2021 Asian Carp Monitoring and Response Plan

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EXECUTIVE SUMMARY

This Asian Carp Monitoring and Response Plan (MRP) was prepared by the Monitoring and Response Work Group (MRWG) and released by the Asian Carp Regional Coordinating Committee (ACRCC). It is intended to act as an update to previous MRPs, and present up-to-date information and plans for a host of projects dedicated to preventing Asian carp from establishing populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Specifically, this document is a compilation of 21 individual project plans, each of which plays an important role in preventing the expansion of the range of Asian carp, and in furthering the understanding of Asian carp location, population dynamics, behavior, and the efficacy of control and capture methods. Each individual plan outlines anticipated actions that will take place in 2021, including project objectives, methodology, and highlights of previous work.

In April 2021, the U.S. Fish and Wildlife Service (USFWS) began transitioning to use of the term ‘invasive carp’ as a replacement for ‘Asian carp’ within its agency operations, planning and communication documents. The new terminology is incorporated in USFWS content within this MRP. The 'invasive carp' terminology refers specifically to Bighead Carp, Silver Carp, Black Carp, and Grass Carp, which is consistent with the prior use of 'Asian carp' in USFWS documents.

The projects undertaken by the MRWG are designed to address three primary objectives for preventing the spread of Asian carp to Lake Michigan. These objectives are:

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

The plans included in this 2021 MRP build upon considerable work completed since 2010. Selected highlights of past efforts are presented below, grouped by primary objective. For a more detailed accounting of the results and findings of previously completed work, please refer to the 2020 Asian Carp Interim Summary Report, presented as a companion document to the 2021 MRP.

HIGHLIGHTS OF PAST EFFORTS

Detection Projects

- A total of 482,675 fish representing 86 species and 8 hybrid groups have been sampled above the EDBS, including 2,949 Banded Killifish (state threatened species) during 2010-2020.

- During 2009-2020 multi-agency efforts found and removed one Bighead Carp and one Silver Carp upstream of the EDBS. Details of these captures can be found on asiancarp.us.
- No small (< 6 inches) Asian carp were captured upstream of Starved Rock Lock and Dam in 2020.
- Observations of eggs, larvae, and juveniles in the upper Illinois River during 2015 - 2020 indicate that some reproduction occurs above Starved Rock Lock and Dam in some years, but the contribution of these fish to the population and the frequency of such occurrences remain uncertain due to lack of Asian carp smaller than 6-inches in the Upper Illinois Waterway (IWW). Overall, numbers of Asian carp eggs and larvae observed during 2020 were very low compared to other recent study years.
- Multi-Agency monitoring downstream of the EDBS used standardized sampling approaches to collect 252,911 fish representing 107 species and 13 hybrid groups during 2020. 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 2020.
- No Asian carp have been captured during sampling in the Des Plaines River. This spans the collection of 13,882 fish since 2011.
- 35 Bighead Carp have been removed from urban ponds since 2011.

Management and Control Projects

- Through Illinois Department of Natural Resources (IDNR) and USFWS harvest efforts, over 5,147 tons of Asian carp have been removed from the IWW below the EDBS since 2010. This tonnage consists of 101,579 Bighead Carp; 1,157,698 Silver Carp; and 10,461 Grass Carp.
- Telemetry study of tagged fish has observed no upstream passage past the EDBS. Three downstream lock passages were observed in the Upper IWW in 2020.
- Law enforcement conservation officers have completed inspections of multiple aquaculture facilities and numerous fish trucks. These and other efforts have resulted in citations and ongoing multi-agency, cross-jurisdictional investigations into the illegal trade of invasive aquatic species.

Response Projects

- A contingency response plan for the Upper IWW has been established. The plan established 2015 as a baseline year for evaluating changes to Asian carp range and population status and prescribes appropriate response actions based on particular changes to population status on a pool-by-pool basis.

In addition to these highlights, a brief summary of work anticipated to be completed in 2021 is provided below for each project, grouped by primary objective. For a detailed description of project plans, methods, and objectives, refer to each project's individual plan for 2021.

DETECTION PROJECTS

Seasonal Intensive Monitoring in the CAWS

Seasonal intensive monitoring is a modified continuation of Fixed and Random Site Monitoring Upstream of the EDBS and Planned Intensive Surveillance in the CAWS. These events will be planned for the spring season (Weeks of June 2^{nd} and 9^{th}) and the fall season (Weeks of September 15^{th} and 22^{nd}). This project includes standardized monitoring with pulsed-DC electrofishing gear and contracted commercial fishers at sites in the CAWS upstream of the EDBS. Monitoring also will include five fixed sites with additional random electrofishing transects and net sets at locations outside of fixed sites to maintain spatial coverage of the waterway. Along with maintaining the spatial coverage upstream of the EDBS, each seasonal intensive monitoring event will provide extra sampling focus on a unique location in the CAWS. The two-week event in the spring will focus on the Lake Calumet/Cal-Sag area of the CAWS. In 2017 one Silver Carp was captured in this area, leading to a successful response operation known as Operation Silver Bullet. The two-week event in the fall will focus on the North Shore Channel/Chicago River. The Seasonal Intensive Monitoring provides a spatially and temporally adequate assessment of relative abundance and distribution of Asian carp in the CAWS upstream of the EDBS.

Strategy for eDNA Sampling in the CAWS

In 2021, the project will focus on Lake Calumet and the Marine Service marina on the Little Calumet River. Sampling will not be conducted in the South Branch Chicago River and areas of the Chicago Ship and Sanitary Canal (CSSC) that have previously been sampled, due to the potential influence of combined sewer overflows.

Telemetry Monitoring Plan

This project uses ultrasonically tagged Asian carp and surrogate species to assess whether tagged fish challenge and/or penetrate the EDBS and pass through navigation locks in the Upper IWW. An array of stationary acoustic receivers and mobile tracking will be used to collect information on Asian carp and surrogate species movements.

USGS Telemetry Project

This project uses real-time acoustic telemetry receivers for detecting bigheaded carp (Silver Carp and Bighead Carp) and surrogate fishes, and also provides supplementary support to telemetry projects, including development and maintenance of the FishTracks DB database, and development of a model to estimate Asian carp movement probabilities. Real-time telemetry receivers are deployed at strategic locations in channel and off-channel areas in the Upper Illinois and Des Plaines river systems and in the CAWS with the intent to support decisions on directing (1) removal efforts by contracted fishing and (2) contingency actions. Location information of tagged bigheaded carp from real-time detections at these receivers are available online to biologists directing day-to-day removal efforts, and as email or text alerts to managers responsible for executing contingency actions. The FishTracks DB acts as a centralized database for telemetry receiver and fish transmitter data, and allows project stakeholders to upload, download, and query relevant datasets. The movement probability model estimates the probability of inter-pool movement throughout the Illinois River, and has been updated and run with up-to-date data.

Monitoring Fish Abundance, Behavior, and Species Composition within the Illinois Waterway and Near the Chicago Sanitary and Ship Canal Electric Dispersal Barrier

This project continues to evaluate non-Asian carp fish behavior between the narrow arrays where the highest-voltage electrical field is located to determine the species of fish present in and directly adjacent to the barrier system. The overarching goal of this multifaceted monitoring program is to quickly identify any change in fish community species composition, fish abundance, or fish behavior near the EDBS, especially with regard to small size classes of fish. This project will provide insights on fish behavioral responses to biological, abiotic, and anthropogenic changes within the system. Additionally, fish surveys supporting barrier clearing operations will be performed "as necessary" to support barrier maintenance needs or requests from the ACRCC.

Early Detection of Asian Carp in the Illinois Waterway for Decision Making

This is a new project for 2021. This early detection project replaces the USFWS efforts towards the Distribution and Movement of Small Asian Carp in the IWW project as well as the Habitat Use and Movement of Juvenile Asian Carp in the IWW Using Telemetry project. The overall objective of this project is to increase targeted, species-specific, early detection sampling of small and large Silver Carp and Bighead Carp in the upper IWW for the purpose of increasing certainty in distribution of each species. The information provided by this Asian carp-focused sampling will aid ACRCC and MRWG agencies in evaluating the current invasion risk of Asian carp to the Great Lakes via the CAWS.

Larval Fish Monitoring in the Illinois Waterway

Larval fish sampling will occur at weekly to biweekly intervals at seven sites located in the Illinois and Des Plaines rivers downstream of the EDBS from late April to October. Additional sampling will occur at sites in the Sangamon, Spoon, Mackinaw, Fox, and Kankakee rivers to assess potential Asian carp spawning in tributaries of the Illinois River. Sampling may occur more frequently during periods when Asian carp eggs and larvae are likely to be present (e.g., May - June, during periods of rising water levels, or shortly after peak flows). Observation of Asian carp eggs or larvae will help to inform other agencies of the upcoming likelihood of capturing young-of-year Asian carp. Analyses of the spatial and temporal distribution of Asian carp eggs and larvae will aid in identifying spawning locations, environmental factors associated with successful reproduction, and factors contributing to Asian carp recruitment.

Movement and Density of Bigheaded Carp in the Illinois River

This project continues previous work by Southern Illinois University (SIU) that has intensively monitored movement and density of Asian carp in the Illinois River since 2012. Hydroacoustic and associated sampling surveys will yield information on trends in density, biomass, and population information such as size structure, catch per unit effort (CPUE), and length-weight relationships of Asian carp in the Illinois River. Because these surveys have been ongoing since 2012, they provide valuable long-term trends. Work comparing surrogate fish movements to bigheaded carps' movement will continue through 2021.

Des Plaines River and Overflow Monitoring
This project performs monitoring for Asian carp within the Des Plaines River using electrofishing and gill netting. The Des Plaines River runs parallel to the CAWS and represents a possible route for Asian carp to bypass the EDBS during overflow events. To prevent this bypass, a physical barrier was constructed between the Des Plaines River and the CAWS. This project continues to monitor for Asian carp in the Des Plaines River to determine the threat posed to the CAWS by Asian carp populations within the Des Plaines River. A minimum of three sampling events will be conducted in 2021, focusing on capturing the spawn and post-spawn time frames.

Alternative Pathway Surveillance – Urban Pond Monitoring
This project provides monitoring and removal efforts for Asian carp that may have been unintentionally stocked in urban fishing ponds in the Chicago Metropolitan Area. Monitoring with environmental deoxyribonucleic acid (eDNA) technology and conventional gears (electrofishing and netting) has previously occurred in local fishing ponds and has detected and removed Asian carp (possibly introduced as contaminants in shipments of stocked sport fish). During 2021, urban pond sampling will be based upon photographic evidence of Asian carp or reports from credible sources.

Multiple Agency Monitoring of the Illinois River for Decision Making
This project began in 2019 and utilizes a standardized sampling approach to (1) effectively monitor Asian carp population demographics (i.e., presence/absence, distribution, and abundance) and (2) assess native fish communities throughout pools of the Illinois River below the EDBS that may be adversely impacted by Asian carp. This project will utilize Long Term Resource Monitoring (LTRM) sampling design to provide a more robust and statistically powerful fish population dataset than past monitoring efforts have produced.

MANAGE AND CONTROL PROJECTS

USGS Asian Carp Database Management and Integration Support
This project uses data compilation and analysis to inform ongoing management and control actions. Compiling data from monitoring and removal efforts into a centralized database (Illinois River Catch Database application) facilitates data standardization, quality, accessibility, sharing, and analysis to aid in Asian carp removal efforts, evaluations of management actions, and modeling efforts (e.g., Spatially Explicit Asian Carp Population [SEACarP] model). Data summarization, visualization, and modeling supports a better understanding of bigheaded carp life history, behavior, and habitat use. Integrating Asian carp-related data and analyses into

decision support tools and products aids in applying control and containment methods in an informed and transparent manner (e.g., improved efficiencies in implementations of the Unified Method, inform targeted removal efforts or deterrent deployments in key locations based on preferential benthic characteristics and environmental conditions).

Contracted Commercial Fishing Below the Electric Dispersal Barrier
Contracted commercial Fishing below the EDBS uses contracted commercial fishers to reduce Bighead Carp, Black Carp, Grass Carp, and Silver Carp numbers and monitor for their expansion in the upper Illinois River and lower Des Plaines River downstream of the EDBS. By decreasing Asian carp numbers, we anticipate reduced migration pressure towards the barrier lessening the chances of Asian carp gaining access to upstream waters in the CAWS and Lake Michigan. Monitoring for upstream expansion of Asian carp should help identify changes in the leading edge, distribution, and relative abundance of Asian carp in the IWW.

Asian Carp Population Modeling to Support an Adaptive Management Framework
This project continues to build upon past efforts to develop a SEACarP model that includes spatial components (i.e., river pools) of the Illinois River system. During 2021, the model will be submitted to for publication in a peer reviewed journal to gather additional feedback. A stock-recruitment relationship will be developed using existing age structure and hydroacoustic data. Statistical catch models will be used to estimate vulnerability to fishing based on fish size, exploitation rates, and immigration to the upper Illinois River. The model will be used to inform adaptive management efforts to control Asian carp populations in the Illinois River.

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEACarP)
This project aims to provide a more robust telemetry dataset to inform Asian carp movement within the SEACarP model. During 2021, this project will focus on maintaining a sufficient number of tagged small and juvenile Asian carp to better understand their movement tendencies, including interactions with dams and macro-habitat selection. Tagging efforts will focus on Peoria and Starved Rock pools. The results of this study will be incorporated in the SEACarP model to better evaluate the risk posed by movement of small and juvenile Asian carp, and to better understand the habitat selection of juvenile Asian carp as they mature.

Asian Carp Demographics
Management of invasive Asian carp in the IWW calls for an adaptive management approach (Walters 1986). Data driven tools are integral parts of the adaptive management framework. They describe existing understanding using systems models that include key assumptions and predictions, which form the basis for further learning and decision making. Providing standardized Asian carp demographic data over time and space will support managing and monitoring efforts of these species within the Illinois River. During 2021 the USFWS Columbia FWCO will collect fisheries-independent data including age, size, and sex structure, length at maturity, and relative abundance during spring (May – June) and fall (September – November)

in each of the lower six pools of the Illinois River (Figure 1) using a random design stratified by habitat type.

Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation

This project is a continuation of previous studies that investigated small fish entrainment, retainment, and upstream transport by commercial barge tows. The USFWS and partner agencies have conducted several years of barge entrainment studies that demonstrate small fish can become entrained and retained in the box-to-rake junction of commercial tows. These previous studies illustrate the need for mitigation technologies capable of removing entrained small fish and, therefore, reducing the risk of upstream transport in the IWW. In 2022, USFWS collaborating with the U.S. Army Corps of Engineers (USACE) and USGS plan to carry out a full-size barge study to test the efficacy of longitudinal bubble array at mitigating entrainment of Asian carp by commercial barge tows. In order to properly prepare for this large project, we plan to conduct a pilot study in 2021 to investigate techniques and develop protocols for capturing and subsequently rearing the necessary number of juvenile Asian carp in captivity.

Alternative Pathway Surveillance in Illinois – Law Enforcement

This project created a more robust and effective enforcement component of IDNR's invasive species program by increasing education and enforcement activities at bait shops, bait and sport fish production/distribution facilities, fish processors, and fish markets/food establishments known to have a preference for live fish for release or food preparation. Inspection and surveillance efforts will take place in the Chicago Metropolitan Area including Cook and the collar counties, with eventual expansion statewide and potentially across state boundaries.

Asian Carp Enhanced Contract Removal Program

This program aims to reduce the abundance of Asian carp in Peoria Pool through controlled and contracted fishing efforts. This program issues fishing contracts to those commercial fishers willing to target Asian carp in Peoria Pool and fulfill contractual obligations of selling, reporting, transporting, and fishing in the identified area. This project also provides critical information about population densities of Asian carp through time in the Peoria Pool as well as the Illinois River system to guide management efforts. This project also works to identify and employ mechanisms for use of the harvested fish by private industry for purposes including human consumption. Through a cooperative relationship of agency and fishers along with end users/markets, advice and support will be provided as necessary to further inform fishers on the delivery of quality and quantity of fish to the end user/markets through this interaction.

RESPONSE PROJECTS

Upper Illinois Waterway Contingency Response Plan

This project has established a set protocol for determining whether detection results merit a direct response action, and laid out a framework for taking response actions, including steps for coordinating between agencies and communicating with the general public. In 2021, relevant agencies will continue developing and refining the response plan, including conducting a tabletop exercise to identify any needed improvements to the plan.

INTRODUCTION AND STRATEGY

This Asian Carp Monitoring and Response Plan (MRP) was prepared by the Monitoring and Response Work Group (MRWG) and released by the Asian Carp Regional Coordinating Committee (ACRCC). It builds upon previous MRPs and presents plans for an integrated suite of projects dedicated to preventing Asian carp from establishing populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. The MRP also seeks to reduce the impact of Asian carp in the Upper Illinois Waterway (IWW) and further reduce the risk of spread toward Lake Michigan. Specifically, this document is a compilation of 21 individual project plans, each of which plays an important role in preventing expansion of the range of Asian carp, and in furthering the understanding of Asian carp location, population dynamics, behavior, and the efficacy of control and capture methods. Each project outlines anticipated actions that will take place in 2021, including project objectives, methodology, and highlights of previous work.

This MRP is the operational extension of the 2021 Asian Carp Action Plan (Action Plan) which outlines funding and actions taken through the U.S. Environmental Protection Agency's (USEPA) Great Lakes Restoration Initiative. The Fiscal Year 2021 Action Plan contains a portfolio of more than 60 high-priority strategic activities for implementation in the coming year. The Action Plan serves as a foundation for the work of the ACRCC partnership — a collaboration of 28 United States (U.S.) and Canadian federal, state, provincial, tribal, and local agencies — to achieve its mission of preventing the introduction and establishment of Asian carp in the Great Lakes.

This MRP is a natural extension of the **Illinois State Comprehensive Management Plan for Aquatic Nuisance Species** and further builds upon the **Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States**. While the clear and overarching goal of the ACRCC is to prevent the introduction and establishment of Asian carp into the Great Lakes, the work of the MRWG is clearly focused on Bighead Carp and Silver Carp in the Illinois Waterway (IWW). For the purpose of this MRP, the term 'Asian carp' refers to Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*), exclusive of Grass Carp (*Ctenopharyngodon idella*) and Black Carp (*Mylopharyngodon piceus*). Where individual projects address Grass Carp and Black Carp, they will be referenced specifically by name, and without using the generic 'Asian carp' moniker. The MRWG believes that techniques showing promise with Bighead Carp and Silver Carp are also techniques that are appropriate for successful surveillance, management/control and response for Grass Carp and Black Carp.

This MRP builds on prior plans developed for 2011 – 2020. More specifically, it is intended to identify actions to be taken in 2021, consistent with the multiyear, 2015 – 2017 MRP that was developed in 2015. This 2021 MRP takes advantage of information gathered since 2011 to provide the most robust suite of activities to accomplish MRWG objectives. The MRP is a living document and will be revisited at least annually. All MRPs to date, including the 2021 MRP, have benefitted from the review of technical experts and MRWG members, including, but not limited to, Great Lakes states' natural resource agencies and non-governmental organizations. Contributions to this document have been made by several state and federal agencies.

This 2021 MRP provides information about project plans, which incorporate new information, technologies, and methods as they have been discovered, field tested, and implemented. A companion document, the 2020 Asian Carp Interim Summary Report (ISR), has also been completed by the MRWG. The 2020 ISR presents a summary of each individual project's activities, results, findings, and recommendations for future actions. Similar to the MRP, the ISR functions as a living document, and will be updated at least annually. Collectively, the 2021 MRP and 2020 ISR present a comprehensive accounting of the projects being conducted to prevent establishment of Asian carp in the CAWS and Lake Michigan. Through these documents, the reader can obtain a thorough understanding of the most current project results and findings, as well as how these findings will be used to guide future activities.

The projects included in the 2021 MRP have been grouped in accordance with the core strategic objectives of the MRWG. These core objectives consist of:

1. **Detection**
2. **Management and Control**
3. **Response**

The projects that will address each of these core objectives are presented on the next page.

Detection

- Seasonal Intensive Monitoring in the CAWS
- Strategy for eDNA Sampling in the CAWS
- Telemetry Monitoring Plan
- USGS Telemetry Project
- Monitoring Fish Abundance, Behavior, and Species Composition within the Illinois Waterway and Near the Chicago Sanitary and Ship Canal Electric Dispersal Barrier System
- Early Detection of Asian Carp in the Illinois Waterway for Decision Making
- Larval Fish Monitoring in the Illinois Waterway
- Movement and Density of Bigheaded Carp in the Illinois River
- Des Plaines River and Overflow Monitoring
- Alternative Pathway Surveillance – Urban Pond Monitoring
- Multiple Agency Monitoring of the Illinois River for Decision Making

Manage and Control

- Multiple Agency Monitoring of the Illinois River for Decision Making
- Contracted Commercial Fishing Below the EDBS
- Asian Carp Population Modeling to Support an Adaptive Management Framework
- Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEACarP)
- Asian Carp Demographics
- Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation
- Alternative Pathway Surveillance in Illinois – Law Enforcement
- Asian Carp Enhanced Contract Removal Program

Response

- Upper Illinois Waterway Contingency Response Plan

In addition to these project plans that directly address the primary objectives of the MRWG, additional key information is provided in this MRP as appendices. Additional project plans for 2021 are provided in the following locations:

- Appendix A: "Zooplankton as Dynamic Assessment Targets for Asian Carp Removal"

Key background information on Asian carp that may be useful to field crews or the general public is provided in Appendices B through M. Appendix L provides descriptions and pictorial displays of common fishing gears that are used during Asian carp field projects. Appendix M provides a summary of the sampling frames established for the Illinois River pools below the EDBS.

CURRENT STATUS

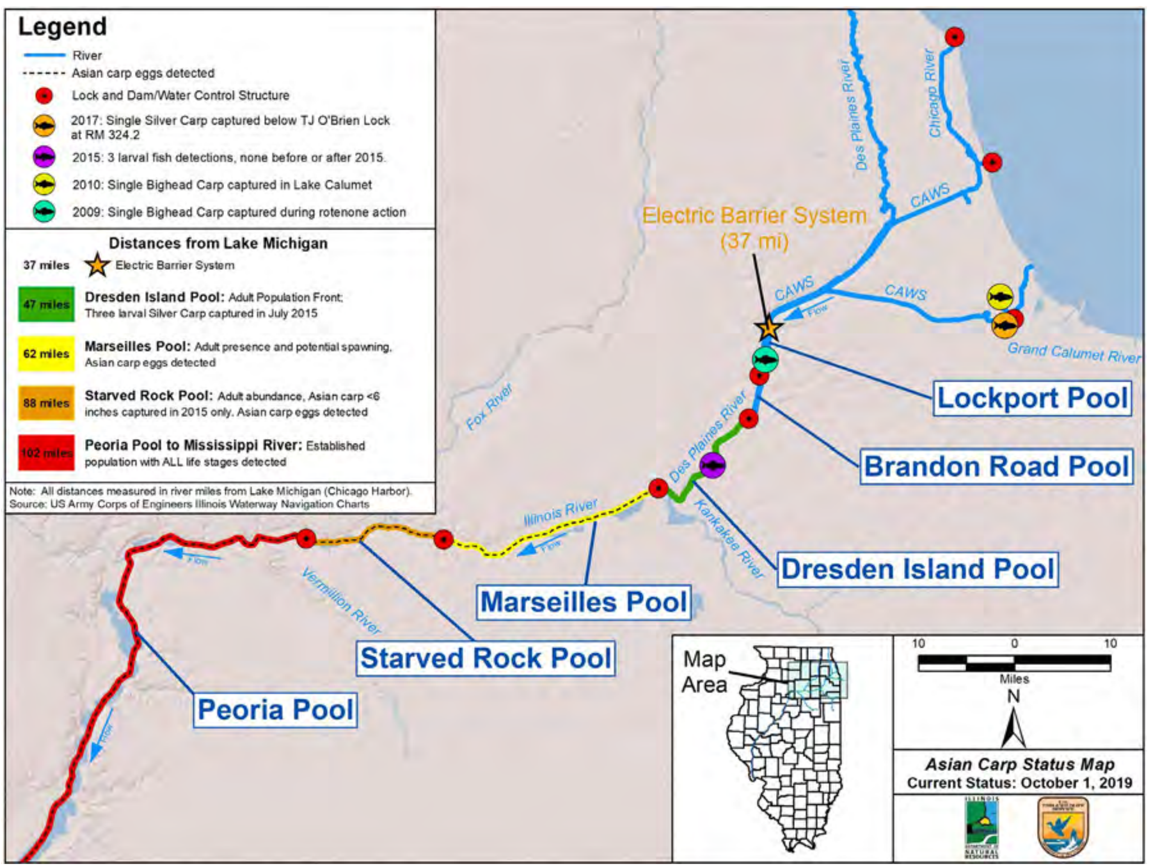
Detection projects have informed agency actions and development of the 2021 MRP. No Asian carp have been detected in Lake Michigan, and no Asian carp have been collected between Brandon Road Lock and Dam and the EDBS since detection efforts were intensified in 2010. Acoustic-based surveys performed in 2019 suggest relative abundance (measured as mean Asian carp density based on hydroacoustic surveys) has been reduced by an estimated 96.7% from 2012 levels. This is an improvement on prior estimates demonstrating relative abundances of adult Asian carp in the Dresden Island Pool decreased between an estimated 59% and 75% from 2012 to 2014 (a 68% average, see MacNamara et al. 2016 contained in Appendix L). This reduction was facilitated, in part, by the mass removal of Asian carp through the strategic use of contract commercial fishing, as well as other factors such as fish migration within the waterway and the degree of reproductive success during those years. These acoustic survey techniques allow for assessment of the Asian carp population on a pool-by-pool basis and evaluation of potential change of risk of Asian carp approaching the electric barrier system, in addition to traditional techniques.

The management and control aspects of this MRP have also contributed to observations of reduced populations (up to 50% declines as noted by MacNamara et al [Appendix L]) in Marseilles and Starved Rock pools, as well as reduced populations (up to 96% decline) in Dresden Island Pool. While spawning activity has been observed in Marseilles and Starved Rock pools in the past, the resulting eggs travel downstream with prevailing flow direction, away from Lake Michigan. Data suggest that any eggs produced in these pools experience mortality or drift downstream to hatch in the Peoria and La Grange pools, below the Starved Rock Lock and Dam. During 2020, eggs were collected as far upstream as Marseilles Pool, and larvae were collected as far upstream as Starved Rock Pool. Overall, numbers of Asian carp eggs and larvae observed during 2020 were very low compared to other recent study years. Larval and juvenile Asian carp are present in the Lower IWW, which acts as the source of Asian carp throughout the IWW. The MRWG believes that small Asian carp (< 6 inches) and those larger Asian carp found above the Starved Rock Lock and Dam have immigrated to the Upper IWW from the Lower IWW. Because Asian carp are produced only in the Lower Illinois River, the strategy of removal above Starved Rock Lock and Dam has increased efficacy for control until such time as much larger commercial harvest of Asian carp further downstream in the lower Illinois River can be effectively accomplished. The 2021 Asian Carp Action Plan recognizes management-based contracts that can be issued to increase removal efforts in the lower Illinois River.

Data collected since 2011 have improved knowledge of where fish are and where fish are not in the IWW. The graphic below summarizes our current knowledge of the status of Bighead Carp and Silver Carp developed through ongoing monitoring and historical accounts. This graphic also denotes 2015 as the baseline year to evaluate progress in future years. 2015 was selected as a baseline year for two primary reasons: (1) the MRWG and ACRCC concurred that the establishment of a baseline year would aid in evaluating the status of Asian carp in the Upper

IWW; and (2) 2015 was characterized by significant monitoring and detection efforts, which led to a thorough understanding of the Asian carp population status, and allowed MRWG to reach a consensus on Asian carp status in 2015. The results of ongoing surveillance and management efforts, including those through December 2019, have been used to establish the current status of Asian carp populations in each pool of the IWW, as described below:

- **Lake Michigan:** No established Asian carp population.
- **CAWS:** No established Asian carp population.
- **Lockport Pool:** No established Asian carp population.
- **Brandon Road Pool:** No established Asian carp population.
- **Dresden Island Pool:** Adult Asian carp population front. Larval Asian carp observed in 2015 and have not been observed since (source of larval carp unknown).
- **Marseilles Pool:** Adult Asian carp consistently present, and Asian carp eggs have been detected. Spawning has been observed.
- **Starved Rock Pool:** Abundant Asian carp present, and Asian carp eggs have been detected. Early life-stage Asian carp (<6 inches total length) were observed in 2015 and have not been observed since.
- **Peoria Pool (downstream to confluence with Mississippi River):** Established population with all life stages of Asian carp present.



Specific highlights from the 2020 field season include:

- No Asian carp collected or observed in Lake Michigan or Brandon Road Pool.
- No small Asian carp detected in Upper IWW.
- 1.08 million pounds of Asian carp removed from Upper IWW.

In 2021, detection efforts below the EDBS will continue to utilize a standardized, scientifically-based multi-agency monitoring framework to provide even more Asian carp and ecologically relevant fisheries data. The methods and protocols that have been adopted are based upon a large river monitoring effort. Additional additive measures may be applied for specific purpose, subject to agency and MRWG review. Those standard methods are found within the fisheries portion of the Long Term Resource Monitoring element of Upper Mississippi River Restoration Program. Those methods can be found here:
https://www.umesc.usgs.gov/reports_publications/ltrmp/fish/fish_methods.html

In addition to these direct findings, data collected via surveillance and management projects have been used to develop a model that combines the propensity of Asian carp to move, the effects of harvest, and basic biological parameters such as age, growth, and condition of Asian carp. The model will serve as a decision support tool to help inform management efforts and strategy over the short term (next 5 years) and long term (> 5 years). Initial results support the MWRG's existing management strategy that focuses localized and intense Asian carp removal efforts in the upper river. However, a long term strategy bolstered by market-driven forces to remove Asian carp in the lower IWW that could lead to much greater removal than can be accomplished in the Upper IWW would lead to increased risk reduction. Achieving these greater removal levels requires working in concert with economic forces in the Lower IWW. Based on the results of modeling work, the amount of fish required to be removed exceeds current funding available to agencies implementing removal projects. Additional commercial fishing pressure is needed to achieve a significant increase in harvest of Asian carp from the Lower Illinois River and other large rivers of the U.S. This increased harvest is necessary to minimize the risk of Asian carp arrival at the EDBS. To that end, ACRCC efforts are evaluating appropriate business models and planning efforts to enable such business development. Although the upstream removal strategy may have less impact on the Asian carp population after downstream harvest efforts begin, the MRWG expects that population suppression above Starved Rock Lock and Dam, and detection above Brandon Road Lock and Dam, will continue for at least the next 10 years. This timeline would likely be extended if effective commercial markets for Asian carp cannot be established and sustained in the relatively near future.

Despite current activities, Asian carp populations may respond in unpredictable ways. Based on this realization, this MRP is designed to respond to unforeseen developments in carp detections. The MRWG will continue to characterize the populations in a pool by pool fashion in the Upper IWW and identify collections that suggest changes to Asian carp range. When such new information presents itself, the MRP prescribes a quick and appropriate response utilizing all potential tools to thwart or further characterize the threat. The Upper Illinois River Contingency Plan found within this MRP prescribes aggressive actions in response to findings contrary to the baseline (2015) presence of Asian carp in the Upper IWW. The MRWG has selected 2015 as an appropriate baseline for comparisons in future years as noted above. The Response Decision Matrix presented below outlines the conditions which trigger response actions on a pool-by-pool basis.

Upper Illinois Waterway Asian Carp Response Decision Matrix*

Direction of flow	Eggs/Larvae			Small Fish			Large Fish		
	Rare	Common	Abundant	Rare	Common	Abundant	Rare	Common	Abundant
Chicago Area Waterway System (CAWS)							1		
Lockport Pool to Electric Barrier System							2		
Brandon Road Pool							3		
Dresden Island Pool									
Marseilles Pool									
Starved Rock Pool									

Notes:

= Significant change from baseline requiring further response action

= Moderate change from baseline requiring further response action

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

1 This status is based upon the collection of a single Bighead Carp by contracted fishers in 2010 and a single Silver Carp in 2017

2 This status is based onpon the collection of a single Bighead carp during piscicide treatment in 2009

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

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

The Upper Illinois River Contingency Plan not only provides quick guidance for agencies' actions, but also communication strategies for inter-agency communication as well as outreach and educational communications with partners and public. The contingency plan has proven useful and is suitable to guide other actions and inter-agency activities even when an emergency action is not observed. The contingency plan was successfully implemented on June 24, 2017 with the capture of a Silver Carp nine miles from Lake Michigan. The event "Operation Silver Bullet" applied the framework of the contingency plan, which continued for two weeks until actions were ceased following the guidelines set forth in the Contingency Response Plan (CRP). The CRP was again successfully implemented on September 9, 2019 to address an increased number of positive environmental deoxyribonucleic acid (eDNA) results in Bubbly Creek.

The CRP provides a communication framework and response procedure that may be utilized for any planned event or in response to findings that may elevate the risk of Asian carp passage into Lake Michigan. These events may include scheduled or unscheduled maintenance of the EDBS system or the opening of hydraulic connections which may allow the passage of Asian carp. The same protocols outlined for a response to an unknown event may be applied in advance of these planned events to reduce the risk of a progressing invasion front.

Grass Carp

Grass Carp have been detected in the Upper IWW since 1986, with records in Illinois since 1971. Reproduction has been documented in the Lower Illinois River as early as 1991. Grass Carp are not as numerous as Bighead Carp and Silver Carp in the Upper IWW pools of Starved Rock, Marseilles, and Dresden Island, but Grass Carp are found in Brandon Road Pool and the CAWS. Since Grass Carp is a large-bodied cyprinid species similar to Silver Carp and Bighead Carp, MRWG believes methodologies included in this MRP and developed based on past work will also provide sufficient gears, methods for detection, and removal techniques for Grass Carp. Most of the Grass Carp detected by MRWG efforts in the CAWS are triploid individuals, which means that they are infertile. However, diploid (fertile) Grass Carp have been detected. There is no record of reproducing Grass Carp in Lake Michigan but reproducing populations have been noted in Lake Erie. Grass Carp are removed by monitoring and removal crews when encountered unless tagged and identified for further research. The USGS Nonindigenous Aquatic Species (NAS) website provides a fact sheet and references to supplement this plan and can be found at: https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=514

Black Carp

Black Carp have not been detected in the Upper IWW, however through 2020, 29 individual fish have been documented in the Illinois River. Seven Black Carp were reported captured in the Illinois River during 2020. Reproduction has been documented in the middle-Mississippi river, but little is known about its success or the general distribution of the species. Illinois Department of Natural Resources (IDNR) has imposed a bounty/reward of $100 for Black Carp captured from large rivers of the Midwest in hopes of increasing data on this species, http://www.asiancarp.us/documents/KeepCoolCallHandout.pdf. Black Carp are considered rare in the Illinois River, but increasing catches in the Mississippi River suggest spawning success and increasing distribution. Since Black Carp is a large bodied cyprinid species similar to Silver Carp and Bighead Carp, MRWG believes methodologies included in this MRP and developed based on past work will also provide sufficient gears, methods for detection, and removal techniques for Black Carp. Reporting protocols and identification tips for suspected Black Carp are included in the Appendices of this plan. Results on the USGS NAS website note triploid (infertile) individuals and diploid (fertile) individuals where the data is available. There is no record of Black Carp captures in the Great Lakes Basin. The USGS NAS website provides a fact sheet and references beyond this plan and can be found at: https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=%20573

GOALS AND OBJECTIVES

As discussed above, the 2021 MRP outlines three broad categories of implementing objectives as a guide for both **short-term** and **long-term** objectives for preventing the spread of Asian carp to Lake Michigan:

1) Detection
2) Management and Control
3) Response

Specific Objectives for the 2021 MRP

1. Provide aggressive Asian carp **detection** in each of the pools upstream of Starved Rock to enable effective response to any detection before invaders challenge the EDBS, CAWS, or further threaten the Great Lakes.
2. Provide aggressive Asian carp surveillance in the Des Plaines and Kankakee rivers outside of the Upper IWW to enable effective response to any detection before invaders challenge the EDBS, CAWS, or further threaten the Great Lakes.
3. Continue to evaluate and review the CRP to assure efficacy and appropriate response. In 2021, convene at least one table-top exercise with agency and identified natural resource professionals to provide insights into effective response techniques, review technologies available, and incorporate lessons learned into an updated CRP and the 2022 MRP.
4. Manage and control Asian carp populations between Starved Rock Lock and Dam and Brandon Road Lock and Dam, with the goal of removing at least 1.1 million pounds of Asian carp during 2021.
5. Continue implementing discipline-specific work groups to improve coordination within and among agencies, and to advise the MRWG about detection technique development, possible efficiencies, acoustic techniques/evaluations, strategy development, or to identify effort no longer needed.
6. Assess and evaluate data from prior and continued efforts to aid in the development and implementation of new strategies to improve the effectiveness of management and control efforts in the future (2020 and beyond).
7. Assess/review technology development (tools) for field deployment in 2021 as a pilot (e.g. longitudinal bubbler arrays). In order to identify key new technologies, strategies for implementing ones under development are necessary. Agency and sub work groups will be formed to implement and evaluate this pilot with the goal to realize additional effectiveness or additional efficacy of existing projects. Such pilots will be reviewed for possible implementation in the 2022 MRP. Discipline-specific workgroups, agencies, and researchers will recommend findings to MRWG co-chairs. Co-chairs will work with ACRCC representatives for concurrence and further review of potential tools.
8. Encourage business development and enhanced contract fishing to increase harvest of Asian carp in the Lower IWW from approximately 4.5 million pounds in year one (project started in fall 2019) to 8 million pounds by conclusion of year four (2024).

9. Establish additional management of the Lower IWW through contract fishing. During 2021, an enhanced contracted fishing program will be continued and expanded. The initial program will have a goal of removing 4.5 million pounds of Asian carp through contracting with any legally licensed Illinois commercial fisher. The program will seek a contract worth 10 cents per pound after the fisher sells the fish, no caveats for purpose of those sales will exist save a minimum sale value of 7 cents per pound. This model may be expanded to other Illinois River pools in the future based upon success, with a four year goal to remove 8 million pounds of Asian carp from Peoria Pool.
10. Remain diligent with outreach and law enforcement activities to discourage other pathways of movement and introduction of Asian carp.

MRWG Work Groups

Discipline-specific work groups will assist in developing the most informed Monitoring and Response Plans in the future. Work groups may also be useful to focus expertise for further evaluation, assist in decision making, or otherwise provide MRWG Co-chairs, agencies, and ACRCC with insights as technical experts on a range of subjects. Expected work groups for 2020 are listed below with leads identified to assist in communication and structure. Co-leads may also be identified to assist with managing these work groups as appropriate and helpful. Workgroups may be added or deleted to serve MRWG and ACRCC needs.

2021 Work Group	Lead/Agency
Contingency Planning	Nick Barkowski/USACE
Removal	Justin Widloe/ILDNR
Hydroacoustic Assessments	Dave Coulter/SIU
Telemetry	Brent Knights /USGS
Modeling	Jahn Kallis/USFWS
Behavioral Deterrent Technologies	Aaron Cupp/USGS
Monitoring	Jim Lamer/INHS, Nathan Lederman/ILDNR

Short-Term (5-year) MRWG Strategic Vision: 2018 – 2022

It is important to note that the short-term strategic vision laid out below is dependent on continued funding at levels similar to 2018 funding received. It is crucial that the necessary funds are available to maintain aggressive removal efforts to reduce the risk of range expansion, as well as to continue focused surveillance to ensure that management agencies have an accurate understanding of changes to Asian carp range, population dynamics, and behavior.

Detection

- Ensure sufficient surveillance effort through standardized multi-agency monitoring deployed throughout the IWW, Des Plaines and Kankakee rivers to inform management and control, or response needs. This includes:
    - Adult fish assessment
    - Small fish assessment
    - Larval/egg assessment
    - Population changes and movements

Management and Control

- Remove Asian carp from between Starved Rock Lock and Dam and Brandon Road Lock and Dam to reduce upstream migratory pressure at the leading edge of the population.
    - Reduce the estimated biomass of Asian carps in the Dresden Island Pool by an additional 50% from the biomass observed in 2015.
    - Reduce the estimated biomass of Asian carps in the Marseilles Pool by an additional 25% from the biomass observed in 2015.
    - Reduce the estimated biomass of Asian carps in the Starved Rock Pool by an additional 25% from the biomass observed in 2015.
- Prevent the movement into or sustained presence of Asian carp between the Brandon Road Lock and Dam and the Lockport Lock and Dam.
    - Link between detection and response actions
- Use existing and newly developed techniques to maximize annual removal efforts of more than 1 million pounds annually.
    - Contracted harvest
    - Agency efforts
    - Telemetry to enhance removal
    - Strategically deploy the Unified Method
    - Establish hydroacoustic steering committee to advise MRWG and ACRCC for enhanced understanding of technique.
- Utilize technical expertise and recommendations provided by discipline-specific workgroups to determine whether algal attractants, complex noise generation, and use of carbon dioxide (CO_2) to herd fish can be effectively incorporated into MRWG actions.
    - If the answer is no or is ambiguous, consider removing techniques that show limited demonstrable effectiveness from future MRPs and MRWG actions.

  - Develop standardized methods for evaluating ongoing research efforts, including set decision points for continuing or stopping research efforts, and recommended timelines for including regulatory input and evaluations.

- Evaluate ongoing management efforts to measure the effectiveness of management actions, adjust activities to improve effectiveness and adapt to future changes.
  - Hydroacoustic surveys to provide reliable estimates of abundance in each of the pools of the IWW below Brandon Road Lock and Dam.
  - Evaluate new methods for characterizing Asian carp populations based on improving technology and implement where appropriate.

- Assist in developing an enhanced market for Asian carps in the lower three pools of the Illinois River.
  - Use established business development techniques to provide guidance and information to agency, industry, and entrepreneurs to improve ability of business establishment and success.
    - This market would build upon the existing commercial fishery in Illinois that can harvest as much as 6 million pounds of Asian carp annually from the Illinois River (4.5 million pounds in Peoria Pool plus additional from downstream pools).
  - Increase total Illinois harvest by expanding the commercial fishery to greater than 4.5 million pounds by 2021 and exceeding 8 million pounds of Asian carp annually by 2024.

Response

- Ensure that response readiness is maintained and responsive to detected changes as noted in the CRP.
  - Hold annual tabletop exercises
  - Establish contingency steering committee
  - Consider other necessary exercises
  - Identify potential new technologies as practicable, permittable, and available

- Enable rapid deployment of needed assets.

- Review Barrier operations and operational changes with close communication and dialogue between USACE and MRWG members.

Long-Term (5+-year) MRWG Strategic Vision: 2022 and beyond

Detection

- Implement an effective, efficient, and sustained standardized detection program to inform ongoing adaptive management and contingency response planning.

Management and Control

- Sustain management and control effort of Asian carp with continued population reduction as baseline 2015 levels in Dresden Island Pool suggest.

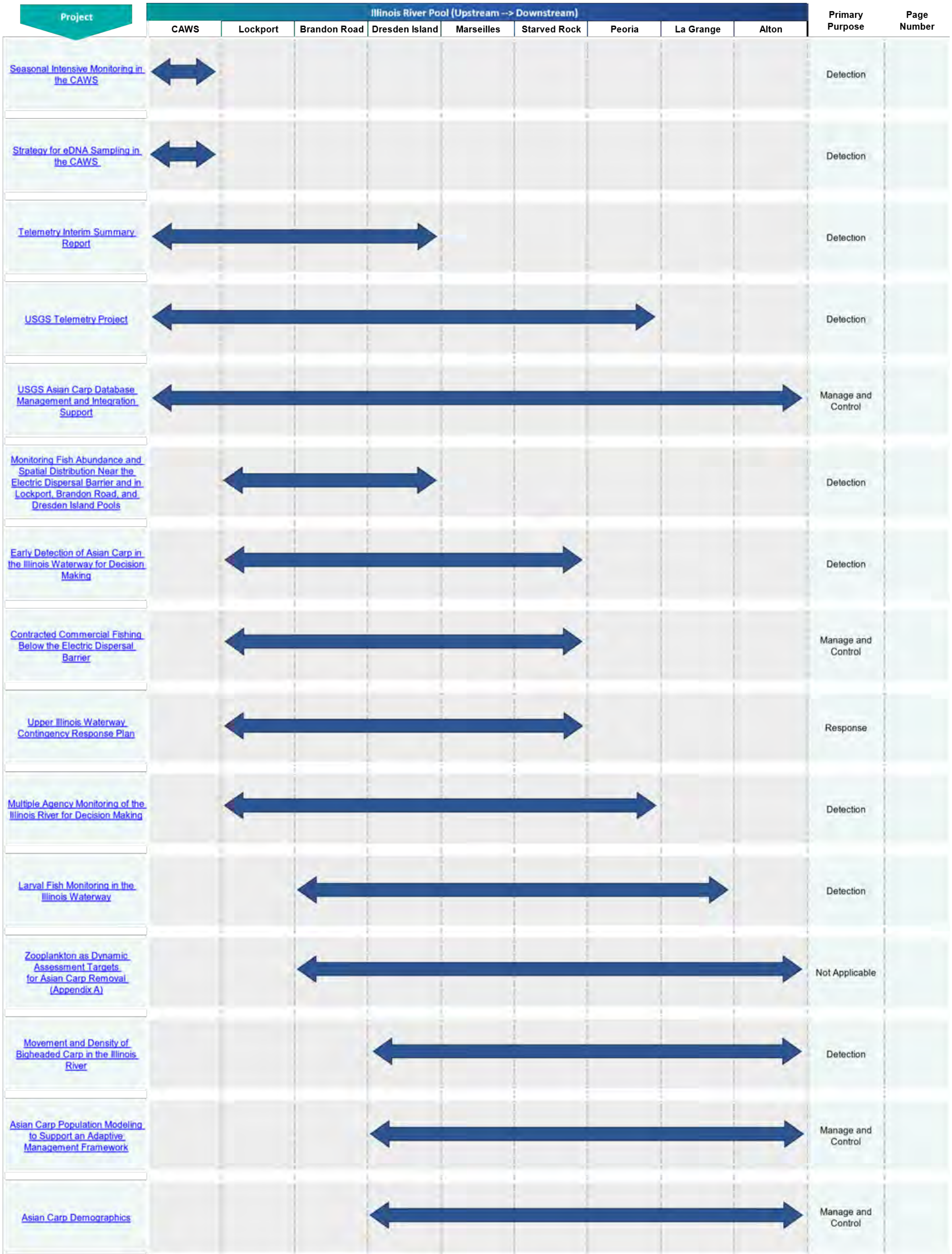
- Provide guidance to minimize Asian carp populations in the Upper IWW with no impacts on native fish or mussel populations, human health and safety, recreational use, or industrial uses of the waterway.
- Dynamic economic business strategy in place in the lower IWW to remove 20-50 million pounds of Asian carp annually.
- Support development of management and control strategies in other river basins, as requested.

Response

- Provide for Contingency Plan and Response in less than 48 hours for all contingency response measures.

PROJECT LOCATIONS

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


Project
Illinois River Pool (Upstream --> Downstream)
CAWS
Lockport
Brandon Road
Dresden Island
Marseilles
Starved Rock
Peoria
La Grange
Alton
Primary Purpose
Page Number
Seasonal Intensive Monitoring in the CAWS
Detection
Strategy for eDNA Sampling in the CAWS
Detection
Telemetry Interim Summary Report
Detection
USGS Telemetry Project
Detection
USGS Asian Carp Database Management and Integration Support
Manage and Control
Monitoring Fish Abundance and Spatial Distribution Near the Electric Dispersal Barrier and in Lockport, Brandon Road, and Dresden Island Pools
Detection
Early Detection of Asian Carp in the Illinois Waterway for Decision Making
Detection
Contracted Commercial Fishing Below the Electric Dispersal Barrier
Manage and Control
Upper Illinois Waterway Contingency Response Plan
Response
Multiple Agency Monitoring of the Illinois River for Decision Making
Detection
Larval Fish Monitoring in the Illinois Waterway
Detection
Zooplankton as Dynamic Assessment Targets for Asian Carp Removal (Appendix A)
Not Applicable
Movement and Density of Bigheaded Carp in the Illinois River
Detection
Asian Carp Population Modeling to Support an Adaptive Management Framework
Manage and Control
Asian Carp Demographics
Manage and Control

Project	Illinois River Pool (Upstream --> Downstream)									Primary Purpose	Page Number
	CAWS	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	La Grange	Alton		
Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEACarP)										Manage and Control	
Asian Carp Enhanced Contract Removal Program										Manage and Control	
Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation										Manage and Control	
Des Plaines River and Overflow Monitoring										Detection	
Alternative Pathway Surveillance – Urban Pond Monitoring										Detection	
Alternative Pathway Surveillance in Illinois – Law Enforcement										Manage and Control	

DETECTION PROJECTS

Seasonal Intensive Monitoring in the CAWS

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

Pools Involved: Chicago Area Waterway System (CAWS)

Introduction and Need:

The Chicago Area Waterway System (CAWS) represents a direct connection between the Mississippi River and Great Lakes basins and serves as a potential avenue for Asian carp (Silver Carp and Bighead Carp) to expand into the Great Lakes. The current Asian carp population front is in Dresden Island Pool, part of the lower Des Plaines River. As a final barrier, the EDBS (EDBS) is operational upstream of the population front within the Chicago Sanitary and Ship Canal (CSSC) to prevent movement of Asian carp between the systems. Downstream of the EDBS, monitoring and removal efforts occur to reduce the risk of Asian carp challenging or bypassing the barrier. However, the threat exists that Asian carp may move through the EDBS undetected or otherwise be introduced upstream of it. Therefore, it is critical to monitor the CAWS for the presence of any Asian carp and to react accordingly if an individual is detected. Results from the Seasonal Intensive Monitoring (SIM) upstream of the EDBS will contribute to our understanding of Asian carp distribution and abundance in the CAWS and guide conventional gear or rapid response actions designed to remove Asian carp from areas where they have been captured or observed. Sampling efforts will continue in 2021 with two seasonal intensive interagency multi-gear sampling efforts in May and October.

Objectives:

(1) Detect and remove Asian carp from the CAWS upstream of the EDBS when warranted.

(2) Determine Asian carp abundance and distribution in the CAWS through intense random and targeted sampling efforts at locations deemed likely to hold fish.

Status:

Detections of Asian carp (Silver Carp and Bighead Carp) environmental DNA (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 Asian carp at five fixed reaches upstream of the barrier. Random area sampling was added in 2012 to increase the chance of detecting Asian carp in the CAWS beyond the designated fixed sites. Extensive sampling performed upstream of the EDBS from 2010 through 2013 (682 hours of electrofishing, 445.8 km (277 mi) of gill/trammel net, 2.2 km (1.4 mi) of commercial seine hauls) resulted in one Bighead Carp being collected in Lake Calumet in 2010. Fixed site and random site sampling effort was then reduced upstream of the barrier to two SIM events and has been conducted in the same manner in subsequent years (2014-2020). SIM in its current form is a modified continuation of the Fixed and Random Site Monitoring Upstream of the EDBS and Planned Intensive Surveillance in the CAWS. SIM utilizes an intensive two-week multiagency sampling effort in the spring and fall of each year using coordinated netting and electrofishing effort at fixed and random sites in a comprehensive effort to detect the presence of Asian carp in the CAWS upstream of the EDBS. Following effort reduction, one Silver Carp was collected in the Little Calumet River in 2017, resulting in a rapid, interagency contingency response effort (see the 2017 Interim Summary Report for additional information). Reduced effort upstream of the EDBS allows for increased monitoring efforts downstream of the barrier. Increases in sampling downstream of the EDBS focuses effort on the leading edge (Dresden Island Pool) of the Asian carp population, serving to further reduce their numbers in that area, reducing the risk of individuals moving upstream towards the EDBS and Lake Michigan by way of the CAWS.

Methods:

Sampling Rreaches: The sampling design includes intensive electrofishing and netting at five fixed reaches and four random site reaches (Figure 1). Random reaches exclude areas of the waterway designated as fixed reaches. Random sample sites will be generated with GIS software from shape files delineating random reaches and will be labeled with Lat-Lon coordinates in decimal degrees.

Upstream Fixed Site Area Descriptions

Site 1 – Lake Calumet. Sampling will be limited to shallower areas north of the Connecting Channel (this avoids deep draft areas with steep walls but includes channel drop off areas that exist north of the Connecting Channel).

Site 2 – Calumet/Little Calumet River from T.J. O'Brien Lock and Dam to its confluence with the Little Calumet River South Leg ~11.3 km (7 mi).

Site 3 – CSSC and South Branch Chicago River from Western Avenue upstream to Harrison Street ~6.4 km (4 mi).

Site 4 – North Branch Chicago River and North Shore Channel from Montrose Avenue north to Peterson Avenue ~3.2 km (2 mi).

Site 5 – North Shore Channel from Golf Road north to Wilmette Pumping Station ~3.2 km (2 mi).

Upstream Random Site Sampling Area Descriptions

Area 1 – Lake Calumet Connecting Channel and Calumet River

Area 2 – Cal-Sag Channel from its confluence with the CSSC to the Little Calumet River

Area 3 – CSSC from Western Avenue downstream to the EDBS

Area 4 – North Shore Channel (between Fixed Site 4 and 5), North Branch Chicago River, and Chicago River

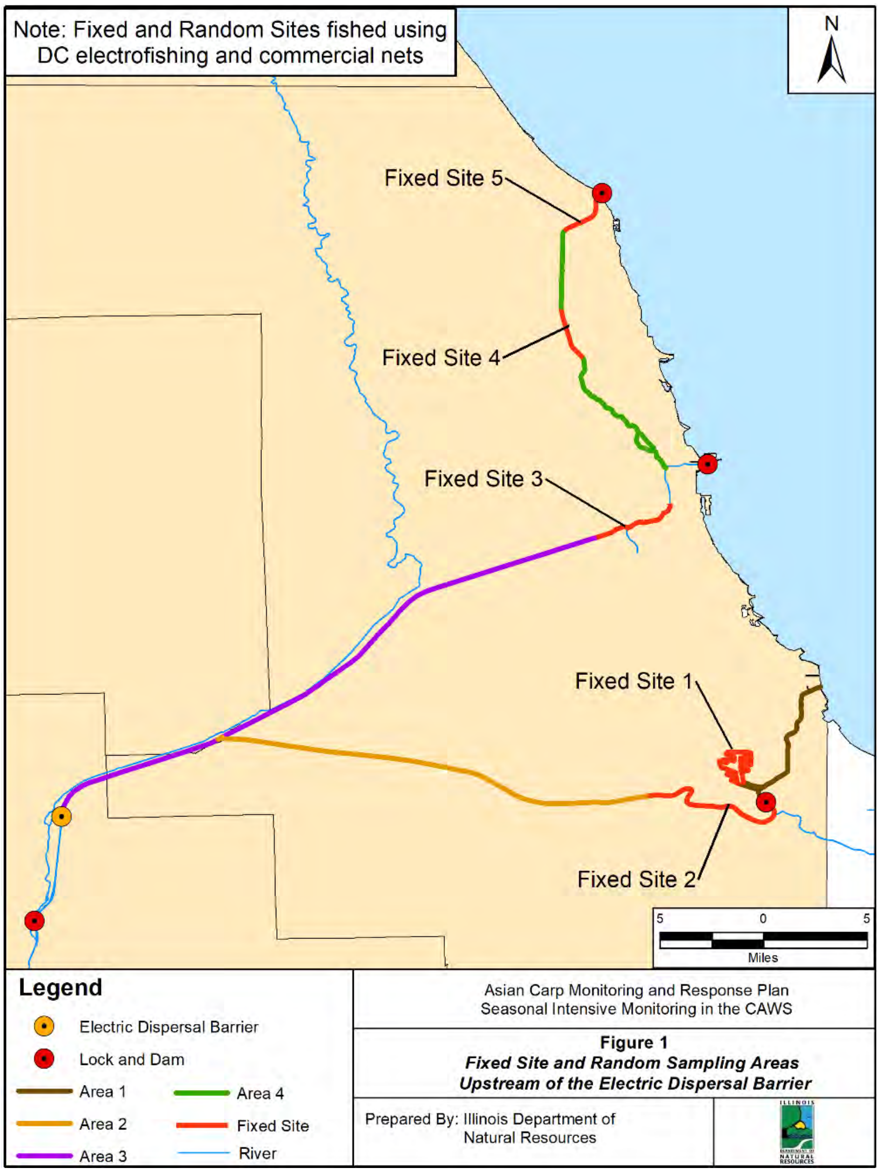


Figure 1. *Fixed site and random site sampling reaches for electrofishing and commercial netting upstream of the EDBS.*

Decontamination Protocol: To prevent contamination of eDNA samples from of residual Asian carp genetic material on sampling equipment (boats, netting gear, etc.), hot water pressure washing and chlorine washing (10% solution) of boats and potentially contaminated equipment used in the SIM is required (see Appendix C). Additionally, nets specifically for monitoring upstream of the EDBS will be used.

Electrofishing Protocol: Pulsed DC Electrofishing will be used at fixed and random sites and include one to two netters (two netters preferred). Random sites are generated with ArcGIS and locations for each electrofishing transect will be identified with GPS coordinates. Fixed or random electrofishing transects will be sampled for 15 minutes in a downstream direction in waterway main channels (including following shoreline into off-channel areas) or in a counter-clockwise direction in Lake Calumet. Electrofishing boat operators may switch the safety pedal on and off at times to prevent pushing fish in front of the boat. Electrofishing may also be used in conjunction with commercial fishers to herd fish into nets. Common Carp will be counted without capture and all other fish will be netted and placed in a tank where they will be identified to species and counted, after which they will be returned live to the water. Schools of young-of-year (YOY) Gizzard Shad < 152.4 mm (6 in) long will be subsampled by netting as many fish as possible from each encountered school and placing them in a holding tank along with other captured fish. YOY Gizzard Shad will be examined closely for the presence of Asian carp and enumerated due to similarities in appearance and habitat between the species. All fish that are not Asian carp will be returned live to the water after data collection. The goal is to complete 150 electrofishing runs during each two-week event.

Netting Protocol: Contracted commercial fishers will set large mesh gill nets that are 3 m (10 ft) deep x 182.8 m (600 ft) long in bar mesh sizes ranging from 88.9-108 mm (3.5-4.25 in) at fixed and random sites per set (Appendix M). Deep water gill nets may also be used as appropriate. One 9.1 m (30 ft) deep gill net for each net boat will be provided by the IDNR as necessary (Appendix M). Locations for each net set will be identified with GPS coordinates. Net sets will be 15-20 minutes long and will incorporate fish herding techniques within 137.2 m (450 ft) of the net (e.g., plungers on the water surface, pounding on boat hulls, or revving trimmed up motors) to increase detection probability (Butler et al. 2018). An agency biologist will be assigned to each commercial net boat to monitor operations and record data. All fish that are not Asian carp will be returned live to the water after data collection. The goal is to complete 150 net sets (gill nets and deep water gill nets) during each two-week event.

Special Protocols:

Lake Calumet/Calumet River (week of May 24): Prior to sampling, crews will set Great Lake pound nets at the entrance to Lake Calumet if water conditions allow to prevent fish immigration/emigration (Figure 2). Pound nets will have a single lead, two adjustable length wings, and a 54.9 m^3 (1938.8 ft^3) mesh cab (catch area) (Appendix M). Pound nets will be checked and emptied each day. Contracted commercial beach seining will occur in the north section of Lake Calumet for two days, then in the south section for one day (Figure 2). The 731.5 m (2400 ft) seine will be staked to shore on one end, deployed in an arc through the water by boat, and winched up on shore. Gill nets, deep water gill nets and electrofishing will also be utilized in Lake Calumet, the Calumet Connecting Channel and the Calumet River as described above (Figure 2). See Appendix M for a more complete description of Asian carp sampling gears.

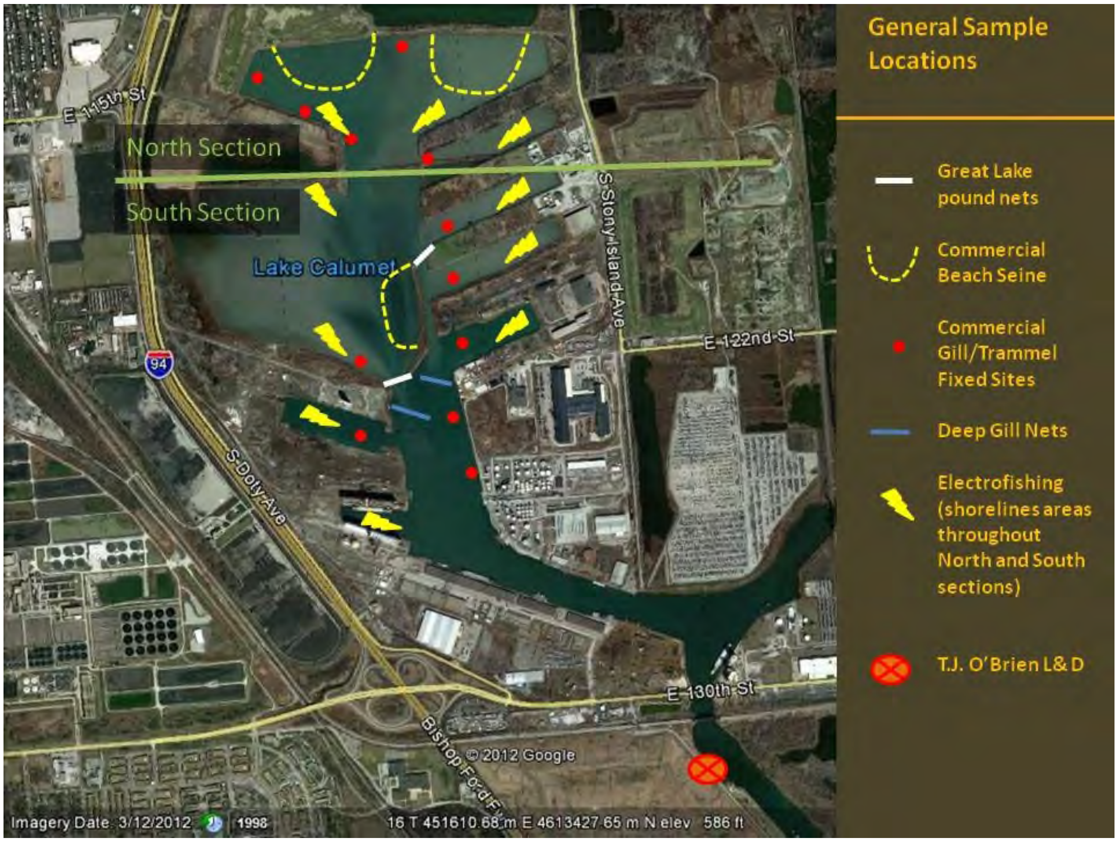


Figure 2. *Sampling locations in Lake Calumet. Sample locations are approximate and subject to change.*

North Shore Channel (week of October 11): Sampling will occur between the Argyle Street Bridge, located just downstream from the North Shore Channel and North Branch Chicago River confluence, and the Wilmette Pumping Station (Figure 3; Appendix D). Teams of two electrofishing boats and one net boat will begin at the upper and lowermost site boundaries and work toward the middle. Each team will work together to set nets across the channel and drive fish to nets with electrofishing and noise from "pounding" on the hull of boats and revving trimmed up motors. Each team will set three nets across the channel at intervals of 457.2 to 731.5 m (500 to 800 yds) apart, after which electrofishing and noise will occur between the nets to drive fish. The net closest to the outer site boundary will then be pulled and reset 457.2 to 731.5 m (500 to 800 yds) closer to the site center and the process repeated until the entire reach has been sampled. To maximize sampling time, electrofishing will begin in the area between the remaining nets while the outer net is being moved. The idea is to leapfrog the nets after each electrofishing and fish driving episode so that each team gradually moves toward the site midpoint.

Chicago River and South Branch Chicago River/Bubbly Creek (week of October 11): Electrofishing will occur around the entire shoreline of the basin between Lake Shore Drive and Chicago Lock and near Wolf Point (confluence of the North Branch Chicago River and Chicago

River) (Figure 3; Appendix D). During this time net boats will set and pull deep water gill nets in areas off of the main navigation channel. Once the entire reach is sampled, crews will travel down river and sample eight barge slips and backwater areas in the South Branch Chicago River near Bubbly Creek (Figure 3; Appendix D). Barge slip sampling will have a block net or gill net set at the entrance of each slip to prevent fish from leaving the slip. Electrofishing boats will then shock from the back of the slip out towards the main channel, driving fish into the block net while collecting stunned fish along the way. A second block or gill net may be set midway within longer slips to sample them more effectively.

Data Collection: For all SIM activities accurate sampling time will be recorded with all fish enumerated and identified to species. GPS coordinates (decimal degrees) will be taken at the location of all net sets and at the beginning of electrofishing runs. Crew leaders should fill in as much information on the data sheets (Appendix H) as possible for each site/transect if not directly recording data in the Microsoft Access Fish App entry application. All field data collected on data sheets will be entered into a Microsoft Access Fish App database.

Detection of Asian carp: Any Grass Carp sampled will be kept and put on ice for transfer to USFWS for ploidy analysis. Otoliths will be removed from Grass Carp and sent to Dr. Greg Whitledge (SIU) for microchemistry and origin analysis. Any Bighead Carp or Silver Carp collected will immediately be reported to the Operations Coordinator and Law Enforcement who will bring a cooler to secure fish (Appendix E). GPS location, time, and specific gear will be recorded as accurately as possible (mesh size, type, depth). Asian carp will then be transferred to Dr. John Epifanio, with tissues shared among research agencies (Appendix E). Furthermore, capture of a Bighead Carp or Silver Carp would initiate a level two rapid response upon conferring with Monitoring and Response Work Group (MRWG) members; additional effort or time frame could change. See Appendix E for more information on protocols and chain-of-custody instructions in the event of capture of a Bighead Carp or Silver Carp upstream of the EDBS.

Figure 3. *Sampling locations in the North Shore Channel, Chicago River and South Branch Chicago River/Bubbly Creek area.*

2021 Sampling Schedule:

Spring Event

- Week of May 17: All fixed and random area sites upstream of the EDBS (see netting and electrofishing protocols)
- Week of May 24: Lake Calumet/Calumet River (see special protocols) and all random area sites upstream of the EDBS (see netting and electrofishing protocols)

Fall Event

- Week of October 4: All fixed and random area sites upstream of the EDBS (see netting and electrofishing protocols)
- Week of October 11: North Shore Channel/Chicago River/South Branch Chicago River/Bubbly Creek (see special protocols) and all random area sites upstream of the EDBS (see netting and electrofishing protocols)

Deliverables:

Results for SIM will be reported daily during events and compiled for monthly sampling summaries. Data will be summarized for an annual interim report and project plan updated for annual revisions of the Monitoring and Response Plan.

Strategy for eDNA Sampling in the CAWS

Participating Agency: U.S. Fish and Wildlife Service (USFWS, Midwest Fisheries Center)

Location: Lake Calumet and Little Calumet River

Pools Involved: CAWS

Introduction and Need:

Monitoring with multiple gears in the CAWS has been essential to determine the effectiveness of efforts to prevent self-sustaining populations of invasive carp from establishing in the Great Lakes. Environmental DNA (eDNA) has been used as a surveillance tool to sample for the genetic presence of Bighead Carp and Silver Carp in the CAWS since 2009. Using multiple detection methods provides a balanced and complete monitoring program in the CAWS, because all monitoring methods have difficulty detecting very low abundance organisms. eDNA sampling offers an additional monitoring method to those used during Seasonal Intensive Monitoring and provides two additional time points in the year to monitor for emerging Asian carp presence. To maintain vigilence above the Electric Dispersal Barrier System (EDBS), eDNA has historically been collected at four regular monitoring sites, however collection has been adapting in both location and sample size in recent years due to emerging research. eDNA sampling events are typically conducted twice per year when conditions allow. Since 2013, eDNA results do not automatically trigger any kind of physical sampling response.

Objectives:

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

Status:

Sampling for eDNA in the CAWS above the EDBS has been conducted since 2009. In 2013, equipment decontamination and separation protocols were implemented. Then in 2014, improved DNA markers were deployed, and in 2015 the processing methodology switched from filtering to centrifugation. Together, these improvements have made for more sensitive and specific eDNA results. For example, in 2015 and 2017, there were zero positive eDNA samples in the CAWS, and in 2016 there was a single sample positive for both species' DNA. Between 2014 and 2018, 1,958 eDNA samples were collected above the EDBS. Of these, 34 have been positive for Silver Carp DNA, 3 have been positive for Bighead Carp DNA. While improvements to the field and lab methods have improved sensitivity, this method should never be expected to find the proverbial "needle in the haystack" or a single fish, but it has been shown to provide detection of rare species when other methods have failed. The low eDNA detection rates observed in the CAWS reflect that only one Silver Carp was captured alive in 2017, and one Bighead Carp was captured alive in the CAWS in 2010. As of 2013, all automatic response actions to eDNA results were terminated. Beginning in September 2017, changes were made to the distribution of eDNA samples collected in the CAWS based on lessons learned deploying eDNA in other carp-infested rivers such as the Wabash and Upper Mississippi rivers. Extra emphasis was put on slack-water and off-channel areas. In October 2018, total sample numbers were increased slightly and concentrated even more heavily in off-channel areas. In 2019, on two occasions in October, an unsually high number of postive DNA detections were observed in the Bubbly Creek area (South Fork South Branch Chicago River). A physical sampling effort followed yielding no observations or captures of live Asian carp. Due to the location of the positives and the proximity to a large wastewater pumping station, followup eDNA samples were collected from the underground sewer lines leading to the pumping station in February 2020. Results revealed that all four sewer intercepers leading to the facility were contaminated with Asian carp DNA, likely from fish markets and households consuming Asian carp. Given this information, sampling of Bubbly Creek and the surrounding area will be discontinued during future sampling events. Due to the coronavirus pandemic, no regular eDNA sampling occurred in the CAWS in 2020.

