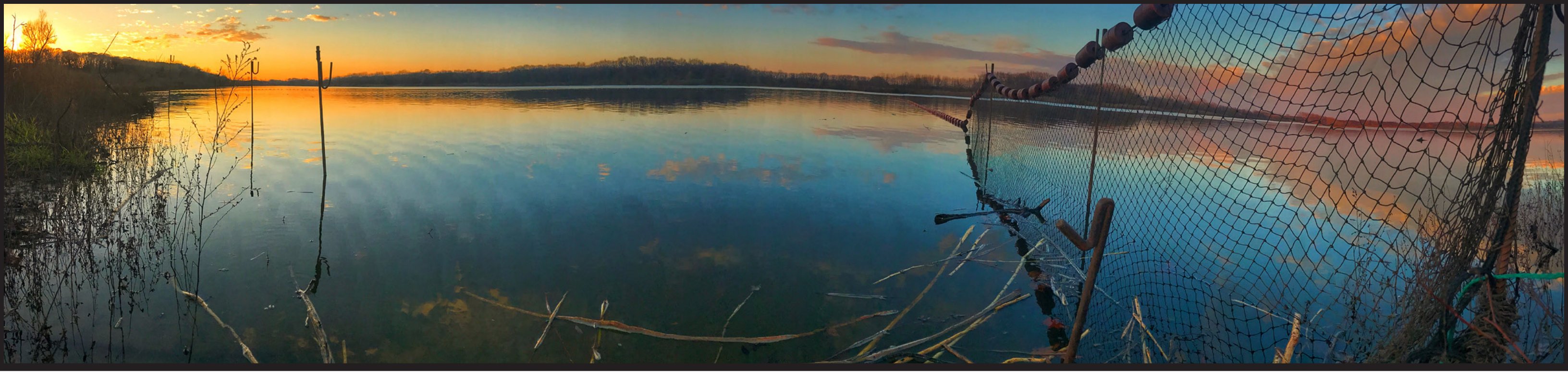

2018

Asian Carp Regional Coordinating Committee

INTERIM SUMMARY REPORT

Asian Carp Monitoring and Response Plan

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

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EXECUTIVE SUMMARY

This Asian Carp Interim Summary Report (ISR) was prepared by the Monitoring and Response Workgroup (MRWG), and released by the Asian Carp Regional Coordinating Committee (ACRCC). It is intended to act as an update to previous ISRs, and present the most up-to-date results and analysis for a host of projects dedicated to preventing Asian carp from establishing populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Specifically, this document is a compilation of the results of 25 projects, each of which plays an important role in preventing the expansion of the range of Asian carp, and in furthering the understanding of Asian carp location, population dynamics, behavior, and the efficacy of control and capture methods. Each individual summary report outlines the results of work that took place in 2016, and provides recommendations for next steps for each project.

This ISR builds upon prior plans developed in 2011, 2012, 2013, 2014, 2015, 2016, and 2017. More specifically, it is intended to act as an update to the 2017 ISR that was developed in 2018. This 2018 ISR is intended to act as a living document, and will be updated at least annually. Updates will provide new project results, as well as incorporate new information, technologies, and methods as they are discovered and implemented. A companion document, the 2019 Asian Carp Monitoring and Response Plan (MRP), has also been completed by the MRWG. The 2019 MRP presents each project's plans for activities to be completed in 2019. Similar to the ISR, the MRP is intended to function as a living document, and will be updated at least annually. In conjunction, the 2019 MRP and 2018 ISR present a comprehensive accounting of the projects being conducted to prevent the establishment of Asian carp in the CAWS and Lake Michigan. Through the synthesis of these documents, the reader can obtain a thorough understanding of the most recent project results and findings, as well as how these findings will be used to guide project activities in the future.

For the purpose of this ISR, the term 'Asian carp' refers to Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*), exclusive of other Asian carp species such as 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.

All ISRs to date, including the 2018 ISR, have benefitted from the review of technical experts and MRWG members, including, but not limited to, Great Lakes states' natural resource agencies and non-governmental organizations. Contributions to this document have been made by various state and federal agencies.

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

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

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

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

In keeping with the overall goal and strategic objectives, the 2018 results for 25 projects are included in this ISR. These summary reports document the purpose, objectives, and methods for each individual project, in addition to providing an analysis of results and recommendations for future actions. The projects are grouped into three general categories:

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

A summary of the highlights of each project is presented below, intended to provide a brief snapshot of project accomplishments during 2018.

DETECTION PROJECTS

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

- Completed 2-two week SIM events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier in 2018.
- Estimated person-hours were spent to complete 103.5 hours of electrofishing, set 122.9 km (76.6 mi) of trammel/gill net, 2.2 km (1.4 mi) of commercial seine, 7 Fyke nets in 2018

- Across all locations and gears in 2018, sampled 31,321 fish representing 61 species and 3 hybrid groups.
- Since 2010, an estimate 29,204 person-hours were spent to complete 1,189.9 hours of electrofishing, set 946.8 km (588.6 mi) of gill/trammel net and 13.3 km (8.3 mi) of commercial seine, tandem trap nets, hoop nets, Fyke nets, and pound nets.
- A total of 423,516 fish representing 73 species and six hybrid groups were sampled, including 2,388 Banded Killifish (state threatened species) from 2010-2018.
- Examined 117,383 YOY Gizzard Shad since 2010 and found no Asian carp.
- Since 2010, 19 non-native species have been captured accounting for 15% of the total fish caught and 26% of the total species.
- From 2011-2016, no Bighead Carp or Silver Carp have been captured or observed. One Bighead Carp captured in Lake Calumet in 2010, and one Silver Carp was captured in Little Calumet River in 2017.
- Recommend continued use of SIM in the CAWS upstream of the Electric Dispersal Barrier for localized detection and removal of Asian carp.

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

- Two eDNA sampling events took place in the CAWS at targeted off-channel and shoreline locations in 2018, resulting in 284 samples collected and analyzed in May and 282 in October.
- Results: In May there were zero positive detection for both species of Asian carp DNA. In October two samples were positive for Silver Carp DNA and one sample was positive for both Silver and Bighead Carp DNA.

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

- 782 ichthyoplankton samples were collected from 12 sites across the length of the Illinois Waterway during April – October 2018, capturing over 86,000 larval fish, including over 51,000 larval Asian carp. Over 72,000 Asian carp eggs were collected in 2018. These numbers of Asian carp eggs and larvae are comparable to those observed during 2015 and 2017, when Asian carp reproductive output was also very high relative to other study years.
- Asian carp eggs and larvae were only present in the Illinois River for a brief time period in 2018, with a large spawning event evident during the last week of June. Water temperature and change in water level appear to be the strongest predictors of the magnitude of Asian carp reproductive output in the Illinois River. However, larval Asian

carp densities are poor predictors of future juvenile Silver Carp abundances, indicating that large spawning events do not always lead to successful recruitment.

- Asian carp eggs were collected in the LaGrange, Peoria, and Starved Rock pools during 2018. Asian carp larvae were only identified from the LaGrange and Peoria pools. Across 9 years of sampling, only a handful of Asian carp larvae have ever been observed upstream of the Starved Rock Lock and Dam, suggesting that the majority of eggs spawned in the upper river are transported into downstream navigation pools before hatching.
- Asian carp eggs or larvae were not observed in the Kankakee or Fox Rivers, but larvae were collected from the Mackinaw, Spoon, and Sangamon Rivers during 2018. Especially large numbers of Asian carp larvae were found in the lower Sangamon River during early July.

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

- One juvenile Silver Carp (222 mm TL) was found in Starved Rock Pool during 2018 field sampling efforts.

Habitat Use and Movement of Juvenile Silver Carp in the Illinois River – The purpose of this project is to gain a greater understanding of juvenile Asian carp behavior and preferred habitats. The project implants juvenile Asian carp with tags and tracks their movements in the Illinois River and associated backwaters via the existing telemetry system.

- A total of 72 juvenile Silver Carp in 2017 and 81 in 2018 have been tagged.
- The mean weekly movement distance of juvenile Silver Carp during 2017 was 943.7 m per week.
- Percent total residency of juvenile Silver Carp during 2017 was 39.4% in backwaters, 36.0% in the main channel, and 24.6% in the side channels.
- Juvenile Silver Carp residence has correlations with river flow velocity and temperature that are different for each macro-habitat type.

Monitoring Efforts Downstream of the Electric Dispersal Barrier – This project includes monthly standardized monitoring with electrofishing gear, netting gear, and commercial fishermen at fixed and random sites downstream of the Electric Dispersal Barrier. It provides crucial information on the location of the Asian carp population front, population density, and specific habitats favored by Asian carp.

- An estimated 25,278.5 person-hours expended sampling fixed, random, targeted, and additional sites downstream the Electric Dispersal Barrier (2010-2018).
- A total of 997.5 hours electrofishing, 1,783 km (1,108 miles) trammel/gill net, 1,922 hoop netting nights, and 635 mini-fyke netting nights (2010-2018).

- A total of 346,222 fish captured, representing 101 species and twelve hybrid groups (2010-2018).
- No Bighead or Silver Carp have been captured in Lockport or Brandon Road pools in any year sampled, but have been collected in Dresden Island Pool totaling 5,493 (2010-2018). Historically, Rock Run Rookery, Mobil Bay and the downstream end of Treats Island within the Dresden Island Pool are locations where Asian carp have been known to congregate and are frequently sampled (Figure 1).
- The leading edge of the Asian carp population is located north of I-55 Bridge in Rock Run Rookery (near river mile 281; 46 miles from Lake Michigan). No appreciable change has been found in the leading edge over the past 10 years.

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

- To date, USACE has acquired 29.1 million detections from 636 tagged fish.
- No live tagged fish have crossed the Electric Dispersal Barriers in the upstream direction.
- A high percentage of tagged surrogate fish in the Lower Lockport Pool continue to be detected near the Electric Dispersal Barrier System.
- There were three upstream lock passages by Common Carp from Brandon Road Pool into Lockport Pool.
- One Grass Carp and one Common Carp moved from Brandon Road Pool to Dresden Island Pool.
- Asian carp continue to be detected throughout the Dresden Island Pool with the majority of detections occurring near the Harborside Marina and Dresden Island Lock.
- Up to 90% of transmitters within Dresden Island Pool were detected near Harbor Side Marina at the Kankakee River confluence, but only accounted for 18.1% of the total detections in the pool in that season and overall for 36% of the detections in pool for the year.

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

- Fish densities directly below the Electric Dispersal Barrier were similar across the majority of the 2018 hydroacustic surveys.
- Fish densities directly below the Electric Dispersal Barrier were releativly low with the majority of surveys indicating mean densities < 4 individual per 100,000 m^3 (annual mean = 2.46 individuals per 100,000 m^3).

- Fish densities ≥ 4 individuals/100,000 m^3 were observed during only three surveys: May 14 (survey mean = 9.09 individuals per 100,000 m^3), August 8 (survey mean = 7.46 individuals per 100,000 m^3) and September 26, 2018 (survey mean = 5.32 individuals per 100,000 m^3).
- Fish densities were greater in the summer and in the downstream pools. The greatest fish density was observed during the summer survey of Dresden Island Pool. The lowest fish density was observed during the spring survey of Lockport Pool.

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

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

Young-of-year and Juvenile Asian Carp Monitoring – Monitoring for small Asian carp is conducted during other sampling events, with gears targeted for small Asian carp. This project provides information on population fronts, recruitment, and the conditions and habitat required for successful recruitment.

- Young Asian carp were sampled from 2010 to 2018 throughout the CAWS, Des Plaines River, and Illinois River between river miles 83 and 334 through sampling from existing monitoring projects.
- Sampling was conducted with active gears (trawls, pulsed-DC electrofishing, and beach seine) and passive gears (mini-fyke nets) in 2018. Mini-fyke nets caught the most Silver Carp <152 mm (i.e., <6 in.). Trawling captured more Silver Carp between 152-304 mm (i.e., 6-12 in.).
- Multiple agencies have completed 2,713 total hours of electrofishing across all years and pools.
- Large numbers of Gizzard Shad <152 mm (6 in) were sampled along the Illinois Waterway during 2018, with catches within the range captured in previous years.

- Catches of small Asian carp in 2014 and 2018 were orders of magnitude higher than other years, suggesting stark differences between strong and weak recruitment years.
- The farthest upstream catch of young Asian carp in 2018 was one Silver Carp (152-304 mm) in the Starved Rock Pool.
- Given that the numbers of small Asian carp sampled differ by orders of magnitude among years, it is recommended that monitoring of small Asian carp be continued to examine recruitment fluctuations and identify abiotic and biotic factors that lead to recruitment success/failure.

Des Plaines River Monitoring – This project included periodic monitoring for Asian carp presence and spawning activity, in the upper Des Plaines River downstream of the old Hofmann Dam site. In a second component, efficacy of the Des Plaines Bypass Barrier constructed between the Des Plaines River and CSSC was assessed by monitoring for any Asian carp juveniles and eggs and larvae that may be transported to the CSSC via laterally flowing Des Plaines River floodwaters passing through the barrier fence.

- Collected 11,830 fish representing 62 species and 3 hybrid groups from 2011-2018 via electrofishing (64.02 hours) and gill netting (21,316 yards).
- No Bighead Carp or Silver Carp have been captured or observed through all years of sampling (2011-2018).
- Ten Grass Carp have been collected, of which six were submitted for ploidy analysis. All six were determined to be triploid.
- Three overtopping events since 2011 have resulted in several improvements to the barrier fence.
- No high-water events occurred in 2018 so there were no times when the barrier was overtopped, therefore ichthyoplankton sampling was not conducted in 2018.

USGS Support for Implementation of MRP – This project focuses on developing tools to support the activities conducted by all other agencies in the effort to control Asian carp migration. Specifically, the project focuses on implementing and evaluating new strategies for monitoring, surveillance, risk assessment, control, and containment of bigheaded carp. This project also works to develop and evaluate databases and decision support tools to streamline the analysis of data collected by other projects.

- Two additional real-time telemetry recievers were deployed to inform removal efforts and contingency actions. One was deployed near Romeoville, Illinois, just downstream of the electric dispersal barrier and the other was deployed near Morris, Illinois, in the west pit of Hanson Material Services.
- A new version of FishTracks telemetery database was released with online upload/download capabilities and enhanced data visualization tools.
- The Illinois River Catch Database (ILRCdb) was released with online upload/download capabilities and automated report generation features.

- Decision support tools to inform removal of adult bigheaded carp and mitigate for bigheaded carp egg/larvae entrainment moved toward completion.
- USGS-CERC has developed a simple, inexpensive procedure for automated processing of side-scan and 360 sonar imagery recorded by recreational "fish finder" systems. The process takes a folder of side-scan image tiles or 360 screenshots and produces a spreadsheet of fish counts per image in seconds or minutes, depending on the number of images. This method provides a quick way to visualize fish counts generated from side-scan data in ESRI ArcMap so that users can identify spatial distributions and determine relative fish abundance.
- An experimental Unified Method for bigheaded carp was conducted at Creve Coeur near St. Louis, Missouri that removed about 240,000 pounds of Asian carp. The controlled design, telemetry and accurate geospatial tracking of efforts will facilitate analyses on driving and capturing techniques that will inform modifications to improve effectiveness.
- Trap nets tested for efficacy on invasive carp include the Merwin trap, the Iruka trap, and pound nets, and the effect of algal attractants to enhance trap net catch was tested.
- Successful deployment of an acoustic barrier in the Chicago Area Waterways (CAWs) provided added protection during electric dispersal barrier maintenance.
- Study plans for the evaluation of experimental acoustic deterrents at Barkley Dam and a backwater in the Wabash River are complete or nearly complete. These studies will provide the large-scale testing needed to inform more permanent deployment of acoustic deterrents at strategic locations.
- Three manuscripts have been submitted for publication regarding the response of fishes to sound including the response of native fishes to a 100hp boat motor sound, deterrence of fishes at Emiquon Preserve in response to a 100hp boat motor sound, and Black Carp auditory evoked potentials. All these efforts are critical to informing the deployment of acoustic deterrents to control Asian carp.
- The FluEgg model was redeveloped from the ground up and ported from Matlab to Python software. The redevelopment was necessary to improve functionality and ease of use, allow for easier integration with hydraulic models and web applications, and improve code structure and documentation for developers.

MANAGE AND CONTROL PROJECTS

Comprehensive Removal Summary – This report presents an analysis of all efforts to remove Asian carp from the Illinois River below the Electric Dispersal Barrier. It summarizes the efforts of multiple removal projects, and analyzes trends in removal totals both over time and spatially, and also analyzes changes in species composition of removed Asian carp.

- Since 2010, contracted fisher and agency staff efforts in the upper Illinois Waterway included: 2,754 miles (4,432.1 km) of gill/trammel net, 22 miles (35.4 km) of commercial seine, 260 pound net nights, 4,963.2 hoop net nights, 550.8 electrofishing hours, and 68.7 electrified paupier hours.

- From 2010-2018, a total of 93,947 Bighead Carp, 868,967 Silver Carp, and 6,216 Grass Carp were removed, totaling 3,880.32 tons.

Barrier Defense Asian Carp Removal Project – This program was established to reduce the numbers of Asian carp downstream of the Electric Dispersal Barrier through controlled commercial fishing. The intent of the project is to reduce the propagule pressure on the Electric Dispersal Barrier by reducing Asian carp populations in Dresden Island, Marseilles, and Starved Rock pools.

