INTERIM SUMMARY REPORT

Invasive Carp Monitoring and Response Plan

2021

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EXECUTIVE SUMMARY

This Invasive Carp Interim Summary Report (ISR) was prepared by the Monitoring and Response Work Group (MRWG) and released by the Invasive Carp Regional Coordinating Committee (ICRCC). 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 invasive carp from establishing populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Specifically, this document is a compilation of the results of 21 projects, each of which plays an important role in preventing the expansion of the range of invasive carp, and in furthering the understanding of invasive 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 2021and provides recommendations for next steps for each project.

This ISR builds upon prior plans developed annually since 2011. This 2021 ISR serves as a record of activities and accomplishments by MRWG agencies during 2021. The MRWG has also completed a companion document, the 2022 Invasive Carp Monitoring and Response Plan (MRP). The 2022 MRP presents each project's plans for activities to be completed in 2022. The MRP is intended to function as a living document and will be updated at least annually. In conjunction, the 2022 MRP and 2021 ISR present a comprehensive accounting of the projects being conducted to prevent the establishment of invasive 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 "invasive 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 "invasive carp" moniker are Bighead Carp (*Hypophthalmicthys nobilis*), Silver Carp (*Hypophthalmicthys molitrix*), Grass Carp (*Ctenopharyngodon idella*), and Black Carp (*Mylopharyngodon piceus*).

All ISRs to date, including the 2021 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 invasive 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 invasive carp in the CAWS, and use this information to inform response and removal actions;

(2) Removal of any invasive 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 invasive carp from moving into the CAWS;

(4) Determination of the leading edge of major invasive 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 invasive carp could become established in the Great Lakes.

In keeping with the overall goal and strategic objectives, the 2021 results for 21 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 invasive carp to guide response and control actions.

(2) **Management and Control:** Prevent upstream passage of invasive 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 invasive 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 2021.

DETECTION PROJECTS

***Seasonal Intensive Monitoring (SIM) in the CAWS* –** This project focuses on conducting two high-intensity monitoring events for invasive 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 invasive carp or invasive carp eDNA.

- Completed two, 2-week SIM events with conventional gears in the CAWS upstream of the EDBS in 2021.
- No Silver Carp or Bighead Carp were captured or observed in 2021. One Bighead Carp was captured in Lake Calumet in 2010, and one Silver Carp was captured in the Little Calumet River in 2017 with no other captures or observations in any other year.
- An estimated 1,350 person-hours were spent completing 136.0 hours of electrofishing, setting 141.1 km (87.7 mi) of gill net, and 2.9 km (1.8 mi) of commercial seine in 2021.
- Across all locations and gears, 30,945 fish were sampled representing 55 species and 5 hybrid groups in 2021.
- An estimated 38,522 person-hours have been spent to complete 1.457.3 hours of electrofishing and setting 1439.1 km (894.2 mi) of gill/trammel net, 22.0 km (13.7 mi) of commercial seine, and 114.2 net nights of tandem trap nets, hoop nets, fyke nets, and pound nets since 2010.

- From 2010-2021, a total of 513,609 fish representing 89 species and 9 hybrid groups were sampled
- Young-of-year (YOY) Gizzard Shad (*n*=130,164) were examined and no YOY invasive carp have been found since 2010.
- Non-native species (*n*=17) have been captured accounting for 15% of the total number of fish caught and 19% of the total species since 2010.

***Strategy for eDNA Sampling in the CAWS* –** This project continues environmental DNA (eDNA) monitoring in strategic locations in the CAWS that will be used to provide information on the location of invasive carp.

- USFWS staff collected 880 samples upstream of the EDBS.
- Positive detections were few and consistent with previous sampling years.

***Telemetry Monitoring Plan* –** This project uses ultrasonically tagged invasive carp and surrogate species to assess if fish are able to challenge and/or penetrate the EDBS or pass through navigation locks. Sampling Season was abbreviated this year due to constraints imposed by the pandemic.

- To date, the USACE has acquired 38.6 million detections from 776 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 was one passage of a Common Carp through the Lockport Lock and Dam.
- Invasive carp continue to be detected throughout the Dresden Island Pool with the majority of detections occurring near the Dresden Island Lock.
- Almost 76% the detected transmitters within Dresden Island Pool were detected at the Des Plaines and Kankakee rivers confluence within a given season. This location registered approximately 40% of all the detections in the pool for the year.

***USGS Telemetry Project* –** This project uses real-time acoustic telemetry receivers for detecting invasive 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.

- Five real-time receivers were deployed and maintained in the upper Illinois Waterway System in 2021.
- Maintained a system to alert key MRWG personnel of detections of bigheaded carp in areas of concern.
- Completed the quality assurance of the dataset to include data for the years 2012 through 2019. This expanded dataset was compiled from multiple agencies and cooperators through FishTracks data repository.

- Made several advances to the multistate movement model previously developed for invasive carp in this system.

Illinois Waterway Hydroacoustics)– 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 tracks were detected within the EDBS in four of seven hydroacoustic surveys.
- Fish abundances were low with a mean of 1.0 large fish targets detected per sur.ey (min = 0, max = 2 individual large fish targets, n = 7).
- Large fish abundance was greatest in Dresen Island Pool (187 large fish targets; 7.6 fish / 100,000 m^3) in September 2021, but declined in November and December. Large fish abundance in Brandon Road and Lockport pools remained fairly low and consistent from September – December, with no abnormal spikes in abundance or aggregations of large fish observed.

Early Detection of Bigheaded Carp in the Illinois Waterway – The overall objective of this project was to increase focused, species-specific, early detection sampling of small (≤ 153 mm TL) and large (> 153 mm TL) Silver Carp and Bighead Carp (bigheaded carp) in the upper IWW for the purpose of increasing certainty in the derived species distributions by reducing the potential for concluding carp are absent from areas where they are actually present. The information provided by this bigheaded carp-focused sampling is intended to aid ICRCC and MRWG agencies in evaluating the current invasion risk of bigheaded carp to the Great Lakes via the CAWS and provide information that may trigger CRP response actions when warranted. This project is an individual-focused bigheaded carp early detection effort that is intended to complement existing population and assemblage-focused monitoring efforts in the IWW such as SIM, MAM of the Illinois River for Decision Making, and hydroacoustic monitoring in the vicinity of the EDBS.

- No small-bodied Silver Carp or Bighead Carp were captured in Lockport, Brandon Road, or Dresden Island pools.
- No large-bodied Silver Carp or Bighead Carp were captured or observed upstream of their known invasion fronts. No bigheaded carps were captured above Brandon Road Lock and Dam.
- 12 large-bodied Silver Carp and 2 large-bodied Grass Carp (*Ctenopharyngodon idella*) were captured during 2021.
- In total, 586 electrofishing runs, 434 electrified dozer trawl, and 167 mini-fyke net sets were completed between March and November 2021.
- In total 58,657 individual fishes comprised of 90 species and 9 hybrid groups were captured.

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

- 508 ichthyoplankton samples were collected from seven sites from the Brandon Road to LaGrange navigation pools of the IWW during May – October 2021, capturing 5,524 invasive carp eggs and 992,765 invasive carp larvae. Two distinct bouts of invasive carp spawning were observed during 2021, associated with distinct increases in discharge and favorable water temperatures. Eggs were collected as far upstream as the Marseilles Pool. A single Grass Carp larvae was also collected in the Marseilles Pool and Silver Carp larvae were collected from the Starved Rock Pool during 2021. Overall numbers of invasive carp eggs and larvae observed during 2021 were very high relative to other recent study years.
- 264 ichthyoplankton samples were collected from Illinois River tributaries during 2021. No evidence of invasive carp reproduction was observed in the Kankakee, but eggs and/or larvae were collected from all other sampled tributaries. The timing and magnitude of reproduction varied among tributaries, but multiple spawning events with very high reproductive output were detected in LaGrange Pool tributaries. Post-gas bladder inflation Silver Carp collected from the Fox River in 2021 represent the first observance of invasive carp larvae older than this key developmental stage upstream of the Starved Rock Lock and Dam since 2015.
- Quantitative PCR screening was used in 2021 to prioritize samples that had a high probability of containing invasive carp eggs or larvae for rapid processing. Overall, 58 of the 220 samples that were subjected to qPCR screening were found to contain at least trace amounts of invasive carp DNA. The total number of invasive carp DNA copies in a sample was found to be a significant predictor of the presence of invasive carp eggs and/or larvae in the sample.

Invasive Carp Stock Assessment in the Illinois River/Management Alternatives – Bigheaded carp (Silver Carp and Bighead 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 2020.
- The ninth year of standardized monitoring of bigheaded carp densities was completed in 2020 from Alton – Dresden Island pools. These data allow for long-term assessments and comparisons of density trends across space and through time.
- Tagging of 188 adult bigheaded carp took place in Alton, LaGrange, and Starved Rock pools to maintain sufficient surveillance to detect adult movements among pools and towards the invasion front.

- Preliminary analysis of movement data indicates that Common Carp respond to similar environmental conditions as bigheaded carp, supporting the use of Common Carp as a surrogate for understanding bigheaded carp movement behavior.
- Bigheaded carp densities in Starved Rock, Marseilles, and Dresden Island pools were not completed due to COVID-related delay in processing capture data.
- Bigheaded carp densities in Alton pool during fall 2020 were similar to past years. La Grange and Peoria pool bigheaded carp densities in fall 2020 were slightly lower than previous years, excluding 2019, which was a flood year.
- 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–Dresden Island pools are also needed to monitor long-term population trends that act as an additional surveillance tool and can assist in making management decisions.

Des Plaines River and Overflow Monitoring – In 2020, sampling was conducted in the upper Des Plaines River from E Romeo Rd (Romeoville, Illinois) to Columbia Woods (Willow Springs, Illinois). 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).

- Capture 1,617 fishes in 2021 including 37 species and 2 hybrid groups from 7.75 hours of electrofishing and 548.6 m of gill netting.
- Collected 15,499 fish representing 67 species and 4 hybrid groups from 2011 – 2021 via electrofishing (89.25 hours) and gill netting (155 sets; 22,205.3 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 2021.
- Four overtopping events since 2011 have resulted in several improvements to the barrier fence. No overtopping events occurred in 2021.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring – This project focuses on sampling and removing invasive 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.

- 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 been removed from Chicago area ponds since 2008.
- One Bighead Carp was incidentally caught by a fisherman in a Chicago area pond in 2016.

- Eighteen of the 21 ILDNR Chicago Urban Fishing Program ponds have been sampled with nets and electrofishing.
- All eight Chicago area fishing ponds with positive invasive carp eDNA detections have been sampled with electrofishing and trammel/gill nets.
- The state record Bighead Carp weighing in at 72 pounds 8 ounces was captured on rod and reel at Humboldt Park Lagoon (Chicago) in 2021.

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 Invasive Carp population [SEICarP] 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 2021, an estimated 11,227 person-hours were expended sampling random sites downstream of the EDBS, including 174 hours of electrofishing, 1,368 hoop netting net nights, 449 minnow fyke netting net nights, and 91 fyke netting net nights.
- A total of 489,104 fish representing 128 species were captured in 2021.
- No invasive carp (large or small) were captured in Lockport or Brandon Road reaches in 2021.
- 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 Reach near the Rock Run Rookery) in 2021.
- Small Silver Carp (< 6 inches/152.4 mm) were captured in Peoria Reach (river mile 215; ~118 miles from Lake Michigan) in 2021. Same as 2020, 14 miles further upriver than 2019.
- Standardization of methods with projects outside of the MRWG MRP allowed those data to be incorporated creating a comprehensive synthesis of each invasive carp species' status across the entire Illinois River Waterway below the EDBS in 2021.

MANAGMENT AND CONTROL PROJECTS

USGS Invasive Carp Database Management and Integration Support – 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 invasive carp removal efforts, evaluations of management actions, and population modeling.

- Completed validation of hydroacoustic survey data (e.g., multi-beam and sidescan sonar), collected in priority management areas throughout the Illinois River and processed into a suite of benthic data layers.

- Completed tracking and activity data from boats and gear deployments into animated visualization overviews of Unified Method fishing events for several Dresden Island Unified Method events.
- Continued development of an online, interactive mapping tool as a centralized access point for existing invasive carp-related data layers.

Contracted Commercial Fishing Below the EDBS – This project uses contracted commercial fishers to reduce invasive 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 invasive carp abundance, we anticipate reduced migration pressure towards the EDBS, lessening the chances of invasive carp gaining access to upstream waters in the CAWS and Lake Michigan.

- Since 2010, contracted commercial fishers' effort in the upper IWW below the dispersal barrier includes 4,799 miles (7,723 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, 104,349 Bighead Carp, 1,327,020 Silver Carp, and 11,473 Grass Carp were removed by contracted fishers from 2010-2021. The total estimated weight of invasive carp removed is 5714.5 tons (11,429,000 lbs.).
- No invasive carp have been collected in Lockport or Brandon Road pools since the inception of this project in 2010.
- The leading edge of the invasive carp population remains near Rock Run Rookery in Dresden Island Pool (~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 invasive carp population in the upper Illinois River. Continued implementation of this project will provide the most current data on invasive carp populations at their leading edge and reduce pressure on the electric barrier system.

Barrier Maintenance Fish Suppression **–** This project outlines the monitoring, assessment, and clearing procedures utilized by the MRWG to take necessary precautions to prevent the passage of invasive carp into the Great Lakes.

- The project is ongoing. Clearing actions are determined on an as needed bases and few clearing actions have been required over the last few years due to the very low risk of invasive carp in the Lockport Pool.

Invasive Carp Population Modeling to Support an Adaptive Management Framework **–** This project involves the creation and refining/updating of the SEICarP model. This model is used to predict invasive 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 with an additional 13,000 fish from 2018 and 2019.

- Solicited critical feedback from quantitative experts including feedback on model assumptions, design, and analysis to promote model-based tool development and improvements and incorporated feedback and rerun model simulations.
- Model predictions indicated that additional lower pool mortality was a more effective long-term control strategy than additional upper pool mortality. Similarly, model results from scenarios that focused on upstream movement deterrence indicated that reduced passage immediately upstream of source populations was more effective than alternative sites located further upstream. Further, model simulations provide evidence that the most effective long-term strategy to manage Silver Carp is by using a combination of control methods. Larger reductions in Silver carp relative abundance were realized by combining upstream movement deterrence with additional mortality in lower and upper pools.
- Continued to work closely with MRWG technical work groups to prioritize future data collections and research using population model assumptions and limitations as a decision support tool.

Telemetry Support for the SEICarP Model – This project supports the SEICarP model by providing additional monitoring of invasive carp via telemetry. Movement is the backbone of the SEICarP 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 invasive 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 invasive carp movement in the IWW is necessary. This research provides an improved understanding of invasive carp movement in the IWW and its effects on population dynamics.

- Data from the five 69 kHz acoustic receivers were collected, processed, and provided to the Telemetry Work Group monthly.
- 100 V-9 acoustic transmitters were implanted into invasive carp, in March 2021, strategically across Peoria pool. Another 49 transmitters were implanted in invasive carp, by staff at SIU, in Alton pool during April 2021.
- Observed a 47% detection rate for the 100 invasive carp tagged in Peoria Pool this year from the six maintained receivers.

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

- Collected over 10,000 Silver Carp from six pools of the Illinois River during 2018 – 2021 sampling and processed nearly 1,700 aging structures.
- Contributed to the comprehensive invasive carp dataset using Silver Carp captured from six pools of the Illinois River with the electrified dozer trawl. Standardized data collections included: length, weight, age, sex, and relative abundance.

- Provided data useful to measure population responses to changes in management strategies (i.e., sex ratio, body condition, age and growth).
- Coordinated with the MRWG Monitoring Work Group to share age and maturity determination procedures.
- Spring 2021 sampling yielded a wide size distribution of fish nearing maturation improving the accuracy and precision of size at maturity estimates used in population modeling.
- Coordinated with the INHS to evaluate the accuracy of Silver Carp age estimates derived from postcleithra. Preliminary results suggested that postcleithra underestimate age.
- Evaluated how the electrified dozer trawl complements a large river multiple-gear sampling approach (e.g., Long Term Resource Monitoring, Multiple Agency Monitoring) with respect to fish community and invasive carp data collections. Preliminary results indicated that the electrified dozer trawl complemented a multiple-gear approach by effectively sampling pelagic species, including Silver Carp.

Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation – This project is a continuation of previous studies that investigated small fish entrainment, retainment, and upstream transport by commercial barge tows. The USFWS and partner agencies USACE and USGS have conducted several years of barge entrainment studies that demonstrate small fish can become entrained and retained in the box-to-rake junction of commercial tows (e.g., Davis et al., 2016). These previous studies illustrate the need for mitigation technologies capable of removing entrained small fish and, therefore, reducing the risk of upstream transport in the IWW.

- In this experimental invasive carp aquaculture pilot study, USFWS raised 1,190 invasive carp (Silver Carp, *Hypophthalmichthys molitrix*; Bighead Carp, *H. nobilis*; Grass Carp, *Ctenopharyngodon idella*) at the NGRREC in Alton, Illinois from <10 mm to 43 mm total length (TL; mean) with a mortality rate of ~90%
- USFWS has contracted additional raceway space at NGRREC and partnered with SIU to produce more invasive carp for the Barge Study in 2022.
- INHS has produced deployment guidelines that should provide a thorough overview of the considerations, planning, and procedures that are required to operate the modular barrier system. The modular electric barrier system should be available to partner agencies for use at locations where preventing passage of invasive carp or other invasive fishes has been determined to be a high priority, and where other deterrent measures are not sufficient or readily available to achieve desired objectives.

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

- ISU successfully investigated two separate merit release incidents where live aquatic species were illegally dumped into Illinois waterways. The individuals responsible were located and criminally charged. The markets selling the aquatic life were brought into compliance with regulations and the wholesale distributors of the products were identified. The species included: red swamp crayfish, tilapia, frogs, Asian swamp eels, American eels, goldfish, and soft-shelled turtles.

- ISU apprehended an Indiana fish hauler who illegally imported and stocked channel catfish into Illinois waters during three separate occasions. The fish hauler was not licensed to sell aquatic life in Illinois and knowingly imported the untested fish without VHS importation permits to increase his profit margins. The investigation revealed the fish were purchased from fish farms that raised fish for food purposes only. Other species of fish such as bluegill and shad were mixed in with some the fish deliveries

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

- Removed more than 3,300,000 pounds this program from the Peoria Pool of the Illinois River in 2021.
- Removed more than 6,725,000 pounds under this program from the Peoria Pool of the Illinois River since its inception in 2019.
- Entered into thirty-one contracts with Illinois-licensed commercial fishers targeting the Peoria Pool.
- Processed more than $332,000 in payments to fisherman.
- Preparation toward a launch event is well under way and is expected in 2022.

RESPONSE PROJECTS

Contingency Response Plan Actions – No response actions were necessary during 2021. As part of the Contingency Response Plan, barrier maintenance fish suppression is conducted to support USACE during maintenance operations at the EDBS. This process includes sampling to detect invasive 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 invasive carp presence at the EDBS at each primary barrier loss of power to water.
- Two 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 300 mm, but in low abundance.
- No invasive carp were captured or observed during fish suppression operations.

INTRODUCTION

The 2021 Interim Summary Report (ISR) presents a comprehensive accounting of project results from activities completed by the Invasive Carp Monitoring and Response Work Group (MRWG) in 2020. These projects have been carefully selected and tailored to contribute to the overall goal of preventing invasive carp from establishing self-sustaining populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Efforts to prevent the spread of invasive 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 invasive carp in the CAWS, and use this information to inform response removal actions;

(2) Removal of any invasive 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 invasive carp from moving into the CAWS;

(4) Determination of the leading edge of major invasive 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 invasive carp could become established in the Great Lakes.

The projects presented in this document represent the results of efforts undertaken during 2020 to further the implementation of each of these objectives.

BACKGROUND

The term "invasive 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 "invasive 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 "invasive carp" refers only to Bighead Carp and Silver Carp, except where otherwise specifically noted.

Invasive 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 invasive carp for food sources, thus limiting their population growth. In the early 1970s, invasive carp were intentionally imported to the US for use in aquaculture and wastewater treatment detention ponds. In these settings, invasive carp were used to control the growth of weeds and algae and pests. Flooding events allowed for the passage of invasive carp from isolated detention ponds to natural river systems. By 1980, invasive carp had been captured by fishermen in river systems in states including Arkansas, Louisiana, and Kentucky.

Flooding events during the 1980s and 1990s allowed invasive carp to greatly expand their range in natural river systems. invasive carp are currently wide spread in the Mississippi River basin, including the Ohio River, Missouri River, and Illinois River. Areas with large populations of invasive carp have seen an upheaval of native ecosystem structure and function. invasive 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 invasive carp populations throughout the central U.S. has had enormous impacts on local ecosystems and economies. Where invasive 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 invasive carp is in the range of billions of dollars per year. A central focus of governmental agencies is preventing the spread of invasive carp to the Great Lakes. Ecological and economic models forecast that the introduction of invasive carp to the Great Lakes could have enormous impacts.

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

PROJECT LOCATIONS

In an effort to more clearly depict the geospatial scale and focus of the projects included in the Monitoring and Response Plan (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	Lead Agency
	CAWS	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	La Grange	Alton			
Seasonal Intensive Monitoring in the CAWS										Detection	6	ILDNR
Strategy for eDNA Sampling in the CAWS										Detection	18	USFWS
Telemetry Interim Summary Report										Detection	22	USACE
USGS Telemetry Project										Detection	44	USGS
USGS Invasive Carp Database Management and Integration Support										Management and Control	109	USGS
Illinois Waterway Hydroacoustics										Detection	48	USFWS, Carterville FWCO, Wilmington Substation
Early Detection of Bighead Carp in the Illinois Waterway										Detection	54	USFWS, Carterville FWCO, Wilmington Substation
Contracted Commercial Fishing Below the Electric Dispersal Barrier										Management and Control	113	ILDNR, INHS
Upper Illinois Waterway Contingency Response Plan										Response	171	ILDNR, USFWS, USACE, USGS, INHS, GLFC, MWRDGC
Multiple Agency Monitoring of the Illinois River for Decision Making										Detection	94	ILDNR, INHS
Larval Fish Monitoring in the Illinois Waterway										Detection	64	INHS
Zooplankton as Dynamic Assessment Targets for Asian Carp Removal (Appendix A)										Not Applicable	A-1	INHS

Project	Illinois River Pool (Upstream --> Downstream)									Primary Purpose	Page Number	Lead Agency
	CAWS	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	La Grange	Alton			
Invasive Carp Stock Assessment in the Illinois River/Management Alternataives				↔	↔	↔	↔	↔	↔	Detection	77	SIU
Invasive Carp Population Modeling to Support an Adaptive Management Framework				↔	↔	↔	↔	↔	↔	Management and Control	132	USFWS Carterville FWCO
Invasive Carp Demographics				↔	↔	↔	↔	↔	↔	Management and Control	139	USFWS Carterville FWCO and USGS Upper Midwest Environmental Sciences Center
Telemetry Support for the Spatially Explicit Invasive Carp Population Model (SEICarP)						↔	↔			Management and Control	139	USFWS Carterville FWCO
Invasive Carp Enhanced Contract Removal Program							↔			Management and Control	169	ILDNR
Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation							↔	↔	↔	Management and Control	157	USFWS Carterville FWCO
Des Plaines River and Overflow Monitoring										Detection	83	USFWS Carterville FWCO
Alternative Pathway Surveillance – Urban Pond Monitoring										Detection	87	ILDNR
Alternative Pathway Surveillance in Illinois – Law Enforcement										Management and Control	166	ILDNR

DETECTION PROJECTS

Seasonal Intensive Monitoring in the CAWS

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Participating Agencies: ILDNR (lead); INHS, USFWS, USACE, and SIU (field support); USCG (waterway closures when needed), USGS (flow monitoring when needed); MWRDGC (waterway flow management and access); and USEPA and GLFC (project support).

Pools Involved: CAWS

Introduction and Need:

Detections of invasive carp (Silver Carp and Bighead Carp) eDNA upstream of the EDBS in 2009 initiated the development of a monitoring plan that utilized boat electrofishing and contracted commercial fishers to sample for invasive carp at five fixed sites upstream of the barrier. Random area sampling began in 2012 increasing the chance of detecting invasive carp in the CAWS beyond the designated fixed sites. Extensive sampling performed upstream of the EDBS from 2010 through 2013 resulted in one Bighead Carp being collected in Lake Calumet in 2010. Fixed site and random area sampling effort was then reduced upstream of the barrier to two SIM events from 2014-2021. Following effort reduction, one Silver Carp was collected in the Little Calumet River in 2017, resulting in a rapid, interagency contingency response effort. Effort reduction upstream of the EDBS allows for increased monitoring efforts downstream of the barrier. Increased sampling downstream of the EDBS focuses sampling effort at the leading edge (Dresden Island Pool) of the invasive carp population, which serves to reduce their numbers in that area, reducing the risk of individuals moving upstream towards the EBDS and Lake Michigan by way of the CAWS. Results from SIM upstream of the EBDS contribute to our understanding of invasive carp abundance in the CAWS and guide actions designed to remove invasive carp from areas where they have been captured or observed.

Objectives:

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

(2) Remove invasive carp from the CAWS upstream of the EDBS when warranted.

Project Highlights:

- Completed 2 two-week SIM events with conventional gears in the CAWS upstream of the EDBS in 2021.
- No Silver or Bighead Carp were captured or observed in 2021. One Bighead Carp was captured in Lake Calumet in 2010, and one Silver Carp was captured in the Little Calumet River in 2017 with no other captures or observations in any other years.
- An estimated 1,350 person-hours were spent completing 136.0 hours of electrofishing, setting 141.1 km (87.7 mi) of gill net, and 2.9 km (1.8 mi) of commercial seine in 2021.

- Across all locations and gears, 30,945 fish were sampled representing 55 species and 5 hybrid groups in 2021.
- An estimated 38,522 person-hours have been spent completing 1,457.3 hours of electrofishing and setting 1,439.1 km (894.2) of gill/trammel net, 22.0 km (13.7 mi) of commercial seine, and 114.2 net nights of tandem trap nets, hoop nets, fyke nets, and pound nets since 2010.
- From 2010-2021, a total of 513,609 fish representing 89 species and 9 hybrid groups were sampled.
- Young-of-year Gizzard Shad (*n*=130,164) were examined and found no YOY invasive carp were found when sampling from 2010-2021.
- Non-native species (*n*=17) have been captured accounting for 15% of the total number of fish caught and 19% of the total species since 2010.

Methods:

Pulsed DC-electrofishing, gill nets, and commercial seine, were used to monitor for invasive carp in the CAWS upstream of the EDBS in 2021 (Figure 1). In previous years, trammel nets, deep

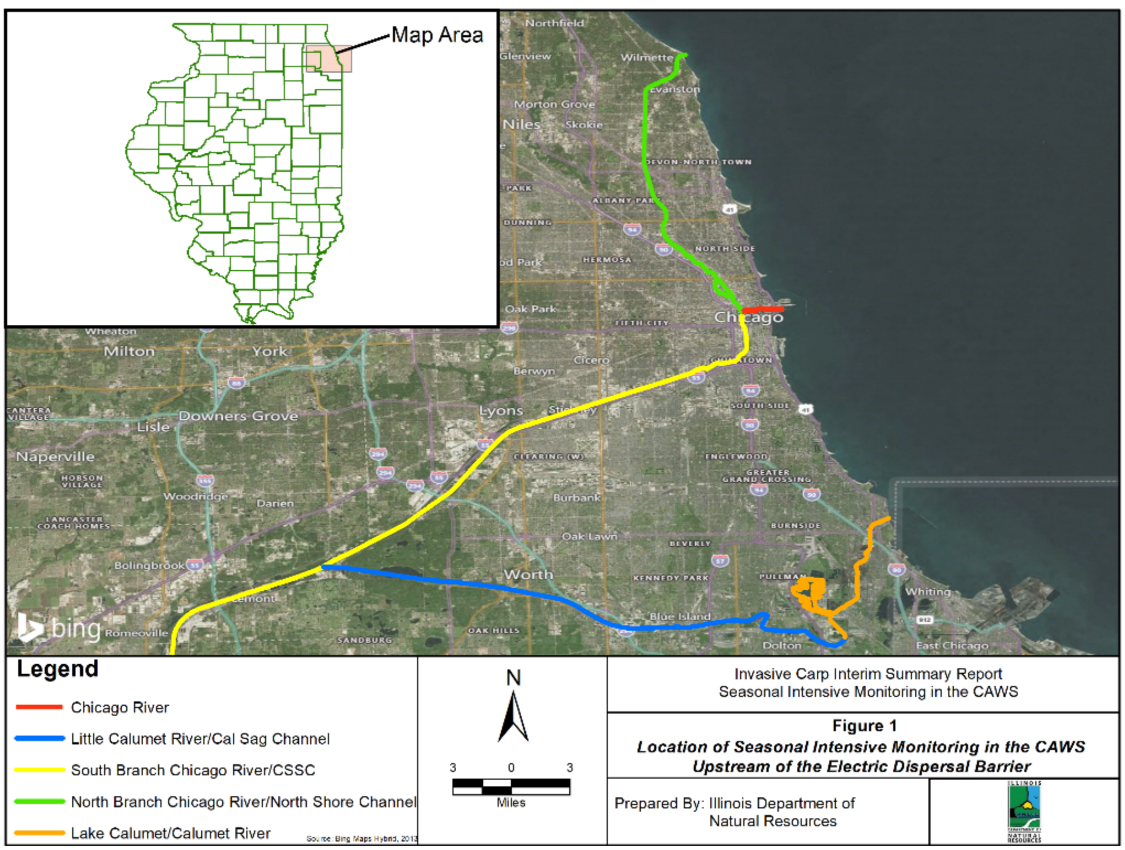

Figure 1. *Location of SIM in the CAWS upstream of the Electric Dispersal Barrier.*

water gill nets, fyke nets, and pound nets were used. Those gear specifications can be found in prior ISRs.

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 2021 Monitoring and Response Plan. Decontamination protocols for followed pulsed-DC electrofishing, and netting can also be found in the 2021 Monitoring and Response Plan. For detailed information on protocols for decontamination, please see previous ISRs.

Results and Discussion:

Previously, SIM took place during the months of June and September. In 2021, SIM took place during the weeks of May 17th, May 24th, October 4th, and October 11th to coincide more closely with eDNA sampling, allowing a more immediate inter-agency response in the event of elevated results. With the change in sampling months, a non-metric multidimensional scaling (NMDS) analysis was used to visually compare community composition across years (Figure 2). NMDS results showed that fish communities were relatively like one another despite different sampling periods, suggesting that changing the sampling period does not have an impact on our ability to detect community changes.

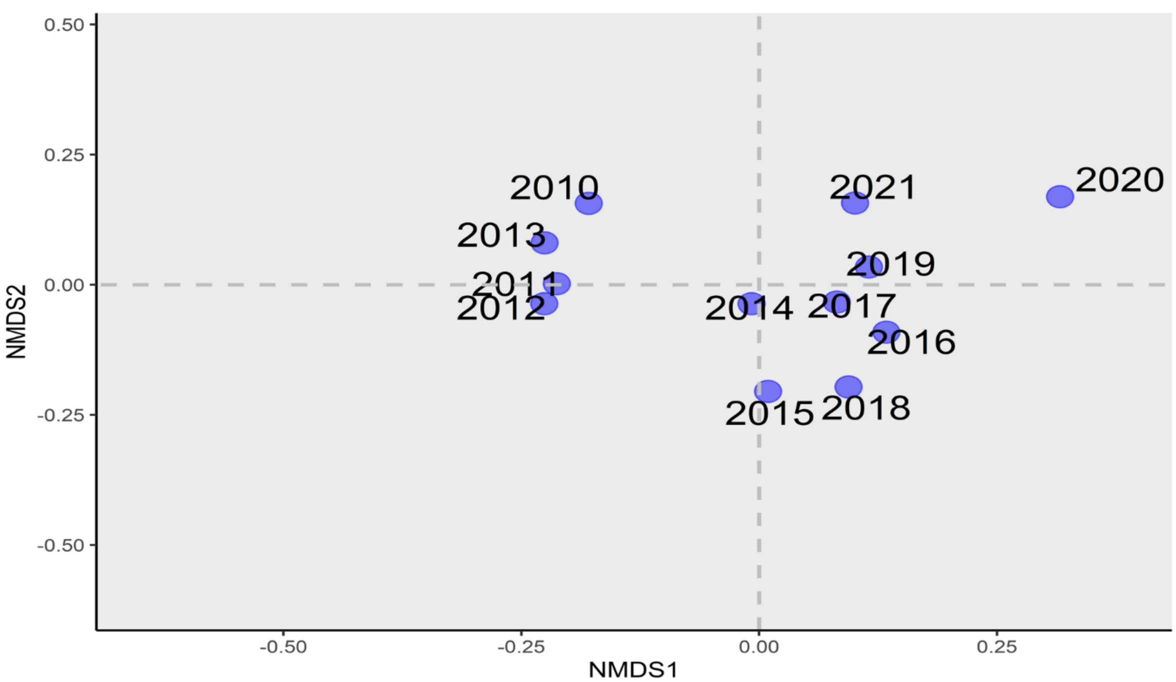

Figure 2. *Non-metric multidimensional scaling (NMDS) analysis comparing community composition across the years, 2010-2021.*

In 2020, sampling effort was nearly all netting (with doubled netting effort), due to agency capabilities during COVID-19. In 2021, we transitioned back to electrofishing and netting to align with effort prior to 2020. To continually focus monitoring effort on the leading edge of the invasive carp population below the EDBS, the same reduced sampling effort protocol established in 2014 upstream of the barrier (CAWS) was followed in 2021 (Figure 3). Effort in 2021 was 136.0 hours of electrofishing (592 transects) requiring an estimated 1,350 person-hours, 141.1 km (87.7 mi) of gill netting (772 sets) utilizing an estimated 2,070 person hours, and 2.9 km (1.8 mi) of commercial seine with an estimated 210 person hours (Table 1).

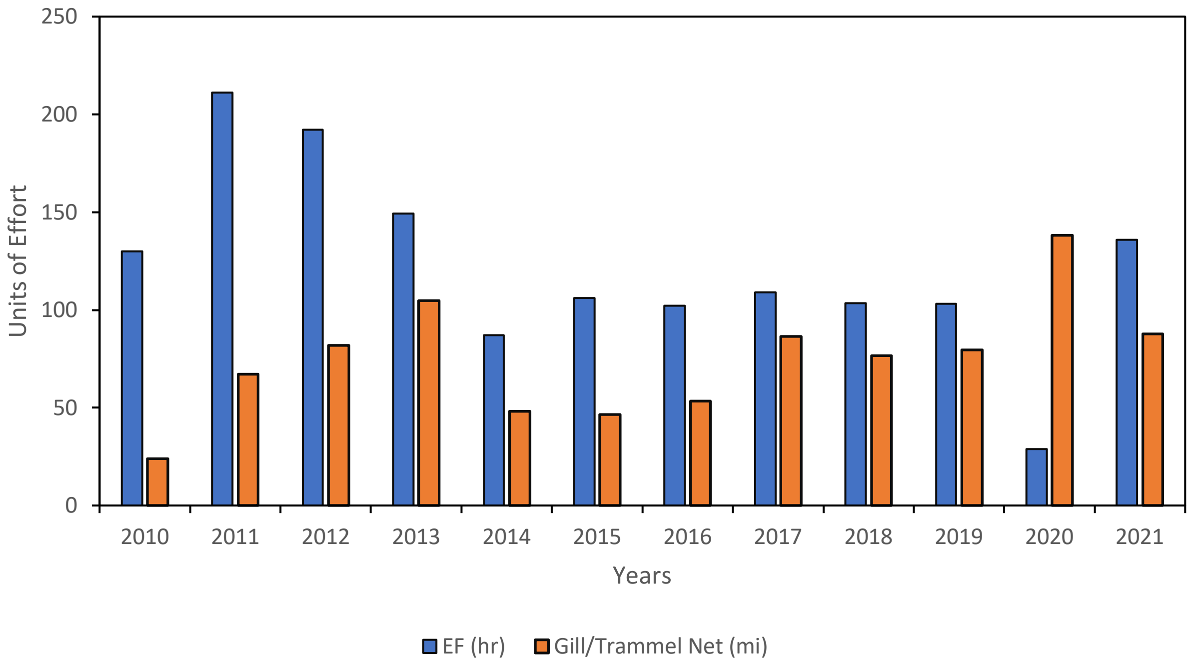

Figure 3. *Total electrofishing and trammel/gill netting effort at fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier System, 2010-2021.*

Across all locations and gears, 30,945 fish representing 55 species and 5 hybrid groups were sampled in 2021 (Table 2). Gizzard Shad and Largemouth bass were the predominant species, comprising 45% of all fish sampled. Seven non-native species were sampled, which included Common Carp and hybrids (Common Carp x Goldfish), Round Goby, Alewife, Goldfish, White Perch, Oriental Weatherfish, and Grass Carp. Non-native species made up 13% of the total species collected and 12% of the total fish by count in 2021. Most species collected in 2021 had been detected in prior years, except for Muskellunge which were detected for the first time. In addition, 4,304 YOY Gizzard Shad were examined, and none found to be YOY invasive carp. No Bighead or Silver carp were captured or observed in 2021.

An estimated 38,522 person-hours have been expended monitoring fixed and random sites upstream of the Electric Dispersal Barrier since 2010. Total effort consisted of 1,457.3 hours of electrofishing (5,875 transects), 1,439.1 km (894.2 mi) of gill/trammel net (7,886 sets), 22.0 km

(13.7 mi) of commercial seine hauls and 114.2 net nights of hoop, pound and fyke nets from 2010-2021 (Table 3). Hoop net use was suspended after 2013 due to low gear efficiency. Fyke nets were not deployed in 2021 due to 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 2021 and will be evaluated based on conditions in the future. A total of 513,609 fish representing 89 species and 9 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 77% of all fish collected. Since 2010, 17 non-native species have been caught, which include Alewife, Bighead Carp, Brown Trout, Chinook Salmon, Coho Salmon, Common Carp and hybrids, Goldfish, Grass Carp, Oriental Weatherfish, Rainbow Smelt, Rainbow Trout, Round Goby, Silver Arrowana, Silver Carp, Threespine Stickleback, Tilapia, and White Perch. Non-native species constitute 15% of the total number of fish caught and 19% of the total species. One Bighead Carp was caught in a trammel net in Lake Calumet in 2010, and one Silver Carp was captured in a trammel net in the Little Calumet River on June 22nd, 2017, with no other captures or observations in other years. Furthermore, 130,164 YOY Gizzard Shad have been examined since 2010 with no YOY invasive carp being identified.

Recommendation:

We recommend continued use of SIM upstream of the EBDS. SIM with conventional gears represents the best available tool for localized detection and removal of invasive carp to prevent them from becoming established in the CAWS or Lake Michigan. Furthermore, we recommend an investigation into the allocation of sampling effort among pools, and a reassessment of pool classifications, which could provide additional clarity for field staff and improve interagency coordination.

References:

Asian Carp Monitoring and Response Working Group (ACMRWG). 2021. 2021 Monitoring and Response Plan for Invasive Carp in the Upper Illinois River and Chicago Area Waterway System. Illinois, Chicago.

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, 2021.*

	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	450	270	248	45	338	1350
Samples (transects)	200	105	130	9	148	592
Electrofishing hours	50	22.3	29.9	0.62	32.9	136
Electrofishing Catch						
All fish (*N*)	8083	7150	5694	0	5207	26134
Species (*N*)	41	36	30	0	34	53
Hybrids (*N*)	3	1	0	0	0	4
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	161.7	320.6	190.4	0	158.3	192.2
Netting Effort						
Estimated person-hours	682.5	592.5	435	150	210	2070
Samples (net sets)	270	211	172	9	110	772
Miles of net	30.7	24	19.5	1.02	12.5	87.7
Netting Catch						
All fish (*N*)	681	187	312	18	123	1321
Species (*N*)	16	8	4	2	6	17
Hybrids (*N*)	0	0	1	0	0	1
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/100 yds of net)	1.3	0.4	0.9	1.0	0.6	0.9
Seine Effort						
Estimated person-hours	210	-	-	-	-	210
Samples (seine hauls)	4	-	-	-	-	4
Miles of seine	1.8	-	-	-	-	1.8
Seine Catch		-	-	-	-	
All fish (*N*)	3490	-	-	-	-	3490
Species (*N*)	18	-	-	-	-	18
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	872.50	-	-	-	-	872.50

Table 2. *Total number of fish captured with electrofishing (EF), gill nets (Nets), and commercial seine (Seine) in the CAWS upstream of the Electric Dispersal Barrier during Seasonal Intensive Monitoring, 2021.*

	CR	CR	CSSC-SB	CSSC-SB	LC-CR	LC-CR	LC-CR	LC-CS	LC-CS	NB-NS	NB-NS	All Sites
Species	**EF**	**Nets**	**EF**	**Nets**	**EF**	**Nets**	**Seine**	**EF**	**Nets**	**EF**	**Nets**	**All Gears**
Alewife*	-	-	-	-	193	-	-	-	-	-	6	199
Banded killifish	-	-	442	-	185	-	-	75	-	144	-	846
Bigmouth buffalo	-	-	-	-	2	35	3	-	2	-	-	42
Black buffalo	-	-	-	-	3	33	-	-	8	-	-	44
Black bullhead	-	-	-	-	9	-	-	6	-	1	-	16
Black crappie	-	-	-	-	17	-	6	-	-	10	-	33
Blackstripe topminnow	-	-	5	-	-	-	-	4	-	11	-	20
Bluegill	-	-	143	-	1108	-	-	239	-	562	-	2052
Bluntnose minnow	-	-	2014	-	101	-	-	177	-	259	-	2551
Bowfin	-	-	-	-	51	-	-	6	-	1	-	58
Brook silverside	-	-	1	-	20	-	--	47	-	-	-	68
Brown bullhead	-	-	-	-	15	-	-	-	-	-	-	15
Bullhead minnow	-	-	9	-	3	-	-	-	-	2	-	14
Central mudminnow	-	-	1	-	-	-	-	-	-	-	-	1
Channel catfish	-	1	28	2	5	46	92	58	3	11	3	249
Carp x goldfish*	-	-	-	1	-	-	-	-	-	-	-	1
Chinook salmon	-	-	-	-	1	2	-	-	1	-	-	4
Common carp*	-	17	513	307	547	123	2	920	141	286	111	2967
Creek chub	-	-	1	-	-	-	-	-	-	-	-	1
Emerald shiner	-	-	92	-	63	-	-	495	-	149	-	799
Flathead catfish	-	-	-	-	-	4	6	-	-	-	-	10
Freshwater drum	-	-	4	1	35	279	740	85	27	2	6	1179

Table 2. *Continued*

	CR	CR	CSSC-SB	CSSC-SB	LC-CR	LC-CR	LC-CR	LC-CS	LC-CS	NB-NS	NB-NS	All Sites
Gizzard shad	-	-	706	1	197	7	2481	1469	-	1428	1	6290
Gizzard shad < 6 in	-	-	1034	-	42	-	-	2615	-	613	-	4304
Golden shiner	-	-	84	-	90	-	-	98	-	217	-	489
Goldfish*	-	-	27	-	52	-	-	36	-	41	1	157
Grass carp*	-	-	-	-	-	-	1	1	-	-	-	2
Green sunfish	-	-	19	-	68	-	-	51	-	43	-	181
Green sunfish x bluegill	-	-	-	-	2	-	-	-	-	-	-	2
Green sunfish x pumpkinseed	-	-	-	-	3	-	-	-	-	-	-	3
Hybrid sunfish	-	-	-	-	-	-	-	1	-	-	-	1
Largemouth bass	-	-	242	-	1877	7	25	430	-	698	1	3280
Muskellunge	-	-	-	-	2	-	-	-	-	-	-	2
Northern pike	-	-	-	-	1	1	10	1	-	2	-	15
Northern sunfish	-	-	-	-	48	-	-	-	-	2	-	50
Orangespotted sunfish	-	-	-	-	1	-	-	5	-	1	-	7
Oriental weatherfish*	-	-	20	-	-	-	-	3	-	46	-	69
Pumpkinseed	-	-	172	-	890	-	-	152	-	104	-	1318
Pumpkinseed x bluegill	-	-	-	-	33	-	-	-	-	-	-	33
Quillback	-	-	-	-	11	1	-	2	-	-	-	14
River carpsucker	-	-	-	-	-	1	1	-	-	-	-	2
River shiner	-	-	1	-	-	-	-	-	-	-	-	1
Rock bass	-	-	-	-	520	-	2	7	-	34	-	563
Round goby*	-	-	29	-	107	-	-	5	-	24	-	165
Sand shiner	-	-	1	-	-	-	-	31	-	-	-	32
Smallmouth bass	-	-	1	-	356	1	2	6	1	2	-	369

Table 2. *Continued*

	CR	CR	CSSC-SB	CSSC-SB	LC-CR	LC-CR	LC-CR	LC-CS	LC-CS	NB-NS	NB-NS	All Sites
Smallmouth buffalo	-	-	-	-	104	134	95	18	4	-	-	355
Spotfin shiner	-	-	15	-	1	-	-	21	-	24	-	61
Spottail shiner	-	-	12	-	9	-	-	3	-	24	-	48
Spotted bass	-	-	-	-	3	-	-	-	-	-	-	3
Tadpole madtom	-	-	3	-	-	-	-	-	-	-	-	3
Threadfin shad	-	-	-	-	-	-	-	1	-	-	-	1
Walleye	-	-	-	-	-	6	11	-	-	2	-	19
Western mosquitofish	-	-	1	-	-	-	-	-	-	-	-	1
White bass	-	-	-	-	10	-	8	9	-	4	-	31
White crappie	-	-	-	-	-	-	-	1	-	-	-	1
White perch*	-	-	-	-	6	-	-	15	-	30	-	51
White sucker	-	-	15	-	13	1	1	17	-	288	-	335
Yellow bass	-	-	-	-	1	-	-	4	-	-	-	5
Yellow bullhead	-	-	58	-	131	-	-	20	-	121	-	330
Yellow perch	-	-	-	-	795	-	4	-	-	1	-	800
Total Fish (N)	0	18	5694	312	8083	681	3490	7150	187	5207	123	30945
Total Species (N)	0	2	30	4	41	16	18	36	8	34	6	55
Total Hybrids (N)	0	0	0	1	3	0	0	1	0	0	0	5

*: Non-native species
CR: Chicago River
CSSC-SB: Chicago Sanitary and Ship Canal
LC-CR: Lake Calumet - Calumet River
LC-CS: Little Calumet - Cal-Sag
NB-NS: North Branch - North Shore

Table 3. *Summary of effort and catch data for all fixed and random site monitoring in the CAWS upstream of the Electric Dispersal Barrier, 2010-2021.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Electrofishing Effort													
Estimated person-hours	1,280	2,180	4,330	1,528	945	990	990	990	990	1,118	195	1,350	**16,866**
Samples (transects)	519	844	765	588	348	422	407	437	414	412	127	592	**5,875**
EF (hrs)	130	211	192	149.3	87.1	106	102	109	103.5	103	28.7	136	**1,457.30**
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	5,244	26,134	**407,391**
Species (N)	51	58	59	56	56	61	59	58	60	48	39	53	**86**
Hybrids (N)	3	3	3	2	2	2	2	2	2	2	1	4	**8**
Bighead Carp (N)	0	0	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	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	182.7	192.2	**279.6**
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	2,655	2,070	**19,903**
Samples (net sets)	208	389	699	959	440	445	498	803	710	711	1252	772	**7,886**
Miles of net	23.8	67	81.7	104.9	48.2	46.6	53.3	86.5	76.6	79.7	138.2	87.7	**894.2**
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	1,964	1,321	**26,421**
Species (N)	17	20	20	30	18	13	18	14	23	19	18	17	**40**
Hybrids (N)	1	1	1	1	1	1	1	1	1	1	1	1	**2**
Bighead Carp (N)	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Silver Carp (N)	0	0	0	0	0	0	0	1	0	0	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	0.81	0.9	**1.7**

Table 3. *Continued.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Seine Effort													
Estimated person-hours	-	-	-	135	135	135	135	135	135	135	135	210	**1,290**
Samples (seine hauls)	-	-	-	3	2	3	3	4	3	4	4	4	**30**
Miles of seine	-	-	-	1.4	0.9	1.4	1.4	1.8	1.4	1.8	1.8	1.8	**13.7**
Seine Catch													
All fish (N)	-	-	-	7,577	1,725	5,989	3,765	2,763	3,110	7,457	2,879	3,490	**38,755**
Species (N)	-	-	-	15	11	14	15	10	10	16	11	18	**28**
Hybrids (N)	-	-	-	1	0	0	0	0	0	0	0	0	**1**
Bighead Carp (N)	-	-	-	0	0	0	0	0	0	0	0	0	**0**
Silver Carp (N)	-	-	-	0	0	0	0	0	0	0	0	0	**0**
CPUE (fish/seine haul)	-	-	-	2,525.70	862.5	1,996.30	1,255.00	690.8	1,036.70	1,864.30	719.8	872.5	**1,291.80**
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**
Table 3. Continued.													
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**

Table 3. *Continued.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
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 Bloomfield
USFWS, La Crosse FWCO

Participating Agencies: USFWS

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 invasive carp from establishing in the Great Lakes. Environmental DNA sampling has been conducted annually, as a surveillance tool to monitor for genetic presence of Bighead Carp and Silver Carp in the CAWS and maintain vigilance above the EDBSer since 2009. Beginning in 2013, eDNA results no longer automatically trigger any kind of response action through the MRP. Since the implementation of dedicated sampling gears for all efforts above the EDBS, and the application of refined DNA markers during sample processing, a low, base-line level of invasive 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 Bighead Carp and Silver Carp by traditional sampling gears above the EDBS, supports the assumption that there is not a self-sustaining, reprouctive population of these invasive carp above the barrier.

Objectives:

(1) Sample for Bighead Carp and Silver Carp DNA in targeted areas of the CAWS to maintain vigilence and compliment other ongoing monitoring efforts above the EDBS.

Project Highlights:

- USFWS staff collected 880 samples upstream of the EDBS.
- Positive detections were few and consistent with previous sampling years.

Methods:

USFWS staff from the La Crosse FWCO conducted spring and fall sampling above the EDBS in the CAWS. For each event, 330 samples (300 samples plus 30 field blanks) were collected in Lake Calumet and 110 (100 samples plus 10 field blanks) were collected in the Marine Services Marina on the Little Calumet River. All sample collection and processing procedures followed the 2021 Quality Assurance Project Plan (USFWS 2021). Field blanks were taken in addition to regular monitoring samples. Field blanks are a quality control measure and should not be included when describing detection rates. All samples are analyzed for the presence of carp eDNA with three marker sets: Silver Carp only, Bighead Carp only, and non-specific invasive carp. The non-specific invasive carp marker set can detect either Bighead Carp or Silver Carp but is not specific enough to say which species of the two. This is reported as a non-specific "Invasive Carp" detection. If both species-specific markers are detected in a water sample, it is reported under the "Bighead AND Silver" category. The Invasive Carp detection category was added to reported results in the 2021 field season. This marker set has always been used in lab analysis but was not publicly reported in previous years.

Results and Discussion:

In the spring, there were zero positive eDNA detections at both sites. In the fall in Lake Calumet, there were 0.6% positive detections (Silver Carp only and invasive carp DNA detection types found) and 0.3% (excluding the invasive carp DNA detections for comparison with past data). There was a 1% positive detection rate (Silver Carp only DNA marker set detected) in the marina. The detection rate in Lake Calumet is slightly higher than spring 2021 and fall 2019 events which had zero detections however it is lower than the 2.2% positive rate observed in spring 2019. The detection rate in the Little Calumet River site is slightly higher than past sampling events in that area which have all had zero positive detections. Although this is the first time that USFWS has detected DNA in the marina, the detection rate is low and the site harbors boats with ballast water compartments and is next to a landfill which, at times, hosts numerous gulls. The lack of prior detections in addition to no captures or observations during an intensive fall physical sampling effort lead by ILDNR, indicates that the positivity likely resulted from secondary vector contributions to the system.

Recommendation:

eDNA sampling efforts in the CAWS are a long-standing part of the USFWS invasive carp eDNA early detection and monitoring program so this project will continue on a semi-annual basis for the foreseeable future. There is interest from MRWG and USFWS to determine how much secondary vectors, such as birds, may contribute to DNA signal in the sampled water in the CAWS. Therefore it's recommended that USFWS seek to add a control site to the sampling regime. This control site would be a closed pond with no connectivity to sampled waters, but will be close enough in proximity to assume that bird activity may be similar. The addition of this site may help gauge if birds are substantial secondary vectors of invasive carp eDNA to waterbodies in the area, including the sampling sites. The control site would be sampled in a similar manner and at a similar sampling density to the actual monitoring sites.

Reference:

U.S. Fish and Wildlife Service (USFWS). 2021. Quality assurance project plan eDNA monitoring of bighead and silver carps. Midwest Region, Bloomington, Minnesota. Available: http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf . (February 2022).

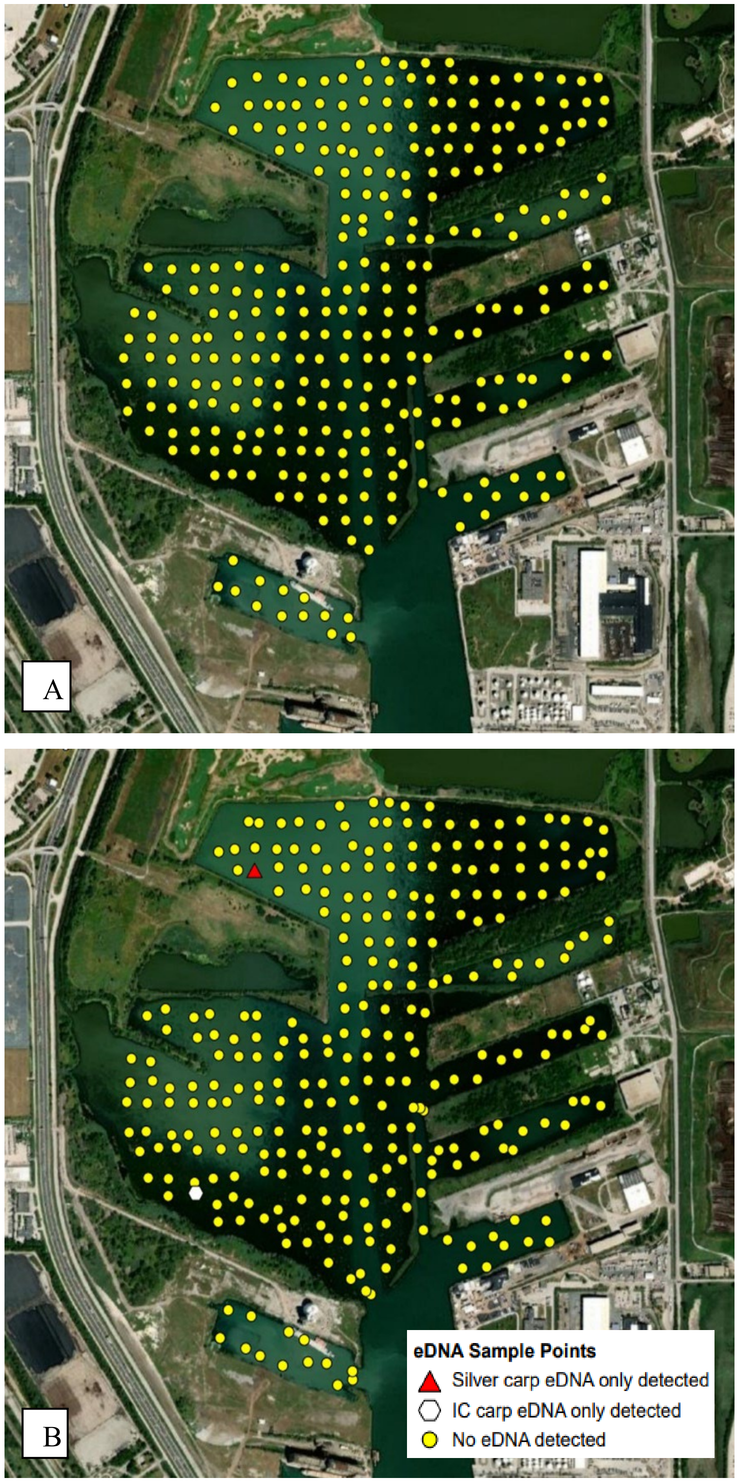

Figure 1. *Detection results for invasive carp eDNA sampling in Lake Calumet in May (A) and September (B) 2021.*

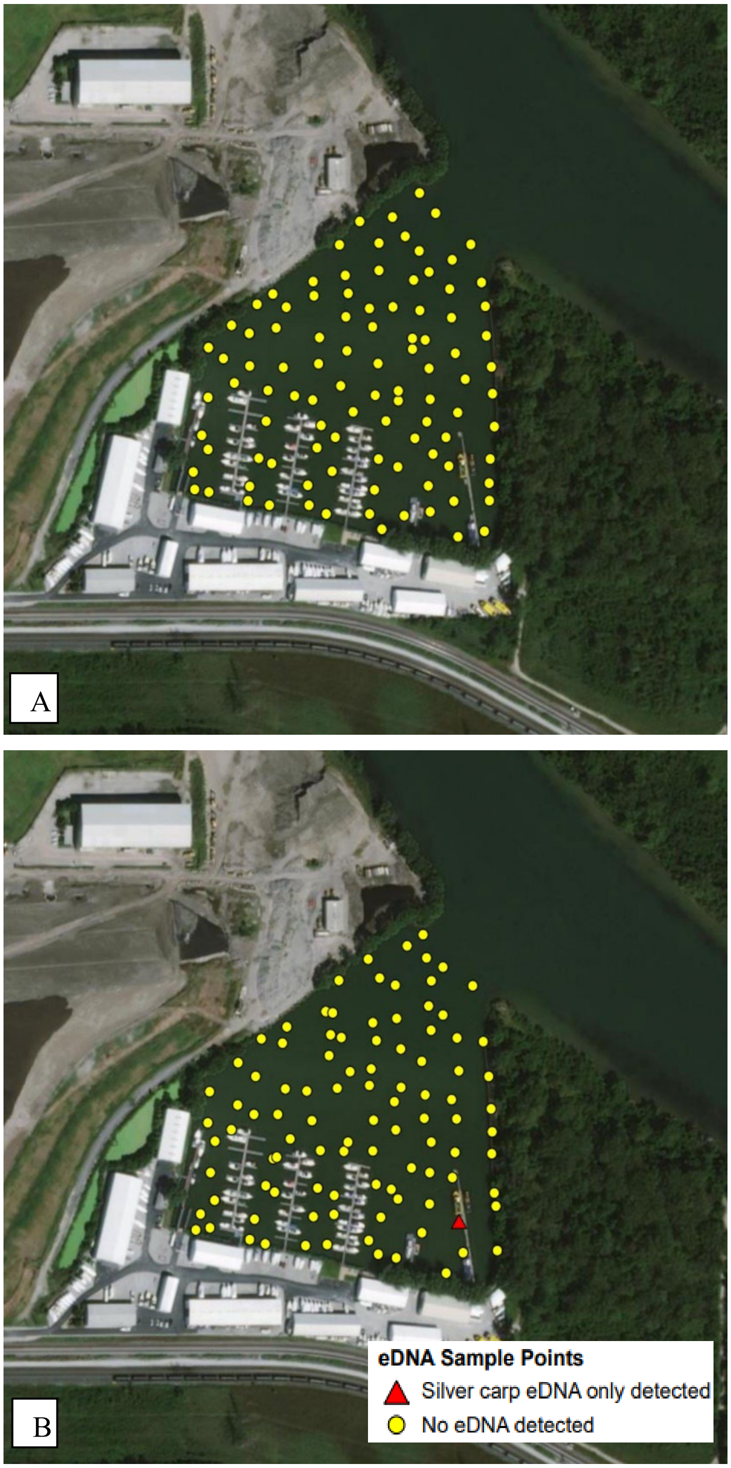

Figure 2. *Detection results for invasive carp eDNA sampling in the Marine Services Marine on the Little Calumet River in May (A) and September (B) 2021.*

Telemetry Interim Summary Report

John Belcik, Dayla Dillon, and Nicholas Barkowski
(USACE – Chicago District)

Participating Agencies: USACE (lead), USFWS, SIU, ILDNR, USGS and MWRDGC (field and project support).