CAWS eDNA sampling has also occasionally included sampling below the Electic Dispersal Barrier. Sampling below the barrier has been adapted based on information obtained through the Monitoring Response Plan (MRP) and has been used to refine eDNA as a monitoring tool for Asian carp. In 2014, eDNA samples were collected below the barrier as part of a calibration study, which ultimately lead to the program switching from filtering to centrifugation. In 2015, eDNA monitoring below the Electric Disperal Barrier began as part of a project to refine the use of eDNA in the Illinois Waterway. eDNA samples were collected along a gradient of Asian carp densities across several pools to see if the eDNA results reflected the population gradient. Indeed, a greater proportion of positive samples occurred in areas of high carp density and reflected the decreasing Asian carp population up river towards the Electric Dispersal Barrier. Efforts for eDNA sampling in 2016 were modified in response to the detection of juvenile Asian carp in Starved Rock Pool and evidence that small fish may be entrained in barge junction gaps. The USFWS increased eDNA surveillance to monitor for potential movement of these juveniles upstream into pools with low or zero carp density: Lockport Pool, Brandon Road Pool, the upper portion of Dresden Island Pool, and part of the Kankakee River above the Wilmington Dam. In 2017, efforts below the EDBS were expanded to the entire Dresden Island Pool, but limited to that single pool. The 2017 eDNA results closely reflected the carp density gradient present in the pool. Hotspots of positive eDNA detections consistently reflected the areas where the most invasive carp were captured by traditional gears in the months surrounding eDNA sampling events. The habitat location of eDNA detections also shifted noticeably between sampling events and was consistent with the predicted movment of Asian carp responding to changing water level conditions observed in systems where their movements were tracked through telemetry. With several years of eDNA data reflecting the Asian carp density gradient and the completion of sampling method comparisons, eDNA sampling below the barrier ceased after 2017. Since 2015, nearly 1600 samples have been collected below the EDBS in various pools.

Methods:

At a minimum, the CAWS will be sampled for Bighead Carp and Silver Carp eDNA in Lake Calumet and the Marine Service marina on the Little Calumet River (Figure 1). Sample sizes in each of these two sites will be increased as samples from the Bubbly Creek area will be reallocated. The distribution of samples will encompass targeted areas that have negligible flow, or depositional bank areas where eDNA may accumulate. Sampling will not occur within seven days of any CSO events that impact the targeted sampling areas. Based on research conducted in the Upper Mississippi River (Mize et al., in reivew) one sampling event will be planned for spring, when Asian carp have been shown to congregate in off-channel habitats in other systems, and one additional event in the fall when discharge and water temperatures are low. eDNA collection events will be shifted slightly from previous years in order to more closely precede Seasonal Intensive Monitoring events. eDNA sample collections may occur in additional locations in the CAWS in 2021 as needed or requested. All eDNA sampling efforts in 2021 will be documented in the 2021 Interim Summary Report. There will be no eDNA sampling conducted below the EDBS in 2021.

Similar to previous years, sample collection and processing methods will follow the most up to date Quality Assurance Project Plan (QAPP 2021) (http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf). The state of Illinois will be notified of the results from the CAWS following our Communication Protocol (see QAPP 2021) after sample processing is complete. Results will then be posted online and made available to the Monitoring and Response Work Group (MRWG) in the 2021 Interim Summary Report.

2021 Schedule:

- Week 1: May – 414 samples
- Week 2: October – 414 samples

Deliverables:

Results of the CAWS sampling event will be reported as positive/negative for sampling summaries for the state of Illinois and then posted online. Data will be summarized for an annual interim report and project plans will be updated for annual revisions to the MRP.

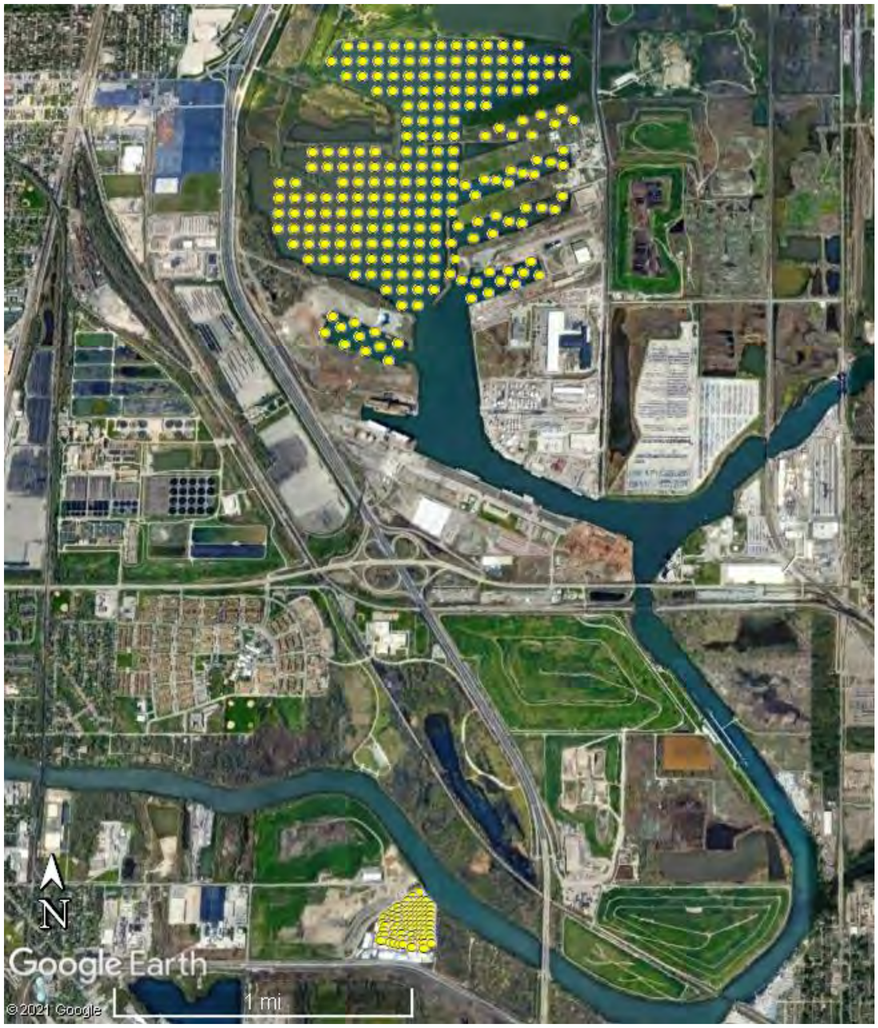


Figure 1. *Distribution of Bighead Carp and Silver Carp eDNA samples (yellow dots) to be collected in Lake Calumet and the Little Calumet River in 2021.*

References:

Mize, E., R. Erickson, C. Merkes, N. Berndt, K. Bockrath, J. Credico, N. Grueneis, J. Merry, K. Mosel, M. Tuttle-Lau, K. Von Ruden, Z. Woiak, J. Amberg, K. Baerwaldt, S. Finney, and E. Monroe. In Revision. Refinement of eDNA as an early monitoring tool at the landscape-level: Study design considerations. Ecological Applications. 50 pp., 1 table, 7 figures, appendix 4 pp.

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Participating Agencies: U.S. Army Corp of Engineers (USACE (lead); Illinois Department of Natural Resources (IDNR), Southern Illinois University Carbondale (SIU), U.S. Geological Survey (USGS), MWRDGC & U.S. Fish and Wildlife Service (USFWS, support)

Pools Involved: Chicago Area Waterway System (CAWS), Lockport, Brandon Road, and Dresden Island

Introduction:

The telemetry monitoring plan includes the tagging of fish with individually coded ultrasonic transmitters in the Upper Illinois Waterway (IWW). The acoustic network proposed is comprised of stationary receivers and supplemented by a mobile hydrophone unit to collect information from acoustic transmitters (tags) implanted into free-swimming Bighead Carp, Silver Carp, and surrogate species. Some form of the telemetry receiver network that USACE maintains has been in place since 2010. The number of receivers and placement locations of those receivers has changed and been adapted to improve detection efficiencies and focus on areas of importance or likely high-density fish areas. Acoustic receiver coverage within the Upper IWW is primarily focused at the Electric Dispersal Barrier System (EDBS) with secondary coverage surrounding lock and dams and emigration routes such as tributaries and backwater areas. As of 2020, USACE operates 28 receivers between the confluence of the Cal-Sag and Chicago Sanitary and Ship Canal (CSSC) and Dresden Island Lock and Dam. Additionally, over the years, other agencies (SIU, USGS, and USFWS) have deployed receivers in support of alternative projects within the same area.

This telemetry monitoring project has provided valuable insights to resource managers about fish behavior at the EDBS, movement between navigation pools, and Bighead Carp and Silver Carp movement within the Dresden Island Pool. The telemetry program has demonstrated a high efficacy for the EDBS to deter large fishes. Telemetry has also helped shed light on barge entrainment risks and fish behavior in response to varying environmental parameters at the EDBS. Tagged fish movements have refined the understanding of how and when fish utilize lock chambers to move between navigation pools within the Upper IWW. Bighead Carp and Silver Carp as well as surrogate species have also been studied using acoustic telemetry at the leading edge of the invasion front within the Dresden Island Pool. Telemetry has located several areas in which Bighead Carp and Silver Carp activity is greatest within the pool including the Rock Run Rookery backwater and the Kankakee River confluence. Movement patterns at the leading edge have also been analyzed to compare differences between species. All this data has been utilized by resource managers and response agencies to improve harvest efforts and make informed decisions on the EDBS operations and maintenance. As more research is conducted on Bighead Carp and Silver Carp and the Upper IWW ecosystem, information gaps are being identified and monitoring plans continue to be refined. For instance, in 2020 an additional receiver was placed in the Des Plaines River immediately downstream of the Lockport Control Works to better understand fish movements between the CSSC and the Des Plaines River.

Acoustic telemetry monitoring is the only continuous monitoring project for the EDBS in 2020. Additional barrier efficacy studies have been completed using alternative monitoring tools such as mark/release and hydroacoustic surveys. These studies have helped to address the deficiencies of acoustic telemetry but cannot be deployed every day throughout the year and can be used to address several information gaps that have been identified at the leading edge of the invasion front. The following goals and objectives have been revised from previous years to focus future efforts on identified knowledge gaps and improving the efficiency of data collection and reporting.

Goals and Objectives:

The overall goal of this telemetry monitoring plan is to assess the effect and efficacy of the EDBS on tagged fish in the CAWS and Upper IWW. The goals and objectives for the 2021 season have been identified as:

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

- **Objective:** Monitor the movements of tagged fish in the vicinity of the EDBS.

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

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

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

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

Telemetry Monitoring Plan

Additional objectives of the telemetry monitoring plan:

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

Status:

Sample size and distribution – In 2010, the workgroup decided that a baseline minimum of 200 transmitters be implanted for telemetry monitoring in the vicinity of the EDBS and that this level of tags be maintained as battery life expires or specimens exit the study area. At the conclusion of the 2020 sampling season there were 120 USACE-tagged fish within the study area with varying expiration dates, 19 will expire early in 2021 (March/April), 23 will expire in September/November of 2021, 78 will remain active through 2021 with the next batch set to expire early 2023. Tag implantations will be required in the spring of 2021 to achieve recommended minimum levels of the sampling size. At the start of the 2021 field season, 50 tags implanted in surrogate fish released within the Lower Lockport Pool will remain active to the approximate end of the field season with twenty-three expiring in either September (13) or November (10). In 2021 it will be necessary to release more tagged fish into Lockport Pool to not only replace the ones that expire, but also replace those the emigrate out of the pool through the Lock and Dam or the Lockport Control Works

Of the tags that were released in the Brandon Road Pool in previous years, all have expired. During the 2021 season 50 tags are anticipated to be implanted to achieve a target number of active tagged fish within the pool (Table 1). Immigration from the Lockport Pool is expected and will assist in maintaining elevated transmitter density in the spring and summer months. Immigration from Dresden Island is possible, though it is not as frequent as from Lockport.

There are currently 54 USACE transmitters that were released within Dresden Island Pool that will remain active through 2021 and none are set to expire during the 2021 sampling season. There is an active removal effort underway in this pool so there is possibility for tagged individuals to be removed and immigration is likely to occur to the Marseilles Pool. To maintain the target goal of 75 USACE tags, 21 transmitters (V13TP-1x-069k-0017m) will be implanted into Asian carp in 2021. The number of tags and season of deployment in each pool is shown in Table 1.

Telemetry Monitoring Plan

Table 1: *Recommended transmitter implementation for the 2021 sampling season. Supplemental tags are required to maintain existing level of coverage within the study area while exact ratios per pool may be changed slightly to account for new focus areas.*

Release Pool/Location	Species	Spring Supplement Tags	Fall Supplement Tags	Total Estimated Tag Distribution
Upper Lockport/ RM300	Common Carp	0	0	0
Lower Lockport/ RM292.7	Common Carp	21	23	75
Brandon Road/ RM286.5	Common Carp	50	0	50
Dresden Island/RM276	Bighead Carp and Silver Carp	21	0	75
Total	-	92	23	200

Methods:

Species selection (primary and surrogate) - Bighead Carp and Silver Carp are the primary species of concern, and their behavioral response to the barriers is of the greatest importance. However, as mentioned previously, populations of both species vary and are considered rare to absent near the EDBS. Therefore, to test the direct response of fish and maintain target density levels within all pools, surrogate species have been tagged and monitored within the Dresden Island, Brandon Road and Lockport pools. Dettmers and Creque (2004) cited the use of Common Carp (*Cyprinus carpio*) as a surrogate species for use in telemetry studies in the CSSC. Common Carp are known to migrate relatively long distances and they grow to large sizes that approximate those achieved by invasive carps. Based on these characteristics, tracking of Common Carp should provide a good indicator of how Asian carp would respond to the dispersal barrier if they were near this deterrent." USACE partnered with SIU in 2019 and 2020 and will continue to do so in 2021 to further understand the differences and similarities between Common Carp and the invasive Bighead Carp and Silver Carp. A total of 50 and 20 transmitters were used in 2019 and 2020 by SIU to implant into Common Carp within the middle reaches of the IWW, 30 more will be set aside in 2021 for their use to continue comparisons to tagged Bighead Carp and Silver Carp behavior, habitat use, and movement patterns. This research is to be reported through SIU under a separate Monitoring and Response Plan (MRP) project title.

Tag specifications and Implantation procedure – Tagging efforts will be focused during late spring (April - May) and fall (October – November) and will follow the surgical and recovery procedures outlined in *Telemetry Master Plan Summary of Findings* by Baerwaldt and Shanks (ACRCC 2012). Adult Bighead Carp and Silver Carp will be collected from Dresden Island Pool (RM 271.5 to 286) and surrogate species will be collected from Lockport Pool and Brandon Road Pool (RM 286 to 304). Fish collected will be weighed, measured, and sex will be identified if possible. To reduce fish mortality during or after surgery due to infection at the incision site, API Stress Coat + will be applied to the fish to promote healing of the incision site (Shivappa et al. 2017). Fish will also be tagged with an external tag to indicate to commercial fishermen and agencies that those fish have an internal acoustic tag. Tagged fish are requested to be released including Bighead Carp and Silver Carp if they are suitable for release, otherwise agencies are to save the fish and return it to USACE so we can save the transmitter and tag a replacement fish. No Bighead Carp and Silver Carp caught in Lockport or Brandon Road pools will be tagged and returned as these areas are upstream of the known invasion front. Any Bighead Carp and Silver Carp captured in Lockport or Brandon Road will be turned over to IDNR for species voucher.

Stationary Receivers – A system of passive, stationary receivers (Vemco VR2W and VR2C) are placed throughout the IWW to monitor movement of tagged fishes. The receivers log data from tagged fish when they swim within the detection range of the receiver (typically within a quarter mile of the receiver). VR2W's will be placed from the Dresden Island Lock and Dam (RM 245 of Dresden Island Pool, Illinois Waterway) to the confluence of the Cal-Sag Channel within the CSSC upstream of the EDBS within Lockport Pool (RM 303.5 of Lockport Pool). At the conclusion of each field season (late November to early December) a minimized network of receivers is left in place at strategic choke points throughout the study area while the remaining receivers are removed to prevent damage from winter conditions. These will be placed directly above and below the EDBS; above and below Lockport Lock; above, below and within Brandon Road Lock; and above Dresden Island Lock. The receiver network is re-established to its full capacity at the commencement of the following season, typically late March.

Figure 1 on the next page shows the general strategy of VR2W placement for 2021 (N=28 USACE receivers). The priority is to achieve the most coverage (detection capacity) in the immediate vicinity of the EDBS with VR2W receivers. To accomplish this, receivers immediately downstream and upstream of the EDBS will provide a system that will help USACE biologists monitor and track any fish movement through the EDBS. The remaining network throughout the system is used to track overall movement, and to determine what type of movement occurs from fish navigating lock structures. Receivers will also be deployed at possible escape routes from the telemetry network such as tributary confluences. Movement through lock structures will be compared to USACE lockage data from Dresden Island, Brandon Road, and Lockport locks. Leading edge movements will be monitored by the receiver network within Dresden Island Pool, Brandon Road Pool, and the Kankakee River. Other significant movement patterns will also be compared to river stage and temperature data.

Receivers will be downloaded bi-monthly, or more frequently if needed, to retrieve data for analysis, and for maintenance of the acoustic telemetry network (i.e. decrease risk of vandalism, ensure operation of device, check battery life, and replacement if necessary). All receivers will be downloaded via Bluetooth-USB capability. The software is available free online from the website www.innovasea.com/fish-tracking/.

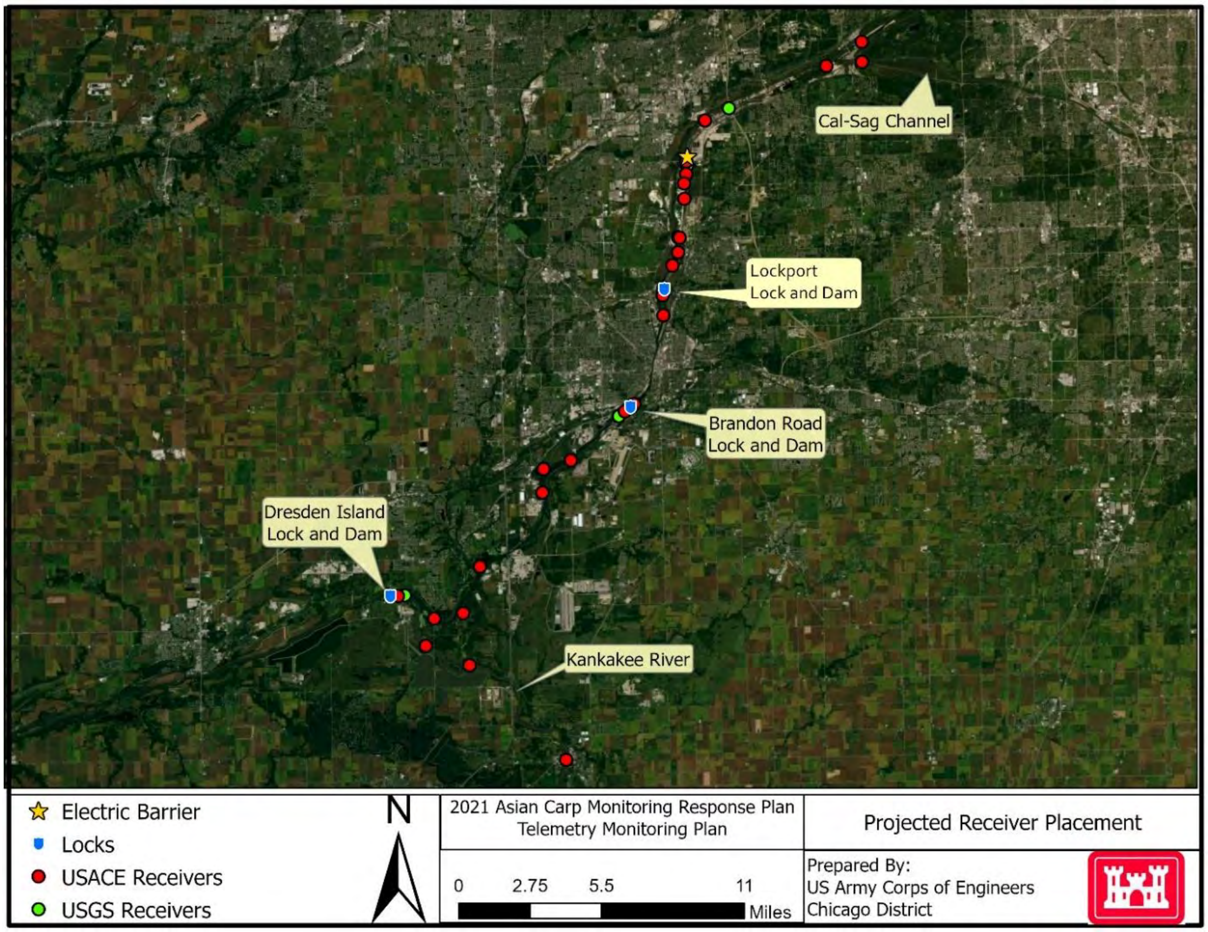

Figure 1: *Proposed USACE 2021 telemetry network to be deployed throughout the IWW.*

Mobile Tracking – In the past, mobile tracking has been used by USACE biologists using a mobile unit (Vemco VR-100 unit with a portable directional and omni-directional hydrophone operated out of a boat) that enabled crews to manually locate any tagged fish using the signal emitted from the transmitter inside the fish. The VR-100 mobile tracking unit will be used as a supplemental tool to help locate congregations of Bighead Carp and Silver Carp in coordination with IDNR contracted commercial fishermen. In doing so, increased harvest of Bighead Carp and Silver Carp may occur. In addition, the VR-100 will be used to further investigate tags that may cross the EDBS or Locks and Dams.

Contingency Measures:

Tagged fish crossing Electric Dispersal Barrier system – As described above, any suspicion (indicated by stationary receiver data) of any tagged fish crossing the EDBS can be confirmed by the mobile tracking unit. This will enable crews to locate the exact location of a fish, instead of the approximation detected by a stationary receiver. USACE leadership, agency leads involved with the telemetry plan, as well as the Monitoring and Response Work Group (MRWG), will be notified immediately of any suspected barrier breach. In some cases, it may be necessary to implement a 24-hour track to confirm if the fish of interest is indeed viable. This may be done using the mobile tracking device or by placing a temporary stationary receiver in the vicinity.

Tagged Bighead Carp and Silver Carp detected in Brandon Road Pool – Any detection of Bighead Carp or Silver Carp within Brandon Road Pool will be verified immediately. Verification of detections may include review of stationary receiver network data for patterns of detection and on-site tracking utilizing the VR-100 mobile receiver. Verified detection of Bighead Carp and Silver Carp within waterways upstream of the Brandon Road Lock and Dam will trigger immediate notification to USACE leadership, agency leads involved with the telemetry plan, as well as the MRWG co-chairs.

Schedule:

A tentative work schedule is presented below.

- March – April 2021: VR2W network inspected and new receivers installed, and range tested.
- April – May 2021: Tagging of surrogate fish in Brandon Road and Dresden Island pools.
- December 2021: Prepare receiver array within the IWW and CAWS for winter months.
- Ongoing: VR2W network maintenance, downloads and mobile tracking.

Deliverables:

All agency leads involved with the telemetry plan, as well as the MRWG, will be notified immediately of any suspected barrier breach or detection of Bighead Carp and Silver Carp above the Brandon Road Lock. Periodic updates will be given to the MRWG in the form of briefings at regular meetings, and the year-end summary report will be compiled after the 2021 sampling season.

References:

Asian Carp Regional Coordinating Committee (ACRCC) Monitoring and Rapid Response Workgroup. 2012. 2011 Asian Carp monitoring and rapid response plan interim summary report.

Dettmers, J.M. and S.M. Creque. 2004. Field assessment of an electric dispersal barrier to protect sport fishes from invasive exotic fishes. Illinois Natural History Survey Center for Aquatic Ecology. Annual Report F-150-R-2.

Shivappa, R.B., L.S. Christian, J.M. Law, G.A. Lewbart. 2017. Laboratory evaluation of different formulation of Stress Coat® for slime production in goldfish (*Carassius auratus*) and koi (*Cyprinus carpio*) PeerJ 5:e3759 https://doi.org/10.7717/peerj.3759

USGS Telemetry Project

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

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

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

Location: Upper Illinois River and Upper Illinois Waterway System

Introduction and Need:

Telemetry of acoustically tagged bigheaded carp and surrogate fish species has become an invaluable tool in management for these species in the Upper Illinois Waterway System and elsewhere. For example, movement probabilities between pools need to be estimated to parameterize the Spatially Explicit Asian Carp Population Model (SEACarP) used for adaptive management in the Upper Illinois Waterway System. 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. Fish removal by contracted fishers has become the primary method of controlling bigheaded carp in the Upper Illinois Waterway System. 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 patterns for bigheaded carp through modeling and real-time telemetry applications informs removal efforts and facilitates planning of contingency actions.

To develop a better understanding of these population dynamics to meet management objectives, an existing network of real-time and non-real-time acoustic receivers in the Upper Illinois Waterway System and elsewhere is collaboratively managed by multiple agencies and universities. A Telemetry Workgroup has been established by the Monitoring and Response Workgroup (MRWG) to ensure that the multi-agency telemetry efforts are coordinated to efficiently and effectively meet MRWG goals. This workgroup plans and executes the placement of receivers, tagging of bigheaded carp with acoustic tags, and data management as needed to meet objectives. Three primary objectives to meet MRWG goals identified by the Telemetry Workgroup included (1) development of a common standardized telemetry database with visualization and analysis tools, (2) transitioning from Program MARK to a custom Bayesian multi-state model for estimating movement probabilities needed for SEACarP and (3) deploying, maintaining, and serving data from real-time acoustic receivers to inform contingency planning and removal. The telemetry database and visualization tools (FishTracks DB) facilitate standardization, archiving, sharing, quality assurance, visualization and analysis of the telemetry data needed for management. In FY2020, modifications and additions to FishTracks DB facilitated more problem-free use of the database and associated applications, as well as useful extraction of information for modeling efforts. Maintenance and improvements to this database have been part of this project (USGS Telemetry Project) since FY2018, but this task will transition to a consolidated USGS database management Monitoring and Response Plan (MRP) project in FY2021 (USGS Asian Carp Database Management and Integration Support). The transition to a custom Bayesian multi-state model to estimate movement probabilities will support more efficient, effective and robust population modeling with SEACarP by overcoming short comings of Program MARK for this purpose. These shortcomings include customizability, extensibility, problems of singularities and poor-convergence, computer crashes, parameter exclusion from models, not providing estimates of movement probability, and not providing estimates of uncertainty. The work on the custom Bayesian multi-state model to estimate movement probabilities will conclude this year and reporting to MRWG will be completed in FY2022. In cooperation with the USACE, USGS will continue to maintain and test the five upstream-most, real-time receiver (see Table 1) to ensure reliability and accuracy of the real-time alerts for informing contingency actions and barrier evaluations. The four downstream most receivers including three at Hanson Materials in Marseilles Pool and one below the Starved Rock Dam in Peoria Pool that were being used to assess relation of real-time detections to catch by contract fishers to informing that fishing will be discontinued. Analysis and reporting from these assessments will be finalized and shared with MRWG in FY2021.

FY2021 Objectives:

(1) Complete custom Bayesian multi-state model and estimate bigheaded carp movement probabilities with 2014-2019 data in FishTracks DB

(2) Deploy, maintain, and serve data from real-time acoustic receivers to inform decisions on contingency actions and the USACE barrier evaluation

Status:

Movement probability model – A Bayesian multi-state transition probability model for the Illinois River Waterway System has been developed and run on the original data used by Coulter et. al. 2018 as a test. In preparation for running the transition probability model on the 2014-2019 FishTracks data, analyses have been conducted on data completeness and quality and issues are being resolved by partners. Programming of analyses to summarize individual fish movement histories by navigation pool (i.e., dwell time analysis) needed for the transition probability model is complete and has been tested on a portion of the FishTracks database.

Real-time receiver network – Five real-time receiver locations (Table 1) will be maintained to support the barrier evaluation study (see USACE Telemetry Monitoring Project) and inform contingency actions. The associated email alert system alerts key MRWG and ACRCC members of detections of Asian carp in strategic locations.

USGS Telemetry Project

Table 1. *Names and locations of the five real-time receivers in the Illinois River and Upper Illinois Waterway System for monitoring acoustically tagged Asian carp.*

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

Methods:

Movement probability model – The USGS in collaboration with personnel on the Telemetry Workgroup and Population Model Workgroup of MRWG developed a Bayesian program to estimate interpool movement probabilities needed for SEACarP. Bayesian methods were used to create a model syntax that maximizes user customizability and extensibility, while avoiding the problems of singularities and poor-convergence inherent to the Program MARK. For example, previous multi-state modeling with Program MARK has been fraught with difficulties (computer crashes, automatically excluding parameters from the model, and not providing estimates) thought to be related to number of states, recapture periods, and specification of random effects to account for individual, and spatial and temporal heterogeneity. As well, Program MARK does not provide uncertainty estimates for the estimated parameters that feed into the SEACarP model. Hierarchical models performed in a Bayesian framework will provide a direct expression of uncertainty estimates of parameters feeding into the SEACarP model.

Real-time receiver network – The five year-round, real-time receivers will be maintained, downloaded and range tested in 2021 to determine maximum range and detection efficiency (percent detections of test tag within 100-m intervals) within the maximum range. Range test results will be presented to MRWG members via teleconference and in a USGS Open-file Report. The real-time email alert system will be maintained and updated as necessary to alert key MRWG and ACRCC members of Asian carp detections of interest to those members.

Schedule:

Movement model

- Complete modeling to estimate movement probabilities and associated uncertainty with the new model and present these results to the Population Workgroup for discussion of data adequacy to inform tagging and monitoring network, and for use with SEACarP – *complete by September 2021*

USGS Telemetry Project

Real-time receiver network

- Complete annual deployments and maintenance including range testing of nine real-time receivers in the Upper Illinois Waterway System – *complete by September 2021*
- Provide email alerts and monthly summaries to managers regarding Asian carp detections on the real-time receivers to inform contingency actions – *complete by September 2021*
- Complete correlation analyses of nearby harvest data and real-time detections at two receivers – *complete by September 2021*

Deliverables:

Movement model

- Model: Bayesian multi-state model that estimates movement probabilities and associated uncertainty
- Presentation: Presentation to Modeling Workgroup on estimated movement probabilities and associated uncertainty with discussion for moving forward with tagging, receiver placement, and SEACarP modeling
- Input for SEACarP: Estimates of movement probabilities and associated uncertainty for parameterizing future SEACarP modeling
- Report: Manuscript for scientific journal article on Bayesian multi-state model for estimating movement probabilities of acoustically tagged bigheaded carp.

Real-time receiver network

- Real-timer receiver network with five real-time receivers in the Upper Illinois Waterway System
- Email alerts and monthly summaries to managers regarding Asian carp detections on the real-time receivers to inform contingency actions
- Real-time receiver data uploaded to the FishTracks database for use in modeling and visualization
- Presentation to Telemetry Workgroup on real-time receiver range testing results and correlation analyses for harvest and real-time detections
- USGS Open-file report on real-time receiver range testing and correlation analysis results for harvest and real-time detections

Monitoring Fish Abundance, Behavior, and Species Composition within the Illinois Waterway and Near the Chicago Sanitary and Ship Canal Electric Dispersal Barrier

Participating Agencies: U.S. Fish and Wildlife Service (USFWS)-Carterville Fish and Wildlife Conservation Office, Wilmington Substation, Wilmington, IL.

Location: Work will take place in the Brandon Road, Dresden Island, and Lockport reaches of the Illinois Waterway including at the Electric Dispersal Barrier System.

Pools Involved: Lockport, Brandon Road, and Dresden Island

Introduction and Need:

The Electric Dispersal Barrier System (EDBS) located within the Chicago Sanitary and Ship Canal (CSSC) operates with the purpose of preventing dispersal of invasive fishes between the Mississippi River and the Great Lakes basins while maintaining continuity of this important shipping route. Numerous field and laboratory studies have examined the complexities associated with operations of the EDBS and sought to identify potential vulnerabilities using a wide range of methods. These studies included telemetered surrogate fish studies, electric field mapping, fish response studies, and studies that examined vulnerabilities associated with commercial barge tow passage (Asian Carp Regional Coordinating Committee [ACRCC] Monitoring and Rapid Response Workgroup 2015, Bryant et al. 2016, Davis et al. 2016, Dettmers et al. 2005, Holliman et al. 2015). The results of these studies suggest that the barrier system reliably deters the passage of large fish. However, results also indicated that vulnerabilities for upstream passage of small wild fish through the EDBS currently exist (Bryant et al. 2016 and Davis et al. 2016).

The goal of this multifaceted monitoring program is to quickly identify any change in fish community species composition, fish abundance, or fish behavior near the EDBS, especially with regard to small size classes of fish. This project will provide insights on fish behavioral responses to biological, abiotic, and anthropogenic changes within the system. Additionally, fish surveys supporting barrier clearing operations will be performed "as necessary" to support barrier maintenance needs or requests from the ACRCC.

Objectives:

(1) Monitor fish abundance and distribution at the EDBS on a fine spatial and temporal scale.

(2) Evaluate potential changes in fish community species composition, fish abundance, and fish behavior in response to biological, abiotic, and anthropogenic influences within the study reaches.

Monitoring Fish Abundance, Behavior, and Species Composition within the Illinois Waterway and Near the Chicago Sanitary and Ship Canal Electric Dispersal Barrier

Status:

Since 2012, USFWS has utilized a wide range of technologies to collect data under this comprehensive monitoring, assessment, and barrier efficacy program. Split beam sonar, side scan sonar, and multi beam sonar imaging systems have been used extensively to monitor fish behavior and abundance near the EDBS over varying temporal and spatial scales. Initial work conducted during the 2012 and 2013 field seasons showed that fish abundance near the barrier varies throughout the year (Parker et al. 2015). During summer large schools of small fish congregated directly below the operational barrier where fish were observed to demonstrate a "challenging" behavior. In some cases, schools of small fish penetrated the entirety of the portion of Barrier IIB with the greatest electric field strength (Parker et al. 2013). Since 2015, hydroacoustic surveys have been completed on a biweekly to monthly basis to gain greater temporal resolution on fish community dynamics. An additional component to this work has been furthering the understanding of complexities introduced at the EDBS r concurrent with passage of commercial barge traffic. Trials conducted during 2015 demonstrated that freely swimming small fish could be entrained and transported over the entire EDBS in junction gaps between barges (Davis et al. 2016). Additional trials conducted during 2016 demonstrated that small wild fish could also be transported upstream across the EDBS in return current flows associated with downstream barge transits at the EDBS (Davis et al. 2016).

In 2020, due to the COVID-19 pandemic, only four barrier surveys were conducted between January 6 and March 4 (compared to 25-27 surveys in a typical year). Fish density within the EDBS ranged from 0 to 2 large-fish targets per survey (overall mean ± SD = 0.75 ± 1.0). Fish density immediately downstream of the EDBS ranged from 1 to 3 large-fish targets per survey (overall mean ± SD = 1.8 ± 1.0).

Pool surveys were conducted in Brandon Road, Dresden Island, and Lockport pools during March 2020. No additional surveys were completed due to the COVID-19 pandemic. Five large fish were detected in Lockport Pool during the survey. These five detections resulted in a calculated mean density of 0.4 large fish targets per 100,000 m^3. Three large fish were detected in Brandon Road Pool during the survey. These three detections resulted in a calculated mean density of 0.4 large fish targets per 100,000 m^3. Twenty-four large fish were detected in Dresden Island Pool during the survey. These 24 detections resulted in a calculated mean density of 1.1 large fish targets per 100,000 m^3.

Methods:

Mobile hydroacoustic fish surveys- Dresden Island Pool, Brandon Road Pool, Lockport Pool, and at the EDBS – Side-looking split beam hydroacoustic and side scan sonar surveys will be conducted immediately above and below the EDBS to assess fish abundance and distribution patterns on a fine temporal scale. Barrier surveys at the EDBS will take place every two weeks.

Monitoring Fish Abundance, Behavior, and Species Composition within the Illinois Waterway and Near the Chicago Sanitary and Ship Canal Electric Dispersal Barrier

Pool surveys will take place every month beginning in January 2021 except in Dresden Island Pool during months when Southern Illinois University (SIU) surveys. Data will be obtained from SIU for those Dresden Island surveys to avoid duplicating effort. The hydroacoustic survey equipment utilized for these surveys consists of a pair of Biosonics® 200 kHz split-beam transducers and a 4125 Edge Tech ultra-high resolution side scan unit. The two split-beam transducers are mounted in parallel on the starboard side of the research vessel 0.15 m below the water surface on Biosonics® dual axis automatic rotators. The side scan unit is attached to a port-side davit at the bow of the research vessel and is lowered less than a meter into the water. This approach, using both systems, will enable each survey to ensonify a large portion of the water column. These surveys will provide information on the size frequency distributions and spatial orientation of fish targets. Results of biweekly surveys will be communicated to the ACRCC as rapid communications if changes in fish abundance or behavioral status are detected.

2020 Schedule:

- Mobile hydroacoustic fish surveys at the EDBS: Biweekly throughout 2021, depending on COVID-19 conditions.
- Mobile hydroacoustic fish surveys in Brandon Road, Lockport, Dresden Island pools: Bimonthly – throughout 2021, depending on COVID-19 conditions.

Deliverables:

- Biweekly report on fish abundance and spatial distribution near the EDBS to the ACRCC/Monitoring and Response Work Group (MRWG).
- Annual reports, presentations, and peer-reviewed articles outlining significant findings of all program study areas.
- Rapid communications to the ACRCC on moderate or significant changes in fish community species composition or fish behavioral observations at the EDBS.

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Early Detection of Asian Carp in the Illinois Waterway for Decision Making

Participating Agencies: U.S. Fish and Wildlife Service (USFWS)-Carterville Fish and Wildlife Conservation Office, Wilmington Substation, Wilmington, Illinois

Location: Targeted sampling for both large and small invasive carp will occur where invasive carp are currently believed to be absent or in low abundance (Dresden Island, Brandon Road, and Lockport pools). Sampling effort in Starved Rock and Marseilles pools, where large invasive carp are abundant but small invasive carp are believed to be mostly absent, will focus on detecting small invasive carp in order to determine and monitor the geographic location of the upstream invasion front of the population expansion. Small fish sampling proposed in the Marseilles and Starved Rock pools is being reviewed and coordinated among the Monitoring and Detection workgroup.

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

Introduction:

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

Early Detection of Asian Carp in the Illinois Waterway for Decision Making

Since the 1970s, invasive Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*Hypophthalmichthys nobilis*) populations have invaded the Mississippi River basin, been expanding upstream, and become established in the Illinois River (Chick and Pegg 2001, Sass et al. 2010). Silver Carp and Bighead Carp pose a significant threat to economically and recreationally valuable fisheries in the Laurentian Great Lakes through competition for limited plankton forage resources (Cooke and Hill 2010)) and threat of harm to lake users and their property (Kolar et al. 2007). The most probable invasion pathway for Silver Carp and Bighead Carp to enter the Great Lakes is through connection of the upper Illinois Waterway (IWW), which includes the Chicago Area Waterway System (CAWS), to Lake Michigan (Kolar et al. 2007).

An Electric Dispersal Barrier System (EDBS), operated by the U.S. Army Corps of Engineers, in Lockport Pool is intended to block the upstream passage of Silver Carp and Bighead Carp through the IWW pathway. Laboratory tests have shown the EDBS is sufficient at stopping large-bodied fishes from passage (Holliman 2011). However, tests with small Bighead Carp (51-76 mm total length [TL]) have indicated that the operational parameters of the EDBS may be inadequate for blocking passage of small-bodied fishes (Holliman 2011). Moreover, research using Golden Shiners (*Notemigonus crysoleucas*) as a non-invasive surrogate species for juvenile Silver Carp, indicated that small fish can become entrained in barge junction gaps and transported through the EDBS (Davis et al. 2016). Furthermore, research using Dual Frequency Identification Sonar (DIDSON) indicated that small fishes (unknown species) can be transported upstream through the EDBS by return water current created during downstream barge movement. These studies illustrate a vulnerability in the EDBS and some potential mechanisms by which small-bodied Silver Carp and Bighead Carp, if present in the vicinity, could pass upstream through the EDBS. For this reason, as well as the potential for established mature invasive carp present in Dresden Island Pool to advance the invasion front upstream via successful reproduction, there is a need for high spatial- and temporal-resolution monitoring data on the distribution of invasive carp in the IWW both upstream and downstream of the EDBS.

The overall objective of this project is to increase targeted, species-specific, early detection sampling of small (≤ 153 mm TL) and large (> 153 mm TL) Silver Carp and Bighead Carp in the upper IWW for the purpose of increasing certainty in the derived species distributions by reducing the potential for type II error. The information provided by this invasive carp-focused sampling will aid the Asian Carp Regional Coordinating Committee and Monitoring and Response Work Group (MRWG) in evaluating the current invasion risk of invasive carp to the Great Lakes via the CAWS and will provide additional information needed in support of the Contingency Response Plan and whether response actions are warranted. This project is an individual-focused invasive carp early detection effort that is intended to complement existing population and assemblage-focused monitoring efforts in the IWW such as Seasonal Intensive Monitoring, Multi-Agency Monitoring of the Illinois River for Decision Making (Multi-Agency Monitoring Program), and hydroacoustic monitoring in the vicinity of the EDBS.

Early Detection of Asian Carp in the Illinois Waterway for Decision Making

Objectives:

(1) Detect the farthest upstream location for both small (currently believed to be Starved Rock Pool) and large (currently believed to be Dresden Island) Silver Carp and Bighead Carp yearly with the purpose of informing Great Lakes invasion risk assessment.

Status:

This is a new project for 2021. This early detection project replaces the USFWS efforts towards the Distribution and Movement of Small Asian Carp in the Illinois Waterway project as well as the Habitat Use and Movement of Juvenile Asian Carp in the Illinois Waterway using Telemetry project. Both the Distribution and Movement of Small Asian Carp in the Illinois Waterway project and the Habitat Use and Movement of Juvenile Asian Carp in the Illinois Waterway using Telemetry will conclude at the end of 2020. Sampling conducted in 2021 will consist of boat electrofishing, dozer trawling, and mini-fyke netting.

Methods:

Sampling site selection will be supplemental to the stratified-random approach of the Multi-Agency Monitoring Program project and will employ a target analysis-informed sampling design with the intent of improving the probability of detecting invasive carp in the upper IWW. Target analysis is a strategic approach aimed at detecting specific invasive species at a defined locality and time using focused methods or technologies (Morisette et al. 2020). When target species are known (e.g., invasive carp), target analysis enables for more effective and cost efficient invasive species surveillance than programs that are broadly-focused detecting the presence of unknown, non-target, invasive species (Hoffman et al. 2016, Morisette et al. 2020). In practice, target analysis is a form of meta-analysis that integrates raw data with modeling and mapping to inform when, where, and how to look for the target species (Morisette et al. 2020).

In 2021, IWW early detection sampling will be conducted via a combination of fixed and random site sampling. Initial sampling sites will be selected using target analysis of data previously collected through MRWG-supported projects such as Distribution and Movement of Small Asian Carp in the Illinois Waterway project, the Habitat Use and Movement of Juvenile Asian Carp in the Illinois Waterway using Telemetry project, Fixed and Random Site Sampling downstream of the EDBS, and Multi-Agency Monitoring Program. Target analysis will focus on determining the habitats both small and large invasive carp life stages are vulnerable to capture in, the gear types that most effectively capture invasive carp in those habitats, and the most effective times to sample. Site selection will be targeted towards detecting both small and large Silver Carp and Bighead Carp. In general, fixed sites will be based on areas where small and large invasive carp have previously been detected. Data from these fixed sites will be used for trend analyses as well as to provide information on habitat preferences that will be used to stratify random site selection. Random sites will be stratified by habitat type (MCB, SC, BW) and habitat area and exclude certain zones that are not useable for each gear type deployed. Floodplain lakes will be sampled following high water events which could have resulted in spawning activity or movement of juvenile carp into the area. Where depth is sufficient, sampling at both fixed and random of sites will include boat-mounted electrofishing, electrified dozer trawling, and mini-fyke netting. During 2021, sampling effort will consist of 2-5 days of sampling per gear per pool per month (approximately 20 electrofishing sites, 20-30 electrified-dozer trawl sites, and 8-15 mini-fyke net sets). Boat-mounted electrofishing will be conducted via the methods described in Bouska et al. (2017) where the boat is maneuvered in a scalloped pattern along the shoreline and the pedal operator applies power to the water at the peak of the loop to drive fish back towards the shore. Electrified dozer trawling will consist of a single 5-minute transect traveling in an upstream direction per site (Hammen et al. 2019). Mini-fyke netting will be conducted in appropriate habitats (shallow side channel and backwaters) within Starved Rock, Marseilles, and Dresden Island pools and will consist of three 24 hour net sets per sampling site.

Physical characteristics and water quality measurements will be measured and recorded at each collection site and will include: Secchi depth, depth, substrate type (i.e, boulder, cobble, gravel, sand, silt, and clay), temperature, specific conductivity, and dissolved oxygen. Water quality measurements will be taken using a YSI Professional Series multi-meter. These metrics will be used to parameterize future target analysis and adaptively increase invasive carp detection probability through continued sampling. Additionally, GPS coordinates and time stamps will be recorded at the start and end of each electrofishing event, trawl run, and mini-fyke net set.

During sampling, all Bighead Carp, Silver Carp, Black Carp (*Mylopharyngodon piceus*), and Grass Carp (*Ctenopharyngodon idella*) will be measured for TL (mm) and mass (g); all other species will be identified to species, recorded, and released to increase processing speed. All threatened and endangered species will be photographed prior to release. During sampling periods that do not overlap with Multi-Agency Monitoring Program sampling, all fishes over 100 mm will be measured for TL (mm) and weighed (g) at 10% of the sampling sites. The sampling sites where all fishes (>100 mm) are measured will be randomly selected prior to the start of each sampling event. This data will be used to inform hydroacoustic early detection efforts. Any fish not easily identified in the field will be preserved in ExCell Plus fixative or 70% ethanol for laboratory identification to the lowest possible taxonomic level. Effort will be quantified as net nights (mini-fykes) and minutes of electrofishing (boat electrofishing and dozer trawl).

Individual gear descriptions for 2021

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

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

Dozer trawl – A 35 mm mesh net at the mouth reducing to 4 mm mesh at the cod end tied to a 2-meter by 1-meter rigid frame mechanically raised and lowered to fish depths from 0 to 1 meter. The net extends approximately 2.5 meters back as it is pulled forward. The target habitat is open water >0.6 meter deep. The trawl is mounted to an electrofishing boat with anodes extending 1.5 m in front of the trawl and the trawl acting as the cathode. Trawl sampling duration will be 5-minute transects.

2021 Schedule:

January – February 2021:

- Gear preparation, planning field logistics, and crew scheduling

March – November 2021:

- Fish sampling, identification, and data entry

November – December 2021:

- Complete fish identification (preserved specimens), data entry, and verification

December 2021 – January 2022:

- Data analyses, prepare report and presentation

Deliverables:

Any invasive carp captured upstream of Dresden Island Pool and any small invasive carp captured upstream of Starved Rock Pool will be reported immediately to Aaron Woldt (USFWS Assistant Regional Director – Fisheries), Charlie Wooley (USFWS Regional Director – Region 3), and the MRWG. An annual MRWG report and presentation will be provided during the winter of 2021 – 2022. Invasive carp capture data from sampling will be used to define future sampling sites. Length and mass data will be provided for the Spatially Explicit Asian Carp Population (SEACarP) model development project and to hydroacoustics monitoring projects.

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Larval Fish Monitoring in the Illinois Waterway

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Participating Agencies: Illinois Natural History Survey (Lead), Eastern Illinois University, Southern Illinois University - Carbondale, U.S. Geological Survey – Central Midwest Water Science Center, U.S. Fish and Wildlife Service (USFWS) – Whitney Genetics Lab (field and lab support)

Location: Ichthyoplankton (i.e., fish embryo and larval life stages) sampling will take place at seven sites in the Illinois and Des Plaines rivers downstream of the Electric Dispersal Barrier System (EDBS) (Figure 1). Sampling for fish eggs and larvae will also occur at sites in the Sangamon, Spoon, Mackinaw, Fox, and Kankakee rivers to monitor for Asian carp spawning in Illinois River tributaries. Sites may be dropped, or additional sites added as needed in order to complete study objectives.

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

Introduction and Need:

Understanding the spatial and temporal dynamics of reproduction by invasive fishes can offer insight into the risk of further population expansion, factors influencing recruitment to the population, and the success of control measures. An evaluation of Asian carp reproduction and the distribution of early life stages in different sections of the Illinois Waterway (IWW) and its tributaries is needed to monitor for changes in the reproductive front of Asian carp populations in this system and to better understand the impacts of removal efforts on the reproductive potential of these populations. These data are used as an early detection system for monitoring the upstream expansion of Asian carp populations and potential reproduction by the newly expanding Black Carp population in Illinois, as well as to quantify the relationship between Asian carp stock abundance and reproductive output to assess the level of removal needed to degrade the ability of Asian carp to perpetuate themselves through reproduction. The threat of Asian carp reproduction in the upper navigation pools of the IWW is particularly acute because of the risks this poses for expansion of the invasion front towards Lake Michigan and subsequent increased potential for these species to challenge the EDBS. The level of spawning occurring in the upper Illinois River affects recruitment occurring downstream; therefore, quantifying the relationship between adult density and reproductive productivity will allow us to establish the levels of Asian carp harvest in the navigation pools of the upper river that will degrade reproductive productivity sufficiently to diminish population growth rate in downstream navigation pools, ultimately reducing the number of fish moving upstream and further contributing to declines in densities in the upper Illinois River.

Reproduction and recruitment of Asian carp in the IWW have been highly variable across years and multiyear efforts are necessary to assess the extent, location, and timing of invasive carp reproduction in the IWW, evaluate conditions affecting reproduction, and monitor for changes in the Asian carp reproductive front. Observations of eggs, larvae, and juveniles in the upper Illinois River indicate that some reproduction and potential recruitment occurs above Starved Rock Lock and Dam in some years. Due to egg and larval drift, reproduction in upper river pools may also be an important source for recruits in downstream pools, particularly the Peoria Pool. Monitoring for any changes to these patterns can help to evaluate the risk for further population growth in the upper Illinois River. Asian carp spawning also appears to occur in some years in smaller tributary rivers. These systems may provide sources of recruits to basin-wide Asian carp populations and may offer insight for the suitability of Great Lakes basin tributaries were Asian carp to become established there. Combining annual assessments of Asian carp eggs and larvae with stock density also provides data needed to quantify stock-reproductive productivity relationships and evaluate the impact of Asian carp removal efforts on the reproductive potential of these populations. Simple relationships between stock abundance and reproductive potential of fish populations are often lacking, in part because of density-dependent processes and spatial and temporal variability in spawning conditions, stock composition, and first-year survival. Quantifying the relationship between adult stock abundance and reproductive productivity, and between reproductive output and recruitment strength will help to refine our understanding of the conditions and level of removal that reduce population growth rate.

Objectives:

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

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

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

Status:

Prior to 2015, Asian carp eggs and larvae were only detected as far upstream as the Peoria Pool of the Illinois River. However, Asian carp eggs were collected from the Starved Rock and Marseilles pools during 2015 – 2018 and 2020, and Asian carp larvae were captured in the Dresden Island Pool during 2015 and the Starved Rock Pool during 2020. It is therefore certain that Asian carp spawn in the upper Illinois River in some years. Hydrodynamic modeling of egg drift through the Illinois River (FluEgg model) combined with a reverse-time particle tracking algorithm has indicated that tailwater areas below the locks and dams on the Illinois Waterway are likely important spawning areas for Asian carp (Zhu et al. 2018).

Additional modeling efforts using a more comprehensive set of egg data are needed to examine the extent of variability in spawning locations among years and the most likely areas of settlement for Asian carp larvae leaving the drift under various flow conditions. Tributary sampling has revealed that Asian carp spawning occurs in smaller tributary rivers of the IWW in some years, with the Fox River the most upstream tributary where Asian carp spawning has been detected. However, the locations of spawning within these rivers, the conditions associated with reproduction in these systems, and the contribution of reproduction in tributaries to basin-wide Asian carp populations remain uncertain.

The numbers of eggs and larvae collected during previous study years have been highly variable, with seemingly low reproductive output during 2010-2013, but moderate to high levels of Asian carp reproduction evident during 2014-2019. Juvenile Asian carp abundances have also been extremely variable. Low numbers of Silver Carp juveniles were produced during years with low production of egg and larval stages, but high levels of reproductive output were no guarantee of high recruitment, likely due to prevailing environmental conditions. Asian carp egg production has been found to be density-dependent, increasing nonlinearly with adult density, and is higher during years with warmer water temperatures and more variable discharge during spring. In collaboration with the Illinois Natural History Collaborative Ecological Genetics Lab and USFWS Whitney Genetics Lab, an ethanol-exchange, quantitative PCR screening method for identifying ichthyoplankton samples likely to contain Asian carp eggs or larvae (Fritts et al. 2019) is being field-tested with samples collected from the Illinois River. This tool may help to substantially increase the efficiency of ichthyoplankton sample processing and may hold promise as an early detection tool for monitoring for Black Carp reproduction.

Methods:

Ichthyoplankton sampling will occur weekly during late April through early July, and biweekly from late July to October. At all IWW sampling sites, samples will be collected using a 0.5 m-diameter ichthyoplankton push net with 500 µm mesh. To obtain each sample, the net will be pushed upstream using an aluminum frame mounted to the front of the boat. Boat speed will be adjusted to obtain 1.0 – 1.5 m/s water velocity through the net. Flow will be measured using a flow meter mounted in the center of the net mouth and will be used to calculate the volume of water sampled. Fish eggs and larvae will be collected in a meshed tube at the tail end of the net, transferred to sample jars, and preserved in 90% ethanol. Four ichthyoplankton samples will be collected at each mainstem site on each sampling date. Sampling transects will be located on each side of the river channel, parallel to the bank, at both upstream and downstream locations within each study site.

At tributary sites (Sangamon, Spoon, Mackinaw, Fox, and Kankakee Rivers), three samples will be collected at each site on each sampling date, one near each bank and another in the center of the channel. Boat-mounted push nets will be used at boatable locations, whereas passive drift nets (0.45 x 0.25 m, 500 µm mesh) will be used at sites where boat access is restricted. Push net sampling will be conducted similar to mainstem sites, whereas passive drift nets will be deployed for 30 – 180 minute durations, depending on stream flow. Relative abundance of adult Asian carp in tributaries will be estimated using modified Long Term Resource Monitoring (LTRM) electrofishing protocols.

Illinois Waterway ichthyoplankton samples will be assessed for the presence of species-specific Asian carp DNA derived from eggs or larvae. Potential presence of adult carp DNA will be removed by exchanging sample ethanol with fresh molecular-grade ethanol. Samples will be gently inverted in the refreshed ethanol, and aliquots of sample preservative will be removed to screen for the presence of DNA derived from Asian carp eggs or larvae. Following DNA extraction, DNA assays for the four taxa of invasive carps will be run in multiplex reactions, following quantitative PCR (qPCR) methodology. Samples will be run in triplicate with a dilution series and no-template controls. The lowest concentration of DNA distinguishable from the control and at which coefficient of variation of estimated copy number is 20% or less will be quantified. Samples with species-specific DNA copy numbers above a given threshold (Fritts et al. 2019) will be considered to have a high probability of containing eggs or larvae of that species of Asian carp. The relationship between DNA copy number and the number of Asian carp eggs and larvae in a sample will also be further assessed following microscopic identification of all specimens.

In the laboratory, fish eggs and larvae will be separated from other materials, and all larval fish will be identified to the lowest possible taxonomic unit. Fish eggs will be separated by size, with all eggs having a membrane diameter larger than 3.5 mm being identified as potential Asian carp eggs and retained for later genetic analysis. Larval fish and egg densities will be calculated as the number of individuals per cubic meter of water sampled. Developmental stages of Asian carp eggs and larvae will be determined in order to provide input for FluEgg modeling being conducted with collaborators at the U.S. Geological Survey Central Midwest Water Science Center to identify spawning locations and zones of larval settlement.

Schedule:

During 2021, larval fish sampling will occur at weekly intervals at all sites during late April through early July, and at biweekly intervals from late July to October. Additional sampling will occur during periods when Asian carp eggs and larvae are considered likely to be present (e.g., during periods of rising water levels or shortly after peak flows). Changes to this proposed sampling schedule may arise from restrictions on travel due to the COVID-19 pandemic. All efforts will be expended to conduct all sampling that is possible during 2021 while following all legal requirements and exercising an abundance of caution regarding staff and community health concerns.

Larval Fish Monitoring in the Illinois Waterway

Deliverables:

Ichthyoplankton monitoring will provide rapid detection of Asian carp reproduction in the IWW. Observations of large-diameter eggs or any identification of Asian carp larvae upstream of the Starved Rock Lock and Dam will be immediately reported to Monitoring and Response Work Group (MRWG) partners. Any detection of Black Carp reproduction at any location in the IWW will also be immediately reported to MRWG. This project will provide a quantified relationship between reproductive productivity and adult density to inform Asian carp removal efforts, with annual updates provided in technical reports and MRWG meetings. The potential for qPCR methods to enhance efficiencies in the design of the ichthyoplankton monitoring program and be incorporated into subsequent years' monitoring efforts will be identified. Results of each sampling event will be reported in monthly sampling summaries. Locations of Asian carp spawning based on FluEgg modeling efforts will be provided to MRWG partners as relevant findings are produced. Data will be summarized and project plans updated for annual revisions of the Monitoring and Response Plan.

References:

Fritts, A.K., B.C. Knights, J.H. Larson, J.J. Amberg, C.M. Merkes, T. Tajjioui, S.E. Butler, M.J. Diana, D.H. Wahl, M.J. Weber, and J.D. Waters. 2019. Development of a quantitative PCR method for screening ichthyoplankton samples for bigheaded carps. Biological Invasions 21:1143-1153. https://doi.org/10.1007/s10530-018-1887-9

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Larval Fish Monitoring in the Illinois Waterway

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

Movement and Density of Bigheaded Carp in the Illinois River

Participating Agencies: Southern Illinois University – Carbondale (SIU, lead), additional assistance/collaboration with U.S. Army Corps of Engineers (USACE), U.S. Geological Survey, Illinois Department ofNatural Resources, Illinois Natural History Survey, U.S. Fish and Wildlife Service (USFWS)

Location: Illinois and Des Plaines rivers from Dresden Island Pool (Brandon Road Lock and Dam) to Alton Pool, along with associated backwaters, side channels, and tributaries.

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

Introduction and Need:

Management goals for bigheaded carp (Silver Carp and Bighead Carp) in the Illinois River focus on limiting upstream dispersal through monitoring, assessing movement barriers, and reducing abundance through contracted harvest. Bigheaded carp spatial distributions vary both seasonally and annually; therefore, quantifying how spatial distributions change through time will help target contracted harvest to maximize removal efforts and minimize costs. Additionally, long-term information on bigheaded carp population characteristics, distributions, and movements, especially along the population front in the upper Illinois River, can provide data to parameterize population models (e.g., Spatially Explicit Asian Carp Population [SEACarP]) that can help evaluate potential effects of management options.

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. Annual densities, particularly in the lower Illinois River, have displayed relatively large annual fluctuations among years (Coulter et al. 2016), necessitating the need for continued assessments of bigheaded carp densities throughout the river. This will identify whether population size in the lower river has increased from previous years and help determine whether harvest or surveillance in the upper river should be altered in anticipation of increased immigration from downstream pools. It is currently unclear whether, or the extent to which, bigheaded carp in the Illinois River exhibit density-dependent effects on reproduction, condition, growth, and movement. Collecting long-term data, particularly density and movement data, will help quantify these patterns which will better inform management decisions and improve models predicting population response to management actions.

Monitoring Bigheaded Carp Movement and Density in the Illinois River and Assessment of Native Fish Passage Through Brandon Road Lock and Dam

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

The spatially-explicit population model of bigheaded carp in the Illinois River (SEACarP) assesses how bigheaded carp populations respond to a variety of management actions (e.g., location and intensity of harvest; location and effectiveness of deterrent technologies). This model draws on a wide variety of data, including bigheaded carp densities and movement data. Collaborations between Monitoring and Response Work Group (MRWG) modeling, telemetry, and hydroacoustic work groups have identified several additional data needs in addition to maintenance of current monitoring efforts. SIU's contribution to continued model support and development will include continued maintenance of the Illinois River stationary telemetry array to document inter-pool movements, deployment of additional acoustic telemetry tags in bigheaded carp (numbers set based on telemetry working group determinations), and continued hydroacoustic monitoring of bigheaded carp densities throughout the Illinois River. Movement information from telemetry efforts will also be critical for maintaining surveillance to detect potential changes in Asian carp spatial distributions (e.g., movements among pools), especially in supporting surveillance efforts with real-time acoustic telemetry receivers.

Objectives:

(1) Quantify Asian carp densities every other month in Dresden Island and Marseilles pools in 2021 using mobile hydroacoustic surveys to pinpoint high density areas that can be targeted during contracted removal. Surveys will also document how distributions of bigheaded carp change through time which can better inform targeted removal and could provide an indication of the effectiveness of harvest efforts. Data collection will occur bi-monthly as long as conditions allow.

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

(3) Maintain SIU's acoustic telemetry array currently in place in the Illinois River used to collect movement and dam passage information. Collected data will be shared with the telemetry working group and those working on the SEACarP model.

Monitoring Bigheaded Carp Movement and Density in the Illinois River and Assessment of Native Fish Passage Through Brandon Road Lock and Dam

Status:

Continues previous work by SIU that has intensively monitored movement and density of Asian carp in the Illinois River since 2012. Hydroacoustic and associated sampling surveys will yield information on trends in density, biomass, and size structure of Asian carp in the Illinois River. Because these surveys have been ongoing since 2012, they provide valuable long-term trends.

Methods:

Spatial and temporal variation in Asian carp densities in Marseilles and Dresden Island pools – Mobile hydroacoustic surveys will occur in main channel, tributaries, side channels, and connected backwater lakes using horizontally oriented split-beam transducers. Surveys will be conducted every other month in Dresden Island and Marseilles pools from March to October, given appropriate sampling conditions. In order to inform hydroacoustic data, catch from ongoing efforts (e.g., contracted removal) in the Dresden Island and Marseilles pools will be sampled throughout the year for species relative abundance and measured for length and weight.

Density estimates of Asian carp in the Illinois River – Hydroacoustic surveys will be conducted in the fall of 2021 throughout the Illinois River (Alton through Dresden Island pools) following the same protocol outlined above for the bi-monthly surveys of Marseilles and Dresden Island pools. Survey sites will be the same locations sampled previously by SIU in order to add to the existing long-term (9 years as of 2020) dataset. Such data are essential to fully understand population dynamics, especially when biotic (e.g., annual variability in recruitment success) and abiotic (e.g., drought, flood years) processes fluctuate through time.

Telemetry data to identify bigheaded carp passage through Illinois River Lock and Dams – The existing acoustic telemetry array of 65+ stationary receivers will be maintained and downloaded on two occasions in 2021. Additional acoustic telemetry tags (150 total tags) will be deployed in Marseilles (25 tags), Starved Rock (25 tags), La Grange (50 tags) and Alton (50 tags) pools to replace expiring tags. Bigheaded carp in other Illinois River pools will be tagged by USFWS and USACE such that numbers of tagged bigheaded carps remain high in all pools within the telemetry array. Stands holding the receivers and hardware will be replaced as necessary. Data from the telemetry array will provide information on numbers of tagged Asian carp moving upstream or downstream through each lock and dam, which provides an indication of the relative numbers of individuals in the population that may be moving among pools. Replacing expiring telemetry tags also maintains sufficient numbers of tagged individuals at-large in each pool for adult surveillance efforts (e.g., monitoring for movements past real-time receivers).

Schedule:

Bi-monthly hydroacoustic surveys will be conducted in the Marseilles and Dresden Island pools every other month from March through October 2021, weather permitting. In addition, annual hydroacoustic surveys will occur in the Alton, LaGrange, Peoria, and Starved Rock pools during October of 2021. Telemetry stationary receivers will be downloaded two times during 2021, once between April – June and once in November.

Monitoring Bigheaded Carp Movement and Density in the Illinois River and Assessment of Native Fish Passage Through Brandon Road Lock and Dam

Deliverables:

Hydroacoustic Asian carp information will reveal how density varies spatially and temporally at the edge of their invasion front. Results will consist of heat maps that visually display Asian carp densities in the Marseilles and Dresden Island pools throughout the year. These maps will be shared with partners in the Removal work group to inform harvest efforts. Fall hydroacoustic sampling will provide a long-term assessment of Asian carp densities throughout the Illinois River (Alton through Dresden Island pools) by comparing 2021 densities to densities from the previous years.

Telemetry data will be used to determine the passage route (number of passages through locks versus dam gates) as well as the environmental conditions and timing associated with upstream passages. These results will provide a spatial and temporal context for the deployment of control measures which will increase the efficiency (both costs and in preventing movement) of the control measures.

References:

Coulter DP, Coulter AA, MacNamara R, Brey MK, Kallis J, Glover D, Garvey JE, Whitledge GW, Lubejko M, Lubejko A, Seibert J (2016) Identifying movement bottlenecks and changes in population characteristics of Asian carp in the Illinois River. Final Report to Illinois Department of Natural Resources.

Des Plaines River and Overflow Monitoring

Participating Agencies: U.S. Fish and Wildlife Service (USFWS)-Carterville Fish and Wildlife Conservation Office Wilmington Substation (lead), and U.S. Army Corps of Engineers (USACE) Chicago District

Location: Des Plaines River above the confluence with the Chicago Sanitary and Ship Canal (CSSC)

Pools Involved: Not applicable

Introduction and Need:

The upper Des Plaines River rises in southeast Wisconsin and joins the CSSC in the Brandon Road Pool immediately below the Lockport Lock and Dam. Invasive carp have been observed in this pool up to the confluence with the Des Plaines River, and have free access to enter the upper Des Plaines River. In 2010 and 2011, invasive carp eDNA was detected in the upper Des Plaines River. No invasive carp eDNA sampling has been conducted in the Des Plaines River since 2011. It is possible that invasive carp present in the upper Des Plaines River could gain access to the CSSC upstream of the Electric Dispersal Barrier System (EDBS) during high water events when water flows laterally from the upper Des Plaines River into the CSSC. The construction of a physical barrier to reduce the likelihood of this movement was completed in the fall of 2010. The physical barrier was constructed by the USACE and consists of concrete barriers and 0.25-inch mesh fencing built along 13.5 miles of the upper Des Plaines River where it runs adjacent to the CSSC. It is designed to stop adult and juvenile invasive carp from infiltrating the CSSC, but it will likely allow invasive carp eggs and fry in the drift to pass. Opportunities for fish to pass occurred during high discharge events in 2011 and 2013 when water breached the physical barrier. USACE reinforced these and other low-lying areas to prevent scouring during future lateral water transfers. These reinforcements withstood high flow events in 2017 and 2019. A high discharge event in 2020 allowed for a few inches of water to pass over the top of the barrier between the Des Plaines River and the CSSC and allow for passage of eggs and larvae. Gear deployed by the USACE did not capture any fish moving between the systems. Scour holes and fence damage have been repaired. Understanding the population status of invasive carp in the Des Plaines River, monitoring for potential spawning events, and determining the effectiveness of the physical barrier are all necessary to inform management decisions and assess risk of invasive carp bypassing the EDBS.

Des Plaines River and Overflow Monitoring

Objectives:

(1) Monitor for Bighead Carp and Silver Carp populations in the Des Plaines River above the confluence with the CSSC.

(2) Monitor for breaches of the barrier and passage of fish during high flow events when water moves laterally from the Des Plaines River into the CSSC.

(3) Monitor for Bighead Carp and Silver Carp eggs and larvae around the physical barrier when water moves laterally from the Des Plaines River into the CSSC.

Status:

This project began in 2011 and is ongoing. Between 2011 and 2020, 13,882 fish have been collected via electrofishing (81.5 hours) and gill netting (23,684 yards). No Bighead Carp or Silver Carp have been collected or observed. Ten Grass Carp have been collected. Six of these were submitted for ploidy analysis and all six were determined to be triploid (sterile).