- Since 2010, contracted fishers' efforts in the Upper Illinois Waterway include: 2,283 miles (3,674km) of gill/trammel net, 22 miles (35km) of commercial seine, 184 pound net nights, and 3,970 hoop net nights.
- A total of 91,204 Bighead Carp, 786,401 Silver Carp, and 5,999 Grass Carp were removed by contracted fishermen from 2010-2018. The total weight of Asian carp removed was 3,639 tons.
- We propose to increase Asian carp harvest using contracted fishers in the upper Illinois Waterway in 2019 (+45 harvest weeks; 109 weeks in 2018 vs 154 in 2019). Since 2010, this program has been successful at managing the Asian carp population in the upper Illinois River. Adding harvest weeks will allow us to remove more Asian carp in 2019 than in previous years, further reducing Asian carp abundance at and near the detectable population front and possibly preventing further upstream movement of populations toward the Electric Dispersal Barrier and Lake Michigan.

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

- The MRWG agency representatives met and discussed the risk level of Asian carp presence at the Electric Dispersal Barrier System at each primary barrier loss of power to water and determined that no barrier clearing actions were required.
- Three 15 minute electrofishing run were completed between Barriers 2A and 2B to supplement existing data in support of the MRWG clearing decision.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on a bi-weekly basis, both below and within the EDBS indicating low fish abundance and no fish over 300 mm.
- An acoustic deterrent system was installed approximately a half mile downstream of the Electric Dispersal Barrier System between February 14 and May 7, 2018 and between November 19, 2018 and April 3, 2019 in support of annual maintenance operations.
- **No Asian carp were captured or observed during fish suppression operations.**

Barrier Defense Using Novel Gear – This project used an electrified paupier in conjunction with other barrier defense efforts to remove Asian carp at their leading edge in the Illinois River. The paupier is a modified frame trawl developed specifically for the capture of Asian carp.

- Fourteen days of effort removed an estimated 37,657 Asian Carp (approximately 109 tons), 99.6% of which were Silver Carp, from the Starved Rock pool of the upper Illinois River. Asian carp were removed at a rate of 7.8 tons/day (tons/d) in 2018, compared to 4.8 tons/d in 2017.
- The proportion of non-target fish in the total catch was similar between the two years, with 9% in 2017 and 10% in 2018.
- The percentage of time spent electrofishing increased from 24% in 2017 to 29% in 2018.
- The addition of a second tender boat, redesign of the fish unloading process, inclusion of hydroacoustic technology, and adjustment of the subsample protocol likely contributed to an increase in harvest during 2018.

Optimization of Mass Removal Techniques - This project focuses on developing and evaluating techniques to optimize the mass removal of Asian carp. Specific focuses include improving herding techniques during mass removal efforts, and improving sonar-based estimates of Asian carp populations.

- Collaborative efforts with USGS operated DIDSON and side-scan techniques to quantify the effects of herding methods (See USGS report)
- When herded, Silver Carp were highly averse to entering hoop or fyke trapping net, but would jump into an open-top ramp net.
- Silver carp were effectively herded at night using a method that combined bright lights with a flexible underwater curtain in a small tributary.
- New Paupier electrofishing anode designs were developed to enhance the gear’s effectiveness over a wider range of conductivities, seasons, and water depths.
- Electrical field mapping showed that insignificant amounts of electricity existed deeper than 2 meters suggesting electrofishing as a herding, detection or capture method in deeper habitats may be largely ineffective without modification.
- The Paupier was used with deep-water wing deployment (3.5m) to target fish deep in the water column and to herd fish during Unified Method events.
- Precision of reader’s estimates using real-time counts was high compared to actual laboratory counts
- Counts were relatively accurate when less than 100 fish appeared on the screen
- Schools of fish likely makeup larger portions of the population than anticipated, indicating caution should be exhibited when relying on 2D hydroacoustic measures when large schools exist.
- The use of traditional waterfowl counting methods may be applicable to carp population estimation when qualifiers for number and size of schools accompany the estimate.

- Very little reader training or computer processing was necessary to conduct precise visual sonar counts.

Using Long-term Asian Carp Abundance and Movement Data to Reduce Uncertainty of Management Decisions – This project encompasses multiple studies with the goal of determining estimates of Asian carp abundance, biomass, size structure, demographics, natal origin, and rates of hybridization. The results of the study will be used to create a spatially-explicit model of Asian carp populations, including an analysis of the probability of inter-pool travel.

- Repeated hydroacoustic surveys in Dresden Island and Marseilles pools identified areas of high bigheaded carp density and how these locations change through time. These data helped direct contracted removal efforts throughout 2018.
- Bigheaded carp densities in Dresden Island and Marseilles pools during fall 2018 did not change from densities in the fall of 2017. Densities in Starved Rock Pool were slightly lower in fall 2018 compared to fall 2017.
- Fall 2018 bigheaded carp densities in Starved Rock, Marseilles, and Dresden Island pools were the lowest or as low as any densities observed in those pools since monitoring began in 2012.
- Hydroacoustic estimates of bigheaded carp densities were significantly, positively related to the number of acoustically tagged individuals detected by telemetry receivers. Change in hydroacoustic density estimates following unified method events in the HMS East and West pits were significantly related to the number of fish harvested.
- Regardless of season, bigheaded carp more frequently used lateral habitats than main channel habitats in Starved Rock Pool. Increasing water temperatures were positively related to lateral habitat use as was increasing main channel discharge.
- Upstream passages at dams of greatest concern in the upper Illinois River continue to be limited with only three upstream passages detected in 2018 (one in Starved Rock; two in Dresden Island). These three passages all occurred through lock chambers.
- Results to date indicate some evidence of upstream passage by native fishes through Brandon Road Lock and Dam. Additional sampling will be used to refine estimates of the relative abundance of native fishes upstream of Brandon Road Lock and Dam that had previously been in the Illinois or Kankakee rivers.

Evaluation of Gear Efficiency and Asian Carp Detectability – This project assessed efficiency and detection probability of gears currently used for Asian carp monitoring (e.g., DC electrofishing, gill nets, and trammel nets) and others potential gears (e.g., mini-fyke nets, hoop nets, trap nets, seines, and cast nets) by sampling at 4 sites in the Illinois River selected to evaluate capture of juvenile Asian carp. Results will inform decisions on appropriate levels of sampling effort and monitoring regimes, and ultimately improve Asian carp monitoring and control efforts.

- Summer catches of age-0 Silver Carp were higher during 2018 than in all previous study years except 2014. Fall catch rates of age-0 Silver Carp were intermediate compared to previous years. Differences in catches of juvenile Silver Carp among years and seasons may be attributable to variation in reproductive output, timing of reproduction, variable survival to juvenile life stages, and ontogenetic changes in habitat association by juvenile Silver Carp. No juvenile Bighead Carp were captured during 2018, and haven't been observed since 2015.
- During 2018, mini-fyke nets collected the highest total numbers of age-0 Silver Carp. Mini-fyke nets have consistently produced higher catch rates of age-0 Silver Carp than all other sampling gears and are likely a preferred tool for monitoring for age-0 Silver Carp in floodplain rivers, especially during the summer months. Beach seines and dozer trawls captured intermediate numbers of age-0 Silver Carp, and may be useful for rapid monitoring purposes or for targeting specific habitats. Pulsed-DC electrofishing is not an effective method for monitoring for age-0 Silver Carp.
- Detection probability modelling using data from adult sampling gears indicates that a gear that produces the highest catches of a particular species may not necessarily be the most efficient gear for purposes of detection. Pulsed-DC electrofishing produces the highest detection probabilities for adult Silver Carp. Hoop nets, fyke nets, and trammel nets produce similar detection probability estimates for adult Bighead Carp, whereas electrofishing, fyke nets, or trammel nets provided the highest probability of detecting Grass Carp, depending on navigation pool. However, when the labor costs associated with each gear were accounted for, the most efficient gear for achieving a 95% cumulative detection probability for Silver Carp varied among pools, with hoop nets, fyke nets, and electrofishing each conveying minimum labor costs in different sections of the Illinois Waterway. Hoop nets and fyke nets provided very similar and low number of labor hours to reach a 95% cumulative probability of detecting Bighead Carp, whereas fyke nets were the most efficient gear for attaining a high cumulative detection probability for Grass Carp.

Unconventional Gear Development – The goal of this project is to develop an effective trap or netting method capable of capturing low densities of Asian carp in the deep-draft canal and river habitats of the CAWS, lower Des Plaines River, upper Illinois River, and possible Great Lakes spawning rivers.

- Alternative configurations for setting pound nets produced highly variable catch rates and no apparent overall differences between parallel and perpendicular sets in open-water settings. Site-specific habitat conditions and local fish distribution may influence catch rates more than net configuration.
- Pound nets are being used for ongoing research, monitoring, and control efforts on the Illinois Waterway. Pound nets are being used in collaboration with USGS to test feeding attractants and evaluate other large entrapment gears.

- Herding fish into surface-to-bottom gill nets with sound or electrical stimuli increased catch rates and detection probabilities of Asian carp. These synergistic capture methods may provide a means of increasing catch rates and improving the probability of detecting Asian carp, and may be useful for targeting both Silver Carp and Bighead Carp simultaneously

Barge Entrainment and Asian Carp Interaction Study and Monitoring Barge Entrainment Dynamics and Assessment of Mitigation Protocols – This project assesses the potential interactions between barge traffic and Asian carp, typically using tagged fish to evaluate the potential for barge movement to entrain small fish and transport them past barriers.

- Five trials were conducted using live Asian carp and a total of 1256 fish were clipped and released in front of the barges, within the rake-to-box junction gap or both. Of the 1256 fish released only 2 were recaptured, one in the left gap and one in the right.
- Sonar data from 2018 is still being processed and may provide further information on other entrained fish.

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

- Provided model results to inform management recommendations for reduction/elimination of Asian carp in Dresden Island pool over a 25 year period while accounting for uncertainty in our understanding of population dynamics. Recommendations relate to the minimum amount of additive mortality required in the upstream pools (Starved Rock, Marseilles, and Dresden Island) and downstream pools (Alton, La Grange, and Peoria) across varying levels of deterrence efficiency (measured as percent reduction in annual upstream movement rates) placed at either the Starved Rock Lock and Dam, the Marseilles Lock and Dam, or the Dresden Island Lock and Dam.
- Updated demographic parameters for Silver carp and Bighead carp across entire Illinois River and Upper Mississippi River and Ohio River systems (Erickson et al. *in review*.; code available at https://github.com/rerickson-usgs/CarpLifeHistoryModels); defining demographic rates in additional locations improves estimates of Illinois River demographics and also provides information on potential source populations that will hopefully be incorporated into the SEAcarP model in the future
- Developed and published findings from a simplified version of the SEAcarP model using Grass carp as the target species (Erickson et al. 2018). General conclusions regarding the effectivness of deterring upstream movement as well as additional mortlaity in downstream versus upstream locations relative to population control were consistent with SEAcarP model findings.
- Worked closely with MRWG technical workgroups to prioritize future data collections and research using the SEAcarP model assumptions and limitations as a decision support tool. These efforts ensure that field-related efforts are coordinated to reach management

goals and provide maximum ability to test assumptions, aliviate limitations, and increase our general understanding of Asian carp population dynamics.

Telemetry Support for the Spatially Explicit Asian Carp Population Model (SEACarP) – This project focuses on collecting telemetry data that is most useful for parameterizing the SEACarP model. Target datasets include Asian carp movement distance and frequency, and preferred macrohabitat environments.

- 130 Asian carp were tagged within the Peoria Pool (Figure 1) ranging in size from 391-635mm TL.
- In addition, 81 small Asian carp (122mm-352mm TL) were tagged as part of the USFWS Distribution and movement of small Asian carp in the Illinois Waterway using telemetry project.

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

- In spring and fall 2018, we completed a demographics protocol in five pools of the Illinois River in 4-5 weeks.
- Executing this standardized sampling method with the electrified dozer trawl to collect demographic data was time efficient and representative. Samples can be used to measure population responses to changes in management strategies.
- Approximately 2,800 Silver Carp measuring 40-872 mm were captured. Size classes varied across pools and seasons.
- Relative abundances of Silver Carp appeared to decrease moving upstream within the Illinois River.
- 25 small Silver Carp (< 153 mm) were captured: 22 in the LaGrange Pool measured 40 to 140 mm and two in the Alton Pool measured 50 to 76 mm.
- Collaborated with ILDNR staff and contract fishers, during a two-week intensive removal effort in Peoria, Marseilles, and Dresden Island to collect fishery-dependent demographic data.
  - Length, weight, and sex data was collected from Asian carp captured in the Dresden Island, Marseilles, Starved Rock, and Peoria pools
  - Aging structures were collected from 62 Silver Carp to supplement the standardized demographics data set. These were larger Silver Carp (650-912) that were less represented in the standard demographics sampling.
- USGS-CERC and USFWS Columbia FWCO convened a group of 12 experts in fish age estimation to develop a range-wide, standard protocol for aging techniques of Silver Carp.
- The USGS-CERC is facilitating a scientific approach for developing the “gold-standard” manual for aging Silver Carp, including the processing of structures and age estimation methods.

RESPONSE PROJECTS

***Contingency Response Plan Actions* –** The Contingency Response Plan establishes specific triggers for response action in the Upper Illinois Waterway, and recommended protocols for conducting response actions.

INTRODUCTION

The 2018 Interim Summary Report (ISR) presents a comprehensive accounting of project results from activities completed by the Asian carp Monitoring and Response Workgroup in 2018. These projects have been carefully selected and tailored to contribute to the overall goal of preventing Asian carp from establishing self-sustaining populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Efforts to prevent the spread of Asian carp to the Great Lakes have been underway for over 8 years. Over the course of this time, goals, objectives, and strategic approaches have been refined to focus on five key objectives:

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

The projects presented in this document represent the results of efforts undertaken during 2018 to further the implementation of each of these objectives.

BACKGROUND

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

Asian carp are native to central and eastern Asia, with wide distribution throughout eastern China. They typically live in river systems, and in their native habitats have predators and competitors that are well adapted to compete with Asian carp for food sources, thus limiting their population growth. In the early 1970s, Asian carp were intentionally imported to the US for use in aquaculture and wastewater treatment detention ponds. In these settings, Asian carp were used to control the growth of weeds and algae and pests. Flooding events allowed for the passage of Asian carp from isolated detention ponds to natural river systems. By 1980, Asian carp had been captured by fishermen in river systems in states including Arkansas, Louisiana, and Kentucky. Flooding events during the 1980s and 1990s allowed Asian carp to greatly expand their range in natural river systems. Asian carp are currently wide spread in the Mississippi River basin, including the Ohio River, Missouri River, and Illinois River. Areas with large populations of Asian carp have seen an upheaval of native ecosystem structure and function. Asian carp are voracious consumers of phytoplankton, zooplankton, and macroinvertebrates. They grow quickly and are highly adapted for feeding on these organisms, allowing them to outcompete native species, and quickly grow too large for most native predators to prey upon. As a result, their populations have exploded in the Mississippi River basin.

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

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

DETECTION PROJECTS

Seasonal Intensive Monitoring in the CAWS

Kevin Irons, Matt O'Hara, Justin Widloe, Rebekah Anderson, Nathan Lederman, Seth Love (Illinois Department of Natural Resources), Andrew Mathis, Eric Hine (Illinois Natural History Survey)

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

Pools Involved: N/A

Introduction and Need:

Detections of Asian carp eDNA upstream of the Electric Dispersal Barrier in 2009 initiated the development of a monitoring plan using boat electrofishing and contracted commercial fishers to sample for Asian carp at five fixed sites upstream of the barrier. In addition, random area sampling began in 2012 in order to increase the chance of encountering Asian carp in the CAWS beyond the designated fixed sites. Based on the extensive sampling performed upstream of the Electric Dispersal Barrier from 2010 through 2013 (682 hours of electrofishing, 445.8 km (277 mi) of gill/trammel net, 2.2 km (1.4 mi) of commercial seine hauls) and only one Bighead Carp being collected in Lake Calumet in 2010, and one Silver Carp collect in Little Calumet River in 2017, fixed site and random area sampling effort was reduced upstream of the barrier to two Seasonal Intensive Monitoring (SIM) events from 2014-2018. The reduction of effort upstream of the Electric Dispersal Barrier will allow for increased monitoring efforts downstream of the barrier. The increase in sampling downstream of the Electric Dispersal Barrier will focus sampling efforts on the leading edge of the Asian carp population, which will serve to reduce their numbers in this area thus mitigating the risk of individuals moving upstream towards the Electric Dispersal Barrier and Lake Michigan by way of the CAWS. Results from SIM upstream of the Electric Dispersal Barrier will contribute to our understanding of Asian carp abundances in the CAWS and guide conventional gear or rotenone rapid response actions designed to remove Asian carp from areas where they have been captured or observed.

Objectives:

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

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

Seasonal Intensive Monitoring in the CAWS

Project Highlights:

- Completed 2-two week SIM events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier in 2018.
- Estimated person-hours were spent to complete 103.5 hours of electrofishing, set 122.9 km (76.6 mi) of trammel/gill net, 2.2 km (1.4 mi) of commercial seine, 7 Fyke nets in 2018
- Across all locations and gears in 2018, sampled 31,321 fish representing 61 species and 3 hybrid groups.
- Since 2010, an estimate 29,204 person-hours were spent to complete 1,189.9 hours of electrofishing, set 946.8 km (588.6 mi) of gill/trammel net and 13.3 km (8.3 mi) of commercial seine, tandem trap nets, hoop nets, Fyke nets, and pound nets.
- A total of 423,516 fish representing 73 species and six hybrid groups were sampled, including 2,388 Banded Killifish (state threatened species) from 2010-2018.
- Examined 117,383 YOY Gizzard Shad since 2010 and found no Asian carp.
- Since 2010, 19 non-native species have been captured accounting for 15% of the total fish caught and 26% of the total species.
- From 2011-2016, no Bighead Carp or Silver Carp have been captured or observed. One Bighead Carp captured in Lake Calumet in 2010, and one Silver Carp was captured in Little Calumet River in 2017.
- Recommend continued use of SIM in the CAWS upstream of the Electric Dispersal Barrier for localized detection and removal of Asian carp.