Introduction and Need:

Acoustic telemetry has been identified within the ICRCC Control Strategy Framework as one of the primary tools to assess the efficacy of the EDBS. The following report summarizes methods and results from implementing a network of acoustic receivers 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 naturalized carp fish species which most similarly mimic body shape and movement patterns) in the area around the EDBS in the Upper IWW. This network was installed and is maintained through a partnership between the USACE and other participating agencies as part of the MRWG MRP (MRWG 2020).

The purpose of the telemetry program is to assess the effect and efficacy of the EDBS on tagged fishes in the CSSC and to assess behavior and movement of fishes in the CSSC and IWW using ultrasonic telemetry.

Objectives:

Goal 1: Determine if upstream passage of EDBS by large fishes has occurred and assess risk of Bighead Carp 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 downstream of the EDBS.

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 placed above and below each lock (N=5) and within Brandon Road lock (N=1).
- **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 Bighead and Silver 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 Carp and Silver Carp have been captured and relay information to the population reduction program undertaken by ILDNR and commercial fishermen.

John Belcik, Dayla Dillon, and Nicholas Barkowski
(USACE – Chicago District)

Additional objectives of the telemetry monitoring plan*:*

- Integrate information between agencies conducting related acoustic telemetry studies.
- Download, analyze, and post telemetry data for information sharing.
- Maintain existing acoustic network and rapidly expand to areas of interest in response to new information
- Support the modeling efforts by USFWS with supportive data and adjust network accordingly in consultation with telemetry working group.

Project Highlights:

- To date, USACE has acquired 38.6 million detections from 776 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 two upstream and two downstream passages of Common Carp through the Lockport Lock and Dam.
- There was one upstream passage of a Common Carp through the Lockport Control Works.
- Invasive carp continue to be detected throughout the Dresden Island Pool with most detections occurring near the Dresden Island Lock.
- Almost 76% of the detected transmitters within Dresden Island Pool were detected at the Des Plaines and Kankakee rivers confluence within a given season. This location registered approximately 40% 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 2020 season there were approximately 135 tags (V16 Vemco transmitters) that remained active and 50 of these transmitters were scheduled to expire within calendar year 2021. During 2021, there were also 10 additional fish that appeared to have experienced mortality, but still had active tags. Further reducing the number of active tagged fish to 75 by the end of 2021. In April and May of 2021, 50 tags were deployed: 19 in Lockport Pool, 23 in Brandon Road Pool, and 8 in Dresden Island pool. The fish tagged in Lockport Pool and Brandon Road Pool were Common Carp, *Cyprinus carpio,* while the fish tagged in Dresden Island Pool were seven Silver Carp, *Hypopthalmichthys molitrix* and one Bighead Carp, *H. nobilis*. One Bighead Carp was collected by USFWS and later removed from the pool during routine monitoring activities.

In the fall of 2021, 39 more tags were deployed: 21 in Brandon Road Pool and 18 in Lockport Pool. The 2021 tagging efforts brought the total number of active tags to 162 tags. As of

November 2021, there are 62 tags active in Lockport Pool, 44 in Brandon Road Pool, and 57 in Dresden Island Pool. There are no tags expected to expire until March 2023.

Tagged surrogate fishes have been previously released below the EDBS, but no tagged invasive carp were released above the Brandon Road Lock. It was determined that no invasive 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 the point of capture only after they were deemed viable and able to swim under their own power. It has been observed that displaced fishes exhibit site fidelity and attempt to return to their original capture location. As such, to induce more approaches to the EDBS, many of the surrogate fishes were previously released within Lower Lockport Pool that were originally captured from the Upper Lockport Pool. Over the last two years, the focus for Lockport Pool has been on capturing and tagging fish from below the barrier to understand how they move throughout the pool. There are several fish previously captured above the EDBS and released below the EDBS with still active tags. Table 1 identifies all fishes containing active transmitters between November of 2020 and November of 2021 along with their release point within the system.

Table 1: *Active Fishes and Release Points within the Study Area in 2021*

Release Location	Species Implanted	Capture Pool	Number of Fish Implanted
Lower Lockport Pool (Downstream of EDBS)	Common Carp	Upper	25
Lower Lockport Pool (Downstream of EDBS)	Common Carp	Lower	37
Lower Lockport sub-total			**62**
Brandon Road Pool	Common Carp	Brandon	44
Brandon Road sub-total			**44**
Dresden Island Pool	Bighead Carp	Dresden	8
Dresden Island Pool	Silver Carp	Dresden	49
Dresden Island sub-total			57
Total			**163**

Methods for stationary receiver deployment and downloads as well as mobile tracking were maintained from previous year's effort. After deployment, data retrieval occurred bi-monthly throughout the season by downloading stationary receivers. A detailed description of methods can be found in the MRP ISR (2012). Those stationary receivers removed for winter in November 2020 were redeployed in March 2021. The layout of receiver positions within the study remained almost the same as the previous year (MRP 2019; Interim Summary Report 2021). The additional receiver placed on the Des Plaines River immediately downstream of the Lockport Control works in 2020 was redeployed with the rest of the network. One additional receiver was placed in the I&M canal in the Brandon Road Pool. The revised study area was covered by 29 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 for 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 four 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 IWW 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.

Detections on each receiver in the network 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 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.

Detection data were compiled for all stations 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 2021 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 pools 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, data was collected within the pool by SIUC and USGS which was shared with USACE. VR2W receivers were placed above and below each lock and dam as well as at 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.

Invasive carp Movement Analysis – A total of 49 USACE tagged invasive carp (Bighead Carp and Silver Carp) were within the Dresden Island Pool at the beginning of 2021. Eight additional fish were tagged in Dresden Island Pool in March; however, one Bighead Carp was removed from the pool by USFWS during routine monitoring for a total of 57 active tags by the end of the field season. 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 2021 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 2021. Fish that demonstrated only downstream movement 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 2021, 38.6 million detections from 776 USACE tagged fish have been recorded within the study area since the telemetry monitoring system was established in 2010. While no tagged fish have been released upstream of the EDBS for several years, the Chicago District continues to maintain receivers upstream of the EDBS to monitor for transit of fish from below the barrier. Results to date have shown that zero live fish have crossed the EDBS in the upstream (northward) direction. The following sections provide new results from data collected in the 2021 sampling season in which 143 transmitters were detected system wide for a total of 2.2 million data points from 17 November 2020 through 22 November 2021.

Goal 1: Determine if upstream passage of EDBS by large fishes has occurred and assess risk of Bighead Carp and Silver Carp presence (Barrier Efficacy).

There was a total of 61 tagged surrogate fishes with batteries still active in 2021 that were released between Lockport Lock and the EDBS. Seven stationary receivers (VR2W) detected movement of 64 tagged surrogate fish throughout the pool in 2021. This discrepancy is due to fish transiting between pools. There was a total of 1,527,092 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 the total seasonal detections at each receiver (Figure 4) 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 5). The percentage of transmitters within the pool detected at each station and in each season provided an indication of relative movement patterns within the pool by the population of tagged fishes (Figure 6). 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 (~6.3% of the total Lower Lockport detections). The area with the highest number of detections was the shallow water barge slip (LL03) just downstream of the EDBS with 26% of the total detections for the pool. Approximately 14% of the detections in Lower Lockport were just below the barrier. Most of those detections occurred in the fall months (39%) and summer months (28.5%). This is in line with previous years when the highest number of detections was typically in the summer and fall having an intermediate number of detections (USACE 2021). Station LL05 showed the second highest number of detections for the year, however due to spring and summer tagging events at this station, the number of detections is likely inflated and does not reflect a true value. During the winter there were nine fish detected at the EDBS, seven of them were detected on LL03 as well. Indicating that at least some of the fish were actively moving between locations during the winter season and approaching the barrier periodically.

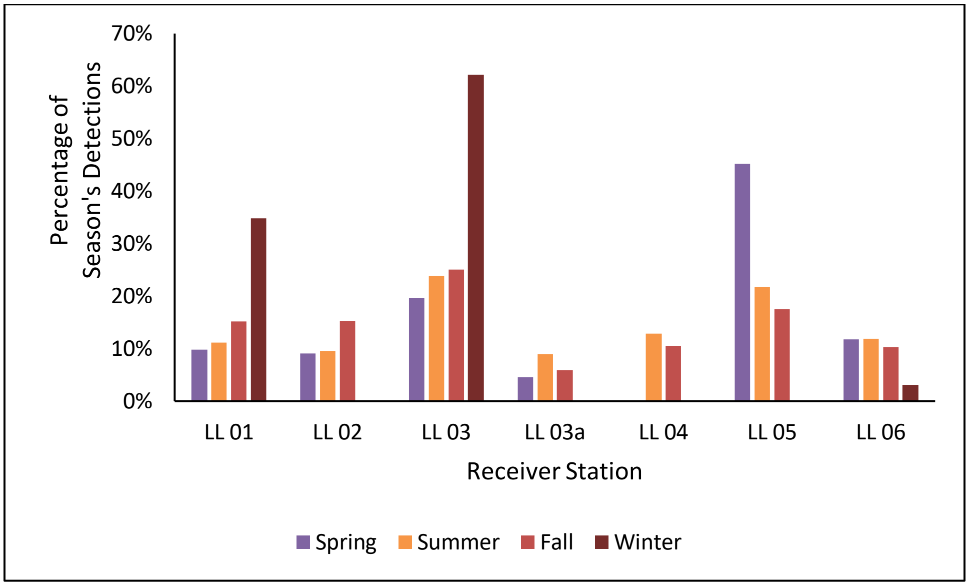

Figure 4: *Percentage of the total number of seasonal detections that have been detected within the Lockport pool throughout 2021.*

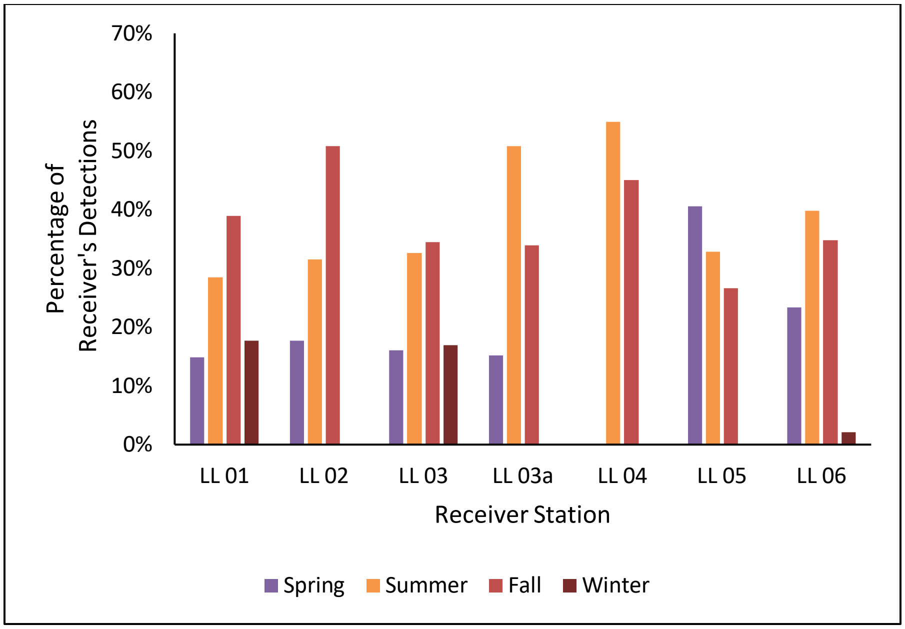

Figure 5: *Percentage of the total yearly detections by receiver in each season in the Lockport Pool in 2021. Uses data from Table 2.*

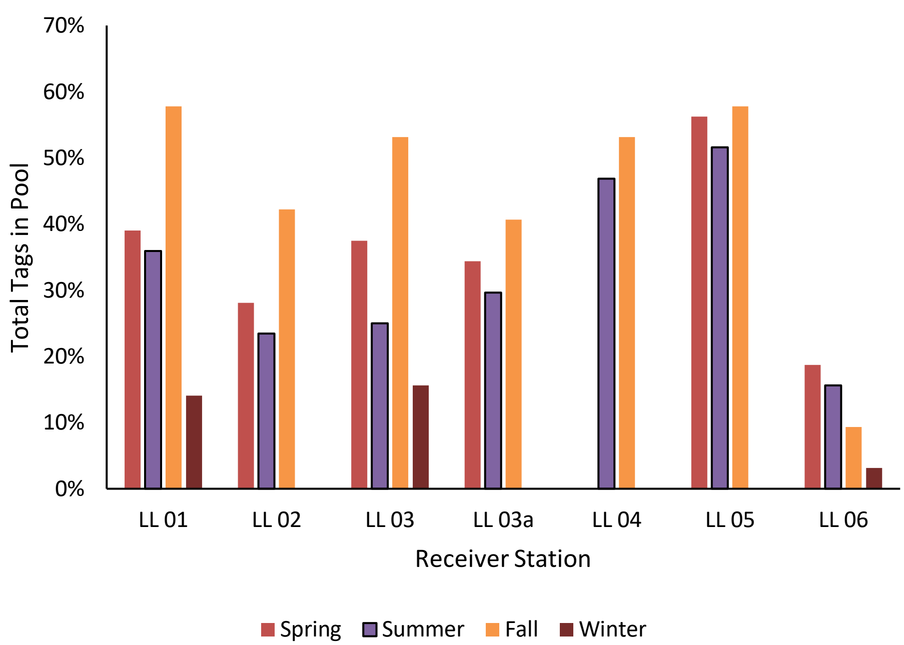

Figure 6: *Percentage of the total number of tags in Lockport Pool detected on a receiver in a season for 2021. Uses data from Table 3.*

Table 2: *Number of detections within the Lower Lockport Pool during 2021. *Values do not indicate a lack of fish, but rather that the receiver was removed from the water during that time. **Indicates a loss of functionality in the receiver at some point.*

STATION	Spring	Summer	Fall	Winter	Total
LL 01	31,723	60,940	83,357	37,845	213,865
LL 02	29,375	52,234	84,126	0*	165,735
LL 03	63,859	130,184	137,262	67,602	398,907
LL 03a	14,627	48,894	32,672	0*	96,193
LL 04	0**	70,410	57,741	0*	128,151
LL 05	146,703	118,558	96,096	0*	361,357
LL 06	37,977	64,898	56,645	3,364	162,884
Total	324,264	546,118	547,899	108,811	1,527,092

Table 3: *Number of tags detected at a station during 2021. *Does not indicate a lack of fish, but rather that the receiver was removed from the system during that time. **Indicates a loss of functionality in the receiver at some point.*

Station	Spring	Summer	Fall	Winter	Total Tags
LL 01	25	23	37	9	43
LL 02	18	15	27	0*	35
LL 03	24	16	34	10	42
LL 03a	22	19	26	0*	42
LL 04	0**	30	34	0*	48
LL 05	36	33	37	0*	55
LL 06	12	10	6	2	16
Total	44	39	56	13	64

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

While not monitored by USACE, data from the first two receivers in Marseilles Pool (RM 271.4 and 271.5) were shared by SIU to be incorporated into this analysis. There were 12 occurrences of inter-pool movement by 11 tagged fishes between November 2020 and November 2021. All movements between USACE monitored pools were by Common Carp, one moved from the Lockport Pool to the Brandon Road pool. Three moved from Brandon Road Pool into the Dresden Island Pool. Another fish moved from Lockport Pool to Brandon Road Pool, then back to Lockport. Lastly, two moved from Brandon Road Pool into Lockport Pool. There were four invasive carp that moved between Dresden Island and Marseilles pools. One in the upstream direction and three in the downstream.

For those four fish that transferred between the Lockport and Brandon Road Pools, three transited through the Lockport Lock. It is likely that these pool transitions were made during lockage events that occurred at or around the time of detection. There has been ample evidence over the last several years of monitoring indicating that lockages are frequently used by fish to move between pools (ISR 2021, ISR 2020, ISR 2019, ISR 2018).

Over the last two years there is evidence showing that the backwater area on the Des Plaines River just downstream of the Lockport Control Works serves as a holding area for fish. In 2021 four Common Carp were consistently detected within that 2.5-acre backwater. One of the upstream bound fish was found in this backwater and did likely travel through Lockport Control Works when the gates were opened on June 26. This fish was continually detected on the downstream side of the control works prior to June 26. On June 26 it began to be consistently detected on the CSSC receiver upstream of the control works without being detected on any of the five receivers it would have to pass to get to this location if traveling through Lockport Lock. Following its transit, it has been detected on all Lower Lockport receivers between July and October 2021. Leading to the belief that this fish is actively moving and is a true transit through the control works and not an anomaly.

When the gates of the control works were open on June 26, they were open for several hours where (assuming six gates were open at the same time) a maximum flow rate of 4,440.12 cubic feet/sec was achieved with a minimum of 740.02 cubic feet/sec (one gate open) (Table 4). Photo 1 and Photo 2 show conditions on the Des Plaines River in 2020 at the control works when most of the gates are fully open. These images show similar water levels on each side of the Lockport Control Works Structure, which may have allowed fish to move through this area. A similar scenario of a fish moving through the Lockport Control Works was suspected to have occurred in 2020 (ISR 2021).

Table 4: *Number of hours each gate was open at the Lockport Control Works and the average daily cubic feet per second (CFS) of water that went through the gates between November 2020 and November 2021. "Average CFS while gate open" is calculated flow rate based on eleevations for one gate fully open. Daily Average CFS calculated from One gate average multipled by (total gate hours / 24hrs).*

Log Date	Gate 1	Gate 2	Gate 3	Gate 4	Gate 5	Gate 6	Gate 7	Total Hours	Daily Average CFS	Average CFS While One Gate is Open
1/13/2021	0.25	0.25	0	0	0	0	0	0.5	16.00	768.00
1/20/2021	0	0	0.25	0.25	0	0	0	0.5	15.00	720.00
2/23/2021	0	0.25	0.25	0	0	0	0	0.5	16.00	768.00
3/5/2021	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1.75	54.00	740.57
6/26/2021	10	0	10	10.25	10.5	10.5	10.5	61.75	1,904.00	740.02
6/27/2021	5.5	0	5	3	3	1	1	18.5	574.00	744.65
6/28/2021	1.75	0	1.75	0	0	0	0	3.5	109.00	747.43
6/29/2021	7	0	7	4	3.25	0	0	21.25	660.00	745.41
8/18/2021	0	0	0	0	0	0.25	0.25	0.5	15.00	720.00
11/2/2021	0	0.25	0	0	0.5	0	0	0.75	23.00	736.00
11/9/2021	0	0	0	0	0	0.25	0.25	0.5	15.00	720.00

There were four instances of fish moving from the Dresden Island Pool into the Marseilles Pool. One was by a Bighead Carp on June 28 that went from the Marseilles Pool, through the lock and as far as Rock Run Rookery over the course of approximately 8 hours. This fish stayed at Rock Run until September 10 when it traveled back to the Dresden Island Lock over the course of 12 hours. This fish was last detected just above the Des Plaines/Kankakee River confluence on September 13. The other three transits were all done by Silver Carp, all in the downstream direction. One transit took place each day on June 26, 27, and 28, and all fish appear to have gone over the Dresden Island Dam and not through the lock. These three transits correspond with a severe weather event in the Chicago area. This weather event subsequently resulted in increased discharge rates within the CAWS and IWW as evidence by the need to open the control works in Lockport (Table 4). It is likely that these increased flows carried the fish over the dam spillways and into the lower pool.

Photo 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.*

Photo 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.*

Overall, from 2010 to 2021, there have been 100 occurrences of tagged fish moving downstream and 51 occurrences of upstream movement between navigation pools by a total of 112 individual tagged fish (Table 5). Inter-pool movement was greatest between the Lockport and Brandon Road Pools accounting for 56.3% (n=85) of all inter-pool movements (upstream n=25; downstream n=60). Most downstream movement into the Brandon Road Pool occurred through the Lockport Control Works approximately two miles upstream of Lockport Lock and Dam (n=35). Movement between the Dresden Island and Marseilles Pools comprised 32.5% (n=49) of all inter-pool movement (upstream n=21; downstream n=28). The lowest inter-pool movement occurred through the Brandon Road Lock and Dam accounting for 11.3% (n=17) of the total. 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. This capture release technique is no longer used in Dresden Island Pool but 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 5: *Total occurrences of inter-pool movement by tagged fish from 2010 to 2021.*

	Up	Down	Total
Lockport Lock	23	25	48
Control Works	2	35	37
Brandon Rd	5	12	17
Dresden Island	21	28	49

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

Throughout 2021 there were 57 USACE tagged invasive carp within the IWW A total of 33 fish were detected within the Dresden Island Pool throughout 2021. Out of those 33 (23 Silver Carp, 3 Bighead Carp, 3 Grass Carp, and 4 Common Carp) fish that were detected within the Dresden Island Pool, 21 were released by USACE (17 invasive carp, four Common Carp), nine by WIU-USGS, and three by USFWS. The 21 USACE tagged invasive carp consisted of two Bighead Carp (1100 and 1000 mm) and 15 Silver Carp (814 ± 73.6 mm). All were tagged between 2017 and April 2021.

In total, the receivers placed in Dresden Island Pool and the adjacent tributaries collected 118,438 detections. The percent of the pool's total detections attributed to each receiver ranged from 0.003 to 36.9%. The station that had the greatest percent of total detections was DI09a at 36.9%. This receiver had the highest percentage of detections for fall and summer as well, both in percent of the pool's overall detections and the total number of detections in each season. Figure 7 shows the percentage of the pool's total detections that occurred within a given season for each receiver. Figure 8 shows the percentage of each season's total detections that occurred at each receiver.

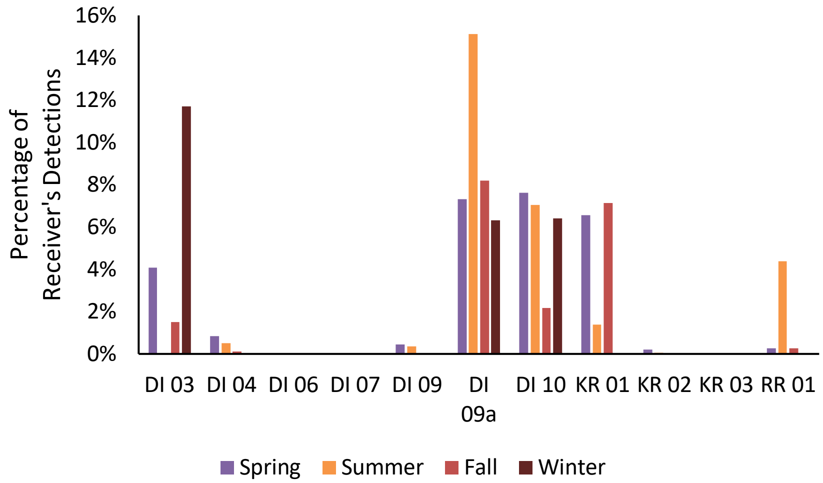

Figure 7: *Percentage of the Dresden Island Pool's total detections shown across receivers in 2021 for each season. Most locations experienced a small number of detections during the year.*

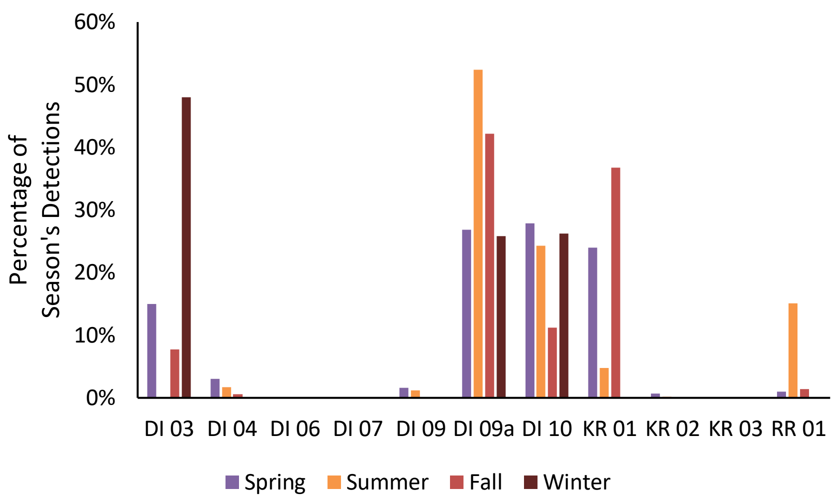

Figure 8: *Percentage of a season's total number of detections that occurred at each receiver within the Dresden Island Pool in 2021*

The stations DI09a, DI10, and KR01 are located at the confluence of the Des Plaines and Kankakee Rivers, where the IL River starts. These three stations typically have some of the highest numbers of detections for the year within Dresden Island Pool. In 2021, DI09a and DI10 account for the two highest number of detections in the Dresden Island pool at 36.9% and 23.2%

respectively. KR01 accounts for 15.1%, behind DI03 (17.3%). Additionally, this confluence area also detected the highest number of tags that within the pool. Figure 9 shows that, as in previous years, a high percentage of the tags detected in the pool pass through and congregate in this area throughout the year. Up to 57.6% of the fish that were detected in the Dresden Island Pool in a season were detected at both the lock and at DI09a. Cumulatively, 70% of the fish within Dresden Island Pool were detected at the lock at some point during the year. The greatest number of stationary or resident fish (fish only detected on one receiver) was also found at DI10. There were six fish that were only found at this location for the whole year. With the highest number of resident fish occurring in the spring at eight fish that did not leave the lock. The winter and summer saw fewer resident fish at the lock (three). Just upstream, an increase from one resident to 10 did occur at DI09a during the winter season. It’s unclear as to why there is an increase in the winter residents at this location, but it could be due to fish using deeper pockets or other habitat features in the area during the winter months.

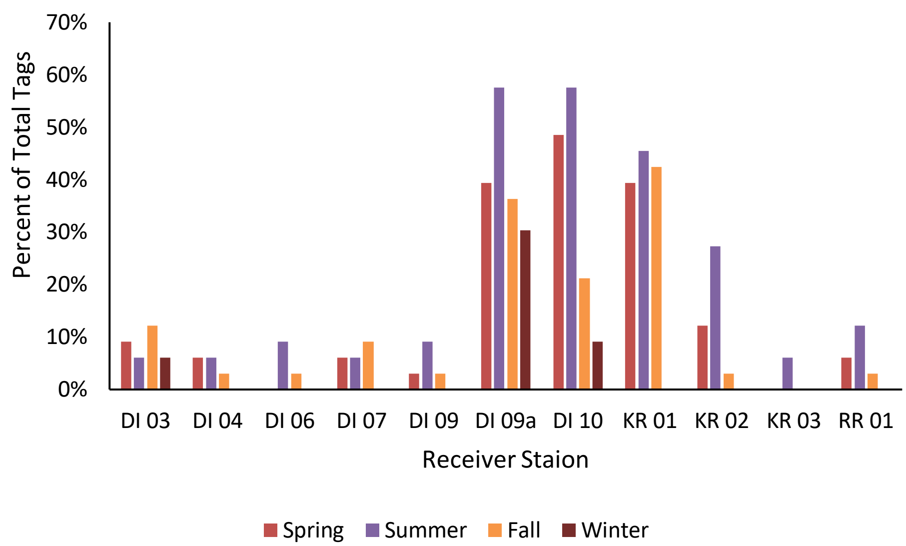

Figure 9: *Percentage of Dresden Island Pool’s total tags that were detected at a given station in a season during 2021.*

There is very little movement of fish between the lower and upper half of the Dresden Island Pool, designated as the areas below and above the I-55 bridge. There were only two fish that transitioned between the upper and lower portions during 2021. One Bighead Carp went from Dresden Island Lock to Rock Run Rookery, spent 74 days (June 29 – Sept 10) within Rock Run, then moved back to the area around the Des Plaines-Kankakee confluence. A Silver Carp moved from Rock Run to Dresden Island Lock over the course of approximately nine hours on June 26.

Other than those two fish, the furthest upstream that an invasive carp was detected was within Big Basin (DI07) below I-55 at RM 276.8.

There are two additional locations of interest in the Dresden Island Pool. The first one being the Brandon Road Lock and Dam (DI03). During 2021 five fish were detected on this receiver, three of them were Common Carp that moved from the Brandon Road Pool into Dresden Island Pool and were only detected at the lock. The other two were Grass Carp. One was determined to have traveled no further than 2.5-miles from the lock throughout the year. The other was observed to have moved from the Brandon Road Lock to just below the I-55 bridge, then back to the lock over the course of approximately three days. No tagged invasive carp were detected approaching Brandon Road Lock in the 2021 sampling season. This is consistent with past observations where very few invasive carps were detected approaching the Brandon Road Lock or even moving past Rock Run Rookery in any appreciable number.

The other location is KR03 which is approximately 0.5 mile downstream of Wilmington Dam. This location did detect two Silver Carp during the 2021 season. Both fish were detected twice, one over six hours, the other over 21 minutes. It is unclear if these were true detections as there are few detections and only one of them was detected at KR02 six miles downstream. Under normal flow conditions, this receiver typically sees few detections as the habitat is not characteristic of what invasive carp typically prefer. Invasive carp typically prefer side channels during times of low flow and have shown a preference for avoiding static areas (DeGrandchamp et al. 2008; Calkins et al. 2012). To get to the Wilmington Dam location, a fish would need to go through approximately 5.5 miles of shallow, rocky water between KR02 and KR03. The Kankakee River experiences a wide range of flow conditions throughout the year and previous data suggests invasive carp may utilize these periods of increased flows to travel upstream to the Wilmington Dam. There were four flood pulses in 2021, the largest of which started on June 26 and corresponds with the time that the two invasive carps were seen at KR03. There were also six additional fish that were only present at KR02 during or just after this flood pulse peaked. It is possible that this heavy flow attracted more fish to the area and some of those fish traveled to the KR03 station. 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 background noise to mask transmitter pings and therefore limit detection probability or the range that fish can be detected. As a result, the number of detections here might not accurately depict the number of tagged fish congregating in this area.

Given the low levels of detections of both this year and past years, invasive carp are likely not drawn to KR03 under normal flows in large numbers as they would be for areas such as backwaters or low flow side channels. Likewise, they are not drawn to DI03, but the reason for this is less clear. It is possible that the low number of fish detected in the pool (33), or collection/release points of tagged fish could be skewing observations. Higher densities of tagged fish could increase yield of detected fish, increasing the chances of seeing new movement patterns. Likewise, invasive carps may have a proclivity of returning to where they are captured from. USACE is exploring options on how to increase detection rates including increasing the tag density and new collection/release locations within Dresden Island Pool.

Recommendations:

USACE recommends continuation of the telemetry program and maintaining the target level of surrogate species tags within the system by replacing expired tags throughout all three pools below the EDBS in the spring and fall of 2022. USACE will continue to collaborate with MRWG partners to maximize our understanding of invasive carp movement and biology within the Dresden Island Pool. USACE recommends continued collaboration with MRWG partners to perform comparisons of surrogate species to Bighead Carp and Silver Carp. Understanding of how well Common Carp and other surrogates represent the behavior of invasive 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 12 years to examine study area wide movement and habitat use for both invasive 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 CAWS.

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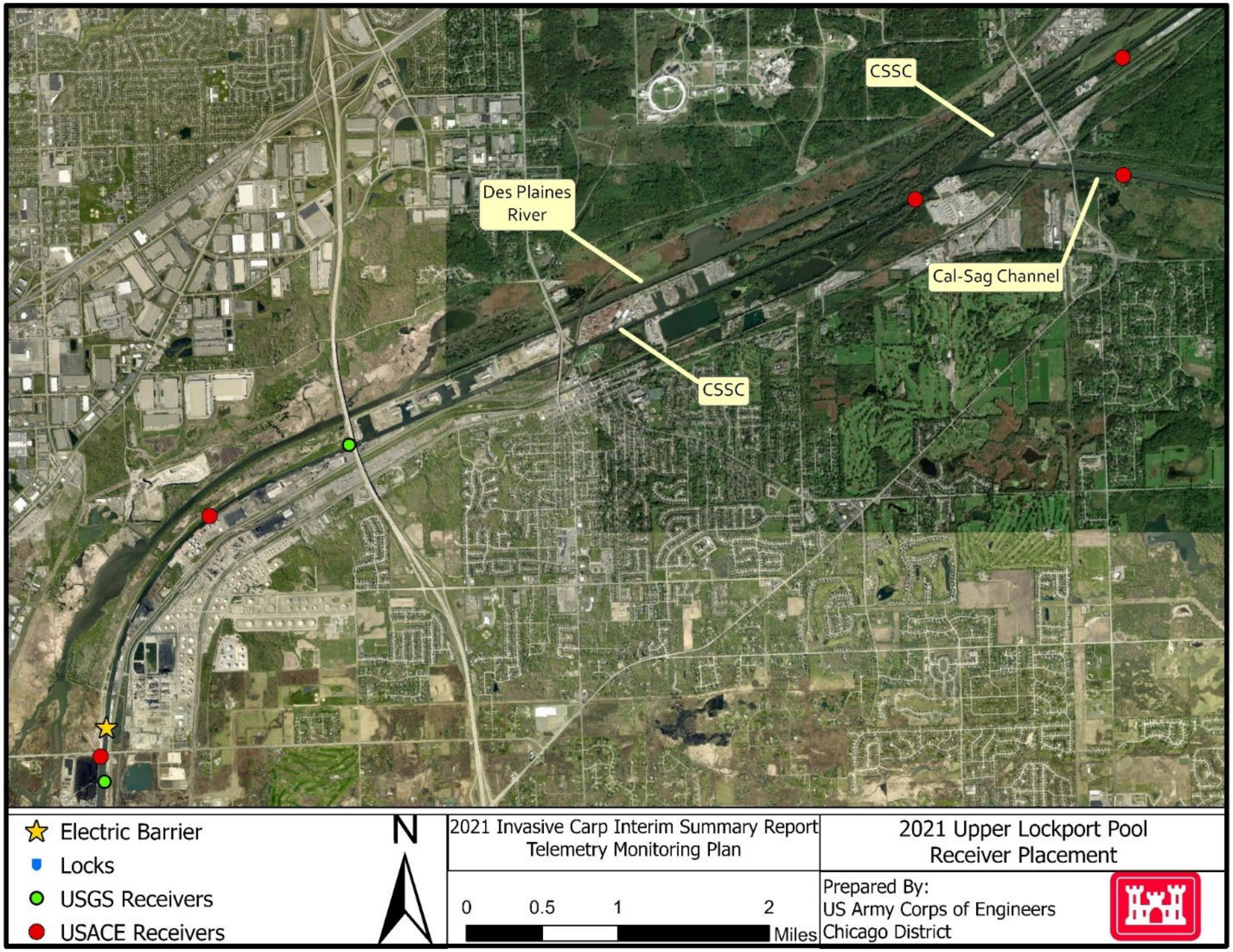
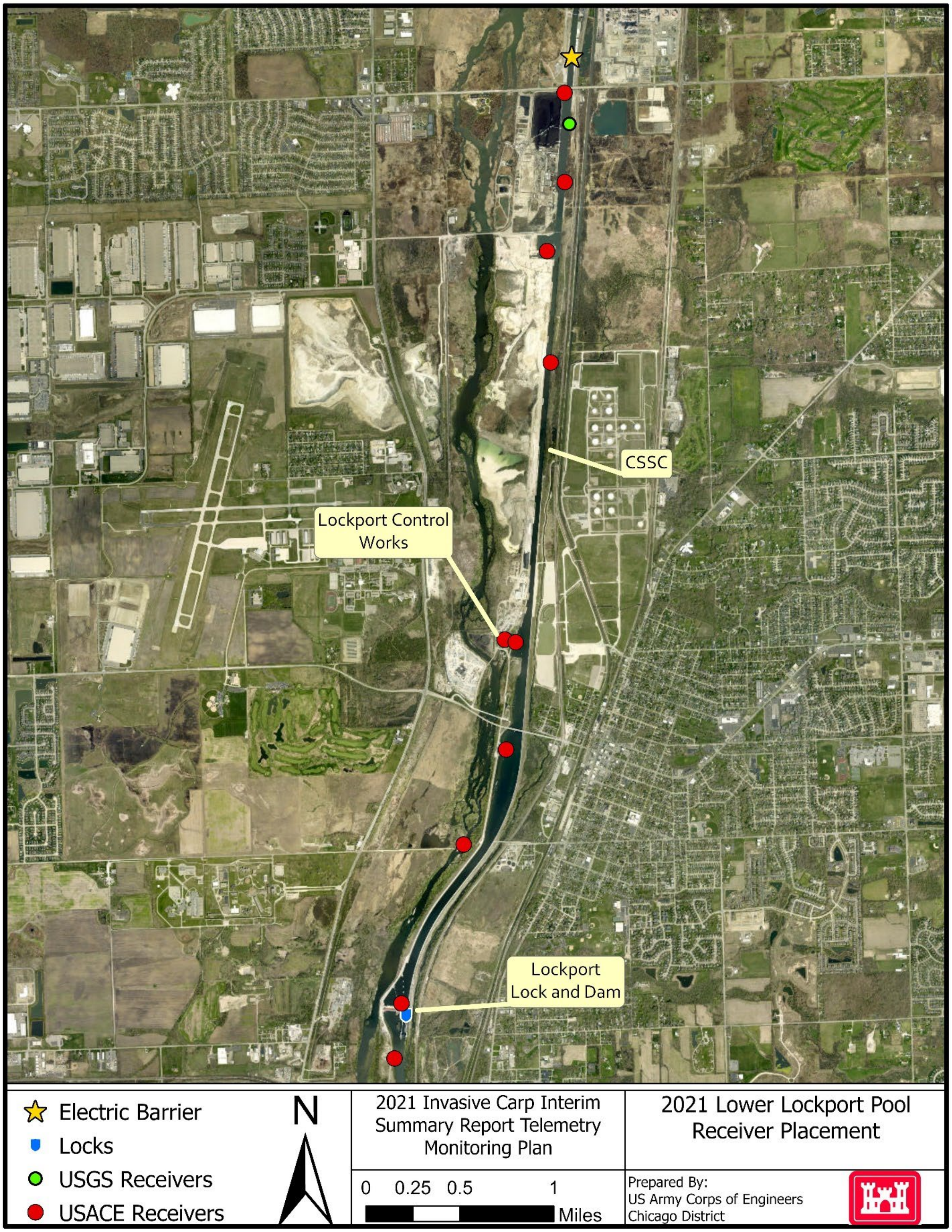
Appendix A

Maps

US Army Corps of Engineers

Telemetry Interim Summary Report




CSSC
Lockport Control Works
Lockport Lock and Dam
Electric Barrier
Locks
USGS Receivers
USACE Receivers
N
2021 Invasive Carp Interim Summary Report Telemetry Monitoring Plan
2021 Lower Lockport Pool Receiver Placement
0 0.25 0.5 1 Miles
Prepared By:
US Army Corps of Engineers
Chicago District


Lockport
Lock and Dam
CSSC
Des Plaines River CSSC
Confluence
I&M Canal
Brandon Road
Lock and Dam
Electric Barrier
Locks
USGS Receivers
USACE Receivers
N
2021 Invasive Carp Interim
Summary Report Telemetry
Monitoring Plan
2021 Brandon Road Pool
Receiver Placement
0 0.25 0.5 1
Miles
Prepared By:
US Army Corps of Engineers
Chicago District

USGS Telemetry Project

Marybeth Brey, Brent Knights, Jessica Stanton, Sean Bailey, Travis Harrison, Doug Appel, and Andrea Fritts (USGS, Upper Midwest Environmental Sciences Center); Jim Duncker and Ryan Jackson (USGS, Central Midwest Water Science Center)

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

Pools Involved: Alton, La Grange, Peoria, Starved Rock, Marseilles, Dresden Island, Lockport, Des Plaines River, CAWS

Introduction and Need:

Tagging of bigheaded carp (i.e., Bighead Carp *Hypophthalmichthys nobilis* and Silver Carp *H. molitrix*) and surrogate fish species with acoustic transmitters has become an invaluable tool in management in the upper IWW (i.e., upper Illinois River, lower Des Plaines River, and CAWS). For example, movement probabilities between adjacent navigation pools need to be estimated to parameterize the SEICarP model. SEICarP is a population model used in scenario planning by the 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 (i.e., tagged) 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 fish movement dynamics to meet management objectives, an existing network of real-time and data-logging acoustic receivers in the upper IWW is collaboratively managed by a multi-agency team (see Participating Agencies section above). A Telemetry Work Group 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 work group plans and executes the placement of receivers, tagging of bigheaded carp with acoustic tags, and management of the telemetry data. Three primary objectives to meet MRWG goals identified by the Telemetry Work Group include (1) development of a common standardized telemetry database with visualization and analysis tools, (2) transitioning from Program MARK to a custom Bayesian multi-state model for estimating movement probabilities needed for SEICarP and (3) deploying, maintaining, and serving data from real-time acoustic receivers to inform contingency planning and fish removal. In 2020, the first objective (telemetry database) was moved from this project to the USGS Database project, leaving two objectives here.

The transition to a custom Bayesian multi-state model to estimate movement probabilities will support more efficient, effective, and robust population modeling with SEICarP by overcoming short comings of Program MARK for this purpose. These shortcomings include lack of customizability and extensibility, poor model convergence, software crashes, parameter exclusion from models, an inability to consistently generate estimates of movement probabilities, and a lack of uncertainty estimates for movement probabilities. A real-time receiver network that is maintained and tested annually will ensure reliability and accuracy of the real-time alerts to bigheaded carp movements that can be used by management to plan contingency actions.

Objectives:

(1) Complete Movement Probability Model: Complete custom Bayesian multi-state model and estimate bigheaded carp movement probabilities with 2012-2019 data in FishTracks database.
(2) Maintain real-time receiver network: Deploy, maintain, and serve data from real-time acoustic receivers to inform decisions on contingency actions and the USACE barrier evaluation

Project Highlights:

Movement Probability Model:

Quality assurance of the 2012-2019 telemetry data from FishTracks being used in the new multi-state movement probability model was completed. An additional parameter was added to the movement model to directly account for the variable numbers of receivers deployed in each river reach and to account for expiring tags (to improve estimates of detection probability). The new movement model was successfully run on the full dataset of tagged silver carp and bighead carp in the Illinois River and have been (1) incorporated into planning efforts by the Telemetry Work Group for receiver deployment and fish tagging to continue monitoring of this vital population dynamic (i.e., movement) and (2) shared with the MRWG Modeling Work Group to be used in parameterizing the SEICarP model for further scenario planning to inform control of bigheaded carp in the Illinois River. A manuscript of the model development is currently in preparation.

Real-time receiver network and alert system:

Five real-time receivers were deployed and maintained in the upper IWW in 2021 (Table 1). The FishTracks telemetry database and the online alert system (for partners), for detections of bigheaded carp in areas of management concern, were continued in 2021.

Table 1. *Locations of real-time receivers on the Upper Illinois Waterway.*
Available at: ***https://il.water.usgs.gov/data/Fish_Tracks_Real_Time/***

Station	Location
Chicago Sanitary and Ship Canal above the EDBS	Lemont, IL
Chicago Sanitary and Ship Canal below the EDBS	Romeoville, IL
Des Plaines River above Brandon Road Lock and Dam	Rockdale, IL
Des Plaines River below Brandon Road Lock and Dam	Rockdale, IL
Illinois River above Dresden Island Lock and Dam	Minooka, IL

*Note: Two additional real-time receivers exist in the Marseilles Pool, supported by another project

Methods:

Movement model: The USGS in collaboration with personnel on the Telemetry Work Group and Population Modelling Work Group of the MRWG developed a Bayesian program to estimate interpool movement probabilities needed for SEICarP. Bayesian 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 Program MARK. For example, previous multi-state modeling with Program MARK has been fraught with difficulties (computer crashes, automatically excluding parameters from the model, and not providing estimates) thought to be related to number of states, recapture periods, and specification of random effects to account for individual, and spatial and temporal heterogeneity. As well, Program MARK does not provide uncertainty estimates for the estimated parameters, whereas, hierarchical models performed in a Bayesian framework provide a direct expression.

Real-time receiver network: A network of five real-time receivers was redeployed and maintained in the Upper IWW by USGS crews in spring and summer 2021. Data access for these receivers was maintained online. Real-time alerts were provided to key personnel via email as requested by partner agencies.

Results:

Movement model: Understanding the movement and dispersal characteristics of invasive Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*) is an important aspect of their management and control in the Illinois River. Summarizing movement rates within and between basins will aid in informing decisions for efficient management and control of these species. In FY 2020, we completed the quality assurance of the dataset to include data for the years 2012 through 2019. This expanded dataset was compiled from multiple agencies and cooperators through FishTracks data repository.

In FY 2021, we also made several advances to the multistate movement model previously developed for invasive carps in this system. The primary advancement was to parameterize the model to directly account for variable numbers of receivers deployed in each river reach throughout the duration of the study. Adjusting the model in this way allows for more robust estimates of detection probability within the model. These detection probability curves also provide a means to evaluate how the current number and arrangement of receivers in each pool are doing at detecting the tagged fish in that pool.

These new models were successfully run on the full dataset of tagged silver and bighead carp in the Illinois River. We are currently working on preparing a manuscript to describe the results of this effort to date. The results will be provided to the MRWG Modeling Work Group to be used in parameterizing the SEICarP model for further scenario planning to inform control of bigheaded carp in the Illinois River and associated Waterway Systems. We are also working with the SEICarP modeling team to begin work to explore possible modeling approaches to determine the effects of fish density and size on pool-to-pool movement rates. Understanding these effects would be useful to further improve the movement models for informing bigheaded carp removal or deterrence in this system.

Real-time receiver network: USGS personnel monitored, downloaded, and maintained data from five real-time receivers in the Upper IWW System in 2021. Locations of the five real-time receivers in the Upper IWW System can be found in Table 1.

Each receiver was programmed to alert partner agencies when bigheaded carp, tagged with ultrasonic transmitters, are detected. Four real-time receivers are in areas of management concern (upstream of the bigheaded carp invasion front in upper Dresden Island Pool; receiver locations 1 – 4 above), and these receivers did not detect a confirmed bigheaded carp in 2021. The one real-time receiver outside of these areas of concern contributes to the broader telemetry network objectives to provide important information on seasonal bigheaded carp movements. All the receivers were accessed remotely, and the data are made available online. Detection data and summaries were shared with partners throughout the year.

Modifications to the real-time receivers in 2021 included the transfer or removal of the receivers supported by this project in all pools below Dresden Island (Hanson Material Services pits in the Marseilles Pool and below Starved Rock Lock and Dam in the Peoria Pool). The receivers in the Hanson Material Services pits are currently funded by another project for uADS field testing at the site.

COVID travel restrictions in 2020 and 2021 prevented us from completing the annual range tests for these receivers. Results from 2019 receiver range testing and detection summaries have been shared in work group meetings. Continued operation of the real-time receivers and alert system is planned for FY 2022, in consultation with the Telemetry and Removal Work Groups.

Illinois Waterway Hydroacoustics

Michael A. Glubzinski and Nathan T. Evans
(USFWS, Carterville FWCO, Wilmington Substation)

Participating Agencies: USFWS Carterville FWCO, Wilmington Substation (lead); USACE-Chicago District (field/logistical support)

Pools Involved: Lockport, Brandon Road, and Dresden Island

Introduction and Need:

The EDBS located within the CSSC operates with the purpose of preventing inter-basin transfer of fishes between the Mississippi and Great Lakes basins. Observational evidence from previous studies suggests that fish may congregate below the EDBS at different times throughout the year, primarily during the summer and fall (Parker & Finney, 2013); however, ultimately, fish interaction with the EDBS is not predictable or well understood. Having a greater understanding of the spatial and temporal patterns of fish density fish within and below the EDBS is important to barrier management, as it allows operational and maintenance decisions to be made in sync with an understanding of potential risk. To determine these periods of elevated risk, split-beam hydroacoustic surveys were planned to be performed within and below the EDBS on a bi-weekly basis throughout 2021. Monthly split-beam hydroacoustic surveys of the Lockport, Brandon Road, and Dresden Island navigation pools of the upper IWW were also scheduled to evaluate the potential for upstream spread of invasive carps and increased pressure on the EDBS from the pools immediately downriver. However, due to the COVID-19 pandemic, projects were not able to be resumed until August 2021. Results from sampling conducted from August to December nonetheless provide some insight into the dynamics of fish densities and distributions in the upper pools of the IWW. Understanding fish assemblage dynamics throughout the upper IWW allows the findings from a range of other research activities at the EDBS to be put into a system-wide context, enabling more refined interpretations of results and allowing managers to make informed decisions.

Objectives:

(1) Evaluate the abundance of fishes within and directly below the EDBS bi-weekly throughout the year to inform contingency response and barrier management.

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

(3) Identify changes in large fish abundance and distribution that could indicate risk of further upstream spread of invasive carp.

Project Highlights:

- Fish tracks were detected within the EDBS in four of seven hydroacoustic surveys, but abundances were low, with an overall mean of 1.0 large fish targets detected per survey (min = 0, max = 2 individual large fish targets, n = 7).
- Fish abundances directly downstream of the EDBS across surveys remained relatively low, with a mean of 3.7 large fish targets detected per survey (min = 0, max = 7 individual large fish targets, n = 7).

- Large fish abundance was greatest in Dresen Island Pool (187 large fish targets; 7.6 fish / 100,000 m^3) in September 2021, but declined in November and December. Large fish abundance in Brandon Road and Lockport pools remained fairly low and consistent from September – December, with no abnormal spikes in abundance or aggregations of large fish observed.

Methods:

Acoustic Fish Surveys at the Electric Dispersal Barrier System

Horizontal, split-beam hydroacoustic and side-scan sonar surveys were conducted biweekly-to-monthly at the CSSC EDBS from August – December 2021 to assess fish density and distribution patterns near the EDBS on a fine temporal scale. Survey transects began approximately 1.2 km below the EDBS at 41°37'46.2756" N, -88°3'41.9724" W. The survey vessel followed 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.

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 transducers were mounted in parallel on the starboard side of the research vessel 0.4 m below the water surface on a dual axis mechanical rotator. The side scan unit was attached to a port-side davit and lowered 1 m into the water. Transducer sampling angles were set and monitored each survey to maintain values of approximately -3.3˚ and -9.9˚ below the water surface to maximize coverage, minimize beam overlap, and allow for fish oriented with the flow to be pinged near side-aspect. Split-beam acoustic data was collected using Visual Acquisition v.6.1® at a range of 0 – 50 m from the transducer face, with a ping rate of 5 pings per second and a 0.4 ms pulse duration. Data collected less than 1 m from the transducer face were removed during post-processing 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, water temperature was measured and input into Visual Acquisition v.6.1® prior to all data collection. The on-axis calibration of the split-beam acoustic transducers was confirmed with a tungsten carbide calibration sphere before disseminating results following methods from Foote et al. (1987).

Split-beam hydroacoustic data were post-processed in Echoview® v. 11.1. Data were loaded into a mobile survey template 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 and checked 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, and fish tracks were identified using the “single target detection – split-beam (method 2)” algorithm within the Echoview Fish Tracking Module®. Large fish targets were classified as those with TS ≥ -28.7 dB (≥ 12 inches [30.5 cm] total length based on the true side-aspect TS of a fish). Each individual fish track was also spatially located within the water column using the split-beam transducer’s capabilities and assigned X, Y, and Z positional coordinates. Methods for processing the side-scan sonar data to supplement the hydroacoustic results are currently being evaluated. Side-scan sonar results will be presented in the future.

Illinois Waterway Pool Surveys

To quantify the density and spatial distribution of the fish community in the upper Illinois Waterway, monthly hydroacoustic surveys were conducted throughout the Lockport, Brandon Road, and Dresden Island navigation pools from September - December 2021. The surveys were conducted using the same equipment, collection techniques, and analysis methods as were employed during the hydroacoustic surveys at the EDBS. Within each navigation pool, upstream and downstream transects were sampled near the channel margin, with transducers facing outwards towards the middle of the channel. Dresden Island Pool was not sampled in October 2021 to avoid duplicating effort with Southern Illinois University, which completed a hydroacoustic survey in the pool that month.

Results and Discussion:

Fish Surveys within and below the Electric Dispersal Barrier

Results from the hydroacoustic surveys conducted within the EDBS indicated semi-regular presence of fish targets >12” within the EDBS from August – December 2021 (4 of 7 surveys detected fish targets within the EDBS); however, abundance was low (mean = 1.0 large fish targets detected per survey; range = 0 to 2 individual large fish targets; Figure 1A). Zero large fish targets were detected within the EDBS during 3 of the 7 surveys. Results from the portion of the hydroacoustic surveys conducted immediately downstream of the EDBS suggested relatively low fish abundance downstream of the EDBS across surveys from August – December 2021 (mean = 3.7 large fish targets detected per survey; range = 0 to 7 individual large fish targets; Figure 1B). Compared to previous years, average numbers of fish targets detected both within and below the EDBS were similar; but variance among surveys was lower. As a note, restricted sampling due to COVID-19 may not have captured spikes in abundance that have been witnessed in the past, particularly during early summer (Figure 1; Parker & Finney, 2013).

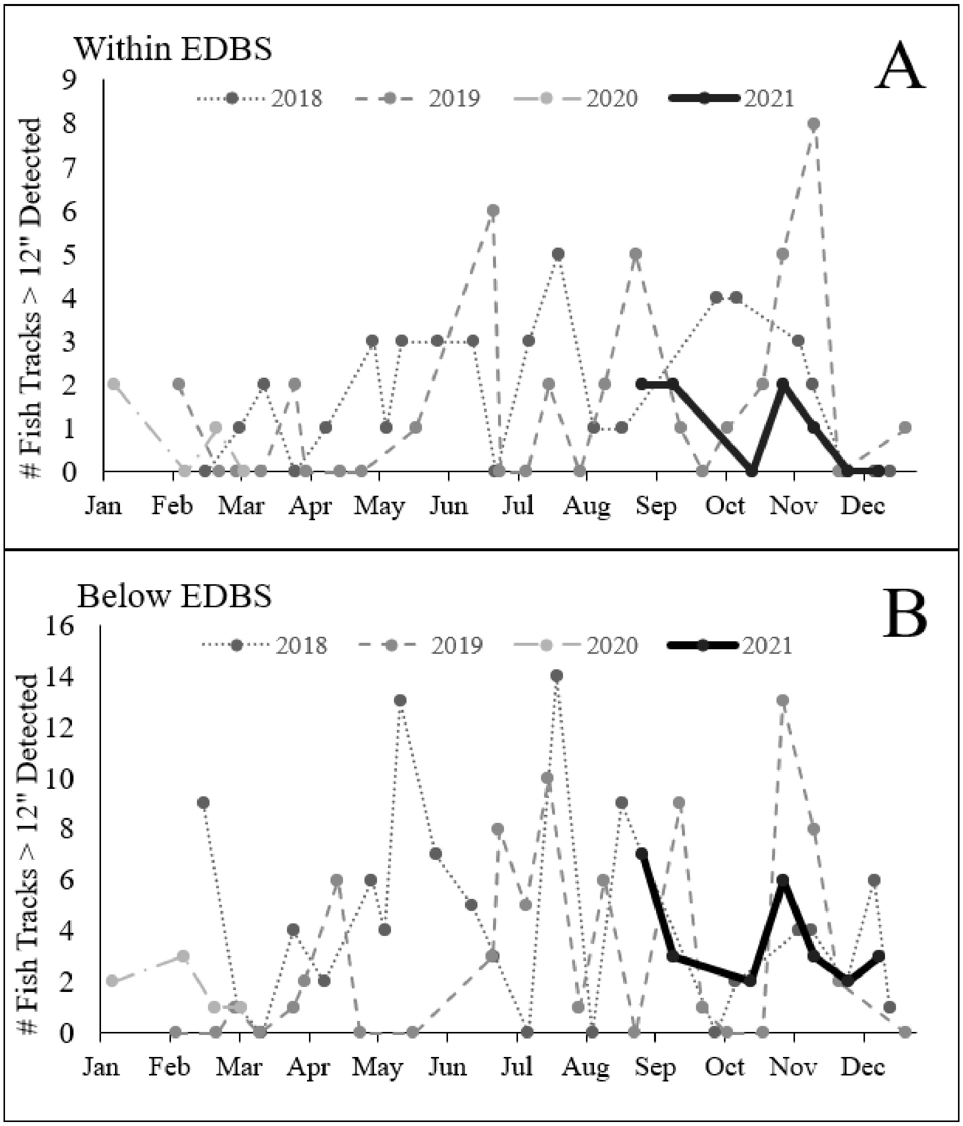


Figure 1. *Number (#) of large fish targets (≥ -28.7 dB) observed within (A) and immediately downstream (B) of the EDBS during split-beam hydroacoustic surveys conducted from August – December 2021 compared with past surveys from 2018 – 2020.*

Illinois Waterway Pool Surveys

Results from hydroacoustic surveys conducted in Dresden Island, Brandon Road, and Lockport pools from September – December 2021 illustrate highest large fish abundances in Dresden Island Pool and similar large fish abundances between Brandon Road and Lockport pools. Large fish abundance and density in Dresden Island Pool was highest in September (187 fish tracks, 7.6 fish/100,000 m^3; Figure 2), but declined sharply in November and December. Notably, a modified unified method removal event organized by the Illinois DNR occurred in Dresden Island Pool in October, which removed 75 large invasive carp and may have contributed to the declines in large fish abundance observed. Mean density of large fish tracks in Dresden Island

Pool across 2021 surveys was 3.2 fish/100,000 m^3 (n = 3). Large fish abundance in Lockport and Brandon Road pools showed less variability, with means of 6.25 large fish targets per survey in Lockport Pool (SD = 4.1, n = 4, mean density = 0.4 fish/100,000 m^3) and 8.5 large fish targets per survey in Brandon Road Pool (SD = 6.1, n = 4, mean density = 0.95 fish/100,000 m^3). No surveys produced abnormally high abundance or distribution patterns that may serve as indicators of an upstream pulse of large fishes – and potentially invasive carps – towards the EDBS and Lake Michigan.

Conclusion

While delayed due to the COVID-19 pandemic, these studies nonetheless continued to provide insight into the dynamics of fish assemblages near the EDBS that are unattainable using traditional fisheries sampling gears, and enabled documentation of large fish abundance trends at the invasion front and in uninvaded ranges of bigheaded carps in the Upper IWW. Insights from these monitoring efforts are valuable for identifying risk and informing management actions.

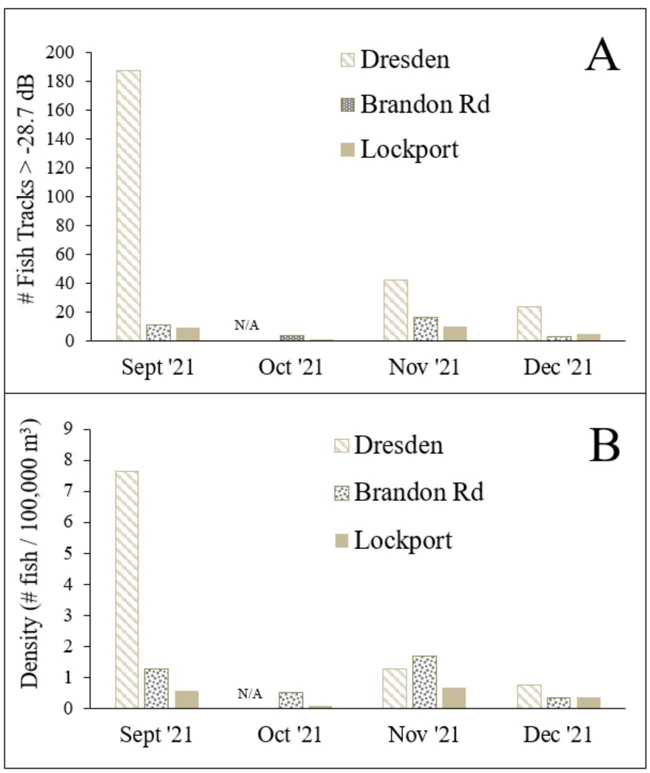


Figure 2. *Number of fish targets (A) and density (B) observed in split-beam hydroacoustic surveys conducted in Dresden Island, Brandon Road, and Lockport Pools from September – December 2021. Fish target density was calculated by dividing the number of observed fish target by the water volume sampled during the survey. Scheduled monthly surveys for January – August 2021 were cancelled due to the COVID-19 pandemic. Dresden Island Pool was not sampled in October 2021 to avoid duplicating effort, as a hydroacoustic survey was already completed that month by Southern Illinois University.*

Recommendations:

(1) Continue monitoring the spatial and temporal patterns of large fish within the Upper IWW to detect changes in abundance that could indicate potential changes in assemblage structure.

