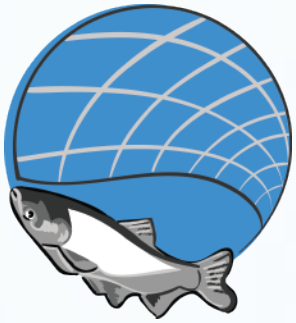
2023

INTERIM SUMMARY REPORT

Invasive Carp Monitoring and Response Plan



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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 20 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 2024 Invasive Carp Monitoring and Response Plan (MRP) for the Illinois Waterway. Each individual summary report outlines the results of work that took place in 2023 and provides recommendations for the next steps for each project.

The 2023 results for 20 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:

- **Detection:** Determine the distribution and abundance of invasive carp to guide response and control actions.
- **Management and Control:** Prevent the upstream passage of invasive carp toward Lake Michigan via the use of barriers, mass removal, and understanding the best methods for preventing passage.
- **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 2023.

HIGHLIGHTS OF 2023 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 2023; no live Silver Carp or Bighead Carp were captured or observed in SIM 2023.
- Captured and removed one Grass Carp from Lake Calumet during spring SIM. From 2010 to 2023, a total of 67 Grass Carp upstream of the EDBS have been removed in the CAWS.
- United States Fish and Wildlife Service (USFWS) staff collected 880 environmental deoxyribonucleic acid (eDNA) samples upstream of the EDBS and 220 samples in Powder

horn Lake (control site); positive detections were few and consistent with previous sampling years.

- No known live tagged fish have crossed the EDBS in the upstream direction.
- Invasive carp show heavy use of Dresden Island Nuclear Power Plant discharge canal when river temperatures are below 20 degrees Celsius (◦C), indicating possible removal windows.
- Mobile hydroacoustic surveys completed in September and October 2023 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 2023 were generally low and similar to past years, except for above-average large fish densities in Brandon Road and Dresden Island pools in October 2023.
- No small invasive carp were captured in Lockport, Brandon Road, Dresden Island, or Marseilles pools.
- No large invasive carp were detected upstream of Brandon Road Lock and Dam.
- Three large Bighead Carp, 290 large Silver Carp, and 14 large Grass Carp were captured and removed from Marseilles, Dresden Island, and lower Kankakee River pools in 2023.
- From May to September 2023, 662 ichthyoplankton samples were collected from 10 sites from the Brandon Road to Alton navigation pools of the Illinois Waterway (IWW). Invasive carp reproductive productivity was very low in 2023 relative to past years of observation.
- In 2023, 194 ichthyoplankton samples were collected from Illinois River tributaries. Large-diameter eggs and invasive carp larvae were collected from the Spoon and Sangamon rivers. No evidence of invasive carp reproduction was observed in other Illinois River tributaries.
- No Bighead Carp or Silver Carp have been captured or observed across all years of sampling in the Des Plaines River.
- The U.S. Army Corps of Engineers (USACE) has acquired 45.7 million detections from 862 tagged fish (invasive carp and surrogate species) between Lockport Pool and Dresden Island pool since 2010.

Management and Control Projects

- A manuscript (Kallis et al. 2023) was published in the *Journal of Applied Ecology,* indicating that the most effective management measures to reduce the Dresden Island invasive carp population are (1) increased harvest in lower pools of the Illinois River, (2) maintaining current harvest efforts in the upper pools of the Illinois River, and (3) placing deterrents at the most downstream lock and dam structure in the upper Illinois River (i.e., Starved Rock Lock and Dam).

- From 2010 to 2023, 105,915 Bighead Carp, 1,729,779 Silver Carp, and 12,408 Grass Carp were removed by contracted fishers. The total estimated weight of invasive carp removed is 14,519,600 pounds (7,260 tons).
- In April 2023, 149 V-9 acoustic transmitters were implanted inside invasive carp – 112 in Peoria Pool and 37 in Starved Rock Pool.
- Collected and processed over 3,800 lapilli otolith aging structures from six pools of the Illinois River from 2018 to 2023, which provided pool-specific age-structure metrics.
- Removed more than 8.4 million pounds under the Enhanced Contract Removal program from the Peoria, LaGrange, and Alton pools of the Illinois River in 2023.
- Continued to see positive media coverage of the Copi brand and the development of new value-added products and new distributor and sales outlets.

Response Projects

- No responses were conducted in 2023.

Acronym	Definition
Cal-S	Micromole per mole
AIS	Aquatic Invasive Species
Cal-Sag	Calumet-Saganashkee
CAWS	Chicago Area Waterway System
CO2	Carbon Dioxide
CPO	Conservation Police Officer
CPUE	Catch per Unit Effort
CRP	Contingency Response Plan
CSSC	Chicago Sanitary and Ship Canal
DNA	Deoxyribonucleic Acid
EDBS	Electric Dispersal Barrier System
eDNA	Environmental Deoxyribonucleic Acid
ERDC	Environmental Research and Development Center
FWCO	Fish and Wildlife Conservation Office
FY	Fiscal Year
GLFC	Great Lakes Fishery Commission
IAP	Incident Action Plan
ICRCC	Invasive Carp Regional Coordinating Committee
ICS	Incident Command System
ILDNR	Illinois Department of Natural Resources
ILRCdb	Illinois River Catch Database
INHS	Illinois Natural History Survey
ISR	Interim Status Report
ISU	Invasive Species Unit
IWW	Illinois Waterway
LTRM	Long-term Resource Monitoring
MAM	Multi-Agency Monitoring
mmol/mol	Millimole per mole
MRP	Monitoring and Response Plan
MRWG	Monitoring and Response Work Group
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
qPCR	Quantitative PCR

Acronym	Definition
RM	River Mile
SCAA	Statistical Catch-at-Age
SEICarP	Spatially Explicit Invasive Carp Population
SIM	Seasonal Intensive Monitoring
SIU	Southern Illinois University
SIUC	Southern Illinois University Carbondale
Sr:Ca	Strontium:calcium
uADS	Underwater acoustic deterrent system
U.S.	United States
USACE	U.S. Army Corps of Engineers
USCG	US. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VPS	Vemco Positioning System
v/cm	Volts per centimeter
YOY	Young-of-Year

INTRODUCTION

The 2023 ISR presents a comprehensive accounting of project results from activities completed by the invasive carp MRWG in 2023. 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 CAWS and Lake Michigan. Efforts to prevent the spread of invasive carp to the Great Lakes have been underway for over 13 years. Throughout 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.

(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 in 2023 to further the implementation of each of these objectives. The ISR includes the project, Field Testing of a uADS In a Marseilles Gravel Pit on the Illinois River, which was mistakenly not included in the FY 2023 MRP.

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 by the “invasive carp” moniker are Bighead Carp (*Hypophthalmicthys nobilis*), Silver Carp (*Hypophthalmicthys molitrix*), Grass Carp (*Ctenopharyngodon idella*), and Black Carp (*Mylopharyngodon piceus*).

Invasive carp are native to central and eastern Asia, with a wide distribution throughout eastern China. They typically live in river systems and have predators and competitors in their native habitats 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 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,

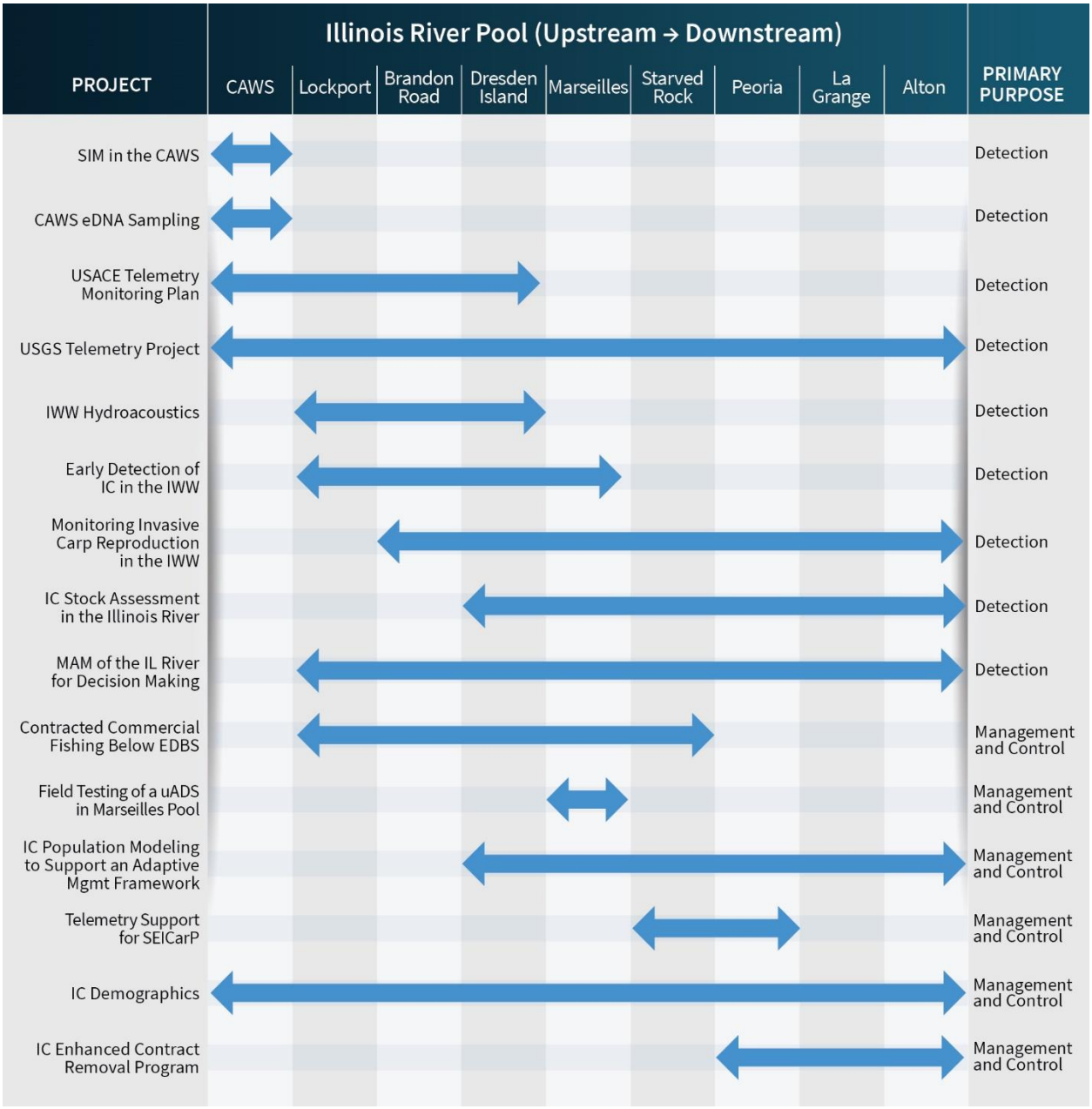
including the Ohio River, Missouri River, and Illinois River. Areas with large populations of invasive carp have seen an upheaval of native ecosystem structure and function. Invasive carp are voracious consumers of phytoplankton, zooplankton, and macroinvertebrates. They grow quickly and are highly adapted 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 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 clearly depict the geospatial scale and focus of the projects included in this ISR, the MRWG has prepared a project location crosswalk. This crosswalk tool allows readers to understand where a specific project focuses its efforts and quickly discern all projects that are operating in a specific portion of the IWW and CAWS.


PROJECT
Illinois River Pool (Upstream → Downstream)
CAWS
Lockport
Brandon Road
Dresden Island
Marseilles
Starved Rock
Peoria
La Grange
Alton
PRIMARY PURPOSE
SIM in the CAWS
Detection
CAWS eDNA Sampling
Detection
USACE Telemetry Monitoring Plan
Detection
USGS Telemetry Project
Detection
IWW Hydroacoustics
Detection
Early Detection of IC in the IWW
Detection
Monitoring Invasive Carp Reproduction in the IWW
Detection
IC Stock Assessment in the Illinois River
Detection
MAM of the IL River for Decision Making
Detection
Contracted Commercial Fishing Below EDBS
Management and Control
Field Testing of a uADS in Marseilles Pool
Management and Control
IC Population Modeling to Support an Adaptive Mgmt Framework
Management and Control
Telemetry Support for SEICarP
Management and Control
IC Demographics
Management and Control
IC Enhanced Contract Removal Program
Management and Control

SEASONAL INTENSIVE MONITORING IN THE CAWS

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

Pools Involved: CAWS

INTRODUCTION AND NEED

Detections of invasive carp (Silver Carp and Bighead Carp) eDNA upstream of the EDBS in 2009 initiated the development of a monitoring plan that utilized boat electrofishing and contracted commercial fishers to sample for invasive carp at five fixed sites upstream of the barrier. Random area sampling began in 2012, increasing the chance of detecting invasive carp in the CAWS beyond the designated fixed sites. Extensive sampling performed upstream of the EDBS from 2010 through 2013 resulted in one Bighead Carp being collected in Lake Calumet in 2010. Fixed site and random area sampling efforts were then reduced upstream of the barrier to two SIM events from 2014 to 2023. Following effort reduction, one Silver Carp was collected in the Little Calumet River in 2017, resulting in a rapid, interagency contingency response effort. One additional Silver Carp was captured in 2022 in Lake Calumet outside of SIM sampling. 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 fixed, random, and targeted sampling efforts at locations deemed likely to hold fish.
- Remove invasive carp from the CAWS upstream of the EDBS.

PROJECT HIGHLIGHTS

- Completed two 2-week SIM events with conventional gears in the CAWS upstream of the EDBS in 2023.
- No live Silver Carp or Bighead Carp were captured or observed in SIM 2023. 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

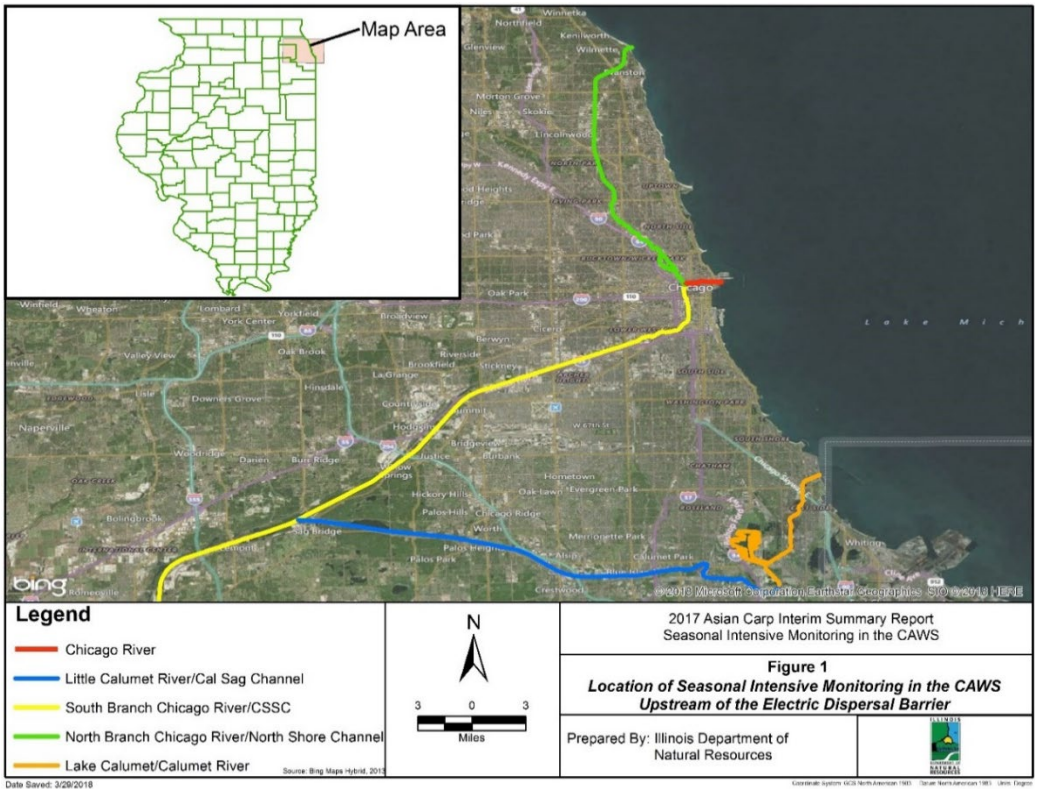
years. One dead Silver Carp was observed in 2018 on the banks of the Cal-Sag Channel, and another dead Silver Carp was observed in 2022 on the banks of the Calumet River. One live Silver Carp was captured in Lake Calumet in 2022 outside of SIM sampling. For more information on response actions, please refer to the Response Project section of the appropriate year's ISR (Interim Summary Reports).

- One Grass Carp was captured and removed from Lake Calumet during spring SIM. From 2010 to 2023, a total of 67 Grass Carp upstream of the EDBS have been removed in the CAWS.
- An estimated 3,066.5 person-hours were spent completing 124.3 hours of electrofishing, setting 157.1 kilometers (98 miles) of gill net and 2.9 kilometers (1.8 miles) of commercial seine in 2023.
- Across all locations and gears, 44,906 fish were sampled, representing 61 species and 3 hybrid groups in 2023.
- An estimated 44,321.5 person-hours have been spent completing 1729.6 hours of electrofishing and setting 1,753.2 kilometers (1089.4 miles) of gill/trammel net, 27.8 kilometers (17.3 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 2023, a total of 555,863 fish representing 88 species and 7 hybrid groups were sampled.
- YOY Gizzard Shad (*n*=138,951) were examined, and no YOY invasive carp were found when sampling from 2010 to 2023.
- Non-native species (*n*=16) have been captured, accounting for 15 percent of the total number of fish caught and 15 percent of the total species since 2010.

METHODS

Pulsed DC-electrofishing, gill nets, and a commercial seine were used to monitor for invasive carp in the CAWS upstream of the EDBS (Figure 1). In previous years, trammel nets, deep water gill nets, fyke nets, and pound nets were also used. Those gear specifications can be found in prior ISRs. Intensive electrofishing and netting occurred at five fixed-site and four random-site sampling areas. Random sites were generated with GIS software from shape files of designated random site areas. New in 2023, random site sampling also took place within fixed site areas, as it was found that the effort level (number of sampling sites per river kilometer) in fixed site areas was much lower than in random site areas. Adding random sites into fixed-site sampling areas increased effort levels within the fixed-site areas and allowed for more thorough surveillance in areas that might hold invasive carp, such as the Little Calumet River. For a more detailed description of fixed and random sampling areas, see the 2023 MRP. Decontamination protocols for PDC electrofishing and netting can also be found in the 2023 MRP.

Figure 1. *Location of SIM in the CAWS upstream of the EDBS.*



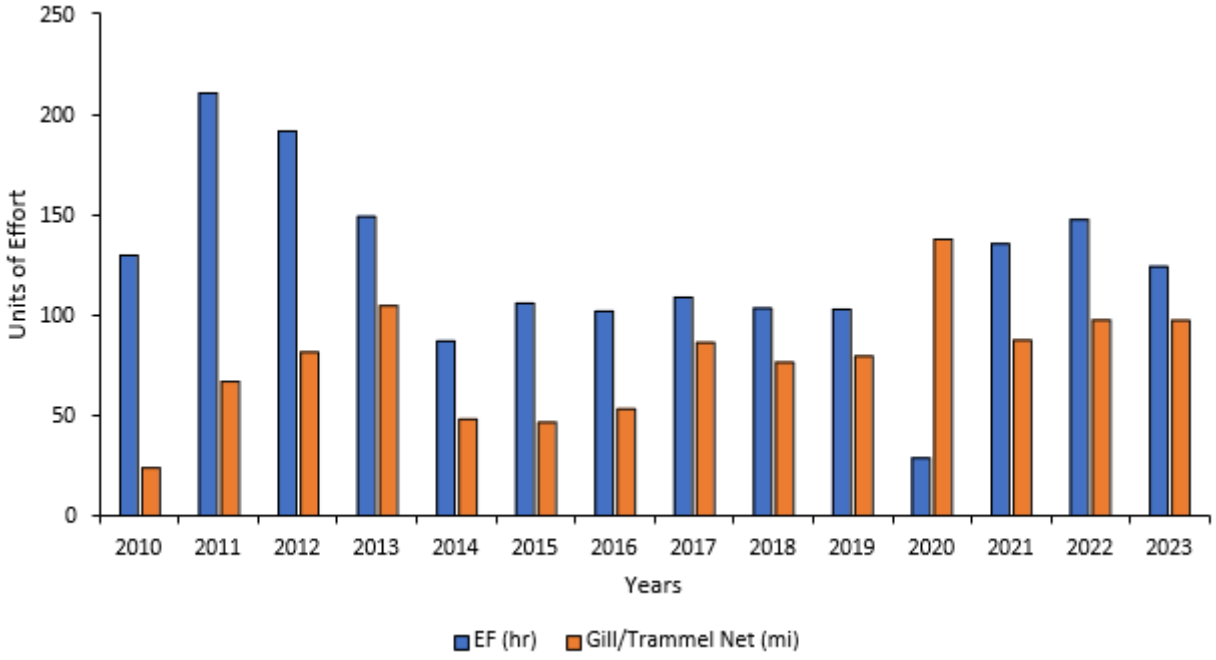
RESULTS AND DISCUSSION

SIM sampling in 2023 took place from May 15 to 26 and October 2 to 13, for a total of 19 sampling days. Sampling in 2022 also took place in May and October. From 2014 to 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 2023 (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 2023 was 124.3 hours of electrofishing (516 transects), with an estimated 1,440 person-hours, 157.1 kilometers (98 miles) of gill netting (860 sets), with an estimated 1,416.5 person-hours, and 2.9 kilometers (1.8 miles) of commercial seine, with an estimated 210 person-hours (Table 1).

Across all locations and gears, 44,906 fish representing 61 species and 3 hybrid groups were sampled in 2023 (Table 2). Gizzard Shad, Largemouth Bass, Emerald Shiner, Common Carp, Bluntnose Minnow, and Bluegill were the predominant species, comprising 76.7 percent of all fish sampled. Twelve non-native species were sampled, including 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 19.6 percent of the total species collected and 9.5 percent of the total fish by

count in 2023. 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.

Figure 2. *Total electrofishing and trammel/gill netting effort at fixed and random sites in the CAWS upstream of the EDBS, 2010 to 2023.*



On May 26, 2023, one live Grass Carp was collected during SIM in Lake Calumet. Ploidy testing on this fish indicated that it was diploid.

An estimated 44,321.5 person-hours have been expended monitoring fixed and random sites upstream of the EDBS since 2010. From 2010 to 2023, the total effort consisted of 1,729.6 hours of electrofishing (7,011 transects), 1,753.2 kilometers (1089.4 miles) of gill/trammel net (9,606 sets), 27.8 kilometers (17.3 miles) of commercial seine hauls, and 114.2 net nights of hoop, pound, and fyke nets (Table 3). Hoop net use was suspended after 2013 due to low gear efficiency. A total of 555,863 fish representing 88 species and 7 hybrid groups have been sampled since 2010 (Table 3). Gizzard Shad, Common Carp, Bluegill, Largemouth Bass, Bluntnose Minnow, and Pumpkinseed were the predominant species sampled, accounting for 82 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 15 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 2022 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 Work Group. 2023. 2023 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 SIM in the CAWS upstream of the EDBS, 2023.*

Effort and Catch	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	547.5	375	262.5	15	240	1,440
Samples (transects)	181	153	91	1	90	516
Electrofishing hours	42.0	36.1	23.0	0.72	22.5	124.3
Electrofishing Catch	-	-	-	-	-	-
All fish (*N*)	11,299	13,963	7,275	0	8,907	41,444
Species (*N*)	46	48	27	0	42	60
Hybrids (*N*)	2	2	2	0	1	3
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	269	386.8	316.3	0	395.9	333.4
Netting Effort	-	-	-	-	-	-
Estimated person-hours	522	371	300	36	187.5	1,416.5
Samples (net sets)	311	236	168	25	120	860
Miles of net	35.3	26.8	19.1	2.84	13.6	97.6
Netting Catch	-	-	-	-	-	-
All fish (*N*)	990	157	262	13	91	1,513
Species (*N*)	17	10	8	1	4	18
Hybrids (*N*)	0	1	0	0	1	1
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/100 yds of net)	1.59	0.33	0.78	0.26	0.38	0.06
Seine Effort	-	-	-	-	-	-
Estimated person-hours	210	-	-	-	-	210
Samples (seine hauls)	4	-	-	-	-	4
Miles of seine	1.8	-	-	-	-	1.8
Seine Catch	-	-	-	-	-	-
All fish (*N*)	1,949	-	-	-	-	1,949
Species (*N*)	21	-	-	-	-	21
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	487.3	-	-	-	-	487.3

Table 2. *Total number of fish captured with electrofishing (EF), trammel/gill nets (Nets), and commercial seine (Seine) in the CAWS upstream of the EDBS during SIM 2023.*

Species	Chicago River		CSSC-S. Branch		Lake Cal-Cal River			Little Cal/Cal-Sag		North Shore Channel-N. Branch		All Sites
-	EF	Nets	EF	Nets	EF	Nets	Seine	EF	Nets	EF	Nets	All Gears
Alewife*	-	-	-	-	332	-	-	3	-	11	-	346
Banded killifish	-	-	117	-	129	-	-	135	-	25	-	466
Bigmouth buffalo	-	-	-	-	64	27	-	13	5	-	-	109
Black buffalo	-	-	-	-	8	60	71	-	15	-	-	154
Black bullhead	-	-	-	-	50	-	-	1	-	-	-	51
Black crappie	-	-	-	-	35	-	8	2	-	30	-	75
Blackstripe topminnow	-	-	26	-	2	-	-	6	-	-	-	34
Bluegill	-	-	489	-	796	-	-	321	-	1,344	-	2,950
Bluntnose minnow	-	-	822	-	155	-	-	1,065	-	997	-	3,039
Bowfin	-	-	-	-	34	-	-	2	-	1	-	37
Brook silverside	-	-	23	-	76	-	-	41	-	38	-	178
Brown bullhead	-	-	-	-	113	-	3	-	-	3	-	119
Brown trout*	-	-	-	-	2	-	-	-	-	-	-	2
Bullhead minnow	-	-	-	-	-	-	-	-	-	2	-	2
Carp x goldfish hybrid*	-	-	10	-	1	-	-	2	4	1	2	20
Central mudminnow	-	-	-	-	-	-	-	1	-	-	-	1
Channel catfish	-	-	155	14	13	26	114	128	16	22	2	490
Channel shiner	-	-	-	-	-	-	-	1	-	-	-	1
Chinook salmon*	-	-	-	-	34	3	-	2	1	-	-	40
Coho salmon*	-	-	-	-	8	-	-	2	-	-	-	10
Common carp*	-	13	613	233	444	212	14	1,080	-	454	86	3,149

Species	Chicago River		CSSC-S. Branch		Lake Cal-Cal River			Little Cal/Cal-Sag		North Shore Channel-N. Branch		All Sites
-	EF	Nets	EF	Nets	EF	Nets	Seine	EF	Nets	EF	Nets	All Gears
Common shiner	-	-	-	-	-	-	-	-	-	-	-	1
Creek chub	-	-	-	-	-	-	-	1	-	1	-	2
Emerald shiner	-	-	218	-	1,454	-	-	2,183	-	550	-	44,05
Fathead minnow	-	-	-	-	-	-	-	3	-	1	-	4
Flathead catfish	-	-	-	-	3	13	1	-	-	-	-	17
Freshwater drum	-	-	30	10	92	255	119	128	89	4	1	728
Gizzard shad	-	-	2,673	1	518	7	1,535	4,322	7	2073	-	11,136
Gizzard Shad < 6 in.	-	-	934	-	1,145	-	-	2,380	-	356	-	4,815
Golden shiner	-	-	105	-	55	-	-	81	-	256	-	497
Goldfish*	-	-	31	1	123	1	3	8	4	61	-	232
Grass carp*	-	-	-	-	-	1	-	-	-	-	-	1
Green sunfish	-	-	259	-	86	-	-	155	-	29	-	529
Green sunfish x bluegill hybrid	-	-	-	-	-	-	-	-	-	1	-	1
Largemouth bass	-	-	376	1	2088	2	31	958	-	1482	-	4,938
Mimic shiner	-	-	-	-	-	-	-	405	-	-	-	405
Northern pike	-	-	-	1	7	-	10	1	-	1	-	20
Northern sunfish	-	-	-	-	1	-	-	-	-	-	-	1
Orangespotted sunfish	-	-	-	-	-	-	-	1	-	-	-	1
Oriental weatherfish*	-	-	10	-	-	-	-	-	-	39	-	49
Pumpkinseed	-	-	263	-	1,244	-	1	170	-	276	-	1,954
Pumpkinseed x bluegill hybrid	-	-	2	-	2	-	-	1	-	-	-	5
Quillback	-	-	-	-	36	13	-	-	-	-	-	49

Species	Chicago River		CSSC-S. Branch		Lake Cal-Cal River			Little Cal/Cal-Sag		North Shore Channel-N. Branch		All Sites
-	EF	Nets	EF	Nets	EF	Nets	Seine	EF	Nets	EF	Nets	All Gears
Rainbow trout*	-	-	-	-	3	-	-	-	-	-	-	3
Redear sunfish	-	-	-	-	-	-	-	-	-	1	-	1
River carpsucker	-	-	-	-	-	7	-	-	-	-	-	7
River shiner	-	-	-	-	19	-	-	4	-	-	-	23
Rock bass	-	-	-	-	484	-	4	3	-	73	-	564
Round goby*	-	-	8	-	108	-	-	11	-	49	-	176
Sand shiner	-	-	-	-	24	-	-	81	-	-	-	105
Shorthead redhorse	-	-	1	-	-	-	-	-	-	-	-	1
Smallmouth bass	-	-	-	-	537	1	1	14	-	2	-	555
Smallmouth buffalo	-	-	-	1	69	355	16	22	14	-	-	477
Spotfin shiner	-	-	19	-	-	-	-	10	-	60	-	89
Spottail shiner	-	-	1	-	77	-	-	13	-	1	-	92
Tilapia*	-	-	1	-	-	-	-	-	-	-	-	1
Walleye	-	-	-	-	-	6	3	-	-	9	-	18
Warmouth	-	-	-	-	20	-	-	-	-	2	-	22
Western mosquitofish	-	-	-	-	-	-	-	34	-	30	-	64
White bass	-	-	2	-	39	-	4	60	-	4	-	109
White crappie	-	-	-	-	-	-	5	5	-	6	-	16
White perch*	-	-	-	-	24	-	2	42	-	5	-	73
White sucker	-	-	14	-	-	-	2	20	-	576	-	612
Yellow bass	-	-	-	-	15	-	-	29	-	1	-	45
Yellow bullhead	-	-	13	-	53	1	-	5	2	29	-	103
Yellow perch	-	-	-	-	676	-	2	8	-	1	-	687

Species	Chicago River		CSSC-S. Branch		Lake Cal-Cal River			Little Cal/Cal-Sag		North Shore Channel-N. Branch		All Sites
-	EF	Nets	EF	Nets	EF	Nets	Seine	EF	Nets	EF	Nets	All Gears
Total fish (N)	0	13	7,275	262	11,299	990	1,949	13,963	157	8,907	91	-
Total species (N)	0	1	25	8	44	17	21	46	9	40	3	-
Total hybrids (N)	0	0	2	0	2	0	0	2	1	2	1	-

*: non-native species

Table 3. *Summary of effort and catch data for all fixed and random site monitoring in the CAWS upstream of the EDBS 2010* to *2023.*

Effort and Catch	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Electrofishing Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Estimated person-hours	1,280	2,180	4,330	1,528	945	990	990	990	990	1,118	195	1,350	1,260	1,440	**19,586**
Samples (transects)	519	844	765	588	348	422	407	437	414	412	127	592	620	516	**7,011**
EF (hrs)	130	211	192	149.3	87.1	106	102	109	103.5	103	28.7	136	148	124.3	**1,729.6**
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	41,444	**477,049**
Species (N)	51	58	59	56	56	61	59	58	60	48	39	53	65	60	**90**
Hybrids (N)	3	3	3	2	2	2	2	2	2	2	1	4	2	3	**8**
Bighead Carp (N)	0	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	**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	333.4	**275.8**
Gill/Trammel Netting Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Estimated person-hours	885	1,725	3,188	1,932	1,125	1,125	1,125	1,485	1,148	1,440	2,655	2,070	1,588	1,416.5	**22,907.5**
Samples (net sets)	208	389	699	959	440	445	498	803	710	711	1252	772	860	860	**9,606**
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	97.6	**1,089.4**
Gill/Trammel 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	1,513	**29,575**
Species (N)	17	20	20	30	18	13	18	14	23	19	18	17	57	18	**43**
Hybrids (N)	1	1	1	1	1	1	1	1	1	1	1	1	2	1	**2**
Bighead Carp (N)	1	0	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	0	**1**

Effort and Catch	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
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	0.06	**1.5**
Seine Effort	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Estimated person-hours	-	-	-	135	135	135	135	135	135	135	135	210	328	210	**1,828**
Samples (seine hauls)	-	-	-	3	2	3	3	4	3	4	4	4	4	4	**38**
Miles of seine	-	-	-	1.4	0.9	1.4	1.4	1.8	1.4	1.8	1.8	1.8	1.8	1.8	**17.3**
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	1,949	**47,885**
Species (N)	-	-	-	15	11	14	15	10	10	16	11	18	19	21	**30**
Hybrids (N)	-	-	-	1	0	0	0	0	0	0	0	0	0	0	**1**
Bighead Carp (N)	-	-	-	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**
CPUE (fish/seine haul)	-	-	-	2,525.7	862.5	1,996.3	1,255.0	690.8	1,036.7	1,864.3	719.8	872.5	1,795.3	487.3	**1,260.1**
Hoop/Trap Net/ Tandem Trap Net	**-**	**-**	**-**	-	-	-	-	-	-	-	-	-	-	-	**-**
Estimated person-hours	-	-	-	-	-	30	28	135	135	-	-	-	-	-	**328**
Samples (sets)	-	-	-	11	-	4	3	8	7	-	-	-	-	-	**33**
Net-days	-	-	-	25.2	-	16	12	52.1	43	-	-	-	-	-	**148.3**
Hoop/Trap Net/ Tandem Trap Net 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**

Effort and Catch	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
CPUE (fish/net-day)	-	-	-	3.7	-	10.75	8.5	5.6	16.1	-	-	-	-		**9.1**
Pound Net Effort	-	-	-	-	-	-	-	-	-	-	-	-	**-**	-	**-**
Estimated person-hours		-	-	-	-	-	-	-	135	-	-	-	-	-	
Net-days	-	-	-	-	-	-	-	8.9	-	-	-	-	-		**8.9**
Pound Net catch	-	-	-	-	-	-	-	-	-	-	-	-	**-**	-	**-**
All fish (N)		-	-	-	-	-	-	-	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 samples (100 samples plus 10 field blanks) were collected in the Marine Services Marina on the Little Calumet River, and 110 samples (100 samples plus 10 field blanks) were collected in Powderhorn Lake (see maps beginning on page 16). All sample collection and processing procedures followed the 2023 Quality Assurance Project Plan (USFWS 2023). 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 were 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 0.3 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 2022 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 2023, there were zero positive eDNA detections in both the May and September sampling events.

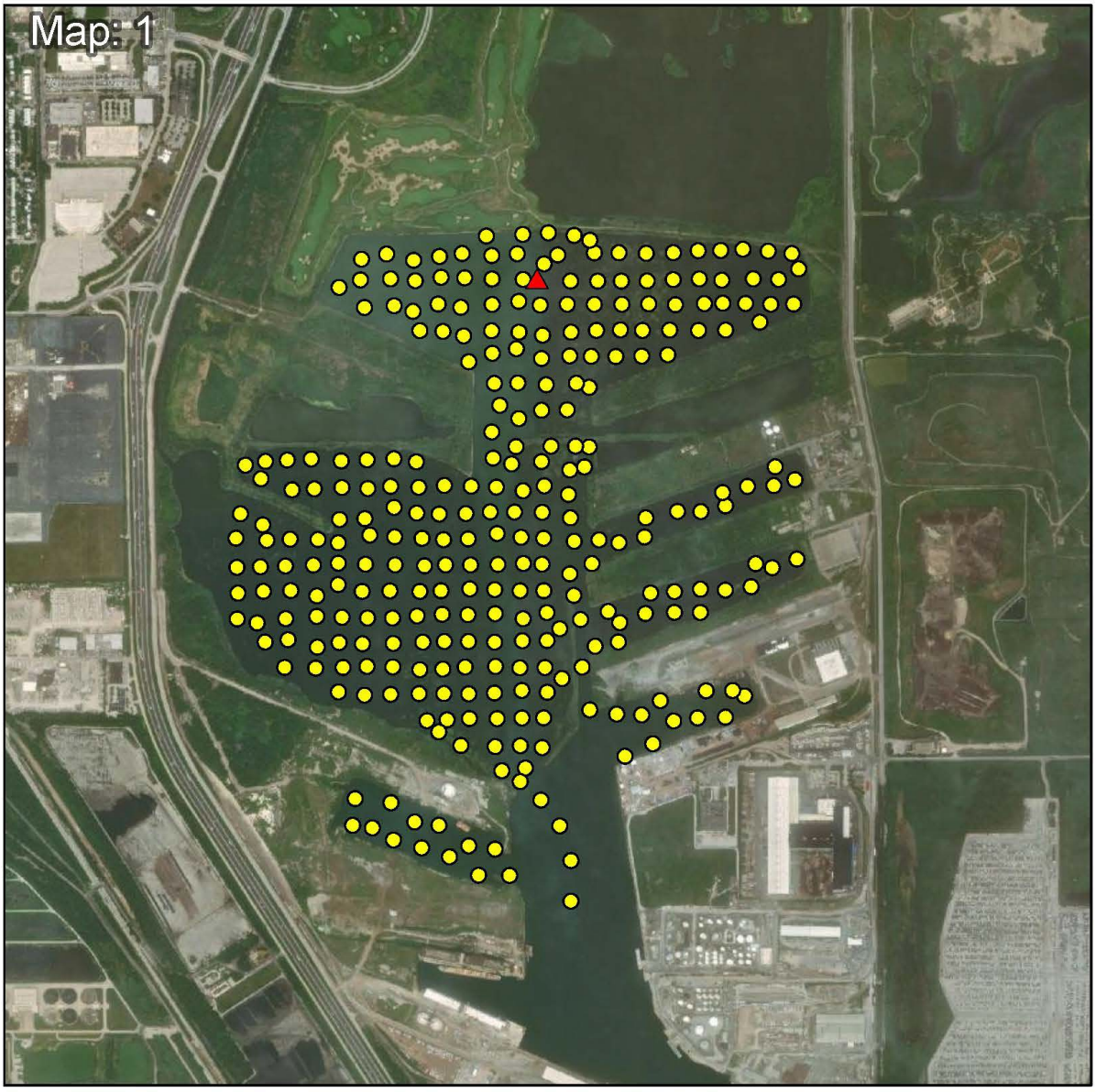
RECOMMENDATIONS

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 of 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.

REFERENCES

U.S. Fish and Wildlife Service (USFWS). 2023. Quality Assurance Project Plan eDNA monitoring of bighead and silver carps. Midwest Region Bloomington, MN. Available: http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf.