Methods:

Pulsed DC-electrofishing, trammel and gill nets, deep water gill nets, Fyke nets, commercial seine, and pound nets were used to monitor for Asian carp in the CAWS upstream of the Electric Dispersal Barrier (Figure 1). Trammel and gill nets were 3 m (10 ft) deep x 91.4 m (300 ft) long in bar mesh sizes ranging from 88.9-108 mm (3.5-4.25 in). Deep water gill nets were 9.1 m (30 ft) deep x 91.4 m (300 ft) long with bar mesh sizes ranging from 69.9-88.9 mm (2.75-3.5 in). The commercial seine was 9.1 m (30 ft) deep x 731.5 m (2400 ft) long and had a cod end made of 50.8 mm (2.0 in) bar mesh netting. Pound nets had a single 100.0 m (328.0 ft.) by 3.0 m (9.8 ft.) lead and two adjustable length wings 3.0 m (9.8 ft.) in depth, and a mesh cab, or catch area, 6.1 m long by 3.0 m wide by 3.0 m deep (19.6 x 9.8 x 9.8 ft.) square made from webbing. The cab had two, 3.0 m (9.8 ft.) long by 2.5 cm (1.0 in.) diameter steel pipes sewn to the bottom of the horizontal panels of the cab serving as weights and one 3.0 m (9.8 ft.) long by 7.6 cm (3.0 in.) diameter capped polyvinyl chloride pipe stitched to the top of the rear horizontal cab panel serving as a float. Fyke nets had a single 15.2 m (50.0 ft.) long by 1.4 m (4.5 ft.) deep lead. The frames of the net were constructed of two, 1.2 m (4.0 ft.) by 1.8 m (5.0 ft.) rectangular bars made of 8 mm (0.3 in.) black oil temper spring steel. Inner wings (vertical wall throats) of the frame extended from outer corners of the front rectangle to the middle of the rear rectangle. A 76.0 mm

(3.0 in.) vertical gap existed on either side of lead between the wings and lead at middle of rear rectangle. A 1.2 m (4.0 ft.) webbing covered gap connected the cab and frame together. The cab was constructed of six, 0.9 m (3.0 ft.) diameter spring steel hoops spaced 61 cm (24 in.) apart from each other. Cab and frame together were 6.0 m (20.0 ft.) in total length.

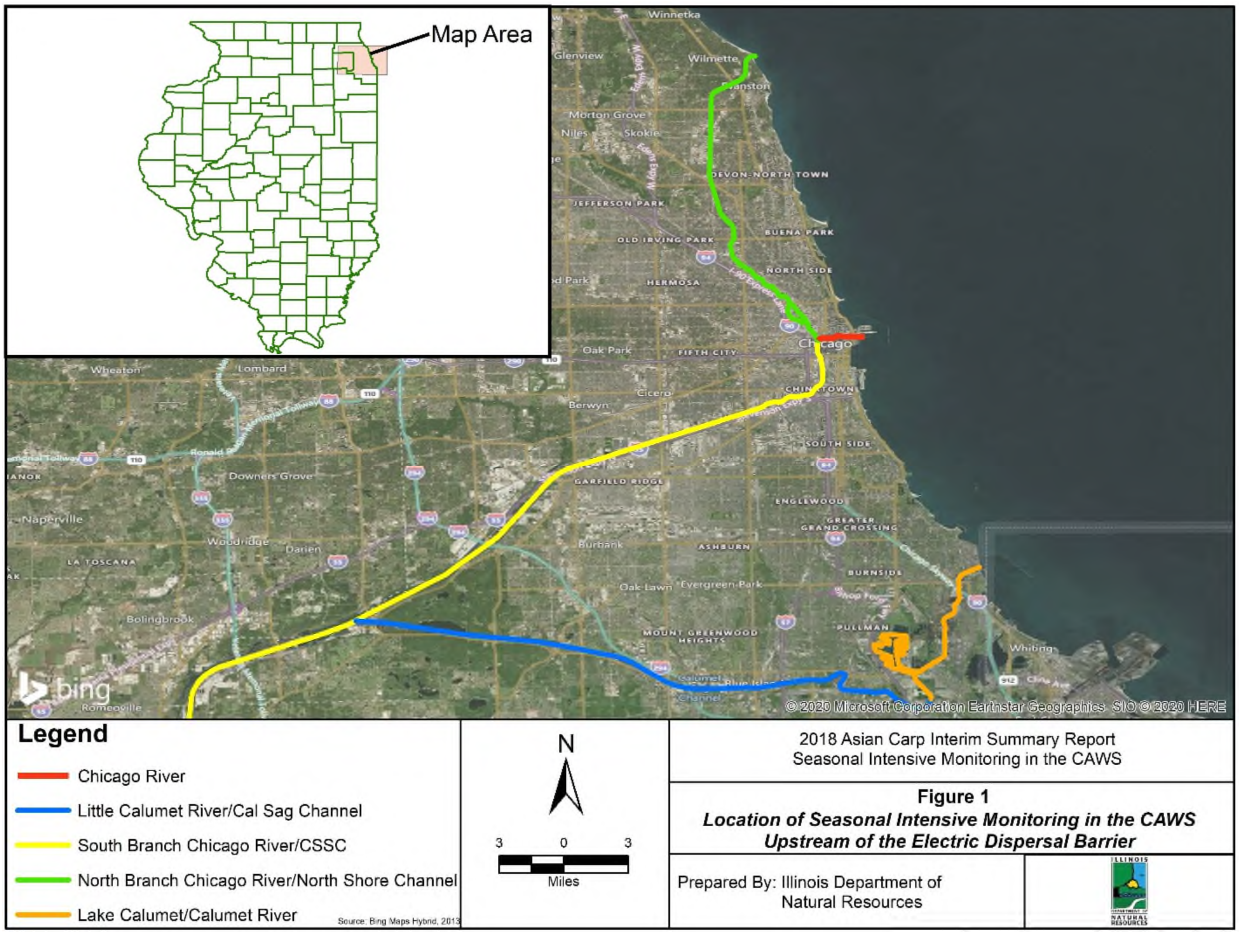

Figure 1. *Location of SIM in the CAWS upstream of the Electric Dispersal Barrier.*

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

Netting Protocol – Contracted commercial fishers were used for net sampling at fixed and random sites. Sets were of short duration and include driving fish into the nets with noise (e.g., plungers on the water surface, pounding on boat hulls, or revving trimmed up motors). In Lake

Calumet, a 731.5 m (2400 ft) commercial seine was also used. Nets were attended at all times. Locations for each net set were located and identified with GPS coordinates. Captured fish were identified to species, enumerated and released. Pound nets and Fyke nets were set by IDNR biologists and checked once every 2 net nights by IDNR biologists and commercial fishers.

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

Results and Discussion:

SIM took place during the weeks of June 4th, June 11th, September 10th and September 17th upstream of the Electric Dispersal Barrier. As established in the 2014 MRP, sampling for Bighead Carp and Silver Carp eDNA preceded SIM (*see* Strategy for eDNA Monitoring in the CAWS interim summary). To continually focus additional monitoring effort on the leading edge of the Asian carp population below the Electric Dispersal Barrier, the same reduced sampling effort protocols established in 2014 upstream of the barrier (CAWS) were followed in 2018 (Figure 2). Effort in 2018 was 103.5 hours of electrofishing (414 transects) with an estimated 990 person-hours, 122.9 km (76.6 mi) of trammel/gill netting (710 sets) with an estimated 1,485 person hours, 2.3 km (1.4 mi) of commercial seine with an estimated 135 person hours, and 7 Fyke nets fished for 43 net nights with an estimated 135 person hours (Table 1.). Across all locations and gears, 31,321 fish representing 61 species and 3 hybrid groups were sampled in 2018 (Table 2.) Gizzard Shad and Common Carp were the predominant species, comprising 50% of all fish sampled. Ten (10) non-native species were also sampled, which included Common Carp and hybrids, Round Goby, Alewife, Goldfish, White Perch, Oriental Weatherfish, Grass Carp, Chinook Salmon, Coho Salmon, Rainbow Trout. Non-native species made up 18% of the total species collected and 18% of the total fish in 2017. Three hundred and sixty-eight (368) Banded Killifish, a state threatened species, were also collected. They were identified and returned to the water alive. In addition, we examined 5,621 young of the year (YOY) Gizzard Shad and found no YOY Asian carp. No Bighead Carp were captured or

Since 2010, an estimated 29,204 person-hours were expended monitoring fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier. Total effort was 1,189.9 hours of electrofishing (4,744 transects), 946.8 km (588.6 mi) of gill/trammel net (5,151 sets), 13.3 km (8.3 mi) of commercial seine hauls and 114.2 net nights of hoop, pound and Fyke nets from 2010-2018 (Table 3). The use of hoop nets was suspended after 2013 due to low gear efficiency. A total of 423,516 fish representing 73 species and 6 hybrid groups have been sampled since 2010 (Table 3). Gizzard Shad, Common Carp, Bluegill, Largemouth Bass, Bluntnose Minnow, Pumpkinseed were the predominant species sampled, accounting for 81% of all fish collected. Since 2010, 16 non-native species have been caught, which include Common Carp and hybrids, Alewife, Goldfish, White Perch, Round Goby, Oriental Weatherfish, Chinook Salmon, Threadfin Shad, Rainbow Trout, Grass Carp, Brown Trout, Coho Salmon, Tilapia, Rainbow Smelt, Silver Arrowana and Threespine Stickleback. Non-native species constitute 15% of the total fish caught and 23% of the total species. Banded Killifish, a state threatened species, have been routinely collected during our monitoring efforts in the CAWS. To date, 2,388 Banded Killifish have been sampled at fixed and random sites upstream of the Electric Dispersal Barrier. No Bighead Carp or Silver Carp were captured or observed in the CAWS upstream of the Electric Dispersal Barrier from 2011-2016. One (1) Bighead Carp was caught in a trammel net in Lake Calumet in 2010, and one (1) Silver Carp was captured in a trammel net in Little Calumet River on June 22nd, 2017. Furthermore, 117,383 YOY Gizzard Shad have been examined since 2010 with no YOY Asian carp being identified.

Recommendation:

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

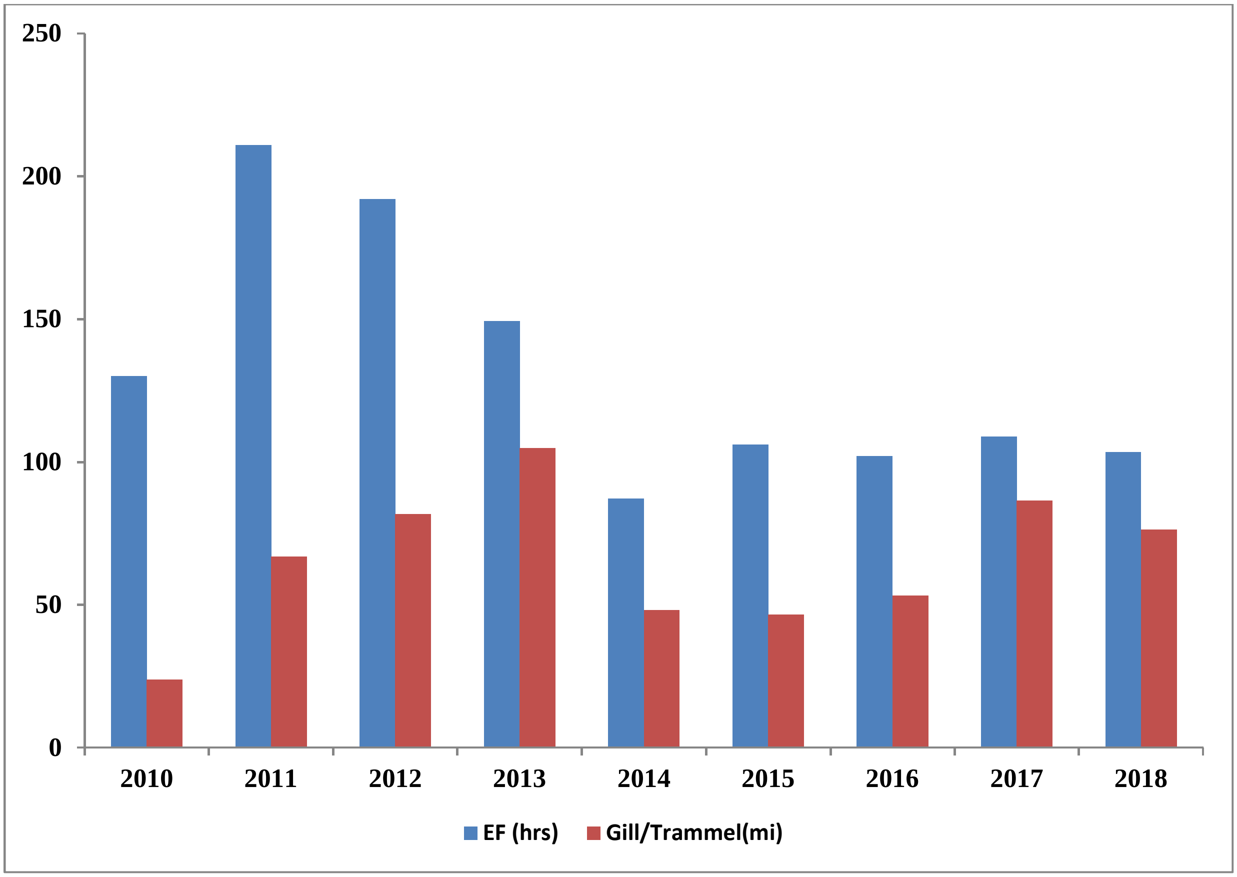

Figure 2. *Total electrofishing and trammel/gill netting effort at fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier, 2010-2018.*

Seasonal Intensive Monitoring in the CAWS

Table 1. *Summary of effort and catch data for Seasonal Intensive Monitoring in the CAWS upstream of the Electric Dispersal Barrier 2018.*

Types of Effort	Lake Calumet/ Calumet River	Little Calumet River/Cal Sag	S. Branch Chi. River/CSSC	Chicago River	N. Branch Chi. River/ N. Shore	Total
Electrofishing Effort						
Estimated person-hours	450	95	190	22	233	990
Samples (transects)	162	69	84	3	96	414
Electrofishing hours	40.5	17.3	21.0	0.8	24.0	103.5
Electrofishing Catch						
All fish (*N*)	7,768	7,073	5,098	75	6,330	26,344
Species (*N*)	41	45	34	10	42	53
Hybrids (*N*)	2	0	1	0	1	2
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	191.8	410.0	242.8	100.0	263.8	241.7
Netting Effort						
Estimated person-hours	368	230	254	35	261	1,148
Samples (net sets)	225	181	150	10	144	710
Miles of net	24.7	20.7	16.7	0.6	13.9	76.6
Netting Catch						
All fish (*N*)	450	177	380	18	149	1,174
Species (*N*)	21	7	3	1	6	23
Hybrids (*N*)	0	1	1	0	1	1
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/100 yds of net)	1.0	0.5	1.3	1.8	0.6	1.0
Seine Effort						
Estimated person-hours	135	-	-	-	-	135
Samples (seine hauls)	3	-	-	-	-	3
Miles of seine	1.4	-	-	-	-	1.4
Seine Catch						
All fish (*N*)	3,110	-	-	-	-	3,110
Species (*N*)	10	-	-	-	-	10
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	1036.7	-	-	-	-	1,036.7
Tandem Trap Net						
Estimated person-hours	135	-	-	-	-	135
Net nights	43	-	-	-	-	43
Trap Net Catch						
All fish (*N*)	693	-	-	-	-	693
Species (*N*)	19	-	-	-	-	19
Hybrids (*N*)	1	-	-	-	-	1
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/net-day)	16.1	-	-	-	-	16

Seasonal Intensive Monitoring in the CAWS

Table 2. *Total number of fish captured w in the CAWS upstream of the Electric Dispersal Barrier during Seasonal Intensive Monitoring, 2017.*

