois Waterway (IWW). This network was installed and is maintained through a partnership between the U.S. Army Corps of Engineers and other participating agencies as part of the Monitoring and Response Workgroup's (MRWG) monitoring plan (MRWG 2019).

The purpose of the telemetry program is to assess the effect and efficacy of the EDBS on tagged fishes in the Chicago Sanitary and Ship Canal (CSSC) and to assess behavior and movement of fishes in the CSSC and IWW using ultrasonic telemetry. The goals and objectives are identified as:

Goal 1: Monitor the Electric Dispersal Barrier System for upstream passage of large fishes and assess risk of Bighead and Silver carp presence (Barrier Efficacy);

- **Objective** Monitor the movements of tagged fish in the vicinity of the EDBS using receivers placed immediately upstream and immediately downstream of the EDBS.
- **Objective** Support EDBS efficacy and mitigation studies through supplemental data collection of tagged fish in the vicinity during controlled experimental trials.

Goal 2: Identify lock operations and vessel characteristics that may contribute to the passage of Bighead and Silver carp and surrogate species through navigation locks in the Upper IWW;

- **Objective** Monitor the movements of tagged fish at Dresden Island, Brandon Road, and Lockport locks and dams using stationary receivers (N=6) placed above and below each lock.
- **Objective** Review and compare standard operating protocols and vessel lockage statistics for Lockport, Brandon Road and Dresden Island locks.

Goal 3: Evaluate temporal and spatial patterns of habitat use at the leading edge of the Bighead and Silver carp invasion front;

- **Objective** Determine if the leading edge of the Asian carp invasion (currently RM 286.0) has changed in either the up or downstream direction.
- **Objective** Describe habitat use and seasonal movement in the areas of the Upper IWW and tributaries where Bighead and Silver carp have been captured and relay information to the population reduction program undertaken by ILDNR and commercial fishermen.

Additional objectives of the telemetry monitoring plan:

- **Objective** Integrate information between agencies conducting related acoustic telemetry studies.
- **Objective** Download, analyze, and post telemetry data for information sharing.
- **Objective** Maintain existing acoustic network and rapidly expand to areas of interest in response to new information.

Project Highlights:

- To date, USACE has acquired 33.5 million detections from 686 tagged fish.
- No live tagged fish have crossed the EDBS in the upstream direction.
- A high percentage of tagged surrogate fish in the Lower Lockport Pool continue to be detected near the EDBS.
- There were seven upstream and 11 downstream passages of Common Carp between the Brandon Road and Lockport pools.
- Asian carp continue to be detected throughout the Dresden Island Pool with the majority of detections occurring near the Harborside Marina and Dresden Island Lock.
- Up to 70% of the transmitters within Dresden Island Pool were detected near Harborside Marina at the Kankakee River confluence. This location registered approximately 81% of all the detections in the pool for the year.

Methods:

Based on MRWG expert opinion, it was recommended that a total of 200 active transmitters in fish be maintained within the study area for telemetry monitoring. At the end of the 2018 season there were approximately 138 tagged fishes (V16 Vemco transmitters) that remained active and 42 of these transmitters were scheduled to expire within calendar year 2019. Additional tagging was required to sustain the recommended levels of the target sampling size as battery life expired and mortalities occurred in previously tagged fish. Because increases in transmitters deployed also increase the burden to stationary receivers for detection, the USACE decided to limit the amount of new tags to be implanted within certain high detection zones of the study area. A total of 20 transmitters (V16; 69 kHz) were implanted into surrogate species in 2019 to maintain adequate transmitter saturation within the Lower Lockport Pool and downstream of the EDBS.

An additional 21 Silver Carp and 2 Bighead Carp were implanted with transmitters within the Dresden Island Pool (V16; 69 kHz). This increased the number of transmitters to 182 that were active for at least a portion of calendar year 2019.

Tagged surrogate fishes have been released below the EDBS; however, no tagged Asian carp were released above the Brandon Road Lock. It was determined that no Asian carp caught in Lockport or Brandon Road pools would be tagged and returned as these areas are above the known upstream extent of the invasion front. Fish captured in Dresden Island Pool were released at or near point of capture only after they were deemed viable and able to swim under their own power. All of the surrogate fishes released within Lower Lockport Pool were originally captured from the Upper Lockport Pool in an effort to induce higher approaches to the EDBS through site fidelity. It has been observed that displaced fishes attempt to return to their original capture location and has been found to increase barrier approaches. Table 1 identifies all fishes containing active transmitters within the winter of 2018 and the field season of 2019 along with their release point within the system.

Table 1: *Active Fishes and Release Points within the Study Area in 2019*

Release Location	Species Implanted	Number of Fish Implanted
Between Barriers	Common Carp	1
Lower Lockport Pool (Downstream of EDBS)	Common Carp	75
Lower Lockport sub-total		**76**
Brandon Road Pool	Common Carp	12
Brandon Road sub-total		**12**
Dresden Island Pool	Bighead Carp	34
	Silver Carp	56
	Silver-Bighead hybrid	2
Dresden Island sub-total		**92**
Total		**182**

Methods for transmitter implantation, stationary receiver deployment and downloads as well as mobile tracking were maintained from previous year's effort. Data retrieval occurred bi-monthly throughout the season by downloading stationary receivers. A detailed description of methods can be found in the MRP Interim Summary Report (2012) with surgical implant procedures adapted from DeGrandchamp (2007), Summerfelt and Smith (1990) and Winter (1996). Those stationary receivers removed for winter in November 2018 were redeployed in March 2019 with the layout of receiver positions within the study remaining the same as the previous year. The revised study area was covered by 27 USACE stationary receivers extending for approximately 33.5 river miles from the Calumet-Saganashkee Channel in Worth to the Dresden Island Lock on the Illinois River (Appendix A – Receiver Network Maps). All stationary receiver locations were identified by a station name. Station names were labeled with a two to three letter indicator of either pool or tributary location (e.g. LL for Lower Lockport or RR for Rock Run Rookery) and numbered from upstream to downstream in the main channel and downstream to upstream within the tributaries. Station identifications allow the database to track all detections made at a single location regardless of the unique receiver ID that may have been deployed at that location at any given time. Finally, there are five real-time receivers that have been installed in previous years by USGS in the area of coverage. One located above and below Brandon Road Lock and Dam, one upstream and downstream of the EDBS, and one upstream of Dresden Island Lock and Dam. The receivers upload detections to a USGS maintained website, providing real-time results and are part of a larger inter-agency effort to strategically cover the Illinois Waterway with this new data transmission technique.

Barrier Efficacy – Barrier efficacy was assessed through a system of eleven stationary receivers with four upstream and seven downstream of the EDBS within the Lockport Pool. Receivers were placed at the lock entrance, in areas offering shallow habitat, in proximity to the EDBS and at the confluence of the CSSC and Cal-Sag Channel (Appendix A). Receiver data were analyzed for individual fish detections that would indicate an upstream or downstream passage through the EDBS. Additionally, data were analyzed to assess temporal and spatial distribution patterns within the Lower Lockport Pool. All detections were recorded and compiled into the detection data set.

As of 1 January 2019, there were a total of 56 tagged surrogate fish (Common Carp) within the Lower Lockport Pool (mean total length ± SD; 621.8 ± 90.5 mm). In order to maintain a similar number of tagged fish within the Lower Lockport Pool across years, an additional 20 Common Carp (615.2 ± 81.6 mm) were tagged and released in 2019 to increase transmitter density bringing the total up to 76. These additional Common Carp were tagged using Vemco V16 transmitters with an estimated battery life of 2,176 days. These Common Carp were captured from Upper Lockport Pool (n=20) and released at the Cargill boat launch within the Lower Lockport Pool downstream of the EDBS. Fish captured above and released below the EDBS increase the likelihood of barrier interaction as they attempt to return to their point of capture.

Detections on each receiver in the Lower Lockport Pool were first screened for false transmitter detections. False detections may occur on a receiver during overlapping ping trains from multiple transmitters or through environmental noise interfering with a ping train of a single transmitter. Detection patterns for each detected transmitter were reviewed bi-monthly following data collection per a standardized screening process. Transmitters were removed from the database if they contained only a single detection, if all detections were separated by prolonged periods or detection patterns across multiple receivers indicated movement that was not feasible considering the swim speed of the fish and barriers to passage. For example, a transmitter may be considered to be a false detection if multiple detections were recorded within the same hour but detected several navigation pools apart from one another. Finally, remaining transmitters were verified with the existing database of deployed transmitters compiled by all participating agencies conducting telemetry work within the IWW and CAWS. Once all false transmitters were removed from the database, the remaining transmitter detections were also reviewed using the same screening criteria to eliminate any false movement or detection patterns.

Detection data were compiled for all stations within the Lower Lockport Pool by the number of detections for all transmitters and the total number of transmitters detected. The total number of detections were calculated for each of the seven stations from the EDBS to the Lockport Lock for the full year and by season. Seasons were defined by monthly data with December to February representing winter, March to May for spring, June to August for summer, and September to November for fall. Each station detection sub-total was then summed across the pool to calculate the total number of detections in 2019 and then further detailed by season. Similarly, the total number of transmitters were recorded for each station independently. Detection data for all stations combined was also reviewed to determine the total number of transmitters detected annually. This process was repeated for each season to obtain total number of detections by station and totaled for the entire pool.

The total annual detections and total seasonal detections across the pool were used to calculate the percentage of detections by each station for the year and within each season. Calculating this percentage metric allows for a better analysis of the data by removing the bias of variable active transmitters throughout the period under review. The total number of detections viewed alone is dependent upon how many active transmitters were present within the pool on any given day. The total number of transmitters present is dependent on immigration/emigration rates, battery life of the transmitters and new transmitters implanted and released within the pool. This same logic applies to the transmitters detected at each station and across the pool for both the full year and within each season. Percentage metrics were calculated for transmitters detected at each station and across the entire pool respectively for each season and annually.

Inter-pool Movement – There are four pools defined within the study area which are demarcated by the lock and dams present within the system and the EDBS. Lockport Pool is defined as all waters upstream of the Lockport Lock including the CSSC and Cal-Sag Channel. Within this analysis, the pool is further separated into Upper Lockport and Lower Lockport. Lower Lockport Pool is characterized by the area downstream of the EDBS and upstream of Lockport Lock and Dam, while Upper Lockport consists of the area upstream of the EDBS to the CSSC and Cal-Sag Channel. The remaining pools include the Brandon Road Pool of the Des Plaines River and the Dresden Island Pool which includes the Des Plaines and Kankakee Rivers. While the Marseilles Pool was outside of the study area this year, additional data was collected at that location by SIUC and USGS which was shared with USACE. VR2W receivers were placed above and below each lock and dam as well as any other potential transfer pathways between pools. Data from the VR2W receivers was analyzed for probable inter-pool movement. Dates with the nearest time interval and the pathway used for each passage were recorded for each tagged fish found to move between pools. Lockage data were reviewed for each passage where a specific time of occurrence could be determined.

Asian carp Movement Analysis – A total of 68 USACE tagged Asian carp (Bighead and Silver carp) were within the Dresden Island Pool at the beginning of 2019 with 23 being added during the year. All Asian carp were tagged following the same methods previously mentioned.

Movement of individual fish were tracked via Vemco VR2W stationary receivers (Appendix A) strategically placed throughout the Des Plaines and Kankakee Rivers. VR2W detections were then uploaded into Vemco VUE. Each station's detection sub-total was then summed across the pool to calculate the percent of total detections in 2019 and then further detailed by season. Detections of tags were recorded and percent of tags detected at each station was calculated for each season of winter (Dec- Feb), spring (Mar-May), summer (June-Aug) and fall (Sept-Nov). Total tags and total detections at each receiver by season were used to observe any movement patterns. Detections for each tag detected were individually analyzed to determine if any fish potentially died during 2019. Fish that demonstrated only downstream movement after tagging or were detected at a single receiver at a consistent rate over several months, were removed from the analysis.

Results and Discussion:

The results discussed in this section will address the three goals of the study. As of November 2019, 33.8 million detections from 686 USACE tagged fish have been recorded within the study area since the telemetry monitoring system was established in 2010. Results to date have shown that zero live fish have crossed the EDBS in the upstream (northward) direction. Two transmitters that were implanted into Common Carp released below the EDBS that were detected upstream of the EDBS as was reported in previous reports (2014 MRP and Interim Summary 2015) are no longer detectable as they have reached their expected lifespan. These transmitters had been presumed to be either expelled from the host fish or the host fish had experienced mortality due to lack of movement on the detected transmitters. One possible avenue for upstream transport is through barge entrainment. Entrainment occurs when a fish becomes trapped in the void space between the rake and box junction of a moving barge. The void space has shown to experience little to no electrical current (USACE 2013) and presents a vulnerability for transporting fish through locks or across the EDBS (Davis et al. 2016). The following sections provide new results from data collected in the 2019 sampling season in which 149 transmitters were detected system wide for a total of 4.7 million data points from 15 November 2018 through 21 November 2019.

Goal 1: Monitor the Electric Dispersal Barrier System for upstream passage of large fishes and assess risk of Bighead and Silver Carp presence (Barrier Efficacy)

There were a total of 75 tagged surrogate fishes with batteries still active in 2019 that were released between Lockport Lock and the EDBS. Seven stationary receivers (VR2W) detected movement of 63 tagged surrogate fish throughout the pool in 2019. There were a total of just over 3.23 million detections within Lower Lockport Pool and zero detections in the Upper Lockport Pool indicating no passage of tagged fish through the EDBS.

The percentage of total seasonal detections found at each station and the percentage of a station's total detections that occurred within a given season were used to compare residency time and habitat use across the pool (Figure 2 and Figure ***1***). The percentage of transmitters within the pool detected at each station provided an indication of relative movement patterns within the pool by the population of tagged fishes (Figure 3). The results of both metrics were reviewed relative to one another to describe how tagged fishes are utilizing the habitat within the Lower Lockport Pool.

The number of detections was lowest in straight channel sections of the canal with deep water which best characterizes station LL03a (~1.2% of annual LL detections). The areas with the highest number of detections were just below the EDBS (LL01) and the shallow water barge slip (LL 03) just downstream of the EDBS with 22% and 25% respectively. Among detections at the EDBS, the number of detections was highest in the summer months (33% of total receiver detections). Alternatively, when detections decreased at the EDBS to the fewest detections for the year, LL 03 (1 mile downstream) experienced an increase in winter with 34% of the station's detections (Figure 2). Many of the fish that were detected during this time were likely overwintering at or near the EDBS. Common Carp often overwinter in deeper areas of a water body, such as what is found in the main channel of the canal at the EDBS or in the barge slip where LL03 is located (Bajer and Sorenson 2009; Penne and Pierce 2008). During the winter there were 14 fish detected at the EDBS, two of them never left detection range the entire season. Half of the fish (nine) detected at LL 03 (18 fish total) were also detected at the EDBS, indicating that at least some of the fish were approaching the EDBS during the winter season. Of those remaining fish, four of them stayed at LL 03 for the whole season and five traveled to other locations in the pool. It should be noted that during the winter months there were five out of the seven receivers deployed in the pool so it is uncertain where these fish were when not detected at the EDBS.

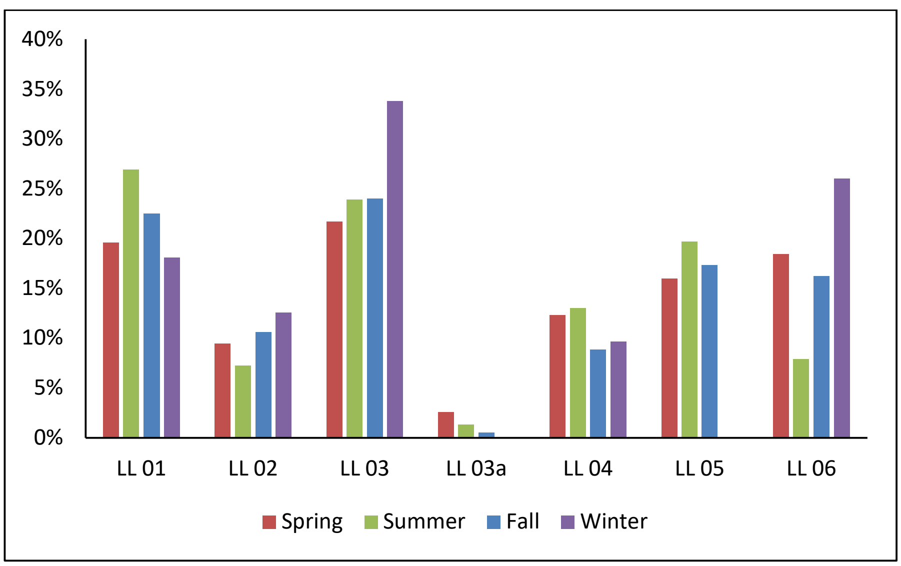

Figure 1: *Percentage of the Lockport Pool's total seasonal detections shown across receivers in 2019.*

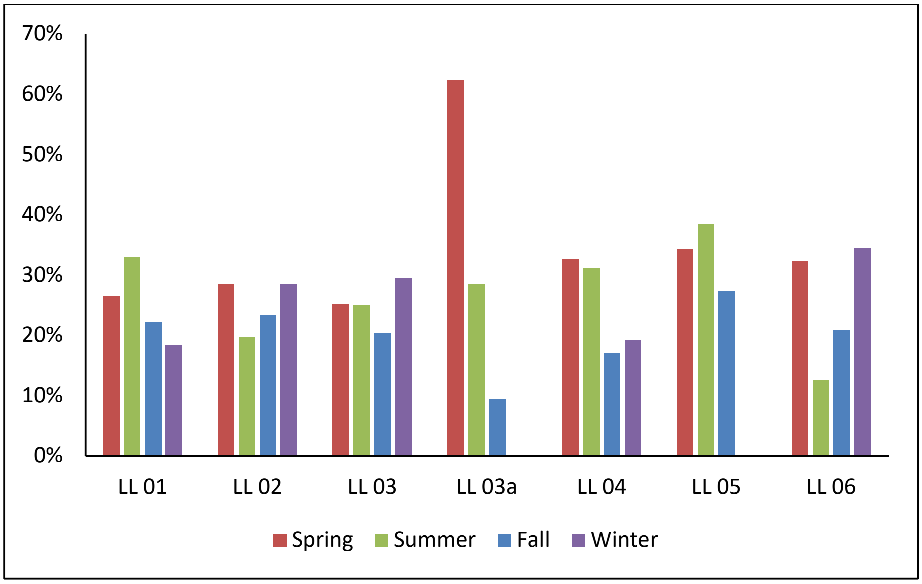

Figure 2: *Percentage of total number of detections per individual receiver across seasons within the Lockport Pool in 2019.*

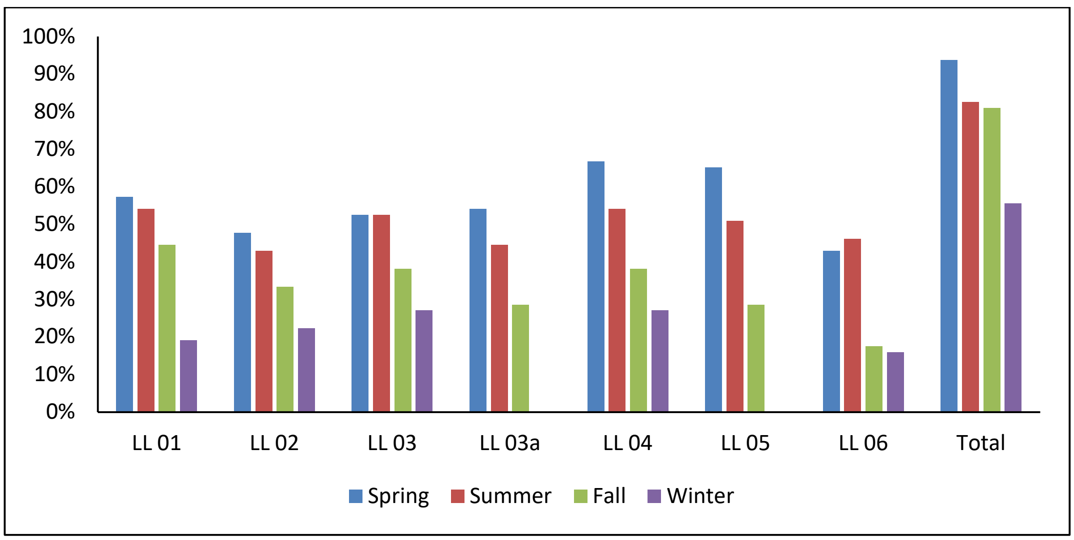

Figure 3*: Percentage of the total number of tags in Lockport Pool detected on a receiver in a season and in total for 2019.*

Table 2: *Number of detections within the Lower Lockport Pool during 2019. *Values do not indicate a lack of fish, but rather that the receiver was removed from the water during that time.*

	SPRING	SUMMER	FALL	WINTER	TOTAL
LL 01	186739	232060	156955	129879	705633
LL 02	90018	62576	73968	90096	316658
LL 03	207034	206407	167548	242710	823699
LL 03A	24645	11261	3709	0*	39615
LL 04	117500	112405	61720	69277	360902
LL 05	152177	170160	120887	0*	443224

LL 06	175820	68096	113178	187015	544109
TOTAL	953933	862965	697965	718977	3233840

Table 3: *Number of tags detected at a station during 2019. *Does not indicate a lack of fish, but rather that the receiver was removed from the system during that time.*

	SPRING	SUMMER	FALL	WINTER	TOTAL
LL 01	36	34	28	12	42
LL 02	30	27	21	14	38
LL 03	33	33	24	17	42
LL 03A	34	28	18	0*	39
LL 04	42	34	24	17	46
LL 05	41	32	18	*0	45
LL 06	27	29	11	10	38
TOTAL	59	52	51	35	63

Goal 2: Determine if Asian carp and surrogates pass through navigation locks in the Upper IWW

There were 27 occurrences of inter-pool movement by 18 tagged fishes between November 2018 and November 2019. The majority of the movements (19) were by 12 Common Carp moving between the Brandon Road and Lockport pools. All of these fish were caught upstream of the EDBS and released below the EDBS; six in 2019, two in 2017 and four in the 2016 season.

For those fish that transferred between the Lockport and Brandon Road pools, 15 of those transits were through the Lockport Lock (6 upstream, 9 downstream). The remaining four were through Bear Trap Dam Control Works when the gates were opened during multiple rain events. Three transits by three fish were downstream on April 29, May 1, and May 2. All three fish returned to the Lockport Pool. Two of those fish transited back to Lockport Pool via Lockport Lock. The remaining upstream transit occurred around October 28 and the observed detection pattern gives the appearance of a potential upstream transit through the Bear Trap Dam Control Works (RM 293.2).

The fish in question (A69-1601-53011, Common Carp) was originally recorded in the Lockport Pool and was brought down into the Des Plaines River and Brandon Road Pool on April 29, 2019 when the Control Works were opened during a rain event. The fish was recorded in the Brandon Road Pool for several months at multiple receivers then was recorded in the Des Plaines River on July 30, 2019 five times over a 10-minute window. The next occurrence was at LL04, located at a mooring cell in the CSSC at Bear Trap Dam Control Works, on October 28 where the fish was continually recorded for the rest of the season. On October 26 and 27, the gates at Bear Trap Dam were open for several hours to allow water to flow from the CSSC into the Des Plaines River. Due to the gates being opened, the CSSC was lowered by approximately 4 feet (Figure 4) with a water velocity of approximately 2.5-3.5 ft/s (Figure 5) at the EDBS. Further downstream, the CSSC was approximately 7 to 10 feet below its average height at the Lockport Lock (MWRD pers. comm.).

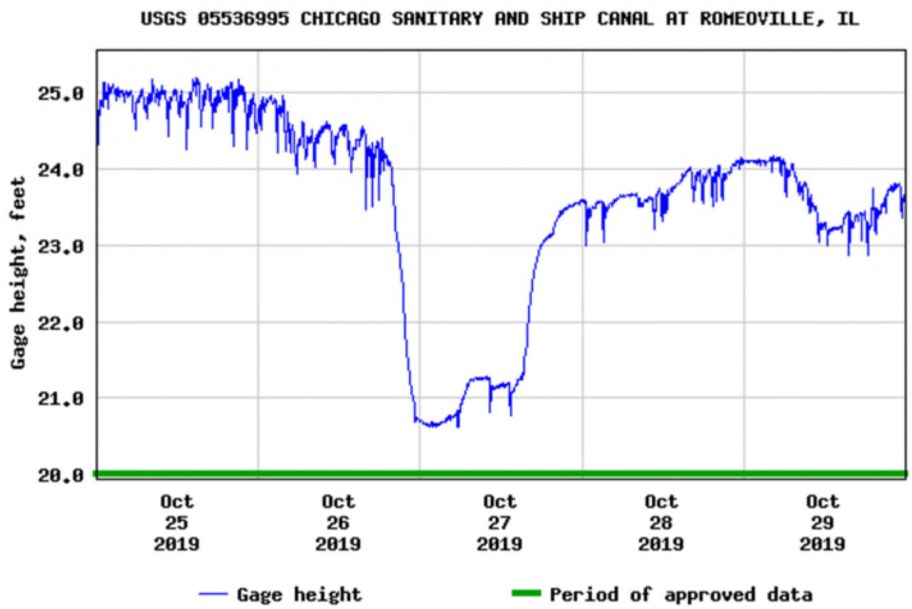

Figure 4: *USGS stream gage data between Oct. 25, 2019 and Oct. 29, 2019 for the Electric Dispersal Barrier System in Romeoville, IL. (https://waterdata.usgs.gov/nwis/rt).*

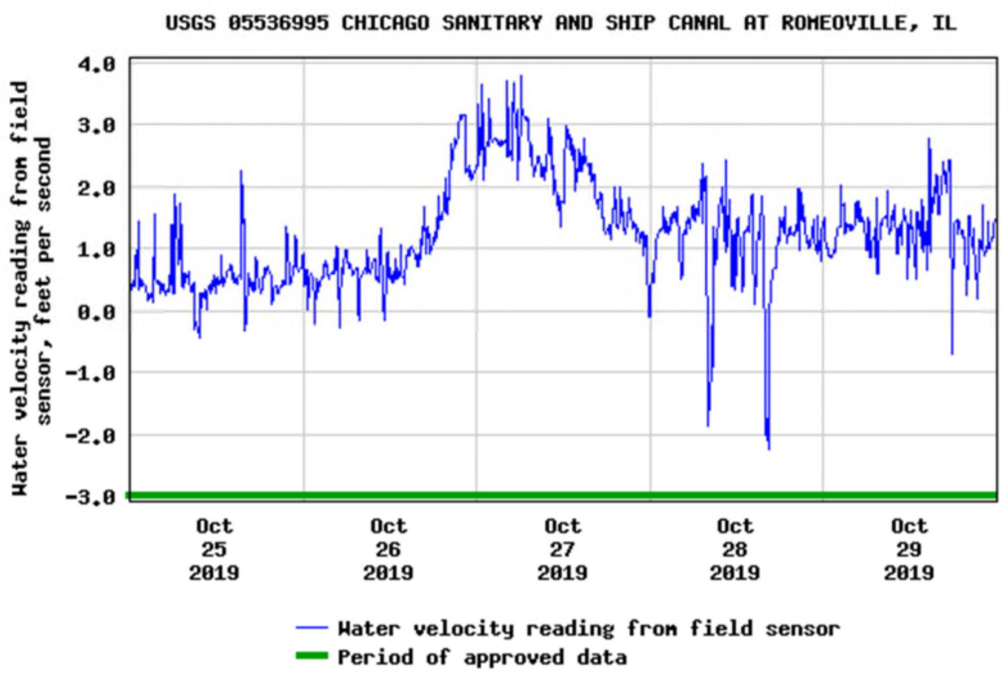

Figure 5: *USGS reported water velocity (ft/sec) between Oct. 25, 2019 and Oct. 29, 2019 for the Electric Dispersal Barrier System in Romeoville, IL. (https://waterdata.usgs.gov/nwis/rt).*

From the time the Fish was detected in the Des Plaines River (July) and when it was detected at LL04 (October) the Bear Trap Dam Control Works gates were opened four additional times (Sept. 27, 28, and 29, and Oct. 3). In addition, there were dozens of lockage events through

Lockport Lock in both the upstream and downstream direction during that time period. This includes 17 (11 down, 6 up) between October 26, 12:01 AM and the time of first detection on October 28 (9:39 AM). It is entirely possible that this fish transited through the Lockport Lock and was not detected on the four receivers between the Des Plaines River and Bear Trap Dam Control Works. Environmental sounds such as engine and mechanical noises can mask a tag's ping train. Alternatively, if the CSSC and Des Plaines River we at similar water elevations when the Bear Trap Dam Control Works gates were open, fish could conceivably pass through into the Lockport Pool. There are currently no USGS stream gages directly downstream of the Bear Trap Dam Control Works on the Des Plaines River or on the upstream side in the CSSC. Therefore it is unknown if the elevations of the water bodies were of similar heights or what the flow conditions were around the time of the suspected transit. However, during a high water event in May of 2020, the gage on the CSSC experienced similar decreases in gage height and biologists visited Bear Trap Dam Control Works to determine the possibility of transport. Pictures 1 and 2 were taken on May 18th, 2020 from the low water crossing used to access the Cargill Boat Ramp in Lockport Pool. The pictures were taken around 1100 CST and the gage height was approximately 24.34 ft (USGS, data is provisional). Due to increased water elevations in the Des Plaines River and with the gates open at Bear Trap Dam Control Works, it appears that water levels were similar on both sides of Bear Trap Dam Control Works (Picture 1) and could theoretically allow fish to move freely between the Des Plaines River and CSSC under the observed conditions. However, based on the conditions of water flowing over the road to Cargill Boat ramp (Picture 2), fish would have to have been on the north side (left of the picture) of the road when the gates were opened. The flow over the road does not appear to allow fish to pass. Several culverts exist under the low water crossing and fish can likely swim through the culvert under lower flow conditions and stage down stream of Bear Trap Dam Control Works. Common Carp have been observed on the north side of the road by USACE biologists, whether they moved to that area when the dam gates were open or if they swan through the culverts is unknown. Without definitive evidence, it is impossible to say how this fish transited the two pools, but given the evidence at hand, it is conceivable this fish transited upstream through the Bear Trap Dam Control Works into Lockport Pool.

Picture 1: *Picture of Bear Trap Dam Control Works. Picture was taken May 18, 2020 from the entrance of the low water crossing to get to Cargill Boat Ramp looking East-Northeast. Water levels appear to be very similar between the water bodies and could conceivably allow fish to move to and from the Des Plaines River and CSSC.*

There were no fish that had migrated between the Brandon Road Pool and the Dresden Island Pool during 2019. There were two Common Carp that were continually found to be just downstream of the Brandon Road Lock gates and were detected in the approach channel and within the lock chamber. However, there is no indication that they were able to transition to the upstream side of the lock at any point during this year.

The other eight cases of interpool movement were between the Dresden Island and Marseilles pools by two Bighead Carp and one bighead-silver hybrid. These lock transits roughly correspond with lockage events at the Dresden Island Lock and Dam and these fish likely swam into the lock when the gates were open and exited into the other pool when the other gates were opened. This is an indication that Asian carp have been and are able to transit between pools by utilizing lockage events. To date very few tagged Asian carp have been documented approaching the Brandon Road Lock chamber. However, given their ability to use a lockage event to transit between navigation pools it remains a possibility for them to transit between Dresden Island Pool and Brandon Road Pool if favorable conditions occur.

Picture 2: *Picture of water flowing over the low water crossing road on the way to the Cargill boat ramp. The picture was taken May 18th, 2020 looking south-southeast. The flow over the road is unlikely to allow fish to move upstream given the conditions.*

Overall, from 2010 to 2019, there have been 83 occurrences of tagged fish moving downstream and 45 occurrences of upstream movement between navigation pools by a total of 97 individual tagged fish (Table 4). Inter-pool movement was greatest between the Lockport and Brandon Road pools accounting for 60% (n=77) of all inter-pool movements (upstream n=22; downstream n=55). The majority of downstream movement into the Brandon Road Pool occurred through the Bear Trap Dam Control Works spillway approximately two miles upstream of Lockport Lock and Dam (n=33). Movement between the Dresden Island and Marseilles pools comprised 30% (n=38) of all inter-pool movement (upstream n=18; downstream n=20). The lowest inter-pool movement occurred through the Brandon Road Lock and Dam accounting for 10% (n=13) of the total. There were no movements through the Brandon Road Lock in 2019. Upstream movement through the Brandon Road Lock has occurred in the past by Common Carp originally captured within the Brandon Road Pool and released within the Dresden Island Pool. This method of capture in one pool and release in a different pool was used to increase the number of upstream lock passage attempts by fishes in the Dresden Island Pool and is not representative of the population originating from the Dresden Island Pool. The same capture and release technique is used to encourage fish to challenge the EDBS by capturing them in the Upper Lockport Pool and releasing them into the Lower Lockport Pool.

Table 4: *Tagged fish inter-pool movement from 2010 to 2019. Downstream is defined as DS, upstream is defined as US, total indicates the total number of interpool transfers seen***.**

Interpool Movement Data			
	Up	Down	Total
LockPort Lock	21	22	43
Control Works	1	33	34
Brandon Rd	5	8	13
Dresden Island	18	20	38

Goal 3: Determine the leading edge of the Asian carp range expansion

Throughout 2019 there were 91 USACE tagged Asian carp within the Illinois Waterways. A total of 71 fish were detected within the Dresden Island Pool throughout 2019. Out of those 71 fish that were detected within the Dresden Island Pool, 39 were released by USACE, 21 by WIU-USGS, 3 by SIUC, and 8 by USFWS. The 39 USACE tagged Asian carp consisted of 11 Bighead Carp (945 ± 85.3 mm), 25 Silver Carp (786 ± 106 mm), and 1 hybrid (878 mm). All were tagged between 2016 and October of 2019.

In total, the receivers placed in Dresden Island Pool and the adjacent tributaries collected 988,211 detections from a total of 62 tagged Asian carp, 7 Grass Carp, and two Common Carp. The percent of the pool's total detections attributed to each receiver ranged from 0.01 to 81%. The station that had the greatest percent of total detections was DI09a (81%). The receiver with the next highest number of detections was DI10 (9%). Figure 6 and Figure 7**Figure *6*** show the percentage of the pool's total number of detections that occurred within a season and the percentage of a receiver's total number of detections that occurred within a season respectively for Dresden Island Pool. The highest number of detections in the pool occurred at station DI09a. This station is located just upstream of the confluence of the Des Plaines and Kankakee rivers. This is a continuation of the detection patterns seen in 2016, 2017, and 2018 (USACE 2017; USACE 2018, USACE 2019). This area encompasses one of the narrowest locations in the pool and has several different habitat types within its vicinity. The receiver is near shallow vegetated habitat, side channel habitat, backwater habitat (harbor slips) and close to an outfall from the I & M Canal. These habitat types may be an attractant to Asian carp, and the placement allows for fish to be detected as they move from the upper portion of the pool to the lower pool. As shown in previous years, this location, the station at the lock (DI10), and Kankakee River (KR01) detect a high number of the total tags in the pool throughout the year (**Error! Reference source not found.**), notably in the summer and fall seasons. The confluence is likely serving as a congregation location for fish to reside in throughout the year. Up to 61% of the fish that were stationary (resident) in the pool during a given season were found at station DI09a (Figure 9).

Resident is defined as a fish only being detected on one receiver during a time frame (seasonally or yearly).

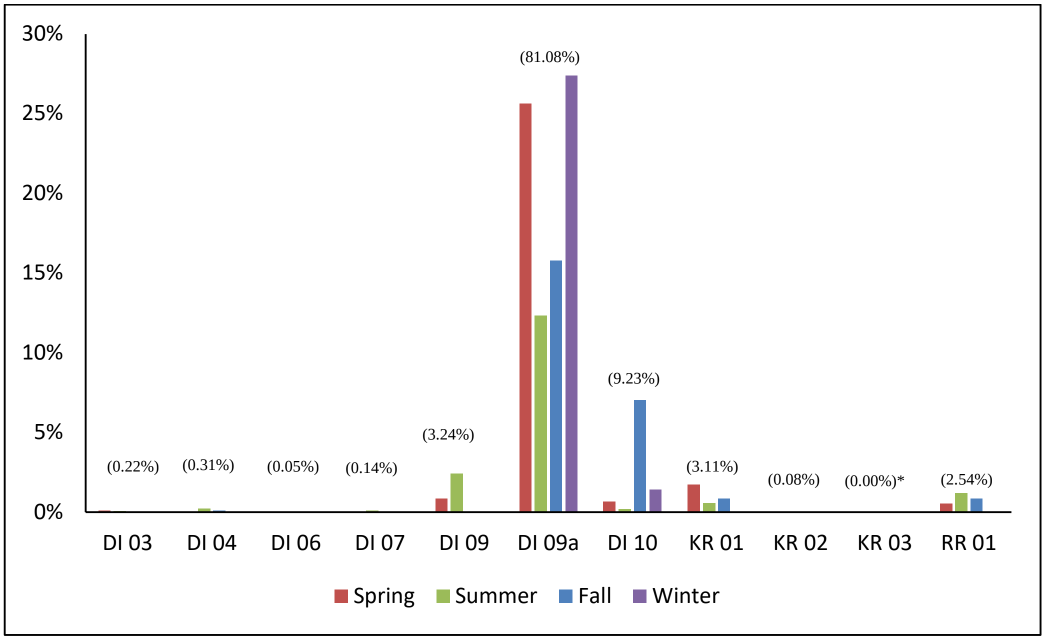

Figure 6: *Percentage of the Dresden Island Pool's total seasonal detections shown across receivers in 2019. Most locations experienced a small number of detections during the year. (Number) indicates percent of pool's total detections across the entire year at that receiver. * under 100 detections for whole year.*

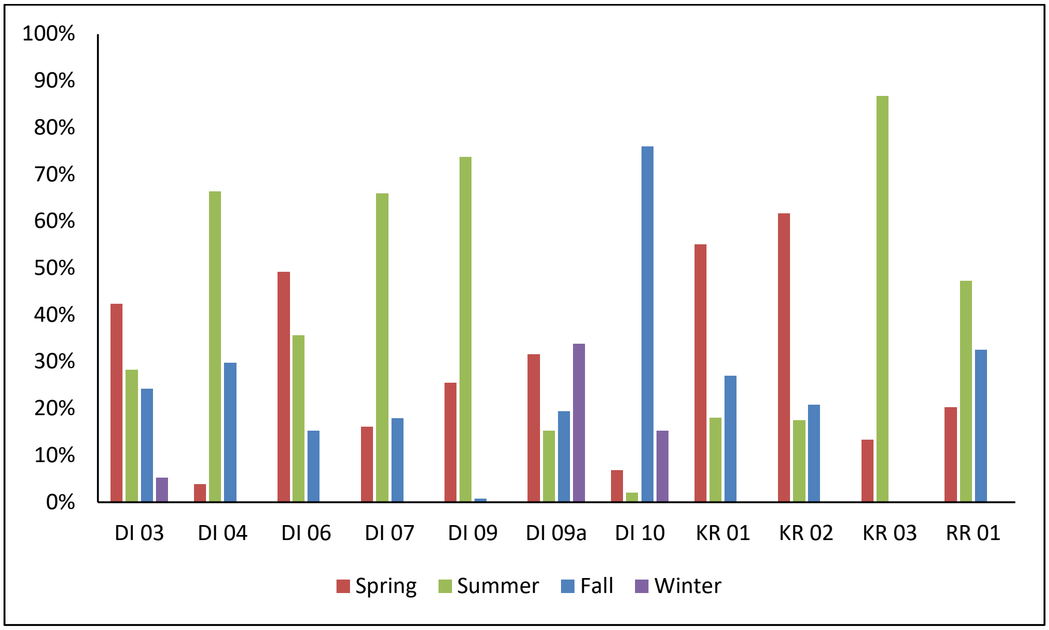

Figure 7: *Percentage of a receiver's total number of detections that occurred within a given season within the Dresden Island Pool in 2019.*

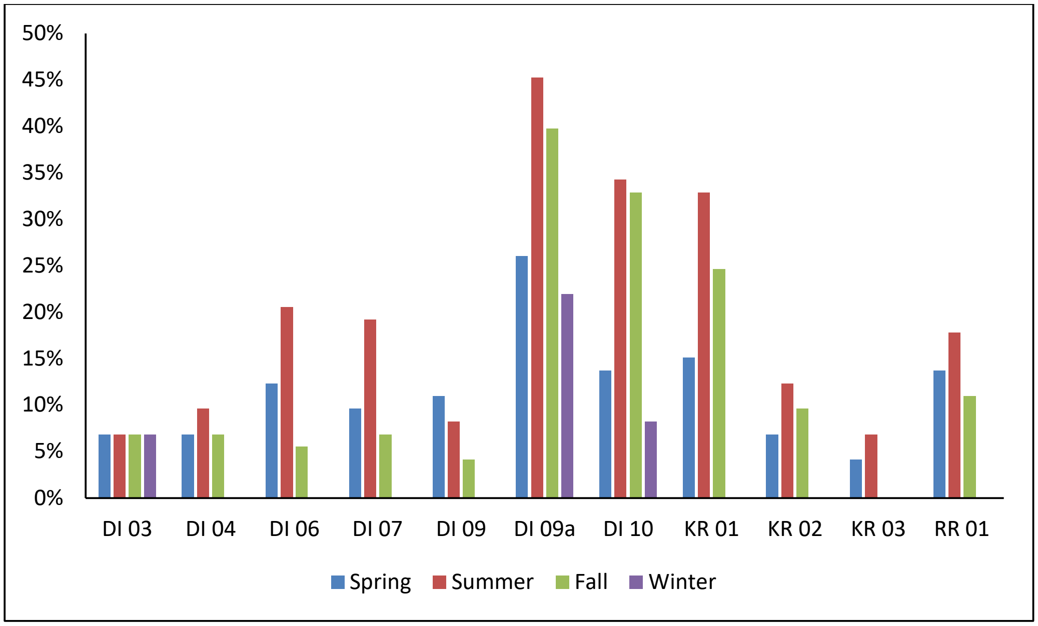

Figure 8: *Percentage of Dresden Island Pool's total tags detected at a given station during the 2019 season.*

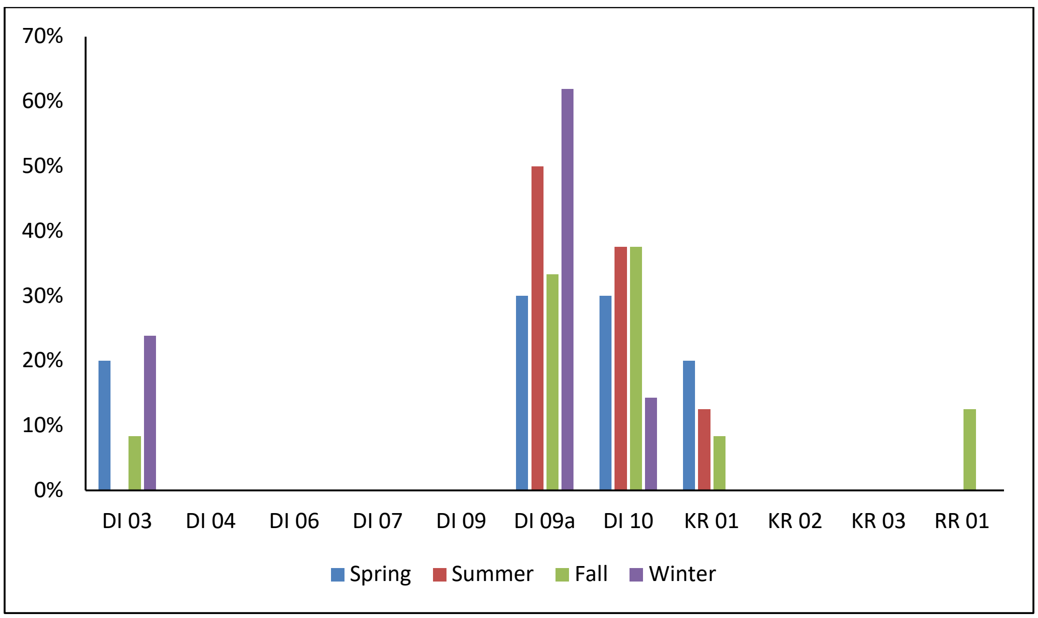

Figure 9*: Percentage of tags detected on a receiver that are considered residents (were not detected on a second receiver) during a season in 2019.*

Total percent active tags detected at each receiver and the percent of total detections were used in conjunction to acquire inferences of seasonal fish movement within the Dresden Island Pool. Percent of active Asian carp tags detected seasonally ranged from 4 to 45% throughout the Dresden Island Pool (Figure 8) (8-70% overall). The number of winter detections were low due to the decreased number of receivers within the pool. During the winter, a limited number of receivers are left in the pool to prevent loss from ice. In spring, summer, and fall, DI09a had the greatest percent of total detections (26%, 12%, and 16% respectively) followed by KR01 (2%, 0.56%, and 0.84%), DI09 (0.83%, 2%, and 0.03%), and DI10 (0.63%, 0.19%, and 7%) respectively (Figure 6). However, during the fall a large tagging effort was conducted in the vicinity of DI10 so it is unknown if the number of detections seen at this location is due to fish congregating or the detection of new fish added to the system. Similarly, 26%, 45%, and 40% of the active tags were detected during spring, summer, and fall at DI09a (Figure 8). These data continue to support the importance of DI09a as potential habitat and potential transition zones for Asian carp movement between the Kankakee River and the upper portions of the pool.

Finally, DI03 detected 7 individual transmitters and KR03 detected 6 individual transmitters during the 2019 season. The receiver at DI03 is located inside of the approach channel of Brandon Road Lock and Dam and KR03 is approximately 0.5 mile downstream of Wilmington Dam. Both locations are not considered to be ideal habitat for Asian carp. The approach channel is narrow and deep with engineered sides. The fish detected within the approach channel included four Grass Carp, two Common Carp, and one Bighead Carp. The lone Bighead Carp (A69-69-1601-23012) was detected nine times on August 12 between 11:35 A.M. and 11:56 A.M. At the beginning of the 2019 telemetry season (November 2018), this fish was first detected within the Marseilles Pool. On July 5th it made three transits between the Marseilles and Dresden Island pools. First was between 7:08 AM and 12:37 PM when it moved to Dresden Island Pool and was detected for approximately 35 minutes on the USGS real-time receiver above Dresden Island Lock. Between 1:32 PM and 8:05 PM the fish transitioned back to Marseilles Pool where it was detected at the downstream real-time receiver for 3hrs 35 minutes. Finally, the fish transitioned back to Dresden Island Pool between 11:41 PM July 5 and 12:50 AM July 6. It was then detected starting at USACE receiver DI10 and on almost every receiver between DI10 and DI04. This fish proceeded to make a series of migrations between Rock Run Rookery and DI04 between July 6 and August 11. Culminating in a series of detections at the USGS real-time receiver and USACE station DI03 on August 12 between 11:13 AM and 12 PM. It resided in the area around DI04 and RM 284.5 until August 17 when it makes its way to Rock Run where it resides until October 24. Between October 24 and November 8 it migrates to the Kankakee River where it was last detected on USACE station KR01 on November 13. It is unknown why this fish approached the lock. The data from USGS stream gage 05538020 stationed in the approach channel during the detection timeframe was examined. There was a slight increase in water velocity of 0.6 ft/s that could trigger a rheotactic response, but there is no stream gage downstream of this area to measure the cumulative flow of the approach channel and dam tail water. Therefore, it is unknown what the flow rate at the location of the detections previous to the approach channel detections was and if this increase in velocity made an appreciable difference and triggered a rheotactic response.

On the Kankakee River, approximately 5.5 miles of shallow, rocky water exists between KR02 and KR03 near the Wilmington Dam. This habitat is typically not considered to be ideal Asian carp habitat. However, six fish were detected on KR03 and consisted of a Grass Carp, three Bighead Carp, and two Silver Carp. These fish were detected 45 times (Grass Carp = 10; Bighead Carp = 10, 9, and 8; Silver Carp = 3 and 5) on May 24, May 25, June 27, June 28, July

2, and July 3. On May 24, two Bighead and one Silver Carp were detected on KR03 and one of the same Bighead Carp was detected again on May 25th. These detections coincide with a flood pulse and increase in water temperature. The river was a foot higher than average with 6,000 additional cfs flowing through the area and water temperatures increased from a daily average temperature of 13.8° C on May 22nd to a daily average of 17.5° C on May 24th and 18.7° C on May 25th. Similarly, between 6:30 PM June 27 and 9:26 AM June 28, five of the six fish were detected 30 times at some point during that time period (Bighead Carp = 6, 8, and 8; Grass Carp = 3; Silver Carp = 5). During this time there was again an approximately one foot increase in river height and 5,000 cft/s discharge increase the daily average water temperature was 23.7°C on June 27th and 28th. At approximately 7 am on July 2 and 8:15 am July 3 a Grass Carp and Silver Carp were each detected twice. At this time the river was already at a slightly higher than average flow and gage height with daily average temperatures just above 25°C, and the river experienced further increases in gage height and flow at approximately 10 AM on July 3. Overall, these detections at KR03 appear to be driven by flood pulses and at time, increases in water temperature.

Given these low levels of detections, Asian carp are likely not drawn to either location in large numbers under normal conditions as they would be expected for areas such as backwaters or low flow side channels. A total of 17 out of the 71 transmitter were detected at KR02, which is located at the start of the rocky section leading to KR03 at some point during the year. Asian carp appear to be coming up to this habitat shift, but not residing in the area for an extended period as the maximum number of detections in a season at KR02 was 479 (spring). It should be noted that because of the rocky habitat and the additional noise from the movement of water over those rocks, there may be enough noise to mask transmitter pings and therefore limit detections or range that fish can be detected and not accurately depict the number of tagged fish congregating in this area. USACE is exploring other receiver placement options for the 2020 season that can give the desired detection coverage to monitor for fish that may be approaching Wilmington Dam.

Due to ongoing work at Brandon Road Lock and Dam, additional emphasis has been placed on Asian carp movements within and around the lock. During the 2019 season one Asian carp was detected approaching the Brandon Road Lock and Dam as detailed above. In previous years, fish have been known to travel into the Brandon Road Lock and Dam approach channel. In 2016, a single Bighead Carp was detected on the receiver within the Brandon Road approach channel in the Dresden Island Pool. This fish was first detected in the approach channel on 9 August at 14:15 and remained near the receiver for approximately 7 hours. This fish then heads downstream (2.8 miles) and is detected just upstream of Rock Run Rookery before returning to the approach channel at 10:01 on 10 August. The Bighead Carp then stages within the approach channel for close to 7 hours again before returning downstream. Another Bighead Carp had a single detection at the lock in 2017 on September 3rd at around 2 am. The movement patterns of these fish appear to be similar to each other in that they stage in or around Rock Run Rookery, move toward the lock, reside there for a short time and then move back downstream close to or in Rock Run. None of these fish entered into the lock chamber because the doors were not open during this time, however increased residency time or other environmental triggers associated with spawning migrations could increase the risk of passage.

Recommendations:

USACE recommends continuation of the telemetry program and maintaining the target level of surrogate species tags within the system by replacing expired tags within the Lower Lockport Pool in early 2020. The number of Asian carp currently tagged within Dresden Island Pool should also be maintained with supplemental and replacement transmitters for these species. USACE is also looking at locations to place a receiver on at the Bear Trap Dam Control Works facility to better understand potential transport of tagged fishes between Lockport Pool and the Des Plaines River. USACE will continue to collaborate with MRWG partners to maximize our understanding of Asian carp movement and biology within the Dresden Island Pool. USACE recommends continued collaboration with SIUC to perform comparisons of surrogate species to Bighead and Silver Carp. Understanding of how well Common Carp and other surrogates represent the behavior of Bighead Carps is important in determining the usefulness of the data collected from those surrogate species near the EDBS. USACE will also continue to investigate the large expanse of data collected over the last 10 years to examine study area wide movement and habitat use for both Asian carp and surrogate species. Continued analysis should occur at the Brandon Road Lock chamber for the telemetry program and the collaboration with partner agencies performing parallel studies will be ongoing. Collaboration with MRWG partners has helped fill in receiver coverage in areas that are lacking in the USACE network. USACE recommends continued collaboration with these partners to further investigate knowledge gaps in fish movement and behavior throughout the Upper Illinois River and the Chicago Area Waterway System.

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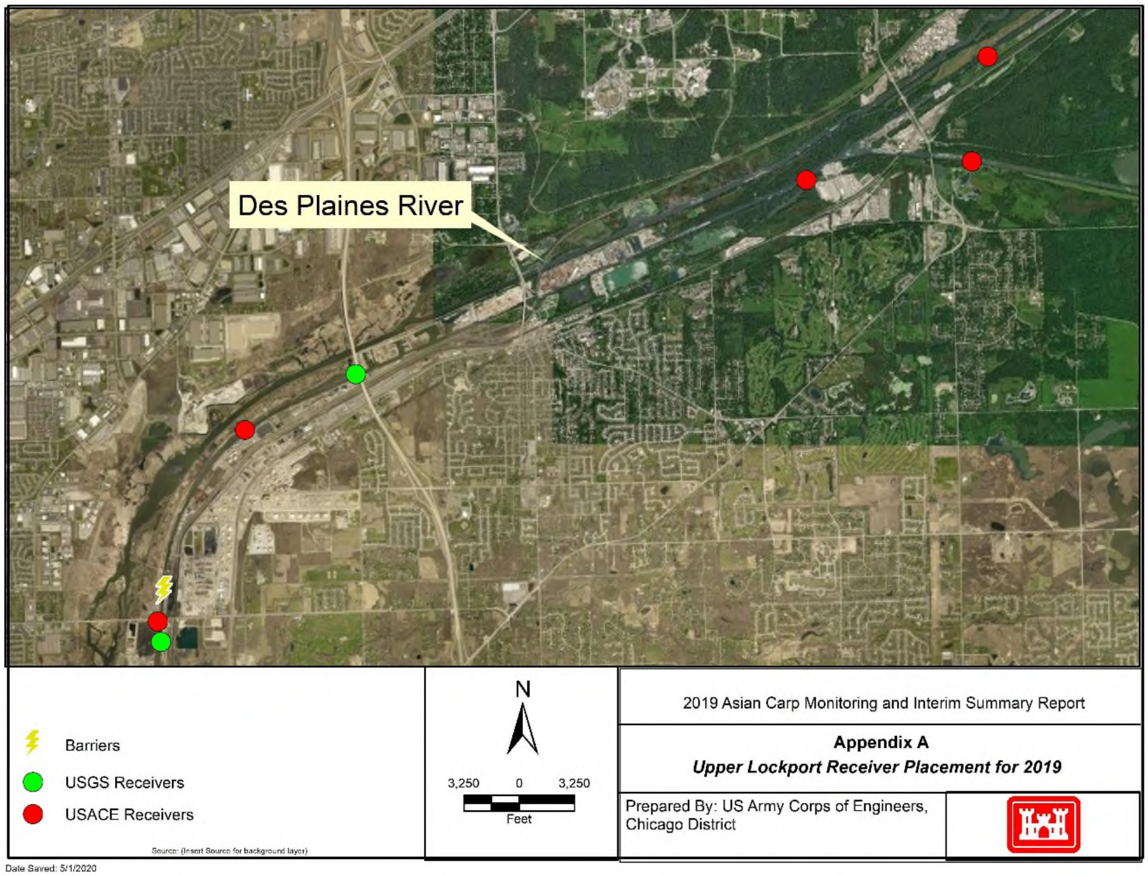
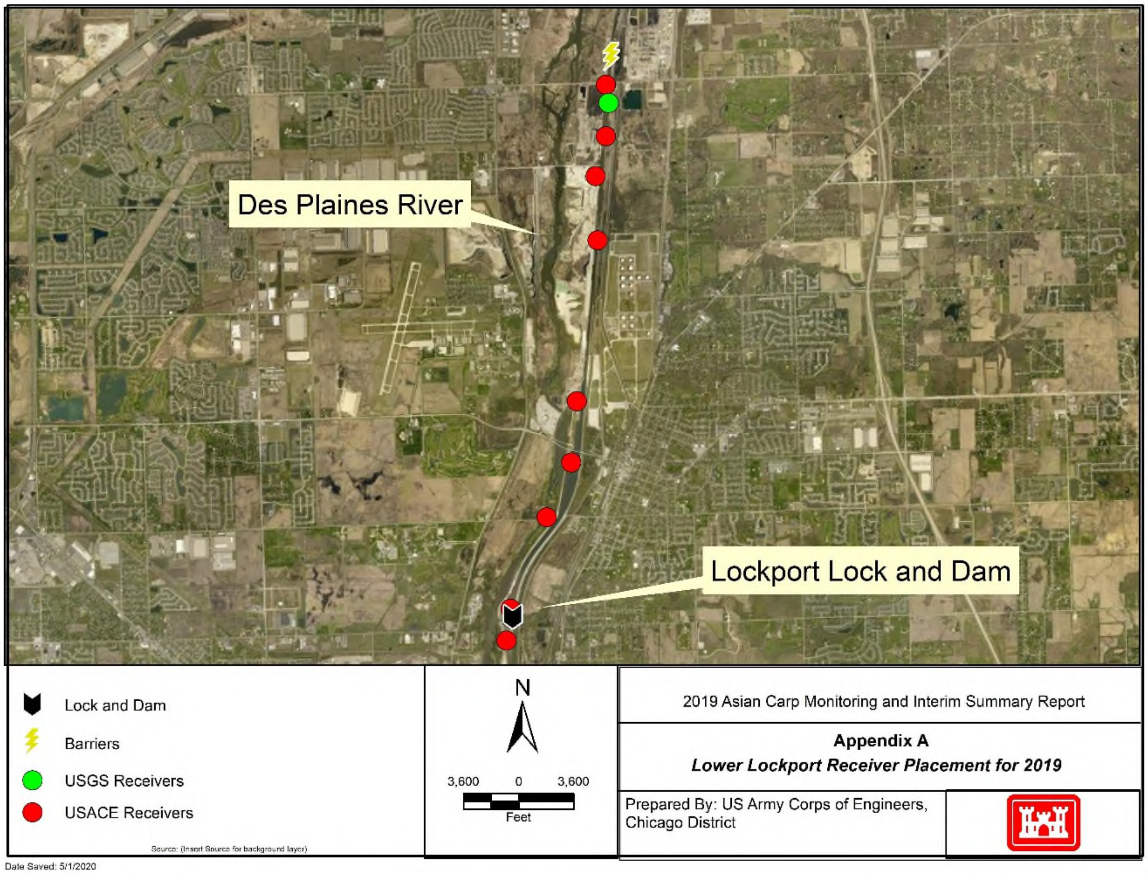
Appendix A: Telemetry Receiver Location Maps

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Lockport Lock and Dam
Lock and Dam
Barriers
USGS Receivers
USACE Receivers
N
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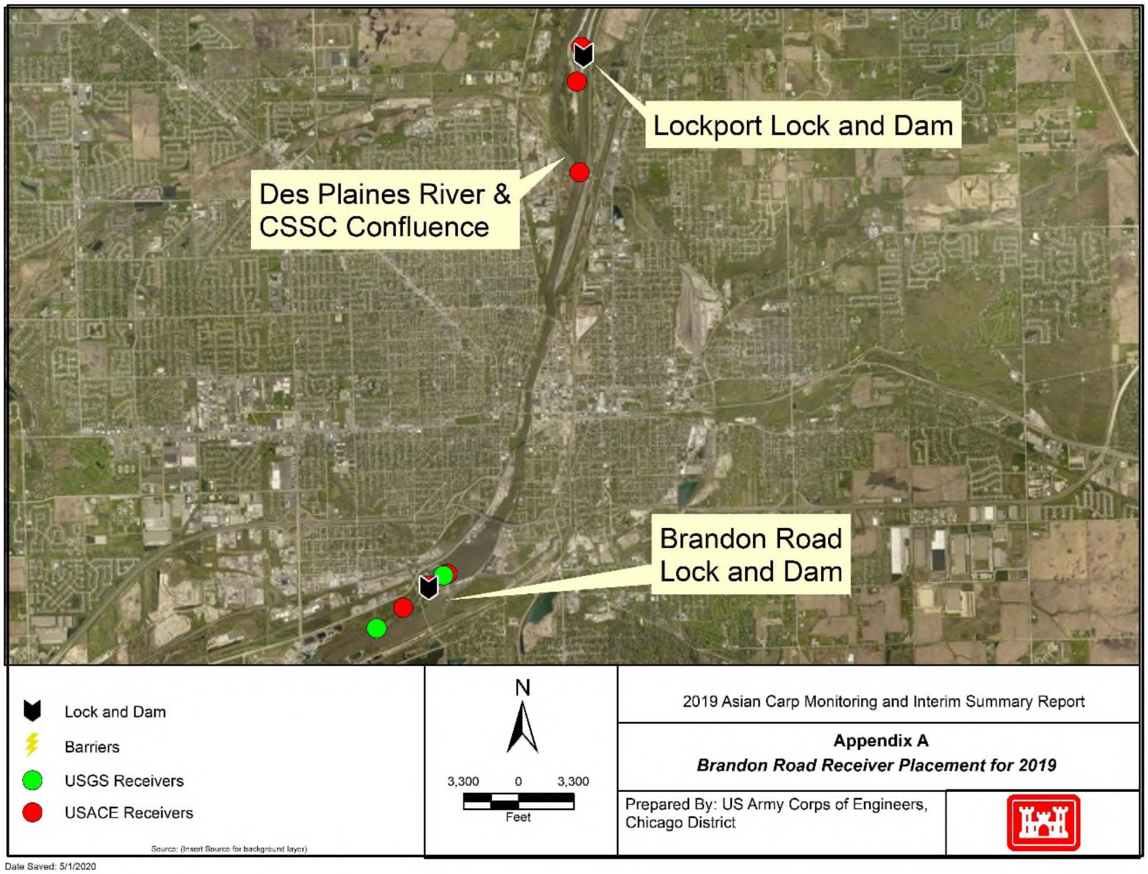
Feet
2019 Asian Carp Monitoring and Interim Summary Report
Appendix A
Lower Lockport Receiver Placement for 2019
Prepared By: US Army Corps of Engineers, Chicago District
Date Saved: 5/1/2020


Lockport Lock and Dam
Des Plaines River &
CSSC Confluence
Brandon Road
Lock and Dam
Lock and Dam
Barriers
USGS Receivers
USACE Receivers
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N
3,300 0 3,300
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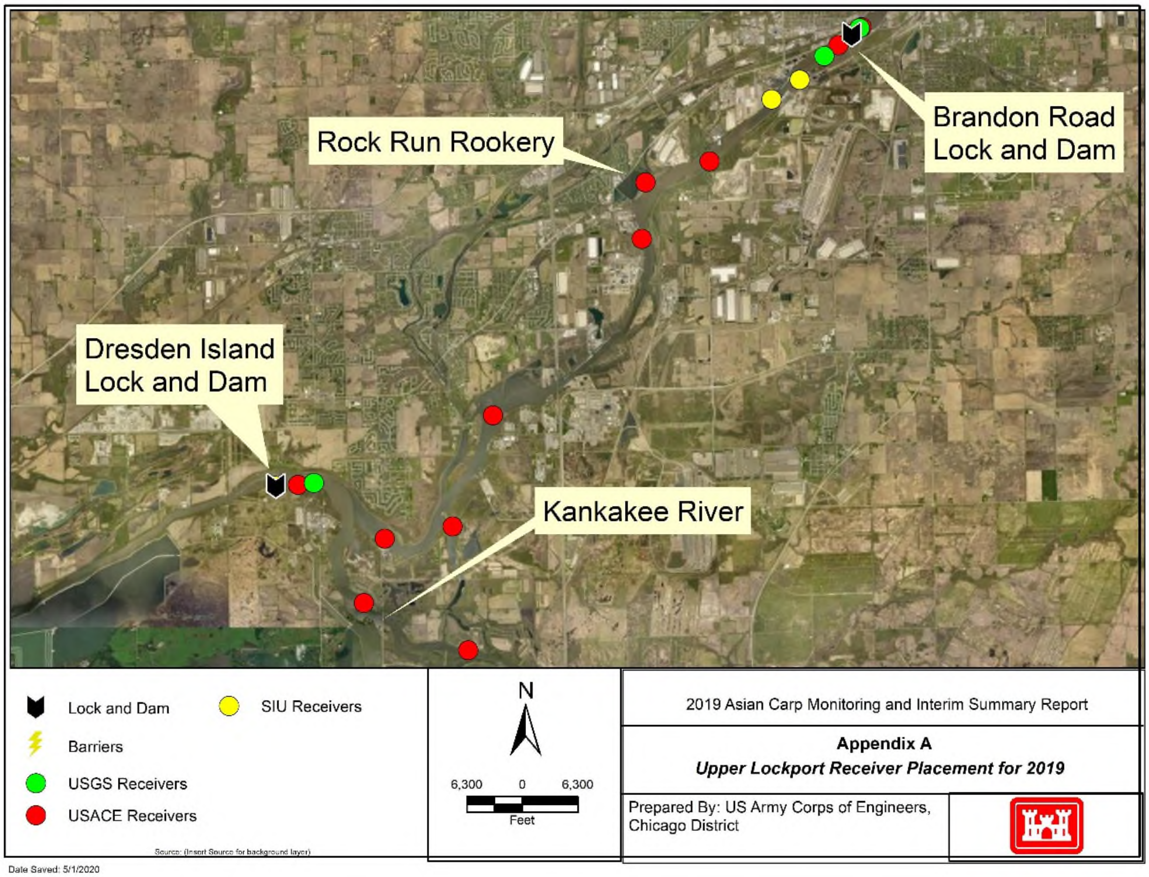
2019 Asian Carp Monitoring and Interim Summary Report
Appendix A
Brandon Road Receiver Placement for 2019
Prepared By: US Army Corps of Engineers, Chicago District
Date Saved: 5/1/2020


Brandon Road
Lock and Dam
Rock Run Rookery
Dresden Island
Lock and Dam
Kankakee River
Lock and Dam
SIU Receivers
Barriers
USGS Receivers
USACE Receivers
N
6,300
0
6,300
Feet
2019 Asian Carp Monitoring and Interim Summary Report
Appendix A
Upper Lockport Receiver Placement for 2019
Prepared By: US Army Corps of Engineers,
Chicago District
Source: (Insert Source for background layer)
Date Saved: 5/1/2020

USGS Real-Time Telemetry in Support of Management

Brent Knights, Marybeth Brey, Doug Appel, and Travis Harrison (U.S. Geological Survey, Upper Midwest Environmental Sciences Center); Jim Duncker (U.S. Geological Survey, Central Midwest Water Science Center);

Participating Agencies: USGS, IL DNR, USACE, USFWS, Southern Illinois University

Pools Involved: Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, and Peoria

Location: Upper Illinois Waterway System

Introduction and Need:

This project uses real-time acoustic telemetry receivers for detecting bigheaded carp (i.e., Bighead Carp *Hypophthalmichthys nobilis* and Silver Carp *Hypophthalmichthys molitrix*), and surrogate fishes, deployed at strategic locations in channel and off-channel areas of the upper Illinois Waterway System (i.e., Illinois and Des Plaines Rivers and Chicago Area Waterway System) with the intent to support decisions on (1) fish removal efforts by contracted fishing, and (2) monitoring and planning of contingency actions. The primary goals and objectives of the Monitoring and Response Workgroup (MRWG) are supported through this project. These real-time receivers, deployed and maintained by USGS, detect bigheaded carp tagged with acoustic transmitters by other agencies as part of their Monitoring and Response Plan (MRP) projects (i.e., USFWS Telemetry to Support the SEAcarP Model; USACE Telemetry Plan, and Southern Illinois University Monitoring Bigheaded Carp Movement and Density in the Illinois River). Location information of tagged bigheaded carp from real-time detections are available online to biologists directing day-to-day fish removal efforts, and as email alerts to managers responsible for executing monitoring and contingency actions. This work also directly supports other MRP projects including the Barrier Defense Asian Carp Removal Project and Upper Illinois Waterway Contingency Response Plan Project.

