INTERIM SUMMARY REPORT

Invasive Carp Monitoring and Response Plan

2022

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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 furthering the understanding of invasive carp location, population dynamics, behavior, and the efficacy of control and capture methods. The MRWG has also completed a companion document, the 2023 Invasive Carp Monitoring and Response Plan (MRP). Each individual summary report outlines the results of work that took place in 2022 and provides recommendations for the next steps for each project.

The 2022 results for 21 projects are included in this ISR. These summary reports document the purpose, objectives, and methods for each 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 the 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 invasive carp population status changes, test these procedures through exercises, and implement if necessary.

A summary of project highlights is presented below, intended to provide a brief snapshot of project accomplishments during 2022.

HIGHLIGHTS OF 2022 EFFORTS

Detection Projects

- Completed two 2-week Seasonal Intensive Monitoring (SIM) events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier System (EDBS) in 2022; no live Silver Carp or Bighead Carp were captured or observed in SIM 2022.
- One dead Silver Carp was observed on the banks of the Calumet River during spring SIM on May 24, 2022. Subsequent sampling did not find any additional Bighead Carp or Silver Carp, alive or dead.
- United States Fish and Wildlife Service (USFWS) staff collected 1,100 eDNA samples

upstream of the EDBS; positive detections were few and consistent with previous sampling years.

- To date, the United States Army Corps of Engineers (USACE) has acquired 41.4 million detections from 787 tagged fish.
- No known live tagged fish have crossed the EDBS in the upstream direction.
- Invasive carp continue to be detected throughout the Dresden Island Pool, with most detections occurring near the Dresden Island Lock and Dam.
- Five real-time receivers were maintained in the Upper Illinois Waterway (IWW) in 2022.
- Mobile hydroacoustic surveys completed in May and June 2022 detected high abundances of large fish targets within the EDBS compared to historical data.
- Large fish densities in mobile hydroacoustic surveys conducted in Lockport, Brandon Road, and Dresden Island pools in 2022 were generally low and similar to past years, except for above-average large fish densities in Brandon Road Pool in November and December 2022.
- No small-bodied Silver Carp or Bighead Carp were captured in Lockport, Brandon Road, Dresden Island, or Marseilles pools.
- No large-bodied Silver Carp or Bighead Carp were captured or observed upstream of Brandon Road Lock and Dam.
- In 2022, 174 large-bodied Silver Carp and 8 large-bodied Grass Carp were captured and removed in Dresden Island Pool, the lower Kankakee River, and Marseilles Pool.
- From May to September 2022, 408 ichthyoplankton samples were collected from seven sites from the Brandon Road to LaGrange navigation pools of the IWW, capturing 1,112 large-diameter eggs and nine invasive carp larvae.
- In 2022, 288 ichthyoplankton samples collected from Illinois River tributaries captured large-diameter eggs from the Spoon River and invasive carp larvae from the Sangamon River but found no evidence of invasive carp reproduction in other Illinois tributaries.
- No Bighead Carp or Silver Carp have been captured or observed across all years of sampling in the Des Plaines River.
- Two Bighead Carp were removed from Humboldt Park in 2022. After the removal, that pond tested negative for invasive carp environmental DNA (eDNA).
- The leading edge of the Bighead Carp and Silver Carp populations remained around river mile 281 (north of I-55 Bridge within the Dresden Island Pool near the Rock Run Rookery) in 2022.

Management and Control Projects

- From 2010 to 2022, 104,349 Bighead Carp, 1,327,020 Silver Carp, and 11,473 Grass Carp were removed by contracted fishers. The total estimated weight of invasive carp removed is 5,805 tons (12,798,193 pounds).
- USFWS conducted 20 hydroacoustic scans within the barrier in 2022.
- Developed a per-capita contribution model that included various barrier scenarios to determine how the location and effectiveness of barriers impacted invasive carp populations. The model is currently under review by coauthors prior to review by the MRWG co-chairs and USGS.
- In November 2022, 150 V-9 acoustic transmitters were implanted into invasive carp – 75 transmitters were strategically spread across Peoria Pool, and 75 were placed in the center of Starved Rock Pool.
- Collected over 14,000 Silver Carp and processed nearly 3,000 lapilli otolith aging structures from six pools of the Illinois River from 2018 to 2022.
- Sampling in the Starved Rock Pool detected 13 and 41 small (less than 200 millimeters) Silver Carp in fall 2021 and spring 2022, respectively. No sub-stock Silver Carp or fish marginally larger were detected during fall 2022 sampling.
- USFWS, USACE, and USGS completed full-scale experimental testing of the ABC Deterrent at Peoria Lock and Dam.
- The Invasive Species Unit (ISU) arrested an individual offering to sell aquarium rocks and live zebra mussels for a $45 “rehoming fee” on Craigslist. Additionally, a non-resident fish hauler who, for profit, illegally imported and stocked live channel catfish into Illinois on multiple occasions pled guilty in court to one count of importing live channel catfish into Illinois without an IL DNR permit.
- Removed more than 5.2 million pounds under the Enhanced Contract Removal program from the Peoria, LaGrange, and Alton pools of the Illinois River in 2022.
- Launched the Copi brand successfully, garnering national and international media attention.

Response Projects

- On July 30, 2022, a member of the public reported the sighting of an invasive carp in Lake Calumet. Based on the credibility of the report, IL DNR and USACE responded to the area with a reconnaissance team of electrofishing boats and contract fishers on August 3, 2022.
- On August 4, 2022, an adult Silver Carp was found and collected by gill netting and electrofishing crews from the IL DNR and the USACE. The capture triggered the ICRCC's CRP
- No Bighead Carp, Black Carp, or Silver Carp were observed or collected during the removal response.
- Four Grass Carp were collected and removed.

INTRODUCTION

The 2022 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 2022. 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 10 years. Over the course of this time, goals, objectives, and strategic approaches have been refined to focus on five key objectives:

(1) Determining the distribution and abundance of any invasive carp in the CAWS and using this information to inform response removal actions;

(2) Removing any invasive carp found in the CAWS to the maximum extent practicable;

(3) Identifying, assessing, and reacting to any vulnerability in the current system of barriers to prevent invasive carp from moving into the CAWS;

(4) Determining the leading edge of major invasive carp populations in the Illinois River and the reproductive successes of those populations; and

(5) Improving 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 2022 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 a 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 U.S. for use in aquaculture and wastewater treatment detention ponds. In these settings, invasive carp were used to control the growth of weeds, 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 widespread 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 startled Silver Carp 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

To depict the geospatial scale and focus of the projects included in the Monitoring and Response Plan (MRP), the MRWG has prepared a project location crosswalk. This crosswalk is intended to be used as a tool to allow readers to quickly understand where a specific project focuses its efforts and quickly discern all projects that are operating in a specific portion of the Illinois Waterway (IWW). The project crosswalk 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 crosswalk 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			
										Detection	6	ILDNR
CAWS eDNA Sampling										Detection	20	USFWS
Telemetry Monitoring Plan										Detection	30	USACE
USGS Telemetry Project										Detection	46	USGS
USGS Invasive Carp Database Management and Integration Support										Management and Control	119	USGS
Illinois Waterway Hydroacoustics										Detection	51	USFWS, Carterville FWCO, Wilmington Substation
Early Detection of Bighead Carp in the Illinois Waterway										Detection	59	USFWS, Carterville FWCO, Wilmington Substation
Contracted Commercial Fishing Below the Electric Dispersal Barrier										Management and Control	123	ILDNR, INHS
Upper Illinois Waterway Contingency Response Plan										Response	205	ILDNR, USFWS, USACE, USGS, INHS, GLFC, MWRDGC
Multiple Agency Monitoring of the Illinois River for Decision Making										Detection	108	ILDNR, INHS
Larval Fish Monitoring in the Illinois Waterway										Detection	72	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										Detection	86	SIU
Invasive Carp Population Modeling to Support an Adaptive Management Framework										Management and Control	137	USFWS Carterville FWCO
Invasive Carp Demographics										Management and Control	170	USFWS Carterville FWCO and USGS Upper Midwest Environmental Sciences Center
Telemetry Support for the Spatially Explicit Invasive Carp Population Model (SEICarP)										Management and Control	166	USFWS Carterville FWCO
Invasive Carp Enhanced Contract Removal Program										Management and Control	202	ILDNR
Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation										Management and Control	190	USFWS Carterville FWCO
Des Plaines River and Overflow Monitoring										Detection	91	USFWS Carterville FWCO
Alternative Pathway Surveillance – Urban Pond Monitoring										Detection	100	ILDNR
Alternative Pathway Surveillance in Illinois – Law Enforcement										Management and Control	199	ILDNR

DETECTION PROJECTS

SEASONAL INTENSIVE MONITORING IN THE CAWS

Participating Agencies: IL DNR (lead); INHS, USFWS, USACE, and SIU (field support); USCG (waterway closures when needed); USGS (flow monitoring when needed); MWRDGC (waterway flow management and access); USEPA and GLFC (project support); Madison Myers, Allison Lenaerts, Andrew Wieland, MJ Oubre (INHS); Claire Snyder, Justin Widloe, Eli Lampo, Nathan Lederman, Charmayne Anderson, Mindy Barnett, Brian Schoenung (ILDNR)

Pools Involved: CAWS

INTRODUCTION AND NEED

In 2009, detections of Silver Carp and Bighead Carp eDNA upstream of the EDBS 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 collected in Lake Calumet in 2010. Fixed site and random area sampling efforts were then reduced upstream of the barrier to two SIM events from 2014 through 2022. 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 efforts 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 toward the EDBS and Lake Michigan by way of the CAWS. Results from SIM upstream of the EDBS 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

- Determine invasive carp population abundance through intense random and targeted sampling efforts at locations deemed likely to hold fish.
- Remove invasive carp from the CAWS upstream of the EDBS when warranted.

PROJECT HIGHLIGHTS

- Completed two 2-week SIM events with conventional gears in the CAWS upstream of the EDBS in 2022.
- No live Silver Carp or Bighead Carp were captured or observed in SIM 2022. One live Bighead Carp was captured in Lake Calumet in 2010, and one live Silver Carp was

captured in the Little Calumet River in 2017, with no other captures or observations in any other previous years. One live Silver Carp was captured in Lake Calumet on August 4, 2022, outside of SIM sampling. For more information on this capture and the subsequent response, please see the Response Projects section of the ISR.

- One dead Silver Carp was observed on the banks of the Calumet River during spring SIM on May 24, 2022. Subsequent sampling did not find any additional Bighead Carp or Silver Carp, alive or dead.
- An estimated 3,176 person-hours were spent completing 148 hours of electrofishing and setting 157.7 kilometers (98 miles) of gill net and 2.9 kilometers (1.8 miles) of commercial seine in 2022.
- Across all locations and gears, 37,036 fish were sampled, representing 65 species and three hybrid groups in 2022.
- An estimated 41,718 person-hours have been spent completing 1,605.3 hours of electrofishing and setting 1,596.5 kilometers (992 miles) of gill/trammel net, 25.7 kilometers (16 miles) of commercial seine, and 114.2 net nights of tandem trap nets, hoop nets, fyke nets, and pound nets since 2010.
- From 2010 to 2022, a total of 550,706 fish representing 89 species and 9 hybrid groups were sampled.
- YOY Gizzard Shad (*n*=134,136) were examined, and no YOY invasive carp were found when sampling from 2010 to 2022.
- Non-native species (*n*=16) have been captured, accounting for 15 percent of the total number of fish caught and 19 percent of the total species since 2010.

METHODS

Pulsed DC-electrofishing, gill nets, and a commercial seine were used to monitor invasive carp in the CAWS upstream of the EDBS (Figure 1). Trammel nets, deep water gill nets, fyke nets, and pound nets were also used in previous years. 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 2022 MRP. Decontamination protocols for pulsed-DC electrofishing and netting can also be found in the 2022 MRP.

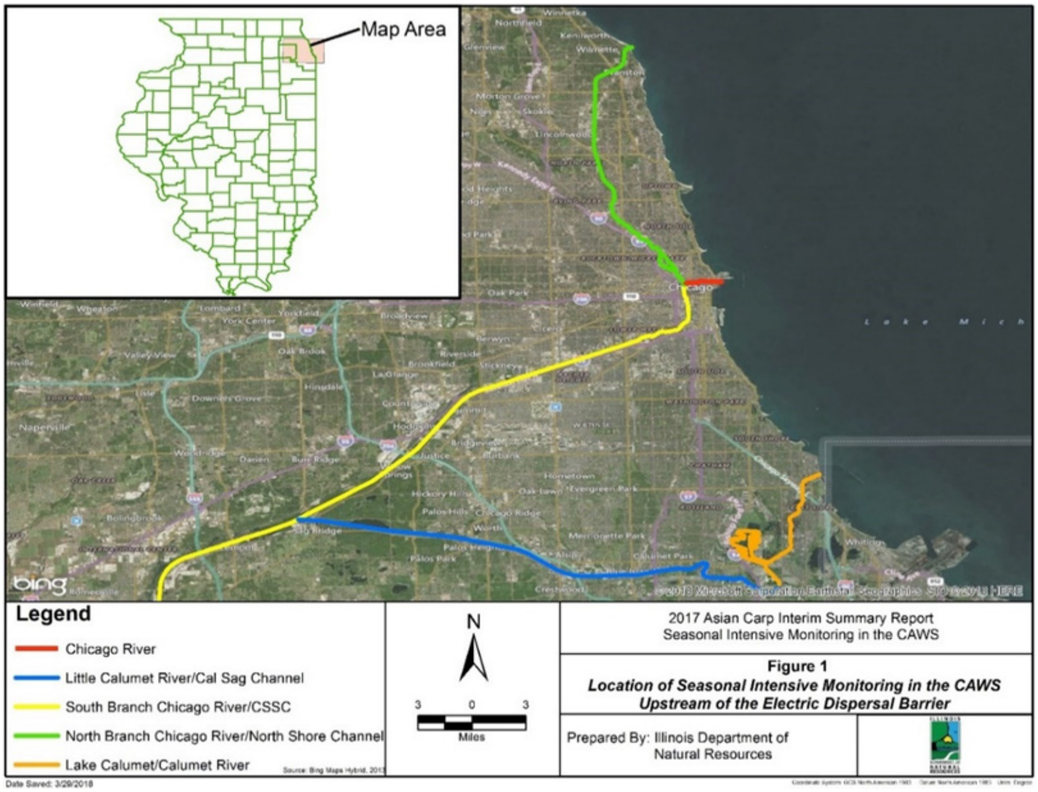


Figure 1. *Location of SIM in the CAWS upstream of the Electric Dispersal Barrier.*

RESULTS AND DISCUSSION

2022 SIM sampling took place from May 16 to 26 and October 3 to 14, for a total of 19 sampling days. Sampling in 2021 also took place in May and October. From 2014 through 2020, sampling events were conducted in June and September. To continually focus monitoring efforts on the leading edge of the invasive carp population below the EDBS, the same reduced sampling effort protocols established in 2014 upstream of the barrier were followed in 2022 (Figure 2). Sampling events in the spring and fall were both preceded by eDNA monitoring (see “Strategy for eDNA Sampling in the CAWS” report in this ISR for more information on protocols and results). Effort in 2022 was 148 hours of electrofishing (620 transects) requiring an estimated 1,260 person-hours, 157.7 kilometers (98 miles) of gill netting (860 sets) utilizing an estimated 1,588 person-hours, and 2.9 kilometers (1.8 miles) of commercial seine with an estimated 328 person-hours (Table 1).

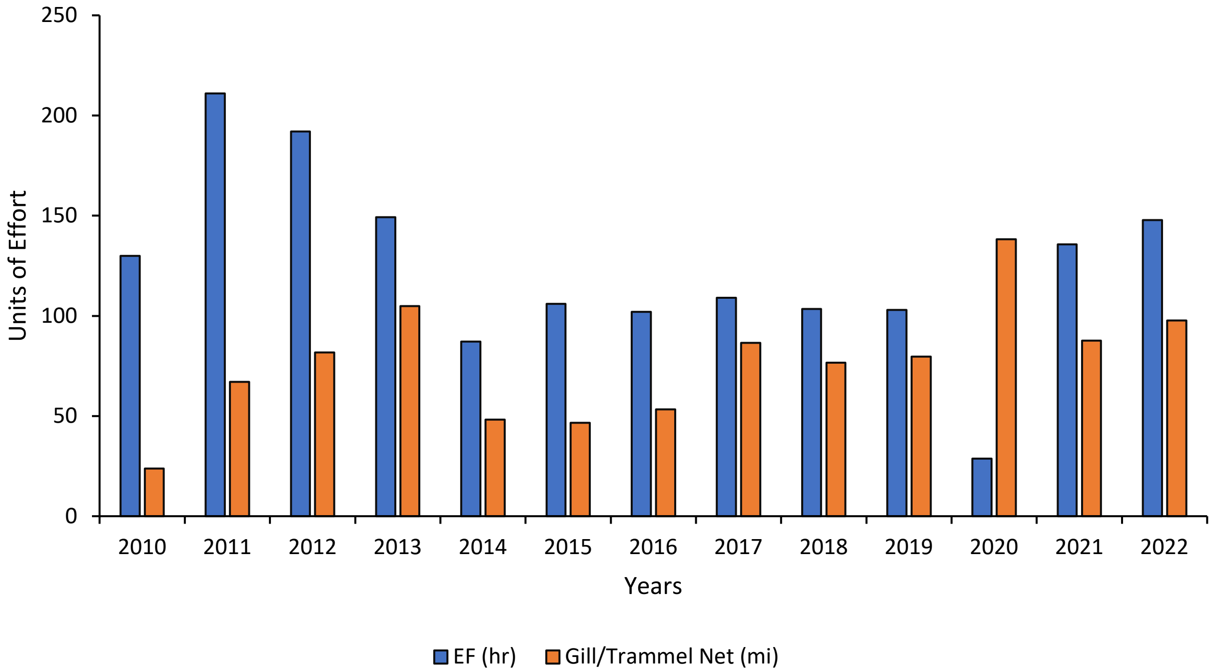


Figure 2. *Total electrofishing and trammel/gill netting effort at fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier System, 2010-2022.*

Across all locations and gears, 37,034 fish representing 65 species and three hybrid groups were sampled in 2022 (Table 2). Gizzard Shad, Bluntnose Minnow, Common Carp, and Largemouth Bass were the predominant species, comprising 61 percent of all fish sampled. Twelve non-native species were sampled, which included Common Carp and hybrids (Common Carp x Goldfish), Round Goby, Alewife, Goldfish, White Perch, Oriental Weatherfish, Grass Carp, Tilapia, Chinook Salmon, Coho Salmon, Brown Trout, and Rainbow Trout. Non-native species made up 13.8 percent of the total species collected and 10.7 percent of the total fish by count in 2022. In addition, 2,688 YOY Gizzard Shad were examined, and none were found to be YOY invasive carp. No live Bighead Carp or Silver Carp were captured or observed.

During spring SIM sampling, a single dead Silver Carp was observed on the banks of the Calumet River during an electrofishing run on May 24, 2022, approximately 3.7 miles from Lake Michigan (41.68852, -87.55290). The fish was 672 millimeters long, and the poor condition of the carcass precluded an accurate weight from being taken. Daily sampling effort was intensified greater than what was outlined in the IAP and MRP following the dead Silver Carp collection. Additional efforts focused on Lake Calumet and the Calumet River. No additional evidence of invasive carp, live or dead, were found during 12.5 extra hours of electrofishing.

Figure 3. *Image of the dead Silver Carp collected on May 24, 2022 in the Calumet River. The adult carp is washed up on shore in an advanced state of decomposition.*

Otoliths were extracted from the dead Silver Carp for microchemistry analysis, which assesses concentrations of elements and isotopes within hard structures to identify where it has been. The analysis indicated the fish was born in an area consistent with the water chemistry of the Illinois River. The middle of the carp's life history indicated use of the Des Plaines River. The edge of the otolith, indicating the carp's most recent recorded life history, showed barium:calcium ratios inconsistent with the use of the CAWS, the Illinois section of Lake Michigan, the Des Plaines River, Illinois River, or most Illinois River tributaries, suggesting the potential use of the Lower Fox River. There were no CAWS or Des Plaines River signatures evident at the otolith edge, indicating this fish had not been in these locations long enough to accrue sufficient otolith growth reflective of those areas to be detected. Thus, it appears that this fish may have been a relatively recent arrival to the CAWS (probably within 6 months before it was found dead under the assumption that otolith growth distal to the last annulus primarily reflects the calendar year 2021 growing season). Although otolith chemistry data from this fish are consistent with the Illinois River watershed, it is not possible to determine whether the fish arrived at its collection location in the Calumet River on its own (breaching the electrical barriers) or if it was illegally transported to the CAWS, based on otolith chemistry data.

This was not the first time a dead Silver Carp has been collected above the electric dispersal barrier. During the Spring 2018 SIM event, one dead Silver Carp was found 21.4 miles from Lake Michigan in the Cal-Sag Channel near Worth, Illinois (41.67681, -87.7945).

Microchemistry analysis from the dead Silver Carp found in 2018 indicated the Silver Carp was born somewhere in the Illinois River watershed, such as the Sangamon, Mackinaw, or Kankakee Rivers. No increase in the strontium-to-calcium ratio was detected near the edge of the otolith, which is expected if an individual had spent time within the Des Plaines River or CAWS above the electric dispersal barrier. It is not possible to determine whether the dead Silver Carp made its way to the Cal-Sag by breaching the electrical barrier through illegal transport or being potentially kicked off a barge with otolith chemistry data, but it had spent little to no time in the area.

Three live Grass Carp were collected during SIM in 2022. Two were collected in the spring in the Calumet River near T.J. O'Brien Lock and Dam and in the Cal-Sag Channel. Ploidy testing on these two fish was indeterminate. One Grass Carp was collected in the fall in Lake Calumet. Ploidy testing on this fish indicated that it was triploid.

An estimated 41,718 person-hours have been expended monitoring fixed and random sites upstream of the EDBS since 2010. The total effort consisted of 1,605.3 hours of electrofishing (6,495 transects), 1,596.5 kilometers (992 miles) of gill/trammel net (8,746 sets), 25.7 kilometers (16 miles) of commercial seine hauls, and 114.2 net nights of hoop, pound and fyke nets from 2010 through 2021 (Table 3). Hoop net use was suspended after 2013 due to low gear efficiency. A total of 550,706 fish representing 89 species and nine 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 percent of all fish collected. Since 2010, 16 non-native species have been caught, including 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, Tilapia, and White Perch and hybrids. Non-native species constitute 15 percent of the total number of fish caught and 19 percent of the total species. Since 2010, 134,136 YOY Gizzard Shad have been examined, with no YOY invasive carp being identified. One live Bighead Carp was caught in a trammel net in Lake Calumet in 2010, and one live Silver Carp was captured in a trammel net in the Little Calumet River on June 22, 2017, with no other captures or observations in other years. One live Silver Carp was captured in Lake Calumet on August 4, 2022, outside of SIM sampling. For more information on this capture and the subsequent response, please see the Response Projects section of the ISR.

RECOMMENDATIONS

We recommend continued use of SIM upstream of the EDBS. 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.

REFERENCES

Invasive Carp Monitoring and Response Working Group. 2022. 2022 Monitoring and Response Plan for Invasive Carp in the Upper Illinois River and Chicago Area Waterway System. Illinois, Chicago.

Table 1. Summary of effort and catch data for Seasonal Intensive Monitoring in the CAWS upstream of the Electric Dispersal Barrier System, 2022.

	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	472.5	292.5	247.5	22.5	225	1260
Samples (transects)	262	144	110	3	101	620
Electrofishing hours	61.5	34.1	26.4	0.25	25.6	148
Electrofishing Catch						
All fish (*N*)	9064	9194	5430	0	4526	28214
Species (*N*)	56	46	30	0	34	65
Hybrids (*N*)	0	0	2	0	0	2
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	147.4	269.6	205.7	0	176.8	190.8
Netting Effort						
Estimated person-hours	599.5	367	337	60	224.5	1588
Samples (net sets)	308	212	189	3	148	860
Miles of net	35.1	24	21.4	0.3	16.8	98
Netting Catch						
All fish (*N*)	644	389	409	6	192	1641
Species (*N*)	17	12	3	1	33	57
Hybrids (*N*)	1	3	0	0	1	5
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/100 yds of net)	1	0.9	1.1	1.1	0.6	1.0
Seine Effort						
Estimated person-hours	328	-	-	-	-	328
Samples (seine hauls)	4	-	-	-	-	4
Miles of seine	1.8	-	-	-	-	1.8
Seine Catch						
All fish (*N*)	7181	-	-	-	-	7181
Species (*N*)	19	-	-	-	-	19
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	1795.3	-	-	-	-	1795.3

Table 2. Total number of fish captured with electrofishing (EF), trammel/gill nets (Nets), and commercial seine (Seine) in the CAWS upstream of the Electric Dispersal Barrier during Seasonal Intensive Monitoring, 2022.

	Chicago R.		**CSSC-S. Branch**		**Lake Cal-Cal R.**			**Little Cal-Cal-Sag**		**North Shore Channel-N. Branch**		**All Sites**
Species	**EF**	**Nets**	**EF**	**Nets**	**EF**	**Nets**	**Seine**	**EF**	**Nets**	**EF**	**Nets**	**All Gears**
Alewife*	-	-	-	-	333	-	-	-	-	12	-	345
Banded killifish	-	-	191	-	75	-	-	182	-	94	-	542
Bigmouth buffalo	-	-	-	-	16	15	13	-	-	-	-	44
Black buffalo	-	-	-	-	8	54	20	1	8	-	-	91
Black bullhead	-	-	-	-	79	-	-	5	-	10	-	94
Black crappie	-	-	4	-	18	-	25	-	-	19	-	66
Blackstripe topminnow	-	-	2	-	9	-	-	11	-	2	-	24
Bluegill	-	-	144	-	844	-	3	234	-	443	-	1668
Bluntnose minnow	-	-	2107	-	199	-	-	968	-	429	-	3703
Bowfin	-	-	-	-	39	1	4	5	-	-	-	49
Brook silverside	-	-	1	-	104	-	-	128	-	15	-	248
Brown bullhead	-	-	-	-	153	-	-	4	-	-	-	157
Brown trout*	-	-	-	-	1	-	-	-	-	-	-	1
Bullhead minnow	-	-	-	-	-	-	-	2	-	-	-	2
Carp x goldfish hybrid*	-	-	2	-	-	1	-	-	3	-	1	7
Central mudminnow	-	-	-	-	1	-	-	-	-	-	-	1

	Chicago R.		CSSC-S. Branch		Lake Cal-Cal R.			Little Cal-Cal-Sag		North Shore Channel-N. Branch		All Sites
Species	**EF**	**Nets**	**EF**	**Nets**	**EF**	**Nets**	**Seine**	**EF**	**Nets**	**EF**	**Nets**	**All Gears**
Central stoneroller	-	-	-	-	-	-	-	3	-	-	-	3
Channel catfish	-	-	45	4	24	30	729	184	10	21	3	1050
Channel shiner	-	-	-	-	1	-	-	-	-	-	-	1
Chinook Salmon*	-	-	-	-	28	16	-	5	-	-	-	49
Coho salmon*	-	-	-	-	44	1	-	2	1	-	-	48
Common carp*	-	6	418	402	573	120	12	959	269	283	184	3226
Creek chub	-	-	-	-	-	-	-	3	-	-	-	3
Emerald shiner	-	-	39	-	448	-	-	1162	-	125	-	1774
Fathead minnow	-	-	-	-	7	-	-	7	-	-	-	14
Flathead catfish	-	-	-	-	14	5	-	-	1	-	-	20
Freshwater drum	-	-	1	3	176	146	1895	24	72	-	3	2320
Gizzard shad	-	-	1230	-	720	13	4312	1291	1	1136	1	8704
Gizzard Shad < 6 in	-	-	538	-	409	-	-	2688	-	357	-	3992
Golden shiner	-	-	23	-	38	-	-	79	-	151	-	291
Goldfish*	-	-	17	-	80	-	-	19	2	7	-	125
Grass carp*	-	-	-	-	2	-	-	-	1	-	-	3
Green sunfish	-	-	71	-	261	-	-	113	-	10	-	455
Green sunfish x pumpkinseed hybrid	-	-	-	-	1	-	-	-	-	-	-	1

	Chicago R.		CSSC-S. Branch		Lake Cal-Cal R.			Little Cal-Cal-Sag		North Shore Channel-N. Branch		All Sites
Species	**EF**	**Nets**	**EF**	**Nets**	**EF**	**Nets**	**Seine**	**EF**	**Nets**	**EF**	**Nets**	**All Gears**
Hybrid Sunfish	-	-	-	-	1	-	-	-	-	-	-	1
Largemouth bass	-	-	304	-	1310	-	39	680	-	647	-	2980
Mimic shiner	-	-	-	-	-	-	-	1	-	3	-	4
Northern pike	-	-	-	-	6	-	2	-	-	1	-	9
Orangespotted sunfish	-	-	-	-	6	-	-	5	-	-	-	11
Oriental Weatherfish*	-	-	38	-	-	-	-	3	-	6	-	47
Pumpkinseed	-	-	74	-	1374	-	1	163	-	147	-	1759
Pumpkinseed x bluegill hybrid	-	-	-	-	1	-	-	-	-	-	-	1
Quillback	-	-	-	-	31	1	-	-	-	-	-	32
Rainbow trout*	-	-	-	-	6	-	-	-	-	1	-	7
River carpsucker	-	-	-	-	4	-	-	1	-	-	-	5
Rock bass	-	-	-	-	258	-	1	7	-	72	-	338
Round Goby*	-	-	55	-	111	-	-	9	-	3	-	178
Sand shiner	-	-	-	-	1	-	-	50	-	-	-	51
Smallmouth bass	-	-	1	-	415	-	22	10	-	1	-	449
Smallmouth buffalo	-	-	-	-	108	237	84	9	20	-	-	458
Spotfin shiner	-	-	27	-	12	-	-	41	-	48	-	128

	Chicago R.		CSSC-S. Branch		Lake Cal-Cal R.			Little Cal-Cal-Sag		North Shore Channel-N. Branch		All Sites
Species	**EF**	**Nets**	**EF**	**Nets**	**EF**	**Nets**	**Seine**	**EF**	**Nets**	**EF**	**Nets**	**All Gears**
Spottail shiner	-	-	7	-	16	-	-	32	-	21	-	76
Tilapia*	-	-	-	-	-	-	-	-	-	1	-	1
Threadfin shad	-	-	-	-	-	-	-	3	-	-	-	3
Walleye	-	-	1	-	1	1	4	-	-	4	-	11
Weed shiner	-	-	-	-	1	-	-	-	-	-	-	1
Western mosquitofish	-	-	6	-	-	-	-	5	-	1	-	12
White bass	-	-	18	-	11	1	11	24	-	5	-	70
White crappie	-	-	10	-	13	-	-	2	-	-	-	25
White perch*	-	-	-	-	17	-	-	10	-	3	-	30
White sucker	-	-	11	-	9	1	3	15	-	443	-	482
Yellow bass	-	-	1	-	1	-	-	18	-	-	-	20
Yellow bullhead	-	-	44	-	51	-	-	22	-	5	-	122
Yellow perch	-	-	-	-	588	-	1	5	-	-	-	594
Total Fish (N)	0	6	5430	409	9064	644	7181	9194	389	4525	192	37034
Total Species (N)	0	1	30	3	56	17	19	46	11	3334	5	65
Total Hybrids (N)	0	0	2	0	0	1	0	0	3	0	1	7

*: non-native species

Table 3. Summary of effort and catch data for all fixed and random site monitoring in the CAWS upstream of the Electric Dispersal Barrier, 2010-2022.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Electrofishing Effort														
Estimated person-hours	1,280	2,180	4,330	1,528	945	990	990	990	990	1,118	195	1,350	1260	**18,146**
Samples (transects)	519	844	765	588	348	422	407	437	414	412	127	592	620	**6,495**
EF (hrs)	130	211	192	149.3	87.1	106	102	109	103.5	103	28.7	136	148	**1,605.3**
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	28,214	**435,605**
Species (N)	51	58	59	56	56	61	59	58	60	48	39	53	65	**87**
Hybrids (N)	3	3	3	2	2	2	2	2	2	2	1	4	2	**8**
Bighead Carp (N)	0	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	**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	190.8	**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	1588	**21,491**
Samples (net sets)	208	389	699	959	440	445	498	803	710	711	1252	772	860	**8,746**
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	98	**992**
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	1,641	**28,062**
Species (N)	17	20	20	30	18	13	18	14	23	19	18	17	57	**43**
Hybrids (N)	1	1	1	1	1	1	1	1	1	1	1	1	5	**2**
Bighead Carp (N)	1	0	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	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	1.0	**1.7**

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Seine Effort														
Estimated person-hours	-	-	-	135	135	135	135	135	135	135	135	210	328	**1,618**
Samples (seine hauls)	-	-	-	3	2	3	3	4	3	4	4	4	4	**34**
Miles of seine	-	-	-	1.4	0.9	1.4	1.4	1.8	1.4	1.8	1.8	1.8	1.8	**16**
Seine Catch														
All fish (N)	-	-	-	7,577	1,725	5,989	3,765	2,763	3,110	7,457	2,879	3,490	7,181	**45,936**
Species (N)	-	-	-	15	11	14	15	10	10	16	11	18	19	**29**
Hybrids (N)	-	-	-	1	0	0	0	0	0	0	0	0	0	**1**
Bighead Carp (N)	-	-	-	0	0	0	0	0	0	0	0	0	0	**0**
Silver Carp (N)	-	-	-	0	0	0	0	0	0	0	0	0	0	**0**
CPUE (fish/seine haul)	-	-	-	2,525.7	862.5	1,996.3	1,255.0	690.8	1,036.70	1,864.3	719.8	872.5	1,795.3	**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**
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**

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	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**

CAWS eDNA SAMPLING

Participating Agencies: USFWS, Matt Petasek (USFWS), Green Bay FWCO

Location: Lake Calumet, Little Calumet River, Powderhorn Lake

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. Since 2009, eDNA sampling has been conducted annually as a surveillance tool to monitor the genetic presence of Bighead Carp and Silver Carp in the CAWS and maintain vigilance above the EDBS. Beginning in 2013, eDNA results no longer automatically trigger any 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 baseline 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 and the 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, reproducing population of these invasive carp above the barrier.

OBJECTIVES

Sample for Bighead Carp and Silver Carp DNA in targeted areas of the CAWS to maintain vigilance and complement other ongoing monitoring efforts above the EDBS.

PROJECT HIGHLIGHTS

- USFWS staff collected 880 samples upstream of the EDBS and 220 samples in Powderhorn Lake (control site).
- Positive detections were few and consistent with previous sampling years.

METHODS

USFWS staff from the La Crosse and Green Bay FWCOs 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, 110 (100 samples plus 10 field blanks) were collected in the Marine Services Marina on the Little Calumet River, and 110 (100 samples plus 10 field blanks) were collected in Powderhorn Lake. All sample collection and processing procedures followed the 2022 Quality Assurance Project Plan (USFWS 2022). 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 differentiate between the two species. 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 the 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

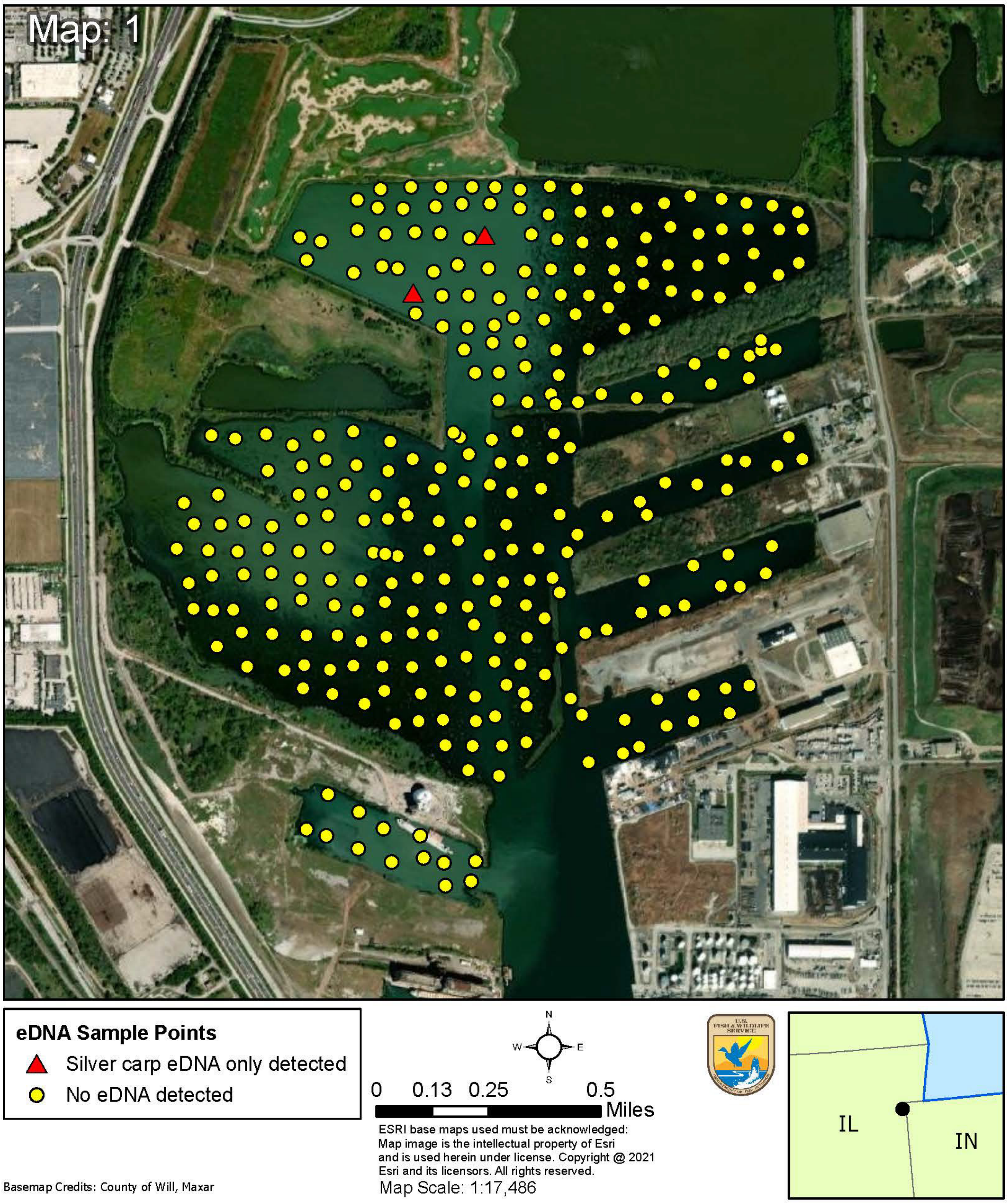
In the May sampling event in Lake Calumet, there were 0.6 percent positive detections (Silver Carp-only detection type). There were zero positive eDNA detections in the Marine Services Marina on the Little Calumet River. In the September sampling event, there were zero positive eDNA detections at both sites. The detection rate in Lake Calumet is consistent with the results from 2021 surveys; however, the overall combined detection rates at both sites are lower than in the last several years.

In 2022, Powderhorn Lake was added as a control site. In the May sampling, there were 0.09 percent positive eDNA detections (Silver Carp-only detection type). In the September sampling event, there were zero positive eDNA detections in Powderhorn Lake. Although this is the first time that USFWS has detected DNA in Powderhorn Lake, the detection rate is low. Multiple factors, including its isolation from the CAWS and the site’s proximity to a landfill, which, at times, hosts numerous gulls, suggest the positivity likely resulted from secondary vector contributions to the system.

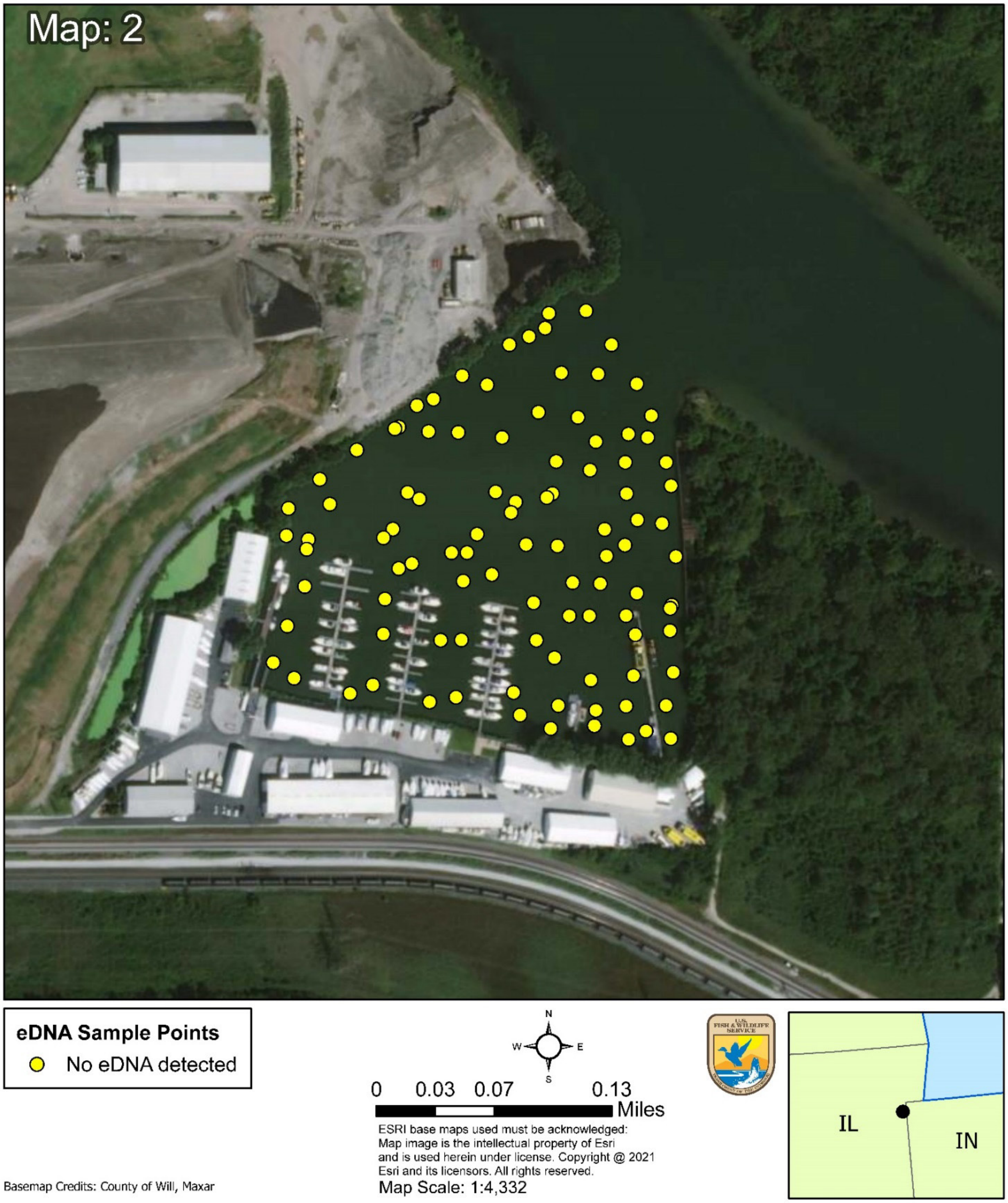
RECOMMENDATIONS

eDNA sampling efforts in the CAWS are a long-standing part of the USFWS Invasive Carp eDNA Early Detection and Monitoring Program and will continue semi-annually for the foreseeable future. The USFWS will continue to investigate how secondary vectors, such as birds, may contribute to DNA signals in the sampled water in the CAWS. Therefore, it's recommended that USFWS continue to conduct eDNA monitoring in these locations similar to previous years. As the additional monitoring of Powderhorn Lake may help gauge if birds are substantial secondary vectors of invasive carp, continued sampling of this site is also recommended.

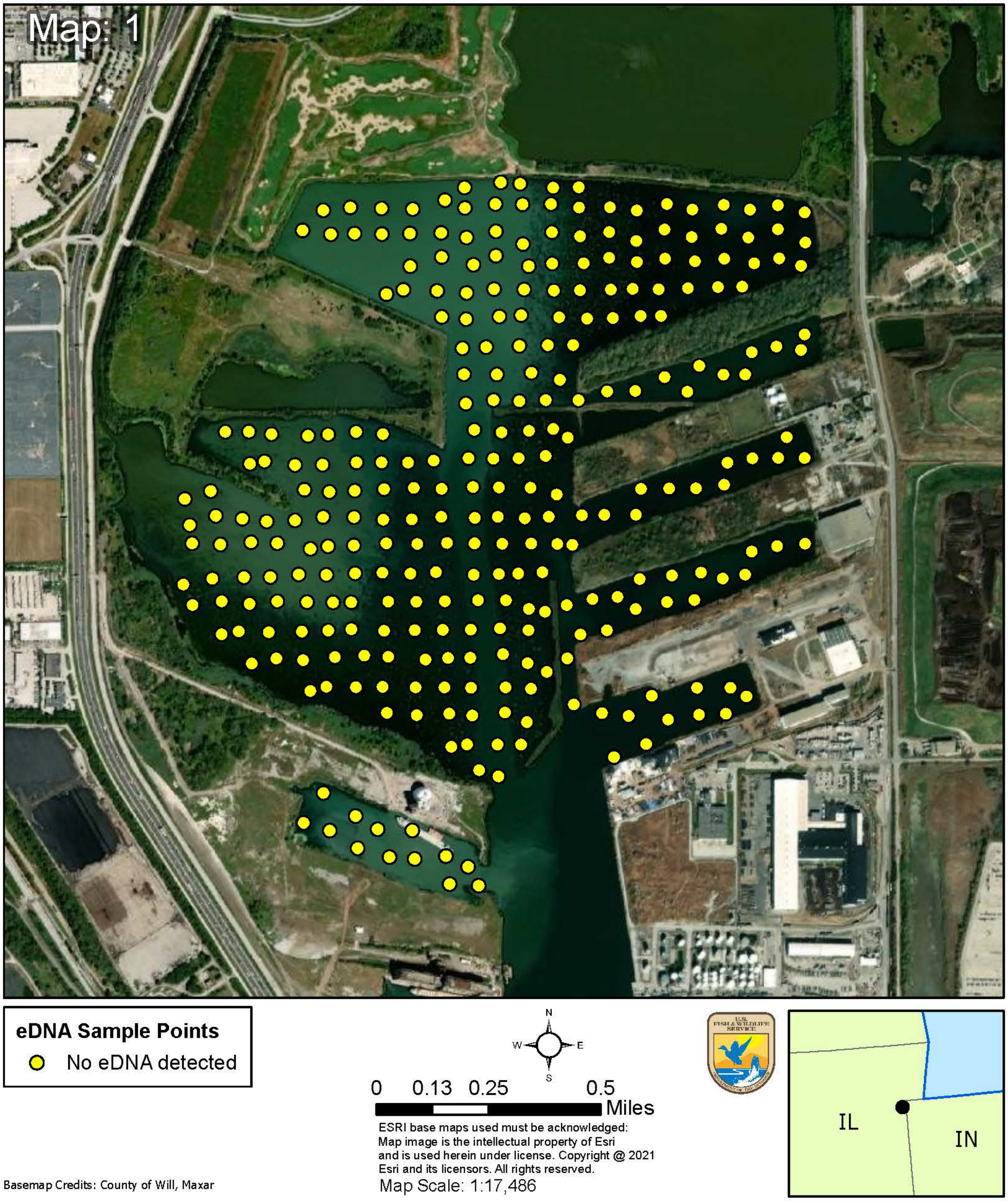
Bighead and Silver Carp eDNA Early Detection Results:
Chicago Area Waterway System
Sampling Period: Week of May 9, 2022
Number of Samples Collected: 330



Bighead and Silver Carp eDNA Early Detection Results:
Chicago Area Waterway System
Sampling Period: Week of May 9, 2022
Number of Samples Collected: 110



Bighead and Silver Carp eDNA Early Detection Results:
Chicago Area Waterway System
Sampling Period: Week of September 26, 2022
Number of Samples Collected: 330



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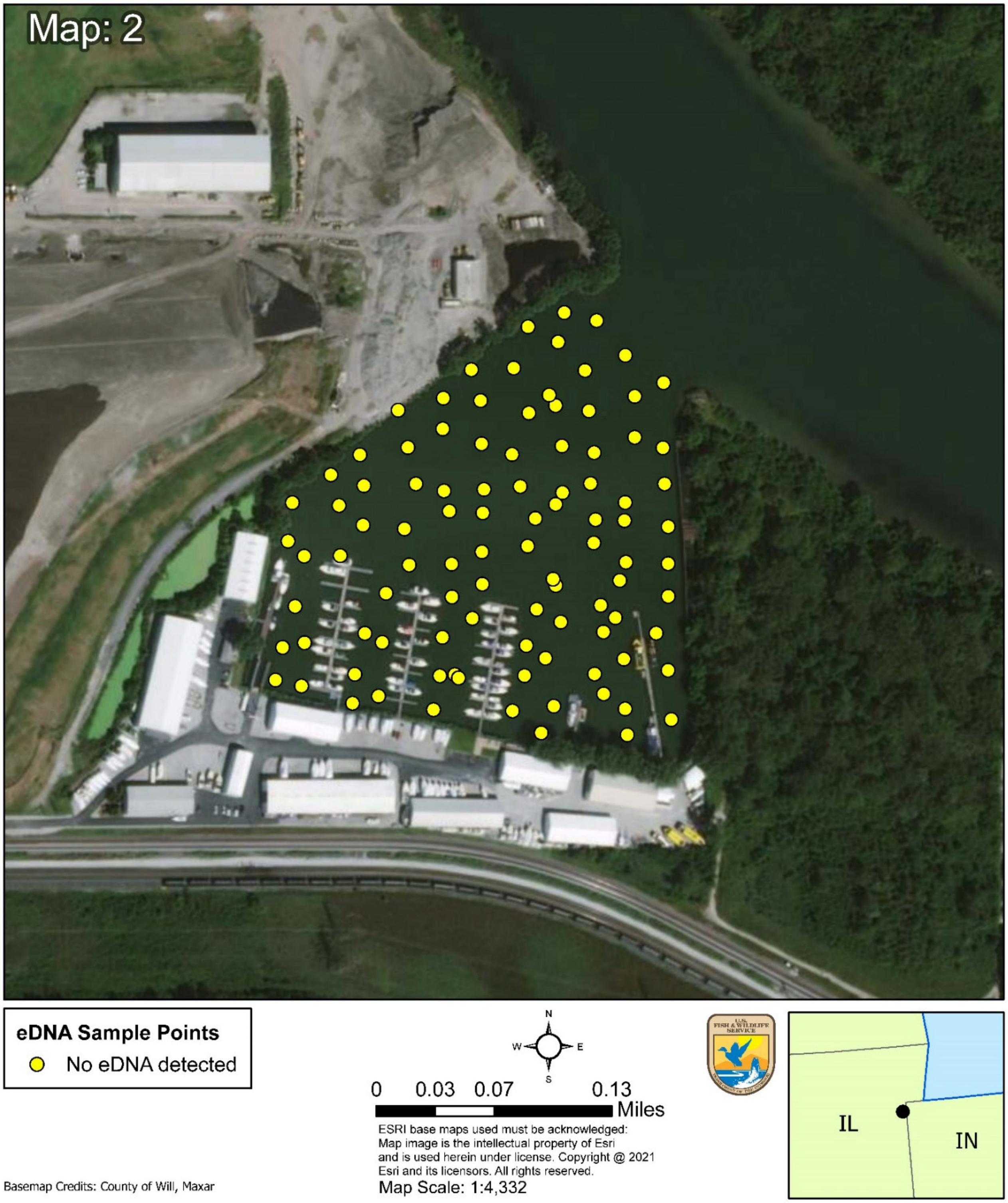
Map Scale: 1:17,486