Methods:

Population monitoring will include electrofishing and gill netting. The project will utilize pulsed-DC electrofishing. One or two dippers will attempt to dip all visible fish, with the exception of Common Carp. The number of Common Carp observed to be incapacitated in the electrical field will be recorded. Gill netting will consist of short-term top to bottom sets. Mesh sizes will be 3- to 4-inch bar mesh. Backwater areas will be blocked off with the net and fish will be driven towards the net via pounding or electrofishing. All non-invasive carp will be identified and released. Any Bighead Carp or Silver Carp collected will be kept for further study, and the Monitoring and Response Work Group (MRWG) will be notified. Grass Carp will be tested for ploidy.

A minimum of three sampling events are currently planned for 2021 that will span from pre-spawn to post-spawn periods. Three backwater areas will be considered fixed sites and will be sampled during each sampling event, if accessible (Figure 1). All accessible shoreline in the backwaters will be sampled with electrofishing gear. Each fixed site will also be sampled with 600 yards of gill net during the spring and fall events. In addition to the fixed backwater sites, main channel habitats will be targeted with electrofishing as time and access allow. With the continuation of the COVID-19 pandemic into 2021, some of these sampling procedures may have to be modified to ensure the safety of staff members.

Des Plaines River and Overflow Monitoring

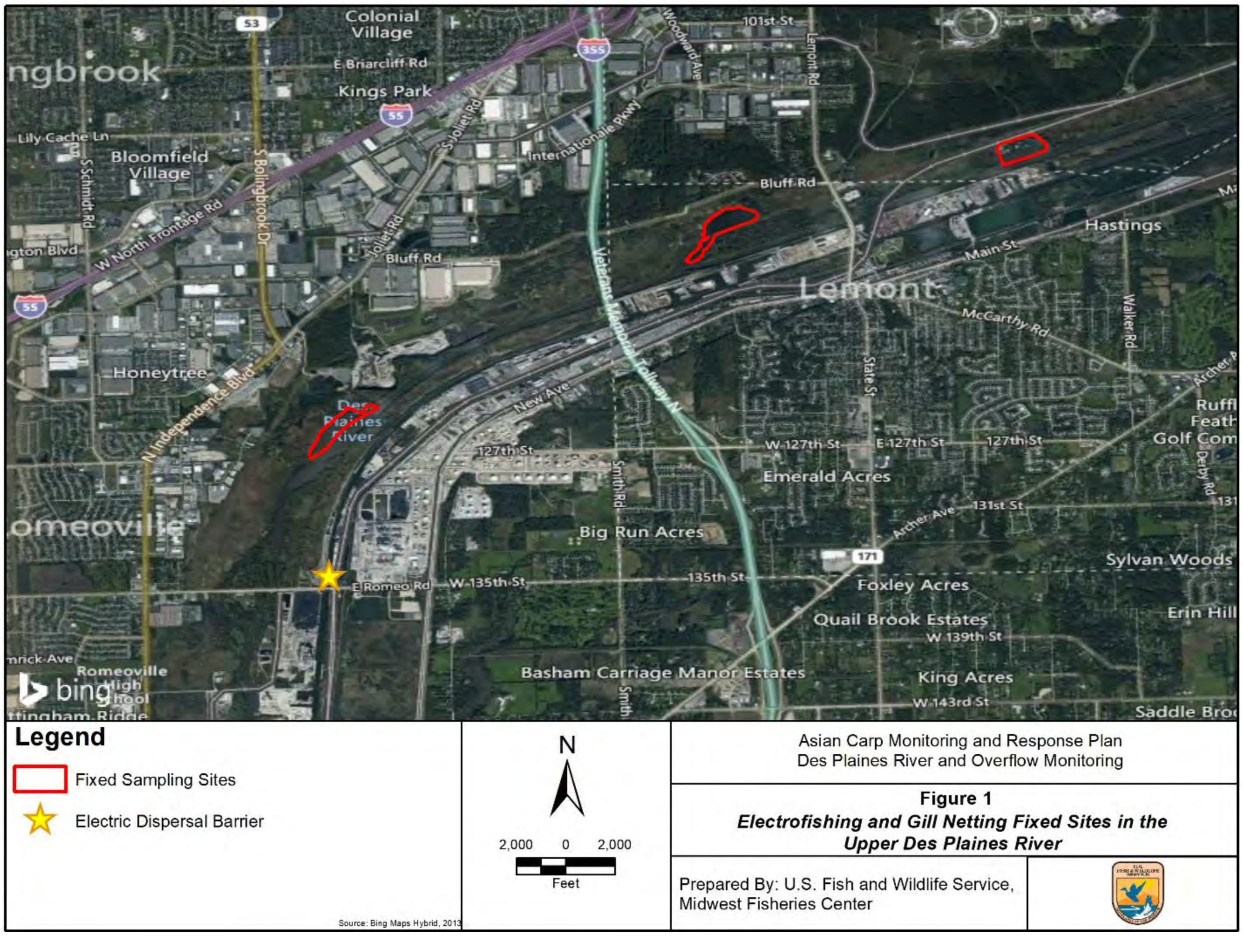

Figure 1. *Fixed site areas for electrofishing and gill netting in the upper Des Plaines River.*

Participating Agencies: Illinois Department of Natural Resources (IDNR, lead), Illinois Natural History Survey (INHS), Southern Illinois University Carbondale (SIU) (otolith chemistry analysis)

Pools Involved: Not applicable

Location: Monitoring will occur in Chicago area fishing ponds supported by the IDNR Urban Fishing Program.

Introduction and Need:

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

As a further response to the Bighead Carp in Flatfoot Lake and Schiller Pond, IDNR reviewed Asian carp captures in all fishing ponds included in the IDNR Urban Fishing Program located in the Chicago Metropolitan area. To date, 10 of the 21 urban fishing ponds in the program have verified captures of Asian carp either from sampling, pond rehabilitation with piscicide, natural die offs or incidental take. One pond had reported sightings of Asian carp that were not confirmed by sampling (McKinley Park). The distance from Chicago area fishing ponds to Lake Michigan ranges from 0.2 to 41.4 km (0.1 to 25.7 mi). The distance from these ponds to the Chicago Area Waterway System (CAWS) upstream of the Electric Dispersal Barrier System (EDBS) ranges from 0.02 to 23.3 km (0.01 to 14.5 mi). Although some ponds are located near Lake Michigan or the CAWS, most are isolated and have no surface water connection to the Lake or 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 Asian carp, nor have any been captured or observed during past sampling events. Nevertheless, examining all urban fishing ponds close to the CAWS or Lake Michigan continues to be of importance due to the potential of human transfer of Asian carp between waters within close proximity to one another, the CAWs, and Lake Michigan.

In addition to Chicago area ponds once supported by the IDNR Urban Fishing Program, ponds with positive detections for Asian carp eDNA were also reviewed. Eight of the 40 ponds sampled for eDNA by the University of Notre Dame resulted in positive detections for Asian carp, two of which are also IDNR urban fishing ponds (Jackson Park and Flatfoot Lake). Asian carp have been captured and removed from two of the eight ponds yielding positive eDNA detections. The distance from ponds with positive eDNA detections to Lake Michigan ranges from 4.8 to 31.4 km (3 to 19.5 mi). The distance from these ponds to the CAWS upstream of the EDBS ranges from 0.05 to 7.6 km (0.03 to 4.7 miles). The lake at Harborside International Golf Course has surface water connectivity to the CAWS. However, no Asian carp have been reported, observed, or captured. Though positive eDNA detections do not necessarily represent the presence of live fish (e.g., may represent live or dead fish, or result from sources other than live fish, such as DNA from the guano of piscivorous birds) all ponds with positive detections were examined for the presence of live Asian carp given the proximity to the CAWS.

Objectives:

(1) Monitor for the presence of Asian carp in Chicago area fishing ponds supported by the IDNR Urban Fishing Program.

(2) Obtain life history, age and otolith microchemistry information from captured Asian carp.

Status:

This project began in 2011 and is on-going. A total of 44 Bighead Carp and one Silver Carp have been removed from 10 ponds. 58 hours of electrofishing and 13 miles of gill/trammel net were utilized to sample 24 Chicago area fishing ponds, resulting in 35 Bighead Carp removed from five ponds since 2011. Additionally, eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have been removed since 2008. Lastly, one Bighead Carp was incidentally caught by a fisherman in 2016. The lagoons at Garfield Park and Humboldt Park have both had Bighead Carp removed following natural die-offs and sampling. All ponds yielding positive eDNA detections and 18 of the 21 IDNR urban fishing ponds have been sampled. Lincoln Park South was not sampled because it was drained in 2008, resulting in three Bighead Carp being removed, and is no longer a source of Asian carp as a result. Auburn Park was too shallow for boat access but had extremely high visibility. Therefore, the pond was visually inspected with no large bodied fish observed. Lastly, Jackson Park and Garfield Park were drained in 2015 and, similar to Lincoln Park South, are no longer a source of Asian carp. A map of all the Chicago area fishing ponds that were sampled or inspected as part of this project can be found in Figure 1. For more detailed results see 2019 interim summary report document (MRWG 2018).

During 2020 our sampling efforts were mitigated due to Covid-19. One call was reported to our agency. A report of a leaping fish within the pond behind the Cancer of Center of America (42.449339 -87.828856) was made on April 4, 2020 by a private citizen. A fisher at the park indicated to the citizen that it was ‘a carp’. The citizen had seen videos of Asian carp leaping into boats and was suspicious it that the reported fish was not an Asian carp. Due to COVID-related restrictions, the agency did not directly respond to this report with a site visit. The pond was assessed remotely to the best of our abilities and findings were reported to the private citizen. The pond was located approximately 1 mile from Lake Michigan, but did not directly connect to Lake Michigan, the Des Plaines River, or the DuPage River. An approximately 65-foot change in elevation exists between Lake Michigan and the pond so direct connection through a flood is highly unlikely. It was determined that there was an extremely low chance of potential transfer into Lake Michigan if the sighting was an Asian carp. Crews are still working to obtain access to the pond to perform an in-person assessment. If access is granted, a response will occur.

Methods:

Sampling Protocol – Trammel and gill nets used are approximately 3 m (10 feet) deep x 91.4 m (300 feet) long in bar mesh sizes ranging from 88.9 – 108 mm (3.5 – 4.25 inches). Multiple nets will be set simultaneously to increase the likelihood of capturing fish. Electrofishing, along with pounding on boats and revving trimmed up motors, will be used to drive fish from both shoreline and open water habitats into the nets. Upon capture, Asian Carp will be removed from the pond and the length in millimeters and weight in grams of each fish will be recorded.

Otolith Microchemistry and Aging – Asian Carp captured in urban fishing ponds will have head, vertebrae, and post-cleithra removed and sent to SIUC for otolith microchemistry analysis and age estimation.

2021 Schedule:

Reports of Asian carp sightings or captures in other Chicago area ponds will be investigated solely based on photographic evidence or reports from credible sources.

Deliverables:

Results of each sampling event will be reported for monthly sampling summaries. An annual report summarizing sampling results will be provided to the Monitoring and Response Work Group (MRWG), agency partners, and any other interested parties.

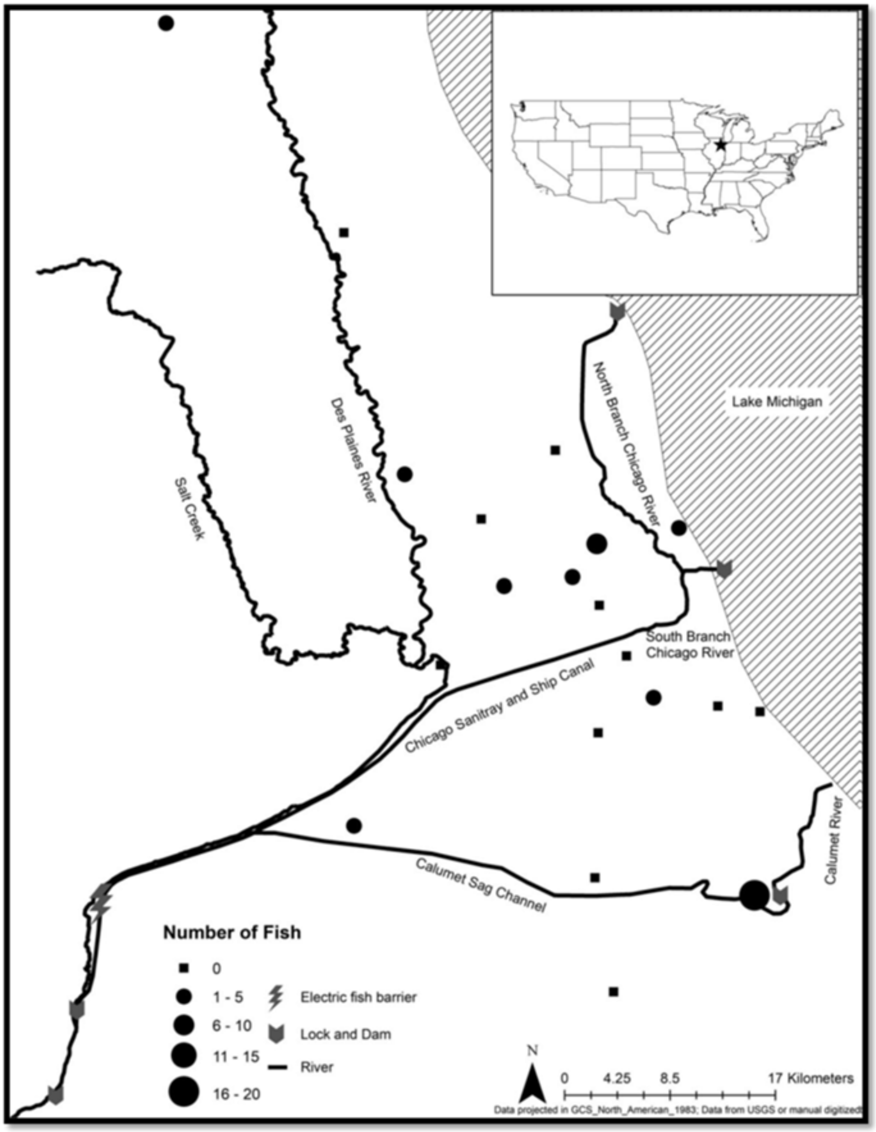

Figure 1. *Chicago area fishing ponds from which Asian Carp have been removed (circles) and those from which no Asian Carp have been collected or reported (squares).*

Multiple Agency Monitoring of the Illinois River for Decision Making

Participating Agencies: Illinois Department of Natural Resources and Illinois Natural History Survey (co-leads), and U.S. Army Corps of Engineers (USACE) – Chicago District (field support).

Location: The Multiple Agency Monitoring of the Illinois River for Decision Making will include data from Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock and Peoria pools of the Illinois River below the Electric Dispersal Barrier System (EDBS) (Figure 1).

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

Introduction and Need:

Detection and monitoring of Asian carp (Bighead Carp, Black Carp, Grass Carp, and Silver Carp) below the EDBS is pertinent to understanding the threat of expansion into Lake Michigan and effectively controlling their spread. Surveillance is particularly important in pools deemed the most upstream expanse for each Asian carp species. The leading edge for Bighead Carp and Silver Carp in 2020 was within the Dresden Island Pool, for Grass Carp was in the Chicago Area Waterway, and for Black Carp was in the Peoria Pool (ACMRWG 2020). Utilizing a standardized, multiple gear approach has been found critical in determining the geographic expanse of Asian carp and monitoring their relative abundance (Ickes et al. 2005; Irons et al. 2011). Additionally, this same multiple gear approach provided critical information on non-target species such as abundance and condition (Love et al. 2017, Irons et al. 2007), recruitment (DeBoer et al. 2018), and fish community structure (Solomon et al. 2016), providing additional lines of evidence toward the presence and impact of Asian carp. Therefore, there is value in monitoring pools downstream of the EDBS (Lockport – Peoria pools) using a standardized, multiple gear sampling approach. Doing so will allow for an accurate, comparable, and representative understanding of Asian carp distribution and abundance. A standardized multiple gear sampling protocol will also allow researchers to further evaluate the impacts of Asian carp on the native fish community.

Objectives:

(1) Monitor the geographic distribution and relative abundance of adult and juvenile Asian carp populations in pools below the EDBS downstream to Peoria Pool.

(2) Provide data capable of detecting spatial and temporal changes in the Asian carp population and native fish community throughout the Illinois River Waterway between the EDBS and Peoria Pool.

(3) Inform other projects (i.e., Contracted Asian Carp Removal, Telemetry Monitoring, Spatially Explicit Asian Carp Population [SEACarP] model, Hydroacoustic surveys) with necessary Asian carp demographic and fish community data to make management decisions.

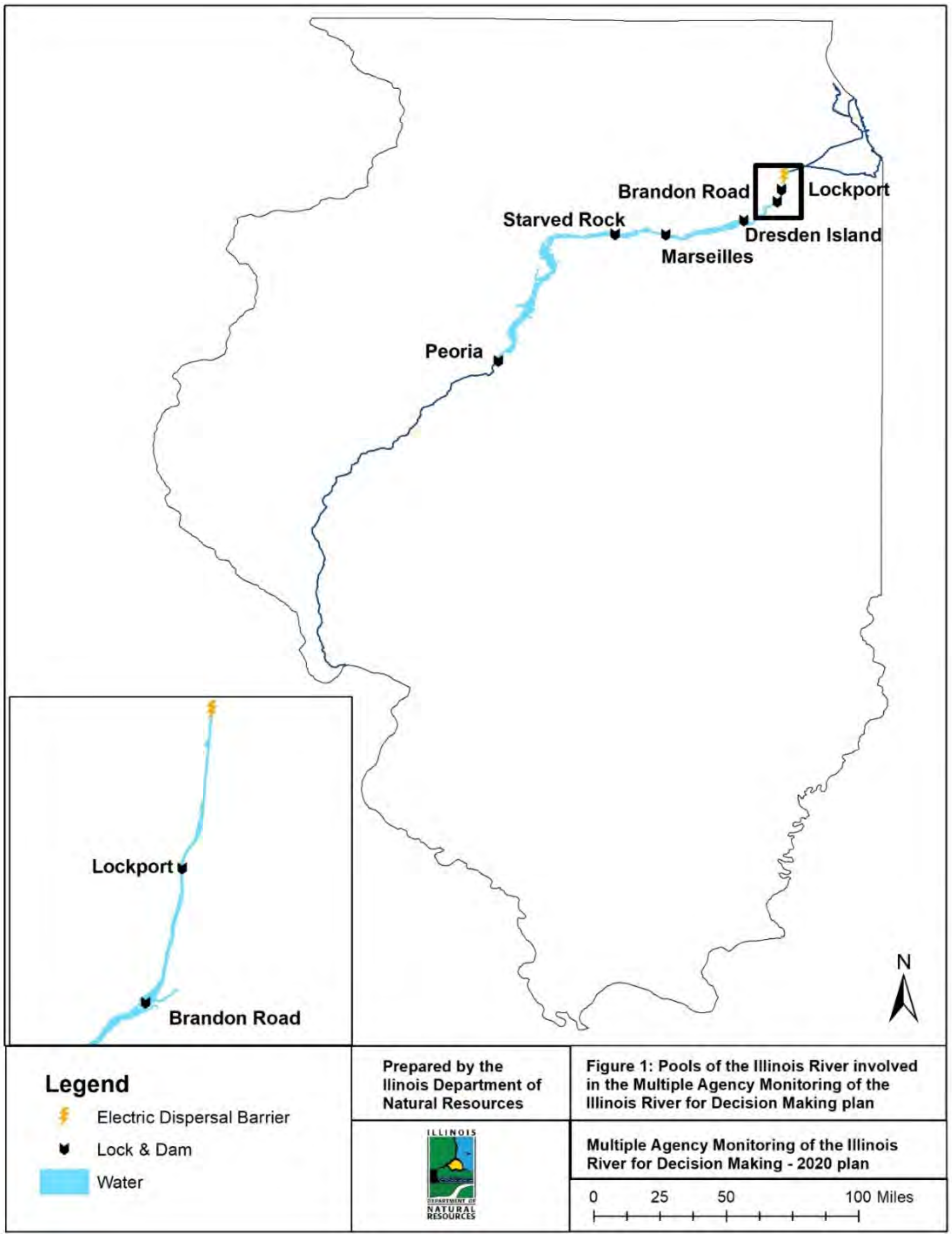

Figure 1. *Map of the sampling reaches of the Illinois River below the Dispersal Barrier to the confluence of the Upper Mississippi River involved in the Multiple Agency Monitoring of the Illinois River for*

Multiple Agency Monitoring of the Illinois River for Decision Making

Decision Making plan: Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, and Peoria pools.

Status:

Much of the Illinois River has been monitored by multiple agencies across numerous projects for decades. The USACE Upper Mississippi River Restoration program (Gutreuter *et al.* 1995, Ratcliff *et al.* 2014) has monitored the La Grange Reach of the Illinois River using a standardized, multiple gear monitoring approach since 1994. The Long-term Survey and Assessment of Large-River Fishes in Illinois formerly, Long-term Electrofishing project (LTEF), has sampled the main channel of the Dresden Island, Marseilles, Starved Rock, Peoria, and Alton pools since 1959. The LTEF transitioned to modeling the Long Term Resource Monitoring (LTRM) electrofishing protocol in 2009 (Fritts *et al.* 2017). That time-tested standardized protocol has been utilized in the Multiple Agency Monitoring of the Illinois River for Decision Making since 2019 creating a comprehensive picture of the spatial and temporal distribution of Asian carp populations within Lockport to Peoria pools of the Illinois River Waterway.

Methods:

Sampling will utilize boat pulsed DC electrofishing (Table 1), fyke netting (Table 2), minnow fyke netting (Table 3) and paired large and small hoop netting (Table 4) in a stratified random approach to target all life stages of Asian carp. Sampling will occur at random sites (Figure 2) among the various aquatic strata (main-channel-border, side-channel-border, backwater, impounded, and tailwater zone) within each river pool during spring (June 15 - July 31), summer (August 1 - September 15), and autumn (September 16 - October 31). Detailed descriptions of gear specifications and sampling protocol can be found in Ratcliff *et al.* (2014), and Appendix L.

Collected fish will be identified to species, measured, and categorized into 10 mm length bins signified by their lower length boundary. Sampled Asian carp will be measured to total length (nearest mm), their sex assigned, and maturity status determined. In addition to length measurements, weight data from all Asian carp individuals greater than or equal to 100 mm and at least three individuals per 10-mm length group greater than or equal to 100 mm from of all other species will be collected during autumn sampling (September 16 – October 31).

Specimens not identified to species in the field will be placed in vials, preserved with 10% formalin or 95% alcohol, and labeled with location code, pool/reach, start date and time, gear code, and stratum code. Preserved specimens will be identified, measured, enumerated and recorded in the laboratory as time permits. Any specimen identified to a species that has not been found previously within the Illinois River or is recognized as state threatened or endangered will be photographed or vouchered (IL-DNR 2018).

Historically sampled fixed sites, upstream of the known Asian carp invasion front (Dresden Island Pool) within Brandon Road Pool and Lockport Pool, will also be sampled with pulsed DC electrofishing (Appendix D). Fixed sites will be sampled every other week during March through November, providing a higher frequency and lengthier temporal range than the randomized sampling design. This fixed and random approach provides additional opportunities to detect whether Asian carp are present near the EDBS in periods outside of the standard sampling window, as well as maintain the collection of historical trend data.

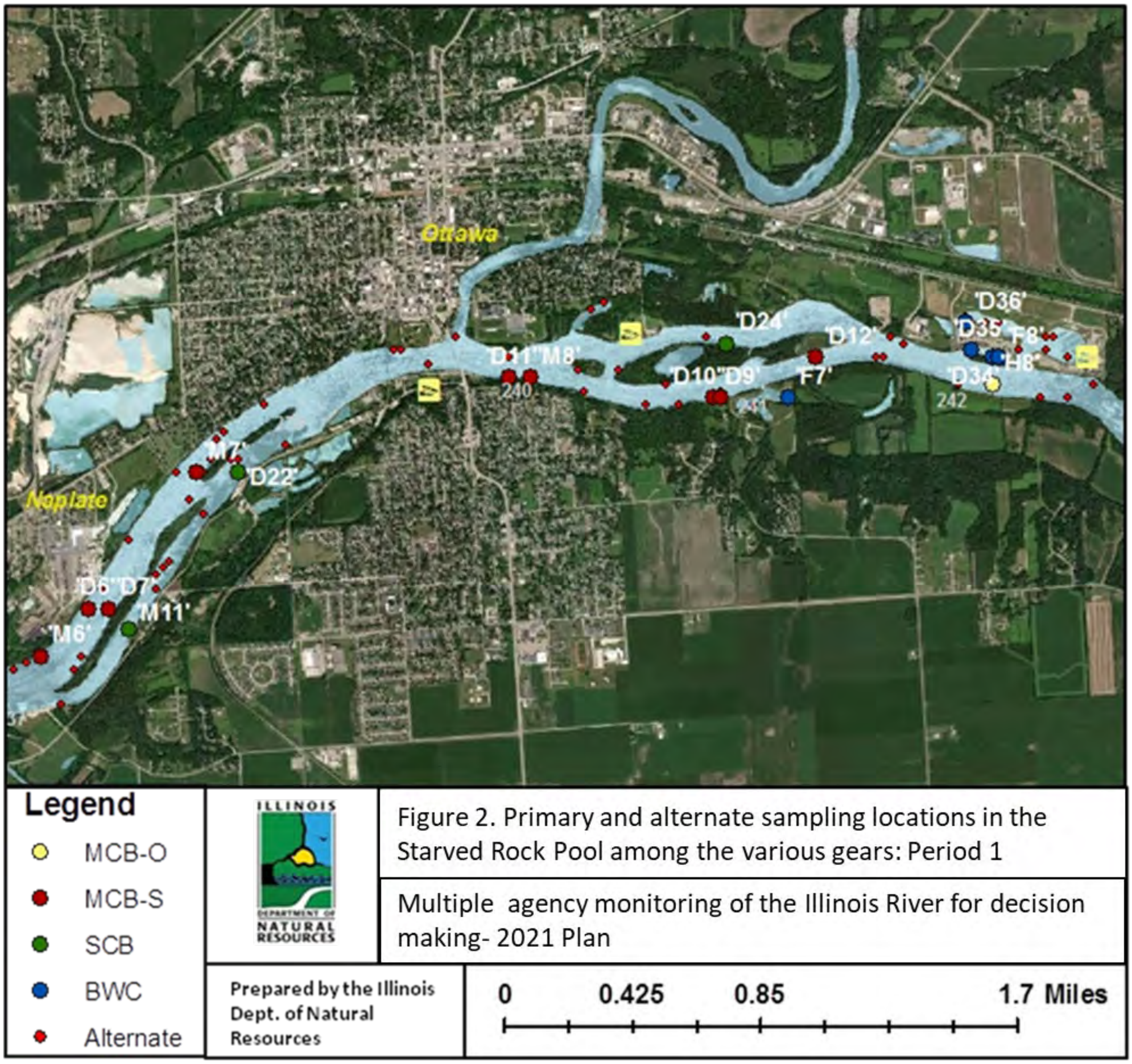

Figure 2. *Minnow fyke net ('M'), Daytime electrofishing ('D'), Paired Hoop Net ('H'), and Fyke net ('F') stratified random sampling locations: main channel border (MCB), side channel border (SCB), and backwater (BWC) habitats with alternate locations in the Starved Rock Pool of the Illinois River for Period 1 from river mile 242 to 237.*

Multiple Agency Monitoring of the Illinois River for Decision Making

Deliverables:

Collected data will be recorded in a standardized Microsoft Access data entry application. Catch and effort data will be preliminarily summarized by each participating agency following the completion of each 6 week period and sent to the Monitoring and Response Work Group (MRWG) Monthly Summary assembler to be posted to https://asiancarp.us/PartnerResources.html. Finalized sampling and fish data collected by each agency will be submitted to the U.S. Geological Survey Upper Midwest Environmental Sciences Center by December 31st using the online portal. Following submission, data will be appended into a single database, summarized for an annual interim report and made accessible to MRWG members upon request from the database curator.

Schedule:

- Sampling coordination: January 1 to June 14
- Sampling techniques workshop: May 28
- Period 1 sampling: June 15 to July 31
- Period 2 sampling: August 1 to September 15
- Period 3 sampling: September 16 to October 31
- Data quality assurance and lab identifications: November 1 to December 31
- Data upload: December 31

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Ratcliff, E. N., E. J. Gittinger, T. M. O'Hara, and B. S. Ickes. 2014. Long Term Resource Monitoring Program Procedures: Fish Monitoring, 2nd edition. A Program Report submitted to the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program. June 2014. Program Report LTRMP 2014-P001. 88 pp. including Appendixes A–G.

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Table 1. *Electrofishing effort by agency and project type among each 6-week time period across habitat strata within the pools of the Illinois River below the Electric Dispersal Barrier system. Strata sampled include main channel border (MCB), side channel border (SCB), and backwater (BWC). Participating agencies and projects include, Illinois Department of Natural Resources Yorkville (IDNR-Y), Illinois Natural History Survey Illinois River Biological Station Asian Carp (IRBS-BSH), Illinois Natural History Survey Illinois River Biological Station Black Carp (IRBS-BC), Illinois Natural History Survey Illinois River Biological Station Long Term Survey and Assessment of Large River Fishes In Illinois (IRBS-LTEF), and the United States Army Corps of Engineers (USACE).*

MCB	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IRBS-LTEF			3	6	3	15
IRBS- BSH				5	8	
IDNR-Y	4	4	9			
USACE	8	8				
Total	12	12	12	11	11	15

SCB	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IRBS-BC				6	12	15
IDNR-Y			4	6		
Total	0	0	4	12	12	15

BWC	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IRBS-BC						15
USFWS					12	
IDNR-Y	3		8	8		
Total	3	0	8	8	12	15

Table 2. *Fyke net effort by agency and project type among each 6-week time period across habitat strata within the pools of the Illinois River below the Electric Dispersal Barrier system. Strata sampled include backwater (BWC). Participating agencies include Illinois Natural History Survey Illinois River Biological Station Asian Carp (IRBS-BSH), and Illinois Natural History Survey Illinois River Biological Station Long Term Resource Monitoring (IRBS-LTRM).*

BWC	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IRBS-LTRM						9
IRBS-BSH			5	5	5	
Total	0	0	5	5	5	9

Table 3. *Minnow fyke net effort by agency and project type among each 6-week time period across habitat strata within the pools of the Illinois River below the Electric Dispersal Barrier system. Strata sampled include main channel border (MCB), side channel border (SCB), and backwater (BWC). Participating agencies include Illinois Department of Natural Resources Yorkville (IDNR-Y), Illinois Natural History Survey Illinois River Biological Station Asian Carp (IRBS-BSH).*

MCB	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IDNR-Y	8	8	8	8		
IRBS-BSH					8	8
Total	8	8	8	8	8	8

SCB	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IDNR-Y			6	6		
IRBS-BSH					6	6
Total	0	0	6	6	6	6

BWC	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IDNR-Y			10	10		
IRBS-BSH					10	10
Total	0	0	10	10	10	10

Table 4. *Paired hoop net effort by agency and project type among each 6-week time period across habitat strata within the pools of the Illinois River below the Electric Dispersal Barrier system. Strata sampled include main channel border (MCB) and side channel border (SCB). Participating agencies include Illinois Department of Natural Resources Yorkville (IDNR-Y), and the Illinois Natural History Survey Illinois River Biological Station Black Carp (IRBS-BC).*

MCB	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IDNR-Y	14	14	8	8		
IRBS-BC					8	8
Total	14	14	8	8	8	8

SCB	**Lockport**	**Brandon Road**	**Dresden Island**	**Marseilles**	**Starved Rock**	**Peoria**
IDNR-Y			6	6		
IRBS-BC					6	6
Total	0	0	6	6	6	6

MANAGEMENT AND CONTROL PROJECTS

USGS Asian Carp Database Management and Integration Support

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

Participating Agencies: U.S. Geological Survey (USGS), Illinois Department of Natural Resources, Illinois Natural History Survey, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Southern Illinois University Carbondale, WIU

Location: Illinois River Waterway system

Pools Involved: Chicago Area Waterway System, Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, La Grange, and Alton

Introduction and Need:

Asian carp tracking, monitoring, and contracted removal will continue throughout the upper Illinois Waterway (IWW) system as part of an adaptive management effort to mitigate, control, and contain Asian carp. To facilitate these actions, there is a need to compile and analyze data from the multitude of partner agencies that are collecting Asian carp-related data throughout the IWW system. These data are often in disparate formats; integrating these data into a common format allows both researchers and managers to assess Asian carp monitoring, control, and removal efforts at several scales. Ensuring the interoperability of these datasets allows for their use in various analyses and modeling efforts. Implementing an interoperable data management framework also provides mechanisms for end users to find and use existing data. Integrating data for use in modeling and analysis furthers the partnership's collective understanding of bigheaded carp (Silver Carp and Bighead Carp) life history, distribution, and movement and can be used to facilitate adaptive management actions (e.g., directing monitoring, sampling, and removal efforts, assessing Asian carp abundance to support modeling efforts, informing deployment of control actions, etc.). An effective data management strategy will streamline the update process, providing partners with timely data and analyses in support of informed decision-making processes.

Objectives:

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

USGS Asian Carp Database Management and Integration Support

(1) Continued maintenance of the FishTracks Telemetry Database (FishTracks) and Illinois River Catch Database (ILRCdb) applications to facilitate objectives 2 and 3 via data compilation, management, and summarization.

(2) Further understanding of bigheaded carp life history and other factors that might influence the efficacy and efficiency of contract removal or other control approaches (e.g., deterrents) and facilitate risk assessment.

(3) Incorporate findings from objective 2 into analyzes, informational products, and decision support tools to inform modeling efforts and management decisions to control bigheaded carp.

Status:

The FishTracks and ILRCdb applications, which contain query-able, downloadable telemetry and catch data (respectively), have been developed, deployed, and released to partners. Standardized data requirements are utilized during the data collection process, and data quality assurance checks are implemented during the data upload process. Automated monthly reporting features have been updated for the ILRCdb.

Work has begun on developing application programming interfaces (APIs) for end users (e.g., modelers) to directly access Asian carp telemetry, monitoring, and removal data stored in the FishTracks and ILRCdb applications. These APIs will be finalized and made available to the partnership's work groups to further enable efficient data integration and analysis. Demographics-related data is already being compiled and utilized by the Modeling Work Group for population modeling efforts. Implementing a data management framework for these data by establishing minimum data standards, similar to telemetry and catch data, will allow for easier integration into analysis-ready workflows.

High-resolution hydroacoustic survey data (from multibeam and side scan sonar) have been collected, validated, and processed into benthic classification layers from priority removal areas of the IWW system (Brandon Road, Dresden Island, Marseilles, Starved Rock, and Peoria pools). These datasets, along with other Asian carp-related datasets, are complete and publicly available but exist in disparate digital data repositories and oftentimes require specialized software to visualize and use. Integrating these datasets into an online, easy-to-use data hub will allow for greater discovery and usability by the multi-agency partnership.

Methods:

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

APIs are being developed to allow direct programmatic access to database applications, enabling data end users (e.g., modelers) to integrate and analyze partnership data into modeling software programs, such as R. In addition, population demographics-related data requirements will be determined, based on Modeling Work Group needs. These data are already being compiled and included in population modeling efforts; establishing core data standards will allow for integration of data from multiple agencies with minimal data post-processing required.

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

Schedule:

- Add new data to FishTracks – annual basis (post-field season).
- Add new data to ILRCdb – approximately monthly basis (excluding non-field season).
- Provide API access to FishTracks and ILRCdb for end users to directly query databases – March 2021.
- Establish data requirements for demographics-related Asian carp data (aligned to Modeling Work Group needs) – June 2021.
- Deploy online hub of Asian carp data sets and tools; integrate existing bathymetric and benthic classification data sets into decision support tool – June 2021.

Deliverables:

(1) Continually maintained database applications for Asian carp-related telemetry, monitoring, and removal data in the IWW system (FishTracks and ILRCdb applications) with customized data reports, upload functionality for data sharing among partner agencies, and query-able data access for end users through an API.

(2) Data management framework for demographics-related data collected by the partnership in the IWW system to facilitate population modeling efforts, including core data elements to integrate demographics data sets based on end user needs.

(3) Online data hub with user-friendly interface for the discoverability and usability of existing Asian carp-related datasets and analytical tools that have been collected, processed, and developed by the partnership (as web mapping and geoprocessing services). Deployment of a decision support tool(s) that integrates existing bathymetric and benthic classification data layers with environmental variables, telemetry, and catch data to analyze bigheaded carp distribution and inform the deployment of control and removal efforts.

Contracted Commercial Fishing Below the Electric Dispersal Barrier System

Participating Agencies: Illinois Department of Natural Resources (IDNR, lead), Illinois Natural History Survey (field support)

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

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

Introduction and Need:

The Contracted Commercial Fishing Below the EDBS project uses contracted commercial fishers to reduce Asian carp (Bighead Carp, Silver Carp, Grass Carp, and Black Carp) relative abundance and monitor for their expansion in the upper Illinois River and lower Des Plaines River downstream of the EDBS. Decreasing Asian carp relative abundance reduces migration pressure towards the barrier, lessening the chances of Asian carp gaining access to upstream waters in the Chicago Area Waterway System (CAWS) and Lake Michigan. Monitoring for upstream expansion of Asian carp should help identify changes in the leading edge, distribution, and relative abundance of Asian carp in the Illinois Waterway (IWW). The "leading edge" is defined as the furthest upstream location where multiple Bighead Carp or Silver Carp have been captured using conventional sampling gears during a single trip or where individuals of either species have been caught in repeated sampling trips to a specific site. Trends in catch data over time may also contribute to the understanding of Asian carp population abundance, distribution, and movement between and among pools of the IWW and can be utilized in conjunction with other Monitoring and Response Work Group (MRWG) projects to better understand population dynamics in areas of concern.

Objectives:

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

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

(3) Inform other projects (i.e., hydroacoustic verification and calibration, Spatially Explicit Asian Carp Population [SEACarP] model, small fish monitoring, telemetry master plan) with Asian carp population distribution, dynamics, and movement in the IWW downstream of the EDBS.

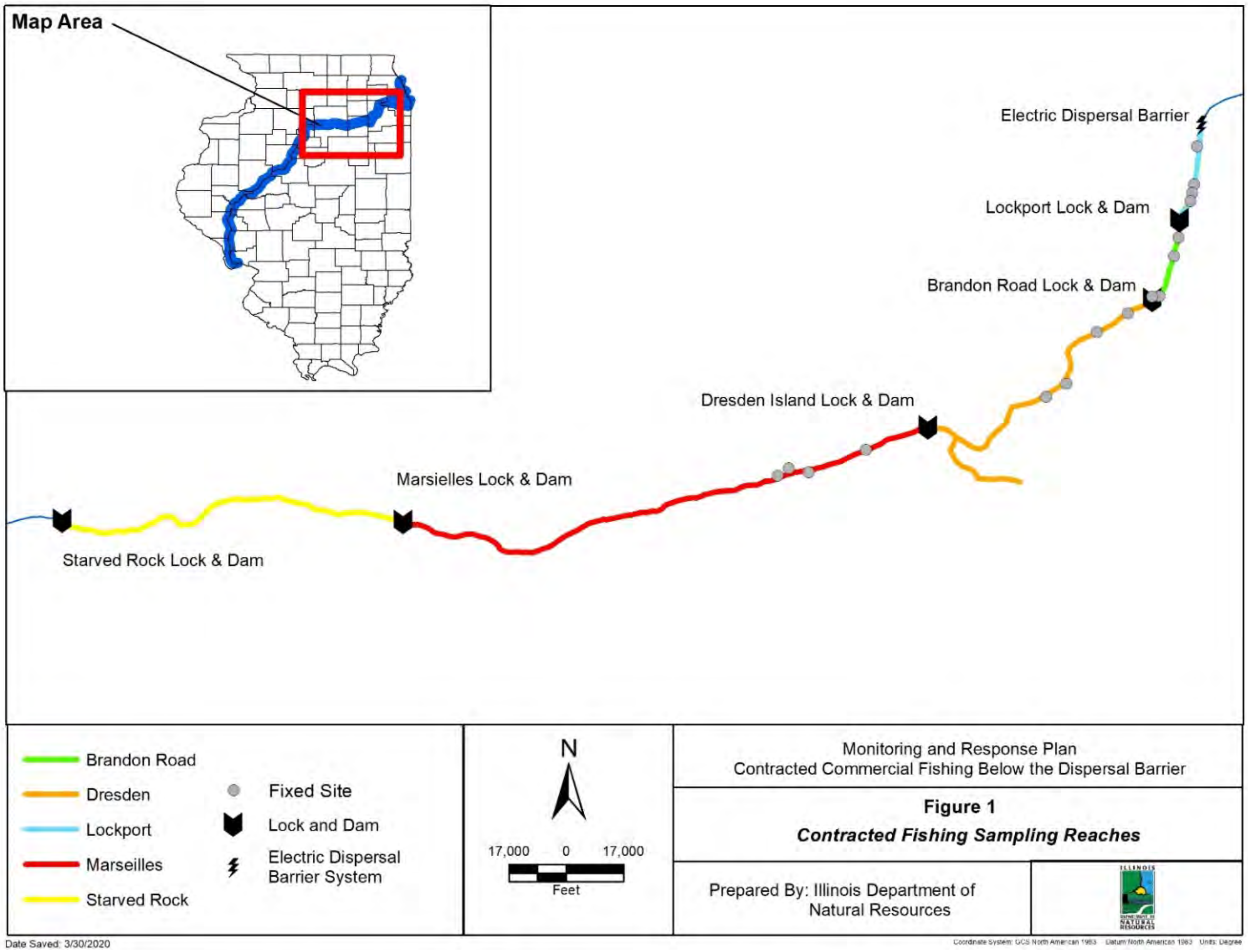

Figure 1. *Contracted commercial fishing sampling area and locations of fixed sites below the Electric Dispersal Barrier System.*

Status:

Contracted commercial fishers have been used in the *Monitoring Efforts Downstream of the Electric Dispersal Barrier System* project and the *Barrier Defense Asian Carp Removal* project (2010-2018). The two projects were combined into a single project in 2019 to provide a more comprehensive view of the ongoing contracted commercial fishing effort and results. Since 2010, contracted commercial fishers' effort in the upper IWW below the EDBS includes 4,283 miles (6,893 km) of gill/trammel net, 19 miles (31 km) of commercial seine, 239-pound net nights, and 4,369 hoop net nights. A total of 101,542 Bighead Carp, 1,157,698 Silver Carp, and 10,461 Grass Carp have been removed. The estimated total weight of Asian carp removed is 5,147.5

tons (10,295,000 lbs.). Contracted commercial fishing effort indicates a decreasing abundance trend of Asian carp progressing upriver from Starved Rock Pool to Dresden Island Pool with no Asian carp captured in Lockport or Brandon Road pools during contracted commercial fishing. One adult Bighead Carp was observed in Brandon Road Pool by a netting crew in October 2011. For more detailed results, consult the 2020 Interim Summary Report.

Methods:

Contracted commercial netting will occur 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 will be 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 will be required to accompany contracted commercial fishing crews working in this portion of the river. Contracted commercial fishers with assisting agency biologists will fish four days of the week during each week of the field season except for two weeks in June and two weeks in September when contracted commercial fishers will be sampling upstream of the EDBS for the Seasonal Intensive Monitoring project (Table 2).

Contract fishing with observing IDNR biologists will occur at targeted sites throughout each pool monthly. Four fixed sites each in Lockport, Brandon Road, Dresden Island, and Marseilles pools will also be sampled monthly (Figure 1). Fixed and targeted site data will be merged to gain a comprehensive understanding of Asian carp spatial and temporal abundance below the EDBS, especially at their upper-most extent in the Dresden Island Pool. This will allow a more thorough understanding of Asian carp relative abundance through time at a pool-wide scale. However, because Asian carp abundance and fishing locations are heterogeneous spatially, areas of special interest to the Monitoring and Response Work Group (MRWG) (Rock Run Rookery and Dresden Island Pool above I-55) will be 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 Island Pool Main Channel Above I-55).

Large mesh (2.5 - 5.0 inch; 63.5mm-127mm) gill and trammel nets set in 100 to 1,200 yard segments will be used and commercial fishers will utilize fish herding (e.g., pounding on boat hulls, hitting the water surface with plungers, running with motors trimmed up) to drive fish into the net. Nets will typically be set for 20-30 minutes with overnight net sets occasionally occurring in off-channel habitat and in non-public backwaters with no boat traffic. Entangled fish will be removed from the net, identified, enumerated, and recorded. All Asian carp and Common Carp will be checked for telemetry tags and all non-tagged Asian carp will be harvested and utilized by private industry for purposes other than human consumption (e.g., chum bait, converted to liquid fertilizer, pet treats, food for injured animals, etc.). All tagged Asian carp and all non-Asian carp by-catch will be released into the water alive. A representative sample of up to 30 individuals of each Asian carp species from each pool will be measured for total length, weighed, and sexed each week to gather morphometric data on harvested carp over time. Asian carp will be placed in totes and all totes will be weighed with a pallet jack scale to determine total weight of Asian carp harvested.

Table 1. *Suggested Boat Launch Locations*

River Pool	Suggested Boat Launches for Contracted Commercial Fishing Sampling
Lockport Pool	• Cargill Launch in Romeoville off W 9th St. (Inform Martin Castro (312) 401-9328)
Brandon Road Pool	• Ruby Street Launch (767 N Bluff St., Joliet, IL 60435) • Joliet Boat Store Launch (724 Railroad St., Joliet, IL 60436)
Dresden Island Pool	• Big Basin Marina under the I-55 Bridge (24045 W Front St., Channahon, IL 60410)
Marseilles Pool	• William G. Stratton State Park Launch (Griggs Dr., Morris, IL 60450) • LST Memorial Public Boat Launch (E. South St., Seneca, IL 61360) • Illini State Park Launch (2660 E. 2350th Rd., Marseilles, IL 61341)
Starved Rock Pool	• Allen Park Launch off Route 71 (400 Courtney St., Ottawa, IL 61350) • Starved Rock Marina off Dee Bennett Road (1130 N 27th Rd., Ottawa, IL 61350)

Schedule:

Sampling will occur from February to December in 2021. The tentative distribution of 2021 contracted commercial fishers' effort is shown in Table 2.

Deliverables:

Results of each sampling event (e.g., each week) will be reported in monthly sampling summaries. Data will also be summarized in an annual interim summary report and project plans updated for annual revisions of the Monitoring and Response Plan.

Contracted Commercial Fishing Below the Electric Dispersal Barrier System

Table 2. *Tentative schedule for 2020 contract fishing below the Electric Dispersal Barrier System.* Locations: LP=Lockport, BR=Brandon Road, DI=Dresden Island, MR=Marseilles, SR=Starved Rock.*

Week of	Location	Week of	Location	Week of	Location
22-Feb**	MR	31-May	MR, SR	8-Nov	MR, SR
1-Mar**	MR	21-Jun	LP, BR, DI, MR, SR	15-Nov	LP, BR, DI, MR, SR
8-Mar	MR, SR	28-Jun	LP, BR, DI	29-Nov	MR, SR
15-Mar	MR, SR	19-Jul	LP, BR, DI	6-Dec**	LP, BR, DI, MR, SR
22-Mar	LP, BR, DI, MR, SR	2-Aug	LP, BR, DI	13-Dec**	MR, SR
29-Mar	MR, SR	23-Aug	LP, BR, DI		
5-Apr	LP, BR, DI	30-Aug	MR, SR		
12-Apr	MR, SR	6-Sep	LP, BR, DI, MR, SR		
19-Apr	MR, SR	27-Sept	LP, BR, DI		
26-Apr	LP, BR, DI	4-Oct	MR, SR		
3-May	MR, SR	11-Oct	MR, SR		
10-May	MR, SR	18-Oct	DR		
17-May	LP, BR, DI, MR, SR	25-Oct	LP, BR, DI, MR, SR		
24-May	LP, BR, DI	1-Nov	MR, SR		

*Additional netting may occur during weeks not listed on this table.
**Weather permitting.

Asian Carp Population Modeling to Support an Adaptive Management Framework

Participating Agencies: U.S. Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office; U.S. Geological Survey Upper Midwest Environmental Sciences Center (leads agencies); Illinois Natural History Survey, Illinois Deprtment of Natural Resources, Southern Illinois University, U.S. Geological Survey Columbia Environmental Research Center (collaborating agencies)

Location: Alton, La Grange, Peoria, Starved Rock, Marseilles, and Dresden Island pools, Illinois River.

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

Introduction and Need:

The goal of this project is to develop objective data-driven tools in support of the adaptive management process and invasive carp control efforts. To accomplish this goal, this project will continue ongoing efforts to develop and implement the Spatially Explicit Asian carp Population (SEACarP) model and develop novel tools to address emerging management questions.

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

Development of the SEACarP model is ongoing. Two limitations of the SEACarP model are tied to the underlying movement model, which describes the rates at which fish move between pools. First, the coverage of the current movement model is limited to the Illinois River. Consequently, the SEACarP model treats the Illinois River as a closed system, despite considerable fish movement between the Illinois River and upper Mississippi River basins.

Second, due to other limitations associated with movement estimates, model-based mortality recommendations are provided on a relatively course spatial resolution (i.e,. pools above versus below Starved Rock Lock and Dam) rather than on an individual pool level. To address these limitations, this project will coordinate with the Monitoring and Response Work Group (MRWG) Telemetry sub-workgroup to deliver an updated movement model with greater spatial coverage and finer spatial resolution. In addition, this project would recode the SEACarP model as needed to accept the updated movement model.

Development of an invasive carp stock-recruitment relationship represents a third area of ongoing model development. The stock-recruitment relationship is fundamental to the management of invasive carp in the Illinois River waterway, because it determines how recruitment rates will respond to control-induced reductions in adult biomass. Although the SEACarP model was originally intended to include an invasive carp-specific stock-recruit relationship, there is no currently available stock-recruitment model that is compatible with the SEACarP model. In response to this knowledge gap, impacts of the stock-recruit relationship on SEACarP model predictions are assessed using sensitivity analysis. FY 2021 activities would address this limitation by leveraging data from the MRWG hydroacoustics workgroup as well as age-structure data from field collections to develop an invasive carp stock-recruitment relationship.

A fourth area of ongoing development involves using the SEACarP model to estimate the rate at which individuals in a given pool contribute to pools located above Starved Rock Lock and Dam. The goal of this per capita contribution modeling effort is to provide assist managers by providing a tool that would prioritize harvest locations (i.e., pools) as a function of invasive carp densities and contracted commercial catch rates.

In addition to ongoing development of the SEACarP model, this project will conduct a feasibility study to determine how successfully statistical catch-at-age or statistical catch-at-length models could be completed using currently available Illinois River data. Statistical catch at age or length modeling will provide insights into the contract commercial harvest program, by estimating fishing mortality rates. Lastly, this project will prepare a final report and manuscript based on results from the current version of the SEACarP model.

Objectives:

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

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

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

(4) Complete Statistical Catch at Length model feasibility study to determine how successfully statistical catch-at-age or statistical catch-at-length models could be completed using currently available Illinois River data.

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

Status:

This is a continuing project from 2020.

- Updated results were presented at the annual MRWG meeting during January 2021 and 2019 Interim Summary Report (ISR) submission.
- Model anlaysis, including control scenarios and sensitivty analysis has been conducted to examine the effects of different control scenarios and parameter uncertainty and model assumptions.
- Progress on communicating the model in the peer reviewed literature including transitioning code into an R package for easier dissementation, indpendent model review by external researchers, update meeting with co-authors including modeling experts and MRWG representatives.
- Updated demographics based on most recent data (over 40,000 individual fish); manuscript under revisions (Erickson et al. *under revision).*
- Coordinated with MRWG sub-workgroups (i.e., Telemetry, Monitoring) to address identified data needs and knowledge gaps.

Methods:

Details about the SEACarP model have been described in previous Monitoring and Response Plans (MRP) and ISRs (Asian Carp Regional Coordinating Committee [ACRCC] 2018). In summary, the SEACarP model is a forecasting simulation model that tracks the sizes and relative numbers of invasive carp in each of the lower six pools of the Illinois River (Figure 1) over a 25-year time period under different control scenarios. Control scenarios are user-specified and include the location (i.e., pool) and magnitude of increased mortality (e.g., harvest, piscicide) and the effectiveness (i.e., percent reduction relative to baseline) of potential upstream movement deterrent(s) at Starved Rock, Marseilles, and Dresden Island locks and dams. Invasive carp population dynamics are modeled in annual time steps using embedded sub-models that describe survival, growth, pool to pool movement, and reproduction. Embedded sub-models were parameterized using empirical results from published literature (i.e., Coulter et al. 2018, Erickson et al. 2020 *under revision*).

Each simulated control scenario is repeated 1,000 times to account for uncertainty in parameter estimates. For each iteration, new sets of growth, condition (i.e., length-weight), size at maturity, and pool to pool movement coefficients are randomly selected from a set of possible values (i.e., posterior distributions from Coulter et al. 2018, Erickson et al. 2020 *under revision*). The performance of different control scenarios is then evaluated based on projected changes in total abundance and biomass through time relative to the no action scenario (i.e., no additional harvest, baseline movement).

Objective one of our project is to subject the SEACarP model to peer-review to improve current modeling efforts and get recommendations concerning future modeling work aimed at achieving ACRCC invasive carp management goals. To accomplish this objective, we collected critical feedback from three separate quantitative researchers using a "friendly review" process and engaged with MRWG representatives and quantitative experts that contributed to model development to gather feedback for purposes of manuscript and report preparation. Our next step is to prepare manuscript for publication in a peer reviewed journal using results from sensitivity analyses and population control (i.e., additive mortality, upstream movement deterrence) simulations.

Objectives two and three of this project will address critical limitations in our understanding of invasive carp populations dynamics, including development of an invasive carp-specific stock recruitment model (Objective 2) and support for movement modeling (Objective 3). In order to parameterize a stock-recruitment relationship, this project will use age structure data to develop age-length keys (ALKs, Ailloud et al. 2019). Next, ALKs will bepaired with existing hydroacoustic data to quantify recruitment (fall age-1 abundance) and spawning stock biomass. Lastly, these metrics will be used to parameterize a stock recruitment model (Ricker 1954). To address limitations associated with the movement model, this project will coordinate with the MRWG Telemetry sub-workgroup to help parameterize an updated movement model with greater spatial coverage and finer spatial resolution. In addition, this project will provide data or technical support for incorporating density and size or maturity status effects on invasive carp movement rates.

Objective four of our project is to implement Statistical Catch at Age (Syslo et al. 2020) or Statistical Catch at Length (SCAA/L) (Sullivan 1999) models to estimate yield or effort required to achieve a given mortality benchmark. Data inputs for SCAA/Ls are extensive, and it is unclear whether existing sampling and harvest data, which would be used to parametrize the model are suitable and available in sufficient quantity to perform a robust analysis. Consequently, we will conduct a feasibility study to determine how successfully SCAA/L modeling could be completed given current data availability. This will be accomplished by coordinating with MRWG co-chairs and sub-workgroup leads. The first step will be to compile sampling and harvest data from all available sources, or alternatively, develop a suitable data summary (e.g., total catch, gear type and specifications, effort). Next, we will engage with quantitative experts that have experience developing and using SCAA/L models to implement a feasibility study. Results from the feasibility study will include:

- Comprehensive data set or data summary describing available data inputs for SCAA/L model analysis.
- Feasibility determination based on expert opinion and existing data.

- Limitations associated with current data availability.
- Data collection recommendations designed to address limitations of current data availability.

Lastly, objective 5 of this project is to conduct preliminary parametrization of a model that will estimate the per capita contribution of size classes and pools to the Dresden Island Pool population (e.g., Wiederholt et al. 2018). Our 2021 efforts will focus on model development, proof of concept, and parameterization.

Schedule:

- July 2021: Updated pool-specific growth, length-weight, and size at maturity estimates
- January – September 2021: Stock recruit data set for the lower three pools of the Illinois River derived from age structure and hydroacoustics data (2012 – present).
- March – April 2021: Data compilation for SCAA/L model feasibility study
- April – July 2021: Coordinate with experts to complete feasibility study
- January – September 2021: Preliminary per capita contribution modeling scoping and model parameterization
- February – September 2021: SEACarP model manuscript/report preparation and submission

Deliverables:

- Comprehensive report and corresponding manuscript describing the SEACarp model and model findings.
- Stock recruit data set for the lower three pools of the Illinois River derived from age structure and hydroacoustics data (2012 – present).
- Per capita contribution modeling scoping and model parameterization.
- Feasibility study for potential Statistical Catch at Age or Catch at Length modeling.
- Updated pool-specific growth, length-weight, and size at maturity estimates.

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

Lead Agency: U.S. Fish and Wildlife Service (USFWS) - Carterville Fish and Wildlife Conservation Office, Wilmington Substation, Wilmington, IL

Location: Peoria and Starved Rock pools within the Illinois Waterway

Pools Involved: Starved Rock and Peoria

Introduction:

The Spatially Explicit Asian Carp Population (SEACarP) model was developed as a means of assessing invasive carp population status in the Illinois Waterway (IWW). Movement is the backbone of the SEACarP model and is the primary source of information about how researchers expect the population to respond to management strategies. Therefore, the model functions as an important tool that can be used by fisheries managers to inform harvest and control of adult invasive carp (Silver Carp and Bighead Carp) in the IWW. Because harvest effects such as changes in fish density and size distributions likely impact movement and will thus influence our ability to predict population responses, continued monitoring of invasive carp movement in the IWW is necessary. Furthermore, the telemetry data collected in support of SEACarP complements telemetry data being collected throughout the IWW describing inter-pool transfer of adult invasive carp and is used to parameterize the transition probability component of the SEACarP model. This research provides an improved understanding of invasive carp movement in the IWW and its effects on population dynamics. An accurate understanding of invasive carp population status is critical for assessing invasive carp invasion risk to the Great Lakes. Data gained from tagging additional invasive carp will improve the accuracy of the model.

Objectives:

(1) Quantify movement frequency and distance by invasive carp in IWW.

(2) Refine movement across locks and dams.

(3) Address limitations with regards to the movement aspect of the SEACarP model by tagging sexually immature fish as well as adults to increase accuracy and precision of pool-to-pool estimates of movement.

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

Status:

This project was started in 2018 and will continue in 2021. During 2018, 130 invasive carp were tagged throughout Peoria Pool. Locations of released fish were distributed throughout the pool as was discussed with the Monitoring and Response Work Group (MRWG) telemetry workgroup. The total length of tagged fishes ranged from 391-635 mm. During 2019, 161 Silver Carp were tagged throughout Peoria Pool. The total lengths of tagged fish ranged from 374 – 776 mm. All fish were collected using standard boat electrofishing and an electrified dozer trawl. In addition, fin clips were taken from each tagged fish and are being analyzed for hybridization. No invasive carp were tagged in 2020 due to COVID-19 working restrictions.

Methods:

In 2021, USFWS staff will tag an additional 150 invasive carp with total lengths between 300 – 500 mm with Vemco V-9 or V-13 tags which are on the 69 kHz frequency. This will give biologists a better understanding of large-scale movement of these smaller individuals that are assumed to move at the same rates as larger, sexually mature individuals within the population model. This large-scale tagging of adult and immature invasive carp will continue to provide additional information for the model to better estimate current levels of exploitation and to bolster estimates of large-scale pool-to-pool movement.

Invasive carp will be captured using boat electrofishing and electrified dozer trawl from the Illinois River in Peoria and Starved Rock pools. Immediately after capture, fish will be held for no more than 1 hour in an aerated 60 gallon holding tank covered with ¼-inch mesh. In order to maintain as close to sterile conditions as possible, one crew member as the dedicated “surgeon” will wear gloves and only handle fish for the process of the incision, tag implantation, and suturing. Another crew member will be responsible for weighing and measuring the fish and recording data. All surgical tools, fish tags, and sutures will be soaked in 70% isopropyl alcohol between surgeries. Only active, healthy looking fish will be selected for surgery. Each fish will be measured for total length (mm) and weight (g), assigned a number, then placed into a foam board with a fish-shaped cut out for surgery. A surgical rubber hose connected to a slow siphon of fresh aerated river water will be placed in the mouth of fish to allow them to breathe during surgery. A wet microfiber towel will be placed over the head of the fish to keep them calm.

The surgery site will be gently washed with several drops of betadine prior to making an incision. Using a #12 hook blade scalpel, a 1 cm (Vemco -5 acoustic tags) or 2.5 cm (Vemco- 9 or 13 acoustic tags) incision will be made in the left ventral side of the body, just behind the pelvic fins, anterior to the anus, taking care not to damage the intestines. Next, the tag will be inserted through the incision and gently pushed towards the anterior of the body cavity. At least two non-absorbable nylon Oasis Brand (Mettawa, Illinois) sutures will be used to close the incision site for acoustic tags. Immediately following suture closure, the incision site will be washed with betadine a second time and rinsed using deionized water. The fish will then be placed into an aerated, salted holding tank for recovery. Once fish equilibrium has been re-established and tags are tested, fish will be returned to the river in proximity to their capture location. Total holding time for fish will generally be less than 2 hours.

Fish will be tracked using the current acoustic array within the IWW. Additional receivers will be placed in areas with reduced coverage and the MRWG Telemetry Work Group will be consulted prior to deployment.

For more information on the SEACarP model please refer to the SEACarP Modeling monitoring and response plan.

Schedule:

- May – June 2021: Gear preparation, planning field work, crew scheduling
- July – November 2021: Fish tagging, range testing, active tracking, data download, gear maintenance and relocations
- November – December 2021: Receiver removal, final data downloads
- December 2021 – January 2021: Data analyses, prepare report and presentation

Deliverables:

Results from this project will be used to support the SEAcarP model. Data will be analyzed and results summarized into a MWRG summary report/presentation for the winter of 2021-2022.

Asian Carp Demographics

Participating Agencies: U.S. Fish and Wildlife Service (USFWS)-Columbia Fish and Wildlife Conservation Office (Columbia FWCO) (lead); Illinois Natural History Survey (INHS) (collaborating agency)

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

Introduction and Need:

Demographic data are commonly used to test for exploitation effects such as skewed sex ratios and increased growth and condition. In addition, demographic data can be used to parameterize population models used to inform management (e.g., Spatially Explicit Asian Carp Population [SEACarP] model). This project will collect demographic data including abundance, size, age, and sex structure, growth, and size at maturity data. In addition, this project will complete an age validation study designed to support development of a standard operating procedure for aging bigheaded carp (Silver Carp and Bighead Carp).

The Multi-Agency Monitoring Program, which was introduced during 2019 provides information including demographic data to inform decisions concerning the management and control of invasive carp in the Illinois Waterway (IWW). After only 2 years of implementation it remains unclear if collections solely through the Multi-Agency Monitoring Program will reach target sample sizes required for robust data analysis. Consequently, the proposed 2021 work described herein is a continuation of previous efforts and includes field collections, laboratory processing, and data analysis. Laboratory processing will include analysis of aging structures collected by the Multi-Agency Monitoring Program. Project results will supplement relative abundance, length-weight, sex structure, and size at age data (i.e., growth) and size at maturity data collected through the Multi-Agency Monitoring Program and other projects supported by the Great Lakes Restoration Initiative (GLRI).

In addition to the previously described field efforts, this project will explore the possibility of an age validation study using laboratory analyses. Aging errors can have considerable impacts on metrics commonly used to manage fish populations, such as age-based growth and mortality estimates. Reducing aging errors would ameliorate data limitations associated with catch-curve analyses designed to estimate invasive carp morality in the Upper IWW. In addition, this effort would reduce uncertainty in model predictions (i.e., SEACarP model). Reducing uncertainty in model predictions is worthwhile because it corresponds to increased confidence with respect to how bigheaded carps would respond to different control scenarios. To accomplish this objective, the USFWS-Columbia FWCO will collaborate with INHS to process structures from previous field collections and complete data analysis and report writing.

Structures will be evaluated by comparing estimated ages to inferred ages of fish corresponding to strong year classes as determined by Long Term River Monitoring (LTRM) length frequency data.

Objectives:

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

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

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

(4) Collaborate with Multi-Agency Monitoring Program to reduce overlap and increase efficient data collection to update parameter estimates associated with the SEACarP model.

Status:

This is a continuing project from 2018-2020. Following are some highlights of this project and relationships to other GLRI-funded projects.

- In fall 2020, a standardized Silver Carp assessment was implemented in the lower three pools of the Illinois River (Alton, La Grange, and Peoria) to collect demographic data. Collections included 1,307 Silver Carp; total effort was 149 5-minute trawls or ~12.5 h of active sampling; 199 Silver Carp were aged. This effort was limited to 3 pools and only fall sampling in 2020 due to COVID-19 restrictions.
- Completed gear evaluation study to determine sample size needed to assess invasive carp populations.
- Trained with U.S. Geological Survey - Columbia Environmental Research Center staff to correctly assign maturity status of small bodied invasive carp.
- Collected aging structures from the lower six pools of the Illinois River during fall 2019 sampling.
- Coordinated with the Multi-Agency Monitoring Program leads – supported efforts to expand Multi-Agency Monitoriong biolgical data collections using lessons learned from two years of implementing the invasive carp demographics project.

Asian Carp Demographics

- Coordinated with Illinois Department of Natural Resources and Monitoring and Response Work Group (MRWG) co-chairs to develop a general approach for evaluating aging structures.

Methods:

The USFWS Columbia FWCO will collect fisheries-independent data including age, size, and sex structure, length at maturity, and relative abundance during spring (May – June) and fall (September – November) in each of the lower six pools of the Illinois River using a random design stratified by habitat type (i.e., backwaters, island side channels, main-channel borders; Figure 1). Habitat classifications are based on aquatic area designations developed by the Habitat Needs Assessment II project (U.S. Army Corps of Engineers [USACE] 2017). Prior to each sampling event, collection sites will be randomly selected from a Geographic Information System that includes habitat data and an indexed 50-m by 50-m grid. Collection sites will be sampled by conducting 5-minute trawls at 4.8 kilometers per hour (calculated by GPS tracking) using electrified dozer trawl (Hammen et al. 2019). Catch rates from 2018 and 2019 will be used to determine pool-specific sample sizes based on criteria from Koch et al. (2014). Maturity status and sex data will be collected during spring sampling in Alton, La Grange, and Peoria pools using macroscopic observations of the gonads. Fish length and weight will be measured for all spring- and fall-caught Bighead Carp and Silver carp. Subsamples consisting of 10 male and 10 female (Coggins et al. 2013) fall-caught Silver Carp per 50-mm total length (TL) class will be retained for laboratory analysis (i.e., age, sex). All non-bigheaded carp captures will be identified to species, counted, and measured to the nearest millimeter.

Asian Carp Demographics

Figure 1. *The six lowest pools of the Illinois River, Illinois.*

Schedule:

February – April 2021:

- Coordinate with INHS to process aging structures and complete data analysis to provide preferred aging structure recommendations.
- Evaluation of structures for precision and accuracy
- Gear preparation, logistics, planning, and scheduling

May – June 2021:

- Spring field sampling and data entry

July – August 2021:

- Data entry, preliminary data analysis and protocol evaluation

September – November 2021:

- Fall field sampling and data entry, coordination with existing invasive carp sampling programs

December 2021–January 2022

- Data analysis, laboratory aging, annual report

Asian Carp Demographics

Deliverables:

The invasive carp demographics project will provide underlying demographic data (i.e., age, length, and sex structure, length at maturity) needed to parameterize decision support tools such as the SEACarP model and test for control effects (e.g., spatial or temporal demographic effects associated with control actions). This project will also provide recommendations derived from previously collected data concerning standard methods and preferred aging structures for Bigheaded carp. Lastly, this project will develop a standardized invasive carp sampling protocol that is directly transferable to other large river systems such as the Missouri and Mississippi river systems. An annual report and presentation summarizing sampling results will be provided to the MRWG, agency partners, and any other interested parties. Finally, a report or manuscript will be produced, characterizing the age, size, and sex structure of the Illinois River bigheaded carp.

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Experimental Field Testing of Longitudinal Bubbler Arrays for Barge Entrainment Mitigation

Participating Agencies: U.S. Fish and Wildlife Service (USFWS)-Carterville Fish and Wildlife Conservation Office, Wilmington Substation, Wilmington, IL

Location: Juvenile invasive carp will be captured from Peoria Pool and transported to the Great Rivers Research and Education Center (Alton, IL) where they will be held in outdoor fish raceways.

Pools Involved: Peoria

Introduction and Need:

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

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

In 2022, USFWS collaborating with USACE and U.S. Geological Survey (USGS) plan to carry out a full-size barge study to test the efficacy of longitudinal bubble array at mitigating entrainment of invasive carp by commercial barge tows. In order to conduct this test, a minimum of 18,000 juvenile invasive carp approximately 40-50 mm total length (TL) will be needed to complete all the experimental trials. Obtaining this quantity of appropriately-sized fishes via direct field capture, at the time of the study, is not feasible. Therefore, invasive carp for the experimental trials will be collected in Peoria Pool as post-larva (8-10mm TL) and transported to the Great Rivers Research and Education Center where they will be "grown out" in fish raceways until the experiment in August/September when the fishes will be approximately 40-50mm TL.