Objectives:

(1) Maintain, deploy, or remove real-time receivers in the Illinois River System in consultation with the MRWG.

(2) Provide bigheaded carp detection data from the network of real-time receivers to biologists directing 1) contingency actions in response to movements of tagged bigheaded carp to areas of concern and 2) fish removal to increase effectiveness and efficiency of those efforts.

(3) Assess the potential usefulness of dectections from some real-time receivers in the Upper Illinois Waterways to inform decisions on fish removal based on analysis of existing or new data, and consultations with the MRWG.

USGS Real-Time Telemetry in Support of Management

Project Highlights:

- Deployed, maintained, and range-tested nine real-time receivers in the upper Illinois Waterway System in 2019.
- Maintained a system to alert key MRWG personnel of detections of bigheaded carp in areas of concern.
- Initiated analyses of receiver detections and catch data from contract fish removal efforts to determine the potential usefulness of real-time receivers to inform decisions on those efforts.

Methods:

A network of real-time receivers was redeployed, maintained, and tested in the Upper Illinois Waterway System by USGS crews in Spring 2019. Data access for these receivers was maintained online. Real-time alerts were provided to key personnel via email as requested by partner agencies. Two new real-time receivers were deployed in the Upper Illinois Waterway at Hanson Material Services gravel pits to determine relations between real-time detections at these receivers and fish catch data from removal efforts. Analyses of existing detection data from receivers and bigheaded carp catch at several other locations typically fished by removal crews was initiated to determine the potential usefulness of real-time receivers at these sites for informing fish removal efforts.

Results:

Seven real-time receivers were redeployed, maintained, downloaded, and range tested in the Upper Illinois Waterway System by USGS crews in spring 2019 to ensure that they were working properly. Two new real-time telemetry receivers were deployed in early spring of 2019 in the Upper Illinois Waterway at Hanson Material Services gravel pits as identified in 2018 consultations with the MRWG biologists who directed fish removal efforts. These two receivers were also range-tested after deployment. Range testing included determination of maximum range and detection efficiency (i.e., percent detections of test tag) for each 100-m interval within the specified maximum range. Range test results were presented to the MRWG members via teleconference and will be made available in a USGS Open-file Report in FY2020. Access to the data for these receivers was maintained online at https://il.water.usgs.gov/data/Fish_Tracks_Real_Time/ (last 24 hours) and https://umesc-gisdb03.er.usgs.gov/Fishtracks/Account/Register (FishTracks database; all data). Locations of the nine real-time receivers in the upper Illinois Waterway System included (1) Chicago Sanitary and Ship Canal near Lemont, Illinois, (2) Chicago Sanitary and Ship Canal below Fish Barrier at Romeoville, Illinois, (3) Des Plaines River above Brandon Road Lock and Dam at Rockdale, Illinois, (4) Des Plaines River below Brandon Road Lock and Dam at Rockdale, Illinois, (5) Illinois River above Dresden Island Lock and Dam near Minooka, Illinois, (6) Hanson Material Services gravel pits entrance channel near Morris, Illinois, (7) Hanson Material Services East Pit near Morris, Illinois, (8) Hanson Material Services West Pit at culvert near Morris, Illinois, and

(9) Illinois River below Starved Rock Lock and Dam at Utica, Illinois. Real-time detection alerts from these receivers were provided to key personnel via email as requested by the MRWG partner agencies. Analyses of catch and detection data were initiated for Illinois River receivers in Hanson Material Services gravel pits and at the mouth of the Kankakee River to determine their potential effectiveness for informing decisions on fish removal efforts in those areas. At the request of the MRWG co-chairs, we also deployed a real-time receiver near the temporary sound deterrent placed below the Electric Dispersal Barriers on the Chicago Sanitary and Ship Canal at Romeoville, Illinois.

USGS Illinois River Catch Database and Visualization

Enrika Hlavacek, Travis Harrison, Brent Knights, and Marybeth Brey (U.S. Geological Survey, Upper Midwest Environmental Sciences Center)

Participating Agencies: USGS, IDNR, USFWS, USACE

Pools Involved: CAWS, Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, and Alton

Introduction and Need:

Contract Asian carp removal and monitoring will continue throughout the Illinois River as needed for adaptive management to mitigate, control, and contain Asian carp. Incorporating all data from removal and monitoring efforts into a centralized database will facilitate data standardization, accessibility, sharing, and analysis to aid in Asian carp removal efforts, evaluations of management actions, and population modeling (e.g., SEAcarP model). An initial version of the Illinois River Catch Database (ILRCdb) was deployed for partner testing in FY 2018, but further development and maintenance are needed to expand database and visualization functionality, and ensure continued data availability, standardization, quality, security, and accessibility.

In 2019, additional catch and monitoring data is being incorporated into the ILRCdb as it becomes available from partners, developing additional database functionality, and finalizing data sharing agreements between partners. Further development of the ILRCdb will focus on improved capabilities for spatial and temporal analyses, and interactive visualization of catch data to support Asian carp removal efforts. These improved visualization capabilities include integrating existing Asian carp-related data layers (including catch data) in a visualization tool to help provide a greater understanding of bigheaded carp habitat, particularly to gain a better understanding of the underlying conditions in areas where large removal efforts have been effective. Incorporating environmental variables (such as water discharge, water temperature, and benthic habitat classification layers), and adding tools to identify areas with similar conditions to user-identified areas of interest or areas of large previous harvests will help to further inform removal efforts.

A suite of benthic data, previously collected for priority removal areas of the main navigation channel and side-channel areas in the Starved Rock, Marseilles, Brandon, and Dresden pools, continue to be post-processed and distributed as usable GIS layers that can be incorporated into the analyses and interactive data visualization tools described above. Continued development of benthic layers for the Illinois River has further applicability for other Asian carp management efforts, including support for planning applications of control and containment strategies, improving HEC-RAS modeling for FluEgg egg drift simulations, and for use in other modeling efforts undertaken with telemetry and hydroacoustic data collected as part of ongoing MRP projects.

USGS Illinois River Catch Database and Visualization

Objectives:

(1) Maintain and serve the ILRCdb for partner access to monitoring and removal data from the Illinois River, to include new catch and demographic data from sampling efforts.

(2) Develop and update functionality of the ILRCdb to ensure that data are secure, easily accessible to partners, and quality assured, and that tools within the ILRCdb are intuitive and easy for partners to use.

(3) Finalize data sharing agreements as Memoranda of Understanding between participating agencies so that it is clear what data are sharable (i.e., included in the database), how data will be formatted and stored, and how data can be used by participating agencies.

(4) Develop a spatial and temporal analysis tool to provide managers the capability to interactively explore ILRCdb catch data relative to location (i.e., pool/reach of the Illinois River), change through time, and in relation to other environmental factors (e.g., water temperature, discharge, and bathymetry).

(5) Create an online, interactive habitat mapping visualization tool for predicting bigheaded carp locations, based on catch data from the ILRCdb, habitat suitability model(s), and water condition indicators. The tool can be used to identify areas of similar habitat and environmental conditions and to support decisions on site selection for focused removal efforts.

(6) Collect, process, and distribute high-resolution benthic data (sonar image mosaics, bathymetry, and benthic habitat classification) for priority management areas of the Illinois River, to be integrated into the visualization tool described in Objective 5. Validation data for previously collected and processed data (from the Brandon Road, Dresden Island, Marseilles, and Starved Rock pools of the Illinois River) will be collected and used as quality control for the development of benthic habitat classification data layers.

Project Highlights:

Updates to the Illinois River Catch Database application and associated visualization and analytical tools include 1) implementation of automated quality control checks during the data upload process into the ILRCdb to ensure data consistency following monitoring and removal data collection protocols, 2) coded development of an analytical tool to visualize the spatial and temporal patterns of catch data, 3) initial development of an online, interactive mapping tool as a centralized access point for existing Asian carp-related data layers, and 4) data collection, processing, and validation leading to the development of benthic habitat data layers of the Illinois River to support adaptive management objectives and informed removal efforts.

USGS Illinois River Catch Database and Visualization

Methods:

The ILRCdb, a PostgreSQL application, is actively maintained, which involves performing routine database maintenance (e.g., ensuring data backups, performing internal consistency checks, rebuilding indexes as needed, etc.) to keep the application online and available to users. New catch and monitoring data being collected by partner agencies are uploaded to the database after passing quality control checks for data consistency (i.e., standardized formatting of data, etc.). New or updated functionality requested by partners (e.g., customized monthly, quarterly, or annual reports) is added based on specific monitoring or management needs, as feasible.

A visualization tool for the spatial and temporal analysis of catch data from the ILRCdb is being developed with web mapping technologies (Python, Leaflet). The heat map analysis provides animated time series maps of catch data on an annual basis, allowing visualization of the time and location of largest removal events throughout the Illinois River. The coded functionality of this analysis will allow for repeatable analysis with updated data from the ILRCdb for a specified time period and visualization of the results in a spatial format.

Development of an online, interactive habitat mapping visualization tool continues, by expanding an existing tool framework to cover the full extent of the Illinois River. Removal and monitoring data from the ILRCdb application, environmental condition variables such as water temperature, and benthic characteristics (like bathymetry layers and substrate classifications) are being incorporated into the online tool, providing a centralized access point for existing Asian carp-related datasets. Analytical functionality to search for geographic areas with similar Asian carp catch events and/or environmental conditions is being developed (e.g., display areas with similar characteristics to an area where previous large catch events have occurred).

In support of the analysis and visualization tool development described above, additional benthic data from priority management areas of the Illinois River are being collected and processed using hydroacoustic surveying equipment. Validation data (i.e., ground truth data) are being collected by means of a statistically valid random sampling design and used in the development of a benthic habitat classification system for the Illinois River system. Sonar mosaics, bathymetry, and other benthic datasets are post-processed into GIS-ready data layers, distributed online through the USGS ScienceBase platform, and incorporated into analytical and visualization tools.

Results and Discussion:

Partner agencies continue to contribute new Asian carp monitoring and removal data from the Illinois River for inclusion in the ILRCdb, similar to the sampling approach used by the Long Term Resource Monitoring (LTRM) element of the Upper Mississippi River Restoration Program, and following data collection protocols and the FISH app (i.e., datasheets). New quality control checks have been implemented to the ILRCdb to minimize potential data errors during the upload process. Additional customized data summary features have been added to support partner agencies' monitoring and removal reporting needs. Data sharing agreements are iteratively being developed as formal Memoranda of Understanding between partners to detail how data will be formatted, stored, and used by partner agencies. Database application updates, new version releases, and feedback for functionality improvements are communicated between contributing partner agencies and developers through the MRWG.

Initial programming development (i.e., coding) of a visualization tool for the spatial and temporal analysis of catch data from the ILRCdb has been developed. It was developed using web mapping technologies for interactive functionality and ease of end user access, the visualization tool generates animated heat map series of catch data from the ILRCdb. The next development step will integrate this analysis functionality with the ILRCdb to allow for time series spatial visualization with updated catch data records from the ILRCdb.

The existing framework of an online, interactive habitat mapping visualization tool has been expanded to cover the full extent of the Illinois River. The tool provides a centralized access point for existing Asian carp-related datasets and analytical search functionality of integrated datasets. Incorporating benthic habitat classification data layers, habitat suitability layers, environmental condition variables, and Asian carp-related monitoring and removal data allows for users to spatially search for areas with underlying conditions similar to areas of large bigheaded carp catch events (or known areas with dense bigheaded carp populations), allowing for targeted removal efforts to continue throughout the Illinois River.

Hydroacoustic survey data, collected throughout the Illinois River in priority management areas, continue to be validated and processed into a suite of benthic data layers. Benthic habitat classification layers (i.e., geomorphology) are being derived from high-resolution bathymetric measures such as slope, roughness, and terrain ruggedness. Combined with sidescan image datasets, classified substrate data layers will be mapped and incorporated into the online visualization tools described above, to support adaptive management and informed removal strategies. These benthic data layers can also be used during the planning, design, and installation of control and containment technologies (e.g., deterrent systems, Unified Fishing Method events) in strategic locations, by providing a detailed, underwater view of lock structures and the river environment.

Monitoring of Fish Abundance and Spatial Distribution Near the Electric Dispersal Barrier and in Lockport, Brandon Road, and Dresden Island Pools

Nathan T. Evans (U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, Wilmington Substation)

Participating Agencies: USFWS Carterville Fish and Wildlife Conservation Office, Wilmington Substation (lead); USACE-Chicago District (field/logistical support)

Pools Involved: Lockport, Brandon Road, and Dresden Island

Introduction and Need:

The Electric Dispersal Barrier System (EDBS) located within the Chicago Sanitary and Ship Canal (CSSC) operates with the purpose of preventing inter-basin transfer of invasive fishes between the Mississippi and Great Lakes basins. Observational evidence from previous studies suggests that fish congregate below the EDBS at different times throughout the year, primarily during the summer and fall (Parker et al. 2015). How fish interact with the EDBS over varying temporal scales (e.g., diel to seasonal) is not well understood. Having a greater understanding of the temporally varying densities and spatial distributions of fish below the EDBS is important to barrier management, as it allows operational and maintenance decisions to be made in sync with potential risk factors. To determine these periods of elevated risk, split-beam hydroacoustic surveys were performed on a bi-weekly to monthly basis throughout 2019. Moreover, split-beam hydroacoustic surveys of the Lockport, Brandon Road, and Dresden Island navigation pools of the upper Illinois Waterway were completed during summer and fall 2019. This work allowed for a greater understanding of the changes in fish densities and size distributions of the fish assemblage in these study areas. Understanding fish assemblage dynamics throughout the upper Illinois Waterway will allow the findings from a range of other research activities at the EDBS to be put into a system-wide context. This will then enable more refined interpretations of results and allow mangers to make better informed decisions. Additionally, identification of areas of high fish density may facilitate ongoing Asian carp removal efforts.

Objectives:

(1) Evaluate the abundance of fishes directly below the EDBS throughout the year.

(2) Determine the density of fishes in the three upper navigation pools within the Illinois Waterway throughout the year.

(3) Identify large fish targets suspected of being Asian carp to inform targeted removal.

Project Highlights:

- Fish abundances both within and directly downstream of the EDBS were similar across the majority of the 2019 hydroacustic survey.
- Fish abundances within the EDBS were low with an annual mean of 1.8 large fish targets detected per survey (min = 0, max = 8 individual large fish targets).

- Surveys with fish abundances > 2 individuals, within the EDBS, were observed during only four surveys: June 24 (6 individuals), August 27 (5 individuals), November 1 (5 individuals), and November 15 (8 individuals).
- Fish abundances directly downstream of the EDBS were releativly low with an annual mean of 3.6 large fish targets detected per survey (min = 0, max = 13 individual large fish targets).
- Fish density was greater in Dresden Island Pool during the summer surveys relative to the densities in Brandon Road and Lockport pools. The greatest fish density was observed during the August survey of Dresden Island Pool. The lowest fish density was observed in during the September survey of Dresden Island Pool. Overall fish density was similar among the three pool during the fall surveys.

Methods:

Acoustic Fish Surveys at the Electric Dispersal Barrier System: A series of side-looking split-beam hydroacoustic and side-scan sonar surveys were conducted below the CSSC EDBS to assess fish density and distribution patterns near the barrier on a fine temporal scale. Surveys at the EDBS took place between February and December 2019 on a bi-weekly to monthly basis. Survey transects began approximately 1.2 km below the EDBS at 41°37’46.2756” N, -88°3’41.9724” W. The survey vessel traversed a path close to the west wall traveling north with the side-looking hydroacoustic transducers aimed towards the east wall. Each transect continued through the EDBS, paused briefly to allow bubbles and wake to disperse, turned south, and then traveled closely along the east wall back to 41°37’46.2756” N. Three consecutive replicate hydroacoustic samples took place on each survey date.

The hydroacoustic survey equipment consisted of a pair of Biosonics® 200 kHz split-beam transducers and a 4125 Edge Tech ultra-high resolution side scan unit. The two split-beam hydroacoustic transducers were mounted in parallel on the starboard side of the research vessel 0.28 m below the water surface on a dual axis mechanical rotator. The side scan unit is attached to a port-side davit and is lowered less than a meter into the water. One hydroacoustic transducer was set to -3.2˚ and the other to -9.6˚ below parallel from the water surface. When necessary, due to boat movement, the rotators we manually repositioned to maintain optimal orientation. Split beam acoustic data was collected using Visual Acquisition v.6® from 1 to 50 m from the transducer face, at a ping rate of 5.0 pings per second, and a 0.40 ms pulse duration. Data collection was set to begin at 1 m from the transducer face in order to avoid near-field interference. To compensate for the effect of water temperature on two-way transmission loss via its effect on the speed of sound in water, temperature was recorded input into Visual Acquisition v.6® prior to all data collections. The on-axis calibration of the split-beam acoustic transducers were confirmed with a tungsten carbide calibration sphere before sampling following Foote et al. (1987).

Monitoring of Fish Abundance and Spatial Distribution Near the Electric Dispersal Barrier and in Lockport, Brandon Road, and Dresden Island Pools

Split-beam hydroacoustic data were post-processed in Echoview® v. 9.0. Data was loaded into a mobile survey template. A mobile survey template was used to identify and estimate the size and location of single fish targets based on angular position and target strength (TS). Data post processing followed standard methods (Glover et al. unpublished data). Data that were collected outside of the analysis bounds (between 41°37’46.2756” N and the IIA Electric Dispersal Barrier’s lower parasitic structure) were removed from further analysis, a bottom line was digitized by hand, areas of bad data caused by air bubbles were removed, single targets were identified using a threshold of > -70 dB for target acceptance, fish tracks were identified using algorithms within the Echoview Fish Tracking Module®, and single target -TS was converted from -dB to target length using equations derived from Love (1977). The settings in Echoview applied a minimum TS threshold of ≥ -28.7 (≥ 12 inches [30.5 cm]) total length based on the true side-aspect TS of a fish. Fish target density within the canal was calculated using the wedge volume sampled method whereby the number of targets detected was divided by the total volume of water in a wedge encompassing the survey transect for each transducer. Each individual target and fish track was also spatially located within the water column using the split-beam transducers capabilities and assigned X, Y, and Z positional coordinates. Methods for processing the side-scan sonar data are currently being developed. Side-scan sonar results will be presented in the future.

Statistical data analyses were performed to determine if significant differences in fish density immediately downstream of the EDBS existed between different survey dates. Density data were tested for normality using the Shapiro-Wilk W test. Data were unable to be normalized via data transformation. Therefore, non-parametric Kruskal-Wallis one-way analysis of variance with significance at $\alpha = 0.05$ was used to test for differences in mean densities between sampling dates.

Illinois Waterway Pool Surveys: To quantify the density and spatial distribution of the fish community in the upper Illinois Waterway, a series of hydroacoustic remote sensing surveys were conducted throughout the Lockport, Brandon Road, and Dresden Island navigation pools in summer (July and August) and fall (September and October) 2019. The surveys were conducted using the same equipment, collection techniques, and analysis methods as were employed during the hydroacoustic surveys at the EDBS. Within the navigation channel, each pool was surveyed by maneuvering the research vessel on clockwise transects around the pool near the channel margin. In areas where the navigation channel was wider than the range of the survey equipment (approximately 50 m) several concentric transects were conducted.

Results and Discussion:

Fish Surveys below the Electric Dispersal Barrier: Results from the hydroacoustic surveys conducted within the EDBS suggest low fish abundance within the EDBS (annual mean = 1.8 large fish targets detected per survey; range = 0 to 8 individual large fish targets) (Figure 1). Zero large fish targets were detected during 11 of the 24 surveys. The low abundance of detected fish correseponded with low fish density throughout the year (annual mean = 0.34

individuals/100,000 m^3, SE = 0.09, n = 24). Only three surveys illustrated mean fish densities ≥ 1 individuals/100,000 m^3: June 24 (survey mean ± SD = 1.24 ± 0.80 individuals/100,000 m^3), August 27 (survey mean ± SD = 1.24 ± 0.90 individuals/100,000 m^3) and November 15, 2019 (survey mean ± SD = 1.43 ± 0.95 individuals/100,000 m^3) (Figure 2). Zero large fish targets were detected during 11 of the 24 surveys. Additiionally, results from the hydroacoustic surveys conducted immediatley downstream of the EDBS suggested low fish abundance downstream of the EDBS (annual mean = 3.6 large fish targets detected per survey; range = 0 to 13 individual large fish targets). Zero large fish targets were detected during 9 of the 24 surveys. The low abundance of detected fish corresponded with low fish density throughout the year (annual mean = 0.31 individuals/100,000 m^3, SE = 0.08, n = 24). During only one survey was a mean fish density density ≥ 1 individuals/100,000 m^3 observed, November 1, 2019 (mean ± SD = 1.41 ± 0.40 individuals/100,000 m^3). The spikes in fish density, within and downstream of the EDBS, indicate periods of short-term elevated fish abundance that are in some cases significantly different from the near zero density annual trend (Kruskal-Wallis $P < 0.01$). High variablity among the sample replicates during the surveys is the result of factors such as weather, barge traffic, and floating debris.

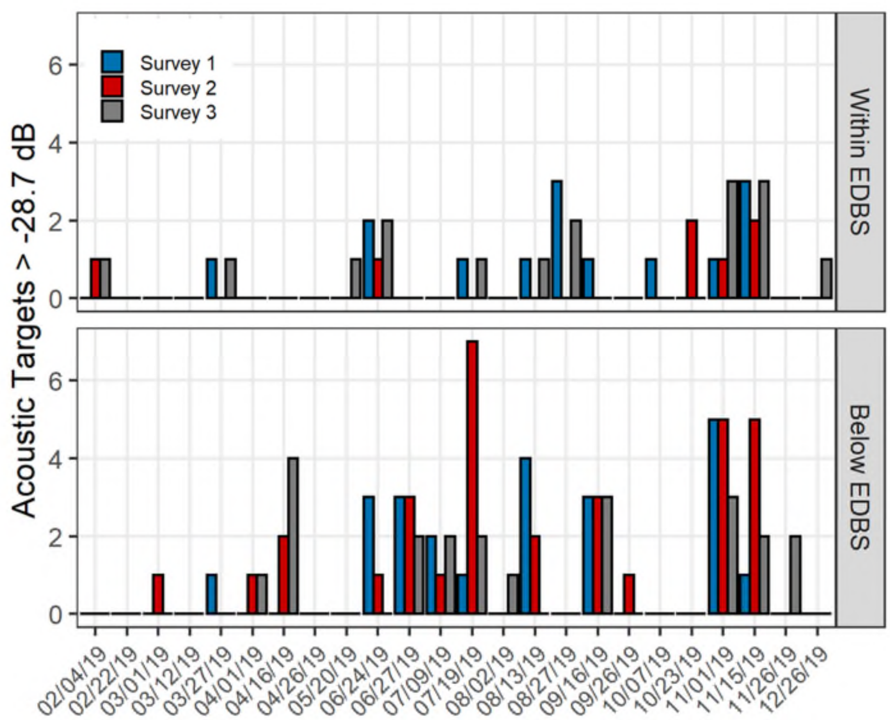


Figure 1. *Number of large fish targets (≥ -28.7 dB) observed within and immediately downstream of the EDBS during split-beam hydroacoustic surveys conducted during 2019.*

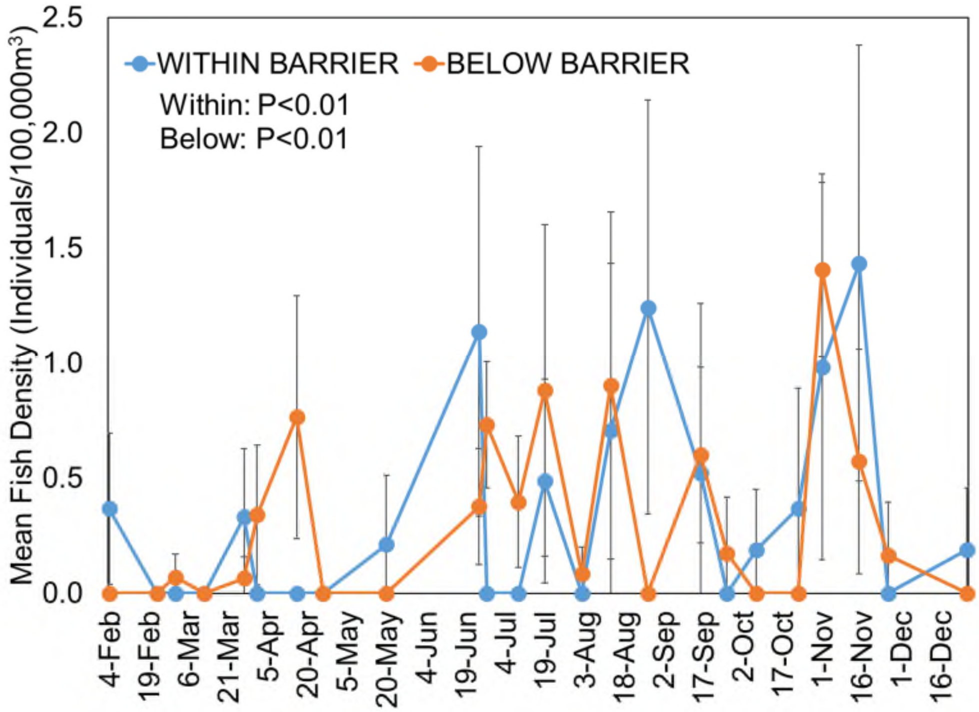


Figure 2. *Mean fish density (individuals/100,000 m^3) observed within and immediately downstream of the EDBS during split-beam hydroacoustic surveys conducted during 2019. Error bars represent ± 1 SE.*

Illinois River Pool Surveys: Results from the summer and fall hydroacoustic surveys conducted in Dresden Island, Brandon Road, and Lockport pools illustrate a greater mean fish densities in Dresden Island during the summer surveys relative to the fall surveys (Figure 3). Seasonal fish density during the summer surveys was approximately 4X to 9X greater than during the fall surveys. Mean fish densities were similar in Brandon Road and Lockport pools. Moreover, mean densities were similar across the summer and fall surveys in Brandon Road and Lockport pools. Overall, fish densities decreased moving upstream with the greatest densities observed in Dresden Island Pool and lower densities observed in Brandon Road Pool and Lockport Pool. The sharp decrease in fish density in Dresden Island Pool between the August and September surveys suggests a decrease in the abundance of large fishes within the pool. This decrease in abundance may indicate a reduction in the number of Asian carp present in the pool due to control efforts or seasonal movement out of the main channel.

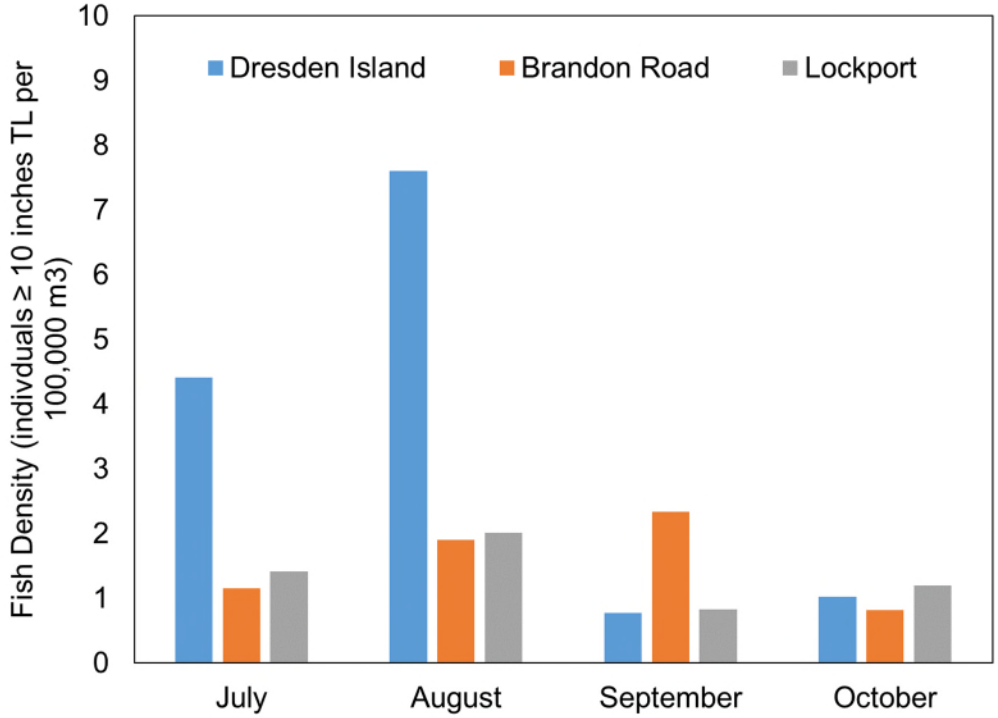


Figure 3. *Mean fish density (individuals/100,000 m^3) observed July, August, September, and October split-beam hydroacoustic surveys conducted during 2019 in Dresden Island, Brandon Road, and Lockport Pools. Surveys were conducted once per month in each of the three navigation pools.*

Conclusion

These studies provided insight about the dynamics of Upper Illinois Waterway fish assemblages that are unattainable using traditional fisheries survey gear. Furthermore, these studies enable for documentation and analysis of spatial and temporal changes in density across the riverscape. Insights from this monitoring can assist in identifying risk and adapting management actions.

Recommendations:

(1) Continue monitoring the abundance dynamics of fish within the Upper Illinois Waterway to detect changes in biomass or habitat utilization that could be indicative of changes in assemblage structure.

(2) Continue monitoring and rapid reporting of survey data to inform management agencies of suspected Asian carp observations.

(3) Increase the extent and temporal frequency of physical capture-based sampling for ground truthing hydroacoustics surveys to improve accuracy in inferring species composition information from hydroacoustics data.

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Love, R. H. (1977). Target strength of an individual fish at any aspect. The Journal of the Acoustical Society of America, 62(6), 1397-1403.

Parker, A.D., Finney, S.T., 2013. Preliminary Results of Fish-Barge Interactions at the Electric Dispersal Barrier in the Chicago Sanitary and Ship Canal. U.S. Fish and Wildlife Service Midwest Fisheries Program. Accessed November 30, 2015, at *http://www.fws.gov/midwest/fisheries/carterville/documents/barge.pdf*

Distribution and Movement of Small Silver and Bighead Carp in the Illinois Waterway

Cory Anderson and Nathan Evans (U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office Wilmington Substation)

Participating Agencies: USFWS Carterville FWCO - Wilmington

Pools Involved: Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, and Peoria

Introduction and Need:

Since the 1970s, invasive Silver Carp (*Hypopthalmichtys molotrix*) and Bighead Carp (*Hypopthalmicthys nobilis*) populations in the Mississippi River basin have been expanding upstream and are established in the Illinois River (Chick and Pegg 2001, Sass et al. 2010). Silver Carp and Bighead Carp pose a significant threat to economically and recreationally valuable fisheries in the Laurentian Great Lakes through competition for limited plankton forage resources (Cooke and Hill 2010). The most probable invasion pathway for Silver Carp and Bighead Carp to enter Lake Michigan is through the upper Illinois Waterway (IWW) including the Chicago Area Waterway System (CAWS) (Kolar et al. 2007). An Electric Dispersal Barrier System (EDBS), operated by the U.S. Army Corps of Engineers, in Lockport Pool is intended to block the upstream passage of Silver Carp and Bighead Carp through the IWW pathway.

Laboratory tests have shown the EDBS is sufficient at stopping large-bodied fishes from passage (Holliman 2011). However, tests with small Bighead Carp (51-76 mm total length [TL]) have indicated that the operational parameters of the EDBS may be inadequate for blocking passage of small-bodied fishes (Holliman 2011). Moreover, research using Golden Shiners (*Notemigonus chrysoleucas*) as a non-invasive surrogate species for juvenile Silver Carp, indicated that small fish can become entrained in barge junction gaps and transported through the EDBS (Davis et al. 2016). Furthermore, research using Dual Frequency Identification Sonar (DIDSON) indicated that small fishes (unknown species) can be transported upstream through the EDBS by return water current created during downstream barge movement. These studies illustrate a vulnerability in the EDBS and some potential mechanisms by which small-bodied Silver Carp and Bighead Carp, if present in the vicinity, could pass upstream through the EDBS. For this reason, there is a need for high spatial- and temporal-resolution monitoring data on the distribution of juvenile Silver Carp and Bighead Carp in the IWW. Additionally, a need is present to understand the reproduction, demographics, and habitat usage of these fishes, in the IWW, so juvenile fish may be targeted for eradication or other management actions.

The objective of this study was to determine the spatial distribution of small Silver Carp and Bighead Carp in the IWW through intensive targeted sampling. For the purposes of this study "small" Silver Carp and Bighead Carp are defined as individuals ≤153 mm TL (6 inches) based on the field limitations of the EDBS (Holliman 2011) as well as discussions within the Monitoring and Response Working Group. Any individuals found smaller than 350 mm TL will be considered juvenile, age 1, based on previously published research on the growth and maturity of Silver Carp and Bighead Carp (Williamson and Garvey 2005). Due to variability in intrapopulation growth rates, it is important to monitor the distribution of juvenile Silver Carp and Bighead Carp as some individuals may represent young fish with accelerated growth. In 2019, sampling techniques included traditional boat electrofishing, mini-fyke nets, and electrified dozer trawl.

Objectives:

(1) Detect the furthest upstream location of juvenile Silver Carp and Bighead Carp yearly.

(2) Determine the distribution and abundance of small Silver Carp and Bighead Carp in the IWW.

(3) Use distribution and abundance data to characterize the risk of small Silver Carp and Bighead Carp entry into the Great Lakes via the CAWS.

Project Highlights:

- Total efforts for monitoring included:
  - 140 crew weeks effort during Multi-agency monitoring of the Illinois River for informed decision making (collaborative efforts) sampling Peoria Pool to Lockport Pool.
  - 6 crew weeks targeted supplemental sampling Peoria Pool to Dresden Island Pool
- A total of 101 Silver Carp ≤ 153 mm TLwere captured in the Peoria Pool, with the furthest upstream at Hennepin, IL (River Mile 207.8, 88 miles from EDBS) during the 2019 field season. No Silver Carp ≤ 153mm were captured upstream of Starved Rock Lock and Dam.

Methods:

Efforts in 2019 differed greatly from years past as the goals of this template were attempted to be fulfilled through a separate monitoring template, Multi-agency monitoring of the Illinois River for informed decision making (MAMIRIDM), rather than exclusively using a targeted sampling approach as in years past (2012-2018). Sampling that was a part of MAMIRIDM was conducted using multiple gears following a stratified-random sampling design similar to that of the Long-term Resource Monitoring Program (LTRM), a long-term fish assemblage and aquatic habitat monitoring project (Ratcliff et al 2014). Sampling under MAMIRIDM took place from the Peoria Pool to the EDBS in Lockport Pool. MAMIRIDM site selection, sampling gears, and sampling methods followed the protocol of the LTRM project manual (Ratcliff et al 2014) but were adapted to fit the upper Illinois River.

In addition to MAMIRIDM effort, USFWS expended 4 crew weeks supplemental targeted sampling effort to attempt to capture young-of year Silver Carp. During supplemental targeted sampling, locations were chosen at the crew leaders' discretion based on best area to deploy gear, water quality conditions, historically captured small Silver Carp or Bighead Carp, and experience gained from the juvenile Silver Carp telemetry project ongoing in the Peoria reach.

For all sampling, physical characteristics and water quality measurements were made at each collection site and included: secchi depth, depth, substrate type (i.e., boulder, cobble, gravel, sand, silt, and clay), temperature, specific conductivity, and dissolved oxygen. Water quality measurements were taken using a YSI Professional Series multi-meter. Additionally, GPS coordinates and time stamps were recorded at the start and end of each electrofishing event, trawl run, fyke net, and mini-fyke net set. All fishes were identified to species and enumerated. As time allowed, fish were measured to total length and weighed. Any fish not easily identified was preserved in Excel Plus or 70% EtOH for laboratory identification to the lowest possible taxonomic level. Effort was quantified as net nights (fykes and mini-fykes) or minutes of electrofishing (boat electrofishing and electrified dozer trawl).

Gear Descriptions:

Descriptions of gears used during targeted sampling efforts are included. Effort as part of MAMIRDIM includes gears that are not in this document but can be referenced on that template or in the LTRM project manual (Ratcliff et al 2014).

Electrofishing: Pulsed DC daytime electrofishing conducted with perpendicular passes into shore, and 2 dippers, for 15-minute sampling periods.

Mini-fyke net: Wisconsin-type mini-fyke nets set overnight in both single and tandem configurations depending on site characteristics. Single nets were set with the lead end staked against the shoreline or another obstruction to fish movement. Tandem nets (with leads attached end to end) were fished in open water areas. All mini-fyke nets had a 24 foot lead and 1/8 inch mesh.

Dozer trawl: A 35 mm mesh net at the mouth reducing to 4 mm mesh at the cod end tied to a 2 m by 1 m rigid frame mechanically raised and lowered to fish depths <1 m. The net extends approximately 2.5 m back as it was pulled forward. The target habitat is open water >0.6 m deep. Length and duration of trawl was dependent on site characteristics.

Results and Discussion:

Much of the 2019 effort was done while fulfilling the goals of MAMIRIDM (140 crew weeks, Table 2). A supplemental four crew weeks were expended on targeted effort for young-of-year Silver Carp and Bighead Carp in Marseilles, Dresden Island, and Starved Rock pools (Table 3). Additionally, 2 weeks of targeted effort were expended in Peoria reach in an effort to collect young-of-year Silver Carp for tagging.

Distribution and Movement of Small Silver and Bighead Carp in the Illinois Waterway

In 2019, young-of-year Silver Carp and Bighead Carp (n = 102) were captured throughout Peoria Pool using electrofishing, mini-fyke netting, traditional fyke netting, and electrified dozer trawl. Small (TL ≤ 153mm) Silver Carp and Bighead Carp were also captured (n = 65) throughout Peoria Pool with the furthest upstream occurrence at Hennepin, IL, river mile 207.8. No age < 1 Silver Carp or Bighead Carp were captured above Starved Rock Lock and Dam during 2019.

Young-of-year Silver Carp collected during 2019 were not found further upstream than the previous two years of sampling. To date, the furthest upstream capture of a young-of-year Silver Carp occurred in 2014 in Marseilles Pool. Catch per unit effort (CPUE) in 2019 of juvenile Silver Carp (TL ≤ 350mm) captured in the Peoria Pool was 6.90 fish per hour using boat electrofishing and electrified dozer trawl (Table 4). This is similar to the CPUE of juvenile Silver Carp observed in 2018 (6.86 fish per hour) and higher than 2015 (2.03 fish per hour) or 2017 (3.74 fish per hour, Table 4). This could potentially indicate a strong year class from both 2018 and 2019 and potentially lead to higher recruitment than observed in previous years.

Recommendations:

The strong 2018 and 2019 year classes of Silver Carp indicates the potential for higher recruitment than what was indicated with prior years of data. Recruitment should continue to be monitored for 2020 and beyond, especially in upstream pools where suitable river conditions for Silver Carp and Bighead Carp spawning occurred in 2019. Due to the low detection probabilities associated with rare species (Bayley and Peterson 2001, MacKenzie et al. 2002), detecting the presence of juvenile Silver Carp and Bighead Carp in the upstream pools of the IWW may require a substantial increase in effective effort, relative to that expended in 2019.

Detection probability is the probability of detecting at least one individual of the species during a particular sampling event, given that the species is are present in the study area (Boulinier et al. 1998, MacKenzie et al. 2002). Detection probabilities are intrinsically low for rare species due to the low number of individuals in the given area as well as imperfect catchability of individuals due to gear inefficiencies and biases (Bayley and Peterson 2001, MacKenzie et al. 2002). Based on the low number of juvenile Silver Carp and Bighead Carp detected in the upper IWW to date, juvenile individuals of these species are assumed to be either rare or absent in the system with the presumed likelihood of occupancy decreasing from downstream to upstream. Therefore, it is imperative that any early detection program for the detection of juvenile Silver Carp and Bighead Carp consider these fishes as rare and adopt a sampling design that maximizes their detection probability. Detection of rare fishes can be improved by increasing the vulnerability of individuals to sampling gears (catchability), through the expenditure of greater effort (which increases the probability a vulnerable individual encounters the sampling gear), or both (McDonald 2004, MacKenzie et al. 2005, MacKenzie and Royal 2005). Moreover, detection probability can be improved by directly increasing the likelihood that a vulnerable individual encounters a sampling gear through targeted sampling of occupied habitats where individuals congregate or are otherwise more susceptible to capture (Rew et al. 2006, Trebitz et al. 2009, Hoffman et al. 2011).

After taking into account the efforts of the new MAMIRIDM template, we recommend that the overall monitoring effort of Silver Carp and Bighead Carp continue to be supplemented in the form of sampling outside the bounds of the MAMIRIDM effort, in the spring (April – June) and fall (November) as weather permits as well as during the ongoing MAMIRIDM effort whenever spawning of Silver Carp or Bighead Carp are documented by field crews. Supplemental efforts should be done using a targeted approach, hitting primarily areas where juvenile Silver Carp and Bighead Carp have been captured previously or where crew leaders deem a possibility of them inhabiting based knowledge of habitat preferences. Gear types should be chosen based on their maximum catchability of age < 1 Silver Carp and Bighead Carp, including fyke nets, mini-fyke nets, electrified dozer trawl, and standard boat electrofishing.

Specific focus should be placed on altering the electrofishing methods targeting small or young-of-year Silver Carp and Bighead carp. Poor capture efficiencies of juvenile Silver carp have been reported by field crews using the LTRM specified electrofishing power goals. The LTRM power goals were designed around maximizing gear standardization and collection of spiny-rayed fishes that are generally abundant in the environment (Burkhardt and Gutreuter 1995). It is our recommendation that electrofishing power goals used to monitor for juvenile Silver Carp and Bighead Carp be tested in pools where recruitment occurs annually. Alternatively, power goals used during monitoring should be increased from the currently used LTRM protocols to a level equivalent to the power used during previous captures of juvenile Silver Carp and Bighead Carp.

The specific focus of this template (monitoring for the distribution and abundance of small Silver Carp and Bighead Carp) should be altered to be more of an early detection of young life stages tracking the recruitment front of Silver Carp and Bighead Carp. The rapid growth and boom/bust years of recruitment (Gibson-Reinemer 2017) that has been documented for these fish demands yearly monitoring to track the front of recruitment since we are often unaware of a strong year class until it is documented during field collection. Tracking recruitment is important because it indicates the leading edge of the population since young-of-year that successfully escape early death and predation will likely grow to become reproducing adults. Additionally, tracking the front of recruitment will provide data on the proximity of small (≤153mm TL) Silver Carp and Bighead Carp to the EDBS.

Distribution and Movement of Small Silver and Bighead Carp in the Illinois Waterway

Table 1. Number of *Silver Carp age < 1 and ≤ 153mm TL captured in Peoria Pool during 2019 sampling. No age <1 silver carp were captured above Peoria Pool during 2019. 2018 captures included for comparison.*

	2019 Peoria Captures	2018 Peoria Captures
N < 153mm TL	65	3
N total < Age 1	102	121
Mean TL (mm)	108	327
Range (mm)	20-305mm	109-350

Table 2. *Total 2019 MAMIRIDM sampling effort expended monitoring for juvenile Silver Carp and Bighead Carp separated by river pools and gear type used. Effort is recorded in hours and number of sites sampled for electrofishing and net nights (same as sets) for mini-fykes and fyke nets. A total of 140 crew weeks were spent to conduct sampling.*

Location	**Peoria**		**Starved Rock**		**Marseilles**	
	Effort	n sites	Effort	n sites	Effort	n sites
Boat Electrofishing	33.75	135	26.75	107	23.25	93
Mini-Fyke (net nights)	-	70	-	67	-	70
Fyke-net (net nights)	-	28	-	-	-	15
Location	**Dresden Island**		**Brandon Road**		**Lockport**	
	Effort	n sites	Effort	n sites	Effort	n sites
Boat Electrofishing	18.25	73	15.75	63	17.25	69
Mini-Fyke (net nights)	-	72	-	36	-	24
Fyke-net (net nights)	-	15	-	-	-	-

Table 3. *Total 2019 targeted (supplemental) sampling effort expended monitoring for juvenile Silver Carp and Bighead Carp separated by river pools and gear type used. Effort is recorded in hours and number of sites sampled for electrofishing and dozer trawl and net nights (same as sets) for mini-fyke nets. Six total crew weeks were spent to conduct sampling.*

	Peoria		**Starved Rock**		**Marseilles**		**Dresden**	
	Effort	n sites	Effort	n sites	Effort	n sites	Effort	n sites
Boat Electrofishing	-	-	2.75	11	1.75	7	7	28
Dozer trawl	5.84	67	-	-	-	-	-	-
Mini-Fyke (net nights)	-	15	-	7	-	-	-	-

Table 4. *Mean annual catch per unit effort (fish/hour) and standard error for Juvenile Silver carp (TL < 350mm) from Peoria Pool using boat electrofishing and dozer trawl from 2015 to 2019. No sampling was conducted in Peoria Pool during 2016.*

Sampling Year	**Mean CPUE (fish/hr)**	**SE**
2015	2.03	0.90
2016	-	-
2017	3.74	1.34
2018	6.86	2.09
2019	6.90	2.51

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Larval Fish Monitoring in the Illinois Waterway

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Participating Agencies: Illinois Natural History Survey (lead), Eastern Illinois University (field and lab support)

Pools Involved: Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, and La Grange

Introduction and Need:

Successful reproduction, as a pre-requisite to population renewal through recruitment, is fundamental to the establishment and spread of invasive species. Understanding the spatial and temporal dynamics of reproduction by invasive fishes can offer insight into the risk of further population expansion, factors influencing recruitment to the population, and the success of control measures. An evaluation of Asian carp reproduction and the distribution of early life stages in different sections of the Illinois Waterway (IWW) and its tributaries is needed to monitor for changes in the reproductive front of Asian carp populations in this system and to better understand the impacts of removal efforts on the reproductive potential of these populations. Reproduction and recruitment of Asian carp in the IWW have been highly variable across years and multiyear efforts are necessary to evaluate conditions affecting reproduction and monitor for changes in the reproductive front. Observations of eggs, larvae, and juveniles in the upper Illinois River indicate that some reproduction and potential recruitment occurs above Starved Rock Lock and Dam in some years. Due to egg and larval drift, reproduction in upper river pools may be an important source for recruits in downstream pools, particularly the Peoria Pool. Monitoring for any changes to these patterns can help to evaluate the risk for further population growth in the upper Illinois River. Asian carp spawning also appears to occur in some years in smaller tributary rivers. These systems may provide sources of recruits to basin-wide Asian carp populations and may offer insight for the suitability of Great Lakes basin tributaries were Asian carp to become established there. Monitoring for Asian carp eggs and larvae can also provide data to assess stock-reproductive productivity relationships and evaluate the impact of Asian carp removal efforts on the reproductive potential of these populations. Simple relationships between stock abundance and reproductive potential are often lacking, in part because of density-dependent processes and spatial and temporal variability in spawning conditions, stock composition, and first-year survival. Quantifying the relationship between adult stock abundance and reproductive productivity, and between reproductive output and recruitment strength will help to refine our understanding of the conditions and level of removal that reduce population growth rate.

Larval Fish Monitoring in the Illinois Waterway

Objectives:

Fish eggs and larvae are being sampled in the IWW and its tributaries to:

(1) Monitor for potential changes in the reproductive front of Asian carp populations;

(2) Monitor for Black Carp reproduction in the IWW

(3) Refine FluEgg model predictions of Asian carp reproductive hotspots; and

(4) Quantify the relationship between Asian carp stock abundance and reproductive output.

Project Highlights:

- 476 ichthyoplankton samples were collected from 7 sites from the Brandon Road to LaGrange navigation pools of the IWW during April – October 2019, collecting over 80,000 larval fish, including 3,595 Asian carp larvae, plus 1,430 Asian carp eggs. Asian carp eggs or larvae were present during late May through June, and a late spawning event was observed at the beginning of October. Asian carp reproduction occurred during periods of rising water levels when the temperature was above 18°C. Asian carp eggs and larvae were only collected in the LaGrange and Peoria pools during 2019.
- 345 ichthyoplankton samples were collected from tributary rivers (Kankakee, Fox, Mackinaw, Spoon, and Sangamon rivers) during 2019. No Asian carp eggs or larvae were collected in the Kankakee or Fox rivers, but larvae were observed in all other tributaries and eggs were collected in the Spoon and Sangamon rivers. Asian carp eggs and larvae were present in tributaries during late June and early July, and were associated with increases in water levels once temperatures were above 18°C.
- Modeling efforts examining the influence of adult spawning stock density and environmental factors on Asian carp reproductive output found that a model with potential spawner density, cumulative degree days by the end of June, and May-June flow rate was most strongly supported by the observed data. Asian carp egg production was found to be highest during years with warmer spring to early-summer water temperatures and higher flow rates and increased nonlinearly with adult density.

Methods:

Larval fish sampling occurred at seven sites in the Illinois and Des Plaines rivers downstream of the Electric Dispersal Barrier during 2019 (Figure 1). Additional sampling took place in five tributary rivers (Kankakee, Fox, Mackinaw, Spoon, and Sangamon rivers). Sampling occurred weekly from April to the end of June and biweekly from July to October. At main channel sites, four larval fish samples were collected at each site on each sampling date. Sampling transects were located on each side of the river channel, parallel to the bank, at both upstream and

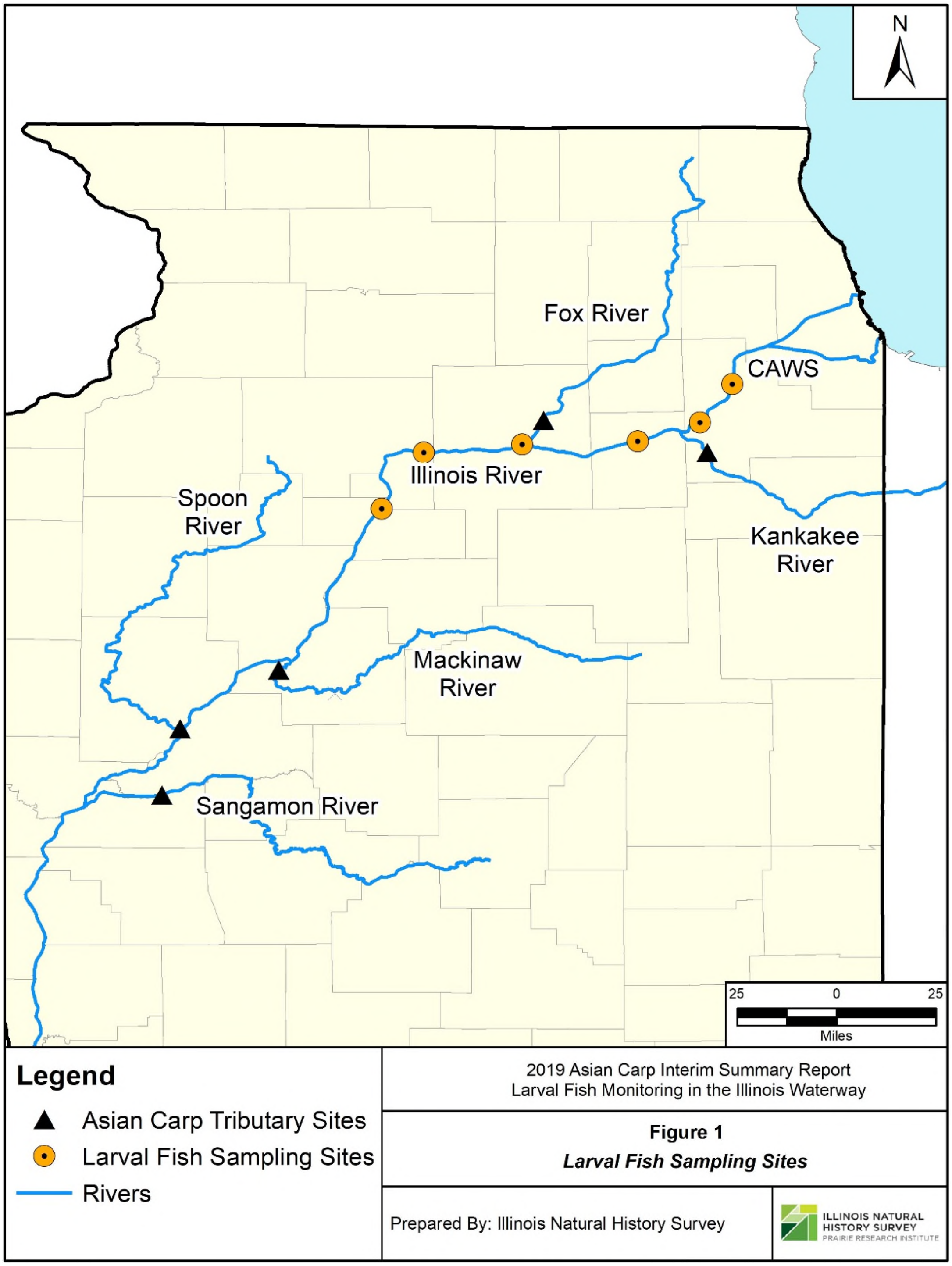

Figure 1. *Map of ichthyoplankton sampling sites in the IWW (circles) and in tributary rivers (triangles).*

downstream locations within each study site. Samples were collected using a 0.5 m diameter ichthyoplankton push-net with 500 µm mesh. To obtain each sample, the net was pushed upstream using an aluminum frame mounted to the front of the boat. Boat speed was adjusted to obtain 1.0 – 1.5 m/s water velocity through the net. Flow was measured using a flow meter mounted in the center of the net mouth and was used to calculate the volume of water sampled.

Fish eggs and larvae were collected in a meshed tube at the tail end of the net, transferred to sample jars, and preserved in 90-percent ethanol. Three samples (one mid-channel and one on each side of the channel) were taken at each tributary site on each sampling date. The Kankakee and Fox rivers were sampled at sites below the furthest downstream dam on each river. Upstream and downstream sites were sampled on the Mackinaw, Spoon, and Sangamon rivers. Downstream tributary locations were sampled with the same boat-mounted push-net method used for main-channel sites, and all tributary sites were also sampled using stationary drift-nets. Larval fish were identified to the lowest possible taxonomic unit in the laboratory. Fish eggs were separated by size, with all eggs having a membrane diameter larger than 4 mm being identified as potential Asian carp eggs and retained for later genetic analysis. Larval fish and egg densities were calculated as the number of individuals per cubic meter of water sampled.

Densities of Asian carp eggs and larvae were summarized by sampling location through time and compared to water temperature and river discharge to examine spatial patterns in Asian carp reproduction, identify conditions associated with spawning, and assess long-term trends in Asian carp reproductive output. Analyses examining the influence of adult spawning stock density and environmental factors on Asian carp reproductive output were performed to better understand the potential for Asian carp removal efforts to diminish the reproductive potential of Asian carp populations in targeted navigation pools. These analyses focused on egg production because previous research has identified the probable origins of eggs collected at various sampling stations in the Illinois River (Zhu et al. 2018) and therefore provides a basis for pairing egg data to pool-specific Asian carp density estimates. Spawning stock density estimates were generated by annual hydroacoustic surveys conducted each October by Southern Illinois University – Carbondale, with each fall density estimate assumed to represent potential spawner density within a navigation pool during the following spring. Based on predicted spawning areas derived from FluEgg model analysis of Asian carp egg collections (Zhu et al. 2018), egg densities in each navigation pool were related to the density of adult Asian carp within that pool and the next upstream pool. Because previous studies have identified water temperature and flow as important abiotic factors influencing Asian carp spawning (Lohmeyer & Garvey 2009, Jiang et al. 2010, Coulter et al. 2016, Song et al. 2018), patterns in seasonal warming and flow were also evaluated for their influence on reproductive output. The majority of Asian carp reproduction in the IWW has been observed during May and June, so cumulative degree days (base 18°C) through the end of May and June, and mean May-June discharge through the nearest upstream navigation dam were used as predictor variables for this analysis. Water temperatures were obtained from U.S. Geological Survey (USGS) gages at Seneca (USGS 5543010) to represent the upper Illinois River pools, and at Florence (USGS 5586300) to represent LaGrange reach locations. Discharge data for each pool was obtained from upstream USACE gages located at the Dresden Island, Marseilles, and Starved Rock lock and dams. Because the Peoria Lock and Dam has wicket gates that are lowered during high flows and therefore would not influence eggs collected in the LaGrange Pool, data from the USGS gage at Kingston Mines (USGS 5568500) was used for LaGrange Pool flow rates.

Reduced maximum likelihood estimation was used to model cumulative annual egg density at each sampling location. Repeated-measures models with sampling station as the repeated unit were constructed to predict Asian carp egg density as a function of adult Asian carp density. The addition of cumulative degree days by the end of May, cumulative degree days by the end of June, mean June discharge, and a combination of degree days and discharge was assessed to determine if these variables improved model fit over the base model with adult carp density alone. A null model (intercept only) was also included to assess whether there was meaningful support for any of the models in the set. Corrected Akaike's information criteria (AIC_c; Anderson 2008) was used to compare models, with models within two AIC_c units considered to have similar support. All variables were natural-log transformed prior to inclusion in models, with a constant of 0.001 added to egg density prior to transformation.

Results and Discussion:

During 2019, ichthyoplankton sampling on the IWW was substantially reduced from that of previous years in order to focus monitoring efforts primarily on upper navigation pools. A total of 476 ichthyoplankton samples were collected from main channel sites on the IWW, collecting over 80,000 larval fish, including 3,595 Asian carp larvae. Additionally, 1,430 Asian carp eggs were collected from main channel locations in 2019. A substantial rise in water level occurred near the beginning of May in 2019, but water temperatures at this time were too low for Asian carp to begin spawning. A second increase in river flows occurred at the end of May, and water temperatures at that time were above the 18°C spawning threshold. Substantial numbers of Asian carp eggs were observed in the upper Peoria Pool at this time, and Asian carp larvae were collected throughout the Peoria and LaGrange Pools, with larvae continuing to be present in the LaGrange Pool throughout June (Figure 2). River flows declined considerably from the end of June and reached a low, stable level during most of August and September. No evidence of Asian carp reproduction in the IWW was observed throughout the summer months of 2019. A rise in river flows began during the middle of September and accelerated during the last week of September. A late spawning event was evident at the beginning of October, with Asian carp eggs collected in the lower Peoria and LaGrange Pools at this time (Figure 2). Water temperatures declined rapidly around this time, with the window of temperatures that are conducive to Asian carp reproduction ending shortly after this late spawning event. No Asian carp eggs or larvae were observed upstream of the Peoria Pool during 2019.

During 2019, an additional 345 ichthyoplankton samples were collected from tributary rivers. The extremely high discharge and prolonged flooding that occurred during 2019 restricted access to some tributary sites during June, prohibiting sampling during some dates when Asian carp eggs or larvae may have been present. However, tributary sampling in 2019 did collect 618 larval fish, including 111 Asian carp larvae, as well as 1,122 Asian carp eggs. No Asian carp eggs or larvae were collected in the Kankakee or Fox Rivers during 2019, but larvae were observed in all other sampled tributaries and eggs were collected in the Spoon and Sangamon Rivers. Asian carp eggs and larvae were present in tributaries during late June and early July, but none were collected after mid-July in 2019 (Figure 3). Peak densities of larvae and eggs in the Sangamon River followed predicted patterns as they coincided with a significant increase in discharge after temperatures were above 18°C (Figure 3).