Basemap Credits: County of Will, Maxar

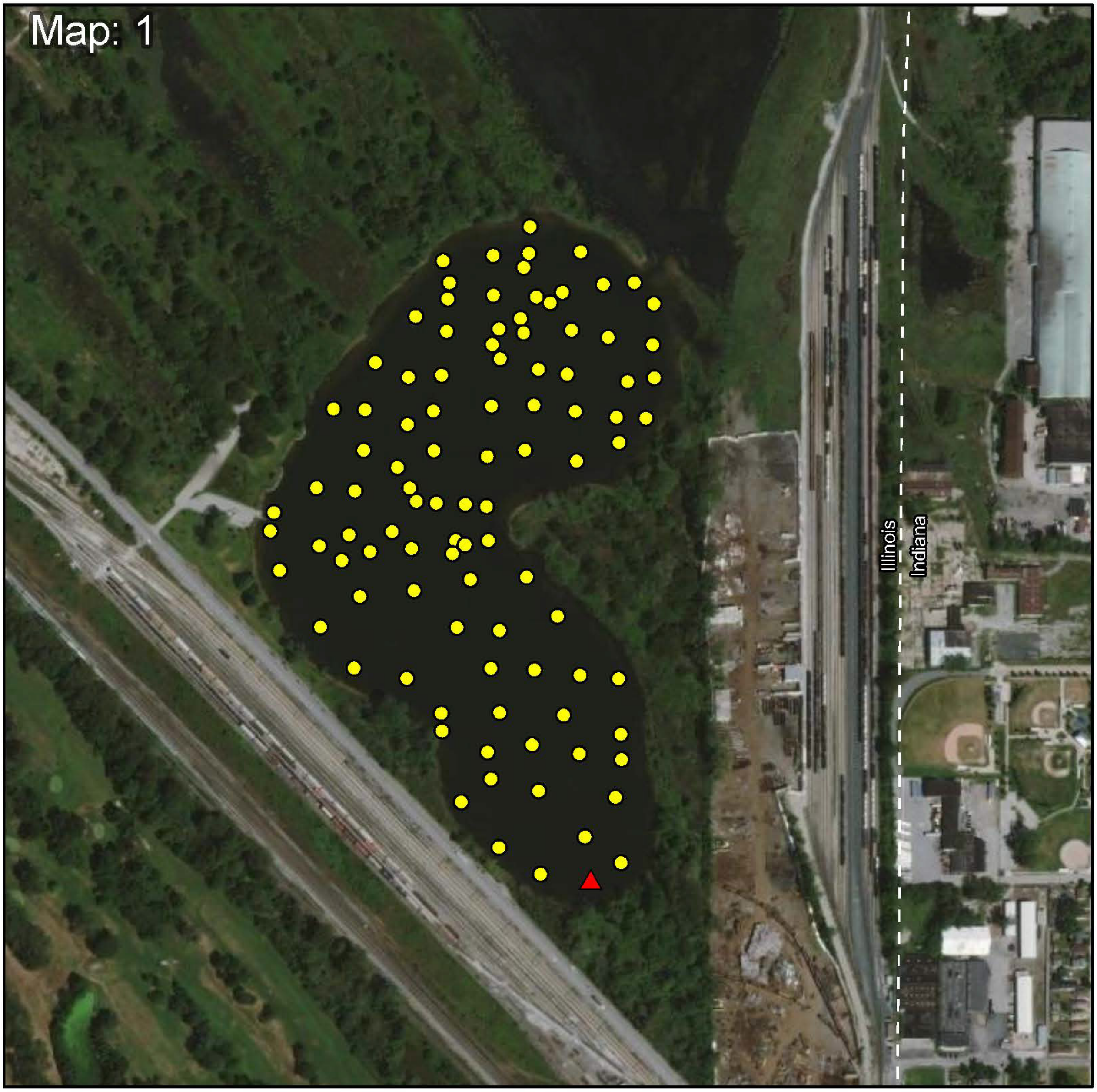
Bighead and Silver Carp eDNA Early Detection Results:
Chicago Area Waterway System
Sampling Period: Week of September 26, 2022
Number of Samples Collected: 110



Map Scale: 1:4,332

Basemap Credits: County of Will, Maxar

Bighead and Silver Carp eDNA Early Detection Results:
Powderhorn Lake
Sampling Period: Week of May 9, 2022
Number of Samples Collected: 110



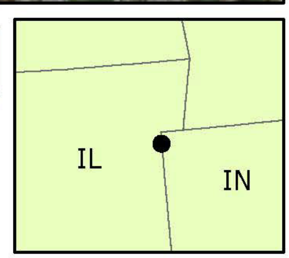
eDNA Sample Points

- ▲ Silver carp eDNA only detected
- ● No eDNA detected

N W E S

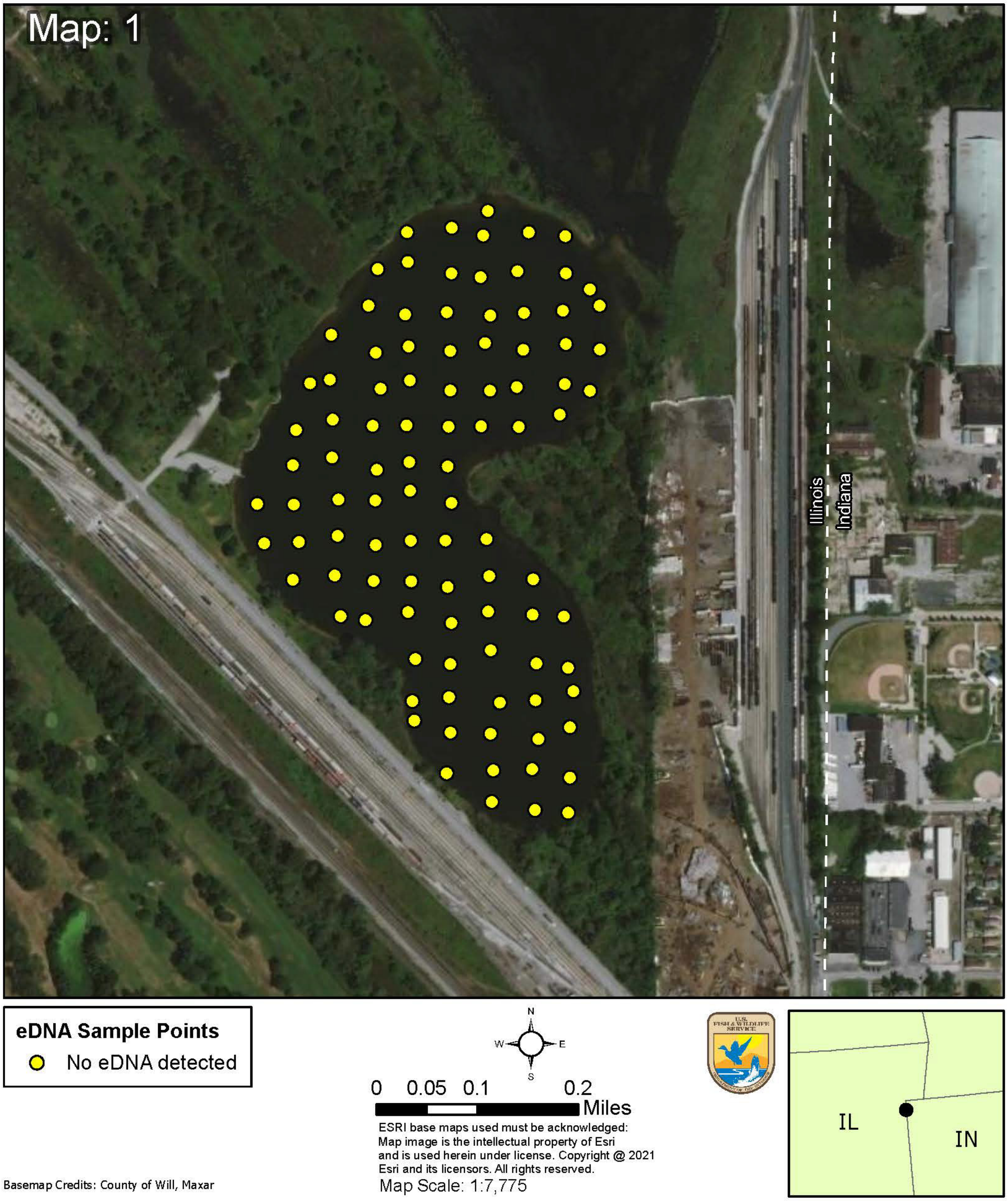
0 0.05 0.1 0.2 Miles

Map Scale: 1:7,775



Basemap Credits: County of Will, Maxar

Bighead and Silver Carp eDNA Early Detection Results:
Powderhorn Lake
Sampling Period: Week of September 26, 2022
Number of Samples Collected: 110



Basemap Credits: County of Will, Maxar

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U.S. Fish and Wildlife Service (USFWS). 2022. Quality Assurance Project Plan (QAPP) eDNA monitoring of bighead and silver carps. Midwest Region Bloomington, MN. Available: http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf

US Army Corps of Engineers

TELEMETRY MONITORING PLAN

Participating Agencies: USACE (lead); USFWS, SIUC, IL DNR, USGS, and MWRDGC (field and project support); Alexander Catalano, John Belcik, Dayla Dillon, and Nicholas Barkowski (USACE – Chicago District)

INTRODUCTION

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 and Silver Carp in the Dresden Island Pool and associated surrogate fish species (locally captured surrogate species: Common Carp) in the area around the EDBS within the CSSC. This network was installed and is maintained through a partnership between the USACE and other participating agencies as part of the MRWG Monitoring and Response Plan (MRWG 2020).

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

GOALS AND OBJECTIVES

- *Goal 1:* Determine if the upstream passage of the EDBS by tagged fish has occurred and assess the risk of Bighead Carp and Silver Carp presence (barrier efficacy).
    - *Objective: Monitor the movements of tagged fish near 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 Carp, Silver Carp, and surrogate species through navigation locks in the Upper IWW.
    - *Objective 1*: 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 the Brandon Road lock (N=1).

  - Objective 2: Review and compare standard operating protocols and vessel lockage statistics for Lockport, Brandon Road, and Dresden Island locks for comparison of known fish passage events.

- *Goal 3:* Evaluate temporal and spatial patterns of habitat use at the leading edge of the Bighead Carp and Silver Carp invasion front.
  - Objective 1: Determine if the leading edge of the Bighead Carp and Silver Carp invasion (currently RM 286.0) has changed in either the up or downstream direction.
  - Objective 2: Describe habitat use and seasonal movement in the Upper IWW and tributaries where Bighead Carp and Silver Carp have been captured and relay information to the population reduction program undertaken by IL DNR and commercial fishermen.

Additional Objectives:

- 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 the network accordingly in consultation with the telemetry working group.

PROJECT HIGHLIGHTS

- To date, USACE has acquired 41.4 million detections from 787 tagged fish.
- No known live tagged fish have crossed the EDBS in the upstream direction.
- A high percentage of tagged surrogate fish in the Lower Lockport Pool continues to be detected near the EDBS.
- One downstream passage of Common Carp occurred through the Lockport Lock.
- Three downstream passages of Common Carp occurred through the Brandon Road Lock and Dam.
- Invasive carp continue to be detected throughout the Dresden Island Pool, with most detections occurring near the Dresden Island Lock and Dam.
- In 2022, zero detections of invasive carp occurred in Rock Run Rookery.

METHODS

Based on MRWG expert opinion, it was recommended 200 active transmitters in fish be maintained within the study area for telemetry monitoring. At the end of the 2021 season, approximately 162 tags (V16 Vemco transmitters) remained active, and no tags expired. In March 2022, 11 tags were deployed in Silver Carp within Dresden Island Pool. This tagging effort brought the number of tags to 169 throughout the study area. As of November 2022, there are 60 tags active in Lockport Pool, 41 tags active in Brandon Road Pool, and 68 tags active in Dresden Island Pool. In March 2023, 24 active tags are expected to expire in Dresden Island Pool.

Tagged surrogate fish have been previously released below the EDBS, but no tagged invasive carp were released above Brandon Road Lock and Dam. 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 volition. It has been observed that displaced fish 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 fish previously released within Lower Lockport Pool 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. Several fish were previously captured above the EDBS and released below the EDBS with active tags. Table 1 identifies all fish containing active transmitters between November 2021 and November 2022, along with their release point within the system.

Table 1: Active Fish and Release Points within the Study Area in 2022

Release Location	Species Implanted	Capture Pool	Number of Tagged Fish
Lower Lockport Pool (Downstream of EDBS)	Common Carp	Upper	25
Lower Lockport Pool (Downstream of EDBS)	Common Carp	Lower	35
Lower Lockport sub-total	--	**--**	**60**
Brandon Road Pool	Common Carp	Brandon	41
Brandon Road sub-total	--	**--**	**41**
Dresden Island Pool	Bighead Carp	Dresden	8
Dresden Island Pool	Silver Carp	Dresden	60
Dresden Island sub-total	--	**--**	68
Total	--	**--**	**169**

Methods for stationary receiver deployment and downloads were maintained from previous years' efforts. 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 (MRWG 2012). Those stationary receivers removed for winter in November 2021 were redeployed in March 2022. The layout of receiver positions within the study remained almost the same as the previous year (MWRG 2020, 2021). 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, Illinois, to the Dresden Island Lock and Dam on the Illinois River in Channahon, Illinois (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, four real-time receivers have been installed in previous years by USGS around coverage. One is located upstream and downstream of Brandon Road Lock and Dam, one is upstream and downstream of the EDBS, and one is 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 11 stationary receivers, four upstream and seven downstream of the EDBS within the Lockport Pool. Receivers were placed at the lock entrance in areas offering shallow habitat near 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 underwent quality assurance/quality control review to remove false detections and dead fish.

The total number of detections and the total number of individual transmitters detected were compiled per receiver station. The total number of detections was 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 representing spring, June to August representing summer, and September to November representing fall. Each station detection sub-total was then summed across the pool to calculate the total number of detections in 2022 and then further detailed by season. Similarly, the total number of transmitters was 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 the total number of detections by station and totaled for the entire pool.

Inter-pool Movement: Four pools are 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 and Dam, 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 Pool consists of the area upstream of the EDBS to the CSSC and Cal-Sag Channel. The remaining pools include Brandon Road Pool of the Des Plaines River and Dresden Island Pool, which includes the Des Plaines and Kankakee rivers. While Marseilles Pool was outside of the study area, data were collected within the pool by SIUC and USGS, which was shared with USACE. VR2W receivers were placed above and below each lock and dam and at any other potential transfer pathways between pools. Data from the VR2W receivers were 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: At the beginning of 2022, 57 USACE-tagged bigheaded carp were within the Dresden Island Pool. In March 2022, 11 additional fish were tagged in Dresden Island Pool for a total of 68 active tags by the end of the field season. The movement of individual fish was tracked via Vemco VR2W stationary receivers strategically placed throughout the Des Plaines and Kankakee Rivers (Appendix A). VR2W detections were then uploaded into the Vemco VUE software. Each station's detection sub-total was then summed across the pool to calculate the percent of total detections in 2022. Detections of tags were recorded, and the percent of tags detected at each station was calculated for the year. Total tags and total detections at each receiver by season were used to observe any movement patterns. Detections for each tag were individually analyzed to determine if any fish potentially died during 2022. 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 2022, 41.4 million detections from 787 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 the transit of fish from below the barrier. Results to date have shown that zero known live tagged fish have crossed the EDBS in the upstream (northward) direction.

Goal 1: Determine if the upstream passage of the EDBS by tagged large fish has occurred and assess risk of Bighead Carp and Silver Carp presence (barrier efficacy).

In 2022, 60 tagged surrogate fish with active batteries were released between Lockport Lock and Dam and the EDBS. Seven stationary receivers (VR2W) detected the movement of 49 tagged surrogate fish throughout the pool in 2022. This discrepancy is mainly due to fish transiting between pools. There was a total of 2,131,446 detections within Lower Lockport Pool and zero detections in the Upper Lockport Pool, indicating no passage of tagged fish through the EDBS.

The number of detections was lowest in straight channel sections of the canal with deep water, which best characterizes station LL 03A. The area with the highest number of detections was the shallow water barge slip (LL 03) just downstream of the EDBS. Approximately 22 percent of the detections in Lower Lockport were just below the barrier. Most of those detections occurred in the fall months (30 percent) and spring months (32 percent). This is different than previous years, where summer months typically have the highest number of detections. During the winter, 31 fish were detected at the EDBS, and 28 of those were detected at LL 03, indicating fish were actively moving between locations during the winter season and periodically approaching the barrier.

Table 2: Number of detections within the Lower Lockport Pool during 2022.
*Values do not indicate a lack of fish, but rather that the receiver was removed from the water during that time.

STATION	SPRING	SUMMER	FALL	WINTER	TOTAL
LL 01	150,215	98,473	140,883	85,165	474,736
LL 02	101,081	35,259	120,353	0*	256,693
LL 03	189,715	187,279	124,419	192,155	693,568
LL 03A	67,021	8,622	62,147	0*	137,790
LL 04	72,136	32,110	78,781	0*	183,027
LL 05	90,813	33,623	116,751	0*	241,187
LL 06	321,164	38,283	34,646	39,352	144,445
TOTAL	705,627	427,530	681,617	316,672	2,131,446

Table 3: Number of tags detected at a station during 2022.
*Values do not indicate a lack of fish, but rather that the receiver was removed from the system during that time.

STATION	SPRING	SUMMER	FALL	WINTER	TOTAL TAGS
LL 01	32	34	36	31	43
LL 02	25	22	21	0*	35
LL 03	27	25	28	28	42
LL 03A	26	19	15	0*	42
LL 04	33	32	20	0*	48
LL 05	32	29	19	0*	55
LL 06	9	10	7	4	16
TOTAL	45	43	47	38	49

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

Only four inter-pool movements by four tagged fish occurred during 2022. All movements between USACE-monitored pools were by Common Carp; one moved downstream from Lockport Pool to Brandon Road Pool via Lockport Lock, and three moved downstream from Brandon Road Pool to Dresden Island Pool. There has been ample evidence over the last several years of monitoring indicating that lockages are frequently used by fish to move between pools (MRWG 2018, 2019, 2020, and 2021).

From 2010 to 2022, 104 occurrences of tagged fish moving downstream and 51 occurrences of upstream movement between navigation pools by a total of 116 individual tagged fish occurred (Table 4). Inter-pool movement was greatest between the Lockport and Brandon Road pools, accounting for 55.5 percent (n=86) of all inter-pool movements (upstream n=25; downstream n=61). Most downstream movement into the Brandon Road Pool occurred through the Lockport Control Works, approximately 2 miles upstream of Lockport Lock and Dam (n=35). Movement between the Dresden Island and Marseilles pools comprised 31.6 percent (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 12.9 percent (n=20) 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 fish 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 periodically to encourage fish to challenge the EDBS by capturing them in the Upper Lockport Pool and releasing them into the Lower Lockport Pool.

Table 4: Total occurrences of inter-pool movement by tagged fish from 2010 to 2022.

	UP	DOWN	TOTAL
LOCKPORT LOCK	23	26	49
CONTROL WORKS	2	35	37
BRANDON RD	5	15	20
DRESDEN ISLAND	21	28	49

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

On March 31, 2022, USACE tagged 11 Silver Carp (838 millimeters, ± 67 millimeters) in collaboration with IL DNR unified method sampling in Dresden Island Pool. All fish were collected from the Dresden Island Nuclear outfall in the lower Dresden Island Pool. The 2022 tagging effort brought the total number of at-large USACE-tagged invasive carp to 68, with 24 tags expiring in March 2023. There were 23 bigheaded carp detected on the USACE acoustic telemetry network within Dresden Island Pool in 2022. Of those 23 fish, 16 were released by

USACE, and seven were released by WIU-USGS. Three Grass Carp released by USFWS were also detected.

A total of 65,594 detections in Dresden Island Pool were by bigheaded carp across 11 receivers. The 23 bigheaded carp detected were all primarily found around the confluence of the Kankakee and Des Plaines rivers. The stations KR10 and DI95 detected 63 percent and 79 percent of all detected bigheaded carp, respectively (Figure 1). At least 53 percent of the tagged fish were detected near Dresden Island Lock and Dam at any time during the year. This is similar to previous years' data, showing a majority of tagged bigheaded carp residing near this area around the confluence or just downstream. Only one bigheaded carp was detected above I-55 during 2022 – from October 21 to 22, a Silver Carp migrated from near the confluence of the Kankakee and Des Plaines rivers to station DI 40. After leaving the detection range of that station, it has not been picked up on receivers further upstream near Brandon Road Lock and Dam or downstream of DI 40. No tagged bigheaded carp were detected within Rock Run Rookery in 2022. Additionally, no bigheaded carp were detected at station KR 30 near Wilmington Dam, unlike in 2021, when two Silver Carp were detected at that station.

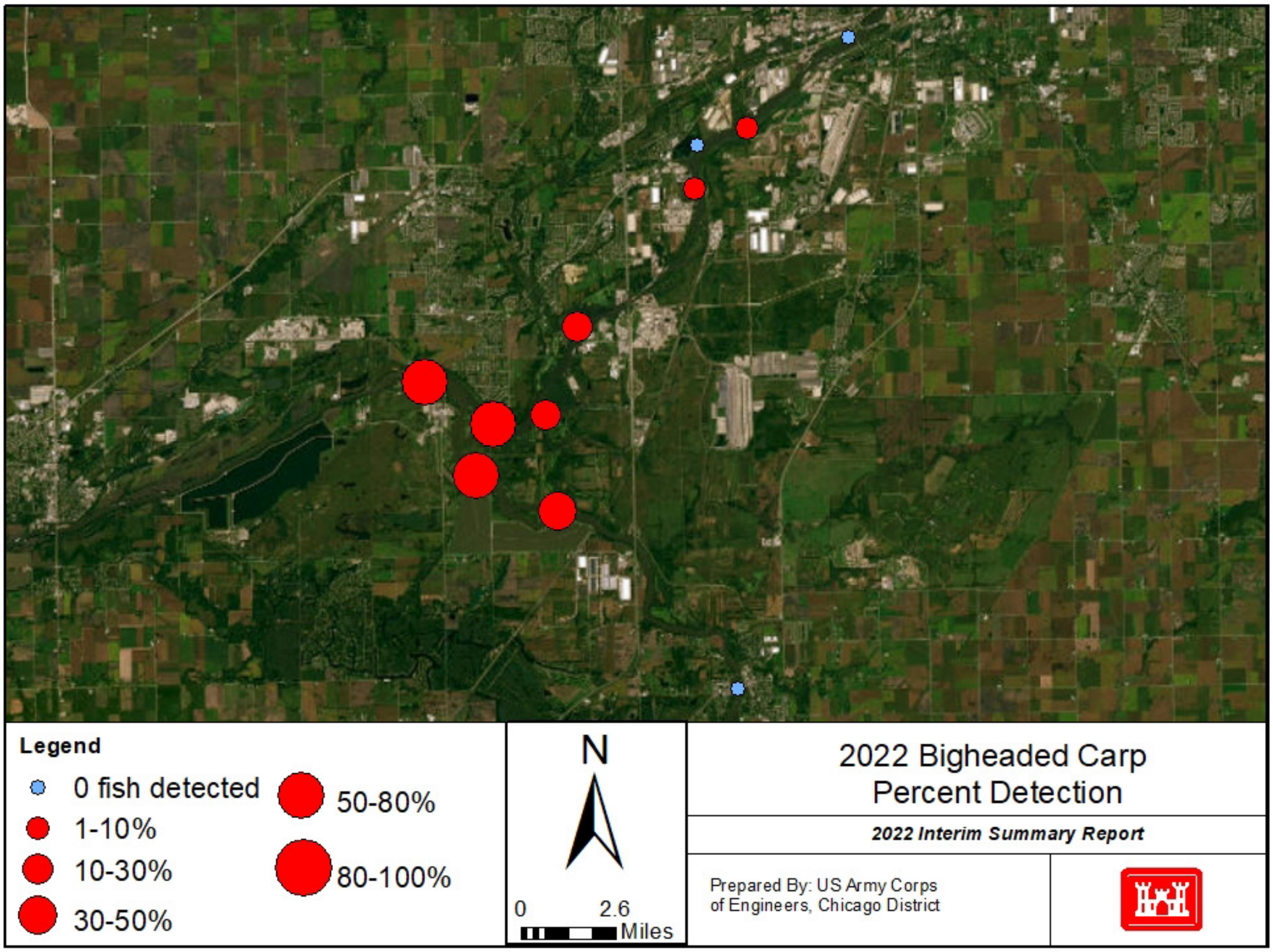

Figure 1. *Percent of total detected bigheaded carp within Dresden Island Pool in 2022.*

RECOMMENDATIONS

USACE recommends continuing 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 2023. 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 how well Common Carp and other surrogates represent the behavior of invasive carp 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 13 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 using the telemetry program, and 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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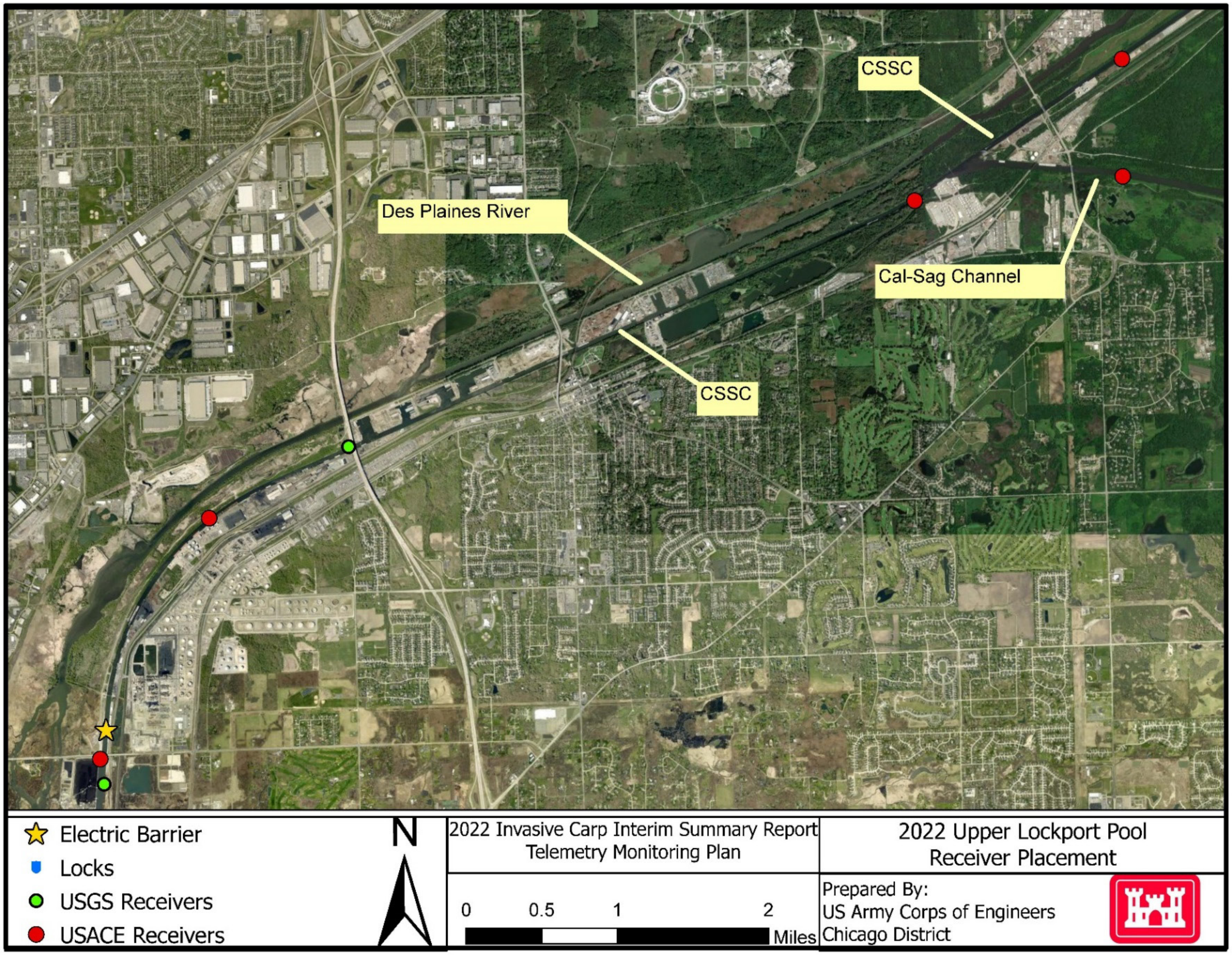
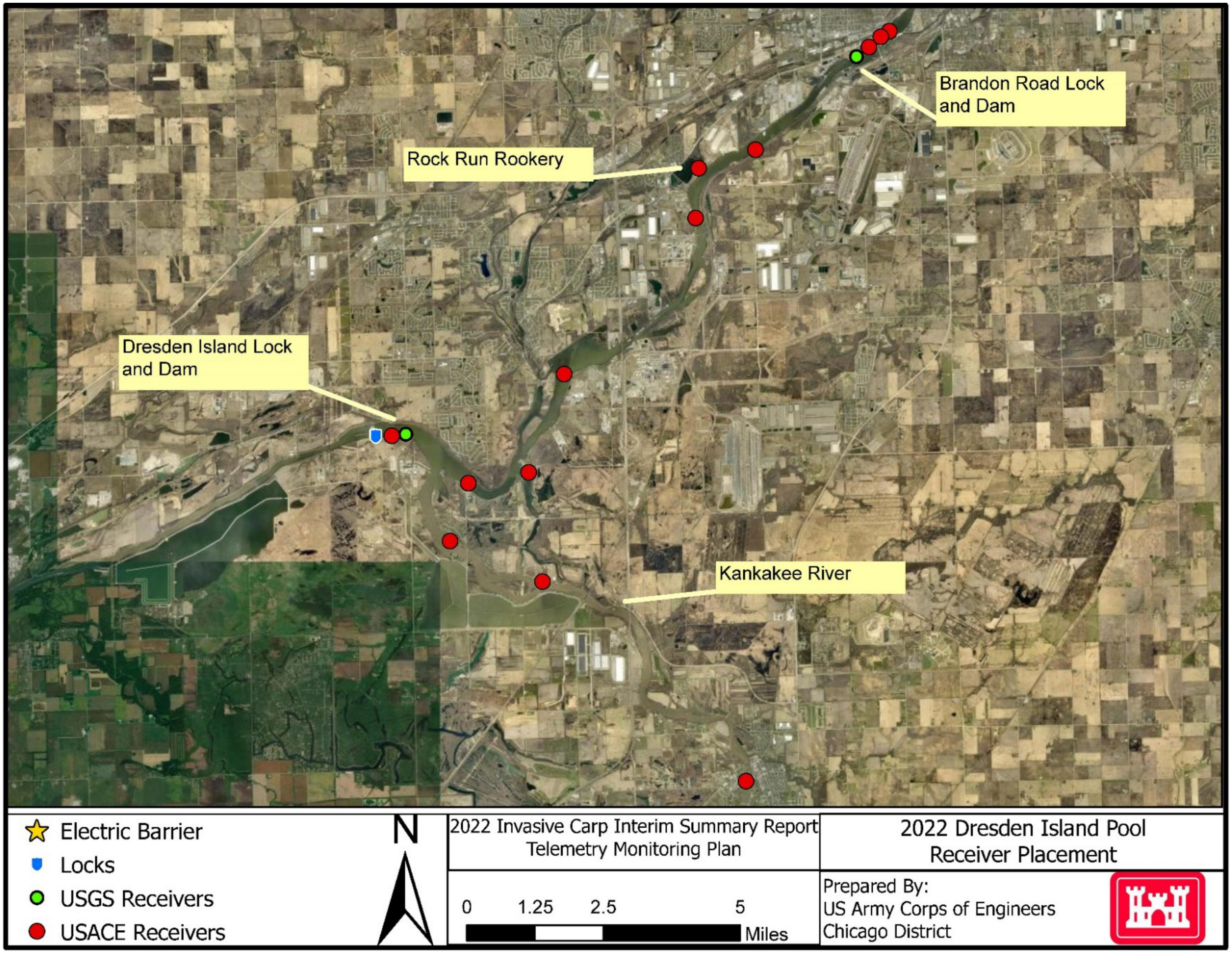
APPENDIX A: RECEIVER NETWORK MAPS


CSSC
Des Plaines River
Cal-Sag Channel
CSSC
Electric Barrier
Locks
USGS Receivers
USACE Receivers
N
2022 Invasive Carp Interim Summary Report
Telemetry Monitoring Plan
0 0.5 1 2 Miles
2022 Upper Lockport Pool
Receiver Placement
Prepared By:
US Army Corps of Engineers
Chicago District


CSSC
Lockport Control Works
Lockport Lock and Dam
Electric Barrier
Locks
USGS Receivers
USACE Receivers
N
2022 Invasive Carp Interim Summary Report Telemetry Monitoring Plan
2022 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
2022 Invasive Carp Interim Summary Report Telemetry Monitoring Plan
0 0.25 0.5 1 Miles
2022 Brandon Road Pool Receiver Placement
Prepared By:
US Army Corps of Engineers
Chicago District



Brandon Road Lock and Dam
Rock Run Rookery
Dresden Island Lock and Dam
Kankakee River
Electric Barrier
Locks
USGS Receivers
USACE Receivers
N
2022 Invasive Carp Interim Summary Report
Telemetry Monitoring Plan
0 1.25 2.5 5
Miles
2022 Dresden Island Pool
Receiver Placement
Prepared By:
US Army Corps of Engineers
Chicago District

USGS TELEMETRY PROJECT

Participating Agencies: USGS, SIU, USACE, IL DNR, USFWS, INHS; Marybeth Brey, Jessica Stanton, Sean Bailey, Doug Appel, and Andrea Fritts (USGS, Upper Midwest Environmental Sciences Center); Ryan Jackson (USGS, Central Midwest Water Science Center)

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

INTRODUCTION AND NEED

Tagging bigheaded carp 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 working group has been established by the MRWG to ensure the multi-agency telemetry efforts are coordinated to efficiently and effectively meet the MRWG goals. This working group plans and executes the placement of receivers, tagging of bigheaded carp with acoustic tags, and management of the telemetry data. Three primary objectives of the telemetry working group to meet MRWG goals include (1) the 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.

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 the shortcomings of Program MARK. These shortcomings include a 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 the reliability and accuracy of the real-time alerts to bigheaded carp movements that can be used by management to plan contingency actions.

OBJECTIVES

- Telemetry project in support of SEICarP modeling
    - *Publish Movement Probability Model:* The Bayesian multi-state model has been completed, and parameter estimates have been shared with the SEICarP modeling group. This manuscript is in review.
    - *Begin a feasibility study to estimate fishing mortality from existing telemetry and mark-recapture data from the Illinois River.* USGS, with partners, will develop a study plan to use existing telemetry data with and without mark-recapture data from the Starved Rock and Marseilles pools of the Illinois River to refine fishing mortality and population estimates of invasive carp in the upper Illinois River.
    - *Explore the feasibility of including additional parameters and predictor variables in a comprehensive invasive carp movement model.* USGS, in coordination with the developers of the SEICarP model, will explore the ability to use existing or collect supplemental telemetry data to parameterize population models that could incorporate fish density, variable environmental parameters (e.g., river flow conditions), or individual-level parameters (e.g., fish length and weight).
- Real-time telemetry in support of barrier evaluations and contingency planning
    - *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*: A Bayesian multi-state transition probability model for the Illinois River has been completed and run using telemetry data from 2012 to 2019. Model movement parameters have been shared with the SEICarP team, and a manuscript of this multi-state model is in review.
- *Real-time Receiver Network and Alert System*: Five real-time receivers were maintained in the Upper IWW in 2022 (Table 1). The FishTracks telemetry database was continued in 2022, and a new simplified alert system for bigheaded carp detections in areas of management interest was rolled out to partners.

Table 1. Locations of real-time receivers on the Upper IWW. 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

The USGS, in collaboration with personnel from the telemetry working group and population modeling working group of MRWG, developed a Bayesian model 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 the number of states, recapture periods, and specification of random effects to account for individual, spatial, and temporal heterogeneity. Program MARK does not provide uncertainty estimates for the estimated parameters, whereas hierarchical models performed in a Bayesian framework provide a direct expression.

A network of five real-time receivers was redeployed and maintained in the Upper IWW by USGS crews in the spring and summer of 2022. Data access for these receivers was maintained online. Real-time alerts were provided to key personnel via email, as requested by partner agencies. A new alert system was developed to summarize daily or weekly detection data into one email alert. Users can now request alert summaries for detections on individual receivers or for all receivers.

RESULTS

Telemetry Project in Support of SEICarP Modeling

- *Movement probability model.* In FY 2022, these new models were successfully run on the full dataset of tagged Silver Carp and Bighead Carp in the Illinois River. A manuscript describing the model and results is currently in review. Data collection and fish tagging will continue with partner agencies to update the movement model through 2025.
- *Begin a feasibility study to estimate fishing mortality from existing telemetry and mark-recapture data from the Illinois River.* USGS worked with the USFWS to draft a preliminary model to guide managers in mark-recapture studies to estimate fishing mortality. Adding telemetry data to this or other models has not yet been completed.
- *Explore the feasibility of including additional parameters and predictor variables in a comprehensive invasive carp movement model.* This sub-objective was not prioritized by partners in 2022, but USGS plans to explore this in 2023.

Real-time Receiver Network

USGS personnel monitored, downloaded, and maintained data from five real-time receivers in the Upper IWW in 2022. Locations of the five real-time receivers in the Upper IWW are shown in Table 1.

Each receiver was programmed to alert partner agencies when bigheaded carp, tagged with ultrasonic transmitters, were 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 through 4 in Table 1), and these receivers did not detect a confirmed bigheaded carp in 2022. The one real-time receiver outside 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 were made available online. Detection data and summaries were shared with partners throughout the year.

USFWS ILLINOIS WATERWAY HYDROACOUSTICS

Participating Agencies: USFWS Carterville FWCO (lead) and USACE, Chicago District (field and logistical support); Michael A. Glubzinski (USFWS, Carterville FWCO, Wilmington Substation)

Pools Involved: Lockport, Brandon Road, and Dresden Island

INTRODUCTION AND NEED

The EDBS located within the CSSC operates to prevent the inter-basin transfer of fish between the Mississippi and Great Lakes basins. Observational evidence from previous studies suggests fish may congregate below the EDBS at different times throughout the year, primarily during the summer and fall (Parker & Finney 2013); however, fish interaction with the EDBS is not predictable or well-understood. Having a greater understanding of the spatial and temporal patterns of fish abundance 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 performed biweekly within and below the EDBS throughout 2022. 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 the upstream spread of invasive carp and increase pressure on the EDBS from the pools immediately downriver. 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

- Evaluate the abundance of fish within and directly below the EDBS biweekly throughout 2022 to inform contingency response and barrier management.
- Determine the density of fish in the three upper navigation pools within the Upper IWW monthly throughout 2022.
- Identify changes in large fish abundance and distribution that could indicate the potential risk of further upstream spread of invasive carp.

PROJECT HIGHLIGHTS

- Mobile hydroacoustic surveys completed in May and June 2022 detected high abundances of large fish targets within the EDBS compared to historical data (11 targets on May 17, 8 targets on June 22; both surveys reflect an aggregate number of detections across three replicate passes). In both surveys, most of the fish targets within the EDBS were detected around or between Barrier IIA and Barrier IIB.
- Fish abundances directly downstream of the EDBS across surveys remained relatively low throughout the year. Spikes in abundance in mid-January, early summer, and mid-November were observed, but trends were overall similar to previous years.
- Large fish densities in mobile hydroacoustic surveys conducted in Lockport, Brandon Road, and Dresden Island pools in 2022 were generally low and similar to past years, except for above-average large fish densities in Brandon Road Pool in November and December 2022. Elevated densities in November were primarily due to the observation of two aggregations of large fish just upstream of the confluence of the Des Plaines River and the CSSC. An electrofishing crew was deployed to investigate. No invasive carp were observed.

METHODS

Acoustic Fish Surveys at the EDBS

Horizontal, split-beam hydroacoustic surveys were conducted biweekly-to-monthly at the CSSC EDBS from January through December 2022 to assess fish abundance and distribution patterns near the EDBS on a fine temporal scale. Survey transects began approximately 1.2 kilometers below the EDBS at 41°37’46.2756”, -88°3’41.9724”. The survey vessel followed a path close to the west wall traveling north with the side-looking hydroacoustic transducers aimed toward 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”. Three consecutive replicate hydroacoustic samples took place on each survey date.

Survey equipment consisted of a pair of Biosonics® 200-kilohertz split-beam transducers mounted in parallel on the starboard side of the research vessel 0.4 meter below the water surface on a dual-axis mechanical rotator. 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 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 to 50 meters from the transducer face, with a ping rate of 5 pings per second and a 0.4-millisecond pulse duration. Data collected less than 1 meter from the transducer face were removed during post-processing to avoid near-field interference. The water temperature was measured and input into Visual Acquisition v.6.1® prior to all data collection to compensate for the effect of water temperature on two-way transmission loss via its effect on the speed of sound in water. 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 was loaded into a mobile survey template to identify and estimate the size and location of single fish targets based on target strength and angular position. Data post-processing followed standard methods. Data that was collected outside of the analysis bounds (analysis bounds: between 41°37’46.2756” and the Demonstration Barrier’s upper parasitic structure) was removed from further analysis, a bottom line was digitized and checked by hand, areas of bad data caused by air bubbles and other sources of acoustic noise were removed, single targets were identified using a threshold of greater than -70 decibels 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 target strength greater than or equal to -28.7 decibels (greater than or equal to 12 inches [30.5 centimeters] total length based on the mean temperature-compensated side-aspect target strength of a fish). Each fish track was also spatially located within the water column using the split-beam transducer’s capabilities, assigned X, Y, and Z positional coordinates, and classified as “within EDBS” or “below EDBS” based on location.

IWW Pool Surveys

In 2022, hydroacoustic surveys were conducted monthly in Lockport and Brandon Road navigation pools from January to June and October to December 2022 to quantify the density and spatial distribution of the fish community in the Upper IWW. No pool surveys were completed in July, August, or September due to staffing shortfalls. Surveys in Dresden Island Pool were only conducted in November and December 2022 due to weather conditions (ice) early in the year and to avoid duplicating efforts with SIU, who completed hydroacoustic surveys in March, May, September, and October. Surveys in April (gear failure) and June through August (also due to staffing shortfalls) were canceled. 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 toward the middle of the channel.

RESULTS AND DISCUSSION

Fish Surveys within and below the Electric Dispersal Barrier

Results from the hydroacoustic surveys conducted within the EDBS indicated the regular presence of multiple fish targets greater than 12 inches within the EDBS from May to October 2022 (The mean was 4.4 large fish targets detected per survey across all replicates; the range was 0 to 11 individual large fish targets across all replicates; Figure 1) with surveys on May 17, 2022 (11 targets) and June 22, 2022 (8 targets) observing the two highest summed numbers of fish targets in the EDBS since project inception. In both surveys, most of the fish targets within the EDBS were detected around or between Barrier IIA and Barrier IIB (Figure 2). Results from the portion of the hydroacoustic surveys conducted immediately downstream of the EDBS suggested shifts between higher and lower fish abundance downstream of the EDBS across surveys throughout the year (the mean was 3.2 large fish targets detected per survey across all replicates; the range was 0 to 9 individual large fish targets across all replicates; Figure 1). Compared to previous years, patterns of fish targets detected below the EDBS were generally similar, with generally low abundances and a few spikes observed in mid-January, May, June, and mid-November. Surveys in 2022 revealed similar patterns of increased abundance within and downstream of the EDBS during the early summer months, as have been witnessed in the past (Figure 1; Parker & Finney, 2013). These consistent trends at this time of year may present a cause for further management consideration and action to reduce the potential for fish passage through the EDBS during these months.

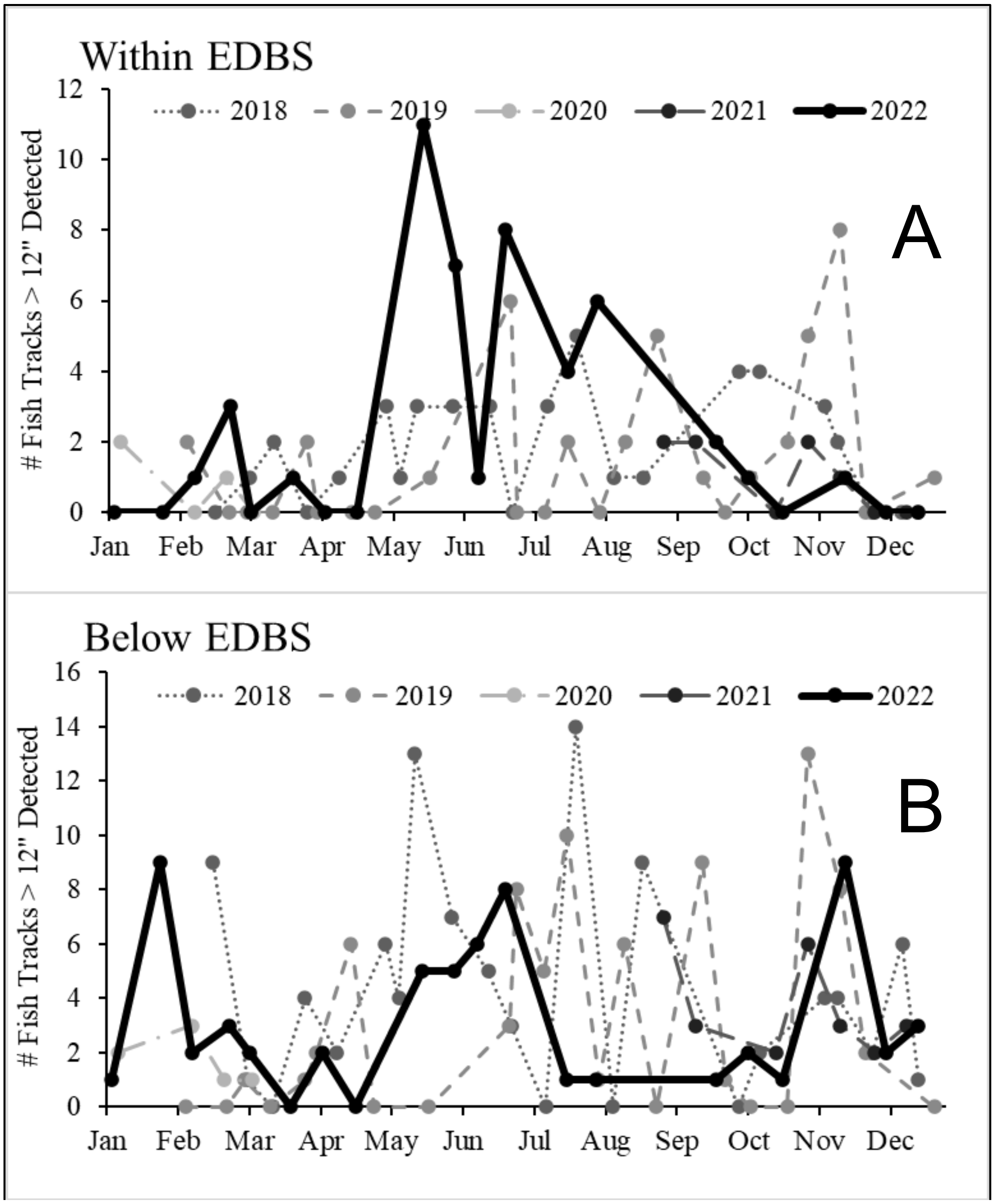


Figure 1. *Number (#) of large fish targets (greater than or equal to -28.7 decibels) observed within (A) and immediately downstream (B) of the EDBS during split-beam hydroacoustic surveys conducted from January through December 2022 compared with past surveys from 2018 to 2021.*

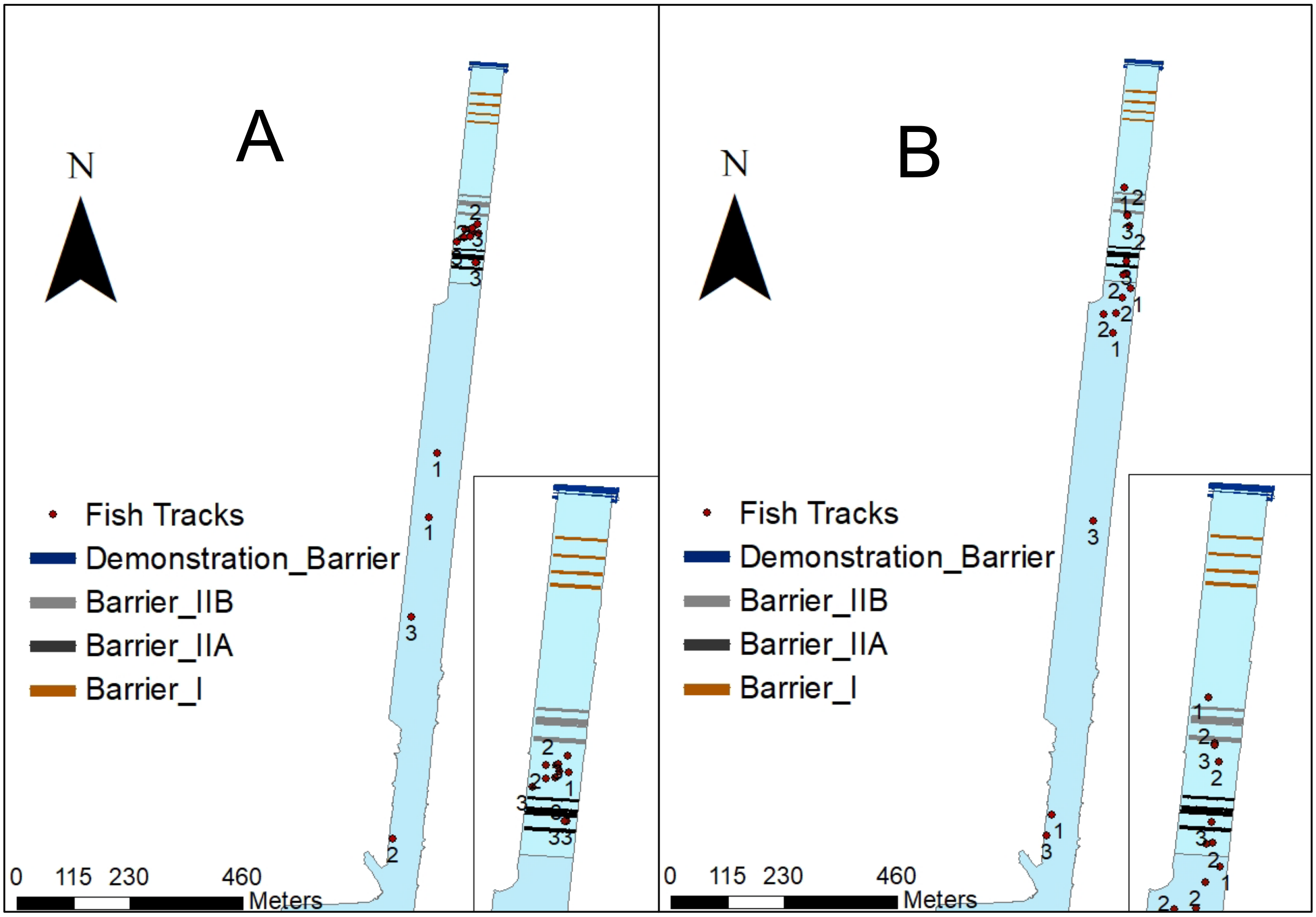


***Figure 2**. Location of the fish tracks greater than or equal to 28.7 decibels observed below the EDBS in the Lockport Pool of the CSSC on May 17 (A) and June 22, 2022 (B). Numbers indicate the replicate run number on which a target was detected.*

IWW Pool Surveys

Results from hydroacoustic surveys conducted in Dresden Island, Brandon Road, and Lockport pools in 2022 illustrated overall similar patterns in large fish abundance to previous years. Abundances during the first half of the year were generally low, with increases in abundance occurring in the fall across all pools (where measured). One instance of elevated abundance of large fish—potentially indicative of the upstream spread of invasive carp—was observed in Brandon Road Pool in November 2022. On November 15, 2022, the highest density of large fish recorded since 2018 in Brandon Road Pool was observed, with two aggregations of large fish observed upstream of the confluence of the CSSC and the Des Plaines River. The MRWG agency leads were notified, and a USFWS electrofishing crew was deployed to conduct fixed and targeted site sampling on November 22, 2022. No invasive carp were observed, but some Common Carp and large Gizzard Shad were captured near the area.

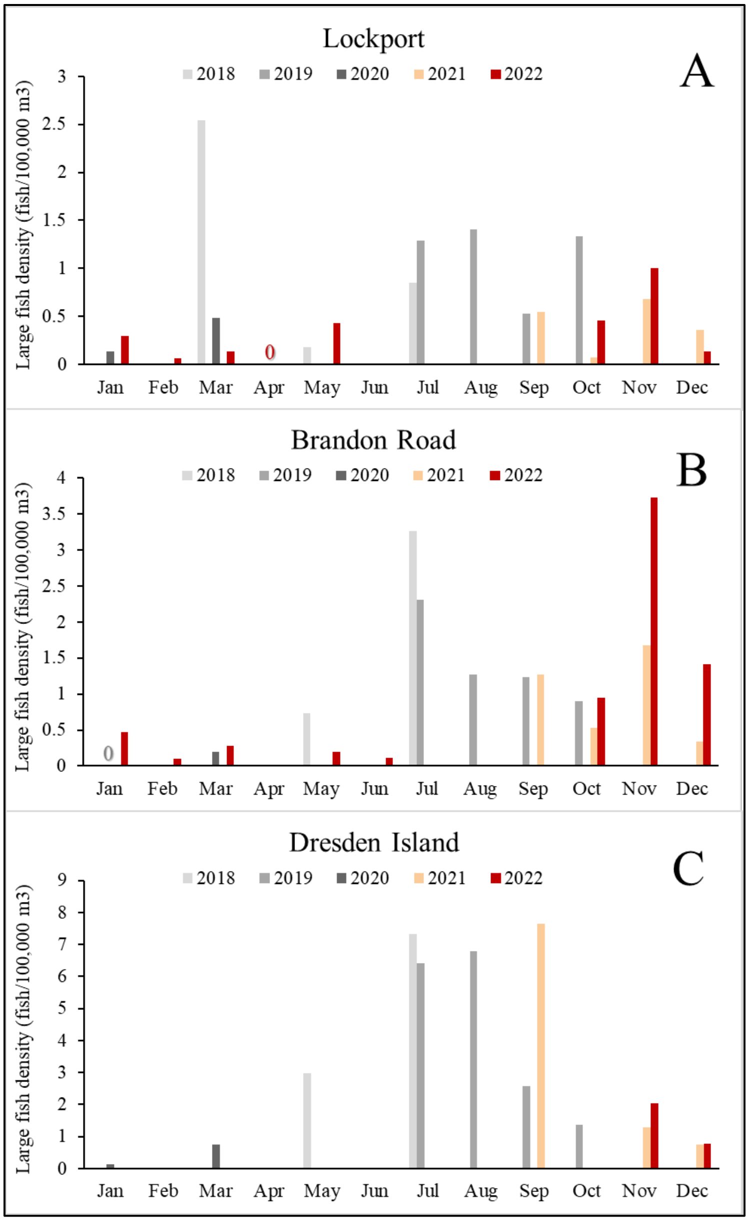


Figure 3. *Density of large fish targets (greater than or equal to -28.7 decibels) from split-beam hydroacoustic surveys conducted in Lockport (A), Brandon Road (B), and Dresden Island (C) pools from 2018 to 2022. Fish target density was calculated by dividing the number of observed fish targets by the water volume sampled during the survey. Months lacking data indicate that a survey was not completed in that month during that year. If a survey was completed and zero large fish targets were detected, a "0" is reported corresponding to the year the survey was conducted.*

CONCLUSION

In 2022, the IWW Hydroacoustics project was overall successful in accomplishing its objectives to inform risk assessment and EDBS maintenance actions by providing insights into trends in abundance of large fish near the EDBS and in the uninvaded/low-density pools immediately downstream. However, observations of the highest abundance of fish targets in the EDBS this year, coupled with a capture of a live adult Silver Carp upstream of the EDBS in August 2022 by the USACE, suggests adaptations to detection and surveillance programs may be warranted to enhance the ability to detect fish—potentially invasive carp—moving upstream and pressuring or potentially passing through the EDBS.