In order to properly prepare for this large project, we plan to conduct a pilot study in 2021 to investigate techniques and develop protocols for capturing and subsequently rearing the necessary number of juvenile invasive carp in captivity.

Objectives:

(1) Capture approximately 50,000 post-larva (8-10 mm TL) invasive carp in Peoria Pool and transport them to the Great Rivers Research and Education Center with minimal mortality.

(2) Grow the captive invasive carp in captivity until August/September when the fishes are approximately 40-50 mm TL.

(3) Calculate mortality loss for the duration of the study to enable estimation of expected loss during the 2022 field study.

Status:

This project is a continuation of the 2020 action item T-6 during which USACE conducted a 1:16-scale laboratory experiment to evaluate the effectiveness of air bubble arrays at removing entrained fish surrogates from barge junction gaps. In 2021, we will conduct a pilot study that seeks to evaluate the feasibility of raising wild-caught invasive carp in captivity. Moreover, USFWS, USACE, and USGS will continue to collaborate on barge entrainment mitigation technology and plan for a full-scale barge entrainment mitigation study in 2022.

Methods:

Small post-larval (8-10 mm TL) invasive carp will be captured from Peoria Pool in May and June 2021 using dip nets, beach seines, and mini-fyke nets. Captured invasive carp will be transported in an oxygen-aerated 200-gallon water tank to the Great Rivers Research and Education Center in Alton, Illinois. Upon arrival to Great Rivers Research and Education Center, the invasive carp will be transferred to mesh live cars that are suspended within the outdoor fish raceways, allowing for effective transfer while reducing the likelihood of fish escape. Raceways will be configured as flow-through systems with fresh Mississippi River water. Fish will be transferred between live cars monthly until the conclusion of the study in September. Transferring fishes between live cars will reduce algae buildup and enable for tracking fish loss throughout the study. All invasive carp will be euthanized at the conclusion of the study. The results of this study will provide a mortality estimate that will enable estimation of the necessary number of invasive carp to capture for the 2022 barge field trials.

2021 Schedule:

January – May 2021:

- Planning, crew scheduling, and equipment preparation

May – June 2021:

- Fish sampling in Peoria Pool followed by transport to Great Rivers Research and Education Center

June – September 2021:

- Grow invasive carp in captivity while monitoring mortality

October – December 2021:

- Prepare report on outcome of study

Deliverables:

Final project report and presentation to the Monitoring and Response Work Group and the Asian Carp Regional Coordinating Committee.

Alternative Pathway Surveillance in Illinois – Law Enforcement

Brandon Fehrenbacher & Colin Vaughan
Illinois Department of Natural Resources

Participating Agencies: Illinois Department of Natural Resources (IDNR, lead)

Location: Surveillance and enforcement details will be conducted throughout Illinois; however, complex investigations may require a multi-agency response which will result in enforcement actions in other jurisdictions.

Pools Involved: Not applicable

Introduction and Need:

The IDNR Invasive Species Unit (ISU) was created in 2012 as a special law enforcement component to the overall Asian carp project. It consists of two Conservation Police Officers fully dedicated to searching for illegal activities within the commercial fishing, aquaculture, transportation, bait, pet, aquarium, and live fish market industries. The ISU focuses its resources on the likely pathways Asian carp could spread by human means. The ISU has made significant arrests in nearly every industry investigated, proving human activities are a high priority risk factor which cannot be ignored.

It is essential to designate personnel within a law enforcement agency to specialized enforcement needs such as invasive species enforcement. This ensures adequate training, experience and time will be spent addressing specific areas of concern. It also provides a direct line of communication for agency personnel, the public and outside agencies to contact for assistance or information. The ISU also facilitates a multi-jurisdictional approach to the long-term protection of the Great Lakes Basin by increasing communication and enforcement efforts amongst law enforcement personnel and other stake holders.

Objectives:

In order to detect, dissuade, prevent and/or apprehend those involved with activities that could spread aquatic invasive species we propose to:

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

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

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

(4) Respond to any requests, complaints, events or suspicious activities that could threaten the Asian carp project.

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

Status:

This project is on-going and has been extended into 2021. The ISU is actively pursuing leads and conducting relevant investigations.

Methods:

The ISU utilizes law enforcement databases, internet search tools, surveillance, inspections and street-level intelligence sources to successfully meet objectives. Investigations into illegal activities associated with any aquatic invasive species will be conducted as they are encountered. The ISU will build upon any newly developed information to guide future project planning.

Schedule:

Surveillance and enforcement activities will take place at yet to be determined times and locations throughout the year.

Deliverables:

Results of inspections and enforcement activities will be summarized and reported to the Monitoring and Response Work Group, as they become available. Data will be summarized for an annual interim report and project plans updated for annual revisions of the Monitoring and Response Plan.

Asian Carp Enhanced Contract Removal Program

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

Location: The Enhanced Contract Removal Program evaluates actions throughout the Illinois River and Illinois Waterway (IWW). Enhanced removal efforts are currently focused in Peoria Pool.

Pools Involved: Peoria

Introduction and Need:

The Asian Carp Regional Coordinating Committee and this Monitoring and Response Plan recognize the value of increased harvest of Asian carp in the Illinois River informed by current fishery stock assessment data. Modeling from Southern Illinois University and U.S. Fish and Wildlife Service have provided insights recommending that removal from downstream reaches can heighten protection of the Great Lakes by preventing fish population growth in upstream reaches.

Objectives:

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

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

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

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

Status:

Enhanced removal efforts which began in September of 2019 focused in the Peoria Pool. As of August 2020, nearly 2 million pounds have been removed under this program. Removal from the lower Illinois River has been recommended and to that end Peoria Pool has been targeted to begin these efforts. The use of targeted contract fishing in the Illinois River is a key component of the multipronged strategy. In 2019 and early 2020, 26 contracts were entered into with

Illinois-licensed commercial fishing. While it has been acknowledged that reducing abundance of Asian carp in the three lower IWW pools would be beneficial, initial contracts target Peoria Pool, with expectation that LaGrange and Alton pools will follow as fish landings and data evaluation suggest.

Enhanced Contract Removal Program

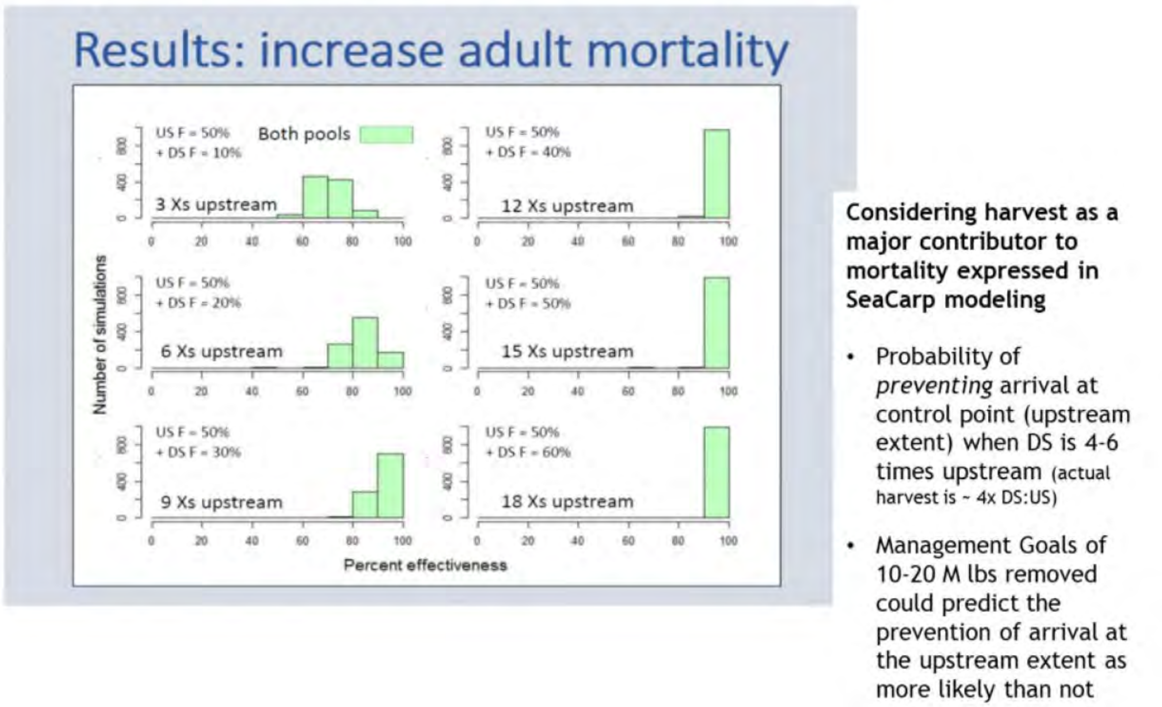


Figure 1: *Effects of increased harvest on likelihood of Asian carp migration; output from SEAcarP model*

RESPONSE PROJECTS

Upper Illinois Waterway Contingency Response Plan

Participating agencies: Illinois Department of Natural Resources **(**IDNR), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE), U.S. Geological Survey (USGS), Illinois Natural History Survey (INHS), U.S. Environmental Protection Agency (USEPA), Great Lakes Fishery Commission (GLFC), Metropolitan Water Reclamation District of Greater Chicago (MWRDGC)

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

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

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

Communication:
Communicating captures of various Asian carp life stages is a critical component of the CRP. While it is recognized that several monitoring strategies require in-depth analysis in both the field and laboratory setting, it is critical that potential changes are immediately forwarded to the MRWG Co-Chairs. Quick and efficient communication allows for appropriate dissemination and rapid implementation of a response action if needed. Not only should new occurrences of Asian carp of any life stage be communicated to the Co-Chairs, but potential population changes in areas where Asian carp are known, as well as rare occurrences of specific life stages within the Upper Illinois River should be reported. It is equally important to recognize and establish a

baseline of understanding as to where all life stages of Asian carp and their life stages have been captured, but it is important to prevent that from convoluting what information needs to be communicated to the Co-Chairs. For example, while Asian Carp less than 6 inches have been captured in Starved Rock Pool, no Asian Carp less than 6 inches have been captured in the pool since2015. Even though those fish were captured previously, it is a rare occurrence and any additional capture of fish less than 6 inches should be reported. In general, it is best to be conservative in the information communicated to the MRWG Co-Chairs and if you are not sure, send the data to the Co-Chairs for consideration.

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

Background:

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

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

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

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

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

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

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

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

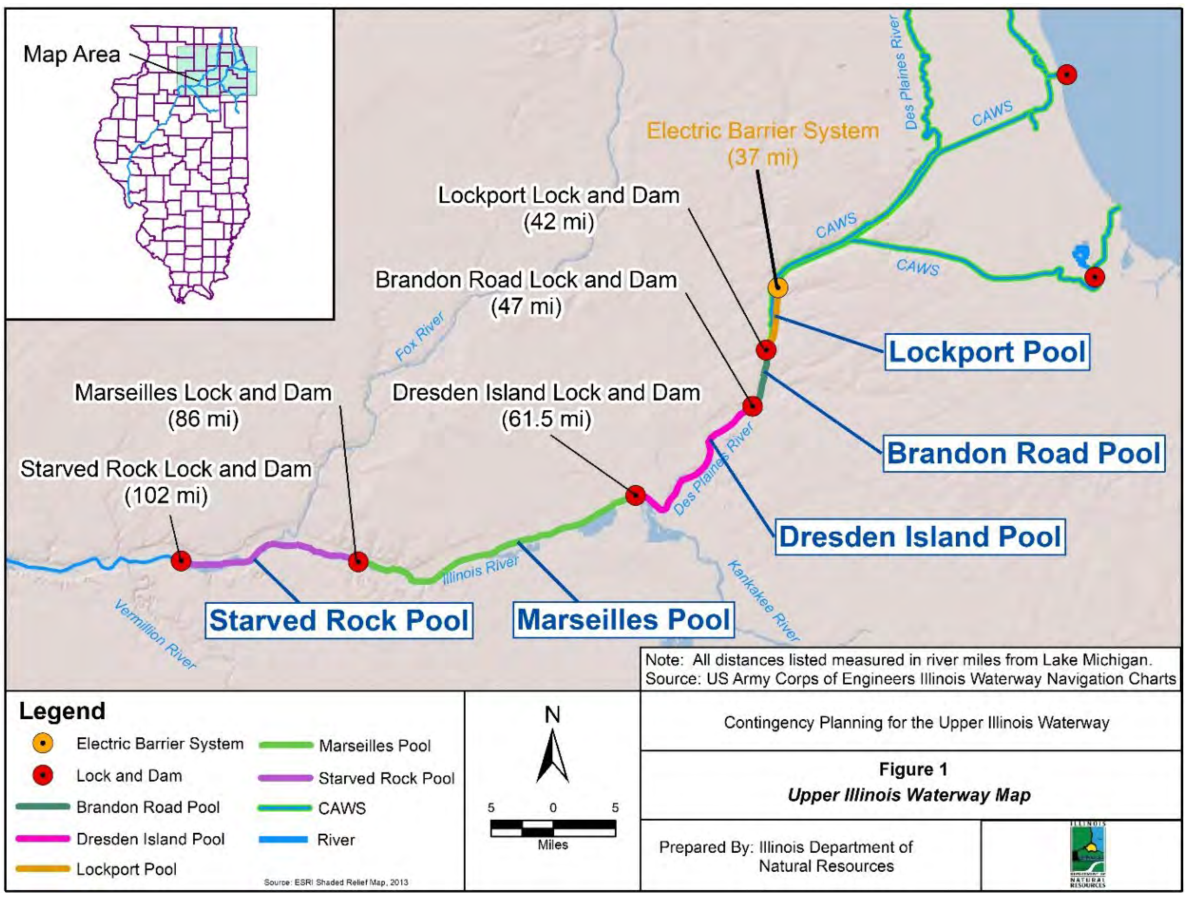


Figure 1. *Illinois Waterway Map and Profile. Note: For the purposes of this map, the Lockport Pool is only highlighted up to the electric barrier system.*

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

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

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

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

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

with other regulatory agencies in the CSSC or other developing technologies when it is determined the need is prudent.

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

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

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

- **Lake Michigan:** No established Asian carp population
- **Chicago Area Waterway System (CAWS):** No established Asian carp population
- **Lockport Pool:** No established Asian carp population
- **Brandon Road Pool:** No established Asian carp population
- **Dresden Island Pool:** Adult Silver Carp and Bighead Carp population front. Larval Asian carp observed for the first time in 2015 and have not been observed since. No Black Carp have been captured

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

Planning Assumptions:

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

Situation Assumptions

- Response actions will be selected based on the waterway conditions, and the time and geographic location of Asian carp detection, and other factors.
- Response actions will be located within the designated area of the upper IWW described in the CRP (from Starved Rock Pool to the Lockport Pool, as depicted in Figure 1).
- For planning purposes, under this CRP, Asian carp primarily refers to Bighead Carp and Silver Carp, however, may also serve to inform potential response actions in the event a Black Carp is captured above Starved Rock Lock and Dam.

Command, Control, and Coordination Assumptions

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

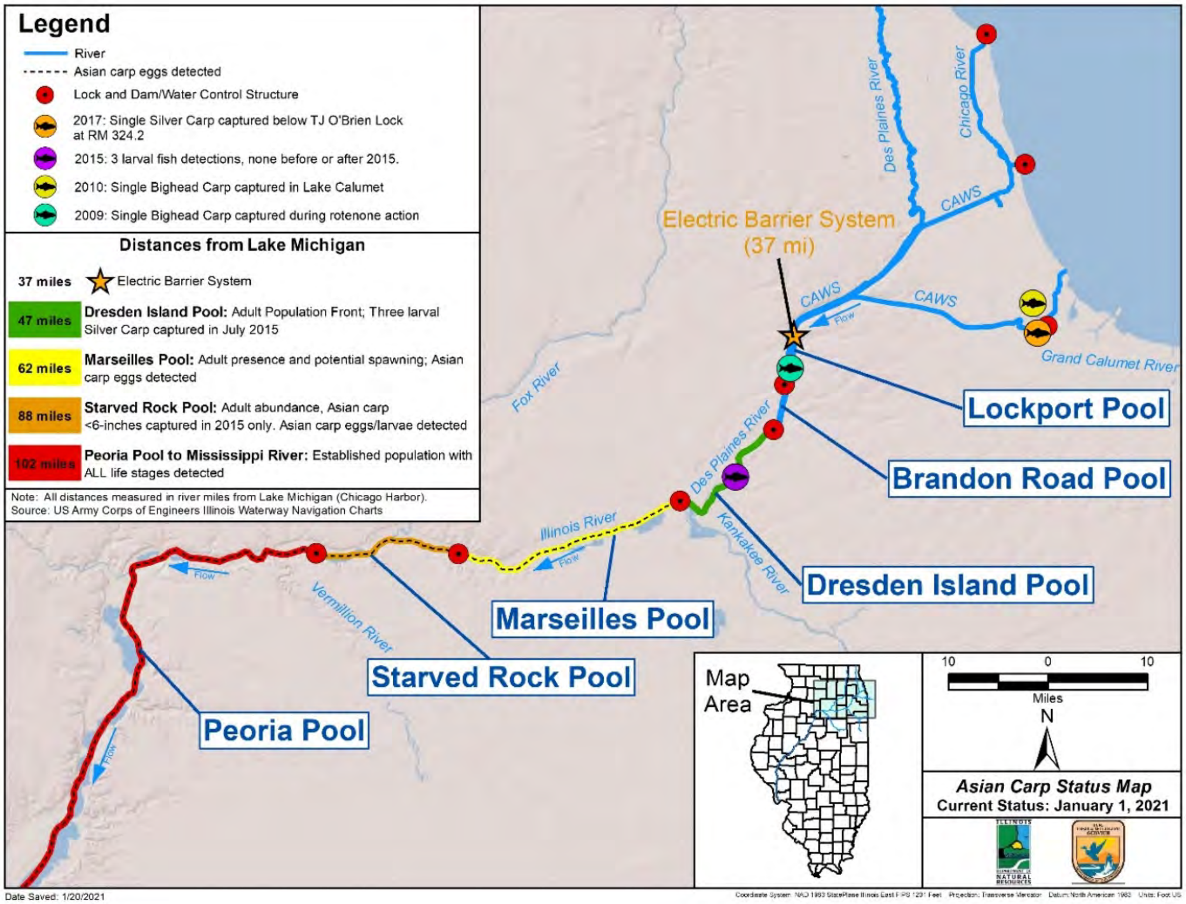


Figure 2. *Asian carp Status Map. Current Status: January 1, 2021.*
[1] *Asian Carp larvae (pre-gas bladder inflation) were captured in the Starved Rock Pool for the first time in 2020. The furthest upstream post-gas bladder inflation larvae (outside of the 3 captured in Dresden Island in 2015) have been captured was at river mile 197 near Henry, IL.*
[2] *Black Carp over 6 inches have been captured in Peoria Pool.*

Logistics and Resources Assumptions

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

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

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

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

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

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

Abundance:
Increased abundance of any life stage signifies a change in the population structure at a given location and increases concern of invasion risk. Generally, larval Asian carp have not been found in the upper IWW. Finding Asian carp larvae would represent a potential change in the dynamics

of the population in the upper IWW. Responses related to the detection of larval Asian carp would likely be directed at other adult or juvenile life stages of Asian carp.

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

Additional Considerations for Actions and Decision-Making Process:
This process will include a recommended set of response actions for decision makers to consider when a change to the baseline condition is identified. Changes may include, but are not limited to, changes in fish population abundance, life stage presence, or new geographical positions in upstream and/or downstream pools, the ongoing rate of change in Asian carp population characteristics, season and/or water temperature, the habitat where fish are sighted or collected, flow conditions, the amount of available data, and whether multiple lines of evidence exist to support changing conditions. The validity of evidence that a response trigger has been met will also be taken into consideration. Evidence of Asian carp presence in new locations within the IWW may come from physical captures, confirmed sightings by trained biologists, or via detections of telemetered specimens on active or passive receivers. These observations may be reported by any activity within the MRP or by external work conducted by other groups. The MRWG will evaluate the validity of each reported observation and discuss whether an actionable trigger has been met. The status of populations is continuously monitored by the MRWG and communication of important findings occurs immediately. Consensus on the current population status on a pool-by-pool basis is made annually with a holistic review of data collected by all MRWG agencies. Quarterly meetings of the MRWG serve as a checkpoint to discuss potential population changes through each sampling season as new data is collected. The group recognized that identified response options are recommendations only. An action(s) could be more or less intense based upon the nature (e.g. magnitude/life stage) and location (e.g. close or far from Lake Michigan/Electric Barrier) of the change. One example scenario is illustrated in Attachment 1. The scenario is based on a change in conditions in Brandon Road Pool and is one example of when a contingency plan is called into action. Attachment 2 provides the decision-making process and flow of likely activities in such an event. This scenario and decision process illustrates what could occur should a change be identified from this Decision Support Framework.

Command, Control, and Coordination

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

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

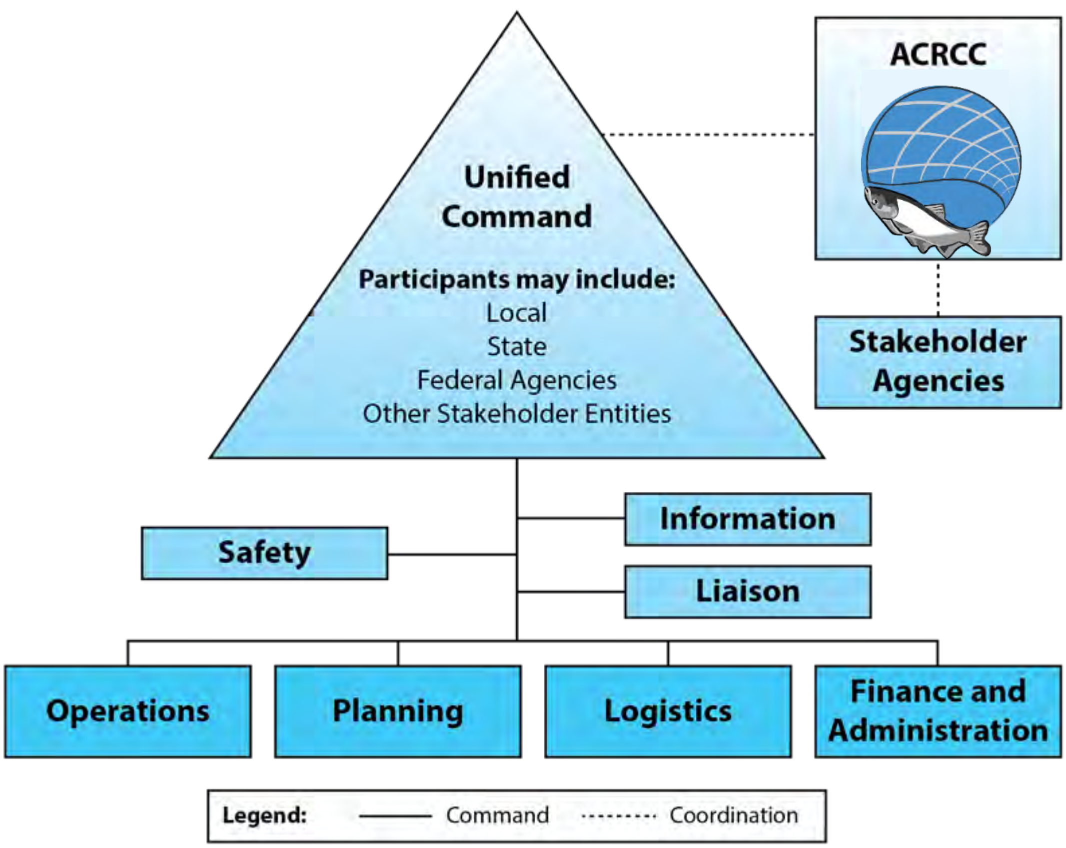


Figure 3. *Unified Command Organization Structure*

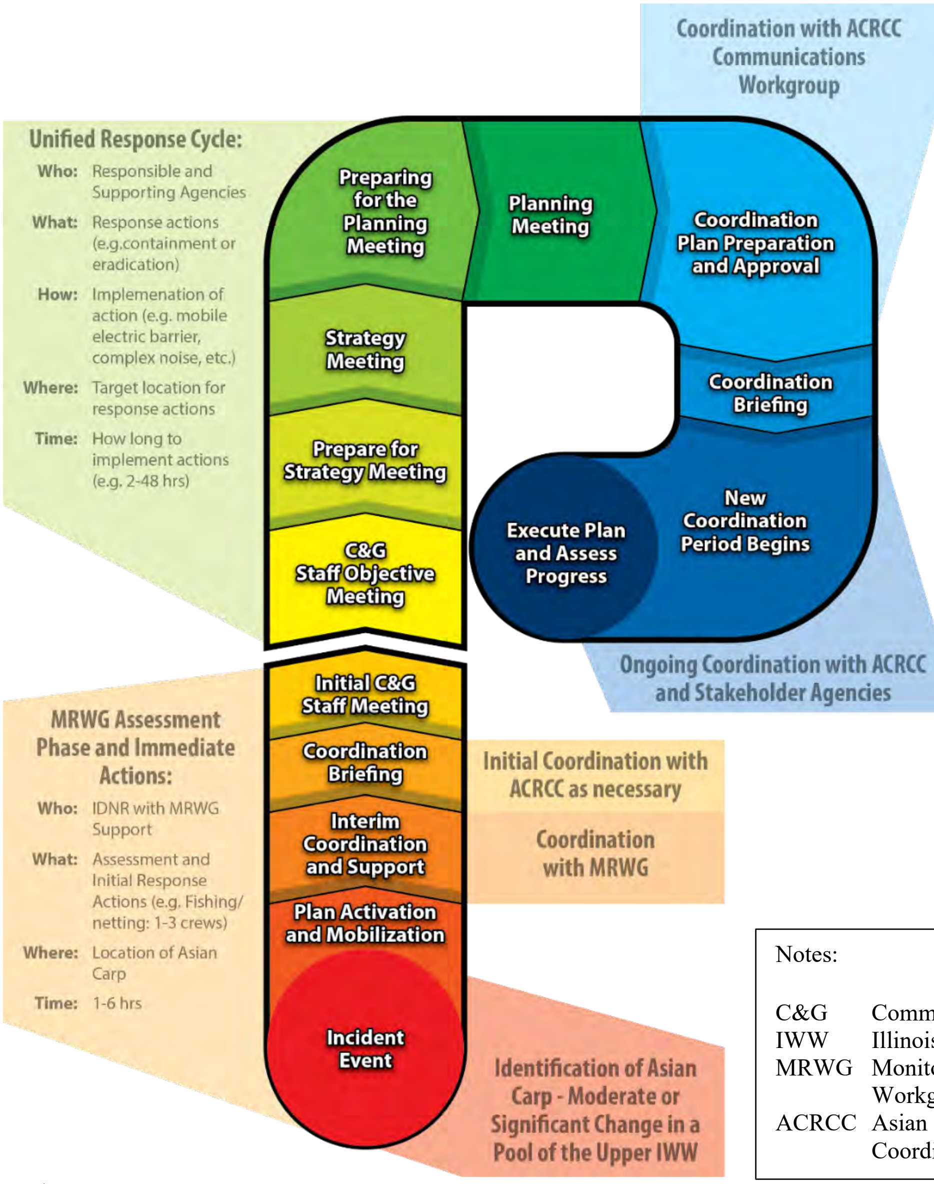
Incident Action Planning:
An Incident Action Plan (IAP) is a standard means of documenting and communicating objectives, strategies, and tactics utilized to address issues resulting from an incident. At the core of a functional IAP are well-written objectives. The standard acronym is "SMART" objectives—objectives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

SMART Objective Example

State agency X will contain 2 miles of the river using block nets within 8 hours of notification.

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

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



Notes:

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

Figure 4. *ICS Planning "P"*

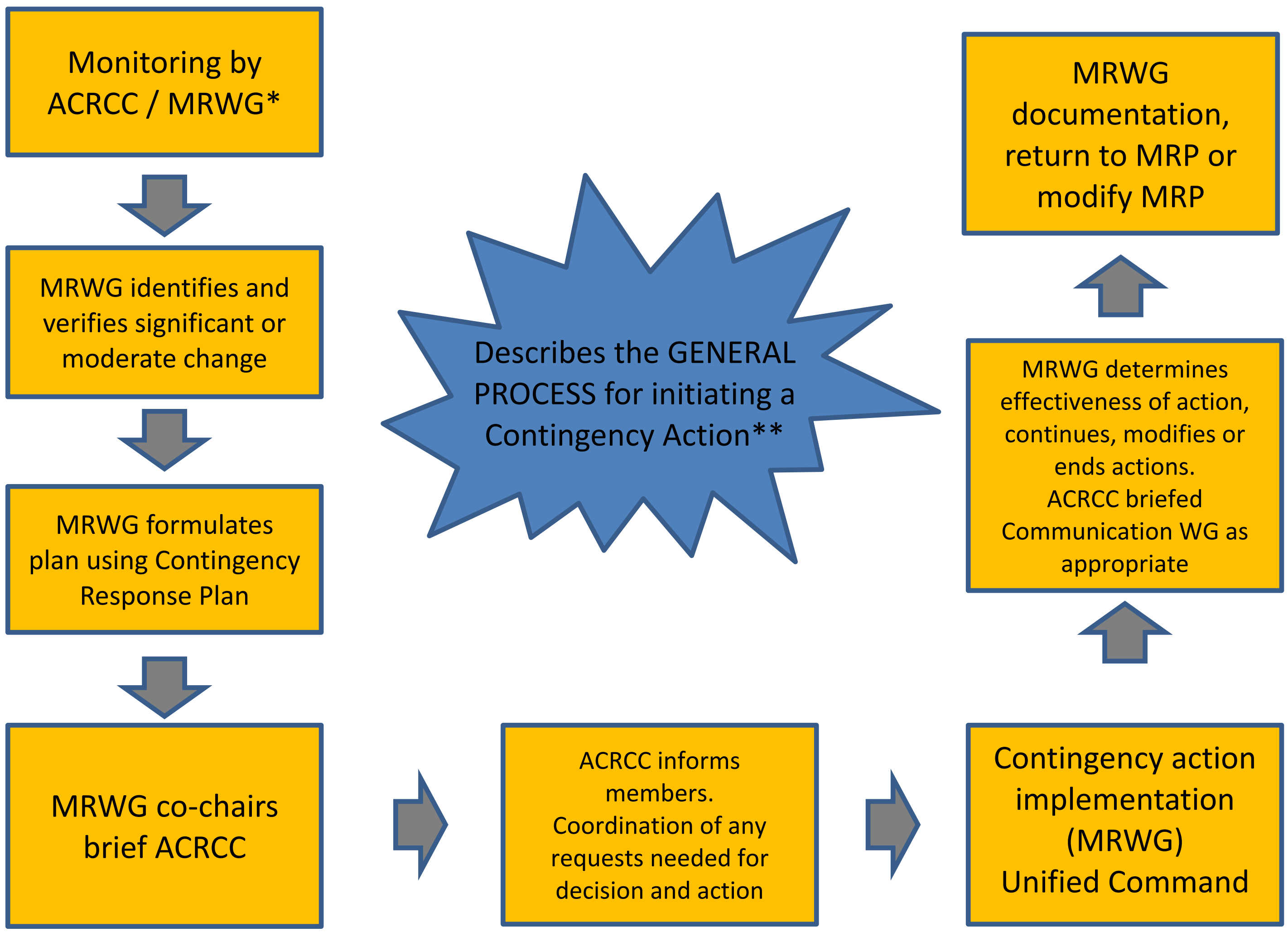
Response Decision Matrix

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

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

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

Upper Illinois Waterway Contingency Response Plan



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

** In this general process, multiple steps may happen concurrently to facilitate the most effective and efficient action is implemented.

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

Upper Illinois Waterway Asian Carp Response Decision Matrix*

Direction of flow

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

Notes:

= Significant change from baseline requiring further response action

= Moderate change from baseline requiring further response action

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

1 This status is based upon the collection of a single Bighead Carp by contracted fishers in 2010 and a single Silver Carp in 2017.

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

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

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

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

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

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

LP Lockport,
BR Brandon Road
* The implementation of some of these actions may require temporary lock closures or navigation restrictions, which fall under the authority of USACE and the US Coast Guard respectively. Temporary lock closures and navigation restrictions would be limited to the time necessary to carry out the supported measures. Such lock closures have supported previous barrier clearing events when electrofishing, water cannons, and/or nets were used to sample fish in and around the barrier system.
1 Additional Resource Considerations (page J-4) describes other measures that may be implemented as necessary and aligned with agency authorities.
2 The current monitoring and response activities are covered under existing federal budgets.
3 Response techniques encompassed by Increased Sampling Efforts under Potential Actions in above table

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

Information and Data Management

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

Essential Elements of Information

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

Citations

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

Appendix A: Barrier Maintenance Fish Suppression

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

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

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

Appendix A: Barrier Maintenance Fish Suppression

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

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

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

Appendix A: Barrier Maintenance Fish Suppression

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

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

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

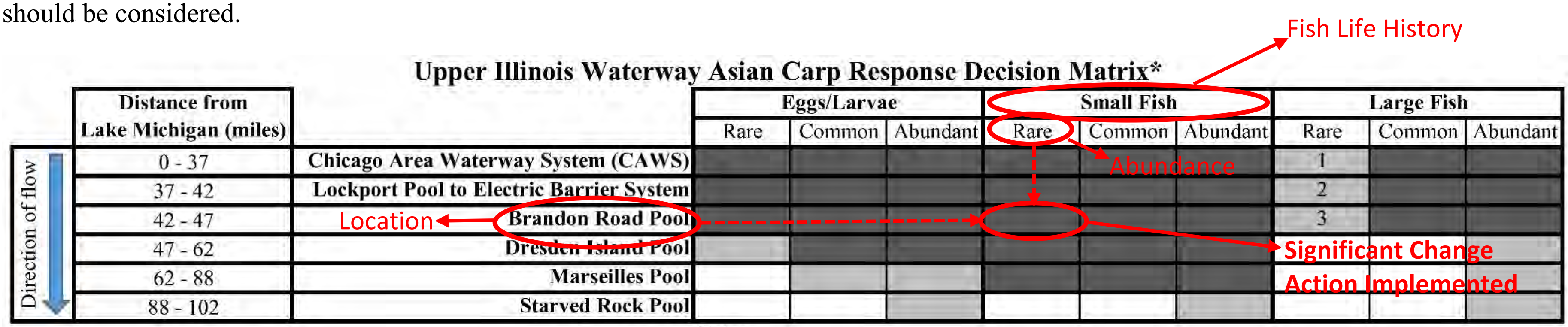
Table 2. *Operational changes anticipated from March 2020 – March 2021*

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

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

Attachment 1: Hypothetical scenario

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



Notes:

- (dark grey) = Significant change from baseline requiring further response action
- (light grey) = Moderate change from baseline requiring further response action
- (white) = No chage/Status Quo from baseline. No further action

1 This status is based upon the collection of a single Bighead Carp by contracted fishers in 2010 and a single Silver Carp in 2017.

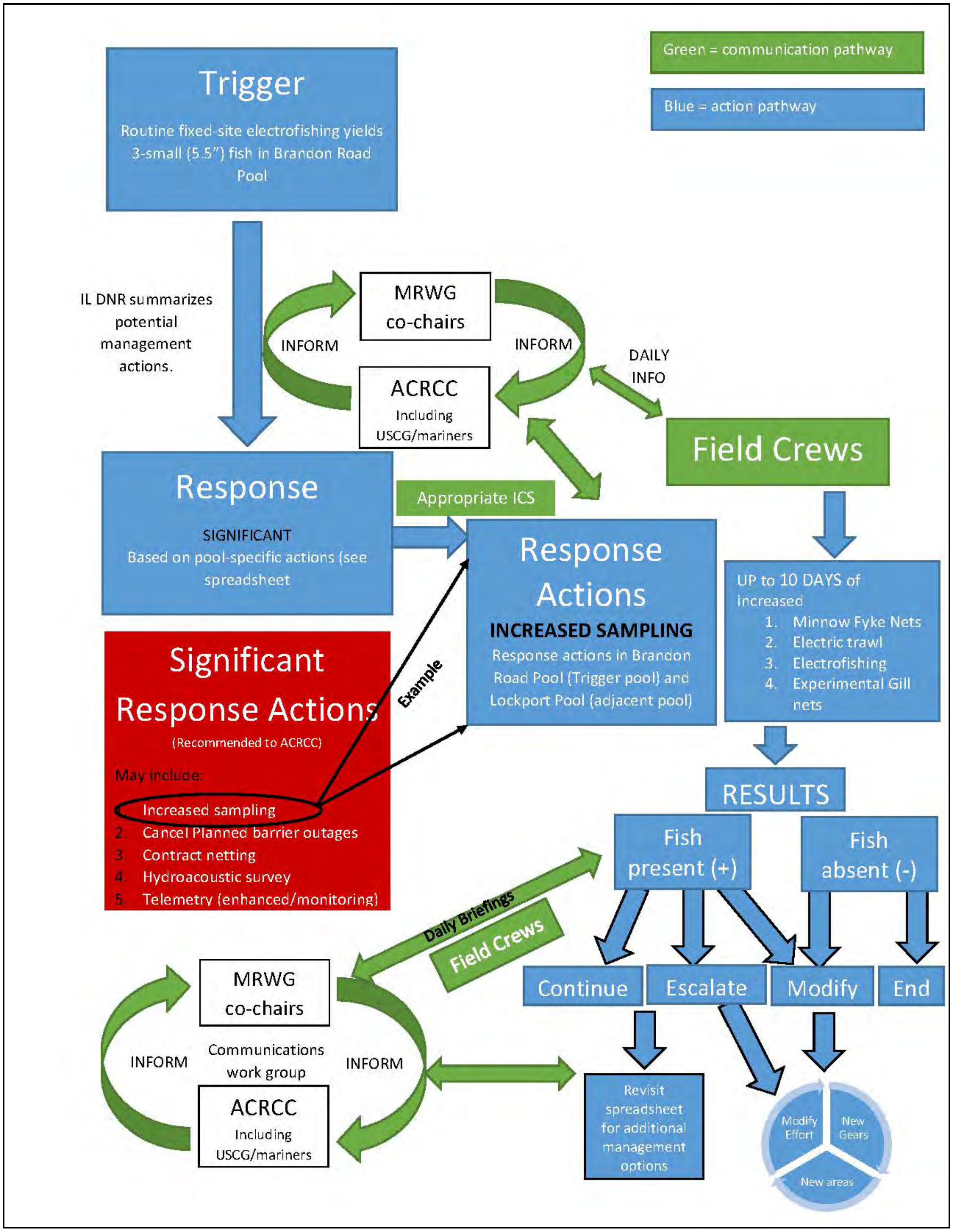
2 This status is based upon the collection of a single Bighead Carp during piscicides treatment in 2009.

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

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

Attachment 2: Sample Action Process

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



Attachment 3: Definitions

Life Stage

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

Size

Term	Definition
Small	Fish that are less than 6 inches (a conservative length designation to inform actions in which the Electric Dispersal Barrier may be challenged by fish found to be less susceptible to electrical deterrence, identified in USACE Efficacy reports).
Large	Fish that are greater than 6 inches.

Populations

Term	Definition
Adult Population Front	The most upstream pool where detection/presence of adult fish is common (see below) and either repeated immigration or recruitment has been verified.
Capture Record	Capture of an adult, juvenile, larvae, and egg verified by agency efforts/personnel, does not notate any qualification of population size/establishment.
Small Fish Population Front	The most upstream pool where detection/presence of small fish is repeatedly recorded and either repeated immigration or recruitment has been verified.
Established	Inter-breeding individuals of Bighead Carp and/or Silver Carp as well as the presence of eggs, larvae, YOY and juveniles that leads to a self-sustaining population.
Range Expansion	Verified population front upstream of the previously identified pool.

Reproduction

Term	Definition
Recruitment	Juveniles survive to be added to an adult population, by successful spawning.
Observed Spawning	Visually documented spawning activity.
Successful Spawning	Spawning that has been confirmed by the collection of eggs or larvae.

Captures

Term	Definition
New Record/ Single Occurrence	When a single fish/egg/larva is collected in a location it was not previously found. Also referred to as a novel occurrence.
Sighting	A visual confirmation with high likelihood (experience/professional opinion) that the item seen was in fact a Bighead Carp, Silver Carp at the noted life stage/activity (spawning behavior could be a sighting; Silver Carp in an electrofishing field but not netted would be a sighting.

Sampling Occurrences

Term	Definition
Rare	One sample containing the targeted species or size group; Asian carp collections are not predictable and may take multiple sampling trips to collect just one individual.
Common	Consistent catches across the pool; Asian carp collection is predictable with one or multiple individuals being collected in a given day/week of sampling.
Abundant	Consistent catches across the pool in large quantities e.g. Asian carp collection is predictable with multiple fish being collected with nearly every deployment of gear, numerous individuals collected often and daily/weekly.

Action Response Level

Term	Definition
No Change/ Current Level	Maintain current levels of sampling effort.
Moderate Change	Heightened level of response may occur along with maintaining current levels of sampling effort. Prior to any moderate change response, the MRWG will convene to evaluate the data and situation and recommend a suite of responses to the ACRCC for implementation. Strategies will then be determined for the best course of action and tools available based on the status change and concurrence with jurisdictional authorities and abilities
Significant Change	Substantial or heightened levels of response may occur along with maintaining current levels of sampling effort. All tools from "moderate change" are available during a significant change response, as are additional robust tools along with "maintaining current levels of sampling effort." for consideration. Prior to any moderate change response, the MRWG will convene to evaluate the data and situation and recommend a suite of responses to the ACRCC. The ACRCC, after reviewing MRWG recommendations, may concur or offer opinions regarding the appropriate response(s) to implement. Prior to any significant change response, the MRWG will convene to evaluate the data and situation, then strategies will be made on the best course of action and tools available based on the status change and concurrence with jurisdictional authorities and abilities

Potential Response Actions

Term	Definition
Increased Sampling Efforts	Modified or increased number of samples using fish sampling/detection methods currently used by MRWG in Monitoring.
Electrofishing	Standard fish sampling method to sample small and adult Asian carp currently used by MRWG in Fixed and Targeted Sampling.
Hoop Netting	Standard fish sampling method to sample adult Asian carp currently used by MRWG in Fixed and Targeted Sampling.
Minnow Fyke Netting	Standard fish sampling method to sample small Asian carp currently used by MRWG in Fixed and Targeted Sampling.
Paupier Net Boat	Experimental fish sampling method to sample small and adult Asian carp currently used by MRWG.
Electrofied Dozier Trawl	Experimental fish sampling method to sample small and adult Asian carp currently used by MRWG.
Icthyoplankton Tows	Standard fish sampling method to sample larvae and eggs of Asian carp currently used by MRWG in Fixed and Targeted Sampling.
Pound Nets	Experimental fish sampling method to sample small and adult Asian carp currently used by MRWG.
Modify Barrier Operations	MRWG and USACE will coordinate upon potential postponements and operations of planned Barrier outages.
Acoustic Deterrent	Noise methods to drive/herd/deter fish including revving of outboard boat motors, banging on boats in the waterway, and deployment of speakers with developed sounds.
Commercial Contract Netting	Mobilizing contracted commercial fisherman and using commercial fishing methods used currently by MRWG in sampling/detection and removal including gill netting, trammel netting, large mesh seine, small mesh seine, and hoop netting.
Hydroacoustics	Electronic Fish survey and locating techniques used currently by MRWG including side-scan sonar, and DIDSON sonar to evaluate the number and density of large or small Asian carp in a given area.
Temporary Flow Control	MWRD authority and ability to reduce flow velocities to complete response actions.
Block Netting	Large nets that can block the waterway or contain selected areas from small and adult Asian carp movement used currently by MRWG for removal.
Mobile Electric Array	Experimental electric array that can be used as temporary barrier or drive/herd and deter small and adult Asian carp.

Other

Term	Definition
Pool	The water between two successive locks or barriers within the river system.
Developing Technologies	Technologies and methodologies currently being investigated that show promise in deterring Asian carp or increases harvest efficiency which are not currently approved for use in the field by the applicable regulatory agencies.

Attachment 4: Authorities

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

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

Illinois Department of Natural Resources (from Illinois Compiled Statutes http://www.ilga.gov/legislation/ilcs/ilcs.asp)

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

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

Section 890.30 Treatment of the Water Area

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

515 ILCS 5/1-135

515 ILCS 5/1-150

ARTICLE 5. FISH PROTECTION

515 ILCS 5/5-5

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

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

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

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

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990

Lacey Act (16 U.S.C. §§ 3371–3378)

Executive Order 13112 of February 3, 1999 - Invasive Species

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

APPENDICES

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

Steven E. Butler, Anthony P. Porreca, Dakota S. Radford, Kristopher A. Maxson, Joseph J. Parkos III, James T. Lamer (Illinois Natural History Survey),
David P. Coulter (Southern Illinois University)

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

Location: Zooplankton sampling will take place in main channel and backwater habitats throughout the Illinois Waterway (IWW) from the downstream terminus of the Chicago Area Waterway System (CAWS) in the vicinity of the Lockport Lock and Dam to the lower Illinois River (La Grange Pool).

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

Introduction and Need:

Due to their ability to efficiently filter large volumes of water and capture small particle sizes, Bighead Carp and Silver Carp can deplete zooplankton densities and alter zooplankton community composition (Sass et al. 2014; DeBoer et al. 2018), potentially competing with native fishes for food resources (Sampson et al. 2009) and altering flows of organic matter (Collins and Wahl 2017). The trophic impact of Asian carp is of great concern because of the importance of zooplankton as grazers as well as prey for fish early life stages and native planktivores. In the Illinois River, densities of large-bodied crustacean zooplankton have been substantially reduced, whereas rotifer densities have increased since the establishment of Asian carp (Sass et al. 2014). An aggressive Asian carp removal program has been implemented in the upper navigation pools of the IWW to limit further advances of Asian carp towards Lake Michigan. One challenge with the removal program has been assessing whether or not removals have caused ecologically meaningful changes in Asian carp abundance. In addition to preventing the expansion of Asian carp into the Great Lakes, this removal program may also benefit native fish assemblages in the IWW by mitigating some of the ecological impacts that Asian carp have had on this system. However, the extent and pace of ecosystem responses to such removals are uncertain. Zooplankton are known to be a rapid index of ecosystem response, as most riverine zooplankton taxa have relatively short generation times and high productivity rates. Additionally, zooplankton are distributed throughout the IWW and are a critical food web component for larval and adult native fishes, making them ideal performance metrics for assessing the effectiveness of Asian carp control efforts. This project will investigate whether zooplankton-based assessment metrics can be used to quantitatively evaluate the extent to which the removal strategy is working to reverse ecosystem impacts from Asian carp in the IWW. This work will help inform management agencies regarding ecosystem responses to Asian carp removals and define ecosystem-based benchmarks for Asian carp control efforts.

Objectives:

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

(2) Assess the sensitivity of a range of zooplankton taxa to Asian carp abundance.

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

Status:

Zooplankton have been sampled from sites throughout the IWW during 2011 – 2020. Comparison of zooplankton data collected during recent years with pre-invasion zooplankton collections indicate that zooplankton assemblages in the Illinois River have been substantially altered since the establishment of Asian carp, with large declines in macrozooplankton such as Cladocerans. Zooplankton communities also exhibit large seasonal, spatial (e.g., between the Upper and Lower IWW), and habitat-specific variation. Underlying environmentally-driven variability in zooplankton metrics must therefore be accounted for in any analyses evaluating relationships between zooplankton and Asian carp abundance. Evaluation of a subset of potential zooplankton performance metrics has indicated that June densities of *Bosmina* are more sensitive to Asian carp density than cyclopoid copepod, *Brachionus*, *Keratella*, and *Polyartha* densities during the same month. A model including Asian carp density, dissolved oxygen concentration, and water temperature explained over half of the observed variance in June *Bosmina* densities. June density of *Bosmina* appeared to exhibit a threshold-like response to Asian carp density, declining rapidly once Asian carp abundance increased above approximately 0.37 Asian carp / 1000 m^3. Further investigation of these and other zooplankton taxa across all months of available data will be necessary to establish which zooplankton taxa provide the most informative metrics for assessing the impact of Asian carp removal on ecosystem recovery.

Methods:

Field sampling for assessment of zooplankton trends will occur biweekly between April and October of 2021 at established sites to maintain consistency and data comparability with past years (Figure 1). Zooplankton will be collected by obtaining vertically-integrated water samples using a diaphragmatic pump. At each site, 90 L of water will be filtered through a 55 µm mesh to obtain crustacean zooplankton (macrozooplankton), whereas 10 L of water will be filtered through a 20 µm mesh to obtain rotifers. Organisms will be transferred to sample jars and preserved in either Lugol's solution (4%; for macrozooplankton) or buffered formalin (10%; for rotifers). In the laboratory, individual organisms will be identified to the lowest possible taxonomic unit, counted, and measured using a microscope-mounted camera and measurement software. Zooplankton densities will be calculated as the number of individuals per liter of water sampled. Density and body size estimates will be used to estimate zooplankton biomass. During zooplankton sampling, data on environmental factors known to influence zooplankton communities in large rivers (turbidity, chlorophyll *a*, total phosphorus, dissolved oxygen, and temperature) will also be collected. Discharge data will be acquired from USGS gages on the IWW. Estimates of Asian carp abundance in each navigation pool will be obtained from hydroacoustic surveys conducted by SIU.

Targets for ecosystem response to Asian carp removals will be developed by using monitoring data to model zooplankton indicators as a function of Asian carp abundance and the seasonal environmental variation driving their spatiotemporal dynamics (e.g., discharge, dissolved oxygen, temperature, total phosphorus, chlorophyll *a*). Models of zooplankton indicators will be parameterized across a range of Asian carp abundances, including navigation pools where Asian carp removal efforts have substantially reduced Asian carp densities during the assessment time period. The influence of environmental values on the relationships between Asian carp density and key zooplankton metrics will be assessed, and metrics that demonstrate the highest sensitivity to Asian carp abundance will be considered further as potential tools for evaluating the impacts of Asian carp harvest. The most informative performance metrics will be modelled using observed environmental conditions and Asian carp densities in each pool to calculate the difference between observed and expected values of each metric. The same models and environmental conditions will then be used to predict what the target metric value would be if Asian carp had been reduced to a specific density, and the difference between the target predictions and observed metric values will be compared to the residuals obtained from the model that used observed Asian carp density. If the target interval (i.e. goal Asian carp density prediction residuals ± 1.5 SE) overlaps the limits based on the observed carp density, Asian carp removal at this site would be concluded to have met the management target for zooplankton recovery. Changes in Asian carp density through time within pools, particularly the substantial declines in the Starved Rock, Marseilles, and Dresden Island pools due to targeted removal efforts in recent years, will be useful for evaluating the utility of any identified performance metrics.

Sampling Schedule:

During 2021, zooplankton sampling will occur bi-weekly at all sites from April to October. At most sites, zooplankton collections will occur concurrently with ichthyoplankton sampling (collected to monitor for Asian carp reproduction) at the same locations. Changes to this proposed sampling schedule may arise from restrictions on travel due to the COVID-19 pandemic. All efforts will be expended to conduct all sampling that is possible during 2021 while following legal requirements and practicing all appropriate safety measures to protect the health of staff and the public.

Deliverables:

Results of 2021 sampling and on-going evaluations of zooplankton response metrics to assess annual variations in Asian carp densities and harvest operations will be provided to Monitoring and Response Work Group partners as relevant findings are produced. Data will be summarized and project plans updated for annual revisions of the Monitoring and Response Plan.

References:

Collins, S.F. and D.H. Wahl. 2017. Invasive planktivores as mediators of organic matter exchanges within and across ecosystems. Oecologia 184:521-530.

DeBoer, J.A., A.M. Anderson, and A.F. Casper. 2018. Multi-trophic response to invasive silver carp (*Hypophthalmichthys molitrix*) in a large floodplain river. Freshwater Biology 63:597-611.

Sampson, S.J., J.H. Chick, and M.A. Pegg. 2009. Diet overlap among two Asian carp and three native fishes in backwater lakes on the Illinois and Mississippi rivers. Biological Invasions 11:483-496.

Sass, G.G., C. Hinz, A.C. Erickson, N.N. McClelland, M.A. McClelland, and J.M. Epifanio. 2014. Invasive bighead and silver carp effects on zooplankton communities in the Illinois River, Illinois, USA. Journal of Great Lakes Research 40:911-921.

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

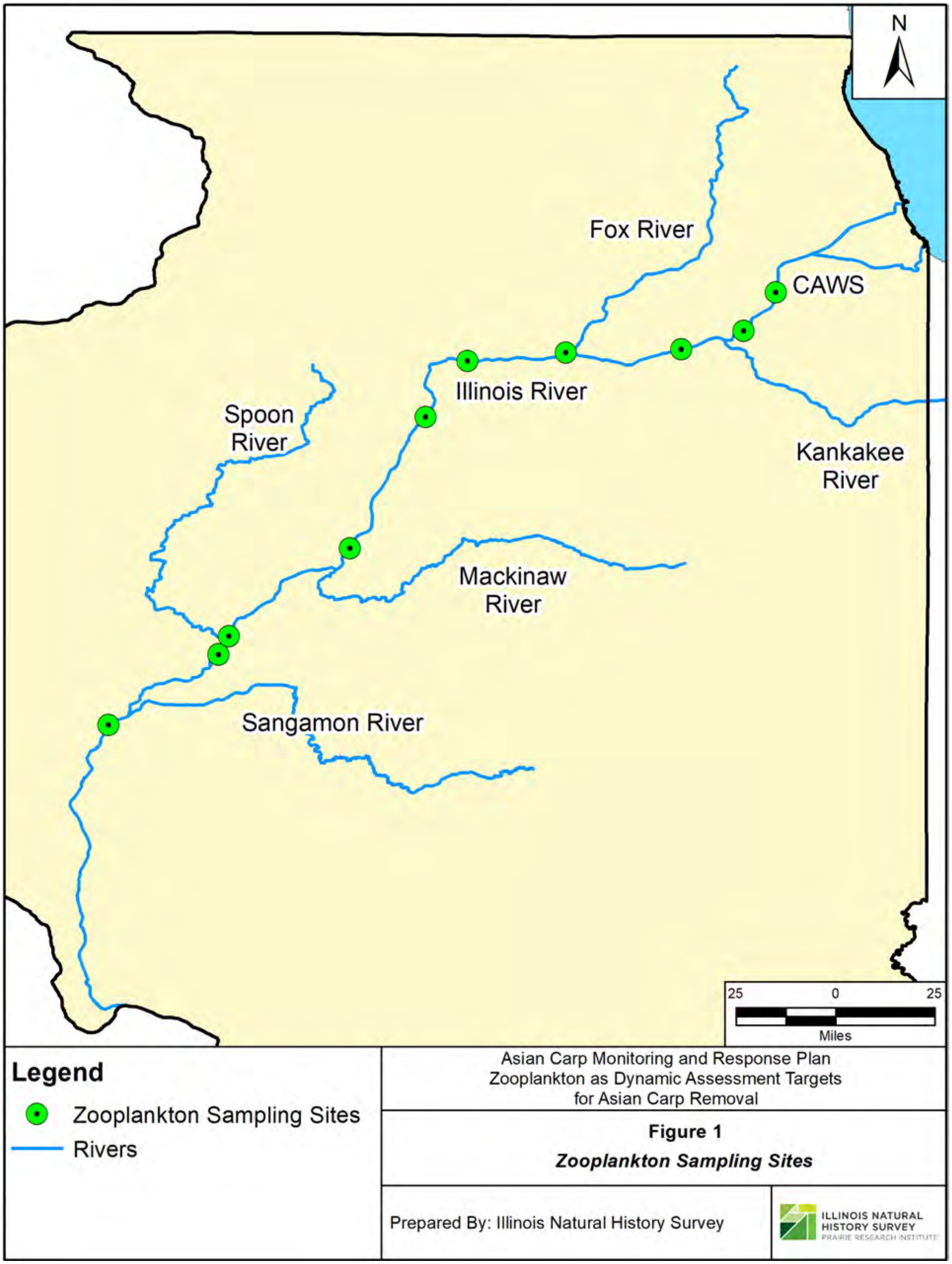


Figure 1. *Map of zooplankton sampling sites in the Illinois Waterway*.

Appendix B: Participants of the Monitoring and Response Work Group, Including Roles and Affiliation

Affiliation acronyms are EA: Engineering, Science and Technology, EPA: U.S. Environmental Protection Agency, GLFC: Great Lakes Fishery Commission, IDNR: Illinois Department of Natural Resources, INHS: Illinois Natural History Survey, UI: University of Illinois, USACE: U.S. Army Corps of Engineers, USCG: U.S. Coast Guard, USGS: U.S. Geological Survey, USFWS: U.S. Fish and Wildlife Service, SIU: Southern Illinois University.

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Best Management Practices to Prevent the Spread of Aquatic Nuisance Species during Asian Carp Monitoring and Response Field Activities

The activities of the Asian Carp Monitoring and Response Plan (MRP) pose a risk of transporting and introducing aquatic nuisance species (ANS), including fish, plants, invertebrates, and pathogens. To slow their spread, it is best to take ANS into consideration during all stages of field work, including planning, while field work is in progress, and cleanup. The best management practices (BMPs) outlined below are designed to be effective, easy to implement, and realistic; when followed correctly, their use should reduce or potentially eliminate the risk of ANS being spread by MRP activities. These BMPs, combined with diligent record keeping, can also benefit the organizations participating in MRP activities by demonstrating that they are taking deliberate action to prevent the spread of ANS.

For the purposes of these BMPs, all equipment utilized in field work that comes into contact with Illinois waters, including but not limited to boats and trailers, personal gear, nets, and specialized gear for electrofishing and hydroacoustics, will be referred to as "gear."

Field activities that use location-specific gear may require less effort to ensure that they are not transporting ANS. Examples include boats, electrofishing gear, nets, or personal gear that are used in sampling only one location. If potentially contaminated gear does not travel, the possibility of that equipment transporting ANS may be eliminated. Maintaining duplicate gear for use in contaminated vs. non-contaminated locations or sampling all non-contaminated locations before moving to contaminated locations may also reduce or eliminate the possibility of ANS spread.

BEST MANAGEMENT PRACTICES

BEFORE TRAVELING TO A SAMPLING LOCATION:

- ***CHECK*** gear and determine if it was previously cleaned.

  Accurate record-keeping can eliminate the need for inspecting or re-cleaning before equipment is used. If it is unknown whether the gear was cleaned after its last use, inspect and remove any plant fragments, animals, mud, and debris, and drain any standing water. If necessary, follow the appropriate decontamination steps listed below.

- ***PLAN*** sampling trips to progress from the least to the most likely-to-be-contaminated areas when working within the same waterbody.

  When feasible, plan on decontaminating whenever equipment crosses a barrier (such as a lock and dam or the Electric Dispersal Barrier) while going upstream.

WHILE ON A WATERBODY:

- ***INSPECT*** and clean gear while working.
- ***OBSERVE*** any ANS that may not have been previously recorded.

  Adjust decontamination plans when new occurrences are observed. Report new infestations at www.usgs.gov/STOPANS, by sending an email to dnr.ans@illinois.gov, and also include in monthly reports to the Monitoring and Response Workgroup.

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AFTER FIELD WORK ON WATERBODY IS COMPLETE:

- ***REMOVE*** plants, animals, and mud from all gear.

  This step can reduce the amount of macrophytes on a boat by 88 percent.[A] *It should occur before gear is transported away from the waterbody to be compliant with Illinois' Public Act 097-0850, which prevents transport of aquatic plants and animals by boats, trailers, and vehicles on Illinois' roadways.*

- ***DRAIN*** all water from your boat and gear.

  Drain all water before gear is transported away from the waterbody to be compliant with Administrative Code Title 17 Section 875.50, which makes it unlawful to transport the natural waters of the state without permission.

- ***DISPOSE*** of unwanted plants and animals appropriately.

- ***DECONTAMINATE*** using a recommended method before using gear at another location.

  Decontaminate whenever there is the potential for gear to transfer ANS. The best method for decontamination varies; see Attachment A for more information about various decontamination methods and gear-specific tips, and Attachment B to inform decisions as to which decontamination method is best for each ANS.

- ***KEEP RECORDS.***

  Develop and follow a Standard Operating Procedure (SOP) and checklist for cleaning equipment. This checklist makes the ANS prevention steps easy to follow and documentable. Complete the SOP and checklist for each sampling event with date, location, recorder's name, and what was done.

  It may be beneficial to develop a lock and tag system to ensure that potentially infested (dirty) gear is not reused before it is decontaminated. Examples could include flagging dirty gear in a particular color (such as red, indicating stop) to designate that it should not be used in the field and flagging decontaminated gear in a different color (green, indicating go) to designate that it is ready for reuse. Alternatively, a colored carabiner could be used to flag boat keys; keys without the appropriate colored carabiner would designate that gear as dirty and therefore unable to be used without being decontaminated.

  Developing a system and keeping records over time demonstrates a solid commitment to ANS prevention, helps build a standard cleaning protocol, and eliminates wasted time spent re-checking or re-cleaning equipment. An appropriate SOP with lock and tag system, color coding, or rotation of gear as described above is minimally expected.

[A] Rothlisberger, J.D., W.L. Chadderton, J. McNulty, and D.M. Lodge. 2010. Aquatic invasive species transport via trailered boats: what is being moved, who is moving it, and what can be done. Fisheries. 35(3):121-132.

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ATTACHMENT A
DECONTAMINATION METHODS AND GEAR-SPECIFIC TIPS

While simple hand removal can reduce the majority of ANS found on gear and equipment[B], additional decontamination methods are recommended to eliminate (kill) any elements that may not be seen. The methods presented here outline a range of effective methods for decontaminating equipment and allow the user to select the most practical option for a specific situation. Successful decontamination depends on a multitude of factors, including the type and life stage of ANS infestation, decontamination method, contact time, and (if necessary) concentration of chemical used. For information on the effectiveness of each method for specific species, see Attachment B.

High-pressure washing is a commonly recommended method of removing organic material, although it is not considered a means of decontamination as defined above. If high-pressure washing is not possible, scrub equipment with a stiff-bristled brush or wash with soapy water to aid in the removal of small organisms and seeds, as well as remove organic material that makes decontamination less effective. Scrubbing could damage the anti-fouling paint and coating of some boat hulls, so check the manufacturer's recommendations. When brushing fabric, be careful to brush with the nap, as brushing against the nap could cause small seeds to become embedded.[B] Brushing should be followed by a rinse with clean water. If these methods of organic material removal are conducted in the absence of decontamination, it is necessary to ensure that wastewater runoff does not contaminate surface waters, as there is potential for live ANS to be removed from gear and carried in wastewater.

Decontamination Methods

1. *Drying*
   Accepted as effective: Dry for five consecutive days after cleaning with soap and water or high-pressure water;[C] *dry in the sun for 3 days.*[D]

   - Make sure equipment and gear is completely dried after the drying period. Surfaces may appear dry while the interior is still wet. Waders, boots, wetsuits, fabric, and wood may be difficult to dry thoroughly.
   - If using shared equipment, it is recommended to keep a log of when things are used to ensure the minimum drying period has been met. If there is any possibility that another individual will use the shared equipment before the recommended drying period is reached, it is safer to disinfect via other means.

2. *Steam Cleaning*
   Accepted as effective: Steam cleaning (washing with 212°F water)[D]

   - Heated water is effective in killing a wide range of organisms and fish pathogens (see Attachment B); although the efficacy of steam cleaning is commonly shared knowledge, its effectiveness is not necessarily supported by references.[F]
   - Steam cleaners can work well in small spaces and on items such as small boat hulls, clothing, and heavy equipment. To be the most effective, all sides, as well as the inside, of all

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[B] DiVittorio, J., M. Grodowitz, and J. Snow. 2010. Inspection and Cleaning Manual for Equipment and Vehicles to Prevent the Spread of Invasive Species [2010 Edition]. U.S. Department of the Interior Bureau of Reclamation. Technical Memorandum No. 86-68220-07-05.

[C] Wisconsin Department of Natural Resources. 2015. Boat, Gear, and Equipment Decontamination Protocol. Manual Code #9183.1.

[D] United States Geological Survey. Movement of field equipment (boats, trucks, nets, seines, etc.) between two separate waterbodies for field sampling. Columbia Environmental Research Center. HACCP Plan. Accessed 4 Nov 2015.

equipment being treated should be sprayed.[E]

- Be careful when steaming over items held together with adhesives because high temperatures can melt bonds. Inflatable PFDs can also be melted by the use of steam.
- The use of personal protective equipment is recommended when working with heated water. Most adults will suffer third-degree burns with a 2-second exposure to 150°F water.[F]

3. *Hot Water*
   Accepted as effective: Washing with high pressure, hot (≥140°F) water for 30 seconds at 90 psi;[E] *washing with hot (≥140°F) water for a 10 second contact time.*[G]

- It is recommended to use pressure washing in conjunction with hot water; otherwise, it can aid in the spread of ANS because it removes organisms, but does not kill them.[F]
- Heated water is effective in killing a wide range of organisms and fish pathogens (see Attachment B).
- While some species are killed at lower temperatures, hot water should be at least 140°F to kill the most species. This method becomes more effective when applied with high pressure, which removes ANS.[F]
- It is important to note that some self-serve car washes do not reach 140°F; however, studies have demonstrated some ANS mortality at temperatures lower than 140°F with an increase in contact time.[H]
- To verify that the hot water spray is effectively heating the contact area, a non-contact infrared thermometer can be purchased at a home supply store.
- When carpeted bunks are present on boat trailers, it is recommended to slowly flush for at least 70 seconds to allow capillary action to draw the hot water through the carpet.[H]
- The use of personal protective equipment is recommended when working with heated water. Most adults will suffer burns with a 6-second exposure to 140°F water.[G]

5. *Virkon® Aquatic*
   Accepted as effective: Applying a 2 percent (2:100) solution of Virkon® Aquatic for 20-minute contact time,[C] *or 10-minute contact time.*[D] *Contact time is species-specific; see Attachment B for more information.*

- Virkon® Aquatic is a powder, oxygen-based disinfectant that is biodegradable and not classified as persistent in the environment.[I]
- As shown in Apendix B-2, Virkon® Aquatic is the best method to use on equipment that has been used in areas that are known to have New Zealand mudsnail (*Potamopytrgus*

[E] Perdrock, A. 2015. Best Management Practices for Boat, Gear, and Equipment Decontamination. State of Wisconsin Department of Natural Resources, Bureau of Water Quality.
[F] U.S. Consumer Product Safety Commission. 2011. Avoiding Tap Water Scalds. Publication 5098. http://www.cpsc.gov/PageFiles/121522/5098.pdf.
[G] Zook, B. and S. Phillips. 2012. Uniform Minimum Protocols and Standards for Watercraft Interception Programs for Dreissenid Mussels in the Western United States (UMPS II). Pacific States Marine Fisheries Commission.
[H] Comeau, S., S. Rainville, W. Baldwin, E. Austin, S. Gerstenberger, C. Cross, and W. Wong. 2011. Sucsceptibility of quagga mussels (*Dreissena rostiformis bugensis*) to hot-water sprays as a means of watercraft decontamination. Biofouling. 27(3):267-274.
[I] Baldry, M.G.C. Biodegradability of Virkon® Aquatic. Accessed 23 November 2015. http://www.wchemical.com/downloads/dl/file/id/68/biodegradability_of_virkon_aquatic.pdf.

antipodarum, NZMS) populations or might be vulnerable to NZMS.[F,J]

- Virkon® Aquatic should not be used on items made of wood. Because the solution soaks into the wood, it may carry residues that could be harmful to fish. Negative impacts of Virkon® Aquatic can be reduced by rinsing equipment with clean water (municipal, bottled, and well) after decontamination is complete.[F]
- Labeling for Virkon® Aquatic indicates it is not corrosive at the recommended dilution; however, solutions have been shown to cause degradation to gear and equipment when used repeatedly.[K]
- Always wear personal protective gear when mixing solutions of Virkon® Aquatic.

6. *Chlorine*
   Accepted as effective: Applying a 500 ppm chlorine solution[C] or a 200 mg/L chlorine solution[D] for a 10-minute contact time.

- As shown in Attachment B, chlorine solutions are not effective on spiny waterflea (*Bythotrephes longimanus*, SWF) resting eggs or NZMS. For this reason, it is recommended to follow chlorine solution treatments with an additional decontamination method or select another decontamination method if SWF or NZMS transport is a concern.
- Note that the chlorine concentration of solutions deteriorates with time, exposure to light and heat, and on contact with air, metals, metallic ions, and organic materials.[K]
- There are no differences in decontamination abilities between solutions using tap water or sterile water to make the chlorine solution. The cleaning and decontamination abilities of chlorine solutions are not impacted by the temperature of the water used.[L]
- Chlorine solutions will begin to lose disinfecting properties after 24 hours, and the more dilute the chlorine solution, the more quickly it will deteriorate. Therefore, it is important to use bleach solutions that are less than 24 hours old.[F]
- When household bleach is used as a chlorine source, be aware of bleach shelf life. If stored at a temperature between 50 and 70°F, household bleach retains its decontamination properties for about 6 months, after which it degrades into salt and water at a rate of 20 percent each year.[M]
- Chlorine solutions may have corrosive effects on certain articles of equipment, but these effects can be reduced by rinsing equipment with clean water after decontamination is complete.[F]
- Because different brands of household bleach vary in the amount of sodium hypochlorite used, differing quantities will need to be used to create the appropriate concentration (Table 1).