Bighead and Silver Carp eDNA Early Detection Results:
Chicago Area Waterway System
Sampling Period: Week of May 8, 2023
Number of Samples Collected: 330



eDNA Sample Points
- Silver carp eDNA only detected
- No eDNA detected

N
W E
S

0 0.13 0.25 0.5
Miles

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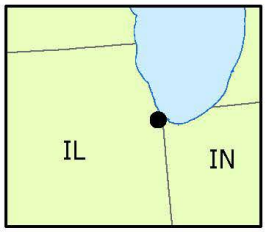
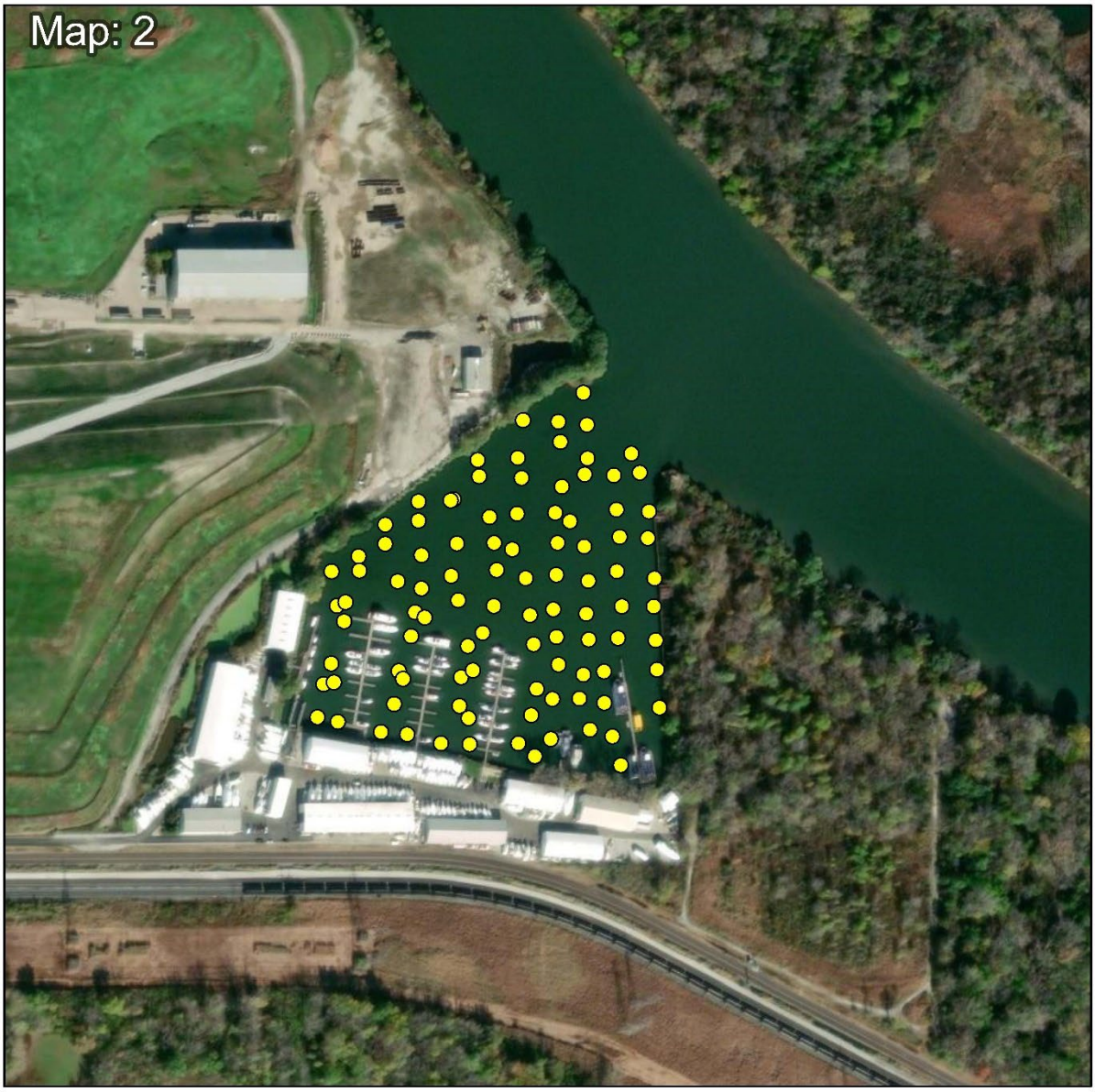


Bighead and Silver Carp eDNA Early Detection Results:
Chicago Area Waterway System
Sampling Period: Week of May 8, 2023
Number of Samples Collected: 110



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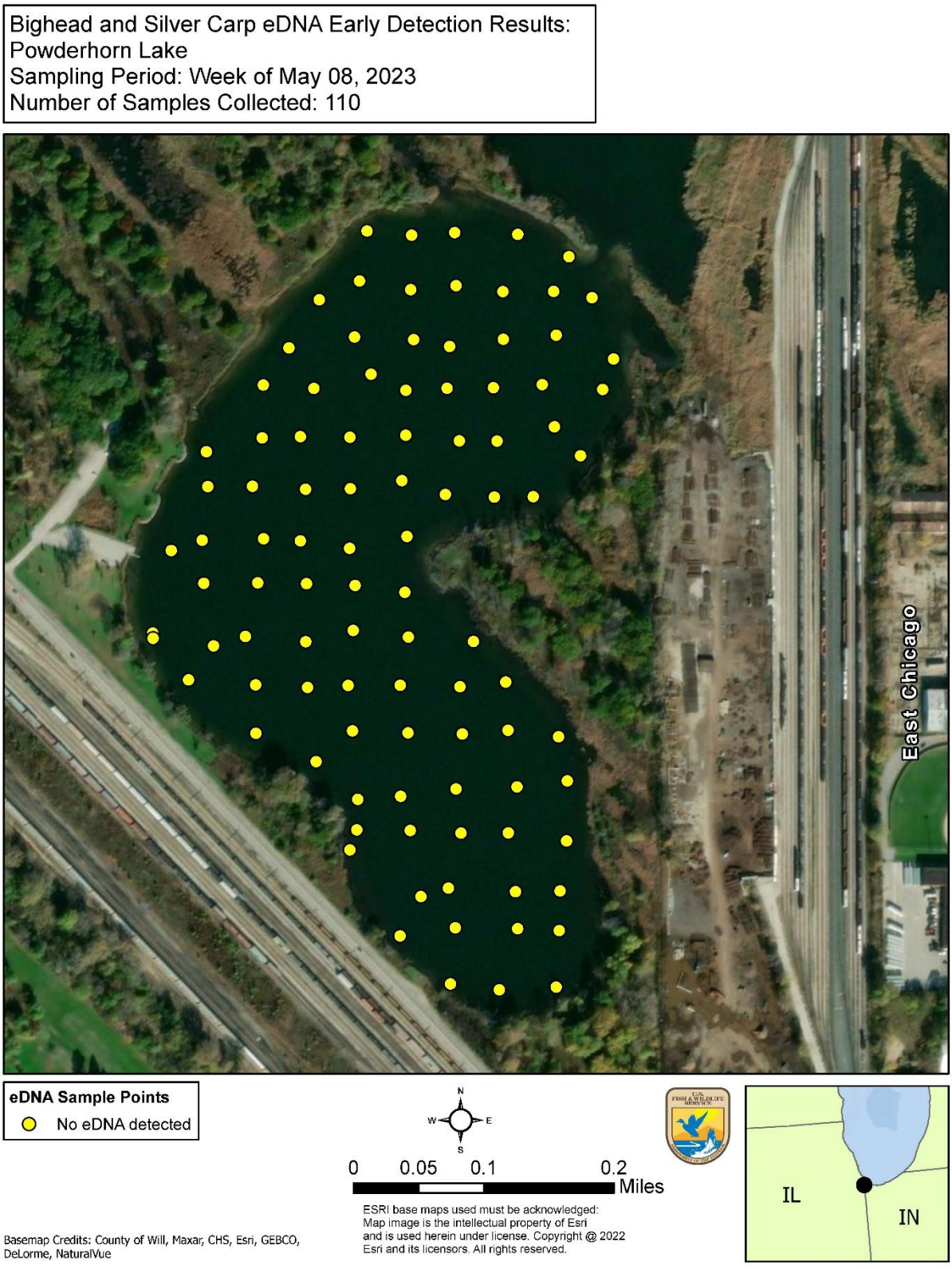
Bighead and Silver Carp eDNA Early Detection Results:
Powderhorn Lake
Sampling Period: Week of May 08, 2023
Number of Samples Collected: 110
East Chicago
eDNA Sample Points
No eDNA detected
N
W
E
S
0
0.05
0.1
0.2
Miles
IL
IN
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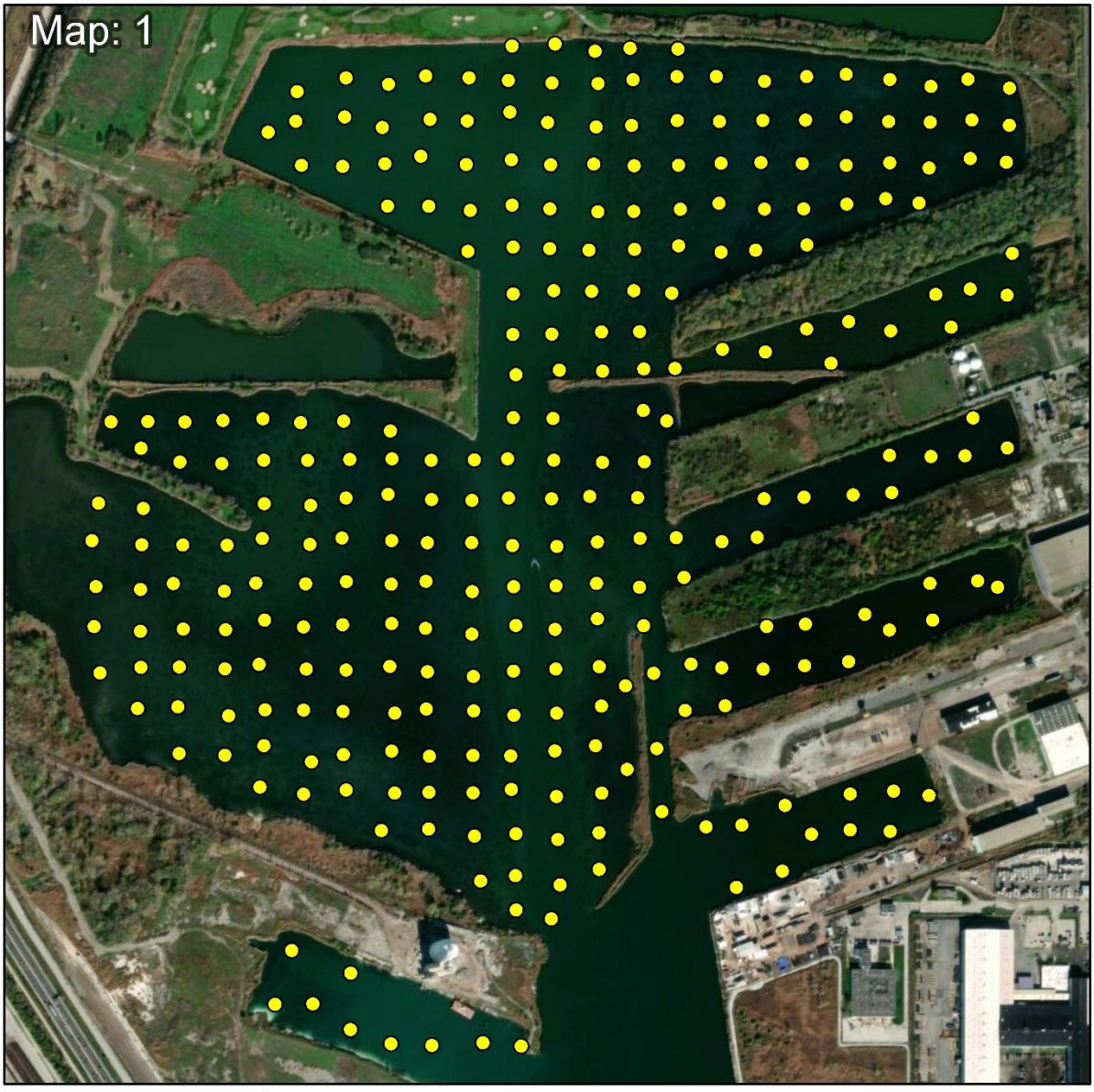
Bighead and Silver Carp eDNA Early Detection Results:
Lake Calumet/Calumet Marina
Sampling Period: Week of September 25, 2023
Number of Samples Collected: 330



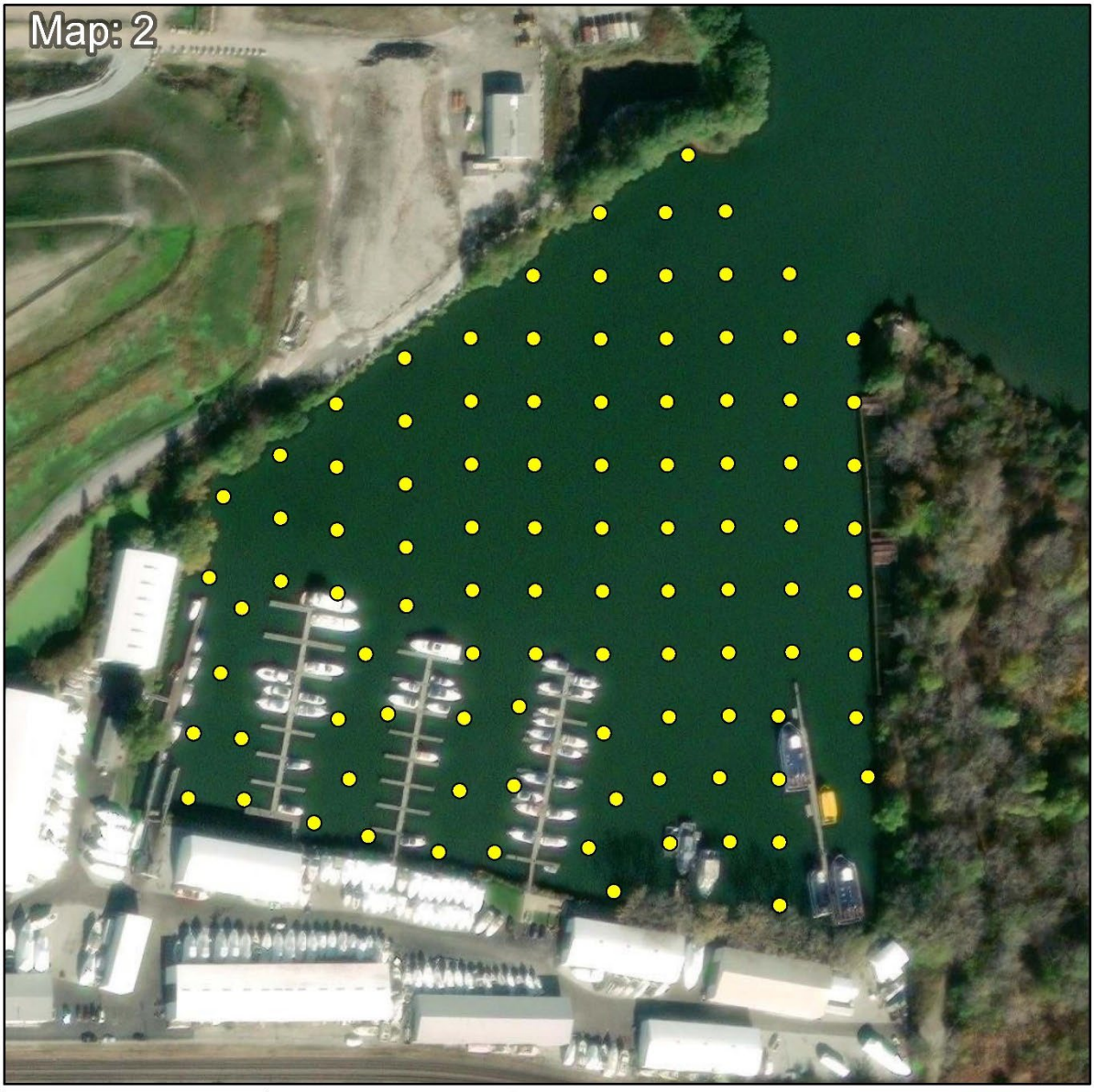
eDNA Sample Points
No eDNA detected

N
W E
S

0 0.05 0.1 0.2 0.3 0.4
Miles

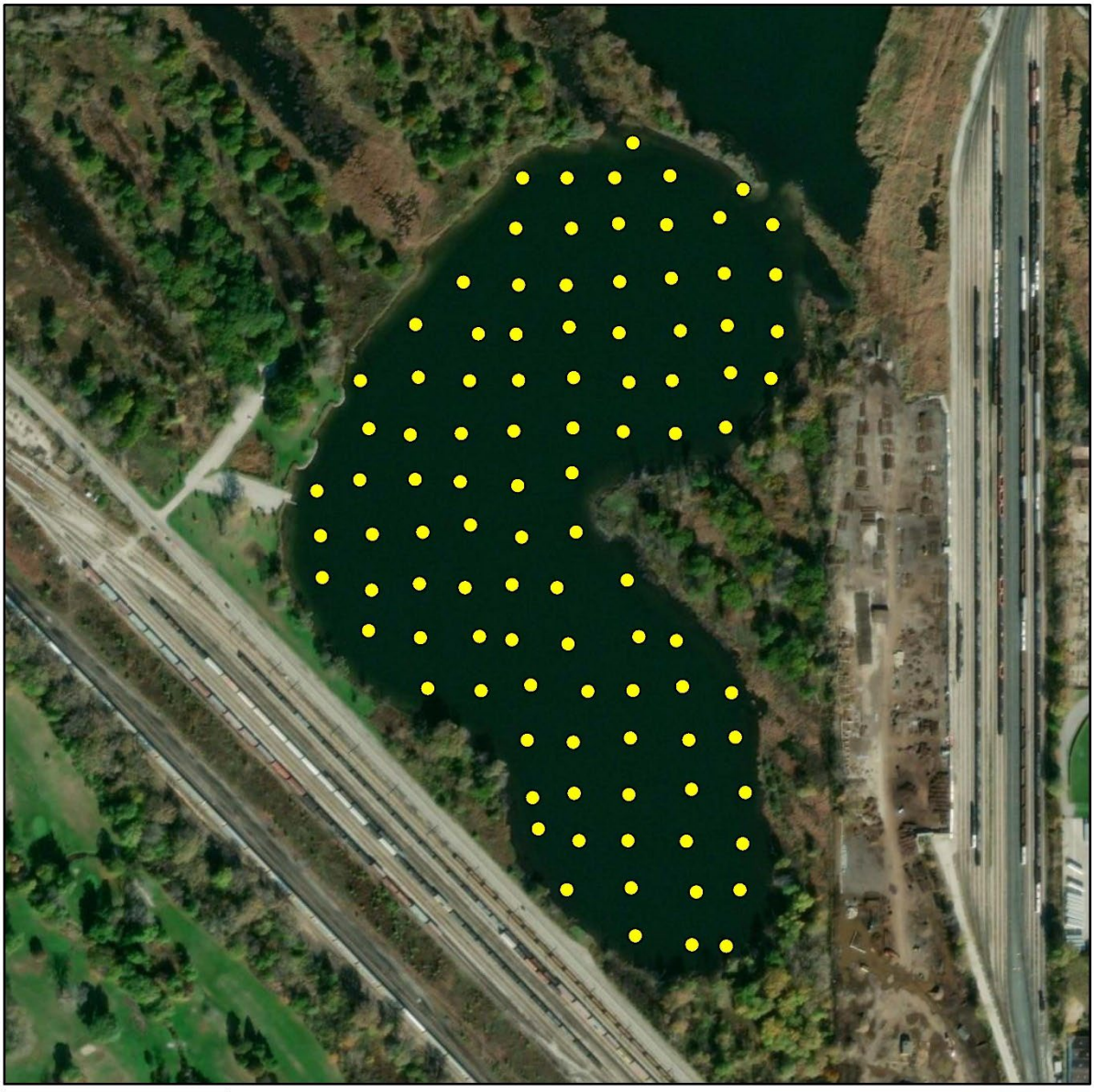
Basemap Credits: County of Will, Maxar, Esri, GEBCO, Garmin, NaturalVue

Bighead and Silver Carp eDNA Early Detection Results:
Lake Calumet/Calumet Marina
Sampling Period: Week of September 25, 2023
Number of Samples Collected: 110



Basemap Credits: County of Will, Maxar, Esri, GEBCO, Garmin, NaturalVue

Bighead and Silver Carp eDNA Early Detection Results:
Powderhorn Lake
Sampling Period: Week of Sept 25th, 2023
Number of Samples Collected: 110



Basemap Credits: County of Will, Maxar, Esri, GEBCO, Garmin, NaturalVue

TELEMETRY MONITORING PLAN

Participating Agencies: USACE (lead); USFWS, SIUC, ILDNR, 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 Action Plan 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 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 ILDNR 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 Work Group.

PROJECT HIGHLIGHTS

- To date, USACE has acquired 45.7 million detections from 862 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 continue to be detected near the EDBS.
- Invasive carp show heavy use of Dresden Island Nuclear Power Plant discharge canal when river temperatures are below 20 ◦C, indicating possible removal windows.
- Three passages (two upstream, one downstream) of Common Carp through Bear Trap Dam occurred within a 4-day window in early July following a large rainfall event when gates were open.

METHODS

Based on MRWG expert opinion, it was recommended that 200 active transmitters in fish be maintained within the study area for telemetry monitoring. At the end of the 2022 season, approximately 169 tags (V16 InnovaSea transmitters) remained active. In 2023, 56 Silver Carp (4 in March, 52 in October) and 3 Bighead Carp (all in October) were tagged within Dresden Island Pool. In May, 14 Common Carp were captured and tagged, with nine released in Lockport Pool and five released into Brandon Road Pool directly below the Bear Trap Dam water control structure on the Des Plaines River. Two additional Common Carp were tagged and released in Brandon Road Pool upstream of Brandon Road Lock and Dam. This tagging effort brought the number of tags to 164 throughout the study area. As of November 2023, 57 Common Carp tags are active (42 detected on 2+ receivers in 2023) in Lockport Pool, 36 Common Carp tags are active (13 detected on 2+ receivers in 2023) in Brandon Road Pool, and 71 USACE tags are active (60 Silver Carp and 3 Bighead Carp detected on 2+ receivers in 2023) in Dresden Island Pool. Nine Common Carp tags are expected to expire in October 2024 in Lockport Pool.

Tagged surrogate fish have been previously released below the EDBS, but no tagged invasive carp were released above Brandon Road Lock and Dam. 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. 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 fishes previously released within lower Lockport Pool were originally captured from upper Lockport Pool. Over the last three years, the focus for Lockport Pool has been on capturing and tagging fish from below the barrier to understand how they move throughout the pool. There are several fish previously captured above the EDBS and released below the EDBS with active tags. Table 1 identifies all fishes containing active transmitters between November 14, 2022, and November 14, 2023, along with their release point within the system. The number of tagged fish will vary from the number of active tags used in analysis due to emigration from the system, mortality, and removal methods before analysis.

Table 1. *Active Fish and Release Points within the Study Area in 2023*

Release Location	Species Implanted	Capture Pool	Number of Tagged Fish
Lower Lockport Pool (Downstream of EDBS)	Common Carp	Upper	11
Lower Lockport Pool (Downstream of EDBS)	Common Carp	Lower	46
Lower Lockport sub-total	--	--	**57**
Brandon Road Pool	Common Carp	Brandon	31
Brandon Road Pool	Common Carp	Lockport	5
Brandon Road sub-total	--	--	**36**
Dresden Island Pool	Bighead Carp	Dresden	4
Dresden Island Pool	Silver Carp	Dresden	67
Dresden Island sub-total	--	--	**71**
Total	--	--	**164**

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 (2012). Stationary receivers removed for winter in November 2022 were redeployed in March 2023. The layout of receiver positions within the study remained almost the same as the previous year (MRP 2020, 2021). The revised study area was covered by 29 USACE stationary receivers extending approximately 33.5 RM from the Cal-Sag Channel in Worth, Illinois, to the Dresden Island Lock and Dam on the Illinois River in Channahon, Illinois (Appendix A). 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. 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.

Barrier Efficacy – Barrier efficacy was assessed through 11 stationary receivers—four upstream and seven downstream of the EDBS within 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 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.

Inter-pool Movement – Four pools are defined within the study area, demarcated by the lock and dams within the system and the EDBS. Lockport Pool is defined as all waters upstream of 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 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 the study area, data was collected within the pool by SIUC and USGS, which was shared with USACE. VR2W/VR2Tx receivers were placed above and below each lock and dam, as well as at any other potential transfer pathways between pools. Data from the VR2W/VR2Tx receivers was analyzed for probable inter-pool movement. Dates with the nearest time interval and the pathway used for each passage were recorded for each tagged fish found to move between pools.

Invasive Carp Movement Analysis – A total of 59 USACE-tagged invasive carp (3 Bighead Carp and 56 Silver Carp) were within the Dresden Island Pool in 2023. The movement of individual fish was tracked via InnovaSea stationary receivers (Appendix A) strategically placed throughout the Des Plaines and Kankakee Rivers. VR2W/VR2Tx detections were then uploaded into the InnovaSea VUE software. Two new receivers were placed during 2023, one within the Constellation Energy Dresden Island Nuclear Power Plant discharge canal (placed in late 2022) and a second to Rock Run Rookery (placed in July 2023), bringing the total receivers within Dresden Island to 13.

Telemetry data from Dresden Island was compared to two abiotic factors: discharge and water temperature. Discharge data obtained from Brandon Road Lock and Dam and Dresden Island Lock and Dam were used to compare the number of unique invasive carp detected per receiver per day. Two sources of discharge were investigated because of the potential influence of the Kankakee River on discharge values from Dresden Island Lock and Dam. Discharge data is displayed in cfs*100 (i.e., 200 cfs*100 = 20,000 cfs). Water temperature data was collected from two locations. The first was from the VR2Tx receiver location within the Constellation Energy Dresden Island Nuclear Power Plant discharge canal starting March 23, 2023, until November 14,

2023. The second temperature data source is from the USGS gage #05539670 on the Des Plaines River near Channahon, Illinois (41.4144, -88.2144). Both data sources are averaged values from data collected throughout each day.

RESULTS AND DISCUSSION

The results discussed in this section will address the three goals of the study. As of November 2023, 45.7 million detections from 862 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 by USACE for several years, the Shedd Aquarium released 80 fish comprised of Largemouth Bass, Common Carp, Bluegill, Pumpkinseed, Black Crappie, Green Sunfish, and Walleye. The Chicago District continues to maintain receivers upstream of the EDBS to monitor any movement 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 the risk of Bighead Carp and Silver Carp presence (barrier efficacy).

In 2023, 69 tagged surrogate fish with active transmitters were released between Lockport Lock and Dam and the EDBS. Seven stationary receivers detected the movement of 57 tagged surrogate fish throughout the pool in 2023. There was a total of 2,905,089 detections within lower Lockport Pool and zero detections in upper Lockport Pool, indicating no passage of tagged fish through the EDBS. A total of 41 unique tagged Common Carp were detected near the EDBS, and the monthly counts ranged from 18 to 40, with July 2023 having the largest number of tagged individuals present (Table 2).

Table 2. *The number of unique fish detected at each station monthly. The total represents the total number of unique fish transmitter numbers detected at that receiver during sample period.*

*Receiver malfunction resulting in no detections.

DATE (MONTH - YEAR)	LL 10	LL 20	LL 30	LL 35	LL 40	LL 50	LL 60
NOV 22	18	17	18	8	14	13	5
DEC 22	21	19	21	5	12	10	5
JAN 23	20	18	20	3	12	12	5
FEB 23	20	17	21	5	11	10	0*
MAR 23	15	14	16	2	9	9	5
APR 23	19	17	18	9	15	17	0*
MAY 23	24	18	20	18	35	34	0*
JUN 23	29	19	21	15	39	34	0*
JUL 23	40	32	32	30	42	38	0*
AUG 23	26	15	15	6	28	28	0*
SEP 23	28	20	19	11	50	26	3

DATE (MONTH - YEAR)	LL 10	LL 20	LL 30	LL 35	LL 40	LL 50	LL 60
OCT 23	29	16	17	8	28	25	7
NOV 23	27	18	20	10	20	19	4
TOTAL	41	33	34	34	43	40	8

- 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.

From 2010 to 2023, there were 107 occurrences of tagged fish moving downstream and 53 occurrences of upstream movement between navigation pools (Table 3). There were five occurrences of inter-pool movement by five tagged fishes in 2023. Four passages occurred by Common Carp, and one passage occurred by a Silver Carp. One Common Carp moved downstream from Brandon Road to Dresden Island, one Common Carp moved downstream from Lockport to Brandon Road via Bear Trap Dam, and two Common Carp moved upstream from Brandon Road to Lockport via Bear Trap Dam. The single Silver Carp passage was downstream from Dresden Island to Marseilles.

Table 3. *Total occurrences of inter-pool movement by tagged fish from 2010 to 2023.*

Location	Up	Down	Total
Lockport Lock	23	26	49
Control Works	4	36	40
Brandon Road	5	16	21
Dresden Island	21	29	50

All three passages through Bear Trap Dam occurred within a 4-day window in early July (July 2, 3, 5, and 6, 2023) when the gates were open following a localized heavy rainfall event in the Chicagoland area. The downstream passage through Bear Trap Dam occurred on July 2, 2023, when the average cubic feet per second was 2,336; however, the upstream passages occurred when the average daily cubic feet per second was 1,573 on July 3, 2023, and 164 on July 5, 2023. One of the Common Carp that successfully passed upstream through Bear Trap Dam was captured in Lockport Pool prior to tagging and released downstream of Bear Trap Dam in early May. One additional Common Carp (of the five released immediately below Bear Trap Dam) had challenged Bear Trap Dam and was detected on the receiver below Bear Trap Dam during the period of open gates in early July but did not successfully pass upstream. The timing of the Common Carp that passed downstream through Brandon Road likely happened during early July, when Brandon Road Lock was closed for construction, and the fish likely passed downstream through Brandon Road Dam, though the exact date is unknown. Similarly, the exact date and

method of passage of the Silver Carp into Marseilles is unknown but likely occurred in early summer. The passage likely occurred close to the start of the Dresden Island Lock closure for repairs, so it is possible to be either a passage through the lock or dam.

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

USACE tagged four Silver Carp (874 mm ± 64 mm) on May 4, 2023, in collaboration with ILDNR commercial fishing in Dresden Island Pool. On October 19 and 20, 2023, in collaboration with ILDNR's Unified Fishing Method, 52 Silver Carp (845 mm ± 55 mm) and 3 Bighead Carp (1,051 mm ± 46 mm) were tagged. On October 19, 2023, 49 Silver Carp and all 3 Bighead Carp were collected from the Constellation Energy Dresden Island Nuclear Power Plant discharge canal, and 3 Silver Carp were tagged in Rock Run Rookery on October 20, 2023. Invasive carp tagged in October were excluded from the analysis due to late tagging coinciding with fall receiver downloads.

A total of 20 invasive carp consisting of 712,848 detections in Dresden Island Pool across 13 USACE receivers and two USGS real-time receivers were included for analysis. A large percentage of the unique fish detected daily from early December until mid-May were detected on receiver DI97, located within the Constellation Energy Dresden Island Nuclear Power Plant discharge canal (Figure 1a). This discharge canal is a thermal refuge and known congregation location for invasive carp within Dresden Island Pool and a successful area for contracted commercial fishermen to target. Invasive carp started to disperse from the discharge canal in early June when water temperatures in the discharge canal hit approximately 25 ◦C and the main channel temperatures were near 20 ◦C. On June 11, 2023, main channel water temperatures had dropped to 20.6 ◦C from 23.5 ◦C, and eight invasive carp moved back into the discharge canal. Using drops in main channel temperature may allow contracted commercial fishermen to further target invasive carp within the discharge canal during warmer months, but these windows will likely be short. Once the main channel water temperature hit 20 ◦C, the percent of unique invasive carp detected on the USGS real-time receiver outside the discharge canal increased. Even during warmer months, when the main channel water temperatures were over 20 ◦C, one to two invasive carp were detected within the discharge canal, although the number of detections was low, indicating fish did not use the canal for very long. Invasive carp started to reappear within the discharge canal for longer periods in mid-October once the main channel temperature started to drop below 15 ◦C and the discharge canal temperature remained around 20 ◦C.

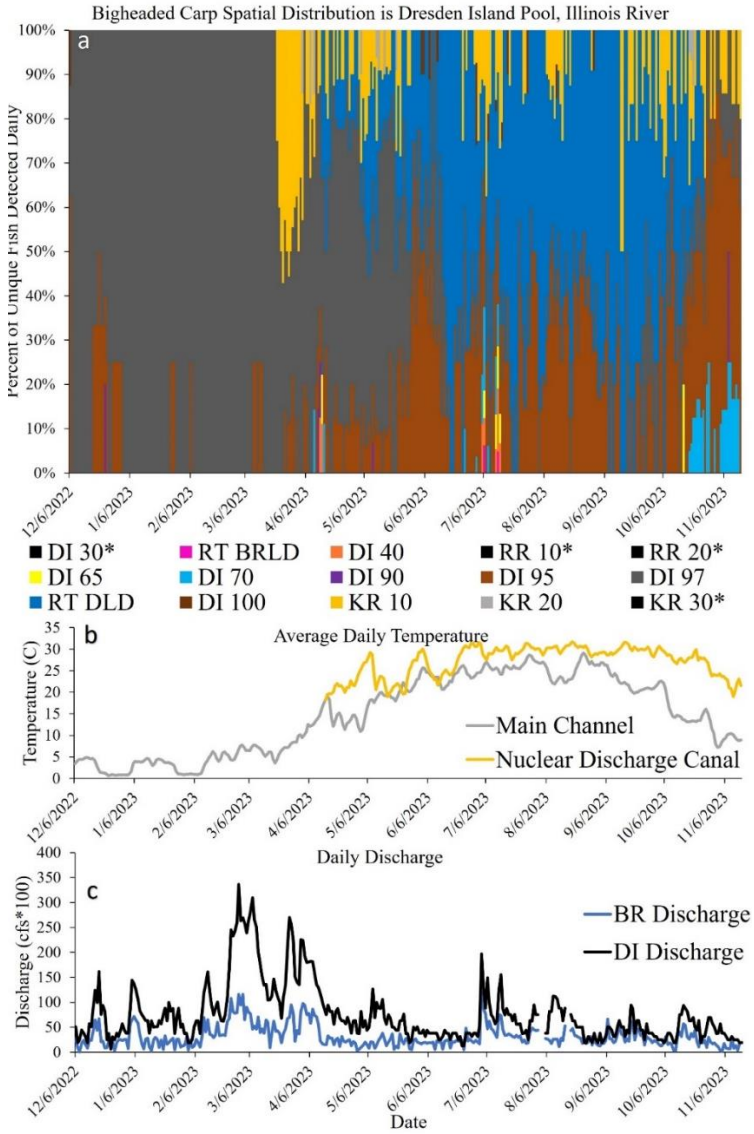
Invasive carp were detected moving upstream to receivers DI65 and DI40, as well as KR20, during early April; this appears to coincide with a major discharge event (Figure 1b) and the first major increase in water temperature of the main channel, as shown in Figure 1c. A similar upstream movement of invasive carp occurred in early July when discharge values increased greatly following a large rainfall event in Chicago (Figure 1b), where a single Silver Carp was detected twice on the real-time receiver below Brandon Road Lock and Dam. However, this fish was not detected on receiver DI30, located within the lock approach, showing that this Silver Carp did not likely approach the lock but rather moved toward the spillway.

No tagged invasive carp were detected within Rock Run Rookery in 2023; however, two tagged Silver Carp with expired transmitters were collected in Rock Run Rookery during an ILDNR response within Rock Run in early September. No tagged invasive carp were detected at receiver KR30, located just downstream of Wilmington Dam.

Figure 1a: *Stacked bar graph representing the percent of unique acoustic-tagged invasive carp detected on acoustic receivers each day. Each color represents a different acoustic receiver. * Denotes receivers that did not detect any invasive carp during the study period.*

Figure 1b: *Line graph showing average daily temperature taken at two different locations throughout the study period. The gold line represents the temperature from within Constellation Energy Dresden Island Nuclear Power Plant discharge canal (41.3949, -88.2696) and the grey represents the temperature from USGS Gage #05539670 (41.4144, -88.2144). Temperature data for the Nuclear Power Plant discharge canal start on 3/23/2023 due to the placement of a new receiver with temperature recording capabilities.*

Figure 1c*: Line graph showing the daily discharge values (cfs: cubic feet per second) taken at Brandon Road Lock and Dam (blue) and Dresden Island Lock and Dam (black) during the study period.*



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 2024. 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 recommends placing two real-time receivers within Dresden Island Pool, one within the discharge canal and one within Rock Run Rookery. Placement of these will allow for instantaneous knowledge of invasive carp use of these habitats and allow for immediate deployment of contracted commercial fishermen. In combination with the placement of a real-time receiver in Rock Run Rookery, additional tagging of invasive carp should occur in Rock Run to determine the timing of when invasive carp start to use Rock Run Rookery. USACE also recommends placing additional VR2 receivers within other areas where contracted commercial fishermen capture invasive carp (e.g., Harborside Marina Backwater) to determine habitat use and timing. USACE recommends increased removal efforts during colder months from October to May when larger numbers of invasive carp are likely to be present in known areas, such as the discharge canal. Coordination between the USACE and ILDNR for removal should occur to maximize efficiency.

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Invasive Carp Monitoring and Response Work Group (MRWG). 2020. 2020 Monitoring and Response Plan for Invasive Carp in the upper Illinois River and Chicago Area Waterway System. Illinois, Chicago.

Invasive Carp Monitoring and Response Work Group (MRWG). 2021. 2021 Monitoring and Response Plan Interim Summary Report for Invasive Carp in the upper Illinois River and Chicago Area Waterway System. Illinois, Chicago.