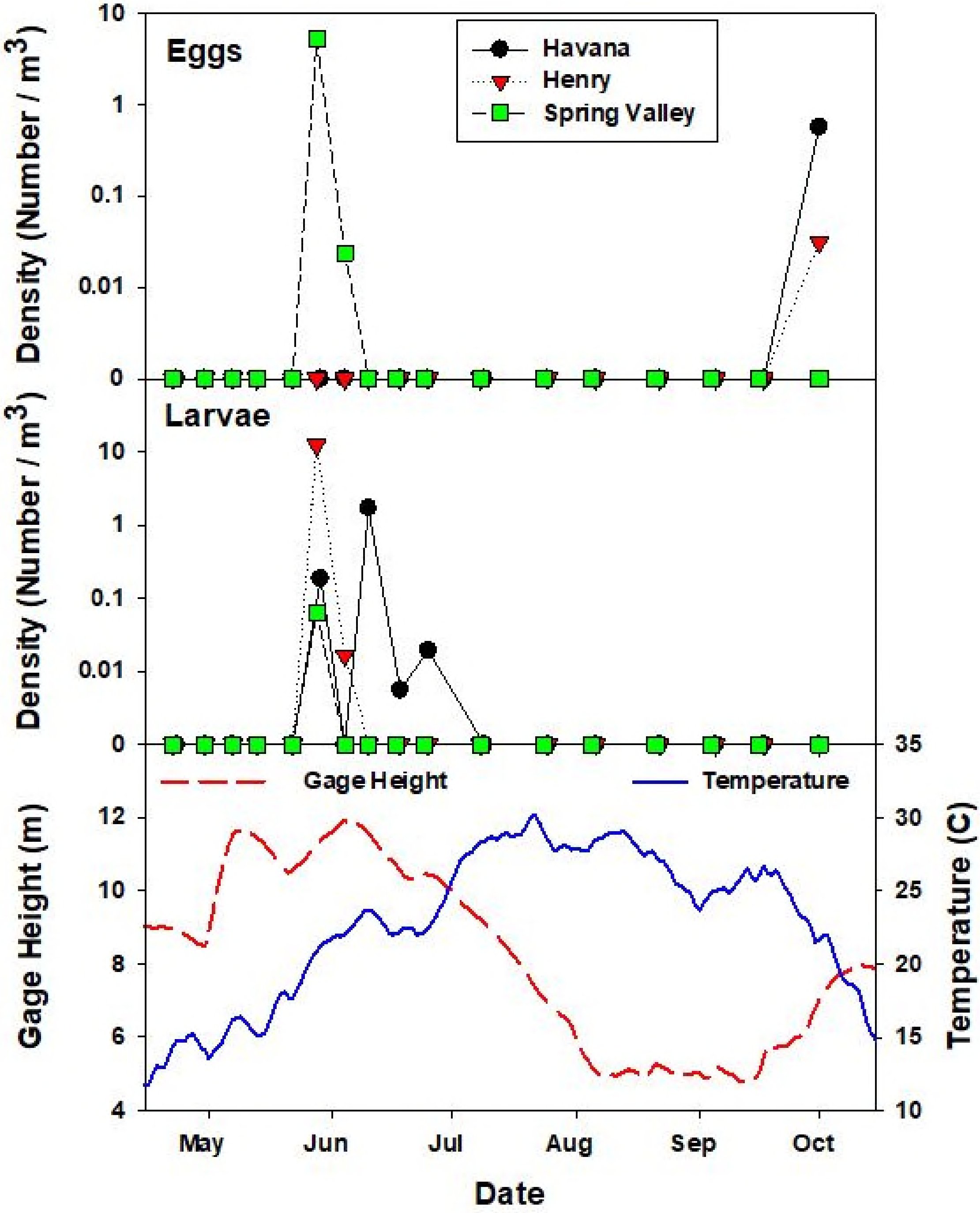

Figure 2. *Densities (number / m^3; note log scale) of Asian carp eggs (top panel) and larvae (middle panel) collected from main channel sites in the LaGrange and Peoria pools of the IWW during 2019. Mean daily gage height (m) and water temperature (° C) of the Illinois River during April – October 2019 (bottom panel) were obtained from USGS gage 5586300 at Florence, IL.*

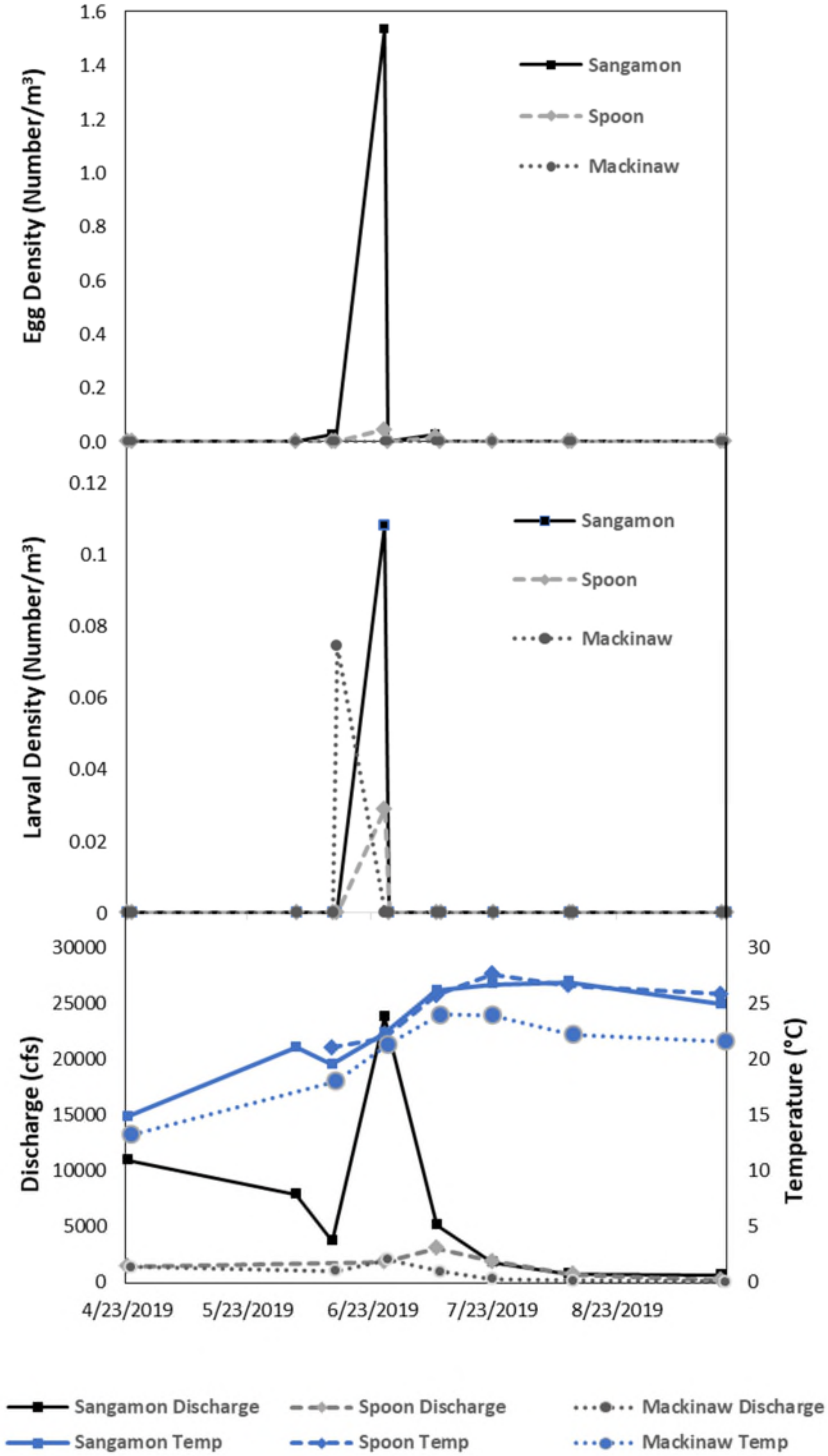

Figure 3. *Density (number / m^3) of Asian carp eggs (top panel) and larvae (middle panel) collected from downstream sites on three tributaries of the Illinois River (Sangamon, Spoon, and Mackinaw rivers) during April – September 2019. Water temperature (^{o} C) was measured at each sampling event and mean daily discharge (cubic feet/second) was obtained from USGS gages (Sangamon River: 5583000; Spoon River: 5570000; Mackinaw River: 5568000).*

Much smaller changes in discharge on the Spoon and Mackinaw Rivers over the same time period may have contributed to lower numbers of Asian carp larvae in those tributaries in 2019. Peak densities of larval Asian carp observed in the tributaries in 2019 were lower than in 2018, particularly in the Sangamon River, but were comparable to some earlier study years (Figure 4).

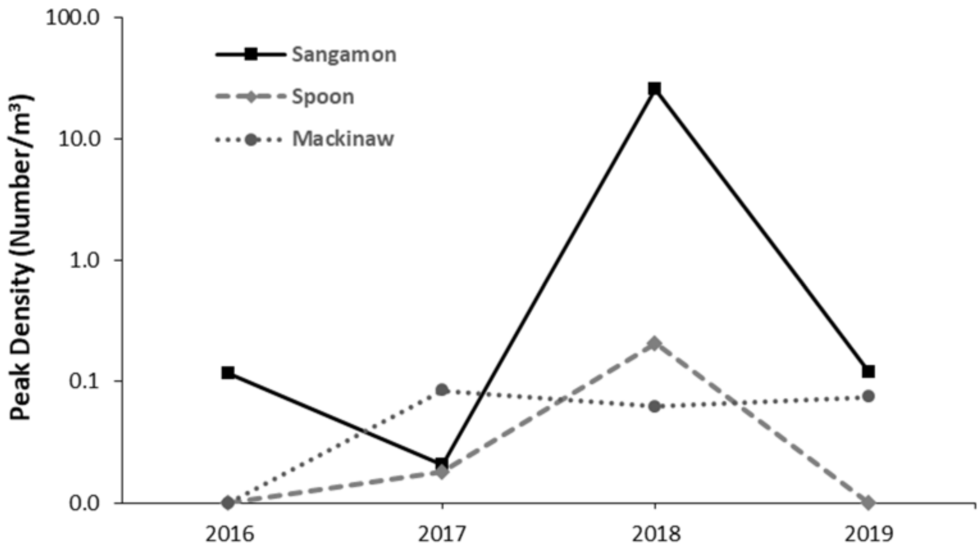

Figure 4. *Peak densities (number / m^3; note log scale) of Asian carp larvae collected from three tributaries of the Illinois River (Sangamon, Spoon, and Mackinaw Rivers) during 2016 – 2019. No larval Asian carp were collected in the Kankakee and Fox Rivers during this time period.*

Across the monitoring period from 2014 to 2019, the largest peaks in Asian carp egg drift at IWW main channel sites occurred from late May through June (Julian days 151-180), with lesser peaks observed during July through September (Figure 5). The largest peaks of Asian carp eggs were collected at stations in the Starved Rock and Peoria navigation pools, whereas the highest peak densities of larvae were observed at downriver sites in the Peoria and LaGrange pools (Figure 6). Comparison of models with linear and nonlinear relationships between adult Asian carp density and total egg density indicated that a quadratic function was most strongly supported (Table 1), suggesting the possibility of density-limitation of reproductive output at very high densities of adults (Figure 7). When abiotic variables were added to models, model support was found to be nearly identical for May and June cumulative degree days (AIC_c = 102.8 and 102.7 for May and June, respectively) and so the decisions was made to only retain June degree days in subsequent analyses. A model that included both June degree days and mean May-June flow rate with adult spawner density was most strongly supported by the observed data (Table 1). Egg production was found to be higher during years with warmer May and June water temperatures and higher flow rates and increased in a saturating manner with adult density (Figure 7).

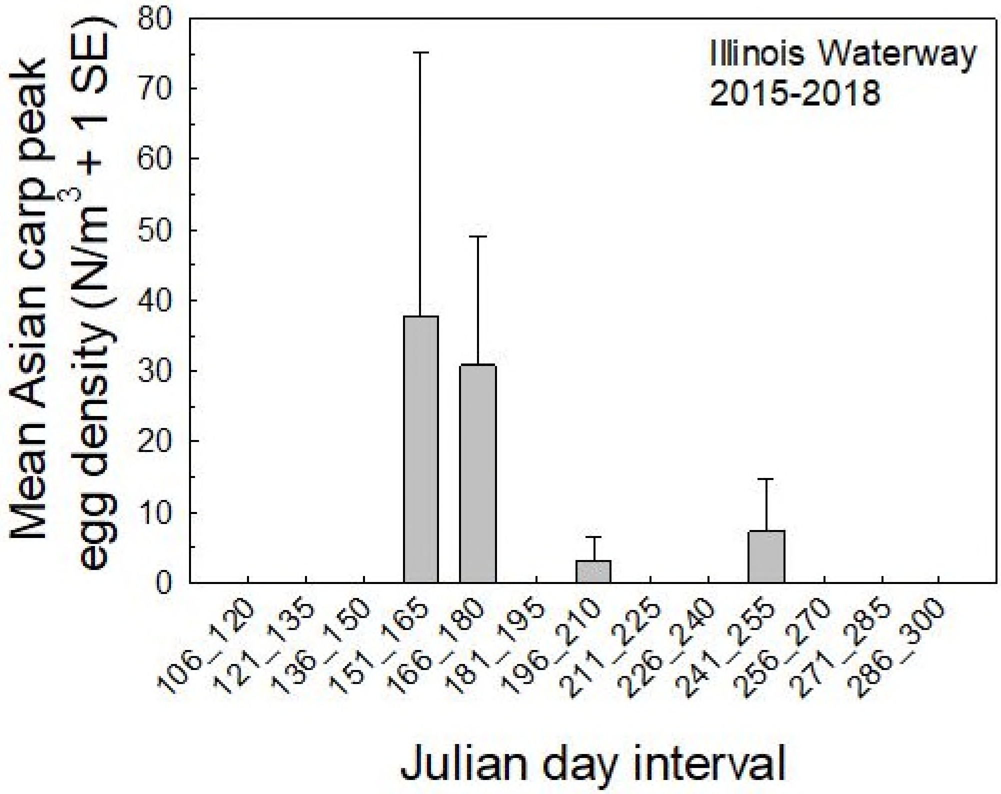

Figure 5. *Timing of peak density of Asian carp egg drift (mean number / m^3 + SE for 15-day intervals) in the IWW during the monitoring period with most complete spatial coverage (2015-2018).*

Asian carp eggs were observed upstream from Starved Rock Lock and Dam every year during 2014 – 2018, but not during 2010 – 2013 or in 2019. In contrast, eggs and larvae have consistently been collected in the LaGrange and Peoria Pools. Habitat conditions, hydrology, and adult Asian carp abundance all differ considerably among different pools of the IWW, potentially contributing to substantial inter-annual variation in reproductive output among navigation pools. Previous studies have noted that Asian carp spawning tends to be associated with a rising hydrograph when water temperatures are above 18°C (Kolar et al. 2007, Lohmeyer & Garvey 2009, Larson et al. 2017), and indeed the majority of collections of Asian carp eggs and larvae across all study years in the IWW were associated with such conditions. If the appropriate combination of abiotic factors to initiate spawning does not occur within a particular navigation pool in a given year, the majority of Asian carp within that pool may not spawn that year. However, consistent collection of at least small densities of Asian carp eggs or larvae in the lower Illinois River suggests that at least a small proportion of the spawning stock may attempt to spawn each year even under suboptimal conditions.

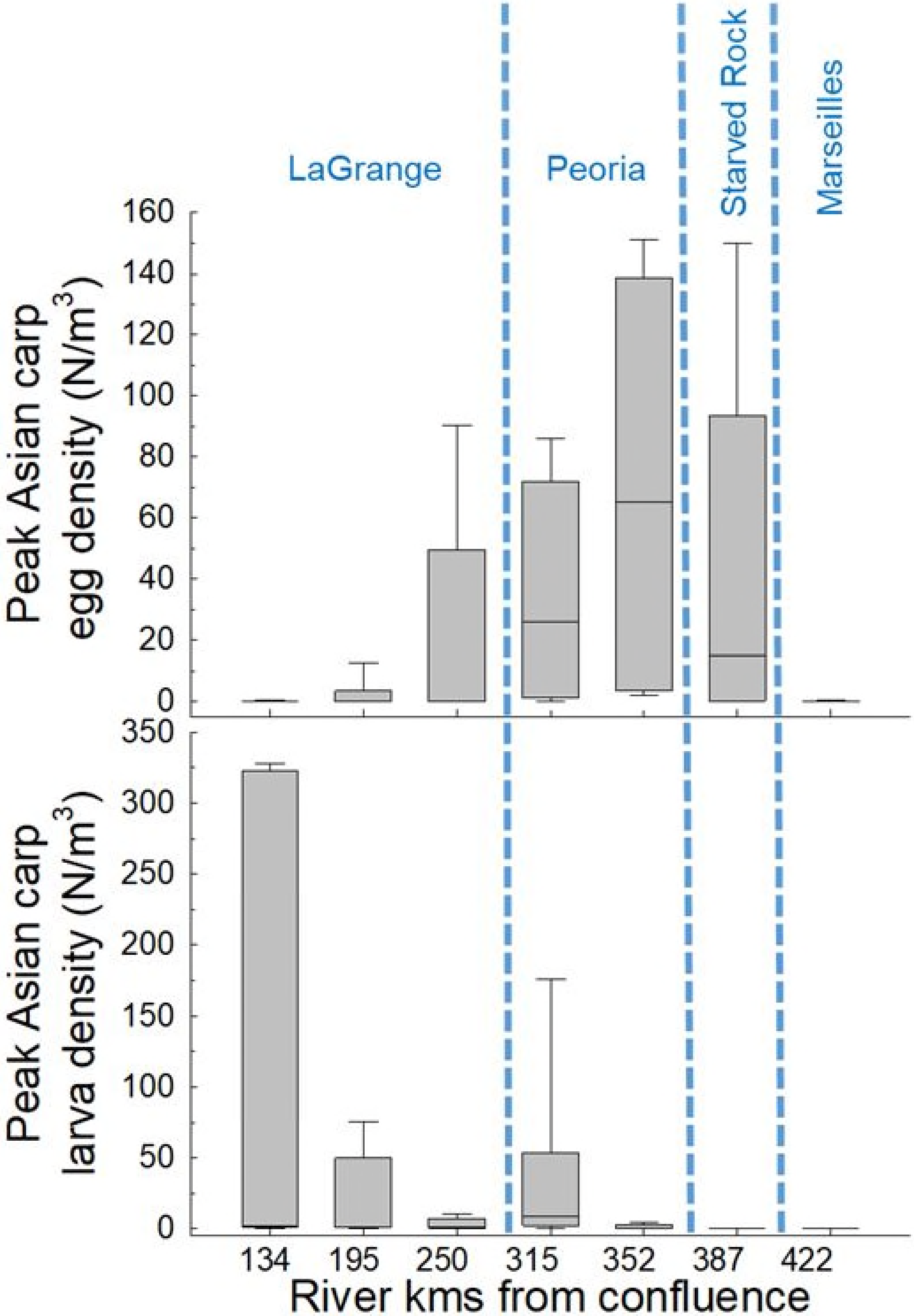

Figure 6. *Box and whisker plots of peak Asian carp egg (top panel) and larval (bottom panel) densities at monitoring stations within the LaGrange, Peoria, Starved Rock, and Marseilles navigation pools of the Illinois River during the monitoring period 2014 through 2019. River kilometers are measured as the distance upstream from the Mississippi River.*

Table 1. *Relative support for models of peak Asian carp egg density at sample stations in the LaGrange, Peoria, Starved Rock, and Marseilles navigation pools. The first model set (models M1 through M4) compares support between linear, quadratic, and logistic formulations of an adult-egg relationship. The second set of models (M1, M3, and M5 through M7) assesses relative model support for models adding cumulative degree days in June, mean flow rate in June, or both to a model with a quadratic adult-egg relationship. Relative support is assessed by comparing model AIC_c scores and the difference in score between each model and the most supported model within the set (Δ), with models ≤ 2 AIC_c apart considered to have similar support. Coefficients of determination (adjusted R^2) are presented for the most supported models in the second set of model comparisons.*

Response	**Model**	**AICc**	**Δ**	**Adjusted R^2**
Total carp eggs	M1. null	122.7	16.1	
	M2. adult density linear	113.9	7.3	
	M3. adult density quadratic	106.6	0	
	M4. adult density logistic	112.1	5.5	
	M1. null	122.7	23.4	
	M3. adult quadratic	106.6	7.3	
	M5. M3 + cumulative degree days June	102.7	3.4	
	M6. M3 + mean June flow rate	103.8	4.5	
	M7. M3 + M5 + M6	99.3	0	0.60

Substantial annual and spatial variation in the density of Asian carp eggs and larvae have been observed within and among IWW tributaries. For example, in 2014, large numbers of Asian carp larvae were collected from the Spoon River, and Asian carp accounted for over 80 percent of the total larval fish sampled in the Mackinaw River, but none were present in any samples from the Sangamon River that year. In contrast, sampling in 2018 found high densities of larval Asian carp in the Sangamon River, with lower abundances in the Mackinaw and Spoon rivers. No evidence of Asian carp reproduction has been found in the Kankakee River, but Asian carp eggs were collected in the Fox River in 2016, although not in any year since. Variation in temperature and hydrological variables among rivers could explain much of this variation, with differences in the timing and magnitude of discharge events potentially influencing the magnitude of reproduction that occurs within each river in a given year. Differences in spawning stock characteristics among different tributaries could also contribute to the observed variation but has not yet been adequately assessed. The majority of Asian carp eggs and larvae have also been collected at downstream tributary sites, but observations of eggs and larvae at upstream

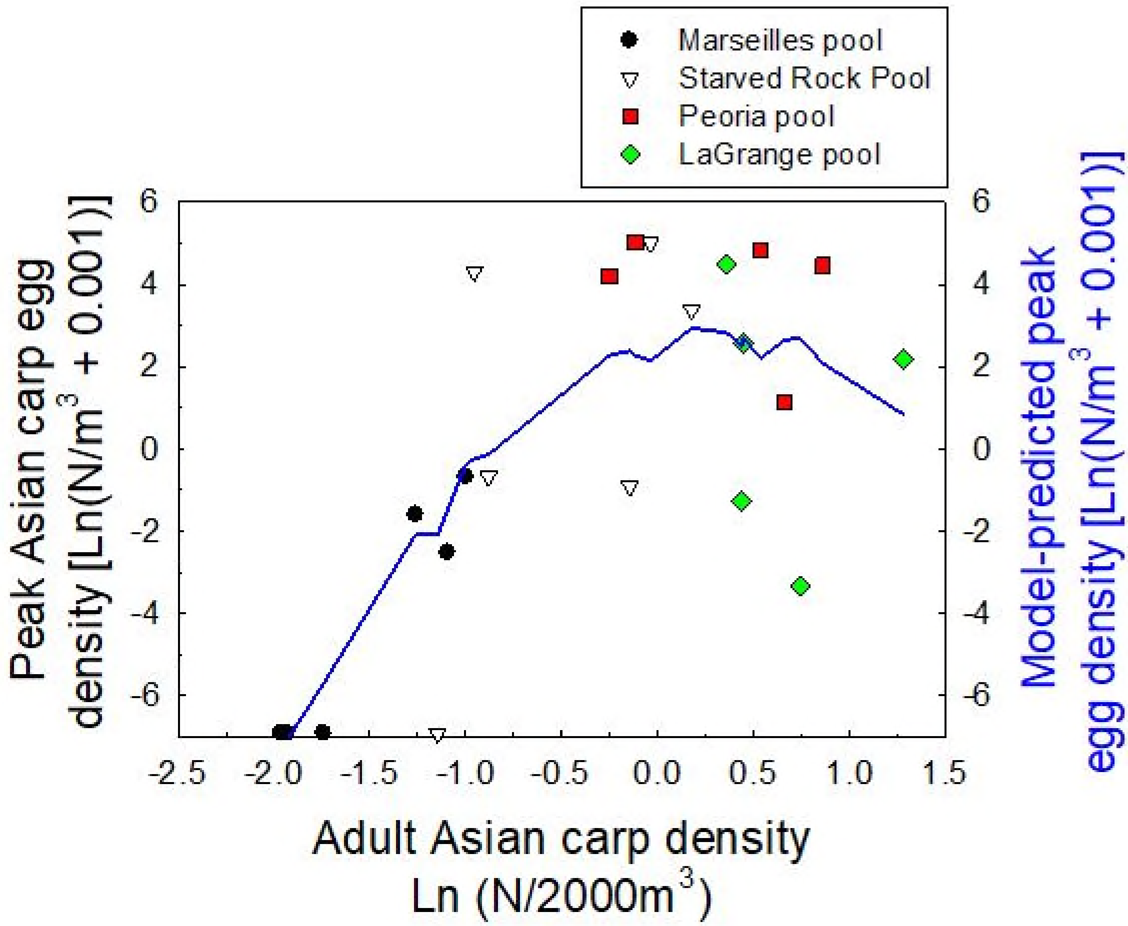

Figure 7. *Annual peak Asian carp egg densities observed at sampling stations within each navigation pool and model-predicted peak annual egg density at each location (solid blue line) plotted over observed adult Asian carp density. Predictions are derived from a model where predictor variables are cumulative degree days by the end of June, mean June flow rate, and a quadratic relationship with adult Asian carp density.*

sampling sites indicate that Asian carp spawning can extend further upstream in tributaries than previously documented. In 2019, almost 60 percent of Asian carp larvae collected in the Sangamon River were captured at a site 137 kilometers from the confluence with the Illinois River. The actual locations of spawning within Illinois River tributaries, the duration of spawning events, and the rate at which eggs and larvae are transported through these systems remain poorly understood. This information would be helpful for better interpreting differences in the magnitude of observed egg and larval densities, for assessing the contribution of eggs or larvae originating in tributaries to the main channel of the Illinois River, and for understanding if larvae potentially settle out of the drift and eventually contribute to recruitment within tributaries themselves. Continued monitoring and analyses are necessary to better understand environmental factors influencing the timing and magnitude of Asian carp reproduction in tributaries, factors contributing to differences in production of eggs and larvae among different tributaries, and the contribution of tributaries to basin-wide Asian carp population growth.

The analysis of factors associated with annual reproductive output by Asian carp should be considered preliminary as the incorporation of additional observations and information is needed to refine these models. The inclusion of combined adult stock estimates from the pool that eggs are collected in as well as the next upstream navigation pool is based on FluEgg model analysis from only a single year (2015; Zhu et al. 2018), so FluEgg analysis of additional years of staged egg data is warranted to more fully assess the assumptions of relevant adult density for each ichthyoplankton sampling station, as well as to quantify the consistency of Asian carp spawning locations in the Illinois River. Additional observations are needed to boost the power of this analysis and to parameterize the model over a wider range of environmental conditions and adult densities. It appears that the current model is overestimating egg density at some of the lower stock densities (Figure 7). Therefore, it may be useful to explore other nonlinear formulations for the relationship between adult density and egg production. Other sources of uncertainty include the relative contribution of spawning in tributaries to egg collections in the main channel of the IWW and potential movement of adult carp among pools prior to spawning. Information on seasonal spawning movements of Asian carp species would be helpful in refining our estimates of spawning stock density, especially below Starved Rock Lock and Dam, where movement between pools may be more prevalent than in the upper Illinois River. While the relationship between egg production of Asian carps and their subsequent recruitment strength is not currently known, identifying an inflection point where reproductive output is very low or eliminated at a particular range of stock densities may create an opportunity to use targeted removals to impose an Allee effect on carp populations in more isolated navigation pools with low immigration rates.

Recommendations:

Ichthyoplankton sampling should continue to evaluate Asian carp reproduction, particularly upstream of the Peoria Pool, to monitor for any changes in the Asian carp reproductive front and to evaluate the effects of Asian carp harvest activities on the reproductive potential of these populations. Continued ichthyoplankton sampling in tributary rivers (Sangamon, Spoon, Mackinaw, Fox, and Kankakee rivers) is warranted to examine the potential for these systems to serve as sources for Asian carp populations in the IWW, and to evaluate the potential for similar rivers in the Great Lakes region to serve as spawning tributaries. Pursuit of further efficiencies in ichthyoplankton sampling and sample processing is recommended in order to make best use of available resources and more quickly provide relevant information to stakeholders. A quantitative PCR (qPCR) method for screening ichthyoplankton samples has demonstrated promise for rapidly identifying samples that are likely to contain Asian carp eggs or larvae (Fritts et al. 2019). Further refinement of such methodology would be extremely useful for being able to quickly determine the likely locations of spawning Asian carp so that response actions could be initiated in a timely manner if warranted. Additionally, further FluEgg modeling is needed to determine the consistency of Asian carp spawning locations in the IWW and provide information to better understand the relevant adult spawner density for assessment of stock - reproductive productivity relationships. Further modeling efforts to evaluate the relationship between adult density and egg production are recommended, as these analyses may assist in evaluating if Asian carp removal efforts are diminishing the reproductive potential of Asian carp in targeted navigation pools.

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Monitoring Bigheaded Carp Movement and Density in the Illinois River

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Participating Agencies: Southern Illinois University (SIU) (lead); Illinois Department of Natural Resources (Illinois DNR) (support); U.S. Fish and Wildlife Service (USFWS) (support); U.S. Army Corps of Engineers (USACE)–Chicago District (support); U.S. Geological Survey (USGS) (support), Illinois Natural History Survey (INHS) (support).

Pools Involved: Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, LaGrange, Alton

Introduction and Need:

Bigheaded carp spatial distributions vary both seasonally and annually; therefore, quantifying how spatial distributions change through time will help direct contracted harvest efforts to high-density locations in order to maximize removal efficiency. Density hotspots, though, shift throughout the year and vary among years. Thus, assessments of bigheaded carp spatial distributions in Dresden Island and Marseilles pools will allow contracted removal to maintain high harvest rates.

Monitoring of bigheaded carp densities via hydroacoustic sampling throughout the Illinois River (Alton to Dresden Island pools) by SIU has been ongoing since 2012 and is a useful metric to evaluate long-term changes in bigheaded carp abundance. Broad-scale density estimates also help inform management actions in the upper river near the invasion front. Annual densities in the lower Illinois River have displayed relatively large annual fluctuations among years (Coulter et al. 2016), necessitating the need for continued assessments of bigheaded carp densities throughout the river. This will identify whether lower river population size has increased from the previous year and help determine whether harvest or surveillance in the upper river should be altered in anticipation of increased immigration from downstream pools. It is currently unclear whether, or the extent to which, bigheaded carp in the Illinois River exhibit density-dependent effects on reproduction, condition, growth, and movement. Collecting long-term data, particularly density and movement data, will help quantify these patterns which will better inform management decisions and improve models predicting population response to management actions.

While annual monitoring provides a snapshot to document long-term trends in bigheaded carp abundance, seasonal surveys can be used to help improve removal by identifying and directing harvest efforts to high-density sites. Dresden Island pool represents the current population front for the adult bigheaded carp invasion in the Illinois River, while Marseilles is the most upstream pool where young-of-year have been found. Frequent hydroacoustic surveys of bigheaded carp densities in these pools will identify locations where bigheaded carp aggregate and can be used to direct removal efforts to changing bigheaded carp spatial distributions throughout the year.

Monitoring Bigheaded Carp Movement and Density in the Illinois River

A spatially-explicit population model of bigheaded carp in the Illinois River was recently developed to assess how bigheaded carp populations respond to a variety of management actions (e.g., location and intensity of harvest; location and effectiveness of deterrent technologies). This model draws on a wide variety of data collected by different agencies including bigheaded carp densities and movement data previously collected by SIU. Collaborations between the Monitoring and Response Work Group's (MRWG) Modeling, Telemetry, and Hydroacoustic Work Groups have identified several additional data needs in addition to maintenance of current monitoring efforts. SIU's contribution to continued model support and development will include continued maintenance of the Illinois River stationary telemetry array to document inter-pool movements, deployment of additional acoustic telemetry tags in bigheaded carp (numbers set based on telemetry working group determinations), continued hydroacoustic monitoring of bigheaded carp densities throughout the Illinois River. Additionally, Telemetry Work Group partners have also identified the need to better understand the meaning of telemetry data collected from surrogate fishes by comparing movements of surrogate species in relation to those of bigheaded carp. SIU will partner with USACE to exploit SIU's existing acoustic telemetry tags in bigheaded carp near Starved Rock Pool and their stationary receiver array.

In order to limit bigheaded carp dispersal towards the Great Lakes, contracted removal reduces propagule pressure along the invasion front. In addition to these removals, the deployment of deterrent or fish barrier technologies to further reduce dispersal is also being considered. One potential concern regarding barrier enhancement (not just at Brandon Road Lock and Dam, but at other dams on other rivers) to limit bigheaded carp movement is potential fragmentation and loss of connectivity for native fish populations. The extent to which native fishes move through Brandon Road Lock and Dam (particularly upstream) is a major knowledge gap. Previous research at SIU has demonstrated that otolith or fin ray chemistry can distinguish fish from the Illinois, Kankakee, and Des Plaines rivers (Whitledge 2009; Smith and Whitledge 2010). Thus, this approach can be used to determine the frequency of occurrence of fishes in the Des Plaines River upstream of Brandon Road Lock and Dam that had previously been in the Illinois or Kankakee rivers (downstream of Brandon Road Lock and Dam). The advantage of this approach is that unlike conventional mark-recapture methods or telemetry, fish do not need to be recaptured or relocated, making this a cost-effective approach for sampling a large number of fish to obtain an initial assessment of native fish movement upstream past Brandon Road Lock and Dam. Knowledge of the extent to which native fishes pass upstream through Brandon Road Lock and Dam could inform assessment of potential impacts of barrier enhancement at Brandon Road Lock and Dam on native riverine fishes.

Objectives:

(1) Quantify Asian carp densities every other month in Dresden Island and Marseilles pools in 2019 using mobile hydroacoustic surveys to pinpoint high density areas that can be targeted during contracted removal. Surveys will also document how distributions of

bigheaded carp change through time which can better inform targeted removal and could provide an indication of the effectiveness of harvest efforts. Data collection will occur bi-monthly as long as conditions allow and results will be available one month after the survey.

(2) Conduct hydroacoustic surveys at standardized sites in fall 2019 from Alton to Dresden Island pools to assess long-term trends in density, biomass, and size structure.

(3) Maintain SIU's extensive acoustic telemetry array currently in place in the Illinois River used to collect movement and dam passage. Share collected data with telemetry working group and those working on the Spatially Explicit Asian Carp Population (SEACarP) model.

(4) Collaborate with USACE to compare the movements of surrogate fish species (i.e., Common Carp) to the movements of bigheaded carp. This will help interpret movement information of surrogate fish species from Dresden Island Pool to the CAWS, as it pertains to hypothetical bigheaded carps in those areas.

(5) Estimate relative abundance of native fishes in the Des Plaines River upstream of Brandon Road Lock and Dam that had previously been in the Illinois or Kankakee rivers using fin ray microchemistry to assess frequency of native fish movement upstream through Brandon Road Lock and Dam.

Project Highlights:

- Repeated hydroacoustic surveys in Dresden Island and Marseilles pools identified areas of high bigheaded carp density and how these locations change through time. These data helped direct contracted removal efforts throughout 2019.
- Fall 2019 bigheaded carp densities in Starved Rock, Marseilles, and Dresden Island pools were the lowest or as low as any densities observed in those pools since monitoring began in 2012. River discharge during sampling dates in the upper river pools were similar to previous years.
- Mean observed bigheaded carp densities in Dresden Island Pool during October of 2019 was 96.7% lower than the mean observed density in 2012.
- Bigheaded carp densities in Alton and Peoria pools during fall 2019 were lower than previous monitoring years which coincided with flooding and historically high river discharge during the time of sampling. Low observed densities may have been caused by fishes moving out of high-flow main channel areas and into shallow, low-flow habitats that were not sampled.
- Upstream passages by bigheaded carp at dams of greatest concern in the upper Illinois River continue to be limited, with one upstream passage occurring at Dresden Island Lock and Dam, two at Marseilles Lock and Dam, and four at Starved Rock Lock and Dam. These results are based solely on SIU's telemetry data, so data combined across agencies could produce additional passage events.

- Tentative results from surrogate fish work indicate that microhabitat selection is different between Common Carp and Silver Carp, but broader habitat use (e.g., main channel vs. side channel) may be similar. Initial results also suggest the ranges occupied by Silver Carp are larger than ranges used by Common Carp. Eight to 34% of fish sampled upstream of Brandon Road Lock and Dam, depending on taxa, exhibited fin ray strontium:calcium ratio (Sr:Ca) suggesting prior residency in the Illinois or Kankakee rivers, and therefore upstream passage through Brandon Road Lock and Dam.

Methods:

Hydroacoustic Surveys – Bi-monthly Heat Maps and Fall Standardized Surveys: Repeated hydroacoustic surveys in the upper Illinois River (Dresden Island and Marseilles pools) in 2019 were completed in March, April, June, and August. Final 2019 surveys in these pools and throughout other Illinois River (Starved Rock and Alton pools) were completed in fall of 2019. All hydroacoustic sampling methods, designs, and analyses followed those outlined in MacNamara et al. (2016). We also completed surveys before and after Unified Method events in Dresden Island Pool and the HMS Pits to quantify potential changes in bigheaded carp density following harvest. Heat maps depicting bigheaded carp spatial distributions were also generated from sampling before Unified Methods and supplied to Illinois DNR to inform harvest crews. Fall hydroacoustic sampling for monitoring long-term bigheaded carp density trends occurred in October 2019 at standardized sites (including main channel, side channel, and backwater sites) following standardized sampling methods used in previous years (since 2012).

Movement and Dam Passage: Utilizing an array of 71+ Vemco 69 kHz stationary receivers maintained by SIU (Coulter et al. 2018; Abeln 2018) as well as stationary receviers maintained by partner agencies (USGS, USACE, USFWS, MDC), the movements of Silver Carp and Bighead Carp implanted by SIU with internal transmitters (Vemco V16 transmitters) were monitored from Alton Pool upstream through Dresden Island Pool. Eighteen new stationary receivers were deployed throughout the river to replace lost receivers and to support the surrogate fish project, resulting in a total of 54 stationary receivers operating throughout the river in 2019. Receiver totals (including those in lock chambers) deployed within pools by SIU were as follows: Dresden Island 3, Marseilles 5, Starved Rock 23, Peoria 10, LaGrange 6, Alton 7). Additional stationary receivers are deployed by other agencies in the Telemetry Work Group: USGS, USACE, USFWS, INHS. Additionally, other bigheaded carp, Grass Carp, and Common Carp implanted with 69 kHZ transmitters by other members of the Telemetry Work Group (MRWG) can also be detected by this array. Stationary receivers were downloaded on two occasions in 2019. Downloaded data for 2019 were initially checked to remove false detections and data were analyzed to identify upstream and downstream passages through lock and dam structures in the study area (*sensu* Lubejko et al. 2017). Additional acoustic telemetry tags were deployed to replace expiring tags in Marseilles Pool (50 new tags – May 2019), and 50 tags in the Alton and LaGrange pools (2 Alton/48 LaGrange – November 2019). An additional 150 tags will be deployed in Alton and LaGrange pools in 2020.

Monitoring Bigheaded Carp Movement and Density in the Illinois River

Surrogate Fish Movements: In collaboration with USACE, this project will utilize an extensive array of stationary receivers (25+) around Starved Rock Lock and Dam (upper Peoria Pool) and within Starved Rock Pool, as well as over 50 already existing acoustic tags in bigheaded carp in Starved Rock Pool to monitor the movements of bigheaded carp and surrogate species. In this case, Common Carp will serve as a surrogate species as this is the most common species tagged as a surrogate for bigheaded carp by USACE above Brandon Road Lock and Dam. Fifty Common Carp were tagged with acoustic telemetry tags in April 2019 (25 in upper Peoria Pool, 25 in Starved Rock Pool). Additionally, seven Common Carp and seven Silver Carp were given temperature sensing acoustic telemetry tags.

Stationary receivers were downloaded twice a year and active tracking of Starved Rock Pool and upper Peoria Pool was conducted monthly from April through October 2019. If enough movement data are collected from temperature tags, these data could be used to assess the thermal habitat use of both species. Additionally, once monthly active tracking (April – October) of tagged Common Carp and Silver Carp in Starved Rock and upper Peoria pools was conducted to collect habitat use data including: general habitat use (main channel, channel border, side channel, backwater, tributary), sediment (sand, silt, rock), and measurements of water quality at 1-min intervals during active tracking (via a YSI multiparameter sonde, including water temperature, dissolved oxygen, and chlorophyll *a*). Active tracking consisted of a boat with an omnidirectional hydrophone deployed over the side travelling at idle speed with flow through main channel and lateral habitats. When a tagged fish was located, a directional hydrophone was used until a minimum decibel strength of the tag was achieved to determine fish location. Once the decibel threshold was reached, habitat information was recorded.

Active tracking and stationary receiver data was quality assurance/quality controlled and then used to estimate home range (kenel density) and distance traveled. Substrate and habitat use were also quantified based on active tracking results. Dam passages upstream and downstream through Starved Rock Lock and Dam by both Silver Carp and Common Carp during 2019 were identified. This project will continue through 2020 and so results presented are preliminary.

Using fin ray microchemistry to evaluate native fish passage through Brandon Road Lock and Dam: Water samples were collected during October 2017-October 2018 from the Des Plaines, Illinois, and Kankakee rivers to verify persistence of previously observed differences in water Sr:Ca among these rivers. Water samples for determination of Sr and Ca concentrations were collected using a syringe filtration technique (0.45 µm pore size) and analyzed using high resolution, inductively coupled plasma mass spectrometry (ICPMS). Native fishes (Smallmouth Buffalo *Ictiobus bubalus,* Bigmouth Buffalo *Ictiobus cyprinellus,* Black Buffalo *Ictiobus niger,* River Carpsucker *Carpiodes carpio,* Quillback *Carpiodes cyprinus,* Largemouth Bass *Micropterus salmoides,* Smallmouth Bass *Micropterus dolomieu,* Channel Catfish *Ictalurus punctatus,* and Longnose Gar *Lepisosteus osseus*) were collected from the Kankakee River, the upper Illinois River, and Des Plaines River upstream of Brandon Road Lock and Dam during August 2017-November 2018. A leading pectoral fin ray was removed from each fish at the base of the fin. A cross-section of the base of the fin ray from each fish was analyzed for Sr:Ca along a transect from the core to the edge of the fin ray using laser ablation-ICPMS. Fin ray edge (the portion of the structure reflecting recent growth) Sr:Ca of fish collected in the Kankakee, Illinois, and Des Plaines rivers was used to characterize Sr:Ca values indicative of fish residency in each river. Fin ray Sr:Ca data along the entire laser ablation transect from fin ray core to edge for fish captured in the Des Plaines River upstream of Brandon Road Lock and Dam were examined to identify individuals that had previously been in the Illinois or Kankakee rivers (and, therefore, must have passed upstream through the lock chamber at Brandon Road Lock and Dam) based on the presence of Sr:Ca values reflective of Illinois or Kankakee river residency at one or more locations within the fin ray.

Results and Discussion:

Hydroacoustic Surveys –Bimonthly Heat Maps and Fall Surveys: Mobile hydroacoustic surveys conducted every other month in Dresden Island and Marseilles pools identified locations where bigheaded carp aggregated and determined how these locations changed throughout the year (Figure 1). Density maps (Figure 1) were provided to MRWG members which helped inform contracted harvest efforts throughout the year.

Bigheaded carp densities in the upper Illinois River remained low relative to past years. Densities in fall 2019 were statistically similar to densities in fall of 2018 in Dresden Island Pool (Figures 2 and 3), with mean observed density in 2018 being 96.7% lower than mean density in 2012. Fall densities in Marseilles Pool were lower than densities in all previous years since monitoring began in 2012. Marseilles water levels were also relatively high during sampling and may have contributed to this decrease in 2019. Fall bigheaded carp densities in the Starved Rock Pool remained similar to recent years, with no statistical difference in densities from 2016 – 2019. In contrast, bigheaded carp densities in lower river pools (Alton and Peoria) were the lowest since monitoring began in 2012 (Figure 4). These pool-wide reductions in densities were due to much lower densities at main channel sites compared to previous years which was likely due to high flow conditions. Main channel discharge, reported by USGS gauging stations, was higher during 2019 sampling than during sampling in all previous years in Alton and LaGrange pools. Discharge in Peoria Pool was the second highest of all survey years. High main channel discharge may have caused fish in 2019 to move into non-main channel habitats to avoid high flow conditions and into areas not sampled during the standardized fall surveys.

The Unified Method events in the HMS East and West pits in Marseilles and Dresden Island pools significantly reduced bigheaded carp densities (Figure 5). Density reductions were larger for Silver Carp than for Bighead Carp, although densities decreased for both species. Bigheaded carp density heatmaps were created and shared with MRWG partners prior to the start of the Unified Methods in order to inform harvest crews on fish spatial distributions.

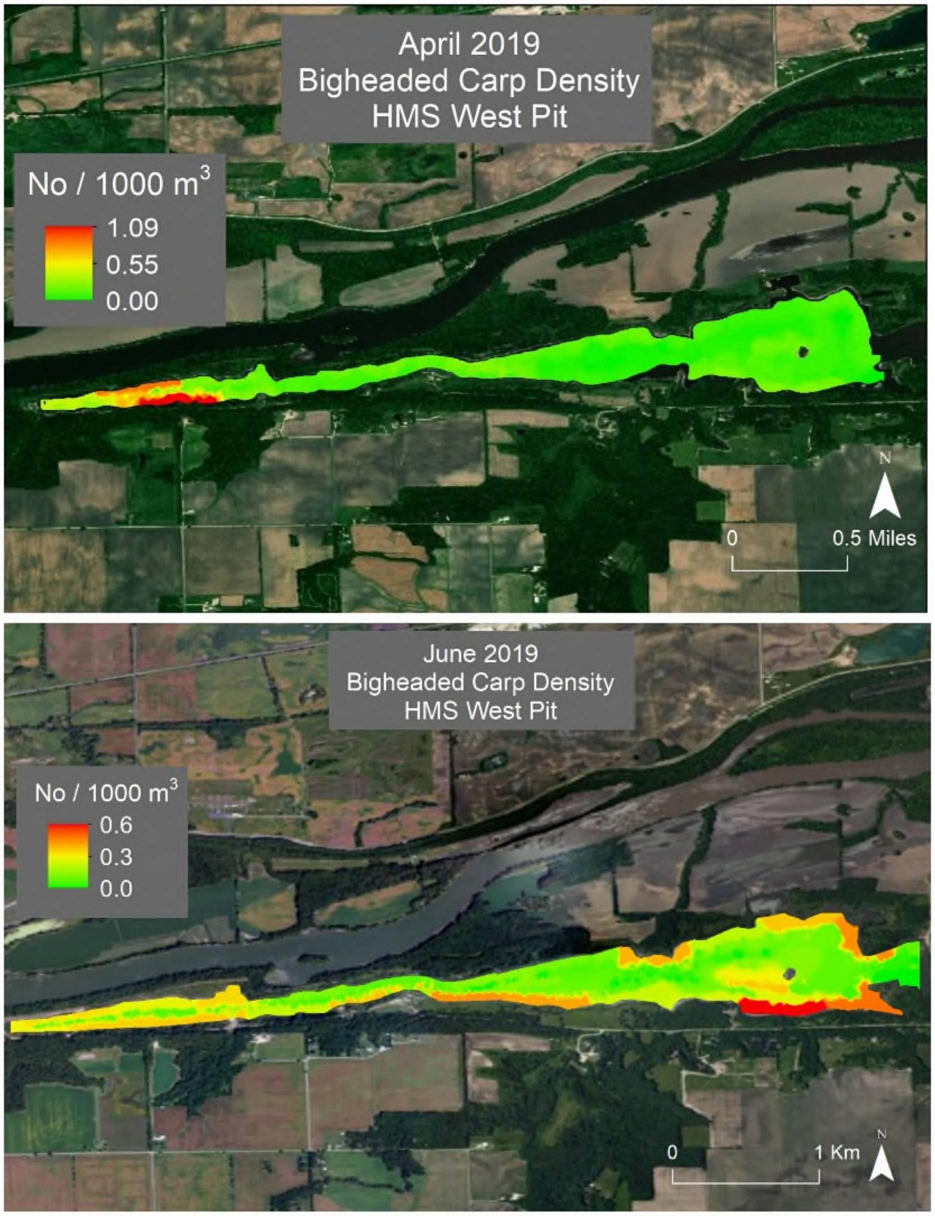

Figure 1. *Example of bigheaded carp spatial distributions and variability in distributions through time, in the HMS West Pit in Marseilles Pool. Density maps were used to direct contracted removal to high-density locations throughout 2019. Densities were observed using mobile hydroacoustic surveys.*

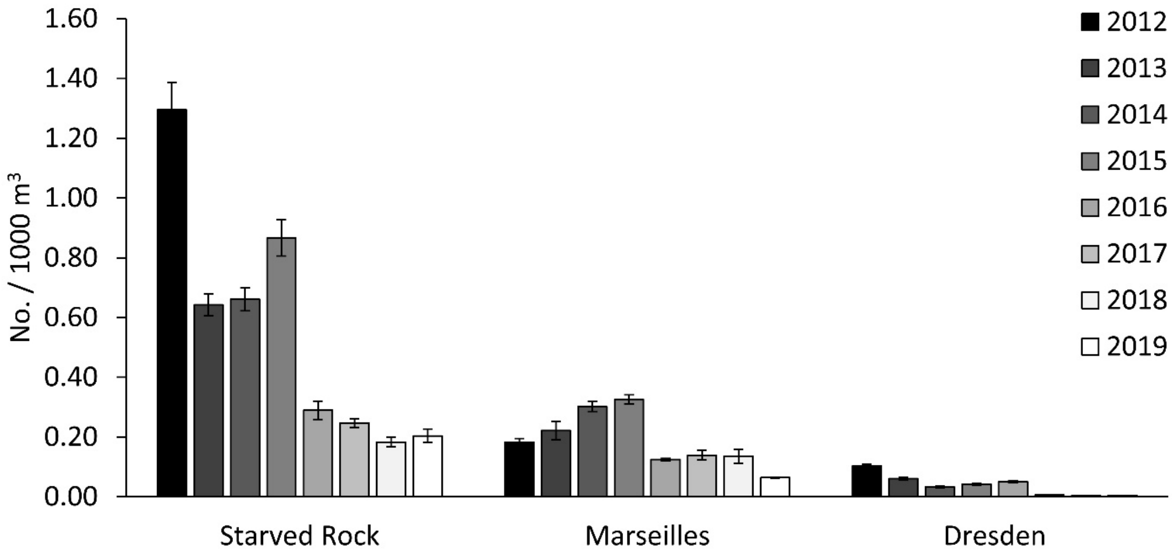

Figure 2. *Mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities estimated from fall hydroacoustic surveys conducted at standardized locations in the upper Illinois River.*

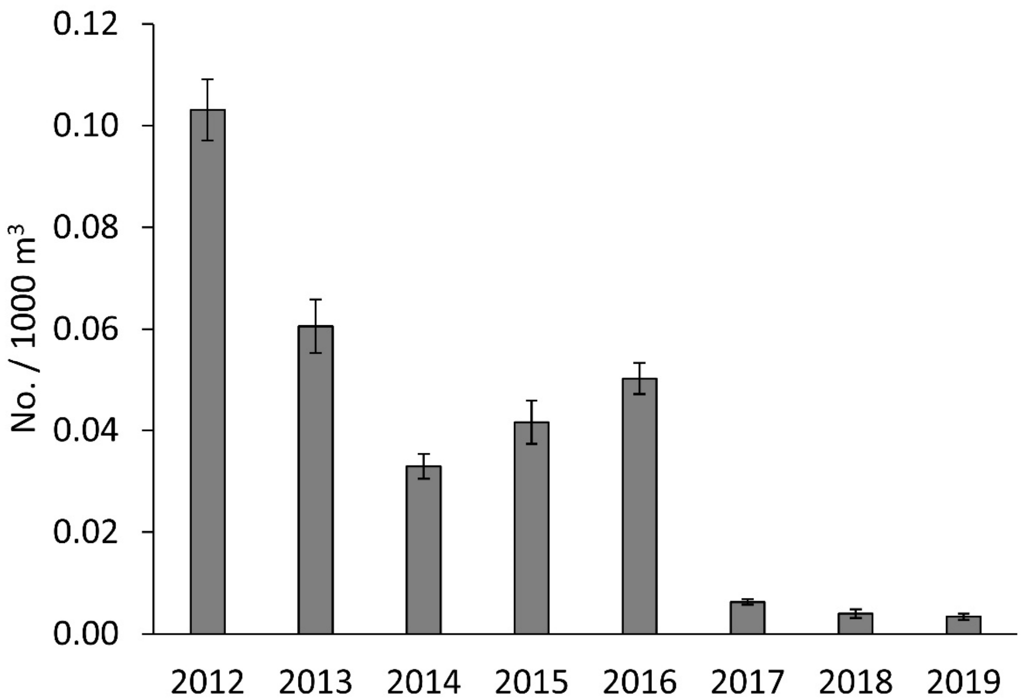

Figure 3. *Mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities estimated from fall hydroacoustic surveys in Dresden Island Pool. Densities in 2019 were similar to 2017 and 2018 but were lower than densities from 2012–2016.*

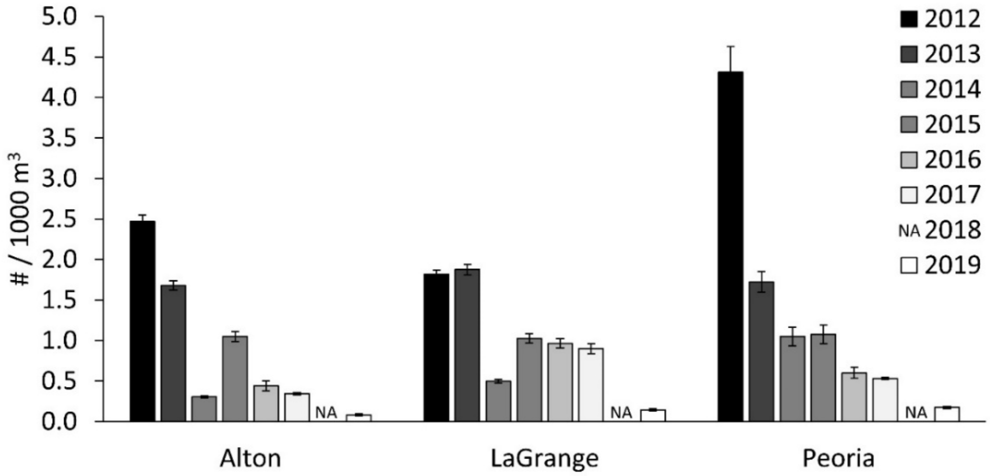

Figure 4. *Mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities from the lower Illinois River in 2019. Water levels and river discharge in the lower Illinois River pools were higher in 2019 than during all previous fall surveys which likely contributed low observed densities.*

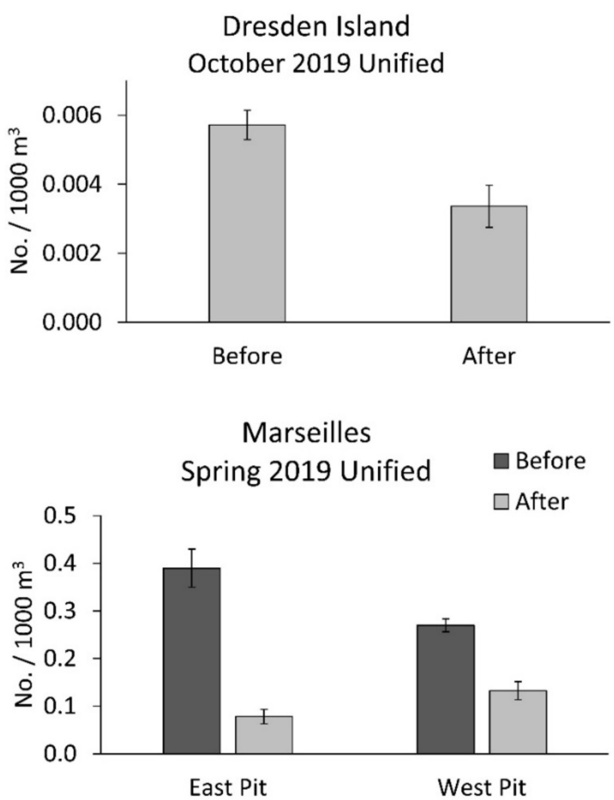

Figure 5. *Mean (standard error) bigheaded carp densities immediately before and after Unified Method events in Marseilles and Dresden Island pools in 2019. All density changes were statistically lower following the Unified Methods.*

Monitoring Bigheaded Carp Movement and Density in the Illinois River

Movement and Dam Passage: SIU stationary receivers collected 1,364,497 detections in 2019 from over 400 different acoustically tagged fishes in the Illinois River. All detection data was submitted for inclusion in the USGS-managed FishTracks telemetry database. Detections of upstream passages towards the invasion front were limited to one upstream passage through Dresden Island Lock and Dam, four through Marseilles Lock and Dam, and seven upstream passages through Starved Rock Lock and Dam by bigheaded carp in 2019 (Table 1). Detections of dam passages in the lower river were limited, as there were relatively few active transmitters in the lower Illinois River in spring 2019 compared to numbers in previous years (numbers increased in fall 2019 and will be further increased in fall 2020).

Surrogate Fish Movement: Home ranges (generated via kernel density analysis) were calculated for individual Common Carp and bigheaded carp from stationary receiver data. Although size of overall ranges was similar, it appears that core home range (50% kernel density) may be larger for bigheaded carp than for Common Carp (Figure 6). However, total distances traveled by individual fish in 2019 was greater for bigheaded carp (mean 30 river km [rkm]/year, $n = 13$) than for Common Carp (10 rkm/year, $n = 40$; Wilcoxon Test: $p < 0.001$).

No difference between species was evident in substrate use ($p = 0.55$); however there was a difference between the species in habitat type used ($p < 0.001$; Figure 7), which appears to be driven by bigheaded carps' increased use of backwater habitats. Both upstream and downstream passage through Starved Rock Lock and Dam occurred in 2019 for Common Carp and for bigheaded carp (Table 1), although insufficient number of passages occurred for statistical analysis. Differences between species in distances covered and habitat use may make it difficult to use Common Carp as a surrogate for bigheaded carp (e.g., as bigheaded carp move further this means they may spread more quickly through a system than Common Carp). However, based on the limited number of dam passages that occurred, Common Carp show potential to be a viable surrogate for bigheaded carp dam passage (most upstream passages occurred in the same month for both species). Continuation of this work through 2020 should provide better insight into the use of Common Carp as a movement surrogate for bigheaded carp. Future analyses will also include habitat selection assessments for Common Carp and bigheaded carp using water quality data.

Table 1. *Identified dam passages by bigheaded carp and Common Carp in the Illinois River in 2019 (only includes SIU data). Table indicates species making passage, the date or range of dates during which passage occurred, which lock and dam (L&D) structure was passed, the route of passage (lock versus dam), and the direction of passage (Direction: US = upstream, DS = downstream).*

Species	Date or Date Range	Dam	Route*	Direction
Bighead Carp	7/6/2019 - 8/4/2019	Dresden Island	Dam	US
Silver Carp	5/22/2019	Marseilles		US
Silver Carp	5/18/2019 - 5/31/2019	Marseilles		US
Silver Carp	5/26/2019	Marseilles		DS
Bighead Carp	5/6/2019 - 5/8/2019	Marseilles		DS
Common Carp	5/3/2019	Starved Rock	Dam	DS
Common Carp	5/6/2019 - 5/7/2019	Starved Rock	Dam	US
Common Carp	5/3/2019 - 5/4/2019	Starved Rock	Dam	DS
Common Carp	5/4/2019	Starved Rock	Lock	DS
Common Carp	5/2/2019 - 5/26/2019	Starved Rock	Dam	DS
Common Carp	6/8/2019	Starved Rock	Dam	US
Common Carp	6/9/2019	Starved Rock	Dam	DS
Common Carp	5/4/2019 - 5/7/2019	Starved Rock	Dam	DS
Common Carp	5/4/2019	Starved Rock	Lock	US
Common Carp	4/26/2019 - 5/11/2019	Starved Rock	Dam	US
Common Carp	6/25/2019 - 8/21/2019	Starved Rock	Dam	DS
Common Carp	9/1/2019	Starved Rock	Dam	US
Bighead Carp	5/28/2019 -5/30/2019	Starved Rock	Dam	US
Bighead Carp	7/20/2019	Starved Rock	Dam	DS
Silver Carp	5/20/2019	Starved Rock	Dam	US
Silver Carp	5/22/2019 - 5/30/2019	Starved Rock	Dam	DS
Silver Carp	5/10/2019	Starved Rock	Dam	US
Silver Carp	5/27/2019	Starved Rock	Dam	DS
Bighead Carp	5/8/2019	Starved Rock	Dam	DS
Common Carp	10/9/2019	Peoria	Lock	DS
Bighead Carp	5/9/2019 - 5/10/2019	Peoria	Lock	US
Silver Carp	5/17/2019	Peoria	Lock	US
Silver Carp	5/31/2019	Peoria	Lock	DS
Silver Carp	6/7/2019	Peoria	Lock	US
Silver Carp	6/7/2019	Peoria	Lock	DS
Silver Carp	5/20/2019	Peoria	Lock	US
Silver Carp	5/30/2019	Peoria	Lock	DS
Silver Carp	5/6/2019	Peoria	Lock	US
Silver Carp	5/30/2019	Peoria	Lock	DS
Silver Carp	6/3/2019	Peoria	Lock	US
Silver Carp	6/3/2019	Peoria	Lock	DS
Silver Carp	6/7/2019	Peoria	Lock	US

Table 1 Continued.

Species	Date or Date Range	Dam	Dam/Route	Direction
Bighead Carp	5/13/2019	Peoria	Lock	DS
Bighead Carp	5/19/2019	Peoria	Lock	US
Bighead Carp	5/11/2019	Peoria	Lock	US
Bighead Carp	5/28/2019	Peoria	Lock	DS
Bighead Carp	5/30/2019	Peoria	Lock	US
Bighead Carp	5/31/2019	Peoria	Lock	DS
Bighead Carp	5/6/2019 - 5/9/2019	LaGrange		US
Bighead Carp	8/14/2019 - 8/18/2019	LaGrange		DS
Silver Carp	5/14/2019 - 5/16/2019	LaGrange		US
Silver Carp	6/8/2019 - 6/13/2019	LaGrange		DS
Silver Carp	5/31/2019 - 6/2/2019	LaGrange		DS
Silver Carp	4/12/2019 - 4/16/2019	LaGrange		US
Silver Carp	6/4/2019 - 6/5/2019	LaGrange		DS
Silver Carp	5/31/2019 - 6/3/2019	LaGrange		US

* Stationary receivers in Marseilles Lock and Dam and LaGrange Lock and Dam were not downloaded, so route of passage was not determined.