RECOMMENDATIONS

- Investigate alternative applications/analyses for hydroacoustic sampling at the EDBS to enhance surveillance and risk assessment efforts (e.g., the feasibility of fixed stationary monitoring system to detect upstream movement of large fish past a point near the EDBS).
- Transition mobile hydroacoustic sampling in Dresden Island, Brandon Road, and Lockport pools from monthly to on-request status to allow time/resources for investigating alternative applications at the EDBS.
- Continue biweekly or monthly mobile hydroacoustic surveys at the EDBS during periods of interest identified by USACE or other agencies to inform barrier operations and maintenance scheduling and assess risk.

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EARLY DETECTION OF BIGHEAD CARP IN THE ILLINOIS WATERWAY

Participating Agencies: USFWS Carterville FWCO; Jen-Luc Abeln, Michael Glubzinski, Tanner Barnes, and Charles Wainright (USFWS, Carterville FWCO Wilmington Substation)

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

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 et al. 2006). Early detection of invasive species is crucial to the success of these strategies because it allows control and eradication efforts to be implemented when abundance is low and individuals are more likely to be spatially restricted (Myers et al. 2000; Mehta et al. 2007). Since the 1970s, invasive Silver Carp and Bighead Carp 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 (collectively known as bigheaded 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 the 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; however, tests with small Bighead Carp (51 to 76 millimeters total length) have indicated that the operational parameters of the EDBS may be inadequate for blocking the passage of small-bodied fishes (Holliman 2011). Studies have also shown that small fish can become entrained in barge junction gaps and transported through the EDBS (Davis et al. 2016). Furthermore, research using Dual Frequency Identification Sonar 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.

Currently, the bigheaded carp population front in the IWW resides in the Dresden Island Pool, approximately 20 kilometers from the EDBS and 70 kilometers from Lake Michigan (ICRCC 2022). While a large effort is underway to reduce potential upstream movements of invasive carp to uninvaded habitats through proposed modifications to Brandon Road Lock (USACE 2018), no deterrents currently exist between the invasion front and the EDBS, and invasive carp have been shown to pass through lock chambers regularly. Therefore, routine efforts designed to detect any invasive carp that may be present in those systems and could pressure the EDBS are warranted. Similarly, small invasive carp (less than or equal to 153 millimeters) are considered absent upstream of Marseilles Lock & Dam (ICRCC 2022). However, due to the risk of fish of this size potentially being able to bypass the EDBS uninhibited or be entrained and transported upstream of the EDBS by barges, increased effort to detect any small invasive carp that may be present between Marseilles Lock & Dam and the EDBS are imperative. Therefore, the overall objective of this project was to increase focused, species-specific, early detection sampling for small (less than or equal to 153 millimeters total length) and large (greater than 153 millimeters total length) Silver Carp and Bighead Carp in the upper IWW to increase 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 the 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.

OBJECTIVES

- Conduct monthly fixed and randomized electrofishing and gill net sampling targeted for large bigheaded carp in Brandon Road and Lockport pools from March to November.
- Conduct monthly fixed and randomized electrofishing, dozer trawling, and mini-fyke netting sampling targeted for small bigheaded carp in Dresden Island Pool, Marseilles Pool, and the Kankakee River from March to November.
- Remove any bigheaded carp captured across all pools, and immediately report any captures upstream of known invasion fronts.

PROJECT HIGHLIGHTS

- No small-bodied Silver Carp or Bighead Carp were captured in Lockport, Brandon Road, Dresden Island, or Marseilles pools.
- No large-bodied Silver Carp or Bighead Carp were captured or observed upstream of Brandon Road Lock and Dam.
- In 2022, 174 large-bodied Silver Carp and 8 large-bodied Grass Carp were captured and removed in Dresden Island Pool, the lower Kankakee River, and Marseilles Pool.
- In total, 358 electrofishing runs, 257 electrified dozer trawl, and 213 mini-fyke net sets were completed between March 14 and December 7, 2022, across all pools.
- In total, 114,269 individual fish comprised of 89 species and 9 hybrid groups were captured.

METHODS

A combination of fixed and random site sampling with habitat stratifications was conducted in pools depending on gear and habitat suitability. 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 be captured in, the gear types that most effectively capture bigheaded carp in those habitats, and the most effective times to sample. Notable areas to target or avoid were incorporated in 2022 site selections based on field experiences from the 2021 sampling year. Fixed sites were located where bigheaded carp 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, and BW) and habitat area, excluding zones that were not useable for each gear type deployed. Fixed and random site sampling included using boat-mounted electrofishing, electrified dozer trawling, and mini-fyke netting. Boat-mounted electrofishing runs were completed using LTRM methods and consisted of 15 minutes of fishing in either an upstream or downstream direction. Electrified dozer trawling consisted of a single 5-minute transect traveling in an upstream direction per site. Mini-fyke netting consisted of 24-hour net sets per sampling site. All captured Bighead Carp, Silver Carp, and Grass Carp were measured for total length (millimeters) and mass (grams) and then euthanized; all other species were identified to species, enumerated, and released.

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). Species richness estimators are one such tool that 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). Rarefaction analyses were used to evaluate the thoroughness of sampling at the applied level of sampling effort in the study areas by estimating species richness using the Mao Tau method for species accumulation and the Chao2 estimator (Chao 1987) 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 was 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 were set overnight. Single nets were set with the lead end staked against the shoreline or another obstruction to fish movement. All mini-fyke nets were constructed of 1/8-inch mesh.

Dozer Trawl: A 35-millimeter mesh net was placed at the mouth, reducing to 4-millimeter 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 meters in front of the trawl and the trawl acting as the cathode. Trawl sampling duration consisted of 5-minute transects.

RESULTS AND DISCUSSION

In 2022, 828 sites across four IWW pools (Lockport, Brandon Road, Dresden Island, and Marseilles) and the lower Kankakee River were surveyed for the presence of both small-bodied and large-bodied Silver Carp and Bighead Carp between March 14 and December 7, 2022 (Table 1). The total effort consisted of 89.6 hours of boat electrofishing, 21.9 hours of electrified dozer trawling, and 212.6 net nights of mini-fyke netting. In total, 174 large-bodied Silver Carp were captured, with all specimens collected downstream of Brandon Road Lock and Dam (Table 2).

Eight Grass Carp were captured downstream of Brandon Road Lock and Dam (Table 3). Among the sampling months, the most adult invasive carp were captured in June (Figure 1). No large- or small-bodied Bighead Carp or small-bodied Silver Carp were captured upstream of their known range during early detection monitoring sampling in 2022.

Table 1. USFWS 2022 targeted Silver Carp and Bighead Carp early detection monitoring sampling efforts in Lockport, Brandon Road, Dresden Island, and Marseilles pools. Pools are organized left-to-right in this table to indicate the 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.

	Marseilles		**Dresden Island**		**Brandon Road**		**Lockport**		**Kankakee**	
	effort	sites	effort	sites	effort	sites	effort	sites	effort	sites
Boat Electrofishing	20.2 h	81	16.0 h	62	17.7 h	72	15.8 h	64	19.8 h	78
Electrified Dozer Trawl	4.5 h	50	3.4 h	40	5.1 h	61	3.8 h	46	5.2 h	60
Mini-Fyke Net	81.7 nn	80	53.4 nn	53	--	--	--	--	77.4 nn	80

Table 2. Silver Carp captured during USFWS early detection monitoring in Dresden Island Pool and the Kankakee River between March 14, 2022, and December 7, 2022. Total catch (number of individuals), mean total length (millimeters), and mean mass (grams) are 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			Marseilles		
Silver Carp	Total Catch	Mean Total Length	Mean Mass	Total Catch	Mean Total Length	Mean Mass	Total Catch	Mean Total Length	Mean Mass
Boat Electrofishing	10	841	7440	6	837	7399	130	777	5952
Electrified Dozer Trawl	--	--	--	2	869	7935	26	770	5456
Mini-Fyke Netting	--	--	--	--	--	--	--	--	--

Table 3. Grass Carp captured during USFWS early detection monitoring in Marseilles and Dresden Island pools between March 14, 2022, and December 7, 2022. Total catch (number of individuals), mean total length (millimeters), and mean mass (grams) are 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 Pool, Brandon Road Pool, or the Kankakee River.

	Marseilles			Dresden Island		
Grass Carp	Total Catch	Mean Total Length	Mean Mass	Total Catch	Mean Total Length	Mean Mass
Boat Electrofishing	7	946	9632	1	985	14468
Electrified Dozer Trawl	--	--	--	--	--	--
Mini-Fyke Netting	--	--	--	--	--	--

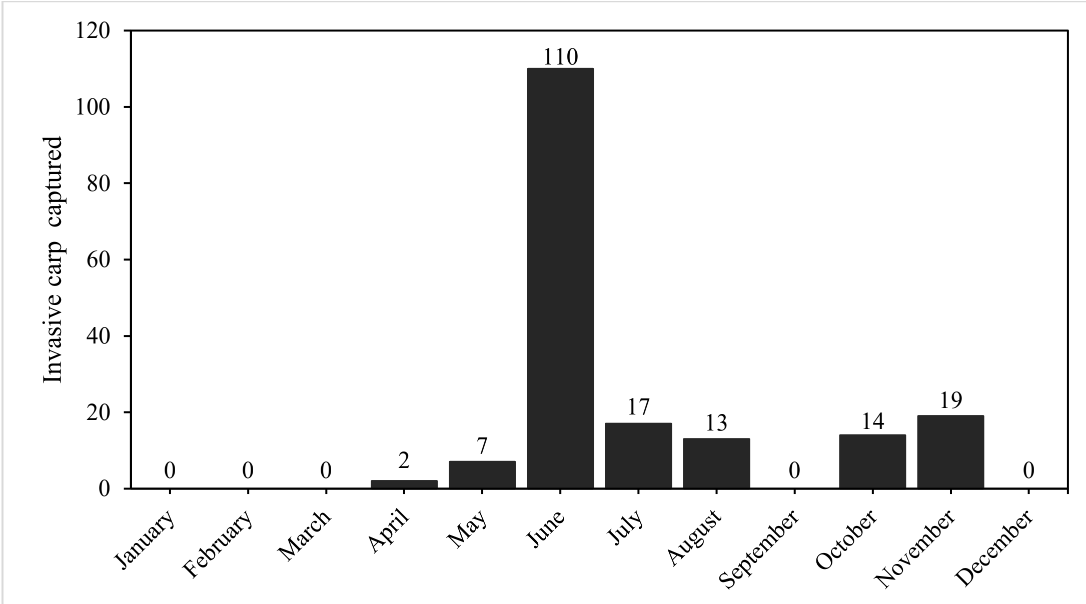

Figure 1. *Monthly distribution of all invasive carp individuals captured by USFWS Early Detection Monitoring program in 2022.*

Across all 2022 samples, non-targeted (all species besides invasive carp) fish bycatch included 114,095 individuals comprised of 87 species and 9 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 June (Figure 3). Bluegill was the most abundant species captured, representing 49.2 percent of the total catch. Other abundance species included Gizzard Shad (11.6 percent of catch), Emerald Shiner (9.1 percent of catch), and Bluntnose Minnow (8.9 percent of catch). The total observed species richness in Lockport Pool was 28 species (Figure 4). The annual mean Chao2 species richness estimate for Lockport Pool, using data from all sampling events, was 43 species (95 percent CI = 19 - 68 species). The total observed species richness in Brandon Road Pool was 42 species. The annual Chao2 species richness estimate for Brandon Road Pool was 68 species (95 percent CI = 33 – 103 species). The total observed species richness in Dresden Island Pool was 73 species. The annual Chao2 species richness estimate for Dresden Island Pool was 99 species (95 percent CI = 64 - 134 species). The total observed species richness in the lower Kankakee River was 78 species. The annual Chao2 species richness estimate for the lower Kankakee River was 93 species (95 percent CI = 72 - 113 species). The total observed species richness in the Marseilles Pool was 71 species. The annual Chao2 species richness estimate for the Marseilles Pool was 82 species (95 percent CI = 67 - 97 species).

Rarefaction analyses suggested that sampling intensity was sufficient to detect most of the species present in Lockport, Brandon Road, lower Kankakee River, and Marseilles pools, as indicated by the overlapping 95 percent CIs and the generally asymptotic species accumulation and estimator curves (Figure 4). The non-asymptotic species accumulation and estimator curves and large 95 percent confidence intervals for the Dresden Island and Brandon Road pools indicate that several of the species that were detected are uncommon (only detected in a few samples) and suggest that additional undetected species are likely present. Therefore, additional sampling efforts may be necessary in the Dresden Island and Brandon Road pools to detect invasive carp life stages that may be present.

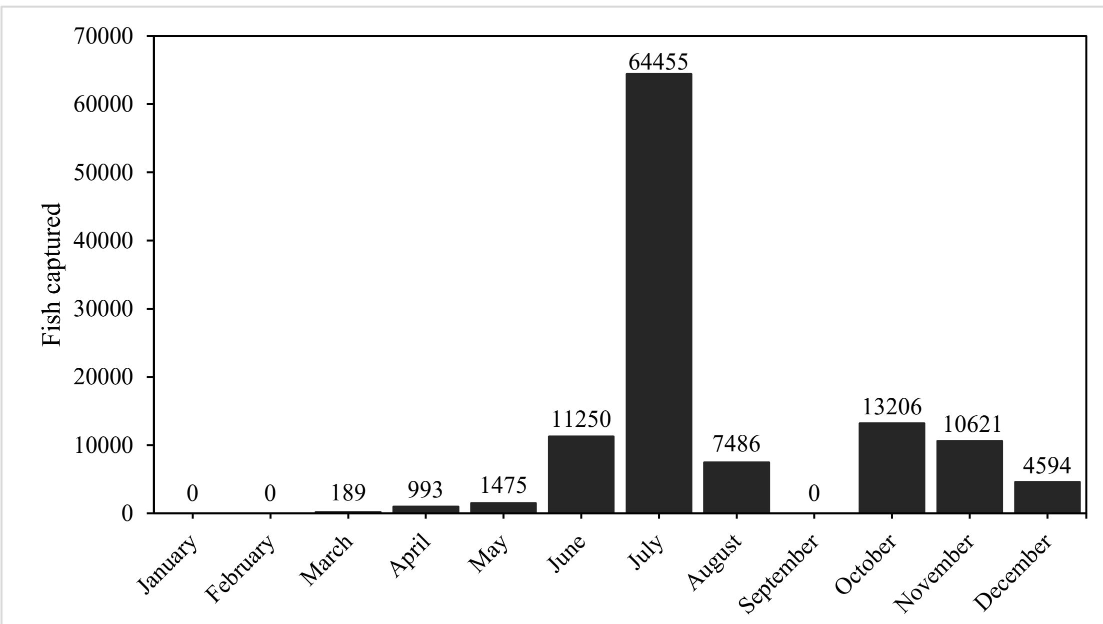

Figure 2. *Monthly distribution of all non-targeted fish bycatch captured by USFWS Early Detection Monitoring program in 2022.*

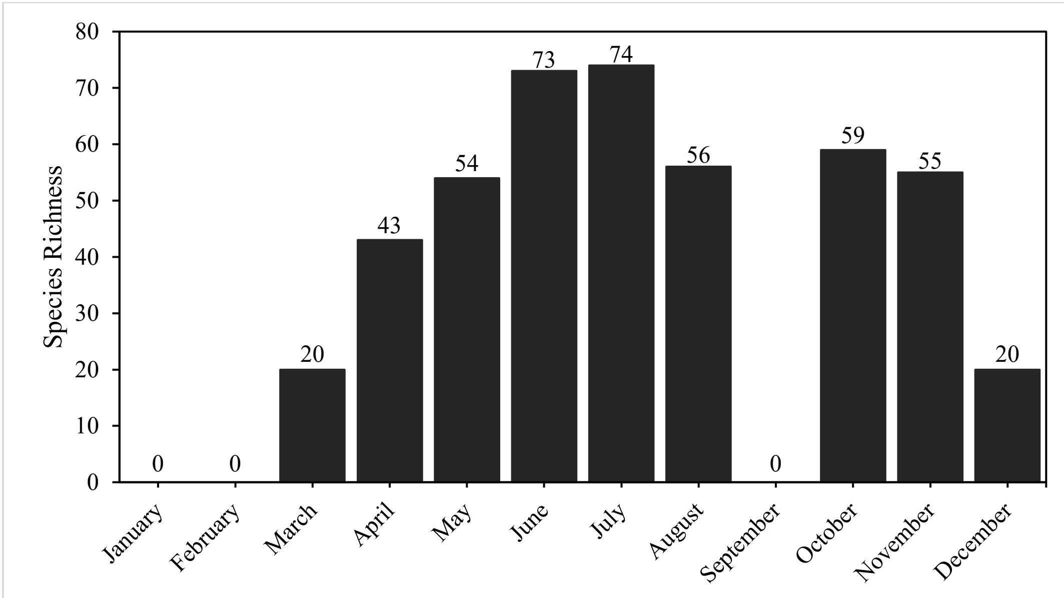

Figure 3. *Monthly distribution of fish species richness captured by USFWS Early Detection Monitoring program in 2022.*

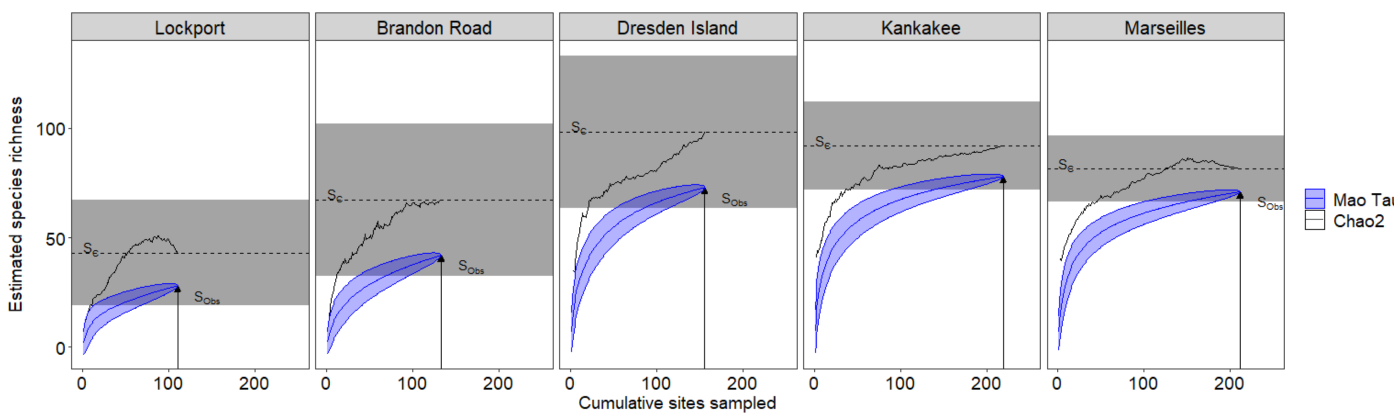

Figure 4. *Species accumulation curve (Mao Tau; blue line with 95 percent CI) and estimated species richness (Chao2; black line) for Lockport Pool, Brandon Road Pool, Dresden Island Pool, and the lower Kankakee River based on 1000 Monte Carlo resamples. The total number of observed species (S_{obs})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

Dozer trawl effectiveness upstream of Brandon Road Lock and Dam was poor, with two-thirds of samples in Lockport and Brandon Road pools capturing no fish. This may have been due to deep (14 to 25 feet) stretches with vertical revetment banks being the prominent habitat in these pools, as the dozer trawl typically functions best in specific areas of the river where the net can be fully deployed (approximately 3 feet), the electrified field can cover the water column (approximately 6 feet) and debris is limited (Miranda and Kratochvil 2008; Hammen et al. 2019). However, given that confidence intervals for species richness estimates in these pools were wide and sampling may not have captured all species present, total effort in these pools should remain consistent or increase in 2023. Therefore, reallocating efforts to a more effective gear for these habitats may be warranted. Gill nets are currently used in other sampling efforts to detect and remove adult invasive carp and have been the primary gear responsible for the capture or observation of all live invasive carp upstream of Brandon Road Lock and Dam since 2010. Since adult invasive carp are not present in Lockport or Brandon Road pools but are present immediately downstream in Dresden Island Pool, prioritizing efforts to detect any potential upstream spread of adults is warranted.

RECOMMENDATIONS

- Continue early detection monitoring for all life stages of invasive carp in the Upper IWW to provide additional assurance that adult invasive carp are absent from the area upstream of Brandon Road Lock and Dam and small invasive carp are absent from the area upstream of Marseilles Lock and Dam.
- Increase sampling efforts in the Dresden Island and Brandon Road pools to increase confidence in detecting any invasive carp life stages that may be present and total species richness.
- Consider replacing dozer trawl with gill nets in Brandon Road and Lockport pools.
- Ensure 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

Participating Agencies: INHS (lead); Eastern Illinois University, SIUC, USGS – Central Midwest Water Science Center, USFWS – Whitney Genetics Lab (field and lab support); Steven E. Butler, Joseph J. Parkos III, Anthony P. Porreca, Mark A. Davis (INHS), Eden L. Effert-Fanta, Tyler J. Pasley, Robert E. Colombo (Eastern Illinois University), David P. Coulter (SIUC)

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 establishing and spreading invasive species (Moyle and Marchetti 2006; Lockwood et al. 2013). Understanding the spatial and temporal dynamics of reproduction by invasive fish 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. 2023), flexible reproductive behavior (DeGrandchamp et al. 2007; Coulter et al. 2013), multiple batch spawning (Camacho et al. 2023; Tucker et al. 2020), and high dispersal rates of offspring (Deters et al. 2013; Coulter et al. 2016). Evaluating invasive carp reproduction and the distribution of early life stages in different sections of the IWW and its tributaries is needed to monitor 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 any upstream expansion of reproducing invasive carp populations and 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 carp 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. 2023), and multiyear efforts have been necessary to assess the magnitude, location, and timing of reproduction, evaluate conditions affecting reproduction, and monitor 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 toward 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. 2023; Schaick et al. 2023), which may complicate management efforts on the mainstem Illinois River and may offer insight into the suitability of Great Lakes basin tributaries should 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; MRWG 2022; Parkos et al. 2023). 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 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 and density-limitation of reproductive output at very high adult densities (Parkos et al. 2023). Continuing assessment of the reproductive productivity of invasive carp populations may therefore aid in evaluating the success of control efforts and refining our understanding of potential compensatory responses to harvest.

OBJECTIVES

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

- Monitor potential changes in the reproductive front of invasive carp populations;
- Monitor Black Carp reproduction in the IWW; and
- Quantify the relationship between invasive carp adult density, reproductive output, and recruitment.

PROJECT HIGHLIGHTS

- From May to September 2022, 408 ichthyoplankton samples were collected from seven sites from the Brandon Road to LaGrange navigation pools of the IWW, capturing 1,112 large-diameter eggs and nine invasive carp larvae. Two large-diameter eggs collected from the Marseilles Pool during July are awaiting genetic determination of species identity. No other evidence of invasive carp reproduction was detected upstream of Starved Rock Lock and Dam in 2022. A cool spring with declining water levels followed by a dry summer likely limited the synchronization of invasive carp spawning activity. Overall, invasive carp reproductive output in the IWW was low in 2022 relative to other recent years of observation.

- In 2022, 288 ichthyoplankton samples collected from Illinois River tributaries captured large-diameter eggs from the Spoon River and invasive carp larvae from the Sangamon River but found no evidence of invasive carp reproduction in other Illinois tributaries. Localized rain events during the spring and summer of 2022 resulted in flashier discharge in the Spoon and Sangamon rivers than in the mainstem Illinois River, contributing to low-magnitude invasive carp reproduction in these systems from May through August.
- Updated analyses examining factors affecting invasive carp reproductive output continued to provide evidence that both adult invasive carp density and environmental conditions influence spatiotemporal variation in the magnitude of invasive carp reproduction. Invasive carp egg drift tends to be highest at intermediate densities of adults and during years with higher seasonal fluctuations in discharge coinciding with warmer water temperatures during May and June.

METHODS

Larval fish sampling occurred at seven sites in the Illinois and Des Plaines rivers downstream of the Electric Dispersal Barrier in 2022 (Figure 1). Additional sampling took place in six tributary rivers (Kankakee, Fox, Vermilion, Mackinaw, Spoon, and Sangamon rivers). Sampling occurred weekly from the beginning of May to mid-July and biweekly from mid-July to the end of September. At main channel sites, a minimum of four ichthyoplankton 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 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-meter diameter ichthyoplankton push net with 500-micrometer mesh. The net was pushed upstream using an aluminum frame mounted to the front of the boat to obtain each sample. Boat speed was adjusted to 1.0 to 1.5 meters per second water velocity through the net. The 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 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. Sample ethanol was exchanged with fresh molecular-grade ethanol 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-milliliter aliquots of sample preservative were removed to screen for the presence of invasive carp DNA. Following DNA extraction, assays for the four taxa of invasive carp were run in multiplex reactions, following qPCR methodology (Fritts et al. 2019; Guan et al. 2019). The number of DNA copies from each taxon present in each extraction replicate was quantified and used to assess the probability that eggs or larvae of each species of invasive carp were present in the sample.

Following extraction of qPCR aliquots, 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 millimeters being identified as potential invasive carp eggs and retained for later genetic analyses. 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.

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. An index of annual invasive carp egg totals was estimated for each monitoring site by multiplying mean egg density on each sampling date by discharge to standardize egg abundances observed under varying discharge conditions, then scaling these estimates from a single second to a 24-hour period and summing these estimates across sampling dates. Updated analyses examining the influence of adult spawning stock density and environmental factors on invasive carp reproductive output were conducted using data collected through 2020 to assess the potential for invasive carp harvest efforts to diminish the reproductive potential of invasive carp populations in targeted navigation pools. Invasive carp spawning stock density estimates were generated by annual hydroacoustic surveys conducted by SIUC. Water temperatures were obtained from USGS gages at Seneca (USGS 5543010) to represent the upper Illinois River pools and at Florence (USGS 5586300) to represent LaGrange reach locations. Discharge data for each pool was obtained from upstream USACE gages located at the Dresden Island, Marseilles, and Starved Rock lock and dams. Data from the USGS gage at Kingston Mines (USGS 5568500) was used for LaGrange Pool discharge.

Based on probable spawning locations identified by FluEgg model analysis of invasive carp egg collections (Zhu et al. 2018), annual egg totals in each navigation pool were related to the combined density of adult invasive carp within that pool and the next upstream pool. Mixed-model methodology with a repeated measures framework was used to model annual egg totals as a function of adult density and spring warming and discharge variables (May through June period). The same environmental factors as used in previous analyses (Parkos et al. 2023) were included in candidate models. These included cumulative degree days (base 18°C) through the end of June and both the mean and coefficient of variation of mean daily discharge during May and June. A null model (i.e., intercept only) was included for comparison to assess whether there was meaningful support for any of the models in the set. To facilitate the comparison of empirical support for each model, adult invasive carp corrected for small sample size (AIC_c), and AIC_c weights were computed for each model (Anderson 2008).

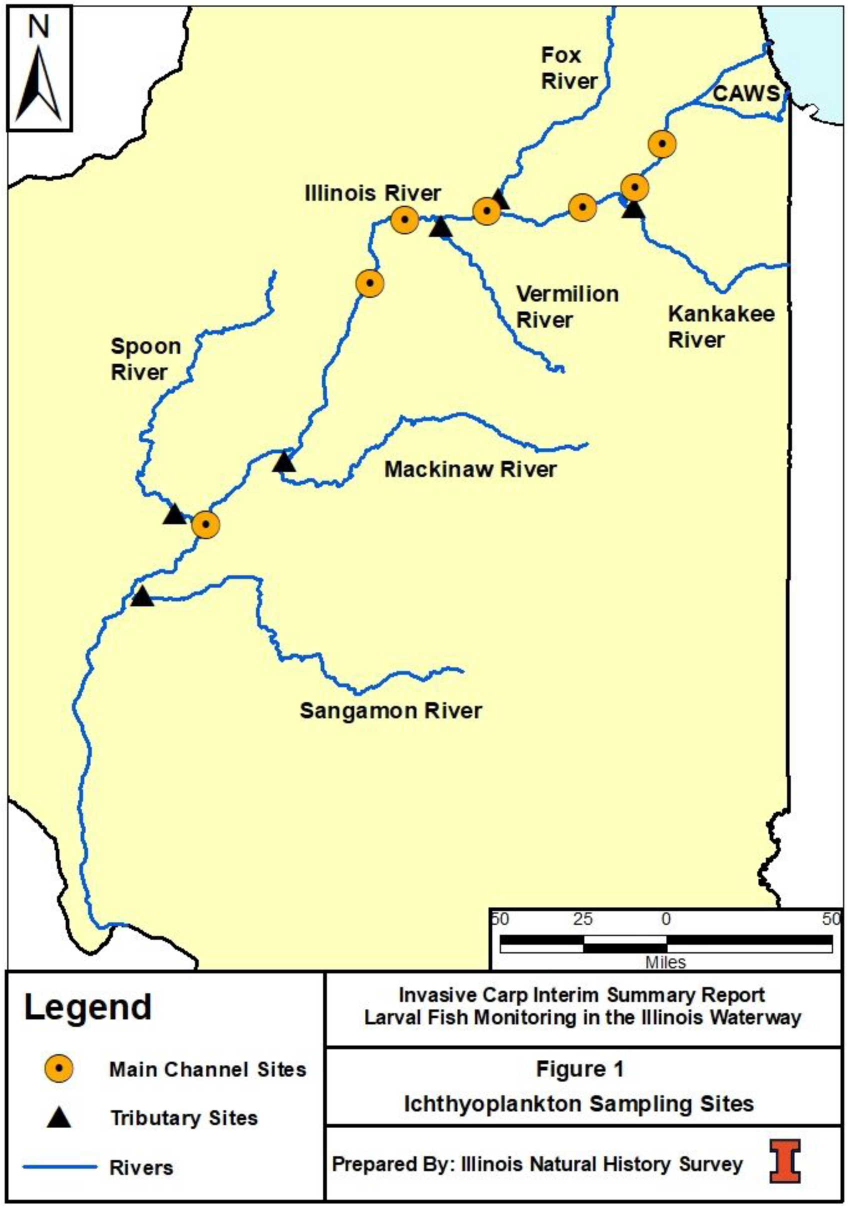

Figure 1. *Map of ichthyoplankton sampling sites in the IWW (circles) and in tributary rivers (triangles).*

RESULTS AND DISCUSSION

In 2022, ichthyoplankton monitoring in the IWW collected 478 samples, capturing 1,112 large-diameter eggs. Nearly all (N = 1,088) of these eggs were collected during the third week of May at Havana in the LaGrange Pool. Only nine invasive carp larvae were collected from main channel monitoring sites in the LaGrange and Peoria pools in 2022.

Two large-diameter eggs collected from the Marseilles Pool in July are awaiting genetic determination of species identity. No other large-diameter eggs or invasive carp larvae have been identified from samples collected upstream of Starved Rock Lock and Dam in 2022. qPCR screening of ichthyoplankton samples was delayed by technical difficulties in 2022; therefore, species-level identification of invasive carp in ichthyoplankton samples is not available at the time of this report. Results of qPCR assays from 2022 will be reported once available. Nonetheless, overall invasive carp reproductive productivity in the Illinois River was low during 2022 relative to other recent study years (Figure 2).

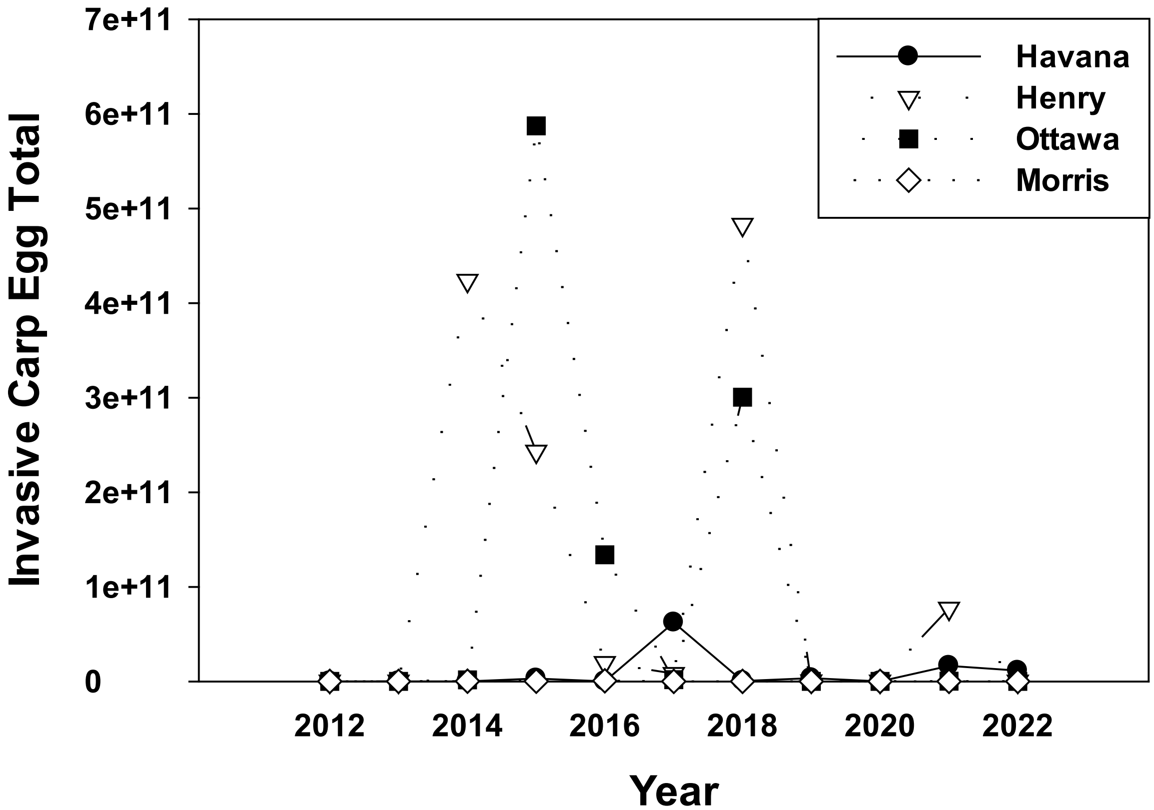

Figure 2. *Index of total annual invasive carp egg drift in the LaGrange (Havana), Peoria (Henry), Starved Rock (Ottawa), and Marseilles (Morris) navigation pools from 2012 to 2022. The index of total annual egg drift was estimated by summing observed egg densities standardized by site-specific discharge and scaled to 24-hour intervals.*

Rain events from February to May resulted in early peaks in discharge in the main channel of the Illinois River in 2022. Water levels returned to near base flow by May in the upper navigation pools and by June in the LaGrange and Peoria Pools. The majority of invasive carp reproduction observed in 2022 occurred during this period of high but declining water levels (Figure 3). Episodic storm events during the summer months resulted in brief and limited increases in discharge, and the only evidence of invasive carp reproduction after June was the collection of two large-diameter eggs at Marseilles Pool and two larvae at Peoria Pool during the second week of July. No invasive carp eggs or larvae were collected after July in 2022.

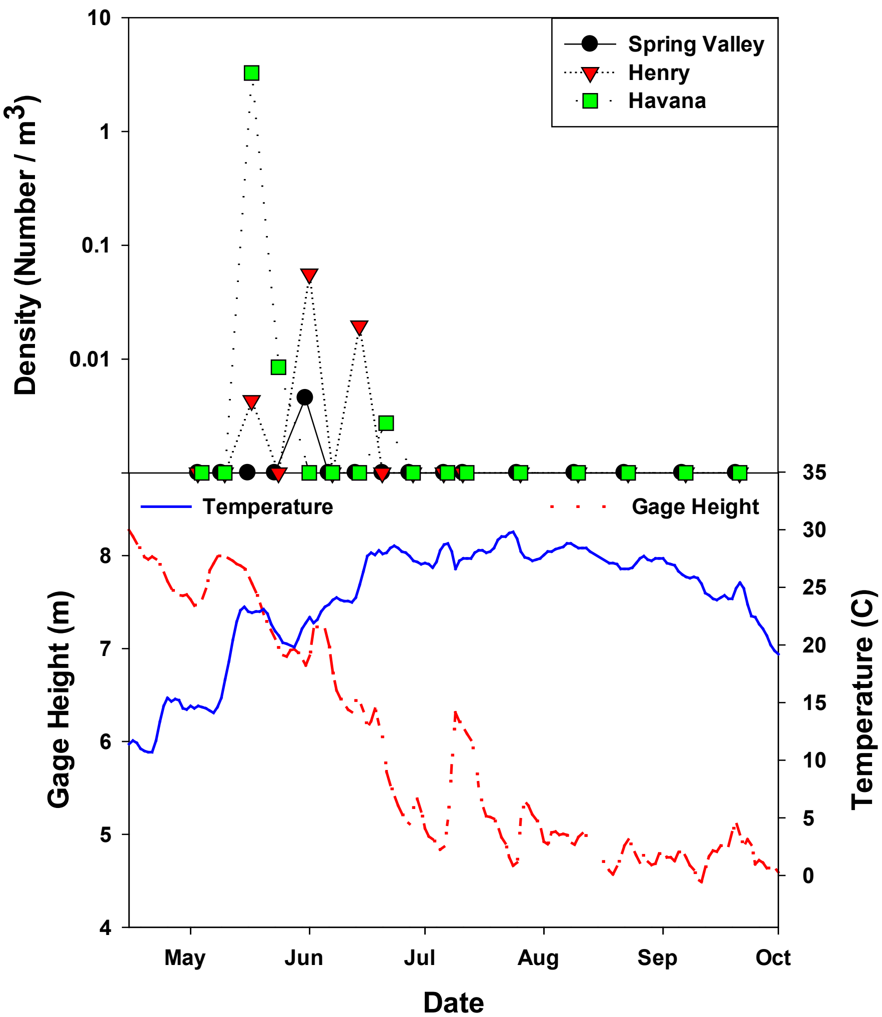

Figure 3. *Densities (number/cubic meter; note log scale) of invasive carp eggs (top panel) collected from main channel sites of the IWW in 2022. Mean daily gage height (meter) and water temperature (°C) of the Illinois River from May through October 2022 (bottom panel) were obtained from USGS gage 55836300 at Florence, IL.*

Tributary sampling collected an additional 288 ichthyoplankton samples in 2022. Large-diameter eggs (n = 14) were collected from the Spoon River, and invasive carp larvae (n = 37) were captured in the Sangamon River, but evidence of invasive carp reproduction was not observed in other Illinois River tributaries in 2022. Localized rain events throughout the spring and summer of 2022 resulted in flashier discharge in the Spoon and Sangamon rivers than in the mainstem Illinois River. Consequently, evidence of low-magnitude invasive carp reproduction in these systems was detected on multiple sampling dates from May through August (Figure 4).

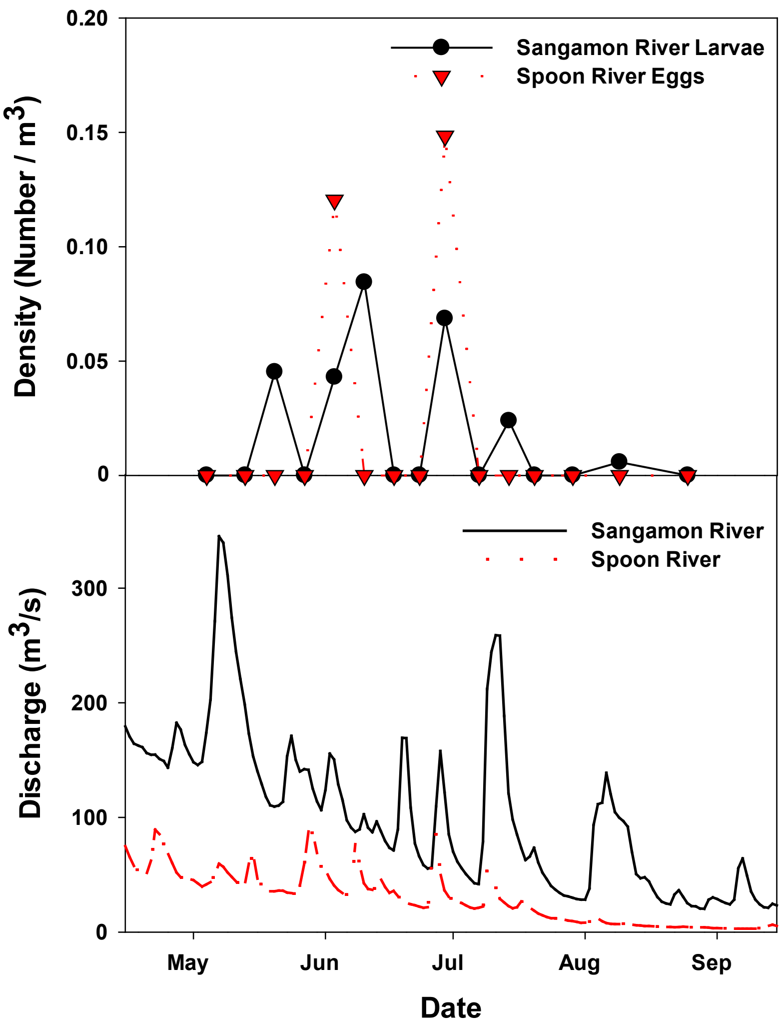

Figure 4. *Density (number/m^3; note log scale) of invasive carp eggs and larvae (top panel) collected from two tributaries of the Illinois River (Sangamon and Spoon rivers) during May – September 2022. No invasive carp eggs or larvae were collected from the Mackinaw, Vermilion, Fox, and Kankakee rivers in 2022. Mean daily discharge (meter^3/second; bottom panel) was obtained from USGS gages (Spoon River:5570000; Sangamon River:5583000).*

Updated analyses examining factors affecting invasive carp reproductive output found nearly identical results to previous analyses that used only data through 2019. As before, both adult invasive carp density and environmental conditions during the May through June period influenced spatiotemporal variation in the magnitude of invasive carp reproduction. A quadratic function best represented the relationship between total annual egg drift and adult density, and models that included adult invasive carp density were more supported by the data than those that only included environmental variables. The most supported model included the quadratic relationship with adult density, discharge CV, and cumulative growing degree days through the end of June (Table 1). Invasive carp egg drift was highest at sites that had intermediate densities of adults within and upstream of the pool containing the monitoring site and during years with higher seasonal fluctuations in discharge coinciding with warmer water temperatures during May and June.

Table 1. Relative support for models of invasive carp total egg drift at sampling locations in the LaGrange, Peoria, Starved Rock, and Marseilles navigation pools of the Illinois River from 2014 to 2020, including a null model that only includes an intercept variable. Models assessed support for the quadratic relationship between adult invasive carp density and total egg drift (Adult Density), cumulative degree days through the end of June (June DDs), Z-transformed mean daily discharge during May and June (Discharge Z), and the coefficient of variation of mean daily discharge during the same period (Discharge CV). Models are ranked by relative support within the considered model set based on AIC scores corrected for small sample sizes (AIC_c). Relative model support is represented by Δ, the difference between the 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).

Model	**AIC_c**	**Δ**	**w_i**
Null	181.1	25.4	< 0.0001
Adult Density	167.5	11.8	0.0025
Adult Density + Discharge Z	164.8	9.1	0.0095
Adult Density + Discharge CV	161.4	5.7	0.0518
Adult Density + June DDs	161.9	6.2	0.0404
Adult Density + Discharge CV + June DDs	155.7	0	0.8959

The low invasive carp reproductive output observed in 2022 is consistent with patterns from previous study years where cool springs with high early rainfall fail to produce large spawning events. Both warming and discharge variables from May to June have consistently been found to affect the magnitude of invasive carp reproduction in the Illinois River. If water temperatures conducive to invasive carp spawning don't coincide with increasing water levels during this period, the reproductive output can generally be expected to be limited. Indeed, the largest increases in water levels in the Illinois River during 2022 occurred prior to water temperatures reaching the threshold thought to be conducive to invasive carp spawning. Large-diameter eggs were collected shortly after temperatures crossed this threshold, but discharge throughout the Illinois River was declining by this time and remained low after June, likely inhibiting synchronized mass spawning by invasive carp. In contrast, localized rain events produced multiple peaks in discharge in two LaGrange Pool tributaries in 2022, triggering periodic, albeit low-magnitude spawning by invasive carp in these systems throughout the summer months. However, no evidence of invasive carp reproduction was detected in four other tributary rivers. Tributaries with larger watersheds, higher discharge, greater turbidity, and higher temperatures have been found to produce higher abundances of invasive carp eggs (Schaik et al. 2023). Differences in spawning stock characteristics among tributaries also likely contribute to observed differences in reproductive output but have not yet been assessed. The contribution of tributaries to basin-wide invasive carp egg and larval production remains unknown but likely varies among the years depending on the timing and magnitude of precipitation events and the subsequent effects on individual watersheds. In some years where reproductive output by invasive carp in the main channel is low, spawning in tributaries may serve to buffer invasive carp populations against the complete loss of a year class, provided that offspring produced by tributary spawning survive and recruit to the population.

Other than two possible invasive carp eggs collected in the Marseilles Pool, no evidence of invasive carp reproduction was observed upstream of Starved Rock Lock and Dam in 2022. Invasive carp eggs have been collected in the Marseilles and Starved Rock pools for several years, and invasive carp larvae have been found in the Starved Rock Pool in 2015, 2020, and 2021. The environmental conditions in the Upper IWW were not conducive to invasive carp spawning in 2022, but previous years when conditions have been more favorable have resulted in varying magnitudes of reproductive output. Changing adult population densities in the Upper IWW may account for some of this variation, as harvest efforts have reduced invasive carp densities upstream of Starved Rock Lock and Dam over the past decade. Continued monitoring for invasive carp reproduction in the Upper IWW will be necessary to identify changes in the distribution patterns of early life stages in this section of the river and assess if continuing harvest efforts are successfully diminishing reproductive output towards the leading edge of the invasion front.

The relationship between invasive carp spawning stock density and total annual egg drift continues to provide evidence of both diminished reproductive output at low adult abundances and density-limitation of reproductive output at very high densities of adults, as a quadratic relationship best describes the relationship between adult density and total egg drift. 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. Reduced functional connectivity between navigation pools in the Upper IWW (Lubejko et al. 2017; Coulter et al. 2018; Zielinski et al. 2018) may contribute to a lack of compensatory reproductive response at low stock densities, thereby increasing the effectiveness of removal efforts of these more isolated invasive carp populations. However, immigration may complicate removal efforts downstream of Starved Rock Lock and Dam, where movement rates between navigation pools are likely much higher (Coulter et al. 2018). Density-dependent reproductive output of invasive carp detectable through the larval stage also implies any variation in stock-recruitment patterns for these species needs to be interpreted cautiously before being ascribed to environmental factors affecting survival from hatching to juvenile stages.

RECOMMENDATIONS

Ichthyoplankton sampling should continue to monitor 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 modeling 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 the 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. Ichthyoplankton sampling downstream of Starved Rock Lock and Dam should continue to monitor potential Black Carp reproduction. qPCR screening of ichthyoplankton samples should be used to assess the likelihood that samples contain invasive carp eggs or larvae, particularly from upstream of Starved Rock Lock and Dam, to prioritize for immediate processing and identification. Specimens from samples that are found to contain high quantities of Black Carp DNA should be subjected to further scrutiny to confirm incidences of Black Carp reproduction.

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INVASIVE CARP STOCK ASSESSMENT IN THE ILLINOIS RIVER

Participating Agencies: SIUC (lead); additional assistance from/collaboration with IL DNR, USACE, USGS, INHS, USFWS; David Coulter, Cameron Davis, Jim Garvey (SIUC)

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 seasonally and annually; 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 and 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 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 that 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 YOY have been found. Frequent hydroacoustic surveys of bigheaded carp densities in these pools identify locations where bigheaded carp aggregate to inform harvest efforts.

The SEICarP model of bigheaded carp in the Illinois River 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). This model draws on a variety of data, including bigheaded carp densities and movement data. Collaborations between MRWG modeling and telemetry working groups have identified data needs, primarily with a better understanding of inter-pool movements. To this end, model support consisted of maintaining the Illinois River stationary telemetry array to quantify inter-pool movements and deployment of additional acoustic telemetry tags in bigheaded carp (numbers set based on telemetry working group determinations). Movement information from telemetry efforts is also critical for maintaining sufficient surveillance efforts to detect potential changes in bigheaded carp spatial distributions (e.g., upstream movements), especially in supporting surveillance efforts with real-time acoustic telemetry receivers.

OBJECTIVES

- Quantify invasive carp densities every other month in Dresden Island and Marseilles pools using mobile hydroacoustic surveys to pinpoint high-density areas that can be targeted during contracted removal.
- Conduct hydroacoustic surveys at standardized sites from Alton to Dresden Island pools during the fall to assess long-term density trends.
- Maintain SIU's extensive acoustic telemetry array currently in place in the Illinois River used to collect movement information and maintain adult surveillance efforts. Share collected data with telemetry and modeling working groups.

PROJECT HIGHLIGHTS

- Repeated hydroacoustic surveys in Dresden Island and Marseilles pools identified areas of high bigheaded carp density and showed how these locations changed over time. These data helped direct contracted removal efforts.
- The 11th year of standardized monitoring of bigheaded carp densities was completed in 2022 from Alton to Dresden Island pools. These data allow for long-term assessments and comparisons of density trends across space and through time.

- Maintaining the stationary acoustic telemetry receiver array throughout the Illinois River ensured sufficient surveillance efforts occurred to detect adult movements among pools and toward 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) were completed in March. Repeated sampling during summer did not occur due to equipment repairs. Final surveys in these pools and throughout other Illinois River (Starved Rock through Alton pools) pools were completed in the fall. All hydroacoustic sampling methods, designs, and analyses followed those outlined in MacNamara et al. (2016). Surveys were completed before the fall Unified Method event in Dresden Island Pool to inform removal about density hotspots prior to harvest and to assess the impacts of removal on the population.

Telemetry – Adult Movements

Utilizing an array of 51 Vemco 69-kilohertz stationary receivers maintained by SIU (Abeln 2018) as well as stationary receivers maintained by partner agencies (USGS, USACE, USFWS, and 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 IWW. Additionally, other fish species implanted with 69-kilohertz transmitters by other members of the telemetry working group can be detected by this array. Stationary receivers were downloaded once in July, with data initially checked to remove false detections, and uploaded to the USGS FishTracks database. Once receivers are downloaded in early 2023, the full 2022 fish detection data will be analyzed to identify upstream and downstream passages through lock and dam structures (e.g., Lubejko et al. 2017*)*. Additional acoustic telemetry tags were deployed to replace expiring tags.

RESULTS AND DISCUSSION

Hydroacoustic Surveys – Bi-monthly Heat Maps and Fall Standardized Surveys

Repeated mobile hydroacoustic surveys in Dresden Island and Marseilles pools identified colocations where bigheaded carp aggregated and determined how these locations changed throughout the year. Density maps (Figure 1) were provided to MRWG members, which helped focus contracted harvest efforts. This sampling was scheduled to occur every other month, but equipment repairs prohibited sampling during summer. Mobile hydroacoustic sampling was completed in October 2022 from Alton through Dresden Island pools to inform long-term population monitoring. Processing of these fall density data is ongoing.