(2) Continue monitoring and rapid reporting of EDBS survey data to inform management agencies of suspected invasive carp observations or changes in large fish abundance near the EDBS.

(3) Explore alternative techniques to provide increased information and/or species inferences from hydroacoustic data to aid detection and response efforts.

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Early Detection of Bigheaded Carp in the Illinois Waterway

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Participating Agencies: USFWS Carterville FWCO – Wilmington Substation

Pools Involved: Lockport, Brandon Road, and Dresden Island

Introduction and Need:

Globally, biological invasion by non-native aquatic species is an issue that can result in both ecological and economic impacts to the affected and connected ecosystems (Lodge et al. 1998, Hoffman et al. 2011). The primary management strategies for reducing the impacts of invasive species on ecosystems are control and eradication (Hulme 2006, Lodge 2006). The success of both of these strategies is closely linked to how early the novel species is detected and subsequently how quickly management action is taken. Early detection is crucial to management successes because the propagule pressure is lower and the individuals are more likely to be spatial restricted (Myers et al. 2000, Mehta et al. 2007). Therefore, early detection programs are inherently challenged by and focused on detecting the presence of rare non-native species (Rew et al. 2006, Mehta et al. 2007, Harvey et al. 2009). Fortunately, the challenges of early detection are analogous to the challenges of threatened and endangered species assessment which focuses on detecting the presence of rare native species. Therefore, many of the sampling techniques and analytical tools developed for threatened and endangered species are transferable to an invasive species early detection context (Trebitz et al. 2009, Jerde et al. 2011). For example, both early detection and endangered species assessment sampling designs often take into consideration habitat preferences and life-history traits of the species in order to improve detection probability (e.g., Rew et al. 2006, Hoffman et al. 2011, Lintermans 2016). Likewise, species richness estimators can be used to assess the thoroughness of sampling efforts at capturing rare species that are present in the ecosystem (Cao et al. 1998, Cao et al. 2001, Kanno et al. 2009).

Since the 1970s, invasive Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*Hypophthalmichthys nobilis*) populations have invaded the Mississippi River basin, expanded upstream, and become 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) and threat of harm to lake users and their property (Kolar et al. 2007). The most probable invasion pathway for Silver Carp and Bighead Carp to enter the Great Lakes is through connection of the upper IWW, which includes the CAWS, to Lake Michigan (Kolar et al. 2007).

An EDBS, operated by the USACE, 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 crysoleucas*) 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 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 greater vicinity, could pass upstream through the EDBS. For this reason, as well as the potential for established mature bigheaded carp present in Dresden Island Pool to advance the invasion front upstream via successful reproduction, there is a need for high spatial- and temporal-resolution monitoring data on the distribution of bigheaded carp in the IWW both upstream and downstream of the EDBS.

Objectives:

The overall objective of this project was to increase focused, species-specific, early detection sampling of small (≤ 153 mm TL) and large (> 153 mm TL) Silver Carp and Bighead Carp in the Upper IWW for the purpose of increasing certainty in the derived species distributions by reducing the potential for concluding carp are absent from areas where they are actually present. The information provided by this bigheaded carp-focused sampling is intended to aid ICRCC and MRWG agencies in evaluating the current invasion risk of bigheaded carp to the Great Lakes via the CAWS and provide information that may trigger CRP response actions when warranted. This project is an individual-focused bigheaded carp early detection effort that is intended to complement existing population and assemblage-focused monitoring efforts in the IWW such as SIM, MAM of the Illinois River for Decision Making, and hydroacoustic monitoring in the vicinity of the EDBS.

Project Highlights:

- No small-bodied Silver Carp or Bighead Carp were captured in Lockport, Brandon Road, or Dresden Island pools.
- No large-bodied Silver Carp or Bighead Carp were captured or observed upstream of their known invasion fronts. No bigheaded carps were captured above Brandon Road Lock and Dam.
- Twelve large-bodied Silver Carp and 2 large-bodied Grass Carp were captured during 2021.
- In total, 586 electrofishing runs, 434 electrified dozer trawl, and 167 mini-fyke net sets were completed between March and November 2021.
- In total 58,657 individual fishes comprised of 90 species and 9 hybrid groups were captured.

Methods

Sampling was conducted via a combination of fixed and random site sampling. Initial sampling sites were selected using target analysis of data previously collected during the Distribution and Movement of Small Asian Carp in the Illinois Waterway project, the Habitat Use and Movement of Juvenile Asian Carp in the Illinois Waterway using Telemetry project, and the MAM project. Target analysis and site selection focused on habitats both small and large bigheaded carp life stages are vulnerable to capture in, the gear types that most effectively capture bigheaded carp in those habitats, and the most effective times to sample. Fixed sites were located where bigheaded carps had previously been captured or in similar habitats across the pools and were selected to provide pool-wide spatial sampling coverage. Random sites were stratified by habitat type (MCB, SC, BW) and habitat area, excluding zones that were not useable for each gear type deployed. Where depth was sufficient, sampling at both fixed and random of sites included boat-mounted electrofishing, electrified dozer trawling, and mini-fyke netting. Boat-mounted electrofishing runs were completed using LTRM methods (Gutreuter et al. 1995) and consisted of 15-minutes of fishing in an upstream direction. Electrified dozer trawling consisted of a single 5-minute transect traveling in an upstream direction per site. Mini-fyke netting consisted of 4-hour net sets per sampling site. All captured Bighead Carp, Silver Carp, and Grass Carp were measured for TL (mm) and mass (g) and then euthanized; all other species were identified to species, enumerated, and released. Rarefaction analyses were used as means to evaluate the thoroughness of sampling at the applied level of sampling efforts in the study areas. Therefore, species richness was estimated using the Mao Tau method for species accumulation and the Chao2 estimator (Chao 1987) for estimated species richness via 1000 Monte Carlo resamples in each study area. All analyses were performed in R 4.1.2 (R Core Team 2021).

Sampling gear descriptions

Electrofishing – Pulsed DC daytime boat electrofishing conducted using two dippers for 15-minute sampling periods. Nets had 3/16-inch bar mesh, 1-foot deep bags, and 9-foot handles.

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. 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-meter by 1-meter rigid frame mechanically raised and lowered to fish depths from 0 to 1 meter. The net extended approximately 2.5 meters back as it was pulled forward. The trawl was mounted to an electrofishing boat with anodes extending 1.5 m in front of the trawl and the trawl acting as the cathode. Trawl sampling duration consisted of 5-minute transects.

Results and Discussion

In 2021, 1197 sites across three IWW pools (Lockport, Brandon Road, and Dresden Island) and the lower Kankakee were surveilled for the presence of both small-bodied and large-bodied Silver Carp and Bighead Carp between March 10th and November 24th. In total, 135 electrofishing samples and 105 electrified dozer trawl samples were completed in Lockport Pool; 172 electrofishing samples and 118 dozer trawl samples were completed in Brandon Road Pool; 152 electrofishing samples, 208 dozer trawl samples, and 88 mini-fyke net samples were completed in Dresden Island Pool; and 131 electrofishing samples, 97 dozer trawl samples, and 80 mini-fyke net samples were completed in the Kankakee River (Table 1). Total effort consisted of 147.0 hours of boat electrofishing, 36.5 hours of electrified dozer trawling, and 168 net-nights of mini-fyke netting. In total, 14 large-bodied Silver Carp were captured, with all specimens collected downstream of Brandon Road Lock and Dam (Table 2). Additionally, two Grass Carp were captured downstream of Lockport Lock and Dam (Table 3). Among the sampling months, the greatest number of invasive carp were captured in November (Figure 1). No large-bodied Bighead or small-bodied Silver Carp or Bighead Carp were captured during sampling in 2021.

Table 1. ***USFWS 2021 targeted Silver Carp and Bighead Carp early detection monitoring sampling effort in Lockport, Brandon Road, and Dresden Island pools.*** *Pools are organized left-to-right in this table to indicate furthest-from to nearest-to the EDBS. Effort for electrofishing and dozer trawling is the total within-pool sampling time in hours (h). Effort for mini-fyke netting is the total within-pool sampling time in net-nights (nn). The number of sampling sites (sites) is the total number of sites sampled with each gear type in each pool.*

	Dresden Island		**Brandon Road**		**Lockport**		**Kankakee**	
	effort	sites	effort	sites	effort	sites	effort	sites
Boat Electrofishing	37.8 h	152	43.0 h	172	33.7 h	135	32.7 h	131
Electrified Dozer Trawl	9.9 h	119	9.7 h	118	8.8 h	105	8.1 h	97
Mini-Fyke Net	88 nn	88	--	--	--	--	80 nn	80

Table 2. ***Silver Carp captured during USFWS early detection monitoring in Dresden Island Pool and the Kankakee River between 10 March 2021 and 24 November 2021.*** *Total catch (number of individuals), mean total length (mm), and mean mass (g) is provided for all specimens captured with each gear type (electrofishing, dozer trawling, and mini-fyke netting) in each sampling area. No Silver Carp were captured in Lockport or Brandon Road pools.*

	Dresden Island			**Kankakee River**		
Silver Carp	Total Catch	Mean Total Length	Mean Mass	Total Catch	Mean Total Length	Mean Mass
Boat Electrofishing	1	717	4850	4	850	5054
Electrified Dozer Trawl	1	730	4840	8	822	5169
Mini-Fyke Netting	--	--	--	--	--	--

Table 3. ***Grass Carp captured during USFWS early detection monitoring in Brandon Road Pool and the lower Kankakee River between 10 March 2021 and 24 November 2021.*** *Total catch (number of individuals), mean total length (mm), and mean mass (g) is provided for all specimens captured with each gear type (electrofishing, dozer trawling, and mini-fyke netting) in each sampling area. No Grass Carp were captured in Lockport or Dresden Island pools.*

	Brandon Road			**Kankakee River**		
Grass Carp	Total Catch	Mean Total Length	Mean Mass	Total Catch	Mean Total Length	Mean Mass
Boat Electrofishing	1	982	11854	1	1025	16000
Electrified Dozer Trawl	--	--	--	--	--	--
Mini-Fyke Netting	--	--	--	--	--	--

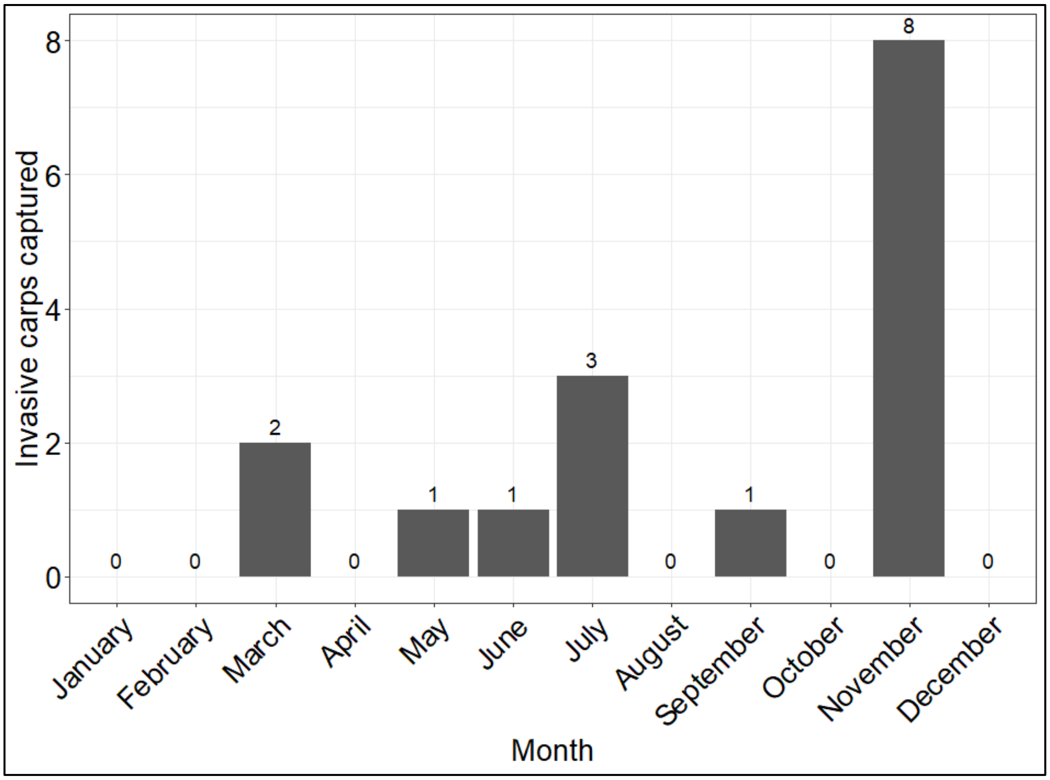

Figure 1. *Monthly distribution of invasive carp individuals captured in 2021.*

Across all 2021 samples non-targeted (all species besides invasive carps) fish bycatch included 58,659 individuals comprised of 89 species and 11 hybrid taxa. Among the sampling months, the greatest number of individuals were captured in July (Figure 2) and species richness was greatest in July and August (Figure 3). Gizzard Shad was the most abundant species captured representing 36.5% of the total catch. Other abundance species included Bluegill (15.4% of catch), Bluntnose Minnow (12.5% of catch), and Emerald Shiner (9.4% of catch). Total observed species richness in Lockport Pool was 33 species (Figure 4). The annual mean Chao 2 species richness estimate for Lockport Pool, using data from all sampling events, was 38 species (95% confidence interval [CI] = 29 - 47 species). Total observed species richness in Brandon Road Pool was 37 species. The annual Chao 2 species richness estimate for Brandon Road Pool was 39 species (95% CI = 34 - 45 species). Total observed species richness in Dresden Island Pool was 72 species. The annual Chao 2 species richness estimate for Dresden Island Pool was 91 species (95% CI = 68 - 113 species). Total observed species richness in the lower Kankakee River was 86 species. The annual Chao 2 species richness estimate for the lower Kankakee River was 131 species (95% CI = 81 - 181 species). Rarefaction analysis suggested that sampling intensity was sufficient to detect most of the species present in Lockport, Brandon Road, and Dresden Island pools as indicated by the overlapping 95% confidence intervals and the generally asymptotic species accumulation and estimator curves (Figure 4). The non-asymptotic species accumulation and estimator curves and large 95% confidence intervals for the lower Kankakee River indicate that several of the species that were detected are uncommon (only detected in a few samples) and suggests that additional undetected species are likely present. This result suggest that additional sampling effort may be necessary in the lower Kankakee River in order to detect all of the species that are present, potentially including invasive carp.

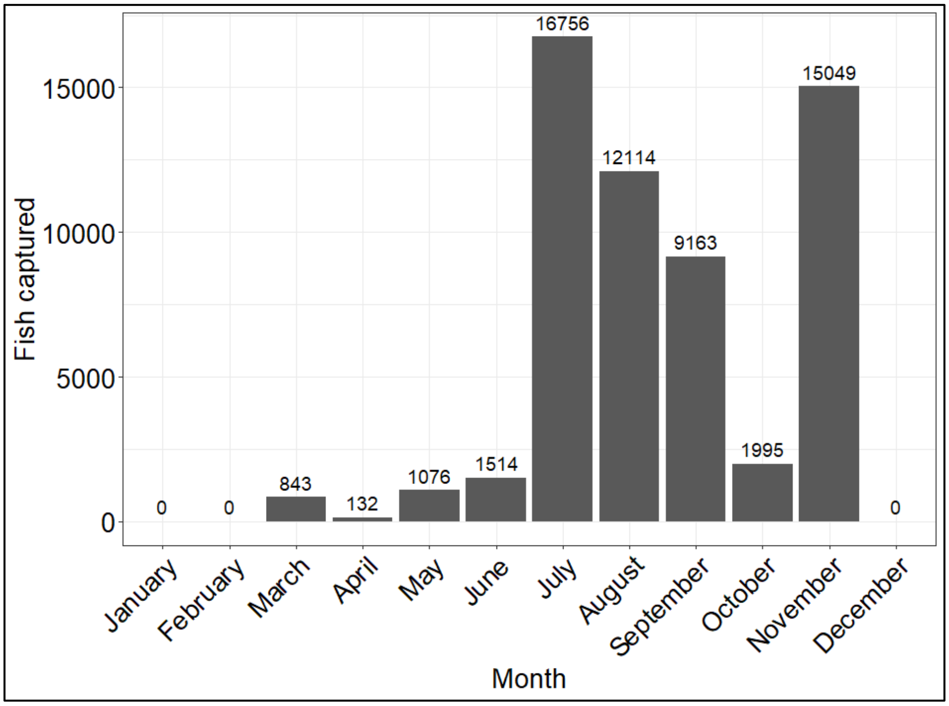

Figure 2. *Monthly distribution of all individual fishes captured in 2021.*

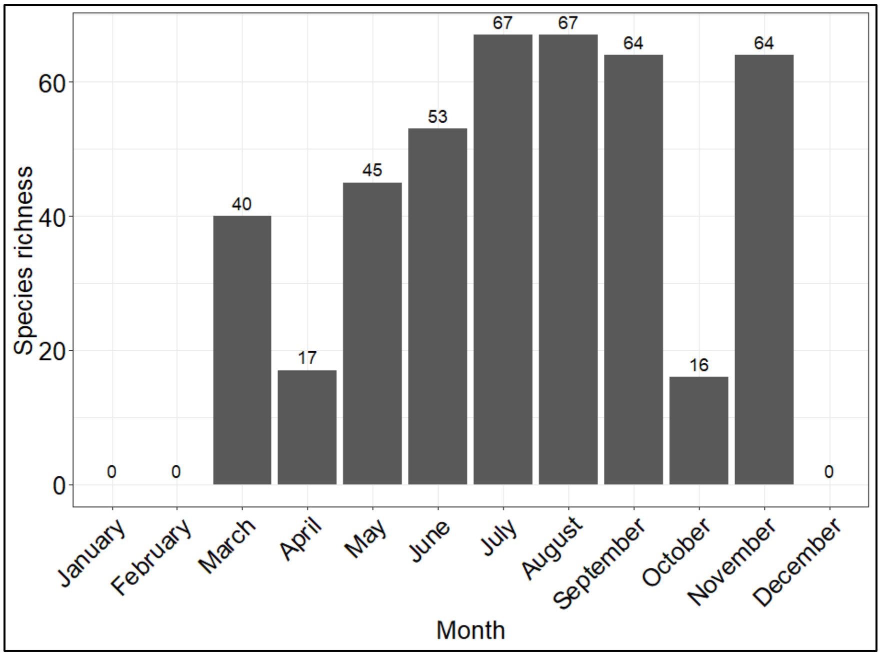

Figure 3. *Monthly distribution of fish species richness captured in 2021.*

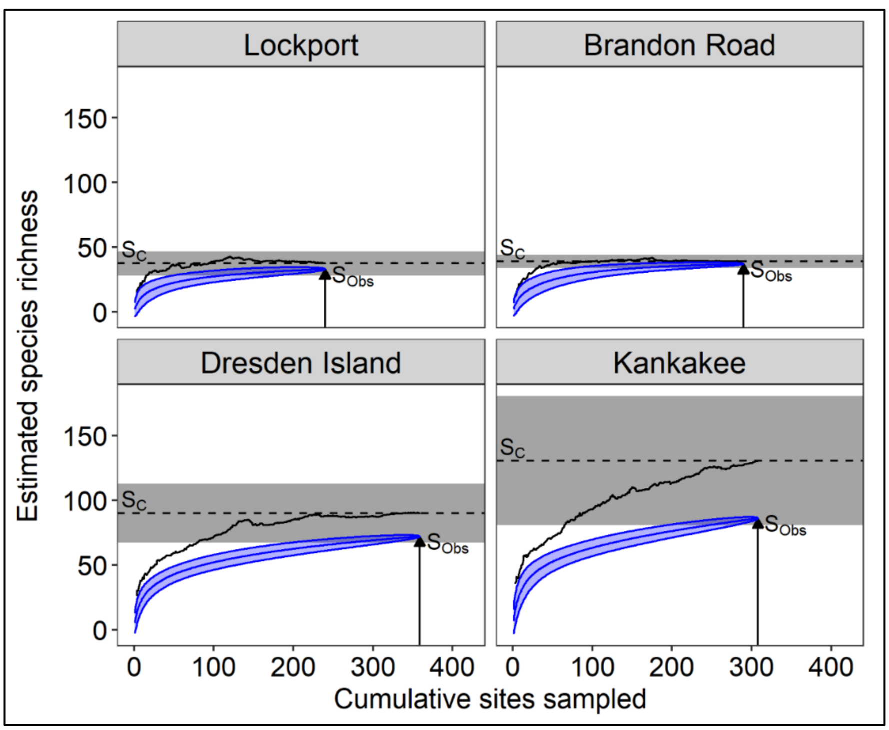

Figure 4. *Species accumulation curve (Mao Tau; blue line with 95% CI) and estimated species richness (Chao2; black line) for Lockport Pool, Brandon Road Pool, Dresden Island Pool, and the lower Kankakee River based on 1000 Monte Carlo resamples. The total number of observed species (S_{obs}) is indicated by the vertical arrow in each plot. The final Chao2 point estimate (S_c) and 95% confidence interval at S_{obs} is indicated by the dashed horizontal line and gray band.*

Recommendations:

(1) Continue early detection monitoring for all life stages of invasive carp in the upper IWW to provide additional assurance that invasive carp are absent from the area upstream of Brandon Road Lock and Dam.

(2) Provide additional monitoring for small (<153mm TL) invasive carp in the vicinity of the small carp invasion front to provide additional assurance that small invasive carp are absent above Marseilles Lock and Dam.

(3) Increase sampling effort in the lower Kankakee River to increase confidence that total species richness is being detected.

(4) Ensure that all data collected as part of the early detection project are uploaded to the USGS-managed MRWG database.

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Larval Fish Monitoring in the Illinois Waterway

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Participating Agencies: INHS (lead), EIU, SIU (field and lab support)

Pools Involved: Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, and LaGrange pools and major tributaries [Kankakee River (Dresden Island), Fox River (Starved Rock), Mackinaw River (LaGrange), Spoon River (LaGrange), and Sangamon River (LaGrange)]

Introduction and Need:

Successful reproduction is fundamental to the establishment and spread of invasive species (Moyle and Marchetti 2006; Lockwood et al. 2013). 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. Invasive carp exhibit reproductive traits that have contributed to their success as invaders in the Mississippi River basin: high fecundity (Williamson and Garvey 2005, Lenaerts et al. 2021), flexible reproductive behavior (DeGrandchamp et al. 2007, Coulter et al. 2013), multiple batch spawning (Camacho et al. 2020, Tucker et al. 2020), and high dispersal rates of offspring (Deters et al. 2013, Coulter et al. 2016). An evaluation of invasive carp reproduction and the distribution of early life stages in different sections of the IWW and its tributaries is needed to monitor for changes in the reproductive front of invasive carp populations in this system and to better understand the impacts of removal efforts on the reproductive capacity of these populations. These data are used as an early detection system for monitoring for any upstream expansion of reproducing invasive carp populations, potential reproduction by the newly expanding Black Carp population in Illinois, and to quantify relationships between invasive carp stock density, reproductive output, and recruitment to assess the level of removal needed to degrade the ability of invasive carps to replenish themselves.

Reproduction and recruitment of invasive carp in the IWW are highly variable among years (Gibson-Reinemer et al. 2017; Parkos et al. 2021) and multiyear efforts have been necessary to assess the magnitude, location, and timing of reproduction, evaluate conditions affecting reproduction, and monitor for changes in the invasive carp reproductive front. Reproduction by invasive carp in the upper navigation pools of the IWW represents a greater threat than it does further downstream due to the risk of expansion of the invasion front towards Lake Michigan and the increased potential for these species to challenge the EDBS. Tributary rivers may also provide sources of recruits to basin-wide invasive carp populations (Larson et al. 2017; Camacho et al. 2020; Schaick et al. 2020), which may complicate management efforts on the mainstem Illinois River and may offer insight for the suitability of Great Lakes basin tributaries were invasive carp to become established there. 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 (Zhu et al. 2018, Parkos et al. 2021). Due to egg and larval drift, reproduction in upper river pools may also 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 or the prospects for fishery-induced declines.

Complementary annual assessments of invasive carp reproduction and stock density also provide data needed to quantify stock-reproduction relationships and evaluate the impact of invasive carp removal efforts on the reproductive potential of these populations. The relationship between invasive carp spawning stock density and the magnitude of reproduction provides evidence of both diminished reproductive output at low adult abundances, as well as density-limitation of reproductive output at very high adult densities (Parkos et al. 2021). Continuing assessment of the reproductive productivity of invasive carp populations may therefore aid in evaluating the success of control efforts and for refining our understanding of potential compensatory responses to harvest.

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 invasive carp populations.

(2) Monitor for Black Carp reproduction in the IWW.

(3) Quantify the relationship between invasive carp adult density and reproductive output.

Project Highlights:

- 508 ichthyoplankton samples were collected from seven sites from the Brandon Road to LaGrange navigation pools of the IWW during May – October 2021, capturing 5,524 invasive carp eggs and 992,765 invasive carp larvae. Two distinct bouts of invasive carp spawning were observed during 2021, associated with distinct increases in discharge and favorable water temperatures. Eggs were collected as far upstream as the Marseilles Pool. A single Grass Carp larvae was also collected in the Marseilles Pool and Silver Carp larvae were collected from the Starved Rock Pool during 2021. Overall numbers of invasive carp eggs and larvae observed during 2021 were very high relative to other recent study years.

- 264 ichthyoplankton samples were collected from Illinois River tributaries during 2021. No evidence of invasive carp reproduction was observed in the Kankakee River, but eggs and/or larvae were collected from all other sampled tributaries. The timing and magnitude of reproduction varied among tributaries, but multiple spawning events with very high reproductive output were detected in LaGrange Pool tributaries. Post-gas bladder inflation Silver Carp collected from the Fox River in 2021 represent the first observance of invasive carp larvae older than this key developmental stage upstream of the Starved Rock Lock and Dam since 2015.

- Quantitative PCR screening was used in 2021 to prioritize samples that had a high probability of containing invasive carp eggs or larvae for rapid processing. Overall, 58 of the 220 samples that were subjected to qPCR screening were found to contain at least trace amounts of invasive carp DNA. The total number of invasive carp DNA copies in a sample was found to be a significant predictor of the presence of invasive carp eggs and/or larvae in the sample. The quantity of organic debris in a sample did not affect the relationship between the number of DNA copies and the probability of the presence of invasive carp eggs or larvae.

Methods:

Larval fish sampling occurred at 7 sites in the Illinois and Des Plaines rivers downstream of the EDBS during 2021 (Figure 1). Additional sampling took place in five tributary rivers (Kankakee, Fox, Mackinaw, Spoon, and Sangamon rivers). Sampling occurred weekly from the beginning of May to mid-July and biweekly from mid-July to early 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 navigation channel, parallel to the bank, at both upstream and downstream locations within each study site. At tributary sites, three samples (one mid-channel and one on each side of the channel) were collected on each sampling date. Tributary samples were collected far enough upstream of the confluence of each tributary with the mainstem Illinois River to ensure that any fish eggs or larvae collected were derived from the tributary itself rather than potentially originating in the Illinois River. All 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.

In the laboratory, main channel ichthyoplankton samples collected from the Dresden Island, Marseilles, Starved Rock, and Peoria pools from May to mid-July were assessed for the presence of species-specific invasive carp DNA derived from eggs or larvae in order to evaluate the potential for quantitative PCR (qPCR) screening to identify samples containing eggs or larvae prior to full sample processing and microscopic identification of specimens. Sample ethanol was exchanged with fresh molecular-grade ethanol in order to minimize the potential for DNA not derived from eggs or larvae to affect results, and samples were gently inverted five times in the refreshed ethanol to mix contents. After a rest period during which detritus settled, three 1 mL aliquots of sample preservative were removed to screen for the presence of invasive carp DNA. Following DNA extraction, dual duplex qPCR reactions (one for Bighead Carp and Silver Carp, one for Grass Carp and Black Carp) were run in triplicate for each ethanol decant sample. Due to the potential for organic matter present within the samples to potentially bind to DNA and influence the probability of false positives, organic matter volume, wet mass, and dry mass were also measured for each sample.

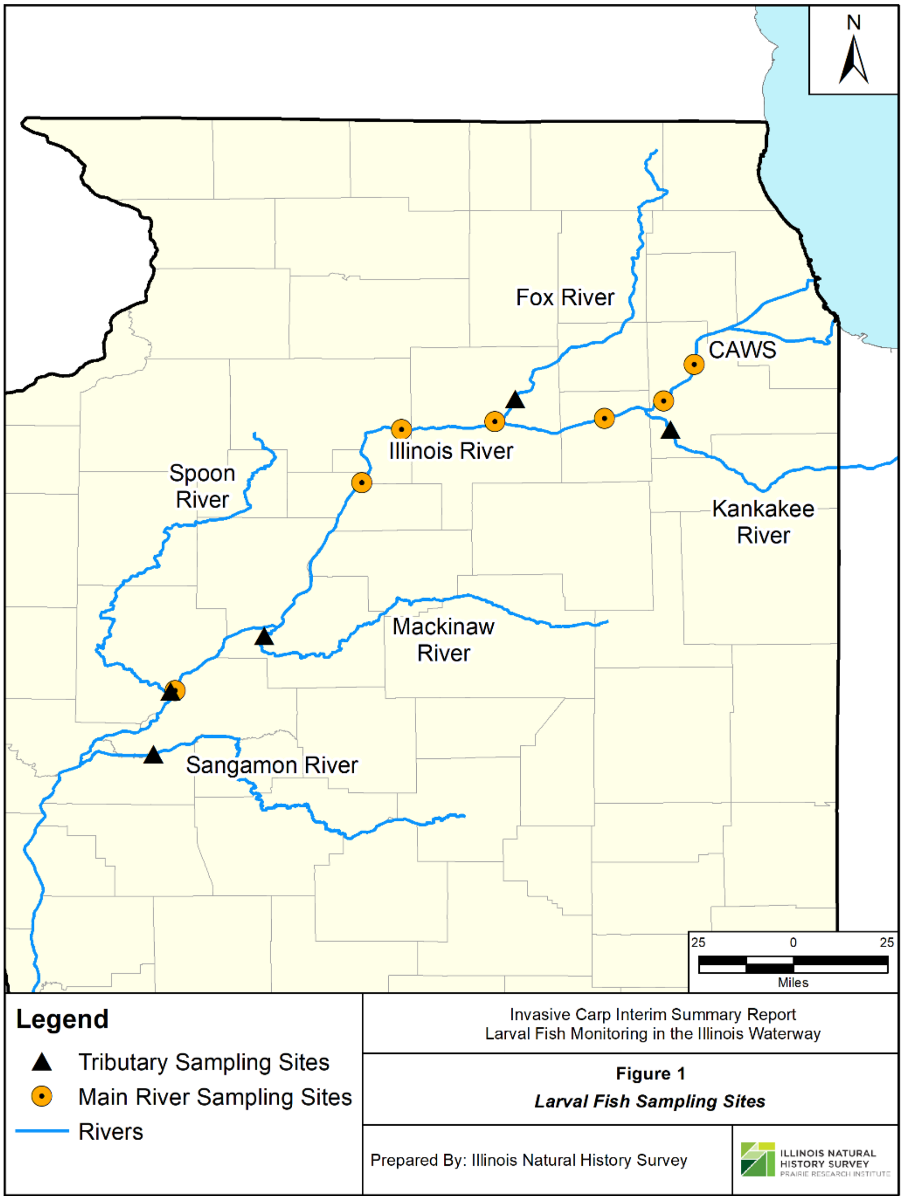

Figure 1. *Map of ichthyoplankton sampling sites in the Illinois Waterway (circles) and in tributary rivers (triangles).*

Fish eggs and larvae were separated from other materials in each sample, and all larval fish were identified to the lowest possible taxonomic unit under dissecting microscopes. Fish eggs were separated by size, with all eggs having a membrane diameter larger than 3 mm being identified as potential invasive carp eggs and retained for later genetic confirmation of identity. Invasive carp larvae were identified according to Chapman (2006) and by comparison to a developmental series of larvae obtained from a hatchery (Osage Catfisheries, Inc.; Osage Beach, MO). Larval fish and egg densities were calculated as the number of individuals per cubic meter of water sampled. Subsets of eggs and larvae were submitted to the USFWS's Whitney Genetics Laboratory for genetic evaluation of species identity.

The relationship between the number of invasive carp DNA copies and presence or absence of invasive carp eggs and larvae in ichthyoplankton samples, and the potential influence of organic matter content on this relationship, was assessed with generalized linear models fit to binomial distributions using the logit link. Densities of invasive carp eggs and larvae were summarized by sampling location through time and compared to water temperature and river discharge to examine spatial patterns in invasive carp reproduction, identify conditions associated with spawning, and assess trends in invasive carp reproductive output. Occurrences of invasive carp eggs and larvae upstream of Starved Rock Lock and Dam were particularly closely scrutinized, as these could represent status changes for upper IWW navigation pools.

Results and Discussion:

During 2021, ichthyoplankton monitoring on the IWW collected 508 samples, capturing 5,524 invasive carp eggs and 992,765 invasive carp larvae. Tributary sampling collected an additional 264 samples and captured 12,872 invasive carp eggs and 1,240 invasive carp larvae. Two distinct bouts of spawning by invasive carp were observed during 2021. A heavy rain event during the second week of May caused a distinct rise in water levels in the upper IWW, but also caused water temperatures to decline below the threshold thought to be conducive to invasive carp reproduction (Figure 2). By the time water temperatures had increased above 18°C again, water levels in the upper IWW had returned to base levels. Due to additional rainfall and the hydrologic lag time common to this system, water levels in the lower Illinois River continued to increase through the fourth week in May, coinciding with water temperatures exceeding 20°C.

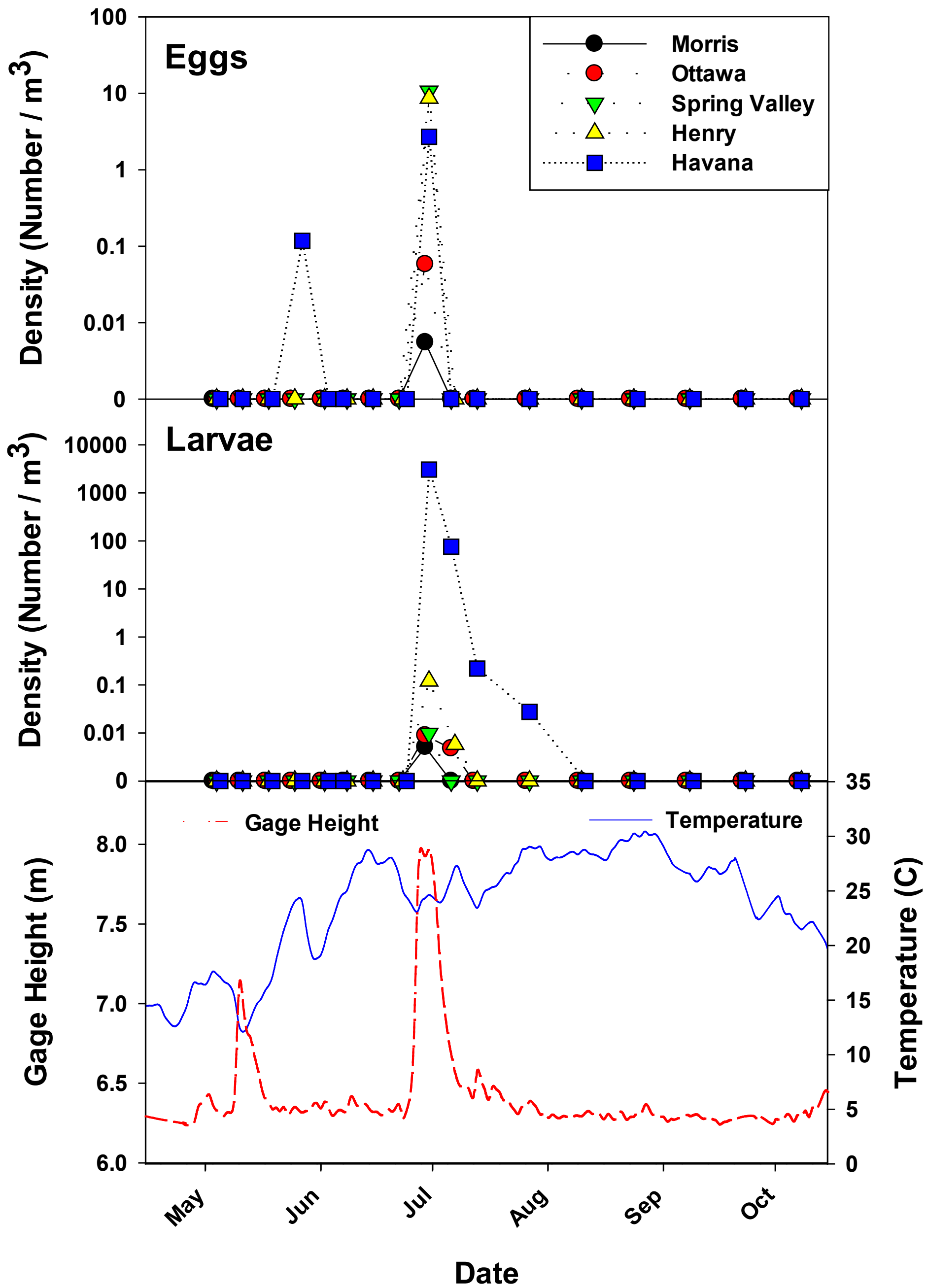

Figure 2. *Densities (number/m^3; note log scale) of invasive carp eggs (top panel) and larvae (middle panel) collected from main channel sites of the Illinois Waterway during 2021. Mean daily gage height (m) and water temperature (° C) of the Illinois River during May – October 2021 (bottom panel) were obtained from USGS gage 5543010 at Seneca, IL.*

LaGrange Pool tributaries also demonstrated a more pronounced increase in discharge at this time (Figure 3). Coincident with the convergence of rising water levels and higher water temperatures, invasive carp eggs were collected in the LaGrange Pool and its tributaries (Sangamon and Spoon rivers) during the last week of May. Small numbers of invasive carp larvae were also collected from these tributaries at this time.

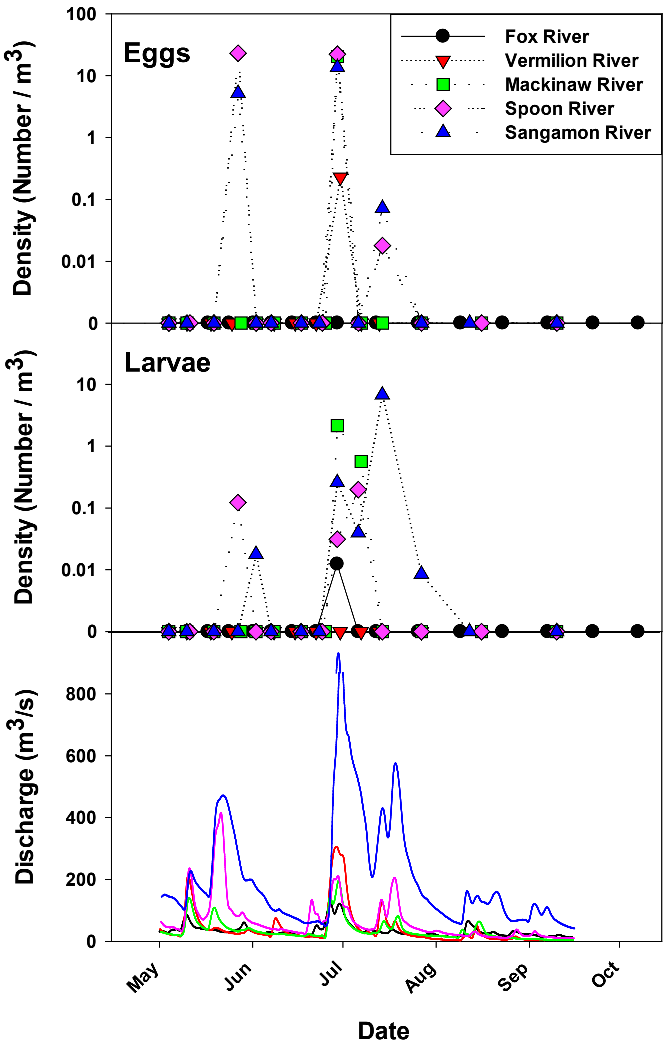

Figure 3. *Density (number/m^3; note log scale) of invasive carp eggs (top panel) and larvae (middle panel) collected from five tributaries of the Illinois River during May – October 2021. No invasive carp eggs or larvae were collected from the Kankakee River in 2021. Mean daily discharge (meter^3/second; bottom panel) was obtained from USGS gages (Fox River:5552500; Vermilion River:5555300; Mackinaw River:5568000; Spoon River:5570000; Sangamon River:5583000).*

Water temperatures remained above 20°C after May, and a substantial increase in water levels occurred again throughout the IWW during the last week of June. At this time, invasive carp eggs and larvae were observed at all sites from the Marseilles Pool downstream, with particularly high egg densities at sites in the LaGrange and Peoria pools (Figure 2). The densities of invasive carp larvae in the LaGrange Pool at this time were the highest that have ever been observed from the IWW (mean = 3,050 larvae/m^3; previous maximum mean density = 176 larvae/m^3 in 2017). Larvae continued to be collected in the LaGrange Pool through the end of July. Illinois River tributaries experienced a similar increase in flows at the end of June and invasive carp eggs were collected in all tributaries of the Peoria and LaGrange pools (Vermilion, Mackinaw, Spoon, and Sangamon rivers), while invasive carp larvae were collected in Starved Rock and LaGrange pool tributaries (Fox, Mackinaw, Spoon, and Sangamon rivers; Figure 3). Localized rain events in mid- to late-July caused additional increases in flows in the Spoon and Sangamon rivers, triggering additional invasive carp spawning and resulting in the highest densities of larvae observed in the Sangamon River in 2021. No invasive carp eggs or larvae were collected from either the IWW or any of its tributaries after July.

No invasive carp eggs or larvae were observed in the Dresden Island or Brandon Road pools or in the Kankakee River during 2021. The single larval specimen (pre-gas bladder inflation stage) collected from the Marseilles Pool in late June was genetically identified as a Grass Carp. This is the first invasive carp larvae ever collected from the Marseilles Pool. However, Grass Carp occur farther upstream in the IWW than bigheaded carp, including upstream of the Electric Dispersal Barrier on the CSSC, and are already present in the Great Lakes basin. This collection from the Marseilles Pool therefore does not signify any significant change in status of an invasive carp population in the IWW. Invasive carp eggs collected from the Starved Rock Pool were primarily identified as Silver Carp (n = 6 of 7), with a small proportion identified as Grass Carp (n = 1 of 7). Invasive carp larvae (also pre-gas bladder inflation) collected in the Starved Rock Pool were also genetically identified as Silver Carp (n = 2 of 2). However, larvae from the Fox River that were identified as Silver Carp (n = 2 of 2) were post-gas bladder inflation stages. Invasive carp eggs have been observed in the Marseilles and Starved Rock pools for several years, and pre-gas bladder inflation larvae were also observed in the Starved Rock Pool in 2015 (Grass Carp larvae) and 2020 (Silver Carp larvae). The post-gas bladder inflation larvae from the Fox River represent only the second time bigheaded carp larvae older than this key developmental stage have been captured upstream of the Starved Rock Lock and Dam. Because invasive carp eggs and larvae must remain suspended in the drift for several days prior to gas bladder inflation, the presence of larvae of these stages in the lower Fox River is surprising. Less than 9 km of river are present on the Fox River from its confluence with the Illinois River to the Dayton Dam, a substantial barrier to fish passage. Eggs and larvae developing to this stage within this short distance of river suggests that some eggs spawned downstream of the Dayton Dam may have been retained by eddies and other complex flow conditions, allowing them to develop in suspension while being transported only a short linear distance.

Reproductive output by invasive carp in the IWW was very high in 2021 relative to many other study years. Years with above-average invasive carp reproduction tend to occur when seasonal fluctuations in discharge coincide with warmer temperatures in May and June (Parkos et al. 2021). Invasive carp spawning tends to be associated with rising water levels when water temperatures are above 18°C (Schrank et al. 2001; Lohmeyer and Garvey 2009; Larson et al. 2017). In contrast to 2021, water temperatures were low during much of May 2020, and water levels were low and stable during and after June 2020, resulting in very low reproductive output by invasive carp in 2020. Environmental factors are undoubtedly important for synchronizing spawning activity and affecting individual reproductive investment, but the influence of adult spawner abundance on egg and larvae production cannot be overlooked. The upper-most pools of the IWW, where invasive carp occur in low densities, tend to produce lower and less consistent numbers of eggs and larvae than downriver pools. However, invasive carp also show evidence of density-limitation of reproductive output at very high densities of adults (Parkos et al. 2021). The diminished reproductive output at low adult densities provides insight into one of the pathways through which sufficient levels of harvest may facilitate achieving the management goal of substantially reducing invasive carp in the IWW through recruitment overfishing (Tsehaye et al. 2013). While the relationship between the densities of the earliest life stages (i.e., embryos and larvae) and recruited individuals is not currently known, successful reproduction is a prerequisite for successful recruitment, and therefore, management that can disrupt reproduction may help attain the goals of the invasive carp harvest program. Conversely, the density-dependent relationship between annual egg and adult abundance documented in the IWW implies that there is the potential for compensatory reproductive output if insufficient numbers of adults are removed.

Substantial variation has also been observed in the abundances of invasive carp eggs and larvae in Illinois River tributaries across study years. Similar to the mainstem Illinois River, relatively high larval densities were observed in the Sangamon, Mackinaw, and Spoon rivers in 2021, and invasive carp larvae were collected for the first time in the Fox River. In contrast, low reproductive output was observed in all tributary rivers in 2020. Environmental conditions varied among tributaries, and some of this variation appears to be associated with the magnitude of observed invasive carp reproductive output in these rivers in a given year. Step-wise multiple logistic regression indicated a positive and significant relationship of temperature (P=0.004) and discharge (P=0.01) with the presence of invasive carp larvae in the tributaries. Tributaries with larger watersheds, higher discharge, greater turbidity, and higher temperatures have also been found to produce higher abundances of invasive carp eggs (Schaik et al. 2020). Differences in spawning stock characteristics among tributaries could also contribute to the observed variation but have not yet been adequately assessed. The contribution of tributaries to basin-wide egg and larval production also remains unknown, but likely varies among years depending on the timing and magnitude of precipitation events and the subsequent effects on individual watersheds.

Quantitative PCR screening of ichthyoplankton samples was used in 2021 to prioritize samples that had a high probability of containing invasive carp eggs or larvae for processing. Overall, 58 of the 220 samples that were subjected to qPCR screening were found to contain at least trace amounts of invasive carp DNA. Of these, 57 contained Silver Carp DNA, 5 had Grass Carp DNA, 3 had Bighead Carp DNA, and 1 sample was found to contain Black Carp DNA. The total number of invasive carp DNA copies in a sample was found to be a significant predictor of the presence of invasive carp eggs and/or larvae in the sample (logistic regression: $P < 0.0001$, McFadden's $R^2 = 0.47$; Figure 4). The quantity of organic debris in a sample did not affect the relationship between the number of DNA copies and the probability of the presence of invasive carp eggs or larvae. A threshold of 10 DNA copies had previously been used to indicate that a sample was likely to contain eggs or larvae, but a lower cutoff appears to be warranted. The current qPCR screening method appears to be more likely to indicate the presence of invasive carp eggs or larvae in a sample at a lower threshold of DNA copy numbers than was found in the initial demonstration of this method by Fritts et al. (2019). Because the threshold number of DNA copies that is chosen to flag samples for rapid processing represents a tradeoff between false positive and false negative rates, minimizing the risk of false negatives must be carefully considered against the added time involved with processing additional false positive samples. Because adult invasive carp are present at the majority of sites where ichthyoplankton sampling is conducted on the IWW, there is always a possibility that DNA not derived from eggs or larvae may occur in a sample, and some false positives are therefore anticipated. Several samples collected in both 2020 and 2021 contained considerable quantities of Silver Carp DNA but were not found to contain any invasive carp eggs or larvae. Additionally, a sample collected in the upper Peoria Pool in 2021 contained a notable quantity of Black Carp DNA, but also did not ultimately contain any invasive carp specimens. Identifying and controlling potential sources of error to minimize false negative and false positive outcomes will help to improve the usefulness of the qPCR procedure.

Recommendations:

Ichthyoplankton sampling should continue to monitor for invasive carp reproduction in the upper IWW to evaluate any changes in the invasive carp reproductive front and assess the effects of invasive carp harvest activities on the reproductive productivity of these populations. Relationships between reproductive output and recruitment should be investigated further to provide a more complete understanding of recruitment mechanisms and evaluate potential compensatory responses among different life stages to invasive carp harvest efforts. Further FluEgg modelling is needed to determine the consistency of invasive carp spawning locations in the IWW and provide information to confirm the relevant adult spawner density for assessment of stock - reproductive productivity relationships. Ichthyoplankton monitoring in tributary rivers should evaluate the relative contribution of these systems as sources of eggs and larvae to the main channel of the Illinois River and assess the potential for similar rivers in the Great Lakes region to serve as spawning tributaries. Quantitative PCR screening of ichthyoplankton samples should identify and control for potential sources of error to minimize false positive and false negative rates and enhance the usefulness of this procedure. Methods to allow for more rapid identification of invasive carp eggs and larvae in ichthyoplankton samples (in-field qPCR) should be explored in order to allow for the capability of communicating the occurrence of spawning events on the same day that sampling occurs.

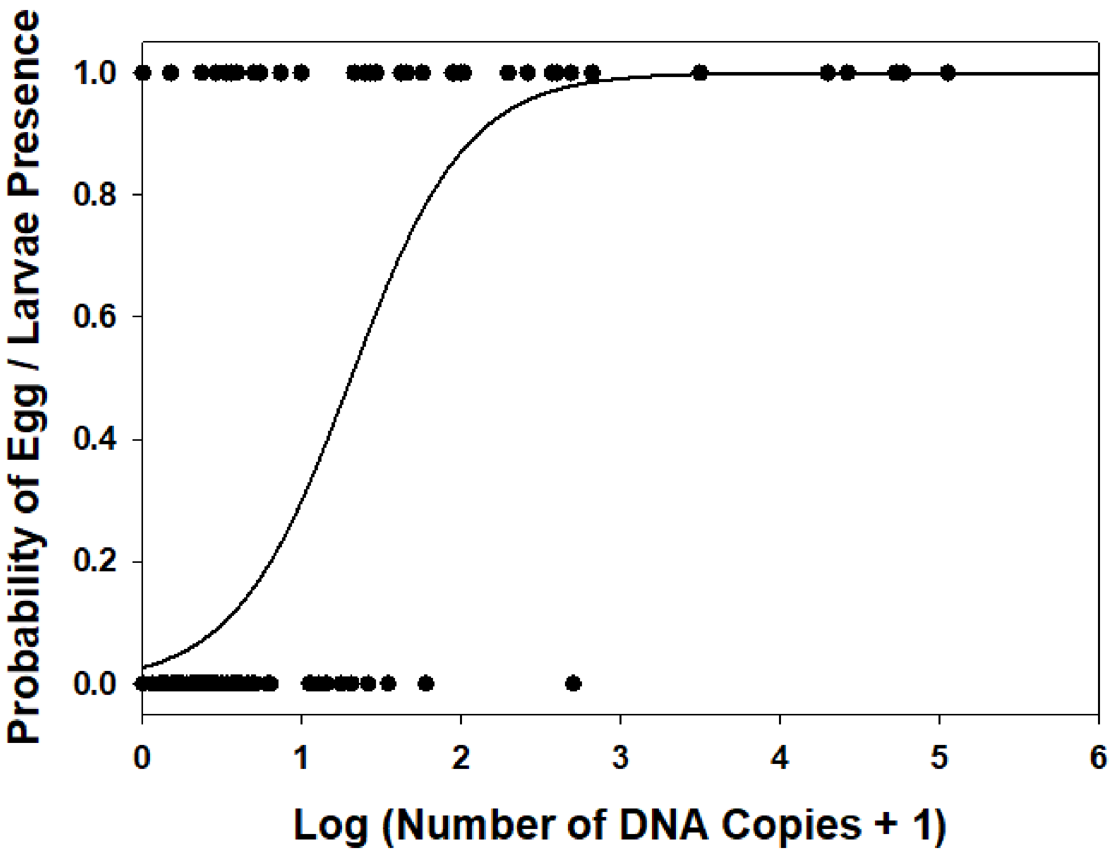

Figure 4. *The relationship between the number of copies of invasive carp DNA (summed across invasive carp species) and the presence of invasive carp eggs or larvae in ichthyoplankton samples collected from the Illinois Waterway during 2020 and 2021.*

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Invasive Carp Stock Assessment in the Illinois River

David Coulter, Jim Garvey (Southern Illinois University)

Participating Agencies: Southern Illinois Universtiy – Carbondale (lead), additional assistance/collaboration with Illinois DNR, USACE, USGS, INHS, USFWS

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

Introduction and Need:

Management goals for bigheaded carp in the Illinois River focus on limiting upstream dispersal through monitoring, assessing movement barriers, and reducing abundance through contracted harvest. Bigheaded carp spatial distributions vary both seasonally and annually; therefore, quantifying how spatial distributions change through time will help target contracted harvest to maximize removal efforts and minimize costs. Additionally, long-term information on bigheaded carp population characteristics, distributions, and movements, especially along the population front in the upper Illinois River, can provide data to parameterize population models. These models simulate the effects of various management actions (e.g., harvest scenarios, locations of enhanced deterrent technologies) to determine which options are most likely to achieve management goals.

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. By monitoring densities across multiple years throughout the river, long-term trends can be identified and related to environmental conditions, reproduction, or management actions. Broad-scale density estimates also help inform management actions in the upper river near the invasion front. 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 also help quantify these patterns which will better inform management decisions, ensure sufficient surveillance efforts, 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 locations. Dresden Island Pool represents the current population front for the adult bigheaded carp invasion in the Illinois River, while Marseilles Pool is the most upstream pool where young-of-year have been found. Frequent hydroacoustic surveys of bigheaded carp densities in these pools identifies locations where bigheaded carp aggregate to inform harvest efforts.

The spatially-explicit population model of bigheaded carp in the Illinois River (SEIcarP) assesses how bigheaded carp populations respond to a variety of management actions (e.g., location and intensity of harvest; location and effectiveness of deterrent technologies). The model draws on a variety of datasets including bigheaded carp densities and telemetry movement data.

Collaborations between MRWG modeling, telemetry, and hydroacoustic working groups have identified several additional data needs in addition to maintenance of current monitoring efforts. SIU's contribution to continued model support and development includes 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), and continued hydroacoustic monitoring of bigheaded carp densities throughout the Illinois River.

Objectives:

(1) Quantify invasive carp densities every other month in Dresden Island and Marseilles pools in 2021 using mobile hydroacoustic surveys to pinpoint high density areas that can be targeted during contracted removal.

(2) Conduct hydroacoustic surveys at standardized sites in fall 2021 from Alton – Dresden Island pools to assess long-term density trends.

(3) Maintain SIU's extensive acoustic telemetry array currently in place in the Illinois River used to collect movement information and for maintaining adult surveillance effort. Share collected data with telemetry working group and those working on the SEIcarP model.

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 2021.
- The tenth year of standardized monitoring of bigheaded carp densities was completed in 2021 from Alton – Dresden Island pools. These data allow for long-term assessments and comparisons of density trends across space and through time.
- Tagging of 152 adult bigheaded carp took place in Alton, LaGrange, and Marseilles pools to maintain sufficient surveillance to detect adult movements among pools and towards the invasion front.

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 2021 were completed in March, June, and August. Final 2021 surveys in these pools and throughout other Illinois River (Starved Rock – Alton) pools were completed in fall of 2021. All hydroacoustic sampling methods, designs, and analyses followed those outlined in MacNamara et al. (2016). We also completed surveys before Unified Method events in Dresden Island Pool to inform removal crews on density hotspots prior to harvest. Fall hydroacoustic sampling for monitoring long-term bigheaded carp density trends occurred in October 2021 at standardized sites (including main channel, side channel, and backwater sites) following standardized sampling methods used in previous years (since 2012). Fall hydroacoustic sampling in Dresden Island Pool occurred prior to a Unified Method removal event.

Telemetry- Adult Movements

Utilizing an array of 51 Vemco 69 kHz stationary receivers maintained by SIU (Abeln 2018) as well as stationary receviers maintained by partner agencies (USGS, USACE, USFWS, MDC), the movements of Silver Carp and Bighead Carp implanted with internal transmitters (Vemco V16 transmitters) were monitored from Alton Pool upstream through Dresden Island Pool. Additional stationary receivers were deployed and maintained by other agencies in the Telemetry Working Group in other locations of the Illinois Waterway. Additionally, other fish species implanted with 69 kHZ transmitters by other members of the Telemetry Working Group (MRWG) can be detected by this array. Stationary receivers were downloaded on two occasions in 2021, with data initially checked to remove false detections and analyzed to identify upstream and downstream passages through lock and dam structures in the study area (e.g., Lubejko et al. 2017*)*. Additional acoustic telemetry tags were deployed to replace expiring tags.

Results and Discussion:

Hydroacoustic Surveys – Bimonthly Heat Maps and Fall Standardized 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. Density maps (Figure 1) were provided to MRWG members which helped inform contracted harvest efforts throughout the year. Hydroacoustic sampling and density heatmaps were also provided to removal crews prior to Unified Method events. Mobile hydroacoustic sampling was completed in October 2021 from Alton – Dresden Island pools. Bigheaded carp densities in 2021 throughout the Illinois River remained low relative to historical densities (Figures 2 & 3). Densities in the upper Illinois River (Starved Rock – Dresden Island pools) were similar to the most recent years sampled. Dresden Island densities in 2021 were slightly higher than densities observed from 2017 – 2020 which may, in part, be due to the timing of hydroacoustic sampling. In 2021, hydroacoustic sampling in Dresden Island Pool was only able to occur prior to the October Unified Method harvest event, whereas sampling from 2017 – 2020 were able to be completed after fall Unified Method events. Fall bigheaded carp densities in the lower Illinois River (Alton – Peoria pools) were relatively low and within the amount of annual variability observed within the previous 3 – 4 years (Figure 2).

Telemetry- Adult Movements

Additional acoustic telemetry tags (152 total) were implanted in bigheaded carp to replace expiring tags in Alton (64 tags), LaGrange (63 tags), and Marseilles (25 tags) pools for maintaining sufficient adult surveillance efforts (e.g., early detection of movements past real-time receivers). SIU stationary receivers were deployed and downloaded from Dresden Island Pool downstream through Alton Pool. All detection data downloaded from stationary receivers throughout the year were submitted for inclusion in the USGS-managed FishTracks telemetry database. These detection data were included in an ongoing USGS-led project to update inter-pool movement probability estimates that will be used to update the SEIcarP model.