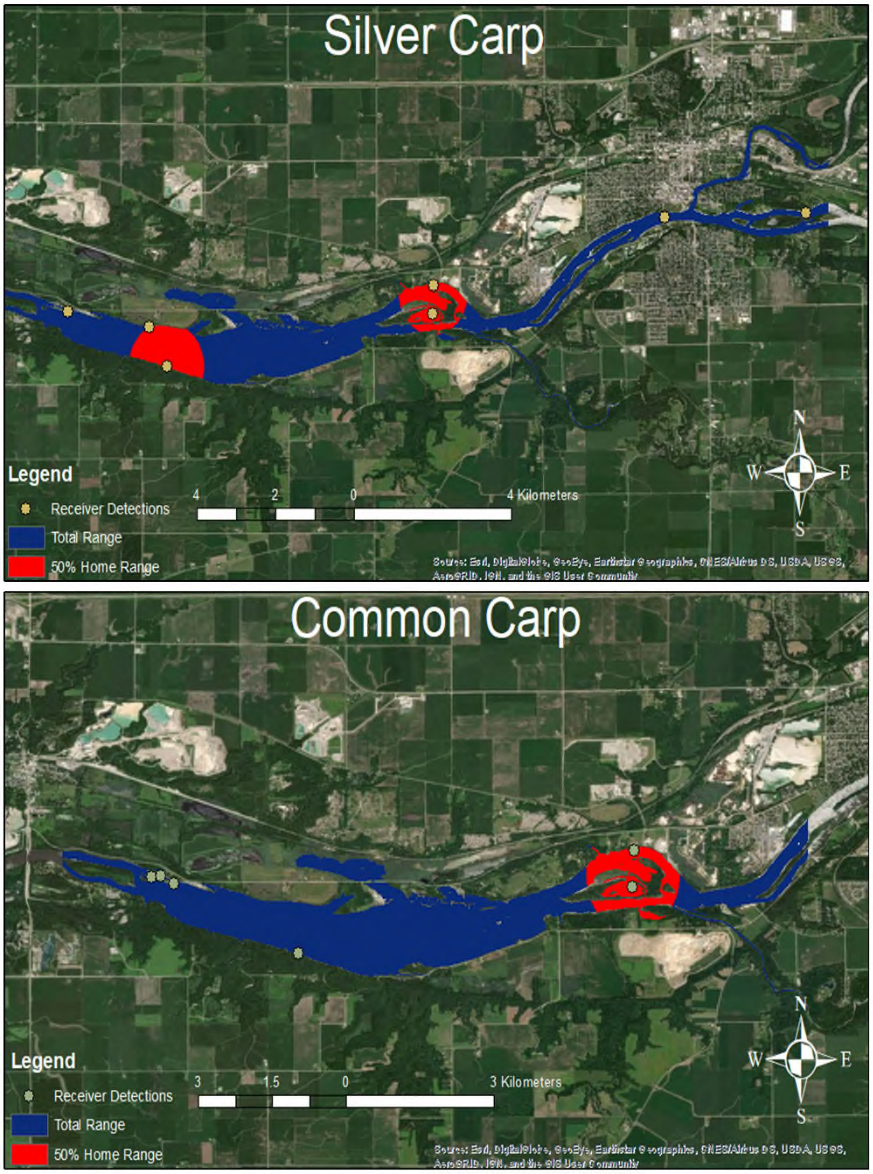

Figure 6. *Example home ranges of a Silver Carp (upper) and a Common Carp (lower) generated via kernel density from stationary receiver data. Both individuals were tagged in the Sheehan Island side channel in Starved Rock Pool.*

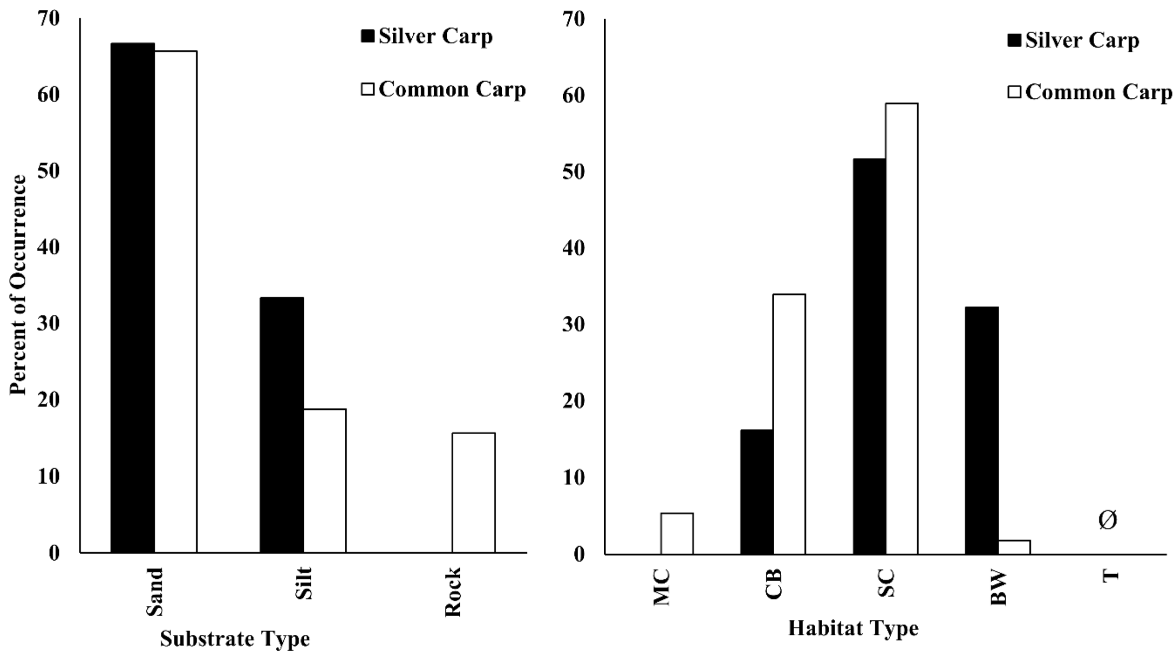

Figure 7. *Distribution of active tracked individuals observed over various substrate types (Left: Silver Carp detections = 6, Common Carp detections = 32) and habitat types (Right: Silver Carp detections = 31, Common Carp detections = 56).*

Using fin ray microchemistry to evaluate native fish passage through Brandon Road Lock and Dam: Water samples collected during 2017–2018 confirmed persistence of differences in water Sr:Ca among the Kankakee, Illinois, and Des Plaines rivers; mean water Sr:Ca was lowest in the Kankakee River, intermediate in the Illinois River, and highest in the Des Plaines River. Likewise, mean fin ray edge Sr:Ca was lowest among fish collected in the Kankakee River, intermediate for fish collected in the Illinois River, and highest for fish collected in the Des Plaines River. Fin ray Sr:Ca also differed among fish families (centrarchids, ictalurids, catostomids, and lepisosteids) within rivers, necessitating interpretation of fin ray Sr:Ca data on a taxa-specific basis. Partial overlap in ranges of fin ray edge Sr:Ca for fish collected in the three rivers was present within all taxa; thus, inter-river movement and Brandon Road Lock and Dam passage was only definitive for fish captured upstream of Brandon Road Lock and Dam that had at least one section of the fin ray with Sr:Ca less than the lower estimated, taxa-specific limits for Des Plaines River-resident fish (indicative of prior occupancy of the Illinois and/or Kankakee rivers). Fish collected upstream of Brandon Road Lock and Dam with fin ray Sr:Ca higher than estimated upper limits for Kankakee- or Illinois River-resident fish throughout the fin ray were classified as having no evidence of passage. Upstream passage was indeterminate for individuals collected upstream of Brandon Road Lock and Dam that did not meet either of the above criteria regarding evidence of passage or lack thereof.

Fin ray transect Sr:Ca data from 204 fishes captured in the Des Plaines River upstream of Brandon Road Lock and Dam were examined for evidence of prior occupancy of the Illinois or

Kankakee rivers, including 114 centrarchids, 27 catostomids, 41 ictalurids, and 22 lepisosteids. Results indicated that 8% of centrarchids collected upstream of Brandon Road Lock and Dam had evidence of upstream passage through Brandon Road Lock and Dam, 2% showed no evidence of upstream passage, and upstream passage through Brandon Road Lock and Dam was uncertain for 90% of centrarchids sampled. For ictalurids sampled upstream of Brandon Road Lock and Dam, 34% had evidence of upstream passage through Brandon Road Lock and Dam, 44% showed no evidence of upstream passage, and upstream passage was uncertain for 22% of individuals. Among catostomids sampled from the Des Plaines River upstream of Brandon Road Lock and Dam, 26% had evidence of upstream passage, 37% showed no evidence of upstream passage, and passage was uncertain for 37% of individuals sampled. For lepisosteids, evidence of upstream passage was present in 18% of individuals, 27% had no evidence of passage, and upstream passage was uncertain for 55% of fish sampled. Results demonstrate that immigrants from downriver have contributed to native fishes present upstream of Brandon Road Lock and Dam.

Recommendations:

Hydroacoustic surveys are needed to inform (via spatial distribution maps) contracted removal and Unified Method events in the upper Illinois River pools as they can provide quite complete coverage of habitats. Bigheaded carp spatial distributions change through time and are not consistent across years, necessitating repeated surveys in Dresden Island and Marseilles pools in order to direct harvest efforts to appropriate locations. Standardized fall hydroacoustic surveys from Alton to Dresden Island pools are also needed to monitor long-term population trends that can indicate responses to environmental conditions, reproductive events, and harvest activities.

Telemetry data demonstrated that dam passage events continue to be highly variable annually, and continued collection of these data will serve to improve dispersal models used in the SEACarP model. It will be important to continue to assess annual variation in dam passages and how passage rates vary as densities of bigheaded carp change throughout the Illinois River (e.g., due to removal efforts and reproduction in lower river pools).

Evidence of upstream passage through Brandon Road Lock and Dam by some native fishes indicates a need for continued consideration of how any actions taken to minimize invasive species passage at Brandon Road Lock and Dam may impact non-target species. Although evidence of upstream passage by some native fishes through the Brandon Road Lock and Dam lock chamber was detected using fin ray microchemistry, the extent to which modification of Brandon Road Lock and Dam to limit invasive species passage would affect native fish populations upstream of Brandon Road Lock and Dam is unknown. Temporal variability in upstream passage by native fishes through the lock chamber at Brandon Road Lock and Dam and the importance of Brandon Road Lock and Dam passage for fish species not included in this study to the native fish assemblage upstream of Brandon Road Lock and Dam are unclear and warrant further study to further inform assessment of potential impacts of barrier modification.

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Habitat Use and Movement of Juvenile Silver Carp in the Illinois River

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Participating Agencies: USFWS Carterville FWCO-Wilmington, USFWS Columbia FWCO

Pools Involved: Peoria Pool

Introduction:

Invasive Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*Hypophthalmichthys nobilis*) populations have been expanding upstream in the Mississippi River and Illinois River since the 1970s (Chick and Pegg 2001, Sass et al. 2010). Silver Carp and Bighead Carp present a serious threat to the economically and recreationally valuable fisheries in the Laurentian Great Lakes (Cooke and Hill 2010). The most likely path for these invasive fish to enter Lake Michigan is through the upper Illinois Waterway (Kolar et al. 2007). An Electric Dispersal Barrier was constructed by the U.S. Army Corps of Engineers (USACE) with the intention of blocking passage of invasive fishes, including Silver Carp and Bighead Carp, through the Illinois Waterway (IWW). Laboratory tests have indicated the Electric Dispersal Barrier is sufficient for stopping large-bodied fish passage but tests on small Bighead Carp (51-76mm total length) have indicated that the operational capabilities of the Electric Dispersal Barrier may be insufficient to block passage of small-bodied fishes (Holliman 2011). Additionally, research using Golden Shiners (*Notemigonus chrysoleucas*) as a surrogate species for juvenile Silver Carp, indicated that small fish can become entrained in barge junction gaps and transported through the Electric Dispersal Barrier as a result of the shipping traffic on the Illinois Waterway (Davis et al. 2016).

The potential for damage to the fisheries in the Great Lakes coupled with the potential weaknesses of the Electric Dispersal Barrier as well as a lack of information surrounding young life stages of Silver Carp and Bighead Carp have led to state and federal agencies devoting resources sampling the upper IWW to evaluate the risks that juvenile Silver Carp pose to the Great Lakes. These studies largely involve using traditional capture-based sampling gears to assess the demographics, reproduction, and habitat use of juvenile Silver Carp and Bighead Carp within the upper IWW. However, traditional sampling gears have relatively low detection probabilities for rare fishes as a result of habitat-specific gear biases, effects of changing environmental conditions, and sparse species distributions (Thorstad et al. 1013). Acoustic and radio telemetry provide a means to directly evaluate habitat use and movement patterns of young life-stage Silver Carp and their risk of breaching the Electric Dispersal Barrier (Cooke et al. 2013, Thorstad et al. 2013). Additionally, information on juvenile Silver Carp habitat preferences can be exploited by monitoring agencies to improve both the effectiveness and efficiency of juvenile Silver Carp early detection monitoring.

Objectives:

(1) Quantify movement frequency and distance of juvenile Silver Carp.

(2) Determine juvenile Silver Carp macro-habitat (main channel, side channel, back water) use and residence times.

(3) Determine if juvenile Silver Carp movement and habitat use is correlated with water temperature, river discharge, and habitat area average depth.

Project Highlights:

- In total, 190 juvenile Silver Carp have been tagged with internally implanted radio or acoustic transmitters. Annual tagging totals included:
    - 72 fish in 2017
    - 81 fish in 2018
    - 37 fish in 2019
- On average, residence times by macro-habitat type for telemetered juvenile Silver Carp were:
    - 2017:150.6 hours in backwaters, 43.2 hours in marinas, 38.1 hours in main channels, 104.4 hours in side channels
    - 2018: 97.6 hours in backwaters, 104.5 hours in marinas, 4.4 hours in main channels, 0.2 hours in side channels*
    - 2019: data download and analyses pending

*Note: lacking spatial/temporal coverage due to lost receivers

Methods:

Prior to the start of this study, Peoria Pool was delineated into four macro-habitat categories: main channel, side channel, backwater, and marinas. Main channel habitats were defined as areas of the river that are dredged to maintain nine-foot depth as well as those areas where commercial barge traffic operates and included adjacent shorelines. Side channel habitats were defined as areas of the river that had flowing current but were separated from the main channel by land. Backwater habitats were defined as areas of non-flowing water, connected to the river, but that are not actively dredged to maintain navigability. Marinas were defined as non-flowing area connected to the river that are actively dredged to maintain navigability. The proportion of available habitat (surface area) was calculated from digital raster graphic topographic maps from the Illinois State Geological Survey, ESRI ArcMap 10.2, and USACE navigational maps.

Juvenile Silver Carp were captured, in the Peoria Pool of the Illinois River, using boat electrofishing and an electrified dozer trawl between Henry, IL and Peoria, IL. Fish collection focused on marinas, backwaters, and side channels due to the morphology of the river in these areas and gear effectiveness. Following tagging, fish were released in proximity to their capture location. Fish tags used were Vemco V5 acoustic transmitters (180 kHz, 0.38 g in water, Vemco Ltd.) and Lotek Nano NTF-3-2 radio transmitters (168 mHz, 0.35g in water, Lotek Wireless).

Immediately after capture, fish were held for no more than one hour in an aerated 60-gallon holding tank covered with 1 cm netting. To maintain as close to sterile conditions as possible, one crew member was the designated “surgeon” who wore gloves and only handled fish for the process of the incision, tag implantation, and suturing. Another crew member was responsible for weighing and measuring the fish and recording data. All surgical tools, fish tags, and sutures were soaked in 70% ethanol between surgeries. Only active fish that appeared healthy based on visual observation were selected for surgery. Each fish was measured for total length (mm) and weight (g), assigned a number, then placed into a foam board with a fish-shaped cut out for surgery. A surgical rubber hose connected to a flow of fresh aerated river water was placed in the mouth of fish to allow them to breathe during surgery. A wet microfiber towel was placed over the head of the fish to keep them calm.

Scales around the surgery site were gently scraped off to expose the tissue underneath. Then, the surgery site was gently washed with several drops of povidone-iodine prior to making an incision. Using a #11-point blade scalpel, a 2 cm incision was made in the left ventral side of the body, just behind the pelvic fins, anterior to the anus, taking care not to damage the intestines. Next, the acoustic tag was inserted through the incision and gently pushed towards the anterior of the body cavity. The radio tag was then inserted in a similar fashion and the antenna was positioned to exit at the posterior corner of the incision. Three non-absorbable antibacterial nylon sutures were used to close the incision site for acoustic tags and a fourth suture was placed to secure the antenna for radio tags. Immediately following suture closure, the incision site was washed with povidone-iodine a second time and rinsed using de-ionized water. The fish was then placed into an aerated, salted holding tank for recovery. Once fish equilibrium was re-established and tags were tested, fish were returned to the river. Total holding time for fish was generally less than four hours.

Acoustic telemetry equipment was deployed prior to tagging fish. A total of 26 Vemco VR2-W 180kHz (Vemco Ltd) hydrophone receivers were placed from Hennepin, IL to Chillicothe, IL. Eighteen receivers were placed between Hennepin, IL and Chillicothe, IL in main channel constriction areas, backwater lake openings, and side channels. In main channel areas and side channel sets, hydrophones were attached to 3/16-inch stainless steel coated cable that dangled from a float, tethered to a concrete anchor. The anchor was then either tethered to a tree on shore and padlocked or attached using a minimum of 25 meters of cable to a Danforth river anchor. Similar deployment methods were used for backwater sets.

Radio telemetry gear was deployed towards the end of the year (beginning September 2017) based on equipment availability. Fish tagging occurred simultaneously with tracking equipment deployment. Ten passive monitoring stations were constructed from the Peoria Lock and Dam to Hennepin, IL at key constriction points and entrances to backwater lakes or side channels. Each monitoring station consisted of a Lotek Wireless SRX800D (Lotek Wireless) datalogging radio receiver, deep cycle 150 Ah battery, and solar charge controller placed inside a weatherproof storage box. The equipment was placed a minimum of 5 meters above any flood plain habitat, usually within tree branches to keep it safe from flooding. A solar panel was mounted at similar heights, facing south, at 41 degrees to the ground and connected to the solar charge controller with 12-gauge wire. Two to three 7-element (1.5 meter) Yagi antennas were mounted a minimum of 6 meters above the ground using aluminum antenna mast poles, or strapped to trees, then attached to the SRX800D using coaxial cable. Generally, each site would have one antenna pointed upstream or downstream in the river channel and one antenna pointed into a backwater or side channel habitat so fish can be differentiated depending on which habitat they are in.

Data were downloaded and consolidated using Vemco-VUE software for underwater stationary acoustic receivers and Lotek SRX-800Host software for VHF radio receivers. Consolidated data files were analyzed using package V-track and its dependencies with Program R. V-track was used to import data, filter data, calculate residence events, and calculate movement events. Residencies were set to occur after 15 subsequent pings at a receiver (25 minutes minimum) and were set to time out if a fish was not detected for at least 60 minutes between pings. Movement events were set to occur if a fish was detected at one receiver and subsequently another receiver.

Results and Discussion:

A total of 81 juvenile Silver Carp were tagged in the Peoria Pool of the Illinois River during 2018, however only 69 survived the tagging process (Table 1). Thirty-five of these fish were tagged using both Vemco-V5 acoustic tags and NTQ-4-1 radio tags. The fish tagged during November 2018 (n=34) were only tagged using the acoustic V5 tags due to their small body size not permitting both tags. All 2018 mortalities were from the November tagging event of the smallest fish. Mean total length of tagged fish was 217 mm and the smallest total length of a tagged Silver carp was 122 mm. During fall of 2019, a total of 37 juvenile Silver carp were tagged using Vemco-V5 acoustic tags and Lotek NTF-3-2 radio tags (Table 1). Total length of these individuals ranged from 120 mm to 285 mm with a mean of 183 mm.

Table 1. *Number (n) of juvenile Silver Carp tagged by month in 2018 and 2019, mean TL (mm), mean mass (g), number of fish tagged.*

Date	n tagged	TL (mm)	Mass (g)
Apr-18	7	279	217
May-18	24	288	242
Aug-18	4	281	272
Nov-18	34	147	29
2018 Total	**69**	**217**	**136**
Oct-19	37	183	105
2019 Total	**37**	**183**	**105**

Habitat Use and Movement of Juvenile Silver Carp in the Illinois River

Telemetry data from 2018 presented a challenge due to equipment loss/vandalism and subsequent data loss. Results may need to be modified as additional receivers are located and retrieved. Average total residence time for telemetered juvenile Silver Carp was highest in marinas (104.5 hours) and backwaters (97.6 hours) with little time spent in main channels (4.4 hours) or side channels (0.2 hours, Table 2). When mean weekly residence time is separated by habitat strata and plotted with mean weekly flow velocity and temperature few clear trends emerge. A spike in marina channel residence times occurred from weeks 19 to 30 during a period of high flow and high temperatures, similar to 2017 results (Figure 1). Main channel and side channel residencies stayed near zero throughout monitoring in 2018 (Figure 1). However, these results are likely biased due to the loss and vandalism of several key receivers located within the main channel and side channel habitats.

Table 2. *Mean habitat residence time (hours) and standard error of radio and acoustic telemetered juvenile Silver Carp tracked throughout tag lifetime in the Peoria Pool of the Illinois River during 2017 and 2018.*

	Backwater	**Main channel**	**Marina**	**Side channel**
2017 Habitat residence time	150.7 ± 38.2	38.1 ± 16.4	43.2 ± 19.9	104.4 ± 77.6
2018 Habitat residence time	97.6 ± 28.2	4.4 ± 1.1	104.5 ± 17.0	0.2 ± 0.0

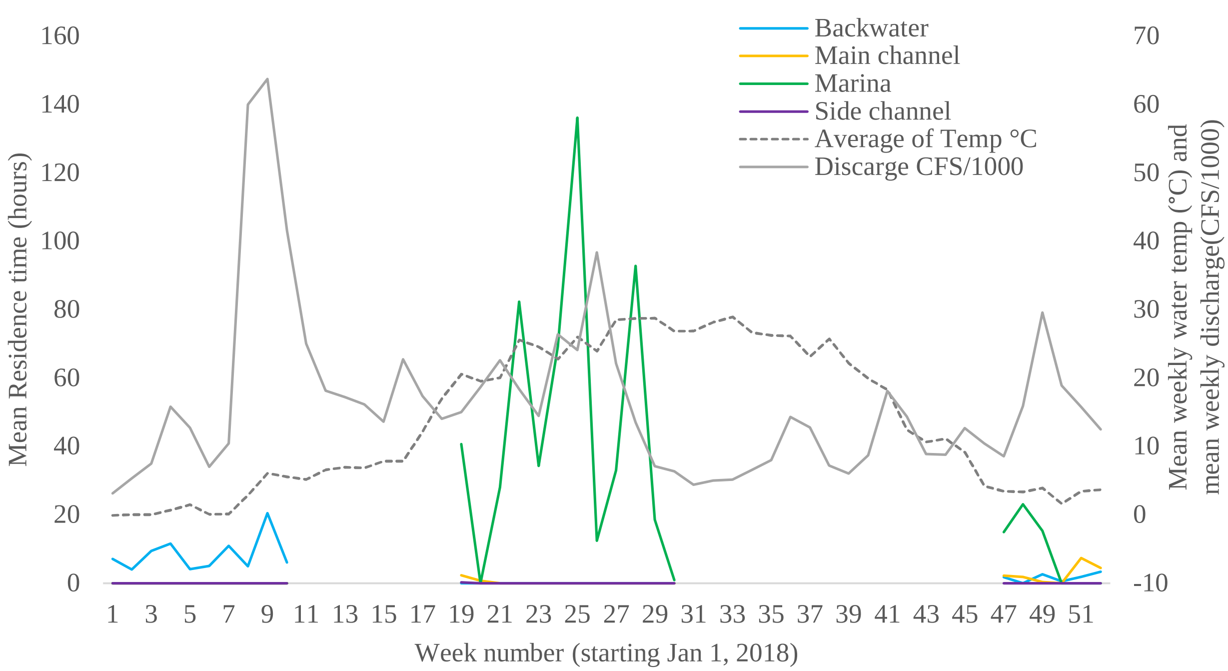

Figure 1. *Mean weekly residence time (hours) of telemetered juvenile Silver Carp in the Peoria Pool of the Illinois River during 2018 separated by macro-habitat. Week numbers begin Jan 1, 2018 and end Dec 30, 2018.*

The lack of data from the missing receivers may be responsible for the discrepancy between the 2018 results and the 2017 results. During 2017 telemetered juvenile Silver Carp were indicated to have mean weekly residence time of greater than 50% in main channel and side channel habitats. Receivers located in backwaters or marinas are often hidden, whereas receivers in flowing water have a visible shore tether and float. Deployment methods were modified for 2019 to attempt to conceal receivers from view.

Movement calculations for 2018 indicated the mean weekly movement distance for telemetered juvenile Silver Carp was 7728.7 meters (Table 3). The mean weekly movement distance is higher than 2017 (2238.2 meters), much higher than what is commonly thought for juvenile Silver Carp, although with a sample size was less than in 2017 (Table 3). Only 29 of the tagged fish in 2018 were included in movement analysis due to other fish having sporadic or non-continuous detections throughout their tag lifetime. We suspect that some of these fish either left the study area or died, while others were in areas of the pool outside of the detection range of receivers.

Table 3. *Mean weekly movement distance (m) and number (n) of fish with recordable movements of acoustic telemetered juvenile Silver Carp tracked throughout tag lifetime in the Peoria Pool of the Illinois River during 2017 and 2018.*

Year	Mean weekly movement distance	n
2017	2238.2	43
2018	7728.7	29

Recommendations:

Telemetry has provided valuable knowledge on the habitat usage and movement characteristics of juvenile Silver Carp. The results of 2017 data indicated that juvenile Silver Carp reside in main channels nearly the same amount of time as backwater habitats. Data from 2018 indicated that juvenile Silver Carp had the most frequent residencies in still-water habitats, marinas and backwaters. However, receiver and associated data loss limited the coverage of Peoria Pool main channel and side channel habitats.

With the close of 2019 field season, USFWS has recommended to end field work for this project, retrieve telemetry gear, download final data, and spend the season processing and analyzing all data collected. Further efforts may be reassessed for 2021 based on results of analyzing previous data and the needs of the Asian Carp Regional Coordinating Committee – Monitoring and Response Workgroup.

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Des Plaines River and Overflow Monitoring

Jen-Luc Abeln and Nathan T. Evans (U.S. Fish and Wildlife Service Carterville Fish and Wildlife Conservation Office, Wilmington Substation)

Participating Agencies: U.S. Fish and Wildlife Service – Carterville Fish and Wildlife Conservation Office Wilmington Substation (lead) and U.S. Army Corps of Engineers (USACE) (field support)

Pools Involved: Not applicable

Introduction and Need:

The upper Des Plaines River originates in Southeast Wisconsin and joins the Chicago Sanitary and Shipping Canal (CSSC) in the Brandon Road Pool immediately downstream of Lockport Lock and Dam. Asian carp (Silver Carp, Bighead Carp, and Grass Carp) have been observed in this pool up to the confluence with the Des Plaines River, and have free access to enter the upper Des Plaines River. In 2010 and 2011, Asian carp environmental deoxyribonucleic acid (eDNA) was detected in the upper Des Plaines River (no samples were taken in 2012 – 2019). If present in the upper Des Plaines River, Asian carp have the potential to bypass the Electric Dispersal Barrier System (EDBS) during flooding events (overtopping) that allow water to flow laterally between the upper Des Plaines River and the CSSC. To reduce the likelihood of Asian carp transfer between the two rivers, the USACE completed the construction of a physical barrier in 2010. The physical barrier consists of concrete barriers and 0.25-inch (6.35 mm) mesh fencing built along 13.5 miles (21.7 km) of the upper Des Plaines River where it runs adjacent to the CSSC. It is designed to stop adult and juvenile Asian carp from infiltrating the CSSC, although it will likely allow Asian carp eggs and fry to pass. Overtopping events in 2011 and 2013 created breaches in the fencing that provided the potential for fish passage. An overtopping event in 2017 allowed water to breach the fence, but not connect to the CSSC. These areas and other low-lying areas were reinforced with chicken wire buried in gravel and/or cement to prevent scouring during future overtopping events. One low-lying area was reinforced with a large berm. Due to the upper Des Plaines River's proximity to the CSSC and its potential to function as a bypass to the EDBS, it is important to understand the risks associated with overtopping events as well as Asian carp distribution and spawning within the river. Likewise, it is critical to determine and understand the effectiveness of the physical barrier at blocking Asian carp movement between the Des Plaines River and the CSSC.

Objectives:

(1) Monitor for the presence of Bighead Carp and Silver Carp and their potential spawning activities in the Des Plaines River above the confluence with the CSSC.

(2) Monitor for eggs and larvae around the physical barrier during high flow events when water moves laterally from the Des Plaines River into the CSSC.

(3) Monitor the effectiveness of the barrier against fishes during high flow events when water moves laterally from the Des Plaines River into the CSSC.

Project Highlights:

- Collected 12,776 fish representing 67 species and 3 hybrid groups from 2011 – 2019 via electrofishing (73 hours) and gill netting (153 sets; 23,684 yards [21,656.7 m]).
- No Bighead Carp or Silver Carp have been captured or observed through all years of sampling.
- Ten Grass Carp have been collected since 2011. No Grass Carp collected in 2019.
- Three overtopping events since 2011 have resulted in several improvements to the barrier fence. No overtopping events occurred in 2019.

Methods:

In 2019, sampling was conducted in the upper Des Plaines River from E Romeo Rd (Romeoville, IL) to Columbia Woods (Willow Springs, IL; Figure 1). Sampling was performed using pulsed-DC boat electrofishing and short term (~1 – 2 hour) surface to bottom gill net sets. Electrofishing runs included two dippers and proceeded for 15 minutes. Gill net sets included 3.5-inch (88.9 mm) and 4-inch (101.6 mm) bar mesh. Fish were driven to the nets using electrofishing boats and/or pounding. Sampling was performed in both backwater and main channel habitats that were accessible to sampling boats. All individual fishes were identified to species then released.

Results and Discussion:

During the nine years of sampling (2011-2019), 73 hours of electrofishing and 153 net sets covering 23,684 yards (21,656.7 m) of gill net resulted in a total catch of 12,776 fishes. Sixty-seven species and three hybrid groups have been collected. Common Carp have been the most commonly collected species, followed by Gizzard Shad, then Bluegill. In 2019, 8.75 hours of electrofishing and four gill net set, 400 yards (365.8 m) total, resulted in 946 fish representing 42 species. No Bighead Carp or Silver Carp have been collected or observed throughout all years of sampling. Ten Grass Carp have been collected since 2011. No Grass Carp were collected in 2019.

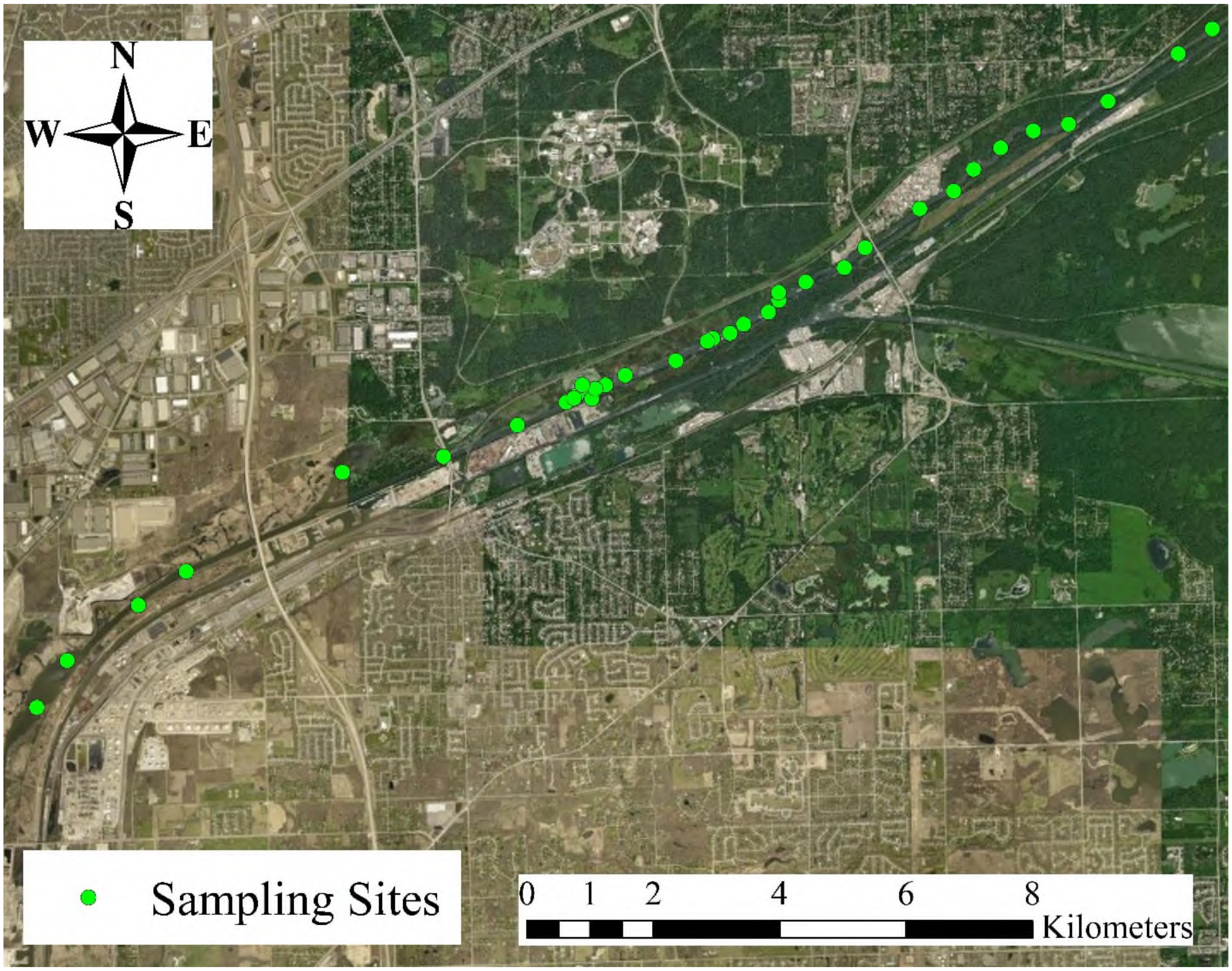

Figure 1: *2019 Sampling sites in the upper Des Plaines River.*

No overtopping events occurred during 2019. Therefore, no ichthyoplankton sampling was preformed to assess egg and larval presence in the Des Plaines River. Overtopping events may be reduced into the future with the McCook Reservoir coming online in 2018. McCook Reservoir provides 3.5 billion gallons (13.2 billion liters) of flood water storage to the Chicago area, including the Des Plaines River.

Recommendations:

- Continue seasonal monitoring for adult and juvenile Bighead Carp and Silver Carp in the upper Des Plaines River with emphasis on backwater habitat.
- Improve monitoring for all life stages of Asian carp by including additional gear types (e.g., mini-fyke nets and experimental multi-panel gill nets) and effort expended towards early detection.
- Monitor Des Plaines River stage during heavy rainfall events and conduct investigations of the physical barrier, as needed, in areas where overflow has occurred.

Des Plaines River and Overflow Monitoring

- Sample icthyoplankton, to monitor for egg and larvae drift, during overflow events especially when temperatures are conducive for reproduction.

Table 1. *Fish species collected (number of individuals) from the upper Des Plaines River between 2011 – 2019. Fishes were sampled via boat-mounted electrofishing and gill netting.*

Species	No. Captured 2019	No. Captured 2011-2018	Totals All Years
Banded Killifish	-	4	4
Bigmouth Buffalo	2	20	22
Black Buffalo	-	7	7
Black Bullhead	1	41	42
Black Crappie	7	308	315
Blackside Darter	-	14	14
Blackstripe Topminnow	10	58	68
Bluegill	33	1039	1072
Bluntnose Minnow	198	581	779
Bowfin	10	135	145
Brown Bullhead	1	-	1
Bullhead Minnow	75	13	88
Carp x Goldfish Hybrid	-	32	32
Central Mudminnow	-	3	3
Central Stoneroller	6	3	9
Channel Catfish	16	404	420
Channel Shiner	2	-	2
Common Carp	30	3422	3452
Creek Chub	1	38	39
Emerald Shiner	128	101	229
Fathead Minnow	-	43	43
Flathead Catfish	-	4	4
Freshwater Drum	-	7	7
Gizzard Shad	147	1381	1528
Golden Shiner	15	160	175
Goldfish	12	103	115
Grass Carp	-	10	10
Grass Pickerel	-	6	6
Green Sunfish	4	156	160
Highfin Carpsucker	-	1	1
Hornyhead Chub	6	8	14
Hybrid Striped Bass	-	1	1
Hybrid Sunfish	-	1	1
Johnny Darter	-	2	2
Largemouth Bass	104	874	978
Logperch	-	4	4
Longear Sunfish	-	1	1

Des Plaines River and Overflow Monitoring

Species	No. Captured 2019	No. Captured 2011-2018	Totals All Years
Longnose Gar	6	65	71
Mimic Shiner	1	-	1
Muskellunge	-	2	2
Northern Pike	6	226	232
Orangespotted Sunfish	1	114	115
Oriental Weatherfish	-	2	2
Pumpkinseed	21	122	143
Quillback	-	19	19
Redear Sunfish	1	-	1
River Carpsucker	1	22	23
River Shiner	7	1	8
Rock Bass	8	45	53
Rosyface Shiner	-	13	13
Round Goby	1	33	34
Sand Shiner	10	154	164
Sauger	2	67	69
Smallmouth Bass	28	131	159
Smallmouth Buffalo	-	32	32
Spotfin Shiner	13	912	925
Spottail Shiner	18	383	401
Spotted Sucker	1	28	29
Suckermouth Minnow	-	1	1
Tadpole Madtom	1	-	1
Walleye	1	9	10
Warmouth	-	6	6
Western Mosquitofish	-	2	2
White Bass	-	1	1
White Crappie	1	2	3
White Perch	-	1	1
White Sucker	9	401	410
Yellow Bass	-	2	2
Yellow Bullhead	1	43	44
Yellow Perch	-	6	6
Sum No. Captured	946	11830	12776
Species Richness (Hybrids)	42	65(3)	67(3)

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

Justin Widloe, Nate Lederman, Eli Lampo, Claire Snyder, Charmayne Anderson, Kevin Irons (Illinois Department of Natural Resources), Allison Lenaerts, Dan Roth, Andrew Mathis, Jehnsen Lebsock (Illinois Natural History Survey), and Dr. Greg Whitledge (Southern Illinois University at Carbondale).

Participating Agencies: Illinois Department of Natural Resources (lead); Southern Illinois University at Carbondale

Pools Involved: Not applicable

Introduction and Need:

The Illinois Department of Natural Resources (IDNR) fields many public reports of observed or captured Asian carp. All reports are taken seriously and investigated through phone/email correspondence with individuals making a report, requesting and viewing pictures of suspect fish, and visiting locations where fish are being held or reported to have been observed. In most instances, reports of Asian carp prove to be native Gizzard Shad or stocked non-natives, such as trout, salmon, or Grass Carp. Reports of Bighead Carp or Silver Carp from valid sources and locations where these species are not known to previously exist elicit a sampling response with boat electrofishing and trammel or gill nets. Typically, no Bighead Carp or Silver Carp are captured during sampling responses. However, this pattern changed in 2011 when 20 Bighead Carp (> 21.8 kg (48 lbs.)) were captured by electrofishing and netting in Flatfoot Lake and Schiller Pond, both fishing ponds located in Cook County once supported by the IDNR Urban Fishing Program.

As a further response to the Bighead Carp in Flatfoot Lake and Schiller Pond, IDNR reviewed Bighead Carp captures in all fishing ponds included in the IDNR Urban Fishing Program located in the Chicago Metropolitan area which revealed, at that point in time, that three additional ponds in the program had verified reports of Bighead Carp from either pond rehabilitation with piscicide or natural die offs (Columbus Park, Garfield Park, Lincoln Park South) (Table 1). One pond had reported sightings of Bighead Carp that were not confirmed by sampling (McKinley Park). The distance from Chicago area fishing ponds to Lake Michigan ranges from 0.2 to 41.4 km (0.1 to 25.7 miles). The distance from these ponds to the Chicago Area Waterway System (CAWS) upstream of the Electric Dispersal Barrier ranges from 0.02 to 23.3 km (0.01 to 14.5 miles). Although some ponds are located near Lake Michigan or the CAWS, most are isolated and have no surface water connection to Lake Michigan or the CAWS upstream of the Electric Dispersal Barrier. Ponds in Gompers Park, Jackson Park, and Lincoln Park are the exceptions. The Lincoln Park South and Jackson Park lagoons are no longer potential sources of Bighead Carp because they were rehabilitated with piscicide in 2008 and 2015, respectively. Gompers Park never had a report of Asian carp, nor have any been captured or observed during past sampling events. Nevertheless, examining all urban fishing ponds close to the CAWS or Lake

Michigan was of importance due to the potential of human transfer of Asian carp between waters within close proximity to one another.

In addition to Chicago area ponds once supported by the IDNR Urban Fishing Program, ponds with positive detections for Asian carp eDNA were also reviewed. Eight of the 40 ponds sampled for eDNA by the University of Notre Dame resulted in positive detections for Asian carp, two of which are also IDNR urban fishing ponds (Jackson Park, Flatfoot Lake) (Table 1).

The distance from ponds with positive eDNA detections to Lake Michigan ranges from 4.8 to 31.4 km (3 to 19.5 miles). The distance from these ponds to the CAWS upstream of the Electric Dispersal Barrier ranges from 0.05 to 7.6 km (0.03 to 4.7 miles). The lake at Harborside International Golf Course has surface water connectivity to the CAWS. However, no Asian carp have been reported, observed or captured. Though positive eDNA detections do not necessarily represent the presence of live fish (e.g., may represent live or dead fish, or result from sources other than live fish, such as DNA from the guano of piscivorous birds or boats/sampling gear utilized in Asian Carp infested waters) they were examined for the presence of live Asian carp given the proximity to CAWS waterways.

Objectives:

(1) Sample fishing ponds in the Chicago Metropolitan area included in the IDNR Urban Fishing using conventional gears (electrofishing and trammel/gill nets) for the presence of Asian carp.

Project Highlights:

- 35 Bighead Carp have been removed from six Chicago area ponds using electrofishing and trammel/gill nets since 2011; three of which are on display at the Shedd Aquarium in Chicago.
- Eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have also been removed from Chicago area ponds since 2008.
- One Bighead Carp was incidentally caught by a fisherman in a Chicago area pond in 2016.
- 18 of the 21 IDNR Chicago Urban Fishing Program ponds have been sampled with nets and electrofishing.
- All eight Chicago area fishing ponds with positive Asian carp eDNA detections have been sampled with electrofishing and trammel/gill nets.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

Methods:

Pulsed DC-electrofishing and trammel/gill nets were used to sample urban fishing ponds. Trammel and gill nets used are approximately 3 m (10 ft.) deep x 91.4 m (300 ft.) long in bar mesh sizes ranging from 88.9-108 mm (3.5-4.25 in). Electrofishing, along with pounding on boats and revving tipped up motors, are used to drive fish into the nets. Upon capture, Asian carp were removed from the pond and the length and weight was recorded. The head of each fish was then removed for age estimation and otolith microchemistry analysis by Dr. Greg Whitledge at SIUC.

Results and Discussion:

A total of 44 Bighead Carp and one Silver Carp have been removed from nine ponds (Table 1). Fifty-eight hours of electrofishing and 13 miles of gill/trammel net were utilized to sample 25 Chicago area fishing ponds, resulting in 35 Bighead Carp removed from five ponds since 2011. Additionally, eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have been removed since 2008. Lastly, one Bighead Carp was incidentally caught by a fisherman in 2016. The lagoons at Garfield and Humboldt Park have had Bighead Carp removed following both natural die-offs and sampling. All ponds yielding positive eDNA detections and 18 of the 21 IDNR urban fishing ponds have been sampled. Lincoln Park South was not sampled because it was drained in 2008, resulting in three Bighead Carp being removed, and is no longer a source of Asian Carp as a result. Auburn Park was too shallow for boat access but had extremely high visibility. Therefore, the pond was visually inspected with no large bodied fish observed. Lastly, Jackson Park and Garfield Park were drained in 2015 and, similar to Lincoln Park South, are no longer a source of Asian carp. A map of all the Chicago area fishing ponds that were sampled or inspected as part of this project can be found in Figure 1.

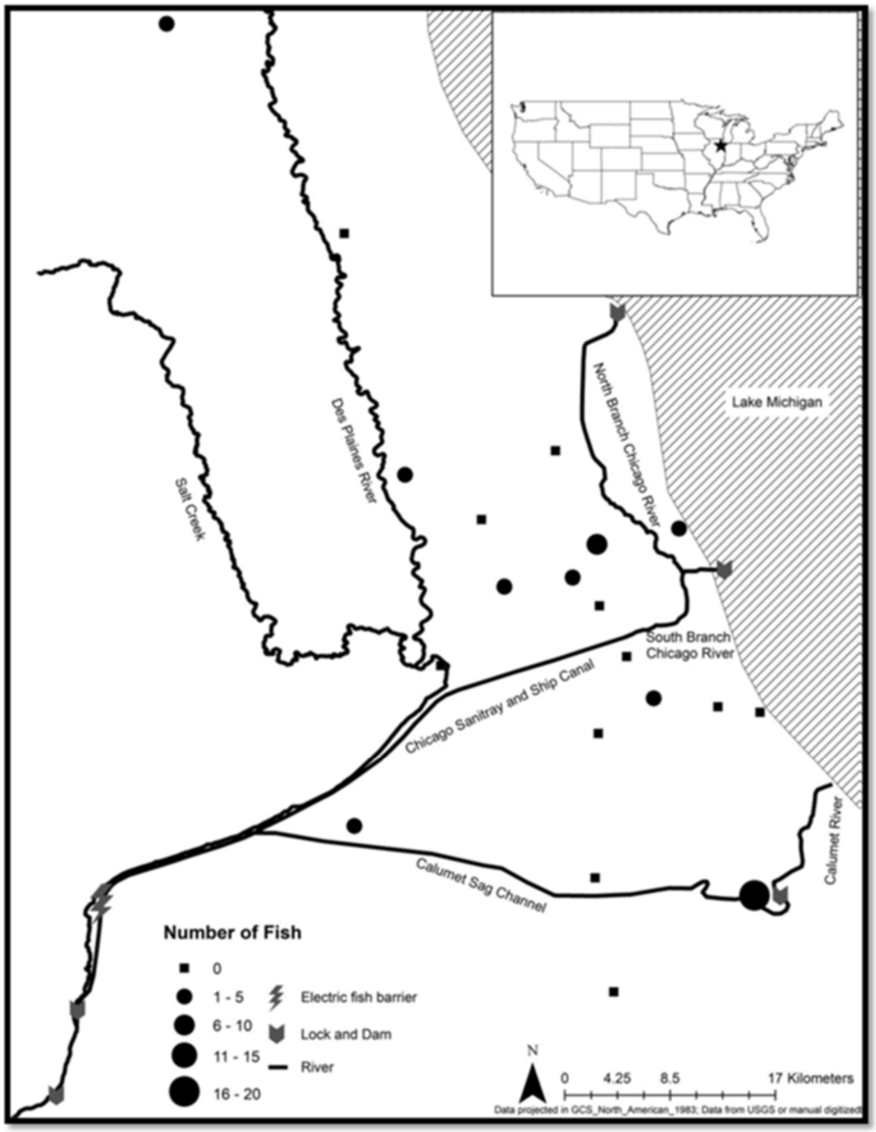

Figure 1. *Chicago area fishing ponds from which Asian carp have been removed (red) and those from which no Asian carp have been collected or reported (yellow).*

Approximately 80% of the Bighead Carp otoliths examined to date exhibited a decline in Sr:Ca from high values in the otolith core (750-1,900 µmol/mol; within 50-150 microns of the otolith center) to lower values (range 400-650 µmol/mol) toward the edge of the otolith (mean 618 µmol/mol within 50 microns of the otolith edge) (Figure 2). Mean otolith Sr:Ca of 618 umol/mol near the otolith edge is consistent with expected otolith Sr:Ca for a resident fish in these Chicago fishing ponds based on Sr:Ca of water samples taken from these sites during 2010-2012 (range 1.5-1.8 mmol/mol) and a regression relating water and Asian carp otolith Sr:Ca (Norman and Whitledge, in press). The higher Sr:Ca near the otolith core suggests these fish were transferred into the lagoons during age-0 or age-1. These data indicate that the fish spent their early life in water(s) with higher strontium-calcium ration (Sr:Ca) and the remainder of their life as residents of the urban ponds. In addition, the otolith core Sr:Ca values are high when compared to that of Bighead Carp of Illinois River origin as well as other sites previously examined in northern Illinois (Figure 3) (Whitledge 2009). A similar trend was observed when comparing otolith core $\delta^{18}O$ and $\delta^{13}C$ values for Bighead Carp, which showed no overlap between Chicago pond fish and Illinois River fish (Figure 4). Therefore, Bighead Carp removed from Chicago area ponds were likely not transplanted adult fish nor bait bucket introductions of juveniles from the Illinois River or other nearby rivers. In contrast, otolith core $\delta^{18}O$ and $\delta^{13}C$ values and Sr:Ca of the Silver Carp collected from Sherman Park Pond fell within the range of otolith $\delta^{18}O$ and $\delta^{13}C$ values and Sr:Ca for Illinois River fish (Figure 3 and 4). Thus, we cannot rule out the possibility that this fish may have been transported (via bait bucket or as an adult) from the Illinois River system to Sherman Park Pond. Given the size (age) of the Bighead Carp at the time of introduction its plausible that they were contaminants in shipments of desirable fish species stocked in the lagoons, likely before the State of Illinois banned transport of live Bighead Carp in 2002 – 2003. This corresponds to a time when Bighead Carp were raised for market in ponds with Channel Catfish in certain regions of the U.S. (Kolar et al. 2007). Shipments of Channel Catfish may be the most likely source of contamination in Illinois urban fishing ponds as catchable-sized catfish are stocked frequently and extensively in these waters throughout the state (IDNR 2010).

Recommendation:

We will investigate reports of Asian carp sightings or captures in Chicago area ponds based strictly on photographic evidence or reports from credible sources.

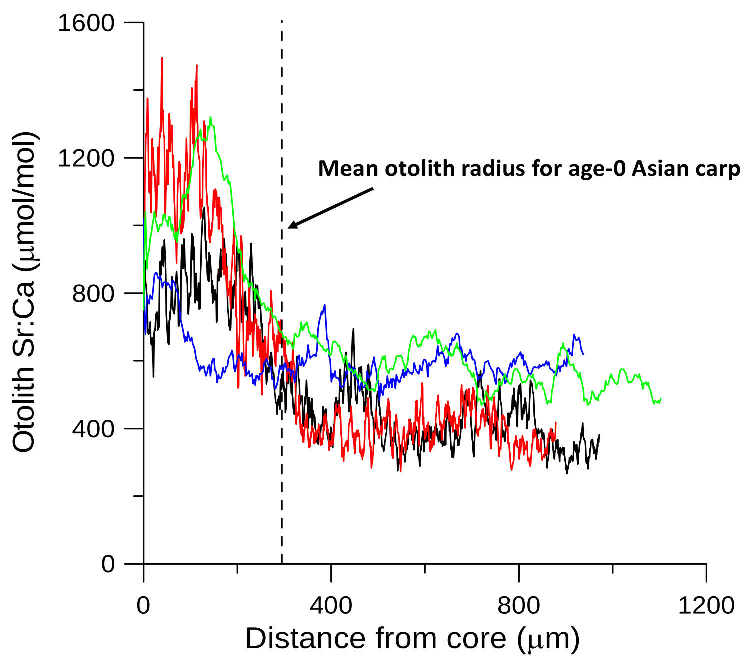

Figure 2. *Example of laser ablation transects for four Chicago pond Bighead Carp otoliths. The dashed line represents the mean otolith radius for age-0 Asian carp taken from nearby rivers.*

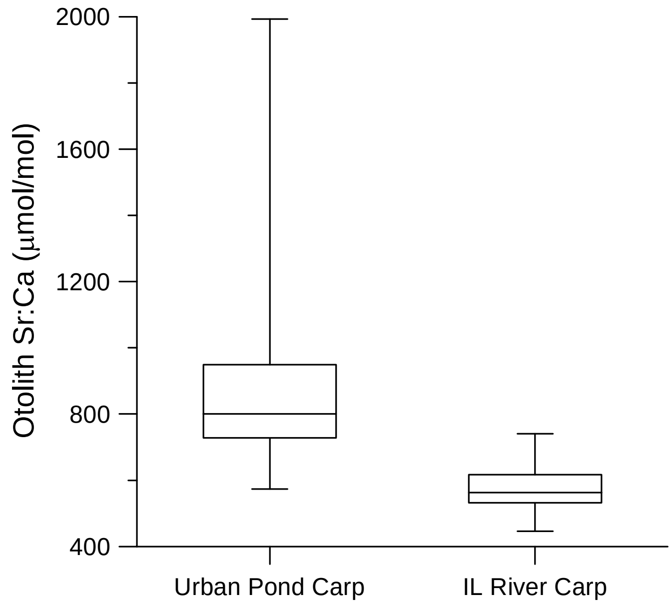

Figure 3. *Boxplots of otolith core Sr:Ca for Chicago pond (N = 24) and Illinois River (N = 81) Asian carp. The minimum value for urban pond carp represents the Silver Carp collected from Sherman Park.*

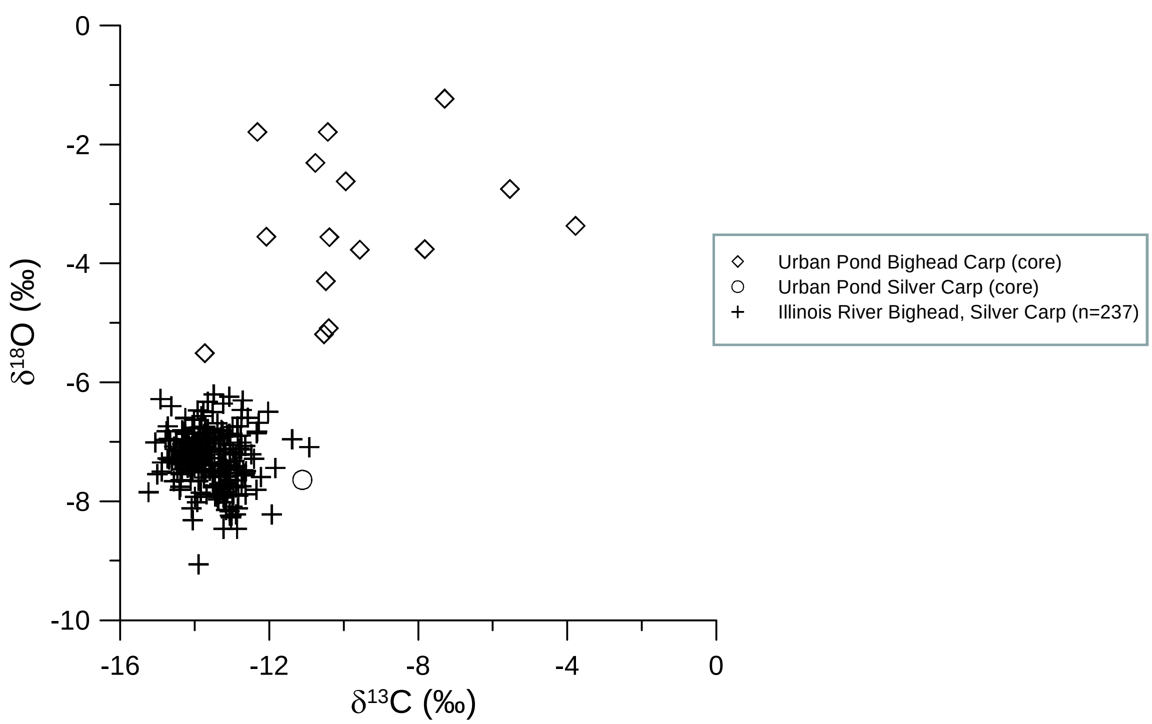

Figure 4. *Otolith Core $\delta^{18}O$ and $\delta^{13}C$ comparing Urban Pond and Illinois River Bighead and Silver carps.*

References:

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Whitledge, G. W. 2009. Otolith microchemistry and isotopic composition as potential indicators of fish movement between the Illinois River drainage and Lake Michigan. Journal of Great Lakes Research 35:101-106.

Table 1. *Sampling location, boat electrofishing effort (hrs.) and gill/trammel netting effort (miles), number of sampling events, number of Bighead Carp and Silver Carp collected, and number of Asian carp removed following natural die-off, pond rehabilitation with rotenone or incidental take. 1 = IDNR urban fishing ponds that had positive eDNA detections, 2 = ponds with positive eDNA detections that are not IDNR urban fishing ponds, 3 = pond that is neither an IDNR urban fishing pond nor had a positive eDNA detection, * = location of the only Silver Carp collected*

Sampling Results

Location	**Electrofishing (hrs)**	**Gill/trammel netting**	**Sampling events *(N)***	**Bighead carp *(N)***	**Silver carp *(N)***	**Asian carp collected post die-off, rotenone rehab, or incidental take**
Cermak Quarry	1.0	–	1	–	–	–
Columbus Park	0.8	0.1	1	–	–	3
Commissioners Park	0.5	0.1	1	–	–	–
Community Park	0.5	0.1	1	–	–	1
Douglas Park	0.5	0.2	1	–	–	–
Elliot Lake	0.8	0.7	7	1	–	–
Flatfoot Lake1	20.0	3.6	1	20	–	–
Garfield Park	3.6	0.1	1	2	–	1
Gompers Park	0.3	–	1	–	–	–
Harborside Golfcourse	2.8	0.9	1	–	–	–
Horsetail Lake2	1.0	0.3	2	–	–	–
Humboldt Park	2.3	0.5	3	8	–	1
Jackson Park1	4.3	1.8	1	–	–	–
Joe's Pond2	0.5	0.3	1	1	–	–
Lake Owens	1.0	0.3	1	–	–	–
Lake Shermerville	1.0	0.3	–	–	–	–
Lincoln Park South	–	–	1	–	–	3
Marquette Park	1.3	0.4	1	–	–	–
McKinley Park	1.0	0.3	1	–	–	–
Powderhorn Lake2	2.0	0.7	1	–	–	–
Riis Park	0.2	–	1	–	–	–
Sag Quarry2	0.6	0.3	1	–	–	–
Saganashkee Slough3	2.0	0.6	1	–	–	–
Schiller Pond	2.0	–	1	3	–	–
Sherman Park *	1.0	0.3	1	–	–	–
Tampier Lake2	5.5	0.6	1	–	–	1
Washington Lake	1.5	0.3	1	–	–	–
Totals	**58.0**	**12.8**	**35**	**35**	**0**	**10**

Multiple Agency Monitoring of the Illinois River for Decision Making

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Allison Lenaerts, Andrew Mathis, Brandon Harris, Claire Snyder, Dan Roth, Jim Lamer, Kris Maxson, Levi Solomon, Jesse Williams, Sam Schaick, (Illinois Natural History Survey)
Matthew Shanks, Nicholas Barkowski, John Belcik (United States Army Corps of Engineers)
Mark Brouder, Nathan Evans (United States Fish and Wildlife Service)

Participating Agencies: Illinois Department of Natural Resources (co-lead); Illinois Natural History Survey – Illinois River Biological Station (co-lead); U.S. Fish and Wildlife Service (field support); U.S. Army Corps of Engineers – Chicago District (field support)

Pools Involved: Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, Alton

Introduction and Need:

Detection and monitoring of Asian carp (Bighead Carp, Black Carp, Grass Carp and Silver Carp) populations in pools below the Electric Dispersal Barrier system are pertinent to understanding their upstream progression and minimize the risk of establishment above the Electric Dispersal Barrier system. Surveillance is particularly important in pools directly upstream for each Asian carp species known expanse with Bighead Carp and Silver Carp being within the Dresden Island Pool, Grass Carp being in the Chicago Area Waterway, and Black Carp being within the Peoria Pool. Extensive monitoring also provides managers the ability to evaluate the impacts of management actions (e.g., contracted removal) and collect data to assist other projects (e.g., SEAcarP). Data collected from a standardized multiple gear sampling approach have been used to create accurate and comparable relative abundance estimates of specific species and detect the presence of previously unrecorded invasive species (Ickes et al. 2005). A standardized multiple gear approach was used here to create a comprehensive dataset that provided an understanding of the current geographic range of Asian carp across all pools downstream of the Electric Dispersal Barrier system, their abundances, and the threat they pose to entering Lake Michigan.

Objectives:

(1) Monitor the geographic distribution and relative abundance of adult and juvenile Asian carp populations in pools below the Electric Dispersal Barrier.

(2) Inform other projects (i.e., Contracted Asian Carp Removal, Telemetry Monitoring, SEAcarP model, hydroacoustic, etc.) with Asian carp demographic and fish community assemblage data necessary for making management decisions.

(3) Provide relevant data to detect changes to the native fish community affected by Asian carp overtime throughout the entire Illinois River Waterway below the Electric Dispersal Barrier system.

(4) Provide a standardized dataset capable of enabling robust and statistically powerful spatial and temporal analyses of Asian carp across the entire Illinois River Waterway below the Electric Dispersal Barrier system.

Project Highlights:

- In 2019, an estimated 11,815.5 person-hours were expended sampling fixed and random sites downstream the Electric Dispersal Barrier system including 187.75 hours of electrofishing, 1177.3 hoop netting net nights, 475.8 minnow fyke netting net nights, and 113.1 fyke netting net nights.
- A total of 150,171 fish representing 108 species and 16 hybrid groups were captured in 2019.
- No Asian carp (large or small) were captured in Lockport or Brandon Road pools in 2019.
- The leading edge of the Bighead Carp and Silver Carp populations remained around river mile 281 (north of I-55 Bridge within the Dresden Island Pool near the Rock Run Rookery) in 2019.
- No small Silver Carp or Bighead Carp (< 6 inches/152.4 mm) were captured in pools up river of Peoria Pool (river mile 201; ~130 miles from Lake Michigan) in 2019.
- Data from projects outside of the Monitoring Response Working Group Monitoring Response Plan were incorporated to create a comprehensive synthesis of each Asian carp species' status across the entire Illinois River Waterway below the Electric Dispersal Barrier system in 2019.

Methods:

The Multiple Agency Monitoring of the Illinois River for Decision Making used the time-tested, standardized, multiple gear approach developed by the U.S. Army Corps of Engineer's Upper Mississippi River Restoration program (Gutreuter *et al.* 1995, Ratcliff *et al.* 2014) to monitor Asian carp populations in the Illinois River Waterway below the Electric Dispersal Barrier system. This approach utilized boat pulsed DC electrofishing, fyke netting, minnow fyke netting, and paired large and small hoop netting in a stratified random approach. Detailed descriptions on gear specifications and sampling protocol can be found in Ratcliff *et al.* (2014).

The standardized sampling protocol used during this project is also used in the U.S. Army Corps of Engineer's Upper Mississippi River Restoration program's Long Term Resource Monitoring (Ratcliff *et al.* 2014), the Long Term Survey and Assessment of Large River Fishes in Illinois Monitoring (Fritts *et al.* 2017), and the Water Level Management Assessment of the Illinois River Project. Therefore, data collected external to the Asian Carp Monitoring and Response Working Group Monitoring Response Plan were incorporated to create a comprehensive dataset that included all pools of the Illinois River. Data outside of the Monitoring and Response Working Group Monitoring Response Plan were provided by United State Geological Survey (USGS) and the Illinois Natural History Survey (INHS). Data were provided to meet the need for timely best science on the condition that neither the USGS, INHS, nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the data.

Historically sampled fixed sites, upstream of the known Asian carp invasion front within Brandon Road Pool and Lockport Pool, were also sampled with DC electrofishing. Fixed sites were sampled every other week in March through November providing a higher frequency and lengthier temporal range than the randomized sampling design. This enabled for determining if Asian carp were present in the relative vicinity of the Electric Dispersal Barrier system or expanded further upriver in periods outside of the standard sampling window as well as maintaining collection of historic trend data.

Overall relative abundance indices, and pool specific relative abundance indices, within each pool below the Electric Dispersal Barrier system, were generated for each Asian carp species within each gear type from the comprehensive dataset. Calculating absolute abundance requires extensive data collection and a probability-based array, which can be extremely costly and time consuming (Hayes et al. 2007). A relative abundance index is considerably easier, less expensive, and less time consuming all the while directly relating to the absolute abundance (Pope et al. 2010). The relative abundance index of catch per unit effort (CPUE) was calculated as the number of fish per hour for electrofishing and the number of fish per net night (24 hours) for fyke net, minnow fyke net, and hoop net samples.