Telemetry – Adult Movements

The addition of 194 acoustic telemetry tags planned to be implanted into fish in Alton and LaGrange pools in 2022 was delayed until the spring of 2023 due to a delay in tag shipment. These additional tags will maintain sufficient adult surveillance efforts (e.g., early detection of movements past real-time receivers). SIU stationary receivers were retrieved and downloaded from Dresden Island Pool through Alton Pool. All detection data downloaded from stationary receivers were screened to remove false fish detections and submitted for inclusion in the USGS-managed FishTracks telemetry database.

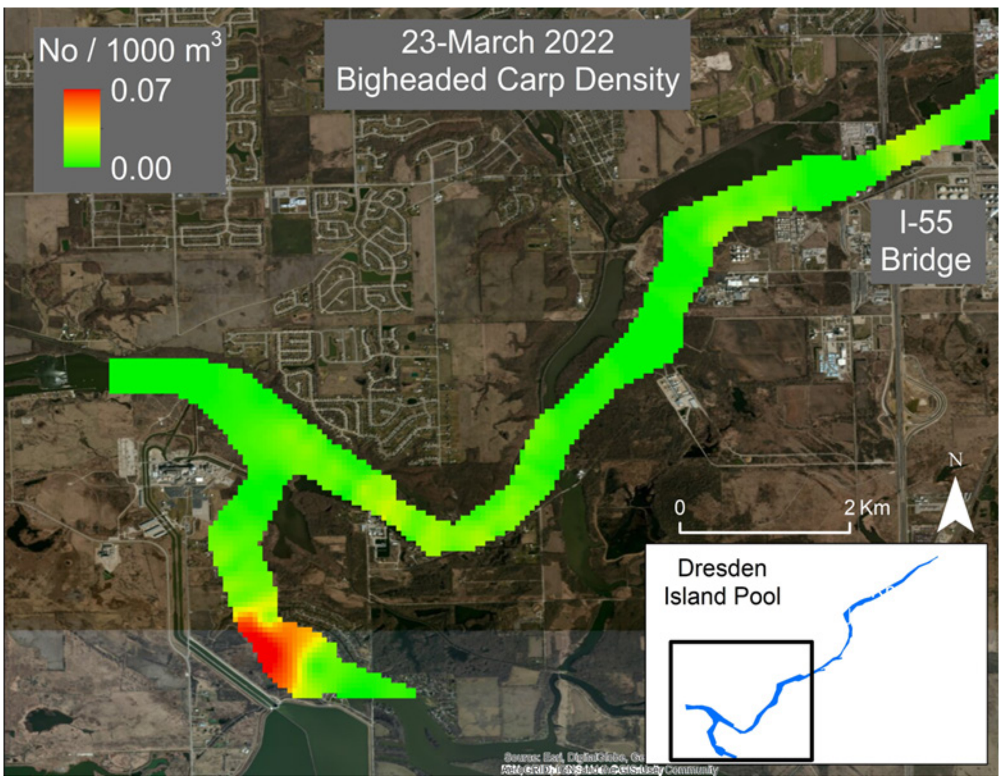

Figure 1. *Example heatmap displaying bigheaded carp spatial distributions in the lower portion of Dresden Island Pool sampled in March 2022 with mobile hydroacoustic sampling. Densities were observed using mobile hydroacoustic surveys.*

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 over 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 through 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 possible movement 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

Participating Agencies: USFWS Carterville FWCO (lead) and USACE (field support); Jen-Luc Abeln (USFWS Carterville FWCO)

INTRODUCTION AND NEED

The upper Des Plaines River originates in Southeast Wisconsin and joins the CSSC in the Brandon Road Pool downstream of Lockport Lock and Dam. Invasive carp have been observed in this pool up to the confluence with the Des Plaines River and have free access to the upper Des Plaines River. In 2010 and 2011, invasive carp eDNA was detected in the upper Des Plaines River (no samples were taken from 2012 to 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, USACE constructed a physical barrier in 2010. The physical barrier consists of concrete barriers and 0.25-inch (6.35-millimeter) mesh fencing built along 13.5 miles (21.7 kilometers) of the upper Des Plaines River where it runs adjacent to the CSSC. Based on mesh size, the physical barrier is designed to stop adult and juvenile invasive carp from infiltrating the CSSC, although it would not likely impede the movement of invasive carp eggs and fry across it.

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. The Des Plaines River crested at a record high of 13.26 feet (4.04 meters) on May 18, 2020. 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 where 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 and detect any potential invasive carp presence and spawning within the river. Likewise, it is critical to determine and understand the effectiveness of the physical barrier in blocking invasive carp movement between the Des Plaines River and the CSSC.

OBJECTIVES

- Monitor the presence of Bighead Carp and Silver Carp in the Des Plaines River above the confluence with the CSSC.
- Monitor invasive carp eggs and larvae from potential spawning activity around the physical barrier during overtopping events when water moves laterally from the Des Plaines River into the CSSC.
- Monitor the effectiveness of the physical barrier against fish during overtopping events when water moves laterally from the Des Plaines River into the CSSC.

PROJECT HIGHLIGHTS

- In 2022, 1,559 fish (31 species) were captured from 2.5 hours of electrofishing and 365.8 meters of gill netting.
- From 2011 to 2022, collected 17,058 fish (67 species and 4 hybrid groups) via electrofishing (91.75 hours) and gill netting (159 sets; 22,571.1 meters).
- No Bighead Carp or Silver Carp have been captured or observed across all years of sampling.
- Since 2011, 10 Grass Carp have been collected. No Grass Carp were collected in 2022.
- Since 2011, four overtopping events have resulted in several improvements to the barrier fence. No overtopping events occurred in 2022; therefore, monitoring for eggs and larvae and evaluating physical barrier effectiveness were not required.

METHODS

In 2022, one sampling event was conducted from July 25 to 28 in the upper Des Plaines River from East Romeo Road (Romeoville, Illinois) to IL-83 (Willow Springs, Illinois) using pulsed-DC boat electrofishing and gill nets (Figure 1). Electrofishing runs included one dipper and proceeded for 15 minutes. Typically, electrofishing runs would utilize two dippers, but the limited availability of field personnel prevented two dippers from being utilized in 2022. Gill net sets consisted of 100 yards (91.4 meters) of 3.5-inch and 4-inch bar mesh netting that was set prior to electrofishing runs near the entrance to backwater habitats and recovered after backwater electrofishing runs had been completed. Sampling was performed in both backwater and main channel habitats that were accessible to sampling boats. All individual fish were identified to species, and all native fishes were released. Two other sampling events were scheduled in 2022 during the spring and fall seasons but were unable to be completed due to low water levels that prevented access to sampling locations.

RESULTS AND DISCUSSION

During the 12 years of sampling (2011 to 2022), 91.75 hours of electrofishing and 159 net sets covering 24,684 yards (22,205.3 meters) of gill net resulted in a total catch of 17,058 fish. A total of 67 species and 4 hybrid groups have been collected. Common Carp have been the most collected species, followed by Gizzard Shad, then Largemouth Bass. In 2022, 2.5 hours of electrofishing and 400 yards (365.8 meters) of gill net resulted in 1,559 fish caught, representing 31 species. No Bighead Carp or Silver Carp have been collected or observed throughout all years of sampling. Since 2011, 10 Grass Carp have been collected, but no Grass Carp were collected in 2022. 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. Therefore, the need for ichthyoplankton sampling in the Des Plaines River might be significantly reduced in the future.

***Figure 1**. 2022 Sampling sites in the upper Des Plaines River.*

RECOMMENDATIONS

- Continue seasonal monitoring for large (greater than 153 millimeters) and small (less than or equal to 153 millimeters) 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., fyke nets and experimental multi-panel gill nets) and effort expended toward early detection.
- Monitor the Des Plaines River stage during heavy rainfall events and conduct investigations of the physical barrier, as needed, in areas where overflow has occurred.
- Sample ichthyoplankton to monitor for egg and larvae drift during overflow events, especially when temperatures are conducive for reproduction.

- Review eDNA results to determine if the presence of invasive carp DNA is detected in the river system in 2023.

Table 1. Fish species collected (number of individuals) from the upper Des Plaines River between 2011 and 2022. Fishes were sampled via boat-mounted electrofishing and gill netting.

Species	No. Captured 2022	No. Captured 2011-2021	Totals All Years
Banded Killifish	36	114	150
Bigmouth Buffalo	1	22	23
Black Buffalo	-	7	7
Black Bullhead	-	43	43
Black Crappie	1	351	352
Blackside Darter	-	15	15
Blackstripe Topminnow	59	128	187
Bluegill	21	1189	1210
Bluntnose Minnow	220	973	1193
Bowfin	12	206	218
Brown Bullhead	-	1	1
Bullhead Minnow	-	88	88
Carp x Goldfish Hybrid	-	60	60
Central Mudminnow	-	4	4
Central Stoneroller	-	9	9
Channel Catfish	1	439	440
Channel Shiner	-	3	3
Common Carp	83	3698	3781

Species	No. Captured 2022	No. Captured 2011-2021	Totals All Years
Creek Chub	-	39	39
Emerald Shiner	-	369	369
Fathead Minnow	-	43	43
Flathead Catfish	-	4	4
Freshwater Drum	-	7	7
Gizzard Shad	551	2202	2753
Golden Shiner	420	314	734
Goldfish	1	175	176
Grass Carp	-	10	10
Grass Pickerel	2	8	10
Green Sunfish	1	169	170
Highfin Carpsucker	-	1	1
Hornyhead Chub	2	44	46
Hybrid Striped Bass	-	1	1
Hybrid Sunfish	-	13	13
Johnny Darter	-	2	2
Largemouth Bass	55	1253	1308
Logperch	-	7	7
Longear Sunfish	-	1	1

Species	No. Captured 2022	No. Captured 2011-2021	Totals All Years
Longnose Gar	2	73	75
Mimic Shiner	-	1	1
Muskellunge	-	2	2
Northern Pike	2	264	266
Orangespotted Sunfish	-	115	115
Oriental Weatherfish	-	2	2
Pumpkinseed	36	206	242
Quillback	-	19	19
Redear Sunfish	-	1	1
River Carpsucker	-	23	23
River Shiner	2	10	12
Rock Bass	1	74	75
Rosyface Shiner	1	49	50
Round Goby	-	40	40
Sand Shiner	1	171	172
Sauger	2	83	85
Sauger x Walleye Hybrid	-	5	5
Smallmouth Bass	8	246	254
Smallmouth Buffalo	1	33	34

Species	No. Captured 2022	No. Captured 2011-2021	Totals All Years
Spotfin Shiner	25	951	976
Spottail Shiner	5	521	526
Spotted Sucker	-	33	33
Suckermouth Minnow	-	1	1
Tadpole Madtom	-	1	1
Walleye	-	10	10
Warmouth	1	9	10
Western Mosquitofish	1	4	5
White Bass	-	1	1
White Crappie	-	4	4
White Perch	-	1	1
White Sucker	5	475	480
Yellow Bass	-	2	2
Yellow Bullhead	-	51	51
Yellow Perch	-	6	6
Sum No. Captured	1559	15499	17058
Species Richness (Hybrids)	31(0)	67(4)	67(4)

ALTERNATIVE PATHWAY SURVEILLANCE IN ILLINOIS – URBAN POND MONITORING

Participating Agencies: IL DNR (lead); SIUC**;** Justin Widloe, Eli Lampo, Claire Snyder, Brian Schoenung (IL DNR), Allison Lenaerts, Andrew Wieland, Madison Meyers, M.J. Oubre (INHS), and Dr. Greg Whitledge (SIUC).

INTRODUCTION AND NEED

The IL DNR fields many public reports of observed or captured invasive carp. All reports are taken seriously and investigated by corresponding via phone/email 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 (greater than 21.8 kilograms, or 48 pounds) were captured by electrofishing and netting in Flatfoot Lake and Schiller Pond, fishing ponds in Cook County once supported by the IL DNR Urban Fishing Program.

As a further response to the Bighead Carp in Flatfoot Lake and Schiller Pond, IL DNR reviewed Bighead Carp captures in all fishing ponds included in the IL DNR Urban Fishing Program in the Chicago Metropolitan area, which revealed 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 kilometers (0.1 to 25.7 miles). The distance from these ponds to the CAWS upstream of the Electric Dispersal Barrier ranges from 0.02 to 23.3 kilometers (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 important due to the potential of human transfer of invasive carp between waters near one another.

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

The distance from ponds with positive eDNA detections to Lake Michigan ranges from 4.8 to 31.4 kilometers (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 kilometers (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. Furthermore, at the request of the IL DNR, USFWS La Crosse FWCO staff collected eDNA water samples from seven urban park ponds in the greater Chicago area to test for invasive carp eDNA. One pond of note, Humboldt Park, tested negative for eDNA after two Bighead Carp were removed in July of 2022.

OBJECTIVES

Sample fishing ponds in the Chicago Metropolitan area included in the IL DNR Urban Fishing Program using conventional gears (electrofishing and trammel/gill nets) for the presence of invasive carp.

PROJECT HIGHLIGHTS

- Since 2011, 35 Bighead Carp have been removed from six Chicago area ponds using electrofishing and trammel/gill nets, three of which are on display at the Shedd Aquarium in Chicago.
- Since 2008, 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.
- Two Bighead Carp were incidentally caught by a fisherman in Chicago area ponds – one in 2016 and one in 2021.

- 18 of the 21 IL DNR Chicago Urban Fishing Program ponds have been sampled with nets and electrofishing.
- Two Bighead Carp were removed from Humboldt Park in 2022. After the removal, that pond tested negative for invasive carp eDNA.

METHODS

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

RESULTS AND DISCUSSION

A total of 47 Bighead Carp and one Silver Carp have been removed from nine ponds (Table 1). Since 2011, 84 hours of electrofishing and 21 miles of gill/trammel net were utilized to sample 28 Chicago area fishing ponds, resulting in 37 Bighead Carp removed from five ponds. Additionally, eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have been removed since 2008. Lastly, two Bighead Carp were incidentally caught by fishermen in 2021. The lagoons at Garfield and Humboldt Park have had Bighead Carp removed following both natural die-offs and sampling. 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. Auburn Park was too shallow for boat access but had extremely high visibility. The pond was visually inspected, and no large-bodied fish were 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.

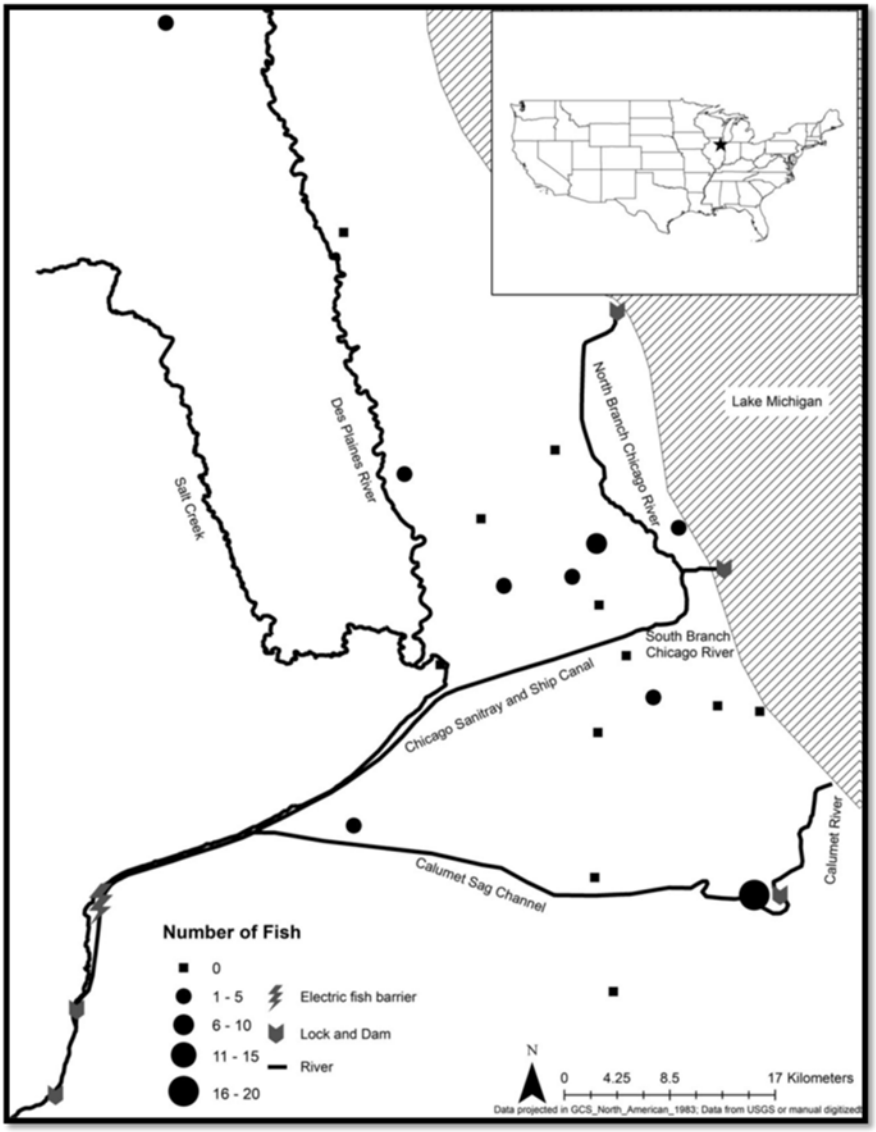

Figure 1. *Chicago area fishing ponds from which invasive carp have been removed and those from which no invasive carp have been collected or reported.*

Approximately 80 percent of the Bighead Carp otoliths examined to date exhibited a decline in Sr:Ca from high values in the otolith core (750 to 1,900 micromoles per mole; within 50 to 150 microns of the otolith center) to lower values (range 400 to 650 micromoles per mole) toward the edge of the otolith (mean 618 micromoles per mole within 50 microns of the otolith edge) (Figure 2). Mean otolith Sr:Ca of 618 micromoles per mole 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 from 2010 to 2012 (range 1.5 to 1.8 micromoles per mole) 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 lives 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 and 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 (Figures 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, it is plausible that they were contaminants in shipments of desirable fish species stocked in the lagoons, likely before the State of Illinois banned the transport of live Bighead Carp between 2002 and 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 Illinois (IDNR 2010). The otoliths of three Bighead Carp are awaiting microchemistry analysis.

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.

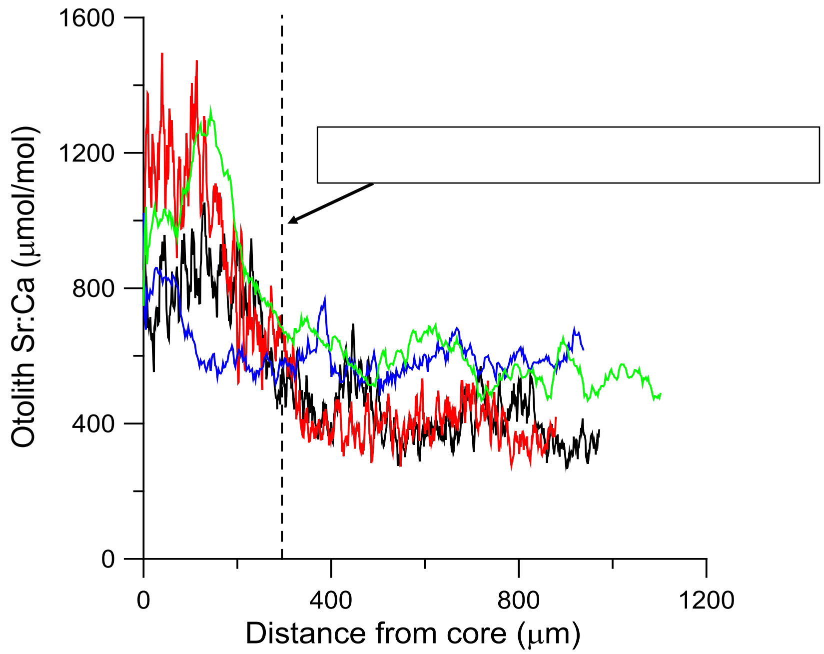

Figure 2. *Example of laser ablation transects for four Chicago pond Bighead Carp otoliths. The dashed line represents the mean otolith radius for age-0 invaisve carp taken from nearby rivers.*

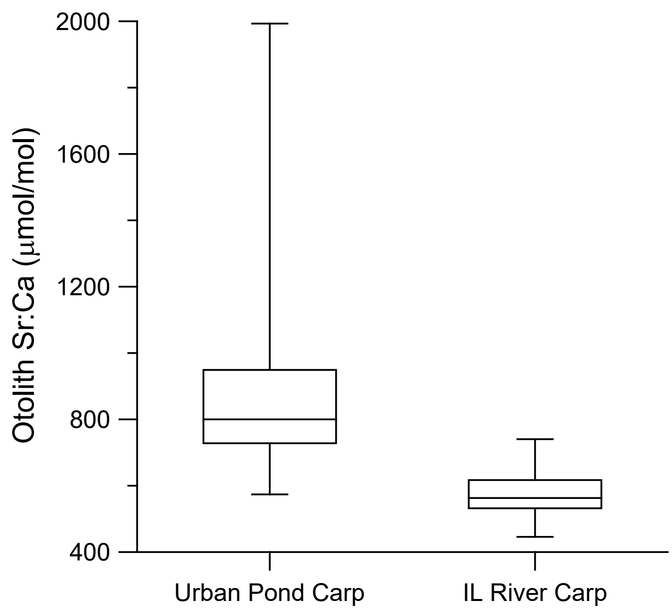

Figure 3. *Boxplots of otolith core Sr:Ca for Chicago pond (N = 24) and Illinois River (N = 81) invasive carp. The minimum value for urban pond carp represents the Silver Carp collected from Sherman Park.*

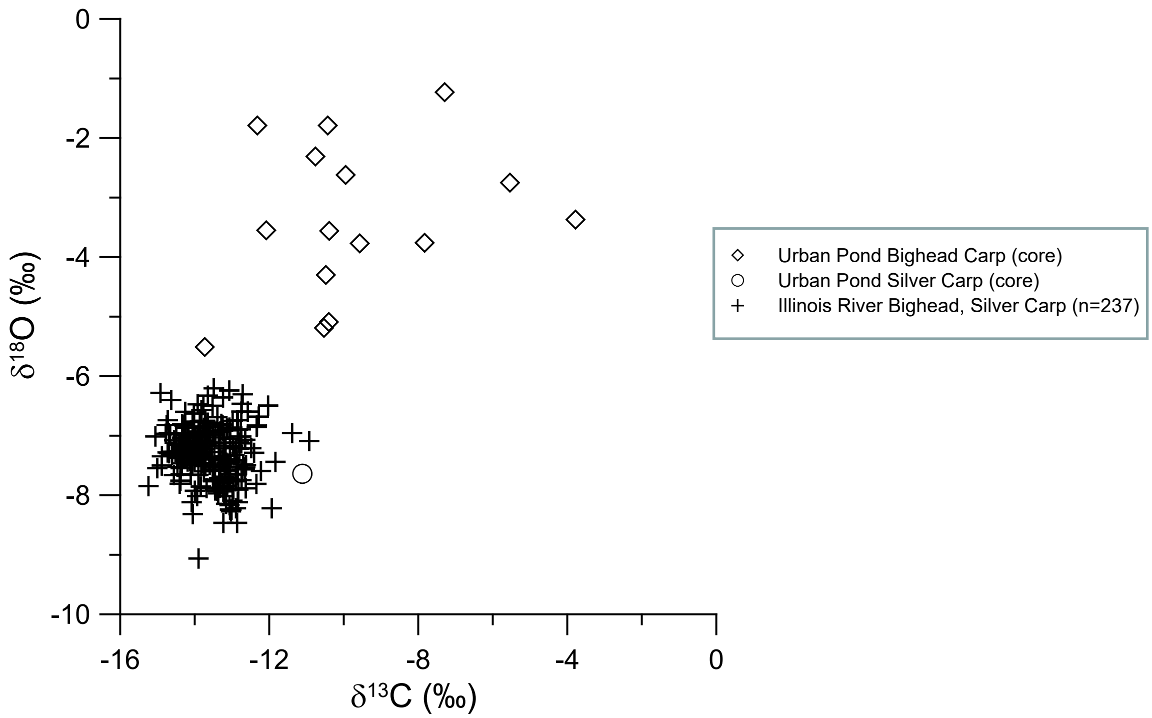

Figure 4. *Otolith Core $\delta^{18}O$ and $\delta^{13}C$ comparing Urban Pond and Illinois River Bighead and Silver Carps.*

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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 (hours), 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 = IL DNR urban fishing ponds that had positive eDNA detections, 2 = ponds with positive eDNA detections that are not IL DNR urban fishing ponds, 3 = pond that is neither an IL DNR urban fishing pond nor had a positive eDNA detection, * = location of the only Silver Carp collected

Sampling Results

	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	–	1	–	–	–
Columbus Park	0.8	0.1	1	–	–	3
Commissioners Park	0.5	0.1	1	–	–	–
Community Park	0.5	0.1	1	–	–	1
Douglas Park	0.5	0.2	1	–	–	–
Elliot Lake	0.8	0.7	7	1	–	–
Flatfoot Lake1	20	3.6	1	20	–	–
Garfield Park	3.6	0.1	1	2	–	1
Gompers Park	0.3	–	1	–	–	–
Harborside Golfcourse	2.8	0.9	1	–	–	–
Horsetail Lake2	1	0.3	2	–	–	–
Humboldt Park	2.3	0.5	3	8	–	1
Jackson Park1	4.3	1.8	1		–	–
Joe's Pond2	0.5	0.3	1	1	–	–
Lake Owens	1.0	0.3	1	–	–	–
Lake Shermerville	1.0	0.3	–	–	–	–
Lincoln Park South	–	–	1	–	–	3
Marquette Park	1.3	0.4	1	–	–	–
McKinley Park	1.0	0.3	1	–	–	–
Powderhorn Lake2	2.0	0.7	1	–	–	–
Riis Park	0.2	–	1	–	–	–
Sag Quarry2	0.6	0.3	1	–	–	–
Saganashkee Slough3	2.0	0.6	1	–	–	–
Schiller Pond	2.0	–	1	3	–	–
Sherman Park *	1.0	0.3	1	–	–	–
Tampier Lake2	5.5	0.6	1	–	–	1
Washington Lake	1.5	0.3	1	–	–	–
Totals	58.0	12.8	35	35	0	10

MULTIPLE AGENCY MONITORING OF THE ILLINOIS RIVER FOR DECISION MAKING

Participating Agencies: IL DNR, INHS (co-leads); USACE – Chicago District (field support)

Pools Involved: Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, and Alton pools of the Illinois River below the Electric Dispersal Barrier (Figure 1).

INTRODUCTION AND NEED

Detection and monitoring of invasive carp (Bighead Carp, Black Carp, Grass Carp, and Silver Carp) populations in pools below the EDBS are pertinent to understanding their upstream progression and minimizing the risk of establishment above the EDBS. Surveillance is particularly important in pools directly upstream for each invasive carp species known expanse: Bighead Carp and Silver Carp are within Dresden Island Pool, Grass Carp is within the CAWS, and Black Carp is within Peoria Pool. Extensive monitoring also provides managers the ability to evaluate the impacts of management actions (e.g., contracted removal) and collect data to assist other projects (e.g., SEICarP). Data collected from a standardized multiple-gear sampling approach have been used to create accurate and comparable relative abundance estimates of specific species and detect the presence of previously unrecorded invasive species (Ickes et al. 2005). A standardized multiple-gear approach was used here to create a comprehensive dataset that provided an understanding of the current geographic range of invasive carp across all pools 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

- Monitor the geographic distribution and abundance of adult and juvenile invasive carp populations in pools below the EDBS downstream to Alton Pool.
- 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 between the EDBS and Alton Pool.
- Provide other projects (e.g., 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 2022, 172 hours of electrofishing, 1,308 hoop netting net nights, 427 minnow fyke netting net nights, and 79.5 fyke netting net nights were completed.
- In 2022, 255,810 fish representing 118 species were captured.
- Zero invasive carp (large or small) were captured in Lockport or Brandon Road pools in 2022.
- The leading edge of the Bighead Carp and Silver Carp populations remained around river mile 281 (north of I-55 Bridge within the Dresden Island Pool near the Rock Run Rookery) in 2022.
- Zero Silver Carp (less than 6 inches or 152.4 millimeters) were captured during MAM sampling in 2022. No significant spawning event was detected in 2022.

METHODS

The MAM of the Illinois River for Decision Making used the standardized, multiple-gear approach developed by the USACE's Upper Mississippi River Restoration program (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 of 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 standardized nature to create a comprehensive dataset that included all pools of the Illinois River. USGS and INHS provided data outside of the MRWG MRP. Data were provided in the preliminary format to meet the need for timely best science on the condition that neither 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 pool-specific relative abundance indices within each pool below the EDBS were generated for each invasive carp species within each gear type from the comprehensive dataset. Calculating absolute abundance requires extensive data collection and a probability-based array, which can be extremely costly and time-consuming (Hayes et al. 2007). A relative abundance index is considerably easier, less expensive, and less time-consuming, all while directly relating to the absolute abundance (Pope et al. 2010). The relative abundance index of CPUE was calculated as the number of fish per hour for electrofishing and the number of fish per net night (24 hours) for fyke net, minnow fyke net, and hoop net samples (Table 1).

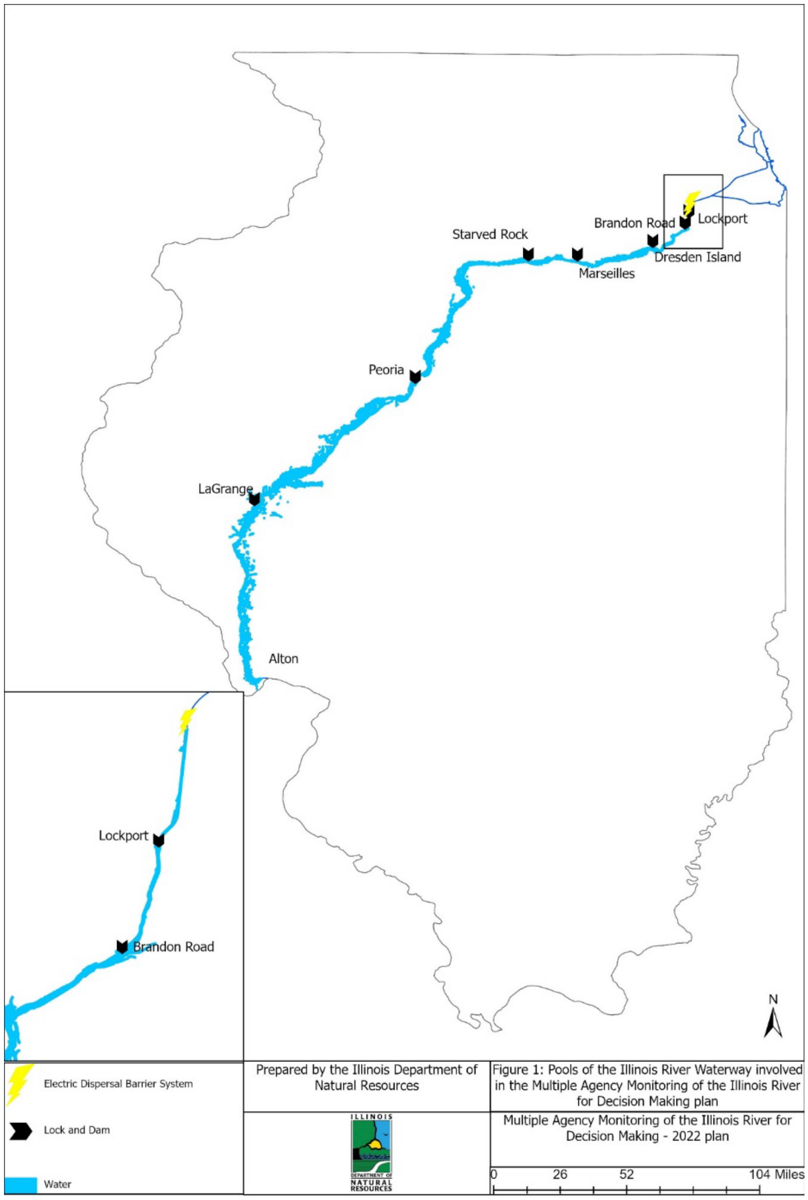

Figure 1. *Map depicting sampling locations for MAM Sampling in 2022.*

RESULTS AND DISCUSSION

Electrofishing Effort and Catch: Total sampling effort included 172 hours of electrofishing (684 transects) downstream of the EDBS in 2022 (Table 1). Electrofishing yielded 87,300 individual fish representing 105 species for a CPUE of 507.5 fish per hour (Table 1). In 2022, electrofishing catch was dominated by Gizzard Shad (30.81 percent; n = 26,897), Emerald Shiner (24.36

percent; n = 20,532), and Blue Gill (6.76 percent; n= 5903). Silver Carp electrofishing captures decreased in 2022. In 2022, total Silver Carp capture represented 2 percent of the total catch (n= 1764) compared to 14.74 percent (n= 7,325 in 2021). Overall, Silver Carp CPUE was 10.3 Silver Carp per hour, a decrease from 2021 levels of 41.6 Silver Carp per hour. Silver Carp CPUE was highest in the lower Illinois River pools (Starved Rock Pool to downstream), with no Bighead Carp, Black Carp, Grass Carp, or Silver Carp captured during electrofishing in the pools nearest to the EDBS (Dresden Island, Brandon Road, and Lockport pools) during 2022 (Table 1). Zero Silver Carp were captured using electrofishing in Dresden Island Pool in 2022, whereas three were captured in 2021. In 2022, no Bighead Carp were captured during electrofishing, similar to 2021. Of the Silver Carp captured during electrofishing in 2022 among all the pools, 1,764 (100 percent) were greater than 6 inches. In 2021, most of the Silver Carp were less than 6 inches (5,740, or 79.3 percent).

Minnow Fyke Netting Effort and Catch: Total sampling effort included 445 minnow fyke nets (427 minnow fyke net nights) downstream of the EDBS in 2022 (Table 1). Minnow fyke netting yielded 157,352 fish representing 102 species for a CPUE (number of fish per net night) of 860 fish per net night (Table 1). Most of the minnow fyke catch was comprised of Emerald Shiner (24.8 percent; n = 39,032), Blue Gill (22.3 percent; n = 35,053), and Gizzard Shad (21.3 percent, n= 33,510). Zero Silver Carp were captured in minnow fyke nets in 2022. In 2021, Silver Carp made up 13.1 percent, or n=50,619, of total catch. No invasive carp were captured in minnow fykes in any pools below the EDBS in 2022.

Hoop Netting Effort and Catch: Total sampling effort included 671 hoop nets (1,308 hoop net nights) downstream of the EDBS in 2022 (Table 1). Hoop netting yielded 8,304 fish representing 49 species for a CPUE of 6.3 fish per net night (Table 1). Smallmouth Buffalo comprised the largest proportion of the hoop net catch (35.7 percent; n = 2,966), followed by Channel Catfish (32.1 percent; n = 2,663) and Common Carp (10.4 percent; n = 861) in 2022. No invasive carp were captured in Lockport, Brandon Road, Dresden Island, or Marseilles pools during hoop netting but were captured in the other downstream pools (three Bighead Carp, 48 Grass Carp, and 30 Silver Carp) in 2022. Greater catch rates of invasive carp in hoop nets were found in the lower river pools compared to the upper river pools (Table 1).

Fyke Netting Effort and Catch: Total sampling effort included 84 fyke nets (79.5 net nights) downstream of the EDBS in 2022 (Table 1). A total of 2,854 fish representing 49 species were captured during fyke netting with a CPUE of 41.9 fish per net night (Table 1). Fyke net catch was dominated by Bluegill (34.1 percent; n = 972), Black Crappie (11.8 percent; n = 337), and White Crappie (8.3 percent; n = 238) in 2022. One Bighead Carp, zero Black Carp, zero Grass Carp, and four Silver Carp were captured during fyke netting. All invasive carp captured during fyke netting were collected below Starved Rock Pool. However, no fyke net samples were collected in Lockport, Brandon Road, Starved Rock, or Alton pools due to a lack of suitable habitat for this gear. Higher catch rates of invasive carp were found in the lower river pools compared to the upper river pools during fyke netting in 2022 as in 2021 (Table 1).

Overall Invasive Carp Catch: Overall relative abundance of invasive carp was highest below Marseilles Pool. La Grange had the highest relative abundance among pools sampled in 2022 as in 2021 (Table 1). The decrease in invasive carp CPUE in 2022 compared to 2021 is due to zero Silver Carp less than 6 inches and two Grass Carp less than 6 inches being captured. The lack of invasive carp less than 6 inches (Table 1) indicates that invasive carp did not have a strong spawning year relative to 2021. In 2022, 98 percent of Silver Carp collected during MAM sampling were collected using electrofishing. Comparing Silver Carp CPUE (fish per hour) captured with electrofishing in 2022 to 2021 shows a decrease in abundance below Starved Rock Pool (Figure 2).

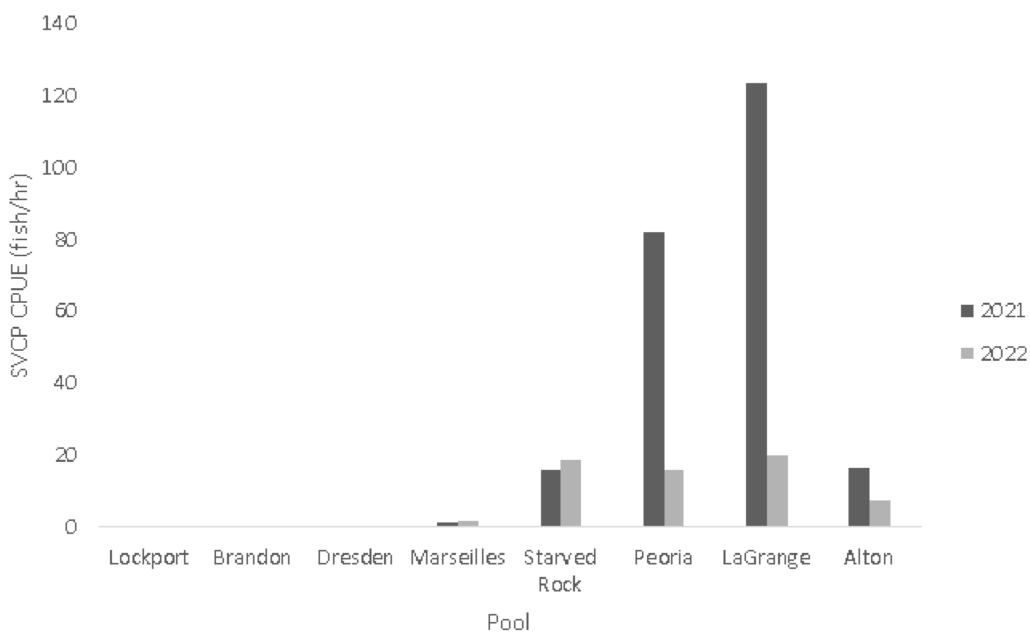

Figure 2. *A comparison of CPUE (fish per hour) of Silver Carp captured using electrofishing in 2022 and 2021 among the various pools of the Illinois River Waterway.*

Size Structure: Bighead Carp catches were between 440 and 810 millimeters total length (*n* = 4), Grass Carp catches were between 20 and 964 millimeters total length (*n* = 136), and Silver Carp catches were between 160 and 942 millimeters total length (*n* = 1798) in 2022. Mean Silver Carp length was larger in upper river reaches compared to lower river reaches (Figure 3). Zero Silver Carp were caught in Dresden Pool in 2022. The mean total length for Silver Carp in Dresden Pool was 895 millimeters in 2021 and 831 millimeters in 2019; no Silver Carp were caught in 2020. The Silver Carp size structure of the pools below Starved Rock increased in

2022, with a mean total length of 575 millimeters in 2022 compared to 389 millimeters in 2021. The increase in size structure of the lower pools is due to a poor Silver Carp spawning class in 2022 compared to Silver Carp's strong spawning year in 2021.

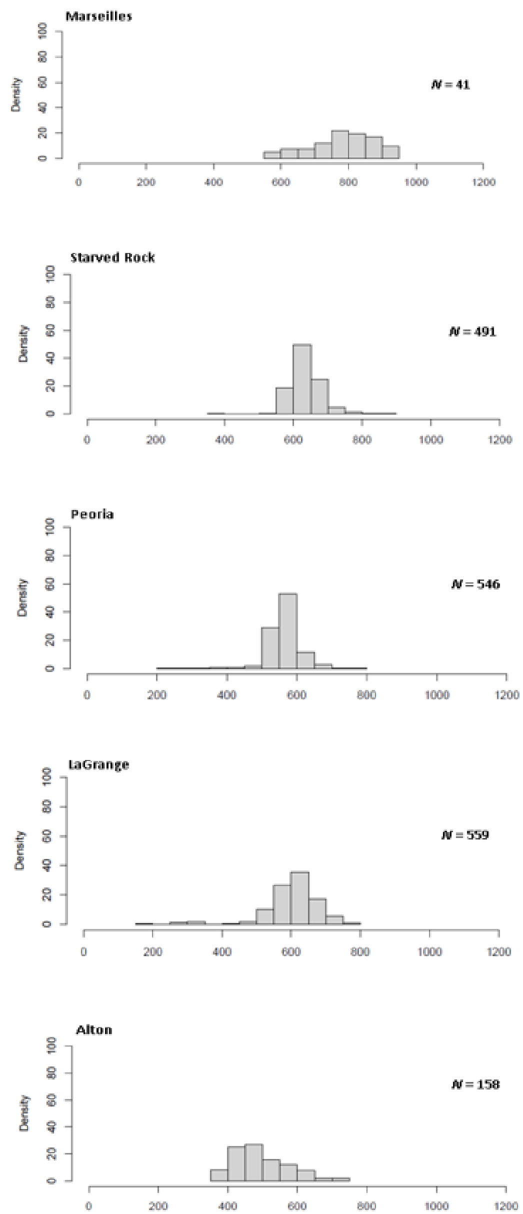

Figure 3. *Overall size structure distribution of Silver Carp captured in all pools of the Illinois River. All gear types (electrofishing, fyke netting, hoop nets, and minnow fyke nets) were aggregated together.*

Geographic Distribution: No invasive carp were captured above the previously known furthest upstream location in Dresden Island Pool in 2022. Zero Silver Carp less than 6 inches were captured in 2022; In 2021, Silver Carp less than 6 inches were captured at river mile 215 (approximately 18 river miles downstream of Lake Michigan) in 2021 (Figure 4). Large Silver

Carp had the highest relative densities in the lower pools, specifically Starved Rock Pool. Large Grass Carp were captured throughout the lower pools, with higher relative densities in Starved Rock, Peoria, La Grange, and Alton pools (Table 1), and large Bighead Carp had the highest relative density below Starved Rock Pool (Table 1). Comparisons of Silver Carp densities in 2022 and 2021 show similar habitat uses in Starved Rock Pool (Figure 5) and Marseilles Pool (Figure 6). Silver Carp primarily used side channels, backwaters, and main channel border habitat in these pools.

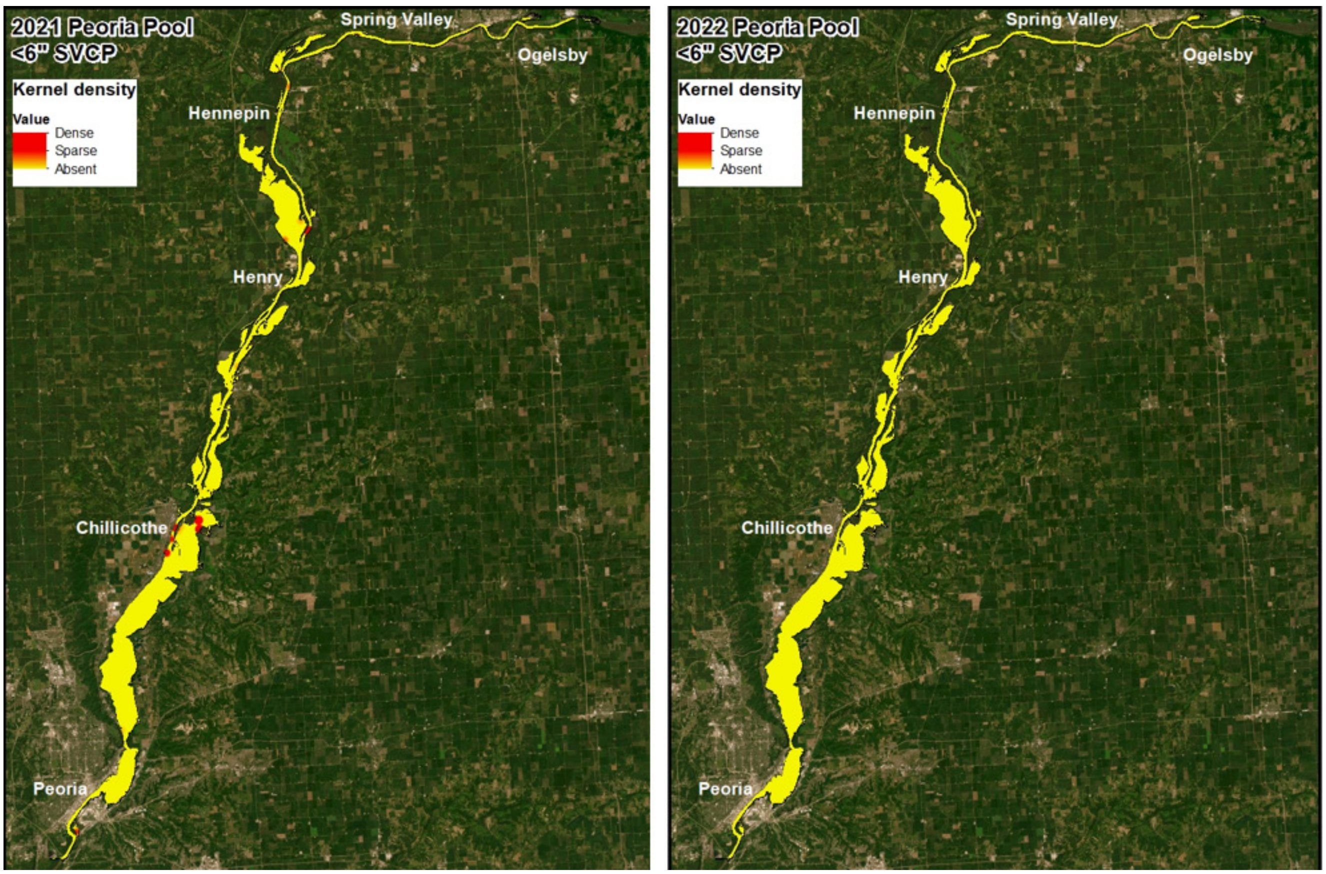

Figure 4. *A comparison of Silver Carp distribution (SVCP) less than 6 inches in Peoria Pool in 2021 and 2022.*

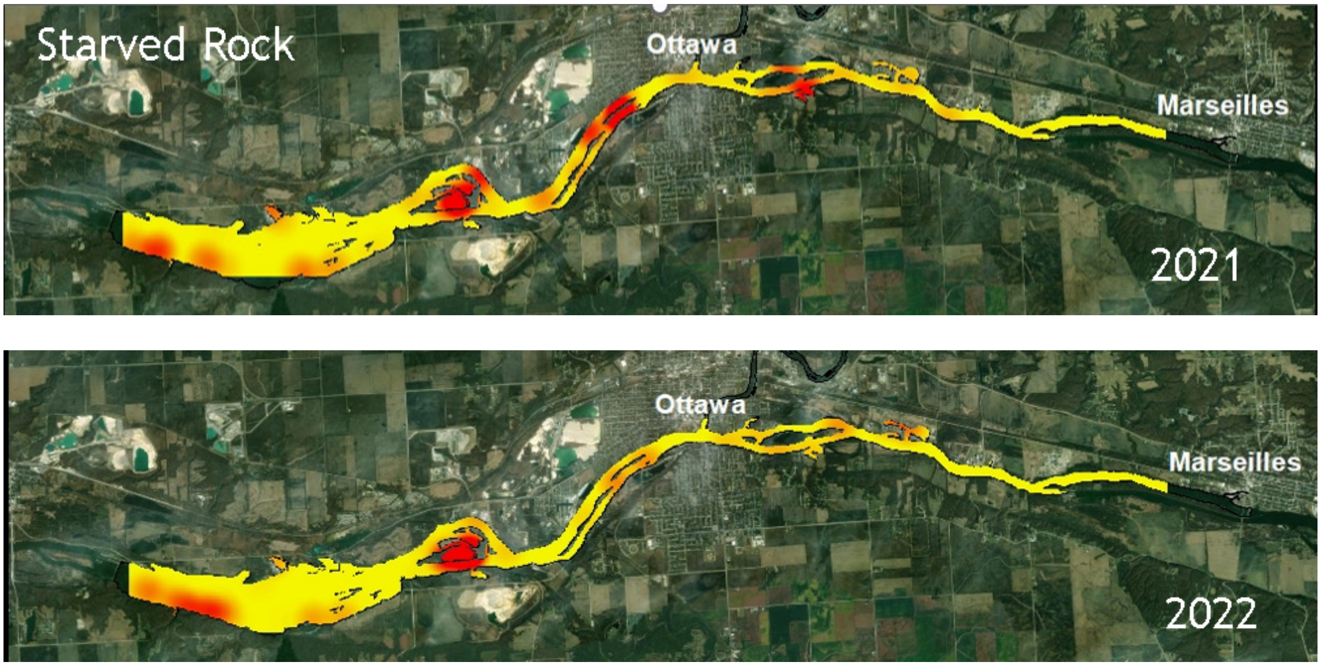

Figure 5. *A comparison of Silver Carp distribution in Starved Rock Pool in 2021 and 2022. Red depicts areas where Silver Carp were abundant.*

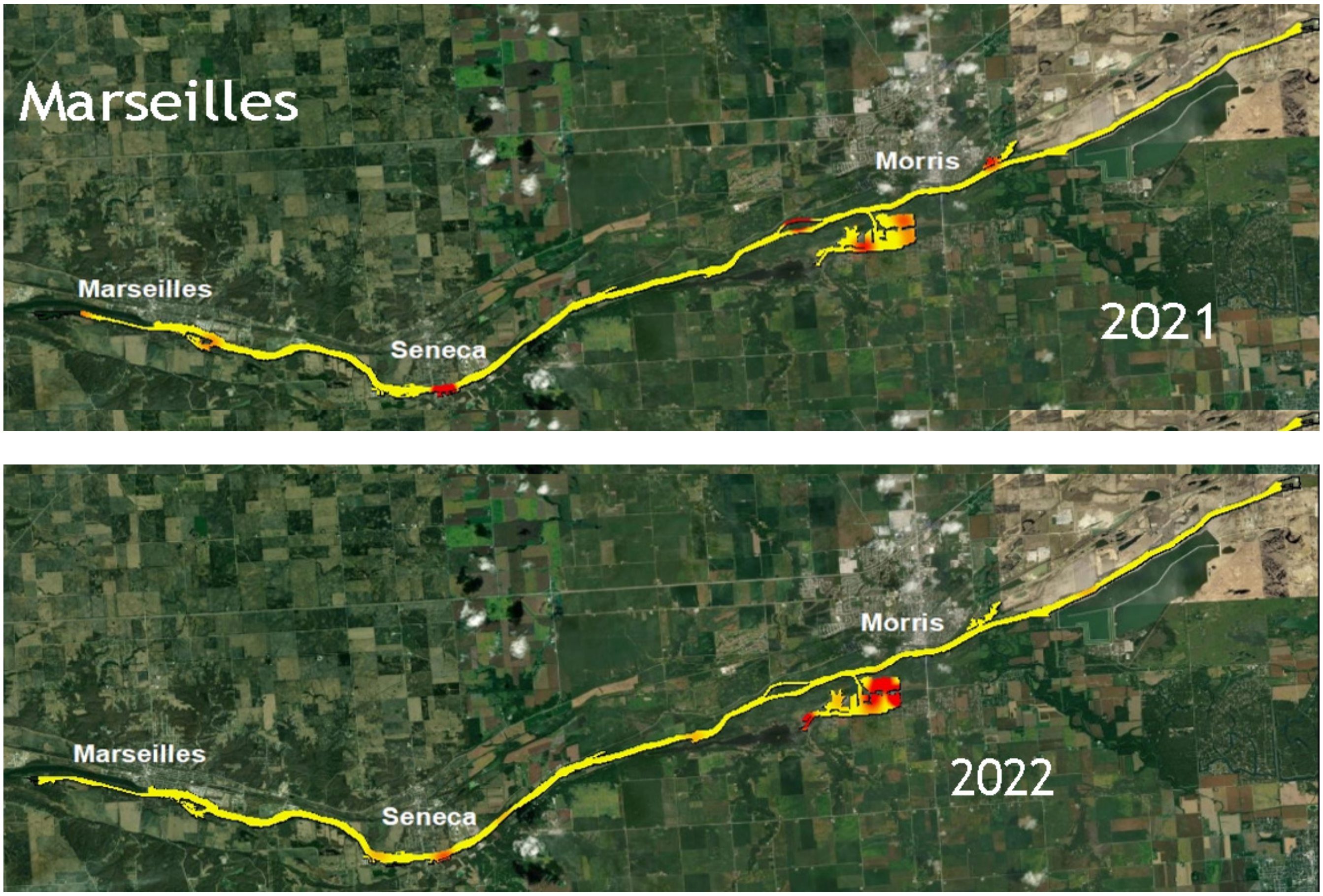

Figure 6. *A comparison of Silver Carp distribution in Marseilles Pool in 2021 and 2022. Red depicts areas where Silver Carp were abundant.*

RECOMMENDATIONS

Implementing a standardized multiple-gear sampling approach created a comparable and comprehensive picture of invasive carp dynamics throughout the entire the 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 Dresden Island Pool. No Black Carp were detected during the monitoring. The numbers and catch rates of small invasive carp (less than 6 inches) were less than what was found in 2021, indicating 2022 was a worse reproductive year with no major spawning event. 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 required to ensure the efficacy of the project should occur. It is also recommended that lapilli otoliths and the sex of a subsample of invasive carp be collected within each pool during the fall as needed to support the invasive carp demographics and the SEICarP model. Collecting these additional metrics should increase the inferences that can be drawn from this dataset and 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.