TELEMETRY MONITORING PLAN
APPENDIX A: RECEIVER NETWORK MAPS

Figure A1. *2023 Upper Lockport Pool Receiver Placement Map*

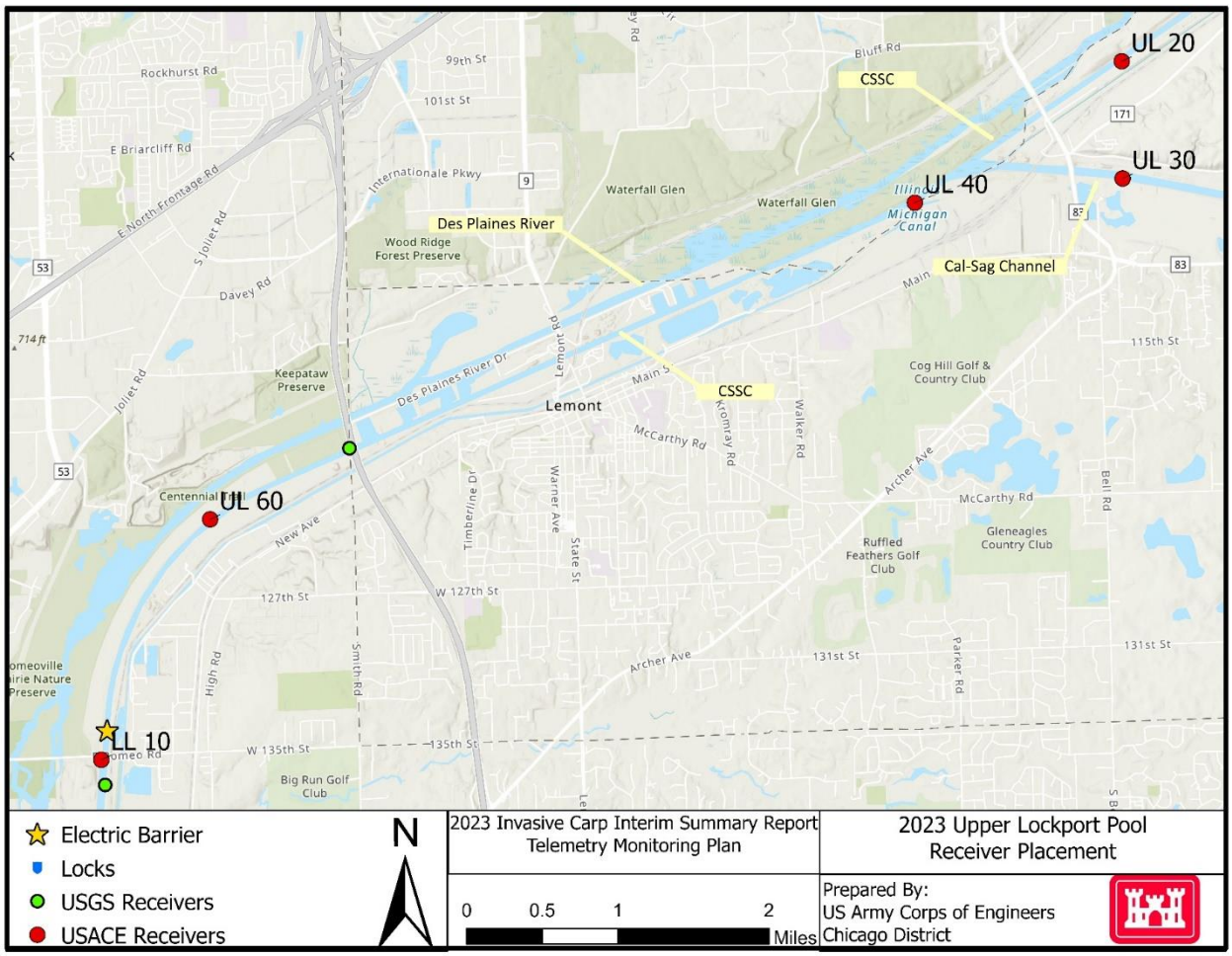


Figure A2. *2023 Lower Lockport Pool Receiver Placement Map*

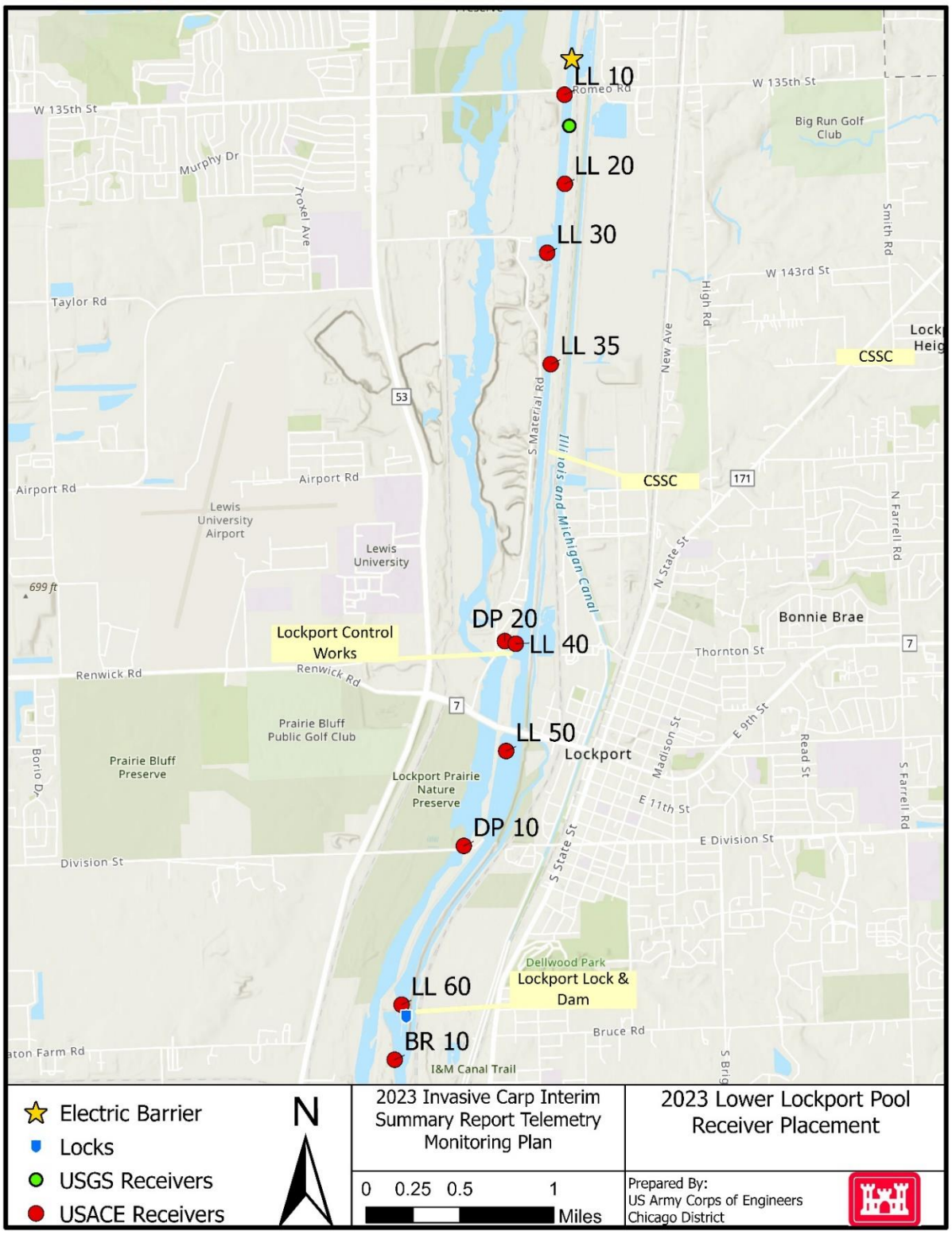


Figure A3. *2023 Brandon Road Pool Receiver Placement Map*

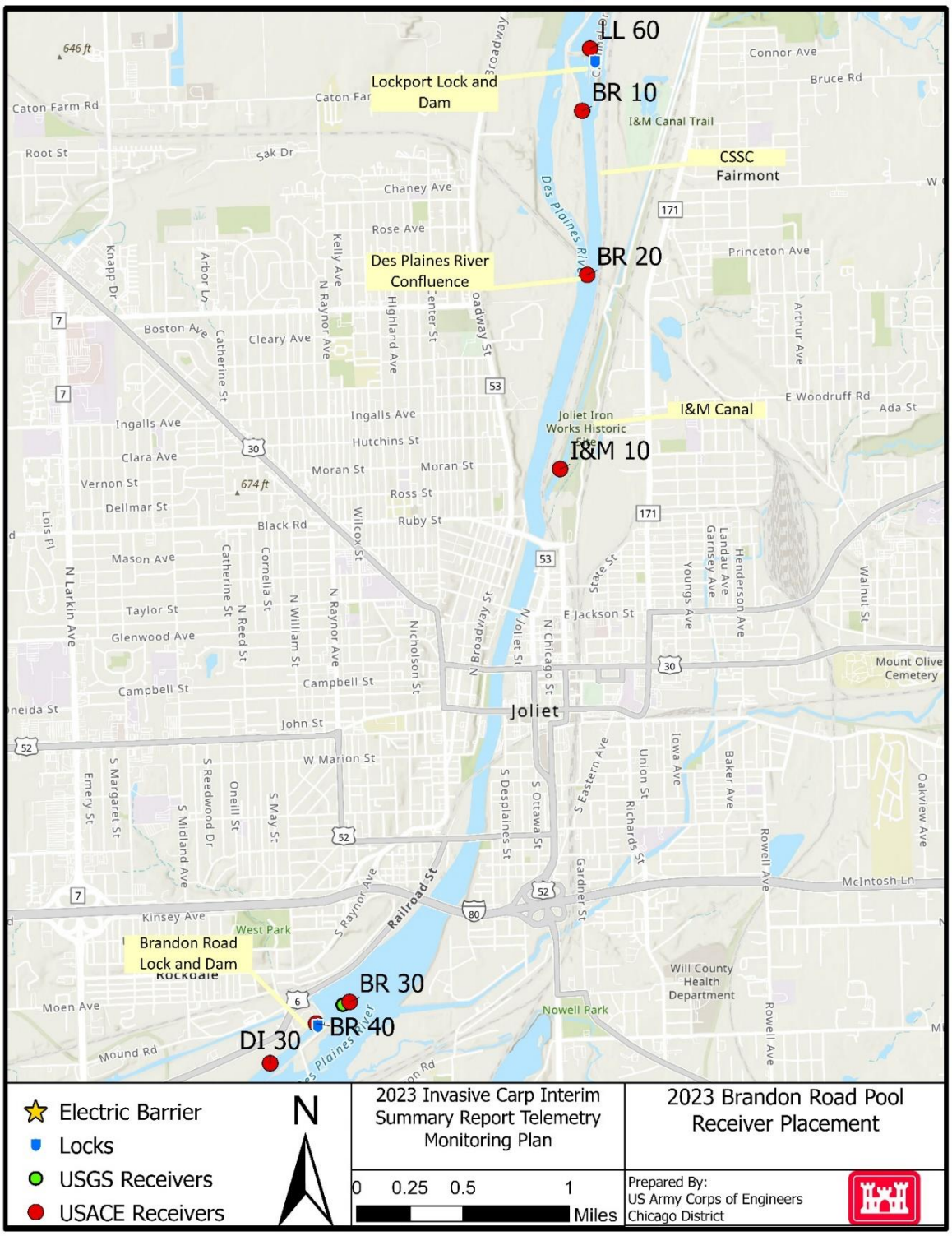
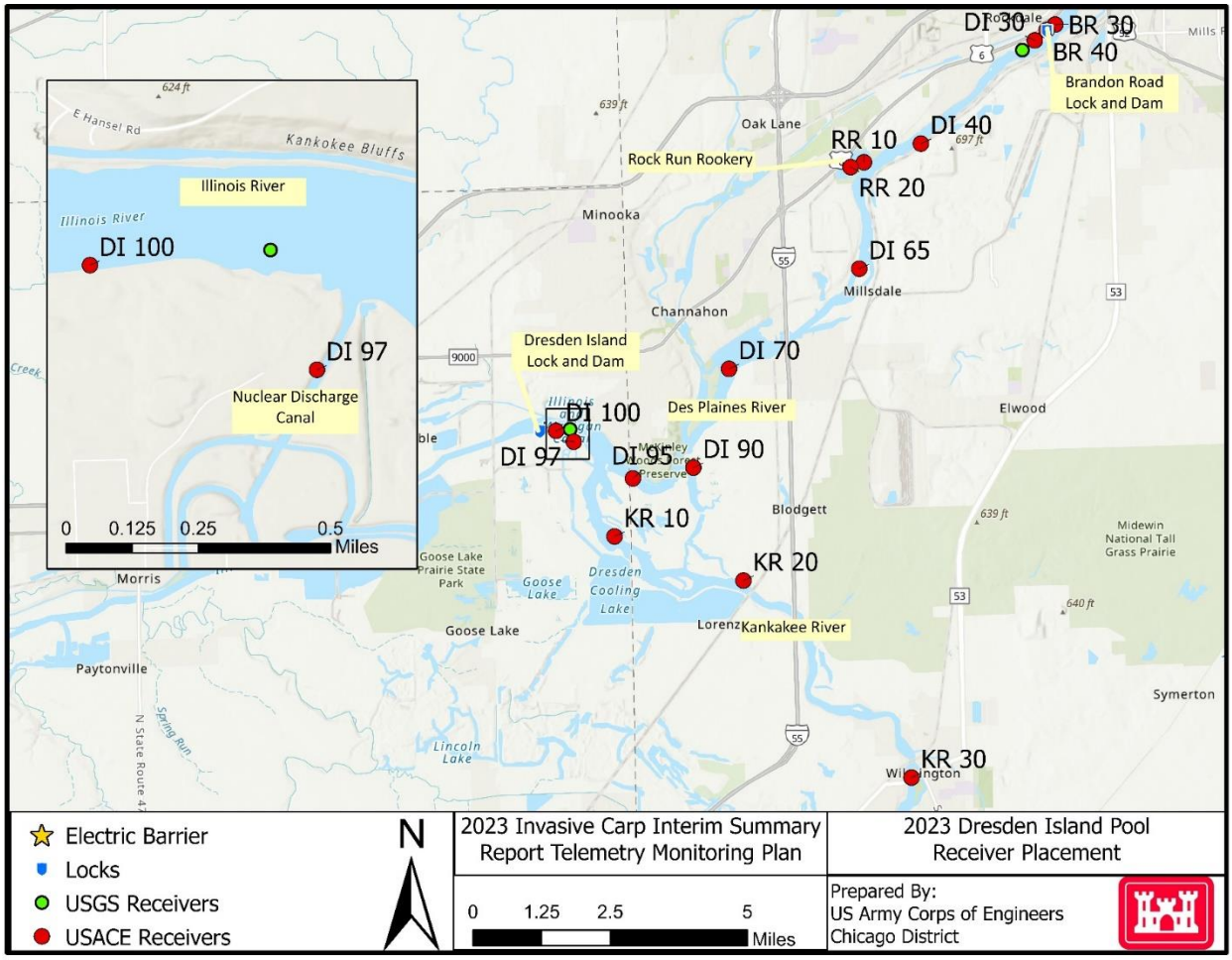


Figure A4. *2023 Dresden Island Pool Receiver Placement Map*



USGS TELEMETRY PROJECT

Participating Agencies: USGS, SIU, USACE, ILDNR, 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 (i.e., Bighead Carp and Silver Carp) and surrogate fish species with acoustic transmitters has become an invaluable management tool in the Upper IWW (i.e., upper Illinois River, lower Des Plaines River, and the CAWS). For example, movement probabilities between adjacent navigation pools need to be estimated to parameterize models, such as the SEICarP Model—a population model used in scenario planning by the MRWG to evaluate alternative management actions (Kallis et al. 2023). These movement probabilities are estimated from the telemetry data obtained from a longitudinal network of strategically placed receivers that detect bigheaded carp that have been implanted with acoustic transmitters (i.e., tagged). In addition, fish removal by contracted fishers has become the primary method of controlling bigheaded carp in the upper Illinois and lower Des Plaines rivers. Variable patterns in bigheaded carp distribution, habitat, and movement, influenced by seasonal and environmental conditions, make targeting bigheaded carp for removal and containment challenging and costly. Understanding these movement patterns for bigheaded carp through modeling and real-time telemetry applications informs removal efforts and facilitates monitoring and contingency actions based on fish movements.

To develop a better understanding of fish movement dynamics to meet management objectives, an existing network of real-time and data-logging acoustic receivers in the Upper IWW is collaboratively managed by a multi-agency team (see Participating Agencies section above). A Telemetry Work Group has been established by the MRWG to ensure the multi-agency telemetry efforts are coordinated to efficiently and effectively meet the MRWG goals. This work group plans and executes the placement of receivers, tagging of bigheaded carp with acoustic transmitters, and management of the telemetry data. After the establishment of a standardized telemetry database (moved to the USGS Database project in 2020), two primary objectives of the Telemetry Work Group to meet the MRWG goals remained. These include (1) providing movement probabilities and telemetry data for population modeling efforts (e.g., population or stock assessment modeling) and (2) deploying, maintaining, and serving data from real-time acoustic receivers to inform contingency planning and fish removal. The specific objectives of the group are assessed annually, and each partner agency has its own tasks. The 2023 USGS-specific objectives are outlined here.

OBJECTIVES

Telemetry Projects in Support of Population Modeling

- Movement probability modeling: The transition to a custom Bayesian multi-state model to estimate movement probabilities will support more efficient, effective, and robust population modeling by overcoming the shortcomings of Program MARK (a Windows-based software application developed for the analysis of data from marked individuals).
- Feasibility study: Estimate fishing mortality from existing telemetry and mark-recapture data from the Illinois River. USGS and SIU 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.
- Feasibility study: Explore the inclusion of additional parameters and predictor variables in a comprehensive invasive carp movement model. USGS, in coordination with the modeling work group, 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. A manuscript of this multi-state model has been accepted for publication (Stanton et al. 2024). An updated model run using data from 2012 to 2024 is planned for 2025.
- *Fishing Mortality Feasibility Study:* USGS and SIU have collated the existing tag recovery and contract removal data from a prior mark-recapture study conducted in the Marseilles and Starved Rock pools in 2012 and 2013, where high and low reward external markings were used. These data are being combined with existing telemetry data from the same period.
- *Real-time Receiver Network and Alert System*: Five real-time receivers were maintained in the Upper IWW in 2023 (Table 1). A new and simplified alert system for bigheaded carp detections in areas of management interest was rolled out to partners in 2022 and expanded to include all real-time receivers in 2023.

Table 1. *Locations of real-time receivers on the Upper IWW. Available at:*

https://il.water.usgs.gov/data/Fish_Tracks_Real_Time

No.	Station	Location
1	Chicago Sanitary and Ship Canal above the EDBS	Lemont, IL
2	Chicago Sanitary and Ship Canal below the EDBS	Romeoville, IL
3	Des Plaines River above Brandon Road Lock and Dam	Rockdale, IL
4	Des Plaines River below Brandon Road Lock and Dam	Rockdale, IL
5	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 Work Group and Modeling Work Group of the MRWG, developed a Bayesian model to estimate inter-pool movement probabilities needed for SEICarP or other population modeling efforts. 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 Program MARK. For example, previous multi-state modeling with Program MARK was 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. Additionally, Program MARK did not provide uncertainty estimates for the estimated parameters, whereas hierarchical models performed in a Bayesian framework provide a direct expression.

One component of the feasibility study to estimate fishing mortality using telemetry and tag return data was to create a model that could be used by natural resource managers to determine the needed tagging effort to estimate fishing mortality for their system. The model was parameterized with constant and variable harvest rates, short- and long-term study durations, varying levels of tagging (between 50 and 4000 individuals per year), two rates of tag retention (best-case and worst-case-scenarios), and two tag reporting rates (best-case and worst case-scenarios). The second component of this study is to use the existing tag-return and telemetry data from the Marseilles and Starved Rock pools from 2012 and 2013.

A network of five real-time receivers was redeployed and maintained in the Upper IWW by USGS crews in the spring and summer of 2023. 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 in Support of Modeling

- *Movement probability model.* The new model was developed and successfully run on the 2012 to 2019 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 through 2024. We will work with the Modeling Work Group to determine the best way to support population modeling efforts using telemetry collected beyond 2019.
- *Feasibility study to estimate fishing mortality from existing telemetry and mark-recapture data from the Illinois River.* USGS worked with the USFWS to create a model to guide managers in mark-recapture studies to estimate fishing mortality. The manuscript is currently in review. USGS also worked with SIU to develop a study plan to incorporate existing telemetry data into the mark-recapture data collected in the Marseilles and Starved Rock pools from 2012 and 2013. Additional model development and analysis are ongoing.
- *Feasibility study to include additional parameters and predictor variables in a comprehensive invasive carp movement model.* This sub-objective was not prioritized by partners in 2023, but USGS plans to explore this in 2024 by meeting with the Modeling Work Group.

Real-time Receiver Network

USGS personnel monitored, downloaded, and maintained data from five real-time receivers in the Upper IWW in 2023. Locations of the five real-time receivers in the Upper IWW are shown in Table 1 (previous page). Two additional receivers, located in the Marseilles Pool, are also maintained by the USGS, but these are funded by another (deterrent) project. Data from receivers are used to alert partner agencies when bigheaded carp tagged with ultrasonic transmitters are detected. Four real-time receivers are in areas of management concern (upstream of the bigheaded carp invasion front in upper Dresden Island Pool; receiver locations one through four in Table 1 [previous page]). Receivers one through three (i.e., those upstream of Brandon Road Lock & Dam) did not detect any confirmed bigheaded carp in 2023. Receiver four (Des Plaines River below Brandon Road Lock and Dam) detected one Silver Carp on two dates in July 2023. All the receivers were accessed remotely, and the data were made available online. Detection data and summaries were shared with partners throughout the year.

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Stanton JC, Brey MK, Coulter AC, Stewert DR, and Knights BK. 2024 (In press). Bayesian multistate models for measuring invasive carp movement and evaluating telemetry array performance. PeerJ.

USFWS ILLINOIS WATERWAY HYDROACOUSTICS

Participating Agencies: USFWS Carterville FWCO (lead) and USACE Chicago District (field and logistical support)

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

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 (USACE 2010; USACE Chicago District *n.d.*). Observational evidence from previous studies suggests fish may be able to bypass the electric barrier by swimming alongside metal-hull barges or by being involuntarily dragged by barges (Parker *et al.* 2015). 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. Throughout 2023, split-beam hydroacoustic surveys were performed within and below the EDBS on a bi-weekly basis to determine these periods of elevated risk. Split-beam hydroacoustic surveys of the Lockport, Brandon Road, and Dresden Island Pools of the Upper IWW were also conducted 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 assisting managers in making informed decisions.

OBJECTIVES

- Evaluate the abundance of fish within and directly below the EDBS bi-weekly throughout the year to inform contingency response and barrier management.
- Determine the density of fish in the three upper navigation pools within the Upper IWW.
- 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 September and October 2023 detected high abundances of large fish targets within the EDBS compared to historical data (13 targets on September 5 and 9 targets on October 5. Both surveys reflect an aggregate number of detections across three replicate passes).
- Fish abundances directly downstream of the EDBS across surveys remained relatively low throughout the year. Spikes in abundance in mid-March and early fall were observed, which differed from trends of previous years.

- Large fish densities in mobile hydroacoustic surveys conducted in Lockport, Brandon Road, and Dresden Island pools in 2023 were generally low and similar to past years, except for above-average large fish densities in October 2023 in Brandon Road and Dresden Island Pools.

METHODS

From February 7 through December 11, 2023, horizontal, split-beam hydroacoustic surveys were conducted biweekly-to-monthly at the CSSC EDBS to provide regular monitoring of fish abundance and distribution patterns. Survey transects began approximately 1.2 kilometers below the EDBS at 41.629521 N, -88.061659 W. 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 the survey start point. 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 during 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.6.4® 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.6.4® before all data collection. A tungsten carbide calibration sphere was used for the on-axis calibration of the split-beam acoustic transducers following methods from Demer *et al.* (2015).

Split-beam hydroacoustic data were post-processed in Echoview® v. 13.1. 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 outlined in Bouska *et al.* (2023). The analysis template followed the general methods reported by MacNamara *et al.* (2016), and single targets were detected using parameter values from Parker-Stetter *et al.* (2009). Data collected outside of the analysis bounds (analysis bounds: between 41.629521 N and the Demonstration Barrier's upper parasitic structure) were 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)

(Bouska *et al.* 2023). 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.

In August and October 2023, hydroacoustic surveys were conducted in Dresden Island, Brandon Road, and Lockport navigation pools to quantify the density and spatial distribution of the fish community in the Upper IWW. The surveys were conducted using the same equipment, collection techniques, and analysis methods used for 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

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 February to December 2023 (mean = 2.2 large fish targets detected per survey across all replicates; the range was 0 to 13 individual large fish targets across all replicates; Figure 1 [A]). Surveys on September 5 (13 targets) and October 5, 2023 (9 targets) observed the two highest summed numbers of fish targets in the EDBS since project inception. 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 (mean = 6.2 large fish targets detected per survey across all replicates; the range was 1 to 19 individual large fish targets across all replicates; Figure 1 [B]). When 2023 observations were compared to previous years, patterns of fish targets detected below and within the EDBS differed. A few spikes were observed in mid-March and early fall rather than in the summer, as observed in previous years (Figure 1). Environmental variables, such as flow and water temperature, were analyzed as possible explanations for community changes. Flow and water temperature both had a weak positive Spearman correlation coefficient; however, they were statistically significant when a generalized linear mixed model was applied (Figure 2). This suggests that flow and water temperature are only two of the potentially many variables affecting the number of large fish detected.

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 2023 compared with past surveys from 2018 to 2022.*

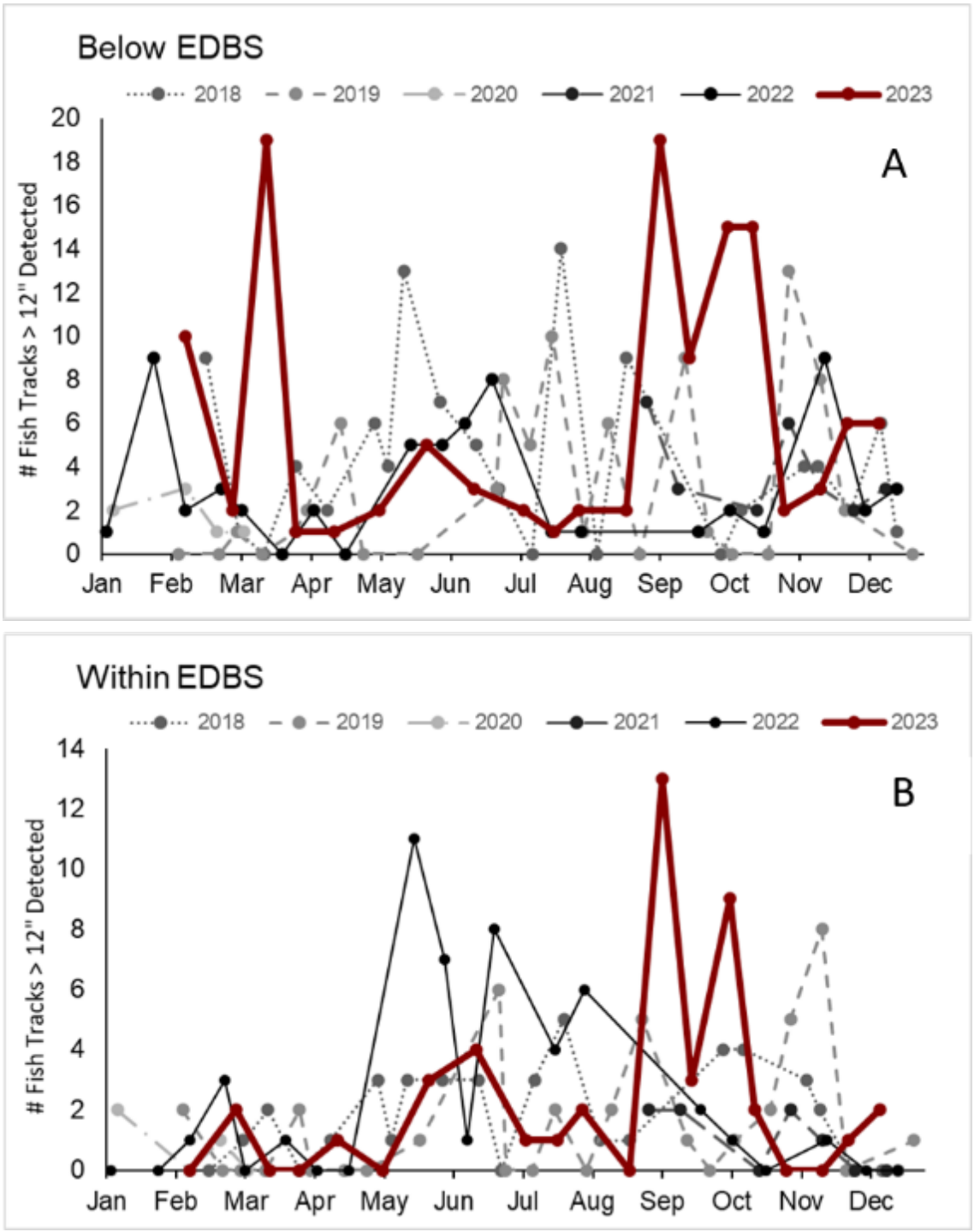
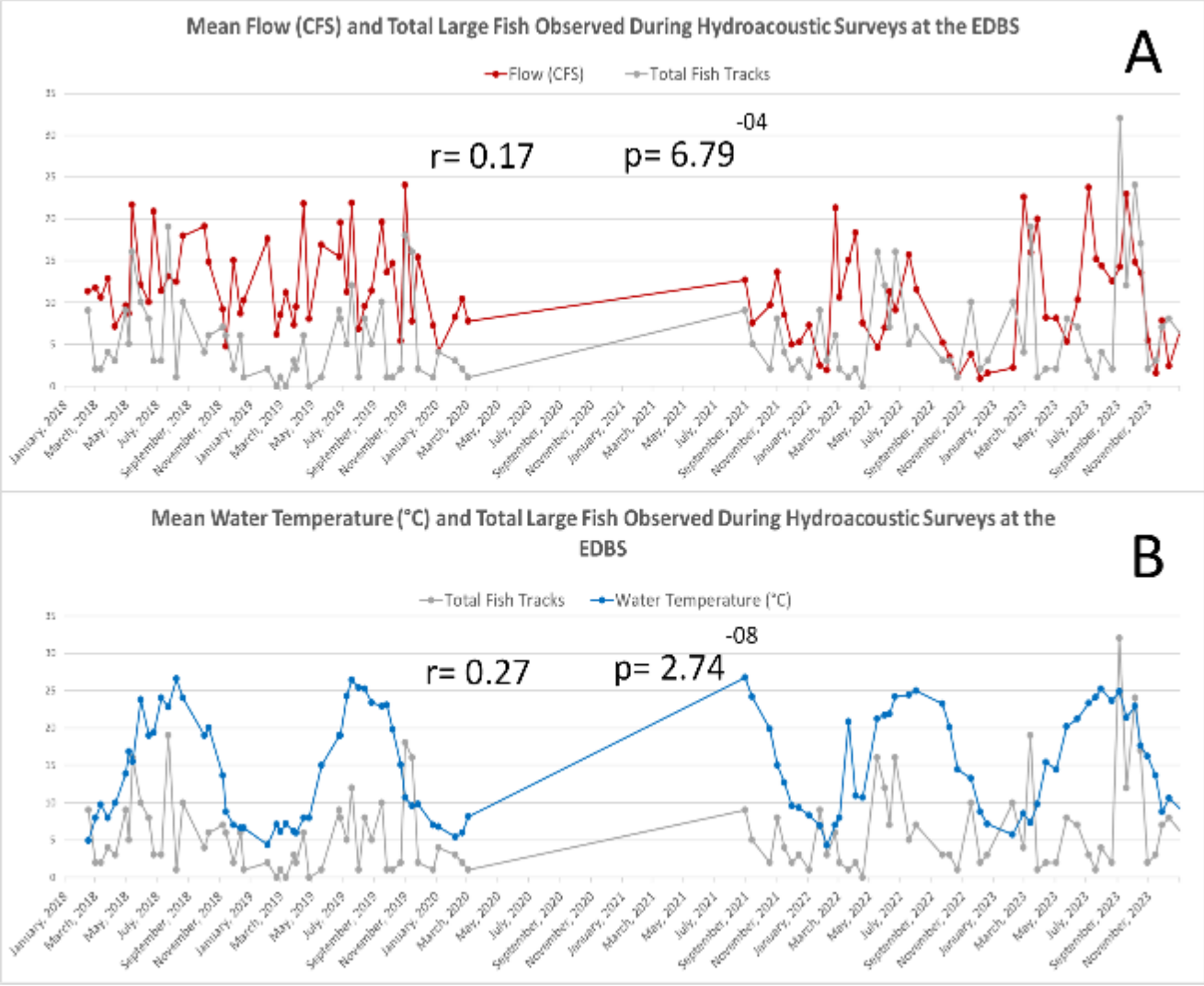


Figure 2. *Mean flow (CFS) (A) and mean water temperature (°C) (B) near the EDBS during split-beam hydroacoustic surveys conducted from February 2018 to December 2023. Both the mean flow rate and water temperature were calculated from data provided by the USGS monitoring location 05536890 CSSC near Lemont, Illinois. Flow was normalized by dividing with a factor of 250. The Spearman's correlation coefficient (r) and generalized linear mixed model (p-value) were used to test the correlation and statistical assumption of both flow and water temperature.*



Results from hydroacoustic surveys conducted in Dresden Island, Brandon Road, and Lockport Pools in 2023 illustrated overall similar patterns in large fish abundance to previous years.

Two instances of elevated abundances of large fish were observed in Dresden Island (October 11) and Brandon Road (October 27) Pools in October 2023. This was the highest density of large fish recorded since project inception in 2018 in both pools (Figure 3). While the cause of the elevated abundances is unknown, these observed peaks were during the same time elevated abundances of large fish were detected during the hydroacoustic surveys in the EDBS in 2023. A

potential shift of large fish targets upstream in both pools can also be seen when comparing the August and October pool scans (Figures 4 and 5). The water temperature in all three pools was analyzed, but no correlation was found that could explain the cause for the movement of large fish targets upstream.

Figure 3. *Density of large fish targets (greater than or equal to -28.7 decibels) from split-beam hydroacoustic surveys conducted in Dresden Island (A), Brandon Road (B), and Lockport (C) Pools from 2018 to 2023. 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.*

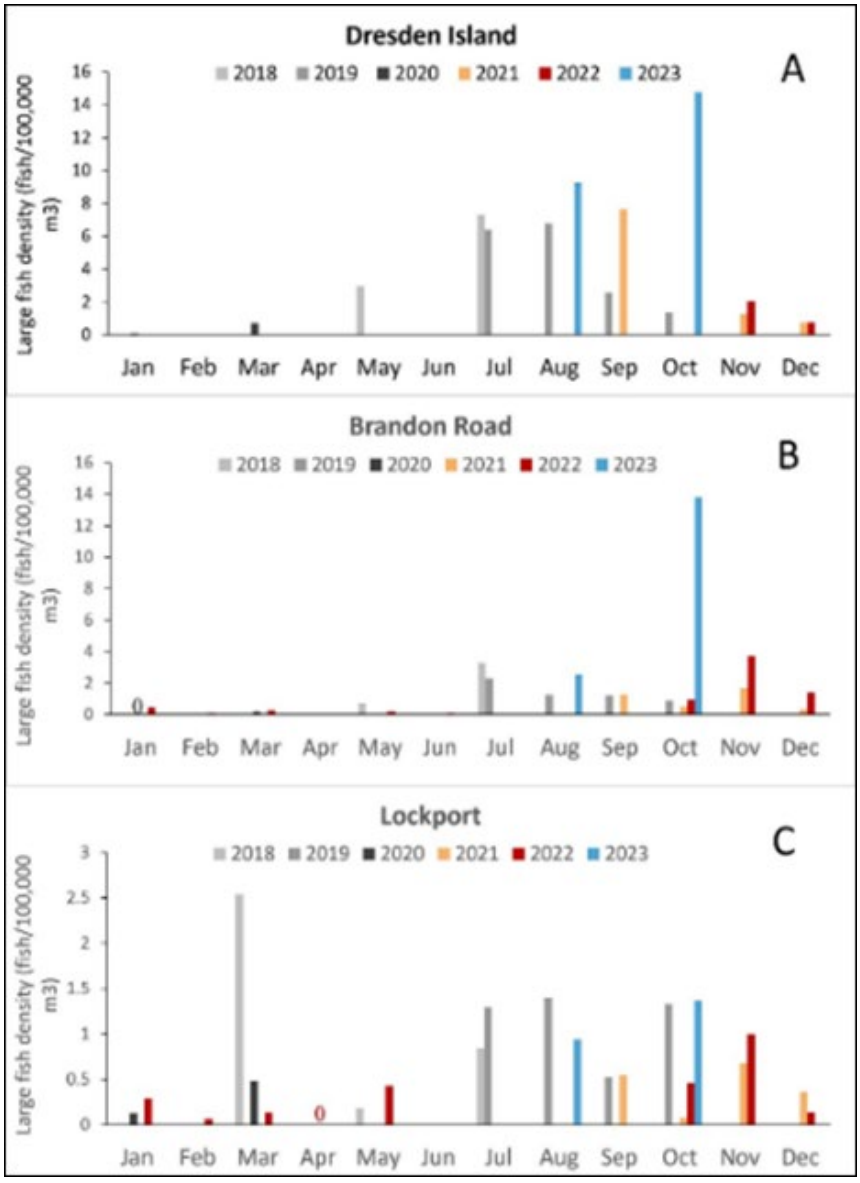


Figure 4. *Heatmap of large fish targets (greater than or equal to -28.7 decibels) from split-beam hydroacoustic surveys conducted in Dresden Island Pool in August (A) and October (B) 2023.*

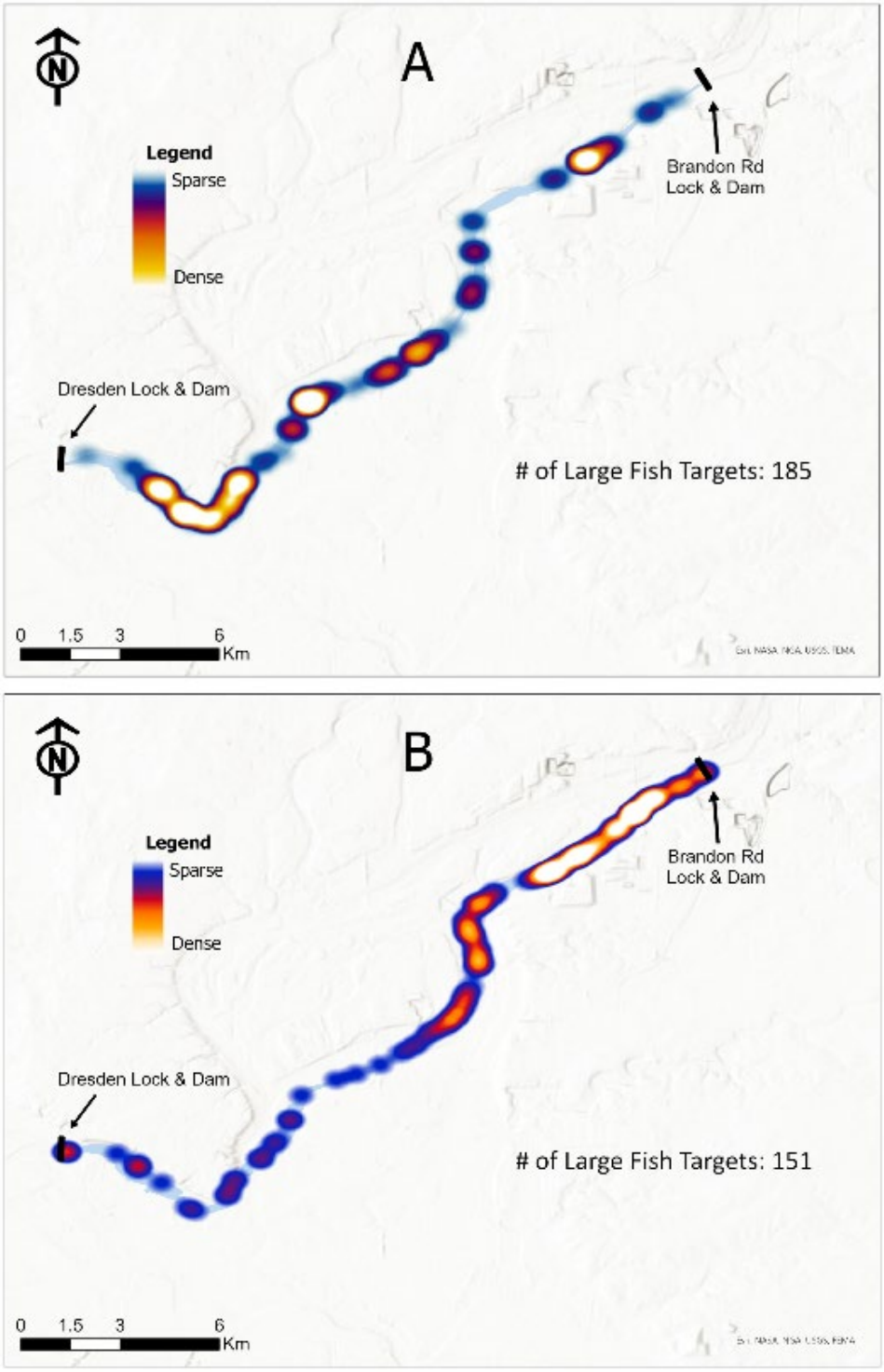
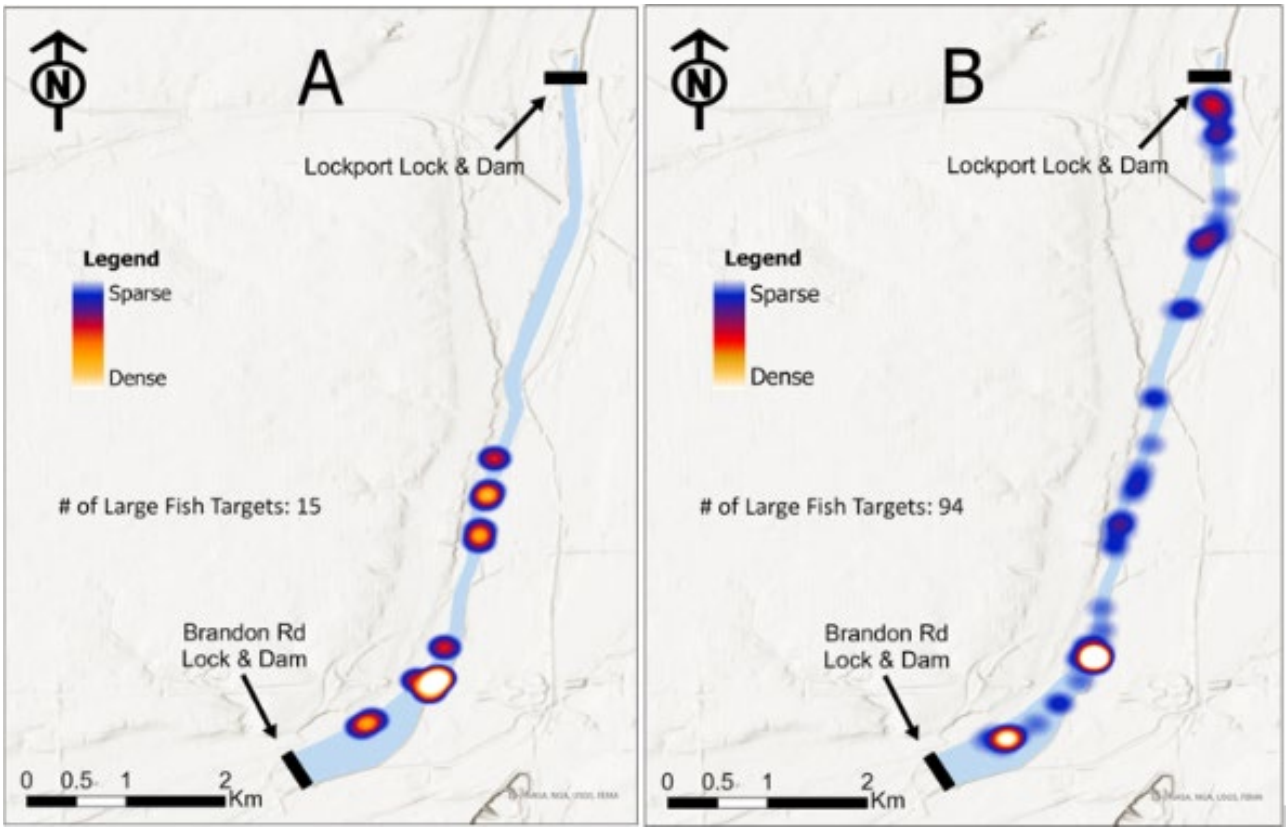


Figure 5. *Heatmap of large fish targets (greater than or equal to -28.7 decibels) from split-beam hydroacoustic surveys conducted in Brandon Road Pool in August (A) and October (B) 2023.*



CONCLUSION

The IWW Hydroacoustics project accomplished its objectives in 2023 by providing insights into trends in abundance of large fish near and immediately downstream of the EDBS and at the invasive carp invasion front (Invasive Carp Problem 2022). While 2023 observations had the highest abundances of fish targets in the EDBS since project inception, the likelihood of these targets being invasive carp is perceived to be low. Immediately after seeing abnormal peaks of large fish targets at the EDBS, USACE was alerted, triggering response efforts. It was determined that the targets were likely schools of gizzard shad moving upstream. Additionally, no invasive carp were observed in any partner effort above Brandon Road Lock and Dam. These findings suggest that sufficient measures are currently being implemented to prevent the upstream movement of invasive carp.

RECOMMENDATIONS

- MRWG discussions in 2023 (Hydroacoustics Work Group 2023) concluded that mobile hydroacoustic surveys at the EDBS could be reduced in 2024 to a monthly monitoring schedule with supplemental surveys occurring during periods of interest.

- Conduct a single hydroacoustic pool scan in 2024 in Dresden Island, Brandon Road, and Lockport Pools in coordination with SIU hydroacoustic efforts.

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EARLY DETECTION OF BIGHEAD CARP IN THE ILLINOIS WATERWAY

Participating Agencies: USFWS Carterville FWCO

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

INTRODUCTION AND NEED

The large (greater than 153 mm) Bighead and Silver Carp invasion front in the IWW is currently in the Dresden Island Pool, approximately 16 kilometers downstream of the EDBS and 76 kilometers downstream from Lake Michigan (ICRCC 2023). The small (less than 153 mm) Bighead and Silver Carp invasion front in the IWW is currently in the Peoria Pool, though small fish were found in Starved Rock Pool in 2015, 2021, and 2022 (ICRCC 2023). The objective of this project is to specifically target the detection of individual invasive carp (all four species) at and above the invasion fronts. This project differs from other IWW monitoring actions by using methods focused on finding invasive carp individuals rather than generalized population and assemblage sampling methods (Multiagency Monitoring of the Illinois River for Decision Making and Hydroacoustic Monitoring projects).

OBJECTIVES

- Conduct monthly fixed and randomized electrofishing and gill net sampling targeted for large invasive carp in Brandon Road and Lockport Pools from March to November.
- Conduct monthly fixed and randomized electrofishing, dozer trawling, and mini-fyke netting sampling targeting small invasive carp in Dresden Island Pool, Marseilles Pool, and the Kankakee River from March to November.
- Remove all invasive carp captured during sampling.
- Report invasive carp detections outside of the current designated status.

PROJECT HIGHLIGHTS

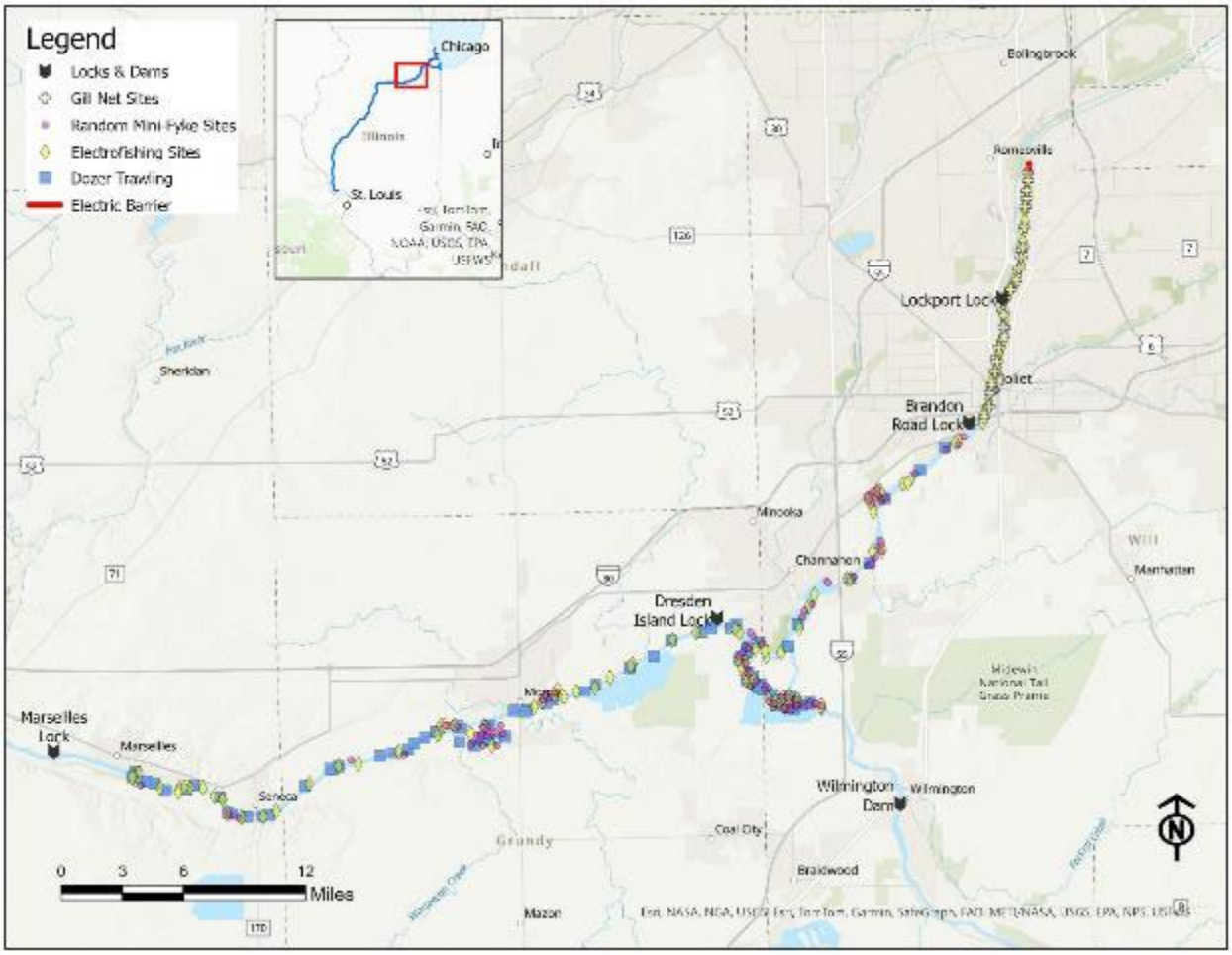
- No large invasive carp were detected upstream of Brandon Road Lock and Dam.
- No small invasive carp were detected in Marseilles, Dresden Island, Brandon Road, or Lockport Pools.
- Three large Bighead Carp, 290 large Silver Carp, and 14 large Grass Carp were captured and removed from Marseilles, Dresden Island, and lower Kankakee River Pools during 2023.
- 557 electrofishing runs, 398 electrified dozer trawls, 183 gill net sets, and 380 mini-fyke net sets were completed across all pools between March 9 and November 22, 2023.