[J] Stockton, K.A. and C.M. Moffitt. 2013. Disinfection of three wading boot surfaces infested with New Zealand mudsnails. North American Journal of Fisheries Management. 33:529-538.

[K] Clarkson, R.M., A.J. Moule, and H.M. Podlich. 2001. The shelf-life of sodium hypochlorite irrigating solutions. Australian Dental Journal. 46(4):269-276.

[L] Johnson, B.R. and N.A. Remeik. 1993. Effective shelf-life of prepared sodium hypochlorite solution. Journal of Endodontics. 19(1):40-43.

[M] Brylinski, M. 2003. How long does diluted bleach last? Email from clorox@casupport.com to the Director of WCMC EHS Dated February 6, 2003. http://weill.cornell.edu/ehs/forms_and_resources/faq/biological_safety.html

Table 1. *Converting household bleach to 500 or 200 parts per million (mg/L) of chlorine solution.*

Sodium hypochlorite concentration of household bleach	Ounces of household bleach per gallon water		Tablespoons of household bleach per gallon water	
	200 ppm	500 ppm	200 ppm	500 ppm
5.0	0.51	1.28	1.02	2.56
5.25	0.49	1.22	0.98	2.44
8.25	0.31	0.78	0.62	1.55

7. *Freezing*

- As a result of the threat posed by fish pathogens and the ability of many pathogens to survive freezing temperatures, it is recommended to utilize freezing in conjunction with other decontamination methods.
- See Attachment B for recommendations regarding the efficacy of freezing for various ANS.

Gear-Specific Tips for Decontamination

To ensure success, organic debris should be removed prior to decontamination. Organic debris can be removed by hand, by scrubbing with a stiff-bristled brush, or by rinsing/power washing with clean municipal, well, or non-surface water.

Nets

- The most effective way to remove organic debris from nets is by rinsing with clean municipal, well, or non-surface water. Power washing is not required, but nets could be sprayed with a garden hose or rinsed in a tub of water to remove debris.
- Nets can be steam cleaned, washed, and dried thoroughly for 5 days, or washed and treated with a decontamination solution. Nets should be placed in the decontamination solution for the appropriate contact time for the solution being used. After rinsing, the nets can be used immediately or hung to dry.
- If nets are rinsed or decontaminated in a tub of water, be sure to thoroughly clean and disinfect the tub.

Personal Gear and Clothing

- Remove organic debris prior to decontamination to ensure success.
- An adhesive roller can be used on clothing to remove seeds and plant materials.
- Note that hot water and steam may damage the seams of rain gear, waders, and boots.[F]
- Waders may take more than 48 hours to dry completely.[F]
- Whenever possible, use a dedicated or completely new set of gear for each waterbody during the work day and disinfect all gear at the end of the day.
- Consider purchase of wading gear and boots with the fewest places for organisms and debris to become attached. One-piece systems with full rubber material and open cleat soles are recommended to reduce likelihood of ANS spread. Mud/rock guards used with stocking-foot waders may minimize contamination on inside surfaces.

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Dip nets, measuring boards, and other gear

- Remove any organic material prior to decontamination.
- Because dissolved oxygen probes and other sensitive electronic gear may be damaged by hand decontamination methods, they should only be rinsed with clean water and allowed to dry. See manufacturer's instructions for further directions on the cleaning of sensitive gear (Sondes, Hydrolabs, and dataloggers).
- For other gear, use steam, hot water, chlorine solution, or Virkon® Aquatic solution to disinfect equipment.
- If using chlorine or Virkon® Aquatic solution, fill a tub with the decontamination solution and place all equipment in the tub for the appropriate contact time. Alternatively, spray with a decontamination solution so that a wet surface is maintained for the appropriate contact time. All gear should be rinsed with clean water before reuse.
- Whenever possible, use a completely new set of gear for each waterbody visited and disinfect all gear at the end of the day.

Boats, trailers, and live wells

- Remove organic material from boats, trailers, and live wells prior to decontamination. Note that scrubbing could damage the anti-fouling paint/coating of some boat hulls, so check manufacturer recommendations.
- Drain water from live wells, bilges, and pumps.
- Whenever possible, foam rubber or carpet trailer pads should be removed when working in ANS infested waters.[C]
- All surfaces (inside and out) should be steam cleaned or sprayed with a decontamination solution and left wet for the appropriate contact time.
- Run pumps so that they take in the decontamination solution and make sure that the solution comes in contact with all parts of the pump and hose.
- If chlorine or Virkon® Aquatic is used, the boat, trailer, bilges, live well, and pumps should be rinsed with clean water after the appropriate contact time.
- Every effort should be made to keep the decontamination solution and rinse water out of surface waters. Pull the boat and trailer off the ramp and onto a level area where infiltration can occur and away from street drains to minimize potential runoff into surface waters.

Motors

- Scrub sediments off the exterior of the motor and then tip the motor down and allow water to drain from engine.
- Running a chemical solution through the engine may void the warranty or damage the engine. Always follow the manufacturer's recommendations as to the appropriate decontamination method.

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ATTACHMENT B
LITERATURE REVIEW ON EFFICACY OF DECONTAMINATION METHODS BY SPECIES[N]

The following tables outline the effectiveness of various decontamination methods for eliminating (killing) common ANS and include citations for determinations.

Key:
☑ = Effective
⊗ = Not Effective
Ⓡ = Additional Research Needed
? = Literature Review Needed

Supporting references are enumerated in superscript and can be found in the References section that follows Tables 1-3. Symbols shown without references depict commonly shared knowledge wherein references or studies that validate the information may exist, but have not yet been found.

Table 1. *Efficacy of treatment methods for macrophytes and algae.*

ANS	Steam Cleaning (212°F)	Hot Water (140°F)	Drying (5 days)	Chlorine (500 ppm)	Virkon® (2:100 solution)	Freezing (-3°C)
Curlyleaf Pondweed	Ⓡ	Ⓡ	☑ [3,55]	Ⓡ	Ⓡ	⊗ [52]
Curlyleaf Pondweed (Turion)	☑	☑ [53]	⊗ [3]	Ⓡ	Ⓡ	?
Eurasian Watermilfoil	☑	☑ [15]	☑ [12,55]	Ⓡ [57]	Ⓡ	⊗ [58]
Eurasian Watermilfoil (Seed)	?	?	⊗ [56]	?	?	?
Hydrilla	?	?	☑ [55,59,60,61]	?	?	?
Yellow Floating Heart	?	?	⊗ [62]	?	?	?
Starry Stonewort	?	?	?	?	?	?
Didymo	☑	☑ [13,70]	☑ [13,70]	☑ [13,48,49,50,51]	☑ [1]	☑ [70]

[N] These tables and the literature review contained within were reproduced from: Perdrock, A. 2015. Best Management Practices for Boat, Gear, and Equipment Contamination. State of Wisconsin, Department of Natural Resources, Bureau of Water Quality.

Table 2. *Efficacy of treatment methods for invertebrates.*

ANS	Steam Cleaning (212°F)	Hot Water (140°F)	Drying (5 days)	Chlorine (500 ppm)	Virkon® (2:100 solution)	Freezing (-3°C)
Faucet Snail	☑	☑ [18]	⊗ [18,35]	⊗ [18]	Ⓡ [18]	☑
New Zealand Mudsnail	☑	☑ [4,65]	☑ [6,66]	⊗ [21]	☑ [10,76]	☑ [4,6]
Quagga Mussel (Adults)	☑ [77]	☑ [7,16]	☑ [14,67]	☑	☑ [9]	☑
Quagga Mussel (Veligers)	☑ [77]	☑ [4,17]	☑ [69]	☑	☑ [9]	☑
Zebra Mussel (Adult)	☑ [77]	☑ [7,8,54,67]	☑ [14,25,67]	☑ [11,19,22]	Ⓡ	☑ [25,27,67,68]
Zebra Mussel (Veligers)	☑ [77]	☑ [4]	Ⓡ	☑	Ⓡ	☑
Asian Clam	☑	☑ [4,37,41,42,43]	⊗ [4,44,45]	⊗ [36,37,38,39,40]	☑ [23]	☑ [46]
Spiny Waterflea (Adult)	☑	☑ [7,47]	☑ [4]	Ⓡ	Ⓡ	Ⓡ
Spiny Waterflea (Resting Eggs)	☑	☑ [2]	☑ [2]	⊗ [2]	Ⓡ	☑ [2]
Bloody Red Shrimp	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
Rusty Crayfish	?	?	?	?	?	?

Table 3. *Efficacy of treatment methods for viruses and diseases.*

ANS	Steam Cleaning (212°F)	Hot Water (140°F)	Drying (5 days)	Chlorine (500 ppm)	Virkon® (2:100 solution)	Freezing (-3°C)
Spring Viremia of Carp Virus (SVCv)	☑	☑ [29,30,31,6,4]	⊗ [4*]	☑ [28,29,30,64]	☑ [28]	⊗ [29]
Largemouth Bass Virus (LMBv)	Ⓡ	Ⓡ	Ⓡ	☑ [24,28]	☑ [24,28]	⊗ [32]
Viral Hemorrhagic Septicemia Virus (VHSv)	☑	☑ [4,72,73]	☑ [4,72,74]	☑ [28]	☑ [28,72]	☑ [26,29,63] ⊗ [75]
Lymphosarcoma	Ⓡ	Ⓡ	Ⓡ		Ⓡ	Ⓡ
Whirling Disease	☑ [33]	⊗ [20,33,71]	☑ [5,33]	☑ [5,20,28,33]	Ⓡ	☑ [5,33]
Heterosporis	Ⓡ	Ⓡ	☑ [34]	☑ [34]	Ⓡ	☑ [34]

References

1. Root, S. and C.M. O'Reilly. 2012. Didymo control: increasing the effectiveness of decontamination strategies and reducing spread. Fisheries. 37(10):440-448.

   Tested the effectiveness of liquid dish detergent, bleach, Virkon®, and salt in killing Didymo. Found that longer submersion times did not significantly increase mortality and a one minute submersion time would be sufficient for all treatments. Exact mortality rates are not listed for each treatment, however, a graph shows the *effectiveness for 1% Virkon® solution at around 80% and the effectiveness for 2% bleach around 95%.*

2. Branstrator, D.K., L.J. Shannon, M.E. Brown, and M.T. Kitson. 2013. Effects of chemical and physical conditions on hatching success of *Bythotrephes longimanus* resting eggs. Limnology and Oceanography. 58(6):2171-2184.

   Frozen in water, not just in air; Hot water: 50°C (122°F) for >5 min (or 1 min at >50°C); Drying: ≥ 6 hr @ 17°C 63°F). Chlorine solutions of 3400 mg L-1 had no impact on hatching success when exposed for up to 5 min.

3. Bruckerhoff, L., J. Havel, and S. Knight. 2013. Survival of invasive aquatic plants after air exposure and implication for dispersal by recreation boats. Unpublished data.

   Studied the impacts of drying on the viability of Eurasian watermilfoil and curlyleaf pondweeds. For Eurasian watermilfoil, single stems were viable for up to 24hrs while coiled strands were viable for up to 72hrs. For curlyleaf pondweed, single stems were viable for 18hrs, and turions were still viable after 28 days of drying.

4. United States Forest Service. 2014. Preventing spread of aquatic invasive organisms common to the Intermountain Region. Intermountain Region Technical Guidance. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5373422.pdf.

   Outlines guidance to avoid spread of ANS during fire management and suppression activities. Recommends treatments for various species based on a literature review; references are outlined in this guidance. For quagga and zebra mussel adults and larvae: ≥140°F (60°C) hot water spray for 5 to 10 seconds, or hot water immersion of ≥120°F (50°C) for 1 minute. Freeze at 0°C for adults. Dry for 5 days. 0.5% bleach solution rinse. 2% Virkon® Aquatic solution for 10 minutes. Drying of >28 days at 70°F needed.

5. Hedrick, R.P., T.S. McDowell, K. Mukkatira, E. MacConnell, and B. Petri. 2008. Effects of freezing, drying, ultraviolet irradiation, chlorine, and quaternary ammonium treatments on the infectivity of myxospores of *Myxobolus cerebralis* for *Tubifex tubifex*. Journal of Aquatic Animal Health. 20(2):116-125.

   Chlorine concentrations of 500 mg/L for >15 minutes; freezing at either -20°C or -80°C for 7 days or 2 months.

6. Richards, D.C., P. O'Connell, and D. Cazier Shinn. 2004. Simple control method to limit the spread of the New Zealand mudsnail *Potamopyrgus antipodarum*. North American Journal of Fisheries Management. 24(1):114-117.

   Drying: Must ensure hot and dry environment (>84°F (~29°C) for 24 hours; ≥104°F (40°C) for >2 hours). Freezing: ≤27°F (-3°C) for 1 to 2 hours.

7. Beyer, J., P. Moy, and B. De Stasio. 2011. Acute upper thermal limits of three aquatic invasive invertebrates: hot water treatment to prevent upstream transport of invasive species. Environmental Management. 47(1):67-76.

   Recommends >43°C (110°F) for 5 to 10 minutes.

8. Morse, J.T. 2009. Assessing the effects of application time and temperature on the efficacy of hot-water sprays to mitigate fouling by *Dreissena polymorpha* (zebra mussels Pallas). Biofouling. 25(7):605-610.

   Recommends a minimum of ≥140°F (60°C) for >10 seconds.

9. Stockton, K.A. 2011. Methods to assess, control, and manage risks for two invasive mollusks in fish hatcheries. M.S. Thesis, University of Idaho.

10. Stockton, K.A. and C.M. Moffitt. 2013. Disinfection of three wading boot surfaces infested with New Zealand mudsnails. North American Journal of Fisheries Management. 33(3):529-538.

    Found that a 2% solution (77 grams/1 gallon water) for 15-20 minutes was effective at killing all NZMS.

11. Cope, W.G., T.J. Newton, and C.M. Gatenby. 2003. Review of techniques to prevent introduction of zebra mussels (*Dreissena polymorpha*) during native mussel (Unionoidea) conservation activities. Journal of Shellfish Research. 22(1):177-184.

    Literature review recommends use of chlorine solutions with concentrations ranging from 25-250 mg/L for disinfecting equipment and supplies.

12. Jerde, C.L., M.A. Barnes, E.K. DeBuysser, A. Noveroske, W.L. Chadderton, and D.M. Lodge. 2012. Eurasian

watermilfoil fitness loss and invasion potential following desiccation during simulated overland transport. Aquatic Invasions. 7(1):135-142.

13. Kilroy, C. 2005. Tests to determine the effectiveness of methods for decontaminating materials that have been in contact with *Didymosphenia geminata*. Christchurch: National Institute of Water & Atmospheric Research Ltd. Client Report CHC 2005-005.

    1% bleach solution resulted in 100% mortality after 30 seconds.

14. Ricciardi, A., R. Serrouya, and F.G. Whoriskey. 1995. Aerial exposure tolerance of zebra and quagga mussels (Bivalvia, Dressenidae) – implications for overland dispersal. Canadian Journal of Fisheries and Aquatic Sciences. 52(3):470-477.

    Adult Dreissena may survive overland transport for 3-5 days.

15. Blumer, D.L., R.M. Newman, and F.K. Gleason. Can hot water be used to kill Eurasian watermilfoil? Journal of Aquatic Plant Management. 47:122-127.

    Submerged at ≥60°C (140°F) for at 2-10 minutes.

16. Comeau, S., S. Rainville, W. Baldwin, E. Austin, S. Gerstenberger, C. Cross, and W.H. Wong. 2011. Susceptibility of quagga mussels (*Dreissena rostriformis bugensis*) to hot-water sprays as a means of watercraft decontamination. Biofouling. 27(3):267-274.

    Recommends a ≥140°F (60°C) spray for 5-10 seconds to mitigate fouling by quagga mussels.

17. Craft, C.D., and C.A. Myrick. 2011. Evaluation of quagga mussel veliger thermal tolerance. Colorado Division of Wildlife Task Order # CSU1003.

18. Mitchell, A.J. and R.A. Cole. 2008. Survival of the faucet snail after chemical disinfection, pH extremes, and heated water bath treatments. North American Journal of Fisheries Management. 28(5):1597-1600.

    Exposed faucet snails to various chemicals, temperatures and pH levels. Virkon® was only tested at a 0.16 and 0.21% solution. 100% of Snails exposed to a 1% solution of household bleach for 24hrs survived.

19. Harrington, D.K., J.E. VanBenschoten, J.N. Jensen, D.P. Lewis, and E.F. Neuhauser. 1997. Combined use of heat and oxidants for controlling adult zebra mussels. Water Research. 31(11):2783-2791.

20. Wagner, E.J. 2002. Whirling disease prevention, control, management: a review. American Fisheries Society. 29:217-225.

    This is a literature review of different chemical and physical control methods of the parasite that causes whirling disease. Studies identified in this review indicate that 5,000 ppm chlorine for 10 min killed the intermediate spores that infect tubifex worms that lead to whirling disease in fish. 130-260 ppm chlorine was recommended in treatment of the direct spores that infect fish. Temperature is effective treatment at 75°C for 10 minutes, but 70°C for 100 minutes was not effective. Recommended heat of 90°C for 10 minutes; bleach at 1600 ppm for 24 hours, or 5000 ppm for 10 minutes.

21. Hosea, R.C. and B. Finlayson. 2005. Controlling the spread of New Zealand mud snails on wading gear. State of California Department of Fish and Game, Office of Spill Prevention and Response, Administrative Report 2005-02.

    NZMS exposed to various dilutions of household bleach for 5 minutes. The only concentration to show an impact was undiluted bleach.

22. Sprecher, S.L., and K.D. Getsinger. 2000. Zebra mussel chemical control guide. United States Army Corps of Engineers – Engineer Research and Development Center. ERDC/EL TR-00-1.

23. Barbour, J.H., S. McMenamin, J.T.A. Dick, M.E. Alexander, and J. Caffrey. 2013. Biosecurity measures to reduce secondary spread of the invasive freshwater Asian clam, *Corbicula fluminea* (Müller, 1774). Management of Biological Invasions. 4(3):219-230.

24. Kipp, R.M., A.K. Bogdanoff, and A. Fusaro. 2014. Ranavirus. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Revision Date: 8/17/2012. http://nas.er.usgs.gov/queries/GreatLakes/SpeciesInfo.asp?NoCache=5%2F6%2F2011+6%3A17%3A25+PM&SpeciesID=2657&State=&HUCNumber=DGreatLakes>.

Recommends 10% bleach/water solution.

25. Boelman, S.F., F.M. Neilson, E.A. Dardeau Jr., and T. Cross. 1997. Zebra mussel (*Dreissena polymorpha*) control handbook for facility operators, First Edition. US Army Corps of Engineers, Zebra Mussel Research Program. Miscellaneous Paper EL-97-1.

    Must ensure hot and dry environment: >25°C for at least 2 days, or 5 days when humidity is high.

26. Batts, W.N. and J.R. Winton. 2012. Viral hemorrhagic septicemia. USGS Western Fisheries Research Center. http://afs-fhs.org/perch/resources/14069231582.2.7vhsv2014.pdf.

27. McMahon, R.F., T.A. Ussery, and M. Clarke. 1993. Use of emersion as a zebra mussel control method. US Army Corps of Engineers Contract Report EL-93-1. http://el.erdc.usace.army.mil/elpubs/pdf/crel93-1.pdf.

28. Yanong, R.P.E. and C. Erlacher-Reid. 2012. Biosecurity in aquaculture, part 1: an overview. Southern Regional Aquaculture Center, SRAC Pub. No. 4707.

    This publication provides an overview of major concepts in biosecurity for aquaculture and is not a scientific study. Based on research (Bowker et al. 2011), recommends chlorine 500 mg/L for 15 minutes or Virkon® Aquatic 0.5 to 1% for 10 minutes to disinfect whirling disease virus, VHS, LMBv, and SVCv. Specifically, for SVCv: bleach = 500 mg/L for 10 minutes, Virkon® = 0.5-1% for 10 minutes or 0.1% for 30 minutes; for VHS: bleach = 200-500 mg/L for 5 minutes, Virkon® = 0.5-1% for 10 minutes; for Whirling Disease: bleach = 500 mg/L for 10-15 minutes, Virkon® = 0.5-1% for 5 minutes; for LMBv: bleach = 500 mg/L for 15 minutes, Virkon® = 0.5-1% for 1 minute.

29. World Organization for Animal Health. 2012. Manual of Diagnostic Tests for Aquatic Animals. http://www.oie.int/international-standard-setting/aquatic-manual/access-online/.

    Direct quotes:

    "The virus is inactivated at 56°C for 30 minutes, at pH 12 for 10 minutes and pH 3 for 2 hours (Ahne,1986)."

    "The following disinfectants are also effective for inactivation… 540 mg litre–1 chlorine for 20 minutes, 200–250 ppm (parts per million… (Ahne, 1982; Ahne & Held, 1980; Kiryu et al., 2007)."

    "The virus is most stable at lower temperatures, with little loss of titre for when stored for 1 month at -20°C, or for 6 months at -30 or -74°C (Ahne, 1976; Kinkelin & Le Berre, 1974)."

    VHSv reference in the above source was quote from another study Arkush, et. Al 2006, this reference has been added. (75)

30. Iowa State University: College of Veterinary Medicine. 2007. Spring Viremia of Carp. http://www.cfsph.iastate.edu/Factsheets/pdfs/spring_viremia_of_carp.pdf.

    Direct Quote:

    "It can be inactivated with…chlorine (500 ppm)… SVCv can also be inactivated by heating to 60°C (140°F) for 30 minutes…" No contact time was given for the bleach solution.

31. Kiryu, I., T. Sakai, J. Kurita, and T. Iida. 2007. Virucidal effect of disinfectants on spring viremia of carp virus. Fish Pathology. 42(2):111-113.

    This study reviewed past literature and displayed the following results: using a Bleach concentration of 7.6ppm for a contact time of 20 min. resulted in 99-99.9% inactivation of SVCv and a concentration of 540 ppm for a 20 minute contact time resulted in >99.9% inactivation of SVCv. This paper also reveals that 45°C heat treatments for 10 minutes have been found SVCv to be 99-99.9% inactivated, while 60°C heat treatments for 30 minutes was recommended for sterilization.

32. Plumb, J.A. and D. Zilberg. 1999. Survival of largemouth bass iridovirus in frozen fish. Journal of Aquatic Animal Health. 11(1):94-96.

    This study found LMBv to be very stable when frozen at -10°C in fresh fish tissue. Infectious doses were still found after freezing for 155 days in fish tissue.

33. Wagner, E.J., M. Smith, R. Arndt, and D.W. Roberts. 2003. Physical and chemical effects on viability of the *Myxobolus cerebralis* triactinomyxon. Diseases of Aquatic Organisms 53(2):133-142.

Various chemical and physical methods for destroying the triactinomyxon (TAM) stage of the myxozoan parasite Myxobolus cerebralis were tested at different exposure/doses. Freezing for 105 minutes at -20°C or drying for 1 hour at 19-21°C, chlorine concentrations of 130 ppm for 10 min, immersion in 75°C water bath for 5 minutes all produced 0% viability of the parasite which causes whirling disease. However at 58°C water bath for 5 minutes, as much as 10% remain possibly viable.

34. DNR/GLFC guidance. 2005. http://dnr.wi.gov/topic/fishing/documents/fishhealth/heterosporis_factsheet.pdf.

Direct Quote:

"Immerse gear in a chlorine bleach solution for five minutes (3 cups of household bleach in 5 gallons of water). Freezing at -4 °F for 24 hours (home freezer) will also kill the spores….completely dry for a minimum of 24 hours for dessication to effectively kill the spores."

35. Wood, A.M., C.R. Haro, R.J. Haro, and G.J. Sandland. 2011. Effects of desiccation on two life stages of an invasive snail and its native cohabitant. Hydrobiologia. 675:167-174.

Compared the effects of desiccation on adults and egg viability on faucet snails and a native snail. Results found desiccation for 7 days produced 73% mortality in faucet snail eggs, and only 62% mortality in adult faucet snails.

36. Ramsay, G.G., J.H. Tackett, and D.W. Morris. 1988. Effect of low-level continuous chlorination on *Corbicula fluminea*. Environmental Toxicology and Chemistry. 7:855-856.

Evaluated long exposure times (2-28 days) at low concentrations (0.2-40 mg/L) of chlorine.

37. Mattice, J.S., R.B. McLean, and M.B. Burch. 1982. Evaluation of short-term exposure to heated water and chlorine for control of the Asiatic clam (*Corbicula fluminea*). Technical Report ORNL/TM-7808. Oak Ridge National Lab., TN (USA).

Evaluated short exposure times (30 minutes) at low concentrations (0, 5, 7.5, and 10 mg/L) of chlorine. Found mortality at 35-43°C (95-110°F) water.

38. Belanger, S.E., D.S. Cherry, J.L. Farris, K.G. Sappington, J. Cairns Jr. 1991. Sensitivity of the Asiatic clam to various biocidal control agents. Journal of the American Water Works Association. 83(10):79-87.

Long exposure time (14-28 days) to low rates (0.25-.04 mg/L) of chlorination.

39. Doherty, F.G., J.L. Farris, D.S. Cherry, and J. Cairns Jr. 1986. Control of the freshwater fouling bivalve *Corbicula fluminea* by halogenation. Archives of Environmental Contamination and Toxicology. 15(5):535-542.

Long exposure time (28-32 days) to low rates (0.2-1 mg/L) of chlorination.

40. Chandler, J.H. and L.L. Marking. 1979. Toxicity of fishery chemicals to the Asiatic clam, *Corbicula manilensis*. Progressive Fish-Culturist. 41:148-51.

Tested concentrations of various chemicals on Asiatic clam. Clorine solutions derived from Calcium hypochlorite had a 96-hr LC_{50} *of 1450mg/L.*

41. Habel, M.L. 1970. Oxygen consumption, temperature tolerance, filtration rate of introduced Asiatic clam *Corbicula manilensis* from the Tennessee River. MS Thesis, Auburn University, Auburn, Alabama, 66 pp.

Found mortality at 35-43°C (95-110°F) water.

42. Coldiron, D.R. 1975. Some aspects of the biology of the exotic mollusk *Corbicula* (Bivalvia: Corhiculidae). MS Thesis, Texas Christian University, Fort Worth, Texas, 92 pp.

Found mortality at 35-43°C (95-110°F) water.

43. Cherry, D.S., J.H. Rodgers Jr., R.L. Graney, and J. Cairns Jr. 1980. Dynamics and control of the Asiatic clam in the New River, Virginia. Bulletin 123, Virginia Water Resources Research Center, Virginia Polytechnic Institute & State University, 72 pp.

Found mortality at 35-43°C (95-110°F) water.

44. McMahon, R.F. 1979. Tolerance of aerial exposure in the Asiatic freshwater clam *Corbicula fluminea* (Muller). In Proceedings, First International Corbicula Symposium, ed. by J. C. Britton, 22741, Texas Christian University Research Foundation.

Two weeks needed for mortality.

45. Dudgcon, D. 1982. Aspects of the dessication tolerance of four species of benthic Mollusca from Plover Cove Reservoir, Hong Kong. Veliger. 24:267-271.

46. Müller, O. and B. Baur. 2011. Survival of the invasive clam *Corbicula fluminea* (Müller) in response to winter water temperature. Malacologia. 53(2):367-371.

Lethal temperature reorted at 0°C; freezing is possible control method that warrants research.

47. Garton, D.W., D.L. Berg, and R.J. Fletcher. 1990. Thermal tolerances of the predatory cladocerans *Bythotrephes cederstroemi* and *Leptodora kindti*: relationship to seasonal abundance in Western Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences. 47:731-738.

>38°C (100°F) for 12 hours.

48. Kilroy, C., A. Lagerstedt, A. Davey, and K. Robinson. 2006. Studies on the survivability of the invasive diatom *Didymosphenia geminata* under a range of environmental and chemical conditions. Christchurch: National Institute of Water & Atmospheric Research.

49. Jellyman, P.G, S.J. Clearwater, B.J.F. Biggs, N. Blair, D.C. Bremner, J.S. Clayton, A. Davey, M.R. Gretz, C. Hickey, and C. Kilroy. 2006. *Didymosphenia geminata* experimental control trials: stage one (screening of biocides and stalk disruption agents) and stage two phase one (biocide testing). Christchurch: National Institute of Water & Atmospheric Research Ltd.

50. Beeby, J. 2012. Water quality and survivability of *Didymosphenia geminata*. Colorado State University, Master's Thesis Dissertation.

Tested the impact of chlorine solutions at the doses of 1.3, 2.5, 5.0, and 10 mg/L.

51. Jellyman, P.G., S.J. Clearwater, J.S. Clayton, C. Kilroy, C.W. Hickey, N. Blair, and B.J.F. Biggs. 2010. Rapid screening of multiple compounds for control of the invasive diatom *Didymosphenia geminata*. Journal of Aquatic Plant Management. 48:63-71.

52. USDA-NRCS, 2009. Curly-leaf pondweed. The PLANTS Database Version 3.5. Baton Rouge, USA: National Plant Data Center. http://plants.usda.gov.

Minimum temp of -33°F; freezing unlikely to cause mortality.

53. Barr, T.C. III. 2013. Integrative control of curly leaf pondweed propagules employing benthic bottom barriers: physical, chemical and thermal approaches. University of California – Davis. Ph.D Dissertation.

Study tested the pumping of heated water under bottom barriers to inhibit turion sprouting. Turions were exposed to treatments and then given recovery period. Those that did not sprout were believed to be unviable. Water of temperatures between 60-80°C (140-176°F) for 30 seconds was sufficient to inhibit growth.

54. Rajagopal, S., G. Van Der Velde, M. Van Der Gaag, and H.A. Jenner. 2005. Factors influencing the upper temperature tolerances of three mussel species in a brackish water canal: size, season and laboratory protocols. Biofouling. 21:87-97.

55. Barnes, M.A., C.L. Jerde, D. Keller, W.L. Chadderton, J.G. Howeth, D.M. Lodge. 2013. Viability of aquatic plant fragments following desiccation. Invasive Plant Science and Management. 6(2):320-325.

Hydrilla reported as "fastest drying plant" of 10 species tested; however, additional viability testing not done due to state transport laws.

56. Standifer, N.E. and J.D. Madsen. 1997. The effect of drying period on the germination of Eurasian watermilfoil seeds. Journal of Aquatic Plant Management. 35:35-36.

EWM seeds are viable to excessive periods of desiccation.

57. Watkins, C. H. and R. S. Hammerschlag. 1984. The toxicity of chlorine to a common vascular aquatic plant. Water Research. 18(8):1037-1043.

Study looked at impact of low chlorine concentrations (0.02, 0.05, 0.1, 0.3,0.5, and 1.0mgL-1) on Eurasian watermilfoil growth over 96-hr period. Rate reductions ranged from 16.2% for plants grown with chlorine concentrations of .05 mgL-1 to 88.2% reduction in growth in a chlorine concentration of 1.0 mg-1.

58. Patten Jr., B.C. 1955. Germination of the seed of *Myriophyllum spicatum L.* in a New Jersey lake. Bulletin of the Torrey Botanical Club. 82(1):50-56.

EWM seeds likely experience increased viability after freezing.

59. Silveira, M.J., S.M. Thomaz, P.R. Mormul, and F.P. Camacho. 2009. Effects of desiccation and sediment type on early regeneration of plant fragments of three species of aquatic macrophytes. International Review of Hydrobiology. 94(2):169-178.

Fragments of Hydrilla was left on trays of sand and clay for 1-4 days inside a greenhouse. Samples left in clay were still viable after 1-4 days of desiccation, however, not sprouts were produced in the sand treatment after one day of drying.

60. Kar, R.K. and M.A. Choudhuri. 1982. Effect of desiccation on internal changes with respect to survival of *Hydrilla verticillata*. Hydrobiological Bulletin. 16(2-3):213-221.

Twigs of Hydrilla verticillata were dried for periods of up to 24hrs and then analyzed for signs of life. Respiration continued for at least 20hrs.

61. Basiouny, F.M., W.T. Haller, and L.A. Garrard. 1978. Survival of Hydrilla (*Hydrilla verticillata*) plants and propagules after removal from the aquatic habitat. Weed Science. 26:502–504.

Hydrilla plants and propagules were dried for up to 7 days, and then replanted. 16hrs of drying resulted in no regeneration of plant fragments, while drying tubers 120 hours and turions for 32 hours resulted in no new sprouting.

62. Smits, A. J.M., R. Van Ruremonde, and G. Van der Velde. 1989. Seed dispersal of three nymphaeid macrophytes. Aquatic Botany. 35:167-180

N. peltata seeds show high tolerance to desiccation.

63. Arkush, K.D., H.L. Mendonca, A.M. McBride, S. Yun, T. S. McDowell, and R. P. Hedrick. 2006. Effects of temperature on infectivity and of commercial freezing on survival of the North American strain of viral hemorrhagic septicemia virus (VHSV). Diseases of Aquatic Organisms. 69:145-151.

Freezing will not completely kill the virus but will reduce infectivity of virus titres by 90%.

64. Ahne, W., H.V. Bjorklund, S. Essbauer, N. Fijan, G. Kurath, J. R. Winton. 2002. Spring viremia of carp (SVC). Diseases of Aquatic Organisms. 52:261-272.

65. Dwyer, W., B. Kerans, and M. Gangloff. 2003. Effects of acute exposure to chlorine, copper sulfate, and heat on survival of New Zealand mudsnails. Intermountain Journal of Sciences. 9:53-58.

>50°C (122°F) for 15 seconds

66. Alonso, A. and P. Castro-Diez. 2012. Tolerance to air exposure of the New Zealand mudsnail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca) as a prerequisite to survival in overland translocations. NeoBiota. 14:67-74.

Dry in full sunlight for >50 hours.

67. McMahon, R.F. 1996. The physiological ecology of the zebra mussel, *Dreissena polymorpha*, in North America and Europe. American Zoologist. 36(3):339-363.

68. Clarke, M. 1993. Freeze sensitivity of the zebra mussel (*Dreissena polymorpha*) with reference to dewatering during freezing conditions as a mitigation strategy. M.S.Thesis. The University of Texas at Arlington, Arlington, Texas.

69. Choi, W.J., S. Gerstenberger, R.F. McMahon, and W.H. Wong. 2013. Estimating survival rates of quagga mussel (*Dreissena rostriformis bugensis*) veliger larvae under summer and autumn temperature regimes in residual water of trailered watercraft at Lake Mead, USA. Management of Biological Invasions. 4(1):61-69.

Veligers experienced 100% mortality after 5 days under summer temperature conditions, and after approximately 27 days under autumn conditions.

70. Kilroy, C., A. Lagerstedt, A. Davey, and K. Robinson. 2007. Studies on the survivability of the invasive diatom *Didymosphenia geminata* under a range of environmental and chemical conditions. Biosecurity New Zealand NIWA Client Report: CHC2006-116. National Institute of Water and Atmospheric Research LTD. Christchurch, New Zealand.

Studied the survivability of D. geminata to determine optimum growing conditions. Then tested the use of disinfection methods on D. geminata being grown in optimum conditions. 100% Cell mortality occurred after 20 min with 40°C water, but 60°C for at least one minute is recommended for rapid treatment. Freezing is stated to be effective at killing D. geminata, however, this study does not list treatment times. A 1% chlorine solution was effective after 1 minute, and a 0.5% solution took 100 minutes to kill ~90% of specimens.

71. Hoffman, G.L. and M. E. Marliw. 1977. Control of whirling disease (*Myxosoma cerebralis*): use of methylene blue staining as a possible indicator of effect of heat on spores. Journal of Fish Biology. 10:181-183.

72. Bovo, G., B. Hill, A. Husby, T. Hästein, C. Michel, N. Olesen, A. Storset, and P. Midtlyng. 2005. Work Package 3 Report: Pathogen survival outside the host, and susceptibility to disinfection. Report QLK2-Ct-2002-01546: Fish Egg Trade. Veterinary Science Opportunities (VESO). Oslo, Norway.

73. Jørgensen, P. 1974. A study of viral diseases in Danish rainbow trout: their diagnosis and control. Thesis, Royal Veterinary and Agricultural University, Copenhagen. 101pp.

122°F (50°C) for 10 minutes or 122°F (50°C)

74. Pietsch, J., D. Amend, and C. Miller.1977. Survival of infectious hematopoietic necrosis virus held under various conditions. Journal of Fisheries Research Board of Canada. 34:1360-1364.

Study done on IHNH virus (similar to VHSv); dry gear for 4 days at 21°C (70°F).

75. Arkush K.D., H.L. Mendonca, A.M. McBride, S. Yun, T.S. McDowell, and R.P Hedrick. 2006. Effects of temperature on infectivity and of commercial freezing on survival of the North American strain of viral hemorrhagic septicemia virus (VHSV). Dis Aquat Organ. 69(2-3):145-51.

In 2006, Arkush et al. found that commercial freezing (held at -20°C for 2 weeks after blast freezing at-40°C) of in vitro VHSv shown a significant 99.9% reduction of the active virus post thaw.

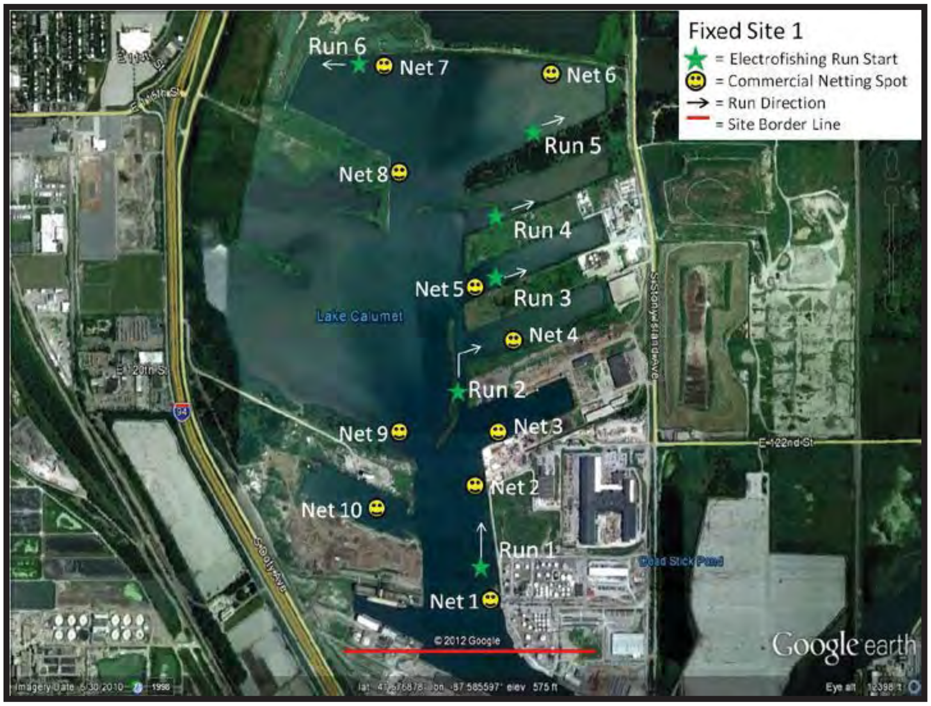
76. Acy, C.N. 2015. Tolerance of the invasive New Zealand mud snail to various decontamination procedures. Thesis submitted in candidacy for Honors at Lawrence University.

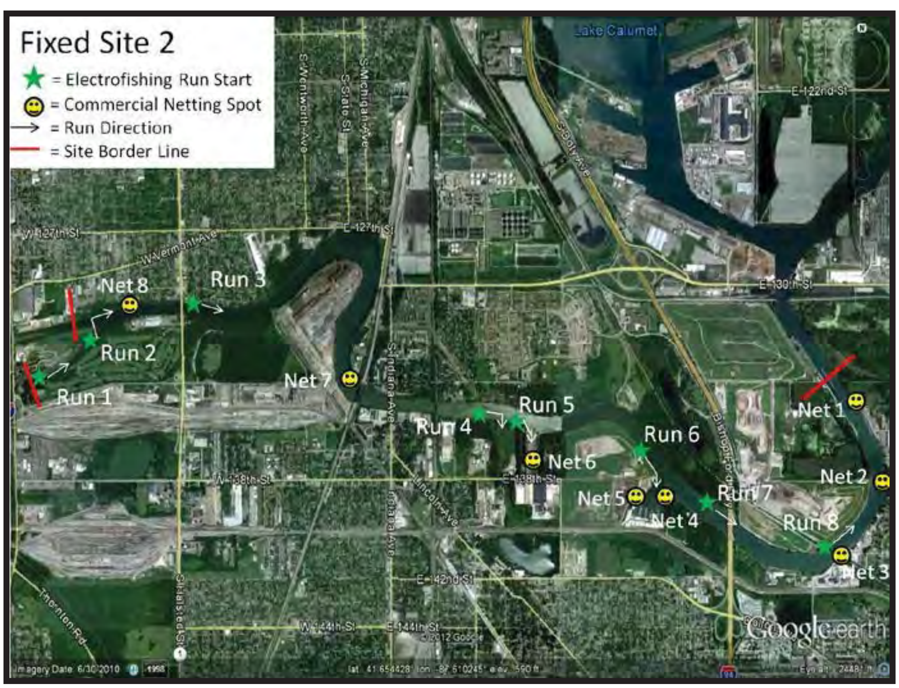
Virkon® was found to be effective after trials of 1, 5, and 10 minute exposures to a 2% solution. Bleach and 409 were also tested. Bleach was found to be effective at 5, 10, and 20 minute exposures to a 400 ppm solution.

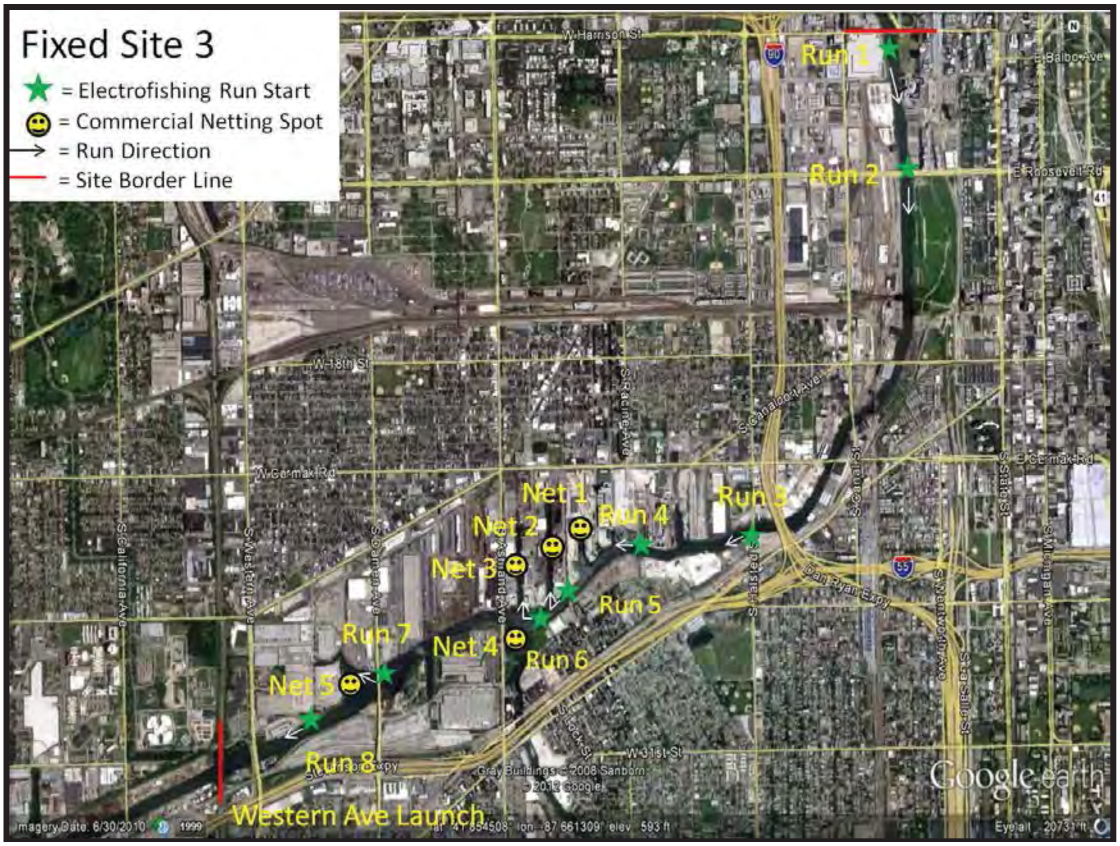
77. DiVittorio, J., M. Grodowitz, and J. Snow. 2010. Inspection and Cleaning Manual for Equipment and Vehicles to Prevent the Spread of Invasive Species [2010 Edition]. U.S. Department of the Interior Bureau of Reclamation. Technical Memorandum No. 86-68220-07-05.

Mentioned steam cleaning as effective, however, no reference or study provided to validate claim.

Appendix D: Detailed Maps of Fixed and Random Site Sampling Locations.






Fixed Site 3
= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Border Line
W Harrison St
Run 1
E Balbo Ave
Run 2
E Roosevelt Rd
W 18th St
S Racine Ave
W Cermak Rd
Net 1
Run 4
Run 3
Net 2
Net 3
Run 5
Run 7
Net 4
Run 6
Net 5
Run 8
Western Ave Launch
S California Ave
S Western Ave
S Damen Ave
S Ashland Ave
S Halsted St
S Canal St
S State St
S Michigan Ave
S Wentworth Ave
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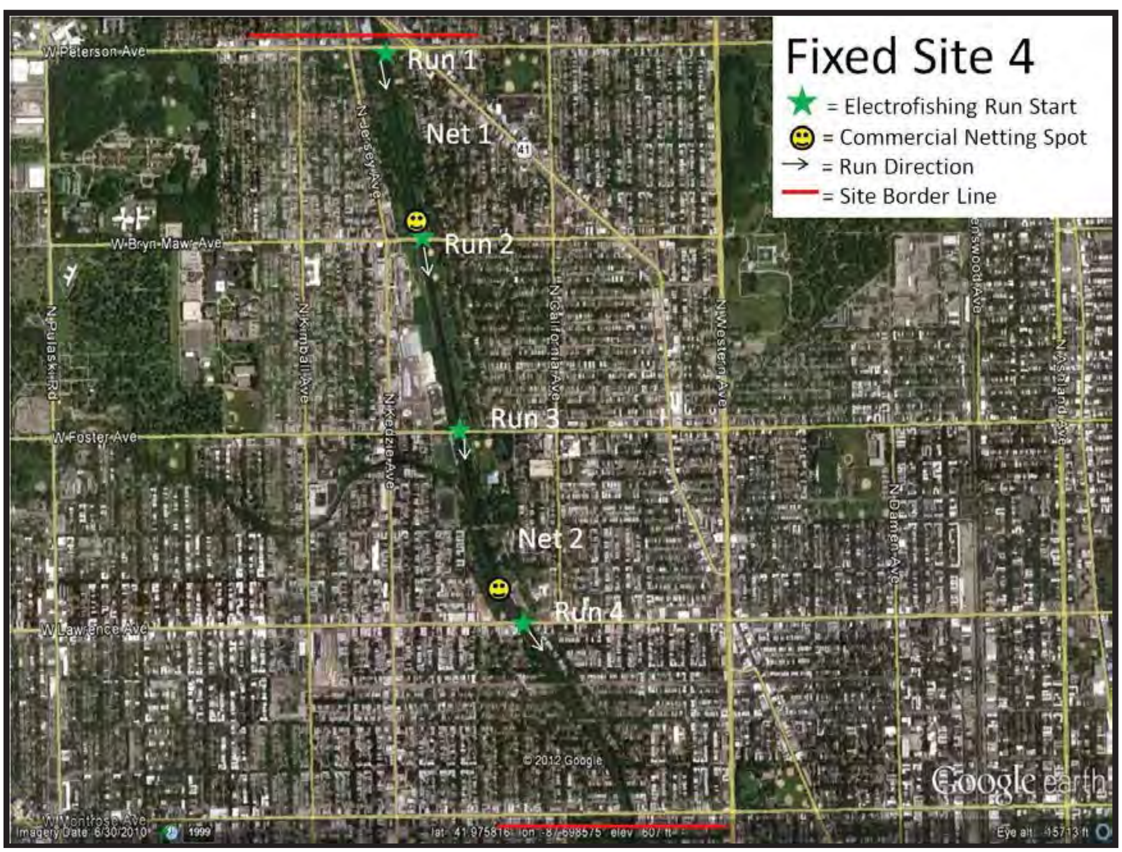
Fixed Site 4
= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Border Line
W Peterson Ave
Run 1
Net 1
W Bryn Mawr Ave
Run 2
N Pulaski Rd
N Kimball Ave
N Kedzie Ave
N California Ave
N Western Ave
N Damen Ave
N Ashland Ave
W Foster Ave
Run 3
Net 2
W Lawrence Ave
Run 4
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© 2012 Google
Google earth
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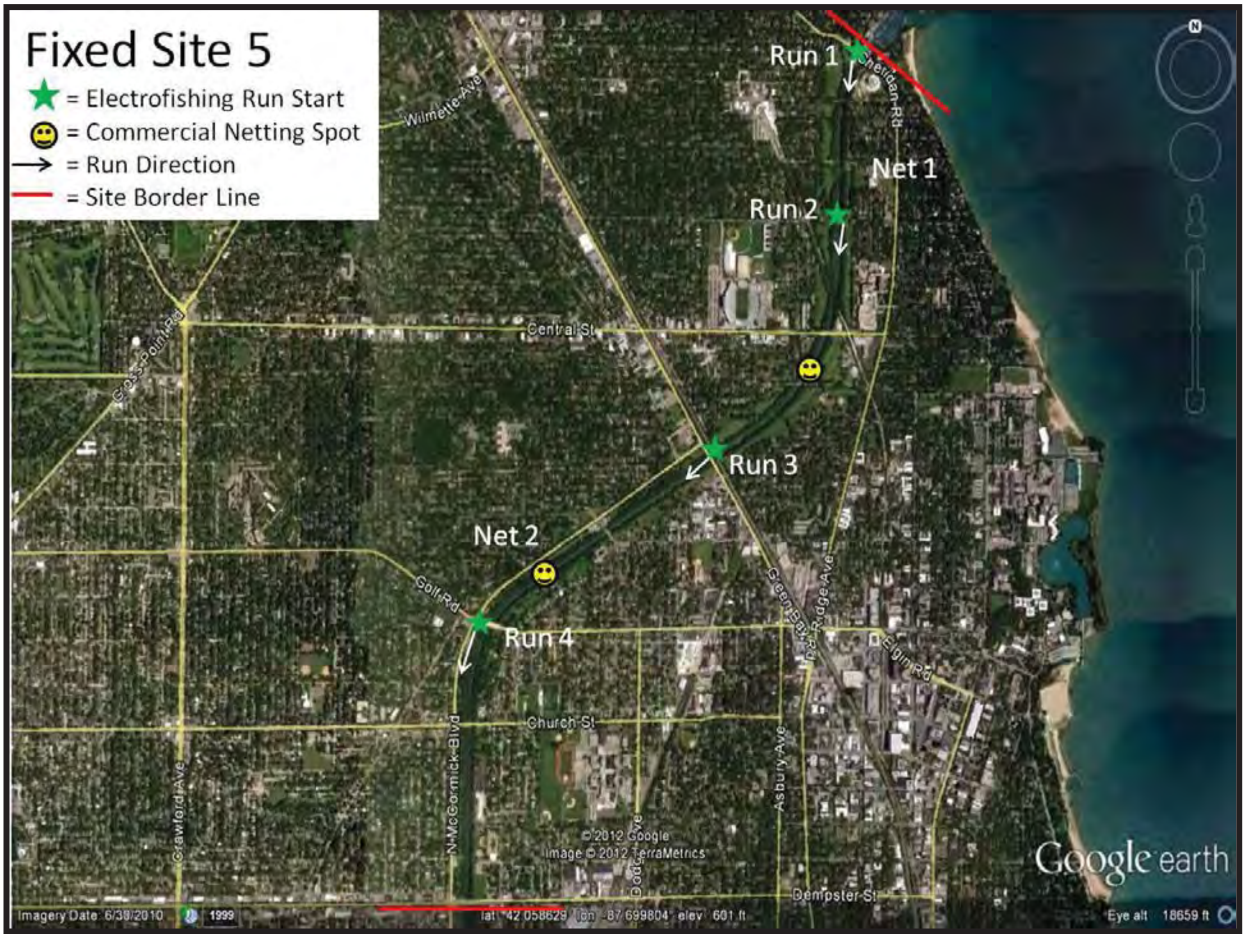
Fixed Site 5
= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Border Line
Run 1
Run 2
Run 3
Run 4
Net 1
Net 2
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Central St
Gross Point Rd
Golf Rd
Church St
Crawford Ave
N McCormick Blvd
Asbury Ave
Ridge Ave
Green Bay Rd
Sheridan Rd
Elgin Rd
Dodge Ave
Dempster St
© 2012 Google
Image © 2012 TerraMetrics
Google earth
Imagery Date: 6/30/2010
1999
lat 42.058629 lon -87.699804 elev 601 ft
Eye alt 18659 ft


Calumet River - Area 1
= Area Boundary
Random Site Area
Lake Calumet
Wolf Lake
Highway 12
Bishop Ford Fwy
Chicago Skyway
S Halsted St
Calumet Ave
© 2012 Google
Image © 2012 TerraMetrics
Google earth
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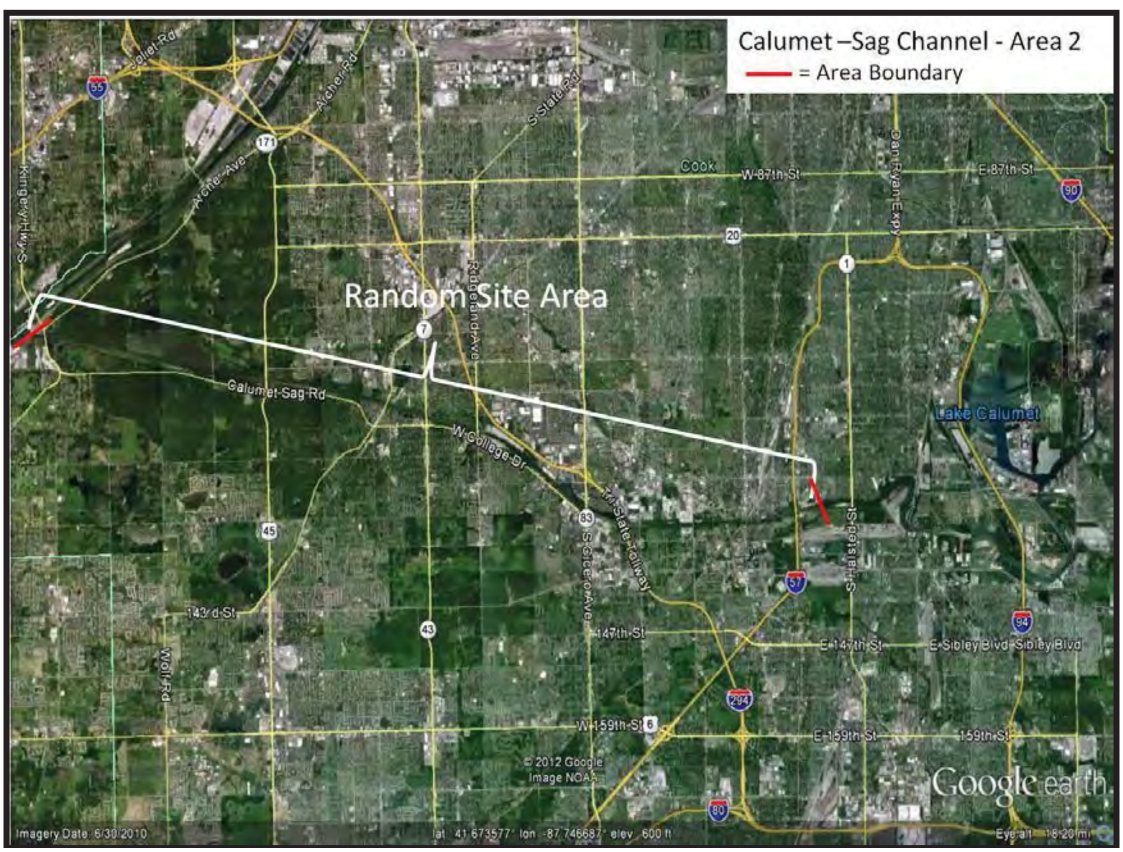
Calumet –Sag Channel - Area 2
= Area Boundary
Random Site Area
Lake Calumet
Archer Ave
Archer Rd
S State St
W 87th St
E 87th St
Dan Ryan Expy
Calumet-Sag Rd
W College Dr
Tri-State Tollway
S Halsted St
143rd St
Wolf Rd
147th St
E 147th St
E Sibley Blvd
Sibley Blvd
W 159th St
E 159th St
159th St
© 2012 Google
Image NOAA
Google earth
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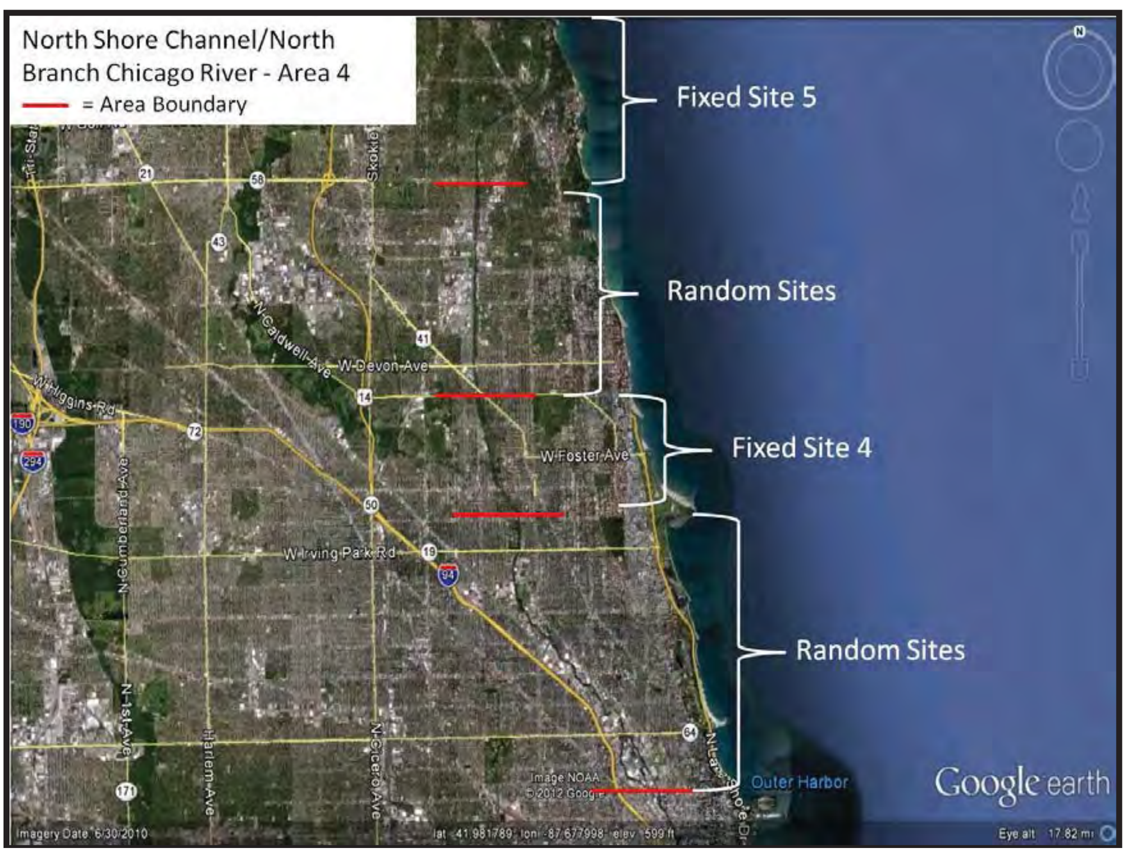
CSSC - Area 3
= Area Boundary
Random Sample Area


North Shore Channel/North
Branch Chicago River - Area 4
= Area Boundary
Fixed Site 5
Random Sites
Fixed Site 4
Random Sites


Lockport Pool North
= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Barrier Line
Dispersal Barrier
E Romeoville Rd
W 135th St
Run 1
Run 2
Net 1
S Independence Blvd
Archer Ave
W 151st St
Google earth
Imagery Date 6/30/2010
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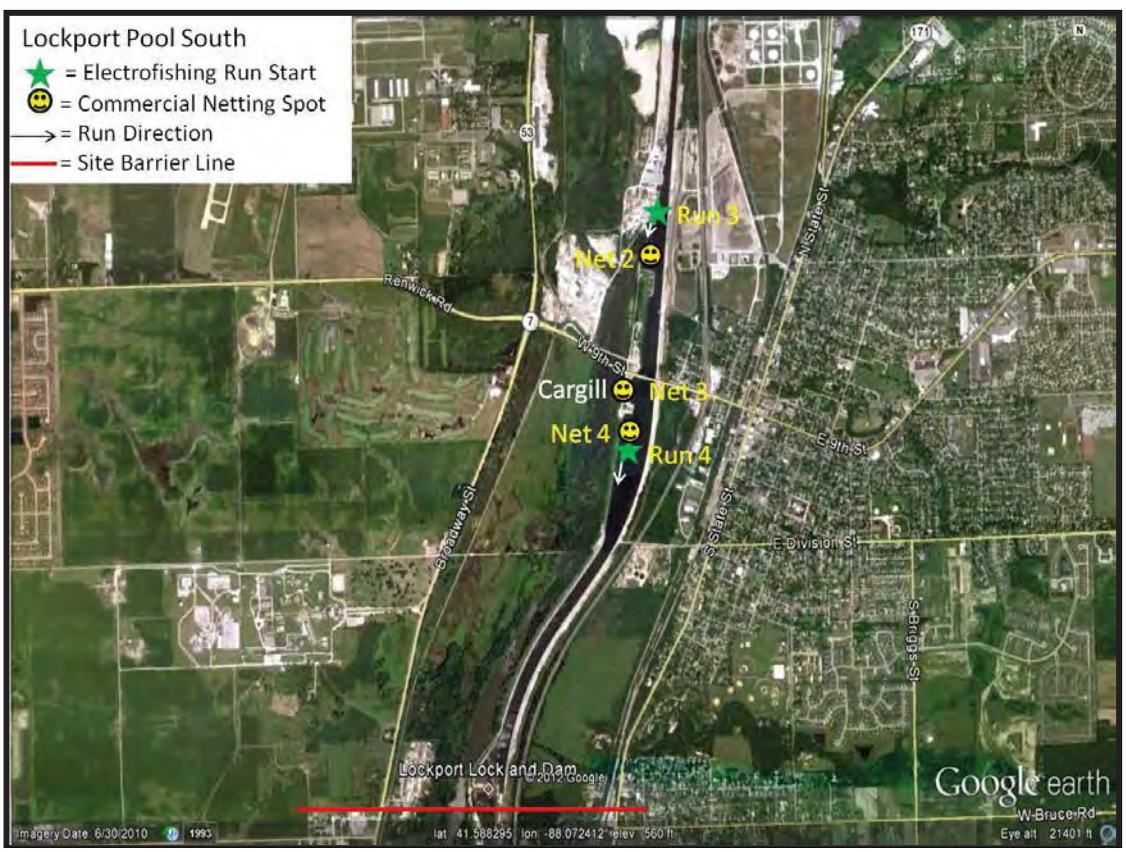
Eye alt 18091 ft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= Run Direction
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Net 2
Renwick Rd
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Cargill
Net 3
Net 4
Run 4
E 9th St
N State St
S State St
Broadway St
E Division St
S Briggs St
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Google earth
W Bruce Rd
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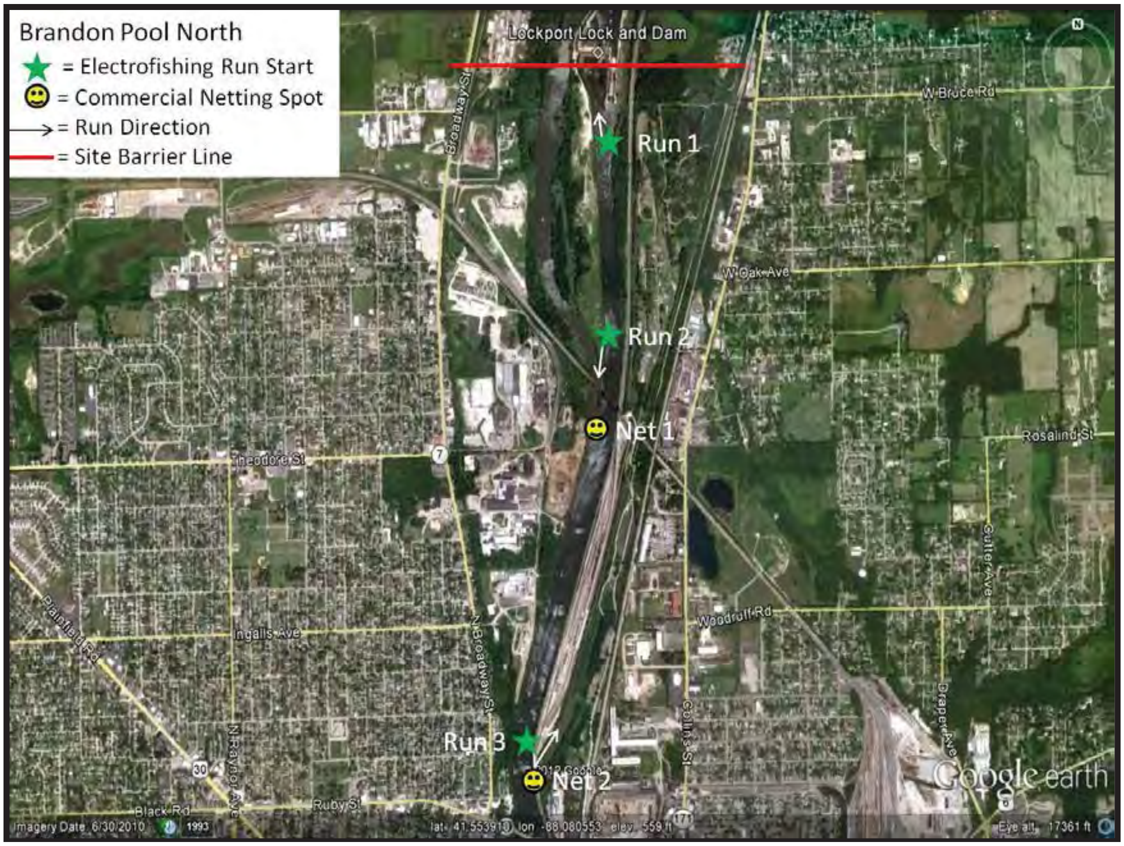
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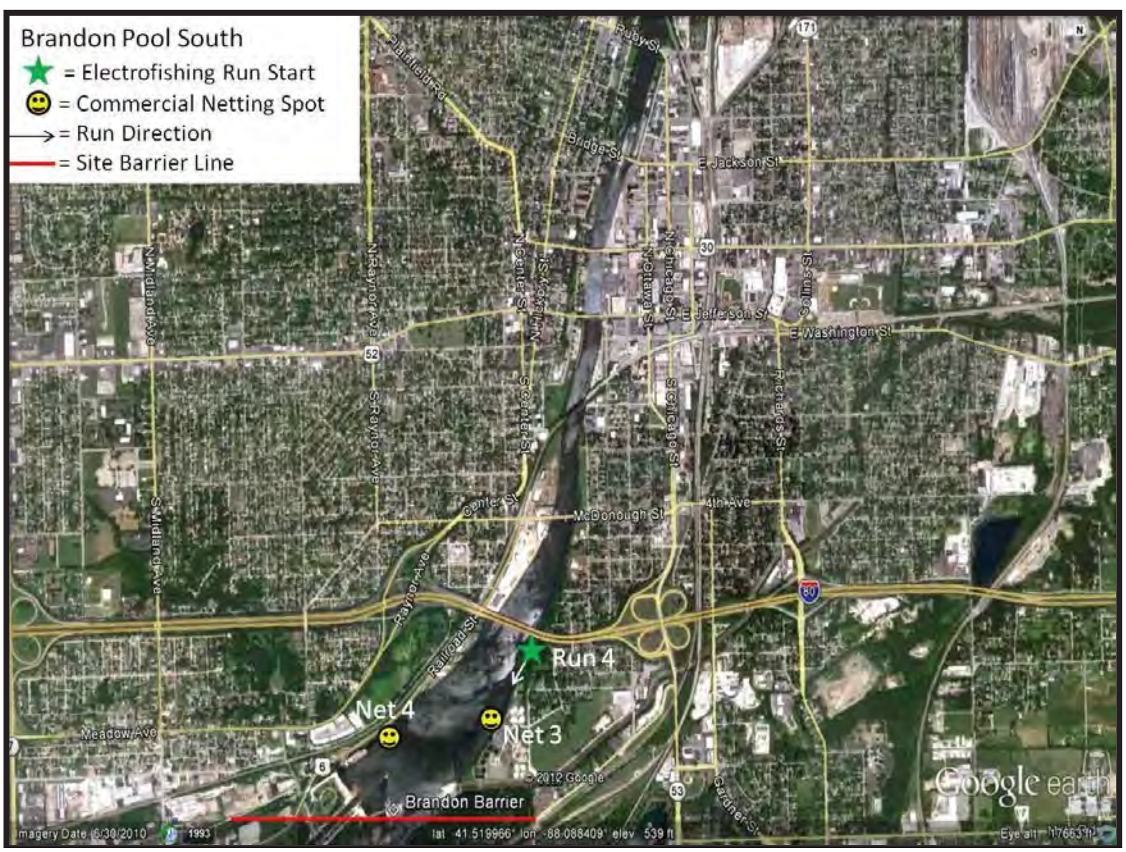
Run 1
Run 2
Net 1
Run 3
Net 2
W Bruce Rd
W Oak Ave
Rosalind St
Theodore St
Woodruff Rd
Ingalls Ave
Plainfield Rd
Black Rd
Ruby St
Broadway St
N Broadway St
N Raynor Ave
Collins St
Draper Ave
Gutter Ave
Google earth


Brandon Pool South
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Ruby St
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N Midland Ave
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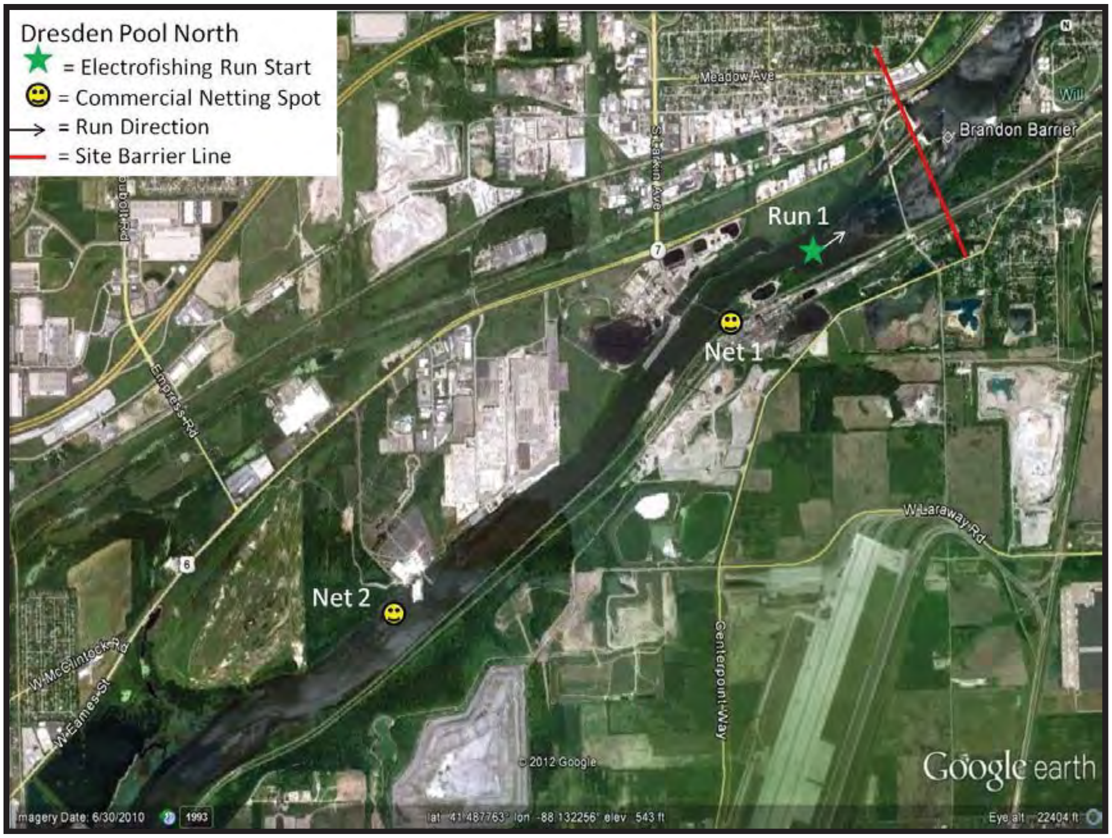
N Ottawa St
N Chicago St
Jefferson St
E Washington St
S Raynor Ave
S Center St
S Chicago St
Richards St
S Midland Ave
Center St
McDonough St
4th Ave
Raynor Ave
Railroad St
Run 4
Net 4
Net 3
Meadow Ave
Brandon Barrier
Gardner St
Google earth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= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Barrier Line
Brandon Barrier
Run 1
Net 1
Net 2
Meadow Ave
Empress Rd
W Laraway Rd
Centerpoint Way
W McClintock Rd
W Eames St
Google earth
© 2012 Google
Imagery Date: 6/30/2010


Dresden Pool South
= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Barrier Line
Net 3
Run 2
Run 3
Net 4
Big Basin Launch
Run 4
W Bluff Rd
Craig Rd
W Manhattan Rd
Centerpoint Way
S Brandon Rd
Image U.S. Geological Survey
© 2012 Google
Google earth
Imagery Date: 6/30/2010


Marseilles Pool North
= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Barrier Line
Run 2
Run 1
Net 1
Negro Slough
Dellos Rd
Image U.S. Geological Survey
© 2012 Google
Google earth
Imagery Date: 4/30/2008
1998
lat 41.386214° lon -88.314243° elev 498 ft
Eye alt 19308 ft


Marseilles Pool South
= Electrofishing Run Start
= Commercial Netting Spot
= Run Direction
= Site Barrier Line
Net 3
Peacock Slough
Peacock Slough
Run 4
Net 4
Run 3
Net 2
Ashley Rd
Washington St
E Washington St
Morris Launch
47
Image U.S. Geological Survey
© 2012 Google
Google earth
Imagery Date: 10/10/2007
1993
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Eye alt 16678 ft

Appendix E: Handling Captured Asian Carp and Maintaining Chain-of-Custody Records

Chain-of-custody is a legal term that refers to the ability to guarantee the identity and integrity of a sample from collection through reporting of the test results. The following are general guidelines to keep chain-of-custody intact throughout the fish collection process.