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MANAGEMENT AND CONTROL PROJECTS

USGS INVASIVE CARP DATABASE MANAGEMENT AND INTEGRATION SUPPORT

Participating Agencies: USGS, IL DNR, INHS, USFWS, USACE, SIU, Marybeth Brey (USGS, Upper Midwest Environmental Sciences Center)

INTRODUCTION AND NEED

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 carp. Other fish will also be tracked to maintain a holistic view of the transmitter distribution in the Upper IWW. 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 analyses and modeling efforts. Implementing an interoperable data management framework provides 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 carp in the IWW.
- Integrate and transform invasive carp-related datasets into actionable information, including the following objectives:
    - Maintain the FishTracks Telemetry Database and ILRCdb applications to facilitate partner (e.g., modeling working group, telemetry working group, etc.) objectives via data compilation, management, and summarization.

- Assist in developing informational products and decision support tools for scientists and managers to facilitate modeling efforts and inform management decisions to control bigheaded carp.
- Regularly communicate with the MRWG working groups to determine if the databases and database structures are meeting partner needs.

PROJECT HIGHLIGHTS

- ILRCdb
  - 2022 IL DNR annual data uploaded.
  - Coordinated with INHS to maintain the fish collection application (FISH app).
- FishTracks Telemetry Database
  - Application software packages upgraded.
  - Ongoing development of the online centralized platform for existing invasive carp-related data layers to support adaptive management objectives and informed removal efforts.
- FishTracks R Package
  - Application software packages upgraded.
- A USGS Geospatial Data Hub (catalog of all available geospatial data, including bathymetry data, for carp-invaded waters) was completed and is in review.

METHODS

The FishTracks Telemetry Database, a Microsoft SQL Server application, and the ILRCdb application, developed in the open-source relational database PostgreSQL, are being actively maintained by 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 annually uploaded into the database applications 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 are being developed to allow direct programmatic access to database applications, enabling data end users to integrate and analyze partnership data into modeling software programs, such as R.

Existing invasive carp-relevant datasets and analytical tools that have been collected, processed, and developed by the multi-agency partnership will be converted into 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 and discharge). An online, user-friendly interface (developed in ArcGIS Online) will allow 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 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 acoustic telemetry data from the Illinois River and upper Mississippi River continue to be collected by partner agencies and included in the FishTracks database. Data collection is uploaded through the 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 loss of critical USGS personnel in 2022 slowed the development process of the FishTracks database, but partner data will continue to be checked for quality and compiled until the database is fully functional in 2023.

A validated hydroacoustic survey data set (e.g., multi-beam and side-scan sonar) collected in priority management areas throughout the Illinois River and processed into a suite of benthic data layers was integrated into an online geospatial data hub (GIS data hub). These benthic habitat classification layers (i.e., geomorphology) derived from bathymetric measures, such as bottom 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.

Developing an online platform for invasive carp-related data, informational products, and decision support tools will provide ease of access and use to 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 users to spatially search for areas with underlying conditions similar to areas of large bigheaded carp catch events (or known areas with dense bigheaded carp populations), enabling 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 ILRCdb, allows researchers to directly query data and integrate them into analyses.

CONTRACTED COMMERCIAL FISHING BELOW THE ELECTRIC DISPERSAL BARRIER

Participating Agencies: IL DNR; INHS; Allie Lenaerts, Andrew Wieland, Madison Meyers (INHS), Eli Lampo, Justin Widloe, Claire Snyder, Brian Schoenung, Kevin Irons, Mindy Barnett (IL DNR)

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

INTRODUCTION AND NEED

Contracted Commercial Fishing Below the Electric Dispersal Barrier uses contracted commercial fishers to reduce invasive carp abundance and monitor for changes in range in the Des Plaines River and upper Illinois River downstream of the Electric Dispersal Barrier. By decreasing invasive carp abundance, we anticipate reduced migration pressure towards the barrier, lessening the chances of invasive carp gaining access to upstream waters in the CAWS 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 with 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 understanding invasive carp population abundance and movement between and among pools of the IWW.

OBJECTIVES

- Monitor 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.

- Reduce invasive carp densities, lessening migration pressure to the Electric Dispersal Barrier, thus decreasing chances of invasive carp accessing upstream reaches (e.g., CAWS and Lake Michigan).
- Inform other projects (i.e., hydroacoustic verification and calibration, SEICarP model, small fish monitoring, and telemetry master plan) on invasive carp population distribution, dynamics, and movement in the IWW downstream of the Electric Dispersal Barrier.

PROJECT HIGHLIGHTS

- Since 2010, contracted commercial fishers' effort in the Upper IWW below the EDBS includes 5,239 miles (8,431 kilometers) of gill/trammel net, 21 miles (34 kilometers) of commercial seine, 239 Great Lakes pound net nights, and 4,369 hoop net nights.
- From 2010 to 2022, 104,349 Bighead Carp, 1,327,020 Silver Carp, and 11,473 Grass Carp were removed by contracted fishers. The total estimated weight of invasive carp removed is 5,805 tons (12,798,193 pounds).
- 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 (approximate river mile 281; 46 miles from Lake Michigan). No appreciable change has been found in the leading edge over the past 11 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 EDBS.

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 June and September. Sampling occurred upstream of the Electric Dispersal Barrier 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 comprehensively understand invasive carp spatial and temporal abundance below the EDBS, especially at their upper-most extent in Dresden Island Pool. However, because invasive carp abundance and fishing locations are spatially heterogeneous 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 to 5.0 inches; 63.5 millimeters to 127 millimeters) 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, and driving with motors trimmed up) were utilized to drive fish into the net (Butler et al. 2018). Nets were typically set for 20 to 30 minutes. Overnight net sets occasionally occurred in off-channel habitats 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 was measured for total length (millimeters), weighed (grams), and sexed (male or female) 1 to 2 times a week to provide estimates of total weight harvested and gather morphometric data on harvested invasive carp over time.

Unified Fishing Methods 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 moving out of areas, and commercial seines were pulled to remove mass amounts of invasive carp.

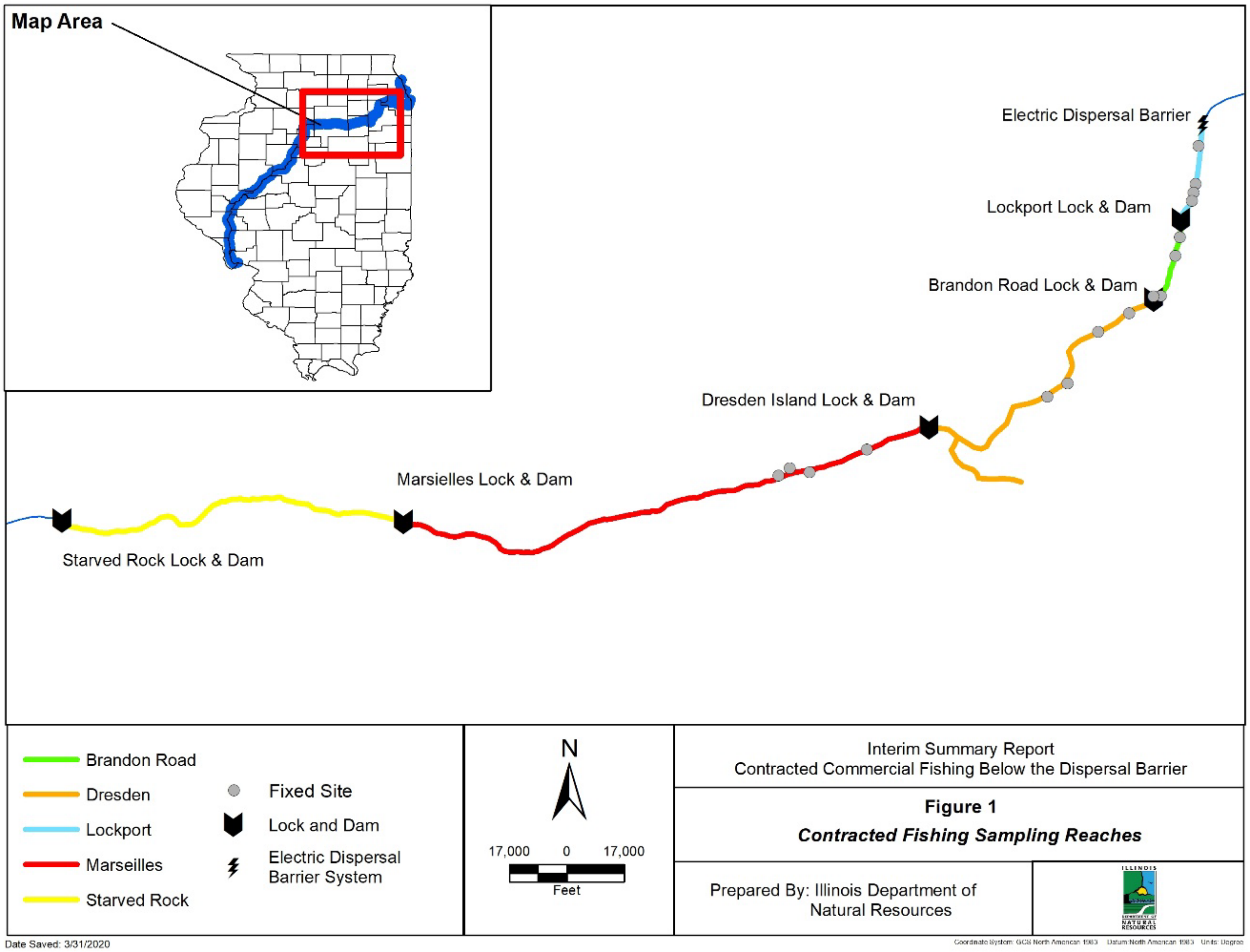

Figure 1. *Contracted commercial fishing sampling area and locations of fixed sites sampling of the contract fishing below the electric dispersal barrier project.*

RESULTS AND DISCUSSION

Since 2010, 5,239 miles (8,431 kilometers) of gill/trammel net, 21 miles (34 kilometers) of commercial seine, 239 Great Lakes pound net nights, and 4,369 hoop net nights have been deployed in the Upper IWW. The total estimated weight of invasive carp caught and removed from 2010 to 2022 was 12,798,193 pounds. Silver Carp remains the most abundant invasive carp species in the upper Illinois River, in contrast to 2010 when Bighead Carp comprised approximately 80 percent of total invasive carp catch.

The 2022 gill/trammel net CPUE (number of fish per 1,000 yards of net) in Starved Rock Pool was 435.7, a decrease from 453.3 in 2020. The gill/trammel net CPUE in Marseilles Pool was 101.3, a decrease from 134.7 in 2021 (Figure 2). The 2022 gill/trammel net CPUE in Dresden

Island Pool (leading edge) was .79 in 2022, a decrease from 1.2 in 2020 (Figure 2). For details regarding gill/trammel CPUE of invasive carp for all pools combined from other years, see those years' respective ISRs found online at www.invasivecarp.us.

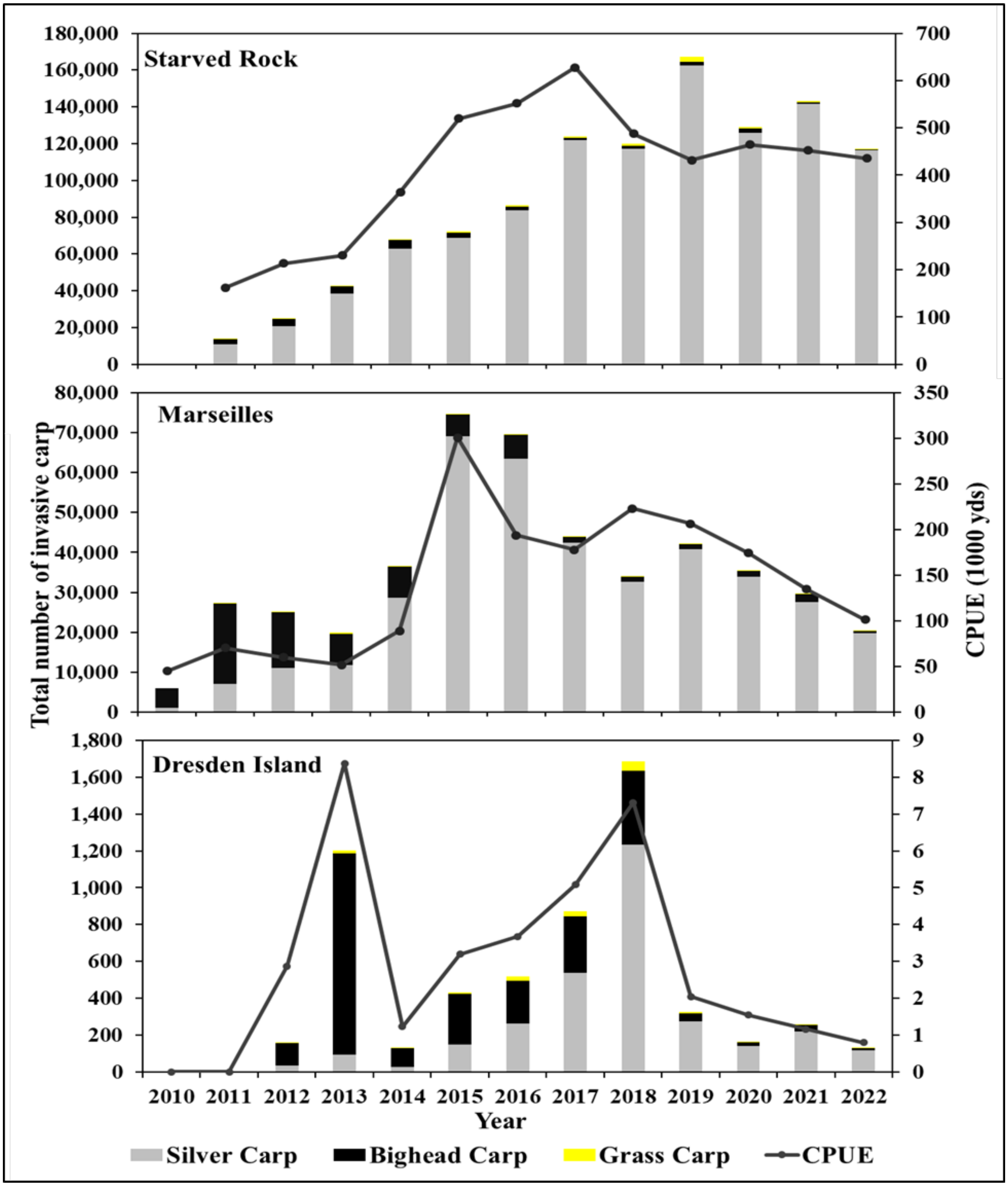

Figure 2. *Annual mean CPUE (number of fish per 1,000 yards of gill/trammel net) of invasive carp for Starved Rock, Marseilles, and Dresden Island pools (2010 to 2022).*

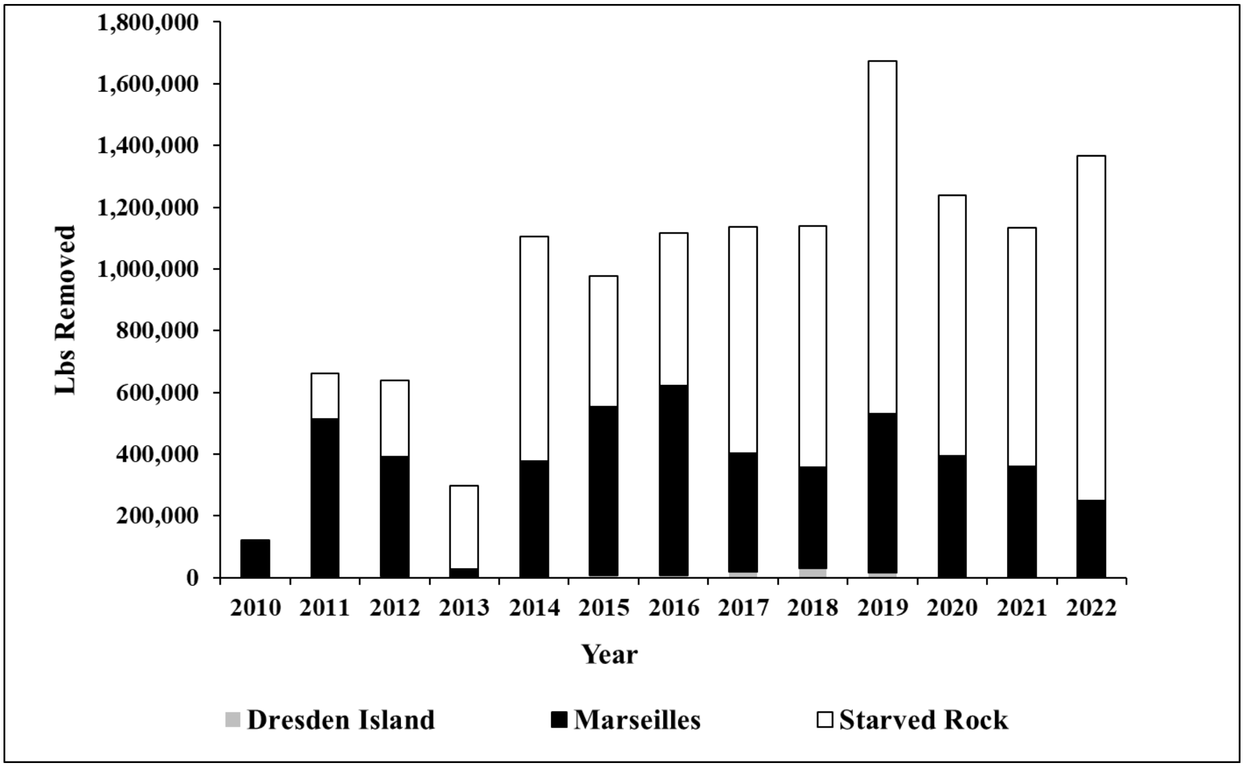

Figure 3. *Invasive carp biomass removed in Dresden Island, Marseilles, and Starved Rock pools (2010 to 2022).*

Effort and Catch of Invasive Carp within Pools

Lockport Pool: In 2022 invasive carp detection efforts included 68,200 yards (62.4 kilometers) of gill/trammel net set. No invasive carp were observed or captured in Lockport pool.

Brandon Road Pool: In 2022 invasive carp detection efforts included 72,400 yards (66.2 kilometers) 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 Carp and Bighead Carp population occurs here. In 2022, 1 percent of the total harvested invasive carp came from Dresden Island Pool. Contracted commercial fishing efforts included 165,390 yards (151.2 kilometers) of gill/trammel net. In 2022, 179 Silver Carp, 11 Bighead Carp, and 4 Grass Carp were harvested from Dresden Island Pool (including Rock Run Rookery, the lower Kankakee River, and the Dresden Nuclear Power Station warm water discharge) (Figure 3). CPUE 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. However, there has recently been a decline in CPUE among all three invasive carp species in Dresden Island Pool, with a steady increase in the effort since the inception of the program. With this decrease in CPUE over time, we infer that the invasive carp population has decreased in Dresden Island Pool.

Marseilles Pool: In 2022, 15 percent of the total harvested invasive carp came from Marseilles Pool. Contracted commercial fishing efforts included 200,885 yards (183.7 kilometers) of gill/trammel net. In 2022, 19,794 Silver Carp, 521 Bighead Carp, and 34 Grass Carp were harvested from Marseilles Pool, amounting to 112.6 tons (248,322 pounds) removed (Figure 3). In 2022, Silver Carp dominated the invasive carp catch in Marseilles Pool (97 percent), consistent with the past eight years. Prior to 2013, Bighead Carp was the dominant invasive carp species caught in the Marseilles Pool (greater than 55 percent). In 2022, the catch of Bighead Carp was 2 percent. The 2022 gill/trammel net CPUE of invasive carp for Marseilles Pool was 101.3, a 25 percent decrease from 2021 (Figure 2).

Starved Rock Pool: In 2022, 85 percent of the total harvested invasive carp came from Starved Rock Pool. Contracted commercial fishing efforts included 316,096 yards (289 kilometers) of gill/trammel and seine net set. In 2022, 116,401 Silver Carp, 288 Bighead Carp, and 437 Grass Carp were harvested from Starved Rock Pool from gill/trammel nets, amounting to 422.2 tons (773,800 pounds) removed (Figure 3). Silver Carp dominated the catch of invasive carp in Starved Rock Pool in 2022 (99 percent), consistent with years past. The 2022 gill/trammel net CPUE of invasive carp for Starved Rock Pool was 435.7, a 5 percent decrease from 2021 (Figure 2).

An additional 355,000 pounds of invasive carp were removed during a combined gill and seine haul effort in December 2022 at Bull's Island in Starved Rock Pool. Though the effort was considered a success from a removal standpoint, it was marred with adverse conditions and technical difficulties. Therefore, individual invasive carp could be identified but not enumerated or weighed individually. Furthermore, with plummeting temperatures and a snowstorm looming, differentiating what fish were captured in what gear type was not a possibility. We believe most of the biomass removed was Silver Carp, and the remaining amount was Bighead Carp, Grass Carp, and Common Carp, but we cannot say with certainty what those percentages are. We are certain that all fish removed were invasive carp and Common Carp, and all bycatch was released. The total weight of this effort is included in the annual pounds removed for the program in 2022; however, no analyses are available at this time.

RECOMMENDATIONS

Since 2010, this program has been successful at managing the invasive carp population in the Upper IWW by significantly decreasing relative biomass near the population front in Dresden Island Pool (Coulter et al. 2018). Despite significant limitations posed by Covid-19 throughout 2021 and part of 2022, all planned effort was accomplished, and the 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 and reduce potential propagule pressure on the Electric Dispersal Barrier. In addition to those core goals, the MRWG detection and removal working group leads identified several future priorities, including gaining a better understanding of invasive carp abundance and distribution in Dresden Island Pool, assessing how invasive carp species respond to removal at multiple scales, and identifying 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 IWW in response to management actions. This project will continue to directly inform multiple MRWG working groups (detection and removal), and objectives will continue to be adapted by working group 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 2024.

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BARRIER MAINTENANCE AND FISH SUPPRESSION

Participating Agencies: IL DNR (lead); USFWS and USACE – Chicago District, (field support); USCG (waterway closures); USGS (flow monitoring); MWRDGC (waterway flow management and access); and US EPA (project support); Nicholas Barkowski, Alex Catalano Dayla Dillon, and John Belcik (USACE– Chicago District) Brian Schoenung, Mindy Barnett, Justin Widloe (IL DNR), Jen Luc-Abeln, and Michael Glubzinski (USFWS Carterville FWCO, Wilmington Substation).

INTRODUCTION

The USACE operates three electric aquatic invasive species dispersal barriers (Barrier 1 [consisting 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 – 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 operates at a setting (0.4 volts/centimeter) that has been shown to induce behavioral responses in fish over 137 millimeters in total length. 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 millimeters long at a setting of 0.79 volts/centimeter or fish greater than 63 millimeters long at a setting of 0.91 volts/centimeter. The higher setting of 0.91 volts/centimeters has been in use since October 2011. Barrier 1 was activated in February 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 volts/centimeter.

All barriers (Barrier 1, 2A, and 2B) must be shut down independently for maintenance approximately every 12 months, and the IL DNR 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 applying 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-operational Barrier 1, 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 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 minutes) unless Barrier 2B experienced an unexpected outage or planned maintenance event. In January 2014, the standard operating procedure was changed to run Barriers 2A and 2B concurrently. This change further increased the efficacy of the EDBS by maintaining continuous power in the water 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 didn't 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-meter 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 ISR 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

- Remove fish greater than 300 millimeters (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.
- Assess fish assemblage less than 300 millimeters in total length between applicable barrier arrays, if present, for species composition to ensure invasive carp juvenile or YOY

individuals are not present. Physical capture gears focused on small-bodied fishes, such as electrified Paupier surface trawls and surface pulsed-DC electrofishing.

- 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 (greater than 300 millimeters 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 low risk. Fish less than 300 millimeters in total length at the barriers are deemed 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 carp.

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.
- Four electrofishing runs were conducted within the barriers after two separate outages in March and June.
- USFWS conducted 20 hydroacoustic scans within the barrier in 2022.
- 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 the upstream movement of fish 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 of less than one minute is considered too short of a duration to allow for the upstream passage of fish. At the occurrence of any barrier outage greater than one minute, USACE notified the MRWG as soon as possible 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 (greater than 300 millimeters) 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.

The MRWG selected a cut-off of 300 millimeters in total length for fish to be removed from the barrier area when a clearing action is recommended. By selecting a cut-off of 300 millimeters, sub-adult and adult invasive carp are targeted, and YOY and juvenile fish are excluded. Excluding YOY and juvenile invasive carp from the assessment was based on over 10 years of sampling in the Lockport Pool with no indication of any YOY invasive carp present or any known locations of spawning. However, monitoring in the lower reaches of the IWW has resulted in the capture of small invasive carp less than 153 millimeters being collected progressively upstream through 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 2016. These records prompted resource managers to take a more conservative approach at the barriers by sampling all sizes of fish between the barriers during a clearing event. It was determined that all fish over 300 millimeters still be removed from the area and fish less than 300 millimeters be sub-sampled to ensure no juvenile or YOY invasive carp are present. Invasive carp less than 300 millimeters have been primarily captured in Peoria Pool, with only a handful of fish captured just upstream of Starved Rock Lock and Dam since 2017.

A key factor in any response is the 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 over 300 millimeters are removed from the barrier or until MRWG deems the remaining fish in the barrier a low risk and a sub-sample of fish less than 300 millimeters 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 millimeters. 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 millimeters 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 2022, Barrier 1, Barrier 2A, and Barrier 2B were the primary barriers to fish passage in the upstream direction within the EDBS at various points during the year. In 2022, 40 total outages of one minute or greater occurred across all the barriers (Table 1). Of the 40 outages that occurred, nine occurred at just the narrow array of Barrier 2B. Planned outages for maintenance, inspections, software updates, and power studies occurred 17 times in 2022, accounting for 42 percent of the total outages. The remaining 23 outages were unplanned and occurred due to utility power loss, function generator issues, various equipment faults, and cooling issues. Similar to 2021, the bulk of the unplanned outages (32 percent) were a result of utility power loss.

Both planned and unplanned outages were coordinated through the MRWG as USACE confirmed schedules. It was determined that no official response actions were needed during 2022, but USACE did conduct four electrofishing surveys within the barriers in March (n=1) and June (n=3) of 2022 as a precaution. No invasive or large-bodied fish were captured during those efforts.

Table 1. Summary of barrier outages for each of the barriers at the EDBS

Barrier	Outages	Planned
1D	6	2
1N	12	9
IIB	18	4
IIA	4	2

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 removing 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 fish greater than 300 millimeters in total length and sub-sample fishes less than 300 millimeters in total length for species identification when deemed necessary. Identification of fish less than 300 millimeters 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 the 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), USFWS La Crosse FWCO, USGS – Upper Midwest Environmental Sciences Center, SIU, and IL DNR

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

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 near the electrical dispersal barriers. Second, critical model assumptions and results from sensitivity analyses are used to provide recommendations concerning data collection 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 increase 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 carp. 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, the impacts of the stock-recruit relationship on SEICarP model predictions are currently assessed using a sensitivity analysis.

In addition to the ongoing development of the SEICarP model, a fourth area of model development involves estimating the rate at which individuals in each 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 the 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 SCAA/L models could be successfully developed using currently available data from Illinois River invasive carp populations is necessary.

These modeling efforts include coordination among state and federal agencies and academic partners. The USFWS leads the US Department of Interior's efforts for this project with considerable support from the USGS.

OBJECTIVES

- Prepare and submit a manuscript for publication in a peer-reviewed journal describing the SEICarP model and the results from sensitivity analyses and population control (i.e., additive mortality and upstream movement deterrence) simulations.
- Collaborate with the MRWG telemetry working group in its efforts to update pool-to-pool movement probabilities.
- Develop a stock-recruitment relationship using existing age structure and hydroacoustics data.
- Work with MRWG co-chairs and working group leads to apply per-capita contribution modeling to invasive carp management.
- Complete the SCAA/L model feasibility study to determine if currently-available Illinois River data will support SCAA/L models or what additional data are required to support these models.

PROJECT HIGHLIGHTS

- Coauthor and USGS completed a review of the SEICarP manuscript, which was submitted to the *Journal of Applied Ecology* for peer review (December 2022).
    - Modeling efforts suggest that 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) are likely the most effective for managing invasive carp.
- Length and age data were used to develop a forward-inverse age-length key following Ailloud et al. (2019). The age-length key will be used to develop a stock-recruit relationship.
- The per-capita contribution model manuscript was published in *Ecosphere* (December 2022).
    - 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.

- Developed a per-capita contribution model that included various barrier scenarios to determine how the location and effectiveness of barriers impacted invasive carp populations. This model is currently under review by coauthors prior to review by the MRWG co-chairs and USGS.
- Received the final report from Michigan State University's Quantitative Fisheries Center determining the feasibility of developing a SCAA/L model for invasive carp in the Illinois River based on currently available age structure and harvest data (Appendix 1).
    - Drs. James Bence and Travis Brendan indicate that current data are likely sufficient to support a SCAA/L model and include suggestions for developing that model and additional data collections that would help support the model.

FUTURE WORK

- Currently, invasive carp population models (i.e., SEICarP and per-capita models) do not account for effects on species other than invasive carp (i.e., Silver Carp and Bighead Carp). Consequently, unintended consequences of control strategies, particularly upstream movement deterrents, 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.
- Initiate discussions with the removal and monitoring working groups to scope collections of demographic data (e.g., size and age) from commercially harvested invasive carp in support of the SCAA/L model.
- Although developing an updated movement model was completed during FY2022, the posterior distributions of movement probabilities have not yet been incorporated into the SEICarP model. Thus, previous limitations regarding the movement model remain. We recommend that the output from the updated movement sub-model 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 working group to determine how to best address this data gap.
- Begin development of SCAA/L model to help understand the Illinois River invasive carp population and the effects of current management efforts (i.e., harvest) on that population to inform future management decisions.

- 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.

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Appendix A: Review of Contemporary Approaches to Fishery Stock Assessment with Special Reference to their Applicability to Bigheaded Carp in the Illinois River

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EXECUTIVE SUMMARY

In this report, we summarize our views regarding possible development of a population assessment model for bigheaded carp in the Illinois River. Because of the existence of hybrids and the potential for unreliable differentiation between silver and bighead carps, we recommend assessing the species (and their hybrids) as a single group. Although several population assessment modeling approaches exist, including surplus production and statistical catch-at-length assessment models, our recommendation is that assessment initially be based on a statistical catch-at-age assessment (SCAA) framework. Even though an SCAA model assumes an age-structured population, length-based data components can easily be accommodated in the framework through age-length transition matrices. We additionally recommend attempting to incorporate a two-region spatial structure to the model, with Region 1 extending from Alton to Starved Rock and Region 2 extending from Starved Rock to the current invasion front. With this spatial model structure, it likely would make sense to assume recruitment came solely come from Region 1 but with two-way exchange between regions for older individuals. Whether movement probabilities between the regions could be estimated is uncertain, but using movement probabilities from previous acoustic telemetry studies as fixed values could be a viable alternative. If there is concern that estimated movement rates are inaccurate, a single assessment model that pooled available data could be pursued that estimated aggregate abundances and mortalities. Alternatively, spatially explicit assessment models have been found to be fairly robust to slight model misspecification, at least at the aggregate population level (region-specific estimates can be sensitive). A challenge in developing the model will be that bigheaded carp are harvested and surveyed through a range of different gear types. If overall bigheaded carp harvest is heavily concentrated in just one or two gears that catch similar ages or sizes of fish then the effort for the other gears may be ignorable. Likewise, calculating an overall measure of effort for the combination of survey gears could prove difficult so a choice may need to be made to limit what data are included in the assessment model. Our largest areas of concern for the assessment modeling effort are the apparent lack of consistent and quality age data as well as the lack of age or size data from the commercial and contracted fisheries operating in the lower Illinois River. We highly recommend initiating some type of age or length sampling program for harvest fisheries in the Illinois River if assessment modeling will be pursued as a meaningful management endeavor. Given nuances of the harvest and survey data available for Illinois River bigheaded carp, we recommend developing the SCAA model incrementally. Initially, developers should strive to develop an SCAA model with the simplest structure possible and with time series of data that are considered to offer the most accurate depiction of total fishery removals and fishery-independent assessment of population assessment. Additional model complexity can then be added. While there is no guarantee that a constructed assessment model will be able to

produce accurate and precise estimates of Illinois River bigheaded carp abundance and mortality, the process of attempting to develop the model will be advantageous in that it will require critically evaluating how harvest and survey effort data are collected and whether modifications to sampling are needed for the data to better represent what is occurring in the population.

INTRODUCTION

In the context of this report, stock assessment constitutes an approach of fitting a model to a potentially diverse collection of data for estimating population abundance (including at age of recruitment), mortality rates, and attributes of fisheries exploiting the population. Contemporary statistical approaches to fishery stock assessment involve fitting time series of data (e.g., annual fishery harvest, annual harvest age composition) by modeling population dynamics over time, predicting observed quantities at discrete time points, making distributional assumptions about observed data and model penalties or random effect components, and iteratively adjusting parameters to be consistent with available data and structural assumptions of the model (e.g., Quinn and Deriso 1999). Such models generally are viewed as including a process or dynamics sub-model and an observation sub-model (e.g., Fournier and Archibald 1982; Deriso et al. 1985; Methot 2009). We further restrict our attention to assessment models that use estimates of absolute fishery removals. We do this because fishery removals are often, as appears to be the case for bigheaded carps in the Illinois River, the only quantity for which absolute scale is known. Other information (e.g., fishery or survey catch per effort) only provides information on relative abundance, and thus absolute magnitude of removals is critical information on the scale of abundance. Harvest amounts are informative about population abundance based on the amount of change that occurs in relative abundance indices or age-structured data. Thus, these kinds of assessments are most reliable when fishing mortality has been substantial over at least part of the time series.

Assessment models are sometimes distinguished based on what quantities are modeled. Hilborn and Walters (1992) popularized the term biomass dynamic models to denote models with aggregated biomass as the response variable. These are also widely referred to as surplus production models. Surplus production models are often fit to only fishery catch and effort data, although they can be fit given a time series of fishery removals and any index of population size. Statistical catch-at-age (SCAA) models track age-structured populations and make use of both fishery-dependent catch-at-age data and at least an index of abundance (either from a fishery-independent survey or based on fishery CPUE). Typically, data on the age composition of survey catch (i.e., relative abundance) from a survey are also used. Statistical catch-at-length (SCAL; also just called length-based) models track dynamics of length size classes and transitions among the size classes (Sullivan 1992). Typically, these models are fit using, at a minimum, a time series of annual fishery catch-at-length and an index of abundance. There is no rule that age-structured models cannot make use of fishery catch-at-length or survey catch-at-length data instead of, or in addition to, age-composition data. Brenden et al. (2011) provides an example of an age-structured model that makes use of catch-at-length data for a fishery exploiting the assessed population. Fournier et al. (1990) in the MULTIFAN package pioneered the use of length-composition data within an age-structured assessment model. The Stock Synthesis package extended the methodology for accounting for mixtures of age and length-composition data (Methot 2000; Methot and Wetzel 2013; Methot et al. 2020). In the case where only length composition data are used in the assessment, this generally requires either very distinct modes in the length-composition data or external information on how fish grow. Over the past 40 years, the general trend in age-structured and length-based assessment modeling has been towards increased model flexibility to allow the incorporation of a variety of data sources (e.g., genetic data), and in some cases to mix processes that are both age- and length-based. This broader construct is often referred to as integrated assessment (Maunder and Punt 2013), although one could envision a biomass-based assessment being an integrated assessment if it was fit using a substantially more diverse set of data than just fishery catch and effort.

Our opinion is that, among the available options, effort should concentrate on constructing an age-structured model for assessing bigheaded carps in the Illinois River that makes use of the range of available data. In particular, we recommend making use of age-composition data when available, but also using length-composition data for sources where age data are not available or not considered reliable. This type of model could be called an integrated assessment, but others would view it as a flavor of a SCAA model. For simplicity, we will refer to this type of model as an SCAA here but recognize it might make use of more than just fishery and survey catch-at-age information. We rule out from further consideration surplus production models and SCAL models. Successful fitting of surplus production models generally requires longer time series than what is available for bigheaded carps in the Illinois River; additionally, successful fitting of surplus production models often requires a range of fishing mortality rates applied over a range of abundances, including levels near carrying capacity (e.g., Hilborn and Walters 1992; Prager 1993). It seems unlikely that bigheaded carps have experienced these conditions in the Illinois River. While SCAL models might be a viable option, given the availability of some age-composition data, we believe that an age-structured model is a better approach because of their superior performance over length-based assessments in both simulations and some applications. In some simulation testing, assessments that combine age- and length-based processes (also called cohort models) have outperformed age-structured models (Punt et al. 2017). Such assessments, however, require specifying how growth varies among individuals, and evaluations of the performance of these methods were based on the nature of this variability being correctly specified. For example, Punt et al. (2017) assumed that variation in growth among individuals via variation in the Brody growth coefficient of a von Bertalanffy model, whereas the most widely used package for fitting cohort models (Stock Synthesis) assumes variation in growth is driven by variation among individuals in asymptotic length of a von Bertalanffy model (Methot and Wetzel 2013). Thus, although we cannot entirely rule out a cohort model as being potentially viable for Illinois River bigheaded carp, we recommend starting with a purely age-structured model in part for simplicity and, in part, because the nature of among-individual variation in growth of bigheaded carp is unknown.

SCAA models have been successfully applied for the assessment of invasive species for which there is a coordinated effort to eradicate or significantly reduce population abundance. There is an ongoing effort in Yellowstone Lake in Yellowstone National Park to annually assess, through SCAA modeling, an invasive lake trout *Salvelinus namaycush* population that is believed to be restricting abundance of a Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* population via predation and to determine the effectiveness of control efforts (Syslo et al. 2020). An SCAA model has also been developed and intermittently used to assess sea lamprey *Petromyzon marinus* in the St. Mary's River, the connecting waterway between lakes Superior and Huron, for the evaluation of large-scale integrated control strategies (Jones et al. 2015; Criger et al. 2021). A major challenge in developing assessment models for invasive species, particularly for populations where control efforts are just beginning in earnest, is that major fluctuations in the control program can occur over time as the program matures and new information is gathered that improves capture efficiency (e.g., location and time of year information for where control efforts should be concentrated). Such fluctuations in the control program may not be captured in databases containing control effort or catch values, which can affect predictions from assessment models.

SPATIAL STRUCTURE

Given the spatial scale of bigheaded carp infestation in the Illinois River and the availability of data for assessment (*see below*), we recommend that the developed SCAA model incorporate spatial structuring, although it should be limited to as few spatial regions as possible. Substantial misspecification of spatial structure can lead to biases in assessment results and adverse consequences in terms of meeting fishery management objectives. A common case is where assessment data are collected from mixtures of multiple spawning populations, but a single population assumption is made (the so-called unit stock assumption) in the assessment model. In such cases, population abundance can be overestimated, which can further lead to inappropriate management advice especially for low-productivity populations (Hutchings 1996; Fu and Fanning 2004; Ying et al. 2011; Hintzen et al. 2015; Li et al. 2015). This may have contributed to overfishing of some Atlantic cod (*Gadus morhua*) and Pacific salmon (*Oncorhynchus* spp.) populations (Hutchings 1996; Morishima and Henry 1999; Fu and Fanning 2004).

When spatial structuring is included in assessment models (including integrated tagging models), movement rates between regions are typically used to determine the proportions of each population re-locating to the different harvest regions. These movement rates are parameters to be either estimated or pre-specified in the assessment. Such movement is generally assumed to occur once a year right after reproduction, and for the rest of the year fishing and natural mortality are assumed to be determined by the region of residence (Eveson et al. 2009; Vandergoot and Brenden 2014; Goethel et al. 2015; Vincent et al. 2017). The assumptions about time-steps and timing are easily modified. The assumption that the overall area being modeled can be broken into “boxes” or regions, within which dynamics between periods of movement can be modeled using a unit-stock assumption is pervasive and to us appears to be a reasonable and simple approximation applicable to many situations including that of bigheaded carps in the Illinois River. The two most common assumptions regarding movements among regions have been termed overlap structure and diffusion or metapopulation structure (Porch et al. 2001; Goethel et al. 2011). The overlap structure applies when fish are assumed to return to their original spawning site to spawn each year and are then reallocated to regions for the next harvest year. The metapopulation structure applies when fish do not move back to their original spawning site, but rather continue to reside in their current region during reproduction and make additional movements from their current residence. There are cases of inappropriate choices between these alternatives, and this can adversely influence assessments and management results (e.g., Fu and Fannings 2004, Li et al. 2015). Given past tagging study results for bigheaded carps, it appears likely that a variant of the metapopulation structure would be appropriate for the Illinois River, likely with just a few regions and perhaps only one source region where successful reproduction occurs with unidirectional, downstream movement of new recruits (Lohmeyer and Garvey 2009; Coulter et al. 2018a,b).

Accurate estimation of movement rates typically requires the incorporation of additional data sources into the assessment model. Movement rates in an assessment model can be estimable in the absence of tagging data, although estimates generally have a lot of uncertainty, there may be confounding in estimates of recruitment, and relatively simple movement dynamics need to be assumed (Bosley et al. 2022). The most common approach when estimating movement rates is to incorporate the results from tag-recovery or tag-recapture studies into the assessment (i.e., integrated tagging model; Eveson et al. 2009; Vincent et al. 2017, 2020). However, estimation problems can be encountered when tagging levels and or the number of recoveries or recaptures are low in some spatial regions. An alternative approach is to prespecify movement rates in the assessment models as fixed quantities (Guan et al. 2013; Li et al. 2015). Given challenges to integrating tagging data sets that provide incomplete coverage over time and space, we recommend starting a spatial assessment that uses pre-specified movement rates. The results from the multistate model fit to acoustic telemetry detection data from the Illinois River by Coulter et al. (2018) would likely prove a useful source of information for movement rates for the initially developed assessment model.

MODEL MULTIPLE SPECIES

There are alternatives to modeling species mixture data when not all individuals are clearly distinguished that are potentially applicable to bigheaded carp in the Illinois River. One approach would be to treat two species as distinct and estimate parameters separately for each species. This could even be applied when some sources of data do not distinguish the identities of the two species. However, such an approach ignores the complexity of hybridization between silver and bighead carps. Potential ways to address this would include ignoring hybrids, explicitly modeling interbreeding and incorporate hybrid categories in the assessment, and combining the two species (and hybrids) into a common population assessed together. Given the high frequency of hybrids in the Illinois River (Lamer et al. 2015), ignoring hybrids in any assessment does not seem viable. Modeling hybridization processes can be very challenging with many additional parameters that need to be estimated, even when substantial genetic data are available (Scribner et al. 2018). Thus, we recommend assessing bigheaded carps as a combined species group.

FITTING APPROACH

Some authors distinguish models by the way they are fit. For example, in the maximum likelihood framework, models that include both process errors and observation errors and integrate over the process errors are called state-space models. Similar models are also called state-space models when fit using a Bayesian approach. Some authors exclude models that include both process and observation errors from being called state-space models when they are fit by penalized likelihood, which generally entails assuming a variance (i.e., penalty) for the process error components and allowing the model to predict the most likely combination of fixed parameters and process errors conditional on this variance. While contrasting different approaches for fitting an assessment model is not a focus of this report, we do recommend attempting either an integrated likelihood or Bayesian approach given that they have been shown to outperform penalized likelihood. To fit stock assessments using integrated likelihood, many organizations are using the software package Template Model Builder as the basis for the modeling effort (see Kristensen et al. 2016). Even if estimation issues are encountered with the integrated likelihood approach, the Template Model Builder software package could still be used for the assessment model by penalized likelihood, so we recommend this software for this modeling effort. However, the first step is begin framing a model for dynamics and predicting available data. Details of how to fit the model can be considered later.

PROTOTYPE PROCESS MODEL

Here we present a prototype process model mainly to add clarity and concreteness to the general recommendations and thoughts given above, not to suggest we have identified the process model that should be used. Often the development of a process model involves many iterative steps as assessment attempts confront the actual data and more is learned. Importantly, the person responsible for developing the assessment model should interact closely with those most familiar with the data to which the model is fit and Illinois River bigheaded carp ecology to ensure that model structure and predictions are appropriate. This involvement early in the model-development process can save a great deal of time and effort.

One of the first considerations to be made is what years and ages will the SCAA model cover. SCAA models can accommodate data sources that span different time periods but given that the model will rely heavily on harvest data to scale population abundance, limiting the assessment to 2011 and later seems appropriate given overlap between when fishery harvest was initiated in the upper Illinois River and time frames for some of the monitoring programs. What ages to include in the assessment model should partly depend on aging accuracy for the structures used to age bigheaded carps. However, assessed ages should also depend on the age composition of the assessed population. For example, the SCAA model for Lake Erie walleye *Sander vitreus* only includes ages 2 to 7 years due, in part, to walleye historically being aged with scales that were found to be of limited accuracy for older fish despite walleye being capable of living 20+ years in the lake. Age-2 is the initial modeled age because that is when fish start being effectively sampled or harvested by fisheries or monitoring programs. When constructing an assessment model for a species that can live considerably longer than the ages included in the assessment, the last age is frequently considered a plus age group that aggregates abundances of older fish rather than assuming older fish disappear from the system.

In a general assessment model using a metapopulation structure, the abundance within a region for ages after the age of recruitment can be specified by age, year, and region as:

$$N_{r,a,y} = N_{r,a-1,y-1} S_{r,a-1,y-1} P_{rr} - E_{r,a,y} + I_{r,a,y}$$

where N represents abundance, S is annual survival rate, P_{rr} is the proportion of the population in a region remaining in the region, E is emigration from the region, and I is immigration to the region, with r, a, and y subscripts denoting region, age, and year. It should be noted that in the above equation we are assuming the proportion of the population that remains in the region does not vary by age or year, but these can be age- and/or time-varying. When trying to estimate population movement rates in an assessment model, making movement age and/or year specific can be problematic even when tagging data are available because this added complexity can greatly increase the number of estimated parameters.

Within an SCAA model, there are various ways for modeling recruitment (i.e., abundance at first modeled age; Maunder and Deriso 2003; Sharma et al. 2019). Frequently, there is interest in incorporating an underlying stock-recruit function in the assessment model and estimating parameters of the function as part of the model fitting process. The desire to estimate the parameters of the stock-recruit function is so that the results can be incorporated in forward-projection models for understanding how the population may respond to harvest or control policies. While this might be desirable, it frequently is difficult to accomplish this and obtain reliable parameters for the stock-recruitment relationship because the time series data do not have enough contrast to discern the shape of a stock-recruit function. Alternatively, in some assessments, annual recruitment in SCAA models is modeled as an average recruitment value that is multiplied by an annual deviation term. These annual deviations can be modeled as independent or correlated errors; regardless, it is important to impose a penalty (i.e., distributional constraint) to constrain the errors in part to prevent overfitting. Thus, by adding a penalty from an expectation, recruitment values are stabilized, and overall assessments can be improved. This could be a benefit of incorporating a stock-recruitment relationship, which gives expected recruitment conditioned on stock size, even if the stock-recruitment function is not reliable (Maunder and Deriso 2003), a result that carries over to spatially structured assessments (Li et al. 2018). There are alternatives to modeling recruit as variation about a stock-recruitment function or about a constant mean, but the key is that recruitments near the end of the time-series are stabilized based on an expectation of what is reasonable, given the limited information in the data on recruitment near the end of the time series.

The SCAA estimates of recruitment and spawning stock biomass sometimes are used to estimate a stock-recruit function for the purpose of forward-projection modeling or to relate recruitment to external (e.g., environmental) variables outside of the SCAA model, although it is important for such post-hoc analysis to account for the uncertainty associated with estimated values (Brooks and Deroba 2015). Given the short time series currently available for Illinois River bigheaded carp, it seems highly likely that prior information on possible stock-recruitment parameters will need to be used in any such analysis. The RAM Legacy Stock Assessment Database is a valuable source of such information (https://www.re3data.org/repository/r3d100012095).

For exploited species, instantaneous total mortality is generally classified into natural (*M*) and fishing mortality (*F*) with the annual survival rate calculated as

$$S_{r,a,y} = \exp\left(-M - F_{r,a,y}\right).$$

While natural mortality could be region- or age-specific, assuming a natural mortality rate that was constant across ages and regions at least at the initial stages of the assessment model development seems reasonable. While in theory, natural mortality can be estimated as part of an assessment model, this generally requires considerable contrast in the level of fishing effort. Consequently, we recommend at least initially assuming natural mortality is constant spatially and temporally and known based on life history theory. Of course, if there is strong information available on age or region specific rates this could be incorporated as known values or priors for the model.

There are many potential approaches to deriving fishing mortality for an assessment model. One possible approach, would be to assume that information on fishing operations can be summarized into a measure of fishing effort reflecting the intensity of fishing operations (*I*) and making age- and region-specific fishing mortality rates loosely proportional to fishing intensity

$$F_{r,a,y} = q_{r,a,y} I_{r,a,y}$$

where q is a so-called catchability coefficient that scales fishing mortality to intensity of fishing operations. Classical SCAA approaches would assume catchability (q) was constant over time and space, and reparameterize in terms of overall catchability and selectivity (s):

$$F_{r,a,y} = q_r \, s_{r,a} I_{r,a,y}, \qquad s_{r,a} = \frac{q_{r,a}}{q}$$

with q_r without age- or year-specific subscript being the age-specific catchability in a region for a chosen age and year for that region defined to have selectivity of 1.0. Often, the selectivity values for remaining ages are determined by a two to four parameter function of age (for each region) so that the fishing mortality rates can be determined from the fishing intensities based on a small number of estimated parameters per region (parameters describing the underlying selectivity function plus the overall q). A variety of approaches have been developed to allow for some time dependence in selectivity (e.g., by allowing one or more parameters of the selectivity function to vary according to random walks or AR(1) processes (e.g., Linton and Bence 2011)). An alternative approach, consistent with evolving state-space approaches, would model the age-specific catchabilities (for each region) as multivariate random walks with correlations among ages (e.g., AR(1)). This approach is analogous to an approach of modeling the age-specific fishing mortality rates over time within each region as multivariate random walks (Nielsen and Berg 2014). The approach of estimating *F* directly rather than making use of fishing effort data is a feasible alternative if (a) useful effort data are not available and (b) there are good quality survey data for each region. By good quality survey data, we mean that measurement error associated with the survey is low (there is no set cutoff but if the log scale estimate of relative abundance had a standard error less than 30% of the estimate (30% CV) most would consider this low), the survey is highly standardized such that catch per effort provides an accurate index of abundance, and the survey catches a wide range of available ages.

Immigration into a region would be calculated as

$$ {}_{r,a,y} = \sum_{i \neq r} {}_{i,a-1,y-1} S_{i,a-1,y-1} \; {}_{i,r} $$

where $P_{i,r}$ is the movement rate into region *r* from the other *i* regions. As previously indicated, in the above equation we show movement rates among regions as being constant across age and time, but this greater complexity can be included.

Emigration away from a region would be calculated as

$$ E_{r,a,y} = {}_{r,a-1,y-1} S_{r,a-1,y-1} \sum_{i \neq r} {}_{r,i} $$

where $P_{r,i}$ represents the proportion of fish present in region r at the time movement that move to the other i regions. The equations for immigration and emigration assume that movement occurs at the end of the year after any region-specific mortality has occurred. As noted above, a starting point would be to obtain the *P* values from the results of a prior analysis of tagging data, although if the tagging data were incorporated as data the *P* could be estimated as part of the assessment model.

The above model is presented in a general form with an unspecified number of regions and no explicit assumptions on what the *P* values can be. The model would be simpler (with relatively few movement parameters if only a few regions were used and/or movement was possible only between specific regions.

OBSERVATION MODELS

Fishery catch (i.e., harvest) at age could be predicted using the Baranov catch equation:

$$ C_{r,a,y} = \frac{F_{r,a,y}}{Z_{r,a,y}} \; {}_{r,a,} \; (1 - \exp(-Z_{r,a,})) $$

were *Z* is the total instantaneous mortality rate (sum of *F* and *M*). If harvest is recorded in yield, model-predicted yield could be obtained by multiplying catch-at-age by average weight-at-age for each region and year.