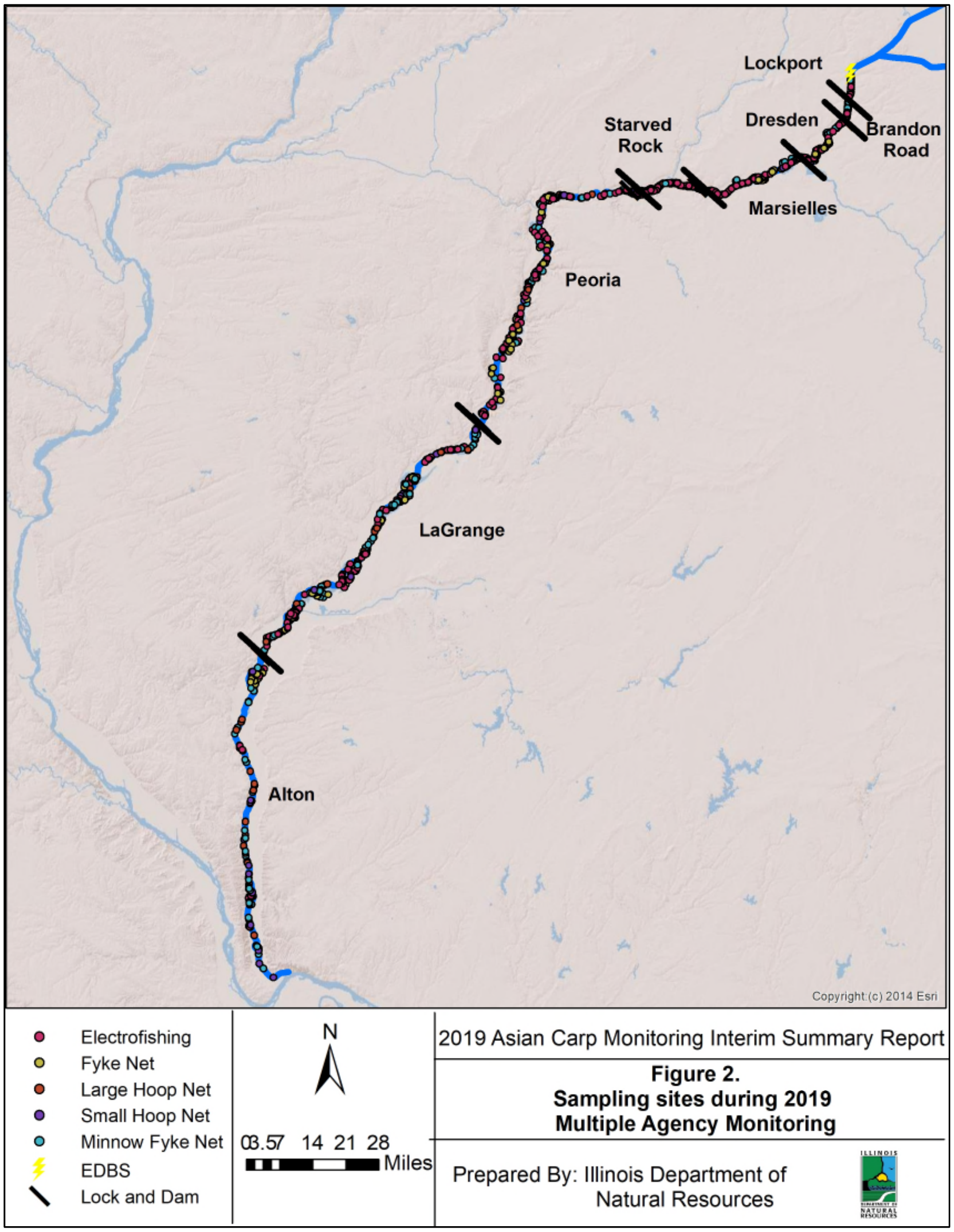

Figure 1. *Sampling sites used during Multiple Agency Monitoring of the Illinois River for Decision Making plan below the electric dispersal barrier within the Illinois River Waterway.*

Results and Discussion:

Electrofishing Effort and Catch

An estimated 3,920-person hours were expended completing 175.8 hours of electrofishing (703 transects) downstream of the Electric Dispersal Barrier system in 2019. Electrofishing yielded 68,799 individual fish representing 97 species and 12 hybrid groups for a mean CPUE±SE of 391.3±35.5 fish/hour (Table 1). Electrofishing catch was dominated by Gizzard Shad (47.2%;

n=31,985), Emerald Shiner (12.1%; n=8,202), Bluegill (6.1%; n=4,111) and Smallmouth Buffalo (3.75%; n=2,427) in 2019 (Table 2). Overall Silver Carp CPUE was 9.81±0.97 fish/hour while Bighead Carp CPUE was 0.03±0.02 fish/hour. Silver Carp CPUE was highest in the lower Illinois River pools (Starved Rock Pool on downstream) while no Bighead Carp, Black Carp, Grass Carp or Silver Carp were captured during electrofishing in the pools nearest to the Electric Dispersal Barrier system (Brandon Road and Lockport pools) during 2019 (Figure 2). In the Dresden Island Pool, the pool nearest to the EBDS with a known Asian carp population, Silver Carp CPUE was 0.06±0.06 fish/hour and no Bighead Carp were captured. Asian carp tended to be larger in size in the upper river pools compared to lower river pools (Figure 3). Of the Asian carp captured during electrofishing in 2019 among all the pools, 52 of them were < 6 inches. All those small Asian carp captured were Silver Carp and 40 of them were captured in Peoria Pool and 12 in Alton Pool. The furthest upstream a small Asian carp (<6 inches) was captured during electrofishing in 2019 was in Peoria Pool (River Mile 201 approximately 120 river miles downstream of Lake Michigan).

Hoop Netting Effort and Catch

An estimated 3,027-person hours were expended setting and running 632 hoop nets (1,177.3 hoop net nights) downstream of the Electric Dispersal Barrier system in 2019. Hoop netting yielded 8,335 fish representing 49 species and 3 hybrid groups for a mean CPUE (number of fish/net night) of 6.5±1.0 (Table 1). Channel Catfish comprised the largest proportion of the hoop net catch (53.6%; n = 4,466), followed by Smallmouth Buffalo (20.05%; n = 1,671) and Common Carp (5.7%; n = 475) in 2019 (Table 3). No Asian carp were captured in Lockport, Brandon Road, Dresden Island or Marseilles pools during hoop netting, but were captured in the other downstream pools (6 Bighead Carp, 28 Grass Carp and 33 Silver Carp) during 2019 (Table 3). Bighead Carp hoop netting CPUE among all pools was 0.04±0.02, while Silver Carp CPUE was 0.03±0.09 in 2019. Greater catch rates of Asian carp in hoop nets were found in the lower river pools compared to the upper river pools (Figure 2). Asian carp captured in hoop nets tended to be larger in upper river pools compared to lower river pools (Figure 3).

Minnow Fyke Netting Effort and Catch

An estimated 4,316-person hours were expended setting and running 466 minnow fyke nets (475.8 minnow fyke net nights) downstream of the Electric Dispersal Barrier system in 2019. Minnow fyke netting yielded 66,520 fish representing 93 species and 6 hybrid groups for a mean CPUE (number of fish/net night) of 139.8±17.8 (Table 1). Most of the minnow fyke catch was comprised of Gizzard Shad (27.6%; n = 17,389), Emerald Shiner (17.8%; n = 11,208), and Bluegill (11.9%; n = 7,513) during 2019 (Table 4). No Bighead Carp, no Black Carp, seven Grass Carp and 13 Silver Carp were captured during minnow fyke effort. Most of the Grass Carp (85%) were captured in La Grange Pool while the majority of Silver Carp (92%) were captured in Peoria Pool during minnow fyke netting. Overall Silver Carp minnow fyke net CPUE among all pools was 0.04±0.02 individuals/net night in 2019 with greater catch rates being found in the lower river compared to the upper river (Figure 2). Minnow fyke netting captured the majority of small Asian carp within all of the pools and among all gears (Figure 3). The furthest upstream a small Asian carp (<6 inches) was captured during minnow fyke nets in 2019 was in Peoria Pool (River Mile 201; approximately 120 river miles downstream of Lake Michigan). This location is further downstream than previous years, as small Asian carp were captured in Marseilles Pool in 2015 and 2016 (river mile 263; approximately 70 miles from Lake Michigan).

Fyke Netting Effort and Catch

An estimated 498.5 hours were expended setting and running 102 fyke nets (113.1 net nights) downstream of the Electric Dispersal Barrier system in 2019 (Table 1). A total of 6,517 fish representing 50 species and 7 hybrid groups were captured during fyke netting with a mean CPUE of 67.7±11 fish/net night (Table 1). Fyke net catch was dominated by Bluegill (37.7%, n =2,459) and White Bass (21.9%; n=1,433) in 2019 (Table 5). A total of 15 Bighead Carp, zero Black Carp, six Grass Carp, and 10 Silver Carp were captured during fyke netting. Fyke nets captured the greatest number of Bighead Carp among any of the capture gears used in 2019. All Asian carp captured during fyke netting were collected below Peoria Lock and Dam. However, no fyke net samples were collected in Lockport, Brandon Road and Starved Rock pools due to lack of suitable habitat for this gear. Overall Bighead Carp fyke net CPUE among all pools was 0.2±0.08 and Silver Carp CPUE was 0.1±0.05. Higher catch rates of Bighead Carp, Grass Carp and Silver Carp were found in the lower river pools compared to the upper river pools during fyke netting (Figure 2).

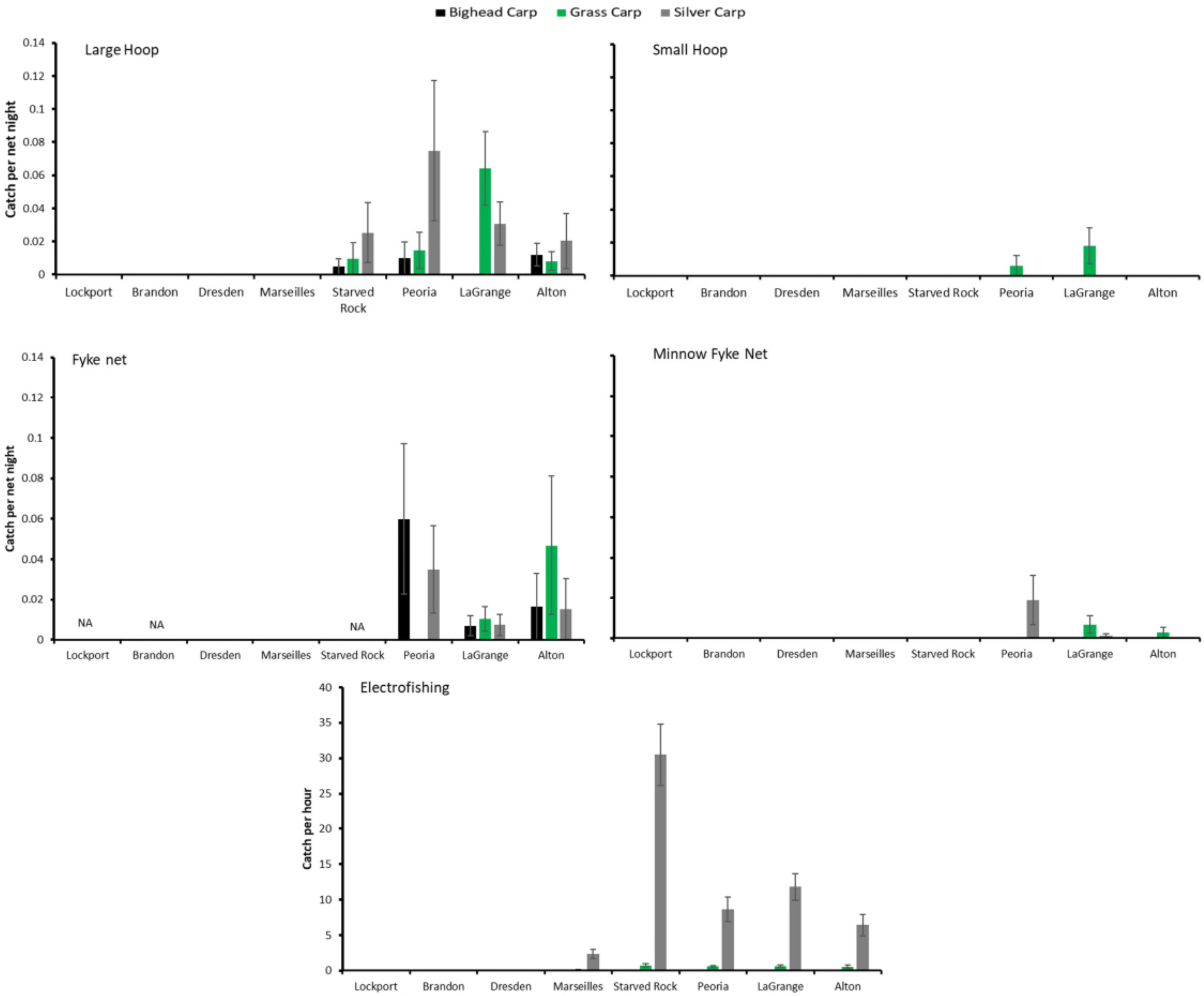

Figure 2. *Mean Catch per unit effort of Bighead Carp (black), Grass Carp (green), and Silver Carp (grey) by gear type among the various pools of the Illinois River Waterway during 2019 sampling. Due to the varying units of efforts nets and electrofishing results should not be directly compared to one another. Error bars represent ± 1 SE,*

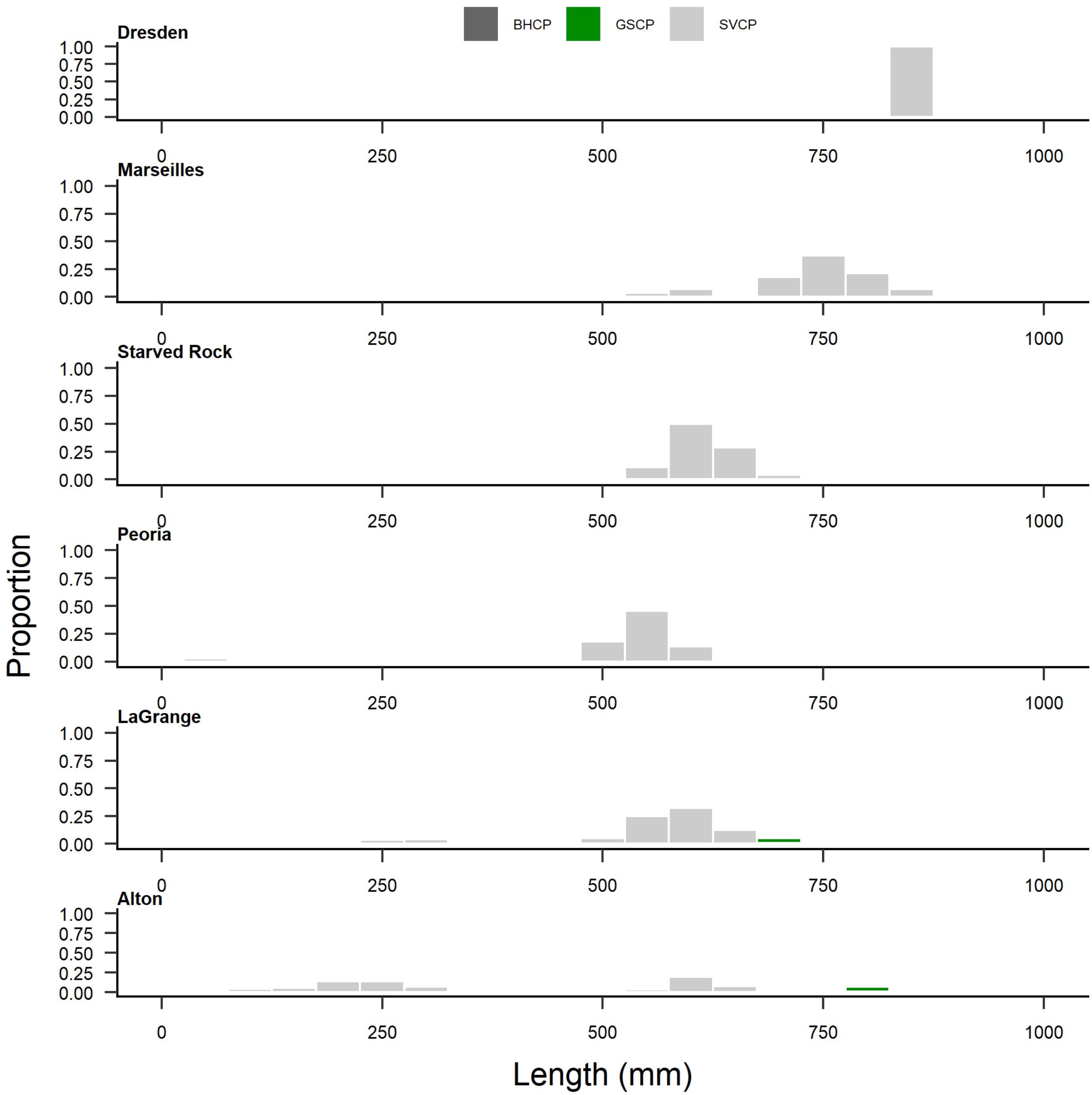

Figure 3. *Overall length frequency distributions, per 50 mm length bin, of Bighead Carp (black), Grass Carp (green) and Silver Carp (grey) captured within each pool of the Illinois River during 2019. All gear types (electrofishing, fyke netting, hoop nets and minnow fyke nets) were aggregated together.*

Recommendation:

Implementing a standardized multiple gear sampling approach created a comparable and comprehensive picture of Asian carp dynamics throughout the entire the Illinois Waterway allowing for a holistic assessment. Standardization also allowed monitoring projects outside of the Monitoring Response Plan to be incorporated, amplifying the robustness of the picture of Asian carp status and detections in the Illinois River Waterway. The leading edge of Asian carp within the Illinois River Waterway does not appear to have encroached closer to the Electric Dispersal Barrier system, with Bighead Carp and Silver Carp remaining in the Dresden Island Pool and no Black Carp being detected at all. The numbers and catch rates of small Asian carp (< 12 inches) were low when compared to previous years (Caputo et al. 2018) potentially indicating a weak year class of Asian carp being produced in 2019 or a result of changes to the monitoring protocol. We recommend continued sampling below the Electric Dispersal Barrier system using electrofishing, fyke netting, hoop netting, and minnow fyke netting following this standardized protocol with minimally the same level of effort. It is also recommended that dorsal spines, lapilli otoliths, pectoral fin rays, postclithera and sex of a subsample of Asian carp be collected within each pool during the fall, in addition to length and weight data, increasing the inferences that can be drawn from this dataset and the ability to aid other Monitoring and Response Working Group objectives. An evaluation of data collected, data quality, and cost among previous sampling protocol (e.g., Fixed Site Monitoring Downstream of the Dispersal Barrier) and the Multiple Agency Monitoring protocol should also occur to ensure the sampling strategy used meets the needs of the Monitoring and Response Working Group. Finally, data collected from projects outside using the same standardized methods of the Monitoring and Response Plan should continue to be incorporated into this dataset, when allowed and appropriate. Inclusion of these data allow for formulating the most comprehensive picture of Asian carp expanse and response within the Illinois River Waterway.

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Table 1. *Electrofishing, hoop netting, minnow fyke netting, and fyke netting effort with catch summaries for 2019 in pools below the Electric Dispersal Barrier.*

Electrofishing Effort - 2019

	Pool							
	Lockport	**Brandon**	**Dresden**	**Marseilles**	**Starved Rock**	**Peoria**	**LaGrange**	**Alton**
Sample Dates				15 June - 31 October				
Estimated person-hours	249	249	523.5	585	562.5	765	680	360
Electrofishing hours	23.25	21.75	18.25	23.25	26.75	33.75	30	10.75
Samples (transects)	93	87	79	93	107	135	120	43
All Fish (*N*)	1,641	3,277	6,129	8,580	6,115	19550	18,365	4,070
Species (*N*)	30	39	55	67	52	68	63	56
Hybrids (*N*)	0	3	5	4	3	6	2	3
Bighead Carp (*N*)	0	0	0	0	4	0	0	1
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	10
Silver Carp (*N*)	0	0	1	54	817	219	354	69
Silver Carp < 6 in. (N)	0	0	0	0	0	40	0	10
CPUE (No. fish/hour)	70.5±17.3	150.66±41.9	336.8±29.2	377.8±38.7	228.7±59.4	579.3±138.4	612.2±81.3	378.6±58.8

Small Hoop Net Effort- 2019

	Pool							
	Lockport	**Brandon**	**Dresden**	**Marseilles**	**Starved Rock**	**Peoria**	**LaGrange**	**Alton**
Sample dates				15 June - 31 October				
Estimated person-hours	105	105	180	247.5	135	225	201	315
Net nights	82.3	80.8	30.2	70.5	81.0	82.7	73.9	78.9
Samples (net sets)	42	41	15	34	41	42	54	42
All Fish (N)	205	293	81	481	355	328	964	1349
Species (N)	8	9	7	9	10	16	14	15
Hybrids (N)	0	2	0	0	0	1	0	1
Bighead Carp (N)	0	0	0	0	0	0	0	0
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Silver Carp (N)	0	0	0	0	0	0	0	0
Silver Carp < 6 in. (N)	0	0	0	0	0	0	0	0
CPUE (No. fish/net night)	2.5±0.3	3.7±1.4	3.7±1.7	7.3±1.3	4.7±1.4	3.9±1.3	9.1±3.4	17.2±7.6

Large Hoop Netting Effort - 2019

	Pool							
	Lockport	**Brandon**	**Dresden**	**Marseilles**	**Starved Rock**	**Peoria**	**LaGrange**	**Alton**
Sample dates				15 June - 31 October				
Est. person-hours	105	105	180	247.5	135	225	201	315
Net nights	81.6	78.0	46.1	72.5	81.0	86.8	69.2	81.8
Samples (net sets)	42	40	24	36	41	42	54	42
All Fish (*N*)	90	283	250	775	1462	629	417	373
Species (*N*)	10	14	11	8	17	19	16	24
Hybrids (*N*)	0	1	0	0	0	0	0	0
Bighead Carp (*N*)	0	0	0	0	5	2	0	3
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	1	15	8	5
Silver Carp < 6 in. (N)	0	0	0	0	0	0	0	0
CPUE (No. fish/net night)	1.1±0.3	3.7±1.4	5.9±1.4	11.3±2.9	18.7±4.4	7.2±2.3	4.0±0.8	4.6±0.8

Fyke Netting Effort - 2019

	Pool							
	Lockport	**Brandon**	**Dresden**	**Marseilles**	**Starved Rock**	**Peoria**	**LaGrange**	**Alton**
Sample dates				15 June - 31 October				
Est. person-hours			67.5	67.5		112.5	221	30
Net nights			14.9	14.5		25.5	50.2	7.6
Samples (net sets)			15	15		28	36	8
All Fish (*N*)			1081	451		1204	3509	272
Species (*N*)			31	25		28	39	23
Hybrids (*N*)			3	0		4	4	2
Bighead Carp (*N*)			0	0		7	2	1
Bighead Carp < 6 in. (N)			0	0		0	0	0
Silver Carp (*N*)			0	0		12	2	1
Silver Carp < 6 in. (N)			0	0		3	0	0

Table 1. *Electrofishing, hoop netting, minnow fyke netting, and fyke netting effort with catch summaries for 2019 in pools below the Electric Dispersal Barrier.*

	Lockport	Brandon	Dresden	Marseilles	Starved Rock	Peoria	LaGrange	Alton
CPUE (No. fish/net night)			75.5±22.1	29.2±8.2		49.0±7.7	100.2±29.7	37.1±7.5

Minnow Fyke Netting Effort - 2019

	Pool							
	Lockport	**Brandon**	**Dresden**	**Marseilles**	**Starved Rock**	**Peoria**	**LaGrange**	**Alton**
Sample dates	15 June - 31 October							
Est. person-hours	120	120	330	675	675	585	1091	720
Net nights	22.2	33.1	66.2	68.9	67.9	61.5	114.7	41.3
Samples (net sets)	24	36	72	70	67	70	84	43
All Fish (*N*)	1195	879	4294	4062	9459	25014	14847	3336
Species (*N*)	18	27	42	52	55	70	60	54
Hybrids (*N*)	2	2	2	1	0	1	1	1
Bighead Carp (*N*)	0	0	0	0	0	0	0	0
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	12	1	0
Silver Carp < 6 in. (N)	0	0	0	0	0	12	0	0
CPUE (No. fish/net night)	58.4±17.9	26.9±5.4	68.2±13.8	68.1±14.3	158.4±29.9	426.53±95.3	186.9±38.2	81.8±24.8

Table 2. *Electrofishing catch summary for 2019 in pools below the Electric Dispersal Barrier.*

Electrofishing Catch - 2019										
Species	**Lockport Pool**	**Brandon Pool**	**Dresden Pool**	**Marseilles Pool**	**Starved Rock Pool**	**Peoria Pool**	**LaGrange Pool**	**Alton Pool**	**No. Captured**	**Percent**
American Eel	0	0	0	0	0	1	0	0	1	0.00%
Banded Darter	0	0	0	0	1	0	0	0	1	0.00%
Banded Killifish	128	43	155	139	10	8	0	0	483	0.71%
Bighead Carp	0	0	0	0	4	0	0	1	5	0.01%
Bigmouth Buffalo	0	0	13	5	6	11	89	22	146	0.22%
Black Buffalo	0	0	6	2	39	3	10	19	79	0.12%
Black Bullhead	1	2	1	0	0	0	0	0	4	0.01%
Black Crappie	0	0	25	9	2	10	60	14	120	0.18%
Black Redhorse	0	0	0	0	0	0	0	0	0	0.00%
Blacknose Dace	0	0	0	0	0	0	0	0	0	0.00%
Blackside Darter	0	1	0	0	1	5	0	2	9	0.01%
Blackstripe Topminnow	1	8	22	36	2	19	15		103	0.15%
Blue Catfish	0	0	0	0	0	0	0	1	1	0.00%
Bluegill	29	132	1396	1185	142	593	528	106	4111	6.07%
Bluegill x Orangespotted Sunfish Hybrid	0	0	0	0	0	2	0	0	2	0.00%
Bluegill x Redear Sunfish Hybrid	0	0	1	0	0	0	0	0	1	0.00%
Bluntnose Darter	0	0	0	0	0	0	0	2	2	0.00%
Bluntnose Minnow	142	101	846	477	2	52	7	0	1627	2.40%
Bowfin	0	0	3	1	0	0	8	14	26	0.04%
Brassy Minnow	0	0	0	0	0	0	0	0	0	0.00%
Brook Silverside	1	1	2	36	0	4	324	190	558	0.82%
Brook Stickleback	0	0	0	0	0	0	0	0	0	0.00%
Brown Bullhead	0	0	1	0	0	0	0	0	1	0.00%
Bullhead Minnow	0	0	68	234	42	325	227	32	928	1.37%
Central Mudminnow	1	0	0	2	0	0	0	0	3	0.00%
Central Stoneroller	0	0	1	0	0	0	0	0	2	0.00%
Channel Catfish	6	14	40	83	48	110	74	62	437	0.65%
Channel Shiner	1	0	3	33	0	5	5	1	48	0.07%
Chestnut Lamprey	0	0	0	0	0	0	1		1	0.00%
Common Carp x Goldfish Hybrid	0	1	1	0	0	2	1	2	7	0.01%
Common Carp	141	366	286	76	30	391	354	133	1777	2.62%
Common Shiner	0	0	0	0	0	0	0	0	0	0.00%
Creek Chub	1	0	0	0	0	0	0	0	1	0.00%
Emerald Shiner	456	606	574	1082	961	3376	1076	71	8202	12.11%
Fathead Minnow	1	2	0	0	0	0	0	0	3	0.00%
Flathead Catfish	0	0	1	11	7	19	59	38	135	0.20%
Freshwater Drum	2	5	16	184	153	273	608	133	1374	2.03%
Gizzard Shad	398	1083	818	1899	1223	11189	13126	2249	31985	47.23%
Golden Redhorse	0	0	57	83	45	13	4	0	202	0.30%
Golden Shiner	16	38	57	7	0	22	28	3	171	0.25%
Goldeye	0	0	0	0	0	0	35	36	71	0.10%
Goldfish	28	47	74	1	0	10	4	10	174	0.26%
Grass Carp	0	0	1	2	20	20	19	6	68	0.10%
Grass Pickerel	0	8	6	4	0	1	6	0	25	0.04%
Greater Redhorse	0	0	0	0	0	0	0	0	0	0.00%
Green Sunfish	17	69	222	305	4	67	64	16	764	1.13%
Green Sunfish x Bluegill Hybrid	0	0	0	1	1	1	0	1	4	0.01%
Green Sunfish x Orangespotted Sunfish Hybrid	0	0	0	0	0	3	0	0	3	0.00%
Green Sunfish x Pumpkinseed Hybrid	0	0	0	1	0	0	0	0	1	0.00%
Green Sunfish x Redear Hybrid	0	0	1	0	0	0	0	0	1	0.00%
Greenside Darter	0	0	0	0	0	0	0	0	0	0.00%
Highfin Carpsucker	0	0	0	2	10	1	2	0	15	0.02%
Hornyhead Chub	0	0	0	0	0	0	0	0	0	0.00%
Hybrid Sunfish	0	10	43	11	0	0	0	0	64	0.09%
Johnny Darter	0	0	2	19	1	3	3	1	29	0.04%
Largemouth Bass	107	124	634	555	58	275	149	39	1941	2.87%
Logperch	0	2	17	196	14	107	29	5	370	0.55%
Longear Sunfish	0	0	0	0	0	0	0	0	0	0.00%
Longnose Gar	2	5	25	5	26	28	53	32	176	0.26%
Mimic Shiner	0	0	0	1	0	0	0	0	1	0.00%
Mississippi Silvery Minnow	0	0	0	0	0	0	0	1	1	0.00%
Mooneye	0	0	0	0	0	6	13	13	32	0.05%
Mud Darter	0	0	0	0	0	4	8	5	17	0.03%
Northern Hog Sucker	0	0	0	2	0	0	0	0	2	0.00%
Northern Pike	0	5	0	3	0	4	1	0	13	0.02%
Northern Sunfish	0	0	0	0	0	0	2	0	2	0.00%
Orangespotted Sunfish	0	36	19	27	61	269	241	177	830	1.23%

Table 2. *Electrofishing catch summary for 2019 in pools below the Electric Dispersal Barrier.*

Electrofishing Catch - 2019

Species	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Starved Rock Pool	Peoria Pool	LaGrange Pool	Alton Pool	No. Captured	Percent
Oriental Weatherfish	18	3	0	0	0	0	0	0	21	0.03%
Paddlefish	0	0	0	0	0	0	1	0	1	0.00%
Pallid Shiner	0	0	0	4	0	0	0	0	4	0.01%
Pugnose Minnow	0	0	0	0	0	2	1	0	3	0.00%
Pumpkinseed	24	62	136	3	6	4	0	0	235	0.35%
Pumpkinseed x Bluegill Hybrid	0	0	1	0	1	0	0	0	2	0.00%
Quillback	0	0	0	21	15	42	1	4	83	0.12%
Red Shiner	0	0	0	17	3	46	177	31	274	0.40%
Redear Sunfish	0	0	27	1	0	13	3	0	44	0.06%
River Carpsucker	0	0	23	253	198	16	20	1	511	0.75%
River Redhorse	0	0	0	0	3	0	0	0	3	0.00%
River Shiner	0	0	2	79	13	30	11	4	139	0.21%
Rock Bass	0	26	26	2	0	0	0	0	54	0.08%
Round Goby	4	62	11	4	0	14	0	0	95	0.14%
Sand Shiner	1	1	2	149	16	12	0	0	181	0.27%
Sauger	0	8	0	11	33	68	43	6	169	0.25%
Sauger x Walleye Hybrid	0	0	0	2	0	1	0	0	3	0.00%
Shorthead Redhorse	0	0	63	34	36	11	32	4	180	0.27%
Shortnose Gar	0	0	0	1	7	26	59	61	154	0.23%
Silver Carp	0	0	2	54	817	291	354	69	1587	2.34%
Silver Carp X Bighead Carp Hybrid	0	0	0	0	1	0	0	0	1	0.00%
Silver Chub	0	0	0	0	2	20	0	0	22	0.03%
Silver Redhorse	0	0	12	4	2	1	0	0	19	0.03%
Silverband Shiner	0	0	0	0	1	45	44	16	106	0.16%
Silverjaw Minnow	0	0	0	0	0	0	0	0	0	0.00%
Skipjack Herring	2	3	1	3	6	85	252	20	372	0.55%
Slender Madtom	0	0	0	0	0	2	0	0	2	0.00%
Slenderhead Darter	0	0	0	16	0	0	0	1	17	0.03%
Smallmouth Bass	0	114	151	150	165	27	17	3	627	0.93%
Smallmouth Buffalo	0	2	136	257	1654	151	184	52	2436	3.60%
Spotfin Shiner	0	0	2	275	75	198	11	15	576	0.85%
Spottail Shiner	2	98	47	422	55	791	155	2	1572	2.32%
Spotted Gar	0	0	0	0	0	1	2	2	5	0.01%
Spotted Sucker	0	0	3	0	0	0	0	0	3	0.00%
Stonecat	0	0	0	0	0	0	0	1	1	0.00%
Striped Bass x White Bass hybrid	0	0	0	0	0	1	1	2	4	0.01%
Striped Shiner	0	0	0	0	0	0	0	0	0	0.00%
Suckermouth Minnow	0	0	0	11	3	8	4	4	30	0.04%
Tadpole Madtom	0	1	0	1	0	7	4	0	13	0.02%
Threadfin Shad	72	90	5	9	1	55	198	110	540	0.80%
Trout Perch	0	0	0	1	0	0	0	0	1	0.00%
Unidentified Buffalo	0	0	1	0	0	0	0	0	1	0.00%
Unidentified Catostomidae	0	0	8	1	0	48	29	25	111	0.16%
Unidentified Centrarchidae	0	0	5	14	0	2	0	0	21	0.03%
Unidentified Cyprinidae	10	0	1	1	5	24	7	0	48	0.07%
Unidentified Darter	0	0	0	2	1	0	0	0	3	0.00%
Unidentified Morone	0	0	0	3	0	0	0	0	3	0.00%
Unidentified Percid	0	0	0	0	0	0	0	0	0	0.00%
Walleye	0	0	2	0	2	5	2	0	11	0.02%
Warmouth	1	0	3	2	2	3	9	15	35	0.05%
Western Mosquitofish	2	0	1	9	0	13	41	2	68	0.10%
White Bass	0	1	0	33	58	225	488	174	979	1.45%
White Crappie	0	0	2	4	0	8	53	2	69	0.10%
White Perch	0	2	0	3	1	7	0	0	13	0.02%
White Perch Hybrid	0	1	0	0	0	0	0	0	1	0.00%
White Sucker	0	37	0	0	0	0	0	1	38	0.06%
Yellow Bass	0	0	3	3	20	12	32	6	76	0.11%
Yellow Bullhead	16	43	7	1	0	2	1	0	70	0.10%
Yellow Perch	0	0	1	0	0	0	1	0	2	0.00%
Total Captured	**1631**	**3263**	**6121**	**8579**	**6115**	**19550**	**19470**	**4070**	**68799**	--
No. Species	30	39	55	65	52	68	63	56	97	--
No. Hybrid	1	2	4	4	1	3	2	3	12	--

Table 3. *Hoop netting catch summary for 2019 in pools below the Electric Dispersal Barrier.*

Hoop Net Catch - 2019

Species	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Starved Rock Pool	Peoria Pool	LaGrange Pool	Alton Pool	No. Captured	Percent
American Eel	0	0	0	0	0	0	1	0	1	0.01%
Bighead Carp	0	0	0	0	1	2	0	3	6	0.07%
Bigmouth Buffalo	0	0	0	0	0	0	1	0	1	0.01%
Black Buffalo	0	0	6	6	9	0	17	1	39	0.47%
Black Crappie	0	1	4	2	3	2	3	24	39	0.47%
Blue Catfish	0	0	0	0	0	0	1	6	7	0.08%
Blue Sucker	0	0	0	0	0	0	1	1	2	0.02%
Bluegill	18	13	22	26	23	192	47	109	450	5.40%
Bluegill x Redear Sunfish Hybrid	0	0	0	0	0	1	0	0	1	0.01%
Brown Bullhead	2	0	0	0	0	0	0	0	2	0.02%
Channel Catfish	75	273	125	612	1066	246	874	1195	4466	53.58%
Common Carp	10	11	40	31	21	153	133	76	475	5.70%
Common Carp x Goldfish Hybrid	0	4	0	0	0	0	0	0	4	0.05%
Flathead Catfish	0	0	5	26	12	8	36	49	136	1.63%
Freshwater Drum	0	0	1	13	5	21	81	148	269	3.23%
Gizzard Shad	2	0	0	0	0	2	0	1	5	0.06%
Golden Redhorse	0	0	0	0	0	0	0	1	1	0.01%
Goldeye	0	0	0	0	1	0	0	0	1	0.01%
Goldfish	1	4	0	0	0	0	0	0	5	0.06%
Grass Carp	0	0	0	0	2	4	20	2	28	0.34%
Green Sunfish	8	1	0	0	0	0	0	1	10	0.12%
Green Sunfish x Bluegill Hybrid	0	0	0	0	0	0	0	2	2	0.02%
Hybrid Sunfish	0	1	0	0	0	0	0	0	1	0.01%
Largemouth Bass	1	0	0	0	0	0	0	0	1	0.01%
Longear Sunfish	0	0	3	0	0	0	0	0	3	0.04%
Longnose Gar	0	0	0	1	0	1	0	1	3	0.04%
Orangespotted Sunfish	1	0	0	0	0	2	0	0	3	0.04%
Pumpkinseed	57	16	21	0	0	2	0	0	96	1.15%
Quillback	0	0	0	4	2	3	0	1	10	0.12%
Redear Sunfish	0	0	1	0	0	1	0	0	2	0.02%
River Carpsucker	0	0	1	0	7	3	0	1	12	0.14%
Rock Bass	0	37	0	0	0	0	0	0	37	0.44%
Sauger	0	1	0	0	1	3	0	1	6	0.07%
Shorthead Redhorse	0	1	0	1	0	1	0	5	8	0.10%
Shortnose Gar	0	0	0	0	1	5	1	8	15	0.18%
Silver Carp	0	0	0	0	5	15	8	5	33	0.40%
Silver Chub	0	0	0	0	0	2	0	0	2	0.02%
Silver Redhorse	0	0	1	0	0	0	0	0	1	0.01%
Skipjack Herring	0	0	0	0	0	0	1	0	1	0.01%
Slender Madtom	0	0	0	0	0	0	0	1	1	0.01%
Smallmouth Bass	0	2	0	0	1	36	0	0	39	0.47%
Smallmouth Buffalo	0	0	101	534	648	227	107	54	1671	20.05%
Spotfin Shiner	0	0	0	0	1	0	0	0	1	0.01%
Striped Bass	0	1	0	0	0	0	0	0	1	0.01%
Striped Bass X White Bass Hybrid	0	0	0	0	0	0	0	0	0	0.00%
Tadpole Madtom	0	0	0	0	0	0	0	2	2	0.02%
Unidentified Catostomidae	0	0	0	0	0	1	0	0	1	0.01%
Walleye	0	0	0	0	0	0	0	0	0	0.00%
Warmouth	0	0	0	0	0	0	0	1	1	0.01%
White Bass	0	0	0	0	8	22	26	9	65	0.78%
White Crappie	0	0	0	0	0	2	22	13	37	0.44%
White Perch	1	1	0	0	0	0	0	0	2	0.02%
White Sucker	0	10	0	0	0	0	0	0	10	0.12%
Yellow Bass	0	0	0	0	0	0	1	1	2	0.02%
Yellow Bullhead	119	199	0	0	0	0	0	0	318	3.82%
Total Captured	295	576	331	1256	1817	957	1381	1722	8335	100%
No. Species	12	15	13	11	19	24	19	28	49	--
No. Hybrid Groups	0	2	0	0	0	1	1	1	3	--

Table 4. *Minnow fyke netting catch summary for 2019 in pools below the Electric Dispersal Barrier.*

Minnow Fyke Netting Catch - 2019

Species	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Starved Rock Pool	Peoria Pool	LaGrange Pool	Alton Pool	No. Captured	Percent
Banded Darter	0	0	0	1	0	18	0	0	19	0.03%
Banded Killifish	344	13	87	36	50	6	0	0	536	0.81%
Bigmouth Buffalo	0	0	1	0	0	5	0	2	8	0.01%
Black Buffalo	0	0	0	0	0	0	0	0	0	0.00%
Black Bullhead	0	0	60	1		3	5	4	73	0.11%
Black Crappie	0	0	56	30	19	66	219	130	520	0.78%
Blacknose Shiner	0	0	0	7	0	0	0	0	7	0.01%
Blackside Darter	0	0	0	0	0	31	13	6	50	0.08%
Blackstripe Topminnow	0	44	31	34	27	99	38	5	278	0.42%
Blue Catfish	0	0	0	0	0	2	0	0	2	0.00%
Bluegill	267	296	2735	1176	667	1598	607	211	7557	11.36%
Bluntnose Darter	0	0	0	0	0	31	0	0	31	0.05%
Bluntnose Minnow	82	77	572	140	394	522	161	7	1955	2.94%
Bowfin	0	0	1	1	0	0	2	0	4	0.01%
Brook Silverside	0	0	0	5	3	11	842	677	1538	2.31%
Brook Stickleback	0	0	0	0	1	0	0	0	1	0.00%
Brown Bullhead	0	2	2	0	0	25	0	0	29	0.04%
Bullhead Minnow	0	0	2	497	1428	186	930	46	3089	4.64%
Carp x Goldfish Hybrid	0	2	1	0	0	0	0	0	3	0.00%
Central Mudminnow	0	2	0	2	1	0	0	0	5	0.01%
Central Stoneroller	0	0	0	0	1	0	3	0	4	0.01%
Channel Catfish	1	1	8	6	34	99	138	59	346	0.52%
Channel Shiner	0	0	2	63	13	38	21	2	139	0.21%
Common Carp	11	142	87	6	5	19	30	12	312	0.47%
Common Shiner	0	0	0	0	0	0	0	0	0	0.00%
Creek Chub	0	0	0	0	1	3	0	0	4	0.01%
Emerald Shiner	0	26	28	354	5244	4579	1072	124	11427	17.18%
Fathead Minnow	0	0	2	2	3	1	1	2	11	0.02%
Flathead Catfish	0	0	0	1	2	5	16	2	26	0.04%
Freshwater Drum	0	0	0	29	4	99	552	367	1051	1.58%
Gizzard Shad	3	24	62	121	54	14902	4858	293	20317	30.54%
Golden Redhorse	0	0	0	0	1	0	0	0	1	0.00%
Golden Shiner	23	2	48	1	1	74	109	7	265	0.40%
Goldfish	0	3	20	0	0	0	0	1	24	0.04%
Grass Carp	0	0	0	0	0	0	6	1	7	0.01%
Grass Pickerel	0	1	0	3	1	2	2	2	11	0.02%
Green Sunfish	110	31	71	60	21	30	60	92	475	0.71%
Green Sunfish x Bluegill Hybrid	0	0	0	0	0	0	0	5	5	0.01%
Green Sunfish x Orangespotted Sunfish Hybrid	0	0	0	0	0	0	1	0	1	0.00%
Hornyhead Chub	0	0	0	0	0	2	0	0	2	0.00%
Hybrid Sunfish	29	7	30	0	0	0	0	0	66	0.10%
Johnny Darter	0	0	12	16	2	119	13	28	190	0.29%
Largemouth Bass	8	6	75	58	44	28	5	15	239	0.36%
Logperch	0	0	2	26	3	106	13	9	159	0.24%
Longear Sunfish	0	0	0	0	1	0	1	0	2	0.00%
Longnose Gar	0	0	4	3	5	9	17	10	48	0.07%
Mimic Shiner	0	0	0	47	7	132	0	0	186	0.28%
Mooneye	0	0	0	0	0	0	0	2	2	0.00%
Mud Darter	0	0	0	0	0	1	30	48	79	0.12%
Northern Pike	0	0	0	0	0	0	0	0	0	0.00%
Orangespotted Sunfish	3	14	10	85	23	103	317	382	937	1.41%
Orangethroat darter	0	0	0	0	0	3	0	0	3	0.00%
Oriental Weatherfish	104	2	3	0	0	0	0	0	109	0.16%
Pallid Shiner	0	0	0	0	1	0	0	0	1	0.00%
Pirate Perch	0	0	0	0	0	0	5	1	6	0.01%
Pugnose Minnow	0	0	0	0	0	0	785	0	785	1.18%
Pumpkinseed	69	8	74	103	49	13	1	0	317	0.48%
Pumpkinseed x Orangespotted Sunfish Hybrid	1	0	0	0	0	0	0	0	1	0.00%
Quillback	0	0	0	0	0	12	0	0	12	0.02%
Red Shiner	0	0	0	0	12	26	258	37	333	0.50%
Redear Sunfish	0	0	0	0	0	4	0	0	4	0.01%
Redfin Shiner	0	0	0	0	0	2	0	0	2	0.00%
River Carpsucker	0	0	0	0	1	61	1	3	66	0.10%
River Redhorse	0	0	0	0	0	1	0	0	1	0.00%
River Shiner	0	0	2	438	838	55	53	0	1386	2.08%
Rock Bass	2	10	6	3	2	1	0	0	24	0.04%
Round Goby	1	67	52	8	7	19	12	0	166	0.25%

Table 4. *Minnow fyke netting catch summary for 2019 in pools below the Electric Dispersal Barrier.*

Minnow Fyke Netting Catch - 2019

Species	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Starved Rock Pool	Peoria Pool	LaGrange Pool	Alton Pool	No. Captured	Percent
Sand Shiner	0	13	25	9	40	141	22	3	253	0.38%
Sauger	0	0	0	0	1	0	5	5	11	0.02%
Shorthead Redhorse	0	0	0	2	0	0	5	2	9	0.01%
Shortnose Gar	0	0	2	0	15	52	37	41	147	0.22%
Silver Carp	0	0	0	0	0	12	1	0	13	0.02%
Silver Chub	0	0	0	0	0	7	0	0	7	0.01%
Silver Redhorse	0	0	2	0	0	0	0	0	2	0.00%
Silverband Shiner	0	0	0	0	1	0	77	89	167	0.25%
Skipjack Herring	0	0	0	8	0	18	1	1	28	0.04%
Slenderhead Darter	0	0	0	0	0	3	7	17	27	0.04%
Smallmouth Bass	0	0	1	2	1	8	0	0	12	0.02%
Smallmouth Buffalo	0	0	0	2	1	202	12	12	229	0.34%
Speckled Chub	0	0	0	0	0	1	3	0	4	0.01%
Spotfin Shiner	1	0	4	169	250	169	7	1	601	0.90%
Spottail Shiner	0	8	17	108	366	3126	1398	28	5051	7.59%
Spotted Gar	0	0	0	3	0	0	1	1	5	0.01%
Spotted Sucker	0	0	0	0	0	2	0	0	2	0.00%
Stonecat	0	0	0	0	0	0	6	1	7	0.01%
Striped Bass x White Bass Hybrid	0	0	0	2	0	1	0	0	3	0.00%
Striped Shiner	0	0	0	2	0	0	0	0	2	0.00%
Suckermouth Minnow	0	0	0	0	0	1	7	9	17	0.03%
Tadpole Madtom	6	2	9	0	2	39	54	1	113	0.17%
Threadfin Shad	0	0	1	60	4	61	24	35	185	0.28%
Trout Perch	0	0	0	10	1	32	0	0	43	0.06%
Unidentified	0	0	0	5	0	6	0	0	11	0.02%
Unidentified Ictiobus	0	0	28	0	0	0	0	0	28	0.04%
Unidentified Carpsucker	0	0	0	0	0	0	0	1	1	0.00%
Unidentified Ictalurid	0	0	0	0	0	0	1	0	1	0.00%
Unidentified Catostomidae	0	0	0	0	0	0	23	19	42	0.06%
Unidentified Centrarchidae	0	1	11	24	4	26	2	6	74	0.11%
Unidentified Clupeidae	0	0	0	92	0	1	0	0	93	0.14%
Unidentified Cyprinidae	0	0	0	135	59	0	11	0	205	0.31%
Unidentified Moronid	0	0	0	0	0	0	0	0	0	0.00%
Unidentified Percidae	0	0	0	0	0	1	1	0	2	0.00%
Unidentified Notropis	0	0	0	0	0	0	0	0	0	0.00%
Walleye	0	0	0	0	1	1	0	0	2	0.00%
Warmouth	0	4	5	2	0	7	4	2	24	0.04%
Western Mosquitofish	0	1	5	15	1	279	911	16	1228	1.85%
Western Sand Darter	0	0	0	2	0	0	0	0	2	0.00%
White Bass	0	0	0	3	18	272	878	284	1455	2.19%
White Cappie	1	4	11	40	6	334	253	134	783	1.18%
White Perch	0	0	0	1	2	36	1	1	41	0.06%
White Sucker	0	0	1	0	0	0	0	0	1	0.00%
Yellow Bass	0	0	0	1	1	1	56	32	91	0.14%
Yellow Bullhead	129	64	20	3	1	9	12	3	241	0.36%
Total Captured	1195	877	4288	4063	9745	27999	15017	3336	66520	100%
No. Species	18	27	42	53	54	69	61	54	93	--
No. Hybrid Groups	2	2	2	1	2	4	5	2	6	--

Table 5. *Fyke netting catch summary for 2019 in pools below the Electric Dispersal Barrier.*

Fyke Netting Catch - 2019

Species	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Starved Rock Pool	Peoria Pool	LaGrange Pool	Alton Pool	No. Captured	Percent
American Eel	0	0	0	1	0	0	0	0	1	0.02%
Bluegill x Orangespotted Sunfish Hybrid	0	0	0	0	0	0	1	1	2	0.03%
Bighead Carp	0	0	0	0	0	12	2	1	15	0.23%
Bullhead Minnow	0	0	0	1	0	0	0	0	1	0.02%
Black Buffalo	0	0	0	2	0	0	0	0	2	0.03%
Black Bullhead	0	0	7	0	0	0	2	2	11	0.17%
Black Crappie	0	0	47	116	0	27	399	38	627	9.62%
Bluegill	0	0	643	265	0	258	1200	93	2459	37.73%
Bigmouth Buffalo	0	0	0	0	0	1	3	0	4	0.06%
Brown Bullhead	0	0	7	0	0	0	0	0	7	0.11%
Bowfin	0	0	0	1	0	4	11	0	16	0.25%
Common Carp	0	0	44	1	0	84	48	12	189	2.90%
Channel Catfish	0	0	27	3	0	7	12	1	50	0.77%
Flathead Catfish	0	0	2	0	0	2	10	3	17	0.26%
Freshwater Drum	0	0	3	4	0	136	84	3	230	3.53%
Goldfish	0	0	4	0	0	0	0	0	4	0.06%
Golden Redhorse	0	0	2	1	0	0	2	0	5	0.08%
Golden Shiner	0	0	4	0	0	0	1	0	5	0.08%
Green Sunfish	0	0	3	5	0	2	20	7	37	0.57%
Green Sunfish x Bluegill Hybrid	0	0	1	0	0	1	1	3	6	0.09%
Grass Carp	0	0	0	0	0	0	3	3	6	0.09%
Green Sunfish x Pumpkinseed Hybrid	0	0	2	0	0	0	1	0	3	0.05%
Gizzard Shad	0	0	58	9	0	38	42	1	148	2.27%
Highfin Carpsucker	0	0	0	0	0	2	0	0	2	0.03%
Longear Sunfish	0	0	1	0	0	0	3	0	4	0.06%
Largemouth Bass	0	0	20	1	0	15	26	0	62	0.95%
Longnose Gar	0	0	22	1	0	7	12	0	42	0.64%
Longnose Gar x Spotted Gar Hybrid	0	0	0	0	0	1	0	0	1	0.02%
Northern Pike	0	0	0	0	0	1	1	0	2	0.03%
New Species	0	0	0	0	0	0	3	0	3	0.05%
Orangespotted Sunfish	0	0	0	1	0	10	22	10	43	0.66%
Pumpkinseed	0	0	104	0	0	2	0	0	106	1.63%
Pumpkinseed x Bluegill Hybrid	0	0	1	0	0	0	1	0	2	0.03%
Redear Sunfish	0	0	1	2	0	0	18	4	25	0.38%
Rock Bass	0	0	6	0	0	0	0	0	6	0.09%
River Carpsucker	0	0	3	4	0	8	5	1	21	0.32%
Sauger	0	0	0	0	0	26	3	0	29	0.44%
Sauger x Walleye Hybrid	0	0	0	0	0	1	0	0	1	0.02%
Shorthead Redhorse	0	0	6	0	0	35	7	1	49	0.75%
Smallmouth Buffalo	0	0	43	1	0	7	6	0	57	0.87%
Smallmouth Bass	0	0	1	0	0	0	1	0	2	0.03%
Shortnose Gar	0	0	1	4	0	66	127	21	219	3.36%
Spotted Sucker	0	0	1	0	0	0	0	0	1	0.02%
Spotted Gar	0	0	0	0	0	0	5	1	6	0.09%
Silver Carp	0	0	0	0	0	7	2	1	10	0.15%
Silver Redhorse	0	0	1	1	0	0	0	0	2	0.03%
Threadfin Shad	0	0	0	1	0	0	6	0	7	0.11%
Unidentified Centrarchidae	0	0	2	0	0	1	0	0	3	0.05%
Unidentified Catostomidae	0	0	0	0	0	10	3	0	13	0.20%
Walleye	0	0	0	0	0	0	1	0	1	0.02%
Warmouth	0	0	0	0	0	1	4	1	6	0.09%
White Bass	0	0	1	5	0	412	1007	8	1433	21.99%
White Crappie	0	0	6	9	0	3	204	36	258	3.96%
White Perch	0	0	3	1	0	3	2	0	9	0.14%
White Sucker	0	0	0	0	0	0	1	0	1	0.02%
Yellow Bass X White Bass Hybrid	0	0	0	0	0	1	0	0	1	0.02%
Yellow Bullhead	0	0	3	0	0	0	0	2	5	0.08%
Yellow Bass	0	0	1	11	0	13	196	18	239	3.67%
Yellow Perch	0	0	0	0	0	0	1	0	1	0.02%
Total Captured	0	0	1081	451	0	1204	3509	272	6517	--
No. Species	0	0	31	25	0	28	39	23	50	--
No. Hybrid Groups	0	0	3	0	0	4	4	2	7	--

MANAGE AND CONTROL PROJECTS

USGS Telemetry Database and Analyses in Support of SEAcarP

Brent Knights, Marybeth Brey, Jessica Stanton, Travis Harrison, Tim Fox, and Enrika Hlavacek (U.S. Geological Survey, Upper Midwest Environmental Sciences Center); Jim Duncker (U.S. Geological Survey, Central Midwest Water Science Center)

Participating Agencies: USGS, IDNR, USFWS, USACE, SIU, WIU

Pools Involved: CAWS, Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, and Alton

Introduction and Need:

Telemetry of acoustically tagged bigheaded carp (i.e., Bighead Carp *Hypophthalmichthys nobilis* and Silver Carp *H. molitrix*) and surrogate fish species has become an invaluable tool in management for these species in the Illinois Waterway System (i.e., Illinois River, lower Des Plaines River, and Chicago Area Waterway System). For example, movement probabilities between adjacent navigation pools need to be estimated to parameterize the Spatially Explicit Asian carp Population Model (SEAcarP). SEAcarP is a population model used in scenario planning by the Monitoring and Response Workgroup (MRWG) to evaluate alternative management actions. These movement probabilities are estimated from the telemetry data obtained from a longitudinal network of strategically placed receivers that detect bigheaded carp that have been implanted with acoustic transmitters. In addition, fish removal by contracted fishers has become the primary method of controlling bigheaded carp in the upper Illinois and lower Des Plaines rivers. Variable patterns in bigheaded carp distribution, habitat, and movement, influenced by seasonal and environmental conditions, make targeting bigheaded carp for removal and containment challenging and costly. Understanding these movement patterns for bigheaded carp through modeling and real-time telemetry applications informs removal efforts and facilitates monitoring and contingency actions based on fish movements.

To develop a better understanding of these fish movement dynamics to meet management objectives, an existing network of real-time and data-logging acoustic receivers in the Illinois Waterway System is collaboratively managed by a multi-agency team (see Participating Agencies section above). A Telemetry Workgroup has been established by the MRWG to ensure that the multi-agency telemetry efforts are coordinated to efficiently and effectively meet the MRWG goals. This workgroup plans and executes the placement of receivers, tagging of bigheaded carp with acoustic tags, and management of the telemetry data. Two primary objectives addressed by this project to meet the MRWG goals included (1) development of a common standardized telemetry database, and (2) estimating movement probabilities and associated uncertainty needed for SEAcarP with a custom Bayesian multi-state model rather than the Program MARK (http://www.phidot.org/software/mark/). The telemetry database (FishTracks) facilitates standardization, archiving, sharing, quality assurance, visualization and analysis of the telemetry data needed for management. Modifications and additions to

FishTracks enable more problem-free use of the database and associated applications for uploading, downloading and visualizing the data, as well as useful extraction of information to meet management goals. The transition to a custom Bayesian multi-state model to estimate movement probabilities will support more efficient, effective and robust population modeling with SEAcarP by overcoming shortcomings of Program MARK for this purpose. The shortcomings in Program MARK potentially overcome by a custom Bayesian multi-state model include lack of customizability and extensibility, problems of singularities and poor-convergence, computer crashes, parameter exclusion from models, and lack of estimates of uncertainty.

Objectives:

(1) *Database:* Development and maintenance of the telemetry database and associated applications

   a. Develop and maintain FishTracks telemetry database for existing (2010-2019) and new bigheaded carp telemetry data from the Illinois, Mississippi and Ohio river basins, including data from real-time and data-logging stationary acoustic receivers.

   b. Add and further develop FishTracks functionality to ensure data are secure, easily accessible to partners, standardized, and quality assured.

   c. Further develop visualization tools in FishTracks via interactions with users so that the visualization tools are intuitive and user-friendly.

   d. Finalize a custom program to analyze telemetry data to inform optimal placement of acoustic receivers to meet management objectives related to multi-state modeling of transition probabilities.

   e. Finalize data sharing agreements as Memorandums of Understanding between participating agencies so that it is clear what data will be sharable (i.e., included in the database), how data will be formatted and stored, and how data can be used by participating agencies.

   f. Hold a workshop for the multi-basin telemetry partnership to demonstrate the functionality of, answer questions about, get feedback on, and promote the use of FishTracks to achieve the MRWG objectives.

(2) *Bayesian multi-state model:* Development of a custom Bayesian multi-state model to estimate bigheaded carp movement probabilities with data in FishTracks

   a. Develop a custom program in Bayesian-capable software to conduct multi-state modeling for estimating movement probabilities and parameter uncertainty needed for scenerio planning with SEAcarP.

   b. Run the new model on a subset of the Illinois River data to assess performance.

   c. Assure the quality of all the historical telemetry data in FishTracks (through 2018) for analyses with the new model.

d. Using the new model, estimate movement probabilities and associated uncertainty with the historical telemetry data to provide input parameters for the SEAcarP model.

Project Highlights:

Database

Functionality updates to the FishTracks include (1) developed a standard operating procedure for data collection, formatting, and upload requirements, (2) implemented an online upload tool to streamline the data upload process and automate quality control checks to ensure data consistency, and (3) developed program to summarize millions of telemetry data records into consolidated datasets for optimizing telemetry receiver placement throughout the network of receivers.

Bayesian multi-state model

The primary advancement for the multi-state model has been configuring the model in a hierarchical Bayesian framework to allow greater flexibility than reliance on the limited parametrization formats and distributions available in software packages such as Program MARK. The new formulation of the model and a model comparison approach for selecting the best model were tested on a subset of data from the Illinois River. Final proofing of the historical FishTracks data that will be used in the multi-state model was initiated.

Methods:

Database

The FishTracks, a Microsoft SQL Server application, is actively maintained at the USGS Upper Midwest Environmental Sciences Center (UMESC). Maintenance involves routine data backups, performance of internal consistency checks, and rebuilding indexes as needed to keep the application online and available to users. New telemetry data is uploaded into FishTracks by UMESC personnel after it is collected, quality assured, and submitted by partner agencies via an upload application. Further quality assurance is conducted at UMESC by a database manager to screen for missing data or potentially aberrant values. Information on missing data and potentially aberrant values is then sent to partners for validation or correction. FishTracks functionality is modified or added based on partner issues and needs (e.g., modeling efforts) identified through quarterly meetings of the Telemetry Workgroup and other interactions with partners. Application updates, new version releases, and data requests are communicated to contributing partner agencies via the Telemetry Workgroup.

Bayesian multi-state model

The USGS, in collaboration with the Telemetry Workgroup and Population Modelling Workgroup of the MRWG, developed a multi-state model to estimate interpool movement probabilities needed for SEAcarP. The “states” represented in these multi-state models are the navigation pools in the Illinois and Des Plaines rivers and upper Illinois Waterway System. Specifically, Bayesian statistical methods were used to create a model syntax that maximizes user customizability and extensibility, while avoiding the problems of singularities and poor-convergence inherent to the rival frequentist Program MARK. For example, previous multi-state modeling with Program MARK has been fraught with difficulties (e.g., computer crashes, automatically excluding parameters from the model, and not providing estimates) thought to be related to model complexity including the number of model parameters derived from the number of states, recapture periods, random effects to account for individual, and allowance for spatial and temporal heterogeneity. In addition, Program MARK does not provide uncertainty estimates for the parameters, and these are desired in the context of scenerio planning with the SEAcarP model. Hierarchical models performed in a Bayesian framework provide a direct expression of uncertainty for parameters to use in the SEAcarP model. USGS further reviewed the historical telemetry data in FishTracks for completeness and aberrant values prior to using it in the multi-state model.

Results:

Database

Partner agencies are contributing new bigheaded carp telemetry data (including real-time receiver data) from the Upper Illinois River, Mississippi River Basin, and Ohio River Basin as they are downloaded from receivers, post-processed, quality assured and uploaded using the online upload application. New quality control checks have been added to FishTracks functionality to catch potential data errors during the upload process. Database maintenance has included extensive data cleaning and logical data testing to correct historical data errors (datasets collected and submitted prior to online upload tool with standardized formatting and automated quality control checks), along with the development of a changelog to document any necessary modifications to existing data. Efforts are continuing to compile existing data to create an optimized receiver network model (i.e., determine the optimal placement of receivers within the telemetry network to facilitate multi-state modeling efforts). A standard operating procedure has been developed to detail data collection and formatting standards. FishTracks application updates, new version releases, and feedback for improvements to new functionality have been communicated between contributing partner agencies and developers through the Telemetry Workgroup.

Bayesian multi-state model

Understanding the movement and dispersal characteristics of invasive Bighead Carp and Silver Carp is an important aspect of their management and control on the Illinois River. Summarizing movement rates within and between basins will aid in informing decisions for efficient management and control of these species. In FY2019, we made several advances to the multi-state movement model previously developed for bigheaded carps in this system. The primary advancement has been configuring the model in a hierarchical Bayesian framework. This Bayesian framework allows greater flexibility than reliance on the limited parameterization formats and distributions available in software packages such as Program MARK. In this new parameterization of the model, we made an important advancement by including a parameter that explicitly accounts for battery state in the model. Not accounting for battery state can bias estimates of survival and/or detection probability in mark-recapture models like these by not letting a fish with dead transmitter batteries move into an unobservable state.

One challenge with any complex model, and particularly hierarchical Bayesian models, is being able to evaluate model fit. This is important both for discriminating between competing model structures and evaluating how well a model fits data. In FY2019 we configured an objective evaluation criterion based on a multinomial kappa statistic that will allow us to choose the model structure that best describes our system.

This new model and model comparison were successfully tested and run on a subset of data from fish tagged in the Illinois River system. We are currently working on preparing an expanded dataset from FishTracks for conducting the analysis of movement probabilities on the entire historical data set through 2019. This analysis on the full data set will provide new parameter estimates and associated uncertainty that can be used in SEAcarP modeling.

USGS Geospatial Support for Unified Fishing Method

Kevin Hop, Andrew Strassman, Jon Vallazza, and Brent Knights (U.S. Geological Survey, Upper Midwest Environmental Sciences Center)

Participating Agencies: USGS, IDNR, USFWS

Pools Involved: Dresden Island

Introduction and Need:

Mass harvest of bigheaded carp (i.e., Silver Carp and Bighead Carp) is challenging, primarily due to their strong gear avoidance behavior. Alternative methods of mass harvest are being explored, including a Unified Fishing Method adapted from a traditional Chinese method. The modified Unified Fishing Method being deployed in the Illinois River incorporates multiple driving, herding, and capture techniques (collectively fishing techniques) in an integrated fashion over multiple days to more efficiently and effectively capture bigheaded carp in a pre-determined area. Implementation of this method requires spatial and temporal coordination among multiple agencies' personnel and contracted fishermen in a unified manner at scales ranging from individual backwaters to entire navigation pools. Better understanding the spatial and temporal aspects of these fishing techniques in relation to movements of fish and catch events during a Unified Fishing Method can improve the efficiency and effectiveness of the implementation of this mass harvest method.

To assess the spatial and temporal coverage of Unified Fishing Method events, GPS tracking devices are being deployed on equipment during events to collect accurate, time-stamped movement data. These data, along with boat activity, telemetered fish movement, and catch event data, are being post-processed in a GIS environment into both overview and animated visualizations of completed events to facilitate evaluations for improving future implementations of the Unified Fishing Method. Standardizing this methodology will facilitate rapid delivery of data visualizations to managers and researchers for evaluation after an event. The cost and feasibility of building and deploying this type of spatial and temporal evaluation system in near-real time (using actively transmitting GPS tracking devices on boats and net equipment) for operations management during an event is also being explored.

Objectives:

(1) Develop a method for data collection on boats, nets, and catch during Unified Fishing method events to minimize spatial and temporal gaps in the data and increase accuracy and standardization.

(2) Develop a method for post-processing the standardized geospatial data (i.e., on boats, nets, catch, and telemetered fish movement during events) into GIS visualizations to facilitate evaluations of the method.

USGS Geospatial Support for Unified Fishing Method

Project Highlights:

- Equipment requirements (i.e., GPS units), deployment techniques (e.g., best placement for ensuring proper data collection), and a methodology for collecting time-stamped GPS tracking and activity data from boats and gear deployments during Unified Fishing Method events has been developed. This methodology was utilized during the Dresden Island Pool fall of 2019 Unified Fishing Method event, implementing improvements to data collection issues that were revealed from gaps in data collection during the Dresden Island Pool fall of 2018 event.
- Geospatial data collected during the Dresden Island Pool fall of 2018 Unified Fishing Method event were post-processed into visualizations of the coordinated effort and used to reduce the time required to clear the same area during subsequent events (e.g., covering Dresden Island Pool with four days of coordinated fishing effort instead of five days). Data from the fall of 2019 event is being processed and visualizations are being refined to incorporate telemetry data to display fish movement relative to boat activities and gear deployments.