METHODS

Target analysis completed in previous years identified a combination of fixed and random site sampling, including habitat stratifications, utilizing appropriate gear types for both large and small invasive carp life stages, and electrofishing power goals targeting invasive carp (Young *et al.* 2023). Sampling site selection in 2023 considered areas to target or avoid based on professional experience from previous sampling years. Fixed sites were located in previous capture sites or similar habitats spaced across the pool. Random sites were stratified by habitat type, such as main channel borders, side channels, and backwaters, proportionally by the spatial area of each habitat. Areas not compatible with a respective gear type were relocated to compatible sites within the same habitat type whenever possible. Gears selected for Marseilles and Dresden Island Pools and the lower Kankakee River were daytime boat electrofishing, electrified dozer trawling, and mini-fyke netting. Gears selected for Brandon Road and Lockport Pools were daytime boat electrofishing and gill netting. All captured invasive carp were measured for total length (mm) and mass (grams) and euthanized. All other fish captured were identified to the species level and enumerated. Native and non-harmful fish species were released, and other invasive species were euthanized. An example of monthly sampling sites for 2023 is shown in Figure 1.

Rarefaction is a common analysis done to assess the effectiveness of a fishery sampling program (Radinger *et al*. 2019). Species richness estimates were made using the Mao Tau method for species accumulation (Colwell, Mao & Chang 2004) and 1000 resamples within each study area by gear. These analyses were performed in R 4.1.2 (R Core Team 2021).

Figure 1. *Example of monthly fixed and random sites sampled by the USFWS Carterville FWCO in 2023.*



RESULTS AND DISCUSSION

USFWS sampled 1,517 sites across four IWW pools (Marseilles, Dresden Island, Brandon Road, and Lockport) and the lower Kankakee River for large and small invasive carp between March 9 and November 22, 2023. A total of 307 large invasive carp were captured (Figure 2). No small invasive carp were observed in this sampling, and no invasive carp were found outside their known range. The total effort consisted of 140.0 hours of boat electrofishing, 33.3 hours of electrified dozer trawling, 28,300 yards of gill nets deployed, and 366.0 net nights of mini-fyke netting. The USFWS captured 118,456 fish that were not invasive carp in 2023, consisting of 88 species and 5 hybrid taxa.

Overall effort levels by gear provide strong confidence that species vulnerable to each gear are being captured consistently in each pool. Across all gears and pools, sampling efforts were able to asymptote all species accumulation curves (Figure 3), indicating there is a low likelihood that

unique species, such as invasive carp, are going undetected in these pools. Additional years of consistent effort and data will assist in determining the variance in the captures. Dresden Island dozer trawl and Brandon Road electrofishing efforts could use additional samples to increase confidence that the accumulation curves were fully asymptotic.

Figure 2. *Location map of invasive carp captured by the USFWS Carterville FWCO in 2023.*

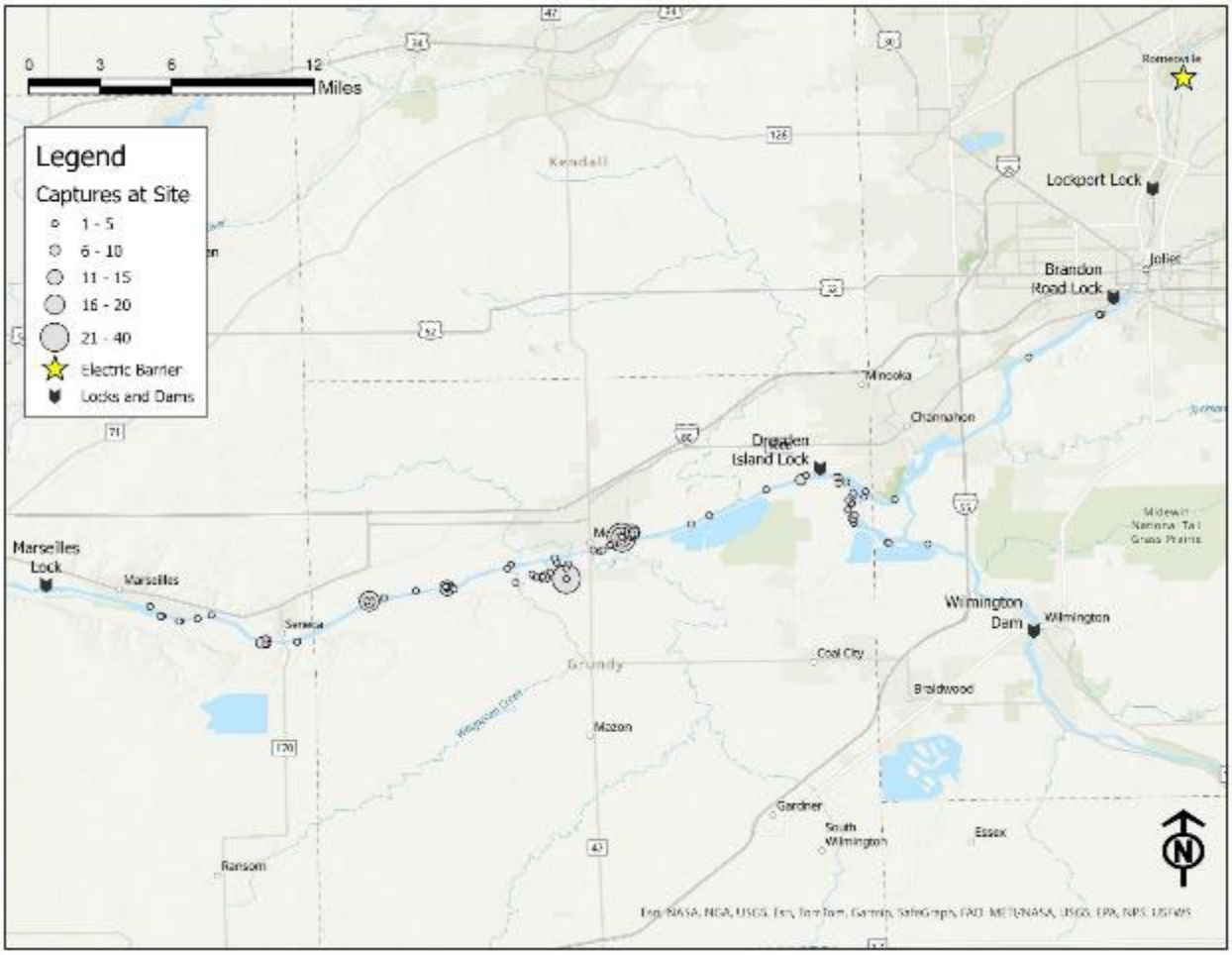
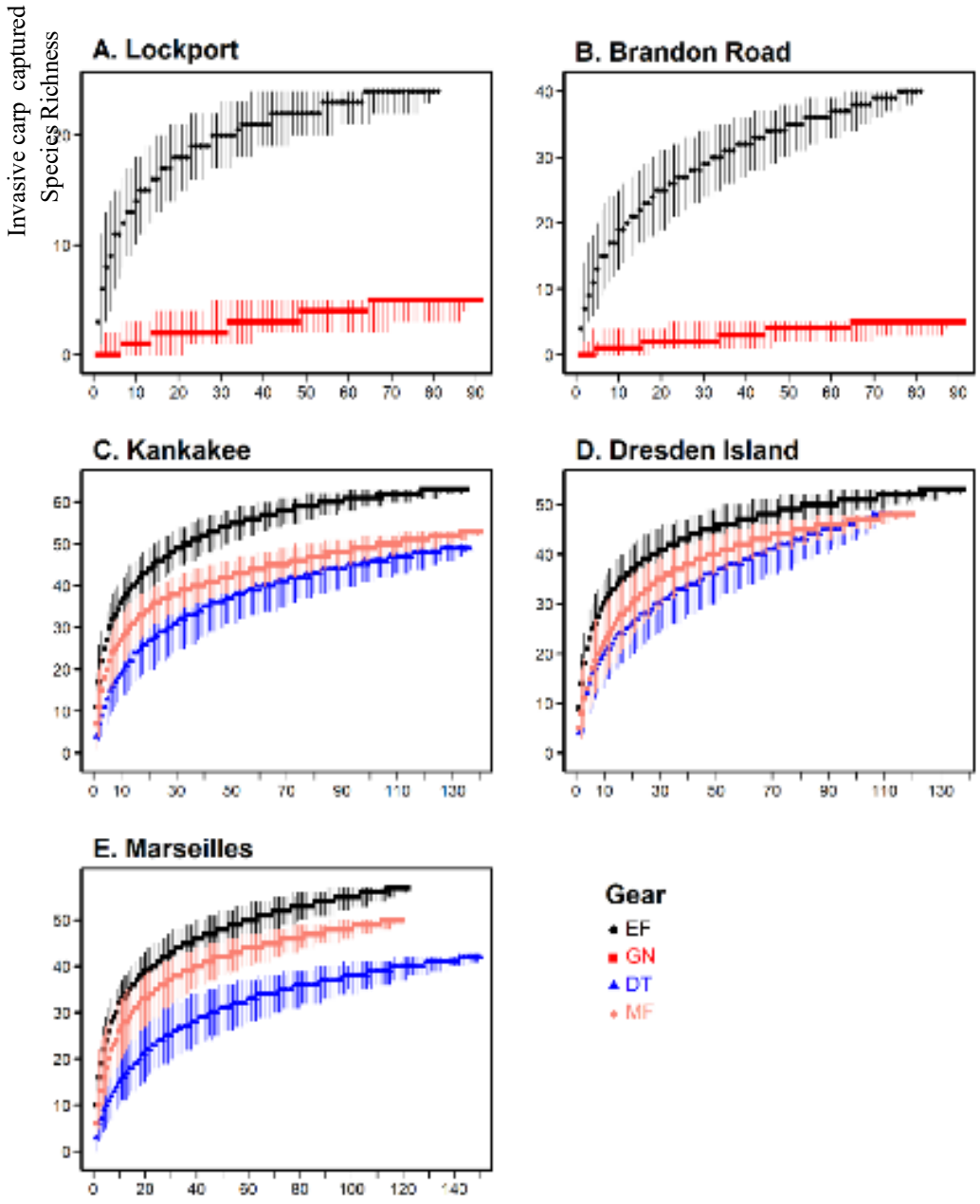


Figure 3. *Species accumulation curves by pool by gear from USFWS Carterville FWCO captures in 2023.*



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 electrofishing sampling effort in Brandon Road Pool to increase confidence in detecting any invasive carp life stages that may be present and total species richness. Dresden Island dozer trawl efforts are being partially converted into Multiagency Monitoring of the Illinois River for Decision Making efforts.

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MONITORING INVASIVE CARP REPRODUCTION IN THE ILLINOIS WATERWAY

ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

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, Nicholas J. Iacaruso, Mark A. Davis (INHS), Eden L. Effert-Fanta, Daniel R. Roth, Braden Whisler, Robert E. Colombo (Eastern Illinois University), James E. Garvey, David P. Coulter (SIUC)

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

INTRODUCTION AND NEED

Successful reproduction is fundamental to the establishment and spread of invasive species (Moyle and Marchetti 2006; Lockwood et al. 2013). Understanding the spatial and temporal dynamics of reproduction by invasive 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 for changes in the reproductive front of invasive carp populations in this system, to monitor for potential reproduction by the newly expanding Black Carp population in Illinois, and to better understand the impacts of removal efforts on the reproductive capacity of these populations. 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 are necessary to assess the magnitude, location, and timing of reproduction, as well as to evaluate the relationship between invasive carp stock abundance and reproductive output to determine if removal efforts are reducing invasive carp densities enough to degrade their ability to perpetuate themselves through reproduction.

The magnitude of invasive carp reproduction varies considerably among the pools and tributaries of the IWW (Parkos et al. 2023; Schaick et al. 2023). Reproduction by invasive carp in the upper navigation pools of the IWW is of concern due to the risk of expansion of the invasion front toward Lake Michigan and the increased potential for these species to challenge the EDBS. Observations of eggs, larvae, and juveniles in the upper Illinois River indicate that some reproduction and potential recruitment occurs above Starved Rock Lock and Dam in some years (Zhu et al. 2018; Parkos et al. 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.

Invasive carp reproductive output is more consistent downstream of Starved Rock Lock and Dam but still varies by several orders of magnitude over the years. Invasive carp spawning also appears to occur in smaller tributary rivers in some years. Large populations of invasive carp can be found in several tributaries of the Illinois River (Sangamon, Spoon, and Mackinaw rivers), although the magnitude of reproductive output varies considerably among these rivers (Schaick et al. 2023). The contribution of tributaries to the reproductive productivity of system-wide invasive carp populations is not well understood, but these rivers may be an important source of early life stages to some navigation pools in some years. Monitoring for any changes to these patterns can help to evaluate the risk for further population growth in the upper Illinois River or determine if harvest efforts are effectively reducing the capacity of invasive carp populations to replenish themselves.

Complementary annual assessments of invasive carp reproduction and stock density 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 the assessment of the reproductive productivity of invasive carp populations may therefore aid in evaluating the success of control efforts and refine our understanding of potential compensatory responses to harvest.

OBJECTIVES

Ichthyoplankton are being sampled in the IWW and its tributaries to:

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

PROJECT HIGHLIGHTS

- From May to September 2023, 662 ichthyoplankton samples were collected from 10 sites from the Brandon Road to Alton navigation pools of the IWW. Invasive carp reproductive productivity was very low in 2023 relative to past years of observation.
- Invasive carp eggs and larvae were collected in samples from the Peoria, LaGrange, and Alton pools during May through the first week of June when IWW water levels were highest. A small number of 2-to-3-millimeter diameter eggs were collected upstream of Starved Rock L&D in 2023 and are awaiting genetic determination of species identity. No other potential evidence of invasive carp reproduction was detected upstream of Starved Rock L&D in 2023. Quantitative PCR screening of collected ichthyoplankton samples suggests that most of the invasive carp reproductive output in 2023 was attributable to Silver Carp. A single sample collected in the upper Peoria Pool in late June contained a

very high quantity of Black Carp DNA but was not found to contain any invasive carp eggs or larvae.

- In 2023, 194 ichthyoplankton samples were collected from Illinois River tributaries. Large-diameter eggs and invasive carp larvae were collected from the Spoon and Sangamon rivers, but no evidence of invasive carp reproduction was observed in other Illinois River tributaries in 2023. Nearly all evidence of invasive carp reproduction in tributary rivers occurred during a period of higher discharge in May. As in the main channel of the IWW, invasive carp reproductive output was very low in tributaries in 2023 relative to previous study years.
- Updated analyses examining factors affecting invasive carp reproductive output found similar results to previous modeling efforts in that both adult invasive carp density and environmental conditions influence spatiotemporal variation in the magnitude of invasive carp reproduction. Invasive carp egg drift is predicted to be highest at intermediate densities of adults and during years with warmer water temperatures during May and June.

METHODS

Ichthyoplankton sampling occurred at 10 sites in the CSSC, Des Plaines River, and Illinois River downstream of the EDBS in 2023 (Figure 1). Additional sampling occurred 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 obtain 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 May to mid-July were screened 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, aliquots of sample preservatives 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 dual duplex reactions, following qPCR methodology (Wozney and Wilson 2017; Fritts 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 mm 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, Missouri). 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.

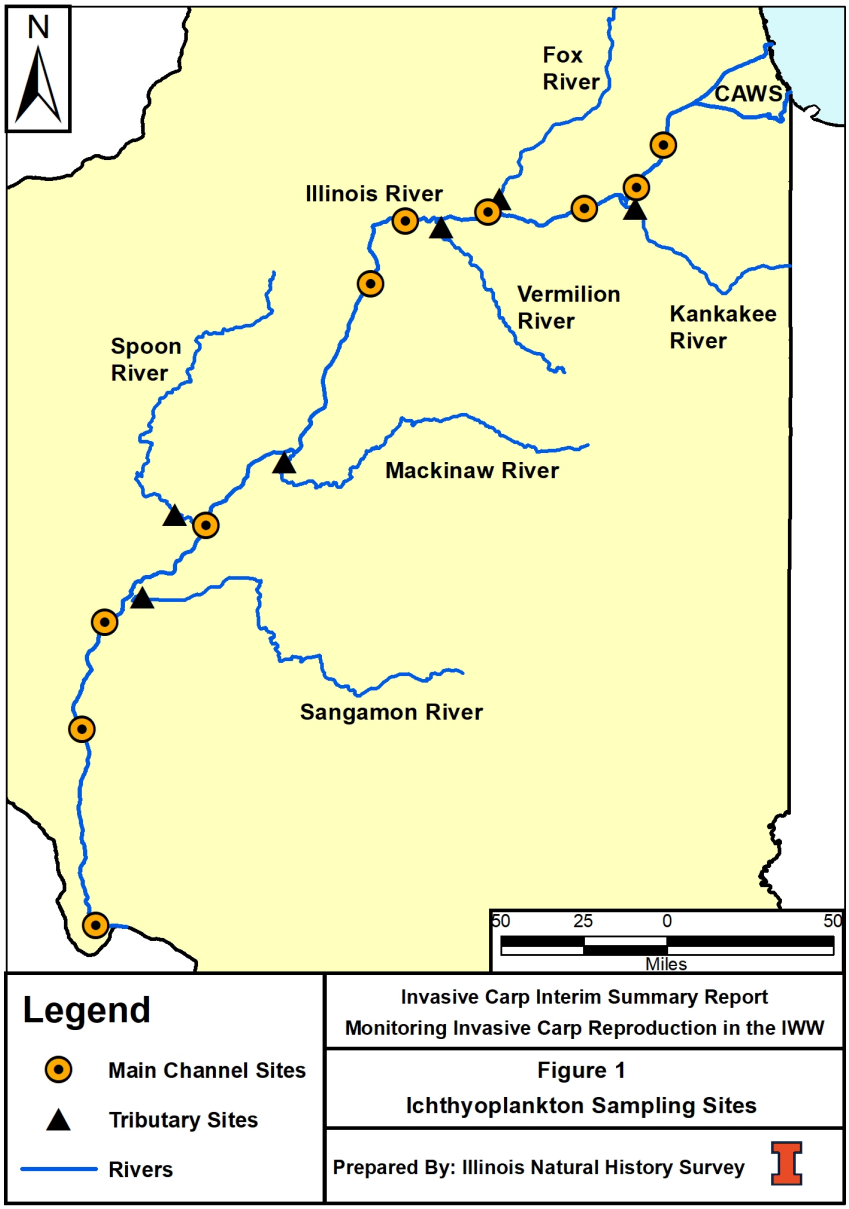
Densities of invasive carp eggs and larvae were summarized by sampling location through time and compared to water temperature and river discharge to examine spatial patterns in invasive carp reproduction, identify conditions associated with spawning, and assess trends in invasive carp reproductive output. 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 2021 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 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. Cumulative degree days through June and mean May through June discharge were highly correlated, so these were not included together in any models. 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 (AICc), and AICc weights were computed for each model (Anderson 2008).

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



RESULTS AND DISCUSSION

In 2023, ichthyoplankton monitoring in the IWW collected 662 samples. Overall invasive carp reproductive productivity in the Illinois River was low during 2023 relative to other recent study years (Figure 2). Invasive carp eggs and larvae were present in samples from the Peoria, LaGrange, and Alton pools during May through the first week of June. From March through May 2023, higher water levels occurred in the Illinois River, but water temperatures were prohibitively low for invasive carp reproduction during much of this time. Invasive carp eggs and larvae were detected on the first sampling dates in May, immediately following a rapid increase in water temperatures (Figure 3). However, water levels rapidly declined to base levels at the end of May and remained low and relatively stable for the rest of the 2023 sampling period. No invasive carp eggs or larvae were identified from any samples after June 1. A small number (n = 13) of 2-to-3-millimeter eggs were collected upstream of Starved Rock Lock and Dam in 2023, but these specimens have embryo characteristics that are inconsistent with those of invasive carp and will be submitted for genetic sequencing to determine their identity. No other potential evidence of invasive carp reproduction was observed upstream of Starved Rock Lock and Dam during 2023. Quantitative PCR screening of collected ichthyoplankton samples suggests that the majority of the invasive carp reproductive output in 2023 was attributable to Silver Carp. A single sample collected at Spring Valley in the upper Peoria Pool in late June contained a very high number of Black Carp DNA copies but was not found to contain any invasive carp eggs or larvae.

Figure 2. *Index of total annual invasive carp egg and larvae drift in the LaGrange (Havana), Peoria (Henry), Starved Rock (Ottawa), and Marseilles (Morris) navigation pools from 2012 to 2023. The index of total annual egg and larvae drift was estimated by summing observed egg and larval densities standardized by site-specific discharge and scaled to 24-hour intervals.*

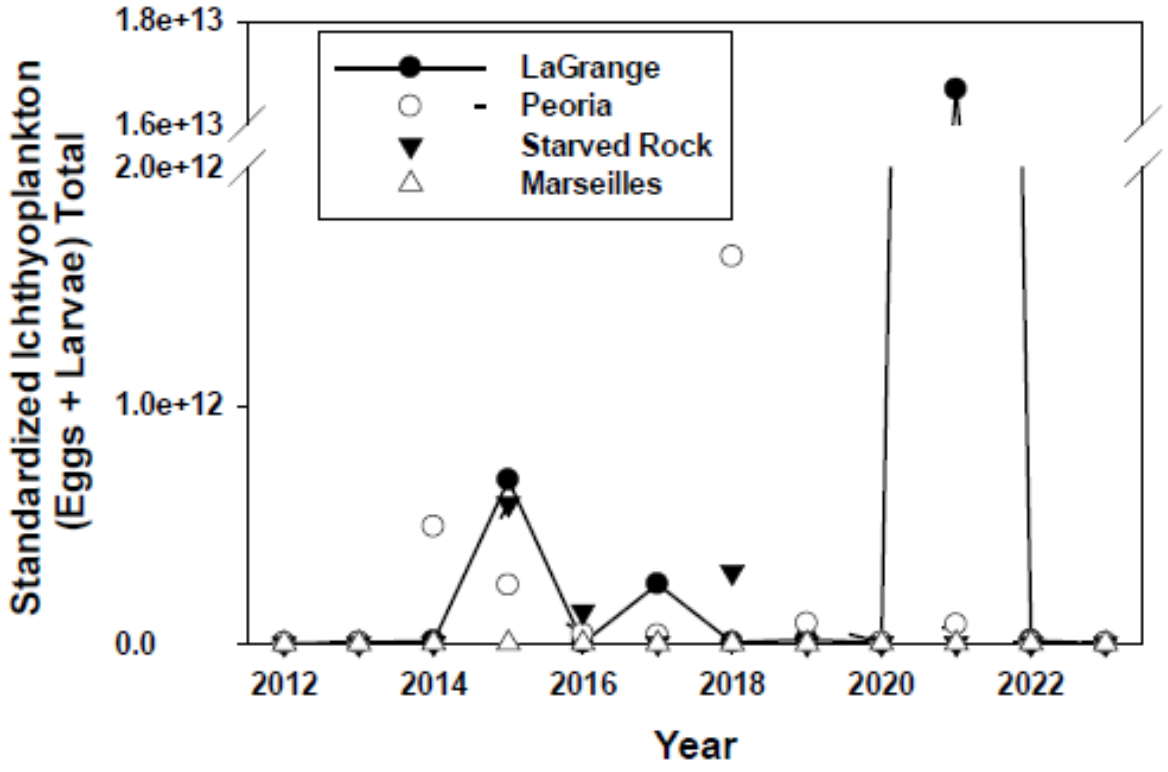
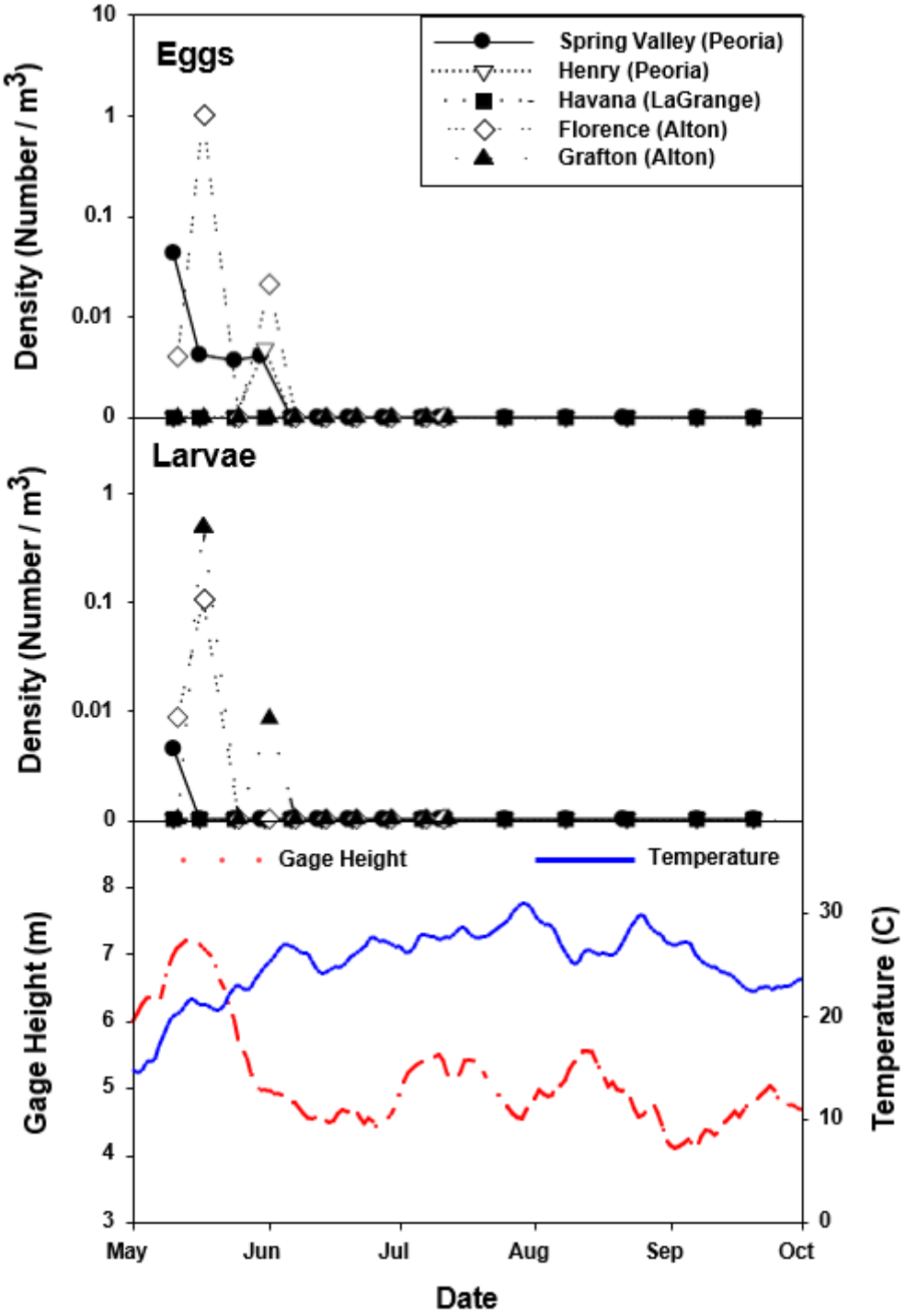


Figure 3. *Densities (number/cubic meter; note log scale) of invasive carp eggs (top panel) and larvae (middle panel) collected from main channel sites of the IWW in 2023. Mean daily gage height (meters) and water temperature (°C) of the Illinois River from May through October 2023 (bottom panel) were obtained from USGS gage 55836300 at Florence, Illinois.*



Tributary sampling collected an additional 194 ichthyoplankton samples in 2023. The Kankakee, Fox, Spoon, and Sangamon rivers were all sampled consistently, but low water levels prohibited access to the Vermilion and Mackinaw rivers on many sampling dates. Large-diameter eggs and invasive carp larvae were collected from the Spoon and Sangamon rivers, but no evidence of invasive carp reproduction was observed in other Illinois River tributaries during 2023. Peak densities of large-diameter eggs and invasive carp larvae were very low in the Spoon and Sangamon rivers in 2023 relative to other recent study years (Figure 4). Substantial increases in discharge in May, particularly in the Sangamon River, were associated with nearly all the invasive carp reproductive output observed in tributaries during 2023 (Figure 5). After May, tributary water levels were generally very low for the remainder of summer 2023. Small increases in discharge in July and August did not result in any evidence of invasive carp reproduction. A single large-diameter egg collected in late July in the Spoon River was sampled during low-flow conditions. Eggs collected from tributaries in 2023 are being submitted for genetic sequencing to verify their identities.

Figure 4. *Peak densities (number/m^3) of invasive carp eggs (circles) and larvae (triangles) collected from two tributaries of the Illinois River (Sangamon and Spoon rivers) during May through September 2016 to 2023.*

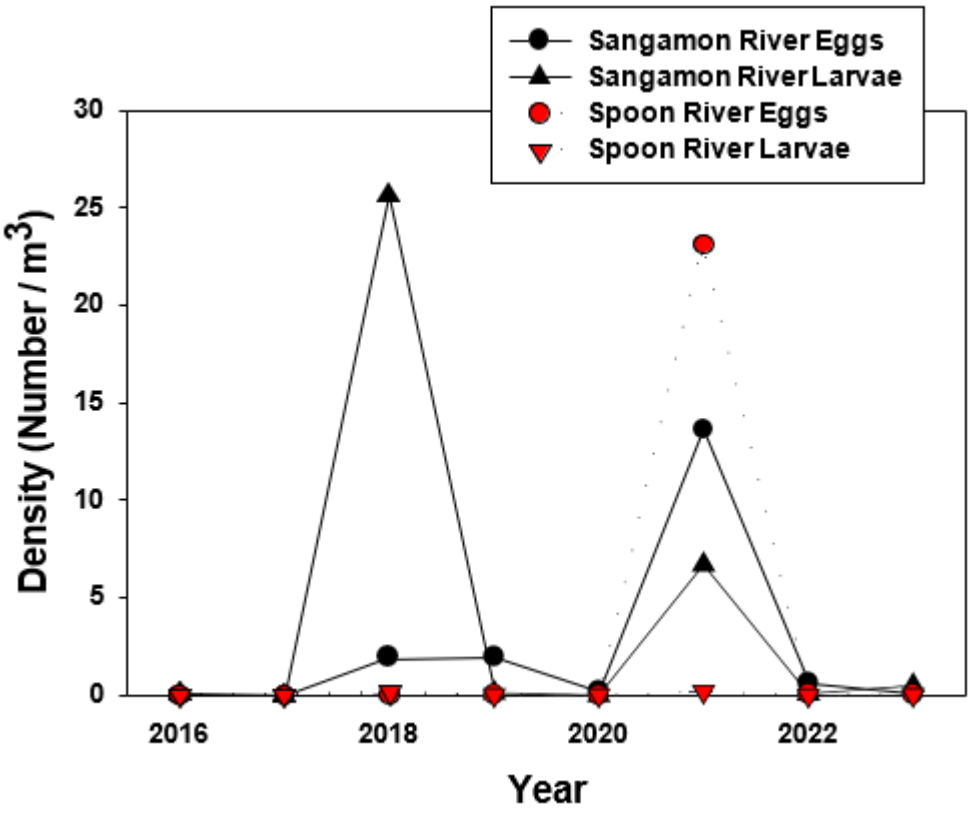
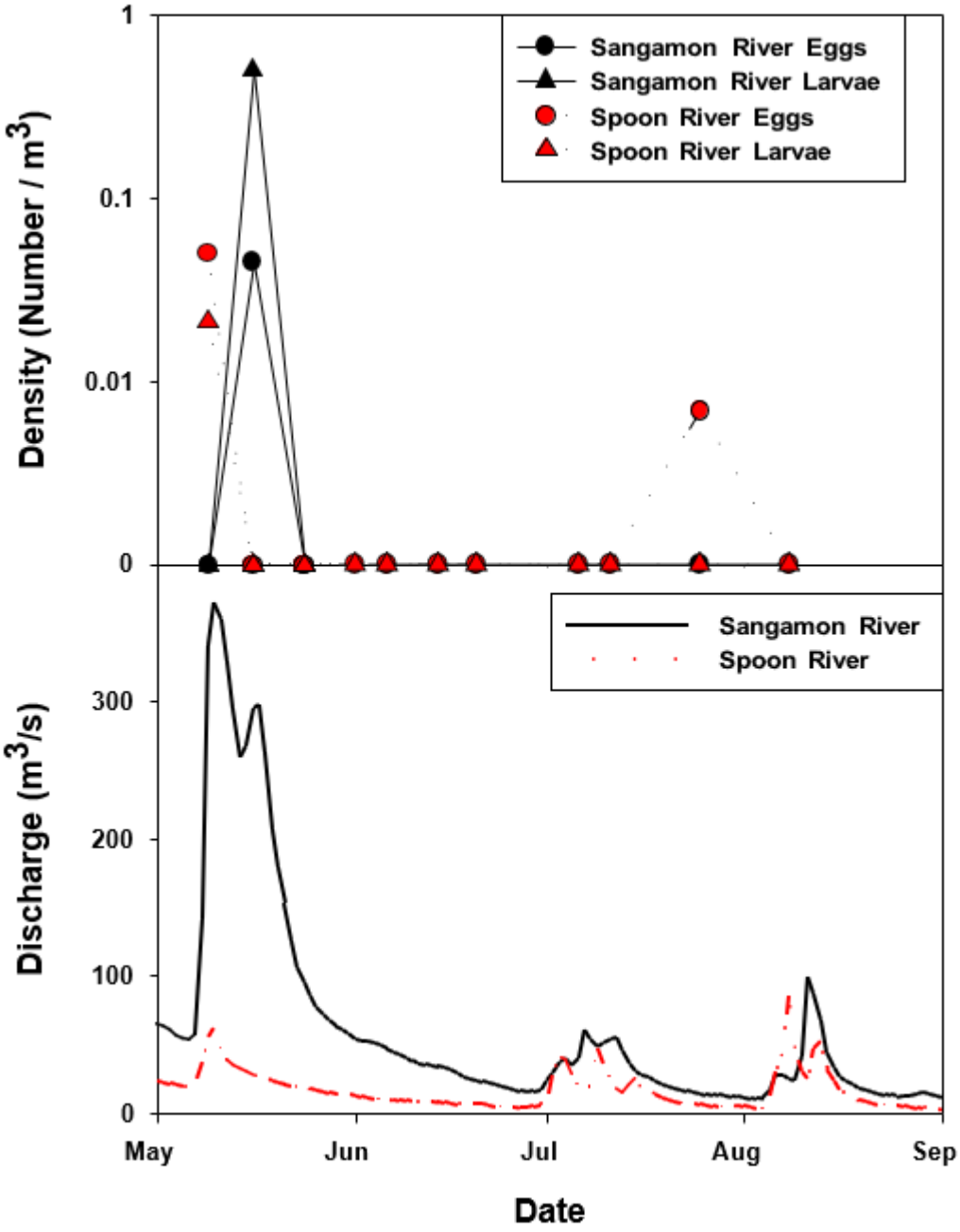


Figure 5. *Density (number/m^3; note log scale) of invasive carp eggs (circles) and larvae (triangles; top panel) collected from two tributaries of the Illinois River (Sangamon and Spoon rivers) during May through September 2023. No invasive carp eggs or larvae were collected from the Mackinaw, Vermilion, Fox, and Kankakee rivers in 2023. Mean daily discharge (meter^3/second; bottom panel) was obtained from USGS gages (Spoon River:5570000; Sangamon River:5583000).*

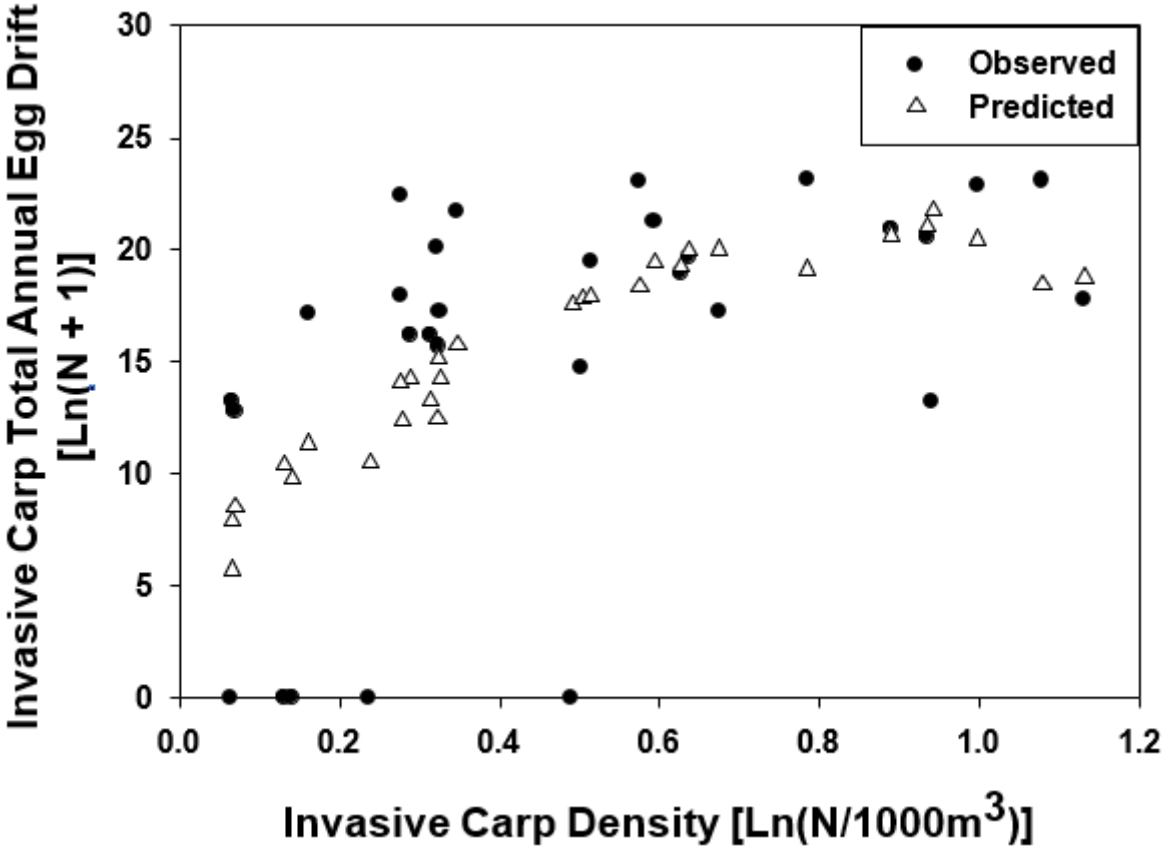


Updated analyses examining factors affecting invasive carp reproductive output found similar results to previous modeling efforts in that both adult invasive carp density and environmental conditions during the May through June period influenced spatiotemporal variation in the magnitude of invasive carp reproduction. A quadratic relationship between total annual egg drift and adult invasive carp density was more supported by the data than a linear relationship, and models that included adult invasive carp density were more supported by the data than those that only included environmental variables (Table 1). The most supported model included the quadratic relationship with adult density 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 (Figure 7) and during years 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 2023, including a null model that only includes an intercept variable. Models assessed support for the linear and quadratic relationship between adult invasive carp density (Adult Density) and total egg drift, Z- transformed mean daily discharge during May and June (Discharge), the coefficient of variation of mean daily discharge during the same period (Discharge CV), and cumulative degree days through the end of June (June CDD). Models are ranked by relative support within the considered model set based on AIC scores corrected for small sample sizes (AICc). Relative model support is represented by Δ, the difference between the model AICc score and the score of the model most supported by the data (i.e., lowest AICc score), and model weight (wi).*

Model	AICc	Δ	wi
Null	217.3	37.8	< 0.0001
Adult Density (Linear)	194.4	14.9	<0.0001
Adult Density (Quadratic)	185.1	5.6	0.042
Discharge	214.5	35.0	<0.0001
Discharge CV	221.6	42.1	<0.0001
June CDD	209.2	29.7	<0.0001
Discharge CV + June CDD	213.6	34.1	<0.0001
Adult Density (Quadratic) + Discharge	182.4	2.9	0.164
Adult Density (Quadratic) + Discharge CV	188.9	9.4	0.006
Adult Density (Quadratic) + June DDs	179.5	0	0.697
Adult Density (Quadratic) + Discharge CV + June DDs	183.6	4.1	0.090

Figure 7. *Observed invasive carp total annual egg drift (dark circles) and modeled predictions (open triangles) derived from a model including adult invasive carp density and cumulative degree days through the end of June (base 18°C) plotted with associated invasive carp adult densities in navigation pools of the IWW during 2014 through 2023 (dark circles). Invasive carp total annual egg drift was calculated by summing observed egg densities standardized by site-specific discharge and scaled up over 24-hour intervals. Adult invasive carp densities were estimated from autumn hydroacoustic surveys in each navigation pool.*



The low invasive carp reproductive output observed in 2022 and 2023 is consistent with patterns from previous study years where cool springs with high early rainfall fail to produce large spawning events. If water temperatures conducive to invasive carp spawning don't coincide with increasing water levels during the spring months, the reproductive output can generally be expected to be limited. Indeed, the largest increases in water levels in the Illinois River during both 2022 and 2023 occurred prior to water temperatures reaching the threshold thought to be conducive to invasive carp spawning. Invasive carp eggs and larvae were collected shortly after temperatures crossed this threshold, but discharge throughout the Illinois River declined by the end of May and remained low after June, likely inhibiting synchronized mass spawning by invasive carp. Warmer springs with pronounced increases in water level after water temperatures have

already exceeded 18°C, as occurred in 2015, 2018, and 2021, typically produce very large spawning events and result in the highest annual reproductive totals.