	Chicago River		CSSC-South Branch			Lake Calumet-Cal River			Little Cal-Cal Sag		N Branch-N Shore		All Sites
Species	Electrofishing	Gill/Tramm	Electrofishing	Gill/Tramm	Seine	Electrofishing	Gill/Tramm	Fyke Net	Electrofishing	Gill/Tramm	Electrofishing	Gill/Tramm	All Gears
Gizzard Shad < 6 in	39	0	1,692	0	0	581	0	0	2,348	0	960	1	5,621
Gizzard shad	0	0	710	0	2584	386	3	25	745	0	1,141	3	5,597
Common carp	17	18	1,100	374	0	706	130	279	959	140	742	134	4,599
Largemouth bass	6	0	314	0	5	831	2	25	497	0	487	1	2,168
Bluegill	2	0	205	0	0	943	1	72	176	0	687	0	2,086
Pumpkinseed	3	0	275	0	0	637	1	25	340	0	199	0	1,480
Emerald shiner	0	0	65	0	0	9	0	0	516	0	194	0	784
Alewife	0	0	2	0	0	623	0	0	12	0	123	0	760
Bluntnose minnow	2	0	123	0	0	113	0	0	374	0	148	0	760
Golden shiner	0	0	176	0	0	94	0	0	84	0	396	0	750
White sucker	0	0	13	0	0	24	0	0	9	0	554	0	600
Yellow perch	0	0	3	0	0	576	0	5	10	0	4	0	598
Rock bass	0	0	0	0	1	542	0	0	6	0	27	0	576
Channel catfish	0	0	29	1	220	36	17	80	102	6	36	5	532
Smallmouth buffalo	0	0	0	0	87	260	121	20	6	10	0	0	504
Black bullhead	0	0	27	0	0	379	0	26	4	0	50	0	486
Smallmouth bass	1	0	5	0	1	462	1	2	2	0	1	0	475
Freshwater drum	0	0	1	4	198	32	99	21	50	13	2	1	421
Green sunfish	0	0	77	0	0	42	0	0	124	0	156	0	399
Banded killifish	2	0	54	0	0	49	0	0	248	0	15	0	368
Round Goby	2	0	23	0	0	133	0	0	36	0	5	0	199
Spotfin shiner	0	0	12	0	0	1	0	0	63	0	82	0	158
Yellow bullhead	0	0	29	0	0	63	0	0	36	0	17	0	145
Bullhead minnow	0	0	25	0	0	2	0	0	100	0	6	0	133
Brown bullhead	0	0	3	0	0	77	9	12	5	1	2	0	109
White perch	1	0	70	0	0	5	0	0	9	0	22	0	107
Goldfish	0	0	22	0	0	19	0	0	13	1	39	2	96
Blackstripe topminnow	0	0	7	0	0	0	0	0	2	0	81	0	90
Black crappie	0	0	0	0	1	7	5	36	0	0	32	0	81
Creek chub	0	0	0	0	0	0	0	0	53	0	25	0	78
Fathead minnow	0	0	0	0	0	2	0	0	20	0	51	0	73
Quillback	0	0	0	0	0	59	1	0	0	0	0	0	60
Bowfin	0	0	0	0	0	35	1	20	2	0	0	0	58
Black buffalo	0	0	0	0	3	1	29	11	0	3	0	0	47
White bass	0	0	1	0	0	13	3	13	9	0	3	0	42
Longnose gar	0	0	0	0	0	0	0	0	40	0	0	0	40
Oriental Weatherfish	0	0	17	0	0	0	0	0	0	0	10	0	27
Northern pike	0	0	2	0	0	2	1	18	0	0	2	0	25
Orangespotted sunfish	0	0	0	0	0	0	0	1	22	0	2	0	25
Yellow bass	0	0	5	0	0	0	0	0	16	0	1	0	22
Bigmouth buffalo	0	0	0	0	10	0	5	0	2	0	0	0	17
Sand shiner	0	0	0	0	0	2	0	0	14	0	1	0	17
River carpsucker	0	0	0	0	0	10	2	0	0	0	0	0	12
Flathead catfish	0	0	0	0	0	0	11	0	0	0	0	0	11
Brook silverside	0	0	1	0	0	1	0	0	8	0	0	0	10
Common shiner	0	0	1	0	0	3	0	0	3	0	3	0	10
Rainbow trout	0	0	0	0	0	1	0	0	0	0	8	0	9
Carp x goldfish hybrid	0	0	0	1	0	0	0	1	0	3	0	2	7
Grass carp	0	0	0	0	0	0	5	0	1	0	0	0	6
Spottail shiner	0	0	0	0	0	1	0	0	0	0	4	0	5
Grass pickerel	0	0	4	0	0	0	0	0	0	0	0	0	4
River shiner	0	0	1	0	0	0	0	0	1	0	2	0	4
Striped bass x white bass	0	0	0	0	0	2	0	0	0	0	2	0	4
Coho salmon	0	0	0	0	0	0	1	0	0	0	2	0	3
Hybrid Sunfish	0	0	1	0	0	2	0	0	0	0	0	0	3
Pallid shiner	0	0	0	0	0	0	0	0	0	0	3	0	3
Skipjack herring	0	0	0	0	0	0	0	0	0	0	3	0	3
Western mosquitofish	0	0	3	0	0	0	0	0	0	0	0	0	3
Chinook Salmon	0	0	0	0	0	0	2	0	0	0	0	0	2
Longear sunfish	0	0	0	0	0	0	0	0	2	0	0	0	2
Central mudminnow	0	0	0	0	0	0	0	0	1	0	0	0	1
Northern hog sucker	0	0	0	0	0	0	0	0	1	0	0	0	1
Redear sunfish	0	0	0	0	0	0	0	1	0	0	0	0	1
Shorthead redhorse	0	0	0	0	0	1	0	0	0	0	0	0	1
Silver redhorse	0	0	0	0	0	0	0	0	1	0	0	0	1
Suckermouth minnow	0	0	0	0	0	0	0	0	1	0	0	0	1
Unidentified Centrarchidae	0	0	0	0	0	1	0	0	0	0	0	0	1
Total Fish	**75**	**18**	**5,098**	**380**	**3,110**	**7,768**	**450**	**693**	**7,073**	**177**	**6,330**	**149**	**31,321**
Species *(N)*	9	1	34	3	10	41	22	20	45	8	42	6	61
Hybrids *(N)*	-	-	1	1	-	1	-	-	-	-	1	1	3

Table 3. *Summary of effort and catch data for all fixed and random site monitoring in the CAWS upstream of the Electric Dispersal Barrier, 2010-2018.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Electrofishing Effort										
Estimated person-hours	1,280	2,180	4,330	1,528	945	990	990	990	990	14,223
Samples (transects)	519	844	765	588	348	422	407	437	414	4,744
EF (hrs)	130.0	211.0	192.0	149.3	87.1	106.0	102.0	109.0	103.5	1189.9
Electrofishing Catch										
All fish (*N*)	33,688	52,385	97,510	45,443	24,492	28,549	22,557	26,198	26,944	357,766
Species (*N*)	51	58	59	56	56	61	59	58	60	73
Hybrids (*N*)	3	3	3	2	2	2	2	2	2	6
Bighead Carp (*N*)	0	0	0	0	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0	0	0	0	0
CPUE (fish/hr)	259.1	248.3	507.9	304.4	281.2	269.3	221.1	239.7	260.3	287.9
Netting Effort										
Estimated person-hours	885	1,725	3,188	1,932	1,125	1,125	1,125	1,485	1,148	13,738
Samples (net sets)	208	389	699	959	440	445	498	803	710	5,151
TRA/GIL (mi)	23.8	67.0	81.7	104.9	48.2	46.6	53.3	86.5	76.6	588.6
Netting Catch										
All fish (*N*)	2,439	4,923	3,060	4,195	1,461	1,062	1,283	1,917	1,174	21,514
Species (*N*)	17	20	20	30	18	13	18	14	23	32
Hybrids (*N*)	1	1	1	1	1	1	1	1	1	1
Bighead Carp (*N*)	1	0	0	0	0	0	0	0	0	1
Silver Carp (*N*)	0	0	0	0	0	0	0	1	0	1
CPUE (fish/100 yds of net)	5.8	4.2	2.1	2.3	1.7	1.3	1.4	1.3	0.9	2.3
Seine Effort										
Estimated person-hours	-	-	-	135	135	135	135	135	135	810
Samples (seine hauls)	-	-	-	3	2	3	3	4	3	15
Miles of seine	-	-	-	1.4	0.9	1.4	1.4	1.8	1.4	6.9
Seine Catch										
All fish (*N*)	-	-	-	7,577	1,725	5,989	3,765	2,763	3,110	24,929
Species (*N*)	-	-	-	15	11	14	15	10	10	16
Hybrids (*N*)	-	-	-	1	0	0	0	0	0	1
Bighead Carp (*N*)	-	-	-	0	0	0	0	0	0	0
Silver Carp (*N*)	-	-	-	0	0	0	0	0	0	0
CPUE (fish/seine haul)	-	-	-	2,525.7	862.5	1,996.3	1,255.0	690.8	1,036.7	1,394.5
Hoop/Trap/Fyke Net Effort										
Estimated person-hours	-	-	-	-	-	30	28	135	135	298
Samples (sets)	-	-	-	11	-	4	3	8	7	26
Net-days	-	-	-	25.2	-	16	12	52.1	43	105.3
All fish (*N*)	-	-	-	93	-	172	102	294	693	661
Species (*N*)	-	-	-	17	-	17	15	17	19	17
Hybrids (*N*)	-	-	-	0	-	0	0	1	1	0
Bighead Carp (*N*)	-	-	-	0	-	0	0	0	0	0
Silver Carp (*N*)	-	-	-	0	-	0	0	0	0	0
CPUE (fish/net-day)	-	-	-	3.7	-	10.75	8.5	5.6	16.1	8.9
Pound Net Effort										
Estimated person-hours	-	-	-	-	-	-	-	135	-	135
Net-days	-	-	-	-	-	-	-	8.9	-	8.9
Pound Net										
All fish (N)	-	-	-	-	-	-	-	646	-	646
Species (N)	-	-	-	-	-	-	-	15	-	15
Hybrids (N)	-	-	-	-	-	-	-	0	-	0
Bighead Carp (N)	-	-	-	-	-	-	-	0	-	0
Silver Carp (N)	-	-	-	-	-	-	-	0	-	0
CPUE (fish/net-day)	-	-	-	-	-	-	-	72.6	-	72.6

Strategy for eDNA Sampling in the CAWS

Kelly Baerwaldt, Jenna Merry, and Emy Monroe
(U.S. Fish and Wildlife Service)

Participating Agencies: U.S. Fish and Wildlife Service (Midwest Fisheries Center and Carterville Fish and Wildlife Conservation Office, Wilmington Sub-Station)

Introduction and Need:

Monitoring with multiple gears in the CAWS has been essential to determine the effectiveness of efforts to prevent self-sustaining populations of Asian carp from establishing in the Great Lakes. Environmental DNA (eDNA) has been used as a surveillance tool to monitor for genetic presence of Bighead Carp and Silver Carp in the Chicago Area Waterway System (CAWS) since 2009. To maintain vigilance above the Electric Dispersal Barrier, eDNA has been collected annually at four regular monitoring sites. eDNA results no longer consdidered a trigger for any kind of response for the Monitoring and Response Plan beginning in 2013.

Objectives:

Sample Asian carp DNA in targeted areas of the CAWS to maintain vigilance above the Electric Dispersal Barrier.

Project Highlights:

- Two eDNA sampling events took place in the CAWS at targeted off-channel and shoreline locations in 2018, resulting in 284 samples collected and analyzed in May and 282 in October.
- Results: In May there were zero positive detection for both species of Asian carp DNA. In October two samples were positive for Silver Carp DNA and one sample was positive for both Silver and Bighead Carp DNA.

Methods:

The CAWS was sampled for eDNA of Bighead Carp and Silver Carp in May and October 2018. The May event immediately preceded the June Seasonal Intensive Monitoring event in the CAWS. eDNA sampling in the fall was intended to precede the September Seasonal Intensive Monitoring event, however significant rainfall just prior to the September event caused the event to be postponed until October (Figure 1). Discharge values were monitored using the USGS gage 05536890 Chicago Sanitary and Ship Canal RN Lemont, IL (https://waterdata.usgs.gov/nwis/uv?site_no=05536890). This gage is located just downstream of the confluence of the CSSC and Cal-Sag Channel (41.691389, -87.964444) and was selected because discharge is measured multiple times daily at this location and it represents a bottleneck of flow from multiple areas of the CAWS.

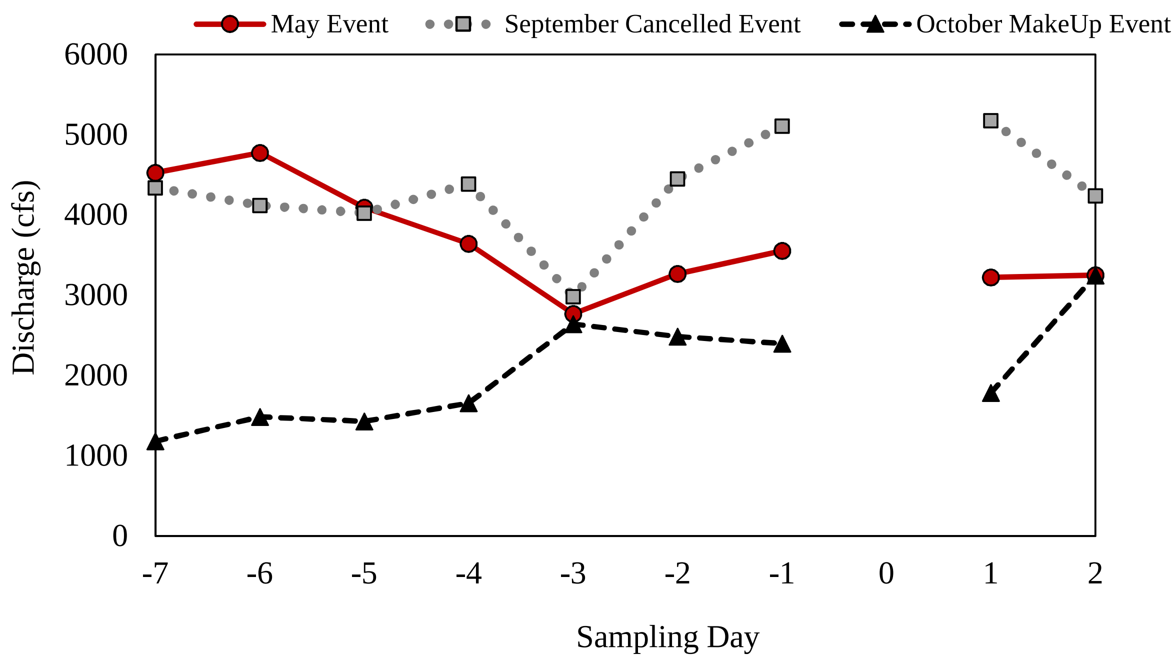

Figure 1. *Average daily discharge (cubic feet per second) for the Chicago Sanitary and Ship Canal at Lemont, IL during (Sampling Day 1 and 2) and seven days prior to (Sampling Day -7 through -1) two completed and one cancelled eDNA collection events in 2018. Flow data were modified from USGS National Water Information System, USGS gage 05536890 Chicago Sanitary and Ship Canal RN Lemont, IL (https://waterdata.usgs.gov/nwis/uv?site_no=05536890). Negative values were removed from the October dataset before being used in this figure. USGS warns data for October are still provisional data and are subject to final revision after their internal review and approval processes are complete.*

Similar to previous years, sample collection and processing followed the Quality Assurance Project Plan (QAPP) (http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf).

During the May sampling event in the CAWS, a USFWS crew collected 284 samples from targeted off-channel and depositional shoreline areas of various locations in the CAWS (Table 1). During the October event, the sampling design was concentrated even more into off-channel areas and fewer shorelines were sampled compared to the May event. Samples were preserved with ethanol until they were delivered to Whitney Genetics Lab (WGL) for analysis. The state of Illinois was notified of results from the CAWS following our Communication Protocol (http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf) after sample processing was complete. Results for these two events were then posted online.

Strategy for eDNA Sampling in the CAWS

Table 1. *Total number of samples collected in targeted areas of the Chicago Area Waterway System (CAWS) during May and October 2018.*

	Samples Collected	
Location	May	October
Chicago Sanitary Ship Canal	23 (25*)	18 (20*)
S Branch Chicago River	47 (51*)	51 (56*)
Chicago River	31 (33*)	30 (33*)
N Branch Chicago River	35 (38*)	35 (38*)
Little Calumet River	79 (87*)	63 (69*)
Calumet River	25 (28*)	41 (46*)
Lake Calumet	44 (48*)	44 (49*)
Total	284 (310*)	282 (311*)

**Cooler blanks (field controls) included in number of samples collected*

Results and Discussion:

Of the 284 eDNA samples (250 ml each) collected upstream of the Electric Dispersal Barrier in May, zero samples were positive for either Silver Carp or Bighead Carp DNA (Figure 2). Of the 282 samples collected in October, two samples were positive for Silver Carp DNA and one was positive for both Silver and Bighead Carp DNA. All eDNA results are available at: http://www.fws.gov/midwest/fisheries/eDNA/Results-chicago-area.html. All three positive samples in October occurred in the same barge slip located on the Chicago Sanitary and Ship Canal (Figure 3).