Methods:

A method for collecting geospatial-ready data during Unified Fishing Method events on boats, gear deployments, and catch events has been developed and will continue to be refined to minimize spatial and temporal gaps for increased data accuracy and standardization. After in-the-field testing, Garmin Oregon and Montana models of GPS units, both capable of time-stamped coordinate tracking (at an interval of every three seconds), were chosen for ease of use and consistency of accurate data collection over LandAirSea GPS units. An individual dedicated solely to geospatial data collection deploys and monitors GPS-tracking devices, assesses geospatial data collected after each day’s removal efforts to ensure proper data collection, and troubleshoots any technical issues encountered during data collection, while allowing other agency event participants to focus on their assigned coordinated fishing activities.

Standardized, time-stamped geospatial data collected during Unified Fishing Method events are post-processed into overview and animated visualizations in a GIS environment. Geospatial data collected during events are downloaded from GPS-tracking devices, formatted into a usable GIS format, and loaded into a GIS (i.e., Esri ArcScene and ArcGIS Pro), along with both telemetry movement and catch event data. Animated visualizations are then created to show the movement of boats and net deployments in relation to telemetered fish movement and catch events, in the context of high-resolution bathymetry data when available for an area. Visualizations can be evaluated to identify areas and times where coordination of boats and net deployments were the most or least effective, for lessons learned to increase effectiveness of future Unified Fishing Method events.

USGS Geospatial Support for Unified Fishing Method

Results and Discussion:

Deploying an onsite GPS manager during Unified Fishing Method events has allowed for (1) consistent preparation and deployment of GPS units on boats each event day; (2) data collection, download, and pre-processing of track data after each event day; (3) troubleshooting and noting GPS device issues to eliminate large gaps in data collection and improve data collection techniques; and (4) observing and tracking boat activities during the event assists in the process of aligning GPS tracks, boat activity, telemetered fish movement, and catch event data when post-processing data into visualizations.

Geospatial tracking data and visualizations from the Dresden Island Pool fall of 2018 Unified Fishing Method event were delivered to event managers to assist with planning the Dresden Island Pool fall of 2019 event. A review of the previous year's effort (covering roughly the same geographic area) presented the opportunity for efficiency gains, by observing periods of downtime between coordinated efforts and reducing the overall event from five days to four days.

Time-stamped, geospatial data were collected again during the Dresden Island Pool fall of 2019 Unified Fishing Method event and post-processed into overview and animated visualizations of the coordinated effort. Potential data loss for one day's collection was minimized by troubleshooting the deployment of a GPS unit for the subsequent event days. Post-processed visualizations are being refined to most effectively incorporate telemetry data to show fish movement relative to boat tracking and activity; data post-processing methodology will be updated accordingly to include integration of telemetry data.

Contracted Commercial Fishing Below the Electric Dispersal Barrier

Andrew Mathis, Dan Roth, Claire Snyder, Allie Lenaerts, Eric Hine (Illinois Natural History Survey); Nathan Lederman, Eli Lampo, Charmayne Anderson, Justin Widloe, Kevin Irons, Mindy Barnett, Seth Love, Rebekah Anderson (Illinois Department of Natural Resources)

Participating Agencies: Illinois Department of Natural Resources (IDNR), Illinois Natural History Survey (INHS)

Pools Involved: Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock

Location: Contracted Commercial Fishing Below the Electric Dispersal Barrier targeted the area between the Electric Dispersal Barrier at Romeoville, IL (~37 miles [60 km] from Lake Michigan) downstream to Starved Rock Lock and Dam, including Lockport Pool, Brandon Road Pool, Dresden Island Pool, Marseilles Pool, and Starved Rock Pool (Figure 1).

Introduction and Need:

Contracted Commercial Fishing Below the Electric Dispersal Barrier uses contracted commercial fishers to reduce Asian carp (Bighead Carp, Black Carp, Grass Carp and Silver Carp) abundance and monitor for changes in range in the Des Plaines River and upper Illinois River, downstream of the Electric Dispersal Barrier. By decreasing Asian carp abundance, we anticipate reduced migration pressure towards the Electric Dispersal Barrier, lessening the chances of Asian carp gaining access to upstream waters in the Chicago Area Waterway System and Lake Michigan. Monitoring for upstream expansion of Asian carp should help identify changes in the leading edge, distribution, and relative abundance of Asian carp in the Illinois Waterway. The “leading edge” is defined as the furthest upstream location where multiple Bighead Carp or Silver Carp have been captured in conventional sampling gears during a single trip or where individuals of either species have been caught in repeated sampling trips to a specific site. Trends in catch data over time may also contribute to the understanding of Asian carp population abundance and movement between and among pools of the Illinois Waterway.

Objectives:

(1) Monitor for the presence of Asian carp in five pools (Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock) below the Electric Dispersal Barrier in the Illinois Waterway.

(2) Reduce Asian carp densities, lessening migration pressure to the Electric Dispersal Barrier, thus decreasing chances of Asian carp accessing upstream reaches (e.g., Chicago Area Waterway and Lake Michigan).

(3) Inform other projects (i.e., hydroacoustic verification and calibration, SEAcarP model, small fish monitoring, telemetry master plan) with Asian carp population distribution, dynamics, and movement in the Illinois Waterway downstream of the Electric Dispersal Barrier.

Project Highlights:

- Since 2010, contracted commercial fishers' effort in the upper Illinois Waterway below the Electric Dispersal Barrier includes 3,892 miles (6,264 km) of gill/trammel net, 19 miles (31 km) of commercial seine, 239 Great Lakes pound net nights, and 4,369 hoop net nights.
- In total, 97,849 Bighead Carp, 997,732 Silver Carp, and 9,373 Grass Carp were removed by contracted fishers from 2010-2019. The total estimated weight of Asian carp removed is 4,528.6 tons (9,057,200 lbs.).
- No Asian carp have been collected in Lockport or Brandon Road Pools since the inception of this project in 2010.
- The leading edge of the Asian carp population remains near Rock Run Rookery in Dresden Island Pool (approximate river mile 281; 46 miles from Lake Michigan). No appreciable change has been found in the leading edge over the past 10 years.
- Since 2010, this program has been successful at managing the Asian carp population in the upper Illinois River. Continued implementation of this project will provide the most current data on Asian carp populations at their leading edge and reduce pressure on the Electric Dispersal Barrier.

Methods:

Contracted commercial netting occurred from February through December in Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock pools of the Illinois Waterway. The section of the Kankakee River from the Des Plaines Fish and Wildlife Area boat launch downstream to the confluence with the Des Plaines River was included in the Dresden Island Pool netting area (Figure 1). These areas are closed to commercial fishing by Illinois Administrative Rule (*i.e. Part 830: Commercial Fishing and Musseling in Certain Waters of the State, Section 830.10(b): Waters Open to Commercial Harvest of Fish)*; therefore, an agency biologist is required to accompany contracted commercial fishing crews working in this portion of the river. Contracted commercial fishers (with assisting agency biologists) fished four days a week during each week of the field season except for two weeks in June and two weeks in September when contracted commercial fishers sampled upstream of the Electric Dispersal Barrier for the Seasonal Intensive Monitoring project.

Fishing occurred in backwater, main channel, and side channel habitats known to hold Asian carp at fixed and targeted sites. Four fixed sites have been established within Marseilles, Dresden Island, Brandon Road, and Lockport pools in habitats Asian carp are suspected to congregate. Each fixed site was sampled once a month by a contracted commercial fisher (Figure 1). Targeted sampling occurred when fixed sites were not sampled and were selected at the discretion of the contracted commercial fishing crew with input from the IDNR biologist assigned to each boat.

Large mesh (2.5 - 5.0 inch; 63.5 mm - 127 mm) gill and trammel nets set in 100 to 1,200 yard segments were used and fish herding techniques (e.g., pounding on boat hulls, hitting the water surface with plungers, driving with motors trimmed up) were utilized to drive fish into the net (Butler et al. 2018). Nets were typically set for 20- to 30-minutes, but overnight net sets occasionally occurred in off-channel habitat and in non-public backwaters with no boat traffic. Entangled fish were removed from the net, identified, enumerated, and recorded. All Asian carp and Common Carp were checked for telemetry tags and all non-tagged Asian carp were harvested and utilized by private industry for purposes other than human consumption (e.g., chum bait, converted to liquid fertilizer, pet treats, food for injured animals, etc.). All tagged Asian carp and all non-Asian carp by-catch were released into the water alive. A representative sample of up to 30 individuals of each Asian carp species (Bighead Carp, Grass Carp, and Silver Carp) from each pool were measured for total length (mm), weighed (g), and sexed (male or female) 1 to 2 times per week to provide estimates of total weight harvested, and gather morphometric data on harvested Asian carp over time.

Week-long Unified Fishing Methods (UFM) were implemented in Dresden Island Pool, and the East and West Pits of Hanson Material Services in Marseilles Pool. Gill and trammel nets were set, and fishers used systematic herding techniques in unison to drive fish into nets. Block nets were used to partition the East and West Pits and the sections were cleared of Asian carp. Great Lakes pound nets were set to block fish from movement out of areas and commercial seines were pulled to remove mass amounts of Asian carp.

Contracted Commercial Fishing Below the Electric Dispersal Barrier

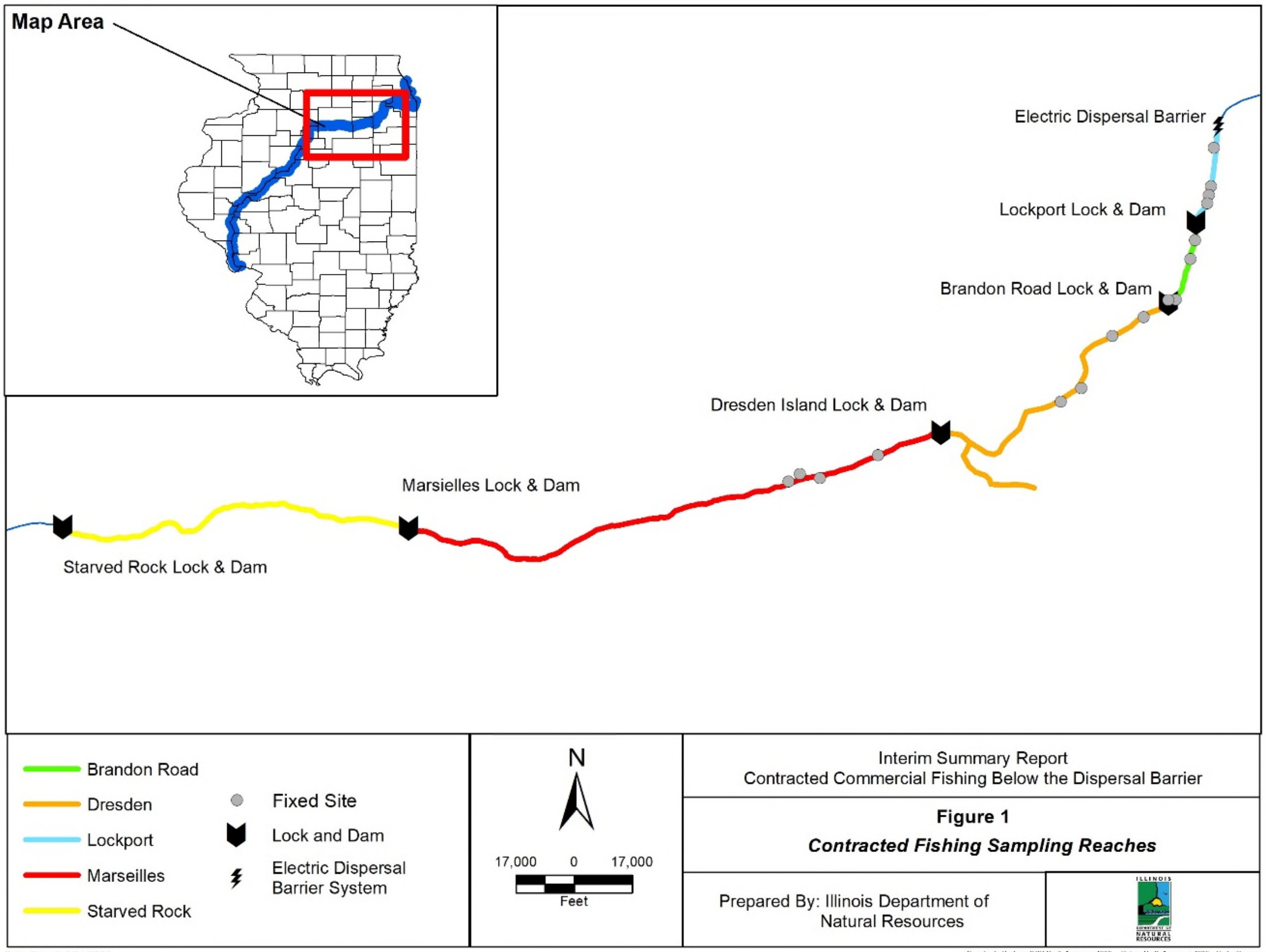

Figure 1. *Contracted commercial fishing sampling area and locations of fixed sites sampling of the contract fishing below the electric dispersal barrier project.*

Results and Discussion:

An estimated 13,782 person-hours were expended harvesting Asian carp via contracted fishing in 2019, an increase from the estimated 11,880 hours expended in 2018. A total of 3,892 miles (6,264 km) of gill/trammel net, 19 miles (31 km) of commercial seine, 239 Great Lakes pound net nights and 3,970 hoop net nights have been deployed in the upper Illinois Waterway since 2010 (Table 1). The total estimated weight of Asian carp caught and removed from 2010 – 2019 was 9,057,200 pounds (1,104,954 individuals: Table 1). Silver Carp, Bighead Carp, and Grass Carp accounted for 80.2% (997,732 individuals), 18.7% (97,849 individuals), and 1.1% (9,373 individuals) of the total tons harvested since 2010, respectively (Table 1). Silver Carp remain the most abundant Asian carp species in the Upper Illinois River, in contrast to 2010 when Bighead Carp comprised approximately 80% of total Asian carp catch.

Contracted Commercial Fishing Below the Electric Dispersal Barrier

The mean 2019 gill/trammel net catch per unit effort (CPUE; number of fish/1,000 yards of net) in Starved Rock and Marseilles Pools combined was 377.7, a slight decrease from 386.3 in 2018 (Figure 2). In Dresden Island Pool (leading edge) total Asian carp CPUE was 2.0 in 2019, a drastic decrease from a record high CPUE of 7.3 in 2018. For details regarding gill/trammel CPUE of Asian carp for all pools combined from other years, see those years' respective Interim Summary Reports (MRRP 2012-2017).

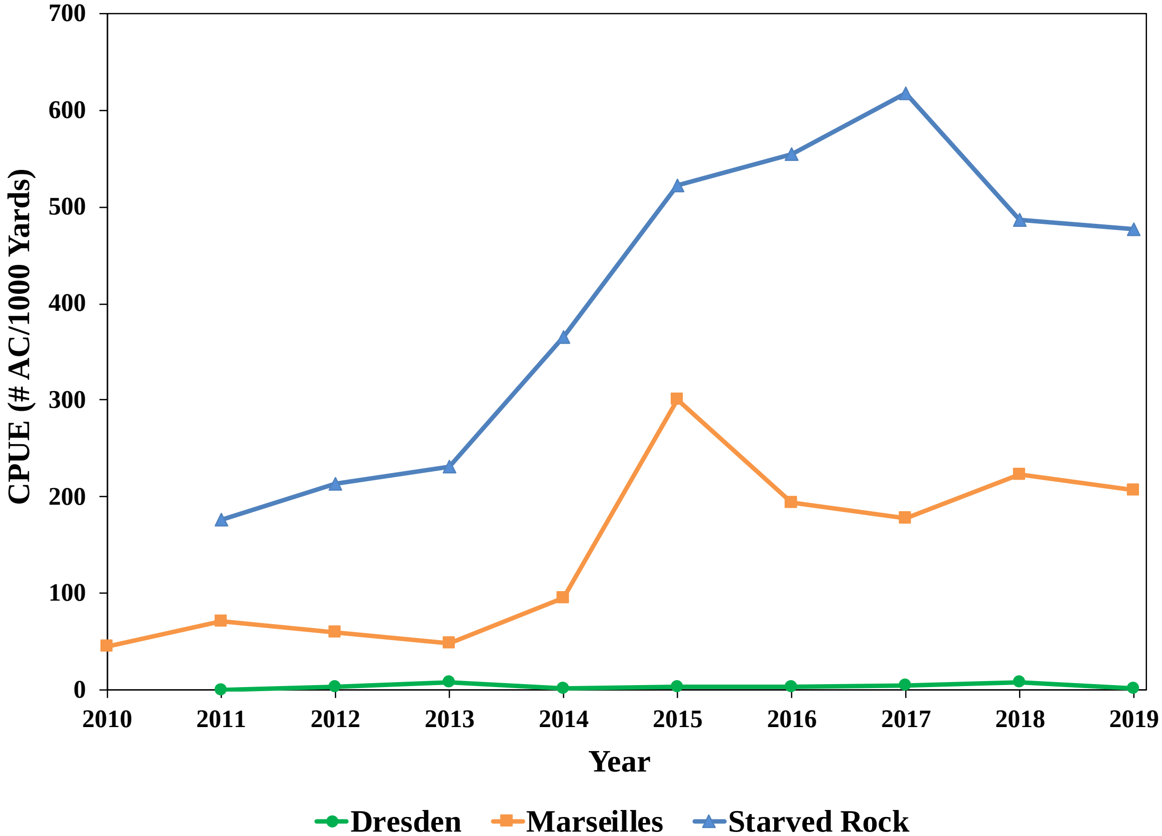

Figure 2. *Annual mean catch per unit effort (CPUE; number of fish per 1,000 yards of gill/trammel net) of Asian carp for Dresden Island (2011-2019), Marseilles (2010-2019), and Starved Rock (2011-2019) pools combined. In 2019, all data from contracted fishing efforts were combined and are represented here.*

Effort and Catch of Asian Carp within Pools

Lockport Pool: In 2019, Asian carp detection efforts included 59,400 yards (54.3 km) of gill/trammel net set. No Asian carp were observed or captured in Lockport pool.

Brandon Road Pool: In 2019, Asian carp detection efforts included 54,000 yards (49.4 km) of gill/trammel net set. No Asian carp were observed or captured in Brandon Road pool.

Dresden Island Pool: Asian carp abundance is relatively low in Dresden Island Pool compared to downstream pools, and monitoring is essential because the leading edge of the Silver and Bighead Carp population occurs here. In 2019, 0.15% of the total harvested Asian carp came from Dresden Island Pool. Contracted commercial fishing efforts included: 158,550 yards (145 km) of gill/trammel net, and two Great Lakes pound net nights. A total of 271 Silver Carp; 45 Bighead Carp; 7 Grass Carp; and 1 Bighead Carp x Silver Carp hybrid were harvested from the Dresden Island Pool (including Rock Run Rookery, lower Kankakee River and the Dresden Nuclear Power Station warm water discharge; Figure 3), amounting to 4 tons (8,000 lbs.) removed. Asian carp relative catch decreased 81% from 2018 (1,686 Asian carp). In 2018, IDNR biologists and contracted fishers gained access to the Dresden Nuclear Power Station's warm water discharge, where most Asian carp catch from Dresden Pool has been concentrated since (60% in 2018, 52% in 2019). With the amount of Asian carp removed from this area in 2018 (1,012 individuals), we believe the population within the pool decreased, leading to a decreased catch rate in 2019.

Unified Fishing Method – Dresden Island Pool: No Spring Dresden Island Pool UFM occurred due to inclement weather and flooding. The Fall UFM in the Dresden Pool occurred from 10/14/2019 to 10/18/2019. Contracted commercial fishers, IDNR/INHS staff, and multiple other agencies (USFWS, USACE, USGS, WIU) sampled the entire Dresden Island Pool, including Rock Run Rookery and the lower part of the Kankakee River. Sampling utilized 26,050 yds (23.8 km) of gill/trammel net, two Great Lakes pound net nights, set at the mouth of Rock Run Rookery, and complex noise and boat electrofishing to herd fish towards nets. A total of 21 Silver Carp, 4 Bighead Carp, and 3 Grass Carp were collected downstream of I-55, and 3 Silver Carp were collected in Rock Run Rookery (31 Asian Carp total). No Asian Carp were collected in new locations upstream of I-55. All netting effort and Asian carp numbers from the UFM are included in the Dresden Island Pool totals in the previous paragraph.

Marseilles Pool: In 2019, 20% of the total harvested Asian carp came from the Marseilles Pool. Contracted commercial fishing efforts included: 204,560 yards (187 km) of gill/trammel net, 1,600 yds (1.5 km) of commercial seine, and 21 Great Lakes pound net nights. A total of 40,834 Silver Carp; 1,311 Bighead Carp; 79 Grass Carp; and 4 Bighead Carp x Silver Carp hybrid were harvested from Marseilles pool in 2019 from all gear types (Figure 3), amounting to 237.1 tons (474,200 lbs.) removed. In total, 80 Silver Carp and 10 Bighead Carp using the commercial seine, and 282 Silver Carp, and 35 Bighead Carp using Great Lakes pound nets. Silver Carp dominated the Asian carp catch in the Marseilles pool in 2019 (96%), consistent with the past seven years. Prior to 2013, Bighead Carp was the dominant Asian carp species caught in the Marseilles Pool (>55%). In 2019, the catch of Bighead Carp was only 3% (Table 1). The 2019 gill/trammel net CPUE (# caught per 1000 yds.) of Asian carp for Marseilles Pool was 206.4, a 7.6% decrease from 2018 (223.4; Figure 2).

Unified Fishing Method – East Pit of Hanson Material Services: The East Pit UFM occurred from 03/25/2019 to 03/29/2019. Contracted commercial fishers with assisting agency biologists set 38,150 yds (34.9 km) of gill/trammel net and deployed two Great Lakes pound nets for a total of 10 net nights. A total of 15,899 Silver Carp, 117 Bighead Carp, and 4 Grass Carp (16,020 Asian carp total) were removed. All netting effort and Asian carp numbers from the UFM are included in the Marseilles Pool totals in the previous paragraph.

Contracted Commercial Fishing Below the Electric Dispersal Barrier

Unified Fishing Method – West Pit of Hanson Material Services: The West Pit UFM occurred from 04/01/2019 to 04/05/2019. Contracted commercial fishers with assisting agency biologists and supporting agencies set 24,550 yds (22.4 km) of gill/trammel net, one Great Lakes pound net was set for 11 net nights, and two commercial seines were pulled, totaling 1,600 yds (1.5 km). A total of 6,364 Silver Carp, 71 Bighead Carp, and 1 Grass Carp (6,436 Asian carp total) were removed. All netting effort and Asian carp numbers from the UFM are included in the totals in the first paragraph under Marseilles Pool.

Starved Rock Pool: In 2019, 80% of the total harvested Asian carp came from Starved Rock Pool. Contracted commercial fishing efforts included: 350,415 yards (320.4 km) of gill/trammel net set. A total of 162,463 Silver Carp, 2,108 Bighead Carp, and 2,830 Grass Carp were harvested from Starved Rock pool in 2019 from gill/trammel nets (Figure 3), amounting to 518.4 tons (1,036,800 lbs.) removed. Silver Carp dominated the catch of Asian carp in Starved Rock Pool in 2019 (97%), consistent with years past. The 2019 gill/trammel net CPUE (# caught per 1000 yds.) of Asian carp for Starved Rock Pool was 477.7, a 1.9 % decrease from 2018 (486.9) (Figure 2).

Catch of Bycatch Species:

Gill and Trammel nets: A total of 247,736 fish representing 41 species and 4 hybrid groups were captured in gill/trammel nets in the 2019 contracted commercial fishing effort (Table 2). Asian carp comprised 84.5% of the total catch, *Ictiobus spp.* (i.e., Bigmouth, Black, and Smallmouth Buffaloes) comprised 12.1% of the total catch, and Common Carp comprised 1.5% of the total catch. A total of 1,449 game fishes representing 14 species and 2 hybrid groups (i.e., *Pomoxis spp.*, *Micropterus spp.*, Ictalurids, Esocids, Percids, Moronids), were captured in gill/trammel nets in 2019. Game fishes comprised 0.58% of the total catch of fishes captured in gill/trammel nets in 2019. Similar to previous years, Flathead and Channel Catfishes were the most dominant game species captured in 2019, occupying 83.7% of the total game fishes captured in gill/trammel nets.

Contracted Commercial Fishing Below the Electric Dispersal Barrier

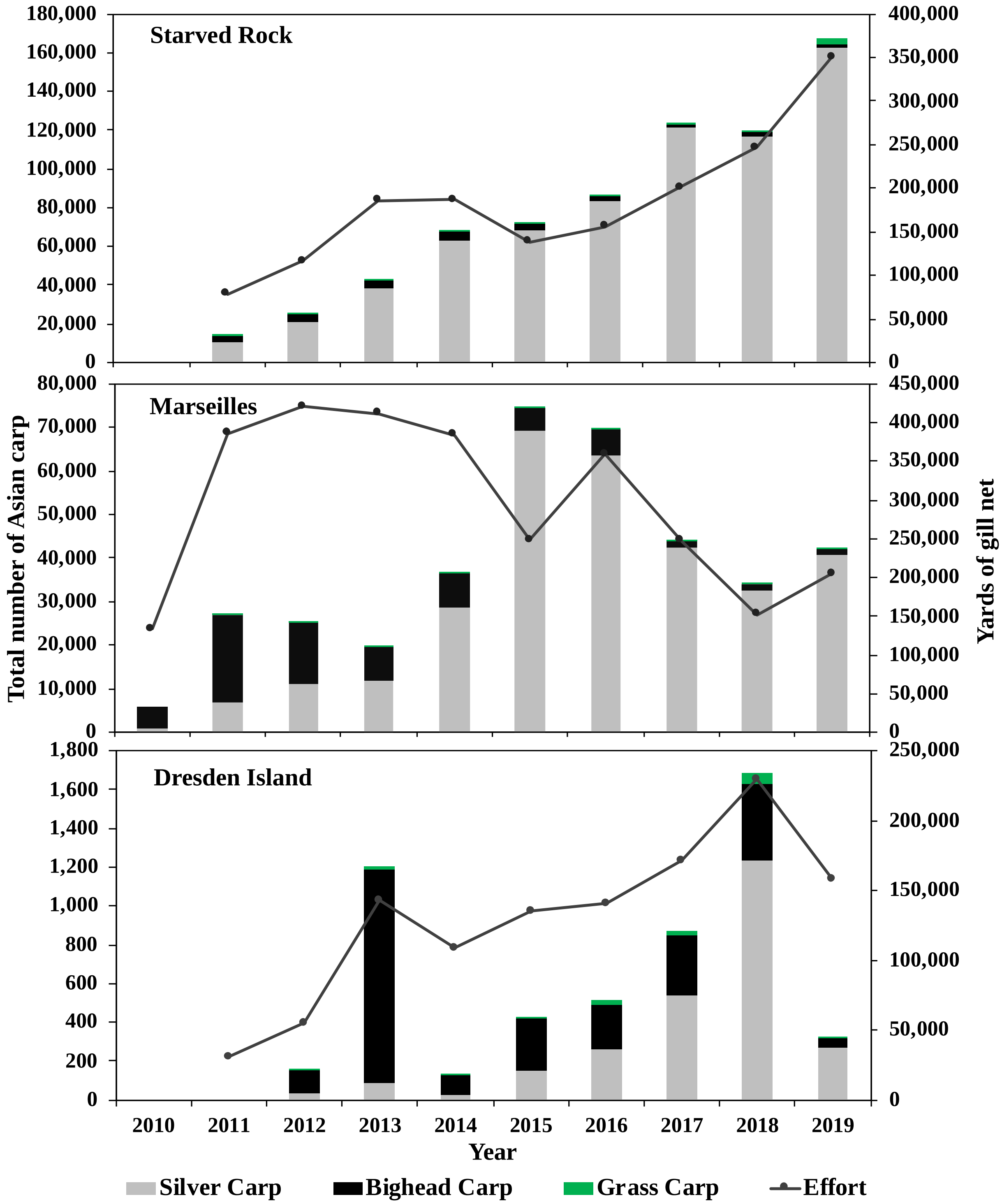

Figure 3. *Trends in effort (yards of gill net) and annual catch of Silver Carp, Bighead Carp, and Grass Carp in Starved Rock (2011-2019), Marseilles (2010-2019) and Dresden Island (2011-2019) pools.*

Commercial Seine: A total of 3,233 fish representing 15 species were captured in a commercial seine in the 2019 contracted commercial fishing effort (Table 3). River Carpsucker comprised 28.8%, Freshwater Drum comprised 25.8%, Gizzard Shad comprised 10.4%, Asian carp comprised 2.8%, and game fishes (i.e., *Pomoxis spp.*, Ictalurids, Moronids, and *Micropterus spp.)* comprised 26.8% of the total catch.

Great Lakes Pound Net: A total of 9,030 fish representing 15 species were captured in Great Lakes pound nets in the 2019 contracted commercial fishing effort (Table 3). Freshwater Drum comprised 84.0%, Smallmouth Buffalo comprised 7.3%, Asian carp comprised 3.5%, and game fishes (i.e., *Pomoxis spp.*, Bluegill, Largemouth Bass, Ictalurids, and Yellow Bass) comprised 4.3% of the total catch.

Recommendations:

Since 2010, this program has been successful at managing the Asian carp population in the upper Illinois River Waterway by significantly decreasing relative biomass near the population front in Dresden Pool (Coulter et al. 2018). Increasing effort in 2019 allowed more Asian carp to be removed than in previous years, further reducing Asian carp abundance at and near the detectable population front, as well as reducing potential propagule pressure on the Electric Dispersal Barrier. Long term harvest data provides information necessary to model changes in Asian carp relative abundance and population demographics among pools of the upper Illinois River Waterway in response to management actions. Contracted commercial fishing is a critical tool in managing Asian carp populations and we recommend this program continue in 2020.

References:

Butler, S.E., A.P. Porreca, S.F. Collins, J.A. Freedman, J.J. Parkos, M.J. Diana, D.H. Wahl. 2018. Does fish herding enhance catch rates and detection of invasive and bigheaded carp? Biological Invasions 21:775-785.

Coulter, D.P., R. MacNamara, D. C. Glover, J. E. Garvey. 2018. Possible unintended effects of management at an invasion front: Reduced prevalence corresponds with high condition of invasive bigheaded carps. Biological Conservation 221:118-126.

Contracted Commercial Fishing Below the Electric Dispersal Barrier

Table 1. *Contracted fishers' efforts by gear type, harvest numbers, and tons of Asian carp removed from Lockport, Brandon Road, Dresden Island, Marseilles and Starved Rock pools, years 2010-2019.*

Year	Effort						Harvest							
River Pool	**Net Sets *(N)***	**Miles of Net**	**Seine Hauls *(N)***	**Miles of Seine**	**Hoop Net Nights *(N)***	**Pound Net Nights *(N)***	**Bighead Carp (N)**	**Silver Carp (N)**	**Grass Carp (N)**	**Total (N)**	**Bighead Carp (tons)**	**Silver Carp (tons)**	**Grass Carp (tons)**	**Total (tons)**
2010														
Lockport	41	4.3	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dresden	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marseilles	1,316	75.5	0	0	0	0	4,888	1,075	0	5,963	53.1	8.1	0	61.2
Starved Rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All pools	1,357	79.8	0	0	0	0	4,888	1,075	0	5,963	53.1	8.1	0	61.2
2011														
Lockport	8	6.5	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	22	6.5	0	0	0	0	0	0	0	0	0	0	0	0
Dresden	47	17.7	0	0	0	0	0	0	0	0	0	0	0	0
Marseilles	671	219.2	0	0	0	0	20,087	7,023	34	27,144	229.4	46.6	0.2	276.6
Starved Rock	151	44.6	0	0	0	0	2,964	10,730	132	13,826	21.4	53.3	0.7	75.3
All pools	899	294.6	0	0	0	0	23,051	17,753	166	40,970	250.8	99.3	0.8	350.9
2012														
Lockport	46	5.9	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	73	13	0	0	0	0	0	0	1	1	0	0	0	0
Dresden	125	31.5	0	0	0	0	120	36	3	159	0.9	0.2	0	1.1
Marseilles	611	238.7	0	0	0	0	13,978	11,090	162	25,230	125.9	64.7	0.7	191.2
Starved Rock	176	66	0	0	0	0	3,994	20,589	243	24,826	22.4	99.8	1.4	123.5
All pools	1,031	355.2	0	0	0	0	18,092	31,715	409	50,216	149.1	164.6	2.1	318.5
2013														
Lockport	112	16.8	0	0	0	0	0	0	1	1	0	0	0	0
Brandon	145	21.4	0	0	0	0	0	0	9	9	0	0	0.1	0.1
Dresden	307	81.5	0	0	0	0	1,095	93	13	1,201	13.5	0.7	0.2	14.4
Marseilles	608	233.8	0	0	0	0	7,742	11,742	384	19,868	73.9	59.8	2.7	136.4
Starved Rock	228	105.8	0	0	0	0	3,938	38,666	369	42,973	21.9	167.8	2	191.6
All pools	1,400	459.3	0	0	0	0	12,775	50,501	776	64,052	109.2	228.3	4.9	342.5

Contracted Commercial Fishing Below the Electric Dispersal Barrier

Table 1. *Continued*

Year	Effort						Harvest							
River Pool	**Net Sets *(N)***	**Miles of Net**	**Seine Hauls *(N)***	**Miles of Seine**	**Hoop Net Nights *(N)***	**Pound Net Nights *(N)***	**Bighead Carp (N)**	**Silver Carp (N)**	**Grass Carp (N)**	**Total (N)**	**Bighead Carp (tons)**	**Silver Carp (tons)**	**Grass Carp (tons)**	**Total (tons)**
2014														
Lockport	253	30.8	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	252	30.1	0	0	0	0	0	0	0	0	0	0	0	0
Dresden	326	62	0	0	0	0	0	25	5	134	1	0.1	0	1.2
Marseilles	509	218.3	3	1.1	0	16	7,828	28,640	198	36,666	70.4	116.2	1	187.6
Starved Rock	228	105.9	1	0.2	367	0	4,430	63,037	561	68,028	21.5	278.4	3	302.9
All pools	1,568	447.1	4	1.2	367	16	12,362	91,702	764	104,828	93	394.7	4	491.7
2015														
Lockport	343	48.2	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	283	49.4	0	0	0	0	0	0	0	0	0	0	0	0
Dresden	375	77.1	0	0	111	0	272	150	11	433	2.4	1	0	3.3
Marseilles	378	141.2	9	1.1	23	25	5,387	69,210	228	74,825	39.6	237.4	1.2	278.2
Starved Rock	198	78.6	4	0.5	141	0	2,908	68,681	641	72,230	13.2	198.2	3.6	215
All pools	1,577	394.5	13	1.6	275	25	8,567	138,041	882	147,490	55.1	436.5	4.9	496.5
2016														
Lockport	473	57.3	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	427	52.3	0	0	0	0	0	0	1	1	0	0	0	0
Dresden	552	80	0	0	0	0	232	263	22	517	2.3	1.5		3.8
Marseilles	486	204	30	7.6	86	67	5,957	63,573	110	69,640	46.6	256	0.4	303.1
Starved Rock	249	88.6	14	2.2	683	0	2,048	83,859	606	86,513	9.7	233.3	3.4	246.4
All pools	2,187	482	44	9.8	769	67	8,237	147,695	739	156,671	58.6	490.8	3.9	553.3
2017														
Lockport	449	52.8	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	484	59.6	0	0	0	0	0	0	1	1	0	0	0	0
Dresden	573	97.6	0	0	343	4	307	538	28	873	5.3	4.3	0.2	9.7
Marseilles	368	140.4	7	2.2	49	74	1,538	42,410	70	44,018	14	178.8	0.4	193.2
Starved Rock	375	114.1	3	1.3	939	0	1,123	121,842	1,118	124,083	4.6	362.7	6.3	373.6
All pools	2,249	464.5	10	3.5	1,331	78	2,968	164,790	1,217	168,975	23.9	545.7	6.9	576.5

Table 1. *Continued*

Year	Effort						Harvest							
River Pool	**Net Sets *(N)***	**Miles of Net**	**Seine Hauls *(N)***	**Miles of Seine**	**Hoop Net Nights *(N)***	**Pound Net Nights *(N)***	**Bighead Carp (N)**	**Silver Carp (N)**	**Grass Carp (N)**	**Total (N)**	**Bighead Carp (tons)**	**Silver Carp (tons)**	**Grass Carp (tons)**	**Total (tons)**
2018														
Lockport	395	43.8	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	391	44	0	0	0	0	0	0	1	1	0	0	0	0
Dresden	960	130.9	0	0	0	8	398	1,235	53	1,686	5	10.2	0.5	15.7
Marseilles	413	86.5	10	2.4	224	22	1,399	32,569	44	34,012	13.3	148.7	0.2	162.3
Starved Rock	585	140.2	0	0	1,404	0	1,648	117,083	1,406	120,137	8	388	6.8	402.8
All pools	2,744	445.4	10	2.4	1,628	22	3,445	150,887	1,504	155,836	26.3	546.9	7.5	580.7
2019														
Lockport	297	33.8	0	0	0	0	0	0	0	0	0	0	0	0
Brandon	263	30.7	0	0	0	0	0	0	0	0	0	0	0	0
Dresden	779	90.1	0	0	0	2	45	272	7	324	0.6	3.3	0.1	4
Marseilles	563	116.2	2	0.9	0	21	1,311	40,838	79	42,228	13.6	222.8	0.8	237.1
Starved Rock	1,131	199.1	0	0	0	0	2,108	162,463	2,830	167,401	11.5	492.3	14.6	518.4
All pools	3,033	469.9	2	0.9	0	23	3,464	203,573	2,916	209,953	25.7	718.3	15.5	759.5
2010-2019														
Lockport	2,417	300.1	0	0	0	0	0	0	1	1	0	0	0	0
Brandon	2,340	307	0	0	0	0	0	0	15	15	0	0	0.1	0.1
Dresden	4,044	668.4	0	0	454	14	2,573	2,612	142	5,327	30.8	21.2	1	53.1
Marseilles	5,923	1,673.90	61	15.3	381	225	70,115	308,170	1,309	379,594	679.8	1,338.40	7.6	2,025.80
Starved Rock	3,321	942.9	22	4.2	3,533	0	25,161	686,950	7,906	720,017	134.1	2,273.80	41.8	2,449.70
All pools	18,045	3,892.30	83	19.4	4,369	239	97,849	997,732	9,373	1,104,954	844.7	3,633.40	50.5	4,528.60

Contracted Commercial Fishing Below the Electric Dispersal Barrier

Table 2: *Total Asian carp and bycatch captured by contracted fishers using gill and trammel nets in the Upper Illinois River (Starved Rock, Marseilles, Dresden, Brandon and Lockport pools) during 2019 and total Asian carp and bycatch species captured since 2010.*

Species	Contracted Fishing Gill and Trammel Net Catch 2019							2010-2019	
	Starved Rock Pool	Marseilles Pool	Dresden Pool	Brandon Pool	Lockport Pool	No. Captured	Percent (%)	No. Captured	Percent (%)
Alligator Gar	0	0	0	0	0	0	0	1	0
American Brook Lamprey	0	0	0	0	0	0	0	1	0
Bighead Carp	2,108	1,266	45	0	0	3,419	0.01	92,512	0.07
Bigmouth Buffalo	271	1,374	317	0	0	1,962	0.01	34,612	0.03
Black Buffalo	67	94	140	0	0	301	0	2,370	0
Black Bullhead	0	0	0	0	0	0	0	3	0
Black Crappie	0	0	0	0	0	0	0	178	0
Blue Catfish	0	2	0	0	0	2	0	40	0
Blue Sucker	7	0	0	0	0	7	0	14	0
Bluegill	1	0	0	0	0	1	0	14	0
Bowfin	2	4	1	0	0	7	0	26	0
Carp x Goldfish	1	2	1	1	0	5	0	176	0
Channel Catfish	499	344	130	8	1	982	0	6,283	0
Common Carp	2,242	542	860	96	75	3,815	0.02	41,974	0.03
Flathead Catfish	118	87	27	0	0	232	0	2647	0
Freshwater Drum	608	700	193	5	0	1,506	0.01	20,695	0.02
Gizzard Shad	17	0	2	0	0	19	0	2,684	0
Gizzard Shad <6 in	1	0	0	0	0	1	0	376	0
Golden Redhorse	30	0	0	0	0	30	0	142	0
Goldeye	6	1	0	0	0	7	0	14	0
Goldfish	0	0	2	3	0	5	0	93	0
Grass Carp	2,830	79	7	0	0	2,916	0.01	8,263	0.01
Greater Redhorse	0	0	0	0	0	0	0	1	0
Highfin Carpsucker	2	0	0	0	0	2	0	6	0
Hybrid Striped Bass	24	11	1	0	0	36	0	107	0
Hybrid Sunfish	0	0	0	0	0	0	0	8	0
Largemouth Bass	8	24	6	0	0	38	0	370	0
Longnose Gar	46	13	52	0	1	112	0	770	0
Mooneye	2	0	0	0	0	2	0	26	0

Table 2. *Continued.* **Contracted Commercial Fishing Below the Electric Dispersal Barrier**

Species	Contracted Fishing Gill and Trammel Net Catch 2019							2010-2019	
	Starved Rock Pool	Marseilles Pool	Dresden Pool	Brandon Pool	Lockport Pool	No. Captured	Percent (%)	No. Captured	Percent (%)
Muskellunge	1	0	0	0	0	1	0	10	0
Northern Hogsucker	0	0	0	0	0	0	0	1	0
Northern Pike	1	3	9	0	0	13	0	43	0
Paddlefish	20	8	0	0	0	28	0	320	0
Quillback	25	1	1	0	0	27	0	970	0
River Carpsucker	700	84	40	0	0	824	0	6,075	0
River Redhorse	1	0	0	0	0	1	0	9	0
Shorthead Redhorse	10	2	1	0	0	13	0	58	0
Shortnose Gar	14	0	4	0	0	18	0	229	0
Silver Carp	162,463	40,472	271	0	0	203,206	0.82	909,451	0.69
Silver Redhorse	28	0	0	0	0	28	0	101	0
Silver x Bighead Carp	0	4	1	0	0	5	0	7	0
Skipjack Herring	36	1	1	0	0	38	0	120	0
Smallmouth Bass	3	23	1	0	0	27	0	42	0
Smallmouth Buffalo	16,149	8,508	3,183	1	0	27,841	0.11	183,142	0.14
Spotted Gar	0	0	0	0	0	0	0	10	0
Striped Bass	0	0	0	0	0	0	0	1	0
Threadfin Shad	0	0	1	0	0	1	0	1	0
UI* Buffalo	121	0	0	0	0	121	0	3,704	0
UI* Carpsucker	0	0	0	0	0	0	0	470	0
UI* Catostomid	0	0	0	0	0	0	0	2,066	0
UI* Moronid	0	0	0	0	0	0	0	865	0
UI* Redhorse	0	0	1	0	0	1	0	12	0
UI* Cyprinid	11	0	0	0	0	11	0	0	0
Walleye	43	3	1	0	0	47	0	218	0
White Bass	10	9	1	0	0	20	0	664	0
White Crappie	8	9	1	0	0	18	0	118	0
White Perch	0	0	0	0	0	0	0	5	0
White Sucker	8	0	0	0	0	8	0	18	0
Yellow Bass	0	3	0	0	0	3	0	197	0
Yellow Bullhead	0	0	0	0	0	0	0	5	0
Total Captured	188,569	53,674	5,301	115	77	247,736	100	1,323,567	100

Table 2. *Continued* **Contracted Commercial Fishing Below the Electric Dispersal Barrier**

No. Species	36	27	26	6	3	41	0	55	0
No. Hybrid Groups	2	3	3	0	0	4	0	4	0

Contracted Commercial Fishing Below the Electric Dispersal Barrier

Table 3. Total *Asian carp and bycatch captured by contracted fishers using commercial seines and Great Lakes pound nets in the Upper Illinois River (Starved Rock-Lockport) during 2019 and total Asian carp and bycatch species captured since 2010.*

Species	Commercial Seine Catch				Great Lakes Pound Net Catch					
	Marseilles 2019	Percent (%) 2019	No. Captured 2010-2019	Percent (%) 2010-2019	Marseilles 2019	Dresden 2019	No. Captured 2019	Percent (%) 2019	No. Captured 2010-2019	Percent (%) 2010-2019
Bighead Carp	10	0.31	4,570	4.57	35	0	35	0.39	625	1.29
Black Buffalo	0	0	18	0.02	0	0	0	0	36	0.07
Black Bullhead	0	0	0	0	0	0	0	0	2	0
Black Crappie	137	4.24	244	0.24	11	2	13	0.14	369	0.76
Bluegill	0	0	6	0.01	0	0	0	0	149	0.31
Bigmouth Buffalo	31	0.96	963	0.96	0	0	0	0	435	0.9
Bowfin	0	0	2	0	0	1	1	0.01	6	0.01
Common Carp	1	0.03	94	0.09	3	2	5	0.06	237	0.49
Channel Catfish	181	5.6	928	0.93	47	2	49	0.54	1,741	3.61
Flathead Catfish	1	0.03	11	0.01	0	0	0	0	14	0.03
Freshwater Drum	834	25.8	9,356	9.35	7,581	2	7,583	83.98	21,500	44.53
Goldeye	0	0	2	0	0	0	0	0	0	0
Golden Redhorse	0	0	23	0.02	0	0	0	0	6	0.01
Grass Carp	0	0	40	0.04	0	0	0	0	1	0
Gizzard Shad	337	10.42	6,042	6.04	0	20	20	0.22	3,270	6.77
Gizzard Shad <6 in.	0	0	482	0.48	0	0	0	0	1,196	2.48
Hybrid Striped Bass	0	0	0	0	0	0	0	0	12	0.02
Highfin Carpsucker	0	0	2	0	0	0	0	0	2	0
Largemouth Bass	4	0.12	69	0.07	6	3	9	0.1	160	0.33
Longnose Gar	0	0	64	0.06	0	3	3	0.03	39	0.08
Mooneye	0	0	2	0	0	0	0	0	0	0
Northern Pike	0	0	1	0	0	2	2	0.02	26	0.05
Paddlefish	1	0.03	5	0	0	0	0	0	0	0
Quillback	0	0	1,586	1.58	0	0	0	0	216	0.45
River Carpsucker	932	28.83	3,758	3.76	52	1	53	0.59	1,377	2.85
Sauger	0	0	24	0.02	0	0	0	0	0	0
Spotted Bass	0	0	0	0	0	0	0	0	8	0.02

Table 3. *Continued.*

Species	Commercial Seine Catch				Great Lakes Pound Net Catch					
	Marseilles 2019	Percent (%) 2019	No. Captured 2010-2019	Percent (%) 2010-2019	Marseilles 2019	Dresden 2019	No. Captured 2019	Percent (%) 2019	No. Captured 2010-2019	Percent (%) 2010-2019
Shorthead Redhorse	0	0	4	0	0	0	0	0	51	0.11
Skipjack Herring	0	0	22	0.02	0	0	0	0	2	0
Smallmouth Buffalo	137	4.24	6,858	6.85	653	6	659	7.3	3,110	6.44
Smallmouth Bass	0	0	4	0	163	0	0	0	2	0
Shortnose Gar	0	0	38	0.04	0	0	0	0	1	0
Silver Carp	80	2.47	58,396	58.35	282	0	282	3.12	4,881	10.11
Silver Redhorse	0	0	10	0.01	0	0	0	0	1	0
UI* Buffalo	0	0	2,159	2.16	0	0	0	0	2,084	4.32
UI* Centrarchid	0	0	71	0.07	0	0	0	0	0	0
UI* Carpoides	0	0	396	0.4	0	0	0	0	903	1.87
UI* Catastomid	0	0	900	0.9	0	0	0	0	1,757	3.64
UI* Moronid	528	16.33	1,225	1.22	0	0	0	0	1,385	2.87
Walleye	0	0	3	0	0	0	0	0	1	0
White Bass	0	0	1,069	1.07	250	0	250	2.77	2,244	4.65
White Crappie	19	0.59	125	0.12	0	0	0	0	49	0.1
White Perch	0	0	11	0.01	0	0	0	0	4	0.01
White Sucker	0	0	3	0	0	0	0	0	4	0.01
Yellow Bass	0	0	487	0.49	66	0	66	0.73	350	0.72
Yellow Bullhead	0	0	0	0	0	0	0	0	28	0.06
Total Captured	**3,233**	**100**	**100,073**	**100**	**8,986**	**44**	**9,030**	**100**	**48,284**	**100**
No. Species	15	--	36	--	11	11	15	--	35	--
No. Hybrid Groups	0	--	0	--	0	0	0	--	1	--

*UI = unidentified

Asian Carp Population Modeling to Support an Adaptive Management Framework

Participating Agencies: US Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office and La Crosse Fish and Wildlife Conservation Office

Pools Involved: Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, Alton

Introduction:

The Spatially Explicit Asian carp Population (SEAcarP) model was developed to inform management and research decisions with the goal of minimizing the abundance of Bighead Carp and Silver Carp (collectively referred to as "Asian carp" in this document) in the upper Illinois River waterway, thereby reducing risk of population expansion toward the Great Lakes and reducing potential impacts on native species. This model provides an objective, data-driven approach to maximize return on investment of management actions and facilitates defining research and monitoring priorities. The spatial structure of the SEAcarP model provides additional insight and sensitivity as compared to prior population models (e.g., Tsehaye et al. 2013, Seibert et al. 2015) because it allows demographics (abundance, size structure, growth, condition, mortality, and recruitment) to be defined separately for each of the six pools of the Illinois River and accounts for movement of Asian carp among these pools, all of which will affect will affect the magnitude and direction of Asian carp populations' response to management actions. The increased precision of population forecasts derived from incorporating spatial structure comes at the cost of increased data requirements. Sensitivity analyses using the SEAcarP model will facilitate prioritizing these data needs relative to their effect on decreasing uncertainty in expectations on how Asian carp populations might respond under different management strategies.

Management scenarios explored herein relate to 1) additive mortality (i.e., mortality in addition to the background, "natural mortality") of adult Asian carp in the lower pools (Alton, La Grange, Peoria) and upper pools (Starved Rock, Marseilles, and Dresden Island) of the Illinois River, and 2) deterrence of movement of Asian carp (all sizes) through existing bottlenecks at Starved Rock Lock and Dam, Marseilles Lock and Dam, or Dresden Island Lock and Dam. Additive mortality and deterrence of movement can be achieved by a variety of tools or strategies. This report focused on the effects of varied levels of both – not the source or cause of the additive mortality or additive deterrence. Recommendations on which tools or strategies are most likely to achieve desired levels of additive mortality or additive deterrence are beyond the scope of this interim summary report.

This project includes coordination among state and federal agencies and academic universities. The US Fish and Wildlife Service (USFWS) leads US Department of Interior efforts for this project with considerable support from the US Geological Survey (USGS). Their Interim Summary Report (ISR), "Asian Carp Population Model to Support an Adaptive Management

Framework, USGS Contribution" describes their contributions to efforts associated with the SEAcarP model.

Objectives:

(1) Estimate demographic rates using the most current data available and incorporate results into the SEAcarP model.

(2) Conduct sensitivity analyses and develop a prioritized list of data and research needs based on results thereof.

(3) Recommend updated mortality benchmarks and fish passage deterrent locations with efficacy requirements based upon new model runs.

(4) Use statistical catch-at-length models to estimate vulnerability to fishing as a function of fish size, exploitation rates, and immigration into the upper Illinois River Waterway.

(5) Share results via the annual coordination meeting.

Project Highlights:

- Updated demographic parameters for Silver Carp and Bighead Carp across the Illinois River as well as some pools in the Upper Mississippi and Ohio rivers including an additional 13,000 fish from 2018 and 2019 (Erickson et al. *in review*.; code available at https://github.com/rerickson-usgs/CarpLifeHistoryModels); defining demographic rates in additional locations improves estimates of Illinois River demographics and also provides information on potential source populations that will hopefully be incorporated into the SEAcarP model in the future.
- Conducted sensitivity analysis, which is included in this report.
- Continued development of SEAcarP by putting code into an R package.
- Worked closely with MRWG technical workgroups to prioritize future data collections and research using the SEAcarP model assumptions and limitations as a decision support tool. These efforts ensure that field-related efforts are coordinated to achieve management goals and provide maximum ability to test assumptions, alleviate limitations, and increase our general understanding of Asian carp population dynamics.

Methods:

Model parameterization:

The SEAcarP model was reparametrized by estimating demographic rates for each pool of the Illinois, upper Mississippi, and Ohio rivers based on data availability. Combining data across multiple basins increases confidence in the overall population estimates and estimates for individual basins, including ones for the Illinois River, which is the current focus of the modeling effort. Results of demographic analyses will be presented in a peer-reviewed publication (Erickson et al. *in review;* code available at https://github.com/rerickson-usgs/CarpLifeHistoryModels). In summary, growth, maturity, and body condition were analyzed using Bayesian hierarchical models as described in the 2019 Asian carp Monitoring and Response Plan (ACRCC 2019). Annual natural mortality was estimated using indirect methods that relate mortality to demographic parameters (Then et al. 2016). Pool-to-pool movement rates were incorporated from a multistate model parameterized in program MARK (Coulter et al. 2018).

Spatially Explicit Asian carp Population model:

Specific details regarding the structure of SEAcarP model and assumptions can be found in the 2018 Asian carp Monitoring and Response Plan (ACRCC 2018). Briefly, the model calculates changes in length-distribution and total abundance across annual time steps for populations in the Alton, La Grange, Peoria, Starved Rock, Marseilles, and Dresden Island pools. The model includes a constant mortality in the absence of additive mortality (i.e., natural mortality), growth as a function of the current size, inter-reach movement consisting of immigration and emigration as a function of current pool location (Coulter et al. 2018), and reproduction as a function of size. In addition, the model includes two user-defined variables – additive mortality as a function of fish size and proportional reductions in movement relative to observed values.

Uncertainty in Asian carp demographic rates were incorporated by repeating 25-year simulations for each management scenario using 1,000 iterations of growth, maturity, natural mortality, and condition parameters, randomly selected from Bayesian posterior distributions. Hence, the parameters drawn from the posterior distributions were time invariant over a given 25-year simulation period. Interannual variability in recruitment, however, was included using a Bernoulli distribution to simulate variability in reproductive success (i.e., frequent year class failure and occasional reproductive success). Specifically, for each time step the number of individuals estimated from the stock-recruitment function was added to the population with probability 0.5, which was estimated from the relative frequency of historically observed successful reproduction in the La Grange pool of the Illinois River using data collected from 2000 – 2015 by the U.S. Army Corps of Engineers Upper Mississippi River Restoration Program Long-Term Resource Monitoring element. Annual reproduction was classified as successful when the catch of age-0 fish (i.e., < 250 mm total length [TL]) was greater than zero. Similar to previous Asian carp population modeling efforts (Tsehaye et al. 2013), a Ricker stock recruitment function (Ricker 1954) with an extremely high steepness was used. Higher steepness values are associated with a high resilience to additive mortality because of high recruitment even at low spawner abundance.

Effects of additive mortality on Asian carp populations were evaluated at 10% intervals from 0 to 100% in the upper pools (Starved Rock, Marseilles, and Dresden Island) and lower pools (Alton, La Grange, and Peoria). The annual time step reduced our confidence in exploring pool-specific effects of additive mortality because finer-scale movement patterns (e.g., seasonal) are required to better understand varying levels of vulnerability to additive mortality across space. Additive mortality was limited to adult fish (i.e., $\geq$ 500 mm TL). Deterrence of movement on Asian carp populations were evaluated in combination with additive upper pool mortality. This deterrence was beyond the levels provided by these locks and dams, which is implicitly included within the SEAcarP model from the movement parameter estimates. A range of different movement deterrence efficiencies – proportional reduction (0 to 100% in 10% intervals) relative to observed values – and locations (i.e., Starved Rock Lock and Dam, Marseilles Lock and Dam, and Dresden Island Lock and Dam) were considered.

The relative effects of the different management scenarios were compared using percent reduction in Asian carp abundance relative to the no-action scenario (i.e., no additive mortality, baseline movement rates). The no-action scenario forecasted population abundance by assuming that any management-directed mortality would cease, and movement rates would continue at previously observed, baseline rates that do not offer additional levels of deterrence beyond existing locks and dams under traditional operations. The relative effect of different scenarios was calculated by dividing the total number of Dresden Island fish alive at the end of the 25-year simulation by the number alive under the no-action scenario using iterations as replicates (N=1,000). Thus, the model produces a distribution of possible response values with uncertainty derived from variation in demographic rates.

Sensitivity analysis:

Although the primary goal of the modeling effort is to inform the decision making process with respect to control via additive adult mortality and deterred movement, tools such as the SEAcarP model could be used to inform other management decisions such as prioritizing field collections and research. To accomplish this secondary goal we used sensitivity analyses to assess the importance of model assumptions and variation in modeled processes (e.g., growth, movement) on model results and hence, model based management recommendations (Objective 2). More specifically, we:

- Explored how the uncertainy in demographic rates (e.g., growth curve) influence model results (i.e., population trajectories).
- Examined the importance of pool to pool movement relative to other sources of spatial variation (e.g.., recruitment, natural mortality) in determining pool-specific Asian carp population sizes.
- Examined how a potentially critical model assumption (i.e., recruitment limited to pools below Starved Rock Lock and Dam) impacts model results.

The SEAcarP model produces a distribution of population trajectories with uncertainty derived from variation in demographic rates. We used this feature to quantify the relative contribution of model inputs (e.g., growth) to total uncertainty in population size at year 25 for all pools. More specifically, we compared results from 1,000 fully stochastic iterations of the no-action scenario to runs in which parameter values were fixed to mean values for all but one function, which varied stochastically. This process was repeated for each function including growth, condition, maturity, and inter-pool movement.

Using a similar approach, we evaluated whether our baseline assumption about Asian carp recruitment in the Illinois River strongly influenced model results. This was accomplished by comparing model results from the no action scenario under baseline assumptions to results that included recruitment in upper and lower pools. Lastly, to assess the need for continued efforts aimed at understanding fish movement (i.e., telemetry), we also examined the importance of the pool to pool movement model relative to other sources of spatial variation (e.g., recruitment, natural mortality) in determining pool-specific Asian carp population sizes.

Finally, we describe progress on model dissemination and present summary results from rerunning the SEAcarP model to evaluate the relative changes in population sizes under different control scenarios (Objective 3) using updated parameter estimates (Objective 1).

Results and Discussion:

Sensitivity analysis

Demographic rates: We used sensitivity analysis to inform future data collection and research priorities by exploring how uncertainty in demographic rates contribute to total variation in predicted population sizes at year 25 in different pools of the Illinois River. The single largest source of uncertainty in population size at year 25 was variation in the growth function, and this was true for all pools (Figure 1). Indeed, some parameter values for the growth function cause populations to either crash or explode. We attributed the SEAcarP model's sensitivity to the growth function to two things. First the length at age relationship is highly variable. Variation in the growth rate model is related to the high degree of natural variability (i.e., individual fish variation), variability introduced by using multiple aging structures to estimate fish age, variation between male and female growth patterns, and to a lesser extent, uninformative data on small fish (Erickson et al., *in review*). Second, growth influences population dynamics in the SEAcarP model in many ways including size at maturity, spawning stock biomass, and natural mortality rates. In summary, the combination of variable growth and the influence of growth on other modeled processes (e.g., recruitment, natural mortality) strongly affects model predictions.

The second most important source of variability in population size was attributed to the pool-to-pool movement model developed by Coulter et al. (2018). The pool-to-pool movement model contributed considerable variability to La Grange and Peoria pool populations, a lesser amount to the Dresden Island Pool population, and the least amount to Alton, Starved Rock, and Marseilles pool populations (Figure 1).

Weight-at-length and size-at-maturity had a relatively negligible contribution to variability in population size (Figure 1). However, size-at-maturity estimates were limited because we did not have data from enough pools to estimate these curves for each pool.

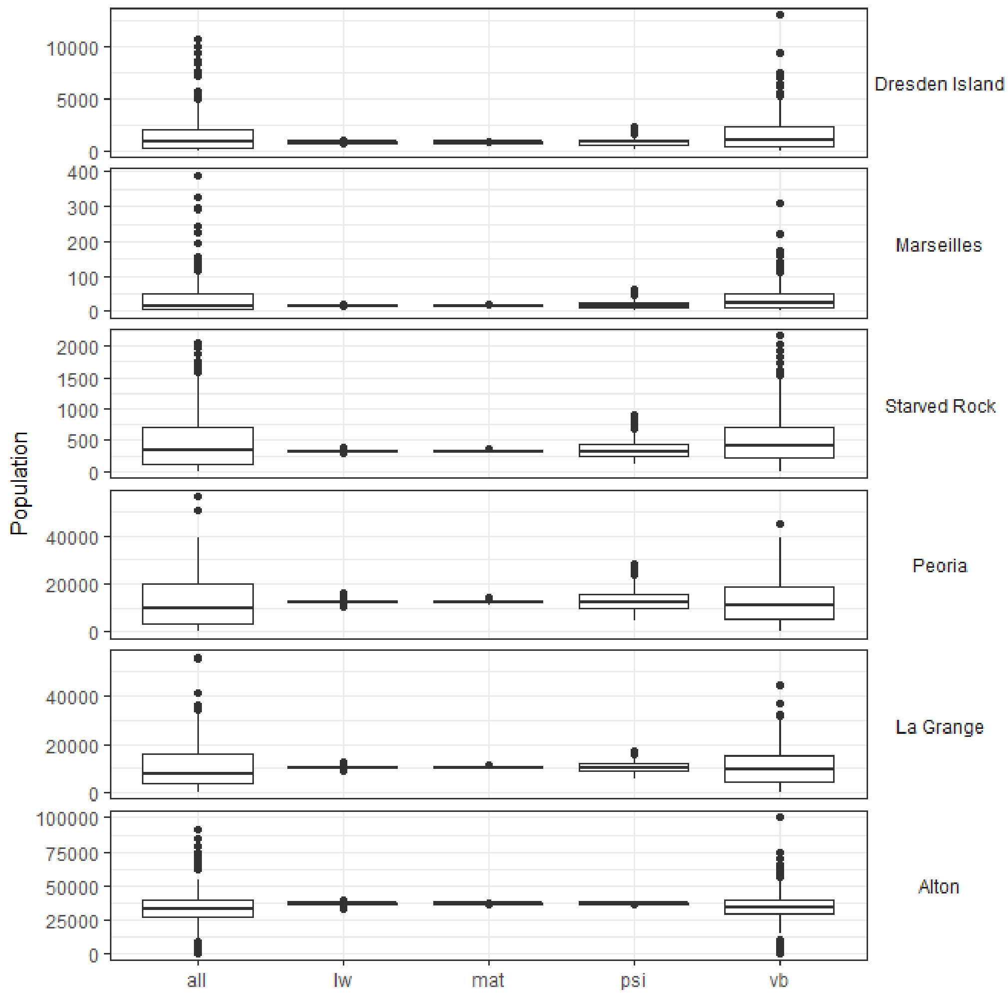

Figure 1: *Effects of uncertainty in demographics rates on distributions of final population size at year 25 for Silver Carp, using iterations as replicates. Results include simulations that incorporated uncertainty from all sub-models (all) or were limited to a single source of uncertainty, specifically uncertainty in the length-weight (lw), size at maturity (mat), movement (psi), or growth (vb) sub-models.*

<u>*Model design and assumptions:*</u> The previous section examined how uncertainty in demographics rates, based upon empirical estimates, impacted model outputs. Similarly, we also sought to understand how the model design and assumptions impacted model outputs. To accomplish this goal, we examined the importance of the pool to pool movement rates and the importance of the model's baseline assumption that recruitment does not occur above Starved Rock Lock and Dam.