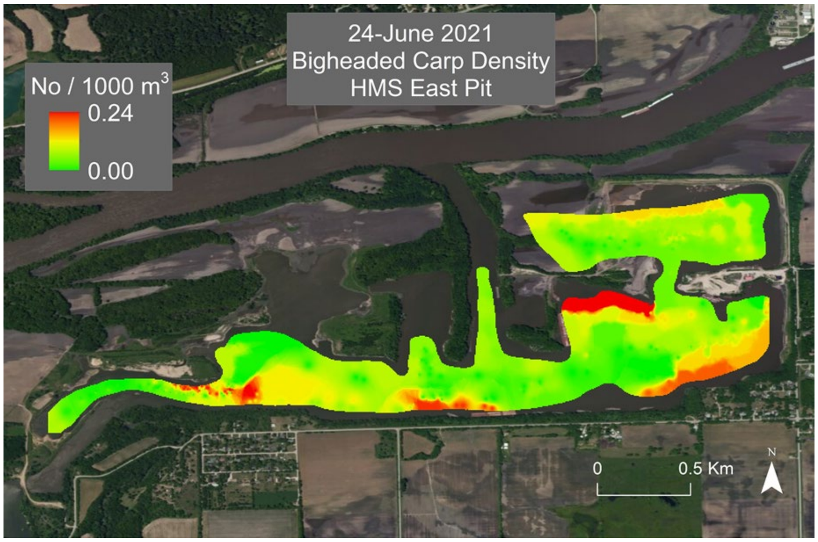

Figure 1. *Example heatmap displaying bigheaded carp spatial distributions in the HMS East Pit in the Marseilles pool sampled in June 2021 with mobile hydroacoustic sampling. Densities were observed using mobile hydroacoustic surveys.*

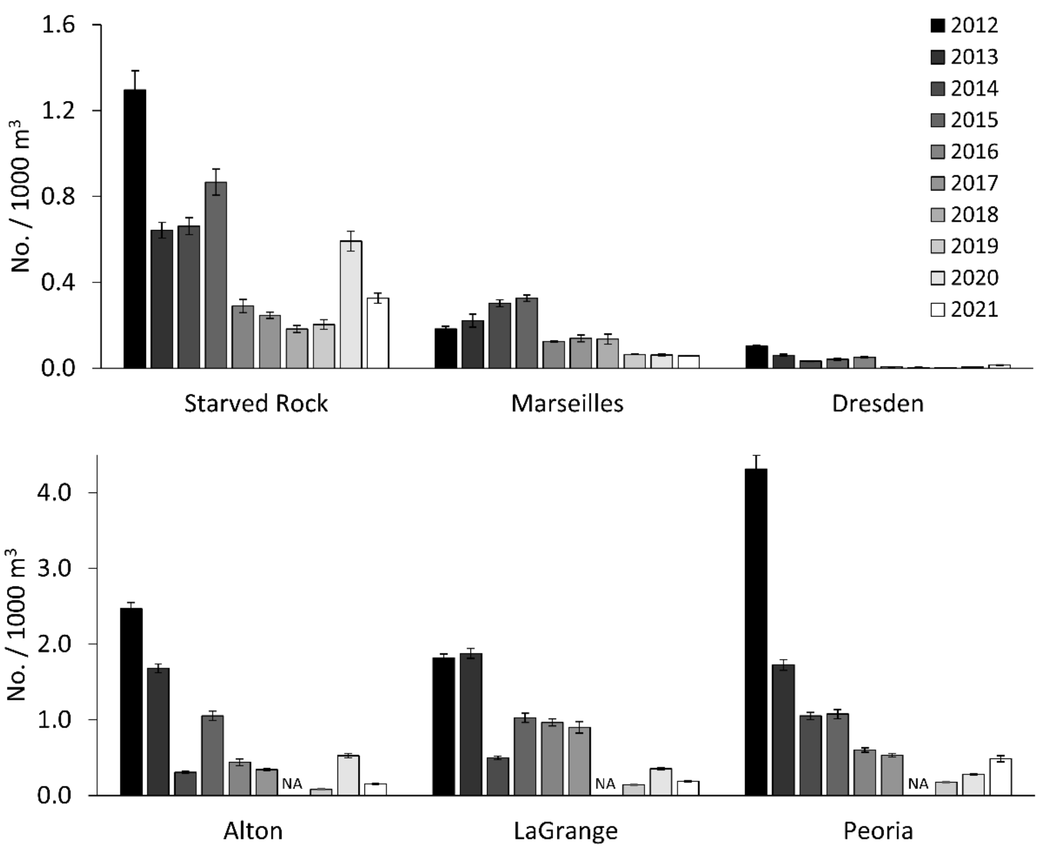

Figure 2. *Long-term mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities from mobile hydroacoustic sampling in the Illinois River during Fall of each year. Note differences in y-axis densities between panels.*

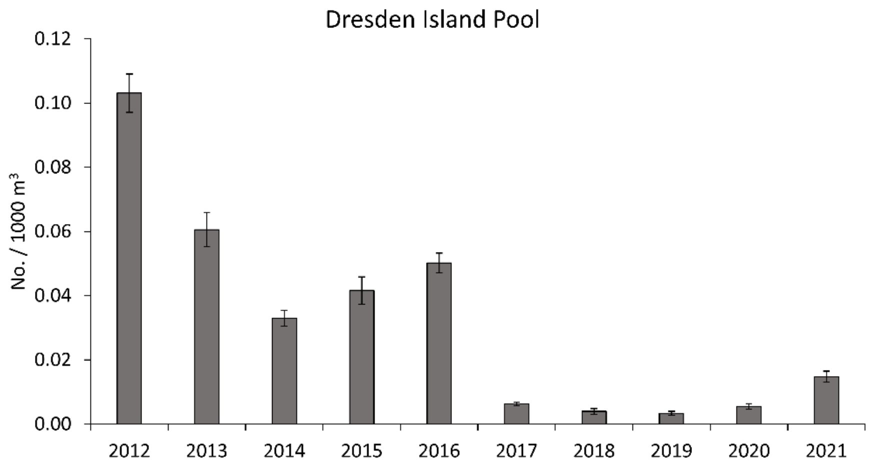

Figure 3. *Long-term mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities from mobile hydroacoustic sampling in the Dresden Island Pool of the Illinois River during Fall of each year. Note that sampling occurred prior to the Unified Method event in 2021, whereas sampling in 2017 – 2020 occurred after Fall Unified Method events.*

Recommendations:

Hydroacoustic surveys are needed to inform (via spatial distribution maps) contracted removal and Unified Method events in the upper Illinois River pools, as the resulting data can increase harvest efficiency. Bigheaded carp spatial distributions change through time and are not consistent across years, necessitating repeated surveys in Dresden Island and Marseilles pools to direct harvest efforts to appropriate locations. Standardized fall hydroacoustic surveys from Alton−Dresden Island pools are also needed to monitor long-term population trends that act as an additional surveillance tool and can assist in making management decisions.

Continued collection of telemetry movement data will serve to maintain sufficient adult surveillance efforts for detecting movement among pools, including toward the invasion front. Movement data will also be needed to improve and update movement models used in the SEICarP model. It will also 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).

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Des Plaines River and Overflow Monitoring

Jen-Luc Abeln and Nathan T. Evans
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Participating Agencies: USFWS – Carterville FWCO Wilmington Substation (lead) and USACE (field support)

Introduction and Need:

The upper Des Plaines River originates in Southeast Wisconsin and joins the CSSC in the Brandon Road Pool immediately downstream of Lockport Lock and Dam. Invasive 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, invasive carp eDNA was detected in the upper Des Plaines River (no samples were taken in 2012 – 2021). If present in the upper Des Plaines River, invasive carp have the potential to bypass the 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 invasive 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 invasive carp from infiltrating the CSSC, although it will likely allow invasive 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. An overtopping event occurred during 2020, with the Des Plaines River cresting at a record high of 13.26 ft (4.04 m) on May 18th. This allowed for a few inches of water to pass from the Des Plaines River to the CSSC. A scour area under six panels in the fencing allowed for potential fish passage. No fish were captured via a seine in the area were the scour occurred and the scour area has since been remediated. 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 invasive carp distribution and spawning within the river. Likewise, it is critical to determine and understand the effectiveness of the physical barrier at blocking invasive carp movement between the Des Plaines River and the CSSC. Overtopping events may be reduced into the future with the McCook Reservoir stage 1 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. Stage 2 is set to come online in 2029 and provide an additional 6.5 billion gallons (24.6 billion liters) of flood water storage.

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:

- Capture 1,617 fishes in 2021 including 37 species and 2 hybrid groups from 7.75 hours of electrofishing and 548.6 m of gill netting.
- Collected 15,499 fishes including 67 species and 4 hybrid groups from 2011 – 2021 via electrofishing (89.25 hours) and gill netting (155 sets; 22,205.3 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 2021.
- Four overtopping events since 2011 have resulted in several improvements to the barrier fence. No overtopping events occurred in 2021.

Methods:

In 2021, sampling was conducted in the upper Des Plaines River from East Romeo Road (Romeoville, IL) to IL-83 (Willow Springs, IL; Figure 1). Two sampling periods were completed from June 28 to July 2 and from October 26-28 using pulsed-DC boat electrofishing. Electrofishing runs included one dipper and proceeded for 15 minutes. Only one dipper rather than two dippers, as in prior years, was used during June/July 2021 sampling due to the COVID-19 pandemic. Two dippers were used in October 2021. Two gill net sets were used on October 28, 2021. 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 eleven years of sampling (2011-2021), 89.25 hours of electrofishing and 155 net sets covering 24,284 yards (22205.3 m) of gill net resulted in a total catch of 15,499 fishes. Sixty-seven species and four hybrid groups have been collected. Common Carp have been the most commonly collected species, followed by Gizzard Shad, then Largemouth Bass. A drastic increase in the number of Banded Killifish was observed this year (Table 1). In 2021, 7.75 hours of electrofishing resulted in 1617 fish representing 37 species and 2 hybrid groups. 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 2021, but one was observed during an electrofishing run in June.

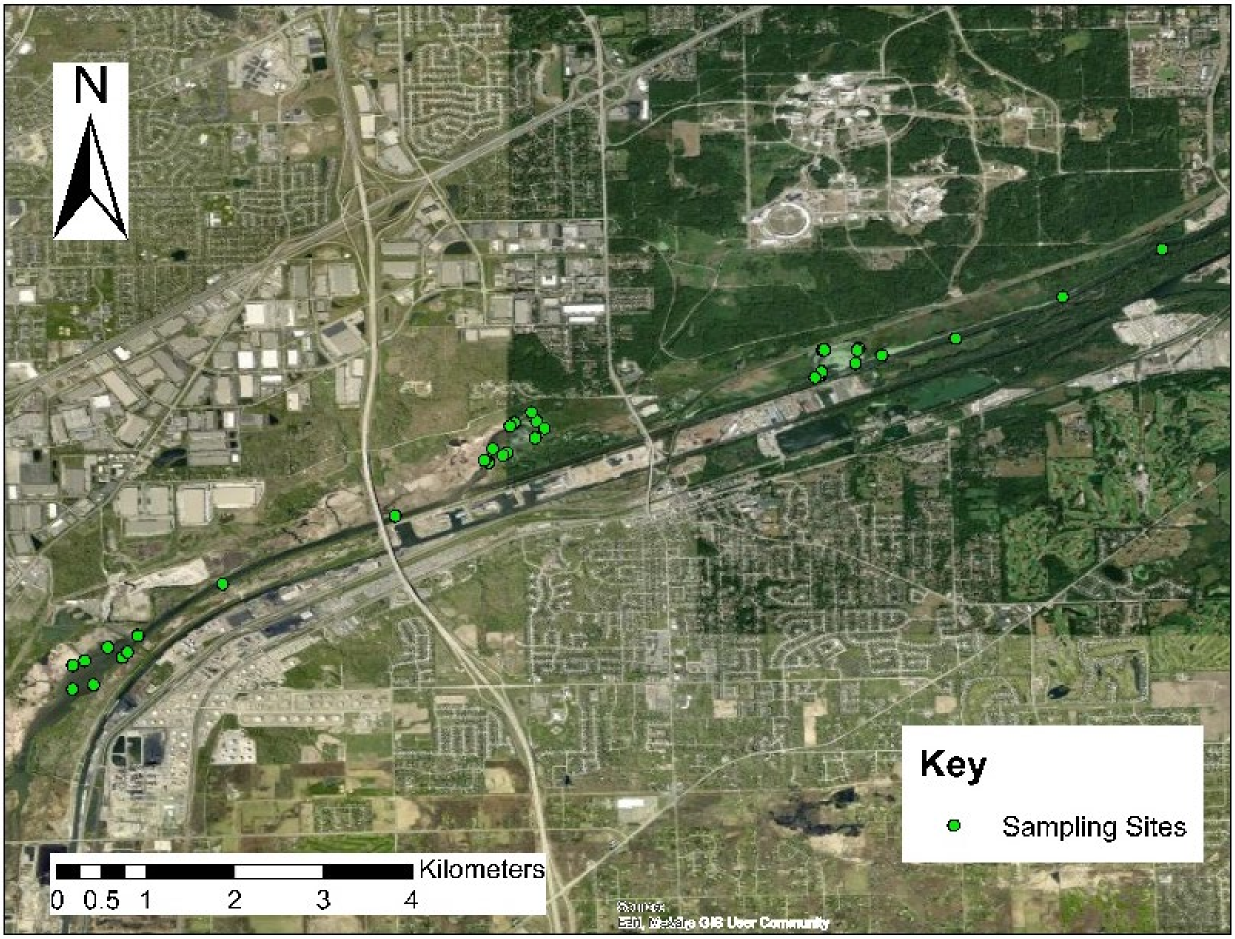

Figure 1: *2021 Sampling sites in the upper Des Plaines River.*

Recommendations:

- Continue seasonal monitoring for large (>153mm) and small (≤153mm) Bighead Carp and Silver Carp in the upper Des Plaines River with emphasis on backwater habitat.
- Improve monitoring for all life stages of invasive 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.
- 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 – 2021. Fishes were sampled via boat-mounted electrofishing and gill netting.*

Species	No. Captured 2021	No. Captured 2011-2020	Totals All Years
Banded Killifish	110	4	114
Bigmouth Buffalo	-	22	22
Black Buffalo	-	7	7
Black Bullhead	1	42	43
Black Crappie	7	344	351
Blackside Darter	-	15	15
Blackstripe Topminnow	51	77	128
Bluegill	53	1136	1189
Bluntnose Minnow	118	855	973
Bowfin	33	173	206
Brown Bullhead	-	1	1
Bullhead Minnow	-	88	88
Carp x Goldfish Hybrid	4	56	60
Central Mudminnow	1	3	4
Central Stoneroller	-	9	9
Channel Catfish	5	434	439
Channel Shiner	1	2	3
Common Carp	154	3544	3698
Creek Chub	-	39	39
Emerald Shiner	118	251	369
Fathead Minnow	-	43	43
Flathead Catfish	-	4	4
Freshwater Drum	-	7	7
Gizzard Shad	492	1710	2202
Golden Shiner	64	250	314
Goldfish	57	118	175
Grass Carp	-	10	10
Grass Pickerel	2	6	8
Green Sunfish	2	167	169
Highfin Carpsucker	-	1	1
Hornyhead Chub	3	41	44
Hybrid Striped Bass	-	1	1
Hybrid Sunfish	4	9	13
Johnny Darter	-	2	2
Largemouth Bass	120	1133	1253
Logperch	-	7	7
Longear Sunfish	-	1	1
Longnose Gar	1	72	73

Table 1. *Continued.*

Species	No. Captured 2021	No. Captured 2011-2020	Totals All Years
Mimic Shiner	-	1	1
Muskellunge	-	2	2
Northern Pike	12	252	264
Orangespotted Sunfish	-	115	115
Oriental Weatherfish	-	2	2
Pumpkinseed	23	183	206
Quillback	-	19	19
Redear Sunfish	-	1	1
River Carpsucker	-	23	23
River Shiner	-	10	10
Rock Bass	10	64	74
Rosyface Shiner	35	14	49
Round Goby	-	40	40
Sand Shiner	-	171	171
Sauger	-	83	83
Sauger x Walleye Hybrid	-	5	5
Smallmouth Bass	44	202	246
Smallmouth Buffalo	1	32	33
Spotfin Shiner	13	938	951
Spottail Shiner	43	478	521
Spotted Sucker	1	32	33
Suckermouth Minnow	-	1	1
Tadpole Madtom	-	1	1
Walleye	-	10	10
Warmouth	3	6	9
Western Mosquitofish	2	2	4
White Bass	-	1	1
White Crappie	1	3	4
White Perch	-	1	1
White Sucker	27	448	475
Yellow Bass	-	2	2
Yellow Bullhead	1	50	51
Yellow Perch	-	6	6
Sum No. Captured	1617	13882	15499
Species Richness (Hybrids)	37(2)	67(4)	67(4)

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

Justin Widloe, Nate Lederman, Eli Lampo, Claire Snyder, Charmayne Anderson, Kevin Irons (ILDNR), Allison Lenaerts, Dan Roth, Andrew Mathis, Jehnsen Lebsock (INHS), and Dr. Greg Whitledge SIU)

Participating Agencies: ILDNR (lead); SIU

Introduction and Need:

The ILDNR fields many public reports of observed or captured invasive 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 invasive 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 ILDNR Urban Fishing Program.

As a further response to the Bighead Carp in Flatfoot Lake and Schiller Pond, ILDNR reviewed Bighead Carp captures in all fishing ponds included in the ILDNR 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 CAWS upstream of the EDBS 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 invasive 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 invasive carp between waters within close proximity to one another.

In addition to Chicago area ponds once supported by the ILDNR Urban Fishing Program, ponds with positive detections for invasive carp eDNA were also reviewed. Eight of the 40 ponds sampled for eDNA by the University of Notre Dame resulted in positive detections for invasive carp, two of which are also ILDNR 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 invasive 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 invasive carp infested waters) they were examined for the presence of live invasive carp given the proximity to CAWS waterways.

Objectives:

(1) Sample fishing ponds in the Chicago Metropolitan area included in the ILDNR Urban Fishing using conventional gears (electrofishing and trammel/gill nets) for the presence of invasive 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 ILDNR Chicago Urban Fishing Program ponds have been sampled with nets and electrofishing.
- All eight Chicago area fishing ponds with positive invasive carp eDNA detections have been sampled with electrofishing and trammel/gill nets.
- The state record Bighead Carp weighing in at 72 pounds 8 ounces was captured on rod and reel at Humboldt Park Lagoon in 2021.

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, invasive 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 SIU.

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. One Bighead Carp was incidentally caught by a fisherman in 2016. In 2021, the state record Bighead Carp was caught on rod and reel in Humboldt Park Lagoon, weighing in at 72 pounds 8 ounces. Otoliths were removed and ILDNR is awaiting results regarding microchemistry analysis and age. 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 ILDNR 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 invasive 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 invasive 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.

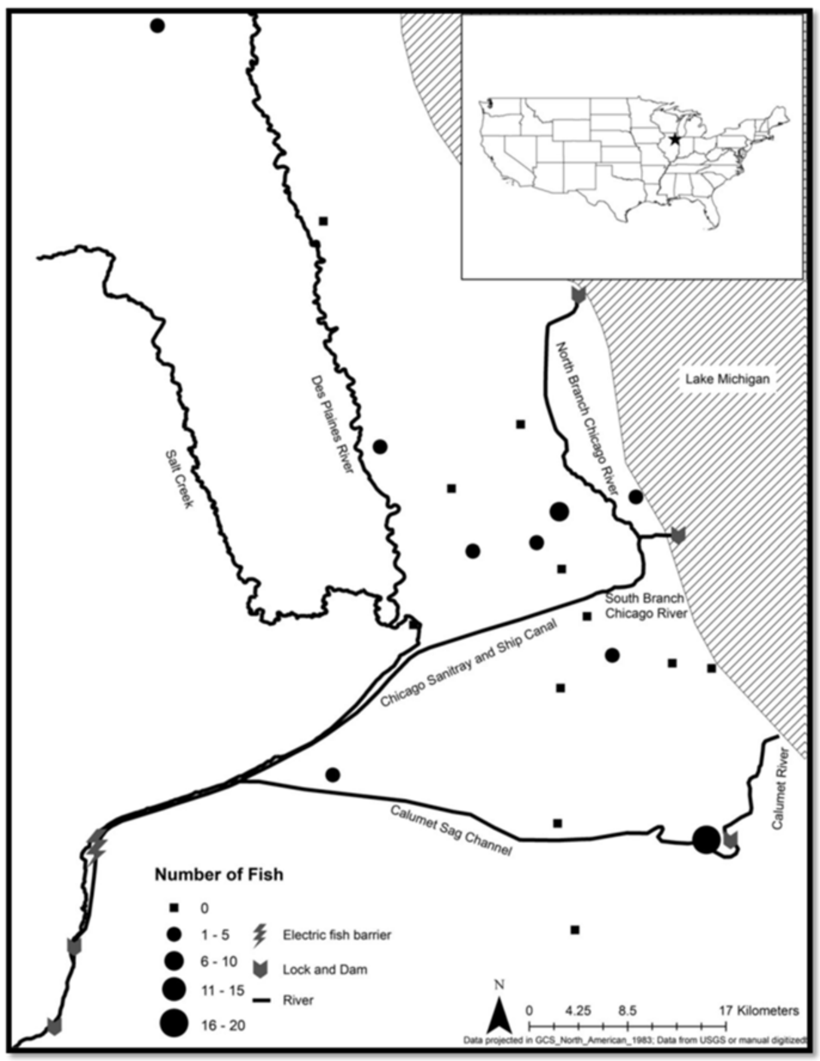

Figure 1. *Chicago area fishing ponds that were sampled or inspected.*

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 Invasive 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 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 (ILDNR 2010).

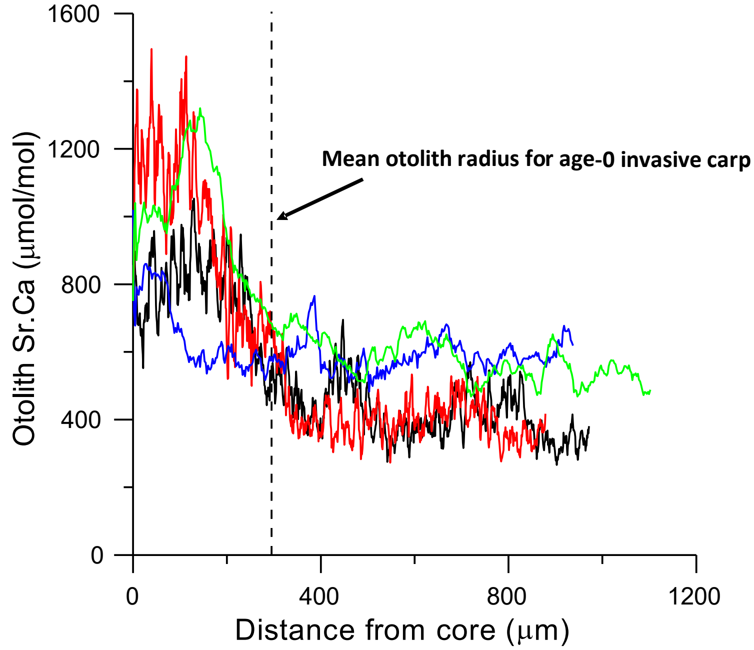

Figure 2. *Example of laser ablation transects for four Chicago pond Bighead Carp otoliths. The dashed line represents the mean otolith radius for age-0 invasive carp taken from nearby rivers.*

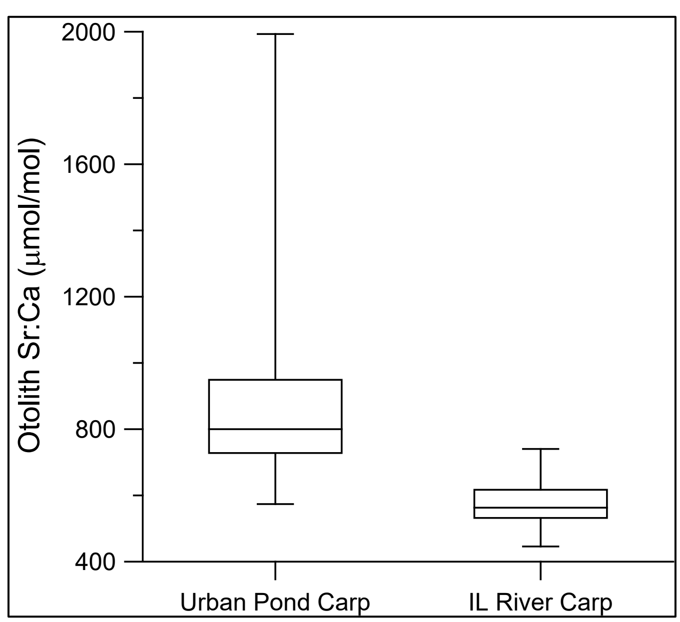

Figure 3. *Boxplots of otolith core Sr:Ca for Chicago pond (N = 24) and Illinois River (N = 81) Invasive Carp. The minimum value for urban pond carp represents the Silver Carp collected from Sherman Park.*

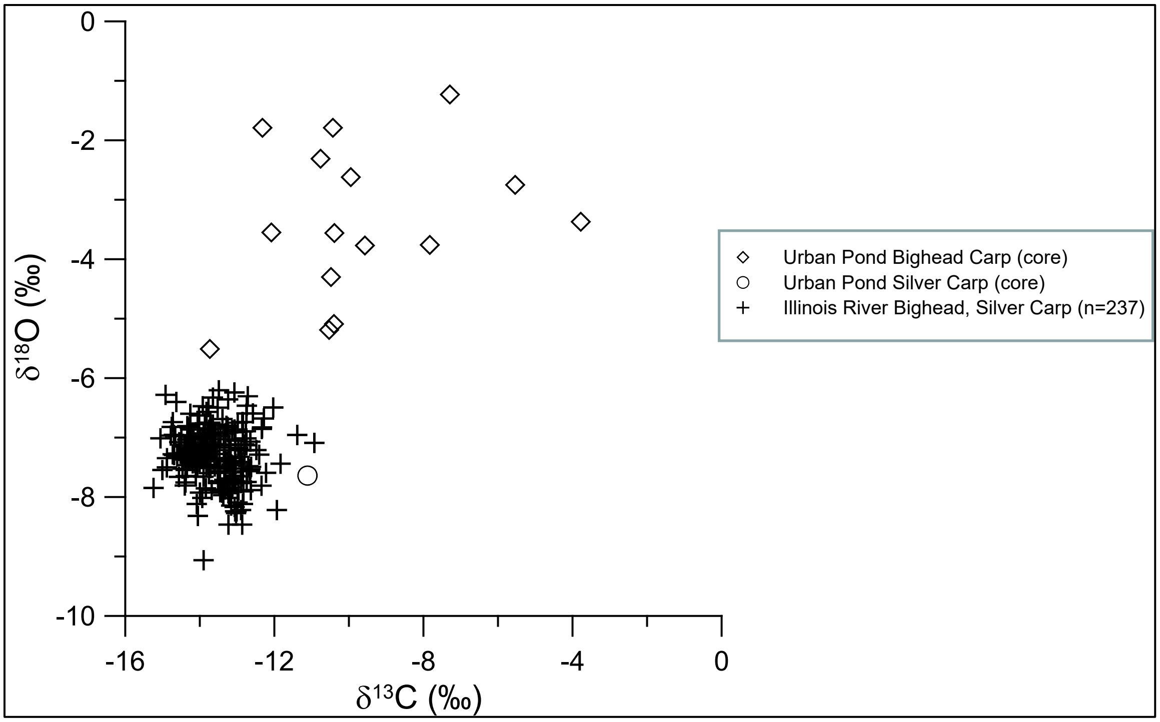

Figure 4. *Otolith Core $\delta^{18}O$ and $\delta^{13}C$ comparing Urban Pond and Illinois River Bighead and Silver Carp.*

Recommendation:

We will investigate reports of Invasive carp sightings or captures in Chicago area ponds based strictly on photographic evidence or reports from credible sources. As part of the monitoring and response effort, ILDNR will resume sampling in 25 of the Chicago area fishing ponds to detect the presence of invasive carp.

References:

ILDNR. 2010. Illinois Urban Fishing Program Division of Fisheries fiscal year 2010 annual report. Illinois Department of Natural Resources, Springfield. http://www.ifishillinois.org/programs/Urban/10URBAN_FISHING_ANNUAL_REPORT.pdf

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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 Invasive carp removed following natural die-off, pond rehabilitation with rotenone or incidental take. 1 = ILDNR urban fishing ponds that had positive eDNA detections, 2 = ponds with positive eDNA detections that are not ILDNR urban fishing ponds, 3 = pond that is neither an ILDNR urban fishing pond nor had a positive eDNA detection, * = location of the only Silver Carp collected.*

Location	Electrofishing (hrs)	Gill/trammel netting	Sampling events (N)	Bighead carp (N)	Silver carp (N)	Invasive carp collected post die-off, rotenone rehab, or incidental take
Cermak Quarry	1.0	0.0	1.0	0.0	0.0	0.0
Colmbus Park	0.8	0.1	1.0	0.0	0.0	3.0
Commissioners Park	0.5	0.1	1.0	0.0	0.0	0.0
Community Park	0.5	0.1	1.0	0.0	0.0	1.0
Douglas Park	0.5	0.2	1.0	0.0	0.0	0.0
Elliot Lake	0.8	0.7	7.0	1.0	0.0	0.0
Flatfoot Lake 1	20.0	3.6	1.0	20.0	0.0	0.0
Garfield Park	3.6	0.1	1.0	2.0	0.0	1.0
Gompers Park	0.3	0.0	1.0	0.0	0.0	0.0
Harborside Golf Course	2.8	0.9	1.0	0.0	0.0	0.0
Horsetail Lake 2	1.0	0.3	2.0	0.0	0.0	0.0
Humboldt Park	2.3	0.5	3.0	8.0	0.0	1.0
Jackson Park 1	4.3	1.8	1.0	0.0	0.0	0.0
Joe's Pond 2	0.5	0.3	1.0	1.0	0.0	0.0
Lake Owens	1.0	0.3	1.0	0.0	0.0	0.0
Lake Shermerville	1.0	0.3	0.0	0.0	0.0	0.0
Lincoln Park South	0.0	0.0	1.0	0.0	0.0	3.0
Marquette Park	1.3	0.4	1.0	0.0	0.0	0.0
McKinley Park	1.0	0.3	1.0	0.0	0.0	0.0
Powderhorn Lake 2	2.0	0.7	1.0	0.0	0.0	0.0
Riis Park	0.2	0.0	1.0	0.0	0.0	0.0
Sag Quarry 2	0.6	0.3	1.0	0.0	0.0	0.0
Saganashkee Slough 3	2.0	0.6	1.0	0.0	0.0	0.0
Schiller Pond	2.0	0.0	1.0	3.0	0.0	0.0
Sherman Park*	1.0	0.3	1.0	0.0	0.0	0.0
Tampier Lake 2	5.5	0.6	1.0	0.0	0.0	1.0
Washington Lake	1.5	0.3	1.0	0.0	0.0	0.0
Totals	**58.0**	**12.8**	**35.0**	**35.0**	**0.0**	**10.0**

Multiple Agency Monitoring of the Illinois River for Decision Making

Participating Agencies: ILDNR, INHS (co-leads), and USACE – Chicago District (field support)

Location: Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, and Alton reaches of the Illinois River below the EDBS.

Introduction and Need:

Detection and monitoring of invasive carp (Bighead Carp, Black Carp, Grass Carp, and Silver Carp) populations in reaches below the EDBS are pertinent to understanding their upstream progression and minimizing their risk of establishment above the EDBS. Surveillance is particularly important in reaches directly upstream of each invasive carp species known expanse with Bighead Carp and Silver Carp being present within the Dresden Island, Grass Carp being in the CAWS, and Black Carp within the Peoria Reach. 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., SEICarP). Data collected from a community based standardized multiple gear sampling approach has created accurate and comparable relative abundance estimates of single species and detected 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 invasive carp across all reaches downstream of the EDBS, their abundances, the threat they pose to entering Lake Michigan, and to begin evaluating impacts of current invasive carp management.

Objectives:

(1) Monitor the geographic distribution and relative abundance of adult and juvenile invasive carp populations in reaches below the electric dispersal barrier downstream of the EDBS.

(2) Provide comparable data capable of detecting spatial and temporal changes in the invasive carp population and native fish community throughout the entire Illinois River Waterway.

(3) Provide other projects (i.e., Contracted Invasive Carp Removal, Telemetry Monitoring, SEICarP model, etc.) with necessary invasive carp demographic and fish community data to inform management decisions.

Project Highlights:

- In 2021, an estimated 11,227 person-hours were expended sampling random sites downstream of the EDBS, including 174 hours of electrofishing, 1,368 hoop netting net nights, 449 minnow fyke netting net nights, and 91 fyke netting net nights.
- A total of 489,104 fish representing 128 species were captured in 2021.

- No invasive carp (large or small) were captured in Lockport or Brandon Road reaches in 2021.
- 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 Reach near the Rock Run Rookery) in 2021.
- Small Silver Carp (< 6 inches/152.4 mm) were captured in Peoria Reach (river mile 215; ~118 miles from Lake Michigan) in 2021. Same as 2020, 14 miles further upriver than 2019.
- Standardization of methods with projects outside of the MRWG MRP allowed those data to be incorporated creating a comprehensive synthesis of each invasive carp species' status across the entire Illinois River Waterway below the EDBS in 2021.

Methods:

The Multiple Agency Monitoring of the Illinois River for Decision Making used the time-tested, standardized, multiple gear approach developed by the USACE's Upper Mississippi River Restoration program (Gutreuter *et al.* 1995, Ratcliff *et al.* 2014) to monitor invasive carp populations in the Illinois River Waterway below the EDBS. This approach utilized daytime 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).

Data collected external to the invasive carp MRWG MRP were incorporated due to the standardize nature to create a comprehensive dataset that included all reaches of the Illinois River. Data outside of the MRWG MRP were provided by USGS and the INHS. Data were provided in the preliminary format 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.

Overall relative abundance indices, and reach specific relative abundance indices, within each reach below the EDBS, were generated for individual invasive carp species across 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 CPUE was calculated for each sample 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. Mean CPUE was than calculated for each capture gear type within each sampling reach and year of sampling. Condition of invasive carp was compared across sampling reaches following the standard weight equation for Silver Carp and Bighead Carp (Lamer et al. 2015).

Results and Discussion:

Electrofishing Effort and Catch

An estimated 4,545-person hours were expended completing 174 hours of electrofishing (696 transects) downstream of the EDBS in 2021 (Table 1). Electrofishing yielded 90,211 individual fish representing 109 species for a mean CPUE of 519.5 ± 32.9 fish/hour (Table 1). Electrofishing catch was dominated by Gizzard Shad (34.55%; n = 31,175), Emerald Shiner (22.75%, n = 20,532), and Silver Carp (14.74%, n = 7,235) in 2021. This was the first year Silver Carp was a dominate catch during electrofishing since the Multiple Agency Monitoring project started in 2019. Silver Carp CPUE was 41.6 ± 13.0 Silver Carp/hour which was an increase from 2020 levels of 8.0 ± 0.8 Silver Carp/hour (Figure 2). Silver Carp CPUE was highest in the lower Illinois River reaches (Starved Rock Reach on downstream) with no Bighead Carp, Black Carp, Grass Carp or Silver Carp captured during electrofishing in the reaches nearest to the EDBS (Brandon Road and Lockport Reaches) during 2021 (Figure 2). In the Dresden Island Reach, the reach nearest to the EBDS with a known invasive carp population, 3 Silver Carp were captured during electrofishing in 2021 equivalent to a mean CPUE of 0.1 ± 0.1. No Silver Carp were captured in Dresden Island using electrofishing in 2020. No Bighead Carp were captured during electrofishing in 2021 as in 2020. Of invasive carp captured during electrofishing in 2021 across all reaches, 5,740 of them were < 6 in. with Silver Carp < 6 in. comprising 79.3 % of all Silver Carp captured in 2021. Small Silver Carp were captured in the Peoria, La Grange, and Alton reaches.

Minnow Fyke Netting Effort and Catch

An estimated 1,725-person hours were expended setting and pulling 460 minnow fyke nets (449 minnow fyke net nights) downstream of the EDBS in 2021 (Table 1). Minnow fyke netting yielded 386,335 fish representing 102 species for a mean CPUE (number of fish/net night) of 869.1 ± 258.7 fish/net night (Table 1). Most of the minnow fyke catch was comprised of Emerald Shiner (38.9%; n = 150,325), Gizzard Shad (17.1%; n = 65,935), Silver Carp (13.1%, n=50,619,) and Grass Carp (5.0%; n = 19,643) during 2021. Mean Silver Carp minnow fyke net CPUE among all reaches was 113.7 ± 57.8 fish/net night in 2021 (Figure 2) which was an increase from the 5.2 ± 3.28 Silver Carp per net night capture in 2020. Mean Grass Carp CPUE in 2021(Figure 2) was 43.7 ± 29.1 fish/net night. Greater catch rates of Silver Carp were found in the lower river compared to the upper river (Table 1). No invasive carp were captured in minnow fykes in Lockport, Brandon Road, Dresden, Marseilles, or Starved Rock reaches. Minnow fyke netting captured most of the invasive carp < 6 in. within all the reaches and among all gears (Table 1).

Hoop Netting Effort and Catch

An estimated 2,040-person hours were expended setting and running 696 hoop nets (1,368.7 hoop net nights) downstream of the EDBS in 2021 (Table 1). Hoop netting yielded 8,104 fish representing 45 species for a mean CPUE (number of fish/net night) of 7.2 ± 0.5 fish/net night (Table 1). Channel Catfish comprised the largest proportion of the hoop net catch (48.2%; n = 3,892), followed by Smallmouth Buffalo (19.1 %; n = 1,545) and Common Carp (11.0%; n = 898) during 2021. No invasive carp were captured in Lockport, Brandon Road, Dresden Island, or Marseilles reaches during hoop netting, but were captured in the other downstream reaches (4 Bighead Carp, 49 Grass Carp, and 27 Silver Carp) during 2021. Greater catch rates of invasive carp in hoop nets were found in the lower river reaches compared to the upper river reaches (Table 1).

Fyke Netting Effort and Catch

An estimated 690 hours were expended setting and running 93 fyke nets (91.3 net nights) downstream of the EDBS in 2021 (Table 1). A total of 4,454 fish representing 49 species were captured during fyke netting with a mean CPUE of 49.5 ± 6.8 fish/net night (Table 1). Fyke net catch was dominated by Bluegill (32.9%, n = 1,466), White Bass (12.7%; n = 569) and Freshwater Drum (8.1%, n = 363) in 2021. A total of 3 Bighead Carp, zero Black Carp, 10 Grass Carp, and 4 Silver Carp were captured during fyke netting. All invasive carp captured during fyke netting were collected below Starved Rock Reach. However, no fyke net samples were collected in Lockport, Brandon Road, Starved Rock or Alton reaches due to lack of suitable habitat for this gear. Higher catch rates of Bighead Carp, Grass Carp, and Silver Carp were found in the lower river reaches compared to the upper river reaches during fyke netting in 2021 as in 2020 (Figure 2).

Overall Invasive Carp catch

Overall relative abundance of invasive carp was highest below Starved Rock Reach, La Grange had the highest relative abundance among reaches sampled in 2021 (Table 1). The increase in invasive carp CPUE in 2021 compared to 2019-2020 was due to the number of Silver Carp < 6 in. and Grass Carp < 6 in. captured in the Peoria, La Grange and Alton reaches. The high catch of Silver Carp and Grass Carp < 6 in. indicates that invasive carp had a stronger spawning year or higher small fish survival in 2021 relative to 2019-2020 (Figure 3). Tracking this year class through time could provide information on mortality, movement, and the impacts of current removal actions.

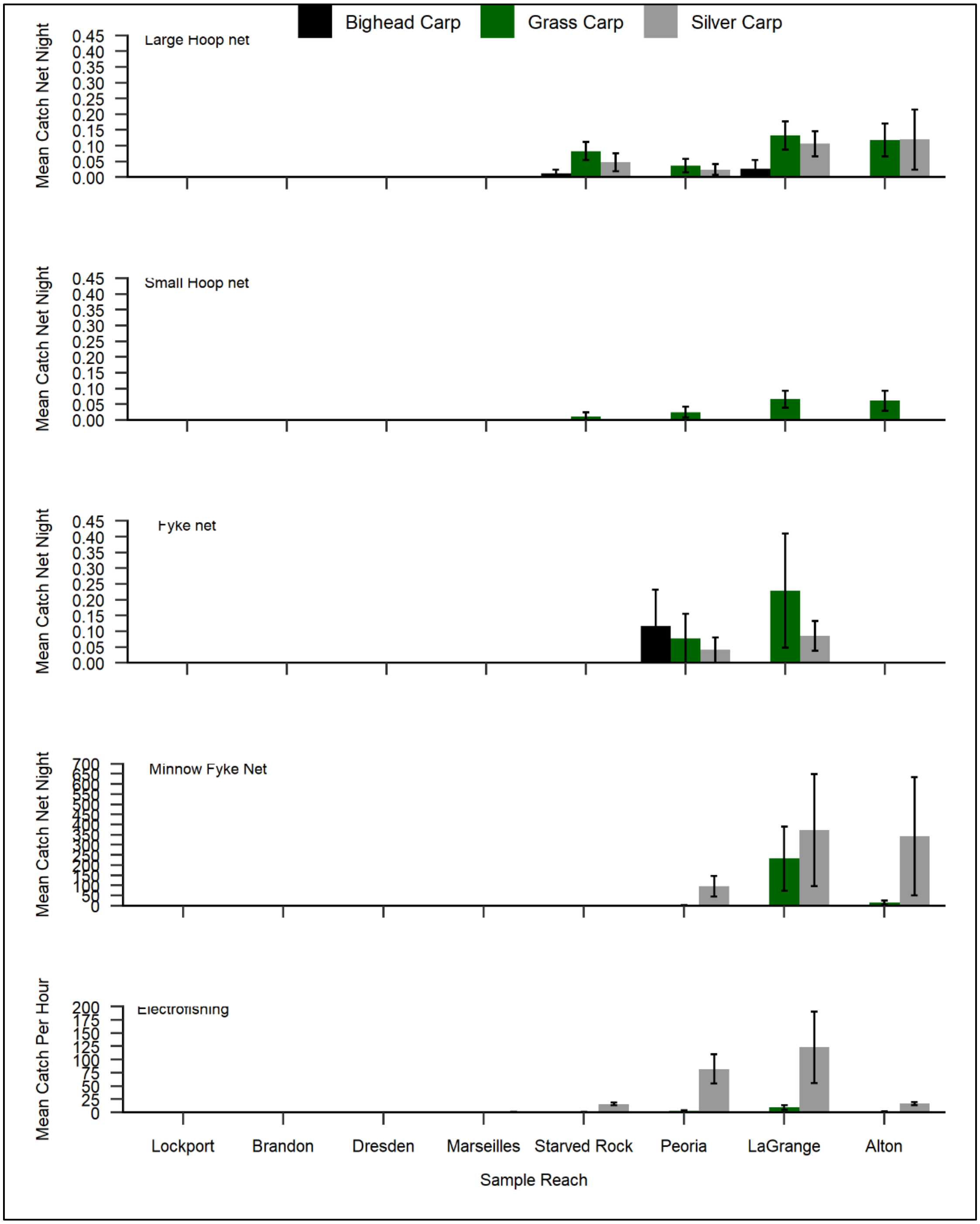

Figure 2. *Mean Catch per unit effort of Silver Carp, Grass Carp, and Bighead Carp by gear type among the various reaches of the Illinois River Waterway during 2021. Due to the varying units of efforts nets and electrofishing results should not be directly compared to one another. Error bars represent ± SE.*

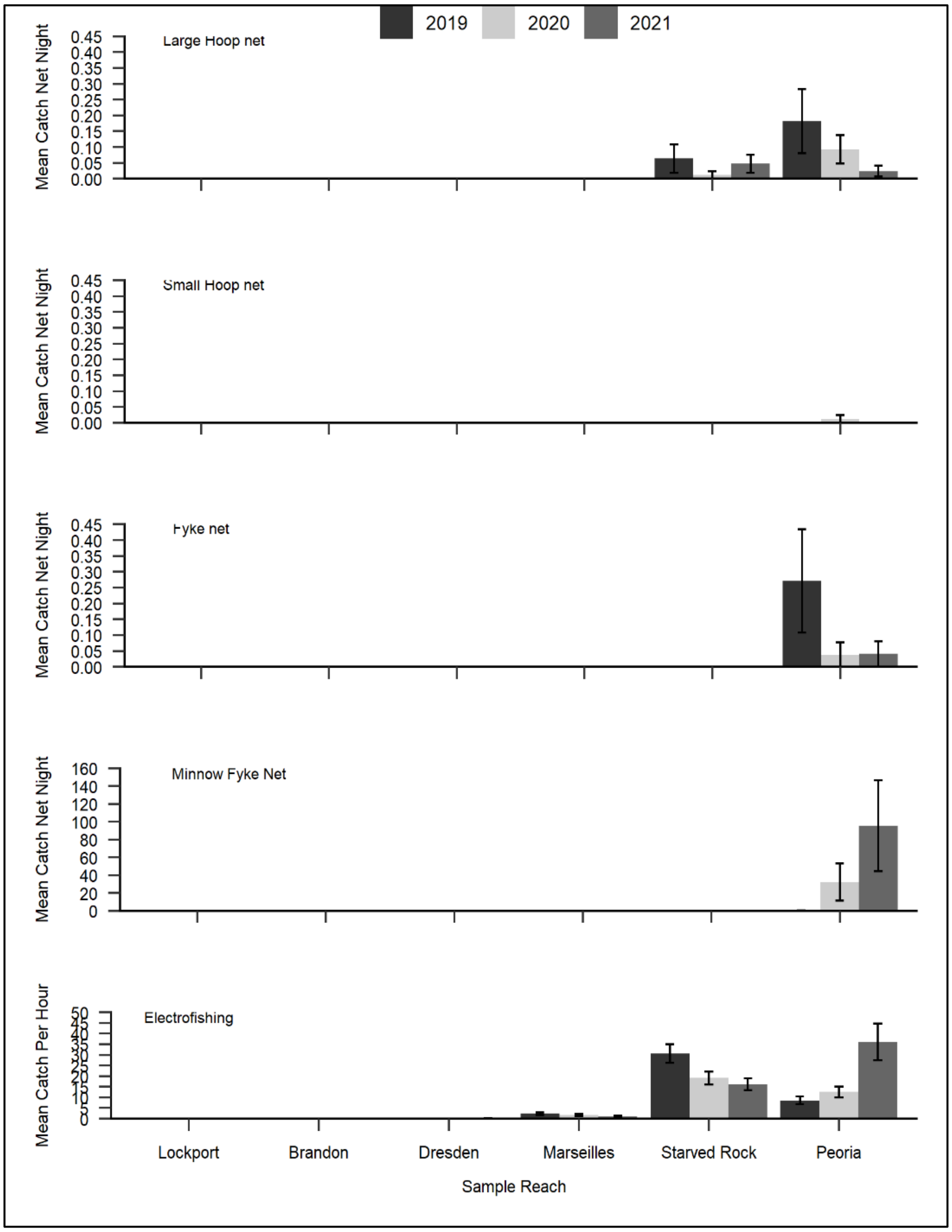

Figure 3. *Mean catch per unit effort of Silver Carp by gear type and year (2019-2021) among the various reaches of the Illinois River Waterway. Due to the varying units of efforts nets and electrofishing results should not be directly compared to one another. Error bars represent ± SE.*

Size Structure

Bighead Carp catches were between 550 - 810 mm in total length, Grass Carp between 10 - 1,072 mm in total length, and Silver Carp between 10 - 961 mm in total length in 2021. Mean total length has been consistently larger in upper river reaches compared to lower river reach since 2019 (Figure 4). Reach specific size structure has been relatively consistent among years in the upper reaches (Figure 4) with the mean total length for Silver Carp being 895 mm in 2021 and 831 mm in 2019. However, Silver Carp size structure of the lower reaches decreased in 2021 with a mean total length of 389 mm compared 556 mm in 2020 and 570 mm in 2019. The decrease in size structure of the lower reaches is due the influence of number of small Silver Carp and Grass Carp captured in 2021 which may indicate a strong invasive carp reproduction or high survival year in 2021 compared to relatively weak reproduction or poor survival in 2019 and 2020.

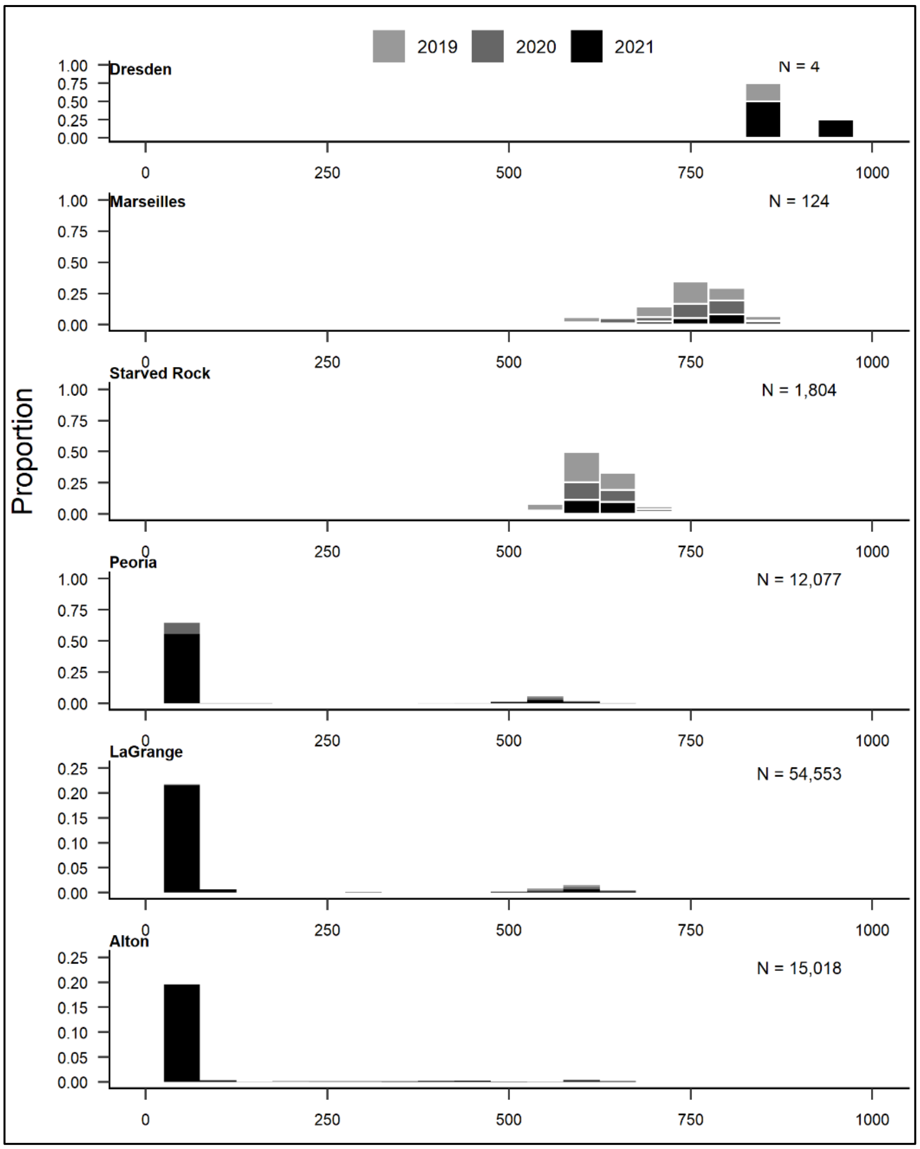

Figure 4. *Proportional length frequency distributions, per 50 mm length bin of Invasive Carp captured within each Reach of the Illinois River by each year since 2019. All gear types (electrofishing, fyke netting, hoop nets and minnow fyke nets) were aggregated together.*

Condition

Individual catches were low for Bighead Carp throughout all reaches and low in the upper reaches for Silver Carp within a year, so conditional information aggregated the data from 2019-2021. Condition of Silver Carp and Bighead Carp was greater in the upstream reaches compared to the downstream reaches (Figure 5). Dresden Island Pool had the highest condition among reaches sampled during Multiple Agency Monitoring with a relatively linear decline in condition indices when progressing downstream. Density dependence may be influencing reach specific condition values as further down river reaches have higher abundance of Silver and Bighead Carp than upper reaches (Coulter et al. 2018). Silver Carp also generally have higher condition indices compared to Bighead Carp in Peoria, La Grange, and Alton reaches (Figure 5) which may require additional exploration into why that might be occurring.

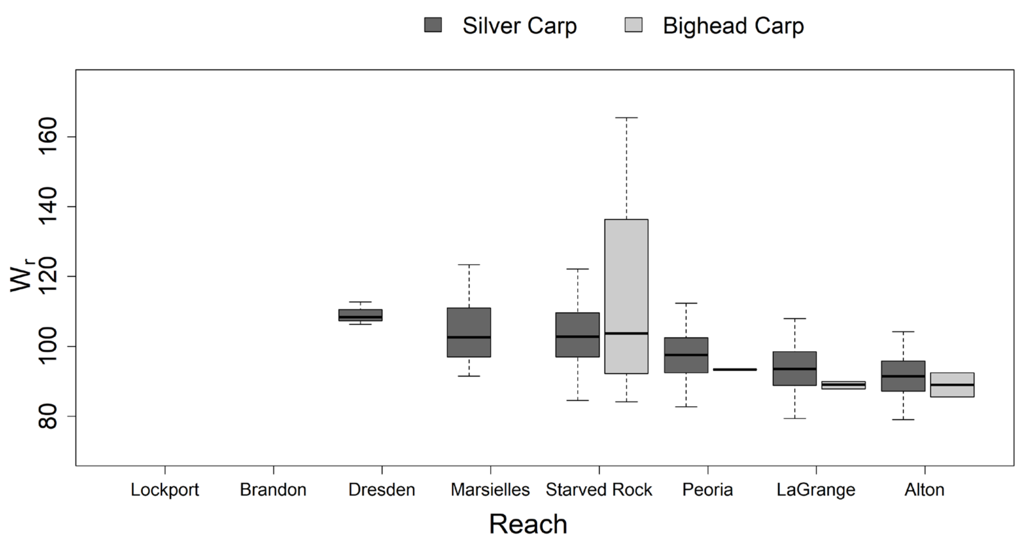

Figure 5. *Box-and-whisker plots of Silver Carp and Bighead Carp condition (W_r) among the various reaches of the Illinois River Waterway in 2019. Whiskers extent to 1.5 times the interquartile range. Black lines in each box denote the median condition index for that box.*

Geographic Distribution

In 2021, no invasive carp were captured above the furthest upstream location that was previously established in the Dresden Island Pool in 2021 (Figure 2). Silver Carp < 6 in. were captured at river mile 215 (~118 river miles downstream of Lake Michigan) which was the same as 2020 but closer to Lake Michigan than 2019 (~132 miles downstream of Lake Michigan) (Figure 6). Large Silver Carp had the highest relative densities in the lower reaches, specifically Starved Rock pool (Figure 6). Large Grass Carp were captured throughout the lower reaches with high relative densities in Starved Rock, Peoria, La Grange, and Alton reaches. Large Bighead Carp have the highest relative density in Starved Rock and Peoria Reaches. Small invasive carp were not captured in the upper reaches. Small invasive carp were caught in greater abundance in 2021 compared to 2020 and 2019 with the highest relative densities in Peoria, La Grange, and Alton Reaches (Figure 6).

Recommendation:

Implementing a standardized multiple gear sampling approach created a comparable and comprehensive picture of invasive carp dynamics throughout the entire Illinois River Waterway allowing for a holistic assessment. Standardization allowed monitoring projects outside of the MRP to be incorporated, amplifying the robustness of the picture of invasive carp status and detections in the Illinois River Waterway. The leading edge of invasive carp within the Illinois River Waterway does not appear to have encroached closer to the EDBS, with Bighead Carp and Silver Carp remaining in the Dresden Island Pool. No Black Carp were detected during any of this monitoring. The numbers and catch rates of small invasive carp (< 6 inches) were greater than what was found in 2019 and 2020 indicating 2021 may have been a better reproductive year or there was higher survival of young of year fish. We recommend continued sampling below the EDBS using a multiple gear approach that includes electrofishing, fyke netting, hoop netting, and minnow fyke netting following this standardized protocol. Minimally, the same level of effort and an assessment of sample size requirement to ensure efficacy of the project should occur. It is also recommended that lapilli otoliths and sex of a subsample of invasive carp be collected within each pool during the fall as needed to support the invasive carp demographics project and the SEICarP model in coordination with the Modeling Work Group. Collecting these additional metrics should increase the inferences that can be drawn from this dataset, supply necessary supplemental data to further assess the impacts of invasive carp removal efforts increasing the ability to aid MRWG objectives. Finally, data collected from projects outside using the same standardized methods of the MRP should continue to be incorporated into this dataset, when allowed and appropriate. Inclusion of these data allow for formulating the most comprehensive picture of invasive carp expanse and response within the Illinois River Waterway.

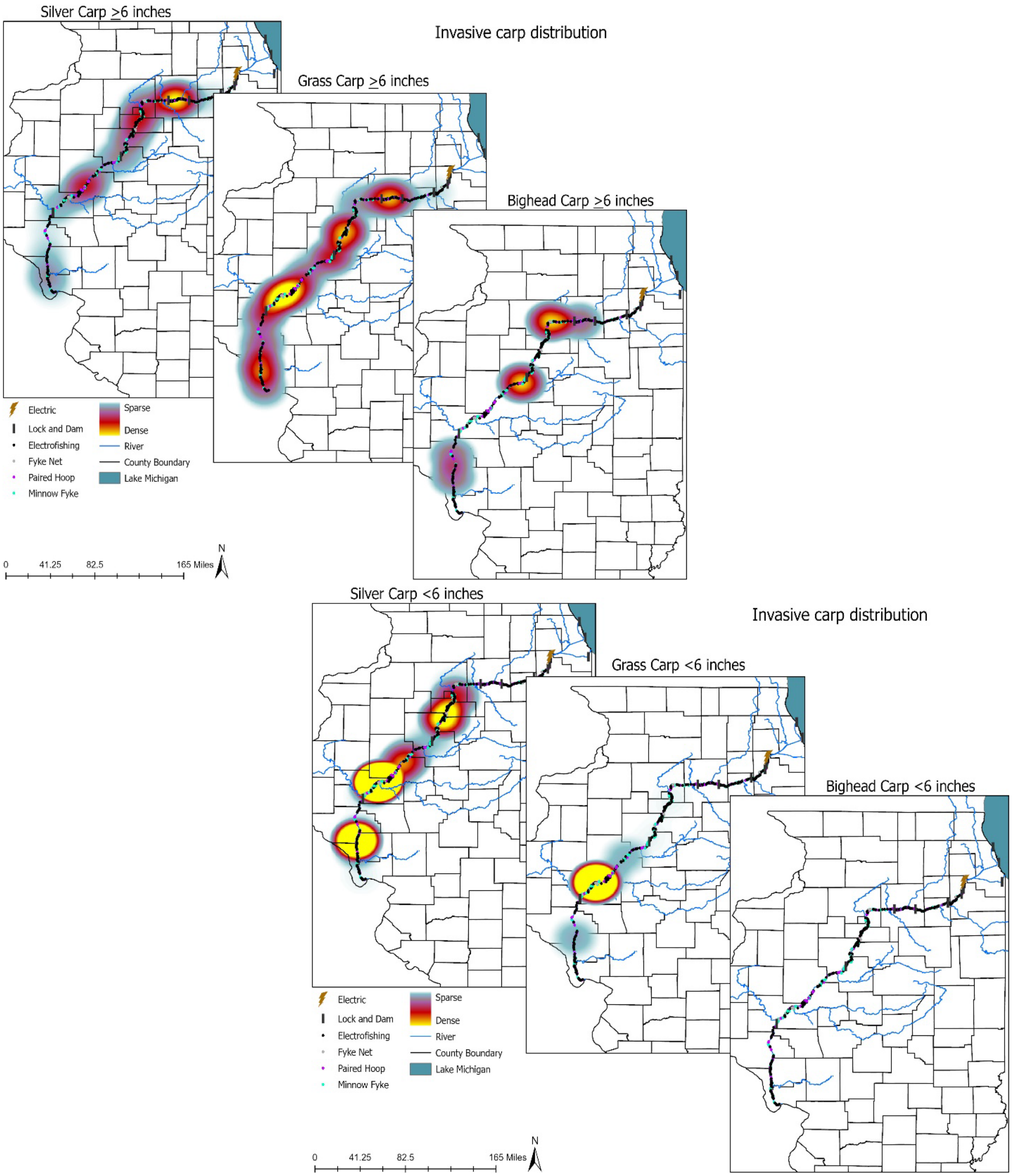

Figure 6: *Spatial distribution of sampling among all gear types with kernel density heat map of invasive carp catch throughout the Illinois River Waterway based off size class (< 6 in. and ≥ 6 in.). Kernel density algorithm was to dynamically indicate area of cool (sparse density; blue) to areas of hot (high density; yellow) relative densities.*

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Table 1. *Electrofishing, hoop netting, minnow fyke netting, and fyke netting effort with catch summaries for 2021 in reaches below the electric dispersal barrier.*

Electrofishing Effort - 2021	**Lockport Reach**	**Brandon Reach**	**Dresden Reach**	**Marseilles Reach**	**Starved Rock Reach**	**Peoria Reach**	**LaGrange Reach**	**Alton Reach**
Estimated person-hours	82.5	90	142.5	187.5	157.5	217.5	277.5	225
Electrofishing hours	11.33	9	20.25	23.25	26.25	33.75	29.93	20.25
Samples (transects)	45	36	81	93	105	135	120	81
All Fish (*N*)	2,755	1,757	7,851	10,436	8,854	21,521	29,325	7712
Species (*N*)	26	31	55	73	60	75	64	63
Bighead Carp (*N*)	0	0	0	0	0	0	0	2
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Bighead Carp CPUE (No. fish/hour)	0	0	0	0	0	0	0	0.09±0.06
Silver Carp (*N*)	0	0	3	24	422	2763	3691	332
Silver Carp < 6 in. (N)	0	0	0	0	0	2272	3263	205
Silver Carp CPUE (No. fish/hour)	0	0	0.14±0.11	1.03±0.40	16.07±2.79	81.86±27.84	123.32±67.74	16.39±2.89
Grass Carp (N)	0	0	0	1	12	87	285	33
Grass Carp < 6 in. (N)	0	0	0	0	0	63	255	9
Grass Carp CPUE (No. fish/hour)	0	0	0	0.04±0.04	0.45+0.12	2.57+1.03	9.52±4.49	1.63±0.34
Small Hoop Net Effort- 2021	**Lockport Reach**	**Brandon Reach**	**Dresden Reach**	**Marseilles Reach**	**Starved Rock Reach**	**Peoria Reach**	**LaGrange Reach**	**Alton Reach**
Estimated person-hours	210	210	210	180	180	270	480	300
Net nights	82.36	81.35	81.43	79.6	82.58	81.87	105.03	82.5
Samples (net sets)	42	42	42	42	42	42	54	42
All Fish (N)	359	379	224	266	756	515	448	215
Species (N)	11	15	12	10	11	12	19	10
Bighead Carp (N)	0	0	0	0	0	0	0	2
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Bighead Carp CPUE (No. fish/night)	0	0	0	0	0	0	0	0.02
Silver Carp (N)	0	0	0	0	0	1	0	1
Silver Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Silver Carp CPUE (No. fish/net night)	0	0	0	0	0	0.01	0	0.01
Grass Carp (N)	0	0	0	0	1	2	7	5
Grass Carp <6 in. (N)	0	0	0	0	0	0	0	0
Grass Carp CPUE (No. fish/net night)	0	0	0	0	0.01±0.01	0.02	0.06±0.02	0.06

Table 1. Continued.