Tributaries exhibited a similar pattern to the main channel in 2023, contrasting with the pattern observed in 2022, when localized rain events triggered periodic, albeit low-magnitude spawning by invasive carp in LaGrange Pool tributaries throughout the summer months. However, no evidence of invasive carp reproduction was detected in four other tributary rivers in either year. 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 over 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. The relative contribution of invasive carp eggs or larvae spawned in tributaries to later life stages is also unknown and could also vary substantially depending on the proximity of each tributary to appropriate nursery habitats in the main channel. If tributary rivers are found to be important sources of recruits for invasive carp populations, management strategies may need to account for invasive carp populations in these smaller systems as well as in main channel habitats (Williams et al. 2023).

No evidence of substantial invasive carp reproduction was observed upstream of Starved Rock Lock and Dam in 2022 or 2023. 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 or 2023, 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 (MacNamara et al. 2016; Love et al. 2018).

Early life stages collected upstream of Starved Rock Lock and Dam have been genetically identified as Silver Carp and Grass Carp. Grass Carp occur farther upstream in the IWW than bigheaded carp, including upstream of the EDBS on the CSSC, and are already present in the Great Lakes basin (Chapman et al. 2013; Embke et al. 2016; Chapman et al. 2021). The Silver Carp population front is currently located in the Dresden Island Pool, although sporadic captures of Silver Carp in the Brandon Road Pool and the CAWS have occurred over the past decade (MRWG 2023). 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 toward the leading edge of the invasion front.

No evidence of Black Carp reproduction has been found in the Illinois River to date, but adult Black Carp are being captured with increasing frequency as far upstream as the Peoria Pool. Quantitative PCR screening of ichthyoplankton samples has identified large quantities of Black Carp DNA in single samples in both 2022 and 2023 that failed to contain any invasive carp specimens, but these results suggest that Black Carp likely occurred near the sampling location in the upper Peoria Pool in both years. Continued monitoring for Black Carp reproduction in the lower Illinois River, using qPCR screening to identify samples that might contain early life stages of Black Carp and genetic sequencing of potential Black Carp eggs and larvae, will be necessary to establish the earliest known reproductive front of this species in this system.

Previous analyses found that variation in discharge and spring warming strongly influenced annual reproductive output (Parkos et al. 2023), but our most recent assessment found that the effect of spring warming alone was most strongly supported by the available data. Invasive carp spawning is widely thought to depend in part on rises in water levels (Schrank et al. 2001; Lohmeyer and Garvey 2009; Larson et al. 2017; Song et al. 2018). However, temperature and precipitation patterns are simultaneously affected by large-scale atmospheric conditions that oscillate across years and may confound the separation of these factors. Further assessment of environmental influences on both initiation of spawning and annual reproductive magnitude may be warranted. 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 annual 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; 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 for invasive carp reproduction, particularly upstream of the Peoria Pool, to evaluate any changes in the invasive carp reproductive front and assess the effects of invasive carp harvest activities on the reproductive potential of these populations. Ichthyoplankton sampling downstream of Starved Rock L&D should continue to monitor for potential Black Carp reproduction. Quantitative PCR screening may be useful for

assessing the likelihood that samples from the Upper IWW contain any invasive carp eggs or larvae or that samples from the Lower IWW contain Black Carp specimens. Relationships between reproductive output and recruitment of invasive carp should be investigated to provide a more complete understanding of recruitment mechanisms and evaluate potential compensatory responses among different life stages to invasive carp harvest efforts. A density-dependent relationship between spawning stock and the embryo life stage has been identified (Parkos et al. 2023), but the role of density-dependence on later developmental stages and the stock-recruitment relationship for invasive carp species in the IWW remains unclear. Further FluEgg modeling (Zhu et al. 2018) 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 further 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.

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INVASIVE CARP STOCK ASSESSMENT IN THE ILLINOIS RIVER

Participating Agencies: SIUC (lead); additional assistance from/collaboration with ILDNR, USACE, USGS, INHS, USFWS; David Coulter, Cameron Davis, Jim Garvey, Tanya Fendler, Joe Mruzek (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 what is 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 various 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 Work 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 Work 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 entire Illinois River used to collect movement information and maintain adult surveillance efforts. Share collected data with Telemetry and Modeling Work 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 12th year of standardized monitoring of bigheaded carp densities was completed in 2023 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 April 2023. Repeated sampling during summer did not occur due to acoustic equipment repairs. Final surveys in these pools and throughout other Illinois River pools (Starved Rock through Alton pools) were completed in the fall of 2023. 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 Work Group in other locations of the IWW. Additionally, other fish species implanted with 69-kilohertz transmitters by other members of the Telemetry Work Group can be detected by this array. Stationary receivers were downloaded in May and November of 2023, with data initially checked to remove false detections, and uploaded to the USGS FishTracks database. Once receivers are downloaded in early 2024, the full 2023 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 every other month, but equipment repairs prohibited sampling during summer. Data through Fall 2022 have been processed in the upper (Figure 2) and lower (Figure 3) Illinois River. Mobile hydroacoustic sampling was completed in October 2023 from Alton through Dresden Island pools to inform long-term population monitoring (Figure 4). Processing of these 2023 fall density data is ongoing.

Telemetry – Adult Movements

In 2023, 157 tags were implanted into bigheaded carp in Alton and LaGrange, while more were planned and postponed due to equipment malfunctions (Figure 3). 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. Dam passages were most common in the lower river pools (Table 1).

Figure 1 *Example heatmap displaying bigheaded carp spatial distributions in the lower portion of Dresden Island Pool sampled in April 2023 with mobile hydroacoustic sampling. Densities were observed using mobile hydroacoustic surveys.*

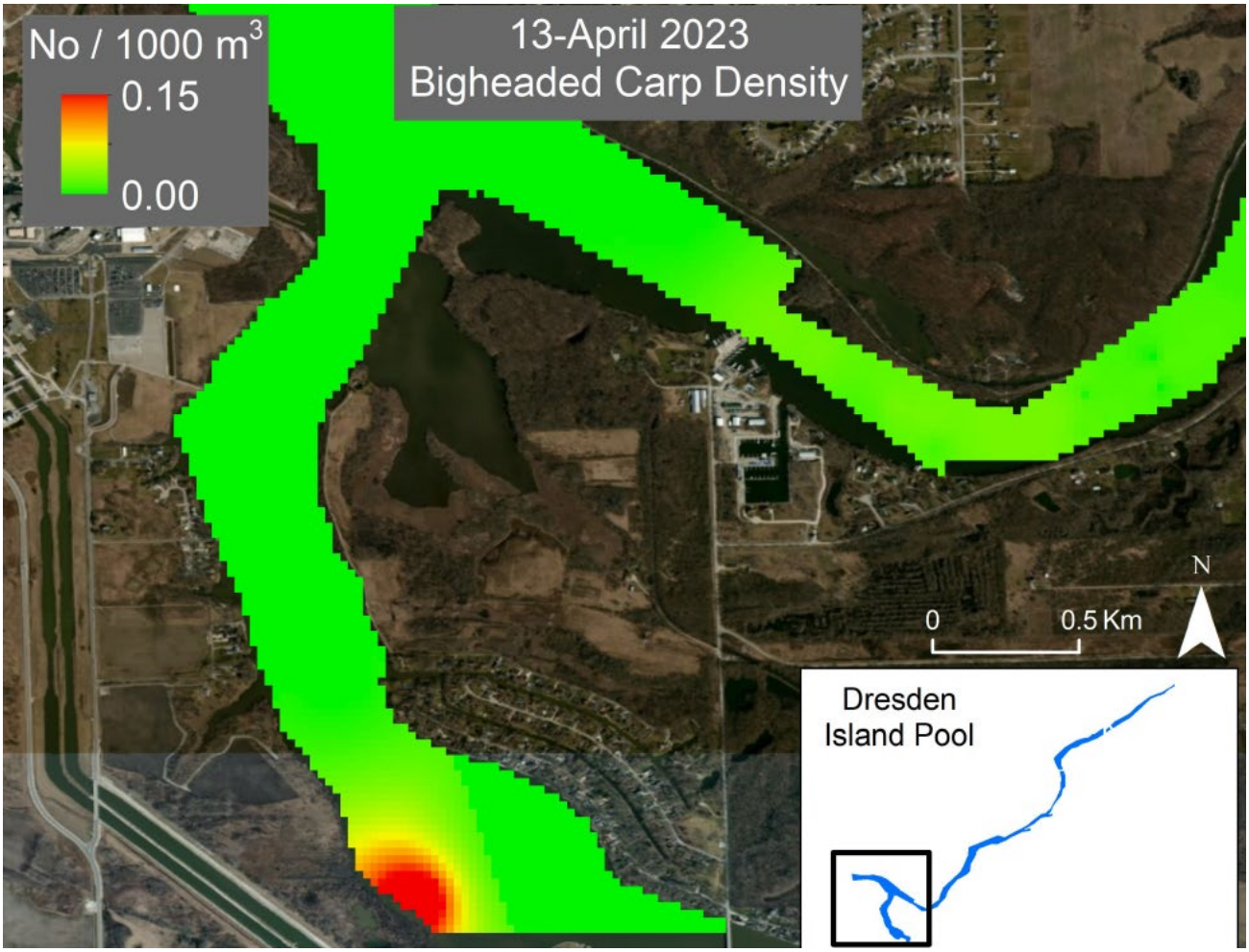


Figure 2. *Densities of bigheaded carp in the* u*pper Illinois River during falls 2012 through 2022 as estimated from standardized hydroacoustic surveys in each pool.*

Upper River

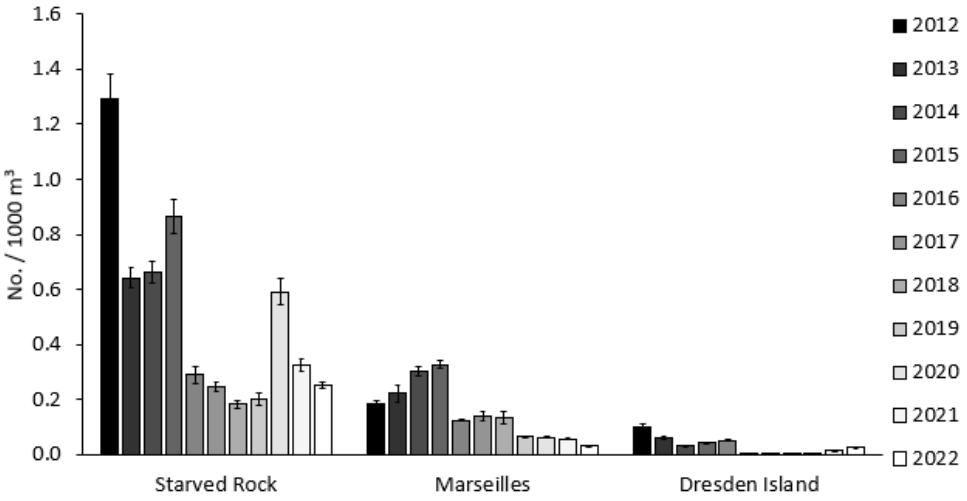


Figure 3. *Densities of bigheaded carp in the* l*ower Illinois River during falls 2012 through 2022 as estimated from standardized hydroacoustic surveys in each pool.*

Lower River

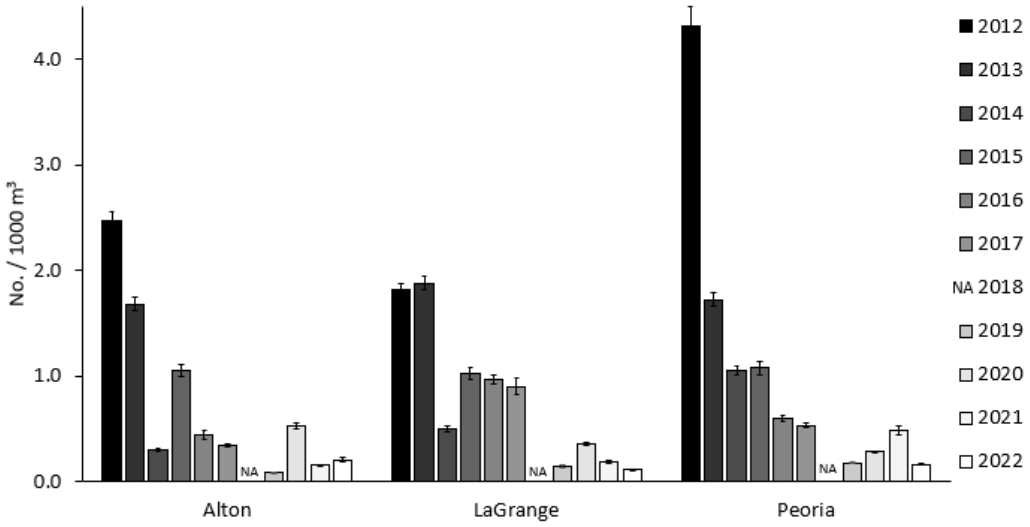
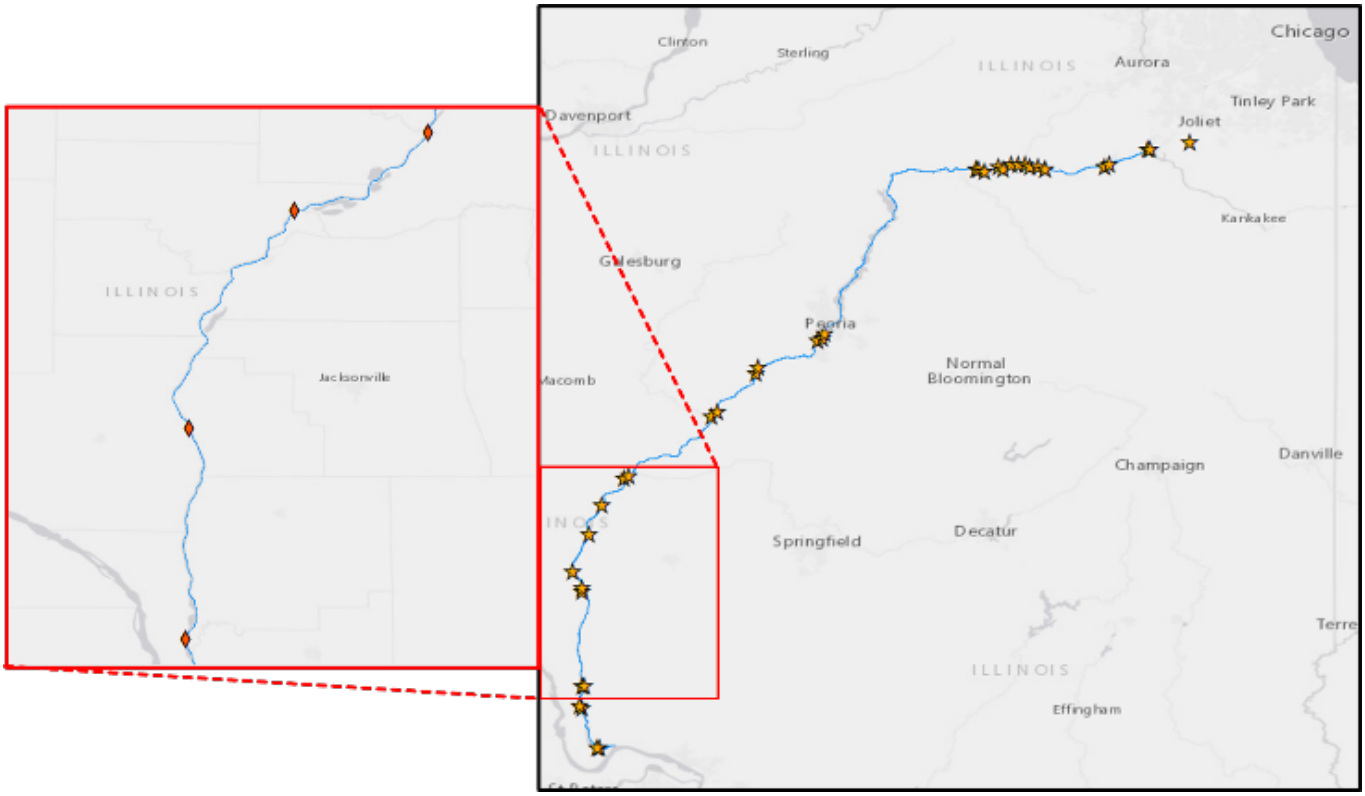


Table 1. *Table summarizing unique bigheaded carp upstream and downstream dam passages in 2022 (a) and 2023 (b). Tag data from SIU, USACE, MDC, Purdue, KDFWR, USGS-UMESC, USFWS Wilmington, and USFWS LAC were used in these summaries.*

2022 (a)	Upstream	Downstream	2023 (b)	Upstream	Downstream
LaGrange	22	23	LaGrange	50	78
Peoria	6	3	Peoria	17	32
Starved Rock	10	20	Starved Rock	7	8
Marseilles	2	10	Marseilles	0	1
Dresden	2	3	Dresden	0	0

Figure 4. *The map on the left illustrates the location where Silver Carp were captured and tagged with acoustic transmitters (diamonds) in 2023 by SIU. The map on the right depicts the locations of SIU-deployed acoustic receivers (stars).*



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)

Pools Involved: N/A

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 (Silver Carp, Bighead Carp, and Grass Carp) have been observed in this pool up to the confluence with the Des Plaines River and have free access to enter the upper Des Plaines River. In 2010 and 2011, invasive carp eDNA was detected in the upper Des Plaines River (no samples were taken in 2012 through 2023). 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. USACE completed the construction of a physical barrier in 2010 to reduce the likelihood of invasive carp transfer between the two rivers. The physical barrier consists of concrete barriers and 0.25-inch (6.35 mm) mesh fencing built along 13.5 miles (21.7 kilometers) of the upper Des Plaines River, where its course is adjacent to the CSSC. The physical barrier's mesh size is designed to stop adult and juvenile invasive carp from infiltrating the CSSC but may not impede the movement of invasive carp eggs and fry (USACE 2010).

Overtopping events in 2011, 2013, and 2020 created breaches in the barrier that provided the potential for fish passage. An overtopping event in 2017 allowed water to breach the barrier but not connect to the CSSC. These areas have been fixed to prevent future breaches. No invasive carp have been captured during sampling throughout this project. It is important to understand the risks associated with overtopping events and detect any potential invasive carp presence and spawning within the river because of the Des Plaines River's proximity to the CSSC and its potential to function as a bypass to the EDBS. 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

- No Bighead Carp or Silver Carp have been captured or observed across all years of sampling.
- No overtopping events occurred in 2023; monitoring for eggs and larvae and evaluating physical barrier effectiveness was not required.
- No Grass Carp were collected in 2023. Ten Grass Carp have been collected since 2011.
- No eDNA sampling was conducted in the Des Plaines River in 2023. eDNA sampling is scheduled for spring 2024.
- In 2023, 1,254 fish (28 species) were captured from 4.5 hours of electrofishing and 365.8 meters of gill netting.
- From 2011 to 2023, 18,312 fish (68 species and 4 hybrid groups) were collected via electrofishing (96.25 hours) and gill netting (163 sets; 22,936.9 meters).
- Since 2011, four overtopping events have occurred, resulting in several improvements to the barrier fence.

METHODS

In 2023, two sampling events were conducted (July 3 to 5 and August 16 to 17) in the upper Des Plaines River from East Romeo Road (Romeoville, Illinois) to IL-83 (Willow Springs, Illinois; Figure 1) using pulsed-DC boat electrofishing and gill nets. Electrofishing runs included two netters and proceeded for 15 minutes. Gill net sets consisted of 100 yards (91.4 meters) of 3.5-inch and 4-inch bar mesh netting that was set before 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. Figure 1 shows the locations sampled in 2023, the total number of fish captured at each site, and the number of species captured at the site.

RESULTS AND DISCUSSION

During the 13 years of sampling (2011 to 2023), 96.25 hours of electrofishing and 163 net sets covering 22,936.9 meters (14.25 miles) of gill net resulted in a total catch of 18,312 fish. A total of 68 species and 4 hybrid groups have been collected during this time. Common Carp, Gizzard Shad, and Largemouth Bass have been the most commonly collected species, listed in order of abundance, across all sampling years. In 2023, 4.5 hours of electrofishing and 400 yards (365.8 meters) of gill net resulted in 1,254 fish caught, representing 28 species (Figure 2). In 2023, Bluntnose Minnow, Largemouth Bass, and Common Carp were the species captured in highest abundance, listed in order of abundance. No Bighead Carp or Silver Carp have been collected or observed throughout all years of sampling. Ten Grass Carp have been collected since 2011, but

no Grass Carp were collected in 2023. Figure 2 contains detailed capture abundances for species across project years.

The USFWS requested eDNA testing to be completed in the Des Plaines River in 2023 to determine if invasive carp genetic material was present. Although eDNA cannot discern living or dead individual presence, a negative test strongly indicates a species' non-presence. The Green Bay FWCO team attempted to complete eDNA sampling in 2023, but low water levels on the Des Plaines River prevented access. Green Bay FWCO has scheduled eDNA sampling again for spring 2024.

Overtopping events are anticipated to reduce significantly over time with the construction of the McCook Reservoir. Stage 1 of the McCook Reservoir has been in operation since 2017 and is expected to be completed in 2024 (Metropolitan Water Reclamation District of Greater Chicago 2023). Stage 1 of the reservoir provides 3.5 billion gallons of stormwater storage, reducing flood damage and combined sewer overflows (Lovell 2016). Stage 2 is expected to be completed in 2029 and expands storage volume by 6.5 billion gallons, for a total of 10 billion gallons of total storage (USACE 2023).

Figure 1. *2023 Sampling sites in the upper Des Plaines River. At each site, total fish counts for 2023 sampling are followed by the number of species observed in 2023 sampling effort (total fish/number of species).*

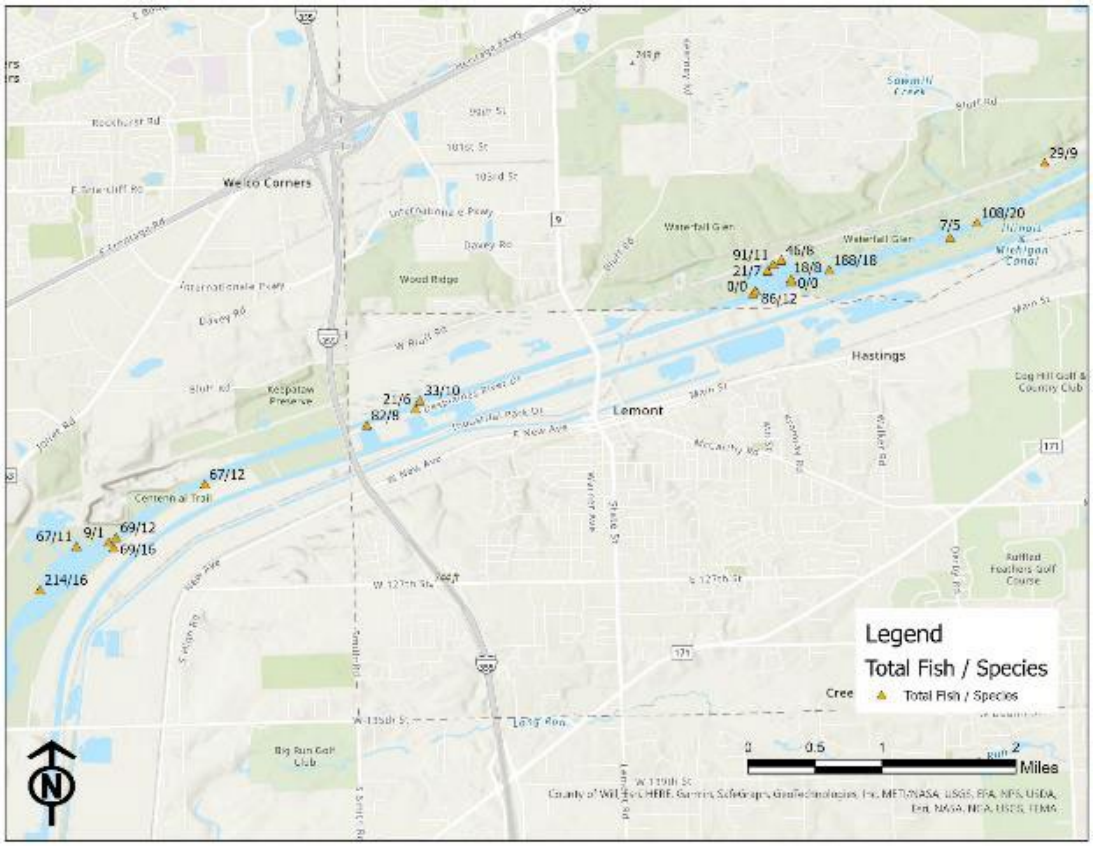
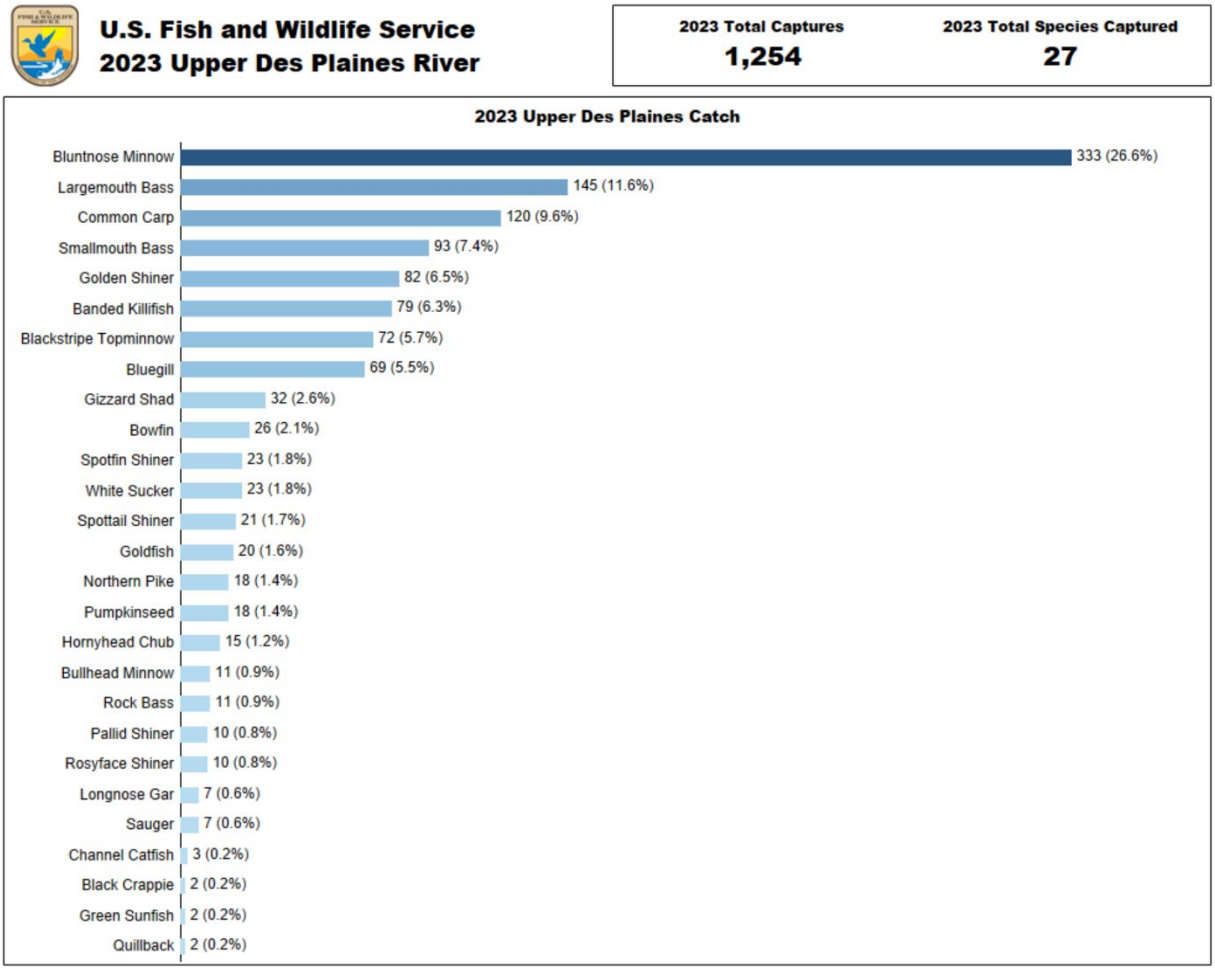


Figure 2. *Total catch for all sites in the upper Des Plaines River in 2023. The largest proportion of species was Bluntnose Minnow (27 percent), Largemouth Bass (12 percent), and Common Carp (10 percent).*



RECOMMENDATIONS

- Continue seasonal monitoring for large (greater than 153 mm) and small (less than or equal to 153 mm) invasive carp in the upper Des Plaines River.
- 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.
- Complete eDNA sampling in 2024 to determine if the presence of invasive carp genetic material is detected in the system.

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ALTERNATIVE PATHWAY SURVEILLANCE IN ILLINOIS – URBAN POND MONITORING

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

Pools Involved: N/A

INTRODUCTION AND NEED

The ILDNR fields many public reports of observed or captured invasive carp. All reports are taken seriously and investigated through phone/email correspondence with individuals making a report, requesting and viewing pictures of suspect fish, and visiting locations where fish are being held or reported to have been observed. In most instances, reports of invasive carp prove to be native Gizzard Shad or stocked non-natives, such as trout, salmon, or Grass Carp. Reports of Bighead Carp or Silver Carp from valid sources and locations where these species are not known to previously exist elicit a sampling response with boat electrofishing and trammel or gill nets. Typically, no Bighead Carp or Silver Carp are captured during sampling responses (Table 1). However, this pattern changed in 2011 when 20 Bighead Carp (greater than 21.8 kilograms [48 pounds]) were captured by electrofishing and netting in Flatfoot Lake and Schiller Pond, both fishing ponds located in Cook County once supported by the ILDNR Urban Fishing Program.

As a further response to the Bighead Carp in Flatfoot Lake and Schiller Pond, ILDNR reviewed Bighead Carp captures in all fishing ponds included in the ILDNR Urban Fishing Program located in the Chicago Metropolitan area, revealing, at that point in time, that three additional ponds in the program had verified reports of Bighead Carp from either pond rehabilitation with piscicide or natural die-offs (Columbus Park, Garfield Park, and 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 EDBS 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 EDBS. Ponds in Gompers Park, Jackson Park, and Lincoln Park are the exceptions. The Lincoln Park South and Jackson Park lagoons are no longer potential sources of Bighead Carp because they were rehabilitated with piscicide in 2008 and 2015, respectively. Gompers Park never had a report of invasive carp, nor have any been captured or observed during past sampling events. Nevertheless, examining all urban fishing ponds close to the CAWS or Lake Michigan was of importance due to the potential for human transfer of invasive carp between waters within proximity to one another.

In addition to Chicago area ponds once supported by the ILDNR Urban Fishing Program, ponds with positive detections for invasive carp eDNA were also reviewed. Eight of the 40 ponds

sampled for eDNA by the University of Notre Dame resulted in positive detections for invasive carp, two of which are also ILDNR urban fishing ponds (Jackson Park and Flatfoot Lake; Table 1).

The distance from ponds with positive eDNA detections to Lake Michigan ranges from 4.8 to 31.4 kilometers (3.0 to 19.5 miles). The distance from these ponds to the CAWS upstream of the EDBS 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 waterways. Furthermore, at the request of the ILDNR, 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.

OBJECTIVE

- Sample fishing ponds in the Chicago Metropolitan area included in the ILDNR 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.
- Eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have also been removed from Chicago area ponds since 2008.
- Two Bighead Carp were incidentally caught by fishermen in Chicago area ponds – one in 2016 and one in 2021.
- 20 of the 21 ILDNR 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 mm (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

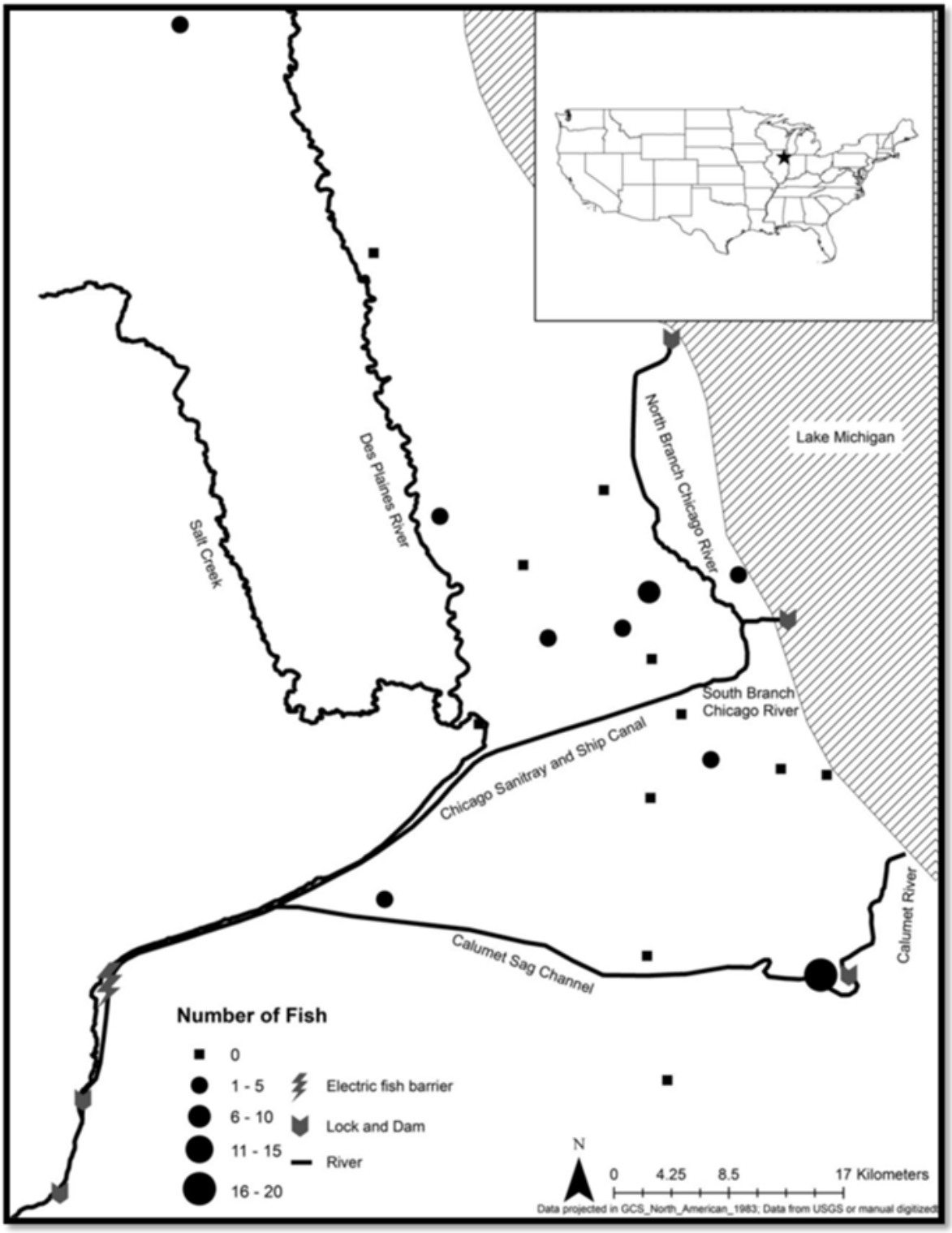
A total of 47 Bighead Carp and one Silver Carp have been removed from nine ponds (Table 1). Since 2011, 84 hours of electrofishing and 21 miles of gill/trammel net were utilized to sample 28 Chicago area fishing ponds, resulting in 37 Bighead Carp removed from five ponds. Additionally, eight Bighead 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 2016 and 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 removed, and is no longer a source of invasive carp. Auburn Park was too shallow for boat access but had extremely high visibility. Therefore, the pond was visually inspected, with no large-bodied fish observed. Lastly, Jackson Park and Garfield Park were drained in 2015 and, similar to Lincoln Park South, are no longer a source of invasive carp. A map of all the Chicago area fishing ponds that were sampled or inspected as part of this project can be found in Figure 1.

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

Location	*Electrofishing (hours)*	*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 Lake	20	3.6	1	20	-	-
Garfield Park	3.6	0.1	1	2	-	1
Gompers Park	0.3	-	1	-	-	-
Harborside Golf Course	2.8	0.9	1	-	-	-
Horsetail Lake	1	0.3	2	-	-	-
Humboldt Park	2.3	0.5	3	8	-	1
Jackson Park	4.3	1.8	1	-	-	-
Joe's Pond	0.5	0.3	1	1	-	-
Lake Owens	1	0.3	1	-	-	-
Lake Shermerville	1	0.3	-	-	-	-
Lincoln Park South	-	-	1	-	-	3
Marquette Park	1.3	0.4	1	-	-	-
McKinley Park	1.0	0.3	1	-	-	-
Powderhorn Lake	2.0	0.7	1	-	-	-

Location	*Electrofishing (hours)*	*Gill/Trammel Netting*	*Sampling Events (N)*	*Bighead Carp (N)*	*Silver Carp (N)*	*Invasive Carp Collected Post Die-off, Rotenone Rehab, or Incidental Take*
Riis Park	0.2	-	1	-	-	-
Sag Quarry	0.6	0.3	1	-	-	-
Saganashkee Slough	2.0	0.6	1	-	-	-
Schiller Pond	2.0	-	1	3	-	-
*Sherman Park**	1.0	0.3	1	-	-	-
Tampier Lake	5.5	0.6	1	-	-	1
Washington Lake	1.5	0.3	1	-	-	-
Totals	**58.0**	**12.8**	**35**	**35**	**0**	**10**

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 µmol/mol; within 50 to 150 microns of the otolith center) to lower values (400 to 650 µmol/mol) toward the edge of the otolith (mean 618 µmol/mol; within 50 microns of the otolith edge) (Figure 2). Mean otolith Sr:Ca of 618 µmol/mol near the otolith edge is consistent with expected otolith Sr:Ca for a resident fish in these Chicago fishing ponds based on Sr:Ca of water samples taken from these sites from 2010 to 2012 (1.5 to 1.8 mmol/mol) and a regression relating water and invasive carp otolith Sr:Ca (Norman and Whitledge, in press). The higher Sr:Ca near the otolith core suggests these fish were transferred into the lagoons during age-0 or age-1. These data indicate that the fish spent their early life in water(s) with higher Sr:Ca and the remainder of their life as residents of the urban ponds. In addition, the otolith core Sr:Ca values are high when compared to that of Bighead Carp of Illinois River origin, as well as other sites previously examined in northern Illinois (Figure 3) (Whitledge 2009). A similar trend was observed when comparing otolith core $\delta^{18}O$ and $\delta^{13}C$ values for Bighead Carp, which showed no overlap between Chicago pond fish and Illinois River fish (Figure 4). Therefore, Bighead Carp removed from Chicago area ponds were likely not transplanted adult fish nor bait bucket introductions of juveniles from the Illinois River or other nearby rivers. In contrast, otolith core $\delta^{18}O$ and $\delta^{13}C$ values and Sr:Ca of the Silver Carp collected from Sherman Park Pond fell within the range of otolith $\delta^{18}O$ and $\delta^{13}C$ values and Sr:Ca for Illinois River fish (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 from 2002 to 2003. This corresponds to a time when Bighead Carp were raised for market in ponds with Channel Catfish in certain regions of the U.S. (Kolar et al. 2007). Shipments of Channel Catfish may be the most likely source of contamination in Illinois urban fishing ponds, as catchable-sized catfish are stocked frequently and extensively in these waters throughout the State (ILDNR 2010). 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 invasive carp taken from nearby rivers.*

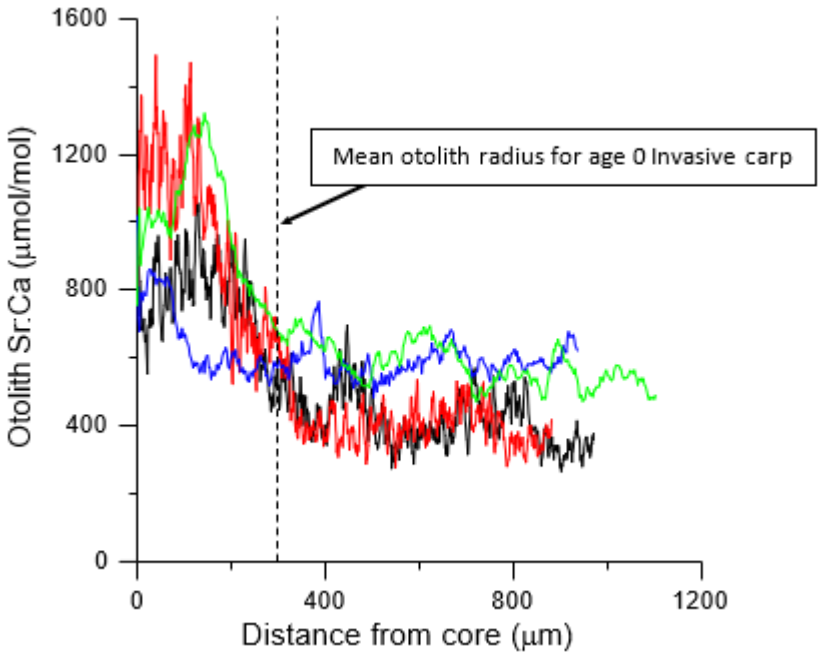


Figure 3. *Boxplots of otolith core Sr:Ca for Chicago pond (N = 24) and Illinois River (N = 81) invasive carp. The minimum value for urban pond carp represents the Silver Carp collected from Sherman Park.*

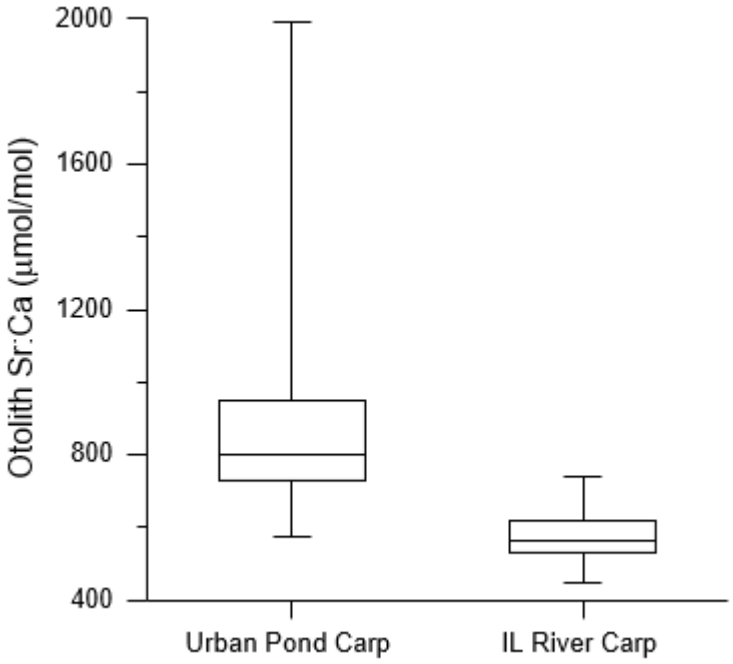
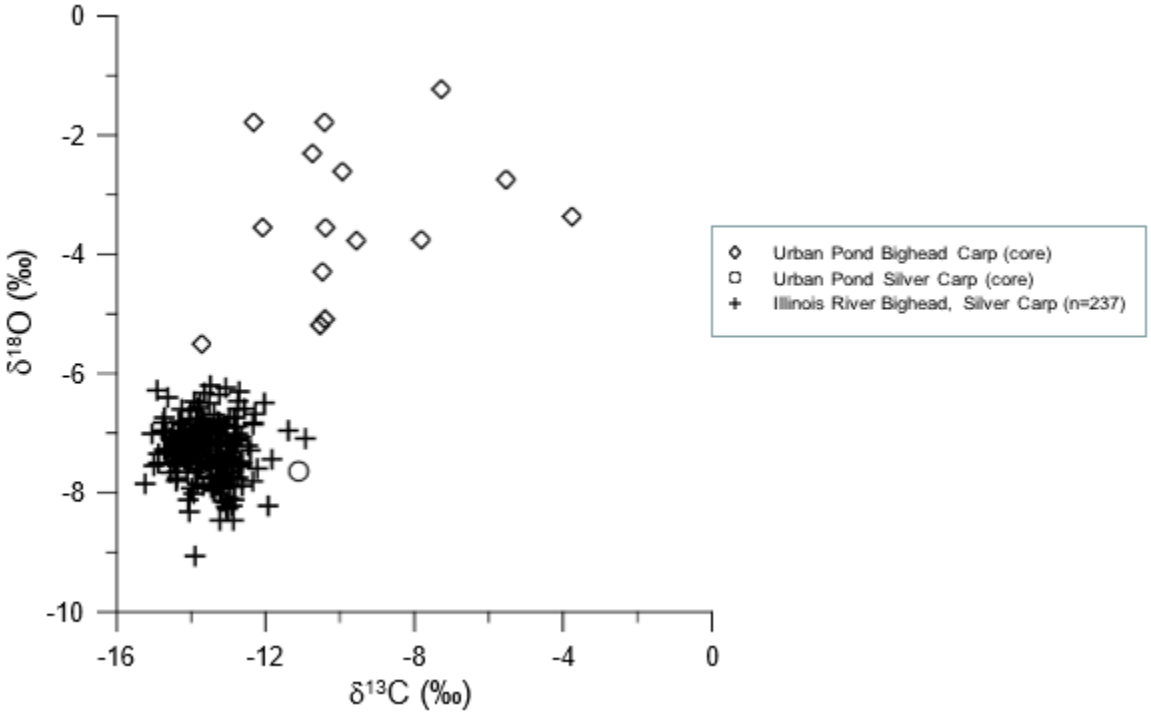


Figure 4. *Otolith Core $\delta^{18}O$ and $\delta^{13}C$ comparing Urban Pond and Illinois River Bighead Carp and Silver Carp.*



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MULTIPLE AGENCY MONITORING OF THE ILLINOIS RIVER FOR DECISION-MAKING

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

Pools Involved: Lockport, Brandon Road, Dresden Island (includes a portion of the Kankakee River), Marseilles, Starved Rock (includes a portion of the Fox River), Peoria, La Grange, and Alton pools of the Illinois River below the EDBS (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 2023, 171 hours of electrofishing, 1,344 hoop netting net nights, 448 minnow fyke netting net nights, 98 standard fyke netting net nights, and 57.5 hours of dozer trawling were completed.