Strategy for eDNA Sampling in the CAWS

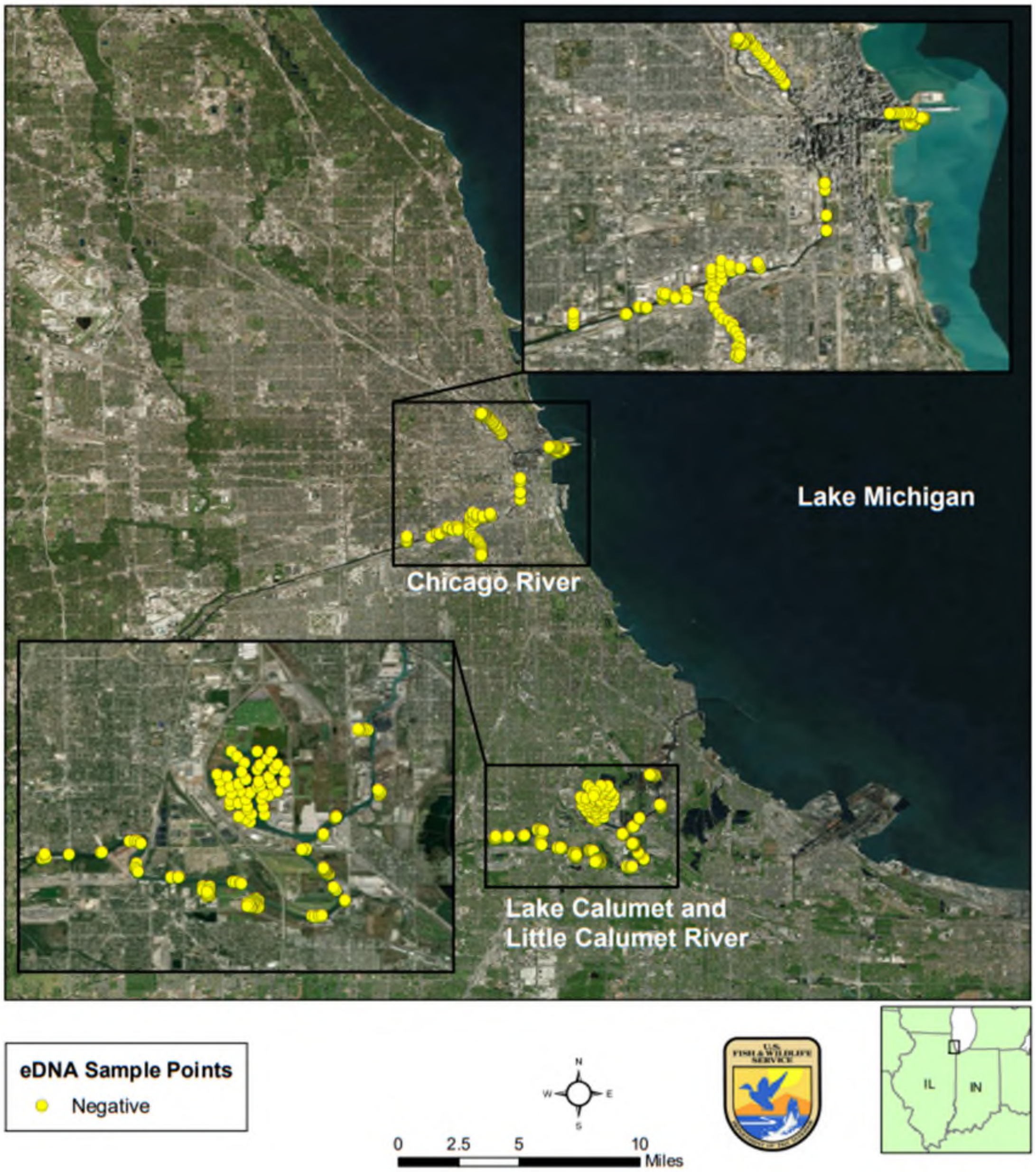

Figure 2. *Sample locations and detection results for Asian Carp eDNA samples collected in the Chicago Area Waterway System (CAWS) in May 2018.*

Strategy for eDNA Sampling in the CAWS

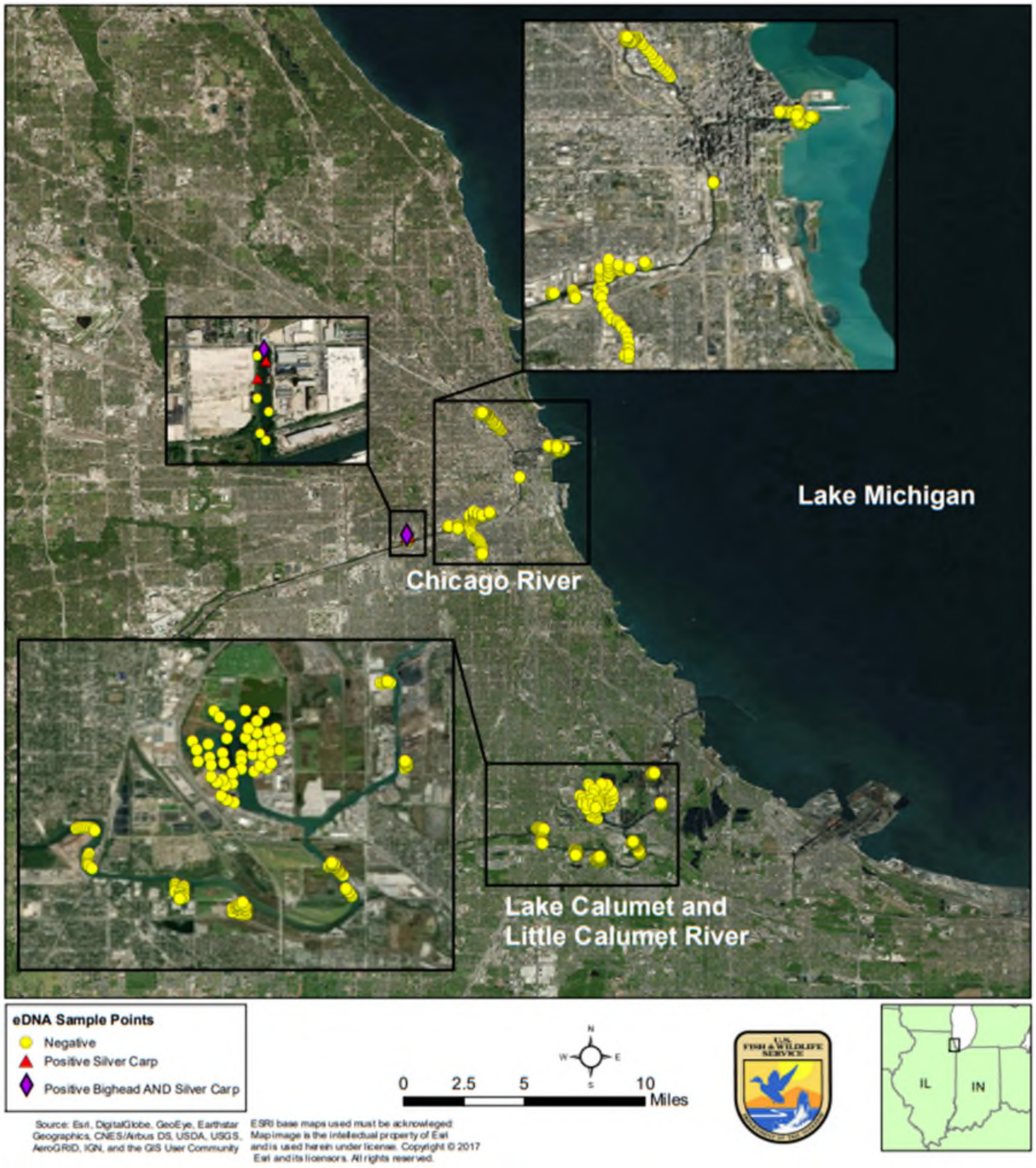

Figure 3. *Sample locations and detection results for Asian carp eDNA samples collected in the Chicago Area Waterway System (CAWS) in October 2018.*

Strategy for eDNA Sampling in the CAWS

These results are consistent with the results of previous years showing few to no detections in these areas indicating a low baseline level of eDNA. These scant baseline levels have remained consistent over the past four years and reflect the use of improved eDNA markers, the change to clean nets by commercial fishers in 2013, and additional equipment decontamination protocols implemented since that time. A steady baseline over the past four years along with the low number of Asian carp captures by other methods indicate that there is likely not a large population of Asian carp residing above the Electric Dispersal Barrier in the CAWS. The concentration of three positive detections in same barge slip is worth noting, however. While there is no way to confirm with eDNA results that a live fish was present in this slip, it is possible. It is also possible that a carcass or other material from an Asian carp was deposited in this slip by a barge travelling from carp-infested waters downstream. In June 2017, a silver carp was captured by commercial fishermen in a marina adjacent to the Little Calumet River. This waterbody connects to the CSSC via the Cal-Sag Channel and there could be a small number of Asian carp residing in the system that are otherwise undetected due to their rare abundance.

Recommendation:

In order to maintain vigilance within the CAWS, USFWS recommends continued eDNA sampling in the targeted areas sampled in October 2018, which focused on slack-water areas, barge slips, marinas, near-shore habitats, etc. The goal of using eDNA in the CAWS is to apply a monitoring tool that has a much lower false negative (fail to detect eDNA that is present) rate than other monitoring methods, which can help provide a balanced and more complete monitoring program in the CAWS. To be clear, the rate of false negative results for eDNA monitoring is controlled by the sensitivity of the genetic assay, quality control measures employed, sample handling procedures, and sampling efficiency. The current FWS eDNA monitoring program has been critically evaluated by external reviewers and found to employ more than adequate quality control measures to have low, or near zero false negative rates from method failure and methods have been experimentally and systematically modified since 2013 to improve sensitivity and sampling efficiency. Thus, eDNA surveillance with the current protocols can be considered to have low false negative rates. Current eDNA methods used by the FWS have some level of a false positive rate where the DNA detected could be from persistence of Asian carp eDNA or from an alternate vector, but the methods employed are specific and use more than enough quality control measures to avoid false positive results from non-target species DNA or contamination. Thus, eDNA is only enhancing monitoring efforts in the CAWS. It is also recommend to discontinue the scheduling of sampling events preceding the Seasonal Intensive Monitoring events and instead sample when the flow and temperature are optimal for eDNA retention and detection (e.g. early spring prior to Asian carp spawning temperature and late fall when flow is low). Care will be taken to avoid sampling during periods of high flows, since high flows likely push eDNA rapidly downstream, and high water temperatures because eDNA degrades more quickly at increased temperatures.

Larval Fish Monitoring in the Illinois Waterway

Steven E. Butler, Scott F. Collins, Joseph J. Parkos III, David H. Wahl (Illinois Natural History Survey), Samuel J. Schaick, Kellie Hanser, Cassi J. Moody-Carpenter, Eden L. Effert-Fanta, Robert E. Colombo (Eastern Illinois University)

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

Pools Involved: Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, and LaGrange Pools and adjacent backwater lakes; Kankakee, Fox, Mackinaw, Spoon, and Sangamon Rivers

Introduction and Need:

Factors affecting the early life stages of fish strongly influence recruitment to adult populations. An evaluation of Asian carp reproduction and recruitment in different sections of the Illinois Waterway is needed to better understand Asian carp population dynamics and the spatial distribution of various life stages within this system. Asian carp eggs are semibuoyant and drift in river currents for approximately a day before hatching. Larvae continue to drift for an additional period of time before settling into nursery areas outside of the main channel. Prior to 2015, larval and juvenile Asian carp had only been collected in the Alton, La Grange and Peoria Pools of the Illinois River, and the potential for Asian carp reproduction in upstream reaches of the Illinois Waterway was unknown. Observations of eggs, larvae, and juveniles in the upper Illinois River during 2015 - 2017 indicate that some reproduction and potential recruitment 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. Reproduction and recruitment are known to be highly variable among years in the Illinois Waterway, but factors influencing this variation are still poorly understood. Asian carp spawning also appears to occur in some years in smaller tributary rivers, but the frequency of spawning in these systems, or the contribution of these rivers to basin-wide Asian carp populations is not known. Information on the spatial and temporal distribution of Asian carp eggs and larvae will help to identify adult spawning areas, determine reproductive cues, and characterize relationships between environmental variables and survival of young Asian carp. This understanding will aid in evaluating the potential for these species to further expand their range in the Illinois Waterway, and may also be useful for designing future control strategies that target Asian carp spawning and exploit the early life history of these species.

Objectives: Larval fish sampling is being conducted to:

(1) Identify locations and timing of Asian carp reproduction in the Illinois Waterway;

(2) Monitor for Asian carp reproduction in the CAWS; and

(3) Determine relationships between environmental variables (e.g., temperature, discharge, habitat type) and Asian carp reproduction and recruitment.

Project Highlights:

- 782 ichthyoplankton samples were collected from 12 sites across the length of the Illinois Waterway during April – October 2018, capturing over 86,000 larval fish, including over 51,000 larval Asian carp. Over 72,000 Asian carp eggs were collected in 2018. These numbers of Asian carp eggs and larvae are comparable to those observed during 2015 and 2017, when Asian carp reproductive output was also very high relative to other study years.
- Asian carp eggs and larvae were only present in the Illinois River for a brief time period in 2018, with a large spawning event evident during the last week of June. Water temperature and change in water level appear to be the strongest predictors of the magnitude of Asian carp reproductive output in the Illinois River. However, larval Asian carp densities are poor predictors of future juvenile Silver Carp abundances, indicating that large spawning events do not always lead to successful recruitment.
- Asian carp eggs were collected in the LaGrange, Peoria, and Starved Rock pools during 2018. Asian carp larvae were only identified from the LaGrange and Peoria pools. Across 9 years of sampling, only a handful of Asian carp larvae have ever been observed upstream of the Starved Rock Lock and Dam, suggesting that the majority of eggs spawned in the upper river are transported into downstream navigation pools before hatching.
- Asian carp eggs or larvae were not observed in the Kankakee or Fox Rivers, but larvae were collected from the Mackinaw, Spoon, and Sangamon Rivers during 2018. Especially large numbers of Asian carp larvae were found in the lower Sangamon River during early July.

Methods:

Larval fish sampling occurred at 12 main channel and backwater sites throughout the Illinois Waterway during 2018 (Figure 1). Additional sampling took place in five tributary rivers (Kankakee, Fox, Mackinaw, Spoon, and Sangamon rivers). Sampling occurred weekly from April to early July, and biweekly from late July to October. At main channel sites, four larval fish samples were collected at each site on each sampling date. Sampling transects were located on each side of the river channel, parallel to the bank, at both upstream and downstream locations within each study site. For backwater sites (Lily Lake in LaGrange Pool, Hanson Material Services Pit in Marseilles Pool), samples were collected at both backwater and adjacent main channel locations. Samples are collected using a 0.5 m diameter ichthyoplankton push-net with 500 µm mesh. To obtain each sample, the net was pushed upstream using an aluminum frame mounted to the front of the boat. Boat speed was adjusted to obtain 1.0 – 1.5 m/s water velocity through the net. Flow was measured using a flow meter mounted in the center of the net mouth and was used to calculate the volume of water sampled. Fish eggs and larvae were collected in a meshed tube at the tail end of the net, transferred to sample jars, and preserved in 90-percent ethanol. The Kankakee and Fox Rivers were sampled at sites below the furthest downstream dam on each river. Upstream, mid-river, and downstream sites were sampled on the Mackinaw, Spoon, and Sangamon rivers. Three samples (one mid-channel and one on each side of the channel) were taken at each tributary site on each sampling date. Downstream locations were sampled with the same boat-mounted push-net method used for main-channel sites, and all sites were sampled using stationary drift-nets. Larval fish were identified to the lowest possible taxonomic unit in the laboratory. Fish eggs were separated by size, with all eggs having a membrane diameter larger than 4 mm being identified as potential Asian carp eggs and retained for later genetic analysis. Larval fish and egg densities were calculated as the number of individuals per cubic meter of water sampled.

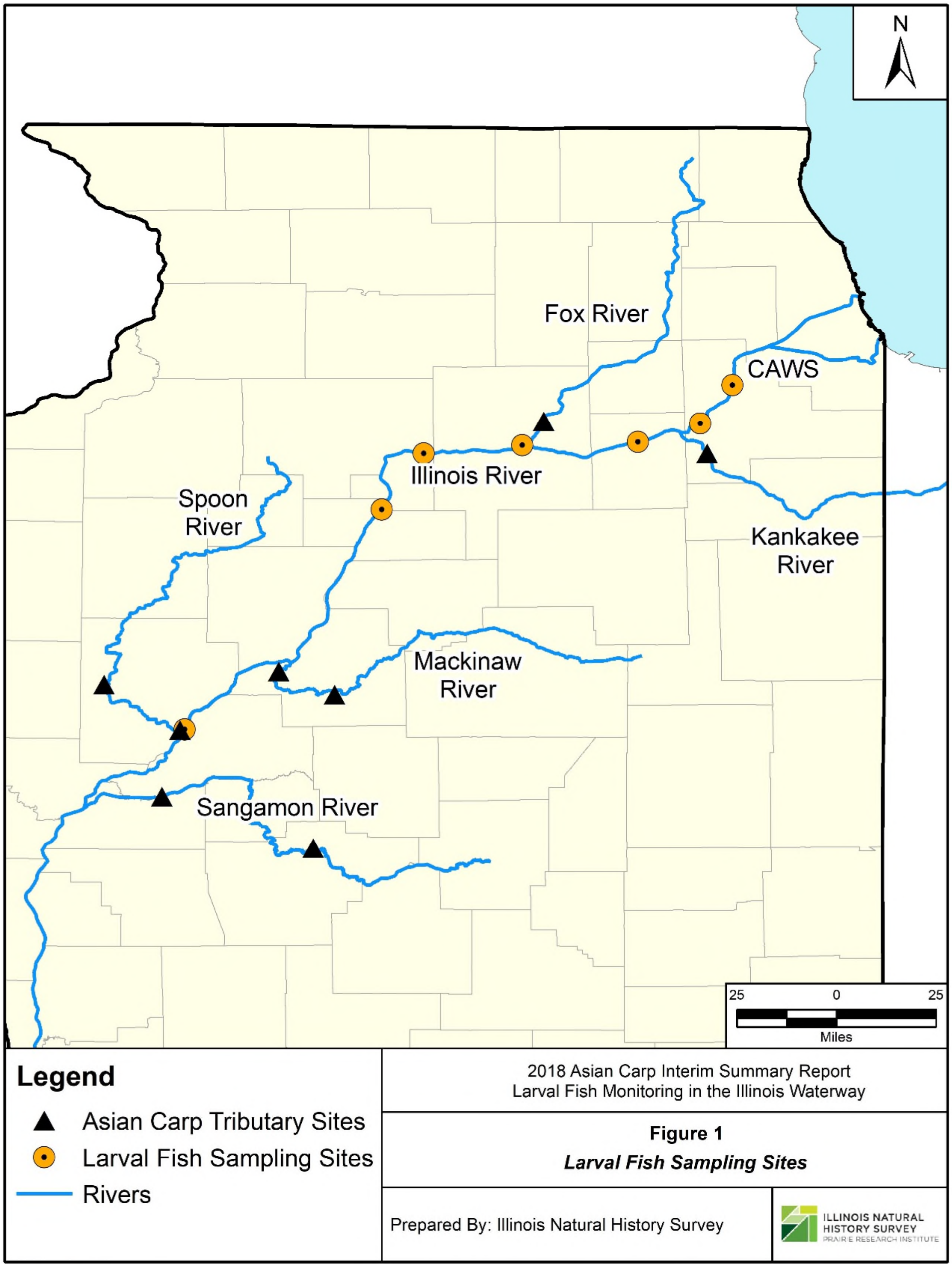

Figure 1. *Map of ichthyoplankton sampling sites in the Illinois Waterway. Sites on the main channel and backwaters of the Illinois Waterway are represented by circles. Sites in Illinois River tributaries are represented by triangles.*

Larval Fish Monitoring in the Illinois Waterway

Results and Discussion:

In 2018, a total of 782 ichthyoplankton samples were collected from main channel and backwater sites of the Illinois Waterway. From these, over 86,000 larval fish have been identified, including over 51,000 larval Asian carp. Additionally, over 72,000 Asian carp eggs were collected in 2018. These numbers of Asian carp eggs and larvae are comparable to those observed during 2015 and 2017, when Asian carp reproductive output was also very high relative to other study years (Table 1). Asian carp eggs and larvae were only present in the Illinois Waterway for a brief time period in 2018 (Figure 2, 3). Small numbers of Asian carp larvae were found in the LaGrange Pool during the first three weeks of June 2018. Asian carp appear to have had a very large spawning event during the last week in June, when extremely high densities of eggs were observed at all sites from the Starved Rock Pool to the upper LaGrange Pool. High densities of Asian carp larvae were also present in the Peoria and upper LaGrange Pools at this time. Small numbers of Asian carp larvae continued to be collected in the lower LaGrange Pool through early July, followed by very large numbers of juvenile Silver Carp captured during gear evaluation sampling in late July (see Evaluation of Gear Efficiency, Young-of-Year and Juvenile Asian Carp Monitoring summaries). No Asian carp eggs or larvae were collected at any site after July in 2018. No Asian carp eggs were collected upstream of the Starved Rock Pool, and no Asian carp larvae were collected upstream of the Peoria Pool during 2018.