Large Hoop Netting Effort - 2021	Lockport Reach	Brandon Reach	Dresden Reach	Marseilles Reach	Starved Rock Reach	Peoria Reach	LaGrange Reach	Alton Reach
Est. person-hours	210	210	210	180	180	270	480	300
Net nights	82.07	81.03	81.05	84.31	84.64	83.57	106.02	84.17
Samples (net sets)	42	42	42	42	42	42	54	42
All Fish (*N*)	286	392	732	702	1,231	629	521	449
Species (*N*)	11	20	17	13	15	19	21	14
Bighead Carp (*N*)	0	0	0	0	0	0	0	0
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Bighead Carp CPUE (No. fish/night)	0	0	0	0	0	0	0	0.01
Silver Carp (*N*)	0	0	0	0	1	8	11	10
Silver Carp < 6in. (N)	0	0	0	0	0	0	0	0
Silver Carp CPUE (No. fish/net night)	0	0	0	0	0.05±0.03	0.02±0.01	0.11±0.04	0.11±0.09
Grass Carp (N)	0	0	0	0	7	3	14	10
Grass Carp<6in. (N)	0	0	0	0	0	0	0	0
Grass Carp CPUE (No. fish/net night)	0	0	0	0	0.08±0.02	0.04±0.02	0.13±0.04	0.12±0.05
Fyke Netting Effort - 2021	**Lockport Reach**	**Brandon Reach**	**Dresden Reach**	**Marseilles Reach**	**Starved Rock Reach**	**Peoria Reach**	**LaGrange Reach**	**Alton Reach**
Est. person-hours	0	0	120	120	0	270	600	0
Net nights	0	0	14.48	15.2	0	26.17	35.42	0
Samples (net sets)	0	0	15	15	0	27	36	0
All Fish (*N*)	0	0	1,304	720	0	624	1,806	0
Species (*N*)	0	0	30	24	0	32	30	0
Bighead Carp (*N*)	0	0	0	0	0	3	0	0
Bighead Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Bighead CarpCPUE (No. fish/night)	0	0	0	0	0	0.12±0.11	0	0
Silver Carp (*N*)	0	0	0	0	0	1	3	0
Silver Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Silver Carp CPUE (No. fish/net night)	0	0	0	0	0	0.04±0.04	0.08±0.07	0
Grass Carp (N)	0	0	0	0	0	2	8	0
Grass Carp < 6 in. (N)	0	0	0	0	0	0	0	0
Grass Carp CPUE (No. fish/net night)	0	0	0	0	0	0.08±0.07	0.23±0.18	0

Table 1. Continued.

Minnow Fyke Netting Effort - 2021	Lockport Reach	Brandon Reach	Dresden Reach	Marseilles Reach	Starved Rock Reach	Peoria Reach	LaGrange Reach	Alton Reach
Est. person-hours	210	240	540	450	390	390	810	330
Net nights	22.89	22.61	68.9	70.85	70.27	68.06	84.6	41.03
Samples (net sets)	24	24	72	73	72	72	84	42
All Fish (*N*)	6,218	3,414	9,858	6,552	11,190	176,555	147,725	24,823
Species (*N*)	26	35	57	52	44	72	62	60
Bighead Carp (*N*)	0	0	0	0	0	0	0	0
Bighead Carp < 6 in. (N)	0	0	0	0	0	2	0	0
Bighead Carp CPUE (No. fish/night)	0	0	0	0	0	0.03	0	0
Silver Carp (*N*)	0	0	0	0	0	6,231	30,604	13,784
Silver Carp < 6 in. (N)	0	0	0	0	0	6,229	30,603	13,784
Silver Carp CPUE (No. fish/net night)	0	0	0	0	0	95.54±51.13	372.78±276.84	340.66±291.48
Grass Carp (N)	0	0	0	0	0	77	18,982	584
Grass Carp < 6 in. (N)	0	0	0	0	0	77	18,982	584
Grass Carp CPUE (No. fish/net night)	0	0	0	0	0	1.14±0.88	231.54±158.66	14.48±9.821

MANAGEMENT AND CONTROL PROJECTS

USGS Invasive Carp Database Management and Integration Support

Travis Harrison, Marybeth Brey, Jayme Strange (USGS Midwest Environmental Sciences Center)

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

Introduction and Need:

Bigheaded carps (Bighead Carp and Silver Carp) tracking, monitoring, and contracted removal will continue throughout the Illinois River and Upper Mississippi River as part of an adaptive management effort to mitigate, control, and contain bigheaded carps. Other fish will also be tracked to maintain a holistic view of the transmitter distribution in the Upper Illinois River Waterway. To facilitate these actions, a need to compile and analyze invasive carp-related data from all agencies exists. Invasive carp-related data include all data sources that could inform the MRWG objectives or projects. These data, often in disparate formats, must be integrated into a common format that allows all agencies the opportunity to assess invasive carp monitoring, control, and removal efforts. Ensuring the interoperability of these datasets allows for their use in various analyzes and modeling efforts. Implementing an interoperable data management framework provides the mechanisms for end users to find and use integrated data. Integrating data for use in modeling and analysis furthers the partnership's collective understanding of bigheaded carp life history, distribution, and movement and can be used to facilitate adaptive management actions (e.g., directing monitoring, sampling, and removal efforts, assessing invasive carp abundance to support modeling efforts, informing deployment of control actions, etc.). An effective data management strategy will streamline the data update process, providing all agencies with timely data and analyses in support of informed decision-making processes.

Objectives:

Provide data management, informational products, and decision support tools to aid and inform the management and removal of bigheaded carps in the Illinois River Waterway system. Integrating and transforming invasive carp-related datasets into actionable information which includes the following objectives:

(1) Continued maintenance of the FishTracks Telemetry Database and Illinois River Catch Database (ILRCdb) applications to facilitate partner (e.g., modeling workgroup, telemetry workgroup, etc.) objectives via data compilation, management, and summarization;

(2) Assist in the development of informational products and decision support tools for scientists and managers to facilitate modeling efforts and inform management decisions to control bigheaded carps; and

(3) Regularly communicate with the MRWG workgroups to determine if the database structures are meeting their needs.

Project Highlights:

(1) Illinois River Catch Database

- 2021 ILDNR annual data uploaded.

- Table metadata documented and stored on web server for distribution to partners
- Initialized document for including partners outside of ILDNR.

(2) FishTracks Telemetry Database

- Application software packages upgraded.
- Fixed bugs in queries, visualizations, and reports.
- All 2021 telemetry data added to the database from USFWS, USGS, USACE, INHS, and SIU.
- Custom annual report completed.
- Data summarized and shared with Modeling Workgroup for Bayesian multi-state model and SEICarP.
- Ongoing development of the online, centralized platform for existing invasive carp-related data layers to support adaptive management objectives and informed removal efforts.

(3) FishTracks R Package

- Application software packages upgraded.
- Updated annual report queries to conclude changes for 2021 annual FishTracks report.
- Updated package to support queries that include over one million detections

(4) Ongoing development and incorporation of bathymetry data into online GIS Data Hub.

(5) CarpDAT invasive carp data catalog.

- Translated USFWS collected carp data catalog needs to architecture plans and tasks.
- Completed initial draft of fish demographics database for internal team review.
- Completed prototype product search interface and readied it for internal review.

Methods:

The FishTracks Telemetry Database, a Microsoft SQL Server application, and the ILRCdb application, developed in open-source relational database PostgreSQL, are being actively maintained by the USGS. This involves performing routine database maintenance (e.g., communicating with end-users, ensuring data backups, performing internal consistency checks, rebuilding indexes as needed, etc.) to keep the applications online and available to partners. New telemetry and catch data collected by partner agencies are uploaded into the database applications annually after passing quality assurance checks for data consistency (i.e., standardized data-formatting). Updates and additions are made to the applications based on partner requests, such as creating customized monthly, quarterly, or annual reports based on specific monitoring or management objectives.

Application programming interfaces (APIs) are being developed to allow direct programmatic access to database applications, enabling data end users (e.g., MRWG Modeling Workgroup) to integrate and analyze partnership data into modeling software programs, such as R. In addition, population demographics-related data requirements will be determined by the CarpDAT Team who will be informed from discussions done in regular meetings with the Modeling Work Group and USFWS national adaptive management framework discussions. These data are already being compiled and included in population modeling efforts. A key goal will be establishing core data standards to allow for integration of data from multiple agencies with minimal data post-processing.”? .

Existing invasive carp-related datasets and analytical tools that have been collected, processed, and developed by the multi-agency partnership will be converted to web mapping and geoprocessing services and integrated into an online data hub for researchers and managers to access these data and tools. Dataset examples include high-resolution hydroacoustic survey data (from multibeam and side scan sonar), benthic classification layers (e.g., landform and substrate classifications), and other relevant environmental data layers (e.g., water temperature, discharge). An online, user-friendly interface (developed in ArcGIS Online) will allow for improved discoverability and usability of existing datasets without the need for specialized software or technical skills. Incorporating existing datasets into analyses and decision support tools aims to further the understanding of invasive carp life history, behavior, and distribution.

Results and Discussion:

Invasive carp monitoring and removal data from the Illinois River continues to be collected by partner agencies and included in the ILRCdb application. Data collection protocols similar to the sampling approach used by the LTRM element of the Upper Mississippi River Restoration (UMRR) Program and the FISH app continue to be used. Data quality control checks are integrated with the ILRCdb during the data upload process to minimize potential data errors. Database application updates, new version releases, and additional customized data summary features are implemented as needed.

Invasive carp telemetry data from the Illinois River and Upper Mississippi River continue to be collected by partner agencies and included in the FishTracks application. Data collection uploaded through application and automatically validated before manual review to minimize potential data errors. Database application updates, new version releases, and additional customized data summary features are implemented as needed.

The validated hydroacoustic survey data (e.g., multi-beam and sidescan sonar), collected in priority management areas throughout the Illinois River and processed into a suite of benthic data layers, are being integrated with the online platform for invasive carp-related data. These benthic habitat classification layers (i.e., geomorphology), derived from bathymetric measures such as slope, roughness, and terrain ruggedness, are available in a GIS-ready format and as web mapping services. These benthic data layers can be incorporated into analyses or online tools to support adaptive management and informed removal strategies. By providing a detailed, subsurface view of the riverine environment, these data layers can be used during the planning, design, and installation of control and containment technologies (e.g., deterrent systems, Modified Unified Method fishing events) in strategic locations. These datasets, along with other invasive carp-related datasets, are complete and publicly available but exist in disparate digital data repositories and oftentimes require specialized software to visualize and use. Integrating these datasets into an online, easy-to-use data hub will allow for greater discovery and usability by the multi-agency partnership.

The development of an online platform for invasive carp-related data, informational products, and decision support tools will provide ease of access to and use of these data and tools. Web mapping services and applications provide for user-friendly visualization and interaction with invasive carp-related data layers (without the need for desktop GIS software) and can be expanded to include analytical functionality. Incorporating data, tools, and analyses can inform targeted removal efforts or deterrent deployments in strategic locations. Integrating benthic habitat classification data layers, habitat suitability layers, environmental condition variables, and invasive carp-related monitoring and removal data allows for users to spatially search for areas with underlying conditions similar to areas of large bigheaded carps catch events (or known areas with dense bigheaded carp populations), allowing for targeted removal efforts to continue throughout the Illinois River. In addition to an online platform, programmatic access to applications such as the FishTracks Telemetry Database and Illinois River Catch Database allows researchers to directly query data and integrate them into analyses.

Contracted Commercial Fishing Below the Electric Dispersal Barrier

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Participating Agencies: ILDNR, INHS

Location: Contracted Commercial Fishing Below the EDBS targeted the area between the EDBS at Romeoville, IL (~37 miles [60 km] from Lake Michigan) downstream to Starved Rock Lock and Dam,

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

Introduction and Need:

Contracted Commercial Fishing Below the EDBS uses contracted commercial fishers to reduce invasive 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 invasive carp abundance, we anticipate reduced migration pressure towards the barrier, lessening the chances of invasive carp gaining access to upstream waters in the Chicago Area Waterway System and Lake Michigan. Monitoring for upstream expansion of invasive carp should help identify changes in the leading edge, distribution, and relative abundance of invasive carp in the IWW. 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 invasive carp population abundance and movement between and among pools of the IWW.

Objectives:

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

(2) Reduce invasive carp densities, lessening migration pressure to the EDBS, thus decreasing chances of invasive carp accessing upstream reaches (e.g., CAWS and Lake Michigan).

(3) Inform other projects (i.e., hydroacoustic verification and calibration, SEICarP model, small fish monitoring, telemetry master plan) with invasive carp population distribution, dynamics, and movement in the IWW downstream of the EDBS.

Project Highlights:

Since 2010, contracted commercial fishers' effort in the upper IWW below the dispersal barrier includes 4,799 miles (7,723 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, 104,349 Bighead Carp, 1,327,020 Silver Carp, and 11,473 Grass Carp were removed by contracted fishers from 2010-2021. The total estimated weight of invasive carp removed is 5714.5 tons (11,429,000 lbs.).

No invasive carp have been collected in Lockport or Brandon Road pools since the inception of this project in 2010.

The leading edge of the invasive carp population remains near Rock Run Rookery in Dresden Island Pool (~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 invasive carp population in the upper Illinois River. Continued implementation of this project will provide the most current data on invasive carp populations at their leading edge and reduce pressure on the electric barrier system.

Methods:

Contracted commercial netting occurred from February through December in Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock pools of the IWW. 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 (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 typically fished four days a week during each week of the field season except for two weeks in both June and September sampling occurred upstream of the EDBS for the SIM project.

Contract fishing occurred at targeted sites throughout each pool monthly. Four fixed sites each in Lockport, Brandon Road, Dresden Island, and Marseilles pools were also sampled monthly (Figure 1). These data were merged to gain a comprehensive understanding of invasive carp spatial and temporal abundance below the EDBS, especially at their upper-most extent in the Dresden Island pool. However, because invasive carp abundance and fishing locations are heterogeneous spatially within pools, areas of special interest to MRWG (Rock Run Rockery and Dresden Island above I-55) were analyzed individually. This will make pertinent results more easily interpreted allowing better relative abundance inferences to be drawn in areas of highest concern (e.g. Dresden Main Channel Above I-55).

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 20-30 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 invasive carp and

Common Carp were checked for telemetry tags and all non-tagged invasive 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 invasive carp and all non-invasive carp by-catch were released into the water alive. A representative sample of up to 30 individuals of each invasive 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) 1-2 times a week to provide estimates of total weight harvested, and gather morphometric data on harvested invasive carp over time.

Unified Fishing Methods (UFM) were implemented in Dresden Island Pool, and the East and West Pits of Hanson Material Services in Marseilles Pool lasting approximately a week each. 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 invasive 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 invasive carp.

Results and Discussion:

An estimated 13,782 person-hours were expended harvesting invasive carp via contracted fishing in 2021 A total of 4,799 miles (7,723 km) of gill/trammel net, 19 miles (31 km) of commercial seine, 239 Great Lakes pound net nights and 4,369 hoop net nights have been deployed in the upper IWW since 2010 (Table 1). The total estimated weight of invasive carp caught and removed from 2010-2021 was 11,429,000 pounds (1,442,842 individuals: Table 1). Silver Carp, Bighead Carp, and Grass Carp accounted for 82% (1,327,020 individuals), 7% (104,349 individuals), and 1% (11,473 individuals) of the total tons harvested since 2010, respectively (Table 1). Silver Carp remain the most abundant invasive carp species in the Upper Illinois River, in contrast to 2010 when Bighead Carp comprised approximately 80% of total invasive carp catch.

The 2021 gill/trammel net catch per unit effort (CPUE; number of fish/1,000 yards of net) in Starved Rock was 453.3, a decrease from 463.9 in 2020. The CPUE in the Marseilles pool was 134.7, a decrease from 174.2 in 2020 (Figure 2). In Dresden Island Pool (leading edge) total invasive carp CPUE was 1.2 in 2021, a decrease from 1.5 in 2020 (Figure 2). For details regarding gill/trammel CPUE of invasive carp for all pools combined from other years, see those years' respective Interim Summary Reports (MRRP 2012-2020).

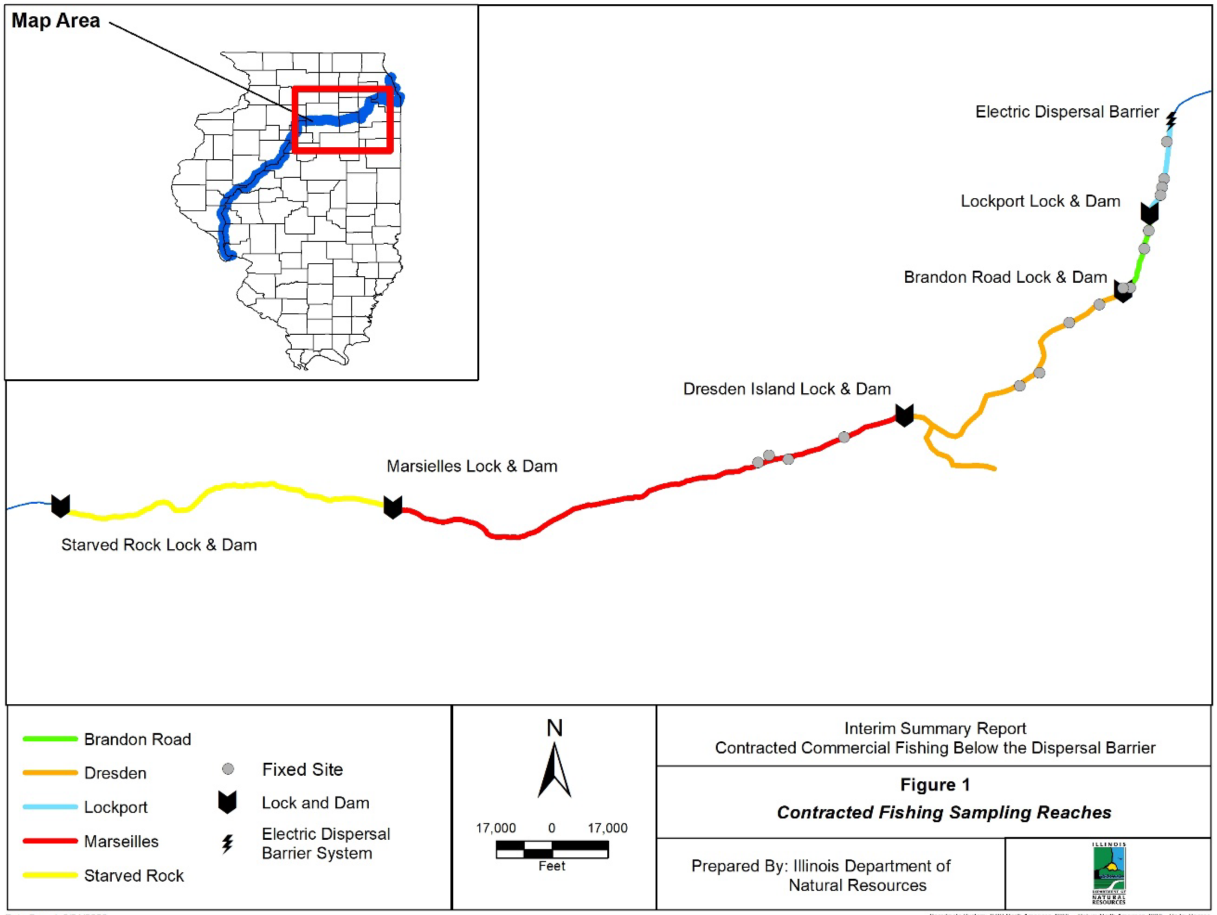

Figure 1. *Contracted commercial fishing sampling area and locations of fixed sites sampling of the contract fishing below the electric dispersal barrier project.*

Effort and Catch of Asian Carp within Pools

Lockport Pool:

In 2021, invasive carp detection efforts included 47,696 yards (43.6 km) of gill/trammel net set. No Asian carp were observed or captured in Lockport pool.

Brandon Road Pool:

In 2021, invasive carp detection efforts included 51,920 yards (47.5 km) of gill/trammel net set. No invasive carp were observed or captured in Brandon Road pool.

Dresden Island Pool:

Invasive 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 2021, 0.1% of the total harvested invasive carp came from Dresden Island Pool. Contracted commercial fishing efforts included: 189,552 yards (173.3 km) of gill/trammel net. A total of 182 Silver Carp, 33 Bighead Carp, and 5 Grass Carp 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 1.59 tons (3,180 lbs.) removed. Catch per unit effort estimates for the entire Dresden Island Pool are highly stochastic, likely due to changes in access to fishing hotspots, varying demographics through time (size structure), and environmental and hydrological variation (Figure 3). However, in recent years there has been a decline in CPUE among all three invasive carp species in Dresden Island Pool, with a steady increase in effort since the inception of the program (Figure 3). With this decrease in CPUE over time, we infer that the invasive carp population has decreased in Dresden Island Pool.

Marseilles Pool:

In 2021, 17% of the total harvested invasive carp came from the Marseilles Pool. Contracted commercial fishing efforts included: 223,520 yards (204 km) of gill/trammel net. A total of 27,536 Silver Carp, 2,035 Bighead Carp, and 52 Grass Carp were harvested from Marseilles pool in 2020, amounting to 189.9 tons (356,680 lbs.) removed (Figure 4; Table 1). Silver Carp dominated the invasive carp catch in the Marseilles pool in 2021 (93%), consistent with the past seven years. Prior to 2013, Bighead Carp was the dominant invasive carp species caught in the Marseilles Pool (>55%). In 2021, the catch of Bighead Carp was 6% (Table 1). The 2021 gill/trammel net CPUE (# caught per 1000 yds.) of Asian carp for Marseilles Pool was 134.7 174.2, a 23% decrease from 2020 (206.4; Figure 2).

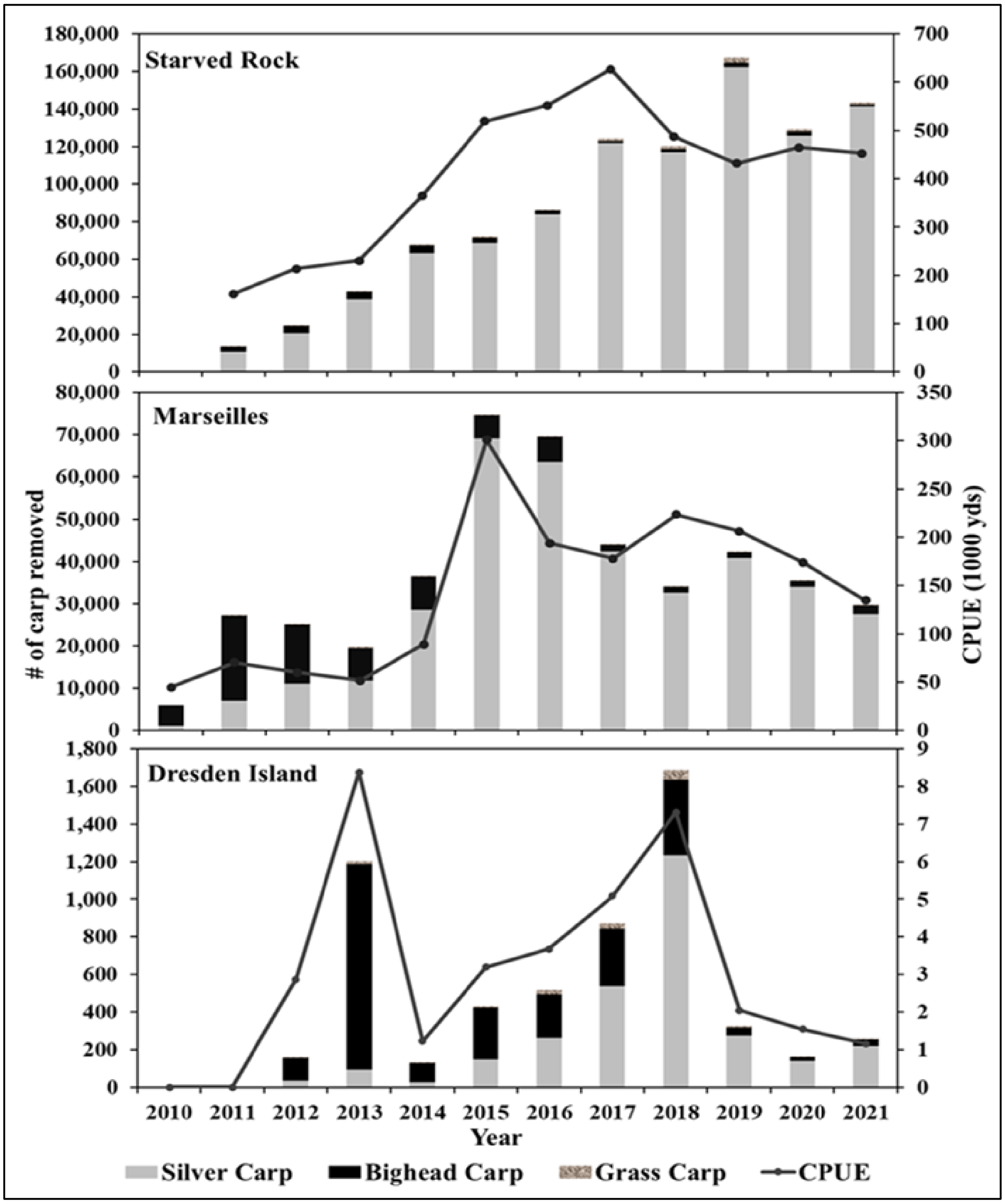

Figure 2. *Annual mean catch per unit effort (CPUE; number of fish per 1,000 yards of gill/trammel net) of invasive carp for Starved Rock (2011-2021; solid black line) and Marseilles (2010-2020; dashed black line), including effort (2010-2020; light grey line).*

Starved Rock Pool:

In 2021, 83% of the total harvested invasive carp came from Starved Rock Pool. Contracted commercial fishing efforts included: 316,096 yards (289 km) of gill/trammel net set. A total of 141,604 Silver Carp, 739 Bighead Carp, and 955 Grass Carp were harvested from Starved Rock pool in 2020 from gill/trammel nets, amounting to 422.2 tons (773,800 lbs.) removed (Figure 4;

Table 1). Silver Carp dominated the catch of invasive carp in Starved Rock Pool in 2020 (99%), consistent with years past. The 2021 gill/trammel net CPUE (# caught per 1000 yds.) of invasive carp for Starved Rock Pool was 453.9, a 2.2 % decrease from 2020 (463.9) (Figure 2).

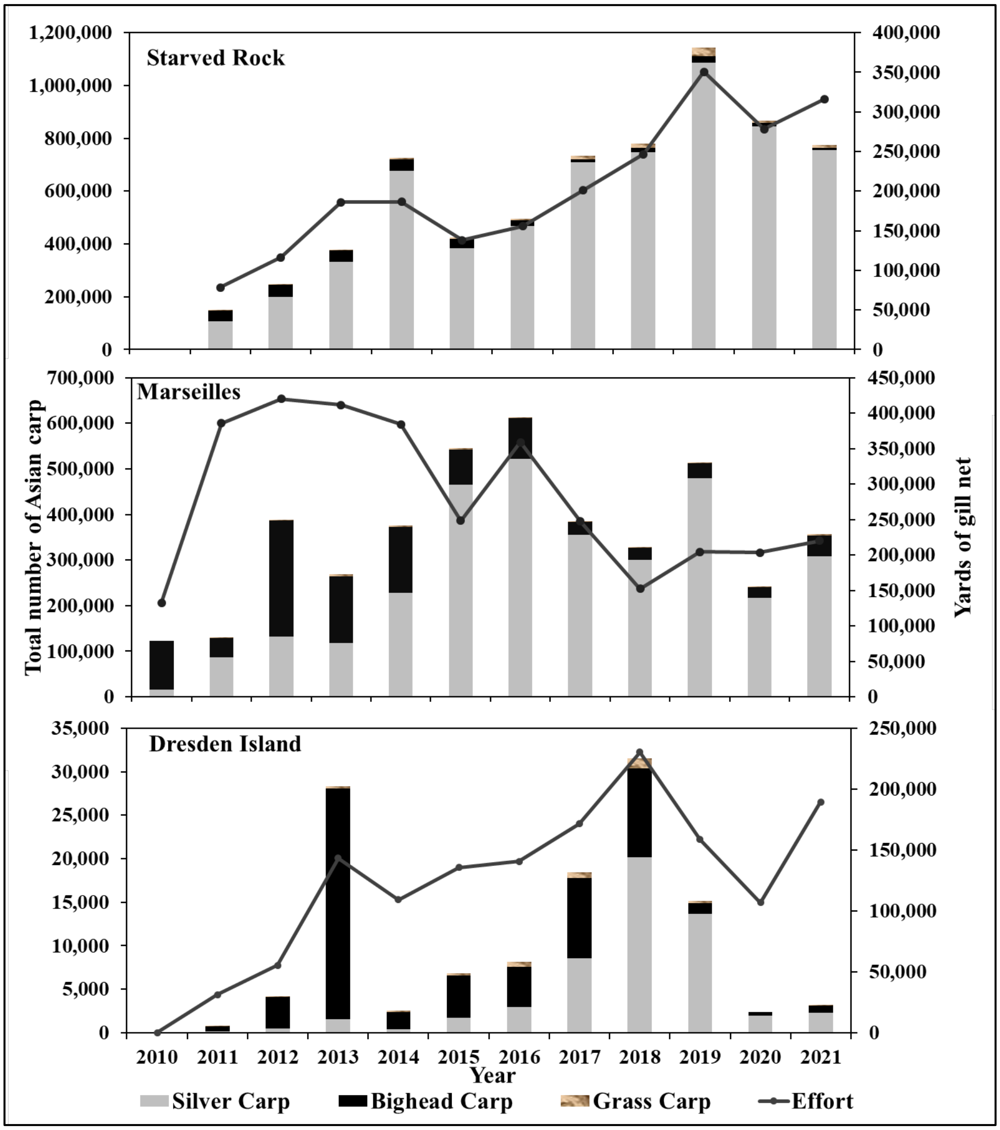

Figure 3. *Annual catch of Silver Carp, Bighead Carp, and Grass Carp in Starved Rock (2011-2021), Marseilles (2010-2021) and Dresden Island (2011-2021) pools.*

Recommendation:

Since 2010, this program has been successful at managing the invasive carp population in the upper Illinois River Waterway by significantly decreasing relative biomass near the population front in Dresden Pool (Coulter et al. 2018). Despite significant limitations posed by Covid-19 throughout 2021, all planned effort was accomplished, and total biomass removed was similar to previous years. With these efforts we hope to further reduce invasive carp abundance at and near the detectable population front, as well as reduce potential propagule pressure on the Electric Dispersal Barrier. In addition to those core goals, MWRG Detection and Removal Workgroup Leads identified several future priorities. These include gaining a better understanding of invasive carp abundance and distribution in Dresden Island Pool, assess how invasive carp species are responding to removal at multiple scales, and identify locations or pools where harvest can have the greatest impact on invasive carp populations. Long term harvest data provides information necessary to model changes in invasive carp relative abundance and population demographics among pools of the upper Illinois River Waterway in response to management actions. This project will continue to directly inform multiple MRWG Workgroups (Detection, Removal), and objectives will continue to be adapted by workgroup leads to better accomplish overall MRWG priorities. Contracted commercial fishing is a critical tool in managing invasive carp populations and we recommend this program continue in 2023.

References:

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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.

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 2010-2021.*

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	41.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	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	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marseilles	1,316.0	75.5	0.0	0.0	0.0	0.0	4,888.0	0.0	1,075.0	5,963.0	53.1	0.0	8.1	61.2
Starved Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All pools	1,357.0	79.8	0.0	0.0	0.0	0.0	4,888.0	0.0	1,075.0	5,963.0	53.1	0.0	8.1	61.2
2011														
Lockport	8.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	22.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dresden	47.0	17.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.1	0.4
Marseilles	671.0	219.2	0.0	0.0	0.0	0.0	20,087.0	34.0	7,023.0	27,144.0	212.8	0.1	43.1	255.9
Starved Rock	151.0	44.6	0.0	0.0	0.0	0.0	2,964.0	132.0	10,730.0	13,826.0	20.5	0.5	53.6	74.6
All pools	899.0	294.5	0.0	0.0	0.0	0.0	23,051.0	166.0	17,753.0	40,970.0	233.5	0.6	96.8	330.9
2012														
Lockport	46.9	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	73.0	13.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
Dresden	125.0	31.5	0.0	0.0	0.0	0.0	120.0	3.0	36.0	159.0	1.8	0.0	0.2	2.1
Marseilles	611.0	238.7	0.0	0.0	0.0	0.0	13,978.0	162.0	11,090.0	25,230.0	127.5	0.8	65.7	194.0
Starved Rock	176.0	66.0	0.0	0.0	0.0	0.0	3,994.0	243.0	20,589.0	24,826.0	22.9	1.5	99.4	123.8
All pools	1,031.9	355.1	0.0	0.0	0.0	0.0	18,092.0	409.0	31,715.0	50,216.0	152.2	2.3	165.3	319.9

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)**
2013														
Lockport	112.0	16.8	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
Brandon	145.0	21.4	0.0	0.0	0.0	0.0	0.0	6.0	0.0	6.0	0.0	0.1	0.0	0.1
Dresden	307.0	81.5	0.0	0.0	0.0	0.0	1,089.0	12.0	90.0	1,191.0	13.3	0.1	0.8	14.2
Marseilles	608.0	233.9	0.0	0.0	0.0	0.0	7,677.0	370.0	11,477.0	19,524.0	73.3	2.6	58.7	134.6
Starved Rock	228.0	105.8	0.0	0.0	0.0	0.0	3,938.0	369.0	38,666.0	42,973.0	21.8	2.0	165.5	189.3
All pools	1,400.0	459.4	0.0	0.0	0.0	0.0	12,704.0	758.0	50,233.0	63,695.0	108.4	4.8	225.0	338.2
2014														
Lockport	253.0	30.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	252.0	30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dresden	326.0	62.0	0.0	0.0	0.0	0.0	104.0	5.0	25.0	134.0	1.0	0.1	0.2	1.3
Marseilles	509.0	218.3	3.0	1.1	0.0	16.0	7,735.0	169.0	28,076.0	35,980.0	72.7	1.0	113.8	187.5
Starved Rock	228.0	105.9	1.0	0.2	366.7	0.0	4,430.0	561.0	63,037.0	68,028.0	21.6	2.9	338.5	363.0
All pools	1,568.0	447.1	4.0	1.3	366.7	16.0	12,269.0	735.0	91,138.0	104,142.0	95.3	4.0	452.5	551.8
2015														
Lockport	343.0	48.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	283.0	49.4	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0
Dresden	375.0	77.1	0.0	0.0	110.8	0.0	272.0	11.0	150.0	433.0	2.4	0.1	0.8	3.4
Marseilles	378.0	141.2	9.0	1.1	22.5	25.0	5,298.0	216.0	68,909.0	74,423.0	39.1	1.2	232.4	272.8
Starved Rock	198.0	78.6	4.0	0.5	141.2	0.0	2,908.0	641.0	68,681.0	72,230.0	16.5	3.1	192.4	212.1
All pools	1,577.0	394.5	13.0	1.6	274.5	25.0	8,478.0	870.0	137,740.0	147,088.0	58.0	4.4	425.6	488.3

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)**
2016														
Lockport	473.0	57.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	427.0	52.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
Dresden	552.0	80.0	0.0	0.0	0.0	0.0	232.0	22.0	263.0	517.0	2.3	0.3	1.5	4.1
Marseilles	486.0	204.0	30.0	7.6	85.7	67.0	5,937.0	76.0	62,642.0	68,655.0	44.7	0.6	260.9	306.2
Starved Rock	249.0	88.6	14.0	2.2	683.1	0.0	2,048.0	606.0	83,859.0	86,513.0	10.8	2.9	233.8	247.5
All pools	2,187.0	482.2	44.0	9.8	768.8	67.0	8,217.0	705.0	146,764.0	155,686.0	57.8	3.8	496.2	557.8
2017														
Lockport	449.0	52.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	484.0	59.6	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
Dresden	573.0	97.6	0.0	0.0	343.3	4.0	307.0	28.0	538.0	873.0	4.6	0.4	4.3	9.2
Marseilles	368.0	140.4	7.0	2.2	48.7	74.0	1,529.0	51.0	40,144.0	41,724.0	13.8	0.4	178.0	192.2
Starved Rock	375.0	114.1	3.0	1.3	938.6	0.0	1,123.0	1,118.0	123,642.0	125,883.0	4.8	6.4	355.3	366.5
All pools	2,249.0	464.5	10.0	3.5	1,330.6	78.0	2,959.0	1,198.0	164,324.0	168,481.0	23.2	7.2	537.6	567.9
2018														
Lockport	395.0	43.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	391.0	44.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
Dresden	960.0	130.9	0.0	0.0	0.0	8.0	398.0	53.0	1,235.0	1,686.0	5.1	0.6	10.1	15.8
Marseilles	413.0	86.5	10.0	2.4	224.5	22.0	1,397.0	35.0	32,369.0	34,012.0	12.9	0.2	150.1	163.3
Starved Rock	585.0	140.2	0.0	0.0	1,403.7	0.0	1,645.0	1,406.0	117,052.0	120,137.0	8.0	7.7	374.0	389.8
All pools	2,744.0	445.4	10.0	2.4	1,628.2	30.0	3,440.0	1,495.0	150,656.0	155,836.0	26.0	8.5	534.2	568.9

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)**
2019														
Lockport	297.0	33.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	263.0	30.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dresden	779.0	93.6	0.0	0.0	0.0	2.0	45.0	8.0	274.0	327.0	0.6	0.1	6.8	7.6
Marseilles	563.0	125.0	5.0	1.5	0.0	26.0	1,586.0	84.0	44,002.0	45,672.0	17.2	0.7	239.4	257.3
Starved Rock	1,131.0	220.5	1.0	0.1	0.0	1.0	2,157.0	2,830.0	163,017.0	168,004.0	11.9	15.8	543.6	571.3
All pools	3,033.0	503.6	6.0	1.6	0.0	29.0	3,788.0	2,922.0	207,293.0	214,003.0	29.7	16.6	789.8	836.2
2020														
Lockport	231.0	27.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	254.0	29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dresden	491.0	60.7	0.0	0.0	0.0	0.0	22.0	3.0	140.0	165.0	0.2	0.0	1.0	1.2
Marseilles	340.0	115.5	0.0	0.0	0.0	0.0	1,414.0	31.0	33,969.0	35,414.0	10.9	0.5	103.6	115.0
Starved Rock	461.0	158.2	0.0	0.0	0.0	0.0	2,257.0	1,054.0	125,857.0	129,168.0	6.5	4.5	411.2	422.2
All pools	1,777.0	391.0	0.0	0.0	0.0	0.0	3,693.0	1,088.0	159,966.0	164,747.0	17.6	5.0	515.8	538.4
2021														
Lockport	440.0	50.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brandon	471.0	54.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dresden	913.0	107.7	0.0	0.0	0.0	0.0	33.0	5.0	182.0	220.0	0.4	0.0	1.2	1.6
Marseilles	258.0	125.0	0.0	0.0	0.0	0.0	2,035.0	52.0	27,536.0	29,623.0	22.8	1.1	154.5	178.3
Starved Rock	533.0	179.6	0.0	0.0	0.0	0.0	739.0	955.0	141,604.0	143,298.0	4.4	4.8	377.7	386.9
All pools	2,615.0	516.9	0.0	0.0	0.0	0.0	2,807.0	1,012.0	169,322.0	173,141.0	27.6	5.9	533.4	566.8

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)**
2010-2021														
Lockport	3,088.0	377.2	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
Brandon	3,065.0	390.2	0.0	0.0	0.0	0.0	0.0	12.0	0.0	12.0	0.0	0.1	0.0	0.1
Dresden	5,448.0	840.3	0.0	0.0	454.1	14.0	2,622.0	150.0	2,933.0	5,705.0	32.0	1.8	27.0	60.8
Marseilles	6,521.0	1,923.2	64.0	15.8	381.3	230.0	73,561.0	1,280.0	368,312.0	443,153.0	700.9	9.2	1,608.4	2,318.4
Starved Rock	4,848.0	1,302.1	23.0	4.3	3,533.4	1.0	28,203.0	9,915.0	956,734.0	994,852.0	149.7	52.1	3,145.0	3,346.9
All pools	22,970.0	4,833.0	87.0	20.1	4,368.8	245.0	104,386.0	11,358.0	1,327,979.0	1,443,723.0	882.6	63.2	4,780.4	5,726.2

Barrier Maintenance Fish Suppression

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Participating Agencies: ILDSNR (lead); USFWS, USACE – Chicago District, (field support); USCG (waterway closures), USGS (flow monitoring); MWRDGC (waterway flow management and access); and USEPA (project support).

Introduction and Need:

The USACE operates three electric aquatic invasive species dispersal barriers (Barrier 1 [which consists of 1D and 1N], Barrier 2A, and Barrier 2B) in the CSSC at approximate river mile 296.1 near Romeoville, Illinois. The Demonstration Barrier was the first barrier constructed by USACE and it 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 (0.4 volts/centimeter; v/cm) that has been shown to induce behavioral responses in fish over 137 mm in total length (Holliman 2011). The Demonstration Barrier is now referred to as 1D and has been integrated into Barrier 1. 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 v/cm, or fish greater than 63 mm long at a setting of 0.91 v/cm (Holliman 2011). The higher setting of 0.91 v/cm has been in use since October 2011. Barrier 1 was activated in February of 2021. Barrier 1 consists of a northern array (1N) and 1D as outlined above. A third array (1S) is planned for construction in FY 2023. Barrier 1 is capable of increased operational settings in comparison to Barriers 2A and 2B, but safety testing is required before USACE can operate above 0.91 v/cm.

All barriers (Barrier 1, 2A, and 2B) must be shut down independently for maintenance approximately every 12 months and the ILDNR 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, 2B, and now Barrier 1 operational, fish suppression actions will be smaller in scope because at least one barrier can remain on while another is taken down for maintenance.

Barrier 2B operated as the principal barrier from the time it was brought online 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 EDBS by maintaining power in the water continuously regardless of a lapse in operation at any single barrier. Due to maintenance needs and cost effectiveness, USACE plans to always operate two barriers, when possible, to minimize any risk of fish passage. However, as barriers are turned on and off for scheduled and unscheduled outages, there is a need to assess the risk of the presence of invasive carp and clear fish from the spaces between the Barriers as deemed necessary by the MRWG. Depending on the sequence of outages, and if the outage(s) are for a length of time sufficient to allow fish passage as deemed by the MRWG, a clearing evaluation/action may need to take place. If a clearing action is needed, but were not to happen, fish have the potential to utilize the outages to "lock through" the EDBS. Locking through happens if an outage were experienced at Barrier 2A, allowing fish present just downstream to move up to Barrier 2B, becoming stuck in the 67 m space between 2A and 2B once 2A is reactivated. If an outage is then experienced at Barrier 2B, the fish trapped between the barriers would then be able to move into the 148 meter area between Barrier 1 and 2B. If Barrier 1 were then to lose power, fish would be able to move into the upper Lockport Pool. The suppression plan calls for an assessment of the risk of invasive 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 ILDNR 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 physical collection (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 in total length between applicable barrier arrays, if present, for species composition to ensure invasive 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 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 invasive carp until further evidence from downstream monitoring suggests a change in the known population front for this size class of invasive carps.

Project Highlights:

- The MRWG agency representatives discussed the risk level of invasive carp presence at the EDBS at each primary barrier loss of power in the water.
- No fish suppression actions were carried out in 2021 after considering the current known risk of invasive carp in the area of the EDBS.
- **No invasive carp were captured or observed during routine fish sampling operations within the Lockport Pool, providing support for not needing suppression activities.**

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 is considered to be too short of a 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 invasive carp passing the barrier, under the conservative assumption that they may be present in Lockport Pool and near or at the barriers. If invasive carp exist near the barriers, the MRWG currently expects only adult fish (> 300 mm) to be present. This risk evaluation may change if small invasive 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 invasive carp in the CAWS and upper IWW 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 invasive carp passing a given barrier. The MRWG decision to initiate a clearing action at the barriers is made only during heightened risk of invasive 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 by the MRWG for fishes to be removed from the barrier area when a clearing action is recommended. By selecting a cut-off of 300 mm, sub adult and adult invasive carp are targeted, and young-of-year and juvenile fish were excluded. Excluding young-of-year and juvenile invasive carp from the assessment was based on over 10 years of sampling in the Lockport Pool with no indication of any young-of-year invasive carp being present or any known locations of spawning. However, monitoring in the lower reaches of the IWW in the spring of 2015 indicated that small invasive carp less than 153 mm were being collected progressively more 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 invasive carps are present. It should be noted that invasive 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 invasive carp being at or in the EDBS. The MRWG has taken a conservative approach to barrier responses by implementing continued work and surveillance below the EDBS despite little evidence that invasive carp are directly below the barrier. 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.

The 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 areas between each barrier. This action is aimed specifically at 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 the affected barriers. Initial response to any loss of power to the water should occur within a week of the outage and upon completion of the sonar survey. 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 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 2021, Barrier 1, Barrier 2A and 2B were the primary barriers to fish passage in the upstream direction within the EDBS at various points during the year. Prior to February of 2021, 2A and 2B and the Demonstration barrier were the primary barriers. Once Barrier 1 was activated and running consistently, 2A and Barrier 1 became the primary barriers. A total of eighty-four (84) outages of one minute or greater occurred across all the barriers during 2021. Approximately 80% of all the outages occurred specifically at the 1N array of Barrier 1. Many of the outages at 1N occurred due to a known utility power feed issue and a cooling system leak.

For example, the cooling system leak identified in June resulted in eleven (11) outages at the 1N array and the utility power feed issue resulted in forty-three (43) outages from March to October. Other unplanned outages at the 1N array resulted from loss of power due to inclement weather. In addition to unplanned outages at 1N, eight (8) unplanned outages occurred at the 1D array and one (1) at IIA. Outages at the 1D array occurred due to power outages, power feed issues from the utility like the issues at 1N, and from a wiring rework that unexpectedly needed to power down 1D briefly. Only one (1) unplanned outage occurred at IIA when power was lost for approximately an hour which affected both IIA and 1D.

Throughout 2021 a total of seventeen (17) planned outages occurred at various barriers. The 1D array at Barrier 1 was off for controls replacement at the beginning of the year. In addition, 1D was turned off for computer programming upgrades and maintenance. Barrier array 1N was turned off for a total of ten (10) times for trouble shooting, maintenance, computer program upgrades and training. Barrier IIB was off for most of 2021. The barrier was turned off in February of 2021 for controls replacement and annual maintenance. Supply chain issues and COVID-19 protocols caused a severe slip in the schedule and is anticipated to be re-activated in March 2022. Finally, Barrier IIA had two (2) scheduled outages in 2021 for a fire alarm repair and in water voltage measurement testing. Voltage measurements were needed to determine if Barrier 1 can remain operational during dive operations at IIA and IIB.

Both planned and unplanned outages were coordinated through the MRWG as USACE confirmed schedules. At different points through the year the outages were reported in groups due to known issues with barrier operations at that time. When Barrier array 1N was first energized, it was considered to be in construction phase while undergoing an endurance run. During that time the contractors had control of the barrier and turned it on and off as needed to fine tune the barrier, troubleshoot, and upgrade various components. It was also determined that due to the power quality feed issues, USACE would report out on outages on a biweekly notification due to several outages occurring per day. A summary of the outages by barrier and whether they were planned or unplanned is in Table 1.

Table 1: *Summary of barrier outages for each of the barriers at the Electric Dispersal Barrier System*

Barrier	Outages	Planned
1D	11	4
1N	67	10
IIB	1	1
IIA	3	2

During 2021, no fish clearing actions occurred because of a barrier outage. Several factors including safety, recent monitoring data, environmental conditions, other barrier operational status, effectiveness of gear types available, and known risk were used to determine the need for a clearing action. Hydroacoustic scans at the barriers were also used to determine the need for a clearing action as well. For most of 2021 USFWS were not able to conduct hydroacoustic scans due to COVID-19 restrictions. However, bi-weekly hydroacoustic scans resumed on August 30 of 2021 and were used in the consideration of a clearing actions based on fish targets identified.

Recommendations:

The MRWG agency representatives should continue to assess the risk of invasive carp presence at the primary downstream barrier. The group should take into consideration the most recent downstream monitoring data, known locations of invasive carp (adults and juveniles), safety, and other biotic and abiotic factors relative to invasive carp movement and dispersal patterns. 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 when deemed necessary. Identification of fishes less than 300 mm will help further inform decision makers on the risk of juvenile invasive carp presence. Deep water gill net sets and other submerged bottom deployed gears are not recommended for 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 invasive carp presence. Additionally, there should be continued research and deployment of novel fish driving and removal technologies such as low dose piscicides, complex noise generation, carbon dioxide and other techniques.

Invasive Carp Population Modeling to Support an Adaptive Management Framework

Participating Agencies: USFWS-Carterville FWCO (lead), USGS – Upper Midwest Sciences Center, SIU, and ILDNR

Pools Involved: Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools; Illinois River.

Introduction and Need:

The goal of this project is to develop objective, data-driven tools in support of the adaptive management process and invasive carp control efforts. To accomplish this goal, this project will continue ongoing efforts to develop and implement the SEICarP model and develop novel quantitative tools such as stock assessment models to address emerging management questions.

The SEICarP model is a simulation-based, mathematical representation of Silver Carp and Bighead Carp population dynamics. The model is used to inform management in the Illinois River in two primary ways. First, the model output is used to provide management recommendations concerning required levels and spatial allocations of mortality and upstream movement deterrence to minimize propagule pressure in the vicinity of the EDBS. Second, critical model assumptions and results from sensitivity analyses are used to provide recommendations concerning data collections and research in the Illinois River and guide ongoing model development aimed at extending model capabilities and reducing uncertainty.

Development of the SEICarP model is ongoing. Two limitations of the SEICarP model are tied to the underlying movement model, which describes the probabilities of fish movement between pools. First, the coverage of the current movement model is limited to the Illinois River. Consequently, the SEICarP model treats the Illinois River as a closed system, despite considerable fish movement between the Illinois River and Upper Mississippi River basins. Second, due to other limitations associated with movement estimates, model-based mortality recommendations are provided on a relatively coarse spatial resolution (i.e., pools above versus below Starved Rock Lock and Dam) rather than on an individual pool level. Updating the movement model to increases the spatial coverage and improve the spatial resolution is critical to addressing these limitations of the SEICarP model.

A third area of ongoing model development is creating a model to describe the stock-recruit relationship for invasive carps. The stock-recruit relationship is fundamental to the management of invasive carp in the Illinois River because it determines how recruitment rates will respond to control-induced reductions in adult biomass. Although the SEICarP model was originally intended to include an invasive carp-specific stock-recruit relationship, there is no currently available stock-recruit model that is compatible with the SEICarP model. In response to this knowledge gap, impacts of the stock-recruit relationship on SEICarP model predictions are currently assessed using a sensitivity analysis.

Invasive Carp Population Modeling to Support an Adaptive Management Framework

In addition to the ongoing development of the SEICarP model, a fourth area of model development involves estimating the rate at which individuals in a given pool contribute to Dresden Island Pool. The goal of this per-capita contribution modeling effort is to assist managers by providing a tool that would prioritize harvest locations (i.e., pools) and the placement of deterrents to movement among pools based on the contribution of individuals to the population at the invasion front.

Lastly, despite its utility for testing management scenarios, the SEICarP model cannot assess the current status of invasive carp populations. To understand the current population size, natural and harvest mortality rates, and other demographic rates, a feasibility study to determine if statistical catch-at-age or -length (SCAA/L) models could be successfully developed using currently available data from Illinois River invasive carp populations if necessary.

These modeling efforts include coordination among state and federal agencies as well as academic partners. The USFWS leads USDOI efforts for this project with considerable support from the USGS.

Objectives:

(1) Prepare and submit a manuscript of the SEICarP model for publication in a peer-reviewed journal using results from sensitivity analyses and population control (i.e., additive mortality, upstream movement deterrence) simulations.

(2) Develop a stock-recruit relationship using existing age structure and hydroacoustics data.

(3) Collaborate with the MRWG Telemetry sub-workgroup in its efforts to update pool-to-pool movement probabilities.

(4) Complete statistical catch-at-age or -length model feasibility study to determine if currently available Illinois River data would sufficiently support these modeling frameworks.

(5) Complete preliminary per-capita contribution modeling scoping and model parameterization.

Project Highlights:

- The SEICarP manuscript has been drafted and reviewed by all coauthors. Currently, the manuscript has been submitted to the USGS review process prior to submission to *Conservation Biology* for peer review.
    - Management recommendations include increased harvest in lower pools of the Illinois River, maintenance of current harvest efforts in the upper pools of the Illinois River, and deterrent placement at the most-downstream lock and dam structure in the upper Illinois River (i.e., Starved Rock Lock and Dam)
- Manuscript describing spatial variation in invasive carp demographics published in the *Journal of Fish and Wildlife Management* (Erickson et al. 2021)

- Development of software for automating model runs (SEICarP and demographics) to update demographics and management recommendations with current data.
- Hydroacoustics and length-at-age data compiled and examined to determine feasibility of developing stock-recruit relationship using currently available data
- Multi-state model to estimate pool-to-pool transition probabilities was updated using a Bayesian approach and data collected since the previous model was published (Coulter et al. 2018).
- Engaged with Michigan State University's Quantitative Fisheries Center to determine the feasibility of developing a statistical catch-at-age or -length model of invasive carps in the Illinois River based on currently available age structure and harvest data.
- Completed the per-capita modeling scoping and parameterization and submitted the resulting manuscript to *Ecological Applications* for peer review
    - The management implications from this modeling effort are consistent with those of the SEICarP model, i.e., increased harvest in the lower Illinois River is more effective than upstream harvest at reducing upstream populations and a deterrent placed at Starved Rock Lock and Dam is most effective at disrupting recruitment to the upper Illinois River via immigration from the lower river.

Future Work:

- Currently, invasive carp population models (i.e., SEICarP and per-capita models) do not account for effects on species other than invasive carps (i.e., Silver Carpand Bighead Carps). Consequently, unintended consequences of control strategies, particularly upstream movement deterrence should be evaluated.
- To evaluate the effectiveness of additional management actions (e.g., increased lower pool mortality), we recommend continued support for ongoing control efforts (e.g., harvest) and monitoring in the focal areas above Starved Rock Lock and Dam.
- Although an updated movement model was developed during FY 2021, the posterior distributions of movement probabilities have not yet been incorporated into the SEICarP model. Thus, previous limitations with regards to the movement model remain. We, therefore, recommend that the output from the updated movement submodel be incorporated into the SEICarP model and updated management recommendations from the SEICarP model be disseminated to the MRWG.
- Although the movement model was updated to include additional information from recent telemetry efforts, movement probabilities for fish moving between the Mississippi and Illinois rivers are still unknown. We recommend collaborating with the MRWG Telemetry Work Group to determine how to best address this data gap.
- Continue engagement with Michigan State University's Quantitative Fisheries Center to develop final report for the feasibility of a statistical catch-at-age or -length model for Illinois River invasive carp and pursue the recommendation of that report.
- If a statistical catch-at-age or -length model is determined to be feasible with currently available data, work towards developing that model to better inform decisions concerning

the additional lower pool mortality recommendations. A statistical catch-at-age or -length model would also allow scaling mortality levels into absolute numbers or biomass rather than a proportion of the population.

- Support 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.

References:

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Telemetry Support for the Spatially Explicit Invasive Carp Population Model (SEICarP)

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Participating Agencies: USFWS, Carterville FWCO, Wilmington Substation (lead), SIU (field support)

Pools Involved: Peoria, Alton

Introduction and Need:

The SEICarP model was developed as a means of assessing invasive carp population status in the IWW. Movement is the backbone of the SEICarP 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 invasive carp (primarily Silver Carp and Bighead Carp) in the IWW. Because harvest effects, such as changes in fish density and size distributions, are likely to impact movement and, will thus influence our ability to predict population responses, continued monitoring of invasive carp movement in the IWW is necessary. The USFWS telemetry data complements telemetry data being collected throughout the IWW describing interpool transfer of adult invasive carps and is used to parameterize the transition probability component of the SEICarP model. This research provides an improved understanding of invasive carp movement in the IWW and its effects on population dynamics.

Objectives:

(1) Collectively tag ≥ 150 individual adult invasive carp within Peoria and Alton pools, with a focus on Silver Carp.

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

(3) Provide data from acoustic receivers to the Telemetry Work Group of the MRWG for use in the SEICarP model.

Project Highlights:

- Data from the six 69 kHz acoustic receivers was collected, processed, and provided to the Telemetry Work Group monthly.
- 100 V-9 acoustic transmitters were implanted into invasive carp, in March 2021, strategically across Peoria pool. Another 49 transmitters were implanted in invasive carp, by staff at SIU, in Alton pool during April of 2021.
- We observed a 47% detection rate for the 100 invasive carp tagged in Peoria Pool this year from the six maintained receivers.

Methods:

The receivers were collected throughout 2021 and the data were uploaded to the FishTracks database monthly. With direction from the Telemetry Workgroup, all receivers were tethered to trees in attempt to reduce receiver loss. Receivers were placed a minimum of 5 river kilometers away from other existing partner receivers to attempt to maximize movement detection. The receivers will be redeployed with the beginning of the new monitoring season in early Spring 2022.

Results and Discussion:

A total of 195,959 detections, that spanned from April 5th to December 13th, from 93 fish were recorded across the six USFWS-maintained 69 kHz receiver array in 2021. We observed a 47% detection rate for the 100 invasive carp tagged in Peoria Pool this year from the six maintained receivers. All data was uploaded to the FishTracks database by December 2021.

Future Work:

Future support of the SEICarP model will continue into FY 2022. USFWS-Wilmington will tag an additional 150 adult invasive carp in Starved Rock Pool and Peoria Pool. Future work will include maintaining the array coverage with a minimum of six 69 kHz receivers, with the possible room for expansion of an additional 2 receivers. The MRWG Telemetry Work Group will be consulted prior to tagging and deployment to optimize placement within the IWW.