Survey indices-at-age could be predicted as proportional to abundance:

$$n_{r,a,y} = q_{sur} s_{sur} N_{r,a,y}$$

where survey selectivity (i.e., relative vulnerability) would be a function of age. In cases where survey gear might become saturated due to high density populations, allowing for density-dependent catchability could be important for the gear. In extreme cases, a survey gear could be uninformative as to the status of the assessed population because CPE does not track with changes in population abundance. As noted for fishery selectivity and catchability, survey selectivity can also be modeled in terms of age-specific catchabilities following random walks. The equation for predicting survey indices is written as though there is just one time series of survey indices for an area and that the survey is done at the start of the year, before mortality. The equation is easily adapted to use an adjusted *N* representing the numbers alive at the time of the survey, and multiple surveys can be used (just subscripted by survey ID).

If the model is being fit to data on fishery or survey indices-at-length the predicted catch or index for ages needs to be converted to predictions for length classes. For catch, the prediction for a length class is:

$$C_{r,l,y} = \sum_{a} C_{r,a,} \; p_{a,l}$$

where $p_{a,l}$ is the proportion of fish of a given age *a* that is in the length bin *l*. Thus, the catch-at-length is just the sum of the catch over ages for the appropriate length category. As written, the equation assumes that the length distribution given age does not depend on region or year, but alternative assumptions could be made. To implement this approach using length data, parameters need to be specified to determine the length distributions at age (the $p_{a,}$). One approach to doing this is to model the mean length-at-age using a simple growth model (e.g., von Bertalanffy), and then assume a distribution (e.g., Normal) and model the dispersion of the distribution in a simple way (e.g., constant CV so $\sigma =$, where σ is the SD for the lengths of fish at an age, and C is the expected length at that age. A description of this is provided in Brenden et al. (2011). Calculations for predicting survey catch-at-length would follow a similar process.

LIKELIHOOD COMPONENTS

When fitting an assessment model, the observation model needs to be completed by specifying distributions for the observed quantities. There are two general approaches to dealing with catch-at-age or catch-at-length data (for either a fishery or survey). One is to pre-calculate proportions at age and total catch and to treat these as independent proportions. The other is to use the catch-at-age or length directly. For either of these approaches there are wide ranges of alternative distributions for the data. For example, a common approach used in the first case is to assume the proportions at age arise as if the age-composition sample came from a multinomial distribution and assume that the total catch came from a lognormal distribution, but there are many alternatives. Likewise, there are alternative choices for catch-at-age in its native form, such as a multivariate lognormal. There is no agreed on best set of distributions to use so our recommendation is to consider a range of alternatives and use model selection approaches to choose among them.

REQUIRED DATA

Given that SCAA models come in many flavors, it is difficult to completely identify the minimum required set of data to construct a model. In our experience, SCAAs are rarely applied with less than 10 years of data although fitting such a model with fewer years of data might be feasible if direct estimates of absolute abundance were available. Fitting an SCAA model to fewer years of data can also be accomplished when recruitment levels do not need to be estimated due to a population being supported solely through stocking, which does not apply to Illinois River bigheaded carps. Generally, SCAAs require total catch (i.e., harvest) of fish by the fishery each year, age-composition estimates of removals in at least some of the years when harvest occurs, and relative indices of abundance or information and assumptions that provide this information over the time series. While length-composition data can sometimes substitute for age composition, this usually requires external information on growth so age-composition predictions can be converted to length-composition predictions. This information on growth might be needed for multiple areas or time periods that have different growth as the model may otherwise be biased.

When the fishery consists of different components (e.g., gear types, fishery types) likely to have very different selectivities, with relative levels of effort of the components changing over time, then the fishery data need to be available separately by component (or if aggregated allowance made for changing catchability and selectivity). While the fishery catch data (summed over separately modeled fishery components) need to represent total removals, fishery effort time series do not need to be available for every time series (and when very good survey data are available fishery effort can be completely ignored. While age- or length-composition information is not required every year, stronger assumptions will need to be made about fishery selectivity as the availability of annual composition data decreases. Although relative indices of abundance are not required every year, it is necessary for some data to be provided that are informative of general trends in relative abundance over the time series. Fishery components that provide both catch and effort can be used to serve this purpose, although confidence in trends will be improved by using fishery independent data. It is important to note that very short (just a few years) relative abundance time series (e.g., from a survey lasting only a few years) provides little information and can even cause assessment performance to degrade due to the need to estimate additional catchability and selectivity parameters for each time-series. While this is an area needing additional research, our working recommendation is to not include surveys that provide less than five years of relative abundances. Generally, age- or length-composition information is required for fishery-independent surveys that provide relative abundance indices, similar to what is needed for harvest components. When relative abundance data are from multiple surveys that do not span the entire modeled time span, it is important for there to be some overlap among the partial time series, so that together they provide information about the overall trend over the assessment period. Alternatively, separate gear comparison studies should be undertaken to better understand how age-specific catches from the surveys compare to each other, and how they might be combined.

Our initial recommendation is to attempt to develop a two-region model with Region 1 extending from Alton to Starved Rock and Region 2 extending from Starved Rock to the current invasion front. Region 1 would be the sole source for assessed recruitment, with movement between Regions 1 and 2 for older fish assumed based on the results from acoustic telemetry studies. With sufficient tagging, results from acoustic telemetry studies could be incorporated in the assessment model so as to estimate movement rates, but we would not attempt to incorporate that data source initially. Assuming this spatial framework, there are two fisheries operating in Region 1 (Lower Illinois River Commercial Fishery; Enhanced Contract Fishery) and one fishery operating in Region 2 (Upper Illinois River Contracted Fishery). For Region 1, the Lower Illinois River Commercial Fishery has data available since around 2000. Based on materials provided, five gear types have been used to harvest bigheaded carps (seine, trammel net, hoop net, basket trap, and trot line). Characterizing total effort for this mixture of gears will likely be problematic due to it being a mixture of passive and active gears, although if overall bigheaded carp harvest is heavily concentrated in just one or two gears that catch similar ages or sizes of fish then the effort for the other gears may be ignorable. One would only need to include total fishery effort if (a) all gears were being modeled as a single fishery, and the fishery data were essential for providing information on relative abundance. While SCAA models can incorporate data from multiple fisheries operating in a single region, the addition of each new gear type requires additional parameters to be estimated and overly complex (i.e., highly parameterized) models can have convergence issues due to inconsistent signals in the data and the need to estimate variances and covariances for parameter estimates. A common approach is to aggregate data from multiple gears together in terms of the catch and calculate an adjusted effort (taking into account the relative fishing power of the combined gears) for the aggregation. This can work when the time-trends of the effort from the combined gears are similar, the different gears have similar selectivity, or just one of the gears dominates the harvest. Thus, it may be feasible to incorporate useful relative abundance information from fishery data, even if reliable or meaningful effort is not available for all gears. Sampling of ages or lengths is not conducted from either the Lower Illinois River Commercial or Enhanced Contract Fisheries, which may be problematic for model estimation and may necessitate making assumptions as to age- or length-specific vulnerabilities to these fisheries. For future assessment modeling efforts, we strongly recommend initiating an age or length sampling program for these fisheries as changes in age or length compositions over time are critical for assessment models to accurately estimate mortality rates. For the Upper Illinois River Contracted Fishery in Region 2, fishing has occurred since 2010 although based on provided metadata the 2010 records may not be accurate. Detailed information is available for fishing effort for the various gears, including both duration and length of gear deployments. Age data for harvested fish do not appear to be available but lengths of 30 randomly selected individuals of each species for each week of contracted fishing back to 2011 were collected from Marseilles and Starved Rock. For Dresden Island, a concerted effort to collect fish lengths did not begin until 2016 so it will be important to assess initially how similar length compositions are from the different areas to determine if problems could arise from pooling the locations together and treating as a single fishery.

Multiple fishery-independent surveys are conducted throughout the Illinois River. In Region 1, a large portion of the lower Illinois River centered at the La Grange Pool is sampled as part of the Long-Term Resource Monitoring (LTRM) Program for the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program. The LTRM is a highly standardized survey involving fixed-site sampling of important river features, simple random sampling of a discrete population of engineered structures, and a spatially stratified random sampling of entire study reaches. The survey has been ongoing since 1993. Historically, as many as 12 gear types were included in the survey but in recent years sampling has been limited to 5 gear types (day electrofishing, small and large mesh hoop netting, mini fyke netting, and tandem fyke netting). As with the commercial fisheries, coming up with an overall measure of fishing effort for this combination of gears could prove difficult so a choice may need to be made to limit what data are included in the assessment model. According to Irons et al. (2011) bighead carp appear more vulnerable to mini-fyke netting and large-mesh hoop nets whereas silver carp are more vulnerable to electrofishing. This may make it necessary to include at least several gear types. Length data are available for calculating size composition of the LTRM catch. Age data have been collected by aging cleithra through a program funded by the LTRM and for silver carp from 2018 to 2020 as part of the LTRM, but at the time of writing it was not known whether these data were available for the assessment modeling. Given the lack of age or length data for fisheries operating in Region 1, we highly encourage that efforts be made to be able to use the cleithra age data for calculating survey age-composition data. Simply using length-composition data may be a viable alternative, but estimation issues may be encountered in estimating an age-structured model with little available age data. Even if age data are not available to use as age composition, it would be important to be able to use the collected age data to be able to estimate the proportion of fish of a given age a that is in the length bin l for converting model predicted catch-at-age to catch-at-length. Erickson et al. (2021) appeared to have used age data from the LTRM for estimating von Bertalanffy growth curves for different regions of the Illinois River. This type of analysis could be used to calculate the proportions needed for converting catch-at-age to catch-at-length, although it would be important to evaluate temporal variation in modeled growth patterns, and account for it if necessary, as well.

Another fishery-independent survey conducted in the Illinois River is the Long-Term Electrofishing (LTEF) Program conducted by the Illinois Natural History Survey (Fritts et al. 2017). This survey has been ongoing since the late 1950s using direct-AC electrofishing at fixed-site locations, although in the late 2000s the survey was expanded to include a stratified-random sampling component using pulsed-DC electrofishing (Fritts et al. 2017). A variety of potential problems have been identified for the direct-AC electrofishing sampling (Fritts et al. 2017). Given that reliable data from the upper Illinois River Contracted Fishery were not available until 2011, it would be reasonable to only include survey data from the LTEF pulsed-DC electrofishing to obviate the problems of the direct-AC electrofishing. In the Illinois River, LTEF pulsed-DC electrofishing sampling is conducted at five navigable reaches. Sampling is conducted at three time periods throughout the summer and into mid fall. Two of the reaches (Peoria and Alton) are located in Region 1, whereas the other three reaches are located in Region 2 (Dresden, Marseilles, and Starved Rock). According to Fritts et al. (2017), the LTEF pulsed-DC electrofishing was in part initiated to mimic electrofishing sampling conducted as part of the LTRM sampling previously described, so in effect it likely can be considered that the LTRM electrofishing sampling at the La Grange pool can be included in the LTEF results meaning there would be three reaches for the LTEF sampling program in Region 1. According to metadata provided, sampling of fish ages is not conducted for this program, although lengths of individual fish are available for calculating length composition of the catch. The catch from the LTEF program may be one of the surveys to consider whether gear saturation could be an issue as conceivably there could be limitations to the number of fish captured during the length of the survey due to physical limitations by dip netters.

In 2018, the U.S. Fish & Wildlife Service Columbia Fish and Wildlife Conservation Office initiated an additional fishery-independent survey in the Illinois River. Five reaches are sampled: three in Region 1 (Alton, La Grange, and Peoria) and two in Region 2 (Starved Rock and Marseilles). Sampling is conducted in both early summer and early fall. Sampling is done using a stratified random design with habitat type used as strata (side channel/island complex, main channel border, and backwater). Sampling consists of either electrified dozer or paupier trawls. Conversion of catches between the different trawl types can be done using existing relationships. Age data for silver carp are being collected during the fall sampling, although based on the metadata provided, the types of aging structures used has shifted as has the sampling strategy. In 2018, postcleithra, scales, vertebrae, pectoral spine, dorsal spine, lapilli otoliths, asteriscus otoliths were collected from the first 5 fish in 50 mm length bins in each pool. In 2019 and 2020, lapilli otoliths were collected from first 10 fish in 50 mm length bins in each pool. In 2021, lapilli otoliths were being collected from first 200 silver carp sampled per pool regardless of length bin, subsequent fish caught were used to fill any 50 mm bins without at least 10 representative fish from the initial 200 collected. Given that there are only a few years of available data from this survey, it may not be possible to immediately incorporate the results from this survey in the SCAA model, although given that age data are collected for this survey it may be worthwhile to try to include this data source, even if limiting assumptions have to be made (e.g., time-invariant catchability and selectivity). It is not clear from the information provided why only silver carp are being aged. For this data source to be of greatest use for assessment modeling, we would recommend also aging bighead carp and hybrids. The supporting document describing the sampling program from this survey includes text about how information gained from seasonal sampling results will be used to adjust sample efforts to reach sample goals to appropriately assess size structure. The details of how this sampling program will be adjusted is important and we recognize one of the goals of the sampling program is to collect enough fish to quantify population dynamics. However, from an assessment modeling standpoint, adjustments to the sampling effort can mask trends in relative abundance that will influence assessment model abundance and mortality estimates.

In our review of the scientific literature for Illinois River bigheaded carps, we did identify some additional data sources that perhaps could be of benefit for the SCAA model. We have already mentioned the acoustic telemetry studies described by Coulter et al. (2018) that may be informative for determining movement rates between the modeled regions. Researchers with Southern Illinois University have conducted hydroacoustic monitoring of bigheaded carp at the Dresden Island, Marseilles, Starved Rock, Peoria, LaGrange, and Alton pools of the Illinois River since 2012 (https://invasivecarp.us/Documents/Interim-Summary-Report-2021.pdf). According to available descriptions, hydroacoustic monitoring is used both opportunistically to inform response effort and for a standardized assessment conducted in the fall. The standardized assessment will be the most valuable from an assessment perspective. Results from hydroacoustic surveys are frequently incorporated in integrated assessment models (Tsehaye et al. 2014; Fisch et al. 2019), although the results are still generally treated as a measure of relative abundance as opposed to absolute abundance.

The modeling work described by Erickson et al. (2021) generating spatially explicit estimates of factors like length-weight relationships, growth curves, female maturity rates will be beneficial for calculating derived variables (functions of parameter estimates) both for model fitting but also for post-hoc determination of desirable variables like spawning stock biomass. As mentioned previously, we would recommend evaluating whether a time-element should be incorporated to these analyses, so that any meaningful annual variation is not ignored. The estimates of natural mortality and their uncertainty from Erickson et al. (2021) could also be incorporated in the SCAA, although an evaluation of the sensitivity of the model to these values would be prudent as the estimates are higher than we initially envisioned and there is considerable uncertainty associated with the estimates.

RECOMMENDATIONS

Successful fitting of an SCAA model that converges on a solution and produces accurate estimates of population demographics, dynamics, and fishery characteristics depends on a wide variety of factors. For one, it depends on the assumed structure of the SCAA model adequately approximating the assessed population and the behaviors and characteristics of individual fish. We previously pointed out the importance of the spatial structure of the SCAA model matching fish movement behavior; however, even smaller details such as assumptions regarding the precise function used to model fishery or survey selectivity or distributional assumptions of process errors also are important. Successful fitting of an SCAA model requires that the time series of data used to fit the SCAA model provide at least somewhat consistent signals as to population status, and that changes in the signal are correctly modeled (e.g., through time varying catchability or selectivity). Finally, a modeling effort such as this requires numerous assumptions be made, violations of which can cause model fitting problems.

For the reasons mentioned above, successful convergence of an SCAA model is not necessarily guaranteed and there can be issues with models no longer working when additional years of data are added to the model. Finally, since true population abundance, mortality rates, and other dynamic rates are unobservable quantities, it can be difficult to know whether estimates are accurate so it can be important to assess things like retrospective patterns in model output (i.e., the tendency for a model to over- or under-estimate parameters or variables of interest in the terminal assessment year), sensitivity of output to model assumptions and structure, and to use simulations to assess model accuracy.

Given nuances of the harvest and survey data available for Illinois River bigheaded carp, we recommend developing the SCAA model incrementally. Initially, developers should strive to program an SCAA model with the simplest structure possible and with time series of data that are considered to offer the most accurate depiction of total fishery removals and fishery-independent assessment of population assessment. As specified previously, our recommendation is to attempt a two-region model with Region 1 extending from Alton to Starved Rock and Region 2 extending from Starved Rock to the current invasion front. Based on our understanding of bigheaded carp biology in the Illinois River, we believe it would be appropriate to model recruitment as arising solely from Region 1 but allowing for exchange among regions for older ages. Once that is completed, model complexity can be added in a stepwise fashion to gauge when the assessment model may become overly complex. Because of the complexity of the fishery-independent monitoring programs, we recommend initially incorporating catch and effort data from just one or two survey gears that you believe does the best job at indexing the relative abundance of the largest segment of the population. The model could then be expanded to account for other survey gears in a stepwise manner.

Given the complexity of the fishery independent monitoring program in terms of type of survey gear, the longitudinal complexity of the Illinois River, some uncertainty regarding what data are available for some of the time series, and inconsistent methodologies (e.g., concerted effort to collect lengths of fish from the Dresden Island contracted harvest did not begin until 2016), we do not know with certainty that this assessment modeling effort will be successful. While we strived to determine as much detail as possible regarding the data collection efforts, in some cases the best way to ascertain the full data availability or consistency of available data sources is to attempt to include it into an assessment. Thus, despite that uncertainty, we are of the opinion that attempting to develop this assessment model is worthwhile for two primary reasons. First, without generating an assessment model of this nature, it will be difficult to accurately assess how the bigheaded carp population in the Illinois River is responding to the control program, and to evaluate how dependent any conclusions about the effectiveness of the control program are to underlying assumptions. A SCAA would make the assumptions explicit. Secondly, even if model development does not prove to be successful, the attempt at developing the model could help identify changes in the control or monitoring program that would permit development of an assessment model in the future. Our largest areas of concern for the assessment modeling effort are the apparent lack of consistent and quality age data as well as the lack of age or size data from the commercial and contracted fisheries operating in the lower Illinois River. There are also potential problems due to the wide range of gear types used for both fishery harvest and population monitoring as this may greatly increase model complexity. We highly recommend initiating some type of age or length sampling program for harvest fisheries in the Illinois River if assessment modeling will be pursued as a meaningful management endeavor. We also recommend given initial consideration as to how catch and effort from different gears in fisheries or monitoring programs will be combined for incorporation in the SCAA model.

ESTIMATED TIME FRAME TO DEVELOP AN INITIAL SCAA MODEL

We estimate that about 6 months of effort would be needed to organize data, and code and evaluate an initial model along the lines of what is described above for an assessment scientist already experienced with SCAA modeling. This presumes the data are in an easily obtainable format and do not require substantial quality assurance/quality control evaluations. From our experience, working fulltime on developing a model like this can be tedious, so a reasonable expectation would be to provide funding to cover 6 months of a developer's effort to develop and fit the initial assessment model allocated over at least a year and possibly two years in part to allow for any needed work to clean up data and to involve biologists and managers in the coding process. In our experience, data cleaning is best left to those who maintain the data, so changes are captured in master databases.

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TELEMETRY SUPPORT FOR THE SPATIALLY EXPLICIT INVASIVE CARP POPULATION MODEL (SEICarP)

Participating Agencies: USFWS, Carterville FWCO (lead), Jen-Luc Abeln (USFWS, Carterville FWCO, Wilmington Substation)

Pools Involved: Peoria, Starved Rock

INTRODUCTION AND NEED

The SEICarP model was developed to assess the 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 the 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 collected throughout the IWW describing the inter-pool transfer of adult invasive carp and is used to parameterize the transition probability component of the SEICarP model. This research provides an improved understanding of the invasive carp movement in the IWW and its effects on population dynamics.

OBJECTIVES

- Collectively tag greater than or equal to 150 individual adult invasive carp within Peoria and Starved Rock pools, focusing on Silver Carp.
- Deploy and maintain an array of six 69-kilohertz receivers in Peoria Pool to enhance detections of transient fish in the pool.
- Provide data from acoustic receivers to the telemetry working group of the MRWG for use in the SEICarP model.

PROJECT HIGHLIGHTS

- In November 2022, 150 V-9 acoustic transmitters were implanted into invasive carp – 75 transmitters were strategically spread across Peoria Pool, and 75 were placed in the center of Starved Rock Pool.
- Data from the six 69-kilohertz acoustic receivers was collected, processed, and provided to the telemetry working group.

METHODS

The receivers were deployed in April 2022 and collected for download in June, July, September, and December 2022. The data associated with downloads were uploaded to the FishTracks database within 2 weeks of download. With direction from the telemetry working group, all receivers were tethered to trees 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. Receivers were removed and downloaded in early December to prevent loss to ice. The current and new receivers will be deployed with the beginning of the new monitoring season in early Spring 2023.

RESULTS AND DISCUSSION

A total of 101,974 detections from 94 fish were recorded across the six USFWS-maintained 69-kilohertz receiver array from April 6 to December 6, 2022 (Table 1; Figure 1). USFWS observed 32 percent of the 75 invasive carp tagged in Peoria Pool one month after tagging. This is a good indication that survivorship among newly tagged fish is positive; however, further months of data is needed to get an overall estimate of survival. All data was uploaded to the FishTracks database by January 2023.

FUTURE WORK

Future support of the SEICarP model will continue into FY 2023. USFWS Carterville FWCO will tag an additional 150 adult invasive carp in Starved Rock Pool and Peoria Pool. Future work will include expanding the array coverage to 20 69-kilohertz receivers across the Peoria and Starved Rock pools or in strategic areas the telemetry working group requests. Expanding the coverage of the array will assist in producing more robust estimates of pool-to-pool transitions when the transition probabilities are estimated again in 2025. Capturing the movements of fish within the larger array helps reduce the probability that fish are transiting undetected and gives a better idea to researchers of individual fish survival. The MRWG telemetry working group will be consulted prior to tagging and deployment to optimize placement within the IWW.

Table 1. Detections of fish at each receiver location in the Peoria Pool.

Receiver	Station Name	# Fish	# Detections
VR2W-129785	RM166.6 Peoria Lake Narrows	30	4,510
VR2W-129781	RM182.4 US Chilli Bridge_Peninsula	21	7,577
VR2W-129779	RM188.1 DS Lacon_MC Sawyer Slough	25	31,645
VR2W-129787	RM194.8 US Upper Henry Island	28	41,241
VR2W-137063	RM202.7 Lower Twin Sisters Island	34	4,412
VR2W-137065	RM216 US of Clark Island	48	12,589
Totals	--	94	101,974

Notes:

- Receiver = serial number
- Station name = combination of RM and geographic/visual location information
- # Fish = the number of unique tagged individuals
- # Detections = the number of recorded detections by a receiver.

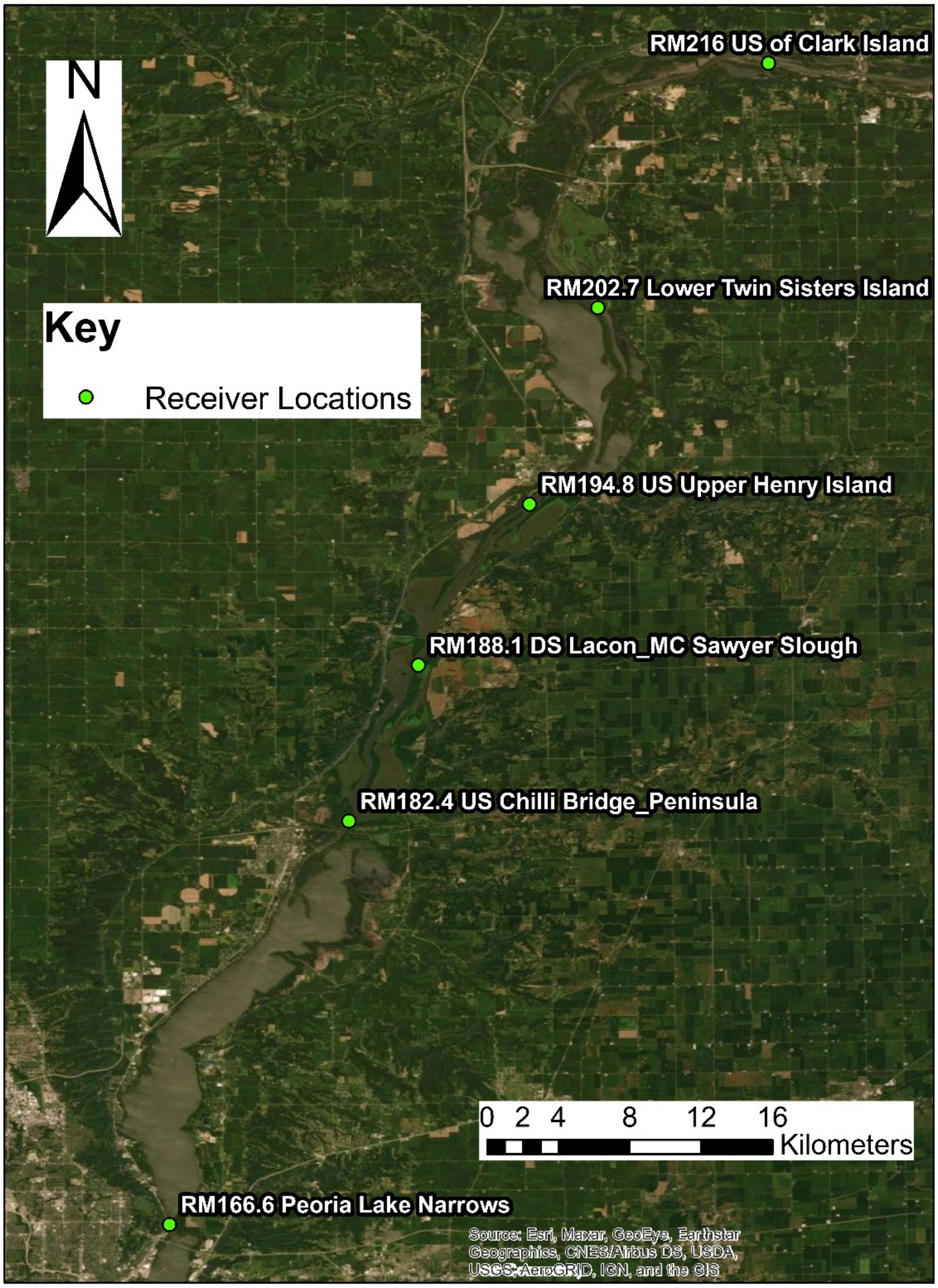

Figure 1. *Map of USFWS-maintained 69-kilohertz acoustic receivers deployed in Peoria Pool throughout 2022.*

INVASIVE CARP DEMOGRAPHICS

Participating Agencies: USFWS Columbia FWCO (lead); INHS and IL DNR; Edward Sterling, Bryon Rochon, Jahn Kallis, Jason Goeckler (USFWS Columbia FWCO)

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, and condition) and data to parameterize decision support tools, such as the simulation-based SEICarP model (ICRCC 2019). Herein, we update Silver Carp demographic data collected from the six lower pools of the Illinois River (Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools) during the spring and fall from 2018 to 2021 with 2022 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 the success of ongoing and future control efforts using multiple indicators.

OBJECTIVES

- Quantify size and sex structure, size at maturity, and relative abundance of invasive carp during spring and fall in the lowest six pools of the Illinois River (Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island).
- Use lapilli otoliths to generate age and growth information for Illinois River invasive carp captures.
- Collaborate with the MAM Program to reduce overlap and increase efficient data collection to update parameter estimates associated with the SEIcarP model.

PROJECT HIGHLIGHTS

- Collected over 14,000 Silver Carp and processed nearly 3,000 lapilli otolith aging structures from six pools of the Illinois River from 2018 to 2022, providing pool-specific metrics in sex ratio, body condition, age, and growth.

- Sampling in the Starved Rock Pool detected 13 and 41 small (less than 200 millimeters) Silver Carp in fall 2021 and spring 2022, respectively. No sub-stock Silver Carp or fish marginally larger were detected during fall 2022 sampling. This suggests that sub-stock fish collected during the spring were likely not evidence of a substantial year class. Captures of sub-stock (less than 250 millimeters) Silver Carp are rarely encountered in the upper pools of the Illinois River, whereas they are captured more consistently from pools located below Starved Rock Lock and Dam, indicative of source-sink population dynamics.
- Spring 2021 to 2022 sampling determined length at maturation for female Silver Carp (50 percent maturity reached at 501 millimeters total length) and for male Silver Carp (50 percent maturity reached at 452 millimeters total length), improving the accuracy and precision of size at maturity estimates provided to the MRWG modeling working group.
- Collaborated with the INHS to evaluate the accuracy of Silver Carp age estimates derived from postcleithra. Results suggest that postcleithra underestimates age. We recommend lapilli otoliths be used consistent with previous research findings (Seibert and Phelps 2013).
- Evaluated contributions of the electrified dozer trawl to a large river multiple-gear sampling approach (e.g., LTRM) with respect to fish community and invasive carp data collections. Results indicated that large river programs seeking a comprehensive view of the fish community, including the pelagic fish community members, such as Silver Carp, would benefit from including the electrified dozer trawl.

METHODS

The USFWS Columbia FWCO collected fisheries-independent data, including age, size, sex structure, length at maturity, and relative abundance during spring (May to June) in the Alton, LaGrange, and Peoria pools, and during fall (September to November) in the Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools, using a random design stratified by habitat type (i.e., backwaters, island side channels, and 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 GIS process that included habitat data and an indexed 50- by 50-meter grid. Collection sites were sampled by conducting 5-minute trawls at 4.8 kilometers per hour (calculated by GPS tracking) using an electrified dozer trawl (Hammen et al. 2019). Catch rates from 2018 to 2021 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, Peoria, and Starved Rock pools using macroscopic observations of the gonads. Fish length and weight were measured for all spring- and fall-caught Silver Carp. In the fall, lapilli otoliths were extracted from the first 200 Silver Carp captured in each pool, with a maximum of 20 Silver Carp per transect. Otoliths were extracted from any fish in an unfilled length bin (10/50 millimeters total length) following the first 200 collected. All non-invasive carp captures were identified to species, counted, weighed to the nearest gram, and measured to the nearest millimeter.

RESULTS AND DISCUSSION

This report summarizes results from field sampling and laboratory age estimates conducted by the USFWS Columbia FWCO. Results from 2018 to 2021 collections were updated with 2022 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 working group to update parameter estimates in the SEICarP model and important inputs for SCAA models recommended by the Quantitative Fisheries Center personnel at Michigan State University.

In 2022, 3,472 Silver Carp (3,103 from standardized electrified dozer trawl transects) were captured in the lower six pools of the Illinois River between two seasons. Spring sampling was used to target locations with younger Silver Carp nearing maturation, with an overall goal of characterizing length at maturity in the lower four pools of the Illinois River (Alton, LaGrange, Peoria, and Starved Rock pools). In spring 2022, 921 Silver Carp (681 stock size individuals greater than or equal to 250 millimeters total length; Phelps and Willis 2013) were collected in 78 5-minute trawls from the lower four pools with the electrified dozer trawl (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 (Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island) of the Illinois River. During fall 2022, 2,183 stock-size Silver Carp were collected in 300 standardized 5-minute trawls from the lower six pools with the electrified dozer trawl (Table 1). An additional 90 Silver Carp were collected in the lower six pools using non-standardized electrified dozer trawl sampling to bolster age structure collections. Along with electrified dozer trawl sampling, supplemental commercial catch data was used to collect Silver Carp in 2021 (N = 168) and 2022 (N = 200) from the Marseilles Pool and in 2019 (N = 19), 2021 (N = 67), and 2022 (N = 78) from the Dresden Island Pool. 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 2022 summary data, including pool-specific effort (number of 5-minute trawls), Silver Carp total catch (number), mean Silver Carp CPUE (number greater than or equal to 250 millimeters per hour) and standard error, and total length range of Silver Carp captured. Results are based on fishery-independent sampling using the electrified dozer trawl.

Pool	Season	Effort (#)	Silver Carp (#)	Mean CPUE (SE)	TL range (mm)
Dresden	Fall	50	0	0 (0)	NA
Marseilles	Fall	50	29	6.8 (2.1)	555-940
Starved Rock	Spring	27	328	125.3 (20.7)	142-820
Starved Rock	Fall	50	343	82.3 (15.9)	525-810
Peoria	Spring	28	109	45.8 (9.7)	130-785
Peoria	Fall	50	1117	331.4 (85.3)	280-810
LaGrange	Spring	10	23	18 (8.6)	135-770
LaGrange	Fall	50	424	101.8 (12.1)	460-860
Alton	Spring	13	460	311.8 (133)	70-780
Alton	Fall	50	270	64.9 (10.9)	380-755

Relative Abundance: Objective one of this project included quantifying Silver Carp relative abundance. Temporal patterns in catch rates of stock-sized Silver Carp varied among sample pools and years, though there was a trend of higher relative abundance in lower pools compared to upper pools each year (Figure 1). Stock-sized Silver Carp were used for analyses because they are assumed to be recruited to the population. Also, previous age data from this effort depicts that the average length at age-1 is over 250 millimeters total length, meaning that stock-sized Silver Carp are no longer susceptible to variable first-year mortality and are likely fully recruited to the population (ICRCC 2021). High water events, sampling time (i.e., temperature), harvest events, and other natural factors affect the catchability of Silver Carp, though it is difficult to isolate the factors that could be influencing within-pool relative abundance estimates on an annual basis. Although several factors may contribute to the lower overall abundance in the upper pools, one of the primary reasons is the lack of recruitment within these pools. The only exception occurred in the Starved Rock Pool, where small (less than 200 millimeters) Silver Carp were detected in low abundances in fall 2021 (N = 13) and spring 2022 (N = 41). Thus, the population size in the upper pools is likely maintained by upstream movement rates from downstream pools that 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 and fishing) is higher in the upper pools due to high commercial harvest efforts (ICRCC 2019). Increased harvest efforts have resulted in thousands of invasive carp being removed from the upper three pools annually, which could reduce population size and overall abundance (ICRCC 2019). However, relative abundance in the lower pools appears to be stable or on an upward trend annually, despite incentivized commercial harvest that has removed nearly 7 million pounds of invasive carp in the Peoria Pool since 2019 (ICRCC 2021). Additional annual pool-specific relative abundance information can be found in the appendix (Figure A.1).

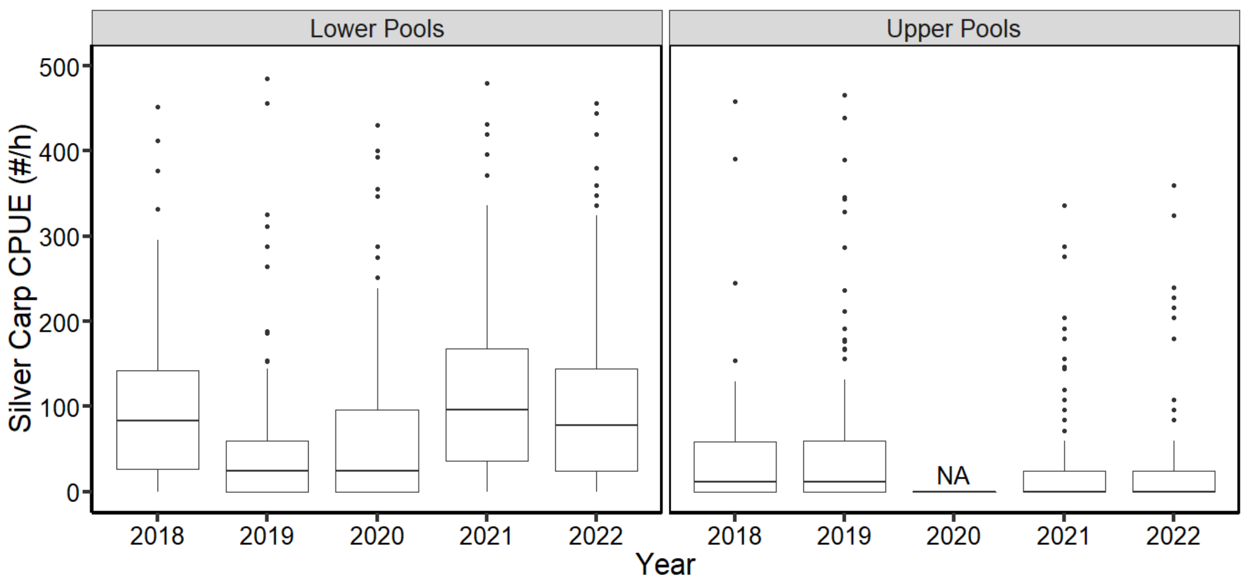

Figure 1. *Boxplots of annual stock-size (greater than or equal to 250 millimeters) Silver Carp CPUE (number/hour) in lower (Alton, LaGrange, and Peoria) pools and upper (Starved Rock, Marseilles, and Dresden Island) pools. Outliers above 500/hour were removed for visualization (N = 31 for Lower Pools, N = 1 for Upper Pools). All fish were sampled using the electrified dozer trawl during fall 2018 to 2022.*

Length Structure: Silver Carp collected from 2018 to 2022 measured 40 to 1,030 millimeters total length, with a mean length of 583 millimeters total length. Catches have been dominated by individuals greater than 450 millimeters total length (90.6 percent) across pools (Figure 2). Results from fall 2022 were similar, with Silver Carp ranging from 280 to 1,004 millimeters total length, with a mean length of 547 millimeters total length.

Length structure data reflected spatial patterns of source-sink dynamics. Sub-stock size Silver Carp were captured more consistently from pools located below Starved Rock Lock and Dam (i.e., source populations), but captures of sub-stock size Silver Carp from pools located above Starved Rock Lock and Dam (i.e., sink populations) were rare. In 2021, 13 individuals were captured in the Starved Rock Pool. In spring 2022 sampling, 41 sub-stock size Silver Carp were detected within the Starved Rock Pool, but no sub-stock Silver Carp or fish marginally larger were detected during fall 2022 sampling. This suggests that sub-stock fish collected during the spring were likely not evidence of a substantial year class. Additional annual pool-specific length distributions can be found in the appendix (Figure A.2).

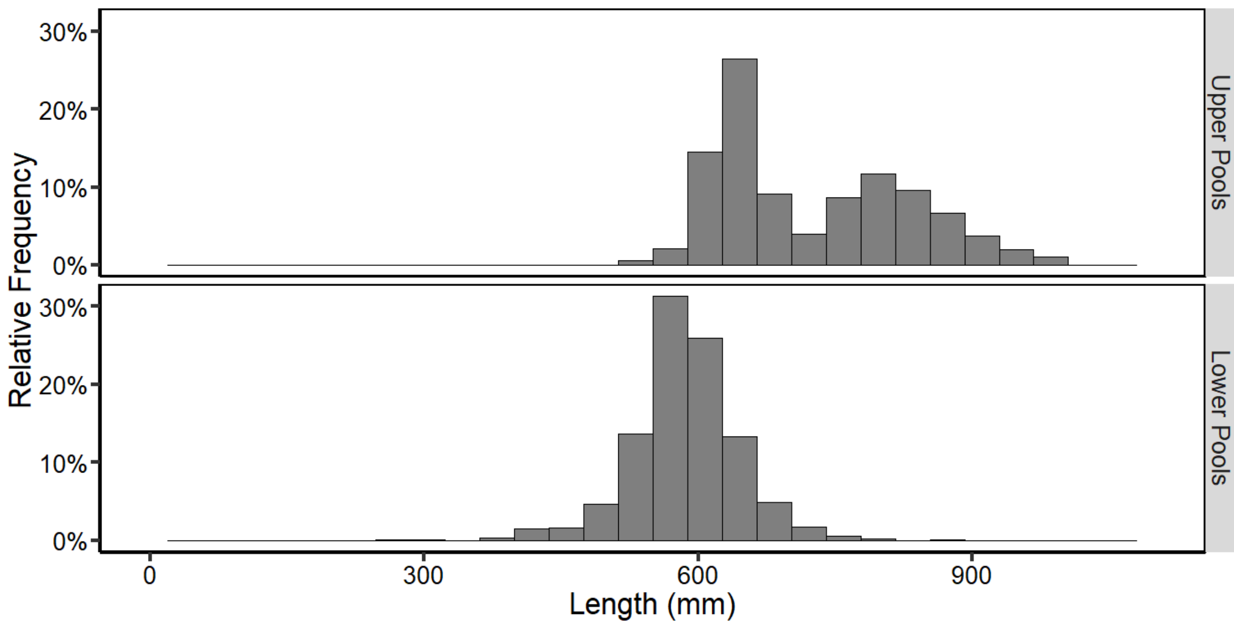

Figure 2. *Relative length-frequency histograms and total catch (N) of Silver Carp sampled using electrified dozer trawl during fall 2022, except for additional (N = 278) samples in the upper pools, which were collected using commercial gill nets.*

Condition: We examined variation in fish condition (i.e., relative weight) 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.

Due to density-dependent effects on resource availability, we expected fish from pools that receive high commercial fishing pressure (i.e., upper pools) would be in greater condition than fish from pools that receive relatively low commercial fishing pressure. Furthermore, we expected fish from pools with low relative abundance would be in greater condition than fish from pools with a higher relative abundance. Patterns in relative weight were consistent with expectations. The upper pools displayed slightly above average condition, while lower pools displayed slightly below average condition (Figure 3). Additional annual pool-specific relative weight information can be found in the appendix (Figure A.3).

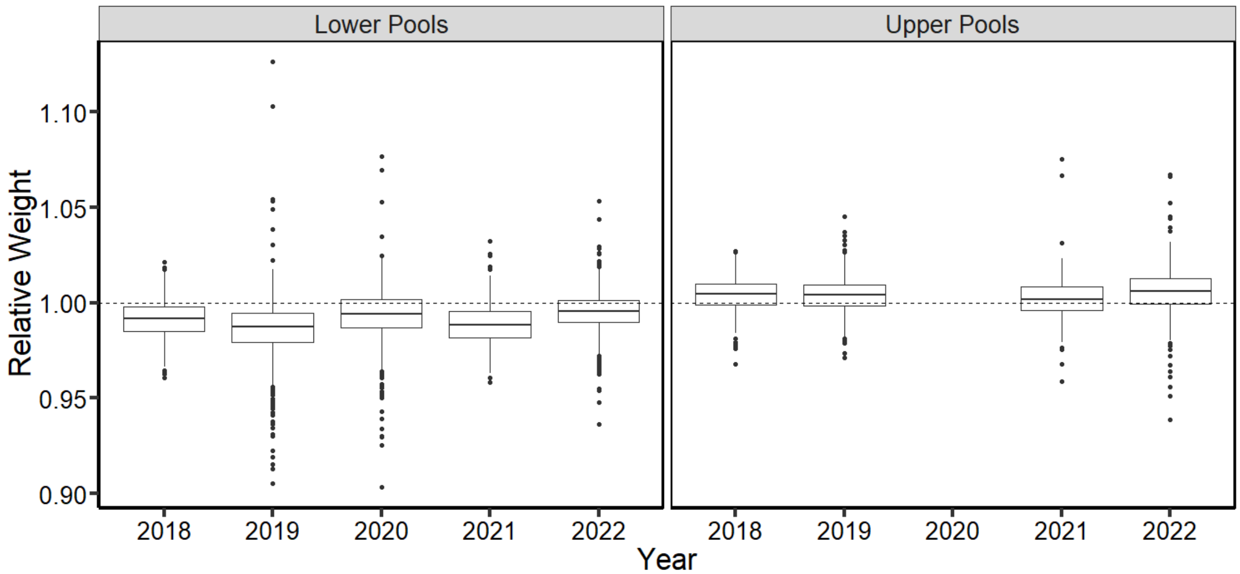

Figure 3. *Boxplots of individual Silver Carp relative weight data by sampling year. All fish were sampled using electrified dozer trawl from fall 2018 to 2022, except for additional 2019 (N = 19), 2021 (N = 235), and 2022 (N = 278) samples in the upper pools, which were collected using commercial gill nets.*

Sex Ratios: Sex of individual fish was determined during spring and fall sampling efforts. The goal of these data collections was 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 (Fenberg and Roy 2008).

In past reports, we observed increased proportions of males in upper pools with high commercial harvest rates. We hypothesized that disproportionately high catches of larger females were likely the cause of these increased male proportions in the upper pools. Analysis of 2018 to 2022 age data revealed subtle differences between male and female growth patterns. Specifically, males and females shared a common theoretical maximum length (785 millimeters) but slightly different t_0 (male: -1.78; female: -2.47) and K (male: 0.187; female: 0.173) von Bertalanffy growth parameter estimates. Patterns in our data still depict higher proportions of males in upper pools, and due to no evidence for sexually dimorphic growth differences, it is unlikely that females are being harvested at a higher rate. Therefore, other hypotheses for higher male sex ratios in the pools above Starved Rock Lock and Dam could be that males are migrating upstream at a higher rate than females, though evidence for sex-specific movement patterns (Pretchel et al. 2018) was beyond the scope of this project.

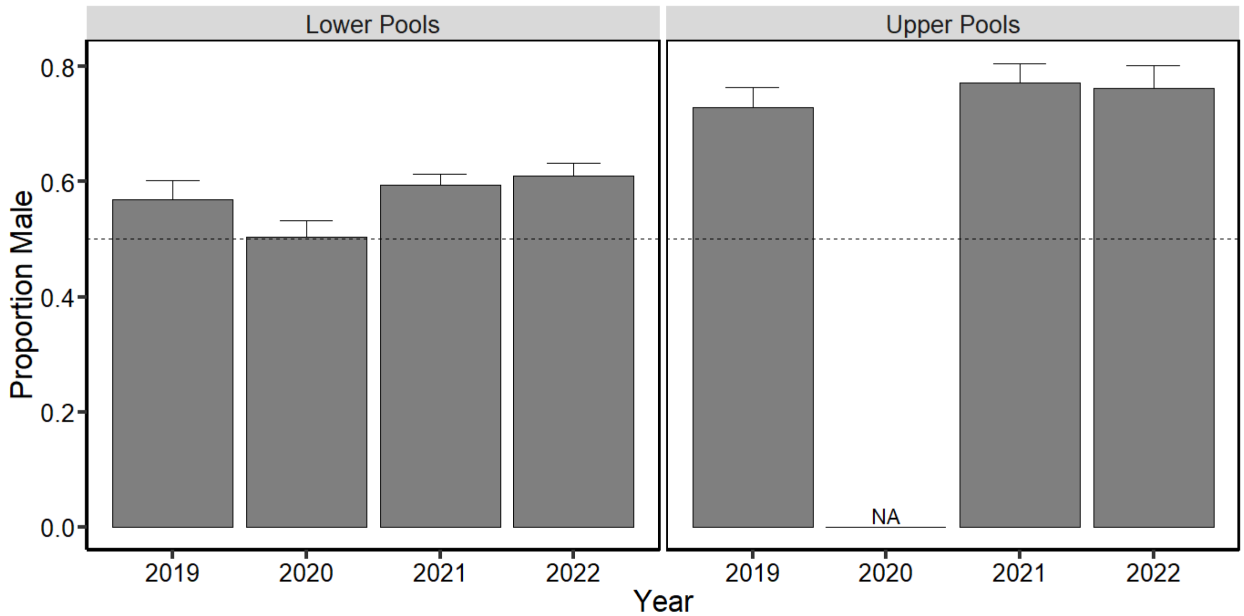

Figure 4. *Pool-specific means and standard errors describing the proportion of Silver Carp males in the total catch. All fish were sampled using electrified dozer trawl in fall 2019 to 2022, except for additional 2019 (N = 19), 2021 (N = 235), and 2022 (N = 278) samples in the upper pools, which were 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 to 2020 due to low numbers of immature Silver Carp captured in spring sampling and very few nearing maturity. However, spring 2021 to 2022 provided numerous immature Silver Carp (N = 890) in the lower four pools of the Illinois River (Alton, LaGrange, Peoria, and Starved Rock pools). Many of these individuals were nearing maturation, allowing a determination of maturity status by the internal examination of the gonads. These samples were only conducted in the four pools because of the dearth of small Silver Carp captured in the upper pools from previous sampling events (see length structure, Figure 2) and the low probability that immature Silver Carp could be captured.

Using logistic regression, we determined length at maturation for female Silver Carp (50 percent maturity reached at 501 millimeters total length; Figure 5) and for male Silver Carp (50 percent maturity reached at 452 millimeters total length; Figure 6). This data helps provide an accurate size at maturity estimate to the modeling working group for invasive carp population models.

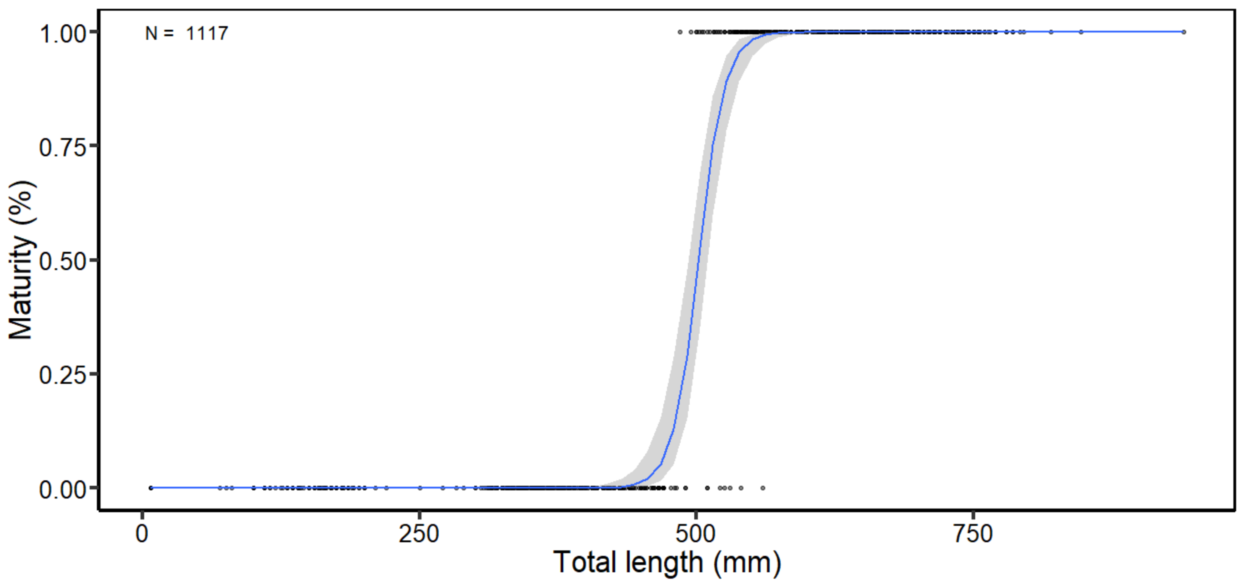

Figure 5. *Estimate of female maturity for Silver Carp captured in spring of 2019 to 2022 in the Alton, LaGrange, Peoria, and Starved Rock pools. The blue line represents percent of females mature at a given length, and grey represents standard error around the estimate.*

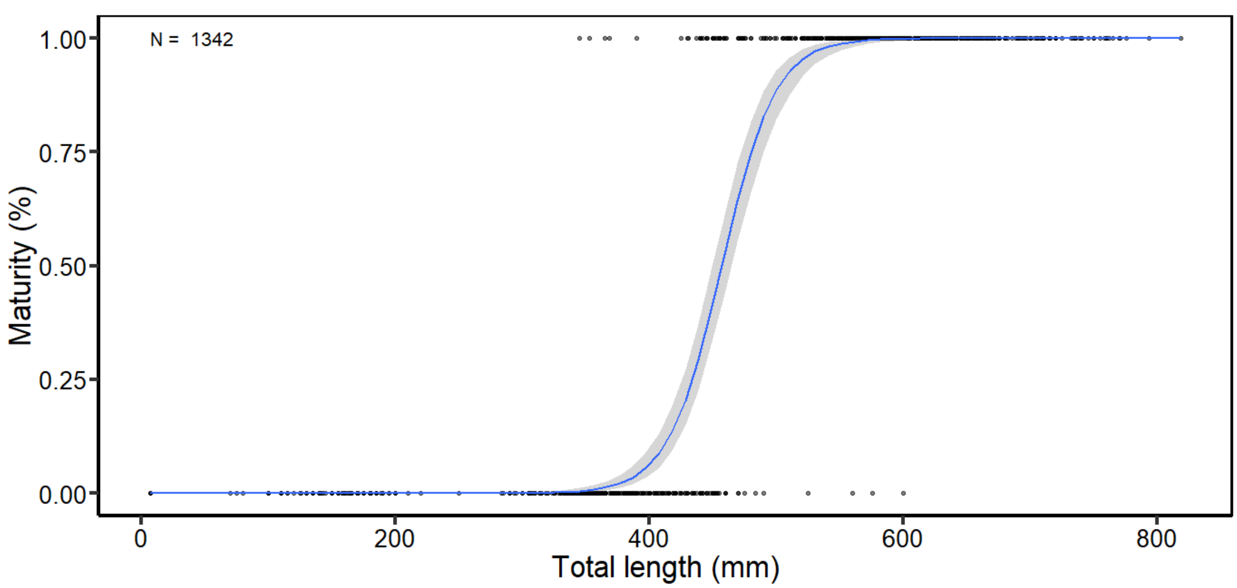

Figure 6. *Estimate of male maturity for Silver Carp captured in spring of 2019to 2022 in the Alton, LaGrange, Peoria, and Starved Rock pools. The blue line represents percent of males mature at a given length, and grey represents standard error around the estimate.*

Age and Growth: Objective two of our project included working with the MAM of the Illinois River for Decision Making 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 parameterizing stock assessment models, such as catch-at-age models. Due to highly variable ages within a length interval and small sample sizes in certain length intervals, applying age-length keys to derive population age structure was problematic. Consequently, we shifted 2021 age structure collections from a systematic collection (i.e., 10 age estimates per 50 millimeter-length bin) to a completely randomized collection to better represent the population age structure. This optimized approach precluded the need to fit an age-length key to unaged fish. For our randomized collection, we removed otoliths from the first 200 Silver Carp per pool (collected in a stratified random sampling design) and then filled any unfilled length bins (10/50 millimeter total length) following the first 200 collected. Age structure collections in 2022 were the same as in 2021, resulting in 1,149 Silver Carp aged in the Illinois River. Most age structures were collected via the electrified dozer trawl in Alton, LaGrange, Peoria, and Starved Rock pools. However, age structures from the Marseilles and Dresden Island pools are primarily collected by commercial gill net catches that were provided through collaboration with IL DNR, INHS, and the USFWS-Wilmington substation.