The SEAcarP model assumes that recruitment does not occur in pools above Starved Rock Lock and Dam. Recent field collections, however, suggest that recruitment may occur in pools upstream of Starved Rock Lock and Dam, at least during certain years (ACRCC 2017). To evaluate how this assumption impacts model results, we compared population trajectories using model runs with and without recruitment above Starved Rock Lock and Dam. Regardless of the specific scenario, including recruitment in the upper pools had negligible effects on lower pool populations (Figure 2). Effects associated with including recruitment in Starved Rock and Marseilles pools were considerable, but isolated. For example, including recruitment in Starved Rock Pool strongly influenced Starved Rock population size, but did not influence population sizes in the other pools. In contrast, including recruitment in Dresden Island Pool resulted in strong increases in the Dresden Island Pool population as well as the Marseilles Pool population. These findings suggest that recruitment above Starved Rock Lock and Dam can influence total population size, however, these impacts appear limited to the pool where recruitment is occurring.

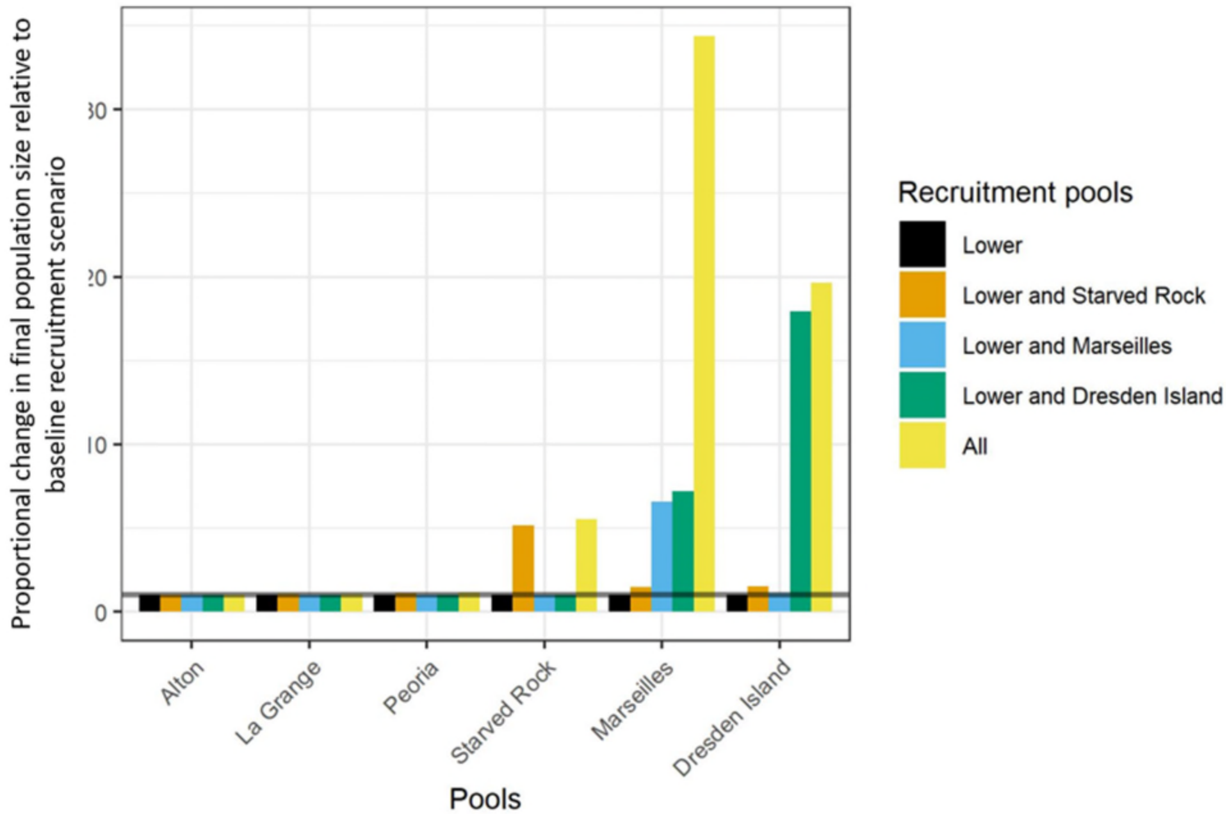

Figure 2: *Mean proportional change in final population size relative to the baseline scenario with recruitment in the lower pools (i.e., Alton, La Grange, Peoria). Means were calculated using 1,000 iterations of the no-action scenario. A value of one (horizontal line) indicates no change.*

The importance of the underlying spatial sub-model was evaluated by examining the stable spatial distribution. The stable spatial distribution describes how a hypothetical population of Asian Carp, in the absence of mortality and recruitment distribute themselves over an indefinite amount of time (Figure 3). These findings illustrate how the movement model by itself suggest large populations in Alton and Dresden Island pools. These pools serve as "sinks" in the model that do not allow fish to easily move out. From a biological perspective, this pattern may reflect upstream and downstream movement from source populations located in the lower Illinois River. Alternatively, this pattern may be a statistical artifact associated with the movement model and telemetry data. For example, the data presently available to describe movement are based on adult fish tagged in the upper Illinois River. These fish may express a higher propensity to move among pools relative to the population as a whole, which potentially biases movement probability estimates. Further, these data were collected during earlier portions of the invasion and may not necessarily predict the distribution and movement patterns of post-invasion population, which is actively exploited (e.g., through contract harvest).

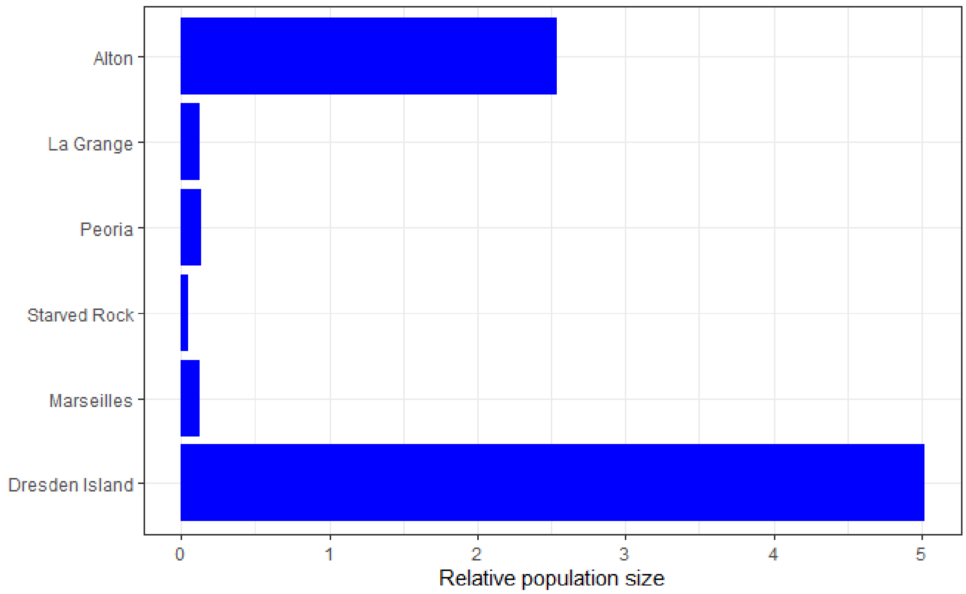

Figure 3: *Expected stable population size base upon movement sub-model for the Silver Carp model.*

Model dissemination

The model has been put into an R package for easier use, and a goal for CY2020 includes dissemination of the model. The model review is underway by outside scientists.

Relative changes in population sizes

The primary purpose of the SEAcarP model is to inform the decision making process with respect to population control via additive mortality of adults and movement detterents (Objective 3). To accomplish this objective, we ran model simulations to examine the relative population size in the Dresden Island Pool at the end of the simulation given different levels of harvest in either the upper or lower pools and with varying decreases in upstream movement at Starved Rock Lock and Dam, using updated parameter estimates (Objective 1). These results were similar to results presented in our 2018 ISR. In summary, our results indicate that an equal percentage of additive mortality (e.g., removing 25% of the population) in the three lower pools (i.e., Alton, La Grange, Peoria) has a greater impact on the Dresden Island Pool population of carp compared to the same percentage of additive mortality in the upper pools (i.e., Starved Rock, Marseilles, Dresden Island). These results indicate that controlling Asian carp populations in the upper pools, including Dresden Island Pool will require controlling lower pool populations, because individuals in the lower pools produce recruits, whereas individuals in the upper pools usually do not produce recruits. However, deciding upon the implementation of increased mortality levels within pools requires consideration of how effective these approaches would be. For example, although our results highlight the importance of increased lower pool additive mortality, the likelihood of achieving recommended mortality benchmarks is likely greater in the upper pools relative to the lower pools. This is because the upper pools have smaller populations and the removal value of one individual from the upper pools would be a higher percentage of the population than removing one individual from the lower pool.

Recommendations:

- SEAcarP modeling indicates that both additive mortality and deterrents to upstream movement, when strategically implemented, could have a significant impact on Asian carp populations and therefore support shared long-term Asian carp management goals. Effectively communicating model results will help managers to help inform decision-making.
- Sensitivity analyses revealed the growth model contributed a considerable amount of variation to model predictions. Implementing standard operating procedures for age determination would decrease uncertainty in the growth sub-model.
- Sensitivity analyses highlighted the importance of the spatial movement model. Continued efforts to understand Asian carp movement in the Illinois River including ongoing telemetry tagging and updating the movement model using contemporary data and techniques will help decrease uncertainty in the spatial movement model.
- Future research designed to address key model assumptions and limitations such as density feedback loops, variation in the relation between size and age, factors influencing pool-to-pool movement probabilities, and size-dependent vulnerability to harvest may be important to understand population dynamics of Asian carp in the Illinois River and how these dynamics are changing.

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Asian Carp Population Modeling to Support an Adaptive Management Framework – USGS Support

US Geological Survey Upper Mississippi Environmental Science Center

Primary Agencies: United States Geological Survey (USGS)

Pools Involved: Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, and Alton

Introduction and overview:

The Spatially Explicit Asian carp Population (SEAcarP) model was developed to inform management and research decisions with the goal of minimizing the abundance of Bighead Carp and Silver Carp (collectively referred to as "Asian carp" in this document) in the upper Illinois River waterway, thereby reducing risk of population expansion toward the Great Lakes and reducing potential impacts on native species. This model provides an objective, data-driven approach to maximize return on investment of management actions and facilitates defining research and monitoring priorities.

The project includes collaboration among state agencies, academic universities, and federal agencies. The U.S. Fish and Wildlife Service (USFWS) currently leads U.S. Department of Interior efforts for this project. Their Interim Summary Report (ISR), "Asian carp population modeling to support an Adaptive Management framework," describes the project in greater detail and presents results from the project. The purpose of this document is to report how U.S. Geological Survey (USGS) contributed to the SEAcarP efforts.

The "Objectives" and "Project Highlights" in this document will be identical to those in the USFWS ISR.

Objectives:

(1) Estimate demographic rates using the most current data available and incorporate results into the SEAcarP model;

(2) Conduct sensitivity analyses and develop a prioritized list of data and research needs based on results thereof;

(3) Recommend updated mortality benchmarks and fish passage deterrent locations with efficacy requirements based upon new model runs;

(4) Use statistical catch-at-length models to estimate vulnerability to fishing as a function of fish size, exploitation rates, and immigration into the upper Illinois River Waterway;

(5) Share results via the annual coordination meeting.

Asian Carp Population Modeling to Support an Adaptive Management Framework – USGS Support

Project Highlights:

- Updated demographic parameters for silver carp and bighead carp across the Illinois River as well as some pools in the Upper Mississippi and Ohio rivers including an additional 13,000 fish from 2018 and 2019; defining demographic rates in additional locations improves estimates of Illinois River demographics and also provides information on potential source populations that will hopefully be incorporated into the SEAcarP model in the future.
- Conducted sensitivity analysis, which is included in this report.
- Continued development of SEAcarP by putting code into an R package.
- Worked closely with Monitoring and Response Working Group (MRWG) technical workgroups to prioritize future data collections and research using the SEAcarP model assumptions and limitations as a decision support tool. These efforts ensure that field-related efforts are coordinated to achieve management goals and provide maximum ability to test assumptions, alleviate limitations, and increase our general understanding of Asian carp population dynamics.

USGS Contributions to the Project:

USGS contributes to this project by leading efforts in model development, model analysis, and documentation. USGS works with the MRWG Chairs through the USFWS to run SEAcarP model scenarios.

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEAcarP)

Eric J. Brossman and Nathan T. Evans
(U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, Wilmington Substation

Lead Agency: U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, Wilmington Substation

Pools Involved: Peoria

Introduction and Need:

The Spatially Explicit Asian carp Population (SEAcarP) model was developed as a means of assessing Asian carp population status in the Illinois Waterway (IWW). Movement is the backbone of the SEAcarP model and is the primary source of information about how researchers expect the population to respond to management strategies. Therefore, the model functions as an important tool that can be used by fisheries managers to inform harvest and control of adult Asian carp (Silver Carp and Bighead Carp) in the Illinois Waterway. Because harvest effects such as changes in fish density and size distributions are likely impact movement and will thus influence our ability to predict population responses, continued monitoring of Asian carp movement in the IWW is necessary. In 2019, the U.S. Fish and Wildlife Service (USFWS) supported the SEAcarP model by tagging Silver Carp in Peoria Pool. Moreover, USFWS collected telemetry data via five 69 kilohertz (kHz) receivers dispersed throughout Peoria Pool. This telemetry data complements telemetry data being collected throughout the Illinois Waterway describing interpool transfer of adult Asian carps and is used to parameterize the transition probability component of the SEAcarP model. This research provides an improved understanding of Asian carp movement in the Illinois Waterway and its effects on population dynamics.

Objectives:

(1) Tag ≥ 150 individual adult Asian carp, between 350 mm and 550 mm in total length, within Peoria Pool.

(2) Deploy and maintain an array of five 69 kHz receivers throughout Peoria Pool.

(3) Provide data from acoustic receivers to the Telemetry Work Group of the Monitoring and Response Group for use in the SEAcarP model.

Project Highlights:

- 161 adult Silver Carp were captured in Peoria Pool and implanted with Vemco V5 acoustic transmitters.

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEAcarP)

- Data from the five 69 kHz acoustic receivers was collected, processed, and provided to the Telemetry Work Group.

Methods

Silver Carp were captured in Peoria Pool marinas and backwaters using an electrified dozer trawl. All captured fishes were identified to species, enumerated, and non-Asian carp were released. Silver Carp were retained for tagging in an aerated livewell. Bighead Carp were destroyed. Silver Carp were measured (Total Length [TL]), weighed (g), and surgically implanted with a 69 kHz acoustic transmitter, marked with an external loop tag, and released near their location of capture. Tissue samples were collected from Silver Carp for hybridization analysis.

All tag numbers and individual fish data were distributed to the MRWG Telemetry Work Group via upload to the FishTracks database. Acoustic receivers were maintained to ensure they were working properly and data were downloaded in summer and fall 2019.

Results and Discussion:

In 2019, 161 adult Silver Carp were captured and implanted with acoustic transmitters throughout Peoria Pool. Tagged Silver Carp measured between 374 and 776 mm TL and weighted between 498 and 5,390 g. Two adult Bighead Carp were captured and destroyed during sampling. A total of 4,095 detections from 53 adult Silver Carp were recorded across the USFWS-maintained 69 kHz receiver array from month to month. All data was uploaded to the FishTracks database in January 2020.

Recommendations:

Future support of the SEAcarP model will continue into FY 2020. U.S. Fish and Wildlife Service-Wilmington will tag an additional 150 adult Asian carp between 350 mm and 550 mm in Starved Rock Pool and Peoria Pool. Future work will include placing additional acoustic receivers to expand the array coverage. The MRWG Telemetry Work Group will be consulted prior to deployment to optimize placement within the Illinois Waterway.

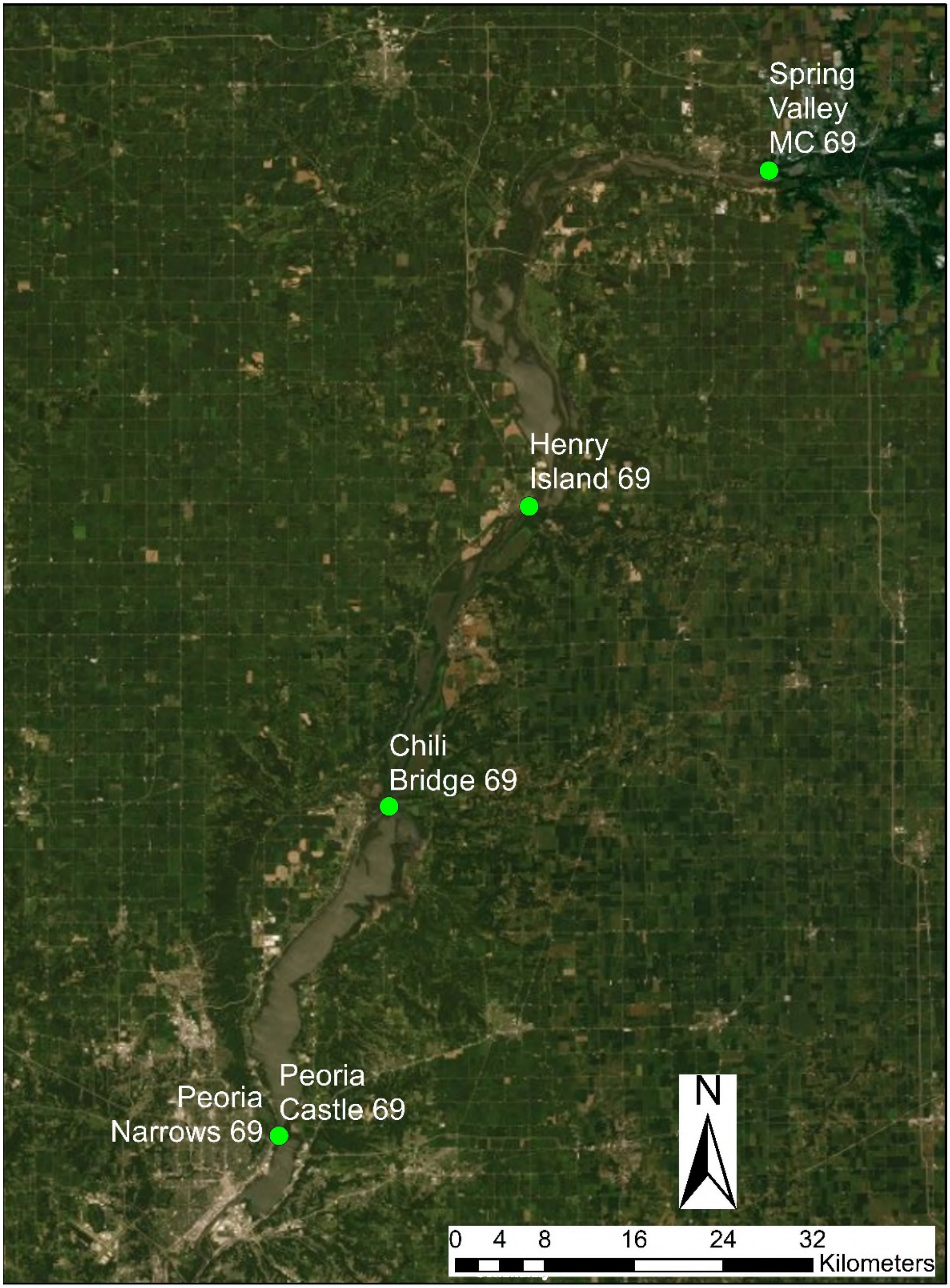

Figure 1. *Map of USFWS-maintained 69-kHz acoustic receivers deployed in Peoria Pool throughout 2019.*

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEAcarP)

Table 1. *Silver Carp tagged in support of the SEAcarP Model in 2019.*

Date	TL (mm)	Weight (g)	Vemco Transmitter ID	Loop Tag ID
4/29/2019	553	1820	A69-1602-25467	10025
4/30/2019	550	1896	A69-1602-25545	10018
4/30/2019	490	1176	A69-1602-25550	10026
4/30/2019	535	1688	A69-1602-25458	10004
4/30/2019	374	498	A69-1602-25542	10017
4/30/2019	514	1328	A69-1602-25461	10023
4/30/2019	513	1608	A69-1602-25543	10012
4/30/2019	448	962	A69-1602-25544	10007
4/30/2019	516	1328	A69-1602-25554	10011
4/30/2019	512	1598	A69-1602-25547	10016
4/30/2019	532	1736	A69-1602-25457	10014
4/30/2019	550	1886	A69-1602-25553	10019
4/30/2019	518	1568	A69-1602-25549	10008
4/30/2019	487	1232	A69-1602-25548	10020
4/30/2019	542	1892	A69-1602-25462	10015
4/30/2019	544	1532	A69-1602-25546	10024
4/30/2019	655	3082	A69-1602-25468	10022
7/29/2019	652	3090	A69-1602-19228	10071
7/29/2019	530	1786	A69-1602-19230	10068
7/29/2019	612	2340	A69-1602-19236	10060
7/29/2019	610	2804	A69-1602-19227	10062
7/29/2019	548	1870	A69-1602-19229	10070
7/29/2019	776	5390	A69-1602-19233	10049
7/29/2019	588	1908	A69-1602-19232	10048
7/29/2019	668	3866	A69-1602-19235	10045
7/29/2019	558	1816	A69-1602-19231	10047
7/29/2019	715	3928	A69-1602-19226	10058
7/30/2019	560	1730	A69-1602-19215	10053
7/30/2019	600	2254	A69-1602-19220	10069
7/30/2019	510	1540	A69-1602-19234	10059
7/30/2019	582	2190	A69-1602-19224	10067
7/30/2019	522	1808	A69-1602-19223	10055
7/30/2019	582	2024	A69-1602-19222	10072
7/30/2019	568	1626	A69-1602-19221	10074
7/30/2019	528	1380	A69-1602-19209	10043
7/30/2019	552	1538	A69-1602-19237	8806
7/30/2019	550	1968	A69-1602-19202	8805
7/30/2019	530	1622	A69-1602-19203	8803
7/30/2019	598	2232	A69-1602-19204	8802

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEAcarP)

Date	TL (mm)	Weight (g)	Vemco Transmitter ID	Loop Tag ID
7/30/2019	578	2290	A69-1602-19225	8804
7/30/2019	579	2240	A69-1602-19212	10061
7/30/2019	570	2084	A69-1602-19206	10042
7/30/2019	512	1310	A69-1602-19219	10034
7/30/2019	560	1608	A69-1602-19208	10063
7/30/2019	540	1746	A69-1602-19207	10046
7/30/2019	538	1800	A69-1602-19213	10051
7/30/2019	582	2364	A69-1602-19216	10065
7/30/2019	532	1548	A69-1602-19214	10054
7/30/2019	512	1412	A69-1602-19217	10056
7/30/2019	572	1866	A69-1602-19218	10073
7/30/2019	496	1240	A69-1602-19205	10040
7/31/2019	538	1542	A69-1602-19238	8815
7/31/2019	538	1684	A69-1602-19248	8218
7/31/2019	556	1768	A69-1602-19272	8809
7/31/2019	520	1404	A69-1602-19273	8810
7/31/2019	536	1514	A69-1602-19274	8811
7/31/2019	562	1820	A69-1602-19275	8813
7/31/2019	550	1774	A69-1602-19276	8814
7/31/2019	557	1678	A69-1602-19239	0
7/31/2019	498	1238	A69-1602-19210	8807
7/31/2019	536	1420	A69-1602-19241	0
7/31/2019	530	1375	A69-1602-19242	0
7/31/2019	544	1765	A69-1602-19243	8223
7/31/2019	544	1568	A69-1602-19244	8222
7/31/2019	540	1776	A69-1602-19245	8221
7/31/2019	532	1432	A69-1602-19240	0
7/31/2019	540	1568	A69-1602-19247	8219
7/31/2019	532	1474	A69-1602-19255	8211
7/31/2019	582	2006	A69-1602-19261	8808
7/31/2019	540	1616	A69-1602-19260	8816
7/31/2019	551	1700	A69-1602-19259	8206
7/31/2019	542	1468	A69-1602-19258	8207
7/31/2019	552	1864	A69-1602-19257	8208
7/31/2019	572	1934	A69-1602-19246	8220
7/31/2019	507	1320	A69-1602-19127	8210
7/31/2019	542	1600	A69-1602-19266	8224
7/31/2019	566	1870	A69-1602-19254	8212
7/31/2019	542	1776	A69-1602-19253	8213
7/31/2019	530	1330	A69-1602-19252	8214

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEAcarP)

Date	TL (mm)	Weight (g)	Vemco Transmitter ID	Loop Tag ID
7/31/2019	538	1488	A69-1602-19251	8215
7/31/2019	532	1606	A69-1602-19250	8216
7/31/2019	552	2088	A69-1602-19249	8217
7/31/2019	542	1852	A69-1602-19256	8209
8/1/2019	514	1178	A69-1602-19135	8842
8/1/2019	526	1414	A69-1602-19134	8167
8/1/2019	549	1460	A69-1602-19152	8158
8/1/2019	522	1466	A69-1602-19130	8835
8/1/2019	518	1526	A69-1602-19131	8836
8/1/2019	532	1700	A69-1602-19268	8839
8/1/2019	570	1804	A69-1602-19132	8838
8/1/2019	562	1700	A69-1602-19133	8840
8/1/2019	566	1570	A69-1602-19137	8844
8/1/2019	554	1744	A69-1602-19138	8845
8/1/2019	548	1744	A69-1602-19271	8833
8/1/2019	493	1118	A69-1602-19140	8848
8/1/2019	526	1482	A69-1602-19129	8831
8/1/2019	566	1704	A69-1602-19143	8849
8/1/2019	458	902	A69-1602-19136	8843
8/1/2019	518	1454	A69-1602-19144	8150
8/1/2019	490	1140	A69-1602-19145	8151
8/1/2019	552	1610	A69-1602-19146	8153
8/1/2019	552	1495	A69-1602-19151	8154
8/1/2019	538	1598	A69-1602-19147	8155
8/1/2019	492	1178	A69-1602-19148	8156
8/1/2019	558	1666	A69-1602-19139	8847
8/1/2019	500	1155	A69-1602-19128	8827
8/1/2019	548	1614	A69-1602-19269	8834
8/1/2019	572	1822	A69-1602-19270	8832
8/1/2019	554	1546	A69-1602-19153	8159
8/1/2019	592	2062	A69-1602-19154	8160
8/1/2019	574	1784	A69-1602-19264	8828
8/1/2019	552	1750	A69-1602-19265	8826
8/1/2019	562	1608	A69-1602-19263	8829
8/1/2019	588	1988	A69-1602-19156	8162
8/1/2019	520	1456	A69-1602-19157	8163
8/1/2019	523	1462	A69-1602-19159	8165
8/1/2019	598	2138	A69-1602-19262	8830
8/1/2019	514	1468	A69-1602-19160	8166
8/1/2019	504	1448	A69-1602-19155	8161

Date	TL (mm)	Weight (g)	Vemco Transmitter ID	Loop Tag ID
12/3/2019	573	1832	A69-1602-19200	2114
12/3/2019	563	1702	A69-1602-19201	2121
12/3/2019	575	1838	A69-1602-19199	2112
12/3/2019	532	1612	A69-1602-19197	2122
12/3/2019	535	1612	A69-1602-19158	2113
12/3/2019	578	1460	A69-1602-19150	2110
12/3/2019	530	1328	A69-1602-19192	2116
12/3/2019	551	1756	A69-1602-19191	2107
12/3/2019	579	2084	A69-1602-19190	2101
12/3/2019	551	1678	A69-1602-19198	2123
12/4/2019	557	1776	A69-1602-19161	2153
12/4/2019	555	1904	A69-1602-19171	2156
12/4/2019	716	3930	A69-1602-19178	2164
12/4/2019	547	1584	A69-1602-19196	2117
12/4/2019	578	1942	A69-1602-19195	2103
12/4/2019	550	1782	A69-1602-19194	2124
12/4/2019	556	1876	A69-1602-19193	2120
12/4/2019	575	1932	A69-1602-19189	2119
12/4/2019	560	1856	A69-1602-19188	2104
12/4/2019	565	2086	A69-1602-19187	2106
12/4/2019	599	2250	A69-1602-19186	2118
12/4/2019	550	1780	A69-1602-19185	2109
12/4/2019	529	1686	A69-1602-19183	2100
12/4/2019	565	1862	A69-1602-19182	2161
12/4/2019	590	1954	A69-1602-19181	2162
12/4/2019	580	1889	A69-1602-19169	2154
12/4/2019	528	1428	A69-1602-19179	2163
12/4/2019	557	1858	A69-1602-19162	2108
12/4/2019	593	2016	A69-1602-19177	2165
12/4/2019	565	1994	A69-1602-19176	2166
12/4/2019	565	1980	A69-1602-19175	2160
12/4/2019	570	2060	A69-1602-19174	2159
12/4/2019	636	2630	A69-1602-19173	2158
12/4/2019	545	1670	A69-1602-19172	2157
12/4/2019	571	1942	A69-1602-19170	2155
12/4/2019	483	1172	A69-1602-19168	2152
12/4/2019	613	2416	A69-1602-19167	2151
12/4/2019	562	2184	A69-1602-19166	2150
12/4/2019	540	1430	A69-1602-19165	2105
12/4/2019	573	1816	A69-1602-19164	2109

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEAcarP)

Date	TL (mm)	Weight (g)	Vemco Transmitter ID	Loop Tag ID
12/4/2019	665	2826	A69-1602-19163	2111
12/4/2019	570	1512	A69-1602-19180	2115

Asian Carp Demographics

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Participating Agencies: US Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office (lead) and Illinois Department of Natural Resources

Pools Involved: Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, Alton

Introduction and Need:

The long-term effects of control measures on the abundance and distribution of Illinois River Asian carp is determined by the extent to which demographic rates (i.e., growth, recruitment, mortality, movement) are altered. To evaluate control success and predict population level responses to different control scenarios requires robust data sets and analyses. Examples include demographic data to test for predicted control effects (e.g., changes in sex ratio, growth, condition) and data to parameterize decision support tools such as the simulation-based Spatially Explicit Asian carp Population (SEAcarP) model. Herein, we report Silver Carp demographic data collected from the six lower pools of the Illinois River (Alton, La Grange, Peoria, Starved Rock, Marseilles, and Dresden Island pools) during spring and fall 2018 and 2019. Data were collected using a combination of fishery-independent (i.e., electrified dozer trawl) and fishery-dependent approaches (i.e., gill nets). The primary goal of these collections were to address data gaps including information on Silver Carp size at maturity and growth and to provide a comprehensive dataset that can be used to evaluate success of ongoing and future control efforts using multiple indicators. For example, in addition to expected reductions in fish density, data collected under this project would allow managers to investigate harvest-induced changes to Silver Carp condition, age structure, growth rate, and sex ratios.

Objectives:

(1) Quantify size and sex structure, length at maturity, and relative abundance of Asian carp during spring and fall in the lowest five pools of the Illinois River (Alton, La Grange, Peoria, Starved Rock, and Marseilles pools).

(2) Using standard methods agreed upon from the Asian Carp Demographics 2018 age and growth workshop (Age Demographic Template 2018), generate age and growth information for the Illinois River Asian carp at all five pools.

(3) Develop spawner and cohort abundance indices for Asian carp using summarized field data (i.e., catch rate, sex ratio, and length structure); use indices to evaluate when year class strength is set and the relationship between fall and spring spawner abundance.

(4) Provide data to update parameter estimates associated with the SEAcarP model.

(5) Identify advantages and limitations of using electrified dozer trawl to inform hydroacoustic data by comparing species composition and size structure from dozer trawl collections with capture gears currently being used to inform hydroacoustics (i.e., gill and trammel nets, electrofishing).

Project Highlights:

- Collected a comprehensive Silver Carp dataset using fish captured from six pools of the Illinois River. Data collections included: length, age, maturity, sex, and relative abundance.
- Deployed a time efficient standardized sampling method using electrified dozer trawl to collect demographic data.
- Project data can be used to measure population responses to changes in management strategies.

Results and Discussion:

Herein, we report results from field sampling conducted by the USFWS Columbia FWCO (Objective 1) and sample processing in the laboratory (i.e., aging; Objective 2). Results include spring and fall 2019 data and results from 2018 collections that were not included in previous ISRs. Laboratory and field data have been incorporated into the larger demographics dataset (Objective 4) managed by the MRWG modeling sub-workgroup and used to update parameter estimates in the SEAcarP model.

In summary, we collected a total of 2,131 Silver Carp from six pools of the Illinois River during spring and fall 2019 sampling using electrified dozer trawl (Table 1). Total effort was 450 5-minute trawls, which translates into 37.5 hours of active sampling. Due to high water levels and associated accessibility and safety concerns, we were unable to sample Alton Pool during spring 2019.

Table 1. *Fall and spring 2019 summary data including pool-specific effort (number of 5-minute trawls), Silver Carp total catch (number), mean Silver Carp catch per unit effort (number/h) and standard error, and total length (TL) range of Silver Carp captured. Results are based on fishery-independent sampling using electrified dozer trawl. Alton Pool was not sampled during spring 2019.*

Pool	Season	Effort (#)	Total catch (#)	Mean CPUE (SE)	TL range (mm)
Dresden	Spring	50	0	0(NA)	NA
	Fall	40	0	0(NA)	NA
Marseilles	Spring	48	40	10(3)	(552-819)
	Fall	50	96	23(4)	(562-886)
Starved Rock	Spring	51	376	89(15)	(505-940)
	Fall	51	489	115(17)	(510-790)
Peoria	Spring	50	51	12(3)	(430-760)
	Fall	50	391	96(23)	(108-895)
La Grange	Spring	50	71	17(4)	(7-760)
	Fall	50	155	37(8)	(190-821)
Alton	Fall	50	462	113(27)	(131-744)

Relative abundance:

Objective one of our project included quantifying Silver Carp relative abundance. Herein, we focus on 2018 and 2019 fall catch data. Pool-specific catch rates were comparable during 2018 and 2019 with exception to La Grange pool, which decreased considerably (approximately 2.5 times) from 2018 to 2019 and Starved Rock pool, which increased approximately 2 times (Figure 1). To provide insights into annual differences in these two pools, we excluded sub-stock length fish (250 mm total length (TL); Phelps & Willis 2013) and reexamined fall catch rate results. This analysis, however did not explain annual patterns observed in La Grange and Starved Rock pools. Lastly, our random sampling design yielded no fish from Dresden Island Pool during fall 2019 sampling.

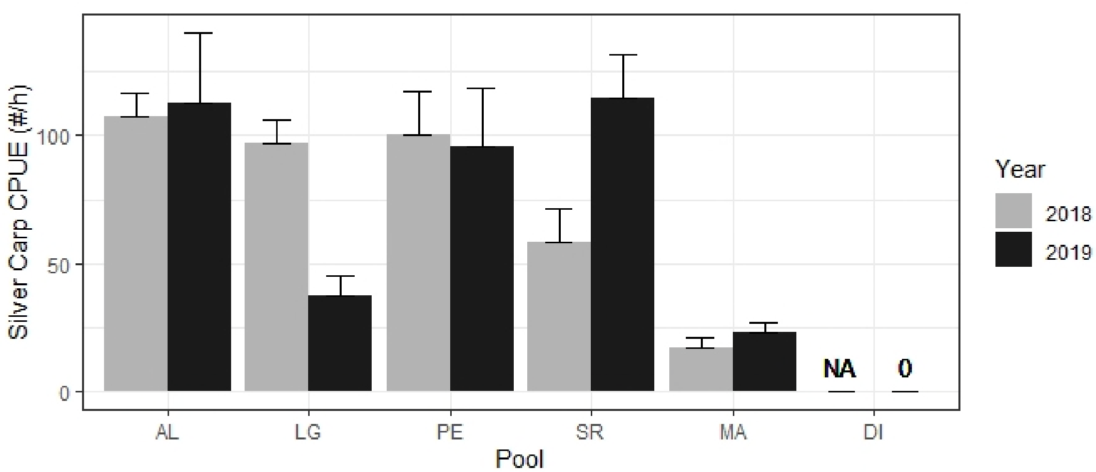

Figure 1. *Mean Silver Carp catch per unit effort (number/h) and standard error. Pool abbreviations include: Alton (AL), La Grange (LG), Peoria (PE), Starved Rock (SR), Marseilles (MA), and Dresden Island (DI). All fish were sampled using electrified dozer trawl during fall 2018 and 2019.*

Asian Carp Demographics

Length structure:

Objective one of our project also included quantifying spring and fall Silver Carp length structure. Data from the previous year of sampling were presented in our 2018 ISR, but are included for reference (Figure 2).

Spring 2019 catch rates were relatively low compared to fall efforts, a result we attributed to high spring water levels (Table 1). Excluding Starved Rock Pool, where we captured 376 fish, sample sizes of individual fish length data from the remaining pools were low (40 – 71). Consequently, we were unable to characterize spring length structure in certain pools (Figure 3).

Fall sample sizes of fish total length (TL) data ranged 96 – 489 individuals. Silver Carp catches were dominated by individuals greater than 450 mm TL in all pools (Figure 3). Mean TL of Silver Carp greater than 450 mm was greater for individuals captured above Starved Rock Lock and Dam (639 mm TL) relative to fish captured below the dam (582 mm TL; Mann–Whitney, $P < 0.001$ two-tailed). Not surprisingly, when we incorporated all sizes into the analysis, including individuals less than 450 mm TL captured from Alton, La Grange, and Peoria pools we observed an even greater size difference in pools above (mean TL = 639 mm TL) and below (509 mm TL) Starved Rock Lock and Dam (Mann–Whitney, $P < 0.001$ two-tailed). Lastly, consistent with other sampling efforts, fish less than 450 mm TL were limited to pools located below Starved Rock Lock and Dam. Alton Pool yielded the greatest number of Silver Carp less than 450 mm TL followed by La Grange and Peoria pools (Figure 3).

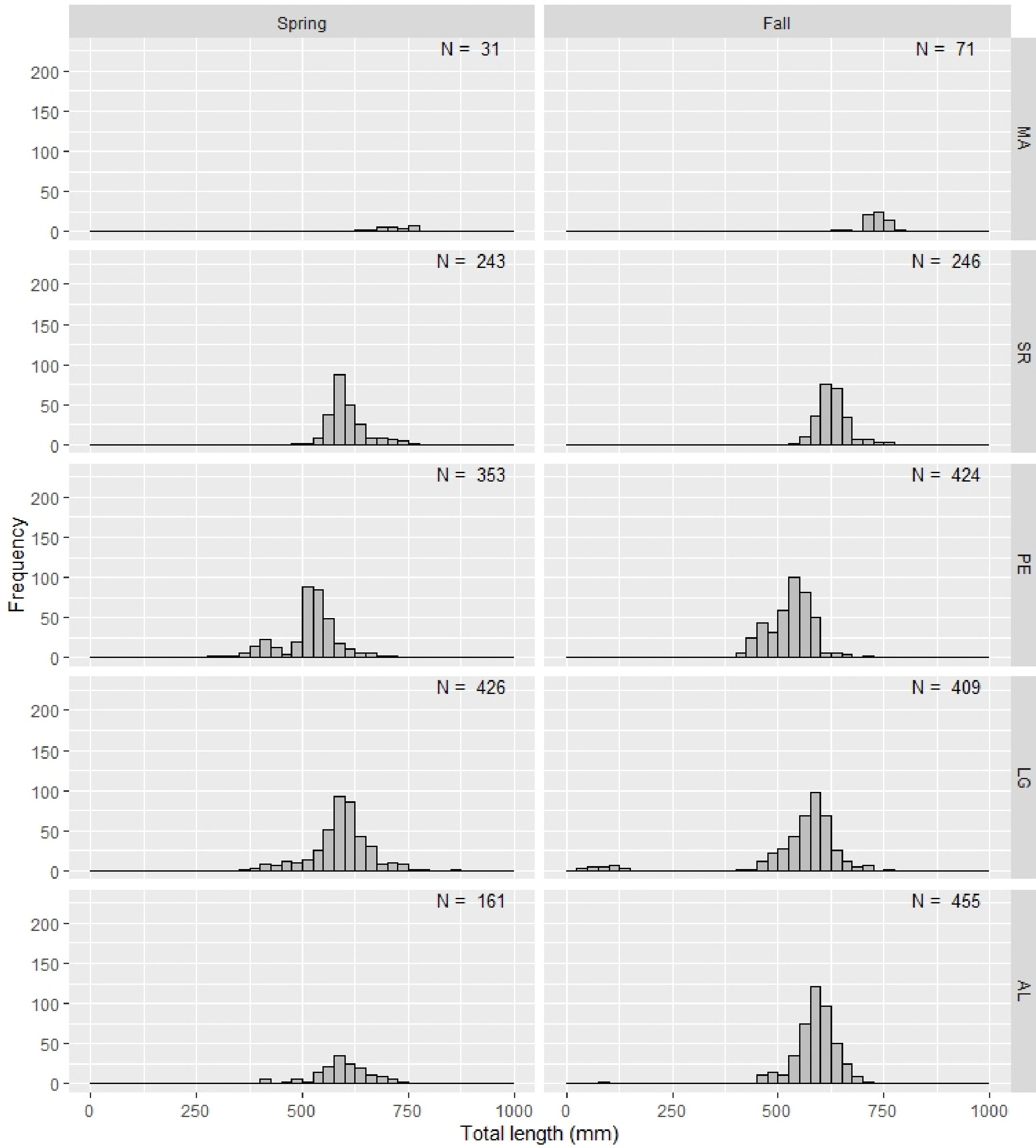

Figure 2. *Length-frequency histograms and total catch (N) of Silver Carp sampled from Alton (AL), La Grange (LG), Peoria (PE), Starved Rock (SR), and Marseilles (MA) pools. All samples were collected using electrified dozer trawl during spring and fall 2018.*

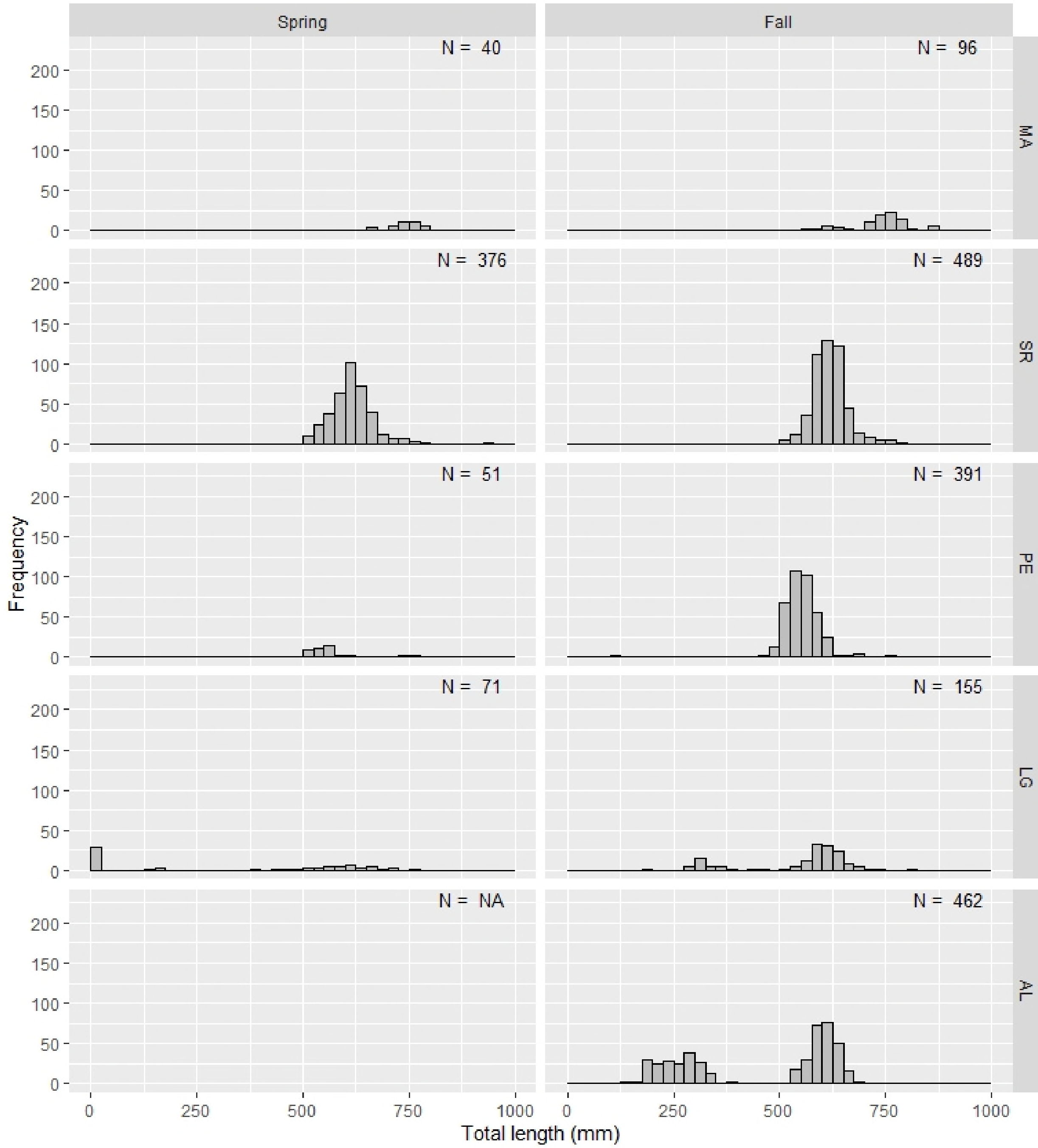

Figure 3. *Length-frequency histograms and total catch (N) of Silver Carp sampled from Alton (AL), La Grange (LG), Peoria (PE), Starved Rock (SR), and Marseilles (MA) pools. All samples were collected using electrified dozer trawl during spring and fall 2019. Alton was not sampled during spring due to high water levels. No fish were captured with the electrified dozer trawl in Dresden Island Pool.*

Condition:

Energy allocation to reproduction strongly influences the relationship between length and weight. To limit the effects associated with reproductive effort, we limited our length- weight analysis to fall data. Results indicated that, with exception to Starved Rock Pool, the rate at which Silver Carp increase in weight per unit length was similar across pools (Figure 4). Differences observed in Starved Rock Pool data were negligible and were unrelated to other explanatory variables such as individual fish sex.

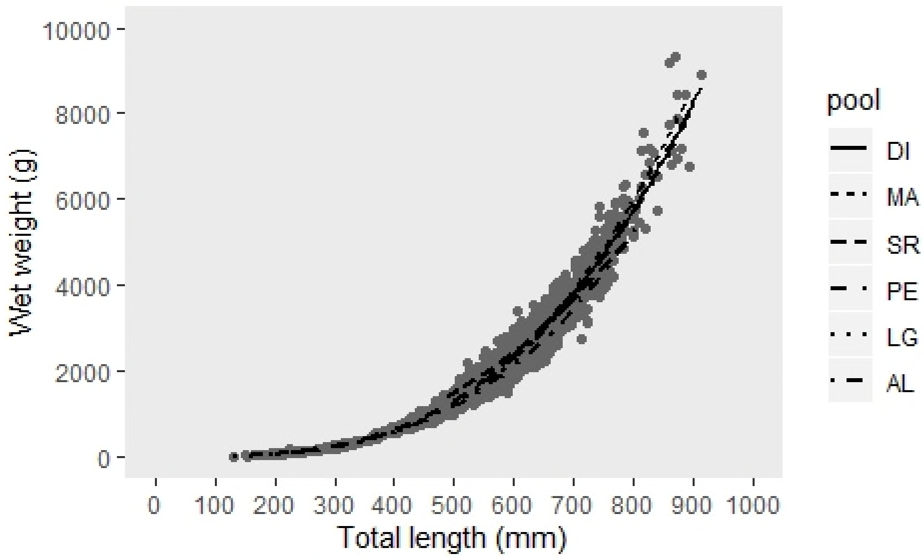

Figure 4. *Silver Carp total length versus wet weight for fish captured from Alton (AL), La Grange (LG), Peoria (PE), Starved Rock (SR), Marseilles (MA), and Dresden Island (DI) pools. All fish were sampled using electrified dozer trawl during fall 2019, except for Dresden Island Pool fish (N = 19), which were collected using commercial gill nets.*

Sex ratios:

We recorded Silver Carp sex of individual fish collected during spring and fall sampling efforts. The goal of these data collections were to provide 1) baseline sex ratio data across pools, 2) data to evaluate the potential implications of using sex-independent demographic rates (e.g., growth, length-weight) in population models, and 3) data to test for potential shifts in population sex structure in response to harvest. For example, exploited populations can be male dominated due to size-based sexual dimorphism and size-biased harvest that preferentially removes large-bodied individuals (e.g., Fenberg and Roy 2008). We expected that if the Illinois River commercial harvest program was influencing sex ratios, the proportional catch of male individuals would be lower in pools that do not receive harvest pressure (i.e., Alton, La Grange, Peoria) relative to those that do (i.e., Starved Rock, Marseilles, Dresden Island). Our results, however, showed no such pattern and hence, no evidence of preferential removal of female fish from the population (Figure 5).

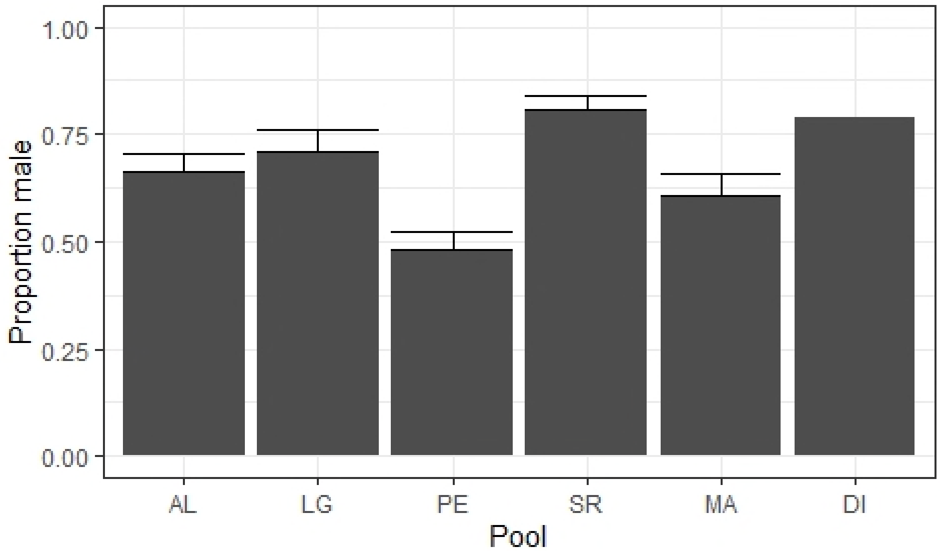

Figure 5. *Pool specific means and standard errors describing the proportion of Silver Carp males in the total catch. Pool abbreviations include Alton (AL), La Grange (LG), Peoria (PE), Starved Rock (SR), Marseilles (MA), and Dresden (DI). All fish were sampled using electrified dozer trawl during fall 2019, except for Dresden Island data (N = 19 individuals), which were collected using commercial gill nets.*

Maturity status:

Similar to other length- or age-structured population models, the SEAcarP model incorporates a size at maturity relationship and uncertainty to estimate recruitment during each annual time step. The relationship between fish size and maturity is typically estimated using empirical data, however, despite a 20 year dataset with over 32,000 individual fish records, the number of immature fish available for analysis is surprisingly low (4 males, 22 females). Consequently, the relation used in the SEAcarP model is based on an indirect approach that links gonad weight to maturity status (Erickson et al. - *in review*). This approach however, dramatically underestimates uncertainty. We sought to address this information gap by collecting spring maturity status and length data. Although we collected over 538 fish during spring 2019, only ten of those fish were 100 – 500 mm TL and of those fish, only four were immature (2 males, 2 females) a result we attributed to the negative effects of high water on fish catchability and overall low densities of smaller immature fish.

Length at age:

Silver Carp age structure and individual length at age data provide important insights into fish mortality rates (e.g., catch curve analysis) and growth (e.g., Von Bertalanffy growth analysis). Available Silver Carp data has been problematic because it is uninformative across certain sizes and the use of multiple aging structures and protocols negatively affect the accuracy and precision of age estimates. Consequently, Objective 2 of our project sought to build a large age structure dataset using lapilli otoliths from fall caught fish. We processed 194 and 348 fish captured during 2018 and 2019 respectively (Figure 6). This includes fish collected during a 2018 intensive removal effort in Peoria, Marseilles, and Dresden Island pools.

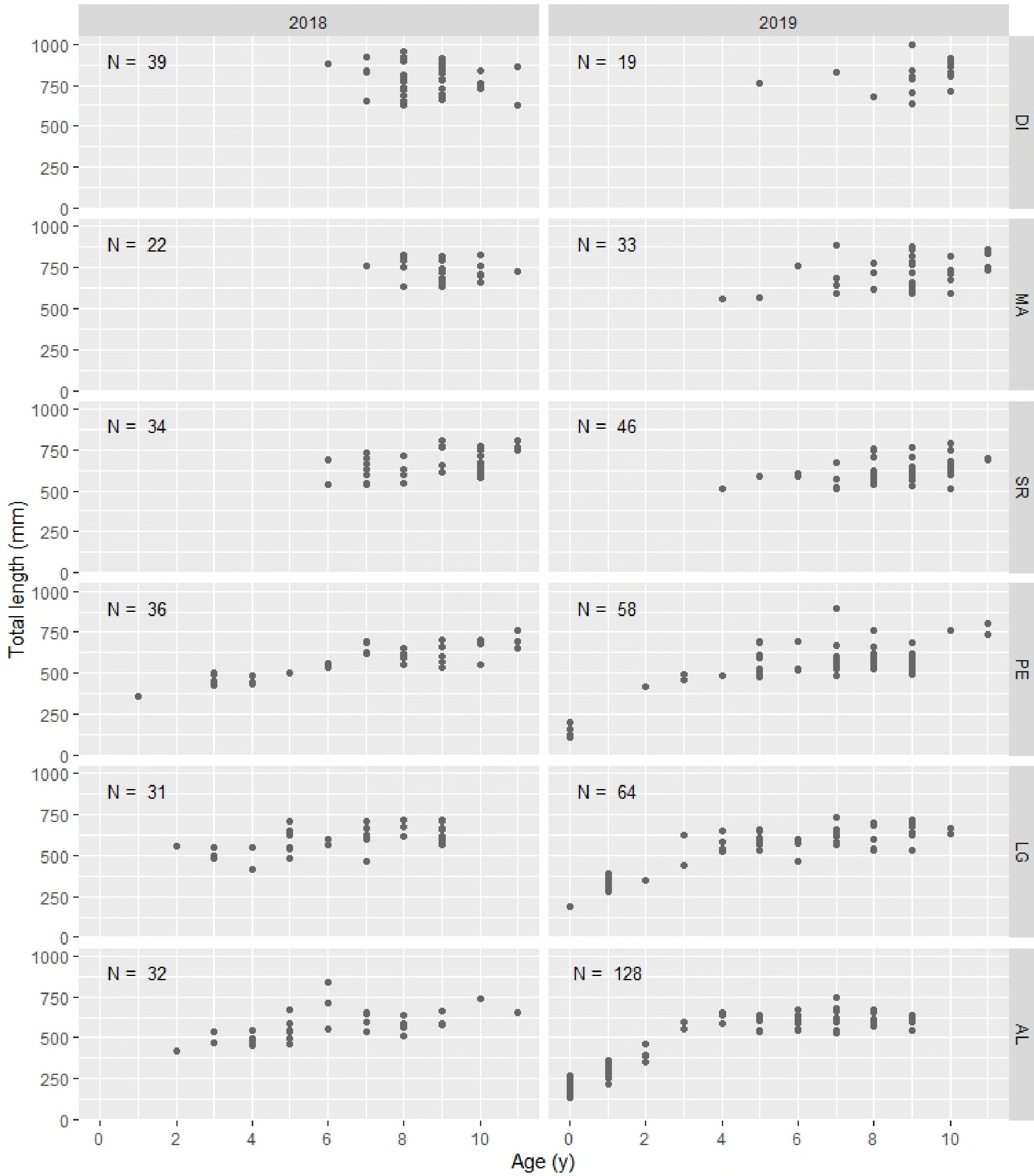

Figure 6. *Pool specific length at age data. Pool abbreviations include Alton (AL), La Grange (LG), Peoria (PE), Starved Rock (SR), Marseilles (MA), and Dresden Island (DI) pools of the Illinois River. Fish were collected during fall 2018 and 2019 using a combination of electrified dozer trawl and commercial gill nets.*

Efforts associated with Objectives 3 and 5 of our project are ongoing. To accomplish Objective 5, we will summarize electrified dozer trawl data using methods described by MacNamara et al. (2016) and compare to other gear types currently used to inform hydroacoustics. To accomplish Objective 3, we will use fall age and relative abundance to provide an index of year class strength.

Recommendations:

Biological systems are inherently complex and respond unpredictably (e.g., Coulter et al. 2018). Consequently, collecting a comprehensive data set allows fisheries managers to understand population responses using retrospective analyses in the Adaptive Management framework (Walters 1986). Data collected under this project provide a broad picture of Illinois River Asian Carp population characteristics using standardized collection methods. We recommend continued fisheries-independent sampling to assess Asian carp status and trends and to provide underlying input data for decision support tools such as the SEAcarP model. In regards to Asian carp specific data needs, we recommend spring sampling in the Alton, La Grange, and Peoria pools to better understand the relationship between fish size and maturity. In addition, we recommend continued fall sampling in the Alton, La Grange, Peoria, Starved Rock, Marseilles, and Dresden Island pools to gather demographic data (e.g., length, age, sex) needed to evaluate management actions and develop future control actions. Finally, to increase Illinois River Asian Carp sampling efficiency across GLRI projects, we recommend coordinating with the newly formed MRWG Monitoring sub-workgroup.

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Evaluation of a Modular Electric Deterrent Barrier

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Participating Agencies: Illinois Natural History Survey (lead)

Pools Involved: Not applicable

Introduction and Need:

Electric barriers have been used to impede or direct the movements of fishes for many years. However, almost all electric barriers used by fisheries agencies are constructed at fixed locations and are therefore stationary. Stationary electrical barriers currently serve as a line of defense in blocking the expansion of Asian carp into the Laurentian Great Lakes. Although useful for specific control purposes, such designs lack spatial flexibility and thus the capacity for adaptive management applications. Modular electric barriers may provide managers with the option to deploy control measures in a variety of locations to achieve various management objectives. A modular deterrent barrier was procured by INHS from Smith-Root, Inc. with the intent of aiding fisheries managers in inhibiting the movement of Asian carp in appropriate locations. Because habitat and environmental conditions (e.g., conductivity, waterbody dimensions) vary spatially, the modular system can potentially be adapted to generate a suitable electric field for deterring fish under a variety of situations. The modular electric barrier may be suitable for management scenarios including potential deployment near stationary barriers when they are powered down for repairs or maintenance, blocking entry into specific habitats (backwaters, side channels, lock chambers), and directing fishes into entrapment or entanglement gears that have previously been shown to be effective for capturing Asian carp. Before routine deployments of this modular barrier can be performed, measures must be taken to thoroughly develop field and safety protocols, evaluate the effectiveness of the barrier system at deterring Asian carp and other fishes, and develop cost estimates to inform management agencies of anticipated deployment and maintenance expenses. This project will evaluate the effectiveness of the modular electric barrier system at preventing passage of Asian carp, provide guidelines for the transport, deployment, and safe operation of the barrier, and offer cost estimates for barrier operation. Findings will aid decision-making by management agencies regarding deployment of this control system, which will contribute to broader efforts to prevent the spread of Asian carp.

Objectives:

(1) Evaluate the effectiveness of a modular electric deterrent barrier for inhibiting passage of Asian carp and other fishes, develop operational protocols, and identify operational costs and constraints.

(2) Conduct field trials to test the effectiveness of the barrier at locations on the Illinois Waterway.

Project Highlights:

- A modular electric deterrent barrier system has been procured by INHS. Because this barrier system is modular, it can be transported and deployed at a variety of locations. This system consists of a series of pulsers, generators, and winch-housed electrode cables that can be scaled to produce an electric field capable of deterring fishes across a range of waterbody conductivities and channel dimensions.
- Pond trials demonstrated that detection rates of Silver Carp and Bighead Carp in the vicinity of the electric barrier could be reduced by >99% when the barrier is in operation, with most positive detections associated with fish mortality. However, detection rates of fishes were also found to be inversely related to barrier power output, suggesting that operating the barrier at lower power settings is not advisable and that any factor that could affect the strength of the electric field (changes in conductivity, boat entrainment, etc.) could provide opportunities for fish passage.
- Field deployments that were planned for 2019 were disrupted by record flooding along the Illinois River and the subsequent damage to roads and levees. Additional plans for field deployments at locations that will likely be less prone to disruption by flooding are being made for 2020.

Methods:

The modular electric barrier system consists of nine pulser cabinets, five generators, and two electrode cables housed on electric barge winches. The system is scalable, such that the number of pulsers and generators can be varied to produce an effective electric field across a range of water conductivities and channel dimensions.

Pond trials were conducted during 2017 and 2018 to assess the effectiveness of the modular barrier system for deterring the movements of Asian carp and other fishes. An RFID antenna was constructed in the center of each pond, and multiple individuals from 7 fish species (4 invasive, 3 native) were PIT-tagged and stocked in the ponds in order to track fish activity in the vicinity of the electric field produced by the barrier. For each experiment, the barrier was installed alongside the pond and the electrodes were extended across the pond, parallel to the RFID antenna. One experiment assessed fish detection rates during periods when the barrier was operating at peak power output, and during periods where the barrier was not operational. A second experiment examined fish detection rates across a gradient of electric power output.

Field trials of the electric barrier system were planned to occur at the Chautauqua National Wildlife Refuge during 2019. During these trails, the barrier system was to be installed on the levee surrounding the refuge, and the electrodes placed across the channel that surrounds the levee. Pound nets were to be installed in the channel to one side of the electric barrier and used to assess relative numbers of fish passing the electric field during periods when the barrier was operational and when it was inactive. However, before field trials could commence, extreme flooding along the Illinois River prevented any field activities from being conducted. Intensive damage to the levees at the Chautauqua National Wildlife Refuge also prevented any further field activities at this location for the remainder of 2019. Additional candidate sites were considered for later field deployments, but logistical constraints ultimately necessitated delaying field deployments until 2020.

Results and Discussion:

In pond experiments, the rate of fish detections in proximity to the electric barrier was substantially reduced during periods of barrier operation compared to periods when the barrier was inactive (Figure 1). The effects of the electric barrier were consistent across species, with native and invasive taxa similarly influenced by barrier operation. The small number of positive detections that occurred while the barrier was operating were mostly associated with fish mortalities, suggesting that either fish were killed by entering the electric field, or died and drifted through the RFID antenna.

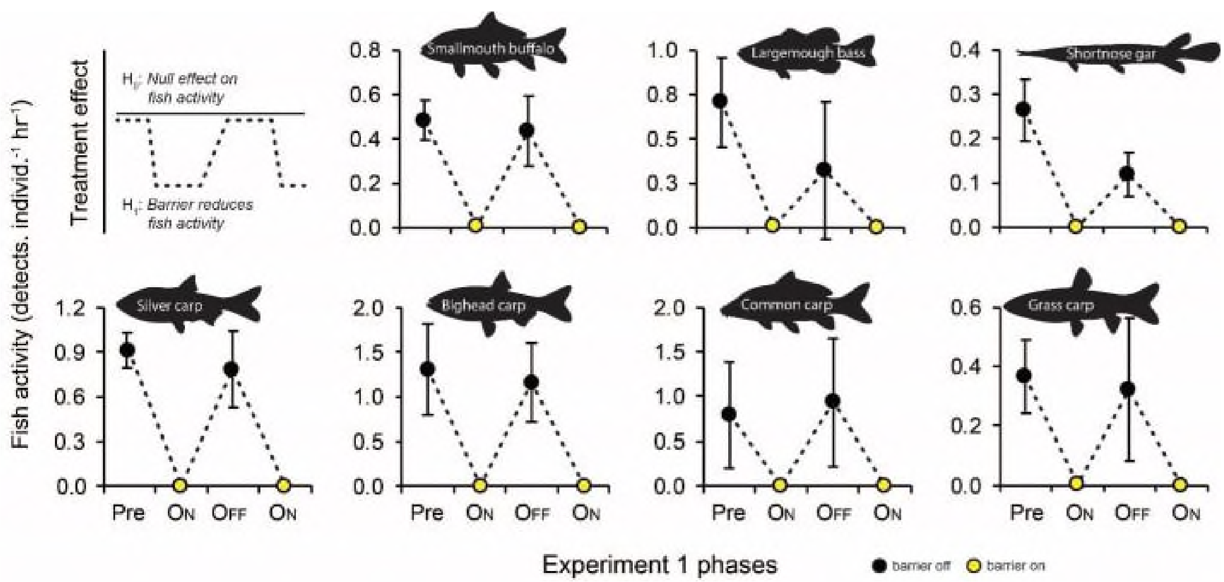

Figure 1. *Fish detection rates (detections per fish per hour ± 95% confidence intervals) during periods when the modular electric barrier was unpowered (black circles) and when it was operational (yellow circles) for seven fish species.*

In trials examining fish responses across a gradient of electric barrier field strength, detection rates of Silver Carp, Bighead Carp, and Smallmouth Buffalo in proximity to the electric barrier decreased considerably relative to background rates even at the lowest power setting (3.6 kW). However, some individuals of each species were still detected crossing the barrier, and these crossings did not result in mortality. Detection rates of Silver Carp and Bighead Carp were increasingly reduced at higher barrier strengths (6.6 kW and 10 kW), but detection rates of Smallmouth Buffalo did not differ across different barrier power setting (Figure 2).