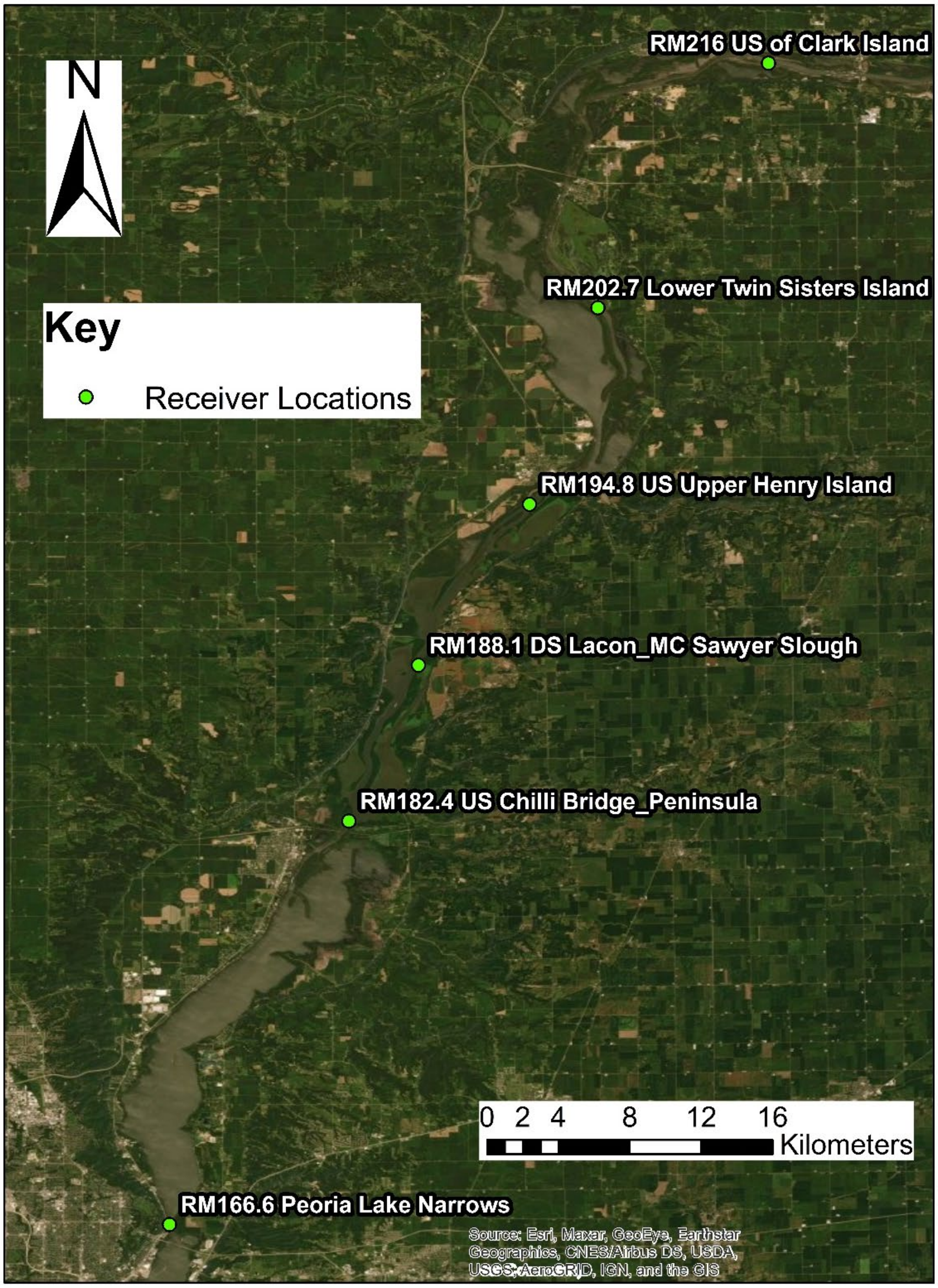

Figure 1. *Map of USFWS-maintained 69-kHz acoustic receivers deployed in Peoria Pool throughout 2021.*

Invasive Carp Demographics

Edward Sterling, Jahn Kallis, Bryon Rochon, Jacob Griffin,
Jason Goesckler (USFWS, Columbia FWCO)

Participating Agencies: USFWS-Columbia FWCO (lead) and ILDNR

Pools Involved: Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools; Illinois River.

Introduction and Need:

Silver Carp management in the Illinois River requires an adaptive management approach. The collection of high quality, fisheries-independent data can help evaluate and inform management and control efforts for Silver Carp. 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 SEICarP model. Herein, we update Silver Carp demographic data collected from the six lower pools of the Illinois River (i.e., Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools) during spring and fall 2018 – 2020 with 2021 data. The primary goal of these collections was to address data gaps including Silver Carp size at maturity, uncertainty in age and growth estimates, and to provide a comprehensive dataset that can be used to evaluate success of ongoing and future control efforts using multiple indicators.

Objectives:

(1) Quantify size and sex structure, length at maturity, and relative abundance of Silver Carp during spring and fall in the lowest six pools of the Illinois River (Alton, LaGrange, Peoria, Starved Rock, Marseilles, Dresden Island).

(2) Use lapilli otoliths to generate age and growth information for Illinois River Silver Carp captures.

(3) Provide recommendations derived from previously collected data concerning standard methods and preferred aging structures for invasive carp.

(4) Collaborate with the Multiple Agency Monitoring project to reduce overlap and increase efficient data collection to update parameter estimates associated with the SEICarP model.

(5) Identify advantages and limitations of using the electrified dozer trawl to inform hydroacoustics data by comparing species composition and size structure from electrified dozer trawl collections with capture gears currently being used to inform hydroacoustics (*Continuation on an objective from 2020 MRP).

Methods:

The USFWS Columbia FWCO collected fisheries-independent data including age, size, and sex structure, length at maturity, and relative abundance during spring (May – June) in the lower three pools, and in fall (September – November) in each of the lower six pools of the Illinois River using a random design stratified by habitat type (i.e., backwaters, island side channels, main-channel borders). Habitat classifications are based on aquatic area designations developed by the Habitat Needs Assessment II project (USACE 2017). Prior to each sampling event, collection sites were randomly selected from a Geographic Information System that includes habitat data and an indexed 50- by 50-m grid. Collection sites were sampled by conducting 5- minute trawls at 4.8 kilometers per hour (calculated by GPS tracking) using electrified dozer trawl (Hammen et al. 2019). Catch rates from 2018 – 2020 were used to determine pool-specific sample sizes based on criteria from Koch et al. (2014). Maturity status and sex data were collected during spring sampling in Alton, La Grange, and Peoria pools using macroscopic observations of the gonads. Fish length and weight were measured for all spring- and fall- caught Silver Carp. For fall caught fish, lapilli otoliths were extracted from the first 200 Silver Carp captured in each pool, with a maximum of 20 carp per transect. Otoliths were also extracted from any fish in an unfilled length bin (10/50mm) following the first 200 collected. All non- invasive carp captures will be identified to species, counted, and measured to the nearest millimeter.

Project Highlights:

- Collected over 10,000 Silver Carp from six pools of the Illinois River during 2018 – 2021 sampling and processed nearly 1,700 aging structures.
- Contributed to the comprehensive invasive carp dataset using Silver Carp captured from six pools of the Illinois River with the electrified dozer trawl. Standardized data collections included: length, weight, age, sex, and relative abundance.
- Provided data useful to measure population responses to changes in management strategies (i.e., sex ratio, body condition, age and growth).
- Coordinated with the MRWG Monitoring workgroup to share age and maturity determination procedures.
- Spring 2021 sampling yielded a wide size distribution of fish nearing maturation improving the accuracy and precision of size at maturity estimates used in population modeling.
- Coordinated with the Illinois Natural History Survey (INHS) to evaluate the accuracy of Silver Carp age estimates derived from postcleithra. Preliminary results suggested that postcleithra underestimate age. We recommend lapilli otoliths be used based on previous research findings (Seibert and Phelps 2013).

- Evaluated how the electrified dozer trawl complements a large river multiple-gear sampling approach (e.g., Long Term Resource Monitoring, Multiple Agency Monitoring) with respect to fish community and invasive carp data collections. Preliminary results indicated that the electrified dozer trawl complemented a multiple-gear approach by effectively sampling pelagic species, including Silver Carp.

Results and Discussion:

Herein, we report summary results from field sampling and laboratory age estimates conducted by the USFWS Columbia FWCO. Results from 2018 – 2020 collections were updated with 2021 data. Laboratory and field data have been shared with MRWG personnel to be incorporated into the overall MRWG database. These data will be used by the MRWG modeling sub-workgroup to update parameter estimates in the SEICarP model.

In 2021, 4,490 Silver Carp were captured the lower 6 pools of the Illinois River between two seasons. Spring sampling was used to target younger Silver Carp nearing maturation with an overall goal of characterizing Silver Carp length at maturity in the lower three pools of the Illinois River (i.e., Alton, LaGrange, and Peoria pools). A total of 1,548 Silver Carp (1,540 stock or larger individuals; ≥250mm; Phelps and Willis 2013) in 150 5-minute trawls were collected from the lower three pools during spring 2021 with the electrified dozer trawl (Hammen et al.

2019; Table 1). Fall sampling was used to characterize Silver Carp population demographics (i.e., length, weight, growth, and relative abundance) in the lower six pools (i.e., Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools) of the Illinois River. In total, 2,645 Silver Carp (2,334 stock or larger individuals) were collected in 304 5-minute trawls from the lower six pools during fall 2021 with the electrified dozer trawl (Table 1). Along with electrified dozer trawl sampling, supplemental commercial catch data was collected in 2021 (N=168) from Marseilles pool and in 2019 (N=19) and 2021 (N=67) from Dresden Island pool. Fisheries-independent electrified dozer trawl data were supplemented using the commercial catch data. Commercial catch data were used to inform length and age structure from pools with sparse catch data from the standard electrified dozer trawl samples. Due to COVID-19 sampling restrictions, no data were collected in Starved Rock, Marseilles, and Dresden Island pools in the 2020 field season.

Table 1. *Spring and fall 2021 summary data including pool-specific effort (number of 5-minute trawls), Silver Carp total catch (number), mean Silver Carp catch per unit effort (number ≥250mm/h) and standard error, and total length (TL) range of Silver Carp captured. Results are based on fishery-independent sampling using the electrified dozer trawl.*

Pool	Season	Effort (#)	Total catch (#)	Mean CPUE (SE)	TL range (mm)
Dresden	Fall	50	0	0 (0)	NA
Marseilles	Fall	50	48	10.8 (3.2)	300-920
Starved Rock	Fall	51	367	83.6 (11.2)	130-771
Peoria	Spring	50	314	75.0 (33.3)	115-770
	Fall	51	940	170.4 (29.6)	85-815
LaGrange	Spring	50	506	122.1 (22.1)	425-847
	Fall	51	741	199.8 (32.5)	68-790
Alton	Spring	50	728	176.0 (26.6)	285-780
	Fall	51	549	99.3 (10.5)	65-760

Relative abundance: Objective one of this project included the quantification of Silver Carp relative abundance. Temporal patterns in Silver Carp catch rates of stock size and larger individuals varied among pools and years. Stock size and larger Silver Carp were used for analyses because they are assumed to be "recruited" and not susceptible to increased first year mortality. It is likely that high water events, sampling time (i.e., temperature), harvest events, and other natural factors affect catchability of Silver Carp. It is difficult to isolate the factors that could be influencing within-pool relative abundance estimates on an annual basis. Though it is unclear how natural climatic variables (i.e., temperature and flood stage) affected catch rates, a trend in relative abundance from lower pools (i.e., Alton, LaGrange, and Peoria pools) to the upper pools (i.e., Starved Rock, Marseilles, and Dresden Island pools) was evident. Lower pools had higher Silver Carp relative abundance in comparison to upper pools during every year, with the exception of increased relative abundance in Starved Rock during 2019 (Figure 1). Several factors contribute to the lower overall abundance in the upper pools. One of the primary reasons is the lack of recruitment in the upper pools, which limits population size based on upstream movement rates from downstream pools that do support recruitment. Population size in the upper pools is also limited by high head lock and dam structures which act as barriers to upstream movement. Another explanation is that total mortality (natural & fishing) is higher in the upper pools due to high commercial harvest efforts (Project: Contracted Commercial Fishing Below the Electric Dispersal Barrier, ICRCC-MRWG 2019). Increased harvest efforts have resulted in thousands of invasive carp removed from the upper three pools annually, which could reduce population size and overall abundance (Project: Contracted Commercial Fishing Below the Electric Dispersal Barrier, ICRCC-MRWG 2019).

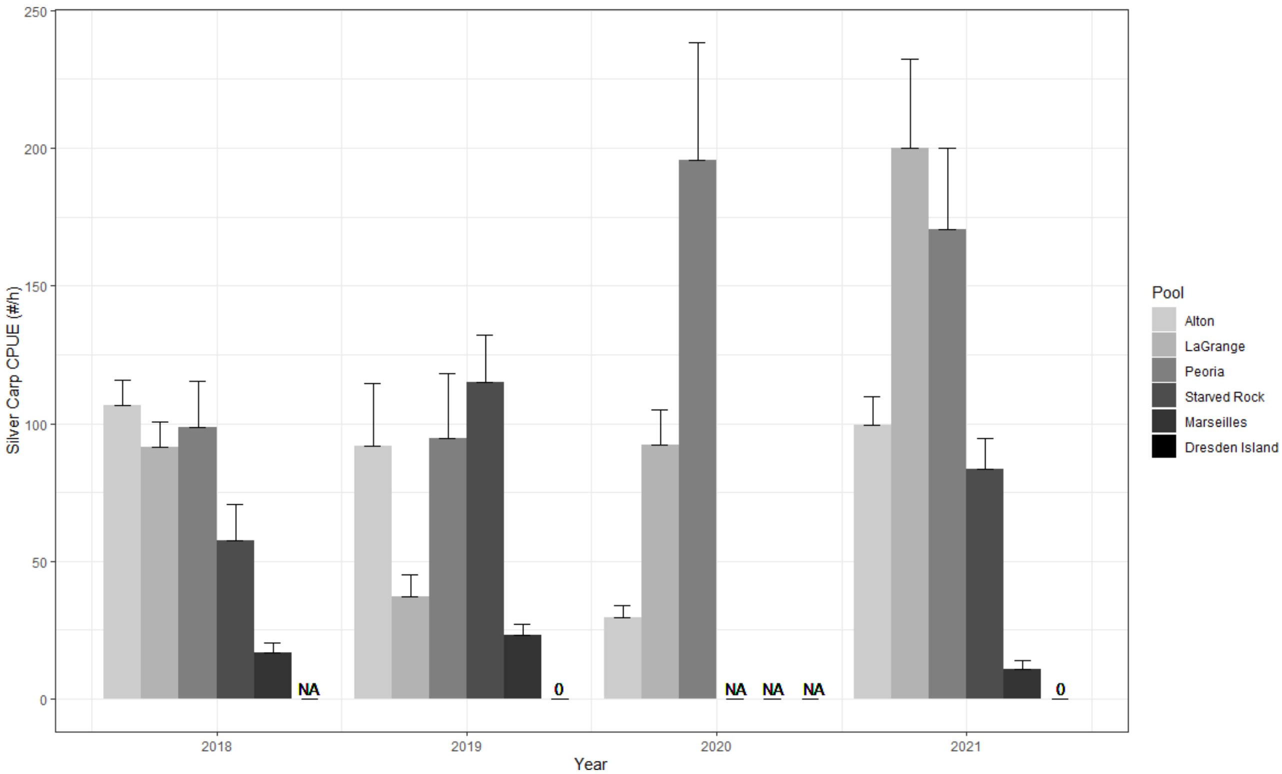

Figure 1. *Pool-specific mean stock (≥250mm) Silver Carp catch per unit effort (number/hour) and standard error. All fish were sampled using the electrified dozer trawl during fall 2018 – 2021.*

Length structure: Silver Carp catches were between 40 – 1,030 mm TL since 2018. Mean length of all Silver Carp captured since 2018 is 560 mm TL and catches have been dominated by individuals greater than 450 mm TL in all pools, regardless of sampling year (Figure 2). Results from 2021 were similar with Silver Carp ranging from 65 – 1,030mm TL and a mean of 551mm TL. Length structure data reflected spatial patterns in source-sink dynamics. Individual fish lengths corresponding to sub-stock sizes were captured from pools located below Starved Rock L&D – source populations – whereas captures from pools located above Starved Rock L&D – sink populations – were devoid of sub-stock sizes with the exception of 13 individual Silver Carp captured in Starved Rock pool in 2021. Among source populations, fish tended to be somewhat smaller in Peoria Pool relative to Alton and LaGrange pools, which were comparable. Among sink populations, mean length increased longitudinally from downstream to upstream (Figure 2), with Starved Rock, Marseilles, and Dresden Island pools exhibiting primarily large individuals greater than 500mm TL. The majority of fish captured in Marseilles and Dresden Island were over 700mm TL (Figure 2). It is important to note that Dresden Island length structure is based solely on supplemental commercial catch and may be skewed for that reason.

Length frequency data were used to explore spatial and temporal recruitment patterns. Patterns in annual pool-specific catches of sub-stock sized fish suggest that there was little to no recruitment associated with the 2019 or 2020 year classes, but relatively high recruitment associated with the

2018 year class, at least in Alton and LaGrange pool populations (Figure 2). This conclusion is supported by 2019, 2020, and 2021 data, which show growth of the 2018 year class. This is further supported by the high number of 2018 cohort fish in our age data, primarily from Alton and LaGrange pools (see age structure, Figure 6).

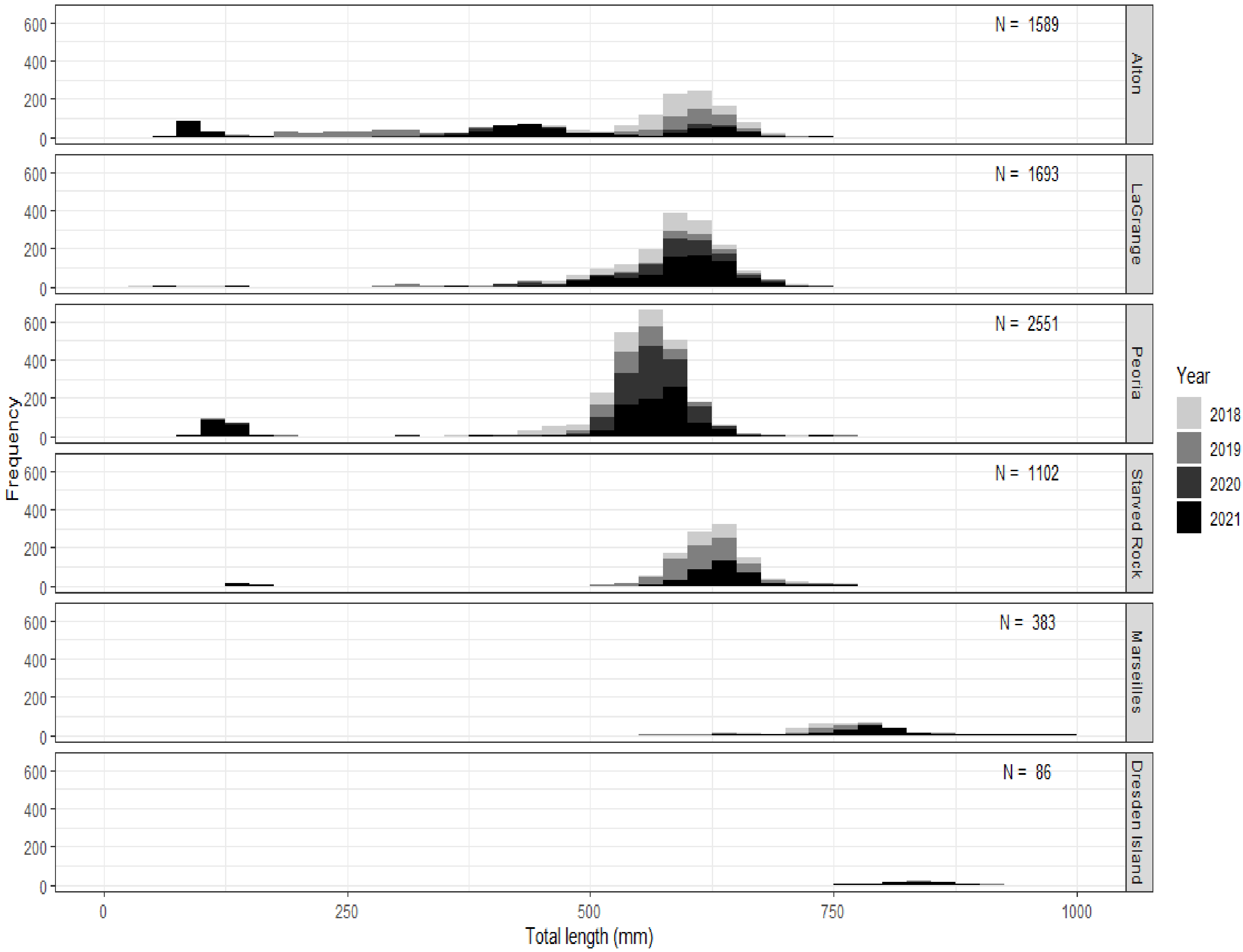

Figure 2. *Pool-specific length-frequency histograms and total catch (N) of Silver Carp sampled from 2018 – 2021. All fish were sampled using electrified dozer trawl during fall 2018 – 2021, except for additional samples in Marseilles (N=168) and Dresden Island (N=86) fish, which were collected using commercial gill nets.*

Condition: We examined variation in fish condition (i.e., relative weight) across pools and among sampling years using a standard weight equation for Silver Carp (Lamer 2015). Relative weight is calculated by dividing individual fish weight by the standard weight of fish of the same length. Relative weight standards are often generated using a 75th regression line percentile approach (Murphy et al. 1991), however, the Silver Carp relative weight equation was developed using a 50th percentile approach (Wege and Anderson 1978, Lamer 2015), which defines a relative weight of 1 as an average condition fish. We expected that fish from pools that receive high commercial fishing pressure would be in greater condition than fish from pools that receive relatively low commercial fishing pressure, due to density-dependent effects on resource availability. Patterns in relative weight were consistent with expectations, as upper pooled displayed slightly above average condition and lower pools displayed slightly below average condition. Relative weight averaged 0.98 in pools below Starved Rock L&D and 1.02 in pools above Starved Rock L&D (Figure 3). Relative weight did not vary substantially among sampling years for any given pool.

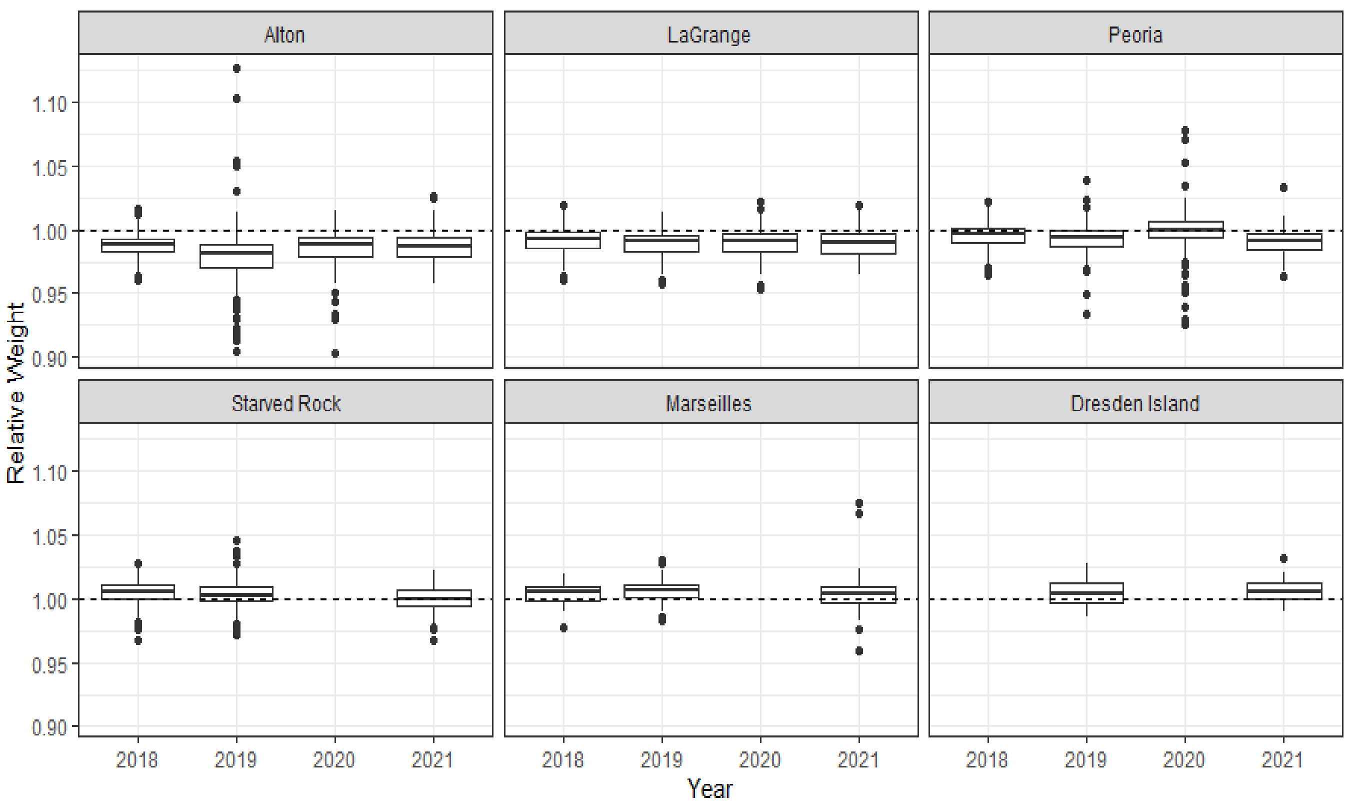

Figure 3. *Boxplots of individual Silver Carp relative weight data by pool and sampling year. All fish were sampled using electrified dozer trawl during fall 2018 – 2021, except for additional 2021 samples in Marseilles (N=168) and 2019 and 2021 samples in Dresden Island (N=19, N=64) fish, which were collected using commercial gill nets.*

Sex ratios: Sex of individual fish was determined during spring and fall sampling efforts. The goal of these data collections were to provide baseline sex ratio data across pools and to provide 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 higher in upper pools that receive intensive contract commercial harvest pressure (i.e., Starved Rock, Marseilles, and Dresden Island pools) in relation to lower pools that did not (i.e., Alton, LaGrange, and Peoria pools). With exception to Marseilles Pool, 2019 results from this project, results were generally consistent with our prediction (Figure 4). Proportion male was higher in pools upstream of Starved Rock L&D relative to downstream pools. Due to COVID-19 sampling restrictions, 2020 comparisons between pools upstream and downstream of Starved Rock L&D were not possible. However, increased harvest in Peoria Pool was initiated in 2019 (Project: Enhanced Contract Fishing in Peoria Pool, ICRCC-MWRG 2020) and consistent with our expectation, the proportion male in Peoria pool was higher during 2020 and 2021 relative to 2019 (Figure 4). In 2021, collections were conducted in all pools. Similar to 2019, upper pools with intense commercial harvest efforts exhibited increased male sex ratios in 2021. Lower pools had increased male sex ratios from 2020, but were still lower than that of the upper pools. The proportion male in Alton and La Grange were lower during 2020 relative to 2019 and 2021, which were not considerably different. Although patterns in our data are consistent with expected exploitation effects, other hypotheses for higher male sex ratios in the pools above Starved Rock L&D could be that males are migrating upstream at a higher rate than females, though there is no evidence for sex specific movement patterns (Pretchel et al. 2018). Ongoing commercial fishing in Peoria pool will help indicate if commercial fishing is in fact contributing to skewed sex ratios.

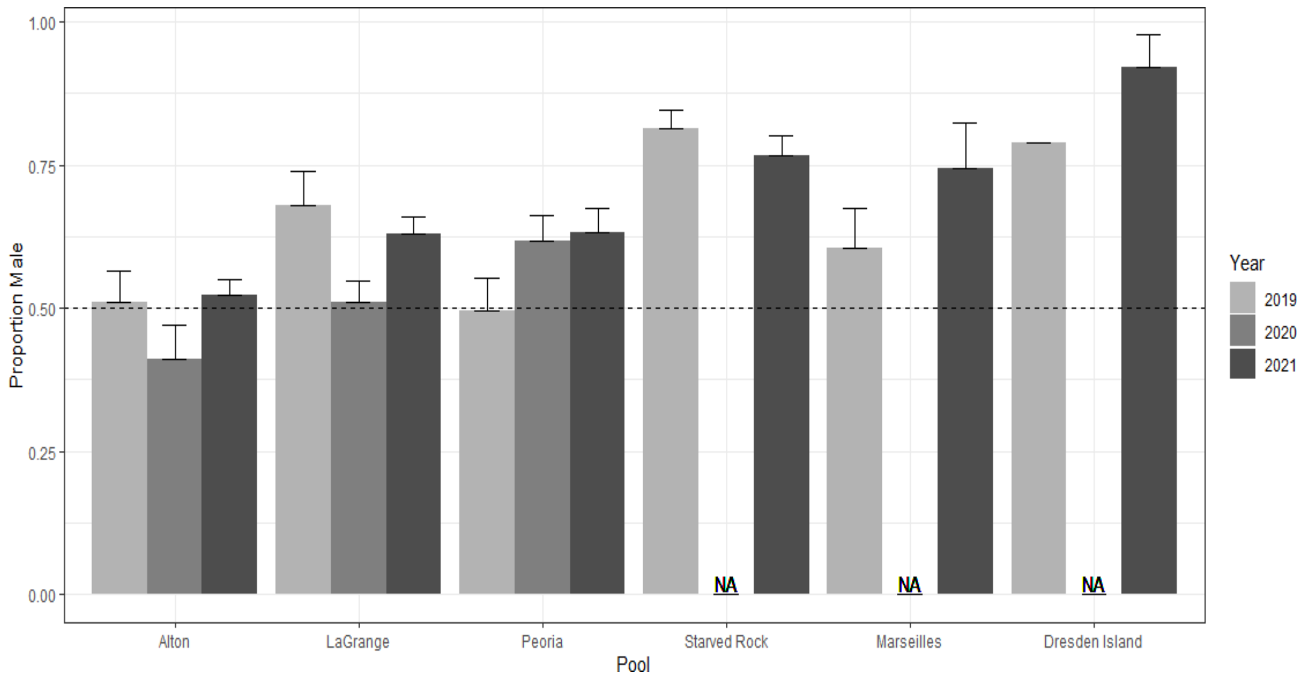

Figure 4. *Pool-specific means and standard errors describing the proportion of Silver Carp males in the total catch. All fish were sampled using electrified dozer trawl during fall 2019 – 2021, except for additional 2021 samples in Marseilles (N=168) and 2019 and 2021 samples in Dresden Island (N=19, N=64) fish, which were collected using commercial gill nets.*

Maturity status: Similar to other length- or age-structured population models, the SEICarP model incorporates a size at maturity relationship and associated uncertainty to estimate recruitment during each annual time step. Maturity status was difficult to assess from 2018 – 2020 due to low numbers of immature Silver Carp captured in spring sampling, and very few nearing maturity.

However, spring 2021 provided numerous immature Silver Carp (N=603) in the lower three pools of the Illinois River (i.e., Alton, LaGrange, and Peoria pools), many of which were nearing maturation, allowing for determination of maturity status via internal examination of the gonads. These samples were conducted in the lower three pools because of the dearth of small Silver Carp captured in the upper three pools from previous samples (see length structure, Figure 2) and the low probability that immature Silver Carp could be captured. Using a logistic regression, we determined length at maturation for female Silver Carp (50% maturity reached at 487mm TL; Figure 5). This data helps provide an accurate size at maturity estimate to the modeling sub- workgroup for invasive carp population models. Proposed 2022 sampling will increase confidence in size at maturity estimates and may help determine any pool specific differences in maturity estimates.

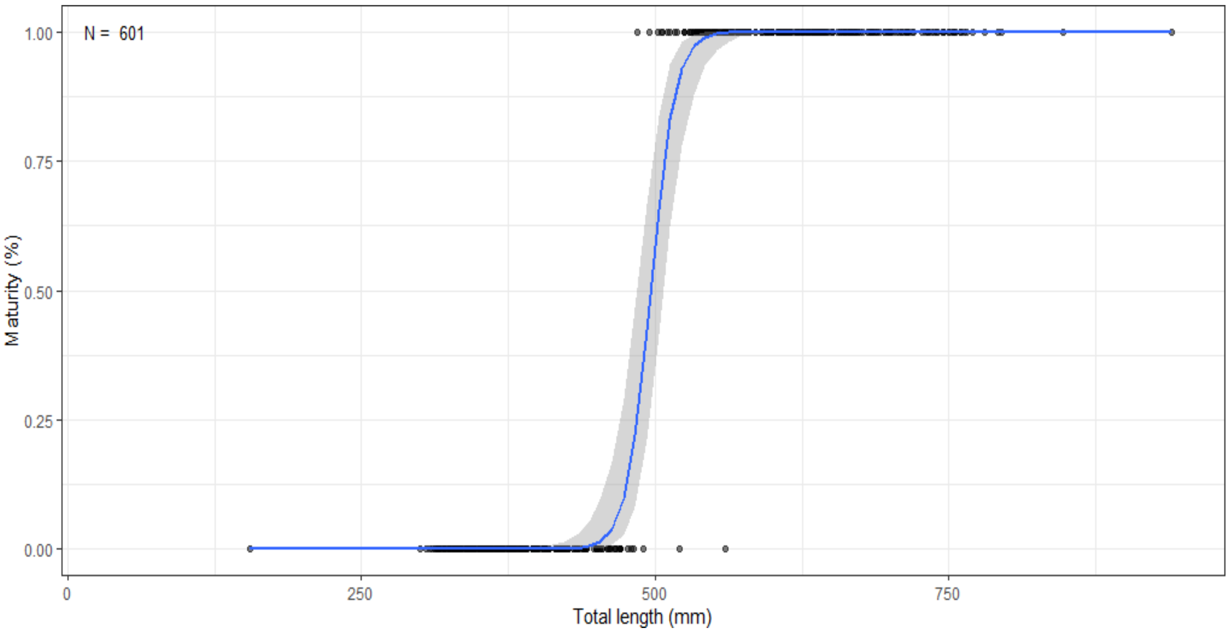

Figure 5. *Estimate of female maturity for Silver Carp captured in spring of 2021 in the Alton, LaGrange, and Peoria pools. The blue line represents percent of females mature at a given length, and grey represents standard error around the estimate.*

Age and Growth: Objective two of our project included working with the Multiple Agency Monitoring of the Illinois River for Decision Making (MAM) project and the Contracted Commercial Fishing Below the Electric Dispersal Barrier project to build a large age structure dataset using lapilli otoliths from fall caught fish. These data are critical for determining population age structure, estimating growth, and parametrizing stock assessment models, such as catch at age models. Since 2018, we have processed hundreds of Silver Carp lapilli otolith samples. Due to high variability in length at age estimates, we decided to shift 2021 age structure collections from a systematic collection (i.e., 10 age estimates per 50 mm length bin) to a completely randomized age structure collection to better represent population age structure, without the need to fit an age-length-key to unaged fish. Specifically, we collected otoliths from the first 200 Silver Carp per pool (collected in a stratified random sampling design) then filled any unfilled length bins (10/50mm) following the first 200 collected. From this effort, 1,118 age samples were collected among all sample pools during 2021. Most age structures were collected via the electrified dozer trawl in Alton, LaGrange, Peoria, and Starved Rock pools. However, Marseilles and Dresden Island pools' age structure is primarily described by commercial gillnet catches that were provided by collaboration with IDNR, INHS and the USFWS Wilmington substation. These data are used to help parameterize estimates for the SEICarP model and for potential statistical catch at age models. Age-frequency histograms provided insights into recruitment patterns and the relationship between age and upstream movement. Although young fish (< age-4) were common in the lower three pools, these age classes were largely unrepresented in the upper pools, with exception to 13 age-0 fish captured in Starved Rock Pool. Age structure of older fish (>age-4) was similar across all pools (Figure 6). These findings suggest Silver Carp move upstream in proportion to year class strength and further the likelihood that upstream movement increases during the third or fourth year of life. In addition, we detected strong year classes in the Alton and LaGrange pools including the strong 2018 cohort, which were age 3 during 2021 (Figure 6). Based on our results, it is possible to see a short-term increase in the number of Silver Carp moving upstream in response to the large number of age-3 fish in the lower pools and the timing (i.e., Age) in which Silver Carp seemingly exhibit upstream movement behavior.

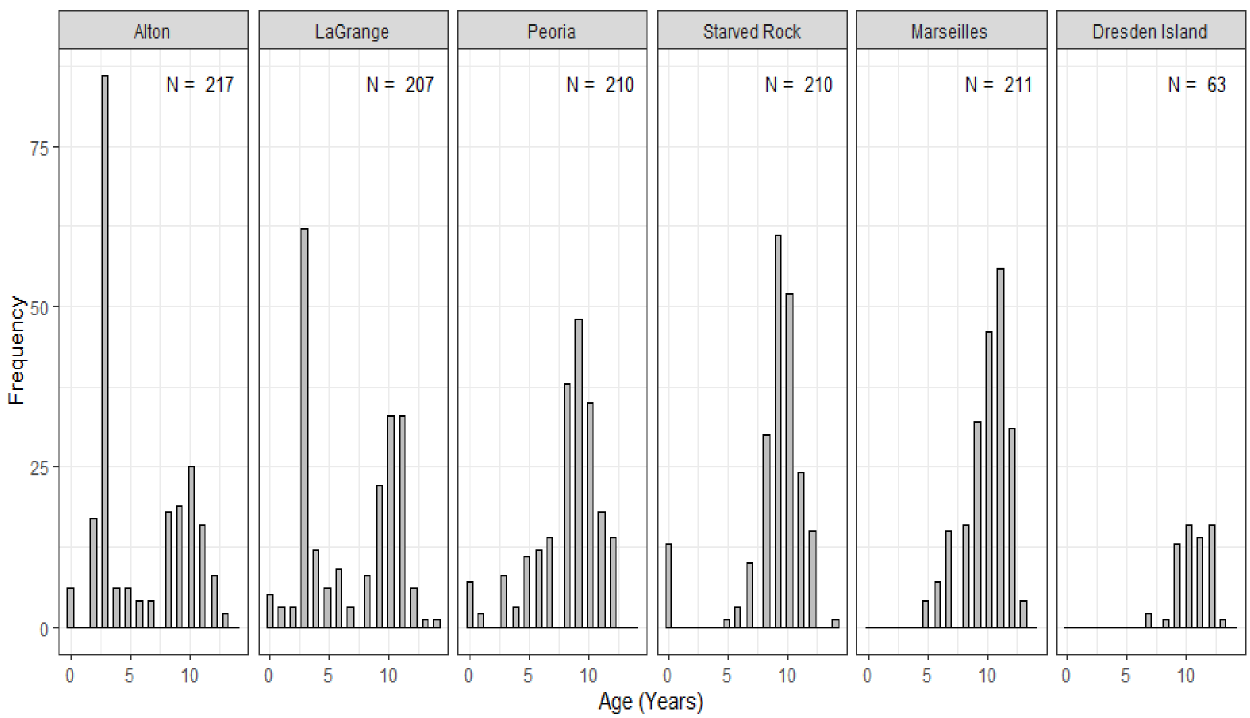

Figure 6. *Pool-specific age frequency data in the lower six pools of the Illinois River. Fish were collected during fall 2021 using the electrified dozer trawl and commercial gill nets in Marseilles (N=168) and Dresden Island (N=63).*

Von Bertalanffy growth models (von Bertalanffy 1938) depict the mean-length at age of Silver Carp between pools (Figure 7). The absence of smaller or younger fish in the upper pools resulted in unreasonable K and t_0 estimates for Marseilles and Dresden Island pools. Von Bertalanffy growth models appeared to show pool specific differences in growth, especially between the upper and lower pools separated by Starved Rock L&D. Theoretical maximum lengths (L_∞) are consistently higher in the upper three pools (i.e., Starved Rock, Marseilles, and Dresden Island pools) relative to the lower three pools (i.e., Alton, LaGrange and Peoria pools) (Figure 7), depicting the likelihood of increased growth potential in the upper three pools.

Growth between pools could be affected by density. Based upon relative abundance metrics (see relative abundance, Figure 1), densities of Silver Carp appear to be highest in the lower three pools in relation to the upper pools. Higher densities could be a driver of the reduced growth potential in the lower pools, as density dependent shifts in fish growth have been documented in other studies (Lorenzen and Ensberg 2002). This conclusion is supported by condition data, which indicated that Silver Carp in the upper pools were in higher condition than Silver Carp captured from the lower pools (see condition, Figure 3). Monitoring growth rates could provide insight to density dependent growth responses to harvest and removal efforts in the future.

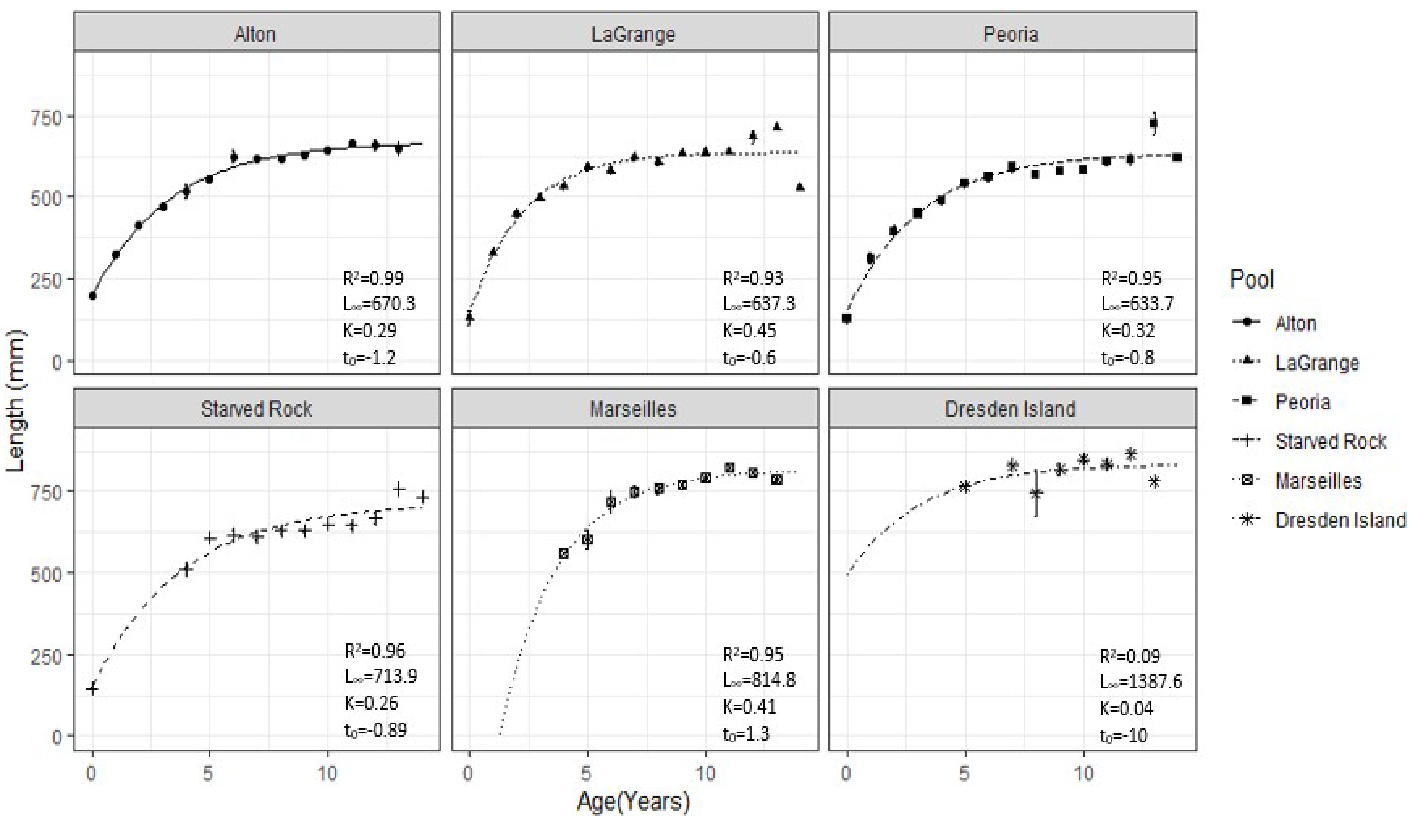

Figure 7. *von Bertalanffy growth models, fit using mean length at age for combined 2018 – 2021 data. Fish were collected during fall 2018 – 2021 using a combination of electrified dozer trawl and commercial gill nets.* L_∞ *is the theoretical maximum length, K is the Brody growth coefficient, and* t_0 *is the theoretical time at length 0.*

Age Structure Validation: Objective three of this project sought to develop recommendations for age structure selection for use in Silver Carp age and growth analyses. Age structure verification is necessary to validate the precision and accuracy of age structures for describing the age and growth of a fish population. Improper age structure selection can bias age and growth estimates, thus biasing demographic estimates and model parameters used for population management (Campana 2001). Although Seibert and Phelps (2013) evaluated the precision of age structures for aging Silver

Carp, no studies have validated the accuracy of an age structure for Silver Carp. Our goal was to use previously collected postcleithra age data and Long Term Resource Monitoring (LTRM) length frequency data from the LaGrange pool of the Illinois River to inform the accuracy of using postcleithra as an age structure for Silver Carp. To accomplish our goal, we assumed that catches of fish aged using postcleithra during 2011 – 2015 were largely dominated by the 2007 and 2008 year classes. This assumption is supported by length frequency data, which showed poor recruitment leading up to and following 2007 and 2008 (Figure 8). Fish collected during 2011 were primarily assigned to the 2007 and 2008 year classes, suggesting postcliethra was an accurate aging structure. However, during subsequent collection years, a large proportion of the population were assigned to year classes which were not represented in the LTRM length frequency data (i.e., 2009 – 2011 year classes; Figure 8). These results suggest that postcleithra underestimate true age of Silver Carp after the first three to four years of life.

We would recommend exercising caution using postcleithra to age Silver Carp. It is noteworthy that these postcleithra were aged via images taken with a dissecting microscope. Further work adapting methods for aging the physical postcleithra structures may help provide more accurate ages for Silver Carp with this structure.

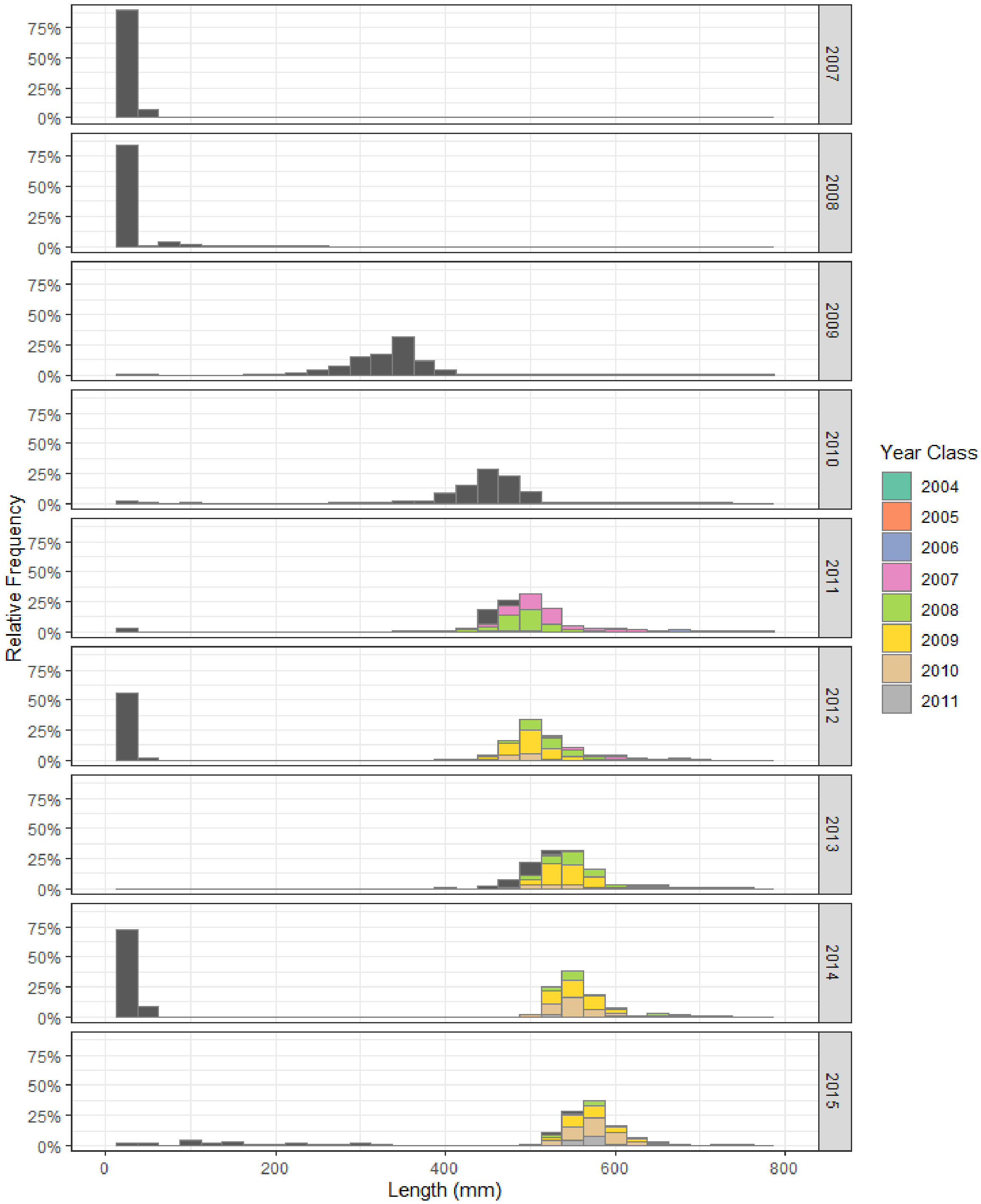

Figure 8. *Silver Carp length frequency histograms from the LaGrange pool of the Illinois River from 2007 – 2015. Black bars represent Silver Carp captured in the Long Term Resource Monitoring Program (LTRM). Color coded data represent postcleithra age data from Silver Carp collected during 2011 – 2015. Colors represent individual year classes between 2004 – 2011.*

Collaboration with MRWG Monitoring sub-workgroup: Objective four of this project included collaboration with the Monitoring sub-workgroup of the MRWG. The MRWG has specific goals to detect, manage and control, and respond to changes in invasive carp populations in the Illinois River. The Invasive Carp Demographics project works collaboratively under the monitoring sub-workgroup with other monitoring and detection projects to help inform management and control of invasive carp. The Invasive Carp Demographics project helps to provide metrics such as pool-specific relative abundance and size distribution that overlap with other management projects such as the MAM. Also, the demographics project helps provide more samples for early detection of small fish that aid other detection projects. Overlap and additions to other monitoring projects helps complement those projects by providing confidence in estimates used to parameterize models. While there are many complementary facets of the Invasive Carp Demographics project, it also provides unique metrics such as maturity, sex ratios, and age data that the modeling workgroup's statistical catch at age models depend on. In 2021, the Invasive Carp Demographics project worked with the MAM, Distribution and Movement of Small Silver and Bighead Carp, and Contracted Commercial Fishing Below the Electric Dispersal Barrier projects to build a comprehensive age data set that resulted in over 1,100 age structures collected that were reported in this document (see age structure, Figures 6&7). All project data has been shared with USGS to be incorporated into the MRWG data repository to be used in analyses by MRWG sub-workgroups. Continued collaboration with other projects will help ensure the best information being provided for invasive carp management, control, and decision making.

Informing Hydroacoustics: Objective five was a continued effort from the 2020 MRP. This objective sought to understand how including electrified dozer trawl sampling benefited multiple-gear sampling approaches (e.g., LTRM, MAM) in the Illinois River, and the tools, such as hydroacoustics Silver Carp density estimates that utilize multiple-gear data sets. To accomplish our objective, relativized (i.e., log(CPUE+1)) genus-specific catch data from the LaGrange pool between 2018 – 2021 LTRM and Invasive Carp Demographics sampling was compiled in a non-metric multidimensional scaling (NMDS) ordination analysis. Results from these analyses revealed high associations of individual fish genera to specific sampling gears (three dimensional stress=0.12, R^2=0.69; Figure 9). Electrified dozer trawl samples, which were implemented in main channel border, island backchannel, and backwater habitat types were strongly associated with pelagic species, including *Hypophthalmicthys*, *Dorosoma*, and *Alosa*.

Our findings suggest including dozer trawl sampling would benefit multiple-gear sampling efforts by providing a better representation of pelagic fish species. Incorporating electrified dozer trawl sampling could also have important implications for tools that rely on multiple-gear fish community data sets. For example, the accuracy of hydroacoustics Silver Carp estimates, which utilize multiple-gear fish community data to apportion hydroacoustics fish targets by species, could possibly benefit with improved pelagic fish community data.

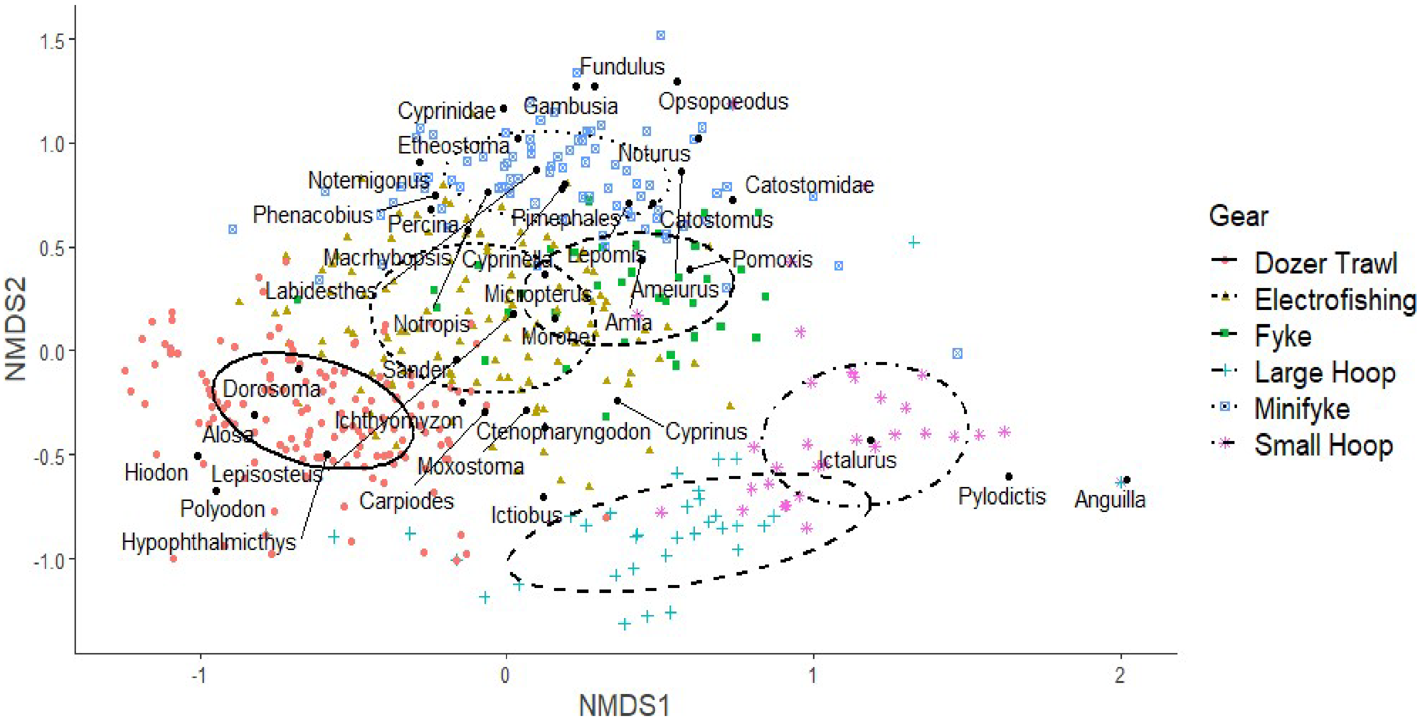

Figure 9. *Non-metric multidimensional scaling (NMDS) for genus-specific catch rates by gear deployment. Individual gear deployments are plotted with 50% confidence ellipses around individual gears. Three dimensional stress=0.12, R^2=0.69.*

Recommendations:

Biological systems are inherently complex and respond unpredictably (Coulter et al. 2018). Collections of high quality demographic data enable managers to understand population responses to harvest and provide tools to inform management and control efforts. Herein, we described results from four years of fisheries-independent biological collections and available fisheries-dependent collections. We recommend continued monitoring through fisheries- independent sampling to inform demographic rates (i.e., length, weight, sex, age, and relative abundance) of Silver Carp in the Illinois River. Demographic rates provide important information to evaluate Silver Carp effects on native species, trigger response actions (e.g., Contingency plan), evaluate control efforts, and explore alternative management and harvest scenarios using model-based tools. We recommend continued coordination with MRWG workgroups to address monitoring objectives, increase efficient demographic data collections, and provide high quality data to support ICRCC and MRWG needs. We also recommend caution when choosing age structures for age and growth estimates of Silver Carp, based on evidence for postcleithra underestimating true age (Figure 8). Given that the electrified dozer trawl captures more Silver Carp per unit time than conventional boat electrofishing (Hammen et al. 2019), and that it enhances the capture of pelagic fishes in relation to other gears (Figure 9), we recommend including standardized electrified dozer trawl data in multiple-gear sampling efforts (e.g., MAM) and analyses, such as hydroacoustics Silver Carp density estimates, that rely on multiple-gear data sets.

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Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation

Charles A. Wainright and Nathan T. Evans (USFWS Carterville FWCO, Wilmington Substation)

Participating Agencies: USFWS Carterville FWCO – Wilmington, IL Substation

Pools Involved: Peoria and Alton

Introduction and Need

This project is a continuation of previous studies that investigated small fish entrainment, retainment, and upstream transport by commercial barge tows. The USFWS and partner agencies USACE and USGS have conducted several years of barge entrainment studies that demonstrate small fish can become entrained and retained in the box-to-rake junction of commercial tows (e.g., Davis et al., 2016). These previous studies illustrate the need for mitigation technologies capable of removing entrained small fish and, therefore, reducing the risk of upstream transport in the IWW.

In 2020-2021, the USACE ERDC facility in Vicksburg, Mississippi utilized a 1:16 scale physical model of Peoria Lock with remote control tow and barges to evaluate the interaction between barges, fluid motions, and nearly neutral buoyant objects under a variety of vessel speeds and barge configurations typical of a navigation lock. The goal of this effort was to evaluate the effectiveness of several potential bubble array configurations at removing small fish entrained in the rake-to-box junction gap of the model barge tow. Results from these experiments indicated that longitudinal bubbler arrays were the most effective of the configurations tested, with greater than 80% effectiveness at flushing particles from rake-to-box junction. However, it is unknown how these scaled-laboratory trial results will translate to full-sized barges with live fish.

In 2022, USFWS, USACE, and USGS plan to carry out a full-scale barge study to test the efficacy of a longitudinal bubble array at mitigating retainment and transport of invasive carp by commercial barge tows. Conducting this test requires at least 18,000 juvenile invasive carp between 40- and 60-mm total length (TL). It is not feasible to obtain this quantity of appropriately sized carp via direct field capture at the time of the study because juvenile carp are elusive. Therefore, invasive carp for the experimental trials will be collected in Peoria, LaGrange, and/or Alton Pools as post-larva (<10 mm TL) and “grown out” in the NGRREC’s and SIU’s fish raceways to 40-60 mm TL. Once grown-out, the captive-raised carp will be used for longitudinal bubbler array field testing in September 2022. The field testing will evaluate the efficacy of the longitudinal bubble array at clearing carp from barge junction gaps, which will inform the design of the automatic barge clearing (ABC) deterrent at Brandon Road Lock and Dam and, potentially, other locations in the Illinois Waterway.

Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation

Objectives:

This study's goal was to determine best practices for rearing captive invasive carp and measure captive invasive carp growth rate and mortality. Study objectives were:

(1) Capture approximately 20,000 post-larva (<10 mm TL) invasive carp in Alton, LaGrange, and/or Peoria Pools and transport them to NGRREC with minimal mortality.

(2) Grow the invasive carp in captivity until the fishes were approximately 40-60 mm TL.

(3) Track growth and mortality throughout the duration of the study.