Table 1. *Dates, effort, and number of larval fish captured during ichthyoplankton sampling activities on the Illinois Waterway during 2010 – 2018.*

Year	Sampling Dates	# Samples	# Larval Fish	# Asian Carp Larvae	# Asian Carp Eggs
2010	Jun 3 – Oct 2	240	2,050	78	-
2011	Apr 27 – Oct 13	560	7,677	2	-
2012	May 1 – Oct 19	722	28,274	490	-
2013	April 30 – Oct 9	614	30,101	327	-
2014	April 30 – Sep 29	558	18,572	5,231	19,704
2015	April 27 – Oct 15	558	79,113	62,170	71,367
2016	April 27 – Sep 28	744	19,513	2,064	7,183
2017	April 26 – Oct 18	820	113,516	58,541	38,805
2018	April 24 – Oct 2	782	86,577	51,125	72,646

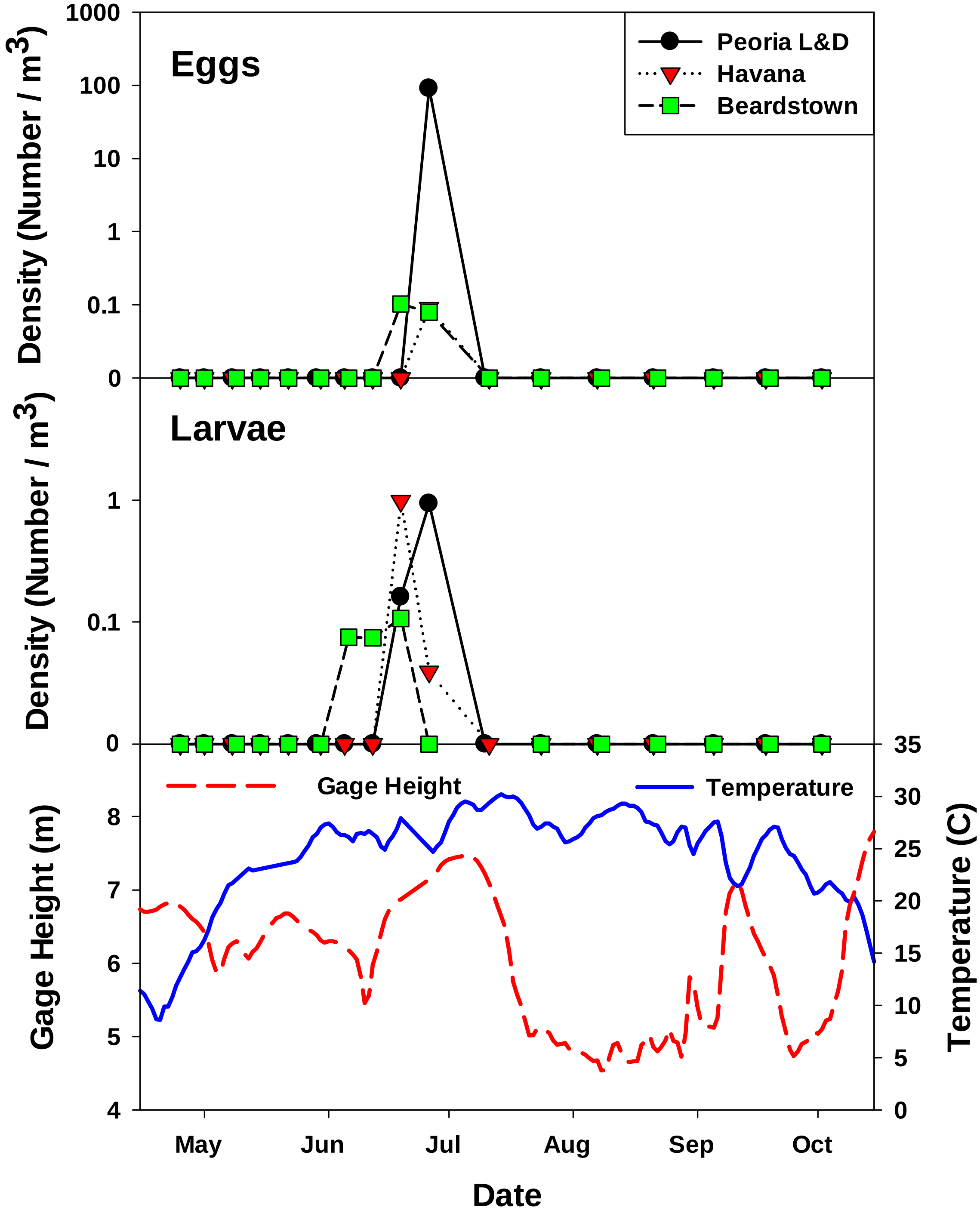

Figure 2. *Densities (number / m^3; note log scale) of Asian carp eggs (top panel) and larvae (middle panel) collected from main channel sites in the LaGrange Pool of the Illinois Waterway during 2018. Mean daily gage height (m) and water temperature (° C) of the Illinois River during April – October 2018 (bottom panel) were obtained from USGS hydrograph 5586300 at Florence, IL.*

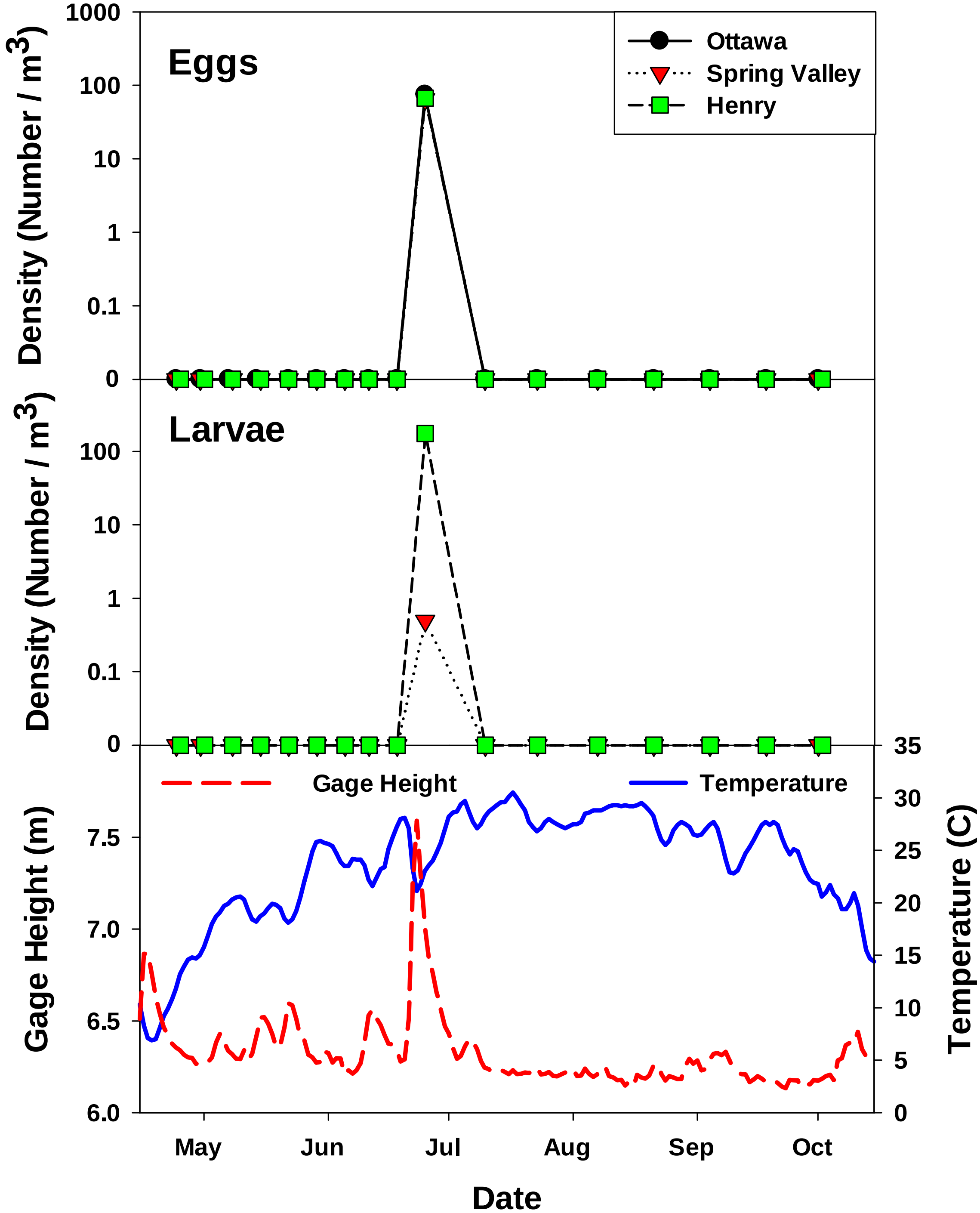

Figure 3. *Densities (number / m^3; note log scale) of Asian carp eggs (top panel) and larvae (middle panel) collected from main channel sites in the Starved Rock and Peoria Pools of the Illinois Waterway during 2018. Mean daily gage height (m) and water temperature (° C) of the Illinois River during April – October 2018 (bottom panel) were obtained from USGS hydrograph 5543010 at Seneca, IL.*

Larval Fish Monitoring in the Illinois Waterway

During 2018, water temperatures throughout the Illinois River were generally above the 18°C threshold thought to be suitable for Asian carp spawning from May until late September. However, the timing of water level changes differed considerably between the upper and lower Illinois River, apparently contributing to differences in the timing of Asian carp reproduction. Collections of Asian carp larvae in the LaGrange Pool followed a prolonged rise in discharge that began in the lower Illinois River in early June and continued into July (Figure 2). In contrast, a substantial increase in river stage in the upper Illinois River only occurred for a brief period during the last week in June, coinciding with the large spawning event that contributed the majority of the Asian carp eggs and larvae collected in 2018 (Figure 3). Asian carp spawning is generally thought to be linked to a rising hydrograph when water temperatures are above 18°C. Indeed, the largest numbers of eggs and larvae collected in the Illinois River in 2014 – 2018 were associated with at least modest increases in discharge at temperatures above 20°C. Some collections of eggs and larvae in previous study years have been associated with steadily declining hydrographs, suggesting that environmental conditions that influence Asian carp spawning are more complicated than currently understood. Nonetheless, preliminary results from both multiple regression and classification and regression tree analyses suggest that temperature and change in water level are the strongest predictors related to the magnitude of Asian carp reproductive output in the Illinois River. These variables alone, however, although suggestive of the proximate mechanisms that affect the timing of Asian carp spawning, do not fully account for variation in Asian carp reproductive productivity in this system.

A variety of factors, from stock composition to environmental conditions, can affect the reproductive potential of a particular stock density. Given the substantial differences in habitat conditions, hydrology, and Asian carp stock abundance among different pools in the Illinois Waterway, factors influencing variation in reproductive output may vary among navigation pools through time. By greatly reducing adult densities, the Asian carp removal strategy that has been implemented in the upper Illinois Waterway may reduce the reproductive potential of Asian carp populations in these pools. Alternately, decreased Asian carp densities could increase the growth, condition, and reproductive potential of remaining individuals (Coulter et al. 2018). Egg densities have been higher in the Starved Rock Pool in recent years compared to the early years of the Asian carp removal program (Figure 4), but additional analyses are required to disentangle the influences of spawning stock abundance and environmental factors on reproductive output. Furthermore, the relationship between reproductive output and recruitment may be affected by numerous biotic and abiotic factors, creating a substantial challenge for understanding Asian carp recruitment processes and conditions that ultimately influence year-class strength. Previous research has noted that sometimes conditions well-suited for Asian carp reproduction fail to produce large numbers of recruits (Gibson-Reinemer et al. 2017). Indeed, larval Asian carp density is a poor predictor of future juvenile Silver Carp relative abundance, with years with very large spawning events sometimes failing to produce many juveniles (Figure 5). Although reproduction is obviously a prerequisite for successful recruitment, the conditions that lead to high reproductive output are not necessarily the same conditions that contribute to high levels of recruitment.

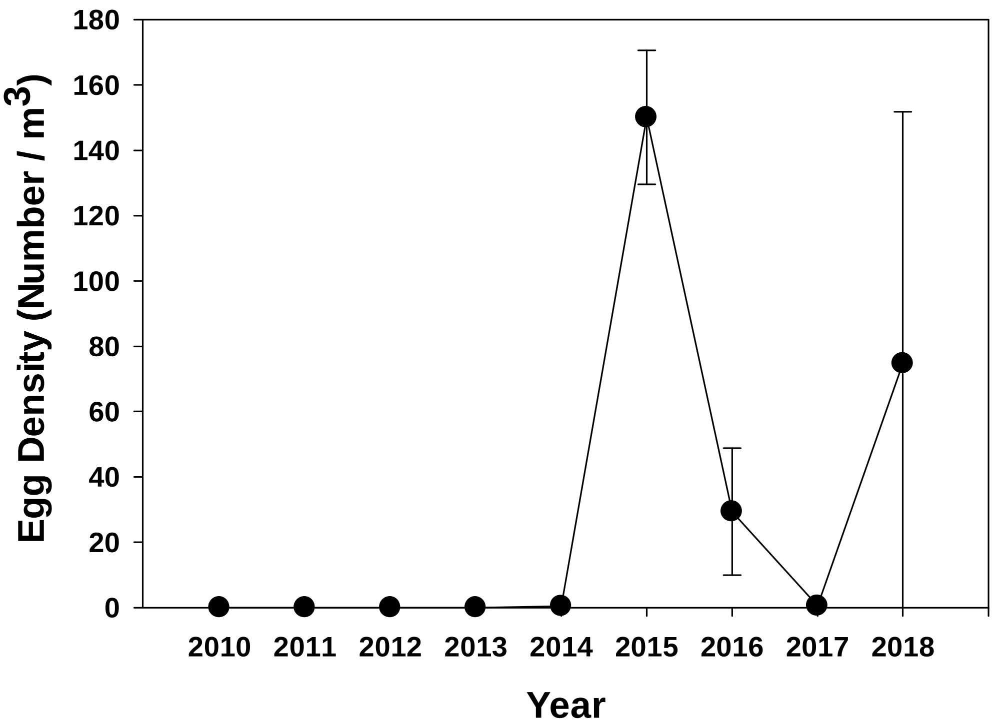

Figure 4. *Peak densities (number / m^3; ± SD) of Asian carp eggs collected from the Starved Rock Pool of the Illinois River during 2010 - 2018.*

Asian carp reproduction has been documented from the upper Illinois River in every year since 2015. Other than three larvae collected from the Dresden Island Pool in 2015, only eggs have been observed upstream of Starved Rock Lock and Dam, although numerous larvae have been collected at Spring Valley, only 20 km downstream of Starved Rock. These observations suggest that the majority of eggs produced in the upper Illinois River are likely transported downstream of the Starved Rock Lock and Dam before hatching. The upper Illinois River has a higher gradient and shorter water residence times than the lower river, potentially not providing sufficient time for eggs that are spawned in the upper navigation pools to develop and hatch before being transported into the Peoria Pool. However, this does not preclude the possibility that under certain combinations of temperature and discharge, some eggs produced in the upper-most pools could hatch and larvae be present upstream of Starved Rock. Hydrodynamic modelling 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). Further modelling efforts examining transport of eggs from these known spawning areas under various temperature and discharge conditions may reveal the probability of eggs hatching and larvae potentially settling within the upper pools of the Illinois River. The potential for eggs or larvae to be retained in side channels, backwaters, or other off-channel areas of the upper Illinois River, or for eggs or larvae to be entrained and transported by barges also warrants further investigation.