Age-frequency histograms provided insights into recruitment patterns and the relationship between age and upstream movement. Although young fish (less than age-5) were common in the lower three pools, these age classes were largely unrepresented in the upper pools, except for 13 age-0 fish captured in Starved Rock Pool. The age structure of older fish (over age-5) was similar between lower and upper pools (Figure 7). In addition, we detected strong year classes in the lower pools, including the strong 2018 cohort, which was age four in 2022 (Figure 7). Furthermore, we detected a large 2019 cohort, which was age three in 2022 (Figure 7). This large 2019 cohort was less noticeable in 2021. However, other studies have documented a large 2019 cohort in the Mississippi and Missouri river basins, which could be the source of this large 2019 cohort (Sterling et al. 2021; Mississippi Interstate Cooperative Resource Association [MICRA] 2021). These two cohorts were detected in the lower pools, with nearly all individuals captured in Alton and LaGrange and very few in Peoria. These young fish have yet to disperse upstream as of age-4 but are entering maturity, which may affect their upstream dispersal rates. These findings suggest Silver Carp move upstream in proportion to year-class strength and further the likelihood that upstream movement may increase dramatically after maturity. Additional annual pool-specific age-frequency histograms can be found in the appendix (Figure

A.4).

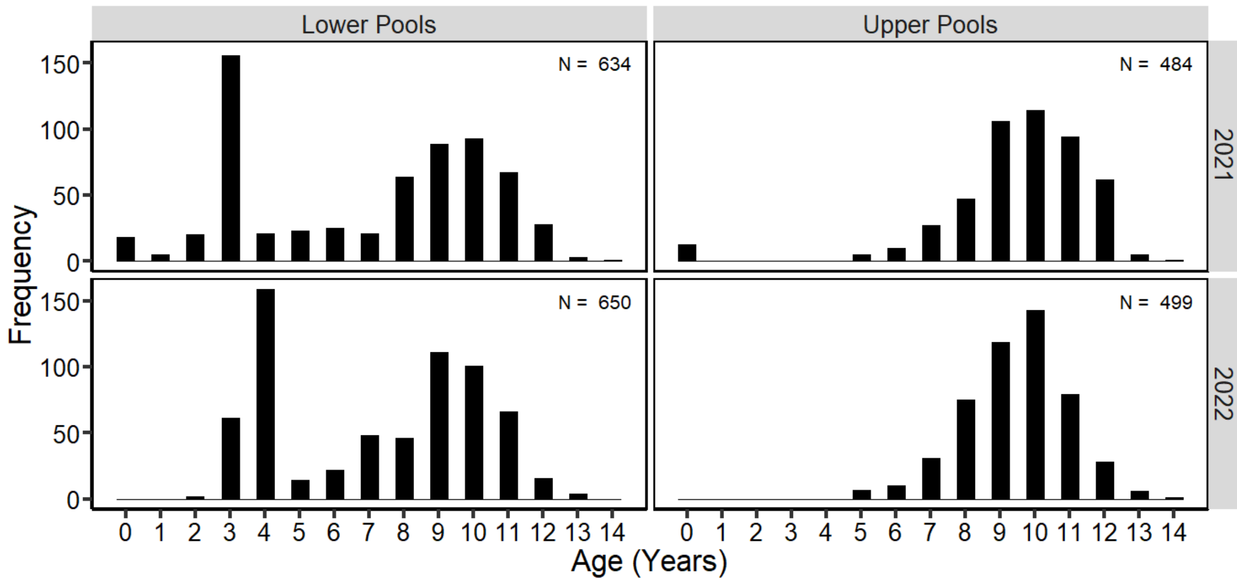

Figure 7. *Pool-specific age frequency data in the lower six pools of the Illinois River. Fish were collected during fall 2021 and 2022 using the electrified dozer trawl and commercial gill nets in the upper pools in 2021 (N = 235) and 2022 (N = 278).*

Von Bertalanffy growth models (von Bertalanffy 1938) depict the mean length at age of Silver Carp between lower and upper pools (Figure 8). Theoretical maximum lengths (L_∞) are consistently higher in the upper pools (i.e., Starved Rock, Marseilles, and Dresden Island pools) relative to the lower pools (i.e., Alton, LaGrange, and Peoria pools) (Figure 8), depicting the likelihood of increased growth potential in the upper three pools. Growth between pools could be affected by density. Based on relative abundance metrics (Figure 1), densities of Silver Carp appear to be higher in the lower pools than 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; Coulter et al. 2018). 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 (Figure 3). Monitoring growth rates could provide insight into density-dependent growth responses to harvest and removal efforts in the future. Additional annual pool-specific growth information can be found in the appendix (Figure A.5).

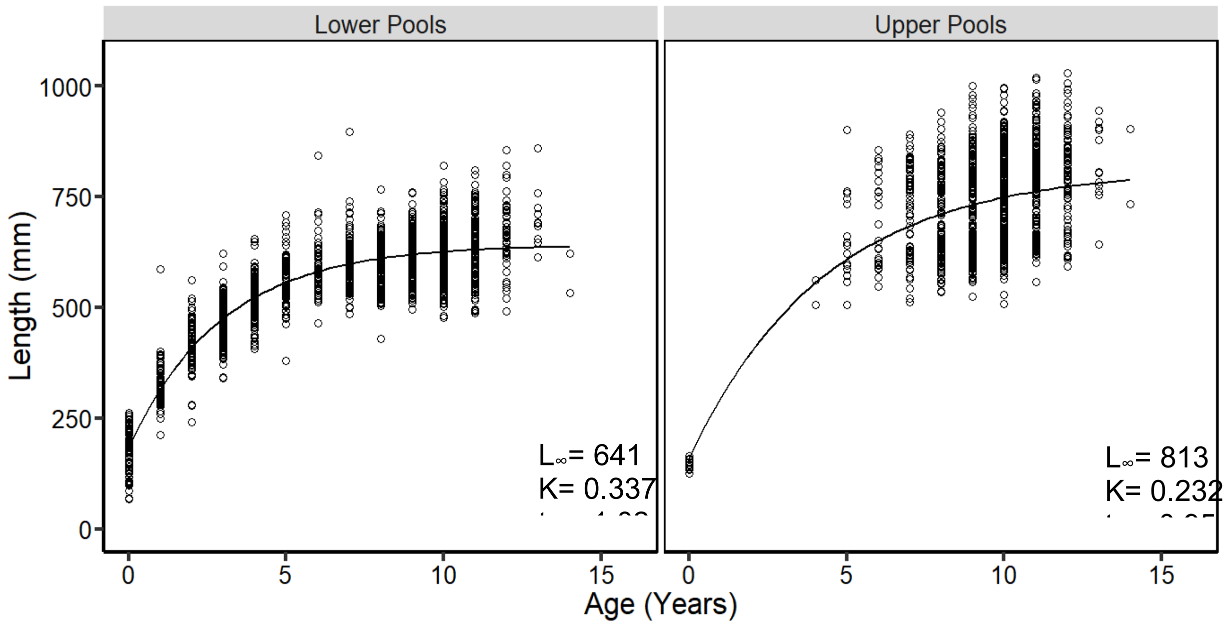

Figure 8. *Von Bertalanffy growth models, fit using mean length at age for combined 2018 to 2022 data. Fish were collected using a combination of electrified dozer trawl and commercial gill nets. L_∞ is the theoretical maximum length, K is the Brody growth coefficient, and t_0 is the theoretical time at length 0.*

Collaboration with MRWG: Objective three of this project included collaboration with the monitoring working group of the MRWG, specifically the MAM Program. 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 with other monitoring and detection efforts under the monitoring working group to help inform the management and control of invasive carp. The Invasive Carp Demographics project provides metrics, such as pool-specific relative abundance and size distribution, that overlap with monitoring projects, such as the MAM Program, and aids detection projects by providing more samples for early detection of small fish. Overlap and additions to other monitoring efforts 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 working group's SCAA models depend on. In 2022, 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 reported in this document (Figures 7 and 8). All project data has been shared with USGS to be incorporated into the MRWG data repository for use in analyses by MRWG working groups. Continued collaboration in 2023 will include the

Invasive Carp Demographics project integrating into the MAM project by utilizing a new standardized gear type (i.e., electrified dozer trawl) alongside MAM gears to provide increased catch of Silver Carp and other pelagic fishes and increased confidence in metrics produced with the MAM project. Collaboration with other projects will help ensure the best information is being provided for invasive carp management, control, and decision-making.

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 five years of fisheries-independent biological collections and available fisheries-dependent collections. We recommend continued monitoring through fisheries-independent sampling to inform demographic information (i.e., length, weight, 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 are confident in size at maturity estimates and sex ratio estimates reported and recommend discontinuing efforts directed at informing these metrics. We recommend sex-specific investigations on upstream movement rates of Silver Carp to determine the cause for increased male proportions in the upper pools. We recommend continued coordination with MRWG working groups to address monitoring objectives, increase efficient demographic data collection, and provide high-quality data to support ICRCC and MRWG needs.

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APPENDIX: ADDITIONAL INFORMATION

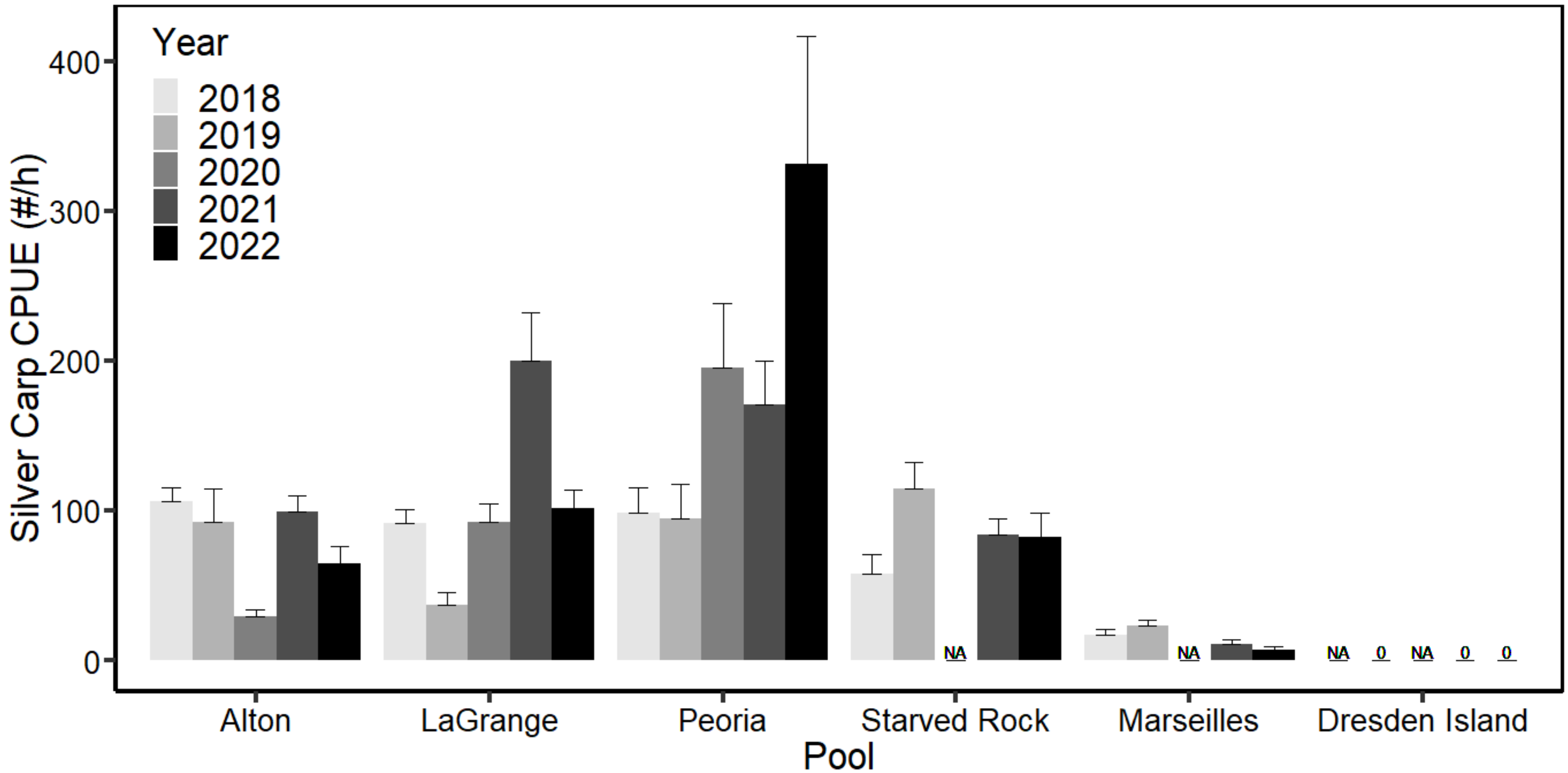

Figure A.1. *Pool-specific mean stock-size (greater than or equal to 250 millimeters) Silver Carp CPUE. All fish were sampled using the electrified dozer trawl during fall 2018 to 2022.*

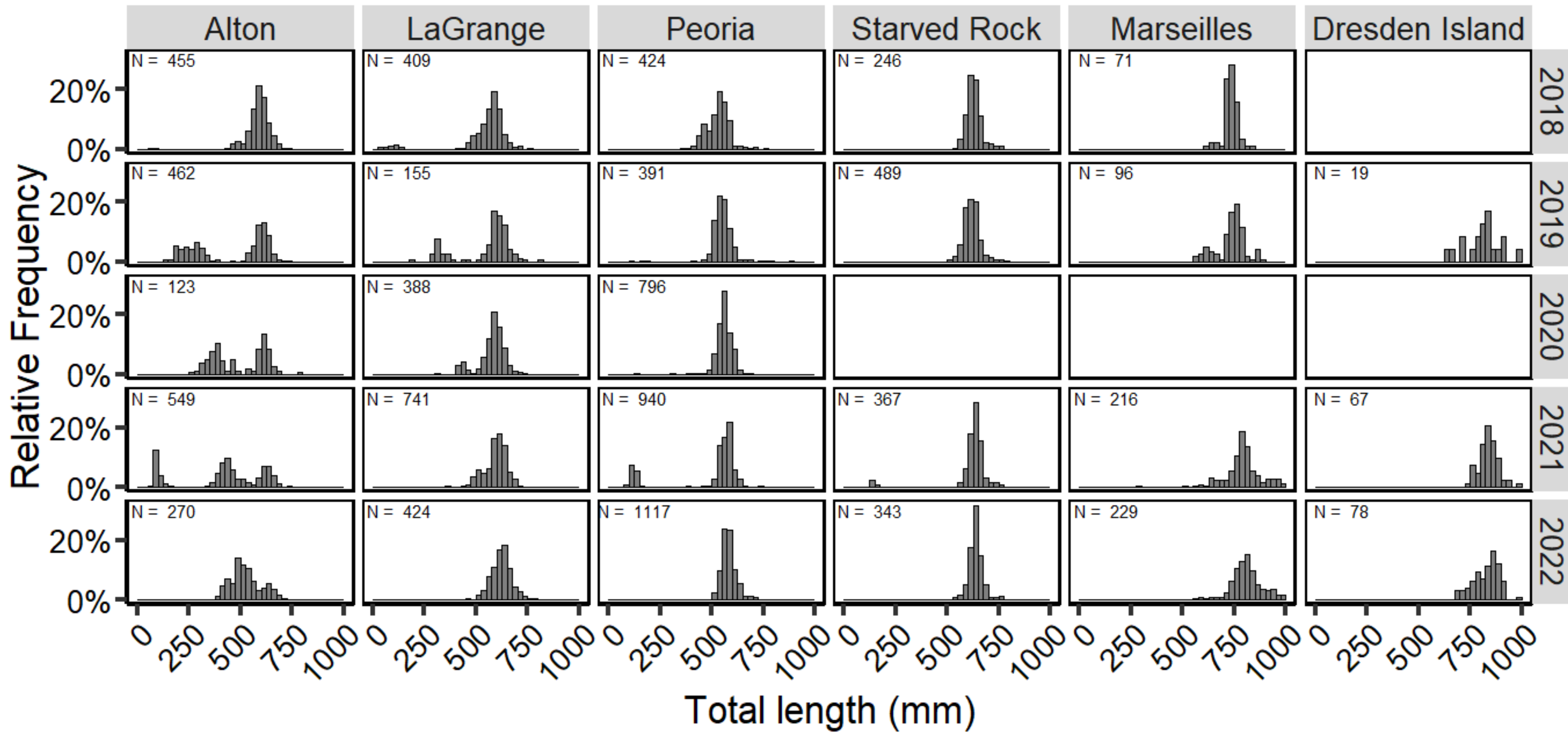

Figure A.2. *Pool-specific relative length-frequency histograms and total catch (N) of Silver Carp sampled from 2018 to 2021. All fish were sampled using electrified dozer trawl during fall 2018 to 2022, except for additional 2021 and 2022 samples in Marseilles (N = 168, N=200) and 2019 to 2022 samples in Dresden Island (N = 19 (2019), N = 67 (2021), N=78 (2022)), which were collected using commercial gill nets.*

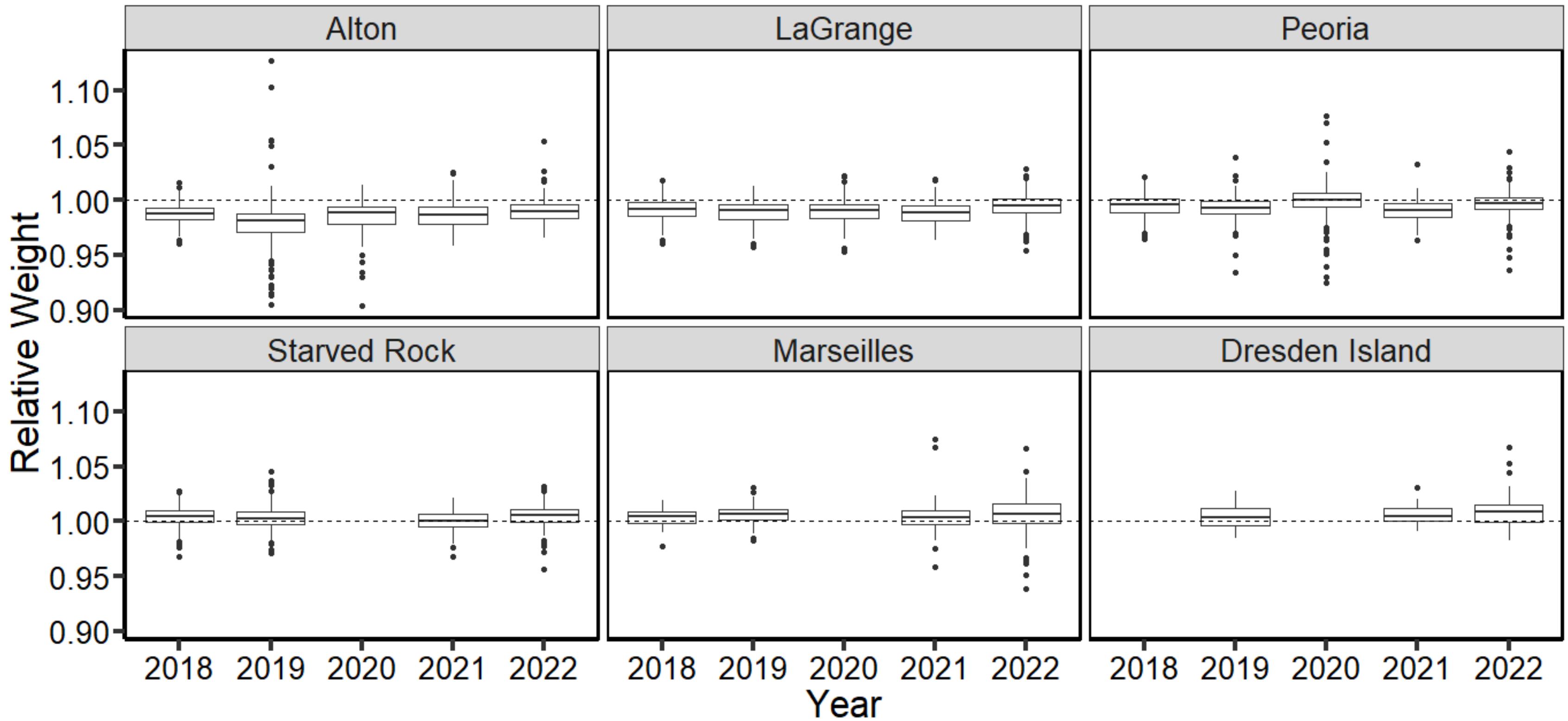

Figure A.3. *Boxplots of individual Silver Carp relative weight data by pool and sampling year. All fish were sampled using electrified dozer trawl during fall 2018 to 2022, except for additional 2021 and 2022 samples in Marseilles (N = 168, N=200) and 2019 to 2022 samples in Dresden Island (N = 19 (2019), N = 64 (2021), N=78 (2022)), which were collected using commercial gill nets.*

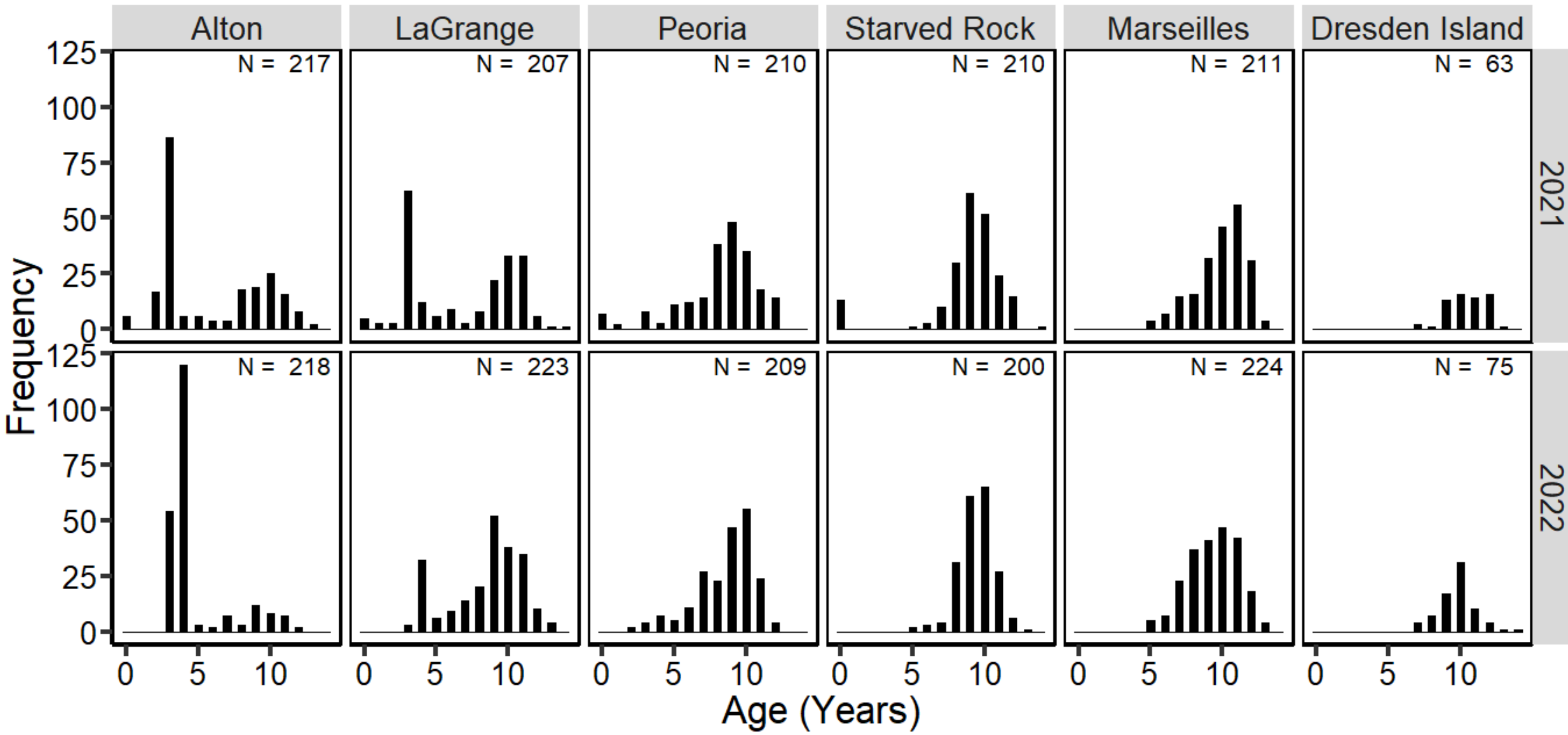

Figure A.4. *Pool-specific age frequency data in the lower six pools of the Illinois River. All fish were sampled using electrified dozer trawl during fall 2018 to 2022, except for additional 2021 and 2022 samples in Marseilles (N = 168, N=200) and Dresden Island (N = 64, N=78), which were collected using commercial gill nets.*

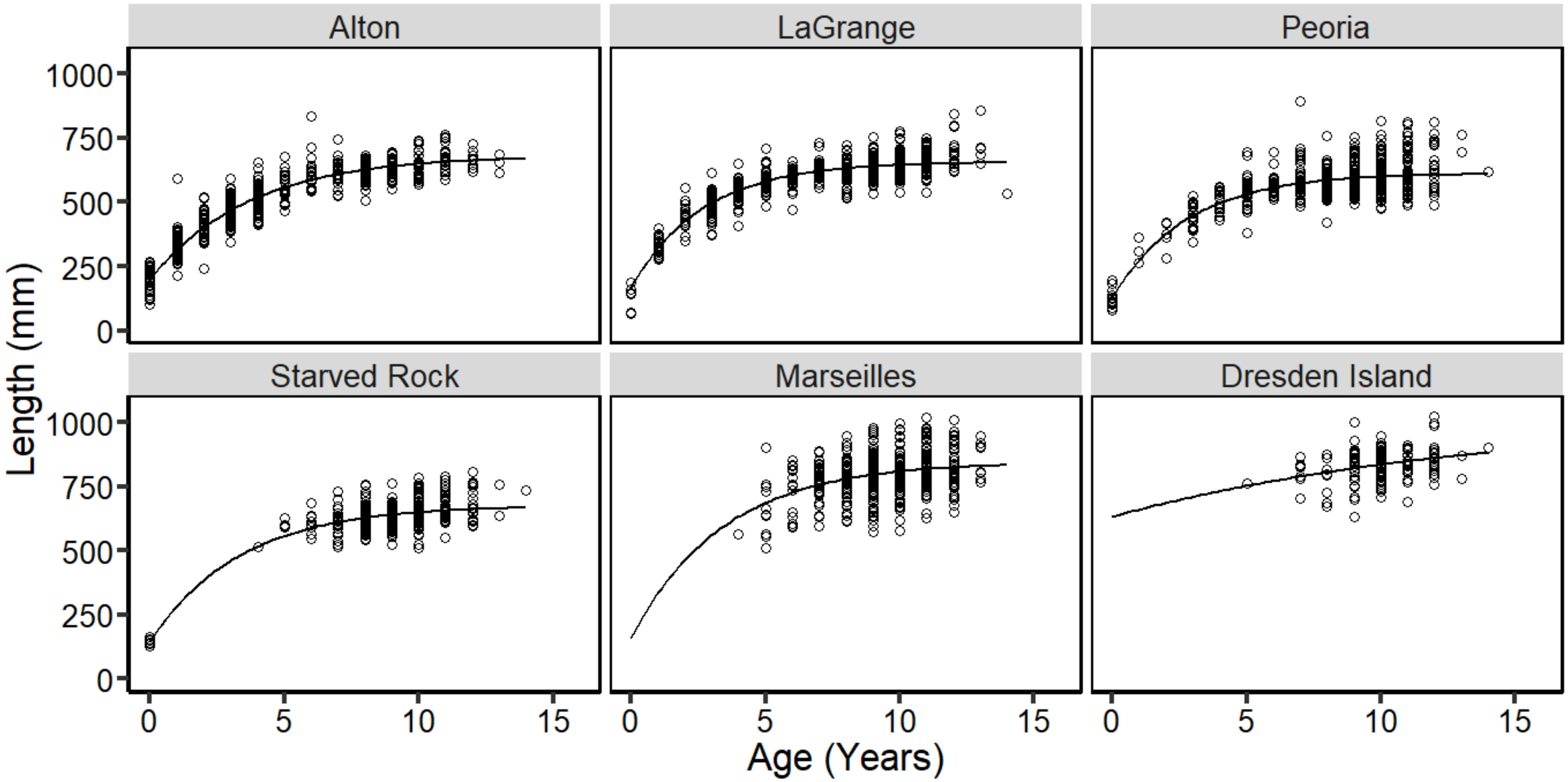

Figure A.5. *Von Bertalanffy growth models, fit using mean length at age for combined 2018 to 2022 data. Fish were collected using a combination of electrified dozer trawl and commercial gill nets. Not all model fits should be interpreted due to skewed data or small sample size.*

EXPERIMENTAL FIELD TESTING OF LONGITUDINAL BUBBLER ARRAYS FOR BARGE ENTRAINMENT MITIGATION

Participating Agencies: USFWS Carterville FWCO (lead); USACE Rock Island District and ERDC and USGS UMESC (field support); Charles A. Wainright and Michael A. Glubzinski (USFWS Carterville FWCO)

Pools Involved: Peoria

INTRODUCTION AND NEED

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

From 2020 to 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 neutrally 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 neutrally buoyant objects (a proxy for 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 percent effectiveness at flushing particles from the rake-to-box junction. However, it was unknown how these scaled laboratory trial results would translate to a full-scale system in a large river with full-sized barges and live fish.

In 2022, USFWS, USACE, and USGS carried out a full-scale study to test the efficacy of the longitudinal bubbler array (ABC Deterrent) in mitigating the retainment and transport of small fish by commercial barge tows in the field. Results from this study will be used to inform the design of the ABC Deterrent at Brandon Road Lock and Dam and potentially other locations in the IWW.

PROJECT HIGHLIGHTS

In 2022, the USFWS, along with partners from USACE and USGS, completed full-scale experimental testing of the ABC Deterrent at Peoria Lock and Dam. The goal of the study was to determine whether small fish would be effectively displaced from the barge junction gap by this deterrent, thereby reducing the potential unintentional upstream transport of small invasive carp. Results of this treatment (deterrent on) vs. control (deterrent off) experiment revealed a highly significant ($p << 0.01$) negative effect of treatment on the recapture rate of small fish planted in the barge junction gap, suggesting the deterrent was effective at displacing the small fish.

METHODS

This study occurred from September 1 to September 20, 2022, at Peoria Lock and Dam in Creve Coeur, Illinois.

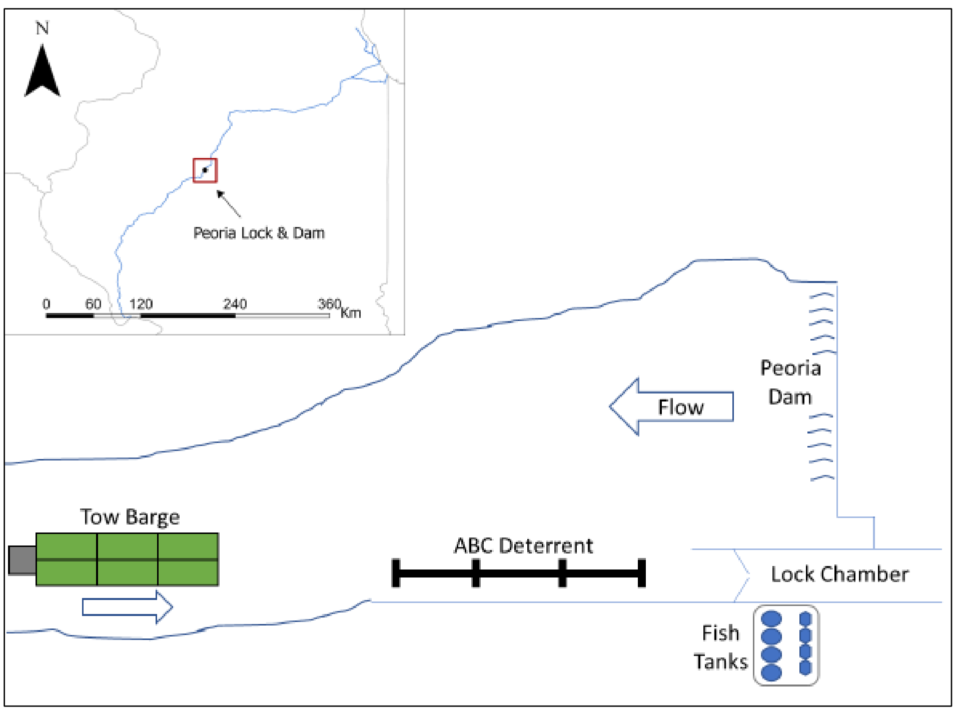

Figure 1. *Location of study site and aerial depiction of project design at Peoria Lock and Dam in Creve Coeur, Illinois.*

All ABC Deterrent trials ('trials' or 'runs') consisted of six barges lashed together in a three-long by two-wide configuration. Barges were pushed upstream into the downstream Peoria Lock approach by a tow boat. Each barge had a rake-end and a box-end, and barges were arranged with the rake-ends faced upstream. Barges were ballasted to draft approximately 8 feet. The junction gap of the two barges nearest the tow boat was selected as the location for fish trials to be conducted and was separated from the middle two barges by approximately 15-foot steel spacers (Figure 2). To provide anecdotal information on the fish presence and distribution in the junction gap, an ARIS 3000 Explorer multibeam sonar was mounted to the outside spacer and deployed approximately 1.5 meters below the water surface, facing into the junction gap.

Figure 2. *A photo of a 15-foot welded steel spacer designed to separate the rear-most and middle barges and allow for gear deployment in the junction gap. An ARIS 3000 Explorer multibeam sonar is also shown mounted to the spacer.*

Although the study was intended to be conducted with live invasive carp captured in Peoria, LaGrange, and Alton pools, low water levels in the lower Illinois River throughout 2022 prevented a successful spawn of invasive carp, and none were captured. Therefore, small golden shiners (mean total length = 57 millimeters, range = 41 to 76 millimeters) were selected as a surrogate species due to their similar body morphology (i.e., deep-bodied, laterally compressed) to small invasive carp, their use in previous barge studies (Davis et al. 2016), and their ability to be readily available from commercial fish farms (Anderson Farms, Lonoke, Arkansas). Hatchery-reared golden shiners were held in aerated flow-through round tanks until they were used in study trials. For each trial, 550 fish were enumerated, and a 10-percent subsample of 55 fish was weighed and measured to total length to ensure that, accounting for potential mortalities, at least 500 fish would be used for each trial, a number comparable to the previous batch sizes for barge entrainment study trials (Davis et al. 2016). Trial fish were batch-marked for visual identification while afield using one of three colors (orange, red, or purple) of non-toxic, water-soluble immersion powder dye (Rit ProLine powder dye). Immersion dyes quickly and temporarily change the external color of batches of fish with minimal handling and allow fish to be visually identified to batch (Bradford et al. 2016). Fish were marked by immersing them in aerated water with dissolved marking powder (190 grams powder to 225 liters water) for 45 to 60 minutes, then allowing the fish to rest in aerated water for approximately 15 minutes. Marked fish were planted directly into the barge rake-to-box junction gap 100 meters before the barge reached the ABC Deterrent.

An odd number of marking colors (three: red, orange, purple) were rotated through while alternating between an even number of treatment levels (two: control, treatment). This odd-against-even design ensured treatment levels were evenly spaced among mark colors, thereby minimizing any potential effect of mark color and/or treatment level on fish recaptures. The immersion marking process used in this study reliably marked fish for about one hour, ensuring each batch of fish would lose its mark before the color was re-used in another trial.

Marking tank water temperature (°C), specific conductivity (microsiemens/centimeter), and dissolved oxygen (micrograms/liter) were recorded before, during, and after marking for each trial using a YSI ProSolo (YSI Inc., Yellow Springs, Ohio, USA) water quality meter.

Fish were recaptured with a custom rectangular 5.6-meter-wide by 3.3-meter-long multi-mesh net that consisted of a 70-millimeter stretch mesh support backing faced with 12-millimeter stretch mesh (Figure 3). The net was supported with a rigid top and bottom pole, which held the net open while it was deployed and retrieved with lines (Figure 4). Captured golden shiners were measured (total length), and their external color (orange, red, purple, no color) was recorded. All other fish captured were identified to species.

Figure 3. *A photo of the custom net used to recapture any fish retained in the barge junction gap after passing over the ABC Deterrent during both control (ABC off) and treatment (ABC on) trials.*

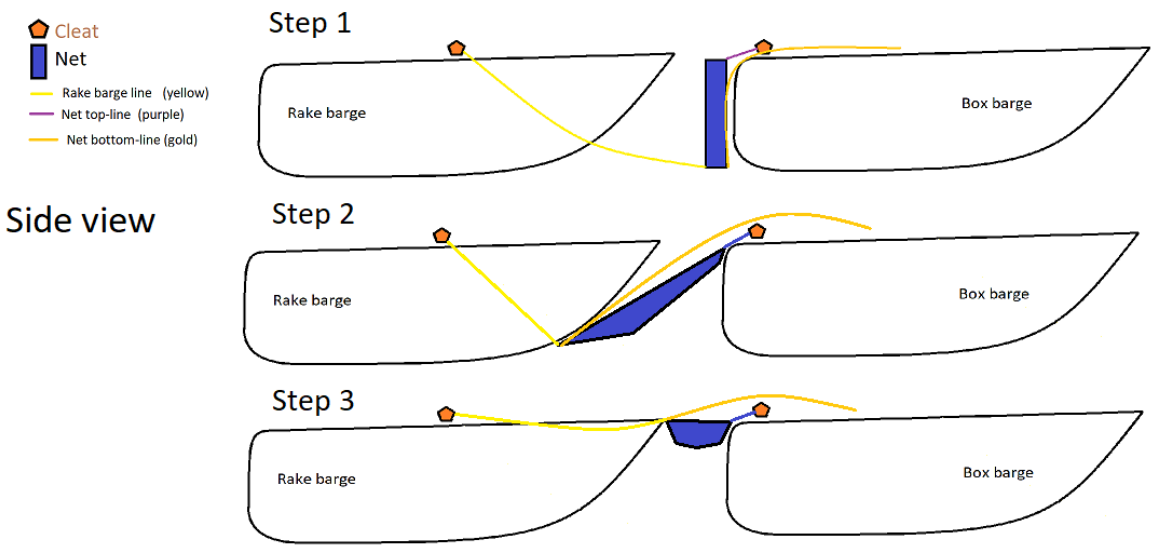

Figure 4. *Side-view diagram depicting how the net was deployed and retrieved in the box-to-rake junction gap to recapture any retained fish. For each deployment, the net top-line and bottom-line were first rapidly lowered to the water's surface adjacent to the box barge, then the rake barge line was pulled until the bottom-line pole was tight to the rake barge, and finally, the bottom lines were pulled up the rake until reaching the water's surface, at which point both top and bottom lines were lifted and the net was pulled onto the deck of the barge.*

The recapture rate (percent, number of recaptures/number of plants) was selected as the response variable to compare control and treatment runs instead of the total number of recaptures to account for variable numbers of planted fish across sample runs (due to mortality). Data distributions for recapture rates for both control and treatment data were heavily skewed and zero-inflated; thus, a nonparametric Mann-Whitney U test was used to test for significant differences between the recapture rate of control and treatment runs. Additionally, a complimentary Cliff's Delta nonparametric effect size metric was calculated to evaluate the strength of the effect size of treatment on the recapture rate ($\delta < 0.15$, negligible; $0.15 \leq \delta < 0.33$, small; $0.33 \leq \delta < 0.47$, medium; $\delta \geq 0.47$ large).

RESULTS AND DISCUSSION

In total, 124 sample runs were completed, and of those, 100 sample runs were analyzed (Table 1). Twenty-four sample runs were removed from analysis due to irregularities, making them incomparable to the rest of the data (e.g., 13 runs were completed before additional 12-millimeter mesh sections were added to the net to reduce fish loss through portions of wider mesh). Across the 100 analyzed runs, 52,013 marked fish were planted into the barge junction gap, and 503 marked fish were recaptured. On average, after mortalities, 523 and 518 marked fish were planted each control and treatment run, respectively, and of those, 1.9 percent and 0.02 percent (or approximately 10 and 0) marked fish were recaptured.

Table 1. Summary data for sample runs used in a comparison analysis to test for differences between control (ABC off) and treatment (ABC on) trials.

		Overall				Per-run							
	Treatment level	Runs (n)	Plants (n)	Total recaptures (n)	Mean recapture rate (%)	Mean plants (n)	Median plants (n)	Min recaptures (n)	Mean recaptures (n)	Median recaptures (n)	Max recaptures (n)	Mean recapture rate (%)	Median recapture rate (%)
	control	50	26,130	499	1.910%	523	530	0	10	6	48	1.916%	1.115%
	treatment	50	25,883	4	0.015%	518	526	0	0	0	2	0.016%	0.000%
Column totals	—	100	52,013	503	—	—	—	—	—	—	—	—	—

Results of Mann-Whitney U-test (Figure 5) revealed a highly significant lower recapture rate for treatment runs (ABC on) than control runs (ABC off; $Z = 8.6819$, $p << 0.01$). Cliff's Delta effect size estimate was large ($\delta = 0.95$, 95 percent confidence interval 0.84 to 0.98), suggesting that treatment type had a large effect on recapture rate.

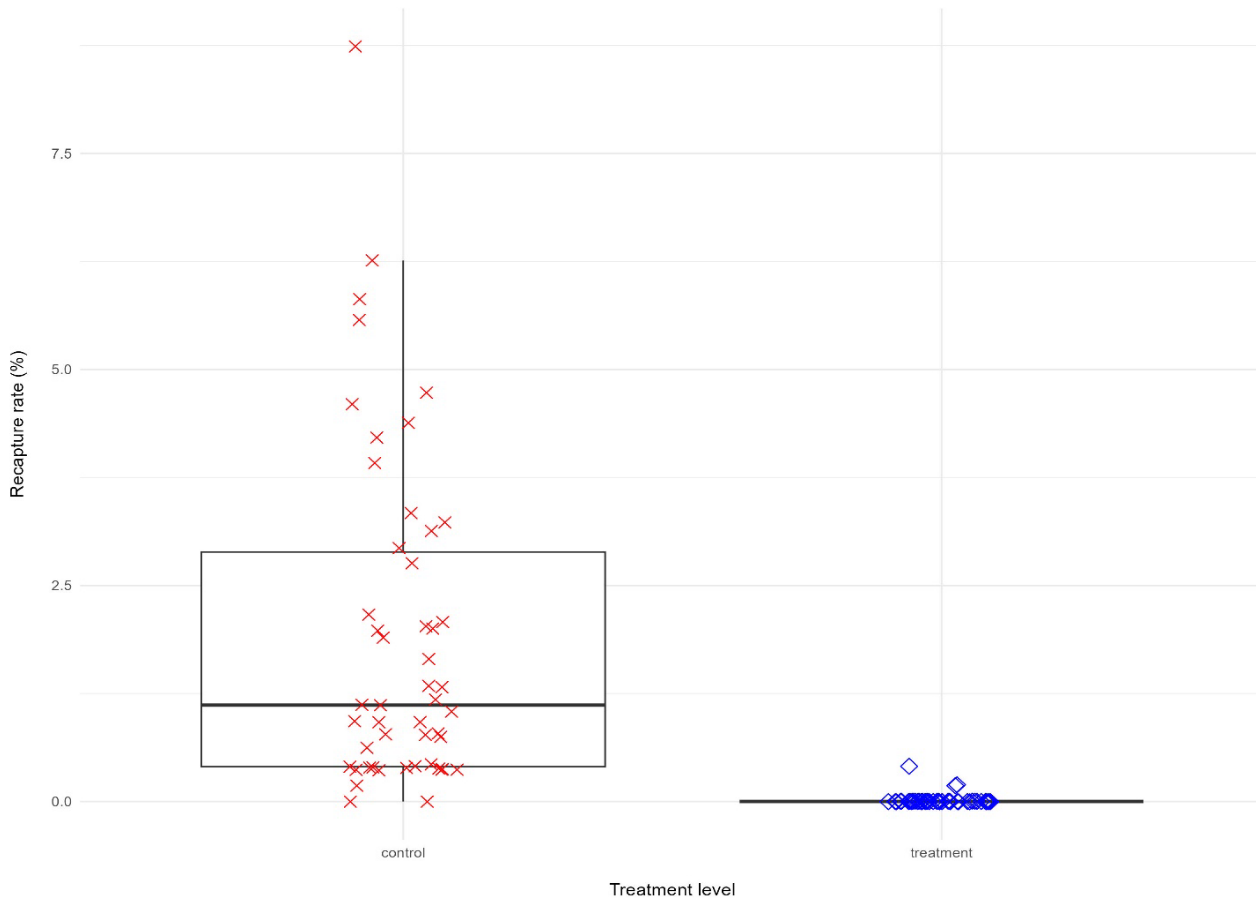

Figure 5. *Comparison of recapture rates between treatment (ABC on) and control (ABC off) field trials conducted in September 2022 at Peoria Lock and Dam in Creve Coeur, Illinois. The central line represents the median recapture rate of each treatment level, and lower and upper extents of a box represent first and third quantiles, respectively.*

Results from this full-scale experimental testing revealed a significantly lower number of golden shiners recaptured from the barge junction gap on trials when the ABC Deterrent was on, suggesting the deterrent was effective at removing entrained or retained small fish from the barge box-to-rake junction gap. The collected data used in this analysis occurred across 8 days, with most samples taken under clear or partly cloudy skies and low flow and river gauge height. It is, therefore, unknown if entrainment/retainment of small fish, or deterrent efficacy, could be influenced by environmental conditions. Specifically, flow velocity could potentially impact the current velocities experienced by fish in the junction gap, altering behavior, and could potentially modify the shape of the bubbler array at high velocities and river stages. Higher river stages would also increase the distance between the deterrent mechanism located on the river bottom and the barge.

While the goal was to conduct this study with wild YOY invasive carp, the lack of a large successful spawn in 2022 necessitated using golden shiners as a surrogate species. The use of a surrogate species could have influenced the results due to differences in behavior and swimming performance that can be present between species (Cano-Barbacil et al. 2020) or between hatchery-raised and wild fish (Salvanes and Braithwaite 2006). However, we feel the similarity in size and body shape between small golden shiners and YOY invasive carp helped offset potential differences, as fish body shape is known to affect swimming performance (Cano-Barbacil et al. 2020).

In general, recapture rates of fish were low for all sampling runs (mean for control trials = 1.9 percent, max = 8.7 percent). There are several possible explanations for this. One, overall retainment and entrainment of fish placed into the junction gap may have been low. In initial test runs, fish were inserted into the junction gap before the barge came up to speed and while it was still a few hundred meters from the ABC Deterrent; however, this methodology was adjusted for all analyzed trials to insert fish at a shorter standardized distance (100 meters) from the ABC Deterrent and when the barge had reached its standard speed to increase the potential that fish would still be in the junction gap while passing over the deterrent. These modifications allowed us to test the primary goal of this study (whether the ABC Deterrent successfully removed fish from the junction gap), since entrainment and retainment of small fish in these gaps are already known to be possible (Davis et al. 2016).

There is also a high potential that some fish released were retained or entrained in the junction gap of the adjacent barges. The barge configuration for this study was three-long by two-wide; therefore, there were adjacent junction gaps between the box and rake of adjacent barges. However, due to the inability to operate a net large enough to sample the junction gaps of both adjacent barges simultaneously (and the inability of the crew to operate two nets simultaneously), fish were released into only one of the adjacent junction gaps, and the net was deployed only in that junction gap. Observational evidence from multibeam sonar data collected with an ARIS Explorer 3000 during the study suggested the routine occurrence of fish moving or being pushed toward the adjacent junction gap, and anecdotal observations of fish swimming near the surface in that junction gap were recorded (USFWS and USACE, unpublished data). Therefore, it is likely that the true retainment and entrainment of fish were higher than reported in our data.

Lastly, it is also possible that some fish that may have still been present in the junction after passing over the deterrent were not recaptured by the net. Although the net was designed to sample most of the water volume present in the junction gap (Figure 4), coverage was not 100 percent. Also, some fish may have escaped from the net during retrieval, pursing, and raising the net to the surface of the deck. Early testing of the net revealed that fish escapement may have been occurring through portions of wider mesh on the outer portions of the net; thus, modifications were made to the net by attaching available small-mesh seine netting before trials used for analysis began. However, although this improved the net, not all areas of the larger mesh were able to be covered, and some sections of the wider mesh remained along the edges and top of the net (Figure 3) that small fish could have escaped through during net retrieval. A net test trial run was conducted after net modifications were completed by releasing 100 marked golden shiners into the junction gap and immediately deploying the net after release. In this trial, 54 percent of the golden shiners were recaptured. We believe this highlights an imperfect recapture rate of the sampling gear but also the ability of the gear to capture fish that were present in the junction gap.

Ultimately, uncertainties associated with environmental conditions, use of a surrogate species, and low recapture rates do not overshadow the primary goal of this study, which was to test whether recapture rates of fish in the junction gap were significantly lower for trials where the ABC Deterrent was operating. Results revealed significantly lower recapture rates for trial runs using the ABC Deterrent; therefore, this study demonstrated the ability of a novel ABC Deterrent to remove small fish that may be present and unintentionally transported in the junction gap of large river barges. In the IWW, this has positive implications for the proposed plan to include the installation of this deterrent in modifications to Brandon Road Lock and Dam to reduce the potential for upstream transport of small invasive carp to uninvaded pools or past the EDBS.

RECOMMENDATIONS

Based on the results of this study, the USFWS recommends considering ABC Deterrents when evaluating and implementing novel techniques to reduce the unintentional transport of small fish potentially entrained in barge junction gaps.

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ALTERNATE PATHWAY SURVEILLANCE IN ILLINOIS – LAW ENFORCEMENT

Participating Agencies: IL DNR (lead); Brandon Fehrenbacher (IL DNR)

INTRODUCTION AND NEED

The IL DNR ISU is a specialized law enforcement component of the ICRCC. Illegal activities within 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 waters. ISU dedicates its time and resources to 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 units such as the ISU. 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 connect with invasive species law enforcement-related issues. Questions or complaints from the public requiring law enforcement assistance about 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 stakeholders.

OBJECTIVES

- Update the invasive species enforcement training curriculum and instruct the course to conservation police officers to maximize outcomes across a larger geographical area.
- Conduct a minimum of 10 inspections on industries linked to the invasive carp trade where the highest likelihood for regulatory violations has been identified.
- Organize and implement a minimum of five fish truck transportation inspection details to determine compliance and gather information on current market trends.
- Investigate all reported suspicious activities and complaints.
- Coordinate enforcement objectives developed by the Great Lakes Law Enforcement Committee to advance and remedy multi-jurisdictional invasive species issues.

PROJECT HIGHLIGHTS

- ISU arrested an individual offering to sell aquarium rocks and live zebra mussels for a $45 "rehoming fee" on Craigslist. An avid fisherman noticed the advertisement and reported it to a Tips hotline. The complaint was investigated by ISU, who arrested the seller during a covert buy operation and seized the products. The seller acquired the zebra mussels as aquatic hitchhikers when buying other aquatic species at an aquarium shop in Chicago, Illinois, in 2019. He was very knowledgeable about the zebra mussels and stated in his advertisement they were great for keeping aquarium water clear.
- A non-resident fish hauler who, for profit, illegally imported and stocked live channel catfish into Illinois on multiple occasions pled guilty in court to one count of importing live channel catfish into Illinois without an IL DNR permit. The catfish were raised at fish farms in Mississippi and Alabama and intended to be sold for food. The fish were not tested for viral hemorrhagic septicemia disease, and video evidence showed other species mixed in with the loads. The defendant received 24 months of court supervision and $227 in fines and court fees. He was ordered to perform 30 hours of community service and pay $10,500 in restitution to the IL DNR Conservation Police Operations Assistance Fund.