(4) Use data captive-carp growth data and historical carp-detection records to predict when captive invasive carp will be available for the Barge Study field trials in 2022.

Project Highlights:

In this experimental invasive carp aquaculture pilot study, USFWS raised 1,190 invasive carp (Silver Carp, *Hypophthalmichthys molitrix*; Bighead Carp, *H. nobilis*; Grass Carp, *Ctenopharyngodon idella*) at the NGRREC in Alton, Illinois from <10 mm to 43 mm total length (TL; mean) with a mortality rate of ~90%. Results of this study were combined with historical data to estimate that captive reared carp will be available for Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation (i.e., "the Barge Study") on August 30, 2022. USFWS has contracted additional raceway space at NGRREC and partnered with SIU to produce more invasive carp for the Barge Study in 2022.

Methods:

COVID-19 statement

USFWS limited field crews to two or fewer people to prioritize staff safety during the COVID-19 pandemic. This crew-size limitation restricted carp collection and travel in 2021.

Collecting carp

About 20,000 post-larval (<10 mm TL) fish were collected on July 19-20 and July 26-27, 2021. Post-larval fish were collected with handheld dip nets from Cooper South Park (Peoria Pool; Peoria, IL; 40.695831, -89.544753), Detweiler Marina (Peoria Pool; Peoria, IL; 40.700902, -89.570982), and Marquette State Park Marina (Alton Pool; Quarry Township, IL; 38.973237, -90.545591). Post-larval invasive carp were collected from marinas because these fish prefer low-flow habitat (Koel et al., 2000) and collecting carp near a boat ramp minimized fish mortality from transporting the fish to NGRREC.

Transporting and rearing carp

Collected post-larval fish were transported in an oxygen-aerated 200-gallon water tank to NGRREC. At NGRREC, fish were acclimated by pumping ~100 gallons of water per hour from the raceway into the holding tank. Fish were deemed acclimated when the transfer tank and raceway dissolved oxygen and water temperature matched. Next, fish were removed from the transfer tank and placed into mesh live cars that were suspended in the outdoor fish raceways. Live cars minimized fish escapees while allowing raceway water to reach captive fish. Raceways were configured as flow-through systems and charged with fresh Mississippi River water. No fish feed (e.g., *Artemia nauplii* or Otohime) was added to the raceways and captive carp presumably ate plankton from Mississippi River water. Livecars were gently scrubbed free of biofilm each week and floating periphyton clumps were removed from surface of the raceway water.

Data collection

Carp mortalities were enumerated weekly while live cars were cleaned.

One fifty-carp sample was dip-netted from the raceway on 20 Aug 2021, 31 Aug 2021, and 17 Sep 2021. Total length was recorded for each carp in these samples. If sampled carp survived length measurement, they were returned to the raceway. If the length measurement caused mortality, carp mortalities were enumerated. The study concluded on 29 and 30 Sep 2021 at which time all remaining captive invasive carp were measured and then euthanized.

A YSI ProQuatro was used to measure raceway dissolved oxygen and water temperature weekly.

Data analyses

All analyses were completed in RStudio version 1.4.1106 (RStudio Team, 2021) running R version 4.1.2 (R Core Team, 2021). Plots were made with R package ‘ggplot2’ version 3.3.5 (Wickham, 2016). Multi-panel plots were arranged with ‘cowplot’ version 1.1.1 (Wilke, 2020). Simple linear regression was analyzed with the lm() function in base-R (R Core Team, 2021). Bootstrap analyses were completed by iteratively re-sampling (10,000 Monte Carlo samples) historical invasive carp larvae detection data (courtesy of Illinois Natural History Survey; INHS) with the slice_sample() function from ‘dplyr’ version 1.0.7 (Wickham et al., 2021). Data summaries were generated using summarize() from ‘dplyr’.

Data availability

Data generated in and used in this study and an annotated R script for this study’s analyses are available upon request.

Results

Carp grew from a total length of less than 10 mm on their first day at NGRREC (i.e., day 0) to a mean total length of 40 mm on their 60th day at NGRREC (Figure 1). Predicted carp mean total length remained within the Barge Study’s total length range (40-60 mm TL) for days 60-90 (Figure 1). Simple linear regression predicted that carp would exceed 60 mm mean TL after day 90 (Figure 1).

1190 invasive carp remained after 64 days in the raceway, with most of these carp being Grass Carp or Silver Carp (Table 1). The mean total length of the remaining 1190 carp was 43.3 mm (sd = 10.6 mm) and the median total length was 43 mm (Figure 2). After 64 days in the raceway, 370 of 1190 carp (~31%) were below the Barge Study's 40 mm carp-length minimum and 55 of 1190 carp (~5%) were above the Barge Study's 60 mm carp-length maximum.

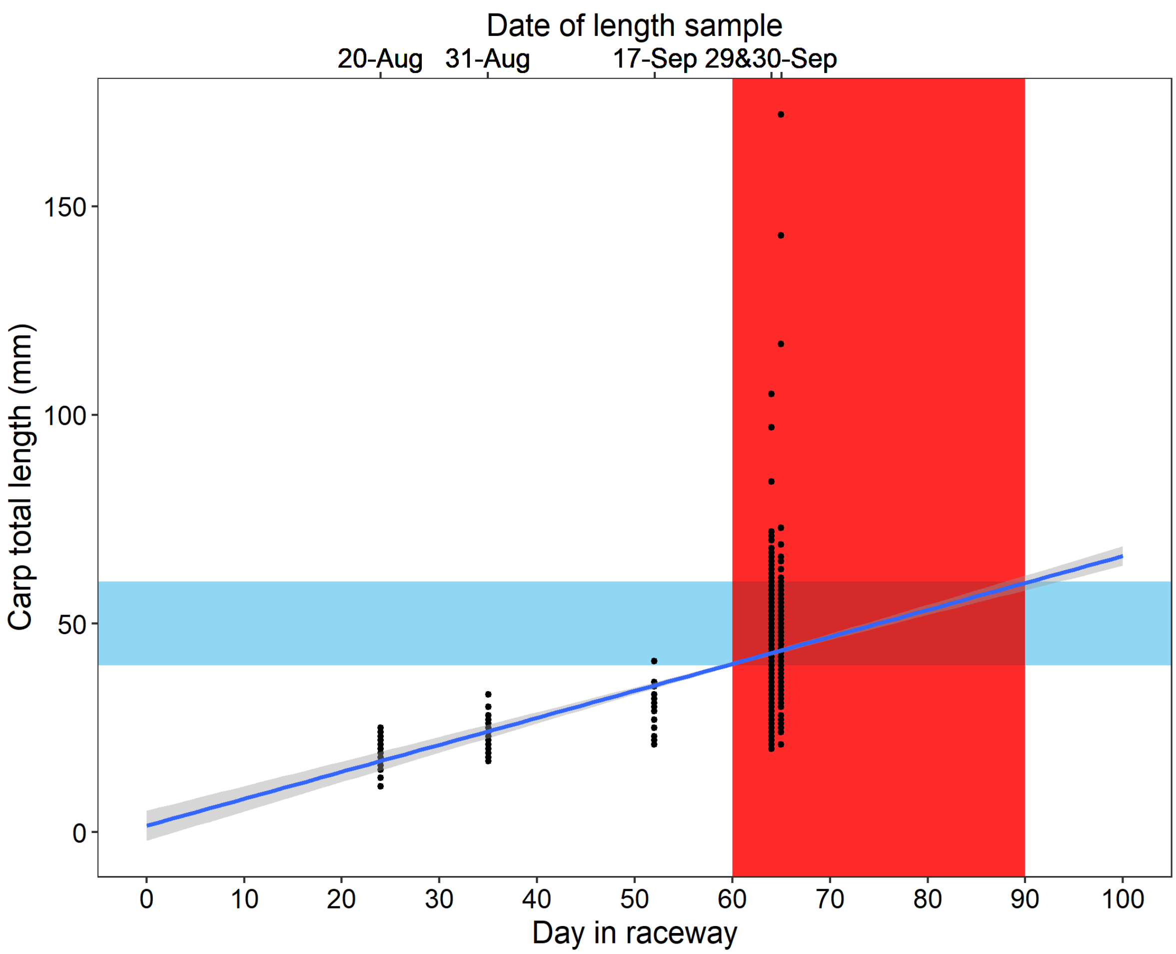

Figure 1. *Time-series and simple linear regression of captive invasive carp total length from NGRREC in 2021. Points are the length of individual carp which were measured during one of the length samples (top-horizontal axis). Predicted mean carp total length is indicated with a solid blue line and the 95% confidence interval around that mean is indicated as a gray bar around the line for each day that carp were captive in the raceway (bottom-horizontal axis). The barge study's target size range (40-60 mm) is indicated as a horizontal blue bar. The time during which captive carp mean total length is expected to be within the barge study's target size range is indicated as a vertical red bar.*

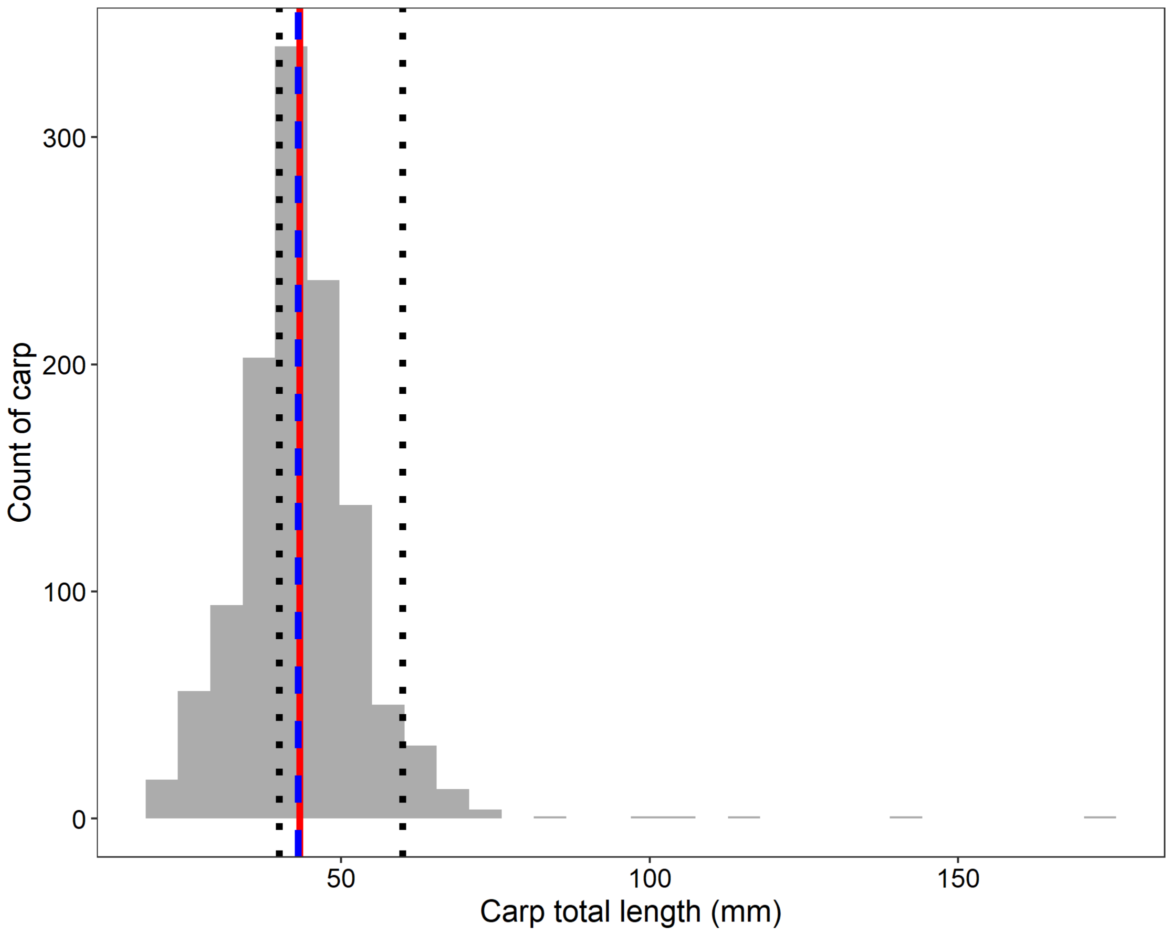

Figure 2. *Total length frequency distribution for the final 1190 captive invasive carp at NGRREC on 29 and 30 September 2021. Mean carp total length is indicated as a dashed blue vertical line. Median carp total length is indicated as a solid red vertical line. The Barge Study's target size range (40-60 mm) is indicated as a pair of dotted black vertical lines*.

Table 1. *Species composition of captive carp at NGRREC on 29 and 30 September 2021.*

Species	Number of Individuals
Grass Carp	594
Silver Carp	518
Bighead Carp	78
Total Invasive Carp	*1190*

Invasive carp eggs and larvae can usually be detected in the lower IWW (i.e., LaGrange and Alton pools) by mid-June (Figure 3). Historical data showed that invasive carp eggs were detected in the lower IWW by June 22 (mean; median = June 18; Figure 3a) and larval invasive carp were detected about a week later (mean = June 28; median = June 25; Figure 3b).

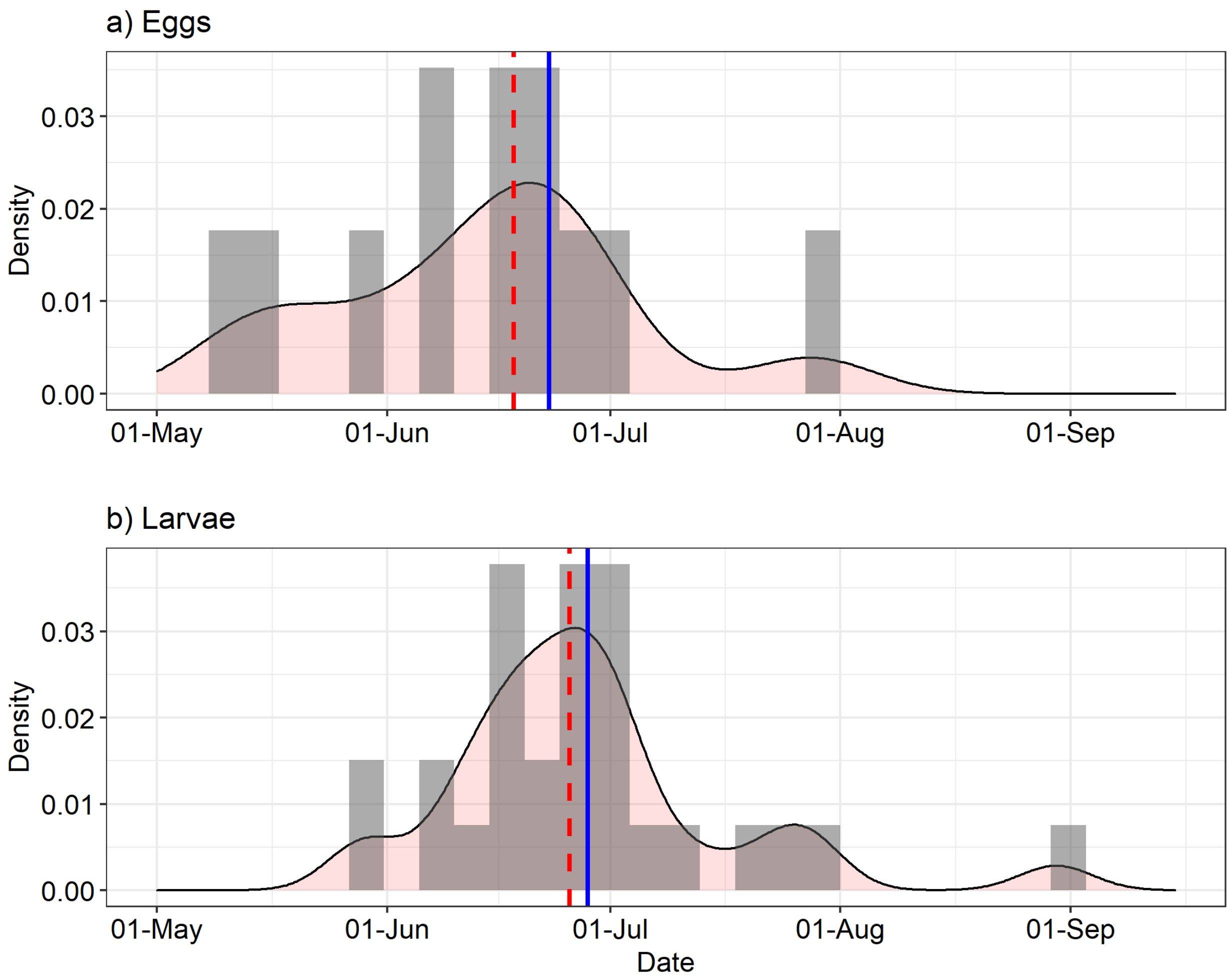

Figure 3. *Time series of invasive carp (a) larvae and (b) egg detections in the lower IWW. Data are from 2010-2021 and courtesy of Illinois Natural History Survey (INHS). In each panel, the mean date of detection is indicated by a solid blue vertical line and the median date of detection is indicated by a dashed red vertical line.*

Bootstrap analyses estimated that captive carp will be ready for the Barge Study on 30 Aug 2022 (Figure 4). This estimate is based on an estimated 60 days to grow captive carp from <10 mm to ≥40 mm TL (Figure 1), plus a five-day grace period, and the historical average of when larval carp are captured in the lower IWW (June 28; mean; Figure 3). The 95% confidence interval around this mean estimate was 24 Aug to 7 Sep 2022.

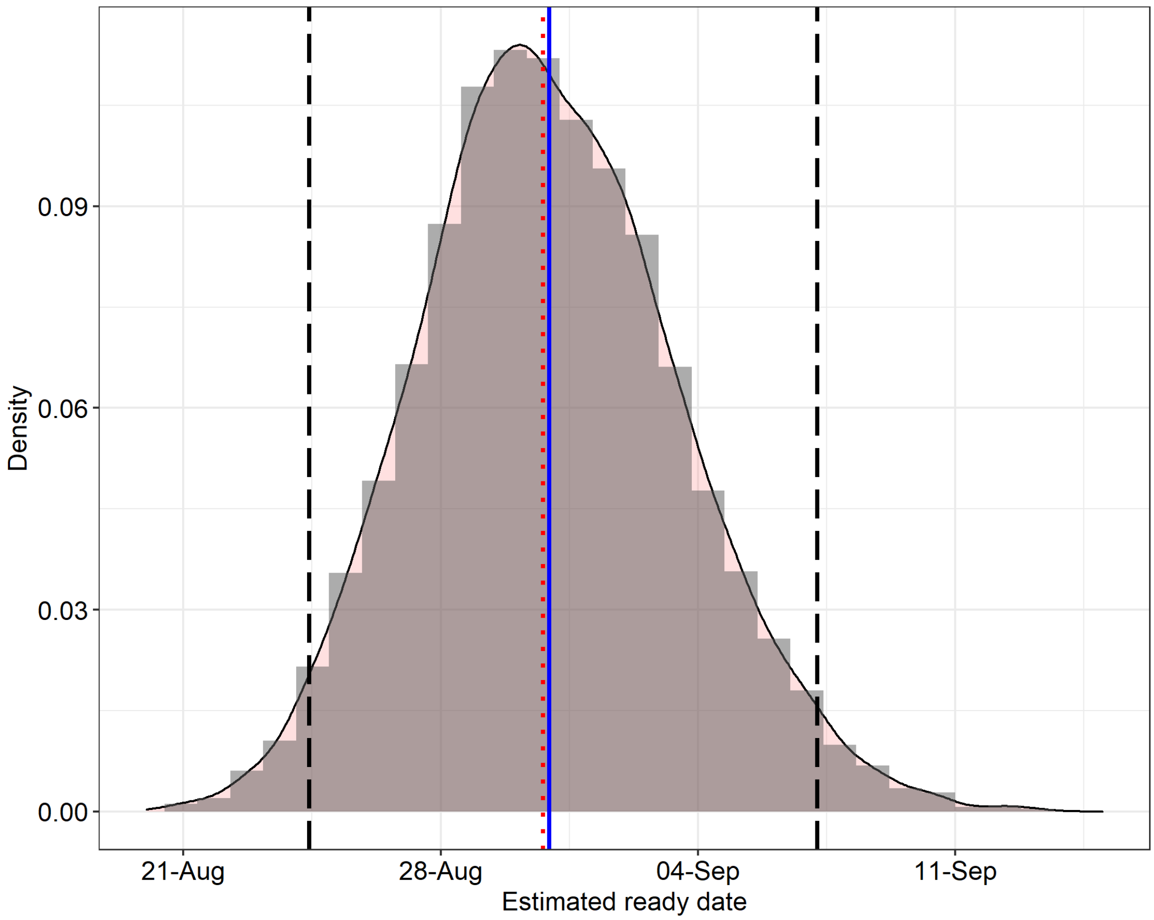

Figure 4. *Distribution of bootstrap estimates of when captive carp will be ready for the Barge Study in 2022. The median estimated ready date is indicated as a red vertical dotted line. The mean estimated ready date is indicated as a blue solid vertical line. The 95% confidence intervals around the mean estimated ready date is indicated as a pair of black vertical dashed lines. N = 10,000 bootstrap estimates.*

Results and Discussion

All four of this study's objectives were completed in 2021. About 20,000 post-larva (<10 mm TL) invasive carp were captured and transported to NGRREC with minimal mortality. Invasive carp were grown in captivity to 40-60 mm TL and their growth rate and mortality were tracked. Captive-carp growth data and historical carp-detection records were used to predict when captive invasive carp will be available for the Barge Study in 2022.

An estimated 90% of the invasive carp captured for this study in 2021 died before the end of the study. However, it was impossible to accurately quantify mortality in this study for two main reasons. First, the precise number of carp with which the study started was unknown. Previous [unpublished USFWS] data showed that post-larval carp were extremely fragile. Thus, post-larval carp collected for this study were not enumerated because doing so would have killed them. Second, few (282; SI Table 1) mortalities were recovered from the raceway, leaving many missing carp. Missing carp may have decomposed before staff could enumerate them or escaped the raceway. It is unlikely that captive carp escaped the raceway because no water was added to nor drained from the raceway for most of the study. Despite significant uncertainty around the mortality rate for carp in this study, it was apparent that the study ended with fewer invasive carp than it began with so additional precautions will be taken in 2022.

The pace at which captive carp grew (~0.6 mm per day; the slope of the line in Figure 1) should be ideal for the 2022 Barge Study. The 2022 Barge Study is scheduled to take place over four weeks, or 28 days. Since linear regression estimated that captive carp will average 40-60 mm for 30 days, rearing carp under the conditions provided by NGRREC will provide right-sized carp for the duration of the 2022 Barge Study. Since water temperature and food availability affect invasive carp growth rates (Cooke & Hill, 2010), these variables could be modulated to achieve desired captive carp growth rates in 2022.

Captive carp should be available for experimental field testing of longitudinal bubbler array by the end of August 2022. This estimate comes from a combination of the estimated lead-time required to grow carp at NGRREC and bootstrap predictions of when larval invasive carp will be available for capture in the lower IWW. If captive carp were to grow at a different rate in 2022 or if the 2022 invasive carp spawn were to occur earlier or later than average, the real timeline for captive carp production would not match this estimate. Despite the uncertainty inherent in predicting the future, this ready-date estimation may be used by collaborators to plan for 2022.

Recommendations:

USFWS recommends scaling-up invasive carp aquaculture for Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation in 2022.

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Supplemental Information

SI Table 1. *Raceway water parameters and invasive carp mortalities from 2021 Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation.*

Date	Water temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µS/cm)	Invasive carp mortalities
26 Jul 2021	28.9	8.27	NA	144
27 Jul 2021	28	6.24	NA	0
20 Aug 2021	26	6.48	368.4	84
30 Aug 2021	28.6	7.63	356.6	3
31 Aug 2021	26.6	5.56	365.5	0
8 Sep 2021	24.2	6.96	350.2	51
17 Sep 2021	22.7	6.78	353.5	0
29 Sep 2021	22.2	8.51	337	0
			Total mortalities	**282**

Alternate Pathway Surveillance in Illinois - Law Enforcement

Brandon Fehrenbacher (ILDNR)

Participating Agencies: ILDNR (lead)

Introduction and Need:

The ILDNR ISU developed in 2012 is a specialized law enforcement component to the ICRCC. Illegal activities within the commercial fishing, aquaculture, transportation, bait, pet, aquarium, live fish market, and sport fishing industries increase the risk of invasive carp or other species getting introduced and established into new areas. ISU dedicates its time and resources searching for and apprehending individuals or businesses that violate environmental rules and regulations. These concentrated efforts produce substantial results on an annual basis, verifying human activities are a credible risk for invasive species expansion. It is essential to designate personnel to specialized assignments such as the Invasive Species Unit. This ensures adequate training, experience, and time will be allocated to specific areas of concern. It creates a liaison for non-law enforcement divisions within an agency and outside agencies to contact with invasive species law enforcement related issues. Questions or complaints from the public requiring law enforcement assistance regarding invasive species can be immediately addressed. Additionally, ISU enables a multi-jurisdictional approach to the long-term protection of the Great Lakes Basin by increasing communication and enforcement efforts amongst law enforcement personnel and other stake holders.

Objectives:

(1) Provide training to Conservation Police Officers on specialized aquatic invasive species enforcement techniques, so concentrated efforts can be maximized across a larger geographical area.

(2) Conduct a minimum of 20 inspections on businesses linked to the invasive carp trade where the highest likelihood for regulatory violations has been identified.

(3) Organize and implement a minimum of 10 fish truck transportation inspection details to ensure legal compliance and gain intelligence on current market trends.

(4) Respond to any requests, complaints, events, or suspicious activities that have a potential to threaten the invasive carp program.

(5) Coordinate enforcement objectives developed by the Great Lakes Law Enforcement Committee to advance and remedy multi-jurisdictional, invasive species issues.

Project Highlights:

- ISU successfully investigated two separate merit release incidents where live aquatic species were illegally dumped into Illinois waterways. The individuals responsible were located and criminally charged. The markets selling the aquatic life were brought into compliance with regulations and the wholesale distributors of the products were identified. The species included: red swamp crayfish, tilapia, frogs, Asian swamp eels, American eels, goldfish, and soft-shelled turtles.

- ISU apprehended an Indiana fish hauler who illegally imported and stocked channel catfish into Illinois waters during three separate occasions. The fish hauler was not licensed to sell aquatic life in Illinois and knowingly imported the untested fish without VHS importation permits to increase his profit margins. The investigation revealed the fish were purchased from fish farms that raised fish for food purposes only. Other species of fish such as bluegill and shad were mixed in with some the fish deliveries.

Methods:

ISU generated enforcement activity based upon surveillance operations, on-site facility inspections, fish truck enforcement details, record and permit audits, Internet monitoring, public complaints, and inner and outer agency leads.

Results and Discussion:

- ISU provided aquatic invasive species enforcement training and techniques to 20 Conservation Police Officers and completed a 40-hour instructor development course to improve the current training curriculum and teaching methods. AIS training provides officers with the knowledge and confidence to enforce AIS regulations which expands the Office of Law Enforcement's capabilities. Trained officers are recognizing the value in AIS enforcement and dedicating more resources towards it.
- Commercial inspections did not detect any illegal activities associated with invasive carp. However, the inspections identified the illegal importation of live non-approved species being imported and sold in Illinois and resulted in the seizure of live red swamp and rusty crayfish on several occasions. Additionally, an illegal shipment of live injurious species was detected and intercepted prior to being imported into Illinois to be sold in the food industry.
- Fish truck inspection details did not detect any illegal shipments of invasive carp but strengthened communications and relationships with industry stakeholders. The inspections provided an opportunity for the legal fish haulers to provide any complaints or concerns of suspicious activity. One of those encounters led to the arrest of an out-of-state fish hauler who was brining illegal fish shipments into Illinois.
- ISU responded to reports of zebra and quagga mussels being inadvertently sold in the aquarium industry as aquatic hitchhikers on other aquarium products. ISU inspected store locations and collected evidence and information to assist with mitigating the impact of the incident. ISU participated in a multi-jurisdiction surveillance operation throughout 2021 as part of an investigation into the illegal transportation, sale, and possession of live injurious species within the pet trade.
- The LAW Committee objective of expanding AIS enforcement efforts to include two species from the AIS Least Wanted List, the yabby and marbled crayfish, was accomplished. ISU documented the notification of regulations and agency contact information to distributors in an official law enforcement report and participated in the targeting of non-compliant offenders.

Recommendations:

Encourage continued cooperation and communications with State and Federal partners to manage invasive species safely and effectively.

Invasive Carp Enhanced Contract Removal Program

Participating Agencies: ILDNR (lead); USEPA and GLFC (project support).

Pools Involved: Peoria Pool

Introduction and Need:

The ICRCC and the MRWG recognize the value of increased harvest of invasive carp in the Illinois River informed by current fishery stock assessment data. Modeling efforts 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 invasive carp per year from the IWW below Starved Rock Lock and Dam.

(2) Removal under the Enhanced Contract Fishing Program for 2020/2021 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 invasive carp.

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

Project Highlights:

- Removed more than 3,300,000 pounds this program from the Peoria Pool of the Illinois River in 2021.
- Removed more than 6,725,000 pounds under this program from the Peoria Pool of the Illinois River since its inception in 2019.
- Entered into thirty-one contracts with Illinois-licensed commercial fishers targeting the Peoria Pool.
- Processed more than $332,000 in payments to fisherman.
- Preparation toward a launch event is well under way and is expected in 2022.

RESPONSE PROJECTS

Upper Illinois Waterway Contingency Response Plan

Participating Agencies: ILDNR, USFWS, USACE, USGS, INHS, USEPA, GLFC, MWRDGC

Introduction and Need:

This CRP describes specific actions within the five navigation pools of the Upper IWW - Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock pools (Figure 1) (River Miles [RM] 231 to 327). In the event a change is detected in the status of invasive carp in those pools, indicating an increase in risk level, this plan will be implemented to carry out response actions. The interagency MRWG has maintained a robust and comprehensive invasive carp monitoring program in the CRP area and will continue these efforts as the foundation for early detection capability in the IWW. Annual ISRs describing these efforts (including extent of monitoring and invasive carp detection probabilities) can be found at www.invasivecarp.us. Based on this experience, the MRWG is confident in its ability to detect changes to invasive carp status in the navigation pools in the upper IWW.

The MRWG and ICRCC member agencies acknowledge that any actions recommended by the MRWG or ICRCC would be considered for implementation by member agencies in a manner consistent with their authorities, policies, and available resources, and subject to the decision-making processes of that particular member agency. Nothing in this plan is meant to supplement or supersede the authorities of the state or federal agencies regarding their particular jurisdictions. For instance, no other state has authority to direct or approve actions affecting the IWW aquatic resources other than the state of Illinois (Illinois Wildlife and Natural Resource Law [515 ILCS 5/1-150; from Ch. 56, par. 1-150]).

Purpose:

The purpose of this CRP is to outline the process and procedures the MRWG and ICRCC member agencies will follow in response to the change in invasive carp conditions in any given pool of the upper IWW.

Communication:

Communicating captures of various invasive carp life stages is a critical component of the CRP. While it is recognized that several monitoring strategies require in-depth analysis in both the field and laboratory setting, it is critical that potential changes are immediately forwarded to the MRWG Co-Chairs. Quick and efficient communication allows for appropriate dissemination and rapid implementation of a response action if needed. Not only should new occurrences of invasive carp of any life stage be communicated to the Co-Chairs, but potential population changes in areas where invasive carp are known, as well as rare occurrences of specific life stages within the Upper Illinois River should be reported. It is equally important to recognize and establish a baseline of understanding as to where all life stages of invasive carp and their life stages have been captured, but it is important to prevent that from convoluting what information needs to be communicated to the Co-Chairs. For example, while invasive carp less than 6 inches have been captured in Starved Rock Pool, no invasive carp less than 6 inches have been captured in the pool since2015. Even though those fish were captured previously, it is a rare occurrence and any additional capture of fish less than 6 inches should be reported. In general, it is best to be conservative in the information communicated to the MRWG Co-Chairs and if you are not sure, send the data to the Co-Chairs for consideration.

Outside of communicating captures and changes to invasive carp populations, it is also important to note the capture of other uncommon invasive species to the ILDNR. The MRWG has a robust monitoring plan and it is possible that MRWG partner agencies may come across other invasive species that may pose a threat to aquatic resources in the region. If a novel or uncommon introduced species is captured during the MRWG monitoring activities, please report those findings to IDNR immediately, so they can make a risk-based decision about the need for additional actions outside of the CRP and MRWG MRP.

Background:

Existing plans for responding to the collection of invasive carps or changing barrier operations have been in place since 2011 and provided guidance focused on potential actions that could be undertaken in and around the USACE EDBS and in the CAWS, upstream of the Lockport Lock and Dam (RM 291). The ICRCC relies on the EDBS within the CSSC at Romeoville, Illinois, operated by USACE, as a key tool to prevent the establishment of invasive carp in the Great Lakes Basin. In support of the current EDBS and the goal of preventing establishment, this CRP ensures invasive carp populations in the upper IWW remain low and that arrival at the EDBS is as low as practicable.

Previous response operations have been successfully conducted by the ICRCC in response to detections of potential invasive carp above the EDBS. This includes an interagency monitoring response in 2017 which used physical detection and capture gears in Lake Calumet and the Little Calumet River and a 2010 response in the Little Calumet River where piscicide was applied to over two miles of waterway. In addition, a response was conducted downstream of the EDBS in 2009 to prevent fish passage during a scheduled maintenance outage in which five miles of the CSSC was treated with a piscicide.

This enhanced CRP expands the geographic scope of contingency planning efforts prior to 2017, as well as the scope of potential tools to be utilized in such an event. This plan also considers operations and status of the EDBS, and related fish suppression considerations, which are detailed in Appendix A.

Finally, this CRP provides a communication framework and response procedure that may be utilized for any planned event or those actions in response to knowledge of actions that may elevate the risk of invasive carp passage into Lake Michigan. These events may include scheduled maintenance of the EDBS or the opening of hydraulic connections which may allow the passage of invasive carp. The same protocols outlined for a response to an unknown event may be applied in advance of these planned events to reduce the risk of a progressing invasion front. An operationalized application of the contingency response process for planned EDBS outages is detailed in Appendix A.

Invasive carp distribution has not changed significantly based on location in the upper IWW since individuals were discovered directly in the Dresden Island Pool in 2006. Conversely, abundances of adult invasive carp in the Upper IWW from 2012 to 2019 have declined through time based on hydroacoustic scans. The 2019 MRP ISR highlights a significant amount of monitoring effort from the Starved Rock Lock and Dam upstream through the CAWS with no evidence of an established population of any life stage above the Dresden Island Pool (MRWG, 2019). Lack of range expansion and decreased abundances may be due to intensive contracted fishing efforts, lack of suitable habitat upstream, water quality conditions, or a combination of other factors not yet fully understood. Despite no evidence of range expansion or increasing abundance of the invasive carp population in the upper IWW, it is generally recognized that fish populations may expand their range and abundance. Examples of introduced fishes exhibiting this phenomenon are available from other locations.

Small invasive carp (less than 6" inches in length) are of special concern when considering response actions because of the risk that smaller fish may not be as effectively repelled by electric barriers or small invasive carp may become inadvertently entrained in areas between barge tows and propelled through locks. In 2017, biologist from the USFWS Carterville FWCO conducted a study in the LaGrange and Peoria pools of the Illinois River specifically focused on invasive carp entrainment. Biologists found that small Silver Carp (less than 60 mm) released into a barge junction gap can be transported upstream while entrained in commercial tow junction gaps over distances of up to 4 miles (Davis and Neeley, 2017). However, such entrainment has not been observed to occur naturally for either Bighead Carp or Silver Carp outside of these studies. Observations of small fish in advance of adult population fronts has not been reported in either the IWW or other large navigable rivers of the U.S.

While the focus of the CRP is related to the status of the more abundant Silver Carp and Bighead Carp in the Upper IWW, the plan is also applicable and adaptable to Black Carp. Black Carp have become a greater concern in the Upper Illinois River over the past several years. Black Carp's diet of mollusks, which include native freshwater mussels, is of special concern due to the imperiled status of many mussel species throughout North America. As of January 2021, the closest known capture of Black Carp occurred within the Peoria Pool. While more data is needed to fully understand population dynamics of Black Carp in the Illinois River, increases in captures within the Peoria Pool or occurrences above Starved Rock Lock and Dam may result in a response action by the MRWG.

Location:

The IWW is a series of rivers and canals running from Lake Michigan circa Chicago, Illinois to the Mississippi River near St. Louis, Missouri. This waterway contains approximately 336 miles of canal and navigable rivers including the Chicago, Calumet, Des Plaines, and Illinois Rivers and connecting canals. The five pools of the upper IWW (upstream toward Lake Michigan) are covered by this document: Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock (Figure 1), RM 231 to 327. Each pool is defined as the body of water between two structures; such as a series of lock and dams, as well as any tributaries connected to that pool. For instance, the Brandon Road Pool is the body of water upstream of the Brandon Road Lock and Dam. The distances (miles) from the upstream structure of a given pool to the EDBS are as follows: Lockport- N/A, Brandon Road- 5.5, Dresden Island-10.5, Marseilles- 26, and Starved Rock-49.5. While LaGrange and Peoria Pools, and Alton Reach of the Lower IWW are not covered by this CRP, the population status and trends are monitored by the MRWG to elevate awareness of potential changes in the upper pools.

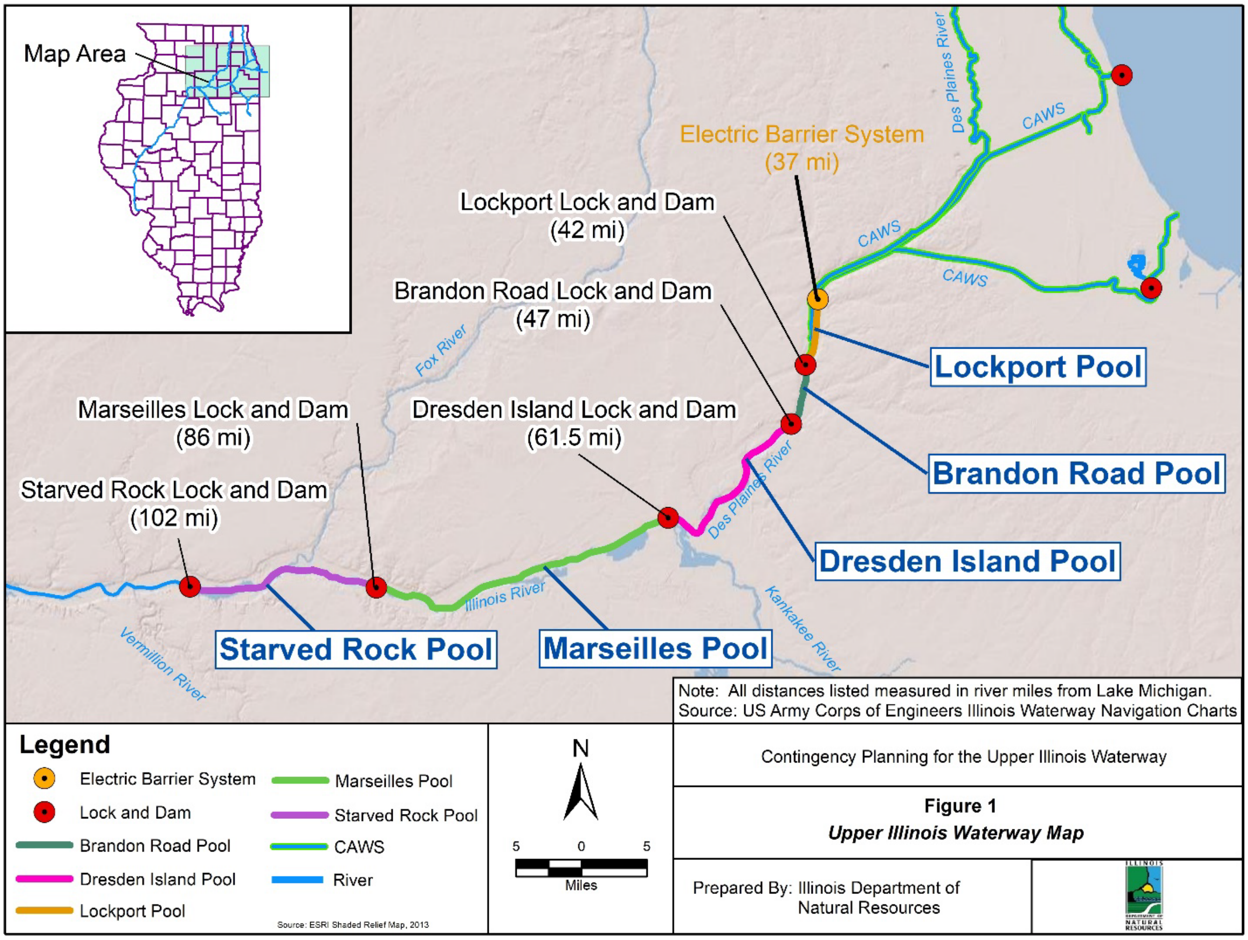


Figure 10. *Illinois Waterway Map and Profile. Note: For the purposes of this map, the Lockport Pool is only highlighted up to the electric barrier system.*

Mission and Goal:

The MRWG convened a panel of experts on local invasive carp populations, waterways, and navigational structures, and charged the panel to evaluate the invasive carp population status, waterway conditions, forecast invasive carp scenarios, and develop a plan to direct appropriate, prudent, and contingency response actions as needed in the upper IWW. Current and/or expected regulatory or other required actions are noted for each contingency measure as practical. The goal of the panel was to define contingency plans to meet the ICRCC mission as stated:

> *The purpose of the ICRCC is to coordinate the planning and execution of efforts of its members to prevent the introduction, establishment, and spread of Bighead, Black, Grass, and Silver Carp populations in the Great Lakes.*

In support of this mission statement, the goal of the CRP is to provide a process to consider appropriate response actions that fully consider available tools and the authorities of member agencies to implement actions. The intent is for the plan to be clear and easy to understand while allowing flexibility needed to ensure response actions fully address situation-specific issues. The plan uses consistent terminology as defined by the MRWG panel of experts and is designed to be effective and transparent. This plan ensures open and transparent communication with the public and special stakeholder groups while providing consistent terminology in relation to the invasive carp populations, ecology, and invasion front dynamics.

The CRP is a living document that will evolve over time as information changes and additional technologies/tools are developed e.g., ozone, thermal, or CO_2 barriers; attractants such as pheromones, audio cues, or feeding stimulants, or other unspecified tools that may be developed at a future time.

Additional Resources Considerations:

This CRP allows for deployment of aggressive monitoring or control tools deemed most appropriate by the MRWG, the ICRCC, and the governmental agency holding locational or operational jurisdictional authority. For example, one of the most aggressive responses in invasive carp prevention occurred in 2009, when approximately five miles of the CSSC was treated with a fish piscicide (Rotenone) in support of an EDBS maintenance operation. This control action occurred at a time when invasive carp abundance and risk of a barrier breech was less understood. The ILDNR remains the sole legal authority to apply piscicide in its waters and has previously made decisions to do so with close consultation of many local, state, and federal partners. Illinois retains the authority, ability, and responsibility to facilitate similar actions and has already determined that this tool is not appropriate for a majority of the rivers, locations, or scopes included in this plan. While not listed as a tool in this CRP for the MRWG to consider, the ILDNR reserves the right to authorize the use of piscicide as appropriate and/or permitted in cooperation with other regulatory agencies in the CSSC or other developing technologies when it is determined the need is prudent.

Temporary modification of lock operations may be used under existing USACE authorities when necessary to support other control measures within the CRP. The duration of the modified operation would be limited to the time necessary to carry out the supported control measures. Such modifications have supported previous barrier clearing events when electrofishing, water cannons, and/or nets were used to sample fish in and around the barrier system. In some instances, restriction of navigation traffic in the waterway may be necessary to safely execute a control measure for operational needs or life/safety concerns of water users. Such restrictions fall under the authority of the USCG. As with temporary modification of lock operations, the duration of the restriction would be limited to the time necessary to carry out the control measure. The USACE and USCG have processes in place to provide timely evaluation and decisions in response to requests for temporary modified operations to support control actions by other entities and fulfill other necessary posting and communication requirements.

Upper Illinois Waterway Contingency Response Plan

Status:

This CRP was placed into operation in spring 2016, building upon existing and complementary response plans, and has been updated annually based on new scientific information and available technical capacity for invasive carp control.

Data collected since 2011 have further clarified where invasive carp are located the IWW. Figure 2 (below) summarizes our current knowledge of the status of Bighead Carp and Silver Carp developed through ongoing monitoring and historical accounts. This graphic was originally established in 2015 as the benchmark year from which to evaluate progress in future years. The MRWG concurred that the establishment of a point of reference would aid in evaluating the status of invasive carp in the Upper IWW and 2015 was characterized by significant monitoring and detection efforts, which led to a thorough understanding of the invasive carp population status. Due to increased efforts the MRWG reach a consensus on invasive carp status in 2015. The results of ongoing surveillance and management efforts, including those through December 2020, have been used to establish the current status of invasive carp populations in each pool of the IWW, as described below:

- **Lake Michigan:** No established invasive carp population
- **Chicago Area Waterway System (CAWS):** No established invasive carp population
- **Lockport Pool:** No established invasive carp population
- **Brandon Road Pool:** No established invasive carp population
- **Dresden Island Pool:** Adult Silver Carp and Bighead Carp population front. Larval invasive carp observed for the first time in 2015 and have not been observed since. No Black Carp have been captured
- **Marseilles Pool:** Adult Silver and Bighead Carp consistently present, and their eggs have been detected. Spawning has been observed. No Black Carp have been captured.
- **Starved Rock Pool:** Abundance of adult Silver Carp and Bighead Carp present, and high densities of their eggs have been detected in some years. Juvenile Silver Carp (<less than 6 inches total length) were observed in 2015 and have not been observed since. In 2020, early stage invasive carp larvae were captured in Starved Rock Pool at RM 238.5 and 240.5 for the first time. These larvae were pre-gas bladder inflation (See definitions in Appendix A). No Black Carp have been captured.
- **Peoria Pool (downstream to confluence with Mississippi River):** Established population with all life stages of Silver Carp and Bighead Carp have been observed. Black Carp over 6 inches have been captured.

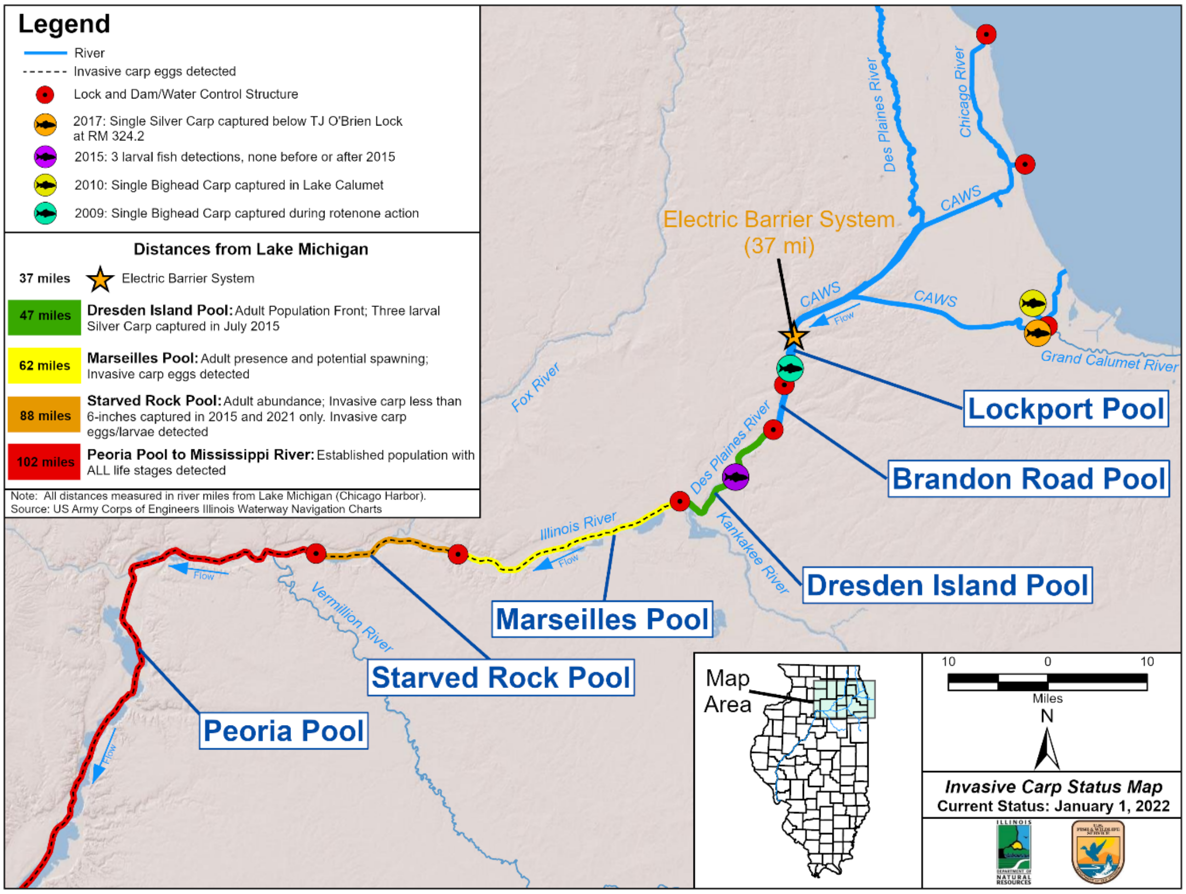


Figure 2. Invasive Carp Status Map. Current Status: January 1, 2022.

- [1] *Invasive carp larvae (pre-gas bladder inflation) were captured in the Starved Rock Pool for the first time in 2020. The furthest upstream post-gas bladder inflation larvae (outside of the 3 captured in Dresden Island in 2015) have been captured was at river mile 197 near Henry, IL.*
- [2] *Black Carp over 6 inches have been captured in Peoria Pool.*

Planning Assumptions:

These planning assumptions anticipate potential realistic situations and constraints on the ICRCC, other stakeholder agencies, and partners. The following assumptions pertain to all responding agencies and their resources as well as the response situation and are relevant to this planning initiative:

Situation Assumptions

- Response actions will be selected based on the waterway conditions, and the time and geographic location of invasive carp detection, and other factors.
- Response actions will be located within the designated area of the upper IWW described in the CRP (from Starved Rock Pool to the Lockport Pool, as depicted in Figure 1).

- For planning purposes, under this CRP, invasive carp primarily refers to Bighead Carp and Silver Carp, *however, may also serve to inform potential response actions in the event a Black Carp is captured above Starved Rock Lock and Dam.*

Command, Control, and Coordination Assumptions

- All response operations will be conducted under the ICS or Unified Command as mandated under Presidential Policy Directive 8.
- Actions recommended by the ICRCC are dependent on agency authority to act at their discretion.

Logistics and Resources Assumptions

- The MRWG may request ICRCC support to leverage additional resources needed to conduct appropriate contingency response actions.
- Illinois as signatory to the Mutual Aid Agreement of the Conference *of Great Lakes & St. Lawrence Governors and Premiers may request assistance if deemed necessary. http://www.cglslgp.org/media/1564/ais-mutual-aid-agreement-3-26-15.pdf*
- The need for mobilization of personnel and resources from outside coordinating agencies may affect the response time and should be planned for accordingly.

Concept of Operations for Response:

The following sections present the implementation options for the local response and coordination with the MRWG and the ICRCC stakeholders. If conditions continue to warrant response, the number of coordinating entities could increase along with the need for additional response operations. This expansion will trigger additional command, control, and coordination elements. The overall incident complexity and ICS span of control principles should guide the incident management organization.

Methods:

Subject matter experts from participating agencies discussed the importance of many factors within the IWW, potentially causing the invasive carp populations to change and result in an increased invasion potential of the Great Lakes. The subject matter experts independently evaluated the extent of change each scenario warranted and then the group met jointly to discuss and develop a consistent opinion about the degree of change. Individuals then made independent assessments as to what level of response they would choose under the varying conditions within the decision support trees. These responses were then discussed and agreed upon by the group, which resulted in the contingency table described in Attachment 1 of Appendix A: Barrier Maintenance Fish Suppression.

Direct Considerations for Response:

The contingency table identifies whether change (moderate or significant) in management or monitoring actions is needed. It then takes into direct consideration: location of invasive carp populations (at the pool scale), life history stages (eggs/larvae, small fish (less than 6”), and large fish), and abundance (rare, common, and abundant) of invasive carp collected.

Pool:

Navigation pool was determined to be the best and most appropriate scale for the location of invasive carp in a population (relation to distance from the EDBS). Since pools are impoundments defined by locks and dams that could at least partially restrict movements of fish, they were chosen as the most appropriate locational references and geographic scales for contingency planning purposes.

Life History:

Fish life history relates to the size of fish (i.e., smaller fish are less susceptible to electricity; larger fish are more susceptible to electricity; management actions may be size-specific) and indicates the occurrence of spawning and recruitment.

Abundance:

Increased abundance of any life stage signifies a change in the population structure at a given location and increases concern of invasion risk. Generally, larval invasive carp have not been found in the upper IWW. Finding invasive carp larvae would represent a potential change in the dynamics of the population in the upper IWW. Responses related to the detection of larval invasive carp would likely be directed at other adult or juvenile life stages of invasive carp.

Electric Barrier Functionality:

The operational status of the EDBS (barrier functionality), directly impacts the ability of invasive carp to potentially breach the barriers and move upstream of the Lockport Pool. That is, decreased barrier function increases the probability of invasive carp passage. Barrier operational status will inform actions considered when planning responses. Meetings of the MRWG and ICRCC will be convened in the event of a complete barrier outage and may lead to response actions. Incomplete outage events at one or more barrier arrays that may allow for upstream passage to the next barrier array have a separate process, Barrier Maintenance Fish Suppression. This process, outlined in Appendix A, uses the same decision-making structure as the Contingency Response Plan in a more routine and operationalized manner.

Additional Considerations for Actions and Decision-Making Process:

This process will include a recommended set of response actions for decision makers to consider when a change to the baseline condition is identified. Changes may include, but are not limited to, changes in fish population abundance, life stage presence, or new geographical positions in upstream and/or downstream pools, the ongoing rate of change in invasive carp population characteristics, season and/or water temperature, the habitat where fish are sighted or collected, flow conditions, the amount of available data, and whether multiple lines of evidence exist to support changing conditions. The validity of evidence that a response trigger has been met will also be taken into consideration. Evidence of invasive carp presence in new locations within the IWW may come from physical captures, confirmed sightings by trained biologists, or via detections of telemetered specimens on active or passive receivers. These observations may be reported by any activity within the MRP or by external work conducted by other groups. The

MRWG will evaluate the validity of each reported observation and discuss whether an actionable trigger has been met. The status of populations is continuously monitored by the MRWG and communication of important findings occurs immediately. Consensus on the current population status on a pool-by-pool basis is made annually with a holistic review of data collected by all MRWG agencies. Quarterly meetings of the MRWG serve as a checkpoint to discuss potential population changes through each sampling season as new data is collected. The group recognized that identified response options are recommendations only. An action(s) could be more or less intense based upon the nature (e.g. magnitude/life stage) and location (e.g. close or far from Lake Michigan/Electric Barrier) of the change. One example scenario is illustrated in Attachment 1. The scenario is based on a change in conditions in Brandon Road Pool and is one example of when a contingency plan is called into action. Attachment 2 provides the decision-making process and flow of likely activities in such an event. This scenario and decision process illustrates what could occur should a change be identified from this Decision Support Framework.

Command, Control, and Coordination

Command and control of an invasive carp response in the IWW will be implemented under the MRWG. The ICS is a management system designed to enable effective and efficient incident management by integrating a combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure. The MRWG will utilize the ICS to manage response operations to maximize efficiency and ensure a standard approach across all participating agencies. Area Command, Unified Command, or single Incident Commander, depending on the needs, will be maintained to determine the overarching response objectives and in implementing individual tactics necessary to accomplish each objective. Local command and control involves directing resources to establish objectives for eradication, control, or identification of invasive carp during a response operation.

Figure 3 shows the basic Unified Command organization structure that will be utilized for any response that requires the mobilization of resources and multi-agency personnel as well as provides a visual representation of the basic command, control and coordination relationships for invasive carp response personnel serving during an event.

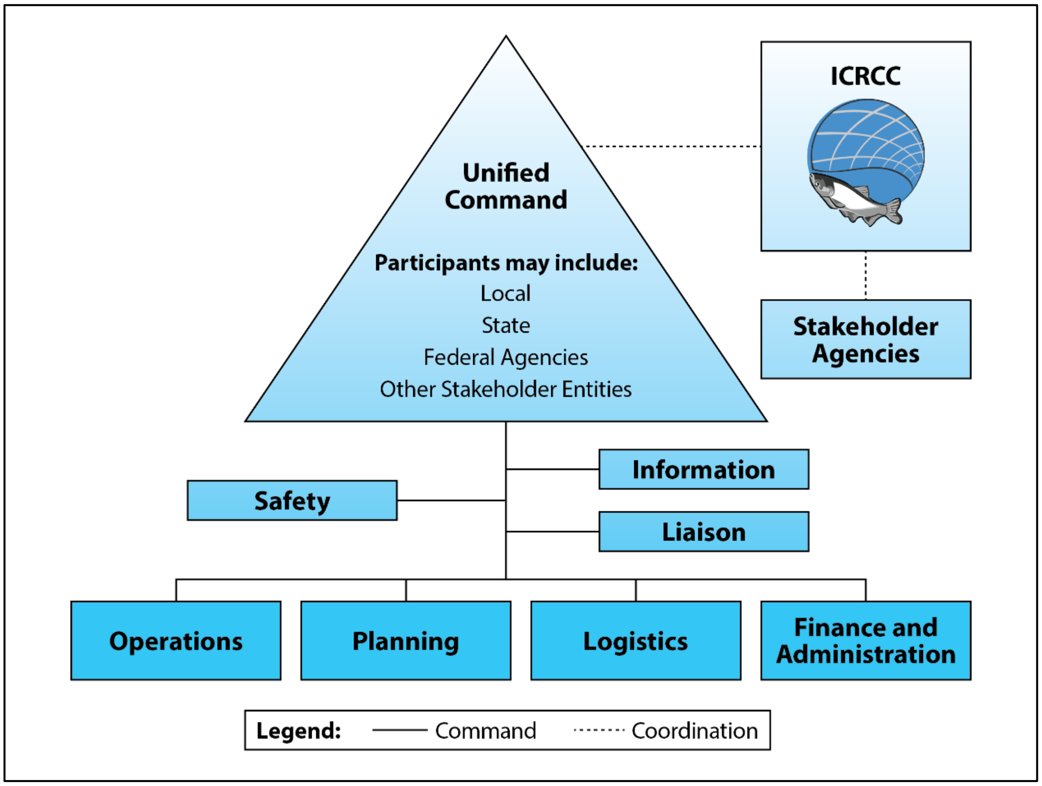


Figure 3. *Unified Command Organization Structure*

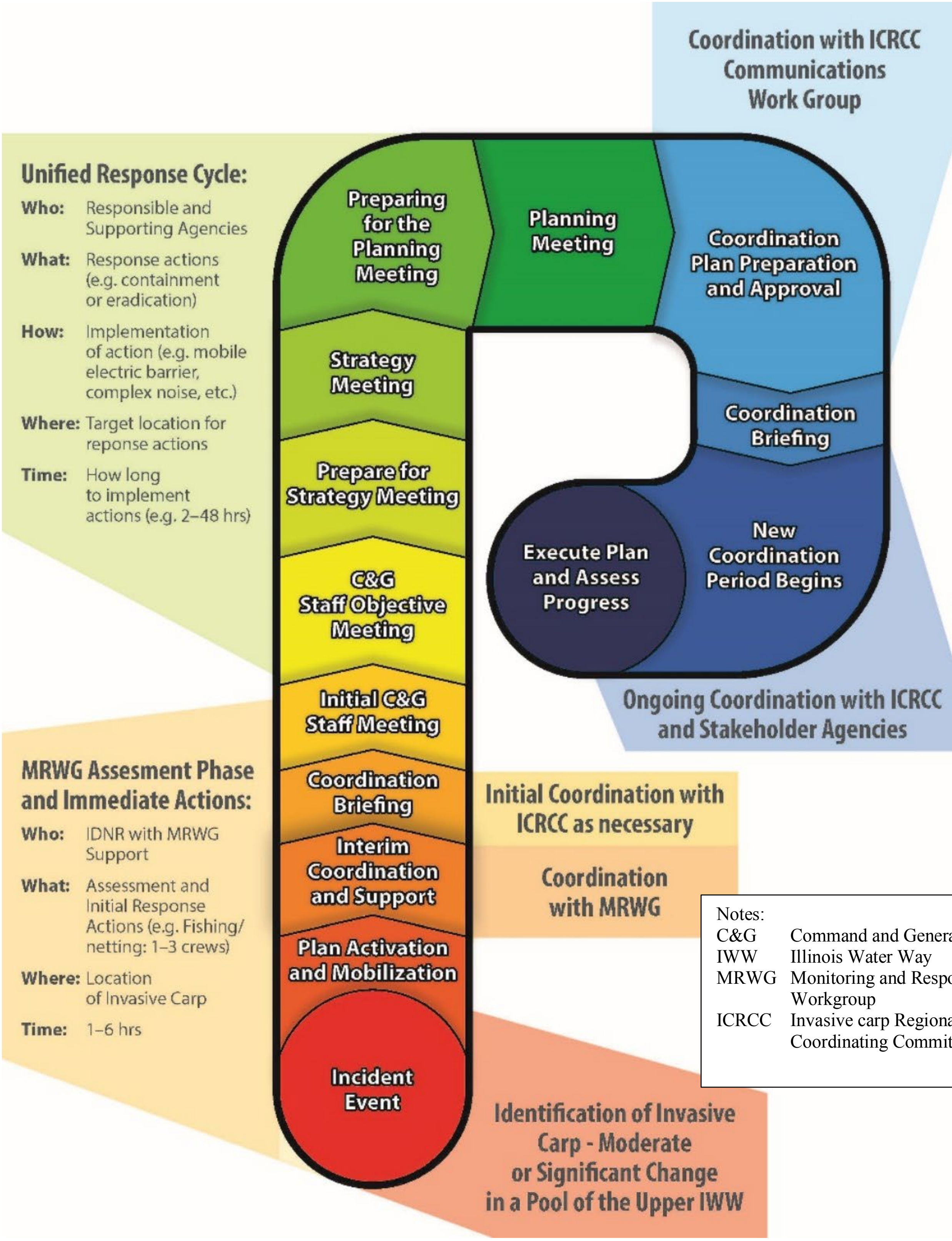
Incident Action Planning:

> **SMART Objective Example**
> State agency X will contain 2 miles of the river using block nets within 8 hours of notification.