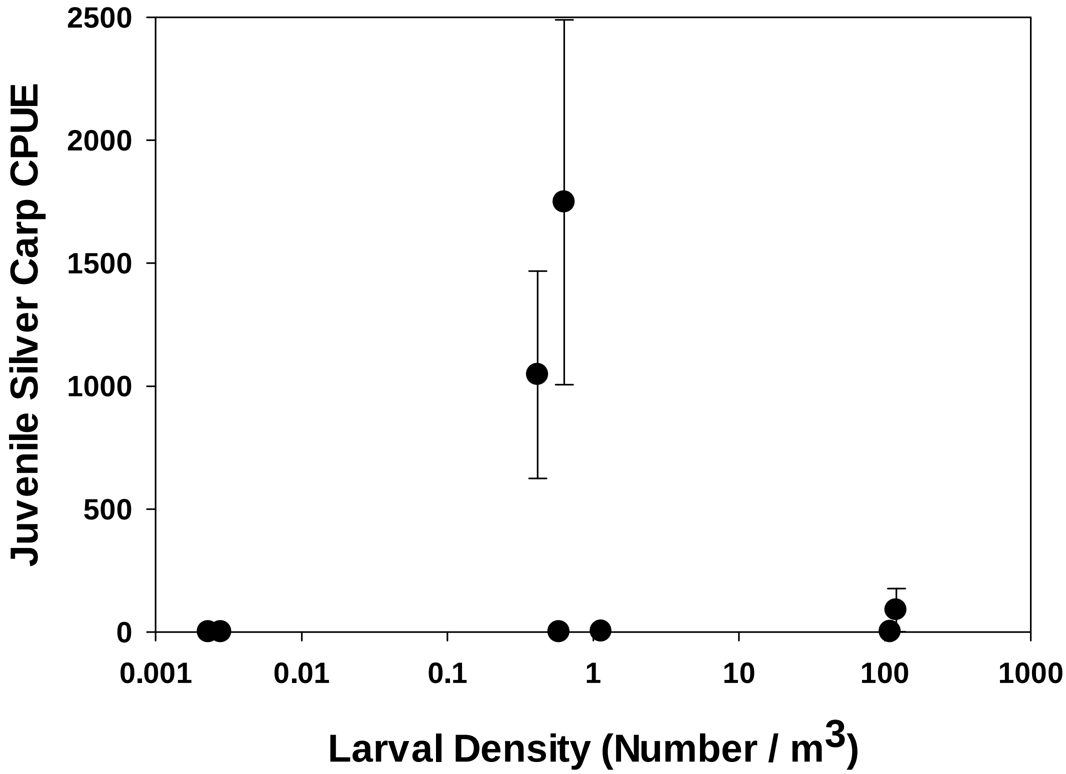

Figure 5. *Mean catch-per-unit-effort (CPUE; number / net-night) of juvenile Silver Carp captured during summer sampling with mini-fyke nets in the LaGrange Pool of the Illinois River (see Evaluation of Gear Efficiency summary) in relation to peak densities (number / m^3; note log scale) of Asian carp larvae collected from the LaGrange Pool of the Illinois River during each year from 2010 - 2018.*

Ichthyoplankton sampling in Illinois River tributaries during 2018 collected 222 push-net samples and 285 drift-net samples, capturing 5,812 total larval fish, including 4,469 Asian carp larvae. No Asian carp eggs or larvae were collected from the Kankakee or Fox Rivers during 2018. However, Asian carp larvae were observed in all other tributaries, with 5 specimens collected from the Mackinaw River, 276 from the Spoon River, and 4,188 from the Sangamon River. The majority of all Asian carp larvae collected from tributaries in 2018 came from the lower Sangamon River on July 2, when 4,184 larvae were collected. Analyses of environmental factors influencing the timing and magnitude of Asian carp spawning in tributary rivers across years, factors contributing to differences in the production of Asian carp eggs and larvae among different tributaries, and evaluation of the contribution of tributaries to basin-wide Asian carp population growth are ongoing.

Recommendation:

Ichthyoplankton sampling should continue to evaluate Asian carp reproduction, particularly upstream of the Peoria Pool, to monitor for any changes in the Asian carp reproductive front and to evaluate the effects of Asian carp harvest activities on the reproductive potential of these populations. Evaluating the relationship between adult stock abundance and reproductive productivity, and the influence of environmental conditions on this relationship, will help to provide an understanding of the level of harvest that may reduce population growth rate. Hydrodynamic modelling of the Illinois Waterway and reverse-time particle tracking have indicated several Asian carp spawning areas in the upper Illinois River. Targeting these areas for removal efforts or developing methods to disrupt Asian carp spawning activities would be warranted to further reduce the number of Asian carp in these pools and to diminish the reproductive potential of these populations. Further modelling efforts should be pursued to provide a robust understanding of Asian carp spawning locations throughout the Illinois River, and to understand where Asian carp larvae spawned in each navigation pool are likely to settle out of the drift under different flow conditions. Continued ichthyoplankton sampling in tributary rivers (Sangamon, Spoon, Mackinaw, Fox, and Kankakee rivers) is also warranted to examine the potential for these systems to serve as sources for Asian carp populations in the Illinois Waterway, and to evaluate the potential for similar rivers in the Great Lakes region to serve as spawning tributaries.

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

Cory Anderson and Rebecca Neeley, USFWS Carterville FWCO Wilmington

Participating Agencies: U.S. Fish and Wildlife Service Carterville FWCO Wilmington Substation

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

Introduction and Need:

Silver Carp (*Hypophthalmichtys molitrix*) and Bighead Carp (*Hypophthalmichtys nobilis*) have been expanding in population and dispersing upstream in the Mississippi River basin since the 1970s and have become established in the Illinois River. Invasive Silver and Bighead Carp pose a significant threat to fisheries in the Great Lakes by competing with economically and recreationally important fish species for limited plankton forage resources. Populations of these fish now threaten to enter Lake Michigan through the upper Illinois Waterway (IWW) with the most probable pathways being the Chicago Sanitary and Shipping Canal or the Calumet River (Kolar et al. 2007). An Electric Dispersal Barrier operated by the U.S. Army Corps of Engineers (USACE) in the Lockport Pool is intended to block the upstream passage of Silver and Bighead Carp through these IWW pathways.

Laboratory tests have shown the Electric Dispersal Barrier is sufficient at stopping large-bodied fish from passage, however, tests using small Bighead Carp (51 to 76 mm Total Length (TL)) indicated that the operational parameters of the barrier may be inadequate for blocking small fish passage (Holliman et al. 2011). U.S. Fish and Wildlife Service (USFWS) research indicated that Golden Shiners (*Notemigonus crysoleucas*) can be entrained in barge junction gaps and transported through the Electric Dispersal Barrier. Other research by USFWS using Dual Frequency Identification Sonar (DIDSON) indicated that small fish (unknown species) are transported upstream through the barrier by return water current during downstream barge movement. These studies show that if Silver and Bighead Carp are present near the Electric Dispersal Barrier these fish may able to breach the barrier through multiple methods. For this reason, there is a critical need to monitor the distribution of juvenile Silver and Bighead Carp below the Electric Dispersal Barrier. Additionally, a need is present to understand the reproduction, demographics, and habitat usage of these fish in the IWW so small fish may be targeted for eradication or other management actions.

The purpose of this study is to determine the spatial distribution of small Silver and Bighead Carp in the IWW through intensive, targeted sampling. Silver and Bighead Carp specimens ≤153 mm TL (6 inches) are considered "small" based on discussions within the Monitoring and Response Working Group and will be the primary focus of this monitoring due to the operational weaknesses of the Electric Dispersal Barrier. Any Silver or Bighead Carp found smaller than 400 mm TL will be considered juvenile based on previously published research on growth and maturity (Williamson and Garvey 2005). Due to variability in intrapopulation growth rates, it is important to monitor the behavior of juvenile Silver and Bighead Carp as some individuals may represent young fish with accelerated growth. A variety of techniques were used in 2018, including: traditional boat electrofishing, tandem and single mini-fyke nets, and dozer trawl.

Objectives:

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

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

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

Project Highlights:

- No small Silver Carp (≤ 153 mm TL) were found above the Starved Rock Lock and Dam during the 2017 field season, however, one individual was caught in Peoria Pool near Lacon, Illinois.
- One juvenile Silver Carp (222 mm TL) was found in Starved Rock Pool during 2018 field sampling efforts.

Methods:

Sampling site selection was conducted in two ways: stratified-random generated sites and "general" sites chosen at crew leader's discretion. Starting this year, in an effort to sample non-routinely visited areas, a series of 18 random sites were generated for Marseilles and Starved Rock pools, during spring, summer, and fall seasons (54 total in each pool). Six random sites were generated in each season for each habitat strata: backwater, side channel, and main channel habitats (18 total). The ratio of sites in each habitat area is subject to change based on data gathered of habitat usage of juvenile Silver Carp studied with telemetry. These random sites were fished using boat electrofishing for 15 minutes, similar to general sampling procedures. During general sampling, locations were chosen at the crew leaders discretion based on best area to deploy gear, water quality conditions, and historically captured small Silver or Bighead Carp.

Physical characteristics and water quality measurements were made at each collection site and included: secchi depth, depth, substrate type (i.e, boulder, cobble, gravel, sand, silt, and clay), temperature, specific conductivity, and dissolved oxygen. Water quality measurements were taken using an YSI Professional Series multi-meter. Additionally, GPS coordinates and time stamps were recorded at the start and end of each electrofishing event, trawl run, and mini-fyke net set.

During random site sampling all fish over 100mm in total length were measured for total length (TL) in millimeters and weighed to the nearest gram. During general sampling all Bighead, Silver, and Grass Carp were measured for TL (mm) and weighed (g). Any other species were tallied and released to increase processing speed. If a small Silver or Bighead Carp had been captured, all fish at that site would be measured for TL (mm) and weighed (g) to provide bycatch information. Any fish not easily identified in the field was preserved in Excel Plus or 70% EtOH for laboratory identification to the lowest possible taxonomic level. Effort was quantified as net nights (mini-fykes) or minutes of electrofishing (boat electrofishing and dozer trawl) (Table 1).

Gear Descriptions:

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

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

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

Results and Discussion:

During the 2018 field season, no small (≤153 mm TL) Silver or Bighead Carp were captured upstream of the Starved Rock Lock and Dam, however, a juvenile Silver Carp (TL 222mm) was captured just upstream of Starved Rock Lock and Dam in Starved Rock Marina on May 14 (Table 2). Only one small Silver Carp was caught in Peoria Pool, from Lacon, IL on September 5 (Table 2).

Efforts during 2018 focused heavily on the Marseilles, Dresden, and Starved Rock pools (Table 3) as no small Silver and Bighead Carp were caught upstream of Peoria during 2017. Field crews were instructed to sample more main channels and side channels than prior years rather than solely sampling backwaters and marinas based on preliminary results of juvenile Silver and Bighead Carp telemetry. Less effort was put into Brandon Road and Lockport pools than prior years in favor of sampling closer to the dense populations of adult Silver and Bighead Carp. If juvenile Silver and Bighead Carp had been captured in Marseilles Pool, more effort would have been put into the upper pools. Sampling in Peoria Pool was only conducted as part of collecting fish for tagging for the Habitat use and movement of juvenile Silver Carp project and support for the SEAcarP model.

The most common species captured during all of 2018 sampling were: Gizzard Shad (*Dorosoma cepedianum*) (n = 17,630), Emerald Shiner (*Notropis atherinoides*) (n = 3,700), Silver Carp (n = 1,359 including juveniles), Smallmouth Buffalo (*Ictiobus bubalus*) (n = 1,135), and Bluegill (*Lepomis macrochirus*) (n = 1,123) (Table 4). The large relative abundance of adult Silver Carp, pelagic minnow species and Gizzard Shad from 2018 sampling efforts indicates fishing is effective for these species with similar capture locations as juvenile Silver Carp.

Recommendations:

Monitoring for the distribution (the leading edge) abundance of small Silver and Bighead Carp remains of critical importance based on the operational limitations of the electric barrier. Added knowledge of the life history and habitat usage of juvenile Silver and Bighead Carp remains important to improve capture efficiency and inform management efforts. Monitoring efforts for juvenile and small Silver and Bighead Carp will continue for 2019. The project design has changed from earlier years and will be modified more to have a more standardized approach to selecting sampling sites and operating field equipment. Data from the Habitat use and movement of juvenile Silver carp telemetry project, started by the Carterville FWCO in 2017, will be used to generate random and targeted sampling locations in Dresden Island, Marseilles, and Starved Rock pools. The main goal of this study will be to detect and determine the upstream most location of juvenile Silver and Bighead Carp in the Illinois Waterway downstream of the electric dispersal barrier.

Table 1. *Total effort in number of sites and minutes (net nights for mini-fykes) separated by gear type and habitat strata for all pools sampled during 2018.*

Gear type	Main channel	Side channel	Backwater	Marina	Tributary
Electrofishing (minutes)	1990	385	713	500	240
Electrofishing (n sites)	135	26	50	34	18
Dozer trawl (minutes)	25	20	144	132	25
Dozer trawl (n sites)	4	3	28	26	5
Mini fyke nets (n net nights)	14	1	21	2	12

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

Table 2. *Small Silver carp (≤153mm) and Juvenile Silver carp (≤400mm) caught in 2018 in Starved Rock and Peoria pools.*

	Starved Rock juvenile SVCP	Peoria small SVCP	Peoria juvenile SVCP
Mean (mm)	222	92	335
n	1	1	74
Range (mm)			223-400
Gear	Electrofishing	Electrofishing	Dozer, Electrofishing

Table 3. *Total 2018 sampling effort by river pool and gear type used. Effort is recorded in minutes and number of sites sampled except for mini-fykes, which are recorded in net-nights.*

	Peoria		**Starved Rock**		**Marseilles**	
	Effort	Num. sites	Effort	Num. sites	Effort	Num. sites
Boat Electrofishing	45	5	770	55	1831	123
Dozer Trawl	286	51	40	8	20	4
Mini-Fyke (net nights)	-	14	-	23	-	13
	Dresden Island		**Brandon Road**		**Lockport**	
	Effort	Num. sites	Effort	Num. sites	Effort	Num. sites
Boat Electrofishing	1062	72	60	4	60	4
Dozer Trawl	-	-	-	-	-	-
Mini-Fyke (net nights)	-	-	-	-	-	-

Table 4. *Mean relative abundance, standard error, and total fish count of ten most common fish species from all of 2018 monitoring efforts.*

Species	Mean % Abundance	SE	n
Gizzard Shad	29.24	0.0155	17630
Emerald Shiner	11.45	0.0095	3700
Silver Carp	10.15	0.0118	1354
Smallmouth Buffalo	7.53	0.0070	1135
Bluegill	3.94	0.0045	1123
Bluntnose Minnow	3.25	0.0054	1100
Largemouth Bass	2.85	0.0034	751
Common Carp	2.78	0.0041	516
Spotfin Shiner	1.80	0.0033	434
Spottail Shiner	1.73	0.0032	619

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

Cory Anderson and Rebecca Neeley, USFWS Carterville FWCO Wilmington

Participating Agencies: U.S. Fish and Wildlife Service Carterville FWCO Wilmington Substation

Pools Involved: Peoria

Introduction and Need:

Small Silver Carp (*Hypophthalmichtys molitrix*) represent a greater risk of breaching the Electric Dispersal Barrier System (EDBS) than larger bodied adults due to the negative relationship between body size and electrical immobilization. Results of research by the U.S. Fish and Wildlife Service (USFWS) has also highlighted passive entrainment of small bodied fishes by barges as a weakness of the EDBS. Multiple state and federal agencies have devoted resources to sampling the upper Illinois River to gain insight into the risks that juvenile Silver Carp pose to the Great Lakes. Traditional sampling gears have limitations, including habitat-specific gear efficiency and detection probability, changing environmental conditions, and sparse species distributions. Identifying habitat areas used by juvenile Silver Carp will help to inform monitoring efforts by the USFWS and Illinois Department of Natural Resources focused on detecting juvenile Silver Carp. Also, knowledge of the habitat usage and movement patterns of juvenile Silver Carp when related to environmental factors are invaluable for future management actions.

Objectives:

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

(2) Determine macro-habitat selection based on periods of residency of juvenile Silver Carp.

(3) Test for correlations in movement and habitat selection to a variety of river conditions: temperature, river discharge, average depth of the habitat area.

Project Highlights:

- A total of 72 juvenile Silver Carp in 2017 and 81 in 2018 have been tagged.
- The mean weekly movement distance of juvenile Silver Carp during 2017 was 943.7 m per week.

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

- Percent total residency of juvenile Silver Carp during 2017 was 39.4% in backwaters, 36.0% in the main channel, and 24.6% in the side channels.
- Juvenile Silver Carp residence has correlations with river flow velocity and temperature that are different for each macro-habitat type.

Methods:

Prior to this study, the Peoria Pool was broken into four macrohabitat categories: main channel, side channel, backwater, and marinas. Areas of the river which are dredged to maintain 9 foot depth and where commercial barge traffic is allowed to operate, as well as, their shorelines were termed, "main channels." Parts of the river, which had flowing current but were separated from the main channel by land were termed, "side channels." Any non-flowing water still connected to the river was termed, "backwater." Finally, any non-flowing area connected to the river that had depth maintained for boat traffic through dredging was termed, "marina." The proportion of available habitat (surface area) was calculated from digital raster graphic topographic maps from the Illinois State Geological Survey, ESRI ArcMap 10.2, and U.S. Army Corps of Engineers navigational maps.

Juvenile Silver Carp to be tagged were captured using boat electrofishing and an electrified dozer trawl from the Illinois River near Henry, Illinois and Lacon, Illinois from June 2017 to September 2017. Fish collection focused on marinas, backwaters, and side channels due to the morphology of the river in these areas and gear effectiveness in this part of the river. Following tagging, fish were released in proximity to their capture location. Fish tags used were Vemco V5 ultrasonic transmitters (180 kHz, 0.38 g in water, Vemco Ltd.) and Lotek NTQ-4 radio transmitters (168 mHz, 0.65g in water, Lotek Wireless).