These procedures should be followed when any Bighead or Silver carp is collected in the Chicago Area Waterway (from Lockport Lock and Dam to Lake Michigan, but also areas where they have not previously been collected (e.g. Brandon Road Pool, Des Plaines River, or Lake Michigan).

1. Keep the number of people involved in collecting and handling samples and data to a minimum.

2. Only allow authorized people associated with the project to handle samples and data. Always document the transfer of samples and data from one person to another on chain-of-custody forms. No one who has signed the chain-of-custody form shall relinquish custody without first having the chain-of-custody form signed by the next recipient.

3. Always accompany samples and data with their chain-of-custody forms. The chain-of -custody form must accompany the sample.

4. Ensure that sample identification and data collected are legible and written with permanent ink.

Specific Instructions for Handling Asian Carp:

1. A. If the boat crew believes they have collected an Asian carp, they should cease further collection and take a GPS reading of the location at which the Asian carp was found or mark the location on a map provided.

   B. The boat crew leader should immediately notify a lead operations coordinator or chief, who will immediately notify the Incident Commander and the Conservation Police Commander, if present. If a command structure is not in place, then immediately contact an Illinois Conservation Police Officer (CPO) by contacting the IDNR Region 2 law office at 847-608-3100 x 2056.

   C. The boat crew will then take the fish to a staging area for identification by the fish biologist stationed at the site. If a staging area has not been designated, the boat crew should proceed to a predetermined meeting location and await the arrival of the CPO. The boat crew will not leave until the CPO arrives and they have recorded the GPS reading on a chain-of-custody form and signed the form over to the CPO. The CPO is to remain with the fish at all times.

   D. Once a fish biologist at the staging area makes a positive visual identification, he/she will identify the fish with a fish tag; take pictures of the tagged fish (See spawn patch preservation and analysis appendix for photo request, Appendix H); measure its total length (mm) and weight (g); determine the fish's gender; identify reproductive status and gonad development as immature, mature – green, mature – ripe, mature - running ripe, and mature – spent; place the fish in a plastic bag; and seal the fish in a cooler with wet ice. The fish biologist at the staging area will place evidence tape across the opening of the cooler and initial it. The fish biologist at the staging area or when no staging area has been designated, the boat crew leader will give the sealed cooler to the IDNR CPO. The fish is to remain under IDNR control at all times.

E. The CPO will then deliver the sealed fish and chain-of-custody form to the sampling laboratory on site or make arrangements for transport to the genetics laboratory at the University of Illinois (contact: Dr. John Epifanio). Soft tissue for genetic testing and hard tissue for aging and/or chemical analysis will be removed at the UIUC laboratory. Additional soft tissue samples will be collected for other cooperating genetics laboratories (e.g., ERDC), as needed. Hard tissue will be transported to SIUC for analysis (contact: Dr. Jim Garvey). Chain-of-custody will be maintained when transporting hard tissue between university laboratories.

2. Only authorized IDNR tissue samplers or persons designated by an operations coordinator or chief will unseal the fish and remove the tissue samples from the fish for preservation and delivery to the lab. The lab samples will maintain the same sample ID as the subject fish but will also include an additional sequential letter (AC 001a, AC001b, AC002a, AC002b, etc) for multiple tissue samples from one fish. While sampling is occurring, the fish and samples will remain under supervision of the IDNR CPO who will maintain the chain-of-custody form.

3. All Asian carp captured during rapid response actions should be treated with care, handled minimally (no photo ops prior to tissue sampling), and transported to the staging area where they will be stored on ice in a cooler (no plastic bags). Captured fish cannot be frozen or preserved with chemicals, as these techniques distort the DNA. The USACE Engineer Research and Development Center (ERDC) has been designated to obtain a tissue sample from any Bighead Carp or Silver Carp collected during a rapid response action. The preferred tissue for DNA analysis is a pectoral fin (the entire fin) removed with a deep cut in order to include flesh and tissue of the fin base. The fin and tissue sample will be stored in a vial containing ethanol preservative (USACE will provide vials and preservative). Samples will be transported to ERDC for sequencing and comparison to the eDNA found in the pool.

CHAIN OF CUSTODY RECORD

	CHAIN OF CUSTODY RECORD	File No. Inv.

Date and Time of Collection:	River Reach:	Collected By:

Notes:

Collection No.	Description of Collection (include river reach, river mileage (if known), and any serial numbers):

Collection No.	From: (Print Name, Agency) To: (Print Name, Agency)	Release Signature:	Release Date:	Delivered Via: □ U.S. Mail □ In Person □ Other:
Collection No.	From: (Print Name, Agency) To: (Print Name, Agency)	Release Signature:	Release Date:	Delivered Via: □ U.S. Mail □ In Person □ Other:
Collection No.	From: (Print Name, Agency) To: (Print Name, Agency)	Release Signature:	Release Date:	Delivered Via: □ U.S. Mail □ In Person □ Other:
Collection No.	From: (Print Name, Agency) To: (Print Name, Agency)	Release Signature:	Release Date:	Delivered Via: □ U.S. Mail □ In Person □ Other:
Collection No.	From: (Print Name, Agency) To: (Print Name, Agency)	Release Signature:	Release Date:	Delivered Via: □ U.S. Mail □ In Person □ Other:
Collection No.	From: (Print Name, Agency) To: (Print Name, Agency)	Release Signature:	Release Date:	Delivered Via: □ U.S. Mail □ In Person □ Other:

Appendix F: Shipping, Handling, and Data Protocols for Wild Captured Black Carp and Grass Carp.

Any suspect black carp collected in the wild in the United States and grass carp collected in the Great Lakes Basin, or other novel locations in the U.S., should be immediately reported to the appropriate resource management agency in the state where the fish was collected. Do ***not*** release suspect black or grass carp unless required by state laws or instructed to do so by the resource management agency.

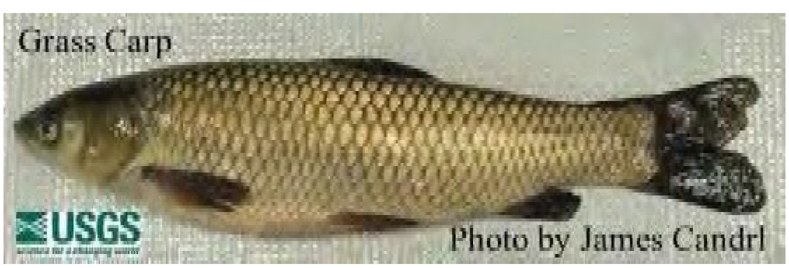
Differentiating black carp from grass carp using diagnostic external characteristics can be very challenging, especially when the two species are not being compared side-by-side. An identification fact sheet is attached for your reference. Careful attention should be given in waters where grass carp are known to occur to confirm that captured individuals are indeed grass carp and not black carp. If you are not positive of the species identification you should report the collection to the appropriate resource management agency to get assistance and further instructions.

Collection information, basic biological data, and digital images should be collected for any suspect black or grass carp as soon as possible after capture. In addition to collection and basic biological data, we are interested in collecting multiple structures and organs from each fish for management and research purposes. Protocols are provided for 1) collection information, basic biological data, and digital images; 2) removal, preparation, and shipment of eyes for ploidy analysis; and 3) preparation and shipment of black and grass carp carcasses.

These protocols are intended to provide resource management agencies, or authorized personnel, with streamlined instructions for the proper collection, preparation, and shipping of data, samples, and carcasses. It is important that all collections of black and grass carp (from the identified locations above) are immediately reported to the appropriate resource management agency in the state where the fish was collected before collecting more than collection information, basic biological data, and digital images.

Step 1: Data Collection

1. Record GPS Location (if available, otherwise a description of collection location);
2. Record date and time of capture, method of capture, and collecting individual or agency;
3. Record fish weight, girth, length, and species (number samples if necessary);
4. Take high resolution digital pictures (see examples below):
    a. Lateral view of fish's entire left side,
    b. Close-up lateral view of head,
    c. Dorsal view of head with mouth fully closed (taken from directly above the fish's head).
5. Record name, telephone number, and/or email address for point of contact;
6. E-mail data and digital images to Sam Finney at sam_finney@fws.gov.
7. Proceed to Step 2.



Example of 4.a: Lateral view of fish's entire left side

Example of 4.b: Close-up lateral view of head

Example of 4.c: Dorsal view of head with mouth fully closed

Step 2: Eyeball Removal, Sample Preparation, and Shipping Procedures for Ploidy Analysis

Materials:

- Forceps; scalpel; blunt or curved scissors
- 50-100 ml plastic containers with leak-proof screw top cap
- Sealable plastic bags to fit several 50-100 ml containers
- Contact lens solution or saline (0.8-1.0% NaCl in DI water)
- Permanent marking pen
- Cooler or insulated container with ice packs, packing tape to seal cooler
- Optional: methanol if freezing and storing samples longer than 8 days.

Procedure for Removing Carp Eyeballs**:**

1. Euthanize fish with an overdose of tricaine methanesulfonate (MS-222) or sharp blow to head.
2. Label small plastic container with collection date, species and sample number if applicable (e.g. 25MAR13, black carp, #12)
3. Insert scalpel blade between the eyeball and socket wall. Taking care not to puncture the eyeball, cut around the circumference of the eyeball, keeping the blade pointed toward the socket wall. You may use forceps to hold the eyeball steady. The goal is to cut the tissue responsible for holding and moving the eye.
4. Once you feel confident all the tissue around the eye is cut, use the blunt or curved scissors to reach behind the eyeball and cut the optic nerve. Once the optic nerve is cut, you should be able to pop the eye out and trim off any excess tissue.
5. Place eye in labeled container, fill to top with buffer solution, and put on ice or refrigerate at 4 to 8°C.
6. Follow Eyeball Sample Preparation and Shipping Procedures below.

Sample Preparation for Overnight Shipment or Storage 1 to 8 Days:

This option will provide the highest quality of samples for analysis.

1. Label a small, plastic container with collection date, species, and sample number if applicable (e.g. 25MAR13, black carp, #12)
2. Remove both eyeballs without puncturing from fish and place in labeled container. (See removal procedures above.) Fill to top with contact lens solution or saline.
3. Place container(s) in a sealable plastic bag to contain leaks and place on ice or in a cooler with ice packs.
4. Ship immediately following shipping procedures for Whitney Genetics Lab (below) or keep refrigerated (4°C - 8°C) up to 8 days.
5. Proceed to Step 3.

Eyeball Sample Preparation for Storage Longer than 8 Days:

If samples cannot be shipped within 8 days, or if many samples will be collected over a known period of time, you can store and ship all together.

a. Label a small, plastic container with collection date, species, and sample number if applicable (e.g. 25MAR13, black carp, #12)

b. Remove both eyeballs without puncturing from fish and place in labeled container. (See removal procedures above.) Fill to top with 20% methanol in contact lens solution or saline.
c. Place container(s) in a sealable plastic bag to contain leaks and place on ice or in a cooler with ice packs. Refrigerate (4°C - 8°C) overnight to allow methanol to diffuse into fish eyes.
d. Move samples to a freezer (-20°C). Store frozen until overnight shipment can be arranged. Sample quality will not degrade as long as sample remain frozen (-20°C) until shipment.
e. Ship to Whitney Genetics Lab following procedures below.
f. Proceed to Step 3.

Shipping Procedures:

1. Contact Whitney Genetics Lab personnel to make Overnight Priority (for morning delivery) shipping arrangements. If possible, ship samples on same day of catch.
2. Do ***NOT*** ship samples until arrangements have been made for receipt of package.
3. Pack samples in a Ziploc bag to prevent leakage and then enclose in a sealed, insulated container with ice packs to maintain 4 to 8°C. Do ***NOT*** use dry ice for shipping. Include collection data (and sample number if necessary) with package. If using a cooler for shipping, make sure lid is taped securely.
4. Ship priority overnight to the attention of Whitney Genetics Lab Contact.
5. Email confirmation of shipment and tracking numbers to recipient.

Contact Information:
Jennifer Bailey – fish biologist
608-783-8451
608-397-4416 (mobile)
jennifer_bailey@fws.gov

Maren Tuttle-Lau – fish biologist
608-783-8403
maren_tuttle-lau@fws.gov

Shipping Address:
Whitney Genetics Lab – La Crosse Fish Health Center
U.S. Fish and Wildlife Service Resource Center
555 Lester Ave, Onalaska, WI, 54650
608-783-8444

Step 3: Carcass Preparation and Shipping Procedures

Carcass Sample Preparation for Overnight Shipment:

If possible, *ship samples immediately on ice on same day of catch*. Otherwise, freeze the carcass before shipping.

1. Pack entire specimen (with eyes extracted) in an insulated container with plenty of ice packs, frozen water bottles, or ice to keep cool. Do ***NOT*** use dry ice for shipping.
2. Include collection data (and sample number if necessary) in double ziplock bag in container.
3. Seal container to contain leaks. If using a styrofoam cooler within a box, make sure the lid is taped and sealed securely.
4. Ship immediately or keep frozen until Overnight Priority shipping arrangements are made.

Shipping Procedures:

1. Contact Columbia Environmental Research Center personnel to make Overnight Priority (for morning delivery) shipping arrangements.
2. Do ***NOT*** ship samples until arrangements have been made for receipt of package.
3. Ship specimen in sealed, insulated container (see sample preparation instructions above) priority overnight to the attention of Duane Chapman or Joe Deters.
4. Email confirmation of shipment and tracking numbers to (dchapman@usgs.gov).

Contact Information:

Duane Chapman
573-875-5399
573-289-0625 (mobile)
dchapman@usgs.gov

Joe Deters
573-875-5399
573-239-9646 (mobile)
jdeters@usgs.gov

Shipping Address:

Duane Chapman or Joe Deters
Columbia Environmental Research Center
U.S. Geological Survey
4200 New Haven Road
Columbia, MO 65201
573-875-5399

Appendix G: List of Asian Carp fish species codes arranged in alphabetical order by fish common name. Four-digit species codes are the same as codes used by the Long Term Resource Monitoring Program (Ratcliff et al. 2014). Nomenclature follows the American Fisheries Society standard naming conventions (Nelson et al. 2004).

Common name	Scientific name	Code
Age-0 fish (young-of-the-year)	Age-0 fish	YOYF
American brook lamprey	Lampetra appendix	ABLP
American eel	*Anguilla rostrata*	AMEL
Banded darter	*Etheostoma zonale*	BDDR
Bigeye chub	*Hybopsis amblops*	BECB
Bigeye shiner	*Notropis boops*	BESN
Bighead carp	*Hypophthalmichthys nobilis*	BHCP
Bigmouth buffalo	*Ictiobus cyprinellus*	BMBF
Bigmouth shiner	*Notropis dorsalis*	BMSN
Black buffalo	*Ictiobus niger*	BKBF
Black bullhead	*Ameiurus melas*	BKBH
Black crappie	*Pomoxis nigromaculatus*	BKCP
Black crappie x white crappie hybrid	*P. nigromaculatus x P. annularis*	BCWC
Blackside darter	*Percina maculata*	BSDR
Blackspotted topminnow	*Fundulus olivaceus*	BPTM
Blackstripe topminnow	*Fundulus notatus*	BTTM
Blacktail shiner	*Cyprinella venusta*	BTSN
Bleeding shiner	*Luxilus zonatus*	BDSN
Blue catfish	*Ictalurus furcatus*	BLCF
Blue sucker	*Cycleptus elongatus*	BUSK
Bluegill	*Lepomis macrochirus*	BLGL
Bluegill x longear sunfish hybrid	*L. macrochirus x L. megalotis*	BGLE
Bluegill x orangespotted sunfish hybrid	*L. macrochirus x L. humilis*	BGOS
Bluegill x redear sunfish hybrid	*L. macrochirus x L. microlophus*	BGRS
Bluegill x warmouth hybrid	*L. macrochirus x L. gulosus*	BGWM
Bluntnose darter	*Etheostoma chlorosoma*	BNDR
Bluntnose minnow	*Pimephales notatus*	BNMW
Bowfin	*Amia calva*	BWFN
Brassy minnow	*Hybognathus hankinsoni*	BSMW
Brook silverside	*Labidesthes sicculus*	BKSS
Brook stickleback	*Culaea inconstans*	BKSB
Brown bullhead	*Ameiurus nebulosus*	BNBH
Brown trout	*Salmo trutta*	BNTT
Bullhead minnow	*Pimephales vigilax*	BHMW
Burbot	*Lota lota*	BRBT
Central mudminnow	*Umbra limi*	CMMW
Central stoneroller	*Campostoma anomalum*	CLSR
Channel catfish	*Ictalurus punctatus*	CNCF
Channel shiner	*Notropis wickliffi*	CNSN
Chestnut lamprey	*Ichthyomyzon castaneus*	CNLP
Common carp	*Cyprinus carpio*	CARP

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Common name	**Scientific name**	**Code**
Common carp x goldfish hybrid	*C. carpio x Carassius auratus*	CCGF
Common shiner	*Luxilus cornutus*	CMSN
Creek chub	*Semotilus atromaculatus*	CKCB
Creek chubsucker	*Erimyzon oblongus*	CKCS
Crystal darter	*Crystallaria asprella*	CLDR
Dusky darter	*Percina sciera*	DYDR
Emerald shiner	*Notropis atherinoides*	ERSN
Fantail darter	*Etheostoma flabellare*	FTDR
Fathead minnow	*Pimephales promelas*	FHMW
Flathead catfish	*Pylodictis olivaris*	FHCF
Flier	*Centrarchus macropterus*	FLER
Freckled madtom	*Noturus nocturnus*	FKMT
Freshwater drum	*Aplodinotus grunniens*	FWDM
Ghost shiner	*Notropis buchanani*	GTSN
Gizzard shad	*Dorosoma cepedianum*	GZSD
Golden redhorse	*Moxostoma erythrurum*	GDRH
Golden shiner	*Notemigonus crysoleucas*	GDSN
Goldeye	*Hiodon alosoides*	GDEY
Goldfish	*Carassius auratus*	GDFH
Grass carp	*Ctenopharyngodon idella*	GSCP
Grass pickerel	*Esox americanus vermiculatus*	GSPK
Green sunfish	*Lepomis cyanellus*	GNSF
Green sunfish x bluegill hybrid	*L. cyanellus x L. macrochirus*	GSBG
Green sunfish x orangespotted sunfish hybrid	*L. cyanellus x L. humilis*	GSOS
Green sunfish x pumpkinseed hybrid	*L. cyanellus x L. gibbosus*	GSPS
Green sunfish x redear hybrid	*L. cyanellus x L. microlophus*	GSRS
Green sunfish x warmouth hybrid	*L. cyanellus x L. gulosus*	GSWM
Greenside darter	*Etheostoma blennioides*	GSDR
Highfin carpsucker	*Carpiodes velifer*	HFCS
Hornyhead chub	*Nocomis biguttatus*	HHCB
Inland silverside	*Menidia beryllina*	IDSS
Iowa darter	*Etheostoma exile*	IODR
Johnny darter	*Etheostoma nigrum*	JYDR
Lake sturgeon	*Acipenser fulvescens*	LKSG
Largemouth bass	*Micropterus salmoides*	LMBS
Largescale stoneroller	*Campostoma oligolepis*	LSSR
Larval fish	Larval fish	LRVL
Least brook lamprey	*Lampetra aepyptera*	LBLP
Logperch	*Percina caprodes*	LGPH
Longear sunfish	*Lepomis megalotis*	LESF
Longnose gar	*Lepisosteus osseus*	LNGR
Longnose gar x spotted gar hybrid	*L. osseus x L. oculatus*	LNST

Appendix G: List of Asian Carp fish species codes arranged in alphabetical order by fish common name. Four-digit species codes are the same as codes used by the Long Term Resource Monitoring Program (Ratcliff et al. 2014). Nomenclature follows the American Fisheries Society standard naming conventions (Nelson et al. 2004).

Common name	Scientific name	Code
Mimic shiner	*Notropis volucellus*	MMSN
Mississippi silvery minnow	*Hybognathus nuchalis*	SVMW
Mooneye	*Hiodon tergisus*	MNEY
Mud darter	*Etheostoma asprigene*	MDDR
Muskellunge	*Esox masquinongy*	MSKG
New species	New species	NWSP
No fish caught	No fish caught	NFSH
Northern hog sucker	*Hypentelium nigricans*	NHSK
Northern pike	*Esox lucius*	NTPK
Northern studfish	*Fundulus catenatus*	NTSF
Orangespotted sunfish	*Lepomis humilis*	OSSF
Orangespotted sunfish x longear sunfish hybrid	*L. humilis x L. megalotis*	OSLE
Orangethroat darter	*Etheostoma spectabile*	OTDR
Ozark minnow	*Notropis nubilus*	OZMW
Paddlefish	*Polyodon spathula*	PDFH
Pallid shiner	*Hybopsis amnis*	PDSN
Pirate perch	*Aphredoderus sayanus*	PRPH
Plains minnow	*Hybognathus placitus*	PNMW
Pugnose minnow	*Opsopoeodus emiliae*	PGMW
Pumpkinseed	*Lepomis gibbosus*	PNSD
Pumpkinseed x bluegill hybrid	*L. gibbosus x L. macrochirus*	PSBG
Pumpkinseed x orangespotted sunfish hybrid	*L. gibbosus x L. humilis*	PSOS
Pumpkinseed x warmouth hybrid	*L. gibbosus x L. gulosus*	PSWM
Quillback	*Carpiodes cyprinus*	QLBK
Rainbow smelt	*Osmerus mordax*	RBST
Red shiner	*Cyprinella lutrensis*	RDSN
Redear sunfish	*Lepomis microlophus*	RESF
Redfin shiner	*Lythrurus umbratilis*	RFSN
Redspotted sunfish	*Lepomis miniatus*	RSSF
River carpsucker	*Carpiodes carpio*	RVCS
River chub	*Nocomis micropogon*	RVCB
River darter	*Percina shumardi*	RRDR
River redhorse	*Moxostoma carinatum*	RVRH
River shiner	*Notropis blennius*	RVSN
Rock bass	*Ambloplites rupestris*	RKBS
Round goby	*Neogobius melanostomus*	RDGY
Rudd	*Scardinius erythrophthalmus*	RUDD
Sand shiner	*Notropis stramineus*	SNSN
Sauger	*Sander canadensis*	SGER
Sauger x walleye hybrid	*S. canadensis x S. vitreus*	SGWE
Shorthead redhorse	*Moxostoma macrolepidotum*	SHRH

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Common name	Scientific name	Code
Shortnose gar	*Lepisosteus platostomus*	SNGR
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	SNSG
Shovelnose sturgeon x pallid sturgeon hybrid	*S. platorynchus x S. albus*	SNPD
Sicklefin chub	*Macrhybopsis meeki*	SFCB
Silver carp	*Hypophthalmichthys molitrix*	SVCP
Silver carp x bighead carp hybrid	*H. molitrix x H. nobilis*	SCBC
Silver chub	*Macrhybopsis storeriana*	SVCB
Silver lamprey	*Ichthyomyzon unicuspis*	SVLP
Silver redhorse	*Moxostoma anisurum*	SVRH
Silverband shiner	*Notropis shumardi*	SBSN
Skipjack herring	*Alosa chrysochloris*	SJHR
Slenderhead darter	*Percina phoxocephala*	SHDR
Slough darter	*Etheostoma gracile*	SLDR
Smallmouth bass	*Micropterus dolomieu*	SMBS
Smallmouth buffalo	*Ictiobus bubalus*	SMBF
Southern redbelly dace	*Phoxinus erythrogaster*	SRBD
Speckled chub	*Macrhybopsis aestivalis*	SKCB
Spotfin shiner	*Cyprinella spiloptera*	SFSN
Spottail shiner	*Notropis hudsonius*	STSN
Spotted bass	*Micropterus punctulatus*	STBS
Spotted gar	*Lepisosteus oculatus*	STGR
Spotted sucker	*Minytrema melanops*	SPSK
Starhead topminnow	*Fundulus dispar*	SHTM
Stonecat	*Noturus flavus*	STCT
Striped bass	*Morone saxatilis*	SDBS
Striped bass x white bass hybrid	*M. saxatilis x M. chrysops*	SBWB
Striped mullet	*Mugil cephalus*	SPMT
Striped shiner	*Luxilus chrysocephalus*	SPSN
Sturgeon chub	*Macrhybopsis gelida*	SGCB
Suckermouth minnow	*Phenacobius mirabilis*	SMMW
Tadpole madtom	*Noturus gyrinus*	TPMT
Threadfin shad	*Dorosoma petenense*	TFSD
Tiger muskellunge	*Esox masquinongy x E. lucius*	MGNP
Trout-perch	*Percopsis omiscomaycus*	TTPH
Unidentified	Unidentified	UNID
Unidentified sturgeons	Acipenseridae	U-SG
Unidentified suckers	Catostomidae	U-CT
Unidentified sunfishes	Centrarchidae	U-CN
Unidentified shads	Clupeidae	U-CL
Unidentified minnows	Cyprinidae	U-CY
Unidentified mooneyes	Hiodontidae	U-HI
Unidentified catfishes	Ictaluridae	U-IL

Appendix G: List of Asian Carp fish species codes arranged in alphabetical order by fish common name. Four-digit species codes are the same as codes used by the Long Term Resource Monitoring Program (Ratcliff et al. 2014). Nomenclature follows the American Fisheries Society standard naming conventions (Nelson et al. 2004).

Common name	Scientific name	Code
Unidentified perches	Percidae	U-PC
Unidentified lampreys	Petromyzontidae	U-LY
Walleye	*Sander vitreus*	WLYE
Warmouth	*Lepomis gulosus*	WRMH
Wedgespot shiner	*Notropis greenei*	WSSN
Weed shiner	*Notropis texanus*	WDSN
Western blacknose dace	*Rhinichthys obtusus*	BNDC
Western mosquitofish	*Gambusia affinis*	MQTF
Western sand darter	*Ammocrypta clara*	WSDR
Western silvery minnow	*Hybognathus argyritis*	WSMW
White bass	*Morone chrysops*	WTBS
White crappie	*Pomoxis annularis*	WTCP
White perch	*Morone americana*	WTPH
White perch x yellow bass hybrid	*M. americana x M. mississippiensis*	WPYB
White sucker	*Catostomus commersonii*	WTSK
Yellow bass	*Morone mississippiensis*	YWBS
Yellow bullhead	*Ameiurus natalis*	YLBH
Yellow perch	*Perca flavescens*	YWPH

Appendix G: List of Asian Carp fish species codes arranged in alphabetical order by fish common name. Four-digit species codes are the same as codes used by the Long Term Resource Monitoring Program (Ratcliff et al. 2014). Nomenclature follows the American Fisheries Society standard naming conventions (Nelson et al. 2004).

Common name	Scientific name	code
Alligator snapping turtle	*Macrochelys temminckii*	ASNT
Blanding's turtle*	*Emydoidea blandingii*	BLDT
Chinese Mystery Snails	*Cipangopaludina chinensis*	CMSN
Eastern musk turtle (formerly common musk turtle)	*Sternotherus odoratus*	CMKT
Eastern snapping turtle (formerly common snapping turtle)	*Chelydra serpentina*	CSNT
False map turtle	*Graptemys pseudogeographica*	FMPT
Midland painted turtle	*Chrysemys picta marginata*	MPTT
Midland smooth softshell	*Apalone mutica mutica*	SMSS
Mississippi map turtle	*Graptemys pseudogeographica kohnii*	MMPT
Northern map turtle (formerly common map turtle)	*Graptemys geographica*	CMPT
Ouachita map turtle	*Graptemys ouachitensis ouachitensis*	OMPT
Red Swamp Crayfish	*Procambarus clarkii*	RSCF
Red-eared slider	*Trachemys scripta elegans*	RESL
River cooter	*Pseudemys concinna*	RCOT
Rusty Crayfish	Orconectes rusticus	RUCF
Spiny softshell	*Apalone spinifera*	SPSS
Western painted turtle	*Chrysemys picta belli*	WPTT
Wood turtle*	*Glyptemys insculpta*	WODT
Yellow mud turtle* (formerly Illinois mud turtle)	*Kinosternon flavescens*	IMDT
Zebra Mussels	*Dreissena polymorpha*	ZEBR

*Rare species. Should be reported to respective state agencies if captured

Appendix H: Sample data sheets.

Asian Carp Monitoring Project - Electro

Date: ____________________

Area Surveyed: ___________________________ Biologist (Crew): ________________________________

Wisc Unit DC: Rate: ______ Duty:______ Range: High or Low Volts:_____ Amps:_________

Smith Root DC: Percent of Setting:________Pulse Per Second Setting:________Amps:________

Other (Describe): ____

Rate Gear Efficency (circle one): Good Moderate Poor

Air Temp: ________ Water Temp: _________ Conductivity: _________ Others: ________________

	Run No.___________ Lat.________________ Lon.________________ Start Time: __________ Shock Time: ________	Run No.__________ Lat.________________ Lon.________________ Start Time: _________ Shock Time: ________	Run No.__________ Lat.________________ Lon.________________ Start Time: _________ Shock Time: ________	
Fish Species	No. of Fish	No. of Fish	No. of Fish	Total No. Fish
Gizzard shad >6 in.				
Gizzard shad juv.<6 in.				
Alewife				
Common carp				
Goldfish				
Carp x Goldfish hybrid				
Freshwater drum				
Smallmouth buffalo				
Bigmouth buffalo				
Black buffalo				
River carpsucker				
Quillback				
White sucker				
Channel catfish				
Yellow bullhead				
Black bullhead				
Largemouth bass				
Smallmouth bass				
Bluegill				
Green sunfish				
Pumpkinseed				
Hybrid sunfish				
Rock bass				
White crappie				
Black crappie				
Golden shiner				
Bluntnose minnow				
Fathead minnow				
Spotfin shiner				
Emerald shiner				
Spottail shiner				
Round goby				
White perch				
White bass				
Yellow bass				

Asian Carp Monitoring Project - Nets

Date: ____________________

Area Surveyed: ______________________________ Biologist (Crew): __________________________________

Air Temp: ________ Water Temp: __________ Conductivity: __________ Others: __________________

Set No.___________ Lat.________________ Lon._______________ Total Yds.__________	Panel No.___________ Type (circle): Tra or Gill Length (yds.)_________ Height (ft.)___________ Mesh (in.)_____________ Start Time: ___________ End Time: ___________		Panel No.___________ Type (circle): Tra or Gill Length (yds.)_________ Height (ft.)___________ Mesh (in.)_____________ Start Time: ___________ End Time: ___________		Panel No.___________ Type (circle): Tra or Gill Length (yds.)_________ Height (ft.)___________ Mesh (in.)_____________ Start Time: ___________ End Time: ___________		
Fish Species	No. of Fish		No. of Fish		No. of Fish		Total
Gizzard shad >6.0 in.							
Common carp							
Goldfish							
Carp x goldfish hybrid							
Freshwater drum							
Bighead carp							
Silver carp							
Grass carp							
Smallmouth buffalo							
Bigmouth buffalo							
Black buffalo							
River carpsucker							
Quillback							
Channel catfish							

Set No.___________ Lat.________________ Lon._______________ Total Yds.__________	Panel No.___________ Type (circle): Tra or Gill Length (yds.)_________ Height (ft.)___________ Mesh (in.)_____________ Start Time: ___________ End Time: ___________		Panel No.___________ Type (circle): Tra or Gill Length (yds.)_________ Height (ft.)___________ Mesh (in.)_____________ Start Time: ___________ End Time: ___________		Panel No.___________ Type (circle): Tra or Gill Length (yds.)_________ Height (ft.)___________ Mesh (in.)_____________ Start Time: ___________ End Time: ___________		
Fish Species	No. of Fish		No. of Fish		No. of Fish		Total
Gizzard shad >6.0 in.							
Common carp							
Goldfish							
Carp x goldfish hybrid							
Freshwater drum							
Bighead carp							
Silver carp							
Grass carp							
Smallmouth buffalo							
Bigmouth buffalo							
Black buffalo							
River carpsucker							
Quillback							
Channel catfish							

Asian Carp Monitoring Project

Date: ____________________

Area Surveyed: ____________________ **Biologist (Crew):** ______________________________

Gear Type (circle one): DC, AC, Nets

Nets (Describe Nets): ____

Fish Species	TL mm	TL mm	TL mm	TL mm	TL mm	TL mm	TL mm	TL mm	TL mm	TL mm
Gizzard shad >6 in.										
Gizzard shad juv.<6 in.										
Alewife										
Common carp										
Goldfish										
Carp x Goldfish hybrid										
Freshwater drum										
Smallmouth buffalo										
Bigmouth buffalo										
Black buffalo										
Quillback										
White sucker										
Channel catfish										
Yellow bullhead										
Black bullhead										
Largemouth bass										
Smallmouth bass										
Bluegill										
Green sunfish										
Pumpkinseed										
Hybrid sunfish										
Rock bass										
White crappie										
Black crappie										
Golden shiner										
Bluntnose minnow										
Fathead minnow										
Spotfin shiner										
Emerald shiner										
Round goby										
White perch										
Yellow Bass										

eDNA Field Data Sheet

DATE______________ NAME________________________________ START TIME____________ SHEET ____of_____

ID	Volume	Latitude	Longitude	Temp	Depth	Habitat	Collect Time	Filter Time

Notes/Comments:

Appendix I: Analysis of Bighead and Silver Carp Spawn Patches.

Spawn Patch Preservation/Analysis:

Bighead and Silver Carp males use their pectoral fins to irritate the vental margin of females during the spawning season (Figure 1). Recent spawning or prespawning interactions between males and females will leave an irritated patch on the breast of the female fish, and scales are often lost. Presence of regenerated scales is evidence that a female fish may have been courted by a male fish (although it is impossible to tell from this feature if spawning actually occurred). The number of annuli in regenerated scales may also be useful in determining the number of years since spawning activity occurred. It is as yet unclear how many scales are lost on average or if scales are lost each time the fish spawns. However, in order to preserve potential information on spawning activity or presence of male fish where a female fish is captured, it is prudent to preserve the breast of Bighead and Silver Carp caught from areas where the presence of Asian carps caught is being investigated if allowable by the state and regulatory bodies. For the 2013 Monitoring and Response Plan participants, fish collected in the CAWS or the Great Lakes should follow the chain of command and custody protocols is of primary importance with biological data being collected after securing the fish. Fish collected in Brandon Road Pool require a voucher per the 2013 MRP. Additional biological data will be processed after those protocols have been followed and likely in a lab setting. For fish collected below Brandon Road Lock and Dam, it is permissible to follow the procedures as long as it would not interfere with ongoing tracking/telemetry.

Figure 1. Spawn patch of a female Bighead Carp, located on the breast of the fish between the pelvic and pectoral fins.

If a Bighead or Silver Carp is caught from the Great Lakes or the CAWS, FIRST FOLLOW ALL PROTOCOLS IN THIS MANUAL; See: **Appendix C. Handling Captured Asian Carp and Maintaining Chain-of-Custody Records**. If there is no conflict with existing protocol, the portion of the fish illustrated in Figure 2 should be photographed as soon as possible after capture, to document abrasions from recent sexual activity. In areas outside of the CAWS and the Great Lakes sections should be preserved from damage to ensure scale regeneration can be analyzed if required by state and regulatory agencies.

Protocols for analysis of scale regeneration in this area are not yet prepared, but care should be taken to preserve the scales and skin in this area. This technique is only useful when employed on female Bighead and Silver Carp. Although external features are useful in identifying the sex of a captured Bighead or Silver Carp, none of these features are 100% reliable in identification of sex. Therefore this portion of the fish should be preserved at least until the sex is determined by the examination of the gonads. When the gonads are examined, care should be taken to avoid cutting through the area of the spawn patch. Note that histological examination of gonads may also be useful in evaluating recent spawning activity.

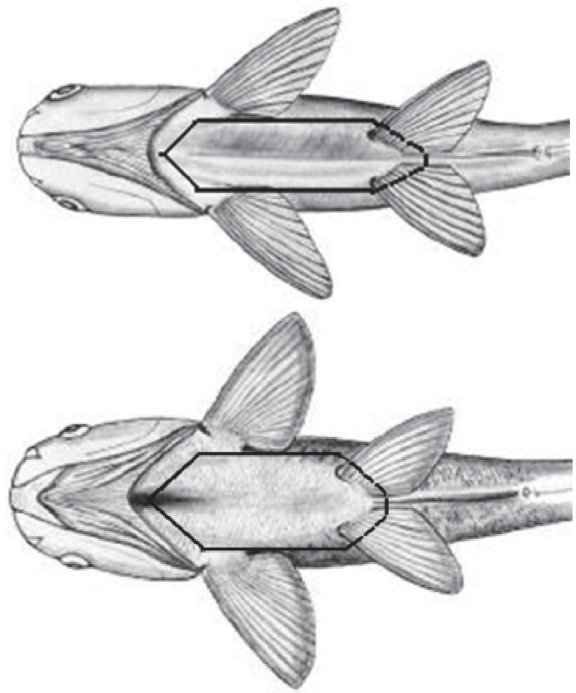

Figure 2. Areas to be preserved for analysis. Silver Carp on left, Bighead Carp on right. (FIRST FOLLOW ALL PROTOCOLS IN THIS MANUAL See: **Appendix C. Handling Captured Asian Carp and Maintaining Chain-of-Custody Records** for fish collected in the CAWS or the Great Lakes; **managers may not allow dissection of fish collected in these areas and need to be consulted about any physical samples being taken**).

Appendix J: Black and Grass Carp Identification

Black and grass carp are very similar in appearance. We do not have a reliable method to tell them apart based on external characteristics, but these photos and general characteristics might help. When in doubt, report the fish to the appropriate resource management agency.

Black carp	Grass Carp
 Photo: Greg Whitledge, SIU	 Photo: James Candrl, USGS

The mouth of **adult** black carp is more subterminal and the operculum is longer than in grass carp. The black carp's head is generally narrower, more cone-shaped, whereas the grass carp's tends to be rounder, blunter. However, the difference can be subtle.

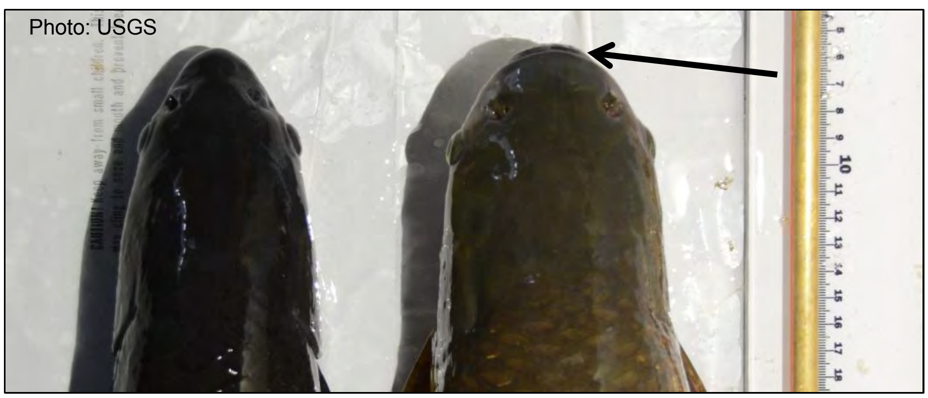
Photo: USGS

The upper lip of a grass carp is visible from above **when the mouth is fully closed.** Young black carp may also exhibit this feature, so it is only useful for **adults**.

J-2


Photo: USGS

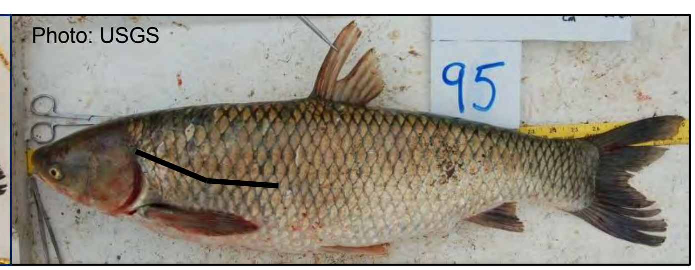

Photo: USGS

If the carcass is in good condition, you might be able to use the angle of the lateral line to ID the fish. "The lateral line of a black carp remains relatively straight moving from the operculum posterior, with a slight dip around the dorsal fin. On grass carp the lateral line takes an initial ventral dip for the first 6-8 scales (about 10°)" (Patrick Kroboth, USGS).

Black carp


Photo: Greg Whitledge, SIU


Photo: USGS


Photo: USFWS


Photo: USGS


Photo: Greg Whitledge, SIU

Grass Carp


Photo: USFWS


Photo: USGS


Photo: USGS


Photo: USFWS

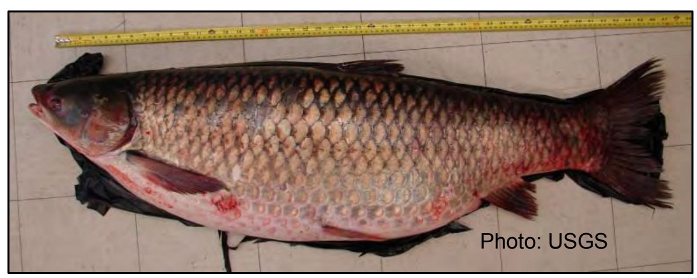
Photo: USGS


Photo: USGS

Black carp tend to have longer pectoral fins than grass carp. The coloration of black carp is described as, “Black, blue gray, or dark brown and the fins in particular are darkly pigmented. In contrast, coloration of grass carp is often described as olivaceous or silvery white, or as olive-brown above and silvery below, and most fins are dusky. Nevertheless, color may not always be reliable” (Nico et al. 2005).

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ORIGINAL PAPER

Bigheaded carps (*Hypophthalmichthys* spp.) at the edge of their invaded range: using hydroacoustics to assess population parameters and the efficacy of harvest as a control strategy in a large North American river

Ruairí MacNamara · David Glover · James Garvey · Wesley Bouska · Kevin Irons

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Abstract The threat posed by bigheaded carps (*Hypophthalmichthys* spp.) to novel ecosystems has focused efforts on preventing further range expansion; upstream progression in the Illinois River is a major concern due to its connection with the uninvaded Great Lakes. In addition to an electric barrier system, commercial harvest of silver carp (*H. molitrix*) and bighead carp (*H. nobilis*) in the upper river is intended to reduce propagule pressure and prevent range expansion. To quantify demographics and evaluate harvest efficacy, the upper river was sampled between 2012 and 2015 using mobile hydroacoustic methods. Reach-specific densities, size structures and species compositions varied interannually but the advancing population was characterized longitudinally as small-bodied, silver carp-dominated at the highest densities downstream, shifting to large-bodied, bighead carp-dominated at the low-density population front. The use of hydroacoustic sampling for harvest evaluation was validated in backwater lakes; there was a significant positive correlation between density estimates and the corresponding harvest catch-per-unit-effort of bigheaded carps. Localized densities of bigheaded carps were reduced by up to 64.4 % immediately post-harvest but generally rebounded within weeks. However, annual sampling of the entire upper river indicated that density of bigheaded carps decreased by over 40 % (between 2012 and 2013) and subsequently remained stable (between 2013 and 2014). The annual harvest of bigheaded carps increased during this period (from 45,192 to 102,453 individuals), in years of contrasting discharge conditions. At this spatiotemporal scale, harvest appears to have contributed to initial reduction, and subsequent maintenance of, bigheaded carps density levels, but discharge likely plays an important role (e.g., through immigration) in determining the extent of its impact. Mobile hydroacoustic sampling enabled robust quantification of the population over varying spatial scales and density gradients, highlighting the potential of this approach as an assessment tool for invasive fishes in riverine environments.

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Keywords Asian carps Bi·head carp Densitygradient· IllinoisRiver·Mississippi–GreatLakesbasins·Removal· Silvercarp

Introduction

Aquaticinvasivespeciescanhavenegativeecological andsocio-economicimpactsinfreshwaterecosystems wheretheyareintroduced(Vituleetal.2009).Asour understandingoftheseadverseeffectsincreases,so toodoesvigilanceregardingpotentialinvaders(Van-der Zandenetal.2010).InthecentralUnitedStates, preventinginterbasinmovementofnon-nativespecies betweentheMississippiandGreatLakesisakey managementobjective(USACE2014).Bigheadedcarps (silvercarp*Hypopthalmichthysmolitrix*andbigheadcarp *H.nobilis*),largeplanktivoresnativetoeastAsia(Kolaret al.2007;Garvey2012),areamongthefishspeciesof highestconcern.Sincetheearly2000s,manystudieshave focusedontheecologyofbigheadedcarpsatthecoreof theirNorthAmericanrange,specificallyintheMiddle Mississippi,LowerMissouriandLowerIllinoisRivers (e.g.,SchrankandGuy2002;WilliamsonandGarvey 2005;Sassetal.2010;Cudmoreetal2012;Garveyetal. 2012; NormanandWhitledge2015).Theoreticalworkhasalso examinedthepotentialthreatposedbythespeciestothe uninvadedGreatLakes(Kocovskyetal.2012; Cuddingtonetal.2014;Zhangetal.2016;seereview byCooke2016).However,criticalinformationon bigheadedcarpsadjacenttonovelecosystemsislimited (seeHayeretal.2014;Stucketal.2015; Coulteretal.2016).Thesearethepropagulesmostlikely tobesuccessfulnewinvadersand,thus,theirpresence correspondstolocationsatwhichimmediatecontrol measuresneedtobeimplemented.

TheIllinoisRiverisamajorMississippiRivertributary thatishydrologicallyconnectedtotheGreatLakesbasin (LakeMichigan)viaanetworkofcanalsandheavily modifiedriverscalledtheChicago-AreaWaterway System(CAWS).Bigheadedcarpsareestablishedinthe lowerreachesofthisriverathighdensities(Sassetal2010; Garveyetal.2012).Intheupperriver,the'lastlineof defense'preventingdispersalintoLakeMichiganisan electricbarriersystemlocatedintheCAWS(Moyetal. 2011),althoughconcernsexistaboutitseffectiveness under certain conditions (Parker et al. 2015). Management agencies aim to reduce the population of bigheaded carps (and hence the likelihood of bigheaded carps reaching and challenging the barrier system) through contracted commercial harvest in the Starved Rock (river km (RKM) 372–394), Marseilles (RKM 394–437) and Dresden (RKM 437–460) reaches of the upper river (Fig. 1). The population front has remained in the Dresden reach for several years (ACRCC 2015), *c*. 17 RKM downstream of the electric barrier system.

As bigheaded carps in the Upper Illinois River represent an immediate threat to Lake Michigan, collection of accurate empirical data on this advancing population is needed to understand range expansion dynamics and develop effective management strategies (Cooke 2016). However, many sampling challenges exist: silver carp and bighead carp occupy a variety of habitat types (e.g., main channel, backwater lakes, side channels) over a relatively large spatial scale (three river reaches extending 88 RKM); both species may respond differently to capture sampling gears like electrofishing or netting (Williamson and Garvey 2005; Irons et al. 2011; Hayer et al. 2014; Collins et al. 2015); and it is likely that a density gradient exists over the 88 RKM occupied by the advancing population, so sampling would have to be equally effective at a variety of densities. Mobile hydroacoustic sampling has begun to feature more prominently in fisheries research in riverine environments (e.g., Lucas and Baras 2000; CEN 2014) and, considering the constraints outlined above, this technology may represent the optimal approach in terms of spatial coverage and unbiased representation of the target species. We therefore initiated a program of mobile hydroacoustic surveys in the Upper Illinois River in 2012 with the objectives of (1) quantifying key demographics (density, size structure and species composition) of the advancing population of bigheaded carps, (2) ground-truthing hydroacoustic density estimates by reference to localized harvest metrics, and (3) evaluating the efficacy of harvest at suppressing overall population levels. We outline a unique sampling framework that can be applied in a variety of contexts (e.g., population assessment, control strategy evaluation, early detection) for management of invasive fish species.

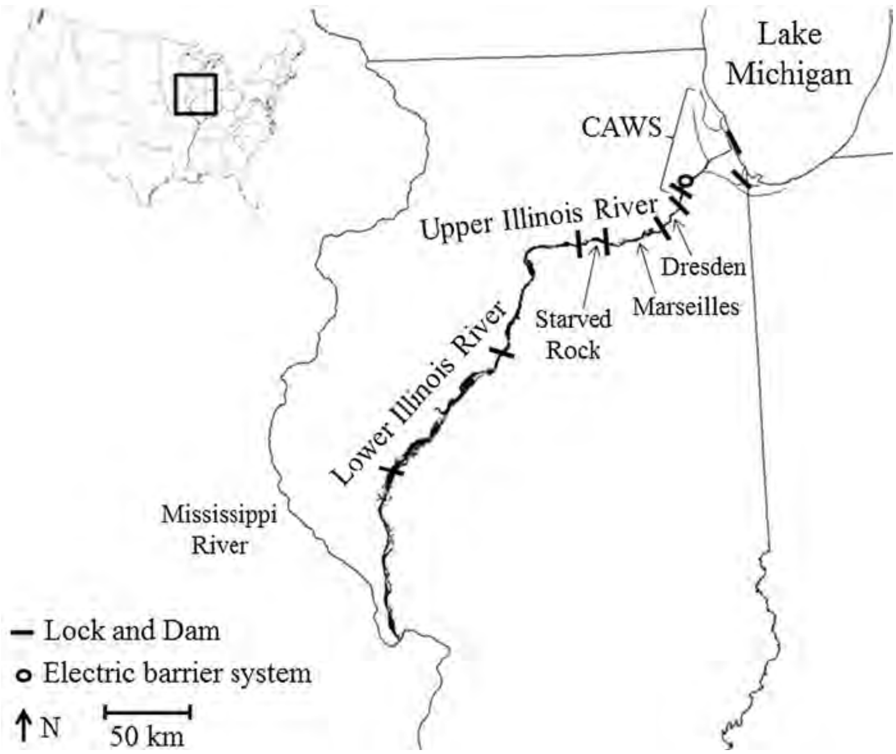


Fig. 1 The Illinois River in central USA. The lower river extends from the confluence with the Mississippi River (RKM 0) upstream to Starved Rock Lock and Dam (RKM 372). The study area consisted of three river reaches (Starved Rock, Marseilles and Dresden) in the Upper Illinois River, between RKM 372 and RKM 460. Also shown is the electric barrier system (RKM 477) located in the Chicago-Area Waterway System (CAWS)

Methods and materials

Harvest program

Commercial fishing is prohibited in the Upper Illinois River but fishing crews have been specially contracted by the Illinois Department of Natural Resources (IDNR) to harvest Asian carps (silver carp, bighead carp and grass carp *Ctenopharyngodon idella*) in the Marseilles and Dresden reaches since 2010 and in Starved Rock reach since 2011. Grass carp accounted for <1 % of the total harvest annually so were not considered further in this study. Each crew consisted of an experienced two-person team whose fishing location, effort, and catch was recorded by an onboard IDNR biologist. Suitable locations in the upper river were fished by up to five crews per day during the season, which extended from March to December (*c.* 340 crew-days per year). All bycatch was returned alive, while Asian carps were donated to a processor for conversion to liquid fertilizer (ACRCC 2015). The program goal was to maximize harvest, so a variety of gear types (e.g., gill and trammel nets, hoop nets, seine hauls) and fishing strategies (e.g. short-set, overnight set) were used, depending on river conditions and location. However, the mainstay of the harvest program has been the use of short-set (20–30 min), large-mesh (7.6–10.2 cm) gill and trammel nets. These accounted for 93.6–98.5 % of crew-days annually. As it was not possible to quantify effort for all gear types combined, we used gill and trammel net catch-per-unit-effort (CPUE; bigheaded carps/1000 m of net) as a relative indicator of harvest intensity and for comparison with hydroacoustic density estimates (see below).

Research vessel, hydroacoustic equipment and settings

The mobile hydroacoustic system (BioSonics DT-X) consisted of two horizontal-orientated split-beam transducers positioned on a stable, 9 m research vessel. The upper acoustic beam extended parallel to the water surface, and the lower beam was offset to ensonify the water column directly below the first beam (Fig. 2). Transducer pitch and horizontal plane was maintained by automatically adjusting dual-axis rotators. Data were collected out to a maximum distance of 50 m, at a ping rate of 5 pings/s and pulse duration of 0.40 ms. Transducers of frequencies

70 kHz (5° beam angle) and 200 kHz (6.6° beam angle) were deployed in various combinations (i.e. two 70 kHz, two 200 kHz, or 70 and 200 kHz) and each transducer was individually calibrated on-axis with the appropriate tungsten carbide sphere (Foote et al. 1987). This involved mooring the research vessel to a fixed object, in sufficiently deep water, with the transducers deployed as shown in Fig. 2 and aimed outward from the shore. The calibration sphere was attached to a 3 m pole using nylon fishing line and suspended in each acoustic beam.

Hydroacoustic sampling throughout the Upper Illinois River

As much boat-accessible habitat (>1–1.5 m depth) as possible within each reach was sampled annually (2012–2014) during September and October. The upper river consists of main channel (typically 150–250 m wide with a minimum depth of 2.7 m maintained over the thalweg for navigation) and connected backwaters. Backwater sites suitable for hydroacoustic sampling included backwater lakes ($N = 3$), side channels ($N = 5$), tributaries ($N = 2$), harbors ($N = 2$) and bays ($N = 1$) of varying size (0.1–1.8 km^2). In the main channel, transects consisted of a nearshore loop following the *c.* 1 m depth contour and a mid-channel loop. Only a single nearshore transect loop was generally required in side channels, bays, harbors and tributaries (Fig. 3). In the typically larger backwater lakes, transect loops were repeated progressively closer to the center, at intervals that would limit beam overlap while ensuring maximum possible coverage (Fig. 3). The acoustic beams were aimed outward from the nearest shoreline for all transects. Vessel speed was kept constant at approximately 6.5 km/h, and transects were as similar as possible to the previous year with some exceptions (e.g., allowing for boat traffic, debris, changes in water levels). River discharge data were obtained from a main channel gaging station at Seneca, IL in the Marseilles reach (http://waterdata.usgs.gov/nwis).

Hydroacoustic sampling of harvest events (ground-truthing of density estimates)

To test whether a relationship existed between localized hydroacoustic density estimates and harvest CPUE, three backwater lakes were sampled during summer 2014 and 2015, independent of the fall sampling outlined above. These lakes were created as gravel quarries that are now either active (East Pit, 1.8 km^2 surface area, 2.7 m mean depth, located at approx. RKM 422 in the Marseilles reach), inactive (West Pit, 1.3 km^2, 2.4 m, RKM 418 in the Marseilles reach), or converted to a nature preserve (Rock Run, 0.3 km^2, 4.4 m, RKM 453 in the Dresden reach) (Fig. 3). Hydroacoustic sampling was undertaken directly before and after harvest events (i.e. within a <24 h period), and subsample length and weight

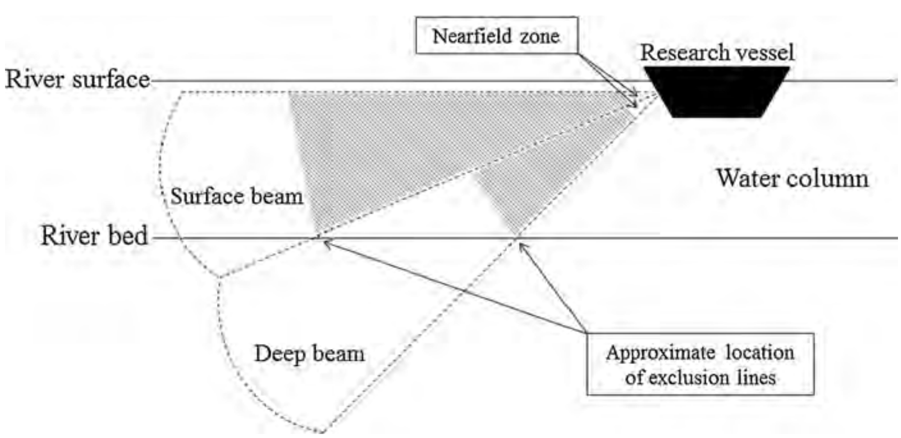


Fig. 2 Schematic (not to scale) depicting the orientation of the two hydroacoustic beams in the water column. Both transducers were deployed 0.4 m below the river surface. Maximum beam length was 50 m but exclusion lines were drawn at the point where the beams intersect the river bed. The areas in which acoustic targets were analyzed are indicated by the *gray shading* (no data analyzed in the nearfield zone or beyond the exclusion *line*). The surface beam typically accounted for *c.* 75 % of the volume of water sampled

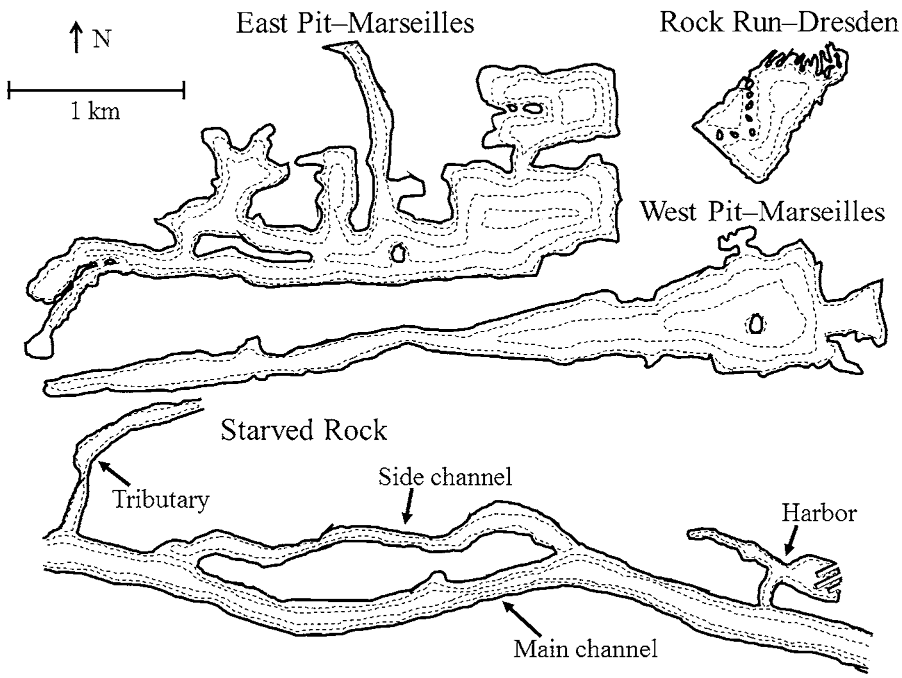


Fig. 3 Typical hydroacoustic transects (*dashed lines*) in three backwater lakes (East Pit, West Pit and Rock Run) and in a section of the Starved Rock reach (with examples of main channel, tributary, side channel and harbor habitat). Note that hydroacoustic transects during the before and after harvest events in the three backwater lakes consisted of a single nearshore loop only, rather the multiple loops undertaken as part of the river-wide surveys (as shown). For all surveys, the acoustic beams were aimed outward from the nearest shoreline

measurements of all species captured were taken. To minimize the time interval between hydroacoustic sampling and the harvest event (and thus the possibility of fish movement between the main channel), transects consisted of a single nearshore loop only (i.e. the area where harvest netting is focused) rather than multiple loops.

Hydroacoustic post-processing

Hydroacoustic data were processed using Echoview 5.4 software. An exclusion line was manually drawn at the point where the acoustic beams intersected the river bed (Fig. 2). Only data in the water column >1 m from the transducers (i.e. two times the near-field zone; Simmonds and MacLennan 2005; Rudstam et al. 2009) and before the exclusion line were analyzed. Areas of high interference (e.g., caused by passing boats or wind-generated waves) where acoustic targets could not be reliably distinguished were also excluded. Background noise was filtered by removing acoustic signals less than −60 decibels (dB). The volume of water sampled was calculated between the near-field and exclusion lines (Fig. 2) using the 'wedge volume sampled' method in Echoview.

Fish targets were identified using Echoview's 'split-beam single target detection (method 2)' algorithm following Parker-Stetter et al. (2009). Echoview's 'fish track detection' algorithm was then used to group targets originating from a single fish (Table 1). All fish tracks were manually inspected and edited to ensure accuracy. The mean compensated target strength (TS; in dB) of each fish track was then converted to fish total length (TL) using the side-aspect TL–TS equation given by Love (1971). Unlike most TL–TS equations, this multi-species equation is not frequency-specific and hence could be applied to the various transducer frequencies used. One shortcoming of using Love's (1971) equation is that it relates to maximum side-aspect target strength; this assumes that fish targets are ensonified near-perpendicular to the acoustic beam axis. Though likely in the main channel due to fish orientation relative to river flow and our parallel transect design, fish orientation may not be as uniform in lentic backwaters (i.e. acoustic ensonification may not always be exactly side-aspect). Adopting a TL–TS equation developed at multiple body aspects, for example 360° (Kubecka and Duncan 1998) could reduce this potential source of bias but, to our knowledge, such studies are all frequency-specific. Thus, for consistency across habitats and transducer frequencies, we opted to use the Love (1971) TL–TS equation and believe that using the mean TS of a fish track for conversion to TL

Table 1 Single target and fish track algorithm properties used for hydroacoustic post-processing

Split-beam single target detection (method 2)	
Min. and max. TS threshold (dB)	Dependent on transducer frequency used (Love 1971); corresponded to fish TL range of 30–120 cm
Pulse length determination level (dB)	6
Min. and max. normalized pulse length	0.6 and 1.5
Max. beam compensation	6
Max. standard deviations of minor and major axis angles	0.6
Fish track detection	
Min. number of single targets	1
Min. number of pings in track	1
Max. gap between single targets	3

adequately accounts for fish targets that may not have been ensonified exactly in the side aspect.

To further improve the accuracy of the fish track algorithms and manual editing, only acoustic targets corresponding to >30 cm TL were included in the analysis (the smallest silver carp or bighead carp captured in any year of the study was 48.8 cm).

Paired sampling

To interpret the acoustic data, we used information gathered annually in each reach during late summer/early autumn from a random site pulsed-DC electrofishing program (The Long-term Illinois, Mississippi, Ohio, and Wabash Rivers Fish Population Monitoring Program; http://wwx.inhs.illinois.edu/fieldstations/irbs/research/ltef-website/; see also McClelland et al. 2012) and the Asian carps harvest program (subsampling of target and bycatch species captured using short-set gill and trammel nets). Fish collected were identified, measured (TL; mm) and weighed (g). Both capture methods were combined to reduce selectivity biases (Williamson and Garvey 2005; Irons et al. 2011; Hayer et al. 2014) and all fish >30 cm TL were separated into three categories (i.e. silver carp, bighead carp, and other fish species). For each reach, proportional abundance of silver carp, bighead carp and other fish species was determined for each 2 cm TL-class (i.e. 30–32, 32–34 cm…) and then linearly interpolated for each 0.1 cm TL increment, up to a maximum of 120 cm TL; if the largest fish captured was less than this cut-off point, a 1.0 bighead carp proportion was assumed for the remaining length increments, which was corroborated with field observations.