- In 2023, 371,145 fish were captured, representing 102 species, 8 hybrid species, and 8 unknown species from family groups (e.g., small individuals from Cyprinidae, Catostomidae, Centrarchidae, etc.)
- Zero invasive carp (large or small) were captured in Lockport or Brandon Road pools in 2023.
- 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 2023.
- Seven small Silver Carp (less than 6 inches or 152.4 mm) were captured during MAM sampling in 2023 in the lower three pools of the Illinois River. No significant spawning event was detected in 2023.

METHODS

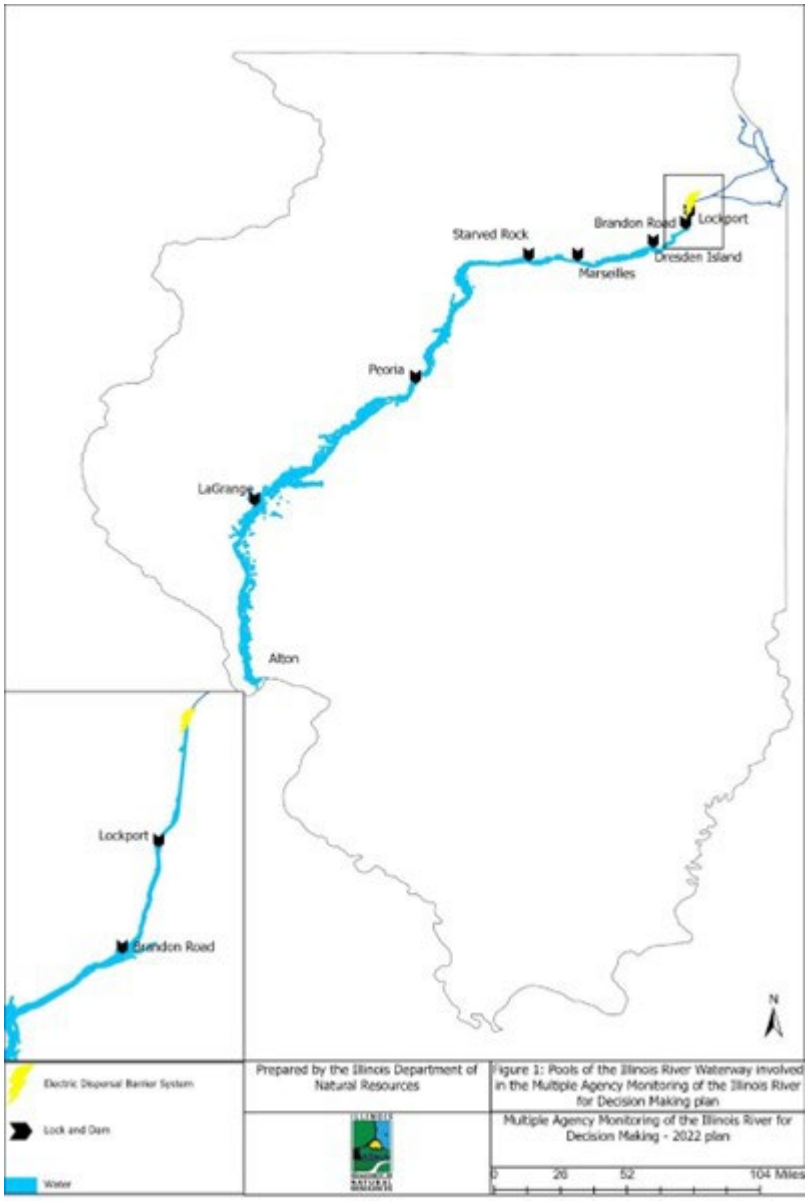
The MAM of the Illinois River for Decision Making used the standardized, multi-gear approach developed by the USACE's Upper Mississippi River Restoration Program (Ratcliff et al. 2014) to monitor invasive carp populations in the Illinois River Waterway below the EDBS. This approach utilized daytime boat pulsed DC electrofishing, standard fyke netting, minnow (hereafter mini) 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). In 2023, electrified dozer trawl was incorporated into the sampling protocol for MAM. The Invasive Carp Demographics Project (ICRCC-MRWG 2022) has used an electrified dozer trawl to collect silver carp for several years. The addition of the electrified dozer trawl to an LTRM-style standardized monitoring approach will help create a more comprehensive picture of the spatial and temporal distribution of invasive carp populations within Lockport to Alton reaches of the Illinois River by sampling pelagic strata and tributaries (Fox and Kankakee rivers). See the MRP for a detailed description of dozer trawl specifications and sampling protocol.

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 dozer trawling and the number of fish per net night (24 hours) for fyke net, mini fyke net, and hoop net samples.

Figure 1. *Map depicting sampling coverage for MAM Sampling in 2023.*



RESULTS AND DISCUSSION

Electrofishing Effort and Catch

The total sampling effort included 171 hours of electrofishing (684 transects) downstream of the EDBS in 2023. Electrofishing yielded 113,784 individual fish representing 91 species, five hybrid species, and small, unknown individuals from five family groups (Cyprinidae, Catostomidae, etc.) for a CPUE of 665.4 fish per hour. In 2023, electrofishing catch was dominated by Gizzard Shad (30.0 percent; n = 34,189), Emerald Shiner (28.8 percent; n = 32,752), Bluntnose Minnow (6.7 percent, n=7,632, and Bluegill (6.0 percent; n= 6,882). Silver Carp electrofishing captures in 2023 were similar to captures in 2022. In 2023, total Silver Carp captures represented 1.3 percent of the total catch (n= 1,451) compared to 2.0 percent (n=1,764) in 2022 and 14.7 percent (n= 7,325) in 2021. Overall, Silver Carp CPUE was 8.5 per hour in 2023, which is slightly less than 2022 (10.3 per hour) and considerably less than 2021 (41.6 per hour). Silver Carp CPUE was highest from Starved Rock Pool downstream through the lower Illinois River pools, 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 2023. Zero Silver Carp were captured using electrofishing in Dresden Island Pool from 2022 to 2023, but three silver carp were captured in 2021. In 2023, one large Bighead Carp was captured during electrofishing in La Grange Pool, and one small Grass Carp was captured in Peoria Pool. Of the Silver Carp captured in 2023 during electrofishing, among all the pools, 0.3 percent (5 of 1,451) of individuals were small (less than 6 inches), and the remaining 99.7 percent were large (greater than 6 inches). In comparison, no small Silver Carp were captured in 2022, but 79.3 (n=5,740) percent of Silver Carp captured in 2021 were small. In 2021, most of the Silver Carp were small individuals (n = 5,740, or 79.3 percent).

Mini Fyke Netting Effort and Catch

The total sampling effort included 448 mini fyke nets downstream of the EDBS in 2023. Mini fyke netting yielded 163,997 fish representing 74 species, two hybrid species, and small, unknown species from seven family groups (Cyprinidae, Catostomidae, etc.) for a CPUE of 366 fish per net night. Most of the mini fyke catch was comprised of Emerald Shiner (32.2 percent; n = 52,815), Bluegill (16.0 percent; n = 26,244), Bluntnose Minnow (12.8 percent, n = 20,974), and Western Mosquitofish (8.6 percent; n = 14,112). Two Silver Carp were captured in mini fyke nets in 2023; one small Silver Carp was captured in La Grange Pool, and one large Silver Carp was captured in Peoria Pool. In comparison, zero Silver Carp were captured in 2022 in mini fykes, but 13.1 percent (n = 50,619) of mini fyke catch were Silver Carp in 2021 (predominantly small individuals). One large Grass Carp was captured in Marseilles Pool.

Hoop Netting Effort and Catch

The total sampling effort included 672 hoop nets (1,344 hoop net nights) downstream of the EDBS in 2023. Hoop netting yielded 7,538 fish representing 47 species and five hybrid species for a CPUE of 5.6 fish per net night. Channel Catfish comprised the largest proportion of hoop net catch (41.2 percent; n = 3,109), followed by Smallmouth Buffalo (17.4 percent; n = 2,206),

Common Carp (12.0 percent; n = 904), and Bluegill (8.3 percent; n = 628). No invasive carp were captured in Lockport, Brandon Road, Dresden Island, or Marseilles pools during hoop netting, but invasive carp were captured in the other downstream pools (six Bighead Carp, 65 Grass Carp, and 47 Silver Carp) in 2023; these catches were similar to 2022. Greater catch rates of invasive carp in hoop nets were found in the lower river pools (Peoria, La Grange, and Alton pools) compared to the Starved Rock Pool in the upper Illinois River.

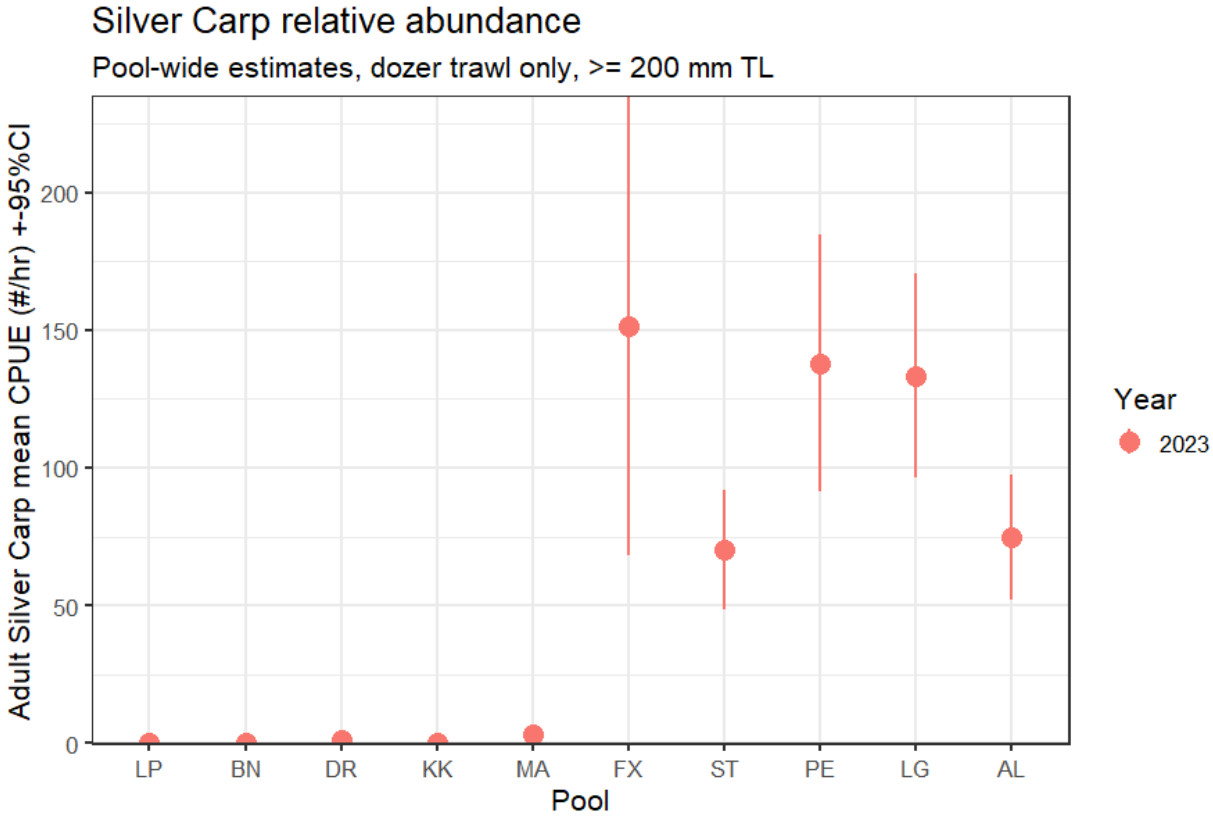
Fyke Netting Effort and Catch

The total sampling effort included 98 fyke nets downstream of the EDBS in 2023. A total of 2,691 fish representing 45 species, four hybrid species, and small, unknown Catostomidae *sp.* were captured during fyke netting, with a CPUE of 27.5 fish per net night. Fyke net catch was dominated by Bluegill (39.4 percent; n = 1,061), Shortnose Gar (15.1 percent; n = 405), White Crappie (6.4 percent; n = 172), and Pumpkinseed (6.2 percent; n = 168) in 2023. Three Bighead Carp, zero Black Carp, five Grass Carp, and nine Silver Carp were captured during fyke netting; none of these individuals were small. All invasive carp captured during fyke netting were collected below Marseilles Pool. However, no fyke net samples were collected in Lockport, Brandon Road, or Alton pools due to a lack of suitable connected backwater habitat for this gear. Higher catch rates of invasive carp were found in the lower river pools of Peoria, La Grange, and Alton pools compared to the upper river pools in 2023, similar to 2021 to 2022.

Dozer Trawl Effort and Catch

The total sampling effort included 57.5 hours of dozer trawling (695 transects) downstream of the EDBS in 2023. A total of 83,135 fish representing 68 species, one hybrid species, and small, unknown individuals from four family groups (Catostomidae, Centrarchidae, Moronidae, and Cyprinidae) were captured during dozer trawling, with a CPUE of 1,445.8 fish per hour. Dozer trawl catch was dominated by Gizzard Shad (69.5 percent; n = 57,790), Emerald Shiner (8.9 percent; n = 7,393), Silver Carp (5.9 percent; n = 4,875), and Threadfin Shad (5.4 percent; n= 4,469) in 2023. Four Bighead Carp, zero Black Carp, 40 Grass Carp, and 4,852 Silver Carp were captured during dozer trawling. All invasive carp were large individuals, except for one small (less than 6 inches) Silver Carp that was captured in Alton Pool. Invasive carp were captured as far upstream as Dresden Island Pool, though not further upstream than MAM had detected them in earlier years. Adult Silver Carp mean CPUE was highest in the Fox River tributary, though may not have been statistically significantly different from similarly high-mean CPUE in Peoria and La Grange pools (Figure 2). Starved Rock and Alton pools mean Silver Carp CPUE were similar. A few Silver Carp were caught in Marseilles and Dresden Island pools.

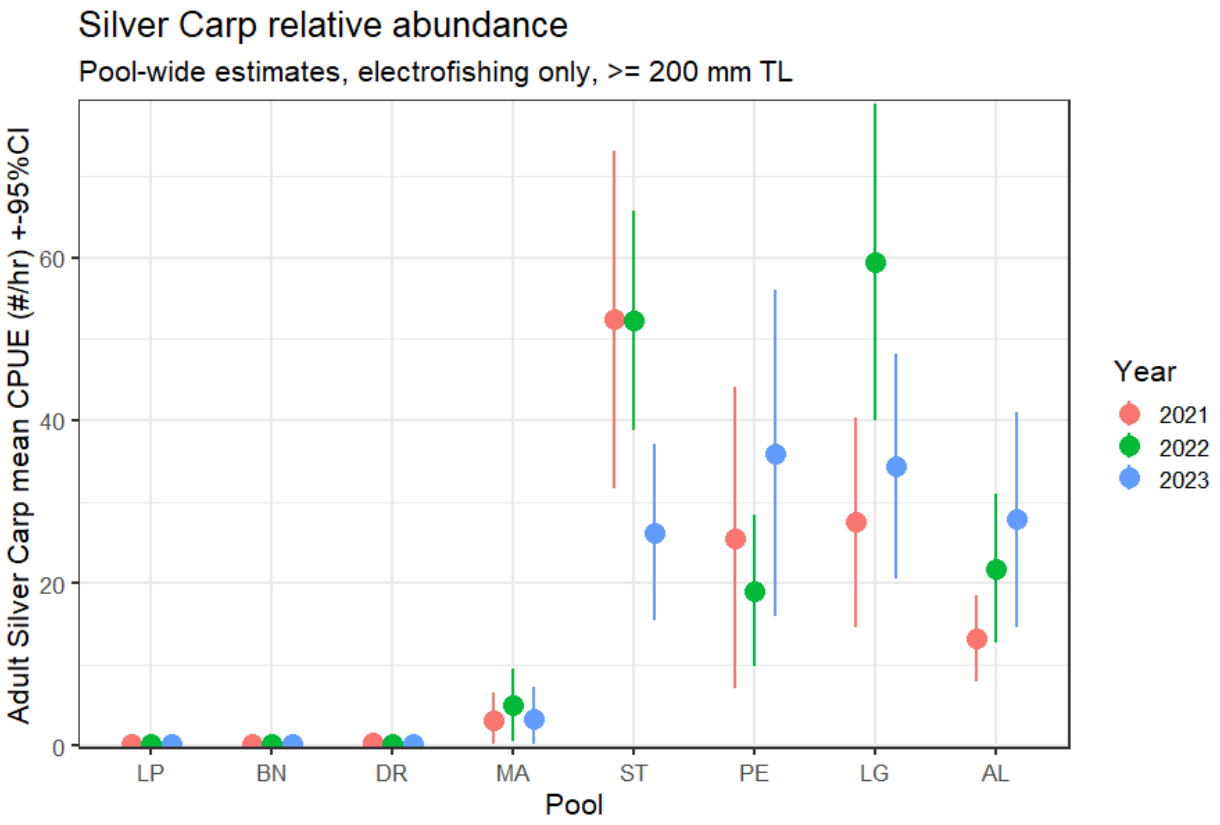
Figure 2. *A comparison of adult CPUE (fish per hour, greater than or equal to 200 mm in total length) of Silver Carp captured using dozer trawling in 2023 among the various pools of the Illinois River Waterway and its tributaries. LP = Lockport, BN = Brandon Road, DR = Dresden Island, KK = Kankakee River, MA = Marseilles, FX = Fox River, ST = Starved Rock, PE = Peoria, LG = La Grange, and AL = Alton.*



Comparisons of Adult Invasive Carp Catch

The overall relative abundance of invasive carp was highest below Marseilles Pool. Peoria and La Grange had the highest electrofishing relative abundance among pools sampled in 2023 (Figure 3). Silver Carp mean electrofishing CPUE in 2023 was relatively higher in Alton and Peoria pools compared to 2022 but relatively lower in Starved Rock and La Grange. Marseilles remained relatively the same. Most of these changes in mean electrofishing CPUE are not statistically significant, though approaches for improving power to detect modest changes are under investigation by IRBS researchers.

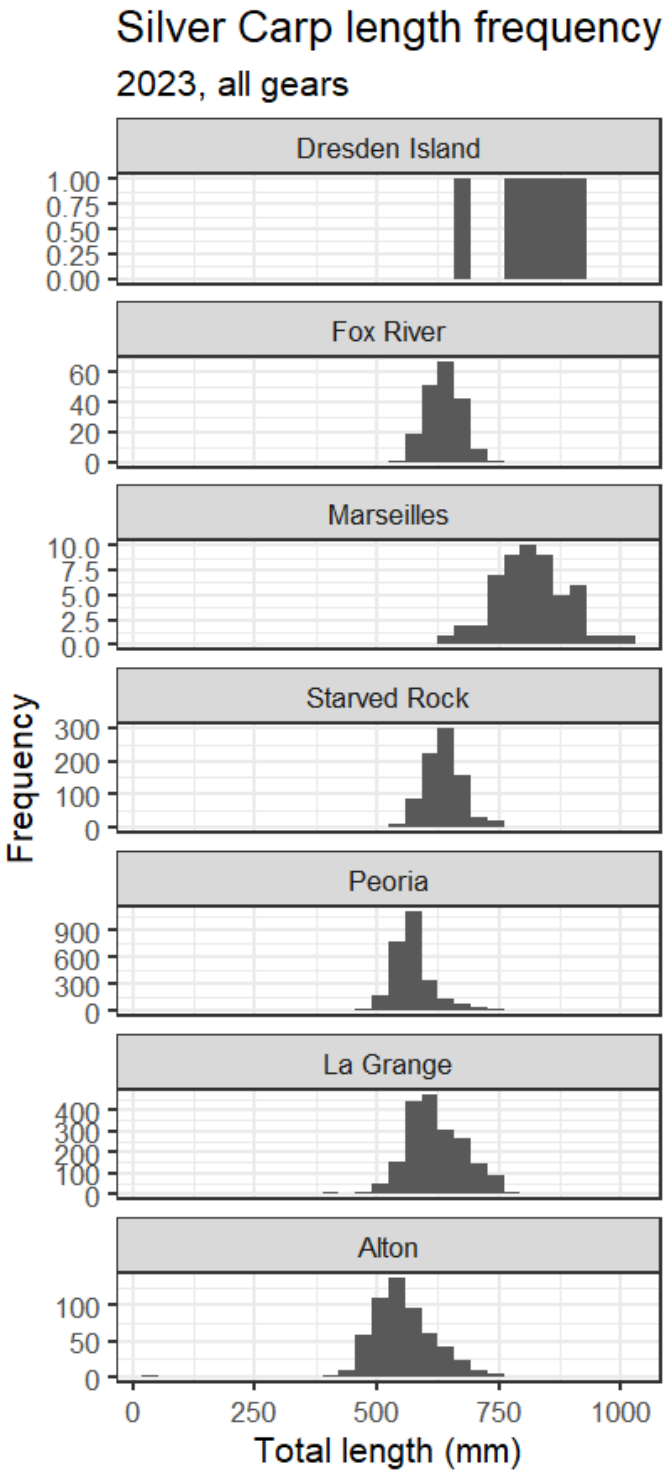
Figure 3. *A comparison of adult CPUE (fish per hour, greater than or equal to 200 mm in total length) of Silver Carp captured using electrofishing in 2021, 2022, and 2023 among the various pools of the Illinois River Waterway. LP = Lockport, DR = Dresden Island, BN = Brandon Road, MA = Marseilles, ST = Starved Rock, PE = Peoria, LG = La Grange, and AL = Alton.*



Size Structure

Bighead Carp catches were between 380 and 891 mm in total length (n = 10), Grass Carp catches were between 50 and 990 mm in total length (n = 114), and Silver Carp catches were between 20 and 1000 mm in total length (n = 6054) in 2023. Mean Silver Carp length was larger in upper river reaches compared to lower river reaches (Figure 4). Six Silver Carp were caught in Dresden Island Pool in 2023. The mean total length for Silver Carp in Dresden Island Pool was 820 mm in 2023, 895 mm in 2021, and 831 mm in 2019; no Silver Carp were caught in 2022 or 2020. The Silver Carp size structure of the pools below Starved Rock increased in 2023, with a mean total length of 588 mm in 2023 compared to 575 mm in 2022. This follows last year's similar increase in lower pools' mean lengths.

Figure 4. *Overall size structure distribution of Silver Carp captured in all pools of the Illinois River and Fox River tributary. All gear types (electrofishing, electrified dozer trawl, fyke netting, hoop nets, and mini fyke nets) were aggregated together.*



Geographic Distribution

In 2023, no invasive carp were captured above the previously known furthest upstream location in Dresden Island Pool. Zero Silver Carp less than 6 inches were captured in Dresden Island Pool in 2023. 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). One Grass Carp (990 mm) was captured in the Marseilles Pool (up from zero in 2022), and zero Grass Carp were captured in the Dresden Island Pool in 2023. For 2024, we have designed a pilot study of supplemental monitoring in Dresden Island Pool and the adjacent Kankakee River, in which locations of historical occurrence data and anecdotal evidence of Silver Carp captures will inform a supplementary sampling frame grid that will be randomly sampled by electrofishing. This hybrid targeted/random sampling should allow us to better understand the relative abundance and distribution of invasive carp in and near the Dresden Island Pool and have higher statistical power for detecting changes in this leading edge of the invasion.

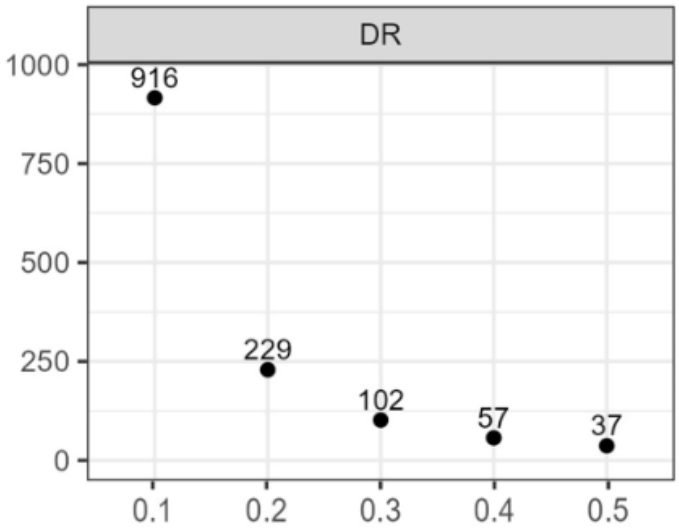
Supporting Research

Power Analyses

We leveraged the first five years of MAM data to perform a power analysis for determining recommended sample size levels for reliably detecting given effect sizes (i.e., percent changes in interannual invasive carp CPUE) at different confidence levels. Results vary depending on the desired effect size, confidence level, actual effect size, study reach, and species. Some examples of recommended sample sizes are visualized in Figure 5. Current effort levels do not always meet recommended sample sizes in all cases, but where reasonable, allocations of additional effort or re-allocation of existing effort may bring these up to standard in the future.

More targeted power analyses were performed using MAM and complementary non-MAM data to inform the establishment of additional effort levels within the supplementary sampling frame in Dresden Island Pool. This pilot study is designed to more finely target random sampling where carp are most likely to occur, thereby shrinking variances of estimated CPUE means and increasing our statistical power to detect modest interannual changes in CPUE in this pool. Data from this supplementary sampling frame should help provide additional security at the leading edge of the invasion, providing early detection of expansions in range or relative abundance in areas of greatest concern.

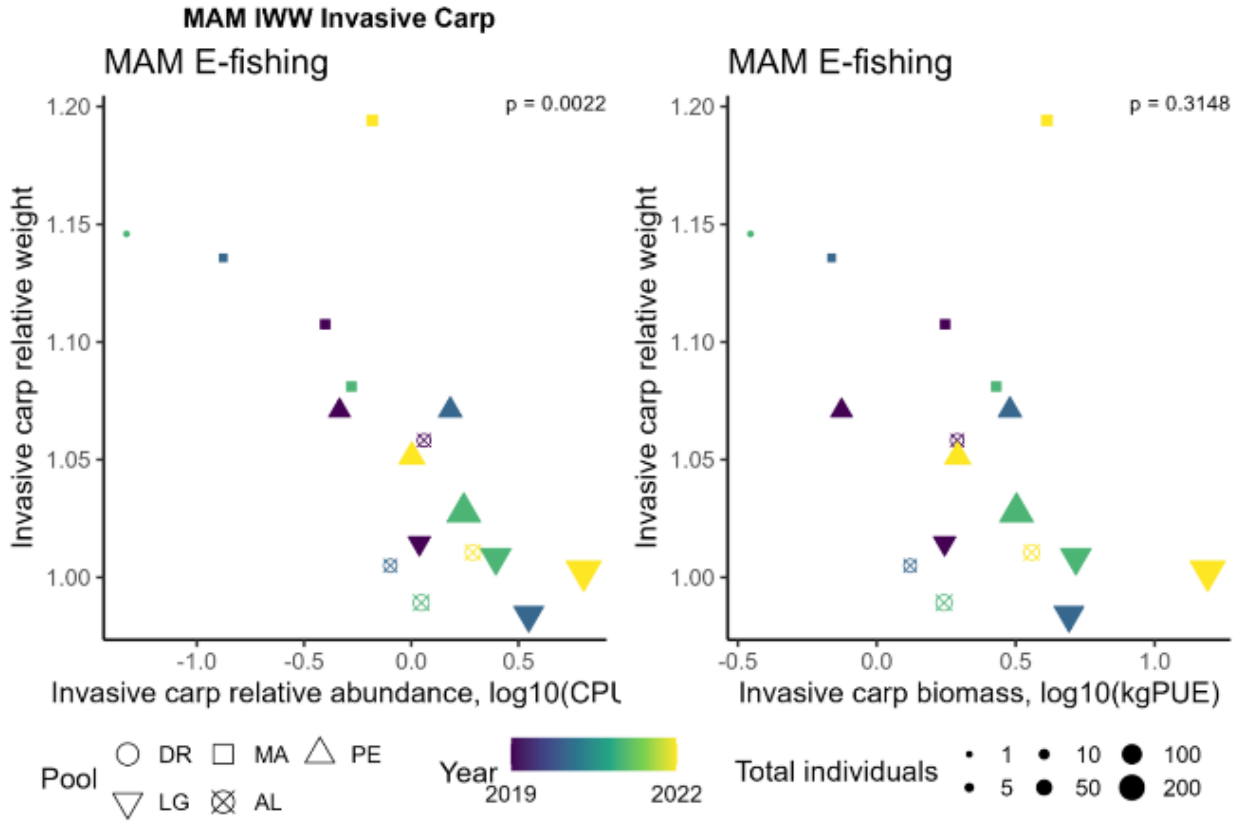
Figure 5. *Recommended sample sizes (y-axis) to detect interannual change in Silver Carp mean CPUE at different effect sizes (x-axis, expressed as a proportion of mean CPUE) for Dresden Island Pool based on previous MAM years' electrofishing effort.*



Evaluating Harvest Success

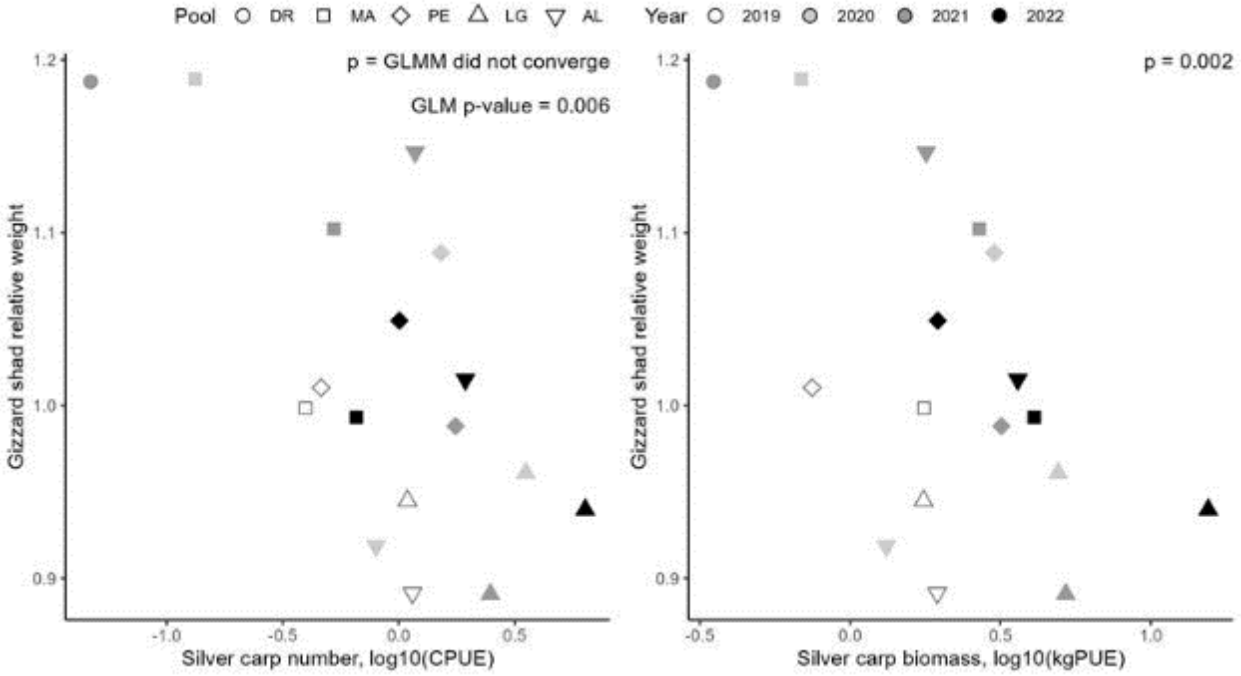
We also leveraged the first several years of MAM data to examine relationships between invasive carp relative abundance and invasive carp body condition (Figure 6). These species' relative weight is likely resource-limited and, therefore, density-dependent. By establishing a relationship between invasive carp relative abundance and invasive carp body condition, we can not only ground our CPUE estimates in this expected ecological relationship but work toward developing it as a management tool whereby observed interannual changes in body condition could be predictive of ongoing changes in relative abundance. Where estimates of relative abundance are unavailable or highly variable, body condition could serve as a secondary line of evidence for increasing or decreasing population size in a given pool. Starved Rock was a consistent outlier of these relationships and may be required to be modeled separately from the other pools.

Figure 6. *Comparisons of invasive carp relative abundance (left, CPUE, number/15 minutes electrofishing) and invasive carp biomass (right, kgPUE, kilogram/15 minutes electrofishing) to invasive carp body condition (relative weight) indicate a strong, negative relationship. Body condition may be developed into a secondary line of evidence for interannual changes in invasive carp population sizes.*



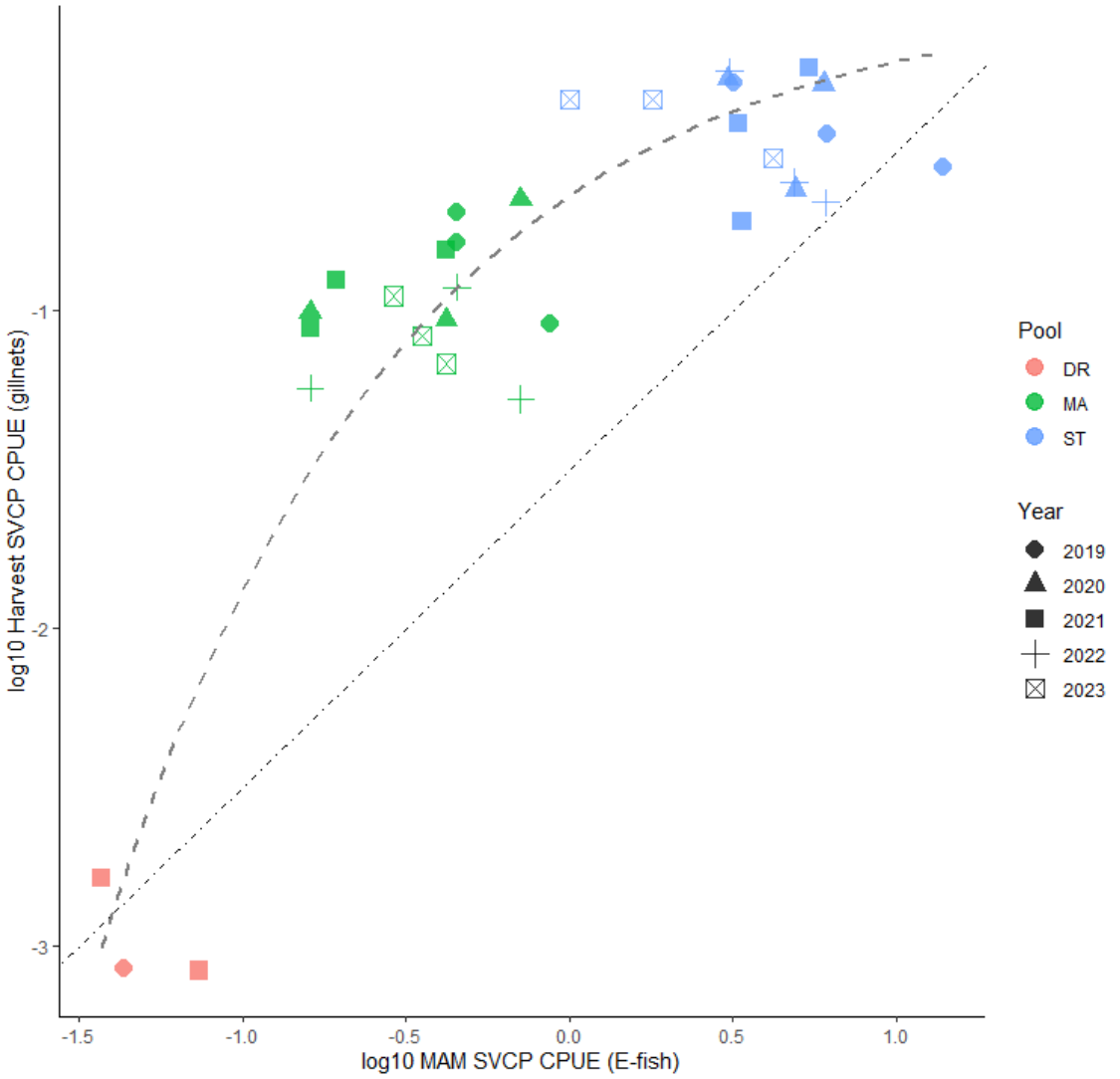
We also examined the relationship between invasive carp relative abundance and the body condition of native planktivorous fishes that may compete directly for consumptive resources with invasive carp. For many species, similar density-dependent relationships existed, whereas invasive carp relative abundance increased, the body condition of native planktivores decreased (Figure 7). Establishing these relationships and then strengthening and refining them with covariates could allow us to predict changes in invasive carp abundance by observing their direct, competitive, and deleterious effects on the native fish community.

Figure 7. *Comparisons of invasive carp relative abundance (left, CPUE, number/15 minutes electrofishing) and invasive carp biomass (right, kgPUE, kilogram/15 minutes electrofishing) to body condition (relative weight) of a native planktivore, Gizzard Shad. The data indicate a strong, negative relationship. The body condition of native planktivores may also be developed into a secondary line of evidence for interannual changes in invasive carp population sizes.*



Furthermore, we quantified catch estimates from contracted and incentivized invasive carp harvest records and evaluated their interannual differences alongside those of the fisheries-independent MAM data. This comparison yielded an important insight for carp management: the harvest data appears to be "hyper-stable" to interannual changes in invasive carp relative abundance, as estimated by MAM electrofishing (Figure 8). This indicates that annual estimates of catch from harvest data may themselves be poor evaluators for the harvest efforts' success in controlling the invasive carp populations. Instead, the standardized and stratified random sampling design of MAM's electrofishing gear is more sensitive to changes in invasive carp relative abundance, making it a better tool for directly evaluating harvest success.