METHODS

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

RESULTS AND DISCUSSION

- An updated AIS training curriculum summarizing crayfish regulations and providing identification tools was provided to all Illinois conservation police officers. Previous AIS training resulted in a significant increase in the detection of bait fishing violations, which prompted officers to ask more questions and seek additional resources on the subject matter. Training remains a key component to increasing AIS enforcement capabilities.
- Inspections on industries linked to the invasive carp trade where the highest likelihood for regulatory violations has been identified did not detect any criminality specifically pertaining to invasive carp. Compliance has improved yearly with the increased inspections. It is important regulatory agencies hold industry stakeholders accountable

with the expectation of being checked. Additionally, the inspections produce valuable intelligence and communication opportunities.

- Fish truck inspection details did not detect any illegal shipments of invasive carp but strengthened relationships among people involved with the fish transportation industry. The inspections provided an opportunity for those legally operating to report suspicious activities.
- ISU investigations included: Enhanced Contract Fishing Program fraud, illegal importation of tilapia, unlawful sale and importation of live non-approved aquatic species (Red swamp crayfish), violations of the Illinois Exotic Weed Act, possession of live State-listed injurious species (Rusty crayfish), sale of live injurious species (Zebra mussels), unfounded invasive carp sightings on Lake Michigan, propagating live injurious species (Yellow flag iris), boat dealership selling boats with live injurious species attached (Zebra mussels), and the illegal sale of Crucian carp.
- ISU gave a presentation on the Memorandum of Understanding on Regional Cooperative Enforcement Operations to members of the LAW Committee. The purpose of the presentation was to increase participation and the use of the Memorandum of Understanding for Joint Forces Operations. ISU attended the Council of Lake Committees meeting in Romulus, Michigan, to increase communications between all Lake Committee members and the LAW Committee. ISU gave a presentation on the LAW Committee's priorities, including establishing or enhancing Organisms in Trade units in each member jurisdiction.

RECOMMENDATIONS

Encourage active steps to be taken to establish or expand permanent Organisms in Trade Law Enforcement Units in each member jurisdiction of the Great Lakes Basin.

INVASIVE CARP ENHANCED CONTRACT REMOVAL PROGRAM

Participating Agencies: IL DNR (lead); USEPA and GLFC (project support)

Pools Involved: Peoria, La Grange, and Alton pools

INTRODUCTION AND NEED

The ICRCC and 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 the protection of the Great Lakes by preventing fish population growth in upstream reaches.

OBJECTIVES

- 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.
- Remove 8 million pounds of invasive carp under the Enhanced Contract Fishing Program in 2022, while working toward removing 15 million pounds by 2023.
- 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.
- Leverage other programs, such as the Market Value Program, to continue building increased demand for harvested invasive carp.
- Leverage the new Copi brand launch toward increased removal.

PROJECT HIGHLIGHTS

- Removed more than 5.2 million pounds under this program from the Peoria, LaGrange, and Alton pools of the Illinois River in 2022.
- Removed nearly 12 million pounds under this program since its inception in 2019.
- Entered into 34 contracts with Illinois-licensed commercial fishers targeting the Peoria, LaGrange, and Alton pools.
- Processed nearly $525,000 in payments to fishermen.

- Launched the Copi brand successfully, garnering national and international media attention, with the development of new value-added products using the brand and increased sales volumes in the months following the event.

RESPONSE PROJECTS

UPPER ILLINOIS WATERWAY CONTINGENCY RESPONSE PLAN SILVER CARP

Participating Agencies: IL DNR (lead); USACE, USFWS, IN DNR

INTRODUCTION AND NEED

On July 30, 2022, a member of the public reported the sighting of an invasive carp in Lake Calumet. Based on the credibility of the report, IL DNR and USACE responded to the area with a reconnaissance team of electrofishing boats and contract fishers on August 3, 2022. On August 4, 2022, an adult Silver Carp was found and collected by gill netting and electrofishing crews from the IL DNR and the USACE (Photos 1, 2, 3, and 4). The capture triggered the ICRCC's CRP, which provides direction for coordinated on-the-water action in the event an invasive carp is discovered in unexpected locations, including in the CAWS.

The Silver Carp capture triggered two additional weeks of intense sampling in the area, as outlined in the ICRCC's 2022 CRP, beginning August 5, 2022, and ending August 19, 2022 (Figures 1 and 2). Crews from IL DNR, USACE, USFWS, IN DNR, and contracted commercial fishers conducted the response monitoring operation in Lake Calumet and adjacent waters within the CAWS (Table 1).

OBJECTIVES

- Remove invasive carp from the CAWS upstream of the Electric Dispersal Barrier, focusing on Lake Calumet and adjacent waters within the CAWS.
- Determine invasive carp population abundance through intense random and targeted sampling efforts at locations deemed likely to hold fish.

PROJECT HIGHLIGHTS

- Multiagency response (IL DNR, USACE, USFWS, IN DNR) utilized the ICS with guidelines set forth in the 2022 MRP Upper Illinois CRP.
- Monitoring crews were deployed daily, beginning in Lake Calumet and then transitioning to a broader area spanning Calumet Harbor to T.J. O'Brien Lock and Dam. The field portion of the operation exceeded 1,500 person-hours.
- Crews from IL DNR, USACE, and USFWS conducted over 57 hours of electrofishing runs.
- Contracted commercial fishers, along with assisting IL DNR biologists, set more than 43 miles of gill net.
- **No Bighead Carp, Black Carp, or Silver Carp were observed or collected during the removal response.**
- Four Grass Carp were collected and removed.
- The response effort produced approximately 550 Smallmouth Buffalo, 137 Flathead Catfish, 125 Common Carp, 66 Freshwater Drum, and an assortment of other native species that were captured and released.

RESULTS

The rapid response action took place during the weeks of August 5 and August 19, 2022, upstream of the Electric Dispersal Barrier. **No Bighead Carp, Black Carp, or Silver Carp were captured or observed during the response**. Efforts for this response consisted of an estimated 1,500 person-hours, including 57 hours of electrofishing runs and 43 miles of gill netting (Table 2).

Across all locations and gears, 858 fish representing nine species were captured and released. Four Grass Carp were captured.

With the conclusion of the rapid response efforts on August 19, 2022, interagency invasive carp monitoring and removal actions in the Upper IWW and the CAWS continued to be guided by the 2022 MRP. The plan included two consecutive weeks of intensive invasive carp monitoring upstream of the electric dispersal barriers in October, including in Lake Calumet. Additional effort was focused in this area based on the August carp finding. No additional invasive carp were collected or observed.

The Silver Carp captured on August 4, 2022, was sent to SIU for analysis to determine the fish's age and origin. The summary of that analysis is provided in Appendix A. The live Silver Carp captured on August 4, 2022, had otolith chemistry consistent with a fish from the Illinois River watershed. It had not been in the CAWS long enough to develop a signature for that area.

An analysis of a dead Silver Carp found in the Calumet River during spring SIM in May is included in Appendix B. This fish also had otolith chemistry consistent with a fish from the Illinois River watershed. It had not been in the CAWS long enough to develop a signature for that area.

RECOMMENDATION

ICS used during the response was a great asset in tracking resources and promoting communication throughout the event. Constant refinement of the CRP is needed as work continues to further our understanding of invasive carp habits and knowledge of the Upper IWW and incorporate additional resources for future responses.

Continued yearly tabletop exercises conducted by the MRWG will prove to be beneficial in the planning and execution of response events.

OPERATION DETAILS

The following table provides details on activities from the initial reporting of one Silver Carp to the conclusion of the rapid response.

Table 1. August Silver Carp Response Activities

Date (2022)	Activity/Report
July 30	• USACE received an acquaintance report of two large Silver Carp in Lake Calumet. • USACE shared the report with MRWG co-chairs, who opted to pivot a contract fishing crew from urban ponds to Lake Calumet to investigate the report.
August 3	• IL DNR and USACE send a reconnaissance team to the area, consisting of one contract fisher and two electrofishing boats – one IL DNR and one USACE.
August 4	• The sampling event uncovered one 38-inch, 22-pound Silver Carp. • IL DNR reached out to USFWS for additional resources.
August 5-6	• Sampling effort expanded to include two additional electrofishing boats with the addition of USFWS personnel.
August 7	• Sampling effort was reduced to two electrofishing boats and one contract fisher due to personnel constraints.

August 8	• No sampling was conducted due to weather conditions.
August 9	• Transitioned to a rapid response plan, which included four commercial boat crews and three electrofishing crews, including IL DNR, USFWS, and USACE staff. • The week's effort focused on Lake Calumet areas beyond the initial report.
August 9 – 12	• Sampling was conducted in Lake Calumet.
August 15	• Sampling was conducted in Calumet Harbor.
August 16	• Sampling was conducted in Calumet River.

Table 2 provides details on sampling efforts and results during the 2-week rapid response.

Table 2. Sampling Efforts and Results

Date	Sampling Location	Gill/Netting Miles	Electrofishing Hours	Number of Invasive Carp Observed or Collected
8/5/2022	Lake Calumet	1.25	6.3	0
8/6/2022	Lake Calumet	1	5.6	0
8/7/2022	Lake Calumet	0	5.6	0
8/9/2022	Lake Calumet	6	5	0
8/10/2022	Lake Calumet	6	5	0
8/11/2022	Lake Calumet	6	5	0
8/12/2022	Lake Calumet	3	0	0
8/15/2022	Calumet Harbor	4	5	0
8/16/2022	Calumet River	4	7	2 Grass Carp collected and removed; 0 other invasive carp
8/17/2022	Calumet River	4	6	1 Grass Carp collected and removed; 0 other invasive carp
8/18/2022	Calumet River	4	6.6	1 Grass Carp collected and removed; 0 other invasive carp
8/19/2022	Calumet River	4	0	0

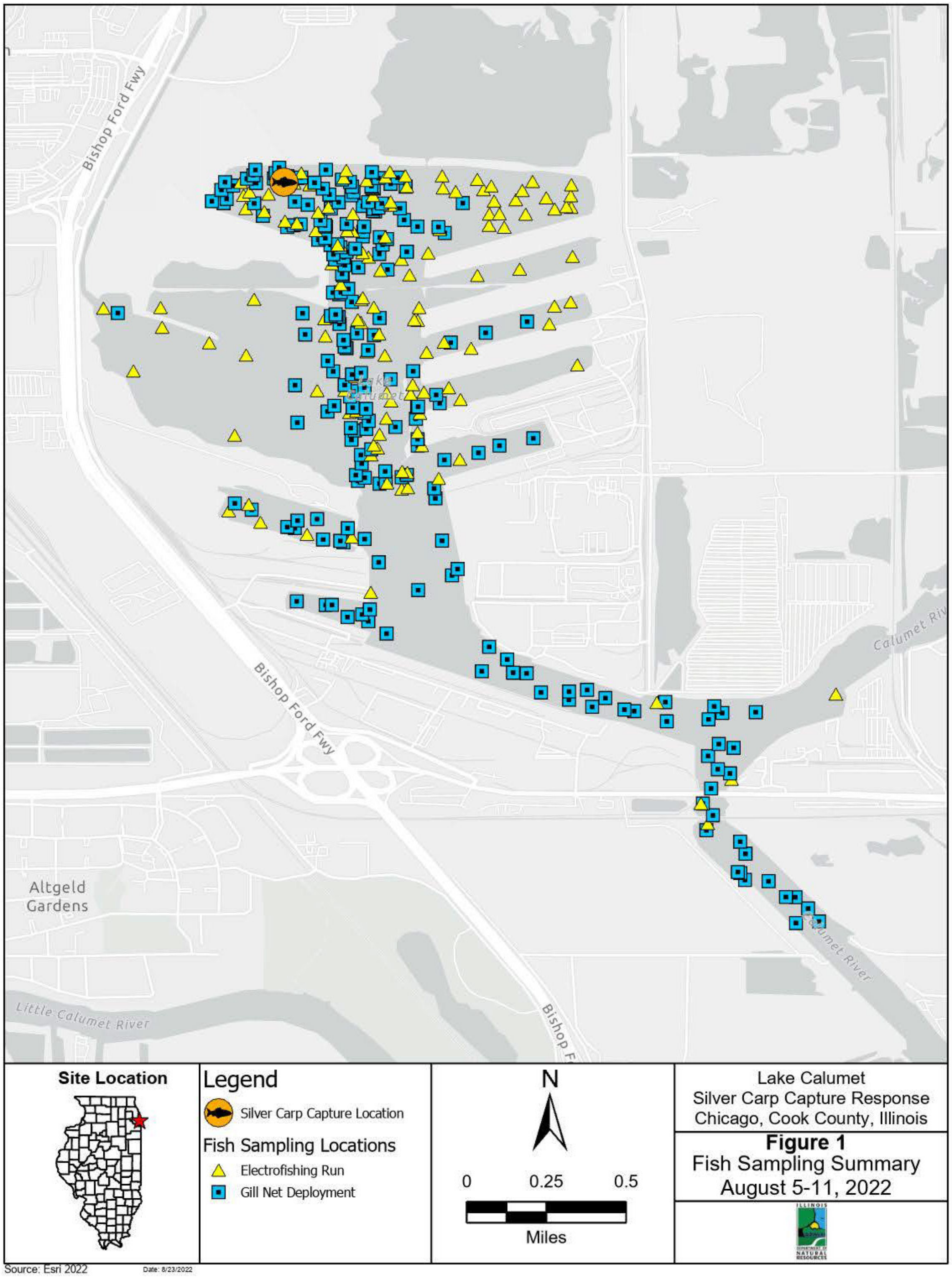


Figure 1. *Fish Sampling Summary, August 5-11, 2022*

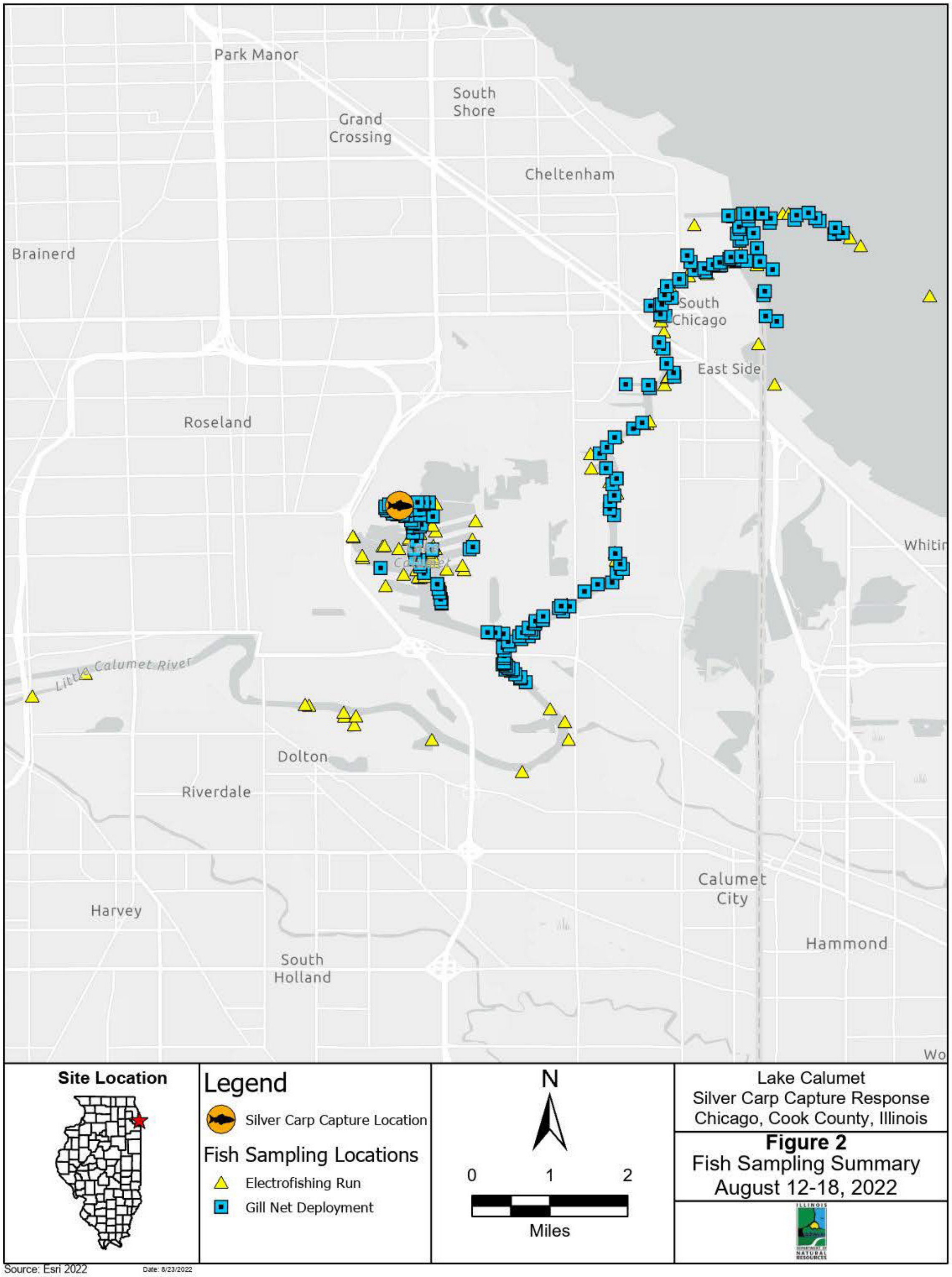


Figure 2. *Fish Sampling Summary, August 12-18, 2022*

PHOTOGRAPHS

Photo 1. *Location where Silver Carp was found in Lake Calumet.*

Photo 2. *Silver Carp captured August 4, 2022, in Lake Calumet.*

Photo 3. *Silver Carp captured August 4, 2022, in Lake Calumet.*

Photo 4. *Silver Carp captured August 4, 2022, in Lake Calumet. Fish was 38 inches in length and weighed 22 pounds.*

ATTACHMENT A: SUMMARY OF OTOLITH MICROCHEMISTRY DATA FOR THE SILVER CARP CAUGHT IN LAKE CALUMET ON AUGUST 4, 2022

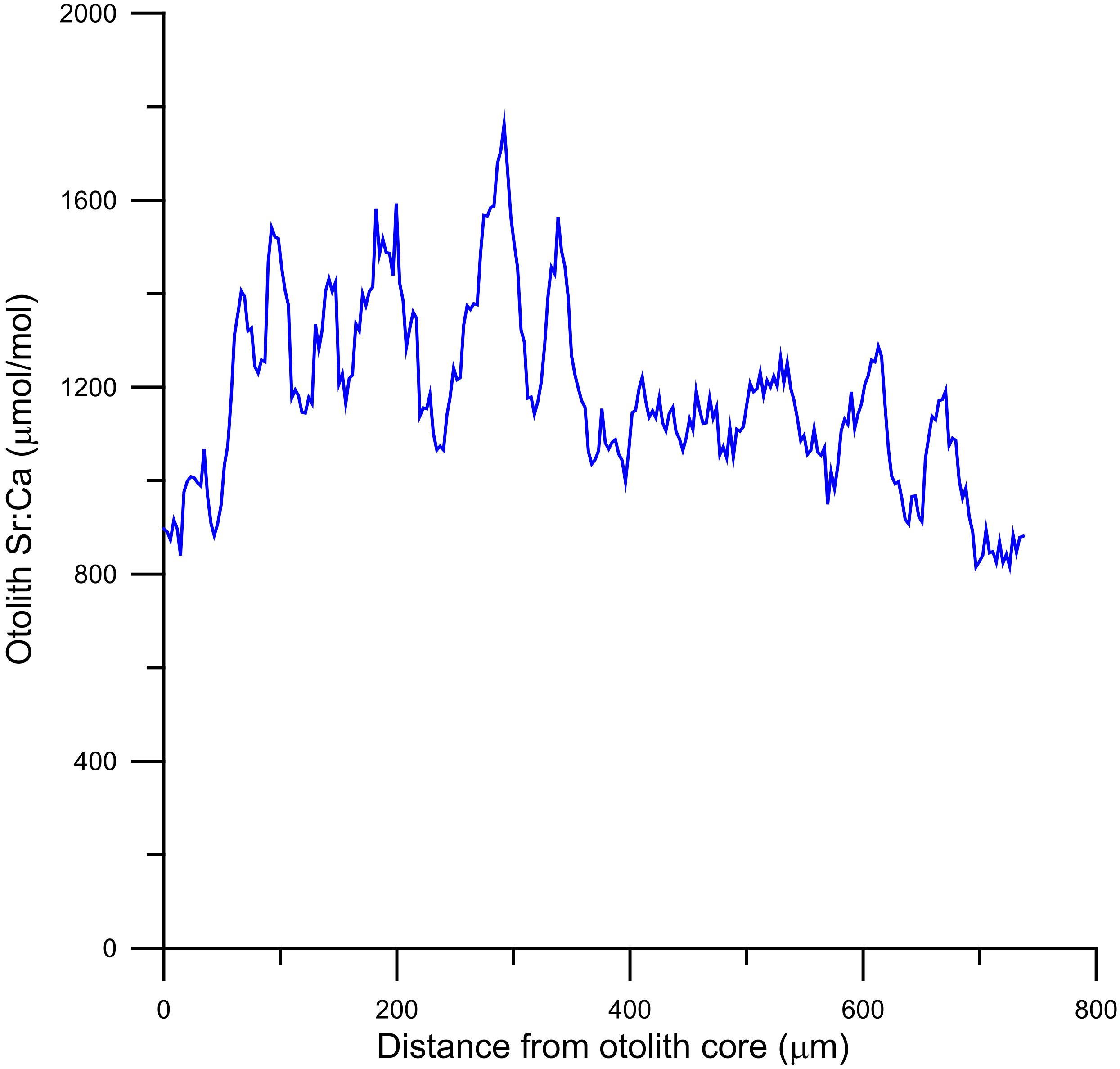
One otolith (a lapillus) was embedded in epoxy, sectioned, and analyzed for Sr:Ca and Ba:Ca along a laser ablation transect from the core of the otolith to its edge. Although the sectioned otolith from this fish did not have as clearly defined annuli as the dead fish found in the Calumet River on May 24, 2022, the Silver Carp caught August 4, 2022, was estimated to be at least age-4 based on visible annuli in the sectioned otolith.

Mean otolith core Sr:Ca (first 25 microns of the laser ablation transect) was 896 micromoles per mole, which is within the range expected for Illinois River Silver Carp. Sr:Ca values greater than 1,100 micromoles per mole, which were present across a large portion of the sectioned otolith, reflect the use of locations with higher water Sr:Ca than the Illinois River; use of the Des Plaines River would be consistent with such values in combination with observed otolith Ba:Ca data (see graphs below). Otolith Ba:Ca was between 2 and 14 micromoles per mole along the laser ablation path (mean 4 micromoles per mole), typical of fish from the Illinois River watershed.

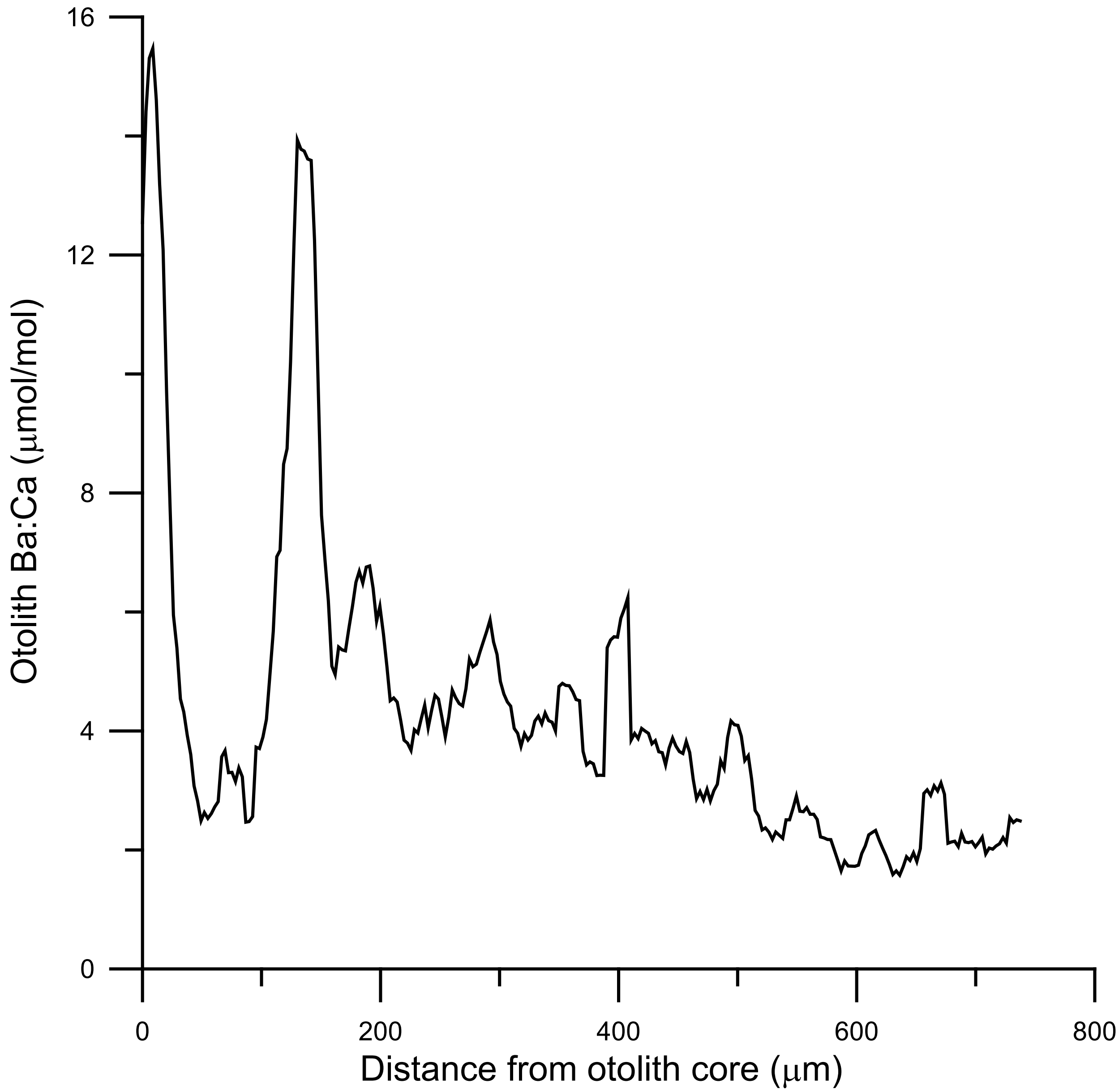
Otolith Sr:Ca over the last 45 micromoles of the laser ablation transect (near the otolith edge) averaged 855 micromoles per mole, which is typical of carp living in the Illinois River but lower than expected for a Silver Carp living in the Des Plaines River or CAWS (greater than approximately 1,000 micromoles per mole). Sr:Ca values lower than expected for the CAWS at the otolith edge indicates that this fish had not been in the CAWS long enough to acquire the CAWS signature prior to its capture and, therefore, may have been a relatively recent arrival to the CAWS.

Although otolith chemistry data from this fish are consistent with the Illinois River watershed, it is not possible to determine whether the fish arrived at its collection location in Lake Calumet on its own or if it was illegally transported to the CAWS based on otolith chemistry data.

Attachment A



Attachment A



Attachment B

ATTACHMENT B: SUMMARY OF OTOLITH MICROCHEMISTRY DATA FOR THE SILVER CARP FOUND DEAD IN THE CALUMET RIVER ON MAY 24, 2022

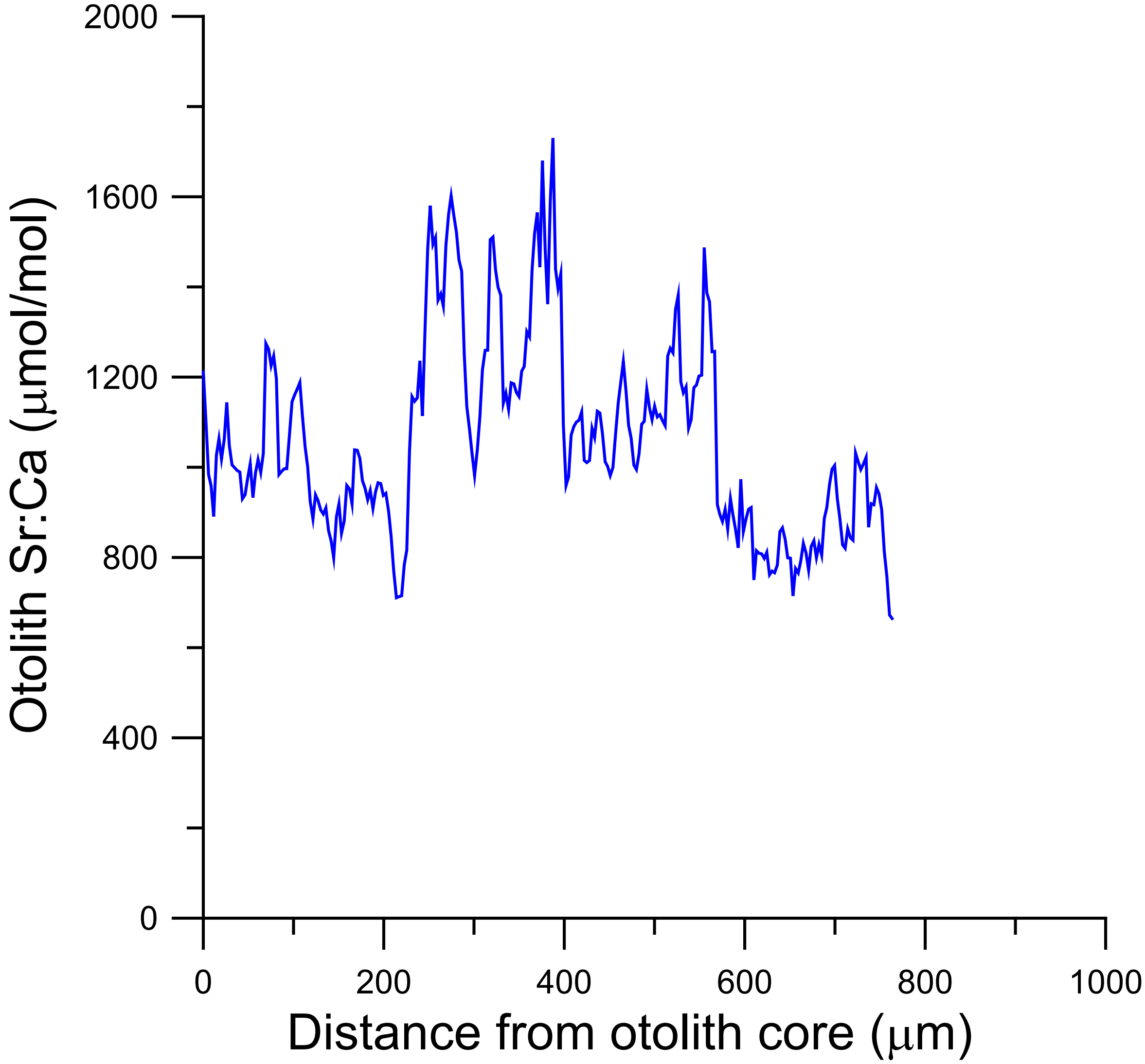
One otolith (a lapillus) was embedded in epoxy, sectioned, and analyzed for Sr:Ca and Ba:Ca along a laser ablation transect from the core of the otolith to its edge. The sectioned otolith from this fish had clearly visible annuli (which doesn't often occur with bigheaded carp otoliths); the fish was estimated to be age-12 based on otolith annuli count.

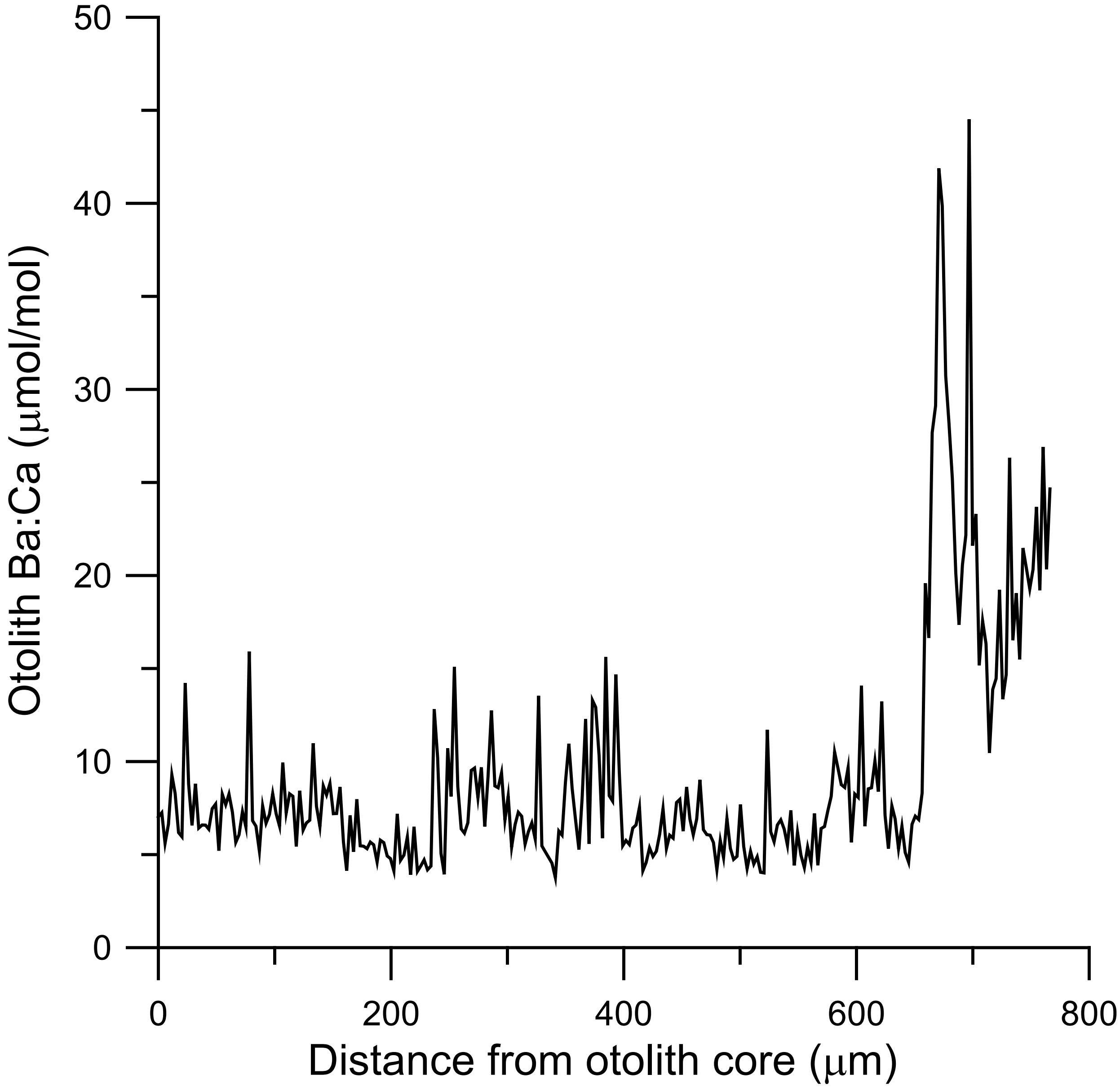
Otolith core Sr:Ca (first 25 microns of the laser ablation transect) was 1,084 micromoles per mole, which is near the upper end of the range expected for Illinois River Silver Carp. Sr:Ca values greater than 1,100 micromoles per mole near the beginning and particularly within the middle portion of the laser transect reflect the use of locations with higher water Sr:Ca than the Illinois River; use of the Des Plaines River would be consistent with such values in combination with observed otolith Ba:Ca data (see graphs below). Otolith Ba:Ca was between 5 and 15 micromoles per mole along most of the laser ablation path (mean 7 micromoles per mole), typical of fish from the Illinois River watershed.

Otolith Sr:Ca over approximately the last 200 micromoles of the laser ablation transect (near the otolith edge) averaged 858 micromoles per mole, which is typical of carp living in the Illinois River but lower than expected for a Silver Carp living in the Des Plaines River or CAWS (greater than approximately 1,000 micromoles per mole). Over the last 110 micromoles of the laser ablation transect, Ba:Ca increased from levels observed earlier in the transect (to an average of 22 micromoles per mole). Such an increase in Ba:Ca is not expected for a fish living in the CAWS, the Illinois section of Lake Michigan, the Des Plaines River, the Illinois River, or most Illinois River tributaries, as there is little variation in water Ba:Ca among these areas. One possible explanation for elevated Ba:Ca near the end of the laser ablation transect could be the use of the lower Fox River (downstream of Dayton Dam) by this fish, where higher water Ba:Ca has been observed. The observation that both Sr:Ca and Ba:Ca at the otolith edge differed from values expected for a Des Plaines River or CAWS-resident carp (Sr:Ca lower, Ba:Ca higher than expected for these areas) indicates that this fish had not been in these locations long enough to accrue sufficient otolith growth reflective of those areas to be detected. Thus, it appears that this fish may have been a relatively recent arrival to the CAWS (probably within 6 months prior to it being found dead, under the assumption that otolith growth distal to the last annulus primarily reflects the calendar year 2021 growing season).

Attachment B

Although otolith chemistry data from this fish are consistent with the Illinois River watershed, it is not possible to determine whether the fish arrived at its collection location in the Calumet River on its own or if it was illegally transported to the CAWS based on otolith chemistry data.





Otolith Ba:Ca (µmol/mol)
0
10
20
30
40
50
0
200
400
600
800
Distance from otolith core (µm)

APPENDIX A

ZOOPLANKTON AS DYNAMIC ASSESSMENT TARGETS FOR INVASIVE CARP REMOVAL

Participating Agencies: INHS (lead); SIU (lab support)
Joseph J. Parkos III, Steven E. Butler, Dakota S. Radford, Anthony P. Porreca, Kristopher A. Maxson, James T. Lamer (INHS); David P. Coulter (SIU)

Pools Involved: Dresden Island, Marseilles, Starved Rock, Peoria, and LaGrange pools 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 can deplete zooplankton densities and alter zooplankton community composition (Sass et al. 2014; DeBoer et al. 2018), potentially competing with native fish 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 and 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 toward Lake Michigan (Tsehaye et al. 2013; MacNamara et al. 2016; Love et al. 2018). One challenge with the removal program has been assessing whether 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:

- Quantify zooplankton density, body size distribution, biomass, and community composition in the IWW;
- Assess the sensitivity of a range of zooplankton taxa to bigheaded carp density; and
- Use sensitive zooplankton taxa to develop benchmarks for evaluating the outcome of bigheaded carp control and removal efforts.

PROJECT HIGHLIGHTS

- A total of 120 zooplankton samples were collected from the IWW in 2022. 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.
- Updated analyses using peak densities of several zooplankton taxa from 2012 to 2020 found that *Bosmina* sp. and cyclopoid copepods appear to be sensitive to variation in bigheaded carp density, whereas assessed rotifer taxa were not. Common macrozooplankton taxa may therefore hold promise as performance metrics for evaluating the extent to which harvest efforts are mitigating the ecosystem impacts of bigheaded carp. Incorporation of environmental conditions into assessment models has consistently been important for separating the signal of invasive carp densities from seasonal conditions affecting zooplankton densities (e.g., phytoplankton abundance).
- Continued zooplankton monitoring and assessment will continue through 2023. A complete evaluation will include a full suite of potential performance metrics (peak and monthly densities and biomass of multiple zooplankton taxa) to identify which metrics prove most informative for assessing the impact of invasive carp removals. The final evaluation, including model parameterization, metric development, and sensitivity analyses, is expected by 2024.

METHODS

Field sampling for assessing zooplankton trends took place biweekly from May to September of 2022 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 liters of water was filtered through a 55-micrometer mesh to obtain crustacean zooplankton (macrozooplankton), and 10 liters of water was filtered through a 20-micrometer mesh to obtain microzooplankton (rotifers and copepod nauplii). Organisms were transferred to sample jars and preserved in either Lugols solution (4 percent for macrozooplankton) or buffered formalin (10 percent 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 taxonomic 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 taxon. Estimates of invasive carp density in each navigation pool were obtained from annual hydroacoustic surveys conducted by SIUC.

Whereas previous analyses examined average June densities of a variety of zooplankton taxa, more recent evaluations examined peak densities of *Bosmina* species, cyclopoid copepods, and *Trichocerca* species as potential assessment metrics of bigheaded carp impacts. Building upon these analyses, models were updated with 2020 zooplankton data, and *Brachionus* sp. was added as a potential performance metric. 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 the May through September periods from 2012 to 2020 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, so these pool-year combinations were not used in the analyses. Zooplankton densities in rivers can be limited by flow rate and primary productivity (Basu and Pick 1997; Kim and Joo 2000); therefore, discharge during peak zooplankton densities and annual peaks in chlorophyll α concentration were investigated as potentially important environmental sources of variation. Because zooplankton can have lagged responses to phytoplankton blooms, peak chlorophyll α observations were acquired from measurements up to one month prior to the observed peak of the target zooplankton taxon. 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 the 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 bigheaded carp density. The model structure was a repeated measures framework with a sampling station as the repeatedly sampled unit and compound symmetric covariance structure. 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. When multiple models had similar levels of support, the most parsimonious model (i.e., the fewest parameters) was chosen. A null model (i.e., intercept only) was also included for comparison to assess whether there was meaningful support for any models in the set. Adjusted coefficients of determination were calculated as a measure of model fit for the most supported models and to compensate for potential overfitting from adding multiple explanatory factors.

RESULTS

In 2022, a total of 120 zooplankton samples were collected from the IWW. Processing of all 55-micrometer samples collected during 2021 has been completed, whereas processing of 20-micrometer samples from 2021 and both 55-micrometer and 20-micrometer samples from 2022 is ongoing. The data derived from these samples and associated water chemistry and hydrology data will be integrated into the long-term data set of zooplankton assemblages in the IWW. Data collected through 2020 were incorporated into updated assessment analyses for 2022.

Bigheaded carp densities during the 2012 to 2020 assessment period exhibited a range of values among navigation pools and years (Figure 1), providing the variation needed to test for responses by various zooplankton taxa. Annual peak densities of a common cladoceran and copepod were found to be sensitive to variation in bigheaded carp density during the assessed time period, whereas peak densities of two common rotifer taxa were not. *Bosmina* sp. exhibited very consistent summer peaks in density each year, typically occurring nearly simultaneously among sites, although varying substantially in magnitude (Figure 2). Cyclopoid copepods, however, demonstrated a much more irregular pattern, with a lack of synchrony among sites and inconsistent timing of peaks among years. Models of peak *Bosmina* sp. and cyclopoid copepod densities that included bigheaded carp density as an explanatory variable were more strongly supported by the data than those that only included environmental factors (Table 1). Chlorophyll *a* was also included as a factor in strongly supported models for both *Bosmina* sp. and cyclopoids, but a model with bigheaded carp density alone had equal support for *Bosmina* sp. However, neither of the most supported models for either *Bosmina* sp. or cyclopoids explained a substantial amount of the variation in observed densities of their respective zooplankton taxa (R^2 less than or equal to 0.34). The model with the lowest AIC_c score for *Brachionus* sp. did include bigheaded carp density as an explanatory variable, but a nearly equally supported and more parsimonious model only included chlorophyll *a* (Table 1). The most supported and parsimonious model for *Trichocerca* sp. also only included chlorophyll *a* as a predictor.

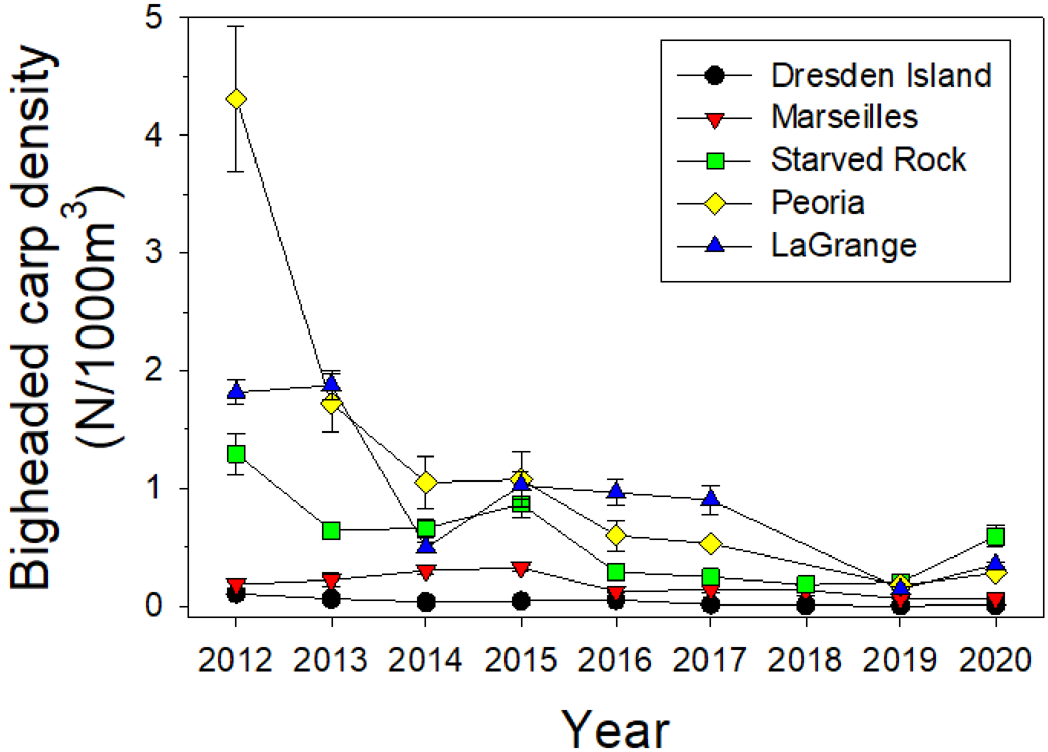


Figure 1. *Annual estimates of bigheaded carp density (number / 1000 cubic meters) within five navigation pools of the Illinois River. Estimates are derived from October hydroacoustic surveys and represent the combined density of bigheaded carp species (Silver Carp and Bighead Carp). Density estimates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

There has been consistent support for taxonomic groups that dominate the macrozooplankton communities of the Illinois River to have potential as performance metrics for bigheaded carp removal efforts. Most previous studies of bigheaded carp effects on zooplankton have lumped different zooplankton taxa into broad taxonomic groups (e.g., cladocerans, copepods, rotifers, etc.), but individual taxa may respond very differently to bigheaded carp abundance and environmental factors. *Bosmina* sp. are among one of the more common cladoceran taxa found in large rivers (Wahl et al. 2008; Burdis and Hoxmeier 2011), and the observed relationship between peak *Bosmina* density and bigheaded carp density is consistent with previous observations of a negative association between cladoceran abundances and bigheaded carp (Sass et al. 2014; DeBoer et al. 2018). Therefore, this group shows promise as a performance indicator that is easily sampled and will be responsive to declines in bigheaded carp abundance. A previous assessment using chydorid densities as a potential performance metric, however, did not demonstrate a similar response, indicating that bigheaded carp planktivory does not affect all cladoceran taxa similarly. The addition of an additional year of data strengthened the evidence that cyclopoid copepods may also serve as an assessment metric for bigheaded carp removal. Nonetheless, there was a substantial amount of variation not accounted for by either model, suggesting additional information may need to be included to provide more accurate and precise parameter estimates. Ideally, a full assessment would include multiple performance metrics to have reinforcing lines of evidence.

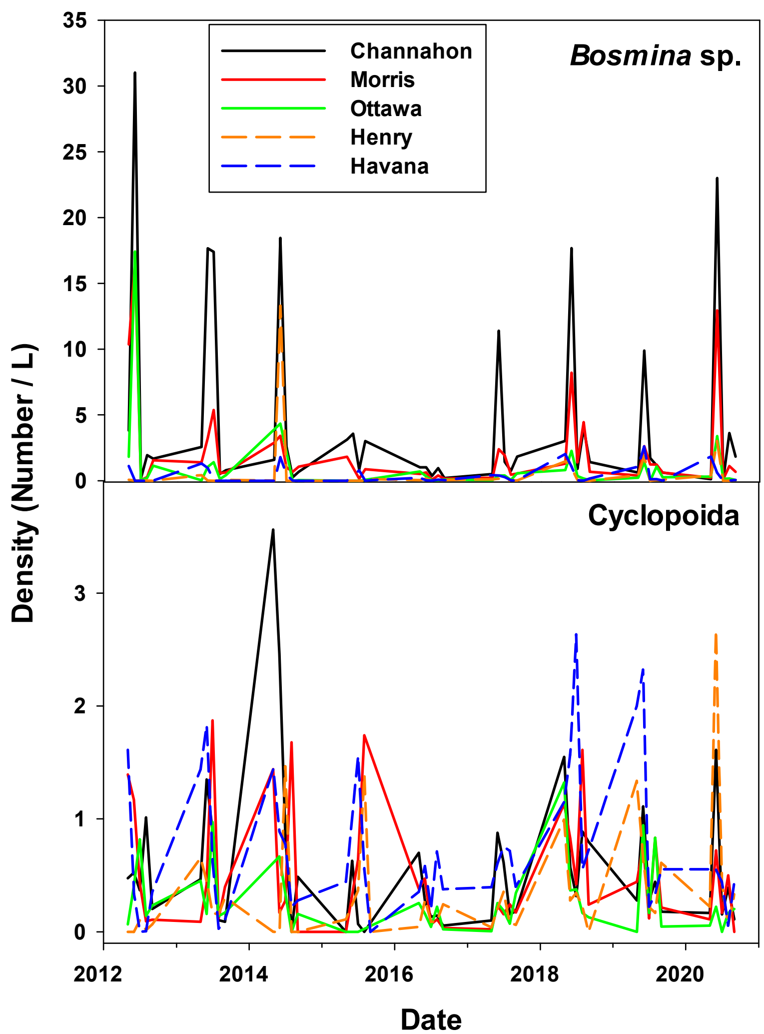


Figure 2. *Mean monthly (May through September) density (Number/liters) of Bosmina sp. (top panel) and cyclopoid copepods (bottom panel) at three upper Illinois River sampling locations (Channahon, Morris, and Ottawa) and two lower Illinois River sites (Havana and Henry) from 2010 through 2020.*

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).

Model	**AIC_c**	**Δ**	**w_i**
***Bosmina* sp.**			
Null	136.2	10.5	0.002
Discharge	136.3	10.6	0.002
Chlorophyll a	136.0	10.3	0.002
Bigheaded Carp	125.7	0	0.372
Discharge + Bigheaded Carp	126.5	0.8	0.25
Chlorophyll a + Bigheaded Carp	125.7	0	0.372
Cyclopoida			
Null	102.5	7.2	0.022
Discharge	103.5	8.2	0.013
Chlorophyll a	100.8	5.5	0.5
Bigheaded Carp	100.1	4.8	0.072
Discharge + Bigheaded Carp	100.6	5.3	0.056
Chlorophyll a + Bigheaded Carp	95.3	0	0.788
***Brachionus* sp.**			
Null	82.4	3.2	0.08

Model	**AIC$_c$**	**Δ**	**w_i**
Discharge	83.5	4.3	0.046
Chlorophyll a	79.4	0.2	0.361
Bigheaded Carp	83.0	3.8	0.06
Discharge + Bigheaded Carp	83.2	4.0	0.05
Chlorophyll a + Bigheaded Carp	79.2	0	0.4
***Trichocerca* sp.**			
Null	81.0	1.8	0.143
Discharge	80.6	1.4	0.174
Chlorophyll a	79.2	0	0.351
Bigheaded Carp	81.8	2.6	0.1
Discharge + Bigheaded Carp	83.0	3.8	0.05
Chlorophyll a + Bigheaded Carp	80.5	1.3	0.183

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 bigheaded carp densities (e.g., DeBoer et al. 2018; Chará-Serna and Casper 2021). Our analyses have found evidence for the importance of including chlorophyll *a* dynamics in models of zooplankton density, likely due to a connection between phytoplankton and zooplankton productivity (Basu and Pick 1997). The relatively rapid time scale of zooplankton population dynamics due to their sensitivity to flow, algae blooms, and other abiotic factors may constrain the amount of information that can be explained by models that collapse environmental variability into monthly metrics or metrics based on peak abundance. Rotifers are known for their rapid turnover rates, potentially explaining the lack of sensitivity of monthly and peak rotifer metrics to inter-annual changes in bigheaded carp densities.

RECOMMENDATIONS

Continued monitoring and assessment of potential zooplankton performance metrics will conclude by the end of 2023. A complete evaluation will account for the influence of environmental factors known to affect zooplankton communities in large rivers (turbidity, chlorophyll *a*, total phosphorus, temperature, and discharge) and the effect of invasive carp densities in different pools of the IWW. Final analyses should expand these investigations to a full suite of performance metrics (peak and monthly densities and biomass of multiple zooplankton taxa) to identify what metrics prove most informative for assessing the impact of invasive carp removals. The most informative performance metrics will then be modeled using observed environmental conditions and invasive carp densities in each pool to calculate the difference between the 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, including 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 including 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 modeled 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. Identified performance metrics will also provide a simple means of communicating the ecosystem responses to harvest efforts to a general audience (e.g., policymakers and the general public). Complete assessment, including model parameterization, metric development, and sensitivity analyses, are expected by 2024.

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