Estimating bigheaded carps demographic parameters

Surveys were analyzed following the protocols developed by Scheaffer et al. (1996) and Parker-Stetter et al. (2009). Main channel transects were separated into two strata, the first stratum consisting of the nearshore loop and the second stratum consisting of the mid-channel loop (Fig. 3). Each 0.926 km (0.5 nautical mile) sampled along these strata represented replicates. Backwaters had one to four strata (depending on whether single or multiple transect loops were undertaken) (Fig. 3) and 0.463 km replicates were used. Initial density calculations were made based on all fish detected (i.e. converted acoustic targets equating to fish of 30–120 cm TL). Stratum-specific fish density $\bar{\rho}_h$ and within-stratum variance $Var(\bar{\rho}_h)$ were calculated as:

$$\bar{\rho}_h = \frac{1}{n_h}\sum_{i=1}^{n_h} \rho_{h,i} \quad (1)$$

$$Var(\bar{\rho}_h) = \frac{1}{n_h - 1}\sum_{i=1}^{n_h} \left(\rho_{h,i} - \bar{\rho}_h\right)^2 \quad (2)$$

where n_h = number of replicates in stratum h and $\rho_{h,i}$ = mean fish density of replicate i within stratum h. For single stratum backwaters, this was the final mean fish density. For multi-strata survey sites, final mean fish density $\bar{\rho}$ and standard error ($SE(\bar{\rho})$) were calculated as:

$$\bar{\rho} = \frac{1}{A}\sum_{h=1}^{L} A_h \cdot \bar{\rho}_h \quad (3)$$

$$SE(\bar{\rho}) = \sqrt{\sum_{h=1}^{L}\left(\frac{A_h}{A}\right)^2\left(\frac{Var(\bar{\rho}_h)}{n_h}\right)} \quad (4)$$

where L = total number of strata, A = volume of water sampled for all strata combined, and A_h = volume of water sampled for stratum h (such that estimates were weighted by the sampled volume in each strata).

Silver carp and bighead carp densities (fish/1000 m^3 of sampled water) and associated 95 % confidence intervals were then calculated for each survey site by assigning the paired sampling proportional abundances to the size-specific densities. To obtain representative reach-specific and upper river density estimates, sampling sites were combined and calculated as above in Eqs. (3) and (4), except strata were substituted by sampling site.

To determine approximate size structure and numerical species composition of bigheaded carps, acoustic targets corresponding to fish TL with a >0.5 silver carp or bighead carp proportional abundance were classified accordingly.

Statistical analysis

Differences between annual hydroacoustic density estimates were assessed by pairwise interval estimation (i.e. whether the 95 % confidence interval of the difference in means contained zero). Changes in size structure were assessed using a non-parametric Kruskal–Wallis H-test, followed by Dunn's post hoc test. A χ^2 test of independence was used to determine whether species composition (silver carp vs. bighead carp) changed. Due to error in both the X and Y variables, the relationship between harvest CPUE and hydroacoustic density estimates of bigheaded carps was examined using reduced major axis (RMA) regression (Sokal and Rohlf 1995). A non-parametric repeated-measures approach (Wilcoxon signed-rank test) was used to determine if hydroacoustic density estimates differed between sampling undertaken before and after harvest events (i.e. for each identical 0.463 km replicate). The critical level of significance was set at $P = 0.05$. All statistical analyses were performed using IBM SPSS Statistics 21, except for RMA regressions performed using RMA for JAVA v. 1.21: Reduced Major Axis Regression software (Bohonak and van der Linde 2004).

Results

Characterizing the advancing population

Main channel and backwater sampling sites in the Upper Illinois River differed in terms of bigheaded carps density. Of the 45 total sampling occasions (15 sites × 3 years), six backwaters had lower densities than the corresponding main channel, whereas, the remaining backwater densities were on average 9.3 times (range = 1.5–23.3 times) higher than the main channel. However, to give a representative overall measure of the bigheaded carps population, and to account for the different number and type of backwaters within each reach, the advancing population was examined by combining main channel and backwater estimates for each reach.

Regardless of year, a significant decreasing bigheaded carps density gradient was apparent from the lowermost Starved Rock reach upstream to the population front (Dresden reach) (Fig. 4). Overall density was highest in Starved Rock, occurring in the range *c.* 0.4–1.6 bigheaded carps/1000 m^3. Annual mean densities of either species were consistently significantly higher in Starved Rock than Marseilles (*c.* 0.15–0.4 bigheaded carps/1000 m^3) and Dresden (<0.15 bigheaded carps/1000 m^3). Silver carp density followed this observed gradient each year (i.e. Starved Rock > Marseilles > Dresden). Bighead carp density was always highest in Starved Rock, while its density was comparable in Marseilles and Dresden during 2012 and 2013, but not 2014 (Fig. 4). Silver carp mean density in Dresden was <0.02/1000 m^3 in all years.

Significant longitudinal shifts in the size structure (H = 501–1319, all $P < 0.001$ (post hoc, all $P < 0.001$)) and species composition (χ^2 = 116–937, all $P < 0.001$) of bigheaded carps were observed from downstream to upstream in the Upper Illinois River during each year (Fig. 5). Within the highest density Starved Rock reach, bigheaded carps were significantly smaller and dominated by silver carp (71.6–83.8 % silver carp). In the lower density Marseilles reach, bigheaded carps were larger, and

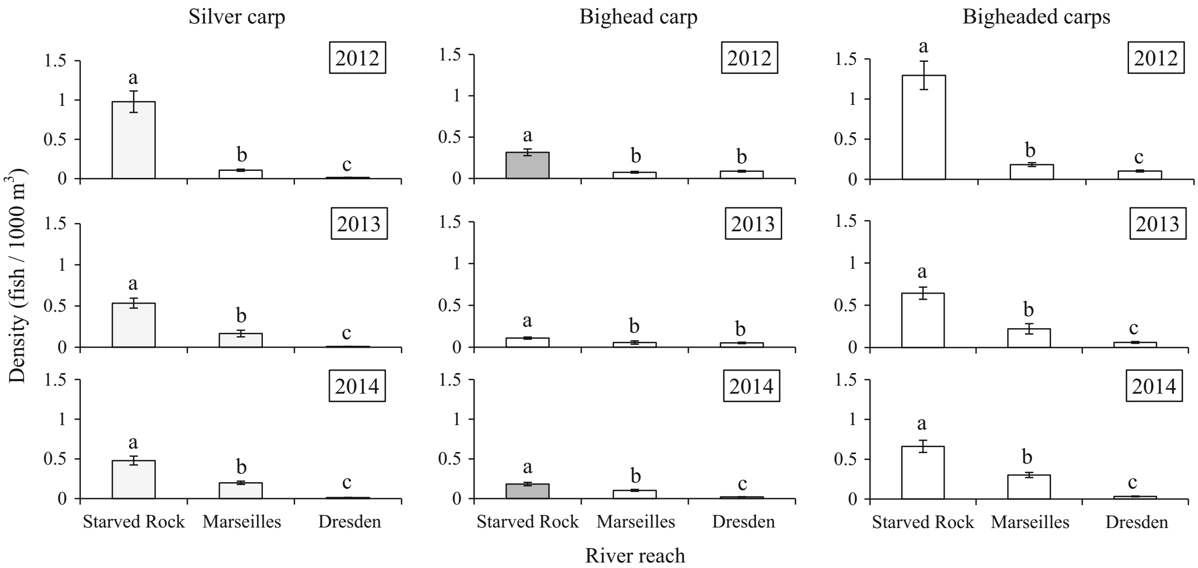


Fig. 4 Mean densities ±95 % confidence intervals of silver carp (*light grey bars*), bighead carp (*dark grey bars*) and bigheaded carps (i.e. both species combined) (*white bars*) in each sampled reach of the Upper Illinois River during 2012–2014. Significant differences ($P < 0.05$) are indicated by *different letters*

though the proportion of bighead carp increased, there was still a silver carp predominance (59.4–74.2 % silver carp). At lowest density, in the Dresden reach (i.e. the population front), bigheaded carps were largest and species composition shifted in favor of bighead carp (15.1–38.2 % silver carp) (Fig. 5).

Validating hydroacoustic density estimates for harvest evaluation

Hydroacoustic sampling of backwater lakes was undertaken on ten occasions before harvest events, and on eight occasions after harvest events. Depending on the lake, one to five fishing crews operated, with effort (total m of net) ranging from 1829 to 14,905 m (mean ± SD = 6963 ± 4325 m). Harvest events captured 1–1301 bigheaded carps (mean ± SD = 589 ± 483 individuals). Hydroacoustic estimates of bigheaded carps density before harvest were significantly correlated with bigheaded carps harvest CPUE ($R^2 = 0.744$; Fig. 6a; Table 2). The density equivalent of harvested bigheaded carps (i.e. the difference in before–after hydroacoustic estimates) was also significantly correlated with bigheaded carps harvest CPUE ($R^2 = 0.823$; Fig. 6b; Table 2).

In nearly all cases, harvest significantly reduced bigheaded carps densities in the short term (i.e. within a <24 h period) by 32.0–64.4 % on average (Table 3). However, at backwater lakes with more than one before–after sequence, densities rebounded to initial levels (Rock Run 2014, East Pit 2015), or exceeded initial levels (East Pit 2014), in as little as 2 weeks (Table 3).

Bigheaded carps population changes throughout the upper Illinois River

Discharge conditions during the surveyed period in 2012 (mean ± SD = 70 ± 25 m^3/s) and 2013 (77 ± 24 m^3/s) were considerably lower than in 2014 (313 ± 142 m^3/s) but, in terms of the overall hydrograph, prolonged high discharge conditions occurred during 2013 and 2014 compared to the lower discharge in 2012, a drought year (Fig. 7 top). The total number of bigheaded carps harvested March–December increased annually from 45,192 in 2012, to 58,374 in 2013 and 102,453 in 2014. Monthly harvest (all gear types) of bigheaded carps within each reach was variable (Fig. 7) and, to a certain extent, harvested quantity (all gear types) and CPUE (gill and trammel nets) of bigheaded carps broadly reflected the advancing populations' density gradient (as described above).

Based on the annual hydroacoustic surveys, bigheaded carps density in the entire upper river (i.e. all

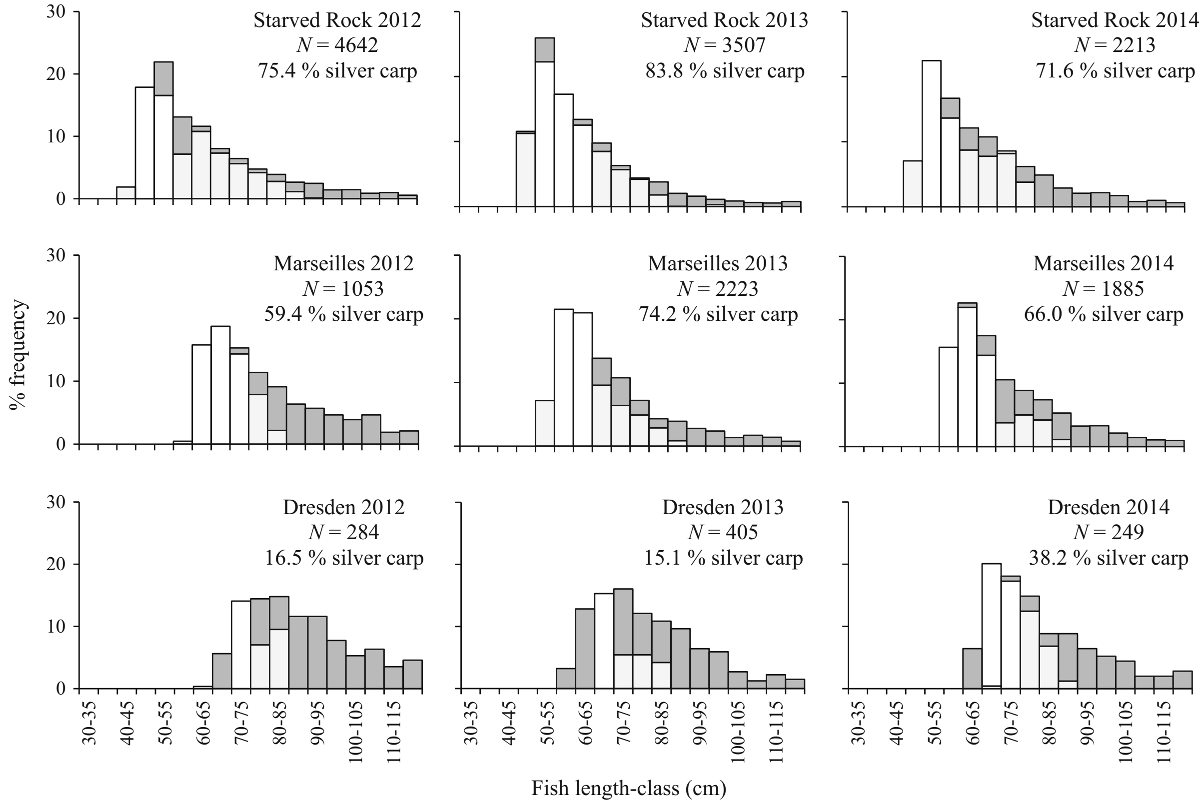


Fig. 5 Hydroacoustic-estimated size distributions of silver carp (*light grey bars*) and bighead carp (*dark grey bars*) sampled in each reach of the Upper Illinois River. Total number of bigheaded carps ensonified, and percent species composition (i.e. silver carp as a % of bigheaded carps), corresponding to each size distribution are shown

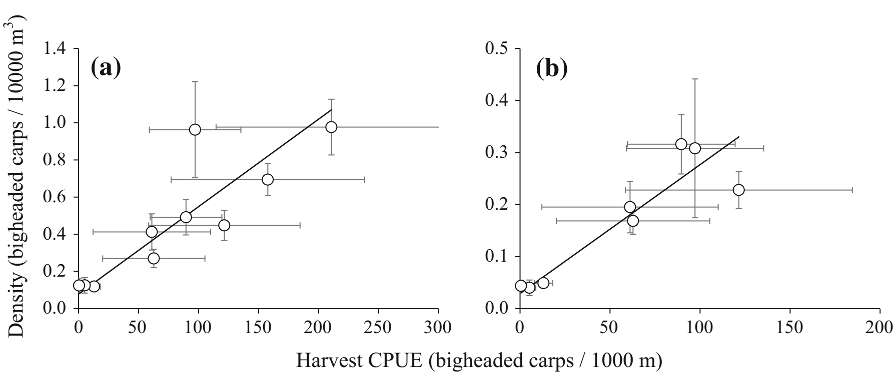


Fig. 6 Reduced major axis regression of **a** bigheaded carps density (before) and bigheaded carps harvest CPUE ($R^2 = 0.740$, $n = 10$) and **b** before–after difference in bigheaded carps density and bigheaded carps harvest CPUE ($R^2 = 0.823$, $n = 8$). All data-points are means ± 95 % confidence intervals

reaches combined) declined significantly, from 0.492 ± 0.053/1000 m^3 in 2012 to 0.278 ± 0.034/1000 m^3 in 2013, but remained stable between 2013 and 2014 (0.254 ± 0.024/1000 m^3). Annual density in Starved Rock mirrored that of the entire river, in contrast to Marseilles (where density did not change

Table 2 Reduced major axis regression estimates for (a) bigheaded carps density (before), and (b) before–after difference in bigheaded carps density, versus bigheaded carps harvest CPUE. Note that the primary statistics (*F* values and *P* values) are from linear least-squares regressions

Variable	Intercept ± SE	Slope ± SE (95 % CIs)	*F*	*df*	*P*	R^2
(a) Bigheaded carps density (before)	0.073 ± 0.090	0.005 ± 0.001 (0.003–0.007)	23.291	1, 8	0.001	0.744
(b) Before–after difference in bigheaded carps density	0.028 ± 0.030	0.003 ± 0.0004 (0.001–0.004)	27.807	1, 6	0.002	0.823

Table 3 Hydroacoustic estimates of bigheaded carps density (mean ± 95 % confidence intervals) before and after harvest events in three backwater lakes of the Upper Illinois River during 2014 and 2015. Bigheaded carps harvest metrics (CPUE and total number of individuals harvested) for the corresponding harvest event are given in parentheses under each pair of density estimates

2014						
East Pit (Marseilles)	6 May → 7 May		19 May → 20 May		7 July → 8 July	
	0.270 ± 0.049[a]	0.101 ± 0.023[b]	0.491 ± 0.095[a]	0.175 ± 0.037[b]	0.963 ± 0.259[a]	0.655 ± 0.126[b]
	(62.5 and 812)		(83.1 and 855)		(87.3 and 1301)	
West Pit (Marseilles)	20 May → 21 May					
	0.119 ± 0.020[a]	0.070 ± 0.023[b]				
	(13.4 and 66)					
Rock Run (Dresden)	8 July → 9 July		24 July → 25 July			
	0.125 ± 0.042[a]	0.078 ± 0.037[a]	0.124 ± 0.039[a]	0.069 ± 0.029[b]		
	(5.1 and 26)		(0.5 and 1)			
2015						
East Pit (Marseilles)	6 Aug → 7 Aug		7 Sep → 8 Sep			
	0.420 ± 0.099[a]	0.217 ± 0.048[b]	0.448 ± 0.081[a]	0.220 ± 0.045[b]		
	(56.6 and 150)		(116.2 and 701)			

Different superscript letters indicate a significant difference ($P < 0.01$) for each before and after sequence

year to year, but did increase significantly between 2012 and 2014) and Dresden (where consecutive annual declines in density occurred) (Fig. 7). At the scale of the entire upper river, the population response appears closely linked with the prevailing seasonal/annual discharge regime, as increasing annual harvest elicited an apparent 43.5 % decline after a drought year, but only maintenance of the reduced density levels following a flood year.

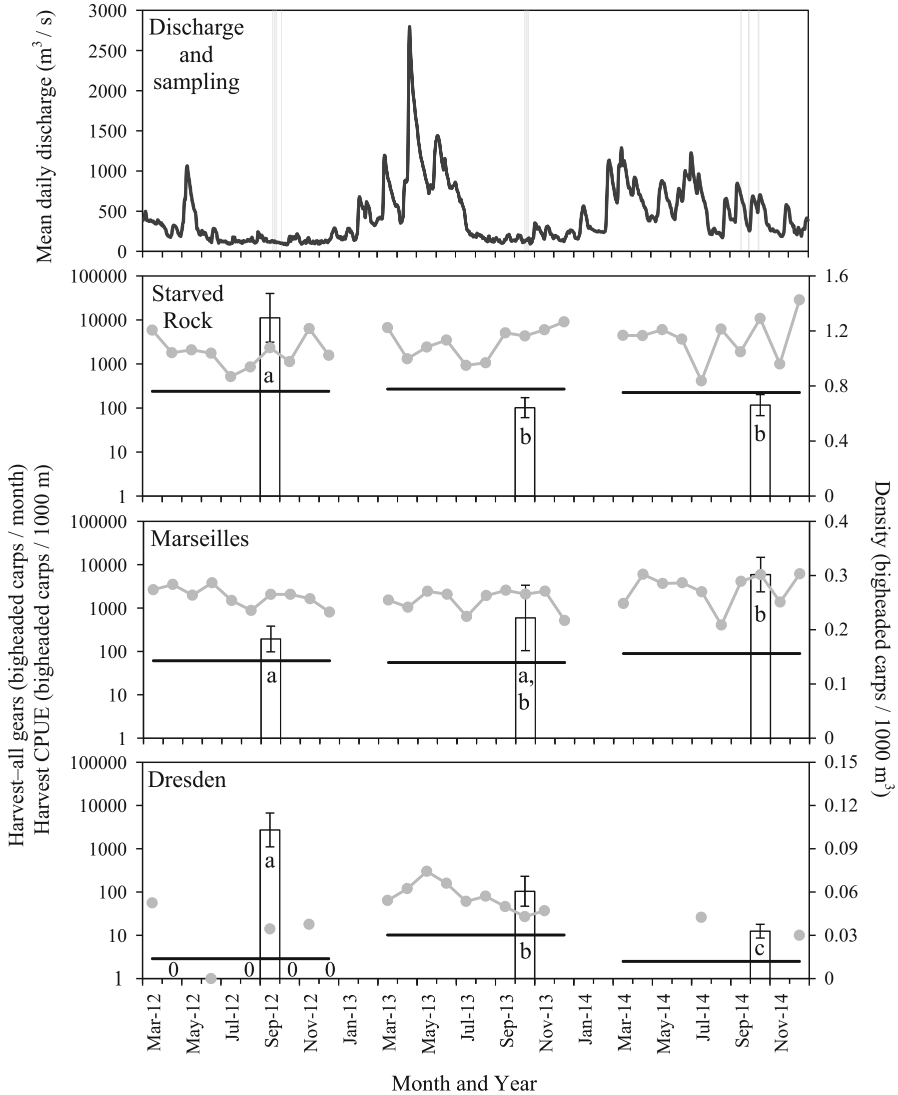
Discussion

The Upper Illinois River, as the conduit that links two major hydrological basins (one invaded and one not), is a critical location at which to investigate bigheaded carps invasion dynamics and the population response to control efforts (Cooke 2016). We adapted marine and large lake hydroacoustic protocols (Simmonds and MacLennan 2005; Parker-Stetter et al. 2009; Rudstam et al. 2009) for use in this shallow riverine environment, to estimate key demographic parameters of the advancing population at the edge of their range and, thus, by extension evaluate the efficacy of harvest in the Upper Illinois River.

Advancing population characteristics

Density of bigheaded carps was assessed on a volumetric basis, on the assumption that it is the most representative measure of population status (i.e. direct measurement rather than extrapolation). Annual fall surveys of the advancing populations' continuous longitudinal distribution confirmed that bigheaded carps were more prevalent downstream than upstream. The advancing population in each reach was

Fig. 7 *Top* Mean daily discharge (*solid black line*, Marseilles reach) and hydroacoustic sampling period (*grey shaded areas*). *Below* Each reach in the Upper Illinois River showing monthly harvest of bigheaded carps for all gears (joined *grey circles*, '0' indicates fishing but no catch, *blanks* indicate no fishing), annual bigheaded carps gill/trammel net CPUE (*horizontal black lines*) and bigheaded carps mean density ±95 % confidence intervals (*white bars*). Note y-axis logarithmic scale for harvest and CPUE, and the different scales for density in each reach. Significant differences ($P < 0.05$) in densities within a reach are indicated by *different letters*



categorized into distinct density components, ranging from the highest levels in Starved Rock to the lowest in Dresden. Site-specific densities within a reach may lie outside the observed ranges (reflecting habitat preferences of bigheaded carps e.g., DeGrandchamp et al. 2008), but these overall classifications provide an indication of the density gradient of this advancing population. Such information is useful where bigheaded carps are expanding their range, so as to quantify the invasion process and set appropriate removal targets (e.g., Tsehaye et al. 2013; Green et al. 2014).

Size structure and species composition also appear linked with each bigheaded carps density component, as body size (both species) and proportion of bighead carp increased from downstream to upstream. To what extent this is attributable to species-specific upstream dispersal or other density-dependent mechanisms is not clear. It also remains to be seen if the interannual variability in size structure and species composition observed within a particular reach reflects natural trends (e.g., a strong year-class) or is harvest-induced through gear selection for a particular species or size-class (Irons et al. 2011; Tsehaye et al. 2013).

Harvest evaluation (short-term, local scale)

The series of before–after harvest experiments in backwater lakes showed that in nearly all cases, density of bigheaded carps was reduced immediately post-harvest. It is probable that the large quantities of bigheaded carps removed by harvest caused most of the observed declines, but fish actively moving from the backwater to the main channel in response to the disturbance of the harvest event may also have contributed. This is especially likely in the smallest lake, Rock Run, which would help explain the somewhat less consistent results there.

Regardless of initial densities, recolonization of the backwater lakes occurred in as little as two weeks. Rebound rate is an important metric for evaluating targeted harvest (Frazer et al. 2012) and it appears that, in these locations at least, some features and/or conditions are continually re-attracting bigheaded carps (e.g. Cuddington et al. 2015). An integrated pest management approach (Koehn et al. 2000; ACRCC 2015), involving removal of individuals present (i.e. by harvest) and prevention of recolonization by new individuals (e.g., by behavioral barriers at strategic locations or manipulation of water levels), may be a rational approach to pursue, but the potential for altering upstream dispersal must also be carefully considered.

Hydroacoustic and capture gear comparisons can be highly variable, with the level of accuracy depending on the environment, gear type and characteristics of the species under consideration (e.g., Mehner and Schulz 2002; Dennerline et al. 2012; Guillard et al. 2012). Though the use of mobile hydroacoustic methods in shallow environments is increasing (e.g., Lucas and Baras 2000; CEN 2014), few studies have verified estimates against known relative abundance indices. The positive density–CPUE relationships obtained during the backwater lake experiments provided the basis upon which to use our river-wide hydroacoustic surveys as a tool to evaluate harvest on a broader spatiotemporal scale (i.e. throughout the upper river over three consecutive years).

Harvest evaluation (long-term, river-wide)

The river-wide fall surveys were not intended to directly correspond with harvest events, as sampling occurred during alternate weeks to harvest. Instead, we aimed to provide 'snapshots' of the population status in the entire upper river, at a comparable stage of each year (i.e. during suitable hydrological conditions, and when the harvest season had been underway for *c.* 6 months). Therefore, while harvested quantities and CPUE of bigheaded carps broadly reflected the density components estimated from the hydroacoustic surveys, they appear to lack the resolution of the hydroacoustic surveys to map fluctuations within these ranges (see Dennerline et al. 2012). The complexity of these reach-specific density trends likely reflects between-reach movement and differential harvest rates. Biases associated with the unstandardized, catch-maximizing approach of the harvest program further confound the interpretation of the capture statistics and highlight the need for the present fishery-independent evaluation.

Despite the large quantities of bigheaded carps removed from the Upper Illinois River annually, harvest alone is clearly not the only factor regulating population dynamics in the river (see also Tsehaye et al. 2013). Total harvest increased annually, yet density did not decline between 2013 and 2014. Instead, the prevailing discharge regime may play a key role. In situ reproduction is currently a negligible source of bigheaded carps in the upstream portion of the river (ACRCC 2015), thus Starved Rock Lock and Dam is the only immigration pathway to the Upper Illinois River from the high density reaches farther downstream (Sass et al. 2010; Garvey et al. 2012). Discharge is important for upstream fish passage at low-head dam structures (Zigler et al. 2004; Tripp et al. 2014) and it is likely that population densities were sustained by high immigration via Starved Rock Lock and Dam to the upper river in the latter two study years due to 'open-river' conditions (i.e. dam gates open to varying degrees to prevent flooding during high discharge). Both silver carp and bighead carp have shown increased movement rates during periods of high water levels (DeGrandchamp et al. 2008; Coulter et al. 2016).

The observed decline in bigheaded carps density in the Dresden reach (*c.* 68 % cumulative decline between 2012 and 2014) is interesting to note, suggesting that continued harvest at the low density population front may be effective (likely aided somewhat by the spatial isolation from higher densities downstream). From an invasion biology perspective, the ability to suppress at such low density has important management implications, both at the

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Conclusions

When viewed in the context of other removal efforts in large rivers (Mueller 2005; Coggins et al. 2011; Franssen et al. 2014), the Asian carps harvest program in the Upper Illinois River compares quite favorably. During the 3 years of sampling, overall density declined to and remained at the lower level, and the population front has not expanded. However, hydrological variability (and possibly other environmental conditions) likely determine the extent of the population response in a particular year. Years with coinciding high discharge, strong year-class and/or successful recruitment are likely to put harvest resources under considerable pressure.

While there are still certain technological limitations associated with the use of hydroacoustic methods in shallow riverine environments (e.g., minimum depth and fish size, appropriate TL–TS equation relative to fish aspect, paired sampling required for species identification), this study nonetheless outlines a fishery-independent sampling framework that will be a valuable addition to management of invasive fishes in the Mississippi River basin and elsewhere. Integration of existing population estimates (Sass et al. 2010; Garvey et al. 2012; this study) with movement ecology (DeGrandchamp et al. 2008; Norman and Whitledge 2015) and simulation modeling (Tsehaye et al. 2013) is an important next step that will help disentangle the complex invasion processes and enable optimum control strategies to be developed.

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APPENDIX L
ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

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Participating Agencies: Illinois Department of Natural Resources, Illinois Natural History Survey, U.S. Fish and Wildlife

Introduction:

Various agencies (e.g., Illinois Department of Natural Resource, U.S. Army Core of Engineers, Illinois Natural History Survey, U.S. Fish and Wildlife), universities (e.g., Eastern Illinois University, Southern Illinois University, Western Illinois University) and personnel (e.g., contracted fisherman, volunteers) collaboratively monitor, remove, and research Invasive Carp (e.g., Bighead Carp [*Hypophthalmichthys nobilis*], Black Carp [*Mylopharyngodon piceus*], Grass Carp [*Ctenopharyngodon Idella*] and Silver Carp [*H. molitrix*]) in the Illinois River. Since numerous entities and personnel actively manage Invasive Carp populations in the Illinois River, standardizing sampling methods among groups and workers is critical. Standardized sampling efforts and methods ensure data collected by these entities and personnel can provide statistically valid interpretations that are comparable among agencies, locations and years. Long term comparisons of standardized sampling data will also allow managers to assess trends in Asian carp dynamics over time and the response of the Asian carp population to management actions.

Objective:

(1) Create a living document (i.e., a continually updated as new data becomes available) describing specifications of sampling gears utilized to deplete, detect, or monitor adult, juvenile, and larval Invasive Carp populations in the Illinois River watershed.

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Adult and juvenile fish capture gears

Active capture gears

Electrofishing (Figure 1):

Flat bottomed aluminum boats, 5.5 to 6.1 m (18.0 to 20.0 ft.) in length powered with 90-horsepower or greater outboard motors served as the boat for electrofishing. One, 3.4 m (11.0 ft.) fiberglass boom was attached to the port rail and starboard rail of the bow of the boat. Each fiberglass boom was created of hollow 3.8 cm (1.5 in.) outer-diameter, and 0.6 cm (0.3 in.) thick walled fiberglass poles and were spaced 3.1 m (10.0 ft.) apart (center to center at ends of booms). Each boom had a 0.9 m (3.0 ft.) diameter round stainless steel anode ring attached to the end of the pole. Anode arrays consisted of four droppers attached equidistance around the ring using 3.1 mm (0.1 in.) diameter uncoated stainless-steel cable and U-bolt cable clamps. Anode droppers cable was 35.6 cm (14.0 in.) in length from the ring to the dropper. Cable-dropper arrangements were 66.0 cm (26.0 in.) in total length. A 7,000-watt generator produced the electrical charge through an electrofishing box. Electrofishing boxes were either a MBS-1D "Wisconsin" style control box or Type VI-A smith-root control box with on foot pedal safety switch. Pulse rate of electrofishing boxes could be adjusted from 10 to 1,000 Hertz and duty cycles from 1% to 100%. Output voltage was adjustable from approximately 100 to 600 volts peak DC, depending on generator watt capacity and water conductivity. Electrofishers used a standardized pulse rate of 60 Hz with 25% duty with a uniform base power goal of 3,000 watts. Power goals (in watts) were calculated based off specific conductivity (micro siemens per centimeter) and temperature (in degrees Celsius) to ensure potential transfer of watt from water to fish was 3,000 watts. When operating at 3,000-watt power goal, an effective voltage gradient varying from 0.1 to 1.0 volts/centimeter was produced out to approximately 1.0 m from the boat hull and 2.0 m from the anode arrays. Dip nets used during electrofishing to capture stunned fish were 30.0 cm (12 in.) deep by 45.0 cm (17.6 in.) wide stitched to an approximately square frame mounted to a 2.4 m (8.0 ft.) fiberglass handle. Bar-measured mesh size in dip nets was 3.0 mm (0.1 in.).

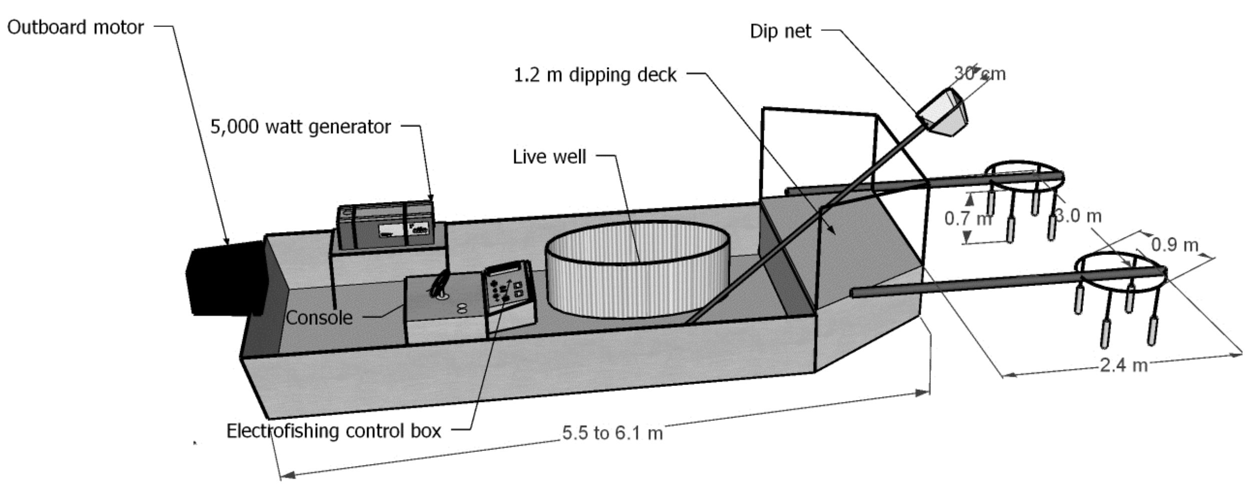

Figure 1. *Schematic of electrofishing boat.*

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Shallow drive electrofishing boat (Figure 2):

A flat-bottomed aluminum boat, 6.1 m (20.0 ft.) in length powered with two 37-horsepower EFI Gator Tail motors served as the shallow drive boat for electrofishing. One, 3.4 m (11.0 ft.) fiberglass boom was attached to the port rail and starboard rail of the bow of the boat. Hollow 3.8 cm (1.5 in.) outer-diameter by 0.6 cm (0.3 in.) thick walled fiberglass booms extended 2.4 m (8.0 ft.) in front of the boat and were spaced 2.7 m (9.0 ft.) apart (center to center at ends of booms) on the port and starboard sides of the bow. Each boom had a 0.8 m (2.5 ft.) diameter round anode ring attached to the end of the pole. Anode rings were constructed of a 1.3 cm (0.5 in.) stainless-steel rod bent and welded into a 76.2 cm (30 in.) outer-diameter circle. Anode arrays consisted of four droppers attached equidistance around the ring using 3.1 mm (0.1 in.) diameter uncoated stainless-steel cable and U-bolt cable clamps. Anode dropper cable was 35.6 cm (14.0 in.) in length from the ring to the dropper. Cable-dropper arrangements were 66.0 cm (26.0 in.) in total length. A 7,000-watt generator produced the electrical charge through an electrofishing box. Electrofishing box was a ETS 82A wave pulse DC (ETS Electrofishing Systems) control box with two dead man mat style safety switches. Pulse rate of electrofishing box could be adjusted from 10 to 1,000 Hertz and duty cycles from 1% to 100%. Output voltage was adjustable from approximately 100 to 600 volts peak DC, depending on generator watt capacity and water conductivity. Electrofishers used a standardized pulse rate of 60 Hz with 25% duty (15% - 20% duty if specific conductivity is over 900) with a uniform base power goal. A dedicated power goal strategy is currently being developed. Power goals (in watts) were calculated based off specific conductivity (micro siemens per centimeter) and temperature (in degrees Celsius) to ensure potential power transfer was great enough to achieve fish immobilization (narcosis) and electrotaxis but avoid tetany (full rigid, non-breathing) of small bodied (15.2 cm [6.0 in]) native species. Dip nets used during electrofishing to capture stunned fish were 30.0 cm (12 in.) deep by 45.0 cm (17.6 in.) wide stitched to an approximately square frame mounted to a 2.4 m (8.0 ft.) fiberglass handle. Bar-measured mesh size in dip nets was 3.0 mm (0.1 in.).

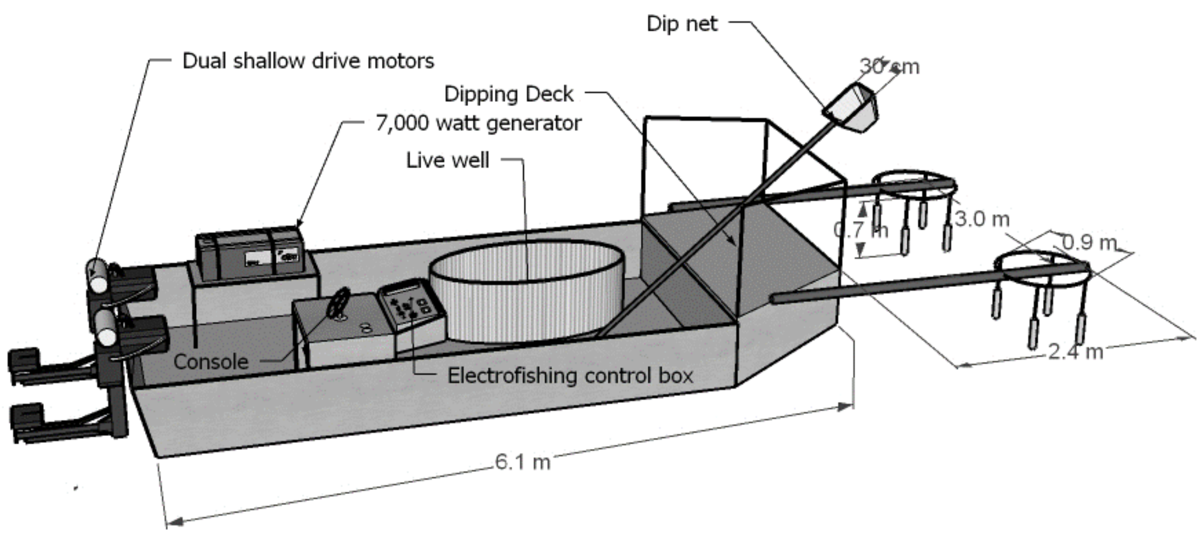

Figure 2. *Schematic of the shallow drive electrofishing boat.*

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Electrified dozer trawl (Figure 3):

A shallow drafting flat bottom aluminum boat 5.5 m (18.0 ft.) or 5.8 m (19.0 ft.) long, 2.4 m (8.0 ft.) wide with a semi-v bow, powered by a 105-horsepower outboard jet drive connected to a jack plate or a 36-horsepower tiller-steer outboard motor served as the boat for the dozer trawl. A 3.8 cm (1.5 in.) powered coated square steel tubing 2.1 m (7.0 ft) wide and 0.9 m (3.0 ft.) tall frame was secured to two 1.2 (4.0 ft.) booms that were attached to the port and starboard side of the bow with 1.3 cm (0.5 in.) a hinge pin. The net of attached to the frame was 1.83 m (6.0 ft.) or 4.6 m (15.0 ft.) long net was stitched to the frame with a combination of zip-ties and nylon cordage. The net was 4.6 m (15.0 ft.) long with a 3.7 m (12.0 ft.) long front portion was made of 35.0 mm (1.4 in.) bar measured mesh which tapered back in a funnel shape to a 0.9 m (3.0 ft.) cod end made of 4.0 mm (0.3 in.) bar measured mesh. The cod end of the net was tied securely closed using 10.2 mm (0.4 in.) nylon rope. The net-frame was held in fishing position (90 degrees to water surface with net opening forward) by double braided kevlar rope attached from the bottom of the frame to 90.7 kg (200.0 lb.) break away nylon cord at the top. Additionally, heavy duty 3.2 mm (0.1 in.) cord mesh with 5.8 cm (2.0 in.) bar measured netting was tied along the bottom of the fishing net to protect the fishing net from snagging on debris during shallow water fishing. A 1,360 kg (3,000.0 lb.) 12v electric winch fed with 4.8 mm (0.2 in.) steel cable was mounted to the deck of the boat. The steel cable was fed through pulleys on the boom arms to lift the boom-arms and subsequently the net-frame from the water when fishing was complete. A three-anode dropper configuration made of a polyvinyl chloride pipe frame was aligned 2.4 m (8.0 ft.) in front of the trawl frame with anode droppers spaced 457.2 mm (18.0 in.) apart. Alternatively, two anode booms space 1.8 m (6 ft.) apart each with an anode ring and four droppers were used occasionally. Anode rings of the booms were constructed of a 1.3 cm (0.5 in.) stainless-steel rod bent welded into a circle. Anode arrays consisted of four droppers attached equidistance around the ring using 3.1 mm (0.1 in.) diameter uncoated stainless-steel cable and U-bolt cable clamps. Anode droppers cable was 35.6 cm (14.0 in.) in length from the ring to the dropper. Cable-dropper arrangements were 66.0 cm (26.0 in.) in total length. A 42-amp Infinity control box produced by Midwest Lake Electrofishing System with a 7,000-watt or a 5,500-watt generator produced the electrical charge. A more detailed version of the electrified dozer trawl design is described in Hammen et al. (in review, USFWS-Columbia).

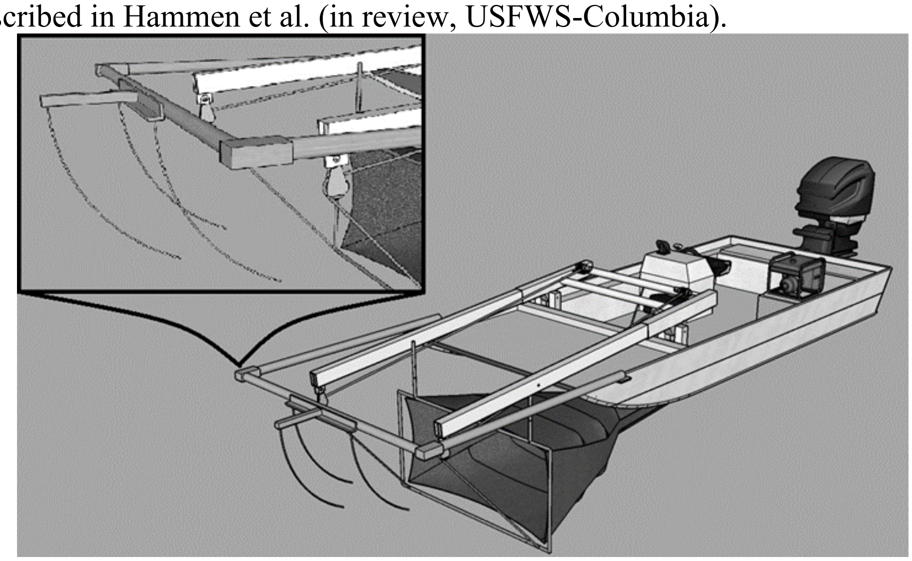

Figure 3. *Generalized schematic of the electrified dozer trawl.*

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Paupier trawl (Figure 4):

The paupier boat was a 7.3 m (24.0 ft.) long, 1.8 m (6.0 ft.) wide, semi-v bow, flat bottom boat powered with a 175-horsepower outboard motor. The bottom of the paupier was coated with a non-conductive abrasion resistant paint. A 4.0 m (13.0 ft.) wide by 1.5 m (5.0 ft.) deep rigid cathodic frame with a net consisting of 38.0 mm (1.5 in.) mesh in the body reducing to 6.0 mm (0.3 in.) mesh in the cod was attached on both sides of the hull of the boat. Three cable anodes droppers were affixed to booms 3.0-4.0m (10.0-13.0 ft.) in front of each frame. An 18.0 cm (7.0 in.) hemisphere anode was suspended in each frame approximately 1.0 m (3.3 ft.) back from the net opening. Cathodic frames were attached to an aluminum gantry which contained an electric winch allowing the frames to be raised and lowered within the water column during sampling. A Wisconsin ETS MBS-1D 72 amp high-output electrofishing box with 7,000-watt generator was used to produce the electrical charge. A more detailed version of the paupier design is described in Doyle et al. (in review, USFWS-Columbia).

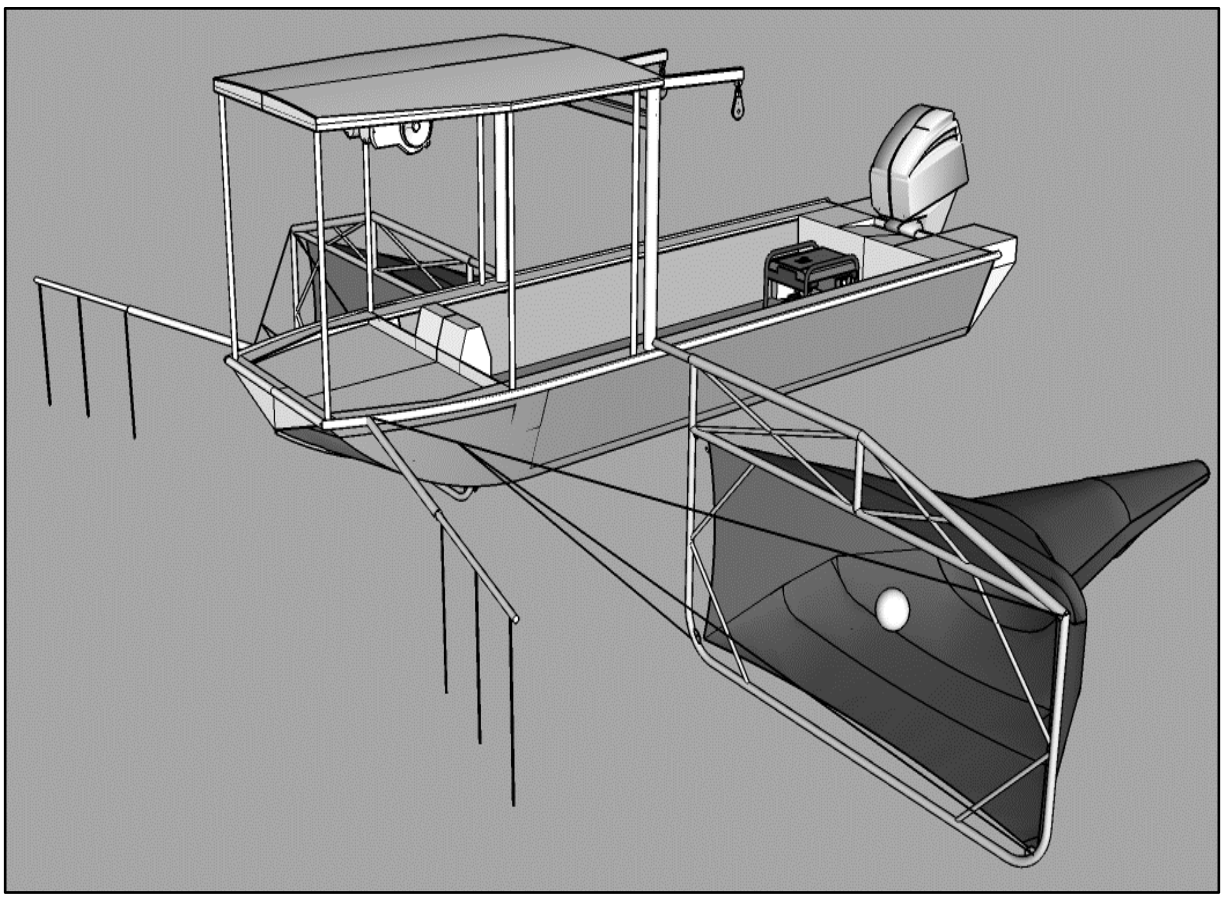

Figure 4. *Schematic of electrified Paupier trawl*

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Seine (Figure 5):

Seines consisted of two wings and a bunt section or a bag (extra material in the middle of the seine concentrating fish) secured to a float line and lead line. Floats were attached every 25.4 cm (10.0 in.) on the float line and a solid core lead line was used as the lead line. Floats were 41.3 mm x 111.0 mm (1.6 in. x 4.4 in.) hard orange foam that produced 85.0 g (3.0 oz.) of buoyancy. Bar measure of mesh was uniform within a seine, but two different mesh sizes of seines were used. The large mesh seine was 50.8 mm (2.0 in.) black asphalt coated bar-measured mesh and the small mesh seine was 1.6 cm (0.6 in.) black asphalt coated bar-measured mesh. Wings had a height of 3.2 m (10.0 ft.) tapering down to the bunt or bag section with a height of 9.1 m (30.0 ft.) for large mesh seines and 6.1 m (20.0 ft.) for small mesh seines. Total length of large mesh seines varied from 274.3 m (900.0 ft.) to 731.5 m (2400.0 ft.). Total length of the small mesh seine was 182.8 m (600.0 ft.).

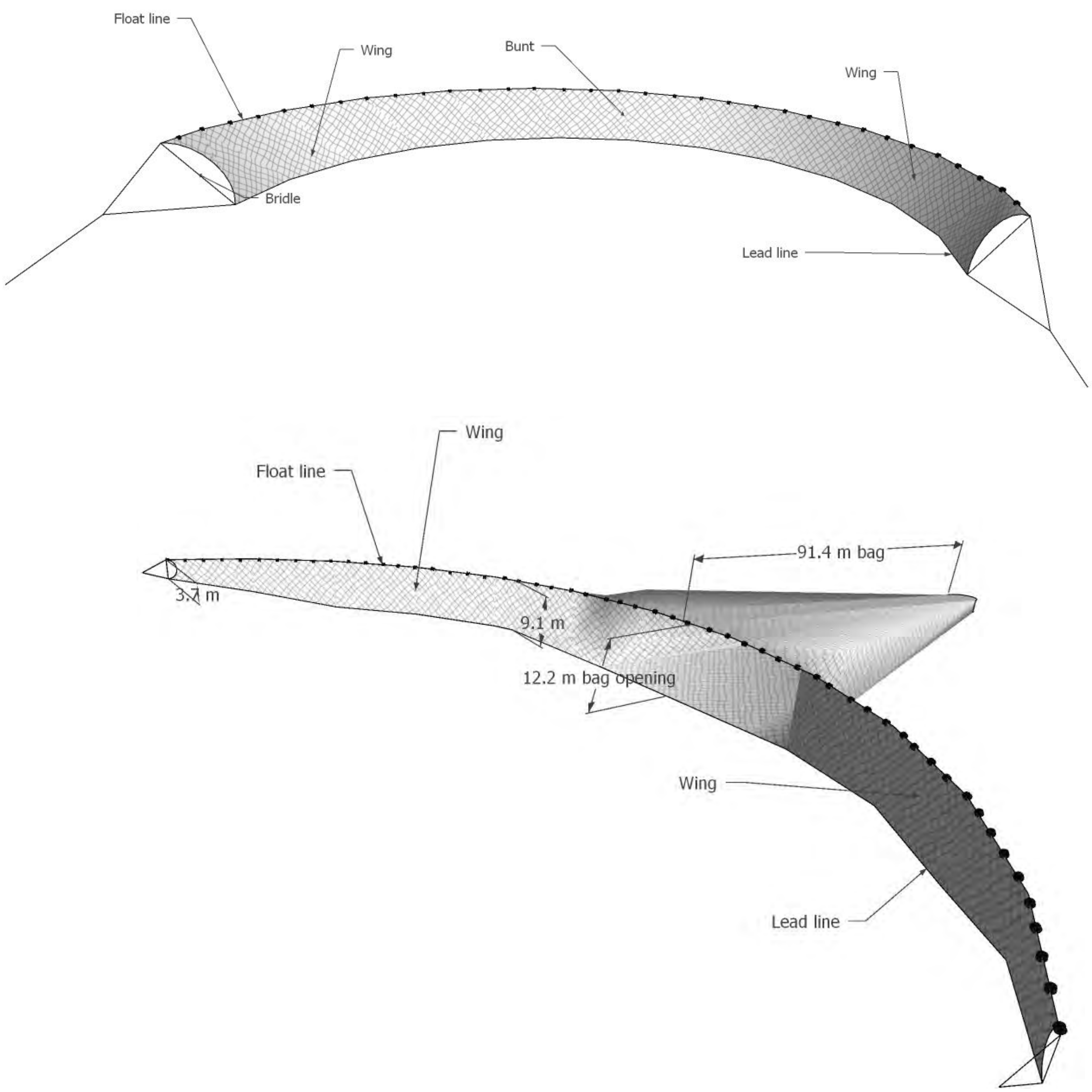

Figure 5. *Generalized schematic of a commercial seine without a bag (top) and with a bag (bottom).*

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Trawl (Figure 6):

The trawl was a two-seam balloon style trawl covered with 4.4 cm (1.8 in.) heavy delta-style bar measured mesh. The headrope was 19.8 m (65.0 ft.) long with floats spaced every 30.5 cm (12.0 in.). Floats were 41.3 mm by 111.0 mm (1.6 in. by 4.4 in.) orange hard foam which produced 85.0 g (3.0 oz) of buoyancy. The footrope was 22.3 m (73.0 ft) long with a 7.9 mm (0.3 in.) proof coil low carbon steel chain sewn to it. The mouth opening of the trawl tapered down from 1.8 m (6.0 ft.) at the brail ends to 3.7 m (12.0 ft.) at the mid-section. The 4.4 cm heavy delta-style asphalt coated mesh was attached to the headrope with 1.0 mm #72 black diameter nylon twine. The cod end of the trawl was 12.2 m (40.0 ft.) tarping down to a 2.1 m (7.0 ft.) stretched circumference catch area. Brail ends (sides of the trawl) of the trawl were 1.8 m (6.0 ft.) deep. Each bridle was attached to a 24.4 m (80.0 ft.) towrope that was securely fastened the stern of one of the towboats.

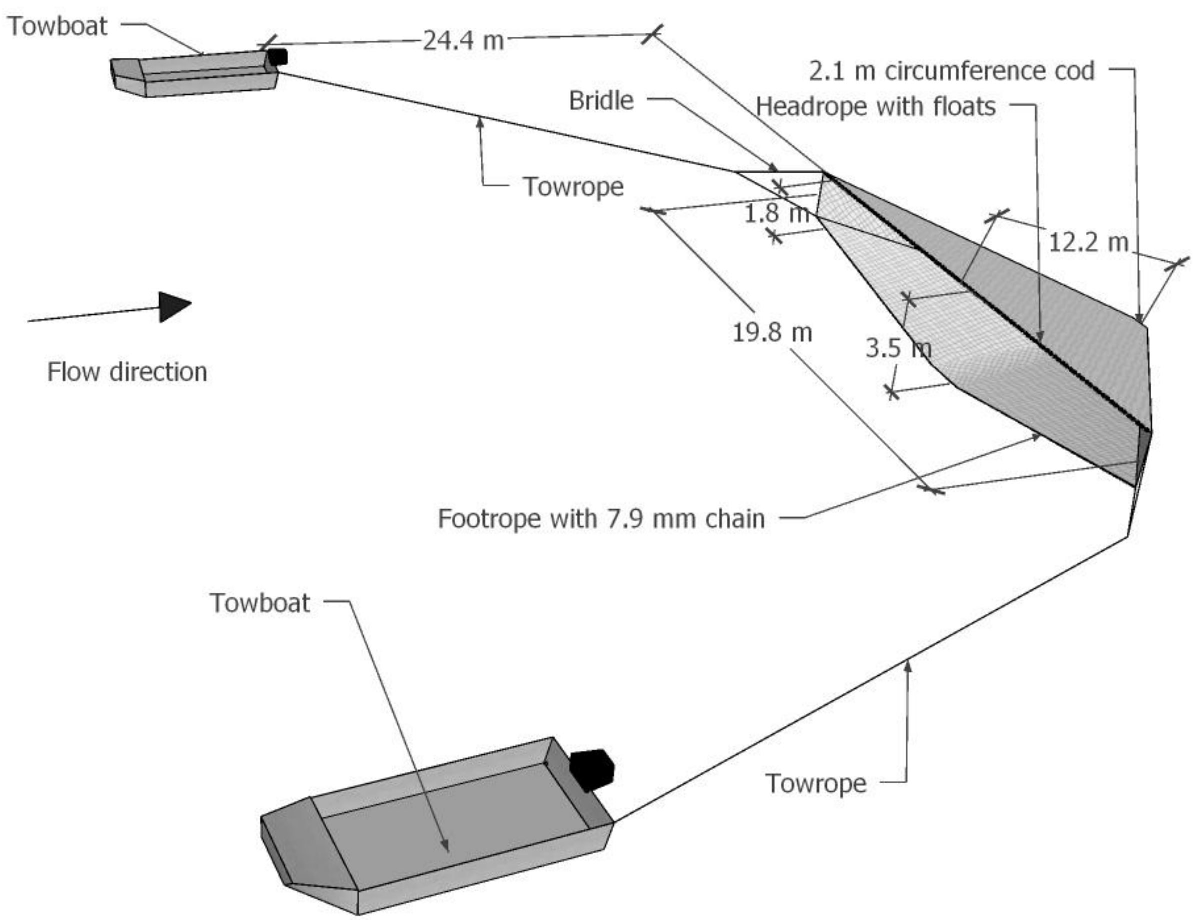

Figure 6. *Generalized schematic of a trawl.*

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Passive capture gears

Deep-water gill net (Figure 7):

Deep-water gill nets were constructed of three single walled panels made of clear monofilament webbing panels stitched vertically together. Each panel was 3.0 m (10.0 ft.) deep and 91.4 m (300 ft.) long. Stitched panels produced a 9.1 m (30.0 ft.) deep net. The multi-paneled net was tied to a single float line and single lead line. Float line was created from 127.0 mm (0.5 in.) foamcore float line producing 9071.0 g (320.0 oz.) of buoyancy. Lead line was created from #30 leadcore line. Hanging ratio (measure of how tightly the webbing is stretched along the float line and lead line on a 0-1 scale; lower number meaning more webbing length per foot of float line) of each panel was 0.5. The bag created (depth of webbing versus the depth of the net) was 0.6 m (2.0 ft.). Bar-measured mesh size of webbing for each panel was 69.9 (2.8 in.), 82.6 mm (3.3) or 88.9 (3.5 in.) attached in a quasi-random experimental fashion (panels of different mesh size attached together to reduce effects of size selectivity). Two multi-panel deep-water gill nets were tied together increasing the total length of the net to 183.0 m (600.0 ft.).

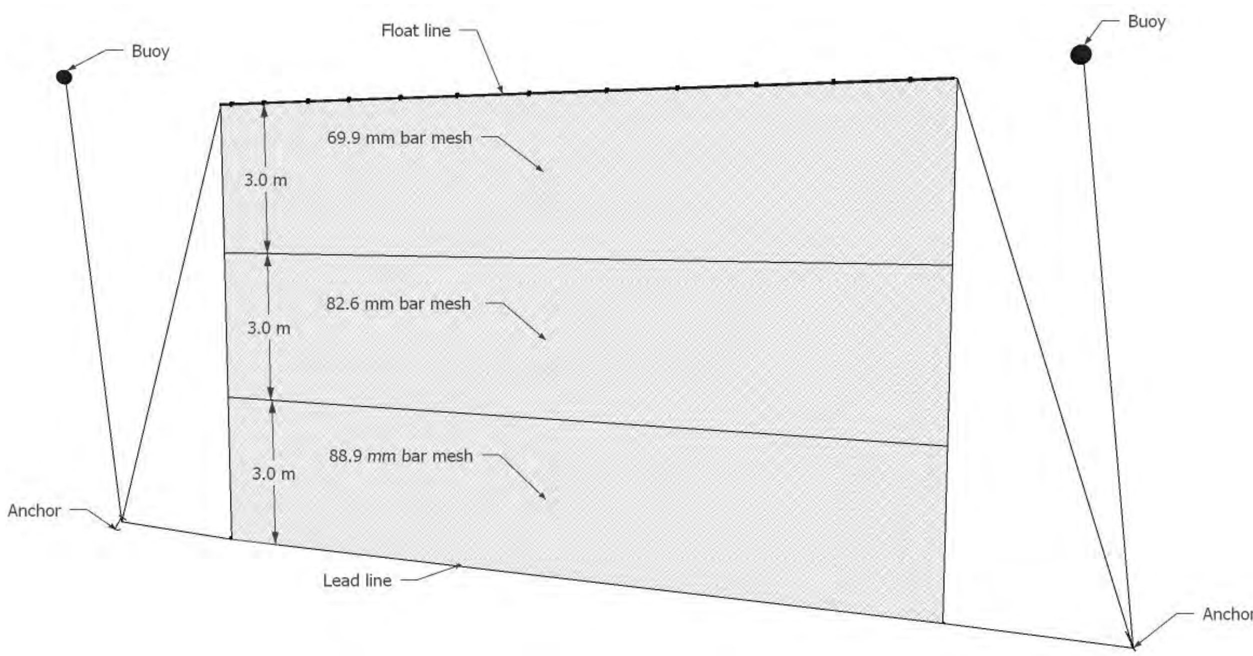

Figure 7. *Generalized schematic of a deep-water gill net.*

Shallow gill net (Figure 8):

Shallow gill nets were constructed of a panel of single walled monofilament, multi-strand monofilament or multifilament webbing stitched to a float line and a lead line in 91.4 m (300.0 ft.) increments. The float line was created from 95.0 mm (0.4 in.) or 127.0 mm (0.5 in.) foamcore float line producing 4,536.0 g (160.0 oz.) or 9,071.0 g (320.0 oz.) of buoyancy, respectfully. Lead line was created from #30 solid leadcore line. Hanging ratio (measure of how tightly the webbing is stretched along the float line and lead line on a 0-1 scale with lower number meaning more webbing length per foot of float line) of each panel varied between 0.5 to 0.2. The bag created (depth of webbing versus the depth of the net) varied between 3.7 m (12.0 ft.) to 1.2 m (4.0 ft.). Color of panel webbing was black, clear, green, purple, red, or white depending on the net. Bar-measured mesh size of webbing varied from 63.5 mm to 127 mm (2.5 - 5.0-in.) depending on the panel. Depth of panel walling varied from 2.4 m (8.0 ft.) to 4.3 m (14.0 ft.) depending on the net. Multiple 91.4 m (300.0 ft.) panels could be tied together increasing the total length of a net to over 914.0 m (3,000.0 ft.).

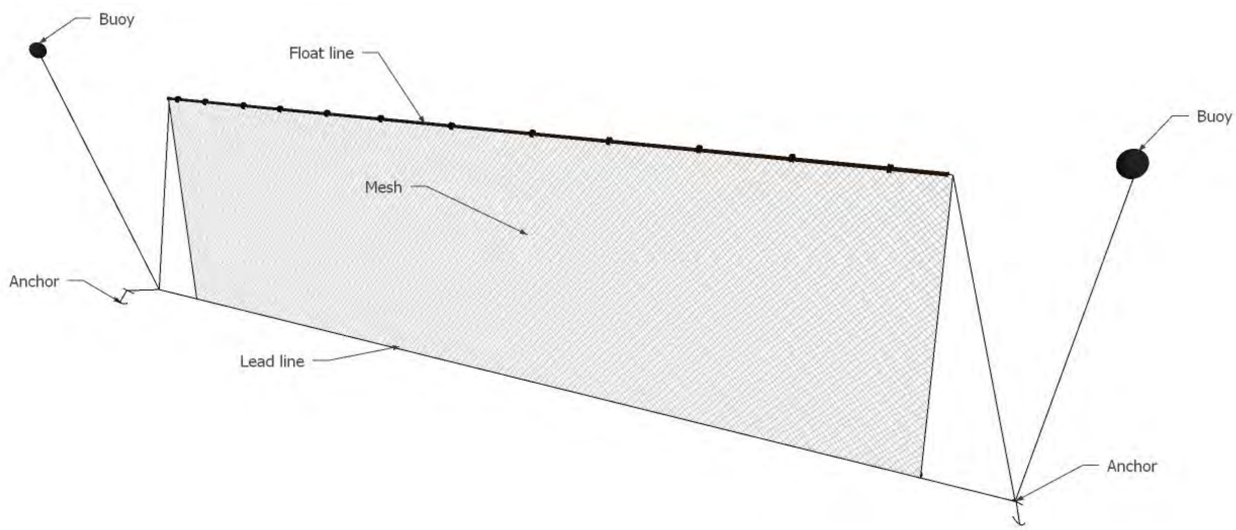

Figure 8. *Generalized schematic of a commercial shallow gill net.*

APPENDIX L
ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

Trammel net (Figure 9):

Trammel nets were constructed of three parallel mesh panels of monofilament, multi-strand monofilament or multifilament webbing stitched to a float line and a lead line in 91.4 m (300.0 ft.) increments. Float line was created from 95.0 mm (0.4 in.) or 127.0 mm (0.5 in.) foamcore float line producing 4,536.0 g (160.0 oz.) and 9,071.0 g (320.0 oz.) of buoyancy, respectfully. Lead line was created from #30 leadcore line. Hanging ratio (measure of how tightly the webbing is stretched along the float line and lead line on a 0-1 scale with lower number meaning more webbing length per foot of float line) of each panel varied between 0.5 to 0.2. The bag created (depth of webbing versus the depth of the net) was 1.2 m (4.0 ft.). Color of webbing included clear, green, red, and white depending on the panel. Bar-measured mesh webbing size of the outer panels were 457.0 mm (18.0 in.) with inner panel bar-measured mesh varying in size from 63.5 mm to 127.0 mm (2.5 to 5.0 in.) depending on the panel. Depth of panel walling varied from 2.4 m (8.0 ft.) to 3.7 m (12.0 ft.) depending on the net. Multiple 91.4 m (300.0 ft.) panels could be tied together increasing the total length of a net to over 914.0 m (3,000.0 ft.).

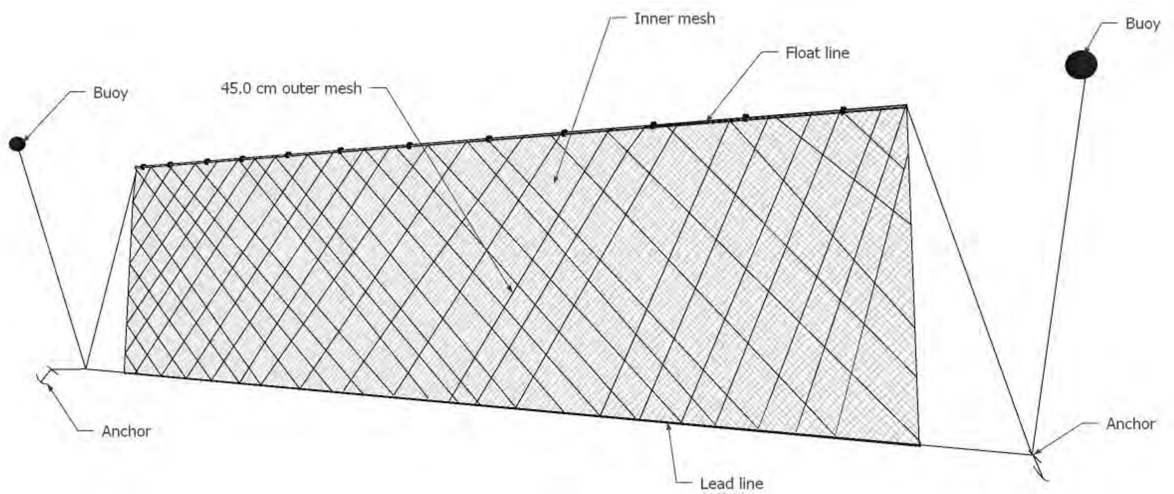

Figure 9. *Generalized schematic of a commercial trammel net.*

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Hoop net (Figure 10):

Hoop nets were constructed of a series of six, 1.8 m (6.0 ft.) fiberglass or spring metal hoops covered in #15 nylon black asphalt coated mesh. Mesh was hung on each hoop with # 21 nylon twine. The first three sections from the mouth between hoops were covered in 8.9 cm (3.5 in.) bar measured mesh and spaced 44.5 cm (17.5 in.) or 5 meshes apart. The last two sections from the mouth between hoops were covered in 6.4 cm (2.5 in.) bar measured mesh and spaced 63.5 cm (25.0 in.) or 10 meshes apart. The cod end was covered in 6.4 cm (2.5 in.) bar measured mesh and 69.8 cm (27.5 in.) or 11 meshes in length. A sand anchor was attached was to tension strings of the cod and a weight plate secured the bridle with a rope 4.0 m to 6.0 m in length tied to the bridle on one end and a buoy on the other ensuring the net remained taught at a length of 6.7 m (22.0 ft.). The weight plate was 1.3 cm (0.5 in.) thick steel plate 30.5 cm (12.0 in.) in length by 20.3 cm (8.0 in.) weighing approximately 6.1 kg (13.6 lbs.). A finger style throat was directed inward from the second and fourth hoop from the mouth of the net and shaped with finger lines. The front finger-style throat hand tapered down to a 61.0 cm (24.0 in.) diameter opening (at rear) and was 53.3 cm (21.0 in.) long. The rear finger-style throat hand tapered down to a 17.8 cm (7.0 in.) diameter opening (at rear) and was 85.9 cm (33.3 in.) long. The front throat had two tension strings secured to the finger lines and tied to the fifth hoop from the mouth of the net. The rear throat had two tensions strings also attached to finger lines secured to the cod-end drawstring. Tension strings were made of #72 black nylon twine.