Figure 8. *Comparisons of silver carp CPUE from MAM electrofishing (number/15 minutes) and harvest gillnetting (number/100 yards) indicate a hyperstable relationship between fisheries-dependent and fisheries-independent data sources.*



RECOMMENDATIONS

Implementing a standardized multi-gear sampling approach has created a comparable and comprehensive picture of invasive carp dynamics throughout the entire Illinois River Waterway, allowing for a holistic assessment. Standardization continues to allow monitoring projects outside of the MRP to be incorporated (e.g., dozer trawl from USFWS this year), 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. A pilot study that combines targeted and random sampling approaches will launch in 2024 to gain further precision on mean CPUE estimates of invasive carp in Dresden Island Pool, at the

leading edge of the invasion, to allow greater statistical power in detecting relatively small interannual changes to CPUE. 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, the last recorded large spawning event, indicating that 2023 may have been a worse reproductive year, with no major spawning event. The few invasive carp caught smaller than 6 inches (n = 7) were caught in the lower three pools. We recommend continued sampling below the EDBS using a multi-gear approach that includes electrofishing, fyke netting, hoop netting, mini fyke netting, and now dozer trawling following this standardized protocol. Minimally, the same level of effort should occur, and future effort levels should follow statistical power analyses when reasonable. 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. The inclusion of these data allows for formulating the most comprehensive picture of invasive carp expansion and response within the Illinois River Waterway.

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USGS INVASIVE CARP DATABASE MANAGEMENT AND INTEGRATION SUPPORT

Participating Agencies: USGS; ILDNR; INHS; USFWS; USACE; SIU; Aaron Murphy, Marybeth Brey, Matthew Walker (USGS, Upper Midwest Environmental Sciences Center)

Pools Involved: N/A

INTRODUCTION AND NEED

Invasive 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 invasive 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 invasive 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 invasive 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 Work Group, Telemetry Work 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 invasive carp.
- Communicate regularly with the MRWG work groups to determine if the databases and database structures meet partner needs.

PROJECT HIGHLIGHTS

ILRCdb

- Maintained access to the database.
- Coordinated with INHS to maintain the fish collection application (FISH app).

FishTracks Telemetry Database

- Continued to collect telemetry data and uploaded it to a temporary SharePoint repository. Data underwent quality control/quality assurance procedures to prepare for incorporation with the FishTracks web application.
- Redesigned role-based access to data to fix security vulnerabilities.
- Initiated redesign for database tables.
- Decided to migrate the existing FishTracks database to a structure with the Ocean Tracking Network data-sharing system.

CarpDAT (Data, Analysis, Tools)

- Created a beta version of CarpDAT metadata catalog based on the Amazon Web Service platform.
- Formalized relationship between USGS and USFWS with an official memorandum of understanding to define roles and responsibilities moving forward.

Invasive Carp Open Data Hub

- Completed and reconciled peer review.
- Started working with the USGS web team to ensure the portal meets current USGS design standards for ArcGIS Online.

Note: Progress in FY 2023 was impacted by staff turnover at USGS. This project is fully staffed now, and several products are planned for FY 2024.

METHODS

The FishTracks Telemetry Database, a Microsoft SQL Server application, and the ILRCdb application, developed in the open-source relational database PostgreSQL, were developed and maintained by USGS. Maintenance included performing routine tasks (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 were annually uploaded into the database applications after passing quality assurance checks for data consistency (i.e., standardized data formatting). Updates and additions were made to the applications based on partner requests, such as creating customized monthly, quarterly, or annual reports based on specific monitoring or management objectives. An R application programming interface was

developed to allow direct programmatic access to database applications, enabling data end-users to integrate and analyze partnership data into modeling software programs.

Existing invasive carp-relevant datasets and analytical tools that have been collected, processed, and developed by the multi-agency partnership will be 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) allows 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

In late 2022, critical personnel left USGS, and those positions were not refilled until July 2023. This impacted the progress of all database development work during FY 2023. The USGS team is now fully staffed and moving forward with upgrades and maintenance on the databases.

Invasive carp monitoring and removal data from the Illinois River continued to be collected by partner agencies in FY 2023. Data collection protocols similar to the sampling approach used by the LTRM element of the Upper Mississippi River Restoration Program and the FISH app were used. Database application updates, new version releases, and additional customized data summary features will be implemented as needed.

During maintenance of the FishTracks Telemetry Database in FY 2023, security vulnerabilities were identified, and the role-based access features were redesigned. Additional issues necessitated the decision to migrate the original FishTracks database to a structure based on the Ocean Tracking Network framework. Development of this new version of FishTracks is ongoing. Meanwhile, invasive carp acoustic telemetry data from the Illinois River and upper Mississippi River continue to be collected by partner agencies for inclusion in the FishTracks database. Data are currently shared with USGS through a temporary SharePoint repository, and quality assurance/quality control is performed to prepare data for inclusion in FishTracks. Database application updates, new version releases, and additional customized data summary features will be implemented as needed.

The CarpDAT metadata catalog will provide researchers and managers with a centralized location to find invasive carp data and information. During FY 2023, USGS and USFWS developed a memorandum of understanding to define development roles and created a demonstration version of the catalog. Deployment is planned using Amazon Web Services in FY 2024.

The USGS Invasive Carp Open Data Hub went through USGS peer review in FY 2023 and is being approved for public release. This ArcGIS Online tool will be continuously updated with additional USGS invasive carp data.

CONTRACTED COMMERCIAL FISHING BELOW THE ELECTRIC DISPERSAL BARRIER

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

Location: 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 EDBS 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 EDBS. By decreasing invasive carp abundance, we anticipate reduced migration pressure towards the barrier, lessening the chances of invasive carp gaining access to upstream waters in the 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 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 EDBS in the IWW.
- Reduce invasive carp densities, lessening migration pressure to the EDBS, thus decreasing chances of invasive carp accessing upstream reaches (e.g., CAWS and Lake Michigan).
- 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 EDBS.

PROJECT HIGHLIGHTS

- Since 2010, contracted commercial fishers’ effort in the Upper IWW below the EDBS includes 5,668 miles (9,122 kilometers) of gill/trammel net, 22 miles (35 kilometers) of commercial seine, 239 Great Lakes pound net nights, and 4,369 hoop net nights.

- From 2010 to 2023, 105,915 Bighead Carp, 1,729,779 Silver Carp, and 12,408 Grass Carp were removed by contracted fishers. The total estimated weight of invasive carp removed is 7,260 tons (14,519,600 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; 452 kilometers 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 EDBS for the SIM project.

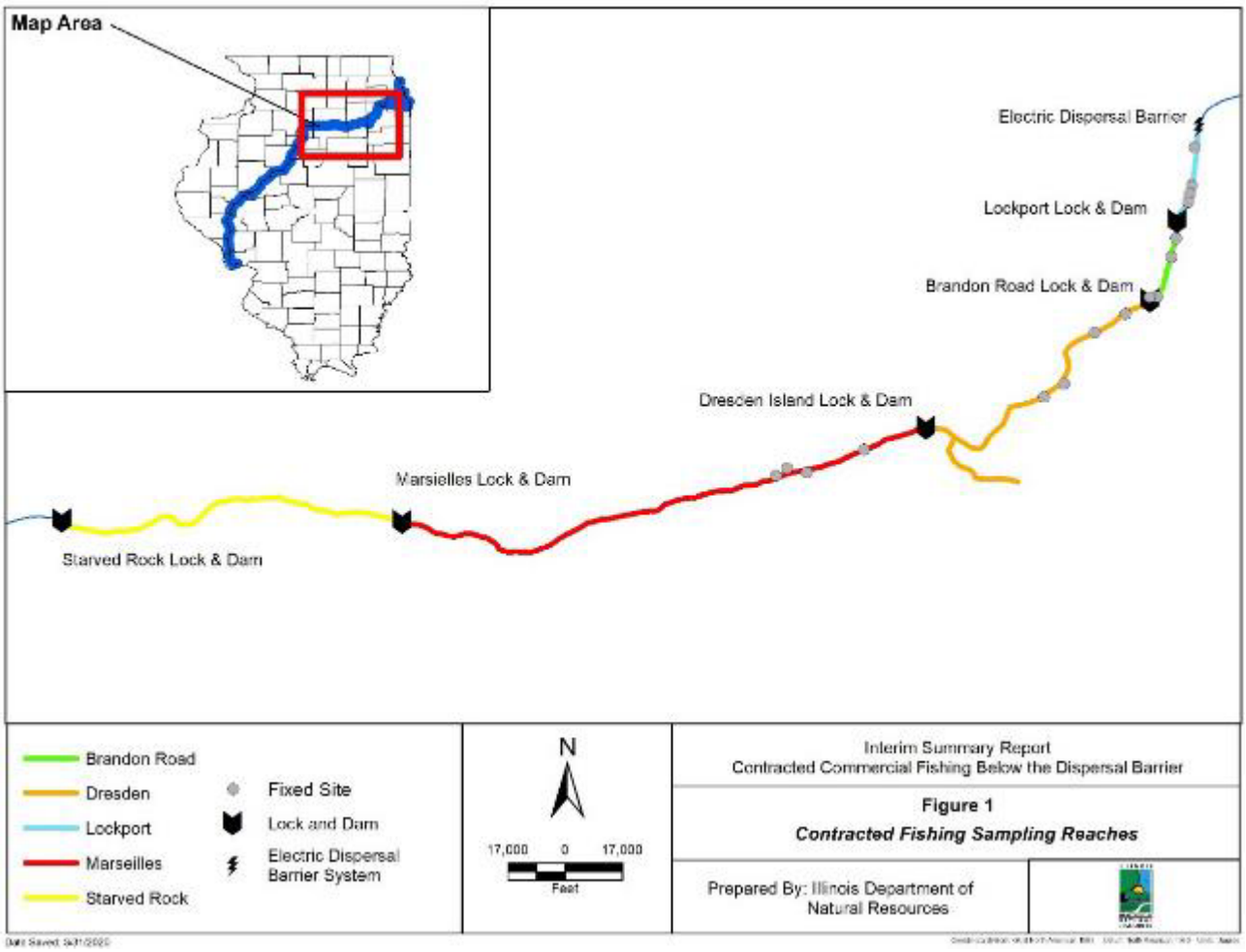
Contract fishing occurred at targeted sites throughout each pool monthly. Four fixed sites each in Lockport, Brandon Road, Dresden Island, and Marseilles pools were also sampled monthly (Figure 1). These data were merged to comprehensively understand invasive carp spatial and temporal abundance below 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 mm to 127 mm) gill and trammel nets set in 100- to 1,200-yard segments were used, and fish herding techniques (e.g., pounding on boat hulls, hitting the water surface with plungers, 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 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 (mm), 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, 5,668 miles (9,122 kilometers) of gill/trammel net, 22 miles (35 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 2023 is 14,519,600 pounds. Silver Carp remains the most abundant invasive carp species in the upper Illinois River, in contrast to 2010 when Bighead Carp comprised approximately 93 percent of total invasive carp catch.

The 2023 gill/trammel net CPUE (number of fish per 1,000 yards of net) in Starved Rock Pool was 380, a decrease from 435.7 in 2022. The gill/trammel net CPUE in Marseilles Pool was 103.5, an increase from 101.3 in 2022 (Figure 2). The 2023 gill/trammel net CPUE in Dresden Island Pool (leading edge) was 2.1 in 2023, an increase from .79 in 2022 (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 2023).*

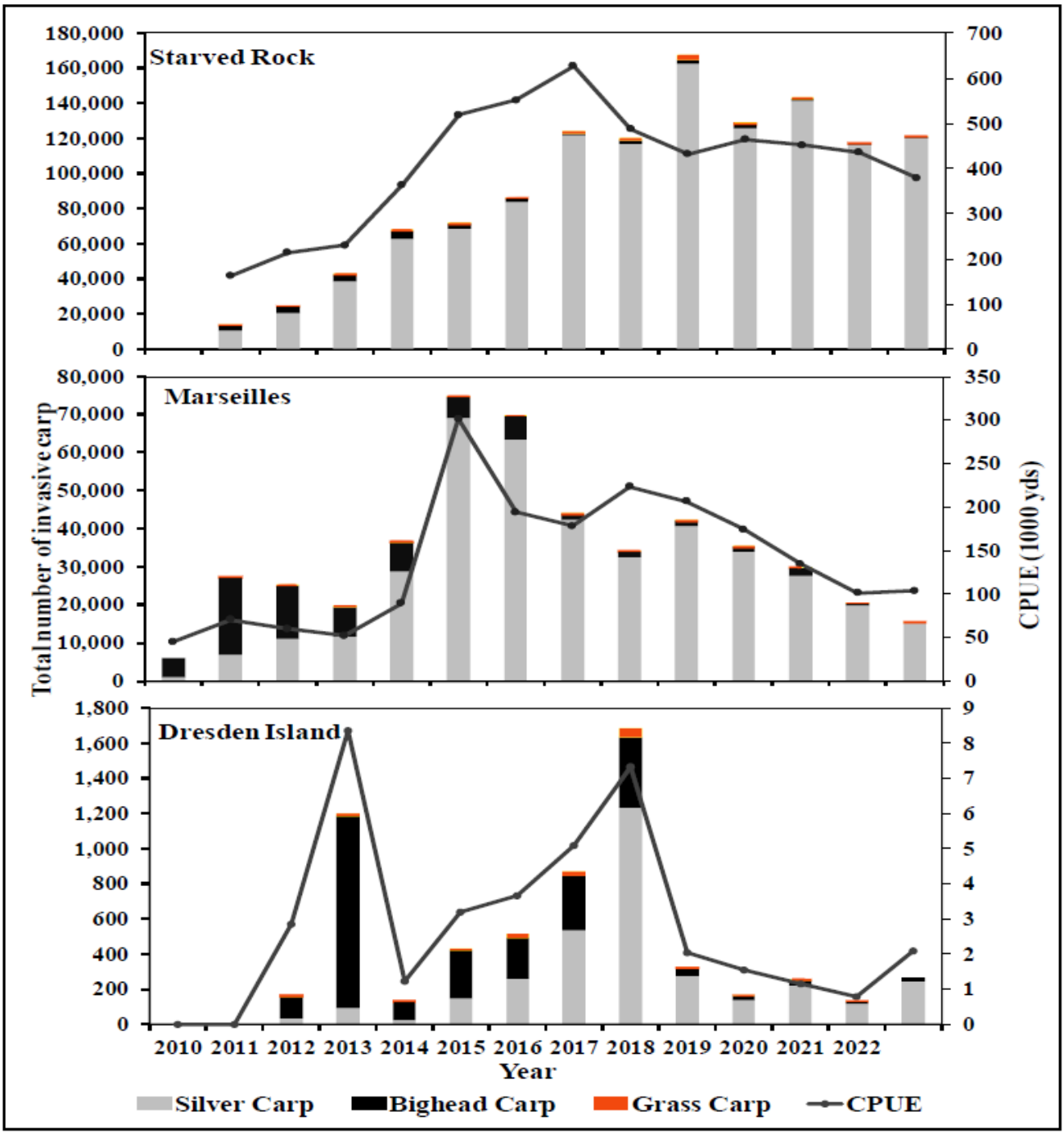
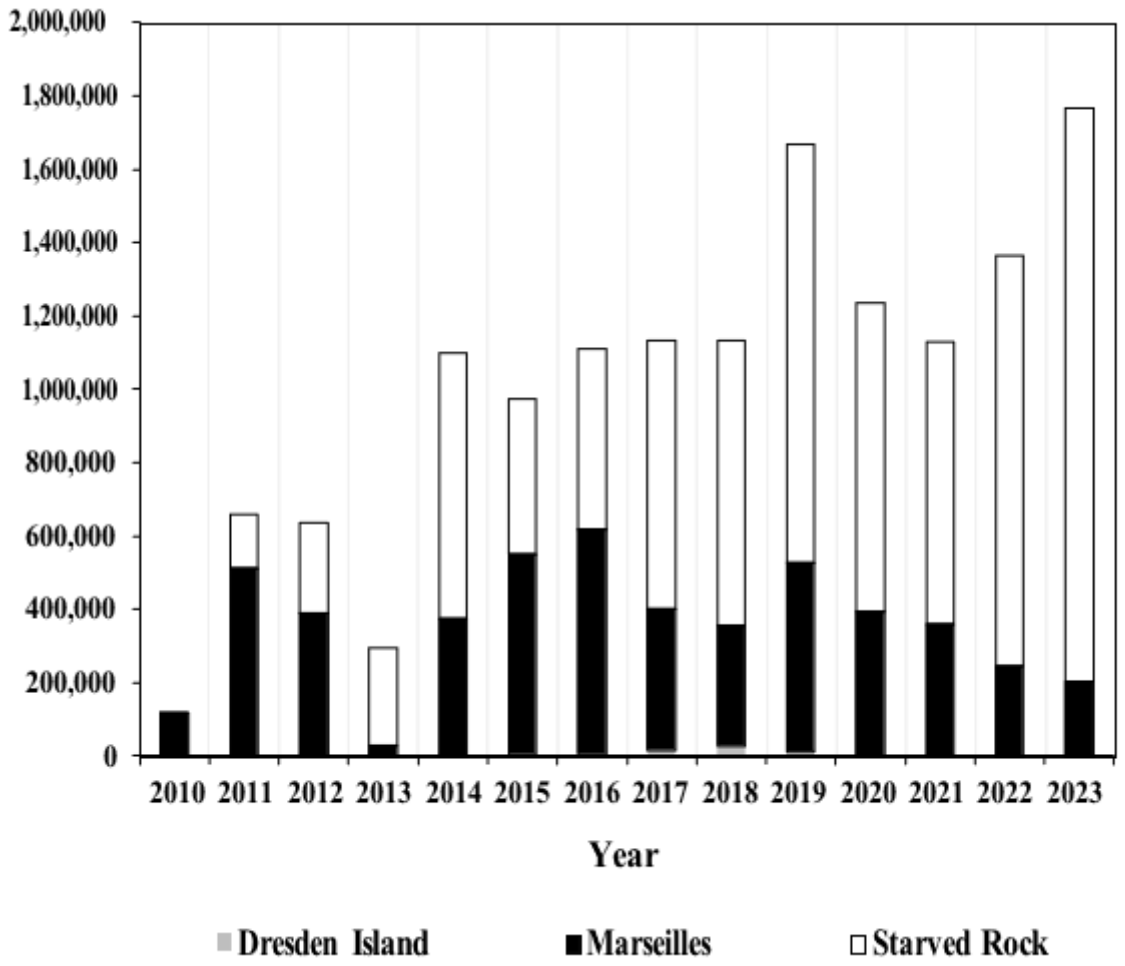


Figure 3. *Invasive carp biomass removed in Dresden Island, Marseilles, and Starved Rock pools (2010 to 2023).*



Effort and Catch of Invasive Carp within Pools

Lockport Pool: In 2023, invasive carp detection efforts included 30,160 yards (27.6 kilometers) of gill/trammel net set. No invasive carp were observed or captured in Lockport Pool.

Brandon Road Pool: In 2023, invasive carp detection efforts included 57,968 yards (53 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 2023, one percent of the total harvested invasive carp came from Dresden Island Pool. Contracted commercial fishing efforts included 132,768 yards (121.4 kilometers) of gill/trammel net. In 2023, 247 Silver Carp and 19 Bighead 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.

Marseilles Pool: In 2023, six percent of the total harvested invasive carp came from Marseilles Pool. Contracted commercial fishing efforts included 151,360 yards (138.4 kilometers) of gill/trammel net. In 2023, 15,362 Silver Carp, 298 Bighead Carp, and 2 Grass Carp were harvested from Marseilles Pool, amounting to 103.4 tons (206,800 pounds) removed (Figure 3). In 2023, Silver Carp dominated the invasive carp catch in Marseilles Pool (98 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 2023, the catch of Bighead Carp was two percent. The 2023 gill/trammel net CPUE of invasive carp for Marseilles Pool was 103.5, a two percent increase from 2022 (Figure 2).

Starved Rock Pool: In 2023, 93 percent of the total harvested invasive carp came from Starved Rock Pool. Contracted commercial fishing efforts included 316,800 yards (290 kilometers) of gill/trammel and seine net set. In 2023, 249,013 Silver Carp, 354 Bighead Carp, and 401 Grass Carp were harvested from Starved Rock Pool from gill/trammel nets, amounting to 782.7 tons (1,565,400) removed (Figure 3). Silver Carp dominated the catch of invasive carp in Starved Rock Pool in 2023 (99 percent), consistent with years past. The 2023 gill/trammel net CPUE of invasive carp for Starved Rock Pool was 380, a 15 percent decrease from 2022 (Figure 2).

In December of 2023, 48 percent (752,439 pounds) of the invasive carp biomass removed in Starved Rock Pool was the end result of a seine haul effort at Bull's Island (Ottawa, Illinois). The effort was considered a major success from a removal standpoint, with 128,553 Silver Carp and 27 Bighead Carp removed. There was minimal bycatch, and Silver carp comprised 99 percent of the biomass removed. The total weight of this effort is included in the annual pounds removed for the program in 2023.

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). 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 EDBS. In addition to those core goals, the MRWG detection and Removal Work 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 work groups (detection and removal), and objectives will continue to be adapted by work 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 FISH SUPPRESSION

Participating Agencies: ILDNR (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 (ILDNR), Jen Luc-Abeln, and Michael Malon (USFWS Carterville FWCO, Wilmington Substation).

Pools Involved: N/A

INTRODUCTION

The USACE operates three electric aquatic invasive species dispersal barriers (Barrier 1 [1D and 1N], Barrier 2A, and Barrier 2B) in the CSSC at approximately RM 296.1 near Romeoville, Illinois. The Demonstration Barrier was the first barrier constructed by USACE, and it became operational in April 2002 and is located farthest upstream at RM 296.6 (approximately 244 meters above Barrier 2B). The Demonstration Barrier is operated at a setting (0.4 v/cm) that has been shown to induce behavioral responses in fish over 137 mm 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 Barriers 2A and 2B can operate at parameters shown to repel or stun juvenile and adult fish greater than 137 mm long at a setting of 0.79 v/cm or fish greater than 63 mm long at a setting of 0.91 v/cm. The higher setting of 0.91 v/cm has been in use since October 2011. Barrier 1 was activated in February of 2021. Barrier 1 consists of a northern array (1N) and 1D, as outlined above. A third array (1S) is under construction in FY 2024. Barrier 1 is capable of increased operational settings in comparison to Barriers 2A and 2B, but safety testing is required before USACE can operate above 0.91 v/cm.

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

Barrier 2B operated as the principal barrier from the time it was brought online and tested in January 2011 through December 2013. During that time, Barrier 2A was held in warm standby mode (so it could be energized to normal operating level in 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 continuously maintaining power in the water regardless of a lapse in operation at any single barrier. Due to maintenance needs and cost-effectiveness, USACE plans to operate two barriers when possible to minimize any risk of fish passage. However,

as barriers are turned on and off for scheduled and unscheduled outages, there is a need to assess the risk of the presence of invasive carp and clear fish from the spaces between the barriers as deemed necessary by the MRWG. Depending on the sequence of outages and if the outage(s) are for a length of time sufficient to allow fish passage as deemed by the MRWG, a clearing evaluation/action may need to take place. If a clearing action is needed but were not to happen, fish have the potential to utilize the outages to "lock through" the EDBS. Locking through happens if an outage were experienced at Barrier 2A, allowing fish present just downstream to move up to Barrier 2B, becoming stuck in the 67-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, the 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 mm (12 inches) in total length from between applicable barrier arrays before maintenance operations are initiated at upstream arrays and after maintenance is completed at downstream arrays by physical collection (surface noise, surface pulsed-DC electrofishing, and surface-to-bottom gill nets).
- Assess fish assemblage less than 300 mm 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, could be utilized in support of this effort.
- 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 mm in total length) as possible between the barriers, as determined with remote sensing gear, or until the MRWG deems the remaining fish in the barrier as low risk. Fishes less than 300 mm in total length at the barriers are deemed a low risk to be invasive carp until further evidence from downstream monitoring suggests a change in the known population front for this size class of invasive 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.

- Electrofishing runs were conducted within the barrier after an abnormal number of large targets were identified from a hydroacoustics scan, and no large-bodied fish were captured or observed.
- Electrofishing runs were conducted biweekly in and around the barrier during Lockport fixed site sampling.
- USFWS conducted 20 hydroacoustic scans within the barrier from February 7 to December 11, 2023.
- 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 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 mm) to be present. This risk evaluation may change if small invasive carp are detected upstream of the known population front for this size class in any given year. Based on the current and joint understanding of the location of various sizes of invasive carp in the CAWS and Upper IWW and the operational parameters of the EDBS, the MRWG believes that either the wide or narrow array of each barrier provides a minimally effective short-term barrier for juveniles or adults. Thus, the MRWG views a total outage of both wide and narrow arrays as a situation of increased risk for invasive carp passing a given barrier. The MRWG decision to initiate a clearing action at the barriers is made only during heightened risk of invasive carp passage based on the most up-to-date monitoring results and current research.

A cut-off of 300 mm in total length was selected by the MRWG for fish to be removed from the barrier area when a clearing action is recommended. By selecting a cut-off of 300 mm, sub-adult and adult invasive carp were targeted, and YOY and juvenile fish were 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 mm. Juvenile Silver Carp were reported in substantial numbers from the Starved Rock Pool beginning in April of 2016, with several individual captures of similar-sized juvenile Silver Carp reported from the Marseilles Pool by October of the same year. 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 mm be removed from the area and fish less than 300 mm be sub-sampled to ensure no juvenile or YOY invasive carp are present. Invasive carp less than 300 mm 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 greater than 300 mm are removed from the barrier or until MRWG deems the remaining fish in the barrier a low risk and a sub-sample of fish less than 300 mm have been identified to species.

The initial clearing action is likely to use split-beam hydroacoustics and side-scan sonar imaging to determine if fish are present in the target area of the EDBS, including the areas between each barrier. This action is aimed specifically at identifying the number of fish over 300 mm. This sonar scan may be completed upon request, or the MRWG may decide to utilize the most recent data available as USFWS continues biweekly surveillance of the vicinity. If one or more fish targets over 300 mm are present, the MRWG will convene and decide if a clearing action is warranted for the area between the affected barriers. Initial response to any loss of power to the water should occur within a week of the outage and upon completion of the sonar survey. Additional clearing actions can range from a 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 2023, 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. A total of 43 outages of one minute or greater occurred across all the barriers during 2023 (Table 1). Of the 43 outages that occurred, six unplanned outages occurred at Barrier 1D, four unplanned outages occurred at Barrier 1N, one unplanned outage occurred at the narrow array of Barrier 2B, four unplanned outages occurred at the wide array of Barrier 2B, and one outage occurred at both the wide and narrow arrays of Barrier 2B. Planned outages for maintenance, inspections, software updates, and power studies occurred 24 times in 2023, accounting for 56 percent of the total outages. The remaining 19 outages were unplanned and occurred due to utility power loss, function generator issues, various equipment faults, and cooling issues. Similar to 2022, the bulk of the unplanned outages (26 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 2023, but

USACE did conduct an electrofishing survey within the barriers on September 18 and biweekly throughout the 2023 field season in Lockport fixed site 1 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	9	3
1N	19	15
IIB	11	3
IIA	3	3

RECOMMENDATIONS

The MRWG agency representatives should continue to assess the risk of invasive carp presence at the primary downstream barrier. The group should consider 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 the removal of fish from between the barriers should include surface, pulsed DC-electrofishing, and noise-scaring tactics (tipped-up motors, push plungers, hull banging, etc.). It is recommended to continue the removal of all fishes greater than 300 mm in total length and to sub-sample fishes less than 300 mm in total length for species identification when deemed necessary. Identification of fishes less than 300 mm will help further inform decision-makers on the risk of juvenile invasive carp presence. Deep water gill net sets and other submerged bottom deployed gears are not recommended for use between the barriers as a removal action due to safety concerns for personnel. However, these tools should continue to be used in the immediate downstream area to enhance understanding of fish species assemblage and risk of invasive carp presence. Additionally, there should be continued research and deployment of novel fish driving and removal technologies, such as complex noise generation, carbon dioxide, and other techniques.

FIELD TESTING OF AN UNDERWATER ACOUSTIC DETERRENT SYSTEM IN A MARSEILLES POOL GRAVEL PIT ON THE ILLINOIS RIVER

Participating Agencies: USGS Upper Midwest Environmental Sciences Center (lead), USACE ERDC (co-lead), ILDNR, USACE – Chicago District, SIU (data-sharing, telemetry support); Mark Roth, Marybeth Brey, William Lamoreux, Todd Johnson, Dan Krause, and Jose Rivera (USGS); Christa Woodley, Aaron Urbanczyk, and Henry Hershey (ERDC)

Location: Heidelberg Materials gravel pits in the Marseilles Pool of the Illinois River near Morris, Illinois.

Pools Involved: Marseilles

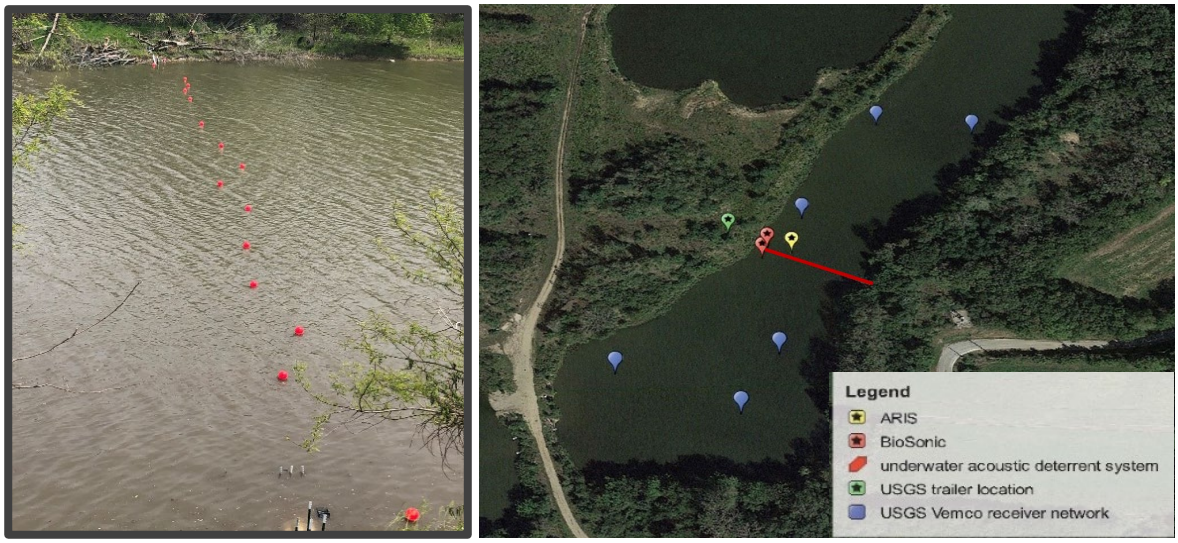
INTRODUCTION AND NEED

Acoustic deterrent technologies are being developed to prevent the spread of invasive carp (Bighead Carp, Silver Carp, Grass Carp, and Black Carp) from the Mississippi River watershed to the Great Lakes. To assess this technology, field testing of the deterrent equipment and newly developed sound stimuli on wild invasive carp populations is essential. Large-scale experimental deployments and testing of UADS are currently installed or proposed at multiple locks and dams. However, there has been limited use or testing of underwater acoustic deterrents in smaller areas where lock infrastructure does not exist (e.g., side channels and backwaters). These more natural areas have important characteristics that differ from hard-structured locks and dams, such as soft substrate, flashy flow conditions, shallow or variable water depth, and inconsistent bathymetry/bottom elevation.

Testing newly developed sound stimuli as deterrents to invasive carp movement should occur at sites where invasive carp are abundant and naturally move. Water depths should generally be greater than 2 meters, and access to electricity should be available to operate the uADS and monitoring equipment to facilitate effective sound propagation. These criteria are met at the Heidelberg Materials (HM), formerly known as Hanson Material Services, gravel pits on the Illinois River near Morris, Illinois. In addition, historical telemetry data and contract catch information are available for this location. Coarse-scale fish behavior (i.e., presence or absence in the HM pits) has been monitored by SIU, USGS, and the USACE since 2012.

To test an installed UADS on resident Silver Carp and Bighead Carp, the USGS Upper Midwest Environmental Sciences Center and the USACE ERDC deployed an underwater speaker array and acoustic monitoring equipment in mid-2021 (Figure 1). Fish behavior has been monitored with Innovasea (69-kilohertz) acoustic telemetry since April 2021 and with stationary BioSonics DTX split-beam transducers (hereafter, BioSonics) and ARIS 3000 multibeam imaging sonar (hereafter, ARIS) most weeks from mid-April until November in 2021 and 2022.

Figure 1. *Left – Image of* u*ADS with speaker locations marked by buoys. Right – Location of the research site on the Illinois River, including the research trailer (green dot),* u*ADS (red line), ARIS 3000 multibeam imaging sonar (ARIS, yellow dot), BioSonics DTX split-beam transducers (BioSonics; red dots), and the original six Innovasea VR2Tx acoustic telemetry receivers that make up the core VPS array (blue dots).*



OBJECTIVES

- Summarize available telemetry data for the HM gravel pits in collaboration with SIU and other ICRCC MRWG partners to assess the natural movement and distribution of fish around the uADS.
- Experimentally assess Silver Carp and Bighead Carp deterrence or passage during cyclic operation (*on* vs. *off*) of the experimental uADS. The uADS will operate on an 80-hour *on*, 80-hour *off* schedule throughout the year.
- Assess fish passage (i.e., movement across the uADS) relative to uADS operation (i.e., *on*/*off*) and environmental conditions (e.g., water depth, temperature, and discharge).
- Evaluate behavioral responses (e.g., number of fish detections, fish swim direction, probability of approaching and moving through the uADS) of Silver Carp, Bighead Carp, and resident native fish using multiple gears (e.g., acoustic telemetry, underwater cameras, or transducers).
- Evaluate the long-term environmental and operational effects on the performance and function of the uADS (i.e., speaker array) and supporting equipment.

PROJECT HIGHLIGHTS

From 2019 to 2023, 201 Silver Carp and two Bighead Carp were implanted with acoustic telemetry transmitters in the HM pits specifically for this project. These fish contribute to the greater Telemetry Work Group of the ICRCC MRWG objectives and ensure adequate numbers of

tagged fish are available to monitor fish behavior and passage across the uADS for this study. The uADS was fully operational from the spring of 2021 through the fall of 2023. In November 2023, the uADS was disassembled and removed from the water. However, the telemetry array will continue to operate during 2024 to monitor the post-deterrent movement of tagged fish in the area.

METHODS

The uADS consists of 16 underwater speakers (LL916C; Lubell Labs Inc., Columbus, Ohio) installed just off the substrate, perpendicular to water flow, across the width of the channel (Figure 2). The uADS operates on an 80-hour *on*, 80-hour *off* loop of ERDC-engineered signals (i.e., plays the same stimuli continuously for 80 hours). The signals and schedule are the same as those operating at Lock 19 on the Mississippi River (Brey et al. 2023). Speaker output is monitored and recorded using underwater hydrophones (SoundTrap ST500; Ocean Instruments, New Zealand). Audio files from these hydrophone recordings will be assessed for signal content, SPL_{rms} (dB re 1 µPa), power spectrum density for the full generated signal, and more specifically to determine if acoustic signals are within the desired range of Silver Carp and Bighead Carp hearing. Hydrophone recordings will also be used to determine ambient and other aberrant signals that occurred near or during the time Silver Carp and Bighead Carp approach and cross over the uADS (e.g., boats or fishing in the area).

The primary mechanism for assessing changes in fish behavior is with acoustic telemetry, specifically, 13 Innovasea (Innovasea, Inc., Boston, Massachusetts) VR2Tx receivers and two reference tags. Six receivers are deployed within line-of-sight of the uADS and make up the "Vemco Positioning System" (VPS) needed to assess the fine-scale fish movements. An additional seven receivers are stationed outside the original VPS array. These seven receivers are used to detect fish in the area (i.e., presence/absence), but they are not in locations that allow for fine-scale positions to be resolved. The effect of uADS operation (i.e., *on/off*) on fish behavior will be assessed using the VPS data, with additional analysis incorporating possible effects of changing environmental conditions.

Sonar equipment was used to further assess fish behavior and movement of tagged and untagged fish in the proximity of the uADS. An ARIS set to 1.1-megahertz frequency and two BioSonics were deployed seasonally starting in 2021. BioSonics were placed on either side of the uADS looking across the channel from the west bank to the east bank. (Figure 1). The ARIS has a field of view that is much more limited; because of this, it was situated to view across the uADS at an angle between two speakers toward the middle of the channel from northwest to southeast (Figure 1). ARIS and BioSonics data will be post-processed using Echoview (Version 14, Echoview Software Pty. Ltd.) to quantify fish targets, obtain total length estimates, and determine the direction of travel. Potential changes in the number of fish detections, fish swim direction, and fish size distribution will be compared for a subset of times when the UADS is *on* or *off*. BioSonics and an ARIS were only deployed in 2021 and 2022. BioSonics and ARIS systems were not redeployed in 2023 due to persistent equipment failures in both 2021 and 2022.

RESULTS AND DISCUSSION

A total of 201 Silver Carp and two Bighead Carp were surgically implanted with 69-kilohertz acoustic telemetry transmitters by the USGS and ERDC in the HM pits as part of this project between October 22, 2019, and April 12, 2023. Thirty-eight Silver Carp were tagged on October 22, 2019, 40 Silver Carp were tagged on May 23, 2021, and 50 Silver Carp were tagged on April 12, 2022. Seventy-three Silver Carp and two Bighead Carp were tagged on April 11 and 12, 2023. These fish contribute to the greater MRWG Telemetry Work Group objectives by ensuring sufficient fish are tagged to adequately monitor fish behavior and passage across the uADS for this study.

In 2022 and 2023, we achieved consistent uADS operation and fish positions using the VPS array. This project operated through 2023 to add one more complete year of data collection for the analyses. During 2022, a total of 124 fish, of which 83 were tagged by USGS, were detected in the larger USGS Innovasea receiver network within HM gravel pits (Figure 2). In 2023, 164 fish, of which 143 were tagged by USGS, were detected in the larger USGS Innovasea receiver network within HM gravel pits. The VPS will continue to operate during 2024.

Figure 2. *Locations of USGS Innovasea receivers within HM gravel pits near the Illinois River that flows along the top of the image.*

In 2022, the Innovasea receivers in the East Pit around the UADS detected 58 individual Silver Carp, of which 49 were tagged by USGS. Of those 58 individuals, fine-scale positioning was achieved for 19 of them. Two additional Innovasea receivers and two reference tags were placed within the VPS array (for a total of six receivers around the UADS) to allow for better fish positioning in 2023. In 2023, 72 individual invasive Carp, of which 71 (70 Silver Carp and one Bighead Carp) were tagged by USGS, were detected around the UADS. Of those 72 individuals, fine-scale positioning was achieved for 25 of them. The larger Innovasea 69-kilohertz receiver

array and the VPS array will continue to operate through 2024 to monitor post-deterrent fish movement. Additional data analysis is ongoing.

In 2022, the BioSonics system generated 1,281 hours of data (approximately 54 days). The ARIS system generated 1,650 hours (approximately 65 days) of data. There were approximately 39 days of overlap in 2022, where both the BioSonics and the ARIS were fully operational. In 2023, the BioSonics and the ARIS systems were not deployed. Additional data analysis is ongoing, and a manuscript is expected in 2024.

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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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 ILDNR

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 focus on developing novel quantitative tools, such as an SCAA model, to address questions regarding the effects of contracted removal efforts on the status of invasive carp populations, as well as continue developing and maintaining predictive simulation-based models designed to address emerging management questions (i.e., the SEICarP model and the per-capita contribution model). These simulation-based and assessment tools can be used in conjunction with one another to iteratively develop new management targets based on the current assessment of the invasive carp population.

The SEICarP and per-capita contribution models are simulation-based mathematical representations of Silver and Bighead Carp population dynamics. These models inform management by providing estimates of the effects of the spatial allocation and magnitude of harvest as well as the location and effectiveness of barriers to upstream movement of invasive carp on the Illinois River invasive carp population (SEICarP) or individual contributions of invasive carp to the Dresden Island population (per-capita contribution). Additionally, the results of these models can be used to understand critical model assumptions and uncertainties and provide recommendations concerning data collection and research in the Illinois River, thereby guiding ongoing model development aimed at extending model capabilities and reducing uncertainty.

Three limitations remain that reduce our confidence in the predictions made by the SEICarP model. While the model is largely complete, it can be iteratively improved by addressing these limitations, and we can increase our confidence in the model outputs and management recommendations. The first limitation is the assumption that invasive carp neither leave nor enter the Illinois River. Currently, 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, the current version of the SEICarP model cannot provide pool-specific recommendations for fish removals because of the limitations in the movement model discussed above. Improving this movement model will allow modelers to improve the spatial resolution of management recommendations, such as the proportion of the carp population that should be removed from each pool. Third, we do not understand the relationship between the parental fish stock and resulting recruitment (i.e., the stock-recruit relationship) for Illinois River invasive carp. Understanding this relationship is critical to the management of invasive carp in the Illinois River because the stock-recruitment relationship determines how recruitment rates will respond to

control-induced reductions in adult biomass. To address the first two limitations, this project will coordinate with the MRWG Telemetry Work Group to determine the feasibility of expanding data collections into the Mississippi River and incorporating the updated movement model with finer spatial resolution into the SEICarP model. Additionally, the development of a stock-recruitment model leveraging data from the MRWG Hydroacoustics Work Group and age-structure data from field collections is underway and will address the third limitation. Furthermore, to improve the utility of the SEICarP model to managers, this project will develop a user interface that will allow managers to independently explore various harvest and barrier scenarios before more in-depth modeling efforts to understand the uncertainty of any recommendations derived from those scenarios.

Lastly, this project will begin the development of an SCAA model following the recommendations of Bence and Brendan (ICRCC 2022). SCAA models are a flexible stock assessment method that can use information from fishery-dependent catch-at-age and a variety of other data sources (e.g., fishery-independent indices of abundance) to estimate the abundance, biomass, and fishery characteristics of age-structured populations through time. An SCAA model of invasive carp in the Illinois River can be used to generate estimates for their biomass and fishing mortality rates, which will allow us to estimate the proportion of invasive carp biomass removed by contracted fishing every year. This information will directly help managers assess the effectiveness of contract removal programs.

OBJECTIVES

- Collaborate with the MRWG Telemetry Work Group to incorporate updated pool-to-pool movement probabilities into SEICarP.
- Develop a stock-recruitment relationship using existing age structure and hydroacoustics data.
- Develop a graphical user interface to allow managers to directly interact with the SEICarP model and to improve communication between managers and the Modeling Work Group.
- Work with MRWG co-chairs and working group leads to apply per-capita contribution modeling to invasive carp management.
- Begin developing an SCAA model following the recommendations of Bence and Brendan (ICRCC 2022).
- Begin discussions with the Removal and Monitoring Work Groups regarding the collection of additional demographic information from harvested invasive carp to support the SCAA model.