An IAP is a standard means of documenting and communicating objectives, strategies, and tactics utilized to address issues resulting from an incident. At the core of a functional IAP are well-written objectives. The standard acronym is "SMART" objectives—objectives that are (1) Specific, (2) Measurable, (3) Achievable, (4) Realistic, and (5) Task-oriented. Objectives can then be inserted into an IAP template. Each response is unique, but the basic concepts of operations and objectives can be the building blocks for a solid IAP that communicates, internally and externally, the jurisdiction's plans for managing an incident.

Incident action planning extends farther than just preparation and distribution of the IAP. This planning includes the routine activities during each operational period of an incident response that provide a steady tempo and routine structure to incident management. The ICS Planning "P" is a guide to the steps, relative chronology, and basic elements for managing an incident. By incorporating the Planning "P" into planning efforts, overlaying anticipated daily operational and logistical chronologies, a local jurisdiction can establish a framework for incident management that provides a rough playbook for local, state, federal, and outside resources to manage invasive carp under catastrophic incident conditions.

Figure 4 depicts the ICS Planning "P" and further describes agencies that may be involved at various steps in the process, what actions may be taken, and when actions will be implemented.



Notes:

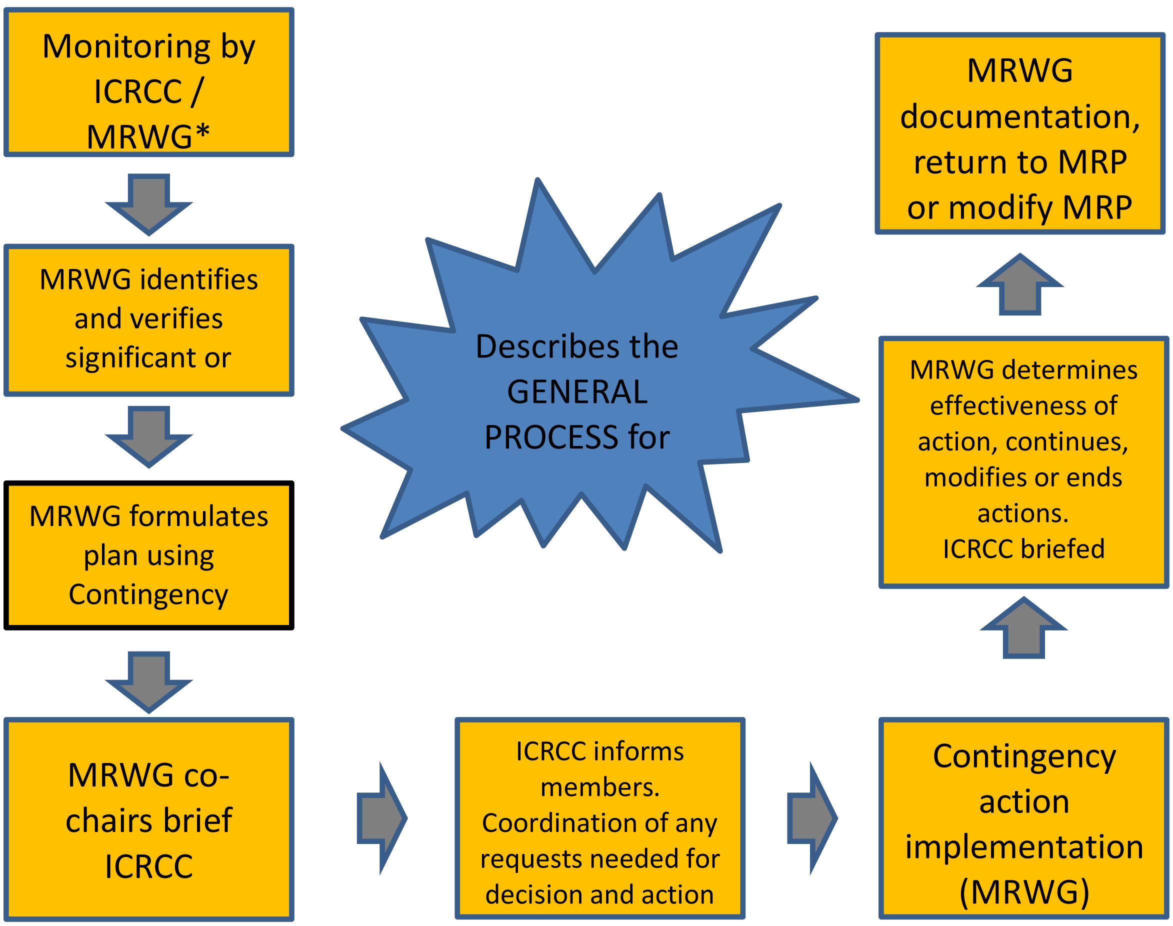
C&G	Command and General Staff
IWW	Illinois Water Way
MRWG	Monitoring and Response Workgroup
ICRCC	Invasive carp Regional Coordinating Committee

Figure 4. *ICS Planning "P"*

Response Decision Matrix

For the purposes of informing contingency response planning in the upper IWW, MRWG developed a situation-based "response decision matrix" that will aid the MRWG in determining the need for a contingency response action. This decision-support guide uses common, agreed-upon definitions (see Attachment 3). The process consists of (1) identifying the pool of interest, (2) identifying the proper life stage of invasive carp captured, observed, or detected (verified physical observations by agency personnel or confirmed telemetry based detections), and (3) identifying whether the sampling result is Rare, Common, or Abundant relative to 2015 reference conditions.

Figure 5 describes the entire contingency response process for all ICRCC stakeholder agencies. The decision support trees are utilized in steps 3 through 7 to assess the need for further response actions.



* Monitoring and Response Workgroup (MRWG) is the working level body of the ICRCC. The MRWG implements the annual MRP and contingency actions subject to agency authorities and approvals by their individual Agency

Figure 5. *Simplified Process Flow Chart for a Contingency Response*

Once all determinations have been made, the decision response matrix (Figure 6) will funnel the user to an action response level. This action response level will identify actions that could occur. Response actions may be determined by new findings in one pool but occur in a different pool. Each pool has an agreed upon set of response actions that can be taken. If change is apparent and a response is warranted, the proper agencies will be notified and can then discuss how best to proceed based upon the options available. A chart of the potential response actions to be considered is provided in Table 1. An example is also provided at the end of the decision support trees for illustrative purposes.

Upper Illinois Waterway Invasive Carp Response Decision Matrix*

	Distance from Lake Michigan (Miles		Eggs/Larvae			Small Fish			Large Fish		
			Rare	Common	Abundant	Rare	Common	Abundant	Rare	Common	Abundant
Direction of Flow	0 - 37	Chicago Area Waterway System							1		
	37 - 42	Lockport Pool to Electric Barrier System							2		
	42 - 47	Brandon Road Pool							3		
	47 - 62	Dresden Island Pool									
	62 - 88	Marseilles Pool									
	88 - 102	Starved Rock Pool									

Notes:

= Significant change from baseline requiring further response action.

= Moderate change from baseline requiring further response action.

= No change/Status Quo from baseline. No further action.

1 This status is based upon the collection of a single Bighead Carp by contracted fishers in 2010 and a single Silver Carp in 2017.
2 This status is based upon the collection of a single Bighead Carp during piscicides treatment in 2009.
3 This status is based upon sightings of 1 Bighead Carp and 1 Silver Carp by MRWG efforts in 2010-2011. No invasive carp have been collected in this pool.
*Baseline for comparison and determination of response action is the status of invasive carp populations as of December 31, 2015.

Figure 6. *Upper IWW Invasive Carp Response Decision Matrix for Silver Carp and Bighead Carp*

Table 6. *Contingency Response Action Matrix*[*1]

Level of Urgency (Action Response Level)	Potential Actions[2]	Applicable Locations	Responsible Agencies	Estimated Time to Implement	Regulatory or Other Requirements	Relative Cost ($-$$$$)
Significant Change	Increased Sampling Efforts[3]	All	IDNR/USFWS	1-7 days	Sampling permits	($$)
	Modify Barrier Operations	LP, BR	USACE	1 day	Coordinate with contractors	($)
	Acoustic Deterrents	All	USGS/USACE	1-7 days	Coordinate with local stakeholders	($$)
	Commercial Contract Netting	All	IDNR	1-7 days	Sampling permits/contracts	($)
	Hydroacoustics	All	USFWS/SIU/USGS	1-7 days	None	($)
	Block Nets	All	IDNR	1-7 days	Notice to navigation	($$)
	Temporary Flow Control	LP, BR	MWRD	1 day	Notice to navigation	($)
	Mobile Electric Array	All	INHS/IDNR	1-7 days	Coordinate with local stakeholders and Coast Guard	($$$)
Moderate Change	Increased Sampling Efforts	All	IDNR	1-7 days	Sampling permits	($$)
	Modify Barrier Operations	All	USACE	1 day	Coordinate with contractors	($)
	Acoustic Deterrents	All	USGSUSACE	1-7 days	Coordinate with stakeholders	($$)
	Commercial Contract Netting	All	IDNR	1-7 days	Sampling permits/contracts	($)
	Hydroacoustics	All	USFWS	1-7 days	None	($)
	Block Nets	All	IDNR	1-7 days	Notice to navigation	($$)
No Change	Maintain Current Level of Effort	N/A	All	Ongoing	N/A	($)

LP Lockport

BR Brandon Road

* The implementation of some of these actions may require temporary lock closures or navigation restrictions, which fall under the authority of USACE and the US Coast Guard respectively. Temporary lock closures and navigation restrictions would be limited to the time necessary to carry out the supported measures. Such lock closures have supported previous barrier clearing events when electrofishing, water cannons, and/or nets were used to sample fish in and around the barrier system.

1 Additional Resource Considerations (page J-4) describes other measures that may be implemented as necessary and aligned with agency authorities.

2 The current monitoring and response activities are covered under existing federal budgets.

3 Response techniques encompassed by Increased Sampling Efforts under Potential Actions in above table

Technique	*Participating Agencies*
Electrofishing	USFWS, IDNR, INHS, USACE
Netting (Gill, Trammel, Pound, ichthyoplankton)	USFWS, IDNR, INHS
Paupier Trawling	USFWS
Fyke Netting	IDNR, USFWS, USACE
Dozer Trawl	USFWS
Telemetry	USGS, USACE, SIU,

Information and Data Management

The ICRCC Communications Work Group will be the primary conduit for ensuring open and transparent communication with both the public and other stakeholder agencies during an invasive carp contingency response operation. The public and stakeholder groups will be notified as early as possible in the process and according to messaging protocols established by the ICRCC Communications Work Groups. There are many factors that may drive potential response actions including the nature of the change, severity of the change, time of year and environmental conditions.

Essential Elements of Information

At all points of the incident management process, Essential Elements of Information (EEI) should be collected and managed in a standard format. Paper forms, when power and electronic systems are not available, and electronic data should be collected with end usage in mind. For instance, if data on how various waterways' conditions are used as the basis for logistical requests and response decisions, these data should be separated and properly analyzed to ensure acquisition of adequate supplies for selected response. For response personnel, simple numerical counts of fish, numbers of each species, and all other critical data must be communicated up the chain early and often. Additionally, routine recording and reporting of staffing levels, available resources, space, capability gaps, and projections are all important for managing overall response under a specific scenario.

References:

Davis, J. J. and R. N. Neeley. (2017). Dynamics of Silver Carp Entrainment and Transport by Commercial Tows on the Illinois Waterway- Preliminary Results 2017 Field Studies. Internal US Fish and Wildlife Service - Midwest Region Fisheries report: unpublished.

Appendix A: Barrier Maintenance Fish Suppression

The USACE operates three Electric Dispersal Barriers (Demonstration Barrier, Barrier 2A and Barrier 2B) for aquatic invasive species in the Chicago Shipping and Sanitary Canal (CSSC) at approximate river mile 296.1 near Romeoville, Illinois. These three separate barriers are operated together in what is referred to as the Electric Dispersal Barrier System or EDBS. The Demonstration Barrier (Demo Barrier) is located farthest upstream (800 feet [243.8 m] above Barrier 2B) and is operated at a setting that has been shown to repel adult fish. Barrier 2A is located 220 feet (67.1 miles) downstream of Barrier 2B and both 2A and 2B now operate at parameters that have been shown to repel fish as small as 3.0 inches (76.2 mm) long in the laboratory (Holliman 2011). Barrier 2A and 2B must be shut down for maintenance approximately every 6 months and the Illinois Department of Natural Resource (IDNR) has agreed to support maintenance operations by providing fish suppression at the barrier site. Fish suppression can vary widely in scope and may include application of piscicide (rotenone) to keep fish from moving upstream past the barriers when they are shut down. This was the scenario for a December 2009 rotenone operation completed in support of Barrier 2A maintenance, which was 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.

The Demo Barrier, Barrier 2B and Barrier 2A have previously been operated with the Demo Barrier in continuous operation and only Barrier 2B or Barrier 2A in concurrent operation. Beginning in January 2014, the EDBS received approval to operate all three barriers concurrently to increase redundancy in the event of an unplanned shutdown. Fish passage opportunities may occur when the furthest downstream active barrier experiences a loss of power in the water allowing fish to move upstream to the next active barrier. Those fish may then be entrained between two electric fields until the next upstream barrier allows passage during an outage or they are flushed downstream. This creates an unacceptable level of risk that invasive carp could gain access to the upper Chicago Area Waterway Systems (CAWS) and Lake Michigan and reduces the redundancy that is considered an essential feature of the entire barrier system. The intent is to drive fish below the barrier system after repairs and/or maintenance have been completed and normal operations have been resumed.

A more specific plan of action has been fleshed out in previous Monitoring and Response Plans (MRP) to address outages at the EDBS and was previously included as a specific project titled "Barrier Maintenance Fish Suppression." The Monitoring and Response Work Group (MRWG) resource agency partners have agreed to support future maintenance operations by providing enhanced monitoring and, if required, fish suppression at the EDBS site. This task is now integrated into the MRP and the Contingency Response Plan (CRP) as a continuous operation as opposed to an annual project. The project is now included as an appendix of the CRP and is used for both planned and unplanned outages at one or more barrier arrays within the EDBS. For each planned or unplanned outage at the EDBS, a protocol is established for notification of the outage, a MRWG resource agency review of the current level of risk for invasive carp presence is documented, and a decision on actionable responses occurs and, if warranted, is implemented.

Appendix A: Barrier Maintenance Fish Suppression

The current approach to fish suppression at the EDBS is to first survey the area with remote sensing gears to assess the need for fish clearing operations either in support of planned barrier maintenance or after an unplanned power loss. If any number of fish >300 mm in total length are present, then additional surveillance to further inform the risk invasive carp pose at this location or possible mechanical collection or driving techniques will be used to move fish downstream out of the target area. Additional actions may be directed to utilize physical capture techniques (electrofishing, netting, trapping, etc.) and/or remote sensing techniques (hydroacoustics, telemetry downloads or mobile tracking) may also be directed by the MRWG to gain up-to-date data for which to make more informed decisions on fish clearing actions. Fish clearing actions within the regulated navigation area of the EDBS are considered high risk to the safety of those staff involved. Water-borne electric fields pose a major obstacle to traditional fish driving and collection techniques. The decision to implement a fish clearing action is always done with extreme caution and considered by MRWG participating agencies in context of all available data.

In recent years, additional deterrents have been implemented to help mitigate the risk of invasive carp movement during winter annual maintenance activities. In the winter of 2017-2018 and 2018-2019 an acoustic deterrent system was deployed by U.S. Geological Survey (USGS) with assistance from U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center and Chicago District personnel. Up to 5 underwater speakers were temporarily welded to a moored tugboat approximately 0.8 miles downstream of the EDBS at the Hanson Material Service barge slip in Romeoville, Illinois. A recording of a 100-hp boat motor sound, a sound shown to deter invasive carp in previous lab studies, was played on loop during the maintenance operations. At the discretion of the MRWG and available resources, the deployment of an acoustic deterrent system will be discussed prior to any future winter barrier maintenance activities. Additional deterrent technologies will also be considered as they are developed, tested and feasible for field applications.

Fish suppression decisions should be made each time there is a planned or unplanned outage at the EDBS which allows an opportunity for fish passage in the upstream direction. The below tables indicate the various operational scenarios that may be experienced at the EDBS with corresponding decision points (Table 1) and anticipated operational changes between March 2019 to March 2020 (Table 2). All operational changes of the EDBS require notification to the MRWG. Notification of operational changes that require a clearing decision will be flagged appropriately with pertinent details included in the notification to clarify the reason for the change in operations. Table 1 outlines those scenarios in which an immediate assessment and clearing decision should be made by action agencies. Additional clearing decisions may be requested from the invasive carp Regional Coordinating Committee (ICRCC) stakeholders or MRWG resource agencies as necessary.

Appendix A: Barrier Maintenance Fish Suppression

Table 1. *Potential operational scenarios at the Electric Dispersal Barrier System and recommended responses*

Barrier Operational Status			Clearing Decision Required
Barrier IIA	Barrier IIB	Demonstration/Barrier I North*	
On	On	On	No
Off	On	On	Yes
On	Off	On	No
On	On	Off	No
Off	Off	On	Yes
On	Off	Off	No
Off	Off	Off	Yes
Off	On	Off	Yes

*Eventually the Demonstration Barrier will be integrated completely with Barrier I. Barrier 1 will consist of three parts: Demo Barrier, Barrier I North and Barrier I South (Construction set for 2022). However, the demonstration barrier will continue to be activated as an individual barrier until Barrier I is through endurance testing and fully operational. Despite both barriers operating separately in the short term, the table above would be applicable for both barriers whether they are operating separately or as one barrier.

Table 2. *Operational changes anticipated from March 2020 – March 2021*

Barrier Operational Status				Clearing Decision	Activity	Season
Barrier IIA	Barrier IIB	Demonstration	Barrier I North*			
On	Off	On	On*	No	Cooling System Upgrade at IIB	Late Winter/Early Spring 2021
Off	On	On	On	Yes	IIA Controls Replacement	Summer 2021
Off	Off	On	On	No	IIB Controls Replacement, IIA Enclosure, and Electrode Inspection	Winter 2021 to Spring 2022

*Barrier I North will go through endurance testing in late winter of 2021. It is anticipated that Barrier I North will continue to be operational, however the results of endurance testing may result in intermittent outages to troubleshoot issues as they arise.

Appendix A: Barrier Maintenance Fish Suppression

Attachment 1: Hypothetical scenario

Small invasive carp are collected in Brandon Road Pool, while the barrier is operating normally. The location is first identified in the matrix, then barrier Efficacy function, next then fish life history, and finally the abundance. Based on this scenario, a significant change in actions should be considered.

Upper Illinois Waterway Invasive Carp Response Decision Matrix* — Fish Life History

	Distance from Lake Michigan (Miles		Eggs/Larvae			Small Fish			Large Fish		
			Rare	Common	Abundant	Rare	Common	Abundant	Rare	Common	Abundant
Direction of Flow	0 - 37	Chicago Area Waterway System					Abundance		1		
	37 - 42	Lockport Pool to Electric Barrier System							2		
	42 - 47	Location Brandon Road Pool							3		
	47 - 62	Dresden Island Pool							Significant Change		
	62 - 88	Marseilles Pool							Action Implementation		
	88 - 102	Starved Rock Pool									

Notes:

= Significant change from baseline requiring further response action.

= Moderate change from baseline requiring further response action.

= No change/Status Quo from baseline. No further action.

1 This status is based upon the collection of a single Bighead Carp by contracted fishers in 2010.

2 This status is based upon the collection of a single Bighead Carp during piscicide treatment in 2009.

3 This status is based upon sightings of 1 Bighead Carp and 1 Silver Carp by MRWG efforts in 2010-2011. No invasive carp have been collected in this pool.

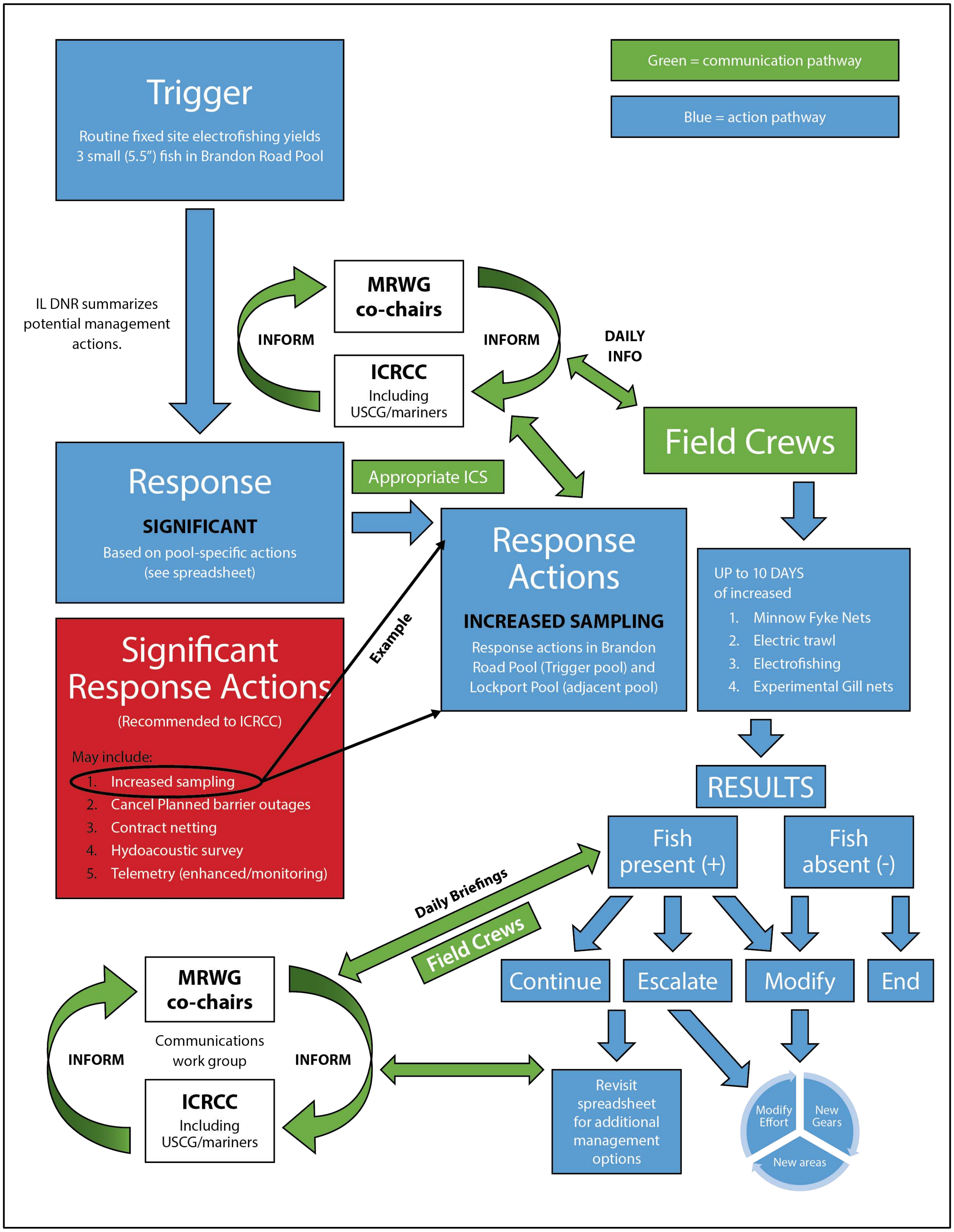
* Baseline for comparison and determination of response action is the status of invasive carp populations as of December 31, 2015.

1 This status is based upon the collection of a single Bighead Carp by contracted fishers in 2010 and a single Silver Carp in 2017.
2 This status is based upon the collection of a single Bighead Carp during piscicides treatment in 2009.
3 This status is based upon sightings of 1 Bighead Carp and 1 Silver Carp by MRWG efforts in 2010-2011. No invasive carp have been collected in this pool.
*Baseline for comparison and determination of response action is the status of invasive carp populations as of December 31, 2015.

Appendix A: Barrier Maintenance Fish Suppression

Attachment 2: Sample Action Process

This example illustrates the process should three small invasive carp be collected in Brandon Road Pool.



Appendix A: Barrier Maintenance Fish Suppression

Attachment 3: Definitions

Life Stage	
Egg	The rounded reproductive body produced by females.
Larvae	A distinct juvenile form of fish, before fins and scales are fully developed. Larvae are further separated into two separate categories (Pre- and Post-Gas Bladder Inflation) as they pose different risks.
Larvae- Pre-Gas Bladder Inflation	Any larval stage from the time of hatching until the time that the gas bladder appears. Bigheaded carp larvae at these stages are generally capable of vertical swimming but are not able to swim horizontally or maintain position in the water column without active swimming, and generally do not feed.
Larvae- Post-Gas Bladder Inflation	Any larval stage from the time the gas bladder appears until fins and scales are fully developed (juvenile stage). Bigheaded carp larvae at these stages are capable of horizontal swimming and maintaining their position in the water column without actively swimming. They begin feeding shortly after gas bladder appearance and are thought to be more capable of actively exiting main channel habitats and selecting nursery areas. Besides the 3 larvae captured in Dresden Island, post-gas bladder inflation larvae have been captured as far upstream as RM 197 near Henry, IL.
Young of Year (YOY)	Fish hatched that calendar year. Also known as age 0 fish.
Juvenile	A post-larval individual that has not yet reached its adult form, sexual maturity or size. A juvenile fish may range in size from 1 inch to over 12 inches long or approximately age 0 to 5, depending on the species.
Adult	A sexually mature organism.
Size	
Small	Fish that are less than 6 inches (a conservative length designation to inform actions in which the Electric Dispersal Barrier may be challenged by fish found to be less susceptible to electrical deterrence, identified in USACE Efficacy reports).
Large	Fish that are greater than 6 inches.

Appendix A: Barrier Maintenance Fish Suppression

Populations	
Adult Population Front	The most upstream pool where detection/presence of adult fish is common (see below) and either repeated immigration or recruitment has been verified.
Capture Record	Capture of an adult, juvenile, larvae, and egg verified by agency efforts/personnel, does not notate any qualification of population size/establishment.
Small Fish Population Front	The most upstream pool where detection/presence of small fish is repeatedly recorded and either repeated immigration or recruitment has been verified.
Established	Inter-breeding individuals of Bighead Carp and/or Silver Carp as well as the presence of eggs, larvae, YOY and juveniles that leads to a self-sustaining population.
Range Expansion	Verified population front upstream of the previously identified pool.
Reproduction	
Recruitment	Juveniles survive to be added to an adult population, by successful spawning.
Observed Spawning	Visually documented spawning activity.
Successful Spawning	Spawning that has been confirmed by the collection of eggs or larvae.
Captures	
New Record/ Single Occurrence	When a single fish/egg/larva is collected in a location it was not previously found. Also referred to as a novel occurrence.
Sighting	A visual confirmation with high likelihood (experience/professional opinion) that the item seen was in fact a Bighead Carp, Silver Carp at the noted life stage/activity (spawning behavior could be a sighting; Silver Carp in an electrofishing field but not netted would be a sighting.
Sampling Occurrences	
Rare	One sample containing the targeted species or size group; invasive carp collections are not predictable and may take multiple sampling trips to collect just one individual.
Common	Consistent catches across the pool; invasive carp collection is predictable with one or multiple individuals being collected in a given day/week of sampling.
Abundant	Consistent catches across the pool in large quantities e.g. invasive carp collection is predictable with multiple fish being collected with nearly every deployment of gear, numerous individuals collected often and daily/weekly.

Appendix A: Barrier Maintenance Fish Suppression

Action Response Level	
No Change/ Current Level	Maintain current levels of sampling effort.
Moderate Change	Heightened level of response may occur along with maintaining current levels of sampling effort. Prior to any moderate change response, the MRWG will convene to evaluate the data and situation and recommend a suite of responses to the ICRCC for implementation. Strategies will then be determined for the best course of action and tools available based on the status change and concurrence with jurisdictional authorities and abilities
Significant Change	Substantial or heightened levels of response may occur along with maintaining current levels of sampling effort. All tools from “moderate change” are available during a significant change response, as are additional robust tools along with “maintaining current levels of sampling effort.” for consideration. Prior to any moderate change response, the MRWG will convene to evaluate the data and situation and recommend a suite of responses to the ICRCC. The ICRCC, after reviewing MRWG recommendations, may concur or offer opinions regarding the appropriate response(s) to implement. Prior to any significant change response, the MRWG will convene to evaluate the data and situation, then strategies will be made on the best course of action and tools available based on the status change and concurrence with jurisdictional authorities and abilities
Potential Response Actions	
Increased Sampling Efforts	Modified or increased number of samples using fish sampling/detection methods currently used by MRWG in Monitoring.
Electrofishing	Standard fish sampling method to sample small and adult invasive carp currently used by MRWG in Fixed and Targeted Sampling.
Hoop Netting	Standard fish sampling method to sample adult invasive carp currently used by MRWG in Fixed and Targeted Sampling.
Minnow Fyke Netting	Standard fish sampling method to sample small invasive carp currently used by MRWG in Fixed and Targeted Sampling.
Paupier Net Boat	Experimental fish sampling method to sample small and adult invasive carp currently used by MRWG.
Electrified Dozier Trawl	Experimental fish sampling method to sample small and adult invasive carp currently used by MRWG.
Ichthyoplankton Tows	Standard fish sampling method to sample larvae and eggs of invasive carp currently used by MRWG in Fixed and Targeted Sampling.
Pound Nets	Experimental fish sampling method to sample small and adult invasive carp currently used by MRWG.

Appendix A: Barrier Maintenance Fish Suppression

Potential Response Actions	
Modify Barrier Operations	MRWG and USACE will coordinate upon potential postponements and operations of planned Barrier outages.
Acoustic Deterrent	Noise methods to drive/herd/deter fish including revving of outboard boat motors, banging on boats in the waterway, and deployment of speakers with developed sounds.
Commercial Contract Netting	Mobilizing contracted commercial fisherman and using commercial fishing methods used currently by MRWG in sampling/detection and removal including gill netting, trammel netting, large mesh seine, small mesh seine, and hoop netting.
Hydroacoustics	Electronic Fish survey and locating techniques used currently by MRWG including side-scan sonar, and DIDSON sonar to evaluate the number and density of large or small invasive carp in a given area.
Temporary Flow Control	MWRD authority and ability to reduce flow velocities to complete response actions.
Block Netting	Large nets that can block the waterway or contain selected areas from small and adult invasive carp movement used currently by MRWG for removal.
Mobile Electric Array	Experimental electric array that can be used as temporary barrier or drive/herd and deter small and adult invasive carp.
Other	
Pool	The water between two successive locks or barriers within the river system.
Developing Technologies	Technologies and methodologies currently being investigated that show promise in deterring invasive carp or increases harvest efficiency which are not currently approved for use in the field by the applicable regulatory agencies.

Appendix A: Barrier Maintenance Fish Suppression

Attachment 4: Authorities

Key authorities linked to response actions are listed below. List may not include all Federal, State, and local authorities tied to ongoing operation and maintenance activities.

Illinois - other Illinois agencies authorities may apply e.g., Illinois Environmental Protection Agency (Illinois EPA), ILDOA but key ILDNR authorities below

ILDNR (from Illinois Compiled Statutes http://www.ilga.gov/legislation/ilcs/ilcs.asp)

20 ILCS 801/1-15; 20 ILCS 805/805-100; 515 ILCS 5/1-135; 515 ILCS 5/10-80

Illinois Administrative Rules (17 ILCS Part 890 Fish Removal with Chemicals)

Section 890.30 Treatment of the Water Area

Authority for 17 ILCS Part 890 Fish Removal with Chemicals (found in statute below):

515 ILCS 5/1-135

515 ILCS 5/1-150

ARTICLE 5. FISH PROTECTION

515 ILCS 5/5-5

USACE

Water Resources Development Act of 2007 Section 3061(b) - Chicago Sanitary and Ship Canal Dispersal Barriers Project, Illinois; Authorization.

Water Resources Reform and Development Act of 2014. Section 1039(c) – Invasive Species; Prevention, Great Lakes and Mississippi River Basin.

USFWS

H.R. 3080 Water Resources Reform and Development Act of 2014

Fish and Wildlife Coordination Act (16 U.S.C. 661-667e; the Act of March 10, 1934; Ch. 55; 48 Stat. 401), as amended by the Act of June 24, 1936, Ch. 764, 49 Stat. 913; the Act of August 14, 1946, Ch. 965, 60 Stat. 1080; the Act of August 5, 1947, Ch. 489, 61 Stat. 770; the Act of May 19, 1948, Ch. 310, 62 Stat. 240; P.L. 325, October 6, 1949, 63 Stat. 708; P.L. 85-624, August 12, 1958, 72 Stat. 563; and P.L. 89-72, 79 Stat. 216, July 9, 1965.

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990

Lacey Act (16 U.S.C. §§ 3371–3378)

Executive Order 13112 of February 3, 1999 - Invasive Species

H.R.223 - Great Lakes Restoration Initiative Act of 2016

Appendix A: Zooplankton as Dynamic Assessment Targets for Invasive Carp Removal

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Participating Agencies: INHS (lead), SIU (lab support)

Pools Involved: Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, and LaGrange Pool and adjacent backwater lakes

Introduction and Need:

Due to their ability to efficiently filter large volumes of water and capture small particle sizes, Bighead Carp and Silver Carp (collectively bigheaded carp) can deplete zooplankton densities and alter zooplankton community composition (Sass et al. 2014; DeBoer et al. 2018), 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; Kramer et al. 2019). The trophic impact of bigheaded 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 (Carpenter et al. 1985; Cushing 1990; Sampson et al. 2009). In the Illinois River, densities of large-bodied crustacean zooplankton have been substantially reduced since the establishment of bigheaded carp (Sass et al. 2014; DeBoer et al. 2018). An aggressive invasive carp removal program has been implemented in the upper navigation pools of the IWW to limit further advances of bigheaded carp towards Lake Michigan (Tsehaye et al. 2013; MacNamara et al. 2016; Love et al. 2018). One challenge with the removal program has been assessing whether or not removals have caused ecologically meaningful changes in bigheaded carp abundance. In addition to preventing the expansion of bigheaded carp into the Great Lakes, this removal program may also benefit native fish assemblages in the IWW by mitigating some of the ecological impacts that bigheaded carp have had on this system. However, the extent and pace of ecosystem responses to such removals are uncertain. Zooplankton are known to be a rapid index of ecosystem response, as most riverine zooplankton taxa have relatively short generation times and high productivity rates. Additionally, zooplankton are distributed throughout the IWW and are a critical food web component for larval and adult native fishes, making them ideal performance metrics for assessing the effectiveness of bigheaded carp control efforts. This project will investigate whether zooplankton-based assessment metrics can be used to quantitatively evaluate the extent to which the removal strategy is working to reverse ecosystem impacts from bigheaded carp in the IWW. This work will help inform management agencies regarding ecosystem responses to bigheaded carp removals and define ecosystem-based benchmarks for bigheaded carp control efforts.

Objectives: Zooplankton are being sampled throughout the IWW to:

(1) Quantify zooplankton density, body size distribution, biomass, and community composition in the IWW;

(2) Assess the sensitivity of a range of zooplankton taxa to bigheaded carp density; and

(3) Use sensitive zooplankton taxa to develop benchmarks for evaluating the outcome of bigheaded carp control and removal efforts.

Project Highlights:

- A total of 131 zooplankton samples were collected from the IWW during 2021. 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 IWW and used to evaluate the effects of invasive carp planktivory on zooplankton metrics and understand the ecosystem responses to invasive carp harvest efforts.
- Previous analyses examined the influence of invasive carp density on average June densities of a variety of zooplankton taxa. New evaluations examined peak annual densities of *Bosmina* sp., cyclopoid copepods, and *Trichocerca* sp. as potential assessment metrics. Of these three taxa, only peak density of *Bosmina* sp. was found to be sufficiently sensitive to invasive carp densities, with densities of *Bosmina* sp. negatively related to invasive carp density. The most supported model included both annual peaks in chlorophyll *a* concentration and annual estimates of invasive carp density as predictors of peak *Bosmina* density.
- The model of peak *Bosmina* density was used to assess whether invasive carp densities within individual navigation pools during the 2012 – 2019 assessment period were reduced to a level that could result in a measurable impact on the indicator species. Based on the *Bosmina* performance metric, there was no evidence of reduced invasive carp impact in the LaGrange and Peoria pools until 2019. The Starved Rock Pool showed evidence of diminished impact from invasive carp in the latter four years of the assessment. Marseilles Pool invasive carp densities were sufficiently low to meet management targets for diminished impact on zooplankton in every year of the assessment period.

Methods:

Field sampling for assessment of zooplankton trends took place biweekly from May to September of 2021 at established sites to maintain consistency and data comparability with previous years. 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 (macrozooplankton) and 10 L of water was filtered through a 20 μm mesh to obtain microzooplankton (rotifers and copepod nauplii). 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 *α* concentration, 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 microscope-mounted camera and measurement software. 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. Estimates of invasive carp density in each navigation pool were obtained from annual hydroacoustic surveys onducted by Southern Illinois University – Carbondale.

Appendix A: Zooplankton as Dynamic Assessment Targets For Invasive Carp Removal

Whereas previous analyses examined average June densities of a variety of zooplankton taxa, new evaluations examined peak densities of *Bosmina* species, cyclopoid copepods, and *Trichocerca* species as potential assessment metrics of bigheaded carp impacts. These taxa were selected because of their numerical importance in main-channel river environments (Wahl et al. 2008; Chick et al. 2010; Burdis and Hoxmeier 2011; Chara-Serna and Casper 2021). Analyses used annual peak densities occurring during May – September periods from 2012 – 2019 at monitoring sites representative of the Dresden Island (Channahon), Marseilles (Morris), Starved Rock (Ottawa), Peoria (Henry), and LaGrange (Havana) navigation pools. Reliable invasive 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 during peak zooplankton densities and annual peaks in chlorophyll *α* concentration were investigated as potentially important environmental sources of variation. Discharge data for sites in the upper IWW were obtained from USACE gages located at the Brandon Road, Dresden Island, and Marseilles lock and dams. Discharge measured at the USGS gage at Henry (USGS 5558300) was applied to Peoria Pool observations and data from the USGS gage at Kingston Mines (USGS 5568500) were used for LaGrange Pool flow rates.

A reduced maximum likelihood approach was used to model annual peak density of each indicator taxa within the five navigation pools as a function of peak chlorophyll *α* concentration, discharge during peak zooplankton density, and pool-scale estimates of invasive carp density. Repeated measures models with sampling station as the repeatedly sampled unit and compound symmetric covariance structure were used. Discharge during peak *Bosmina* sp. density was correlated with invasive carp density ($r = +0.53$, $P = 0.002$), and so to avoid collinearity issues in the analyses, these two variables were not included together in any models. Invasive carp density was not correlated with discharge during peak density of either cyclopoid copepods or *Trichocerca* rotifers ($P \geq 0.17$) and so the combination of these two factors were included in these model sets. Akaike's information criteria corrected for small sample bias (AIC_c; Anderson 2008) was used as the basis for 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. Models that included invasive carp density and were the most supported by observed zooplankton densities were next used to assess whether or not invasive carp densities have been reduced to a level where their impacts are diminished to target levels within individual navigation pools.

The assessment procedure compares residuals from model-based predictions under observed (i.e., actual invasive carp densities) and target conditions (i.e., reduced invasive carp densities). Control intervals (i.e., residuals ± 1.5 standard error calculated from predicted zooplankton densities based on observed environmental and invasive carp values) represent the uncertainty typically associated with predictions based on simple ecological models. If the target variance (i.e., residuals ± 1.5 standard error calculated from model-based predictions based on target invasive carp densities) falls outside the control interval, then the management goal of reducing the planktivorous effects of bigheaded carp can be interpreted as having not been met (Trexler and Goss 2009). If target-based variance overlaps the control interval, then bigheaded carp density can be interpreted to be sufficiently reduced to mitigate their ecosystem effects. For this initial assessment, the smallest invasive carp density observed during the 2012 – 2019 assessment period (0.003 invasive carp/1000 m^3; 2019 estimate from Dresden Island Pool) was used as the management target because it is both a desirably low density and does not project model predictions beyond the range of invasive carp densities used to parameterize the models. Assessments were only conducted for navigation pool-year combinations that contained all of the information required by the assessment model.

Results and Discussion:

During 2021, a total of 131 zooplankton samples were collected from the IWW. Sample processing is ongoing. The data derived from these samples, and associated water chemistry data, will be integrated into the long-term data set of zooplankton assemblages in the IWW. Data collected through 2019 were incorporated into the updated assessment analyses. Invasive carp densities varied within and among years, thereby providing the variation needed to test for zooplankton responses (Figure 1).

Among the three zooplankton taxa categories evaluated, only peak density of *Bosmina* sp. was found to be sufficiently sensitive to invasive carp densities (Table 1). For cyclopoids, the most supported model in the comparison set did include annual estimates of invasive carp density, along with annual peaks in chlorophyll *a* concentration; however, the overall support for and variation explained by this model was low (Table 1). None of the models of peak *Trichocerca* density that included invasive carp density had strong support from the data (Table 1). Unlike the copepod and rotifer models, a relationship between invasive carp density and peak density of the cladoceran *Bosmina* was supported by the data. The most supported model included both annual peaks in chlorophyll *a* concentration and annual estimates of invasive carp density within navigation pools (Table 1). Densities of *Bosmina* sp. appeared to be negatively related to invasive carp density (Figure 2). Based on these results, we used peak density of *Bosmina* sp. as an indicator of invasive carp impact.

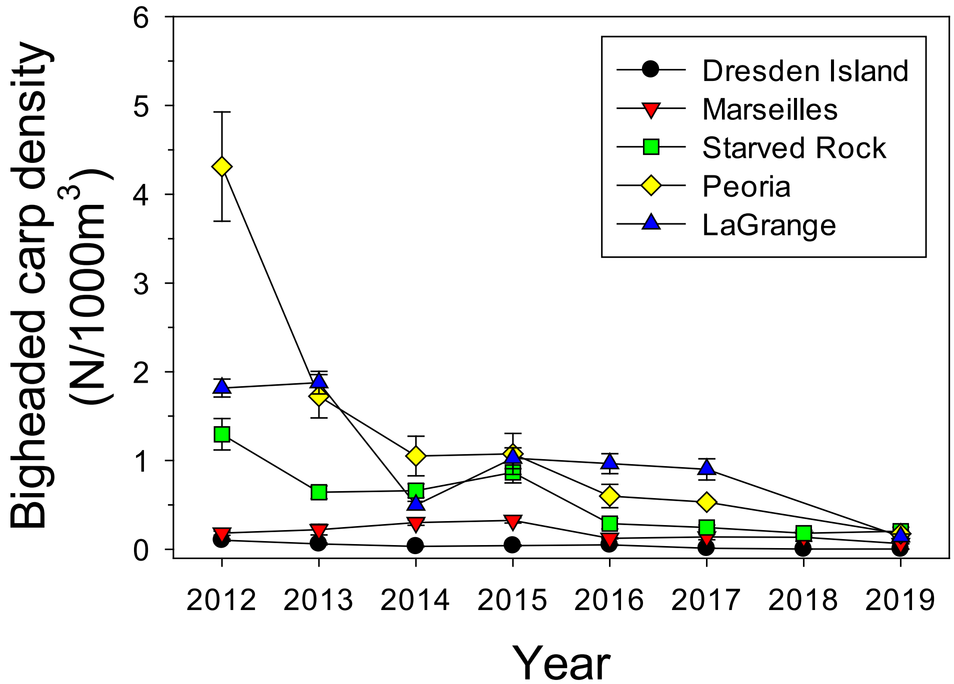

Figure 1. *Annual estimates of bigheaded carp density (number / 1000 m^3) within five navigation pools of the IWW.. Estimates are derived from October hydroacoustic surveys and represent the combined density of bigheaded carp species (Silver Carp + Bighead Carp). Density estimates for Peoria and LaGrange Pools were not available for 2018.*

The most supported model was used to predict values of the indicator metric (peak *Bosmina* density) for the Marseilles, Starved Rock, Peoria, and LaGrange Pools based on observed values of chlorophyll *a* concentration and both observed and target (i.e., 0.003 individuals/1000 m^3) densities of invasive carp. Because of missing values for either chlorophyll *a* concentration or invasive carp density, only six years were assessed for ecosystem response in the Starved Rock Pool and five years for the Peoria and LaGrange navigation pools. These pools in the lower Illinois River generally contained high densities of invasive carp during all but one year (2019) of the assessment period (Figure 1), and based on the *Bosmina* performance metric, 2019 was the only year when the target of reduced invasive carp impact was met within these pools (Figure 3). Starved Rock Pool, with the next highest density of invasive carp, showed evidence of diminished impact from invasive carp in the latter four years of the assessment (Figure 3), generally matching the decline in invasive carp abundance measured during the hydroacoustic surveys (Figure 1). Based on the *Bosmina* performance metric, Marseilles Pool densities of invasive carp were sufficiently low to meet management targets for diminished impact on zooplankton in every year of the assessment period (Figure 3).

Appendix A: Zooplankton as Dynamic Assessment Targets For Invasive Carp Removal

Table 1. *Relative support for models of zooplankton performance metrics, including a null model that only includes an intercept variable. Models are ranked by relative support within the considered model set based on AIC scores corrected for small sample size (AIC_c). Relative model support is represented by 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), and model weight (w_i). Adjusted R^2 reports the amount of variance explained by the most supported model. Investigated performance metrics were annual peak densities of Bosmina sp., cyclopoid copepods, and Trichocerca sp. Explanatory variables considered were annual peak values of chlorophyll a concentration, flow (cfs) during peak zooplankton density observations, and annual estimates of invasive carp density. Global models included all explanatory variables.*

Response	Model	AIC_c	Δ	w_i	R^2
Peak *Bosmina* density	intercept	117.5	9.1	0.008	
	Peak chlorophyll *a*	113.1	4.7	0.07	
	Flow during zoop peak	117.2	8.8	0.009	
	Invasive carp density	111.2	2.8	0.181	
	Chlorophyll + carp density	108.4	0	0.733	0.48
Peak cyclopoid density	intercept	90	5.2	0.034	
	Peak chlorophyll *a*	87.7	2.9	0.108	
	Flow during zoop peak	89.8	5	0.038	
	Invasive carp density	88.5	3.7	0.073	
	Flow + carp density	88.6	3.8	0.069	
	global	86.3	1.5	0.218	
	Chlorophyll + carp density	84.8	0	0.461	0.20
Peak *Trichocerca* density	intercept	66.5	1	0.136	
	Peak chlorophyll *a*	65.6	0.1	0.213	
	Flow during zoop peak	65.7	0.2	0.203	
	Invasive carp density	67.8	2.3	0.071	
	Flow + carp density	67.9	2.4	0.067	
	Chlorophyll + carp density	67.4	1.9	0.087	
	global	65.5	0	0.224	

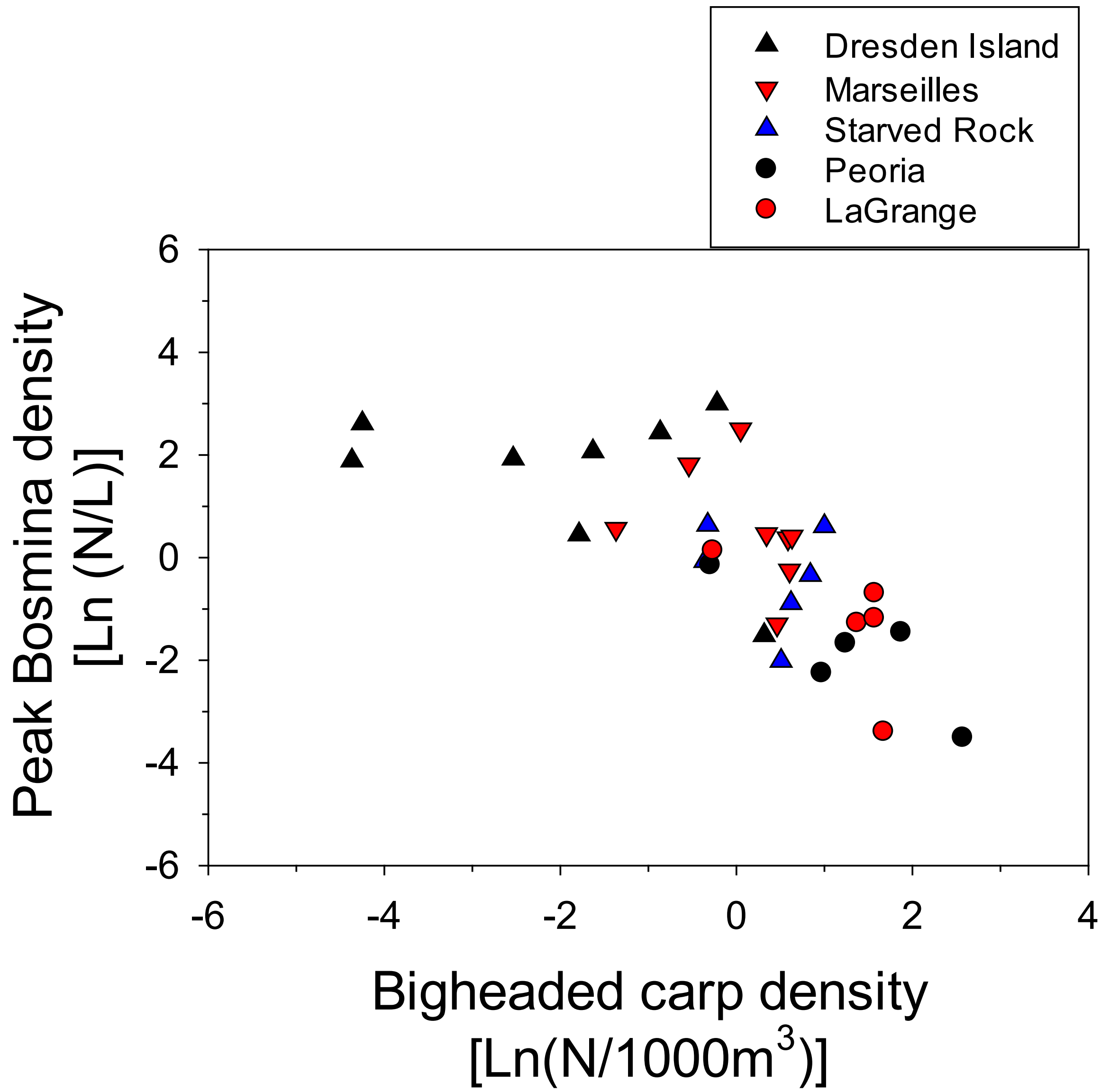

Figure 2. *Partial residuals plot of peak Bosmina sp. density versus bigheaded carp (Silver Carp + Bighead Carp) density in five navigation pools (Dresden Island, Marseilles, Starved Rock, Peoria, and LaGrange) of the Illinois River over the period 2012 – 2019. Partial residuals were calculated by accounting for variation associated with annual values of peak chlorophyll a concentration. Circles are lower Illinois River locations and triangles are upper Illinois River sites.*

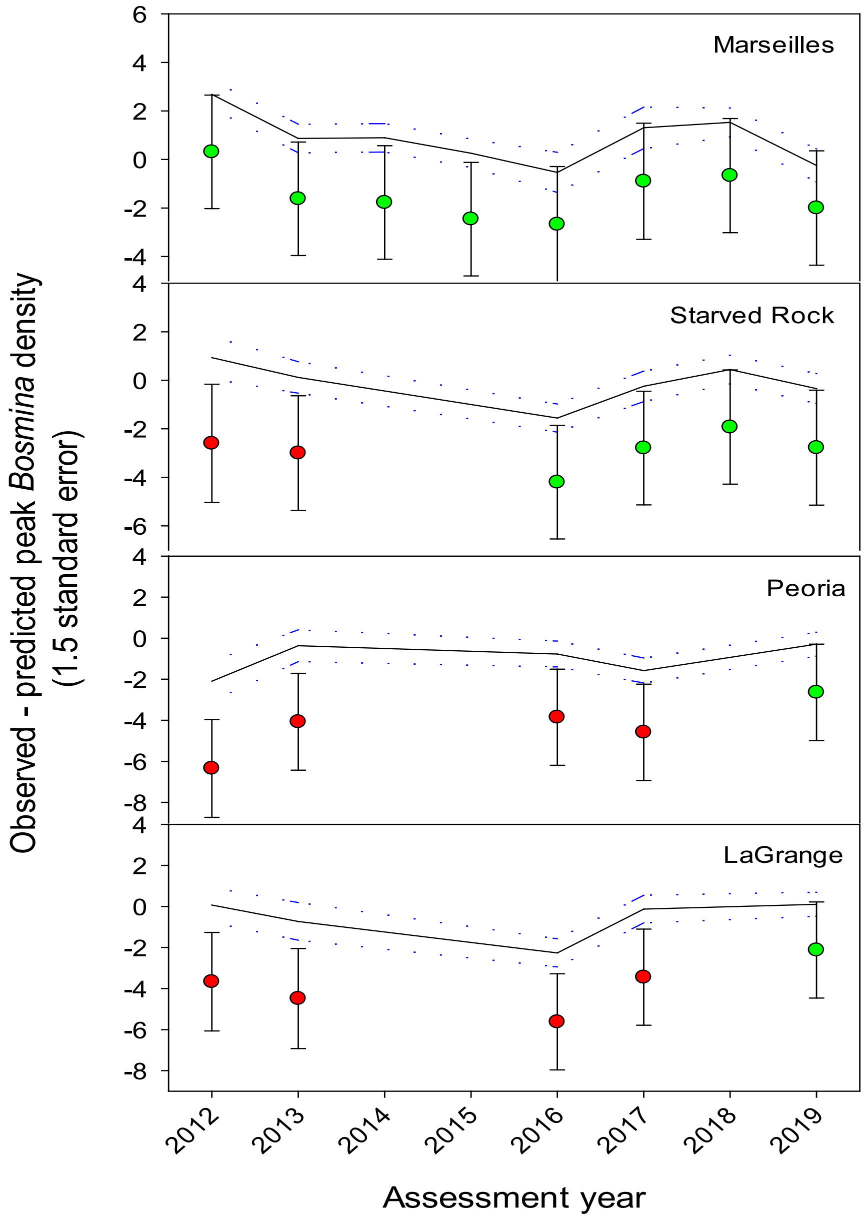

Figure 3. *Assessment plots for navigation pools during the 2012 – 2019 assessment period. Residuals from model predictions based on observed environmental conditions are the control intervals and plotted as solid black lines with ± 1.5 standard error (dashed blue lines). Performance metric residuals from model predictions using target invasive carp densities are plotted as red and green circles with ± 1.5 standard error. When target variance is outside of control intervals, the assessment point is red and considered to be a year when the management target was not achieved. When target variance overlaps the control interval, the point is green and the management target of diminished ecosystem impact was considered to be achieved.*

Different zooplankton taxa may be expected to vary in their apparent sensitivity to invasive carp density due to size-dependent vulnerability to planktivory, life history characteristics, and sensitivity to both biotic and abiotic factors. Previous analyses have indicated considerable spatiotemporal variation in zooplankton assemblage composition, density, and biomass within the IWW, likely driven by seasonal environmental variation and spatial differences in temperature, water chemistry, and hydrology, as well as varying invasive carp densities. Assessment results based on use of peak *Bosmina* density as a performance metric generally reflected measured changes in invasive carp density. Notably, although the 2019 estimates of invasive carp density in the Peoria and LaGrange pools had higher uncertainty than usual because of high discharge and river stage during hydroacoustic surveys, the assessment analysis provided another line of evidence that invasive carp densities were in fact low compared to other years. The relative sensitivity of other zooplankton taxa to invasive carp density matched results from our previously reported analyses in that *Bosmina*, but not any of the copepod or rotifer taxa examined, was an informative performance metric. *Bosmina* are among one of the more common macrozooplankton taxa found in large rivers (Wahl et al. 2008; Burdis and Hoxmeier 2011) and the observed relationship between peak *Bosmina* density and invasive carp density is consistent with previous observations of a negative association between cladoceran abundances and invasive carp (Sass et al. 2014; DeBoer et al. 2018). Therefore, this group shows great promise as a performance indicator that is easily sampled and will likely be responsive to declines in invasive carp abundance. However, a previous assessment using Chydorid densities as a potential performance metric did not appear to show a similar response, indicating that bigheaded carp planktivory does not affect all cladoceran taxa similarly. Most previous studies of bigheaded carp effects on zooplankton have lumped different zooplankton taxa into broad taxonomic groups (e.g., Cladocera, copepods, rotifers, etc.), but individual taxa may respond very differently to bigheaded carp abundance as well as environmental factors. Ideally, a full assessment would include multiple performance metrics in order to have reinforcing lines of evidence.

Recommendations:

Continued monitoring and analyses of zooplankton data from the IWW 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 invasive carp densities in different pools of the IWW. Future analyses should expand these investigations to additional performance metrics (peak and monthly abundances of multiple zooplankton taxa) to identify which metrics prove most informative for assessing the impact of invasive carp removals. The most informative performance metrics will then be modelled using observed environmental conditions and invasive carp densities in each pool to calculate the difference between observed and expected values of each metric. Additional factors may also be desirable to add to performance metric models to reduce dispersion around model predictions. For example, the inclusion of the annual abundances of native planktivores, such as Gizzard Shad (*Dorosoma cepedianum*), may reduce some of the variation not explained by a model. Future analyses may also benefit from inclusion of other management targets for invasive carp density that are still within the predictive power of the models. Performance metrics that appear to offer high predictive power will then be modelled using observed environmental conditions to predict what the target metric value would be if invasive carp had been reduced to a specific density, and the difference between the target predictions and observed metric values will be compared to the residuals obtained from the model that used observed invasive carp density. If the target interval (i.e. goal invasive carp density prediction residuals ± 1.5 SE) overlaps the limits based on the observed carp density, invasive carp removal at this site would be concluded to have met the management target for zooplankton recovery. Changes in invasive 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 invasive 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 bigheaded 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).

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