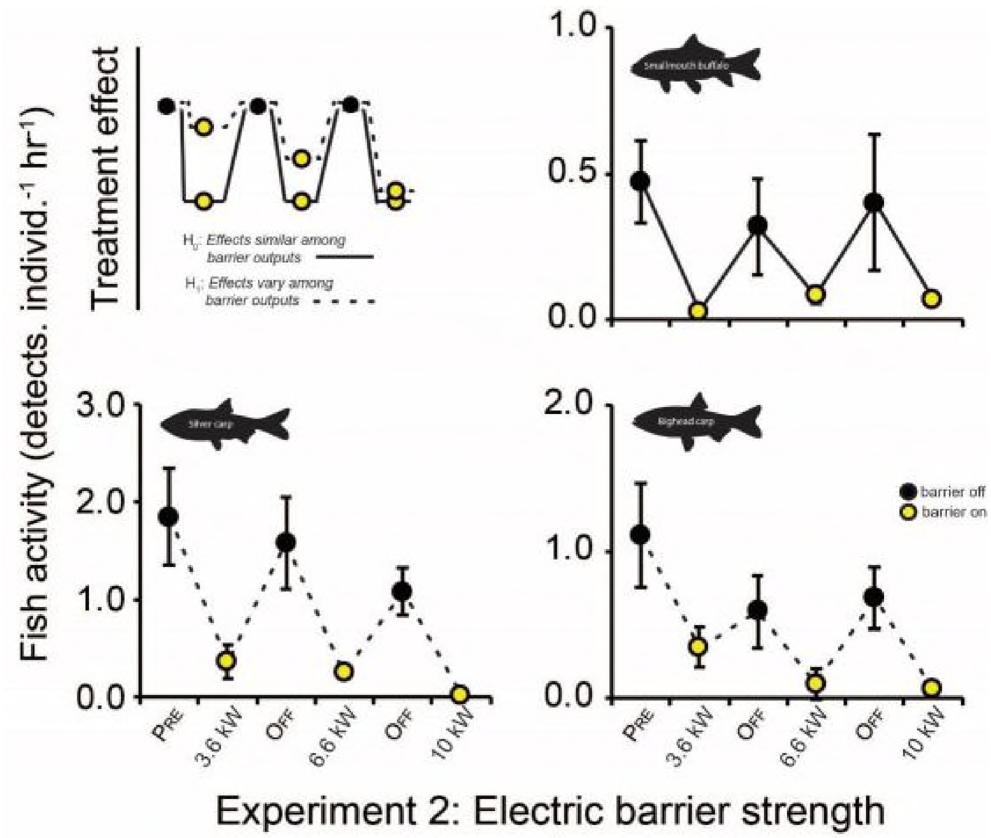

Figure 2. *Fish detection rates (detections per fish per hour ± 95% confidence intervals) in response to 3.6 kW (low), 6.6 kW (medium), and 10 kW (high) outputs by the modular electric barrier. Data points represent phases while the electric barrier was unpowered (black circles) and when it was operational (yellow circles) for three fish species.*

The modular electric barrier was found to be effective at deterring movements of all fish species examined. However, all of the fish tested in pond trials were adults, and no information is available on effectiveness at deterring juvenile fishes, or smaller-bodied taxa. Larger fish are often more susceptible to the effects of electric fields, and further evaluation is needed to determine best practices for inhibiting passage of smaller-bodied fish. Fish behavior when encountering the electric field is also not well understood, but could be exploited to better deter passage, or to develop methods to direct fishes into specific areas for removal purposes.

Deploying and operating the modular barrier system requires considerable planning and logistical consideration. Transporting the barrier components required one or more trailers, and all components must be tightly secured while in transit to prevent damage. Due to the size and weight of the generators, pulsers, and winches, a tractor, forklift, or skid steer is recommended for moving the barrier components into place. Powering the generators requires a considerable amount of gasoline. Pond trials required 45-50 gallons of gasoline over a 24-hour period. Because the generators have 15-gallon tanks, refueling the generators is periodically required. Alternatively, the generator gas lines could be connected to a larger fuel reservoir. To ensure safety and consistent barrier output, experienced personnel must monitor the barrier at all times while in operation. Because of the potential dangers of operating electrical equipment around water, strict safety measures must be followed at all times, and steps must be taken to restrict access by the public to the barrier vicinity.

Recommendations:

The modular electric barrier system does appear to be an effective tool for deterring fish movements, and further testing is recommended to identify optimal operating procedures, additional applications, and system limitations. Although the barrier had a strong effect on fish movements, it was not 100% effective at preventing passage, particularly at lower operating power. Therefore, field applications that are intended to minimize fish passage should only operate at the maximum power applicable to the channel dimensions and waterbody conductivity present at a site (goal of minimum 1 V/cm). Additionally, operators should be aware that any factors that may affect the strength of the electric field (changes in conductivity, boat entrainment, etc.) may allow for fish passage, and procedures should be considered to minimize such risks.

Field trials are required to further evaluate the effectiveness of this technology under conditions that are likely to be experienced during future deployments. Although pond trials have been helpful for understanding many of the logistical and operational issues involved in deploying the modular barrier system, additional considerations are necessary when transporting and operating the barrier in the field. Transportation logistics, fuel supply, interagency coordination and permitting, and additional safety concerns make any field application a more complex undertaking those in a controlled pond environment. Field trials planned for 2020 will provide valuable insight into the challenges of operating the modular barrier in a remote setting. An operations manual will be developed by INHS, to complement the manual provided by Smith-Root by providing relevant guidance on storage, planning, transportation, safety, operating procedures, and cost breakdowns under a variety of scenarios that may be encountered in the field. Once field trials are completed and operations manuals are finalized, the modular electric barrier is expected to be available to assist various agencies as a portable fish deterrent tool.

Alternate Pathway Surveillance in Illinois - Law Enforcement

Brandon Fehrenbacher & Colin Vaughan (Illinois Department of Natural Resources)

Participating Agencies: Illinois Department of Natural Resources (lead)

Pools Involved: Not applicable

Introduction and Need:

The Illinois Department of Natural Resources (IDNR) Invasive Species Unit (ISU) was created in 2012 as a special law enforcement component to the overall Asian carp project. It consists of two Conservation Police Officers with a combined 30+ years of law enforcement experience who are dedicated to searching for illegal activities within the commercial fishing, aquaculture, transportation, bait, pet, aquarium, and live fish market industries. The Unit focuses its energies and resources on the likely pathways Asian carp could spread by human means. ISU has exposed the risks human activities bring to the entire Asian carp project by making significant arrests in nearly every industry it has investigated. ISU consistently demonstrates the necessary role it plays alongside many others working diligently to protect the waterways. The capabilities and knowledge of the Unit advance and adapt significantly each year.

Objectives:

(1) Develop an invasive species and aquatic life industry enforcement training curriculum for the Conservation Police Academy to enhance capabilities of law enforcement in protecting the State from invasive species threats.

(2) Implement a multi-jurisdictional surveillance operation of potential or suspected illegal commercial fishing activities on applicable river systems.

(3) Obtain the proper security clearance and inspect shipments of live aquatic species being imported into Chicagoland airports.

(4) Conduct commercial inspections within the aquatic life industry to ensure compliance of relevant laws.

(5) Investigate all complaints, events and suspicious activities that pose a threat to the Asian carp project.

(6) Allocate adequate time to complete training and stay updated with current trends and regulations related to the aquatic life industry.

Alternate Pathway Surveillance in Illinois - Law Enforcement

Project Highlights:

- An out-of-state pond stocking company investigated by the Invasive Species Unit was criminally charged and pled guilty to unlawfully importing Viral Hemorrhagic Septicemia (VHS) susceptible species into Illinois without permits. The court ordered restitution to the Department in the amount of $11,494.00. The investigation revealed the company imported, sold, and stocked live gizzard shad, fathead minnows, bluegill, red ear sunfish, and largemouth bass without a non-resident aquatic life dealer's license and often without VHS import permits.
- A total of 39 businesses within the Great Lakes region selling live Red Swamp Crayfish on the Internet and shipping them to customers through mail delivery services were identified and sent official notification letters containing jurisdictional regulations and agency AIS personnel contact information. The effort signified a proactive approach to protecting resources while simultaneously providing those within the industry easy access to regulatory information and personnel. News of the initiative reached the highest levels of state government and will serve as a model for limiting the spread of additional species in the future.

Methods:

ISU generated enforcement activity from the public, agency personnel, outside agencies, surveillance operations, on-site facility inspections, fish truck inspections, record audits, permit reviews and the Internet.

Results and Discussion:

- ISU developed an 8-hour Invasive Species and Aquatic Life Industry Enforcement curriculum and taught the course at two Illinois Conservation Police academy classes. ISU participated in the development of a commercial fishing workshop for Conservation Police Officers in Havana, Illinois and presented invasive species enforcement techniques to the class. Training efforts have resulted in increased awareness and enforcement of invasive species regulations throughout Illinois.
- A complex multi-state commercial fishing compliance and intelligence gathering operation was developed involving six agencies and covering nine river systems. The operation was cancelled due to the COVID-19 pandemic, but now that the planning phase is complete, it can easily be implemented in the future.
- ISU met with inspectors at a Chicagoland airport and determined pursuing a security clearance wasn't necessary. Inspectors invited ISU to work alongside them as guests, which does not require a separate security clearance. ISU provided a list of Illinois prohibited species to the inspectors who agreed to contact ISU if any species of concern were discovered.
- Commercial inspections within the aquatic life industry resulted in the issuance of 13 citations and 13 written warnings to wholesale and retail aquatic life dealers, and 14

citations and 4 written warnings to commercial fishermen for records violations. Aquaculture facility inspections discovered an out-of-state fish dealer illegally shipping tilapia into Illinois without permits. Hundreds of pounds of live Red Swamp Crayfish, an Illinois prohibited species, were seized from food markets in the Chicagoland area.

- Investigations into complaints and activities posing a threat to the Asian carp project included:
  - Surveillance, evidence gathering, and charges filed against on an out-of-state fish dealer illegally transporting Asian carp from Illinois into another state;
  - Illegal importation of live trout, tilapia, and catfish without permits;
  - Facebook advertisements of illegal species for sale;
  - Ice fishing guide service - illegal commercialization of the resources;
  - Food markets selling live prohibited species;
  - Illegal importation of live Red Swamp Crayfish to Chicagoland area food markets;
  - An unlicensed bait shop selling live juvenile Asian carp as bait.
- ISU attended the following: Aquatic Resources Task Force meeting – Missouri & Ohio; Great Lakes Fishery Commission Law Enforcement Committee meeting – Ypsilanti, MI & Windsor, Ontario; Loyola University – collaborate with a crayfish expert; Wildlife Fraud Investigators training – Scottsdale, AZ; IL Environmental Crimes Task Force meeting.

Recommendations:

Encourage continued cooperation and communications with state and federal partners in order to safely and effectively manage invasive species in our waterways.

Asian Carp Enhanced Contract Removal Program

Participating Agencies: Illinois Department of Natural Resources (lead); US Environmental Protection Agency and Great Lakes Fishery Commission (project support).

Pools Involved: Peoria Pool.

Introduction and Need:

The ACRCC and MRWG recognize the value of increased harvest of Asian carp in the Illinois River informed by current fishery stock assessment data. Modeling from SIU and USFWS have provided insights recommending that removal from downstream reaches can heighten protection of the Great Lakes by preventing fish population growth in upstream reaches.

Objectives:

(1) Aid in reaching a target removal rate of 20 to 50 million pounds of Asian carp per year from the IWW below Starved Rock Lock and Dam.

(2) Removal under the Enhanced Contract Fishing Program for 2019/2020 has a goal of 4.5 million pounds, while working toward a goal of removing 15 million pounds by 2022.

(3) Coordinate fishers and processors to increase cooperation with an end goal of increasing the scale of removal operations to satisfy larger orders for harvested Asian carp.

(4) Leverage other programs such as the Market Value Program to continue building increased demand for harvested Asian carp.

Project Highlights:

- More than 518,000 pounds have been removed under this program. Removal from lower Illinois River has been recommended and to that end Peoria Pool has been targeted to begin these efforts.
- Nineteen contracts were entered into with Illinois-licensed commercial fishers targeting the Peoria Pool.
- Processed more than $51,000 in payments to fisherman.
- Issued RFP for Branding & Marketing Strategy Development and Implementation.

Barrier Maintenance Fish Suppression

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Rebecca Neeley (US Fish and Wildlife Service – Carterville Fish and Wildlife Conservation Office)

John Belcik, Nicholas Barkowski (US Army Corps of Engineers – Chicago District)

Participating Agencies: Illinois Department of Natural Resources (lead); US Fish and Wildlife Service and US Army Corps of Engineers – Chicago District, (field support); US Coast Guard (waterway closures), US Geological Survey (flow monitoring); Metropolitan Water Reclamation District of Greater Chicago (waterway flow management and access); and US Environmental Protection Agency (project support).

Pools Involved: Lockport

Introduction:

The US Army Corps of Engineers (USACE) operates three electric aquatic invasive species dispersal barriers (Demonstration Barrier, Barrier 2A, and Barrier 2B) in the Chicago Sanitary and Ship Canal at approximate river mile 296.1 near Romeoville, Illinois. The Demonstration Barrier became operational in April 2002 and is located farthest upstream at river mile 296.6 (approximately 244 meters above Barrier 2B). The Demonstration Barrier is operated at a setting that has been shown to induce behavioral responses in fish over 137 mm in total length (Holliman 2011). Barrier 2A became operational in April 2009 and is located 67 meters downstream of Barrier 2B which went online in January 2011. Both Barrier 2A and 2B can operate at parameters shown to repel or stun juvenile and adult fish greater than 137 mm long at a setting of 0.79 volts per centimeter, or fish greater than 63 mm long at a setting of 0.91 volts per centimeter (Holliman 2011). The higher setting has been in use since October 2011. USACE is currently constructing a permanent upgrade to the Demonstration Barrier which will be regarded as Permanent Barrier 1 (Barrier 1). Barrier 1 will be capable of increased operational settings in comparison to Barriers 2A and 2B.

All three barriers (Barrier 2A, 2B, and the Demo) must be shut down independently for maintenance approximately every 12 months and the Illinois Department of Natural Resources has agreed to support maintenance operations by conducting fish suppression and/or clearing operations at the barrier site. Fish suppression can vary widely in scope and may include application of a piscicide such as rotenone to keep fish from moving upstream past the barriers when they are down. Rotenone was used in December 2009 in support of Barrier 2A maintenance, before Barrier 2B was constructed. With Barrier 2A and 2B now operational, fish suppression actions will be smaller in scope because one barrier can remain on while the other is taken down for maintenance.

Barrier 2B operated as the principal barrier from the time it was brought on line and tested in January 2011 through December 2013. During that time, Barrier 2A was held in warm standby mode (so it could be energized to normal operating level in a matter of minutes) unless Barrier 2B experienced an unexpected outage or planned maintenance event. In January 2014, standard operating procedure was changed to run Barriers 2A and 2B concurrently. This change further increased the efficacy of the Electric Dispersal Barrier System (EDBS) as a whole by maintaining power in the water continuously regardless of a lapse in operation at any single barrier. Because the threat of Asian carp invasion is from downstream waters, there is a need to assess risk for the presence of Asian carp and clear fish as deemed necessary by the MRWG from the 67 meter length of canal between Barrier 2A and 2B each time Barrier 2A loses power in the water for a time sufficient to allow fish passage. Without a clearing evaluation and potential action, there is a possibility that fish may utilize barrier outages to 'lock through' the EDBS. Locking through happens if an outage were experienced at Barrier 2A. This would allow fish present just downstream to move up to Barrier 2B. If Barrier 2A were to then come back online, those fish that moved below Barrier 2B would then be trapped between the barriers. If an outage is then experienced at Barrier 2B, the fish trapped between the barriers would then be able to move past into the area between Barrier 2B and the Demonstration Barrier or into upper Lockport pool if the Demonstration Barrier were de-energized. The suppression plan calls for an assessment of the risk of Asian carp passage at the time of the reported outage and further clearing actions if deemed necessary. This Interim Summary Report outlines the number of changes in the EDBS operations that triggered a fish clearing decision by the MRWG, the decisions that were made by the MRWG, and the results of any actions taken in response to changes in EDBS operations.

Objectives:

The IDNR will work with federal and local partners to:

(1) Remove fish >300 mm (12 inches) in total length from between applicable barrier arrays before maintenance operations are initiated at upstream arrays and after maintenance is completed at downstream arrays by collecting or driving fish into nets from the area with mechanical technologies (surface noise, surface pulsed-DC electrofishing and surface to bottom gill nets) or, if needed, a small-scale rotenone action.

(2) Assess fish assemblage <300 mm (12 inches) in total length between applicable barrier arrays, if present, for species composition to ensure Asian carp juvenile or young of year individuals are not present. Physical capture gears focused on small bodied fishes such as

electrified paupier surface trawls and surface pulsed-DC electrofishing could be utilized in support of this effort.

(3) Assess the results of fish clearing operations by reviewing the physical captures and surveying the area between barrier arrays with remote sensing gear (split-beam hydroacoustics and side-scan sonar). The goal of fish clearing operations is to remove as many fish (>300 mm in total length) as possible between the barriers, as determined with remote sensing gear or until the Monitoring and Response Workgroup (MRWG) deems the remaining fish in the barrier as a low risk. Fishes <300 mm in total length at the Barriers are deemed a low risk to be Asian carp until further evidence from downstream monitoring suggests a change in the known population front for this size class of invasive Asian carps.

Project Highlights:

- The MRWG agency representatives met and discussed the risk level of Asian carp presence at the EDBS at each primary barrier loss of power to water.
- Five 15 minute electrofishing run were completed between Barriers 2A and 2B to supplement existing data in support of the MRWG clearing decision.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on a bi-weekly basis, both below and within the EDBS indicating fish over 300mm, but in low abundance.
- An acoustic deterrent system was installed approximately a 0.75 miles downstream of the EDBS between November 19, 2018 and April 3, 2019 in support of annual maintenance operations.
- **No Asian carp were captured or observed during fish suppression operations**

Methods:

An "outage" is defined as any switch in operations at the barriers that would allow for upstream movement of fishes within the safety zone of the CSSC or any complete power loss in the water. A change in operations at the barrier that results in a loss of power in the water less than one minute are considered to be too short in duration to allow for upstream passage of fish. At the occurrence of any barrier outage greater than one minute, the MRWG was notified as soon as possible by the USACE and convened with key agency contacts to discuss the need for a barrier clearing action. The decision to perform a clearing action based on a barrier outage was based on factors related to the likelihood of Asian carp passing the barrier, under the conservative assumption that they may be present in Lockport Pool and near or at the barriers. If Asian carp exist near the barriers, the MRWG currently expects only adult fish (> 300 mm) to be present. This risk evaluation may change if small Asian carp are detected upstream of the known population front for this size class in any given year. Based on the current and joint understanding of the location of various sizes of Asian carp in the CAWS and upper Illinois Waterway and the operational parameters of the EDBS, the MRWG believes that either the wide or narrow array of each Barrier provides a minimally effective short-term barrier for juveniles or adults. Thus, the MRWG views a total outage of both wide and narrow arrays as a situation of increased risk for Asian carp passing a given barrier. The MRWG decision to initiate a clearing action at the barriers was made only during heightened risk of Asian carp passage based on the most up to date monitoring results and current research.

A cut-off of 300 mm in total length was selected for fishes to be removed from the barriers area when a clearing action was recommended by the MRWG. By selecting a cut-off of 300 mm, sub adult and adult Asian carp were targeted and young-of-year and juvenile fish were excluded. Excluding young-of-year and juvenile Asian carp from the assessment was based on over five years of sampling in the Lockport Pool with no indication of any young of year Asian Carp present or any known locations of spawning. However, continued monitoring in the lower reaches of the Illinois Waterway in the spring of 2015 indicated that small Asian carp less than 153 mm were being collected progressively upstream over time. Juvenile Silver Carp were reported from the Starved Rock Pool beginning in April of 2016 in substantial numbers with several individual captures of similar sized juvenile Silver Carp reported from the Marseilles Pool by October. These records prompted resource managers to take a more conservative approach at the barriers by sampling all sizes of fishes between the barriers during a clearing event. It was determined that all fishes over 300 mm still be removed from the area and that fishes less than 300 mm be sub-sampled to ensure no juvenile or young of year Asian carp are present. It should be noted that the of Asian carp less than 300 mm have been primarily captured in Peoria Pool with only one fish captured just upstream of Starved Rock Lock and Dam since 2017.

A key factor to any response is risk of Asian carp being at or in the EDBS. The MRWG has taken a conservative approach to barrier responses in that there is little evidence that Asian carp are directly below the barrier, but with the understanding that continued work and surveillance below the EDBS is necessary to maintain appropriate response measures. Considering budgetary costs, responder safety, and continued monitoring in reaches directly below the barrier, the MRWG will continue to discuss the need for a clearing action as best professional judgment suggests. A barrier maintenance clearing event will be deemed successful when all fish >300 mm are removed from the barrier or until MRWG deems the remaining fish in the barrier a low risk and a sub-sample of fish <300 mm have been identified to species.

Initial clearing action is likely to use split beam hydroacoustics and side scan SONAR imaging to determine if fish are present in the target area of the EDBS, including the area between Barrier IIA and IIB or between the active barrier array and the demonstration barrier, aimed at specifically identifying the number of fish over 300 mm. This sonar scan may be completed upon request or the MRWG may decide to utilize the most recent data available as USFWS continues bi-weekly surveillance of the vicinity. If one or more fish targets over 300 mm are present, the

MRWG will convene and decide if a clearing action is warranted for the area between affected barriers. Initial response to any loss of power to the water should occur within a week of the outage; upon completion of the sonar survey, fish detections, sizes, and locations will help formulate timely clearing efforts if deemed necessary. Additional clearing actions can range from nearly "instantaneous" response with electrofishing to combined netting and electrofishing, or any combination of other deterrent technologies that may or may not require US Coast Guard (USCG) closures of the Canal/Waterway. The USCG generally requires at least a 45 day notice for requests to restrict navigation traffic in the waterway.

Results and Discussion:

During 2019, Barrier 2A and 2B were the primary barriers to fish passage in the upstream direction within the EDBS at various points during the year. During periods when Barrier 2A was designated as the primary barrier, it experienced a loss of power in water at both arrays for an extended duration (minimum = 5 minutes; maximum = 103 days and 1 hour) a total of 21 times (**Table 1**). The majority of these shut downs coincide with various maintenance events. Both 2A and 2B were powered down for the period between January 7th and 29th (January 7, 9, 10, 11, 14, 15, 16, 17, 18, 21, 22, 23, 24, 25, 28, 29) due to dive operations for 2B electrode replacement. The wide array of 2A was turned on at the end of each day's dive operations and turned off at the start. The 2A narrow remained off for the entire period. Barrier 2A was briefly turned on from January 29th to February 1st and then powered down again for dive operations/annual maintenance and cooling system upgrades until May 15th. During the 103 day shutdown at barrier 2A, barrier 2B was also shut down over three separate periods. Those include February 1-15 for Dive Operations, February 25-March 15 for dive Inspections, and March 25 – 30 for annual Maintenance. The full list and duration of 2B outages can be found in **Table 2**. At all times when both 2A and 2B were powered down the demonstration barrier remained active. During the period of annual maintenance and electrode replacement between November of 2018 to April of 2019 an acoustic deterrent system was established downstream of the barrier with assistance from USGS. The system was implemented to further reduce risk of any upstream fish passage. During winter maintenance and electrode replacement bi-weekly calls were held to update stakeholders on maintenance progress and discuss risk and needs for potential clearing actions. Based on extreme cold temperatures, seasonal movement patterns of Asian carp, sufficient evidence from downstream sampling. Implementation of an acoustic deterrent system, as well as safety, no clearing actions were conducted. Extreme cold temperatures or abnormally high flows within the canal restrain the ability of the workgroup to effectively deploy clearing teams. During such instances, the workgroup relied on best professional judgment, downstream sampling efforts and telemetry results to assess the risk of breach.

Outside of planned outages related to maintenance and electrode replacement, barrier 2A lost power in the water four additional times (minimum = 5 minutes, maximum = 15 days, 6 hours), however barrier 2B was operational. During these unplanned outages, risk for Asian carp presence at the barrier and the likelihood of fish moving upstream was communicated to the MRWG at each primary barrier outage. The MRWG determined formal clearing actions between the barriers were not required due to a very low risk of Asian carp presence. There were two occasions in which additional electrofishing monitoring actions were taken at the EDBS to further support the MRWG decision. These monitoring actions performed at the EDBS utilized DC electrofishing. The monitoring actions were taken on June 26 and August 16 in response to a prior barrier outage at 2A. USACE completed four 15 minute electrofishing runs (two between 2A/2B and two between 2B/Demo) on June 26 and one on August 16 (between 2A/2B). These actions were an effort to help assess the risk for Asian carp presence during routine monitoring activities of the Lockport Pool and in response to hydroacoustic scans of the barrier indicating large fish targets within the barrier. No Asian carp were captured, but other fish species were.

On June 26 there were 11 species (40 individuals) collected within the EDBS. Of those 40 individuals, 31 were collected between 2A and 2B and consisted of Common Carp (2), Freshwater Drum (1), Channel Catfish (1), Bluegill (1), Green Sunfish (2), Bluntnose Minnow (4), Fathead Minnow (2), Spotfin Shiner (2), Emerald Shiner (9), Round Goby (2), and Banded Killifish (5). Between the Demo and 2B there were nine Common Carp Collected. On August 16 several fish under 100mm were captured, including Emerald Shiner (86), Spotfin Shiner (1), and Round Goby (1). One Gizzard Shad at 230mm was also captured in August.

Additional monitoring actions were undertaken by USWFS Wilmington sub-office using hydroacoustic sonar scans throughout the year. They completed 26 sonar scans between the barriers on a bi-weekly to monthly basis between February and December. Results from these scans showed large fish present during 14 of the 26 scanning events within the barrier and 16 times below the barrier. These scans were part of normal monitoring activities of the EDBS and were not specifically requested by the MRWG, but they helped further assess the risk for fish presence between Barriers 2A and 2B.

Several of the 2019 outages were coordinated by USACE with the MRWG as planned outage events at Barriers 2A and 2B in support of planned maintenance operations. A concurrent shutdown of Barrier 2A and 2B was needed periodically to support dive operations and inspection and replacement of the in-water component at those barriers. USACE planned these outages to occur at a time of the year when fish activity and water temperatures are expected to be the lowest. The Demonstration Barrier was also operated continuously during the planned concurrent outages. The MRWG was notified of the annual maintenance work in November and updated with progress reports during bi-weekly calls. The installation of a temporary acoustic deterrent system was also coordinated during this time. It was determined that real-time receiver data from the vicinity of the barriers would be used in conjunction with USFWS sonar scans to supplement existing monitoring data. Barrier scans indicated that there was one large fish present within the barriers at the end of December. However, data from the real-time receiver just downstream of the barrier indicated this was likely a tagged Common Carp.

Table 1: *Loss of power to the water at the primary active Barrier 2A in 2019. *Indicate an annual maintenance event where the wide array was turned off at the start of daily dive operations and on after dive operations concluded for the day. The narrow array was never powered on during this time.*

Barrrier	Start Date	End Date	Outage Duration (DD:HH:MM:SS)
IIA	26-Dec-18	8-Jan-19	13:08:24:00
IIA*	9-Jan-19	9-Jan-19	00:10:24:00
IIA*	10-Jan-19	10-Jan-19	00:10:24:00
IIA*	11-Jan-19	11-Jan-19	00:08:36:52
IIA*	14-Jan-19	14-Jan-19	00:10:18:29
IIA*	15-Jan-19	15-Jan-19	00:10:03:26
IIA*	16-Jan-19	16-Jan-19	00:10:06:41
IIA*	17-Jan-19	17-Jan-19	00:10:15:37
IIA*	18-Jan-19	18-Jan-19	00:09:17:05
IIA*	21-Jan-19	21-Jan-19	00:10:15:57
IIA*	22-Jan-19	22-Jan-19	00:11:07:43
IIA*	23-Jan-19	23-Jan-19	00:09:56:16
IIA*	24-Jan-19	24-Jan-19	00:10:17:59
IIA*	25-Jan-19	25-Jan-19	00:08:02:07
IIA*	28-Jan-19	28-Jan-19	00:07:34:38
IIA*	29-Jan-19	29-Jan-19	00:07:00:12
IIA	1-Feb-19	15-May-19	103:01:10:02
IIA	16-May-19	21-May-19	04:21:20:19
IIA	5-Jun-19	20-Jun-19	15:06:06:00
IIA	25-Jul-19	25-Jul-19	00:00:05:00
IIA	14-Aug-19	14-Aug-19	00:05:25:00

Table 2: *Loss of power to the water at the primary active Barrier 2B in 2019; the Demonstration Barrier was in full operation at each of the time and dates below.*

Barrrier	Start Date	End Date	Outage Duration (DD:HH:MM:SS)
IIB	7-Jan-19	29-Jan-19	22:06:57:19
IIB	1-Feb-19	15-Feb-19	14:00:19:58
IIB	25-Feb-19	15-Mar-19	18:06:33:18
IIB	25-Mar-19	30-Mar-19	05:00:05:56

Recommendations:

The MRWG agency representatives should continue to assess the risk of Asian carp presence at the primary downstream barrier. The group should take into consideration the most recent downstream monitoring data, known locations of Asian carp (adults and juveniles) and other biotic and abiotic factors relative to Asian carp movement and dispersal patterns. This summary also recommends continued use of hydroacoustics to survey in between the Demonstration Barrier and Barrier 2A for fish of all sizes as a primary means of identifying risk for potential Asian carp presence prior to any other clearing action. Clearing actions that address removal of fish from between the barriers should include surface, pulsed DC-electrofishing and noise scaring tactics (tipped up motors, push plungers, hull banging, etc). It is recommended to continue the removal of all fishes greater than 300 mm in total length and to sub-sample fishes less than 300 mm in total length for species identification. Identification of fishes less than 300 mm will help further inform decision makers on the risk of juvenile Asian carp presence. Deep water gill net sets and other submerged bottom deployed gears are not recommended for further use between the barriers as a removal action due to safety concerns for personnel. However, these tools should continue to be used in the immediate downstream area to enhance understanding of fish species assemblage and risk of Asian carp presence. Additionally, this summary recommends continued research and deployment of novel fish driving and removal technologies such as low dose piscicides, complex noise generation, etc.

RESPONSE PROJECTS

eDNA Detection Response – Bubbly Creek

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Claire Snyder, Dan Roth (Illinois Natural History Survey)

Participating Agencies: Illinois Department of Natural Resources (lead); Illinois Natural History Survey; United States Army Corporation of Engineers; United States Fish and Wildlife Service (field support); US Coast Guard (waterway closures when needed); United States Geological Survey (flow monitoring when needed); Metropolitan Water Reclamation District of Greater Chicago (waterway flow management and access); and United States Environmental Protection Agency and Great Lakes Fishery Commission (project support)

Pools Involved: CAWS

Introduction and Need:

The U.S. Fish and Wildlife Service Whitney Genetics Lab found an increased number of positive Bighead Carp and Silver Carp environmental DNA (eDNA) detections during their October 8-10, 2019 sampling of the Chicago Area Water System (CAWS) above the Electric Dispersal Barrier. Collected water samples indicated that of the 414 samples, 49 were found to be positive for Silver Carp eDNA and 27 were found to be positive for Bighead Carp eDNA (Figure 1).

Detections followed a thorough and extensive multiple agency assessment of the CAWS looking for Bighead Carp and Silver Carp from September 9th to September 20th, 2019. No Bighead Carp or Silver Carp were found during that assessment. In addition, following ten consecutive years of intensive fish monitoring in the CAWS that included 1,425 hours of electrofishing, 701 miles of gill/trammel net, 11 miles of seine, 13 net pound net nights, 18 hoop net nights, and 175 fyke net nights one Bighead Carp and one Silver Carp have been captured.

Out of the abundance of caution, the Illinois Department of Natural Resources (IDNR) led the Asian Carp Regional Coordinating Committee (ACRCC) agencies in an intensive two-week sampling of the waters surrounding the eDNA detections in Bubbly Creek.

Objectives:

(1) Remove Asian carp from the CAWS upstream of the Electric Dispersal Barrier as warranted focusing on area where high rates of positive eDNA detections.

(2) Determine Asian carp population abundance through intense targeted sampling efforts at locations deemed likely to hold fish.

eDNA Detection Response – Bubbly Creek

Project Highlights:

- A two-week, multiagency response utilized the Incident Command System with guidelines set forth in the 2019 Monitoring Response Plan Upper Illinois River Contingency Response Plan.
- Dissolved oxygen levels were extremely low during sampling within the area where positive detections were located.
- No Bighead Carp or Silver Carp were captured or observed during the response.

Paired Electrofishing and Gill netting:

- Crews from the IDNR, USACE, USFWS and contracted fishers completed 152 paired electrofishing and gill netting samples
  - 14.6 hours of electrofishing
  - 17.3 miles of net
- Crews captured 85 individual fish representing 4 species and 1 hybrid group.

Electrofishing:

- Crews from the IDNR, USACE, USFWS completed 112 electrofishing runs at targeted and random sites (28 hours total).
- Crews captured 2,170 individual fish representing 25 species and 1 hybrid group

Gill/trammel netting:

- Contracted commercial fishers along with assisting IDNR biologist, set 10.3 km (6.4 mi) of gill net at targeted sites
- Crews captured 241 individual fish representing 5 species and 2 hybrids

eDNA Detection Response – Bubbly Creek

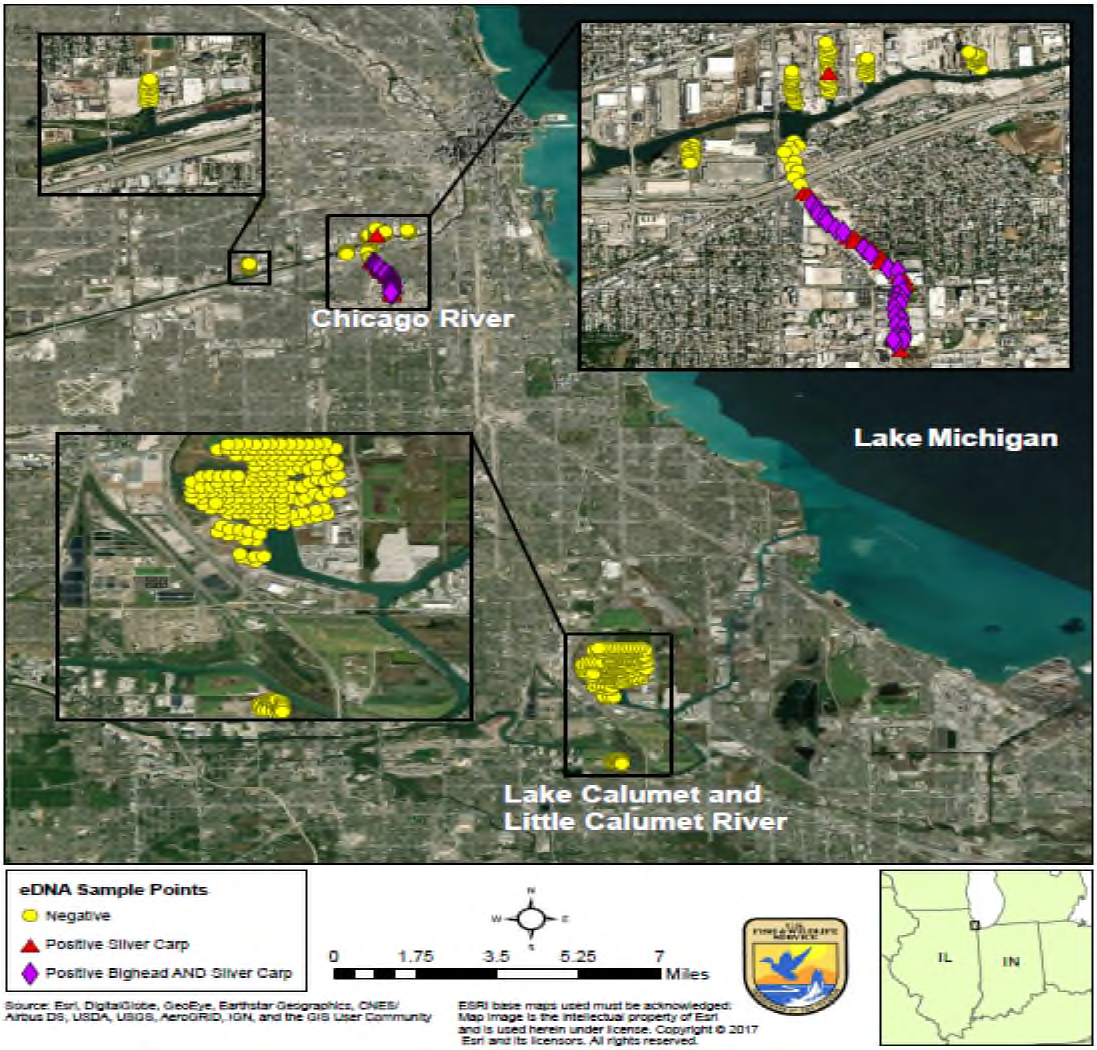

Figure 1. *Geographic locations of water collections and results of ensuing Bighead Carp and Silver Carp eDNA analysis.*

Methods:

Response actions for changes in the status of Asian carp in pools of the Illinois River are implemented following guidelines put forth in the Upper Illinois Waterway Contingency Response Plan in the 2019 Monitoring and Response Plan. Environmental DNA (eDNA) is typically not a trigger for a response, but due to the large number of detections found by U.S. Fish and Wildlife Service Whitney Genetics Lab, the response was treated as if a live fish had been detected above the Electric Dispersal Barrier.

The MRWG response team utilized the Incident Command System (ICS) to manage operations efficiently and ensure a standard approach across all participating agencies was used. ICS is a managerial system for integrating a combination of facilities, equipment, personnel, procedures, and communications within a common organizational structure to facilitate an efficient and effective response. Each response week was unique, but the basic concept of operations and objectives described within the Incident Action Plan (IAP) served as building blocks for internal and external communications of the objectives, strategies, and tactics during response. At the core of the IAP were well-written objectives that are (1) Specific, (2) Measurable, (3) Achievable, (4) Realistic, and (5) Task-oriented otherwise known as “SMART” objectives.

Description of Capture Gears — Pulsed DC-electrofishing, gill nets, and block net were used in an attempted to capture any Bighead Carp and Silver Carp during the eDNA response. Gill nets were 3.0 m (10.0 ft) deep x 91.4 m (300.0 ft) long with bar mesh sizes ranging from 82.6-101.6 mm (3.25-4.0 in). Block net was 9.1m (30.0 ft) deep x 152.4 m (500.0 ft). Pulsed DC-electrofishing boats followed gear standards described by Ratcliff (2017).

Random and Targeted Site Sampling- Random sampling sites were generated using a Geographic Information System (GIS) software within a 10-mile area in and surrounding Bubbly Creek and distributed prior to the start of the event. Targeted site locations were selected while in the field by agency biologist or contract fisherman in areas deemed to potential hold Bighead Carp or Silver Carp and safety criteria were met to deploy gear within that same 10-mile area. GPS coordinates (decimal degrees) were recorded each sampling site during the response as well as a suite of water quality metrics including: Dissolved Oxygen (mg/l), Specific Conductivity (S/m) and water temperature (°C).

Paired Electrofishing and Gill netting Protocol— Agency electrofishing crews and contracted fishing crews collaboratively monitor for the presence of Bighead Carp and Silver Carp at targeted sites. Electrofishing crews consisted of a pilot and two dip-netters and contracted fishing crews were made up of a capitan, deckhand and agency biologist. Contracted fishing crews deployed a series of gill nets in short term sets (e.g., 10-30 minutes). Fish were drove into deployed gill nets using noise (e.g., plungers on the water surface, pounding on boat hulls, or revving trimmed up motors) and pulsed DC-electrofishing. Pulsed DC electrofishing used 60 Hz with 25% duty and a uniform base power goal of 3,000 watts. Power goals (in watts) were calculated based off specific conductivity (micro siemens per centimeter) and temperature (in degrees Celsius) to ensure potential transfer of watt from water to fish was 3,000 watts. Captured fish were identified to species, enumerated, and released.

Electrofishing Protocol – Each pulsed DC-electrofishing boat consisted of one pilot and two dip-netters to collect fish sampling at targeted and random sites. Electrofishers used a standardized pulse rate of 60 Hz with 25% duty with a uniform base power goal of 3,000 watts as described in the paired sampling protocol. Adult Common Carp were counted without capture and all other fish were netted, placed in a holding tank, identified, counted, and returned live to the water. Due to similarities in appearance and habitat use, young-of-year Gizzard Shad < 152.4 mm (6 in.) in total length were examined closely for the presence of young of year Bighead Carp and Silver Carp and enumerated.

Gill Netting Protocol – Contracted commercial fishers used gill nets at targeted sites. Sets were of short duration and utilized noise (e.g., plungers on the water surface, pounding on boat hulls, or revving trimmed up motors, electrofishing driving) to drive fish into the net similar to methods described in the pairing fishing protocol. Captured fish were identified to species, enumerated, and released.

Results and Discussion:

The Bubbly Creek eDNA detection response event took place during the weeks of November 4th and November 11th, 2019 upstream of the Electric Dispersal Barrier. No Bighead or Silver carp were captured or observed during Operation Bubbly Creek. Effort for this response consisted of 42.6 hours of electrofishing (112 transects and 152 paired samples) with an estimated 540 person-hours, 40 km (23.7 miles) of trammel/gill netting (208 sets) with an estimated 900-person hours. An estimated 1,260-person hours were allocated for the field operations of this event (Table 1). Across all locations and gears, 2,496 fish representing 27 species and 2 hybrid groups were sampled (Table 2). Gizzard Shad and Common Carp were the predominant species, comprising 64% of all fish sampled. Four nonnative species were also sampled, which included Common Carp and hybrids, Round Goby, Goldfish, and Tilapia.

Non-native species made up 31% of the total species collected during the operation. Seventy-five (75) Banded Killifish, a state threatened species, were also collected. They were identified and returned to the water alive. In addition, we examined 765 young of year (YOY) Gizzard Shad and found no YOY Asian carp

Recommendations:

The Bubbly Creek eDNA detection response event was the 2nd response event since Operation Silver Bullet (2017) utilizing the Upper Illinois Waterway Contingency Response Plan, and as a result, many lessons were learned. The Incident Command System used during this operation proved, once again, to be a great asset in tracking resources and promoting communication throughout the event. Constant refinement of the contingency response plan is needed as work continues to further our understanding of the Asian carp habits, our knowledge of the upper Illinois Waterway, and incorporate additional resources for future responses. Continued yearly table top exercises conducted by the Monitoring and Response Workgroup will prove to be beneficial in the planning and execution of future response events. We also recommend that the Upper Illinois Waterway Contingency Response Plan continued to be used as a guide when developing a response action following a change in the status of Asian carp within the Illinois River Waterway.

Table 1. *Total effort and number of fish captured with electrofishing and gill nets during the Operation Bubbly Creek.*

Electrofishing Effort	
Estimated person-hours	540
Samples (transects)	112
Paired samples	152
EF (hrs)	42.6
Electrofishing Catch	
All fish (*N*)	2170
Species (*N*)	27
Hybrids (*N*)	2
Bighead Carp (*N*)	0
Silver Carp (*N*)	0
CPUE (fish/hr)	51
Netting Effort	
Estimated person-hours	900
Samples (net sets)	208
TRA/GIL (mi)	23.7
Netting Catch	
All fish (*N*)	326
Species (*N*)	5
Hybrids (*N*)	2
Bighead Carp (*N*)	0
Silver Carp (*N*)	0
CPUE (fish/100 yds of	1.3

Table 2. *Total number of fish captured with electrofishing and trammel/gill nets during Operation Bubbly Creek Bullet, 2019.*

Species	Gill Net	Electrofishing
Banded killifish	0	75
Bullhead minnow	0	4
Black bullhead	0	3
Brook silverside	0	1
Bluegill	0	200
Buntnose minnow	0	64
Common carp	297	453
Carp x goldfish hybrid	1	0
Emerald shiner	0	32
Freshwater drum	1	0
Goldfish	25	2
Golden Shiner	0	122
Green sunfish	0	25
Gizzard shad	0	88
Gizzard shad < 6 in	0	765
Hybrid sunfish	0	1
Largemouth bass	1	250
Pumpkinseed	0	40
Pumpkinseed x	0	0
Bluegill hybrid	0	1
Rainbow trout	0	1
Round goby	0	1
Rock bass	0	2
River shiner	0	1
Spotfin shiner	0	21
Smallmouth bass	0	4
Sand shiner	0	1
Tilapia	0	1
Walleye	0	3
White sucker	1	4
Yellow bullhead	0	5
Total per gear type	326	2170
Total		2496

APPENDICES

Appendix A: Using Zooplankton to Measure Ecosystem Responses to Asian Carp Barrier Defense and Removal in the Illinois River

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David P. Coulter (Southern Illinois University)

Participating Agencies: Illinois Natural History Survey (lead), Southern Illinois University (lab support)

Pools Involved: Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, and La Grange

Introduction:
Due to their ability to efficiently filter large volumes of water and capture small particle sizes, Bighead Carp and Silver Carp can deplete zooplankton densities and alter zooplankton community composition (Spataru and Gophen 1985, Burke et al. 1986, Xie and Yang 2000, Lu et al. 2002), potentially competing with native fishes for food resources (Schrank et al. 2003, Sampson et al. 2009) and altering flows of organic matter (Collins and Wahl 2017). The trophic impact of Asian carp is of great concern because of the importance of zooplankton as grazers as well as prey for fish early life stages and native planktivores (Cushing 1990, Carpenter et al. 1985, Sampson et al. 2009). The potential impacts that Asian carp could have on Great Lakes fisheries poses a substantial risk to recreational and commercial fisheries economies of several states, provinces, and tribes. Due to these risks, an aggressive Asian carp removal strategy has been implemented in the Illinois Waterway to limit further advances of Asian carp towards Lake Michigan. In addition to aiding in preventing the expansion of Asian carp towards the Great Lakes, this removal program may also benefit native fish assemblages in the Illinois Waterway by reversing some of the ecological impacts that Asian carp have had on this system. Asian carp are known to have depressed the abundance of crustacean zooplankton taxa in the Illinois River (Sass et al. 2014, DeBoer et al. 2018), and targeted removals may help aid in the recovery of historical zooplankton abundances. Because of their rapid life cycles, zooplankton taxa have the potential to quickly respond to Asian carp removal, thereby providing an immediate assessment of whether or not sufficient numbers of fish have been removed to allow for ecosystem recovery. This project will develop specific zooplankton-bases assessment metrics to quantitatively evaluate the extent to which the removal strategy is working to reverse ecosystem impacts from Asian carp in the Illinois Waterway. This work will help inform management agencies regarding ecosystem responses to Asian carp removals and define explicit targets for evaluating the outcome of Asian carp control efforts.

Appendix A: Using Zooplankton to Measure Ecosystem Responses to Asian Carp Barrier Defense and Removal in the Illinois River

Objectives: Zooplankton are being sampled throughout the Illinois Waterway to:

(1) Assess zooplankton abundance, biomass, and community composition in the Illinois Waterway through time;

(2) Assess the magnitude and time lag for ecosystem responses to past and ongoing Asian carp removal operations; and

(3) Compare current zooplankton abundances, body size distributions, and biomass with targets derived from pre-invasion conditions to develop a stoplight assessment tool for evaluating the outcome of Asian carp control and removal efforts.

Project Highlights:

- A total of 151 zooplankton samples were collected from the Illinois Waterway during 2019. The data derived from these samples, and associated water chemistry data, will be incorporated into the long-term data set of zooplankton assemblages in the Illinois Waterway.
- Preliminary analyses of potential zooplankton performance metrics revealed that June densities of *Bosmina* are more sensitive to Asian carp density than cyclopoid copepod, *Brachionus*, *Keratella*, and *Polyartha* densities during the same month. A model incorporating Asian carp density, dissolved oxygen concentration, and water temperature explained 65 percent of the observed variance in June *Bosmina* densities.
- Once all potential performance metrics have been evaluated across all months of available data, observed environmental conditions and Asian carp densities will be used to calculate expected densities of key zooplankton taxa when Asian carp densities are reduced to a target density. The difference between these target predictions and the observed densities of the performance metric will be compared to the residuals from the model that used observed Asian carp density to assess whether Asian carp removals have met management targets for zooplankton recovery.

Methods:

Field sampling for assessment of zooplankton trends took place biweekly from April to October of 2019 at established sites to maintain consistency and data comparability. Zooplankton were collected by obtaining vertically-integrated water samples using a diaphragmatic pump. At each site, 90 L of water was filtered through a 55 μm mesh to obtain crustacean zooplankton and 10 L of water was filtered through a 20 μm mesh to obtain microzooplankton. Organisms were transferred to sample jars and preserved in either Lugols solution (4%; for macrozooplankton) or buffered formalin (10%; for rotifers). Data on environmental factors known to influence zooplankton communities in large rivers (temperature, dissolved oxygen concentration, turbidity, chlorophyll a, total phosphorus concentration) was also collected on each sampling site visit. In the laboratory, individual organisms were identified to the lowest possible taxomomic unit, counted, and measured using a digitizing pad. Zooplankton densities were calculated as the number of individuals per liter of water sampled. Biomass was calculated using standard length-mass regressions for each taxa.

Initial analyses were conducted to evaluate the influence of Asian carp densities and environmental factors in different navigation pools on five potential performance metrics: mean June densities of *Bosmina* sp., cyclopoid copepods, *Polyartha* sp., *Brachionus* sp., and *Keratella* sp. June densities were chosen for initial examination because this is an ecologically important time in the Illinois River when there are seasonally high densities of zooplankton and larval fish, and these taxa were selected because of their numerical importance in main-channel river environments (Reckendorfer et al. 1999; Kim and Joo 2000; Wahl et al. 2008; Chick et al. 2010; Burdis and Hoxmeier 2011). Analyses used data from 2012-2018 collected at monitoring sites representative of the Dresden Island (Channahon), Marseilles (Morris), Starved Rock (Ottawa), Peoria (Henry), and LaGrange (Havana) navigation pools. Asian carp density estimates were generated by annual hydroacoustic surveys conducted each October by Southern Illinois University – Carbondale. Reliable Asian carp density estimates were not available for the Peoria and LaGrange pools in 2018 and so these pool-year combinations were not used in the analyses. Discharge data for each pool was obtained from upstream USACE gages located at the Dresden Island, Marseilles, and Starved Rock Lock and Dam. Data from the USGS gage at Kingston Mines (USGS 5568500) was used for LaGrange Pool flow rates. A reduced maximum likelihood approach was used to model mean June density of each zooplankton taxa at each sampling station. Repeated measures models with sampling station as the repeatedly sampled unit and compound symmetric covariance structure were used. We initially assessed whether adding mean June values for water temperature, discharge, dissolved oxygen concentration, or a combination of these variables improved model fit from a base model with only Asian carp density. However, carp density was correlated with June flow rate ($r = + 0.47$, $P = 0.01$). Therefore, to avoid collinearity issues in the analysis, flow rate was dropped as a factor in the model set. Akaike's information criteria corrected for small sample bias (AIC_c; Anderson 2008) was used as the basis of our model comparisons, with models within two AIC_c units considered to have similar support. A null model (i.e., intercept only) was also included for comparison to assess whether there was meaningful support for any of the models in the set. Adjusted coefficients of determination were calculated as a measure of model fit for the most supported models and to compensate for potential overfitting from adding multiple explanatory factors.

Results and Discussion:

During 2019, a total of 151 zooplankton samples were collected from the Illinois Waterway. The data derived from these samples, and associated water chemistry data, will be incorporated into the long-term data set of zooplankton assemblages in the Illinois Waterway. Analyses of potential zooplankton performance metrics revealed that June densities of *Bosmina* are more sensitive to Asian carp density than cyclopoid copepod, *Brachionus*, *Keratella,* and *Polyartha* densities during the same month. The most supported cyclopoid model did not explain much variation (adjusted $R^2 = 0.29$) and most model parameters were not significant ($P > 0.05$). June densities of the three rotifer taxa were even less responsive to Asian carp than cyclopoids, with the most supported model for each taxa explaining only 10% or less of observed variation. Mean June density of *Bosmina*, however, does show some initial promise as a performance metric for assessing the effects of Asian carp removal. A model including Asian carp density, dissolved oxygen concentration, and water temperature was the most supported by the data (Table 1) and explained over half of the observed variance (model: $F_{1,26} = 51.96$, $P < 0.0001$, adjusted $R^2 = 0.65$; intercept = 73.47 ± 21.37, t = 3.44, df = 22.4, $P = 0.002$; Asian carp density = -0.79 ± 0.26, t = -3.01, df = 7.83, $P = 0.02$; water temperature = -19.27 ± 6.14, t = -3.14, df = 22.5, $P = 0.005$; dissolved oxygen = -6.36 ± 1.58, t = -4.03, df = 23.1, $P = 0.0005$). June density of *Bosmina* appeared to exhibit a threshold-like response to Asian carp density, declining rapidly once Asian carp abundance increased above approximately 0.37 Asian carp / 1000 m^3 (Figure 1).

The observed relationship between *Bosmina* density and Asian carp density is consistent with previous observations of negative associations between Asian carp relative abundance and cladoceran abundances in the Illinois River (Sass et al. 2014). However, rotifer abundances in the Illinois River have also been found to be positively associated with Asian carp abundance, potentially due to release from competition or predation by larger-bodied crustacean zooplankton (Sass et al. 2014), but the analyses of 2012-2018 data found that Asian carp density accounted for very little of the variation in densities of rotifer taxa. This discrepancy could be due to the narrow time frame that was used in the current analyses, with zooplankton densities typically being high during the month of June (Wahl et al. 2008), potentially masking some of the effects of grazing by Asian carp. Previous analyses have indicated considerable spatiotemporal variation in zooplankton assemblage composition, density, and biomass within the Illinois Waterway, likely driven by seasonal environmental variation and spatial differences in temperature, water chemistry, and hydrology, as well as varying Asian carp densities. Further investigation of these and other zooplankton taxa across all months of available data will be necessary to better separate the influences of environmental factors from both long- and short-term chances in Asian carp densities and to establish which zooplankton taxa provide the most informative metrics for assessing the impact of Asian carp removal on ecosystem recovery. Earlier comparisons also indicate that backwaters may experience greater fluctuations in zooplankton densities than main channel sites where Asian carp are established. Because backwaters are known to contain high densities of Asian carp relative to main channel habitats, and are often the focus of removal efforts, further examination of backwater zooplankton metrics in association with Asian carp abundance may reveal different relationships than at main channel sites.

Table 1. *Relative support for five models of June Bosmina sp. density, including a null model that only includes an intercept variable. Models are ranked by relative support within the considered model set using corrected AIC scores (AIC_c), with Δ the difference between model AIC_c score and the score of the model most supported by the data (i.e., lowest AIC_c score). Adjusted R^2 reports the amount of variance explained by the most supported model.*

June *Bosmina* density model	AIC_c	Δ	adjusted R^2
null	137.5	28.9	
Asian carp density	131.5	22.9	
Asian carp + water temperature	124.2	15.6	
Asian carp + dissolved oxygen	122.4	13.8	
global model	108.6	0	0.65

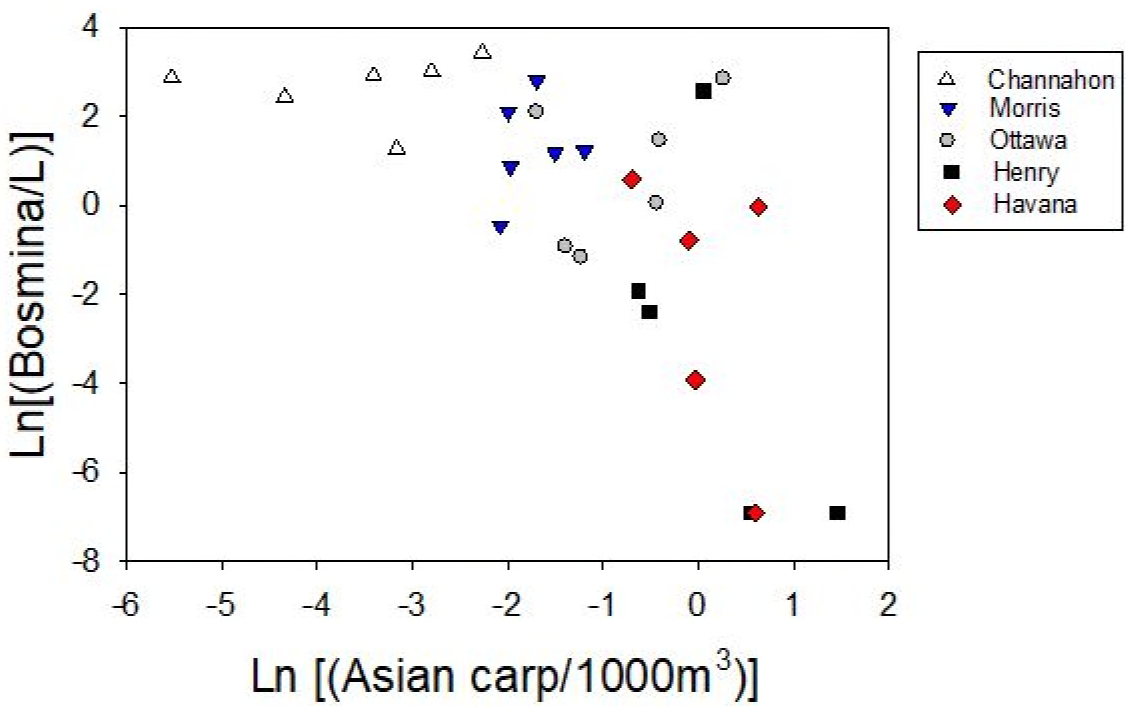
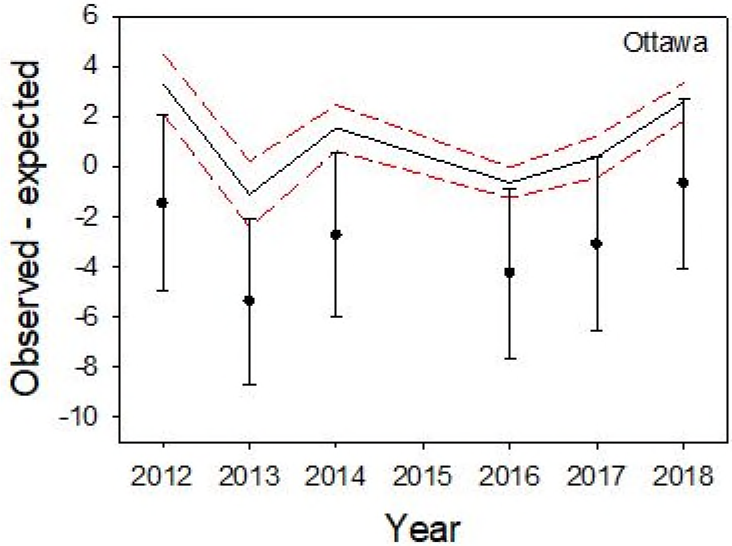


Figure 1. *Mean June density of Bosmina sp. density versus Asian carp density in five navigation pools of the Illinois Waterway during 2012-2018. Collection location for each zooplankton density estimate is identified by symbol type and color. Asian carp density is estimated in October for navigation pools containing each collection location.*

Recommendations:

Continued monitoring and analyses of zooplankton data from the Illinois Waterway will assess the influence of environmental factors known to affect zooplankton communities in large rivers (turbidity, chlorophyll *a*, total phosphorus, temperature, discharge), as well as the effect of Asian carp densities in different pools of the Illinois Waterway. Future analyses should expand these investigations to additional zooplankton taxa and other months to identify which metrics prove most informative for assessing the impact of Asian carp removals. Nonlinear functions should also be assessed to evaluate the type of relationship that best fits the observed data. If June *Bosmina* density remains one of the more informative performance metrics, observed environmental conditions and Asian carp densities at a given site would be entered into the model to calculate the difference between observed and expected densities of *Bosmina* sp. and 1.5 standard error intervals around these residuals. Then the same model and environmental conditions would be used to predict the density of *Bosmina* sp. if Asian carp had been reduced to a goal density, and the difference between these target predictions and the observed *Bosmina* densities will be compared to the residuals obtained from the model that used observed Asian carp density. If the target interval (i.e. goal Asian carp density prediction residuals ± 1.5 SE) overlaps the limits based on the observed carp density, Asian carp removal at this site would be concluded to have met the management target for zooplankton recovery (see Figure 2 for an example using the lowest observed Asian carp density from the Dresden Island Pool as a management target). Changes in Asian carp density through time within pools, particularly the substantial declines in the Starved Rock, Marseilles, and Dresden Island pools due to targeted removal efforts in recent years, will be useful for evaluating the utility of any identified performance metrics. As Asian carp harvest is expected to accelerate in the Peoria Pool, continued collection of zooplankton samples will be needed to evaluate if these removal efforts are meeting management targets for reversing the ecosystem effects of planktivorous Asian carp. Identified performance metrics will also provide a simple means of communicating the ecosystem responses of harvest efforts to a general audience (e.g., policy makers and the general public).



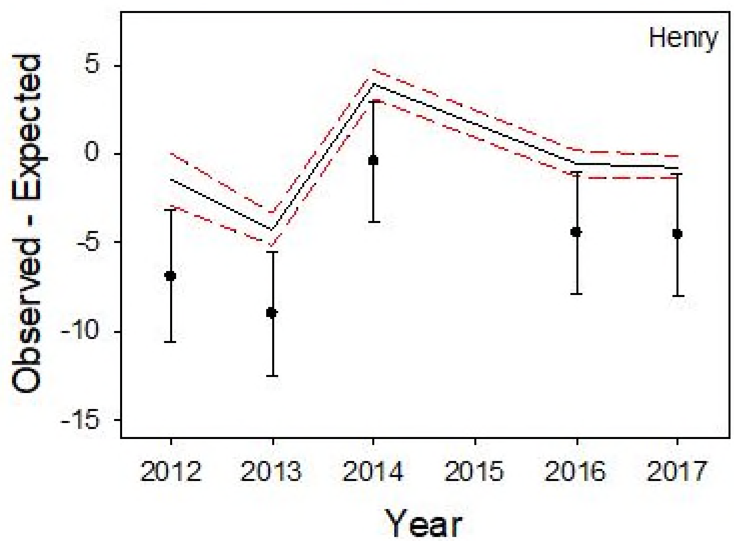


Figure 2. *Illustration of zooplankton assessment approach (see Trexler and Goss 2009 for more details on this method) using June Bosmina sp. density as a performance metric (PM) for the Ottawa (Starved Rock navigation pool) and Henry (Peoria navigation pool) sites. Solid black lines represent deviances between observed and model-predicted PM values under observed Asian carp densities and dashed red lines are 1.5 standard error intervals (control limits). Deviances between model-predicted and observed PM values if target Asian carp density is used in the model are plotted as circles ± 1.5 standard error. For the purposes of illustration, the lowest Asian carp density observed during the modelling period (0.003 fish/1000m^3; Dresden Island navigation pool) was used as the management target. Years where target intervals and control limits overlap would represent scenarios when management targets have been met for recovery of zooplankton abundance.*

Appendix A: Using Zooplankton to Measure Ecosystem Responses to Asian Carp Barrier Defense and Removal in the Illinois River

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