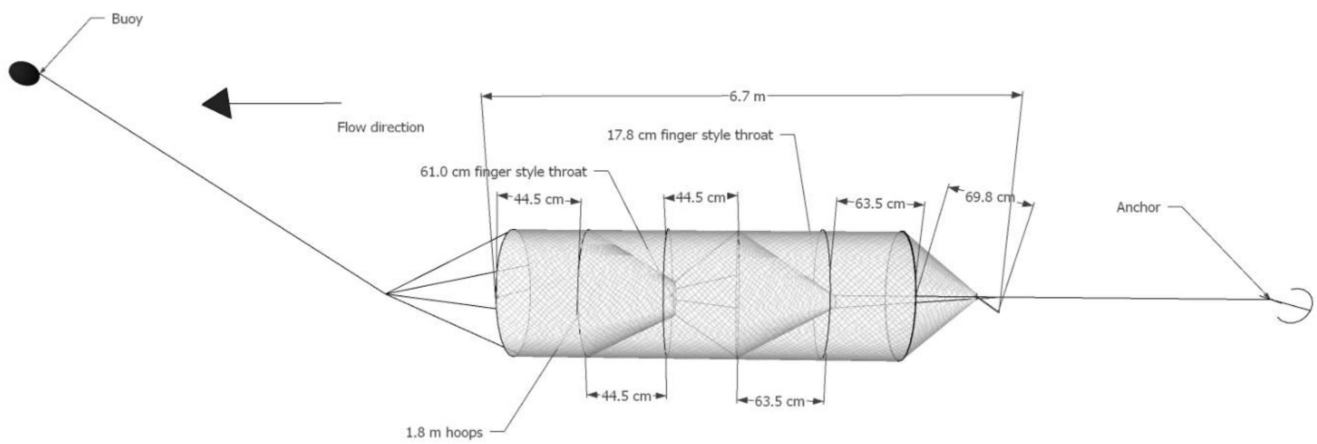

Figure 10. *Schematic of commercial hoop net*

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Great lakes style pound net (Figure 11):

Pound nets had a single 100.0 m (328.0 ft.) long by 3.0 m (9.8 ft.) deep lead and two adjustable length wings that were longer than 150.0 m and 3.0 m (9.8 ft.) deep. Floats were attached every 91.4 cm (36.0 in.) on the float line of the lead and wings. Lead line of the lead and adjustable wings were created of solid core lead line. Floats were hard black plastic 127.0 mm (5.0 in.) in length by 51.0 mm (2.0 in.) in diameter which produced about 147.0 g (5.2 oz.) of buoyancy. The lead and adjustable wings were stitched to the heart joining the lead and wings to the mesh cab. The mesh cab or catch area, was a 6.1 m long by 3.0 m wide by 3.0 m deep (19.6 x 9.8 x 9.8 ft.) mesh square. The cab had two, 3.0 m (9.8 ft.) long by 2.5 cm (1.0 in.) diameter steel pipes sewn to the bottom of the horizontal panels of the cab as weights and one 3.0 m (9.8 ft.) long by 7.6 cm (3.0 in.) diameter capped polyvinyl chloride pipe stitched to the top of the rear horizontal cab panel for a float. Inner wings (wall throats) of the mesh cab, created a tunnel that extended from the outer corners of the heart to the middle of the rear rectangle mesh panel of the cab, with a 38.0 cm (15.0 in.) vertical gap between wings and either side of lead. Bar measured mesh size of webbing in pounds nets were either 3.8 cm (1.5 in.) or 6.4 cm (2.5 in.) black asphalt coated web depending on the pound net being used.

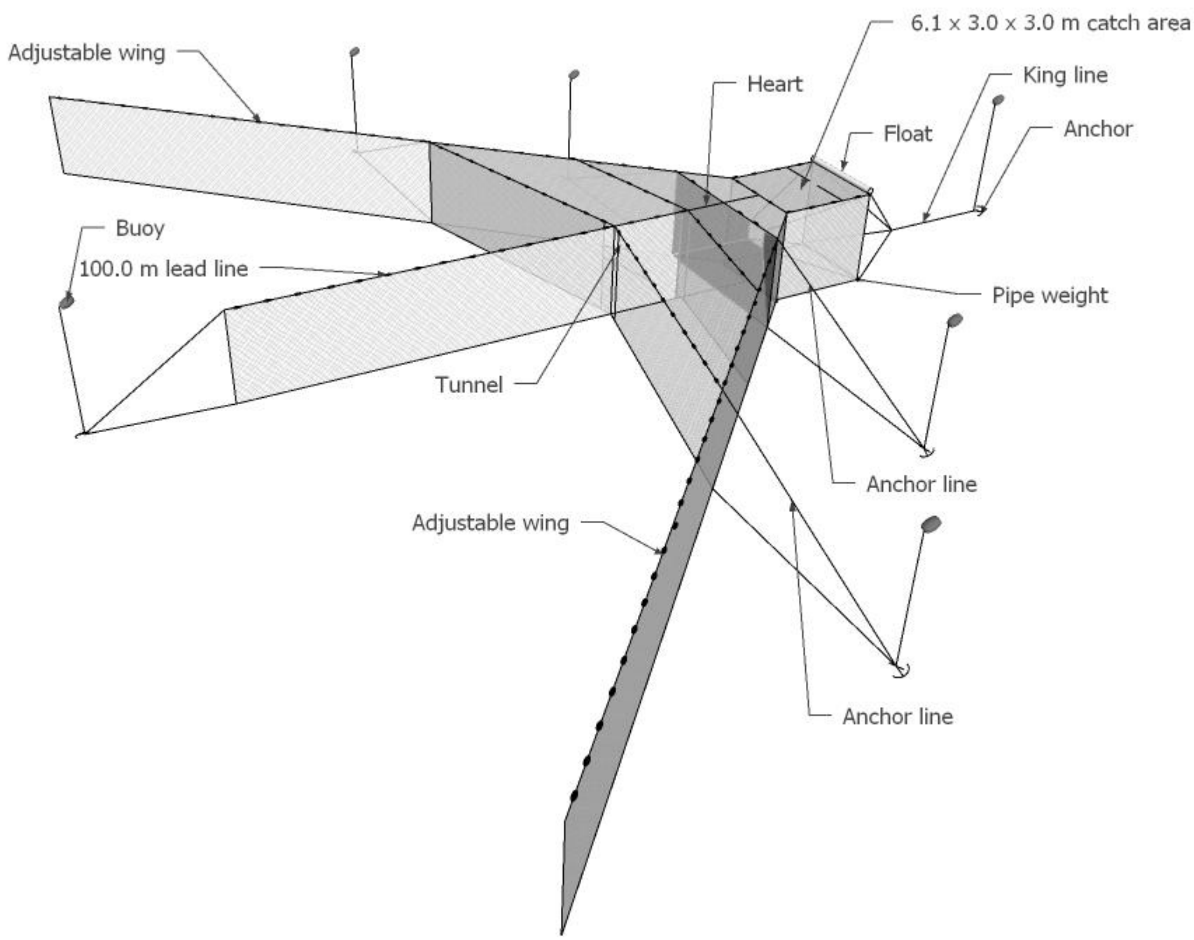

Figure 11. *Schematic of the great lakes style pound net*

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ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

Mini modified fyke net (Figure 12):

Mini modified fyke nets had a single, 5.0 m (16.4 ft.) long by 0.6 meter (2.0 ft.) deep lead. Floats were attached to the float line of the lead every 91.4 cm (36.0 in.) and lead weights attached every 45.7 cm (18.0 in.) along the lead line. Floats were made of 41.3 mm x 111.0 mm (1.6 in. by 4.4 in.) black hard foam that produced 85.0 g (3.0 oz.) of buoyancy. Weights were 38.0 mm (1.5 in.) long, made from lead weighing approximately 28.3 g (1.0 oz.). The lead continued to the rear of the rectangular frame and was sewn to the vertical crossbar stitching the frame and lead together. The frame of the net was constructed of two, 0.6 m by 1.2 m (2.0 ft. by 4.0 ft.) rectangular bars made of 8.0 mm (0.3 in) black oil temper spring steel. Inner wings (vertical wall throats) of the frame extend from outer corners of the front rectangle to middle of the rear rectangle. A 5.1 cm (2.0 in.) vertical gap existed between wings and either side of the lead at middle of rear rectangle. A 0.76 m (2.5 ft.) webbing covered gap connected the cab and frame together. The cab was constructed of two, 8 mm (0.3 in.) spring steel hoops that were 0.6 m (2.0 ft.) in diameter, spaced 0.6 m (2.0 ft.) apart. Cab and frame combined created a net that was 2.7 m (9.0 ft.) in total length. A single throat in the cab was attached to the first hoop from the mouth and tapered down to a 50.0 mm (2.0 in.) diameter hole at the rear. The throat was created with a 50.0 mm (2.0 in.) inner diameter by 6.4 mm thick (2.0 x 0.3 in.) stainless steel or nickel-plated ring sewn in the mesh. Four tension strings tied to the ring were secured to the rear hoop. A 1.8 m (6.0 ft.) long by 5.0 mm (0.2 in.) diameter braided nylon drawstring was sewn in a casing on the cod end secured the cod end closed. All webbing for the net was 3.0 mm (0.1 in.) ace type nylon netting coated with green latex type dip.

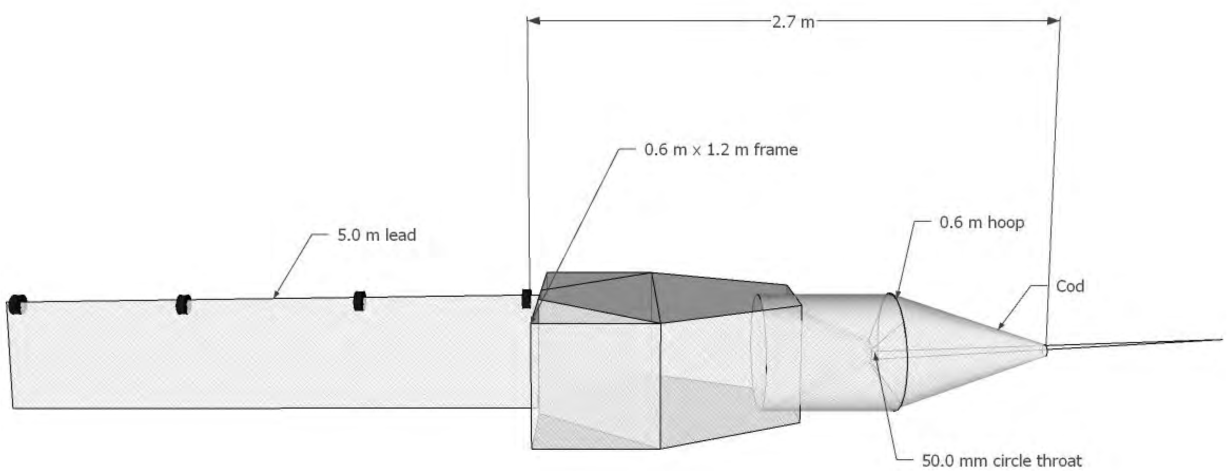

Figure 12. *Schematic of mini modified fyke net*

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Modified fyke net (Figure 13):

Modified fyke nets had a single 15.2 m (50.0 ft.) long by 1.4 m (4.5 ft.) deep lead. Floats were attached every 91.4 cm (36.0 in.) on the float line of the lead, and lead weights every 30.5 cm (12.0 in.) along lead line of the lead. Floats were made from 7.6 cm (3.0 in.) by 3.8 cm (1.5 in.) polyvinyl chloride sponge producing about 156.0 g (5.5 oz.) of buoyancy. Weights were 38.0 mm (1.5 in.) long lead weighing approximately 28.3 g (1.0 oz.). Lead continued into the rear of the net frame and was sewn to the vertical crossbar joining the frame and lead. The frame of the net was constructed of two, 1.2 m (4.0 ft.) by 1.8 m (5.0 ft.) rectangular bars made of 8.0 mm (0.3 in.) black oil temper spring steel. Inner wings (vertical wall throats) of the frame extended from outer corners of the front rectangle to the middle of the rear rectangle. A 76.0 mm (3.0 in.) vertical gap existed on either side of lead at middle of rear rectangle. A 1.2 m (4.0 ft.) mesh covered gap connected the cab and frame together. The cab was constructed of six, 0.9 m (3.0 ft.) diameter spring steel hoops spaced 61.0 cm (24.0 in.) apart from each other and covered in webbing. Cab and frame together were 6.0 m (20.0 ft.) in total length. The front throat of the cab began at the first hoop from the mouth and was a 203.0 mm (8.0 in.) square style throat, 20 meshes long, and knitted to 40 meshes around (10 per side) at rear. The rear end of the front throat was attached to the third hoop with 4 tension strings. The rear throat of the cab began at the third hoop from the mouth and was a 102.0 mm (4.0 in.) crowfoot style throat 28 meshes long, knitted to 32 meshes around at rear. The rear end of the second throat was attached to cod end drawstring with 2 tension strings. A 2.4 m (8.0 ft.) long, 6.0 mm (0.3 in.) diameter asphalt coated braided nylon drawstring secured the cod end closed. All finger lines were made of #15 black nylon twine and tension strings were made of #72 black nylon twine. Webbing for the modified fyke net was 18.0 mm (0.8 in.) bar measured mesh coated with a black asphalt coating.

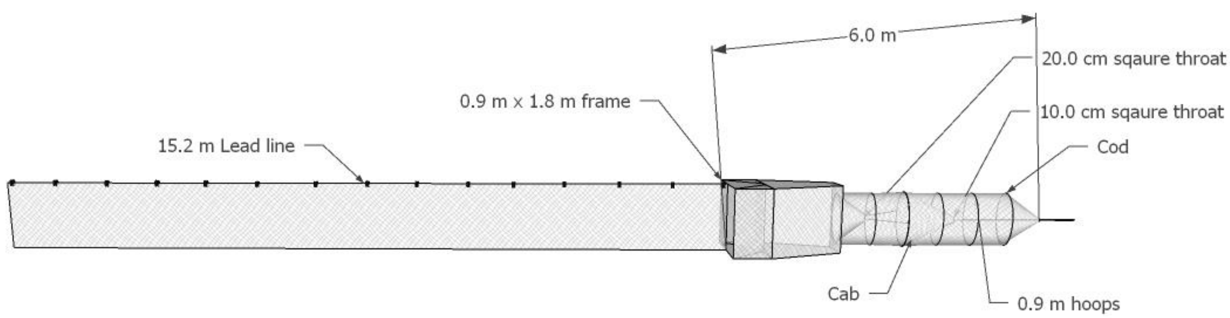

Figure 13. *Schematic of modified fyke net*

APPENDIX L
ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

Larval fish capture gears

Active capture gears

Larval pushnet (Figure 14):

Larval pushnets were created from a nylon-mesh cone stitched to a steel rod cylinder secured to an aluminum frame. The nylon mesh cone was 500 µm mesh and was 3.0 m (9.8 ft.) in total length that tapered down to an 8.9 cm (3.5 in.) diameter circle at the distal end. The steel rod cylinder was made of 3.2 mm (0.1 in.) stainless steel rod bent and welded into a 0.5 (1.6 ft.) diameter circle. The distal end of the nylon mesh cone had an 8.9 cm (3.5 in.) adapter secured to it allowing a 1,000 ml hard-plastic plankton bucket to be attached. The plankton bucket had multiple rectangular sections removed and covered with 504 µm stainless steel mesh facilitating the rinsing of the net and the collection of organisms after net retrieval. A flow meter or flow rocket was secured one-fourth the distance of the diameter of the steel cylinder in the net mouth (approximately the middle of the mouth) to estimate volume of water filtered. The pushnet was attached to an aluminum hexagon frame with industrial strength zip ties. The hexagonal frame was secured to the bow of the boat with 2.8 m (9.2 ft.) long aluminum bars.

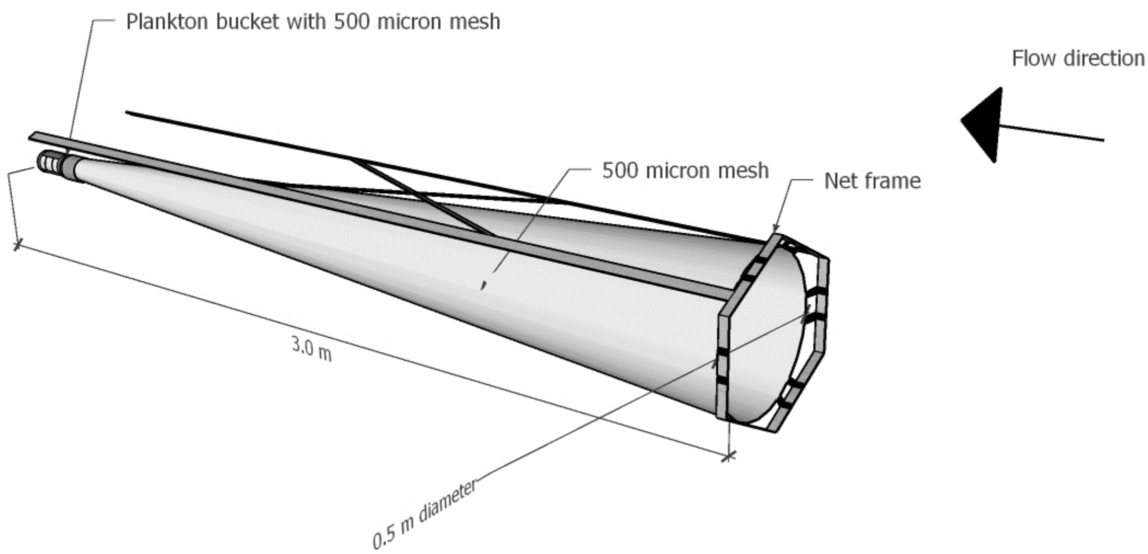

Figure 14. *Generalized schematic of a pushnet.*

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Passive capture gears

Larval driftnet (Figure 15):

Larval driftnets were created from 1.0 m (3.3 ft.) long plankton net stitched to a 0.3 m (0.8 ft.) by 0.5 m (1.5 ft.) rectangular made from 3.2 mm (0.1 in.) aluminum rod stock. Mesh pores of the plankton net were 500 µm. The plankton net tapered down to an 8.9 cm (3.5 in.) circumference circle on the distal end. An adapter was secured to the distal end of the plankton net allowing a 1,000 ml hard-plastic plankton bucket to be attached. The driftnet bucket had multiple sections cut out from the sides and covered with 504 µm stainless steel mesh facilitating the rinsing of the net and the collection of organisms after net retrieval. Flow was recorded prior to setting a driftnet with a flow meter for an estimate of the volume of water sampled. Drift nets were anchored to the river bottom using rebar stakes.

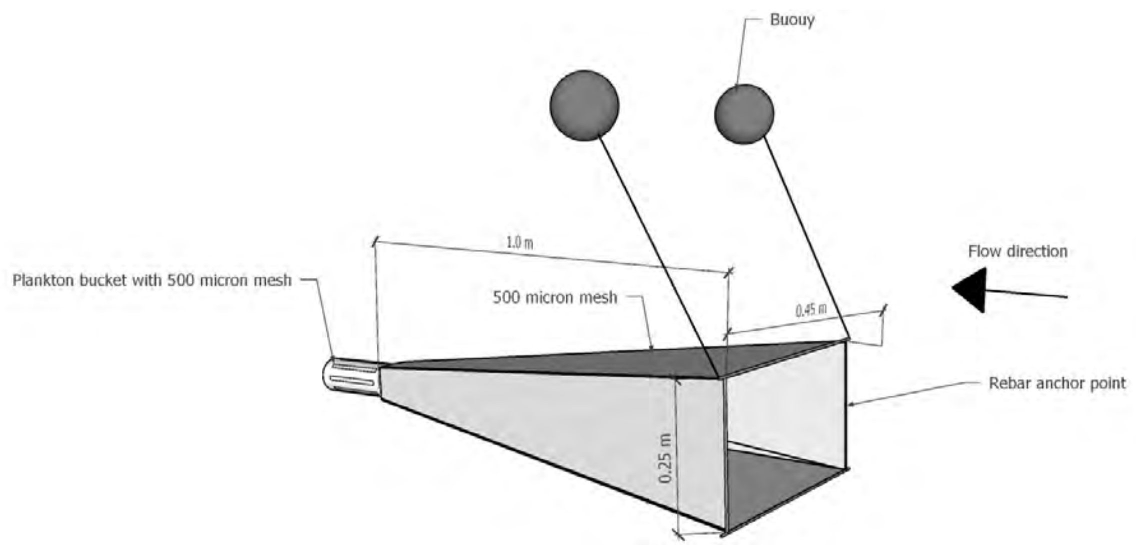

Figure 15. *Generalized schematic of a drift net.*

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Larval quadrafoil light trap (Figure 16):
Quadrafoil light traps consisted of a collection pan, a cloverleaf array and a closed cell floatation block. Collection pans were constructed of a 30.0 cm (11.8 in.) diameter aluminum pan with 5.1 cm (2.0 in.) tall sides. Six, 3.8 cm (1.5 in.) diameter drain holes were drilled into side of the collection pan and covered with 250 µm mesh allowing water to drained from the trap while retaining captured organisms upon retrieval. The cloverleaf array was created from four half circle polycarbonate tubes 10.2 cm (4.0 in.) in diameter with 6.4 mm (0.25 in.) thick polycarbonate cemented to a top and bottom 30.0 cm (11.8 in.) diameter by 6.4 mm (0.3 in.) thick clear polycarbonate circles. The top polycarbonate circle of the cloverleaf array was secured to the closed cell floatation block with four, 4.8 mm (0.2 in.) by 25.4 mm (1.0 in.) stainless steel eye bolts. The closed cell floatation block consisted of the top polycarbonate circle of the cloverleaf array, a 30.0 cm (11.8 in.) diameter by 10.0 cm (3.9 in.) thick Styrofoam middle and a 30.0 cm (11.8 in.) diameter by 6.4 mm (0.3 in.) thick polyvinyl chloride top. The bottom polycarbonate circle was secured to aluminum collection pan with two paracord straps using four 3.2 mm (0.1 in.) zinc plated spring snap link carabiners on each end which were clipped to one of the rigging point eyebolts. A 20.0 mm diameter by 25.0 cm long capped central light tube at the center of the cloverleaf array stored the light source for light traps. Light sources for light traps were green photochemical light sticks. Rigging point eyebolts served as a point to tether the trap to a tree, the bank, or anchor at each sampling location.

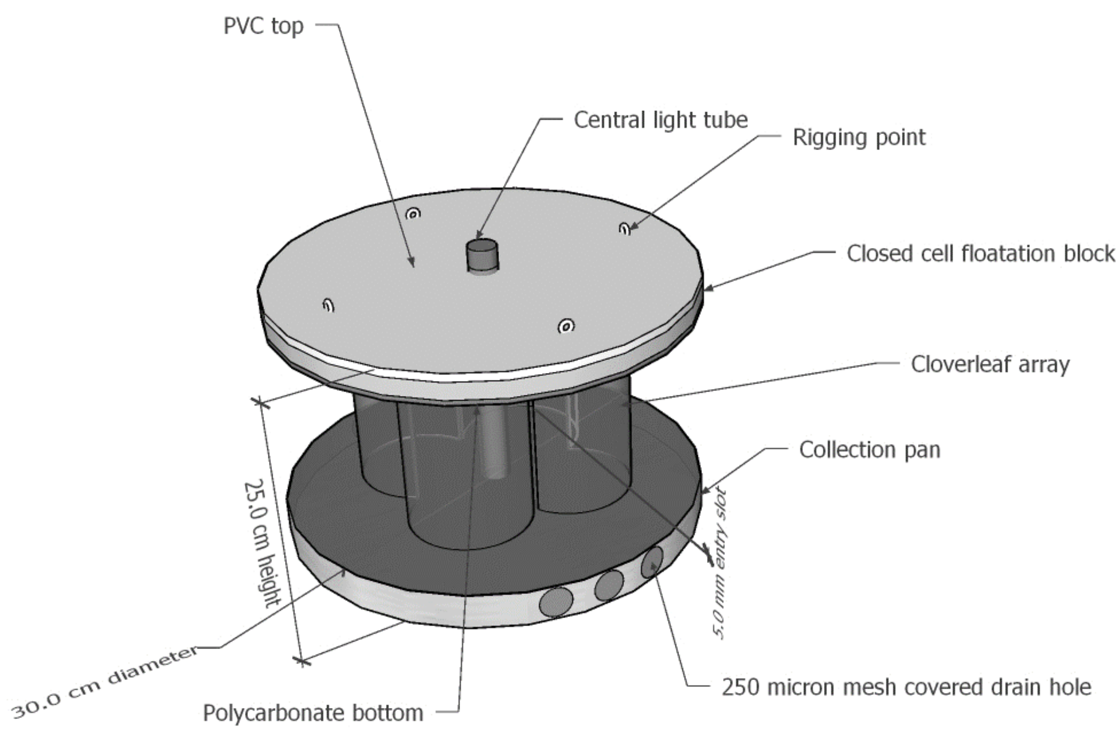

Figure 16. *Schematic of Quadrafoil light trap*

APPENDIX L
ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

Non-capture gears

Nets

Block net (Figure 17):

Block nets consisted of nylon mesh webbing sewn to a float line and a lead line. Float lines had 7.6 cm (3.0 in.) by 3.8 cm (1.5 in.) polyvinyl chloride sponge floats attached every 30.5 cm (12.0 in.). Each float produced about 156.0 g (5.5 oz.) of buoyancy. Lead lines were 95.3 mm (0.3 in.) braided solid leadcore rope. Webbing of block nets was 7.9 mm (0.3 in.) bar measured nylon mesh covered in a black asphalt coating. Depth of block nets where either 9.1 m (30.0 ft.) or 6.1 (20.0 ft.) with webbing depths of 9.8 m (32.0 ft.) or 6.7 m (22.0 ft.), respectfully. Total lengths of block nets were either 152.4 m (500.0 ft.), 304.8 m (1,000.0 ft.) or 762.0 m (2,500.0 ft) with the webbing fully stretched to the same length as the total length of the block net (hanging ratio: 1.0 [measure of how tightly webbing is stretched along float and lead lines]). Block nets were used in conjunction with other sampling gears (e.g., electrofishing, gill/trammel nets) as they did not directly sample fish but prevented fish movement out of or into a new area.

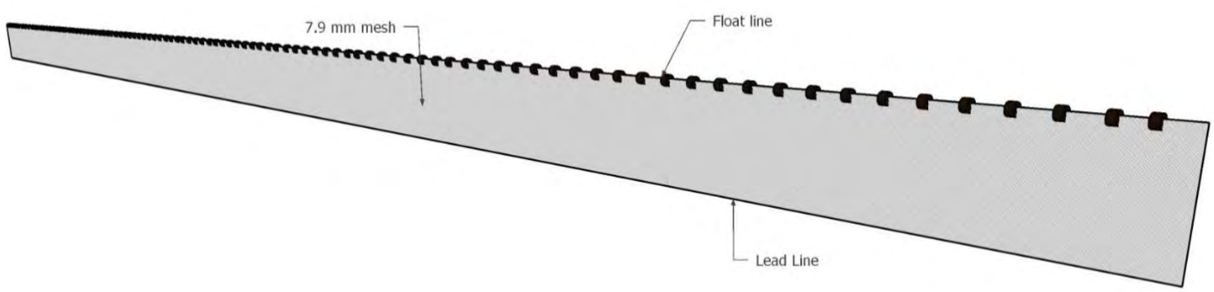

Figure 17. *Generalized schematic of a block net.*

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ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

Sampling boats

Netting boat (Figure 18):

Flat bottomed aluminum boats, 4.9 m to 8.7 m (16.0 ft. to 28.0 ft.) in length powered with 90-horsepower or greater counsil or tiller controlled outboard motor set various active and passive capture gears. Outboard motors were controlled with a tiller handle or steering counsel. Netting boats had 2.3 m (7.5 ft.) wide hull with sides around 66.0 cm (25.0 in.) tall. Netting boats were made of 3.2 mm (0.1 in.) thick aluminum. A front 1.5 m to 2.3 m (5 ft. to 7.4 ft.) aluminum deck created a front platform with larger netting boats having a 1.0 m (3.2 ft) long step up to the deck. Under the step in larger netting boats was a 94.6-liter (25.0 gallon) fuel cell while smaller boats had a removable gas tank toward the stern. Two, 91.4 cm (36.0 in.) by 75.0 cm (29.5 in.) by 40.0 cm (16.0 in.) deep dry storage boxes were on the port and starboard freeboards in the stern of both the larger and smaller netting boats. Coupled with the outboard motor was a 3-blade stainless steel propeller.

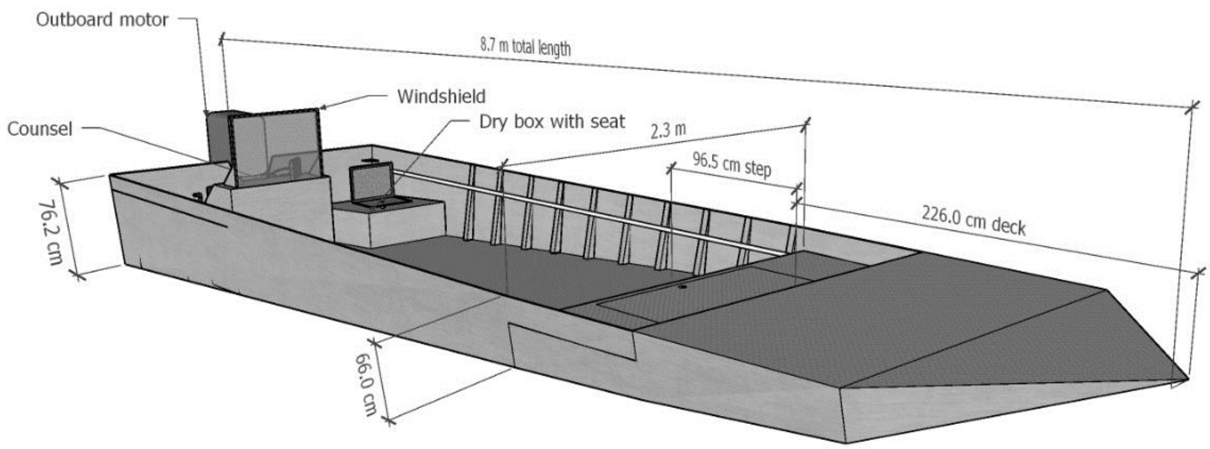

Figure 18. *Generalized schematic of netting boat.*

APPENDIX L
ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

Shallow drive boat (Figure 19):

The shallow drive boat used to drive fish and set gill/trammel net in shallow water was 5.5 m (18.0 ft.) long by 1.5 m (5.0 ft.) wide semi-v bottom with 61.0 cm (24.0 in.) tall sides of 3.2 mm (0.1 in.) thick aluminum. A front 1.4 m (4.6 ft.) aluminum deck coated in non-skid rubber created a front platform. Under the front deck was a 45.4-liter (12.0 gallon) fuel cell. The floor of the shallow drive boat was coated with non-skid rubber. Two, 91.0 cm (36.0 in.) by 73.6 cm (29.0 in.) dry storage boxes were on the port and starboard freeboards in the stern. A 38.1 cm by 58.4 cm by 38.1 cm (15.0 in. by 23.0 in. by 15.0 in.) aluminum float pod was welded to the starboard and port side of the transom. The hull of the shallow drive boat was coated with Gator Gilde. A 2017 Mudd Buddy HDR 44 tbd reverset power trim shallow drive motor with a V twin motor and 42 mm (16.5 in.) Mikuni carburetor was attached to the transom of the shallow drive boat. The shallow drive motor was made from cast aluminum and stainless steel with a 9.7 cm (3.8 in.) thick outdrive casting cover, an aluminum transmission cover and a stainless steel lower drive tube. An electric shift controller, allowed shifting of the shallow drive motor. A standard BPS "Q" performance muffler was attached to the shallow drive motor as well as a capacitor discharge ignition automatic advanced ignition with a 4650-rev limiter and a 50-amp charger. Coupled with the shallow drive motor was a 2-blade stainless steel hammer propeller.

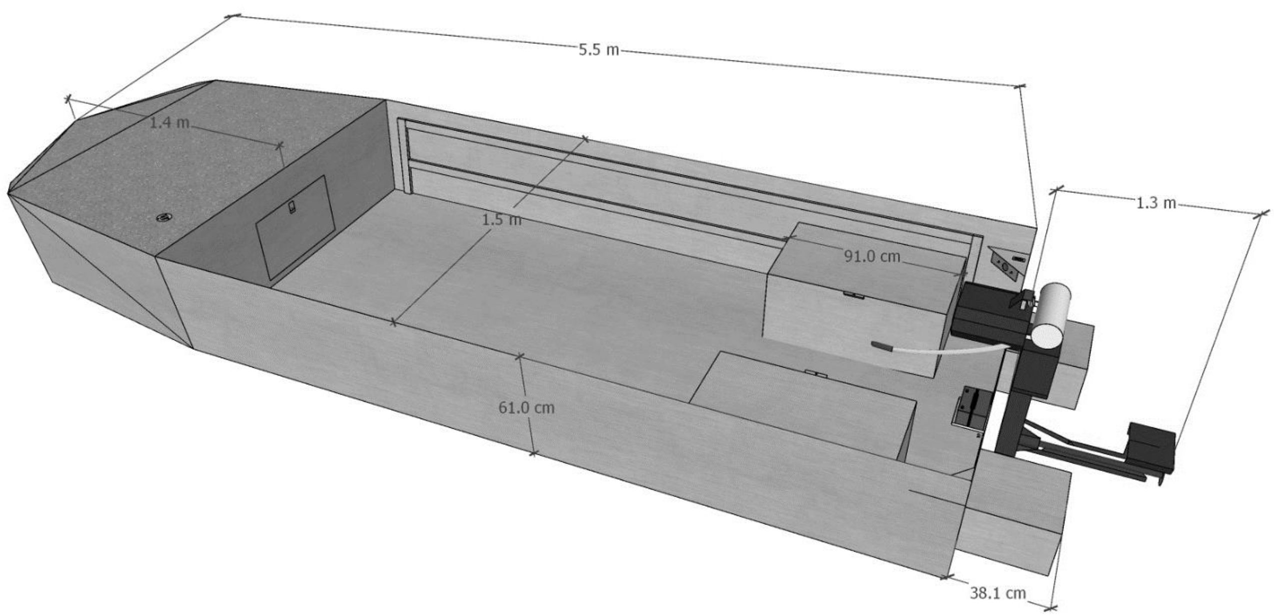

Figure 19. *Schematic of the shallow drive boat.*

APPENDIX L
ASIAN CARP MONITORING AND RESPONSE EQUIPMENT

Table 1. *List of equipment vendors used during Asian Carp monitoring and response sampling. Use of trade names is for descriptive purpose and does not imply endorsement by an agency.*

Description	Vendor	Vendor contact
	Boats and Motors	
Electrofishing boat (aluminum, 5.5 + m)	Oquawka	www.oquawkaboats.com
Electrofishing boat trailer	Oquawka	www.oquawkaboats.com
Net boat (aluminum 5.5 + m)	Blue Ridge Custom boats, Oquawka, Kann, or AAD welding	https://www.facebook.com/pg/Blue-Ridge-Custom-Boats-1547565388875733/about/ www.oquawkaboats.com http://www.kannmfg.com/products/marine/ http://www.aadcustomboats.com/
Net boat trailer	Blue Ridge Custom boats, Oquawka, or Kann or AAD welding	https://www.facebook.com/pg/Blue-Ridge-Custom-Boats-1547565388875733/about/ www.oquawkaboats.com http://www.kannmfg.com/products/marine/ http://www.aadcustomboats.com/
Shallow drive boat (aluminum)	AAD welding	http://www.aadcustomboats.com/
Shallow drive boat trailer	AAD welding	http://www.aadcustomboats.com/
90 + HP outboard motors	Evinrude, Mercury, Yamaha	http://www.evinrude.com/en-US?redirect=false https://www.mercurymarine.com/en/de/engines/outboard/ https://yamahaoutboards.com/en-us/
Shallow drive motor	MudBuddy	http://www.mudbuddy.com/hdsport.htm
Miscellaneous: anchor, batteries, bilge pump, lights fuel tanks, rope, safety equipment		
	Electrofishing components	
MBS-1D Electrofishing control box	ETS Electrofishing	http://etselectrofishing.com/
Type VI-A Electrofishing control box	Smith-Root	https://store.smith-root.com/type-via-electrofisher-system-p-9.html
5,000 watt generator	Honda	http://powerequipment.honda.com/
Electrofishing boat booms	WS Hampshire	http://www.wshampshire.com/index.html
Electrofishing dip nets	Duraframe	http://www.duraframedipnet.com/
Holding tank fill pump	Rule	http://www.xylemflowcontrol.com/rule/
Holding tank (~379 liters)	Various suppliers	——
Miscellaneous: boots, gloves, life jacket, raingear, safety equipment, tank aeration, tank dip net		
	Net gear	
Mini Fyke net	Miller Net Company	http://www.millernets.com/
Fyke net	Duluth Nets Miller Net Company	http://duluthfishnets.com/ http://www.millernets.com/
Hoop net	Brown Fisheries Miller Net Company Memphis net	ronbrown.brownfisheries@gmail.com http://www.millernets.com/ http://www.memphisnet.net/
Gill/trammel nets	Brown Fisheries Memphis net	ronbrown.brownfisheries@gmail.com http://www.memphisnet.net/
Pushnet	Wildco	http://wildco.com/
Driftnet	Wildco	http://wildco.com/
Quadrafoil light trap	Aquatic Research Instruments	http://www.aquaticresearch.com/default.htm http://www.forestry-suppliers.com/

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	Forestry Suppliers	
Description	**Vendor**	**Vendor contact**
	Net get	
Pound net	Stuth Fishing	stuthfishing@charter.net
Seine	Commercial fisherman	——
Trawl	Commercial fisherman	——
Miscellaneous: anchors, floats, grapple, net preservative, rebar/stakes, rope, twine, webbing,		

Appendix M: Asian Carp Monitoring Sampling Strategy

Participating Agencies: Illinois Department of Natural Resources, Illinois Natural History Survey, U.S. Fish and Wildlife, U.S Army Corps of Engineers

Introduction:

The Monitoring and Response Working Group (MRWG) has detected, managed and controlled, and responded to Asian Carp (Bighead Carp, Silver Carp, Grass Carp, and Black Carp) within the Illinois River Waterway since 2010. Data collected during these efforts index Asian carp abundance, determine their geographic expanse, describe their demographics in each of the upper Illinois River Waterway pools triggering response actions as needed. The goals of these efforts are to reduce the likelihood of Asian carp becoming establishing within the Chicago Area Waterway System (CAWS) and Lake Michigan.

Collection of meaningful, interpretable, and insightful data from such a large and diverse system like the Upper Illinois River requires an appropriately and comprehensively designed approach. A variety of sampling protocols, utilizing numerous gear types (traditional and novel) and site selection methodologies (probabilistic and nonprobabilistic) has been used within the Upper Illinois River Waterway since 2010. These multiple projects using differing sampling approaches allowed for single year inferences to be drawn but created difficulties drawing across years inferences due to differing effort levels and gears being used. A standardized mixed sampling design began in 2019 across all the pools of the upper Illinois River. Standardization should increase efficiency within the Monitoring and Response Work Group (MWRG) by reducing redundancy among project objectives and increase capabilities for trend analysis. The sampling approach was modeled off of the Long Term Resource Monitoring Program of the Upper Mississippi River Restoration Program (Ickes et al. 2014). The objective of this section is to detail the sampling frame and sampling design differences within the upper Illinois River Waterway by the MRWG from the model.

Sampling Frame:

The U.S. Geological Survey's Upper Midwest Environmental Sciences Center created sampling frames of all Illinois River pools in 1989 (UMESC 1991). Aquatic areas were generated by generalizing land cover/use data from 1 : 15,000-scale color infrared aerial photos collected in 1989 or 1991 into a land/water data set. Areas classified as water within aerial photography were further classified as specific aquatic areas. Aquatic areas were defined by permanent geomorphic conditions of backwater, impounded areas, main channel, side channel, and tailwater zones (Wilcox 1993). Backwater and main channel area were further delineated to include a "shoreline" portion facilitating sampling gears deployment only along the shoreline.

Field validations of the initial 1989 strata designations were obtained during 2019. Adjustments to the original GIS-based strata were made to better align with ground truthed observations

(Figure 1-6). Changes centralized around defining barge slips as backwaters, removing or reclassifying miscategorized side channels, and removing unsampleable areas from the sampling frame (Table 1). Aquatic areas were then converted into 50 x 50 meter grids. Due to the size of Lockport, a smaller grid size of 25 x 25 meter grid was used. Density of strata within each pool was summarized and used to allocate effort (Table 2).

Table 1. *Pool and locations of aquatic area changes in the original 1989 classification for the 2019 Monitoring and Response Working Group sampling frame.*

Pool	Location	1989 stratum	2019 stratum
Lockport	Barge Slips	Side Channel	Backwater
	Right descending bank flat downstream of Cargill ramp	Side Channel	Main Channel
	Des Plaines River	Side Channel	Non-sampled area
Brandon	Des Plaines River Confluence	Side Channel	Non-sampled area
Dresden Island	Left descending bank of treats island	Backwater	Side Channel
	NRG Joliet Generating Station	Backwater	Non-sampled area
	Moose Island	Side Channel	Backwater
	Illinois and Michigan Canal	Backwater	Non-sampled area
	Exelon Nuclear Plant cooling ponds	Backwater	Non-sampled area
Marseilles	First 500 meters below Dresden Island Lock and Dam	Side Channel	Tailwater
	Illinois and Michigan Canal	Backwater	Non-sampled area
Starved Rock	First 500 meters below Marseilles Dam	Side Channel	Tailwater
	Flat upriver of Peoria lock and dam on left descending bank	Backwater	Side Channel
Peoria	Split Rock Lake	Backwater	Non-sampled area

Sample Selection:

Units of effort are gear and strata specific (Table 3). Effort level is dependent on the size of the pool and the proportion of each strata within each pool (Table 4). A specified number of points were randomly selected from the sampling grid within each sampling strata for each gear type within each pool using a reselection is procedure in the statistical software package (SAS). Sites were selected at the intersections of the sampling grid, as opposed to the center of the cells.

Appendix M: Asian Carp Monitoring Sampling Strategy

Table 2. *Strata population sizes by study reach and stratum in the Upper Illinois River Waterway. The number of sampling frame elements composing each stratum in each study reach is denoted.*

Classification	Lockport	Brandon	Dresden	Marseilles	Starved Rock	Peoria
Main channel, off-shore	315	159	1,548	1,573	1,300	7,537
Main channel, shoreline	619	295	915	1,577	745	3,784
Side channel	-	-	239	143	2,189	487
backwater, off-shore	-	-	470	393	70	31,195
backwater, shoreline	29	-	322	521	207	5,009
Total	**963**	**454**	**3,494**	**4,207**	**4,511**	**48,012**

Sampling intensity by gear type among pools meets those of the Long Term Resource Monitoring Program of the Upper Mississippi River Restoration Program effort within the LaGrange Reach of the Illinois River at a minimum (Ickes and Burkhardt 2002). Effort intensity was increased from the LaGrange Reach model in pools closer to the electric dispersal barrier (e.g., Lockport and Brandon) when effort was not deemed sufficient for management needs. Current effort level also is consistent with the effort amount put forth during baseline establishment in 2016 for the contingency response plan (MRWG 2016).

Table 3. *List of sampling gears used to collect Asian Carp in Upper Illinois River Waterway sampling areas (SRS). X indicates that the particular gear is used in the sampling area and a blank indicates it is not used. [L, Lockport pool, B, Brandon Road Pool, D, Dresden Island pool, M, Marseilles Pool, S, Starved Rock, P, Peoria. [MCB-O, main channel border-open water; MCB-S, main channel border shoreline, SCB, side channel border; BWC-S, backwater, contiguous-shoreline; MCB-M, main channel border-mourning cell]*

	Sampling area				
	SRS strata				Engineered Structures
Sampling gear	**MCB-O**	**MCB-S**	**SCB**	**BWC-S**	**MCB-M**
Day electrofishing		X	X	X	X
Fyke netting				X	
Mini fyke netting		X	X	X	
Large hoop netting	X		X		
Small hoop netting	X		X		
Pools	**L,B,D,M,S,P**	**L,B,D,M,S,P**	**L,B,D,M,S,P**	**L,B,D,M,S,P**	**L,B,D**

A number of nonrandom ("fixed") sites will also be sampled regularly. Main channel mourning cells are a predominant engineered structure in Lockport, Brandon Road Pools, and Dresden Island Pools. These features cannot be sampled effectively using the random sampling procedures as they have no area-based weight to incorporate into the larger sampling frame. Since these areas have been sampled previously as fixed sites, these sites will continue to be sampled with daytime electrofishing uninterrupted (Table 3). This combined design allows for statistically valid inferences within sampled strata across the entire study to be generated overtime.

Table 4. *Sampling allocations by gear type within each pool in Upper Illinois River each year. Sample allotments within a gear are proportional to the area that strata represents within the entire pool.*

Gear	Lockport	Brandon	Dresden	Marseilles	Starved Rock	Peoria
Day electrofishing	57	48	72	93	105	135
Fyke netting	0	0	15	15	15	30
Large hoop net	42	42	42	42	42	36
Small hoop net	42	42	42	42	42	36
Minnow fyke net	24	24	42	42	42	42
Total	**165**	**156**	**213**	**234**	**246**	**279**

References:

Asian Carp Monitoring and Response Working Group (ACMRWG). 2016. 2016 Monitoring and Response Plan for Asian Carp in the Upper Illinois River and Chicago Area Waterway System. Illinois, Chicago.

Ickes, B. S., R. W. Burkhardt. 2002. Evaluation and proposed refinement of the sampling design for the long term resource monitoring program's fish component. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, October 2002. LTRMP 2002-T001. 17 pp., https://www.umesc.usgs.gov/documents/reports/2002/02t001.pdf

Ickes, B.S., Sauer, J.S., and Rogala, J.T., 2014, Monitoring rationale, strategy, issues, and methods: UMRR-EMP LTRMP Fish Component. A program report submitted to the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program, Program Report LTRMP 2014–P001a, 29 p., *http://pubs.usgs.gov/mis/ltrmp2014-p001a/*

Upper Midwest Environmental Sciences Center (UMESC). 1991. 1989-1991 Aquatic Habitats – Upper Mississippi River System. La Crosse, Wisconsin.

Appendix M: Asian Carp Monitoring Sampling Strategy

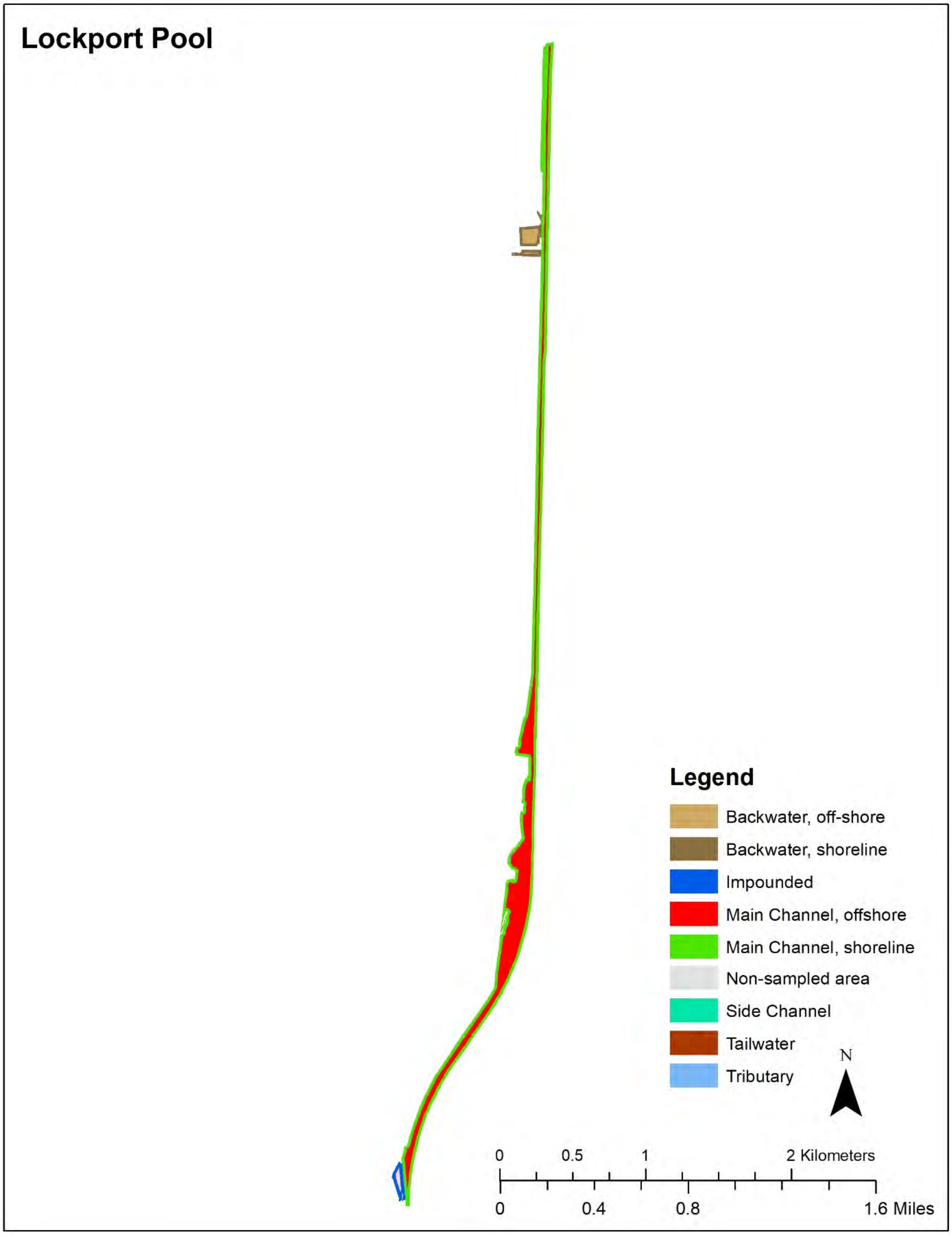

Figure 1. *Lockport Pool sampling strata from the 1989 coverages modified with 2019 field observations.*

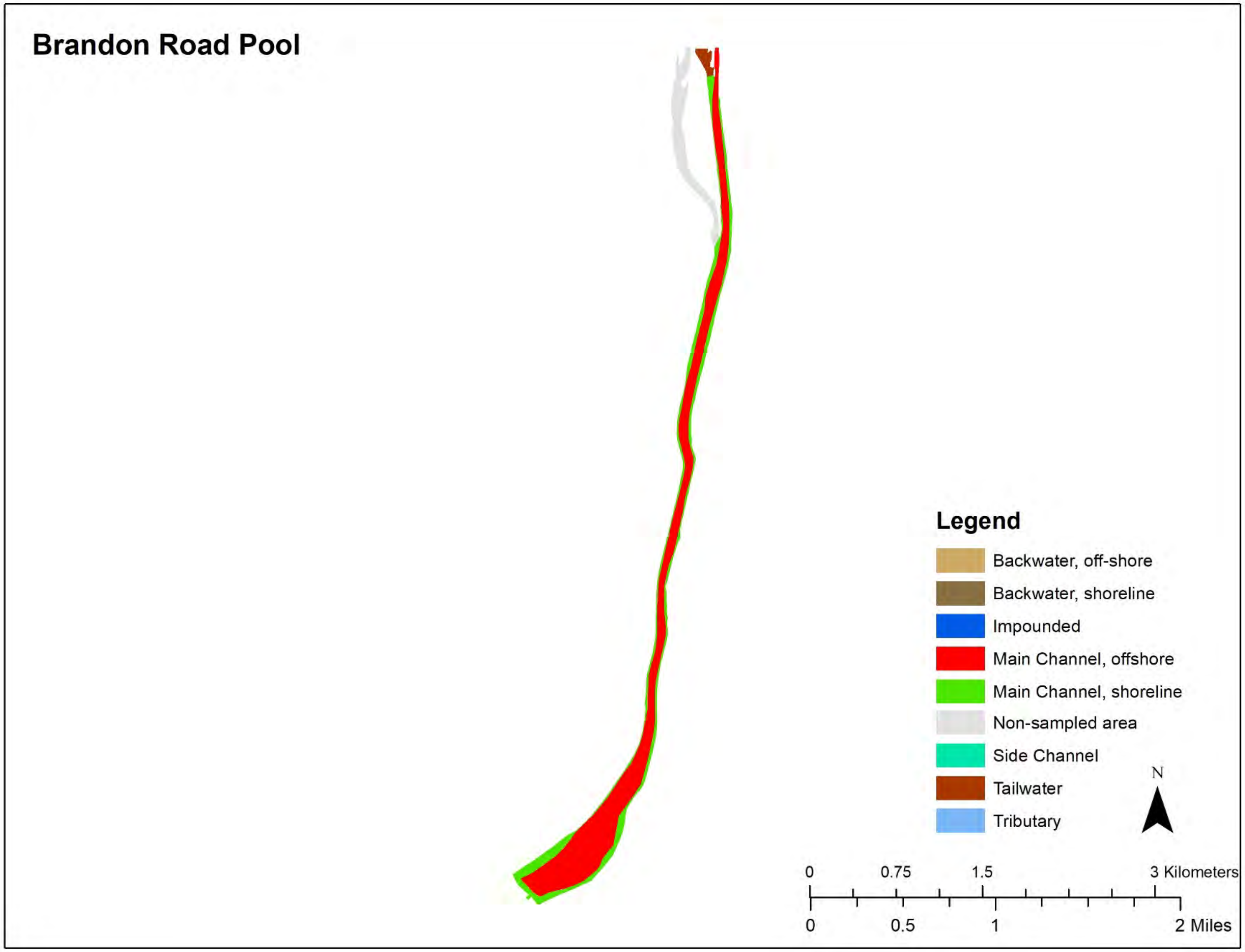

Figure 2. *Brandon Road Pool sampling strata from the 1989 coverages modified with 2019 field observations.*

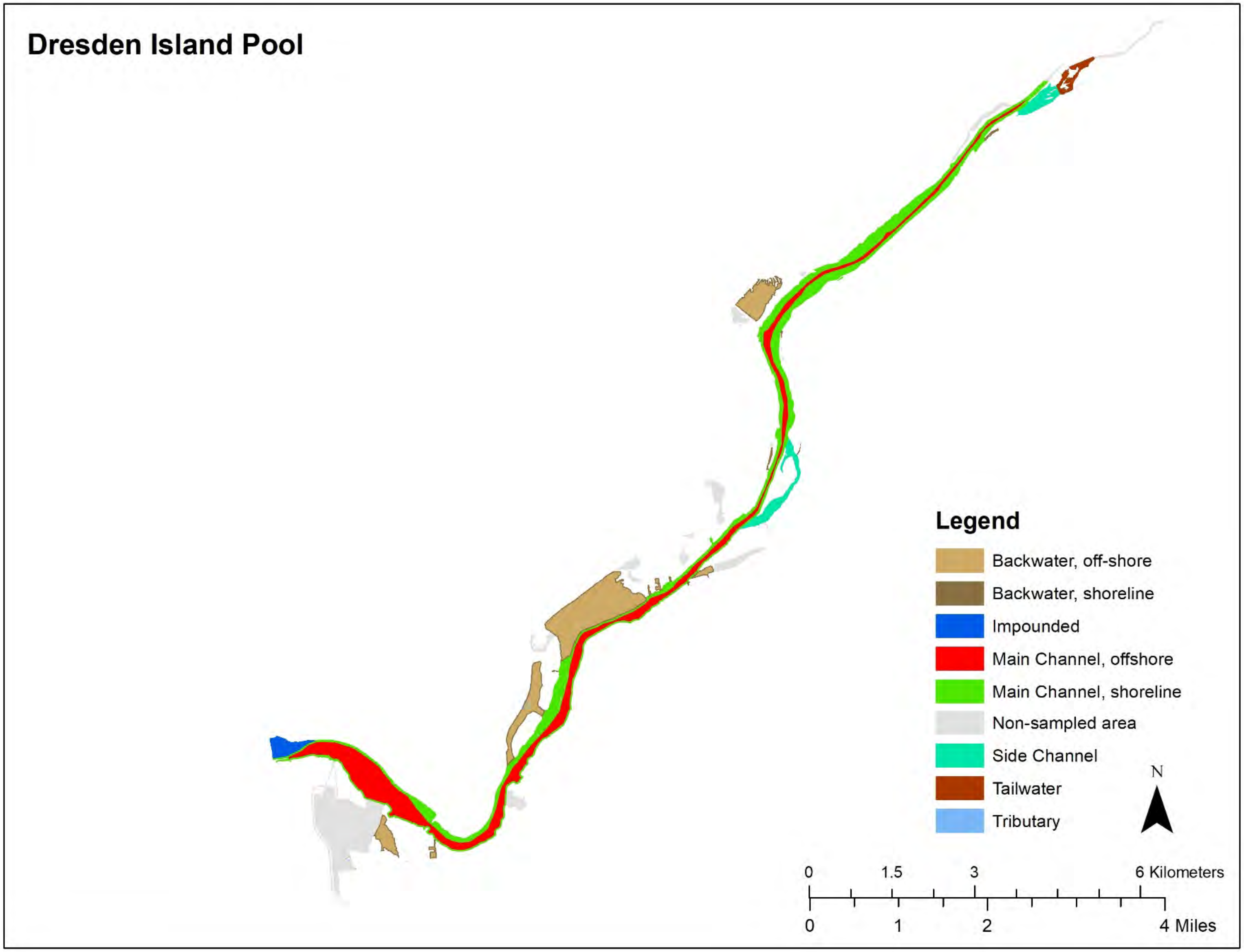

Figure 3. *Dresden Island Pool sampling strata from the 1989 coverages modified with 2019 field observations.*

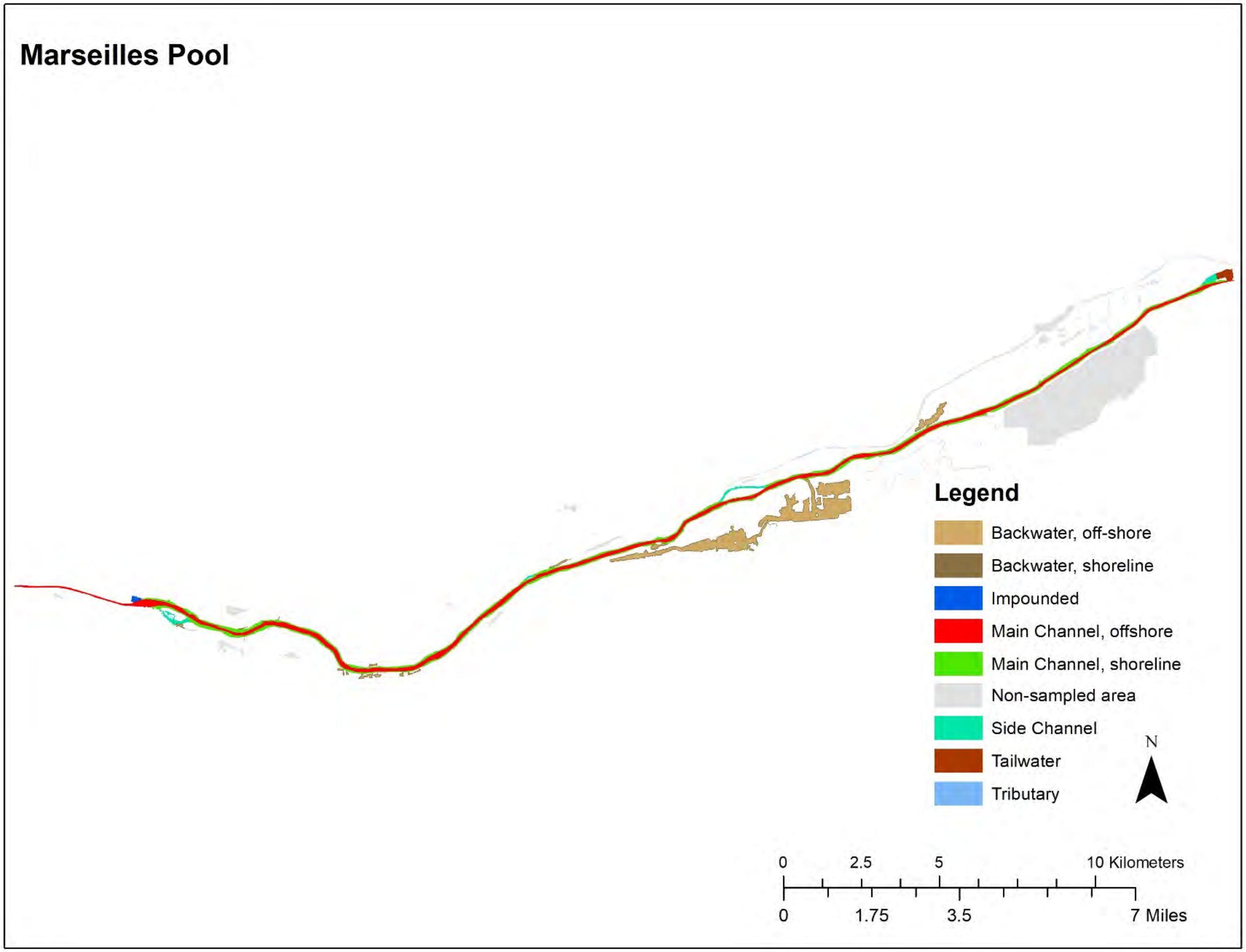

Figure 4. *Marseilles Pool sampling strata from the 1989 coverages modified with 2019 field observations.*

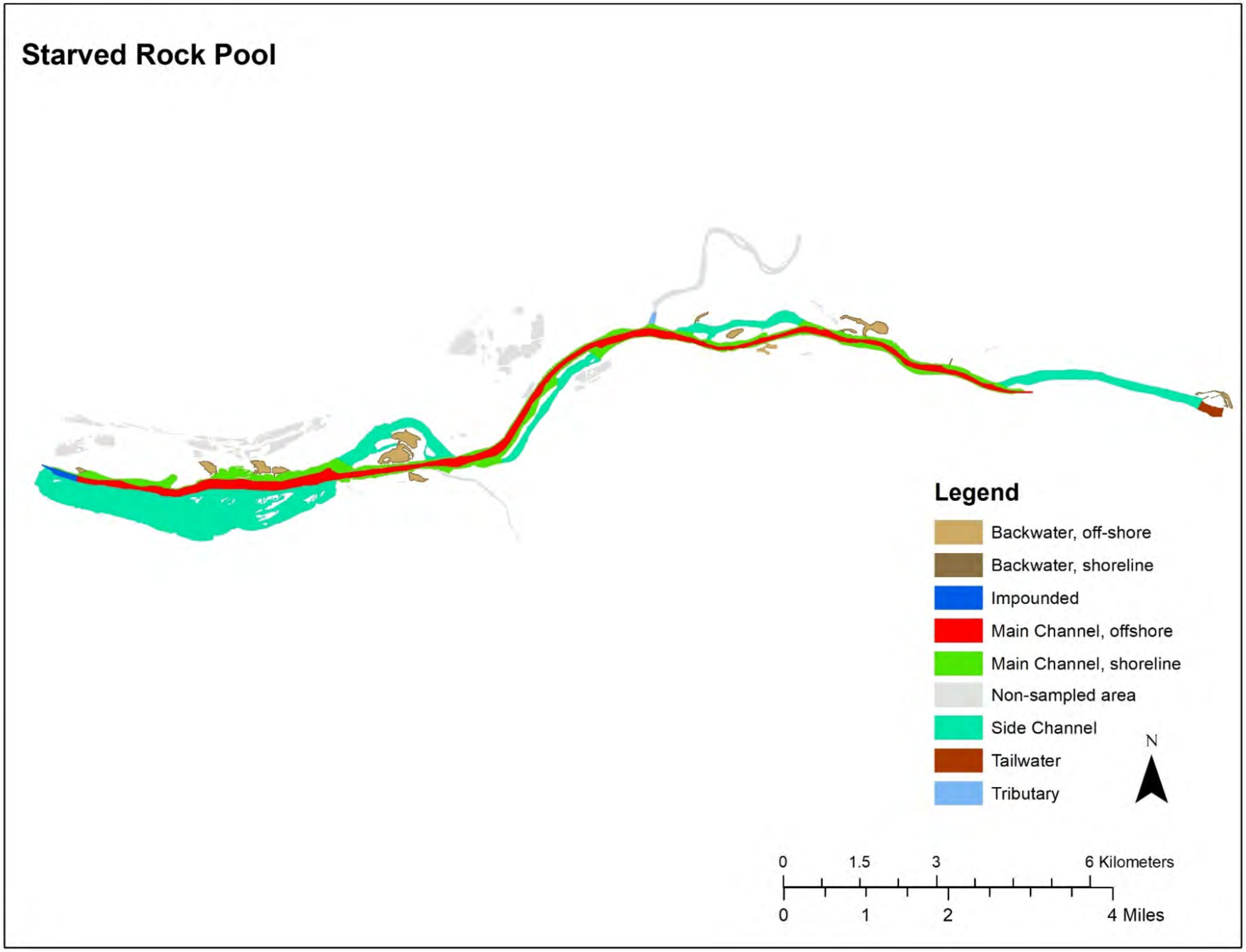

Figure 5. *Starved Rock Pool sampling strata from the 1989 coverages modified with 2019 field observations.*

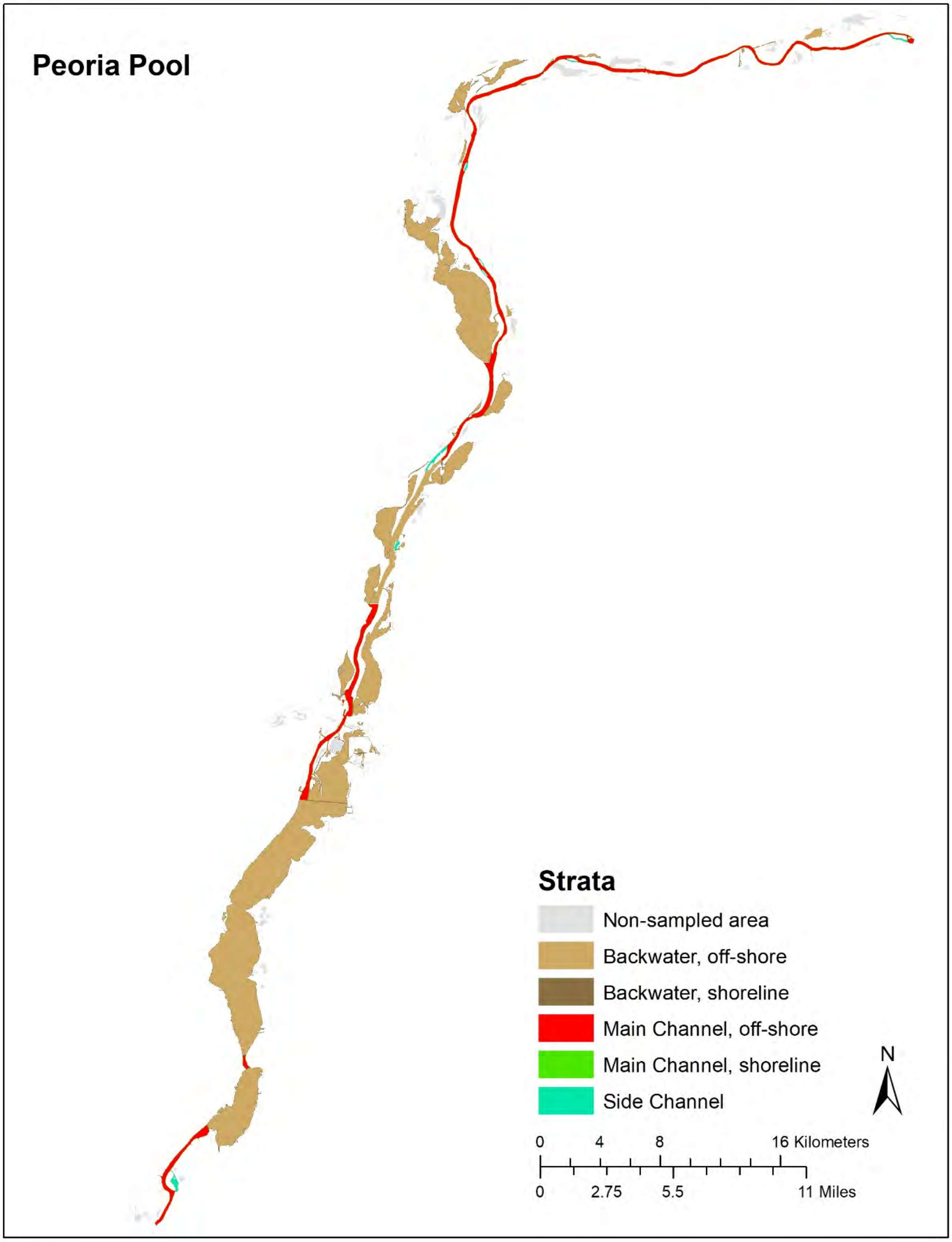

Figure 6. *Peoria Pool sampling strata from the 1989 coverages modified with 2019 field observations.*