PROJECT HIGHLIGHTS

SEICarP

- A manuscript (Kallis et al. 2023) was published in the *Journal of Applied Ecology,* and the results indicate that the most effective management measures to reduce the Dresden Island invasive carp population are:
    - Increased harvest in lower pools of the Illinois River.
    - Maintaining current harvest efforts in the upper pools of the Illinois River.
    - Placing deterrents at the most downstream lock and dam structure in the upper Illinois River (i.e., Starved Rock Lock and Dam).
- The SEICarP model has entered a maintenance phase. Periodic updates will occur only when major changes to model inputs (e.g., transition probabilities) or partner requests (for specific management scenarios) make it necessary.

Graphical User Interface

- Development is complete.
- Currently undergoing USGS software review prior to public release.

Sensitivity Analysis

- Results indicate that the SEICarP model is most sensitive to changes in parameter values for Alton Pool, including harvest, von Bertalanffy growth, stock-recruit relationship, length-weight, and among-pool transition probabilities.
- Manuscript accepted for publication in the *Journal of Fish and Wildlife Management* (January 2024).

Deterrent Effects on Per Capita Contributions

- Deterrents (assuming 50 percent effectiveness) placed at Peoria, Starved Rock, or Marseilles locks and dams are most effective at limiting the growth of the Dresden Island invasive carp population.
- Deterrents, with no harvest effects, cause small increases in the metapopulation growth rate because the movement to areas without viable recruitment is reduced.
- A deterrent at Marseilles Lock and Dam is most effective to maximize reductions in the Dresden Island population growth rate while minimizing increases in the metapopulation growth rate.
- Manuscript accepted to *Biological Invasions* (December 2023).

Stock-recruit Relationship

- An age-length key and density estimate of age-1 (recruits) and age-2+ (spawning stock) have been developed.

- Development of the stock-recruit relationship is ongoing.

Movement Model Comparisons

- Determine if model fitting approaches impact transition probability estimates.
- Maximum likelihood estimation and Markov Chain Monte Carlo approaches resulted in similar transition probabilities when models were constrained.
    - Transition probabilities for unobserved movements among pools were constrained to zero for the maximum likelihood estimation approach.
    - The Markov Chain Monte Carlo approach was constrained by using informative priors.
- The maximum likelihood estimation approach converges quickly but estimates transition probabilities of zero for unobserved among-pool movements (e.g., Starved Rock Pool to Marseilles Pool).
- The Markov Chain Monte Carlo approach converges more slowly but can estimate low, non-zero transition probabilities for unobserved among-pool movements.
- A manuscript (Labuzzetta et al. 2024) was published in *Movement Ecology*.

SCAA Model

- Current fisheries-dependent data will not support the SCAA model.
    - There are some fisheries-dependent catch-at-age data for the upper river (N=356; 2019 to 2022 in Dresden Island Pool and N = 567; 2021 to 2022 in Marseilles Pool).
    - There are no fisheries-dependent catch-at-age data available for the lower Illinois River.
- Additional sampling programs must be implemented if developing an SCAA model for the Illinois River invasive carp population is a priority.
    - Collections must focus on fisheries-dependent data from all pool and gear combinations, such as total catch and effort, age, length, weight, and sex, from a subset of captured fish.
- Currently in discussions with other work groups (e.g., removal, monitoring, enhanced contract harvest) to develop sampling plans for collecting fisheries-dependent data to support the SCAA model.

FUTURE WORK

- Continue discussions with the Removal and Monitoring Work Groups to scope collections of fisheries-dependent data in support of the SCAA model.
- Determine priorities for developing interim analyses to examine changes in the invasive carp population and/or the effects of harvest, with input from the MRWG, such as:

  - Changes in the abundance or condition of native species.
  - Changes in length distributions of invasive carp catches either in the commercial catch or fisheries-independent surveys.
  - Length-based Bayesian estimates of fishing mortality.
- Collaborate with the Telemetry Work Group to understand movement to and from the Mississippi River.
- Complete the stock-recruit analysis.
- 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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TELEMETRY SUPPORT FOR THE SPATIALLY EXPLICIT INVASIVE CARP POPULATION MODEL (SEICarP)

Participating Agencies: USFWS, Carterville FWCO Wilmington Substation (lead), SIU, USACE Chicago District, USGS

Pools Involved: Peoria, Starved Rock

INTRODUCTION AND NEED

The SEICarP model was developed to assess the invasive carp population status in the IWW. SEICarP is a movement probability model used to inform researchers how invasive carp populations respond to management strategies (Brey *et al*. 2022). The model functions as an important tool that can be used by fisheries managers to inform harvest and control of adult invasive carp (primarily Silver Carp and Bighead Carp) in the IWW. Harvesting from source populations downriver to reduce propagule pressure and physical barriers (dams) is believed to reduce movement probabilities upstream (Kallis *et al*. 2023; Baker 2017). The USFWS telemetry data complements telemetry data being collected throughout the IWW describing inter-pool transfer of adult invasive carp and is used to parameterize the movement probability component of the SEICarP model. This research provides an improved understanding of invasive carp movement in the IWW and its effects on population dynamics. Variations in invasive carp movement, distribution, and habitat in the IWW make targeting invasive carp challenging and costly (ICRCC 2023). A multi-agency telemetry array maintained across the pools in the Upper IWW provides the parameters for the SEICarP model. A large telemetry array can be used to better understand movement patterns to inform harvesting efforts and facilitate monitoring and contingency response actions based on invasive carp movement through these joint efforts (ICRCC 2023). The USFWS Carterville FWCO Wilmington Substation's involvement maintains the portion of the acoustic telemetry array that spans the Peoria and Starved Rock Pools.

OBJECTIVES

- Collectively tag 150 individual adult invasive carp within Peoria and Starved Rock pools, primarily Silver Carp.
- Deploy and maintain an array of 20 69-kilohertz receivers (Innovasea) within Peoria and Starved Rock Pools to enhance detections of transient fish and inter-pool movement.
- Provide data from the acoustic receiver array to the Telemetry Work Group of the MRWG for use in the SEICarP model.

PROJECT HIGHLIGHTS

- In April 2023, 149 V-9 acoustic transmitters (Innovasea) were implanted inside invasive carp (112 in Peoria Pool and 37 in Starved Rock Pool). One transmitter was determined to be defective and was not used.

- Data from the 20 (14 VR2Tx and six VR2W) 69-kilohertz acoustic receivers were collected, processed, and provided to the Telemetry Work Group.

METHODS

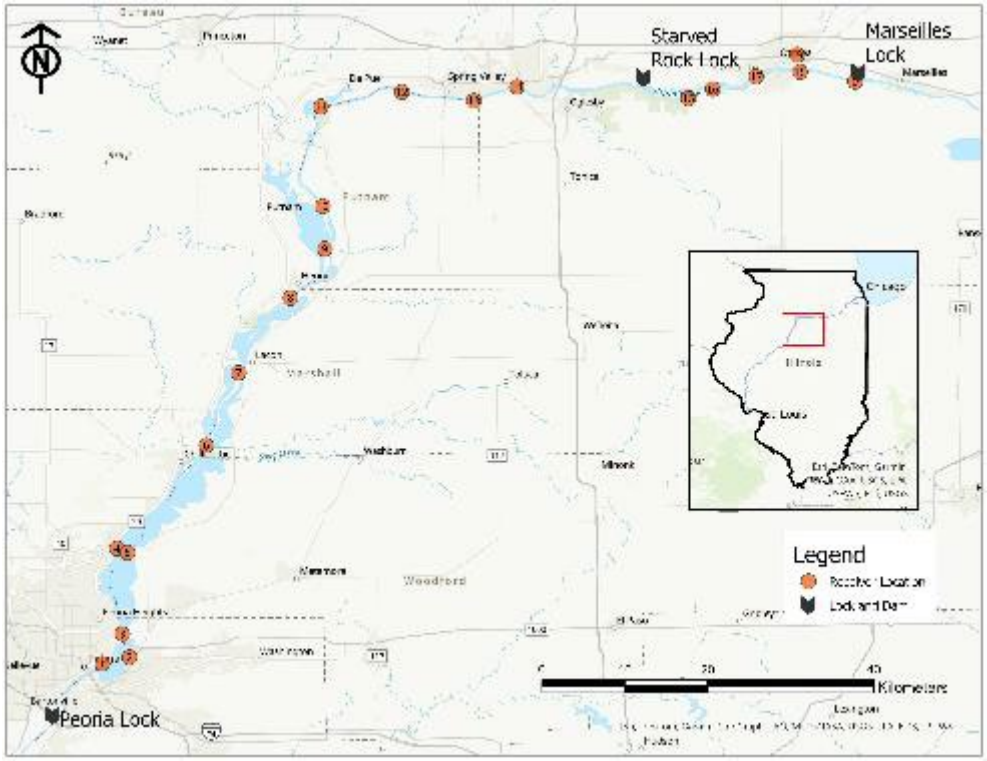
The location of each receiver station in the Peoria and Starved Rock Pools is shown in Figure 1. In March 2023, 20 69-kilohertz "Innovasea" acoustic receivers were deployed and downloaded monthly through November 2023. The data was uploaded to the FishTracks telemetry database within 2 weeks of being collected. With direction from the Telemetry Work Group, all receivers were tethered to trees to reduce the loss of the receiver. Receivers were placed a minimum of 5 river kilometers away from other agencies' receiver arrays, ensuring no overlap in the arrays and maximizing movement detection. In November 2023, the receivers were removed and downloaded to prevent potential ice flows from breaking receivers from their tethers. The receiver array will be redeployed in March 2024 with the beginning of the new monitoring season.

RESULTS AND DISCUSSION

From March 6 to November 17, 2023, 1,938,634 detections from 463 transmitters were recorded across the 20 USFWS-maintained 69-kilohertz receiver array (Table 1). This was higher than last year's results (*101,974 detections from 94 transmitters), likely due to the increased size of the array (increased from six* 69-kilohertz *receivers in 2022 to 20 receivers in 2023, along with the additional 149 transmitters implanted in April 2022).* Fourteen of the detected transmitters were from internal transmitters within the VR2Tx series receivers. Three hundred-eight of the detected transmitters were either from USFWS-tagged fish from previous years or fish tagged by other agencies. Thirty-four inter-pool movements were recorded (1 above Starved Rock Pool, 33 below Peoria Pool) outside the telemetry array, summarized in Table 2. All 149 fish tagged in 2023 by USFWS were detected at least once during the 2023 field season. One hundred-seventy-nine fish were from previous tagging years (2018 to 2022).

In addition to the telemetry data, an estimation of Silver Carp abundance in Starved Rock Pool was made based on recapture data. Between November 28 and December 5, 2023, 21 USFWS-tagged fish were captured during a commercial fishing harvest that yielded an estimated 128,523 Silver Carp. One tagged fish represented approximately 6,120 fish. USFWS is currently tracking about 100 individual Silver Carp in Starved Rock Pool. This gives an estimate of 612,000 Silver Carp in Starved Rock Pool. Nineteen of those fish had recoverable transmitters that will be reused in future tagging.

Figure 1. *Locations of USFWS Carterville FWCO acoustic receiver stations across Peoria and Starved Rock Pools.*



The number of unique transmitters (fish) and detections are summarized across the 2023 season in Table 1 and Figure 2. All data was uploaded to the USGS FishTracks database by January 2024. Figure 3 summarizes the total number of fish detected within each movement category.

During this season, two receivers (lower Peoria Lake Point River Left RM 164.8 and Chillicothe Bridge Peninsula RM 182.4) were replaced by spare receivers, and one receiver (Peru DS Route 251 Bridge RM 222.8) was recovered by commercial fishermen near Henry, Illinois. The remaining four receivers were not retrieved. At the end of the season, 16 receivers were recovered. All data was uploaded to the USGS FishTracks database by January 2024.

In Peoria Pool, most of the detections reported were from RM 188.1 Lacon Sawyer Slough and RM 194.8 Upper Henry Island (Figure 2 and Table 1). Four of the six receivers in Starved Rock Pool had detection numbers above 150,000 (Figure 2 and Table 1). The number of detections was likely low for the Fox River because it's a tributary. The numbers were low for the Marseilles Dam Tailwater (RM 244.5) because the receiver was lost in June 2023 and not replaced due to persistently high flow velocities (Figure 2). The number of fish detected was highest at RM 188.1 Lacon Sawyer Slough in the Peoria Pool and RM 241 Bulls Island MC Abandoned Harbor in the Peoria Pool (Figure 2).

Table 1. *Data downloaded from 69-kilohertz Innovasea VR2Tx and VR2W receivers from April 4 to November 17, 2023. "Receiver Number" corresponds to receivers shown in Figure 1.*

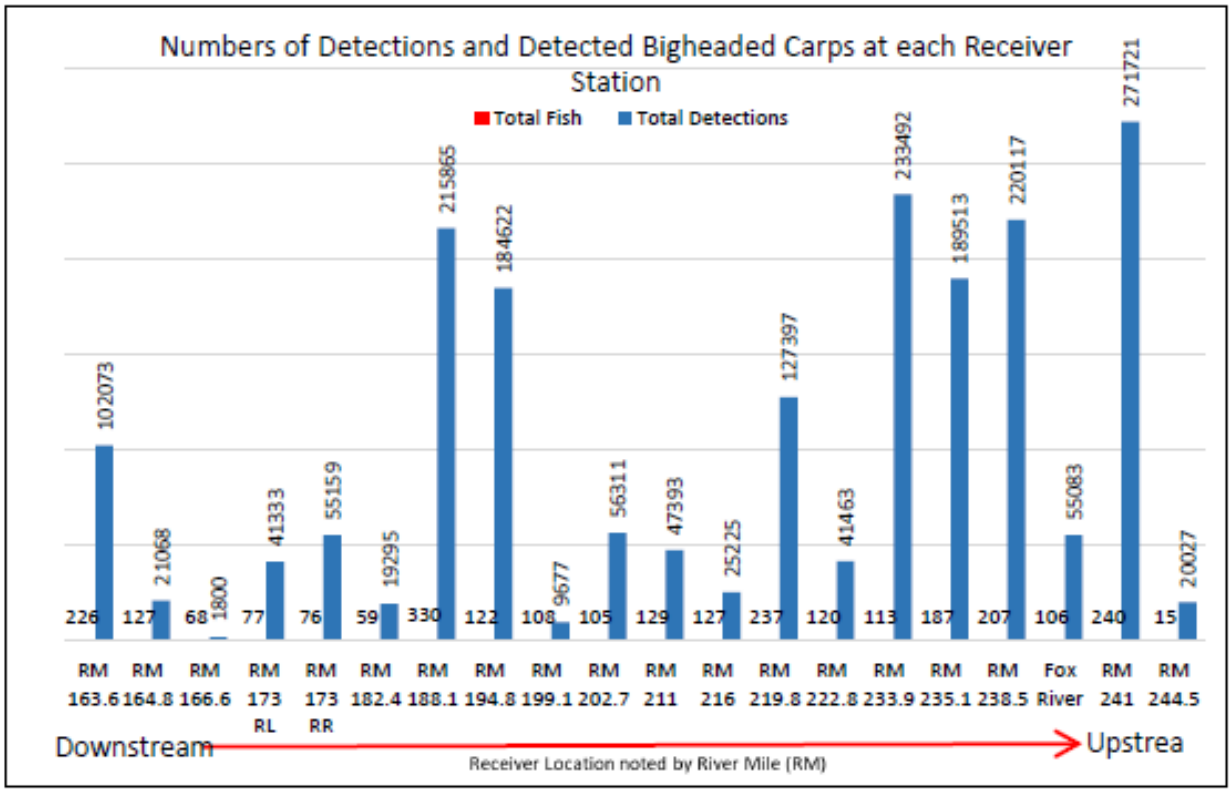
Receiver Number	Receiver ID	River Mile	Station Name	Number of Fish	Number of Detections
1	VR2Tx-489037	163.6	MC Detweiler Marina	226	102,073
2	VR2Tx-137066	164.8	Lower Peoria Lake Point River Left	127	21,068
3	VR2W-129787	166.6	Peoria Lake Narrows	68	1,800
4	VR2Tx-489040	173.0	Upper Peoria Lake River Right	76	41,333
5	VR2Tx-489209	173.0	Upper Peoria Lake River Left	77	55,159
6	VR2W-137064	182.4	Chillicothe Bridge Peninsula	59	19,295
7	VR2W-129785	188.1	Lacon MC Sawyer Slough	330	215,865
8	VR2Tx-489207	194.8	US Upper Henry Island	125	184,622
9	VR2W-129781	199.1	Senachwine Lake Peninsula	110	9,677
10	VR2Tx-489039	202.7	Lower Twin Sisters Island	105	56,311
11	VR2W-137065	211.0	MC near Depue Lake Channel	129	47,393
12	VR2W-129779	216.0	US of Clark Island	127	25,225
13	VR2Tx-489206	219.8	US Spring Valley River Left	237	127,397
14	VR2Tx-489211	222.8	Peru DS Route 251 Bridge	120	41,463

Receiver Number	Receiver ID	River Mile	Station Name	Number of Fish	Number of Detections
15	VR2Tx-489205	233.9	Lone Point Delbridge Side Channel	113	233,492
16	VR2Tx-489212	235.1	MC Sheehan Island	187	189,513
17	VR2Tx-489038	238.5	Hitt-Mayo Straight	206	220,117
18	VR2Tx-489204	Fox River	Fox River Island US of Rt 6 Bridge	106	55,083
19	VR2Tx-489208	241.0	Bulls Island MC Abandoned Harbor	240	271,721
20	VR2Tx-489213	244.5	Marseilles Dam Tailwater	15	20,027
-	-	-	**Total unique transmitters and detections**	**463**	**1,938,634**

Table 2. *Summary of inter-pool movements outside of USFWS telemetry array.*

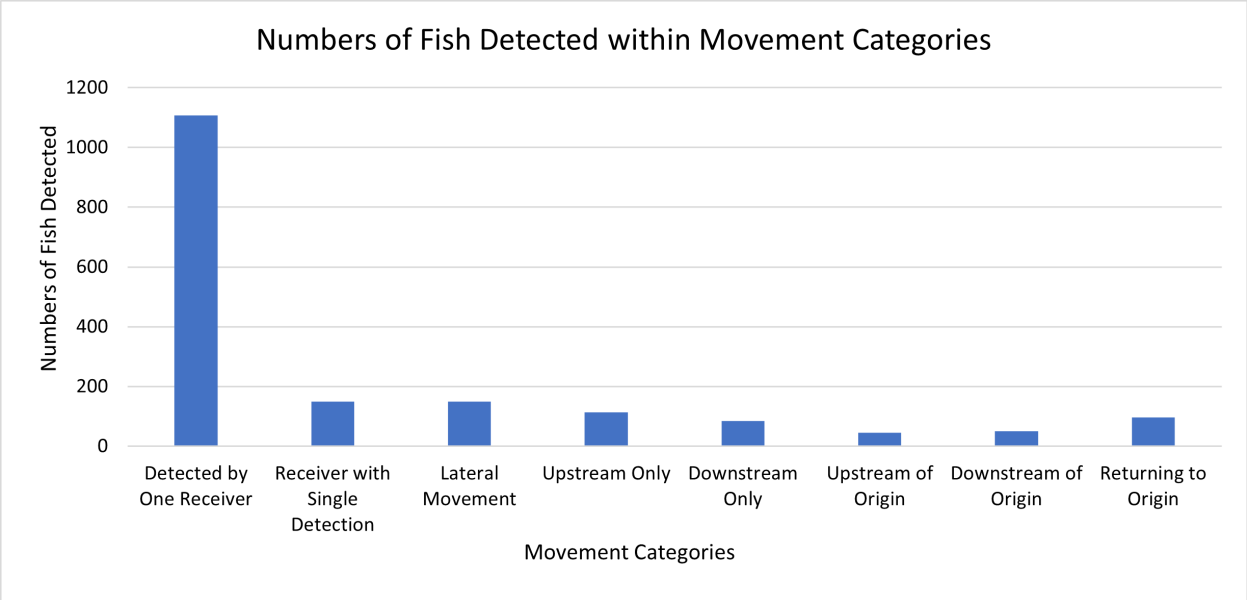
Species	Original Pool	Recovered Pool	Number of Unique Fish
Silver Carp	Peoria	Alton	10
Silver Carp	Peoria	LaGrange	8
Silver Carp	Peoria	Marseilles	1
Silver Carp	Peoria	Starved Rock	9
Silver Carp	Starved Rock	LaGrange	2
Silver Carp	Starved Rock	Peoria	4

Figure 2. *Distribution of numbers of detected fish and their detections at each receiver station across the 2023 field season. River left is denoted "RL". River right is denoted "RR."*



Results from the number of fish detected within eight movement categories show that most of the fish were detected by a single receiver during detection periods. Detection periods are detections made by tagged individuals between receiver deployments and data retrieval. There were no longitudinal movements by these individuals; detections were fish swimming within the detection field of that receiver. Little longitudinal movement occurred within each pool, as fewer individuals were detected by other receivers during detection periods (Figure 3). Receivers with single detections are receivers with only one detection from a single unique transmitter (fish). Lateral movements are noted when a transmitter is detected by receiver stations directly across the channel from each other. These instances were seen at the RM 173 upper Peoria Pool River Left and River Right receivers, as well as between the Detweiler Marina and lower Peoria Lake River Left receivers (Figure 1). Upstream-only and downstream-only movements were noted where fish were detected by other receivers without regressing to their origin at the beginning of the detection period. Upstream, downstream, and returning to origin note longitudinal movements but return fully or partially to their origin at the end of the detection period.

Figure 3. *Number of fish detections within each movement category across the 2023 field season.*



FUTURE WORK

USFWS Wilmington Substation plans to resume its support of the SEICarP model and redeploy its receiver array in March 2024. The larger array used this season across Peoria and Starved Rock Pools was able to detect two downstream pool-to-pool transitions. Additional detected pool-to-pool movements will assist the SEICarP model estimation of transition probabilities. The 2024 field season array will consist of 18 69-kilohertz receivers instead of 20 due to receiver loss. Changes in receiver deployment design have been made to help reduce the risk of lost receivers in the future. Receiver placement will be based on detections from the 2023 field season and strategic placements suggested by the MRWG Telemetry Work Group. Capturing the movements of fish within the larger array helps reduce the probability that fish are transiting undetected and gives researchers a better idea about individual fish survival. The Wilmington Substation will tag another 150 adult bigheaded carps between Peoria and Starved Rock (100 and 50, respectively) in April 2024. The MRWG Telemetry Work Group will be consulted before tagging and deployment to optimize placement within the IWW.

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INVASIVE CARP DEMOGRAPHICS – MULTIPLE AGENCY MONITORING SUPPORT

Participating Agencies: USFWS Columbia FWCO (lead); USFWS Carterville-Wilmington FWCO; INHS and ILDNR; Edward Sterling, Bryon Rochon, Jahn Kallis, Jason Goeckler (USFWS Columbia FWCO)

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

INTRODUCTION AND NEED

Detection and monitoring of invasive carp (Bighead Carp, Black Carp, Grass Carp, and Silver Carp) populations in the Illinois River are critical for achieving management goals. To address this important information need, natural resource agencies collaborate to implement a standardized multiple-gear sampling approach (the MAM of the Illinois River for Decision Making project). This standardized multi-gear sampling approach provides an accurate, comparable, and representative understanding of invasive carp distribution and abundance throughout the Illinois River. Additionally, incorporating age data collections into these efforts provides the information needed (e.g., age structure) to inform stock assessment models used to quantify the success of control efforts.

The USFWS's Invasive Carp Demographic project is collaborative with the MAM of the Illinois River for Decision Making project. This project includes electrified dozer trawl sampling and laboratory processing of field samples. Please see the MAM of the Illinois River for Decision Making ISR for the electrified dozer trawl sampling methodology. The physical capture data from this project is summarized in the MAM ISR and hereafter is not discussed. The focus of this report is solely on age structure results.

OBJECTIVES

- Coordinate with MAM of the Illinois River for Decision Making project to provide an additional gear type (i.e., electrified dozer trawl) to existing standardized sampling protocols to complete field sampling, data processing and analysis, and reporting to achieve MAM of the Illinois River for Decision Making project objectives.
- Provide Silver Carp age structure results in pools of the Illinois River.

PROJECT HIGHLIGHTS

From 2018 to 2023, over 3,800 lapilli otolith aging structures were collected and processed from six pools of the Illinois River, providing pool-specific age structure metrics.

METHODS

The USFWS Columbia FWCO collected fisheries-independent data, including age, size, and sex, during three time periods (June through October) in the Alton, LaGrange, Peoria, Starved Rock,

Marseilles, Dresden Island, Brandon Road, and Lockport Pools using a random design stratified by habitat type (i.e., backwaters, island side channels, main-channel borders). Sampling was conducted using the electrified dozer trawl (Hammen et al. 2019; Drews 2020). Further details describing fish collection procedures are provided in the MAM ISR.

During time period three of MAM (September 15 to October 31), lapilli otoliths were extracted from the first 100 Silver Carp captured in each pool, with a maximum of 20 Silver Carp per transect. Otoliths were extracted from any Silver Carp in an unfilled length bin (10/50 mm total length) following the first 100 collected. These data represent the age structure of the population. To help characterize the age structure of the fishery, additional lapilli otoliths were collected from invasive carp (200 invasive carp/pool) in Marseilles and Dresden Island Pools using additional fisheries-independent (i.e., standard electrofishing) and fisheries-dependent (i.e., commercial gillnets) methods. These additional collections were necessary because invasive carp densities are low in Dresden Island and Marseilles. Age structures from the Marseilles and Dresden Island Pools were provided through collaboration with ILDNR, INHS, and the USFWS Wilmington Substation.

Lapilli otoliths collected from this sampling effort were aged by personnel from the USFWS Columbia FWCO. One otolith per fish was prepared by sanding on a transverse plane until reaching the nucleus. Prepared otoliths were mounted in putty, submerged in glycerol, illuminated with a fiber optic light, and viewed using a dissecting scope. Three independent readers aged each otolith, and a final age was recorded using a minimum of two-thirds consensus (Maceina and Sammons 2006; Seibert and Phelps 2013). If a two-thirds consensus could not be reached, the otolith was omitted from our dataset.

RESULTS AND DISCUSSION

Field collection summary results coinciding with objective number one are described in the MAM of the Illinois River for Decision Making ISR.

Herein, we report summary results addressing objective two, providing Silver Carp age structure results for pools of the Illinois River. The age structure collection included collaboration with the MAM project and the Contracted Commercial Fishing Below the Electric Dispersal Barrier project to build a large age structure dataset using lapilli otoliths from fall-caught fish. These data are critical for determining population age structure, estimating growth, and parameterizing stock assessment models, such as catch-at-age models.

Results from 2021 to 2022 collections were updated with 2023 data. Specific methods for age structure collections between 2021 and 2022 can be found in the 2022 Demographics ISR (Project: Invasive Carp Demographics, ICRCC-MRWG 2022). Laboratory data have been shared with the MRWG to be incorporated into the overall MRWG database. These data could be used by the MRWG modeling sub-workgroup to update parameter estimates in the SEIcarP model, as well as provide important inputs for SCAA models recommended by the Quantitative Fisheries Center personnel at Michigan State University.

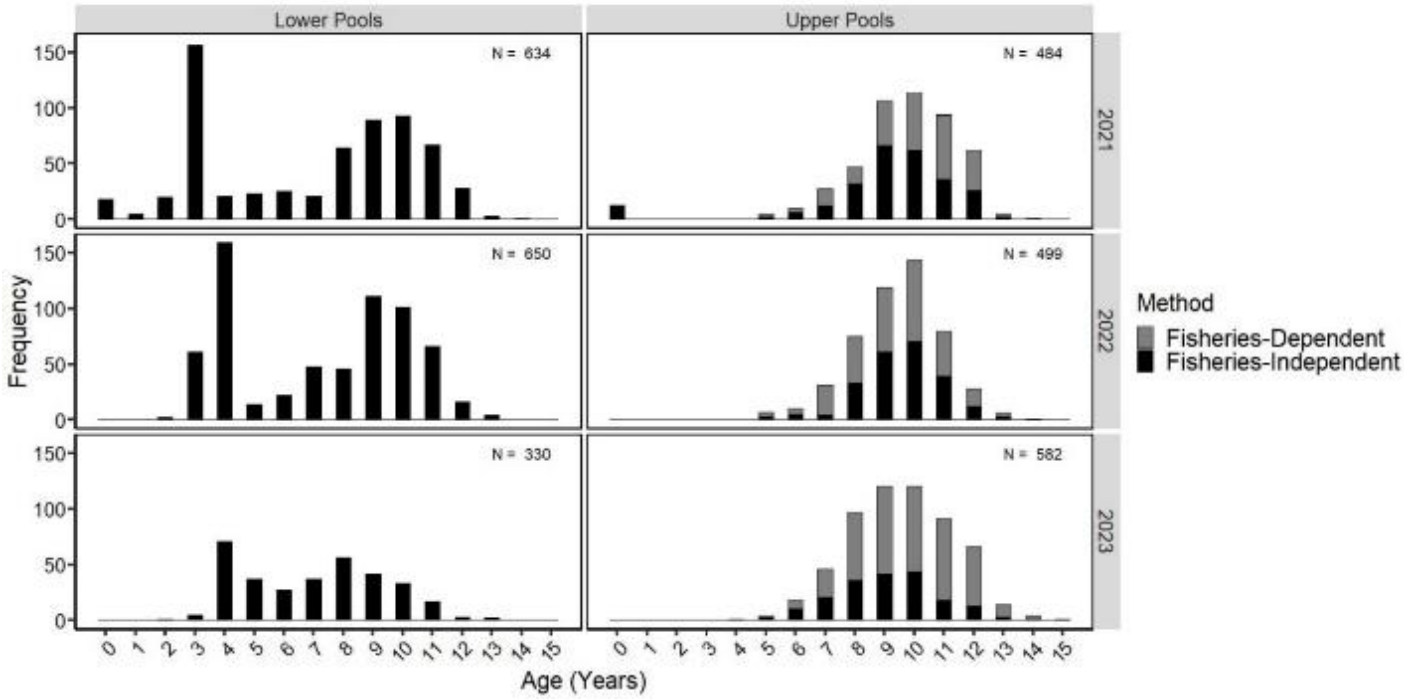
In 2023, 929 invasive carp (912 Silver Carp) were captured, and lapilli otolith age structures were removed during the fall period in the lower six pools of the Illinois River. No invasive carp were captured in Brandon Road or Lockport Pools. In total, 524 age samples were collected with electrified gears (i.e., electrified dozer trawl and standard electrofishing), and 405 age samples were collected with fisheries-dependent gears (i.e., gillnet). All the fisheries-dependent samples were collected in the Marseilles and Dresden Island pools.

Table 1. *Fall 2023 age collection summary data, including Silver Carp total catch (number fisheries-independent, number fisheries-dependent), Bighead Carp total catch (number fisheries-independent, number fisheries-dependent), total length (TL) range, and age (years) range of invasive carp captured.*

Pool	Silver Carp (#)		Bighead Carp (#)		TL range (mm)	Age range (years)
	Independent	Dependent	Independent	Dependent		
Dresden Island	18	192	2	14	736-1012	6-20
Marseilles	64	199	1	0	511-1001	5-14
Starved Rock	107	0	0	0	541-907	4-15
Peoria	110	0	0	0	360-970	3-11
LaGrange	122	0	0	0	400-765	2-13
Alton	98	0	0	0	416-752	3-13

Age-frequency histograms provided insights into recruitment patterns and the relationship between age and upstream movement. Although young, immature 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 in 2021. The age structure of older fish (greater than age-5) was similar between lower and upper pools (Figure 1). We observed strong 2018- and 2019-year classes in the lower pools, which were age-4 and -5 in 2023 (Figure 1). Studies have documented a large 2019 cohort in the Mississippi and Missouri River basins, which could be the source of the cohort identified through our work (Mississippi Interstate Cooperative Resource Association 2023). These two young cohorts were observed in Alton, LaGrange, and Peoria Pools but have yet to disperse upstream. However, they are entering maturity, which may affect their upstream dispersal rates. Furthermore, the age structure in the lower pools is beginning to trend toward a younger population in 2023 compared to 2021 and 2022. This could indicate that the large 2018 and 2019 cohorts are displacing older fish to distribute upstream. The upper pools continue to maintain a generally older migrant population (Figure 1). The fisheries-dependent age structure also appeared similar to the fisheries-independent collections, providing confidence that our fisheries-independent sampling describes the same population that is targeted for removal (Figure 1). Annual pool-specific age-frequency histograms can be found in Appendix A (Figure A-1).

Figure 1. *Pool-specific (Lower Pools- Alton, LaGrange, and Peoria pools; Upper Pools- Starved Rock, Marseilles, and Dresden Island pools) Silver Carp age frequency data in the lower six pools of the Illinois River. Fisheries-independent samples collected during fall 2021 through 2023 using the electrified dozer trawl and standard electrofishing are indicated in black, and fisheries-dependent age structures collected during fall 2021 through 2023 are indicated in gray.*



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, thus providing tools to inform management and control efforts. We recommend continued monitoring through fisheries-independent and fisheries-dependent age structure collections to inform demographic information 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. Our continued collaboration with the MAM project to provide efficient, high-quality fisheries-independent data and the Contracted Commercial Fishing Below the Electric Dispersal Barrier project to provide efficient fisheries-dependent age structure collections is essential for modeling efforts. We also recommend continued coordination with MRWG workgroups to address monitoring objectives, increase efficient demographic data collection, and provide high-quality data to support ICRCC and MRWG needs.

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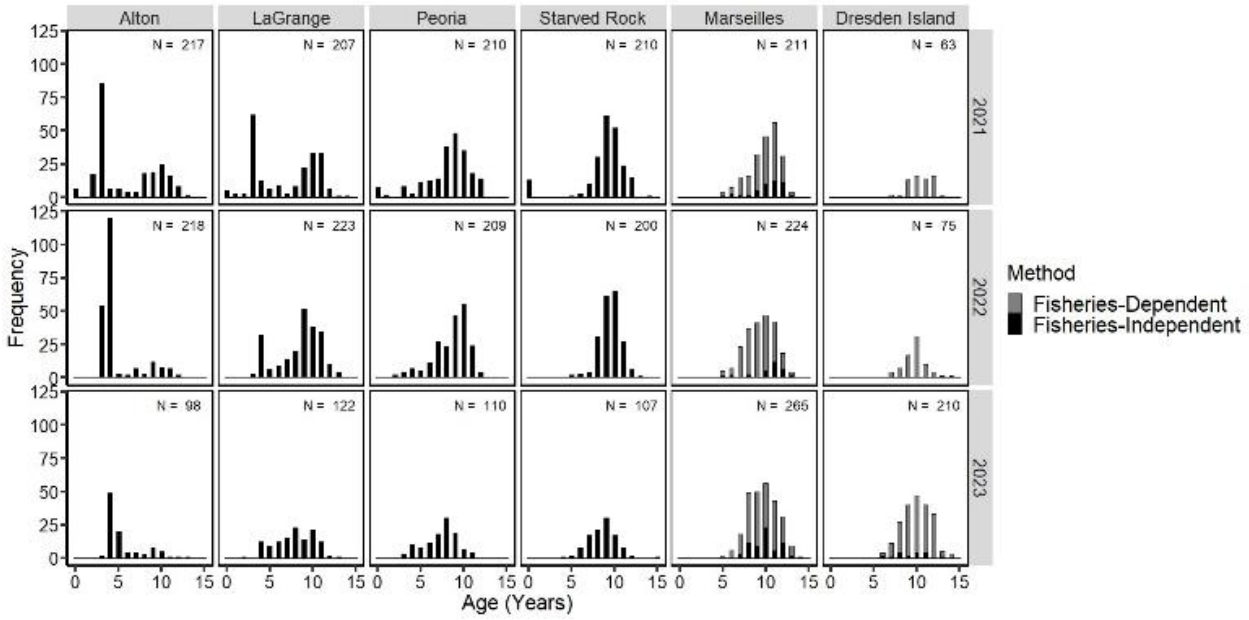
INVASIVE CARP DEMOGRAPHICS
APPENDIX A: ADDITIONAL DATA

Figure A-1. *Pool-specific Silver Carp age frequency data in the lower six pools of the Illinois River. Fisheries-independent samples collected during fall 2021 through 2023 using the electrified dozer trawl and standard electrofishing are indicated in black, and fisheries-dependent age structures collected during fall 2021 through 2023 are indicated in gray.*



ALTERNATE PATHWAY SURVEILLANCE IN ILLINOIS – LAW ENFORCEMENT

Participating Agencies: ILDNR (lead); Brandon Fehrenbacher (ILDNR)

Pools Involved: N/A

INTRODUCTION AND NEED

The ILDNR 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 being introduced and established into new waters. ISU is dedicated to confronting individuals or businesses that violate laws and regulations enacted to protect our waterways. These concentrated efforts firmly establish, on an annual basis, that human activities remain a foreseeable risk to invasive species expansion. It is critical, therefore, that local, state, and federal agencies tasked with resource protection establish and train their own specialized units. ISU provides qualified experts to liaise with other law enforcement personnel, non-law enforcement personnel from other divisions or agencies, and the public searching for answers to their focused inquiries.

OBJECTIVES

- Create a user-friendly reference guide for CPOs that contains guidelines to address the most frequent aquatic invasive species violations.
- Surveil and inspect industries linked to the invasive carp trade where experts identify the highest likelihood of regulatory violations.
- Coordinate Joint Forces Operations to investigate aquatic invasive species (AIS) violations that occur across multiple jurisdictions.
- Promote the development of Aquatic Organisms in Trade Law Enforcement Units in each Great Lakes Basin jurisdiction.

PROJECT HIGHLIGHTS

Twenty-five Illinois CPOs participated in a three-hour workshop focusing on how to thoroughly investigate the possession or sale of crayfish as an invasive species. The training included an overview of the damage caused by invasive crayfish, identification of live specimens, and specialized AIS law enforcement techniques. Experts in the study of crayfish, students, and staff from Loyola University and Office of Law Enforcement personnel developed and administered the training. Participants received crayfish identification guides and translation cards listing useful phrases for communicating with non-English speaking individuals on AIS issues. The training inspired officers to function as “force multipliers,” resulting in a noticeable increase in law enforcement’s detection and seizure of illegally possessed crayfish species from anglers or

businesses selling to consumers. ISU staff will use this event as a blueprint for future training related to other invasive species.

METHODS

ISU-generated enforcement activity resulted from suspect surveillance operations, on-site facility inspections, focused enforcement details, audits of industry records and permits, topic-specific monitoring of the Internet, public complaints, and government agency-related leads.

RESULTS AND DISCUSSION

Quick reference guides were developed and distributed to all Illinois CPOs that featured Black, Grass, Silver, and Bighead Carp; snakehead (fish); marbled, rusty, and red swamp crayfish; and various invasive plant species. The guide includes pathways where officers are more likely to encounter each species, addresses frequent questions and issues associated with each species, and discusses various enforcement options available to officers.

Snippets of the enforcement actions include:

- While inspection and surveillance details related to the trade in invasive carp did not identify chargeable criminal behavior, they did produce valuable intelligence and opportunities to communicate directly with persons having an interest in invasive carp and unveiled unrelated criminal activity that officers must address in the future. Deterrence through compliance checks plays a critical role in regulatory oversight by holding businesses and individuals accountable for their harmful behaviors.
- Inspections by officers of aquatic life dealers near Chicago identified three fish markets that illegally possessed or sold live Asian swamp eels. Enforcement personnel issued violation notices to the New York and Massachusetts distributors responsible for shipping the eels to Illinois.
- An extensive surveillance of a pet shop owner led to his admission that he illegally possessed and sold live snakehead fish. Information gathered during the investigation generated additional leads.
- An inspection of a Wisconsin fish truck driver and his load of fathead minnows entering Illinois uncovered the use of a falsified importation permit.
- A fish dealer from Tennessee was apprehended importing live channel catfish into Illinois without the required viral hemorrhagic septicemia (VHS)-import permits or aquatic life dealer's license. Further investigation revealed that the fish were commercially harvested from the Mississippi River but not screened for diseases or aquatic hitchhikers.
- A crayfish dealer from Texas was cited after a market inspection in Illinois revealed he had illegally shipped 1,770 pounds of live red swamp crayfish into Illinois.

- A Joint Forces Operation focused on the illegal transportation, possession, and sale of live Asian swamp eels. Officers in three states coordinated their covert and overt activities, inspections, and interviews to identify and stop the actions. Post investigation, one of the agencies added Asian swamp eels to its injurious species list, thereby increasing penalties for future non-compliance.
- Presentations on the necessity of Aquatic Organisms in Trade Law Enforcement Units throughout the Great Lakes Basin were given at the Multi-State Attorney General's Office Environmental Crimes Task Force meeting; the Law Chief's meeting in Ann Arbor, Michigan; the Great Lakes Law Enforcement Committee meeting in Duluth, Minnesota; and the Fish Health Committee meeting in South Bend, Indiana. The expansion of these specialized units will increase enforcement of AIS regulations and resource protection. Feedback from the presentations was positive. Promoting this initiative to individuals in positions who can help achieve this goal should prove beneficial.

RECOMMENDATIONS

Encourage upper management in each GLFC member agency to establish permanent Organisms in Trade Law Enforcement Units. Seek expansion of AIS training for CPOs to further aid in bridging the gap between law enforcement and non-law enforcement personnel.

INVASIVE CARP ENHANCED CONTRACT REMOVAL PROGRAM

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

Pools Involved: Peoria, La Grange, and Alton (Illinois River)

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 upstream.

OBJECTIVES

- Aid in reaching a target removal rate of 20 million pounds of invasive carp per year from the IWW below Starved Rock Lock and Dam.
- Remove a cumulative total of 8 million pounds of invasive carp under the Enhanced Contract Fishing Program by 2024.
- Coordinate fishers and processors to increase 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 Copi brand launch toward increased removal.

PROJECT HIGHLIGHTS

- Removed more than 8.4 million pounds under this program from the Peoria, LaGrange, and Alton pools of the Illinois River in 2023.
- Removed nearly 20.4 million pounds under this program since its inception in 2019.
- Entered into 40 contracts with Illinois-licensed commercial fishers targeting the Peoria, LaGrange, and Alton pools.
- Processed over $840,000 in payments to fishermen.
- Continued to see positive media coverage of the Copi brand and the development of new value-added products and new distributor and sales outlets.