Immediately after capture, fish were held for no more than one hour in an aerated 60 gallon holding tank covered with ¼ inch mesh. In order to maintain as close to sterile conditions as possible, one crewmember was the designated "surgeon" who wore gloves and only handled fish for the process of the incision, tag implantation, and suturing. Another crewmember was responsible for weighing and measuring the fish and recording data. All surgical tools, fish tags, and sutures were soaked in 70% ethanol between surgeries. Only active fish that appeared healthy based on visual observation were selected for surgery. Each fish was measured for total length (mm) and weight (g), assigned a number, and 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 was placed in the mouth of fish to allow them to breathe during surgery. A wet microfiber towel was placed over the head of the fish to keep them calm.

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

Acoustic telemetry equipment was deployed prior to tagging fish. A total of 26 Vemco VR2-W 180kHz (Vemco Ltd) hydrophone receivers were placed from Hennepin, IL to Chillicothe, IL. Eighteen receivers were placed between Hennepin, IL and Chilicothe, IL in main channel constriction areas, backwater lake openings, and side channels. In main channel areas and side channel sets, hydrophones were attached to 3/16 inch stainless steel coated cable that dangled from a float, tethered to a concrete anchor. The anchor was then either tethered to a tree on shore and padlocked or attached to an 800lb Danforth style river anchor using a minimum of 75 feet of cable. Similar deployment methods were used for backwater sets.

Radio telemetry gear was deployed towards the end of the year (beginning September 2017) based on equipment availability. Fish tagging occurred simultaneously with tracking equipment deployment. Ten passive monitoring stations were constructed from the Peoria Lock and Dam to Hennepin, IL at key constriction points and entrances to backwater lakes or side channels. Each monitoring station consisted of a Lotek Wireless SRX800D (Lotek Wireless) datalogging radio receiver, deep cycle 150 AH battery, and solar charge controller placed inside a weatherproof storage box. The equipment was placed a minimum of 15 feet above any flood plain habitat, usually within tree branches to keep it safe from flooding. A solar panel was mounted at similar heights, facing south, at 41 degrees to the ground and connected to the solar charge controller with 12 gauge wire. Two or three 7-element (1.5 meter) Yagi antennas were mounted a minimum of 25 feet above the ground using aluminum mast poles, or strapped to trees, then attached to the SRX800D using coaxial cable. Generally, each site would have one antenna pointed upstream or downstream in the river channel and one antenna pointed into a backwater or side channel habitat so fish can be differentiated depending on which habitat they are in.

Active tracking was not conducted in 2018 due to time limitations with tagging fish and crew limitations. In the future active tracking will be conducted periodically, at least every other month, by boat. Acoustic active tracking will be conducted using a Vemco VR100 (Vemco Ltd.) mobile telemetry receiver unit and 180 kHz underwater hydrophone, mounted to an aluminum pole and attached to the front of the boat. Radio tracking will be conducted using a Lotek SRX800M (Lotek Wireless) mobile radio telemetry receiver unit and a 4-element or 6-element fixed mast Yagi antenna mounted 12 feet above the boat on an aluminum pole, or a 3-element handheld Yagi antenna when fish are in close proximity. Tracking will be conducted by driving at 5 mph or less down the river channel and into each backwater lake, side channel, and marina area, while monitoring for fish detections. Active tracking data will primarily be used to inform field efforts of fish outside of the receiver deployment zone.

Results and Discussion:

A total of 81 juvenile Silver carp were tagged in the Peoria Pool of the Illinois River during 2018, however only 69 survived the tagging process (Table 1). Thirty five of these fish were tagged using both acoustic V5 tags and NTQ radio tags. The fish tagged during November 2018 (n=34) were only tagged using the acoustic V5 tags due to their small size not permitting both tags. All 2018 mortalities were from the November tagging event of the smallest fish. Mean total length of tagged fish was 217 mm and the smallest total length of a tagged Silver carp was 122 mm (Table 1).

Table 1. *2017 and 2018 Juvenile Silver Carp tagged by month, mean TL (mm), mean wt (g), number of fish tagged.*

Date	n tagged	Mean TL (mm)	Mean wt (g)
June 2017	2	232	188
July 2017	40	331	333
August 2017	10	321	253
September 2017	6	277	202
October 2017	14	366	459
2017 Total	**72**	**329**	**331**
April 2018	7	279	217
May 2018	24	288	242
August 2018	4	281	272
November 2018	34	147	29
2018 Total	**69**	**217**	**136**

Data from 2018 fish is still being collected and analyzed so it is not currently reported. Results from 2017 data analysis have been included and will be updated when possible. Juvenile Silver Carp occupied backwater habitat strata the greatest frequency of times (n = 1461 residencies) and spent the greatest mean time in these areas (10.55 hours), however there was no significant difference between backwater areas and main channels (Table 2). These results are similar to the preliminary data analyzed from telemetry in 2016, which indicated juvenile Silver Carp were being detected in main channel habitats as often as in backwaters. Juvenile Silver Carp had average residence times of 9.65 hours in main channels and stopped near receivers 982 times (minimum of 30 minutes) (Table 2).

Table 2. *Mean residence time and number of residences of telemetered juvenile Silver Carp in the Peoria Reach of the Illinois River separated by habitat strata during 2017 acoustic telemetry.*

Receiver strata	Mean Residency (hours)	n residences
Backwater	10.55	1461
Main channel	9.65	982
Side channel	6.58	562

When mean weekly residence events are plotted with river discharge, trends emerge between residency, river discharge, and temperature (Figure 1). A moderate positive relationship was observed between residencies in backwaters and river discharge (R = 0.45) and a moderate negative relationship was observed in main channels (R = -0.46) and side channels (R = -0.68) and river discharge. This suggests juvenile Silver Carp avoid the channel areas during high flows and instead enter backwaters or floodplain areas during those times (Figure 1). Additionally, temperature had a strong negative correlation with backwater residencies (-0.79), however temperature data was not collected for the duration of the study due to issues with the monitoring station (Figure 1).

Mean weekly movement distance (mean of 943.7 m per week) of juvenile Silver Carp fluctuated greatly throughout the field season but was generally higher between June and September (Figure 2). Roughly half (52%, n = 395 movements) of movements recorded were fish moving between backwater and adjacent main channel areas. This is similar to what was analyzed based on residence times, with juvenile Silver Carp stopping most frequently in backwater and main channel areas. Most other movements (42%) were fish moving up or downstream in the main channel between receivers. When movements were analyzed alongside river discharge there was no correlation (-0.28), despite current velocity being a trigger for adult Silver Carp spawning activity (Figure 2). When mean weekly movement distances are plotted with temperature, a weak positive correlation (0.41) can be seen; as temperature decreased, the movement distances of fish decreased (Figure 2). This would be expected based on the physiology of fish and the general decrease in activity during winter.

To date, the results of this study indicate that juvenile Silver Carp reside in main channels nearly the same amount of time as backwater habitats. This study also suggests that movement cues may differ from adult Silver Carp due to juveniles entering backwaters during high flows when adults typically swim upstream to spawn. Juvenile Silver Carp had mean weekly movements averaging about 1 km throughout the year but decreasing during late fall and early winter. More data will be collected and further analysis conducted to determine the mean distance juvenile Silver Carp swim upstream. Additionally, efforts will be made to sample other water quality parameters to test for correlations with movements and residencies. Results from 2018 and 2017 will be used in 2019 to generate targeted sites in upper pools for monitoring juvenile Silver Carp with the goal to increase capture efficiency upstream.

Recommendations:

Telemetry provides valuable knowledge on the habitat usage and movement characteristics of juvenile Silver Carp. Based on data from the study to date, juvenile Silver Carp are spending a large portion (over 50%) of residence times in main channel and side channel habitats. If this remains true, it will be important to tailor monitoring regimes in the upper pools of the Illinois River to reflect this habitat usage. Additionally, juvenile Silver Carp averaged a movement distance of 800 meters per week in the main channel. Continued telemetry studies and more data will provide insight as to what drives these movement patterns. Because of the danger of juvenile Silver Carp entering the Great Lakes through the Illinois Waterway and the relatively low success of catching small Silver carp in upper reaches, this project should continue for 2019 and potentially 2020 to best inform the monitoring efforts in upper reaches.

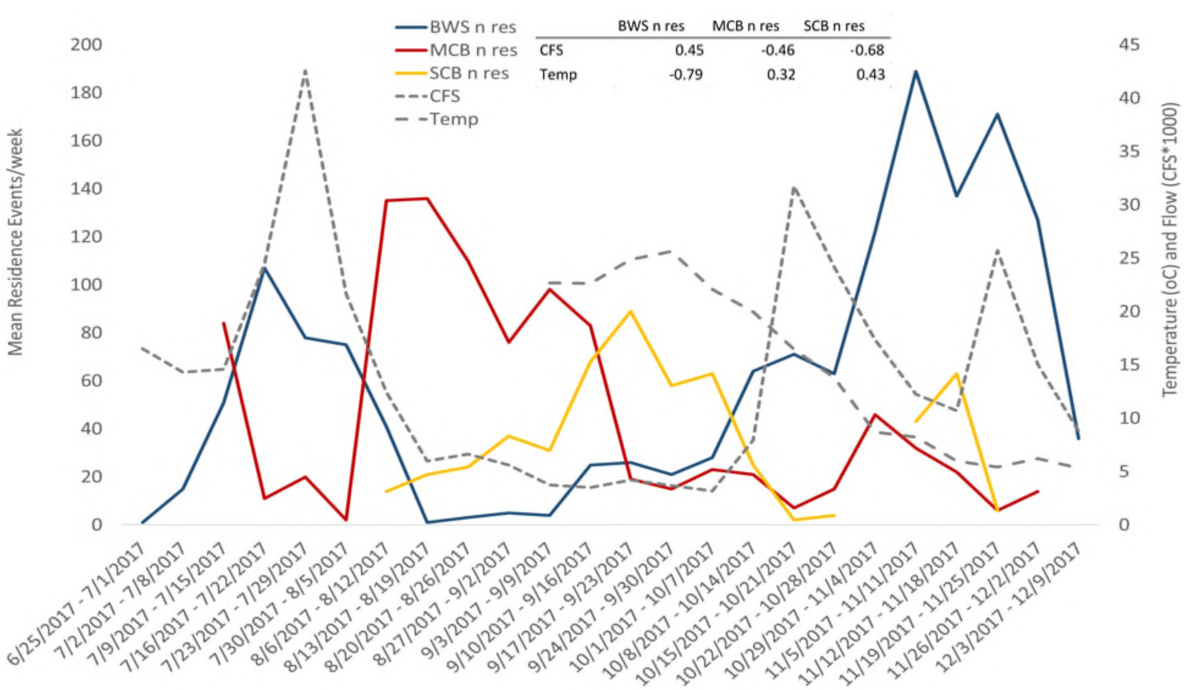

Figure 1. *Mean weekly residence events by habitat area of telemetered juvenile Silver Carp, mean weekly river discharge (CFS*1000), and mean weekly water temperature (°C) in the Peoria Reach of the Illinois River. Pearson correlation R-values are included in the table near the top of the chart.*

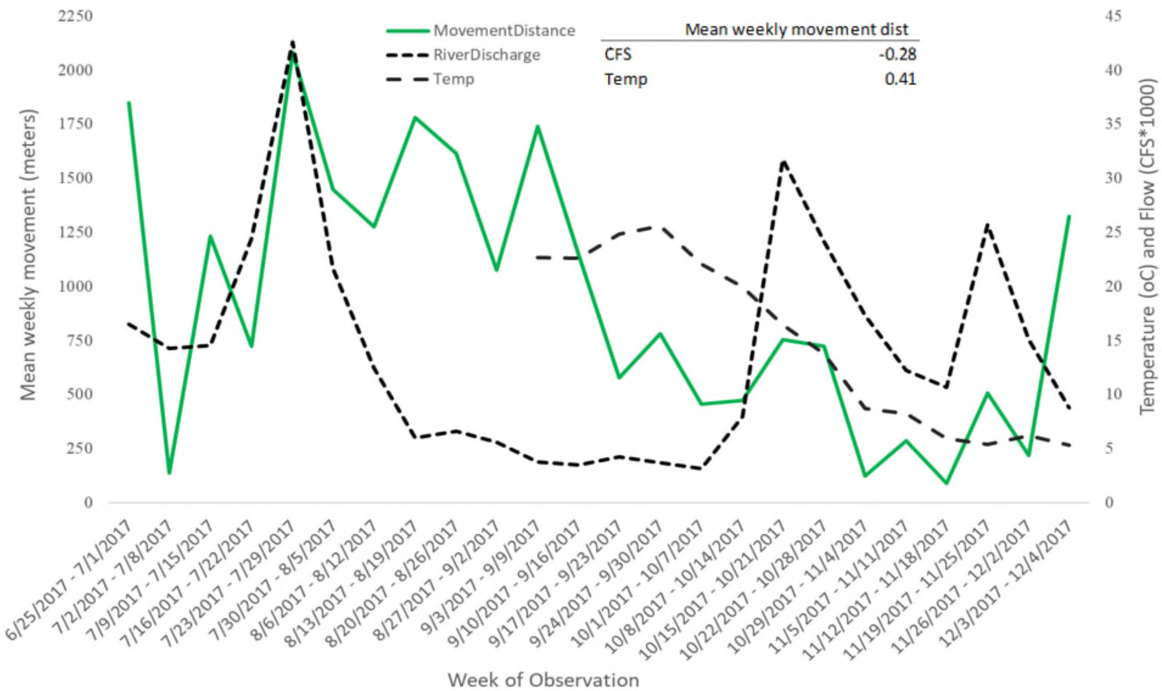

Figure 2. *Mean weekly movement distance (meters, solid line) of telemetered juvenile Silver Carp, mean weekly river discharge (CFS*1000), and mean weekly water temperature (^{o}C) in the Peoria Reach of the Illinois River. Pearson correlation R-values are included in the table near the top of the chart.*

Monitoring Efforts Downstream of the Electric Dispersal Barrier

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Participating Agencies: Illinois Department of Natural Resources (lead); Illinois Natural History Survey – Illinois River Biological Station (field Support); U.S. Fish and Wildlife Service – Carterville (Wilmington), Colombia, and La Crosse Fish and Wildlife Conservation Offices (field support); U.S. Army Corps of Engineers – Chicago District (field support)

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

Introduction and Need: Standardized sampling is essential to managers monitoring population growth and range expansion of aquatic invasive species. Information learned from consistent and long-term monitoring (i.e., presence/absence, distribution, and abundance of target species) is imperative to understanding the threat of possible invasion upstream the Electric Dispersal Barrier. We use pulsed-DC boat electrofishing, hoop and mini-fyke netting, and contracted commercial fishers to sample for invasive Asian carp in the four reaches below the Electric Dispersal Barrier: Lockport, Brandon Road, Dresden Island, and Marseilles pools. These efforts are useful to monitor changes in the leading edge, distribution, and relative abundance of Asian carp in the Illinois Waterway over time. The 'leading edge' is defined as the farthest upstream location where multiple Bighead or Silver Carp have been captured in conventional sampling gears during a single trip or where individuals of either species have been caught in repeated sampling trips to a specific site. Our nine years of data (2010-2018) provide a working knowledge of Asian carp abundance and distribution downstream the Electric Dispersal Barrier and the potential threat of upstream movement to the CAWS.

Objectives:

(1) Monitor for the presence of Asian carp in the four pools below the Electric Dispersal Barrier.

(2) Determine relative abundance of Asian carp in locations and habitats where they are likely to congregate.

(3) Supplement Asian carp distribution data obtained through other projects (i.e., Asian Carp Barrier Defense project, telemetry master plan).

(4) Obtain information on the non-target fish community to verify sampling success, guide modifications to sampling locations, and assist with detection probability modeling and gear evaluation studies.

Monitoring Efforts Downstream the Electric Dispersal Barrier

Project Highlights (electrofishing, commercial netting, and hoop/mini fyke netting):

- An estimated 25,278.5 person-hours expended sampling fixed, random, targeted, and additional sites downstream the Electric Dispersal Barrier (2010-2018).
- A total of 997.5 hours electrofishing, 1,783 km (1,108 miles) trammel/gill net, 1,922 hoop netting nights, and 635 mini-fyke netting nights (2010-2018).
- A total of 346,222 fish captured, representing 101 species and twelve hybrid groups (2010-2018).
- No Bighead or Silver Carp have been captured in Lockport or Brandon Road pools in any year sampled, but have been collected in Dresden Island Pool totaling 5,493 (2010-2018). Historically, Rock Run Rookery, Mobil Bay and the downstream end of Treats Island within the Dresden Island Pool are locations where Asian carp have been known to congregate and are frequently sampled (Figure 1).
- The leading edge of the Asian carp population is located north of I-55 Bridge in Rock Run Rookery (near river mile 281; 46 miles from Lake Michigan). No appreciable change has been found in the leading edge over the past 10 years.

Methods:

As in previous years, the 2018 sampling design included pulsed-DC boat electrofishing, gill/trammel netting, and hoop/mini-fyke netting at fixed, random, and targeted sampling locations in pools downstream the Electric Dispersal Barrier: Lockport, Brandon Road, Dresden Island, and Marseilles pools. Commercial netting efforts were focused in Lockport, Brandon Road, and Dresden Island pools. The fixed sampling locations (four sites/pool sampled regularly since 2010) are primarily in the upper portions of each pool below lock and dam structures and in habitats where Asian carp are likely to congregate (backwaters and side channels habitats). Electrofishing random sites were computer generated for main channel sampling locations (112 computer generated sites per pool). Targeted commercial netting replaced random netting in 2015 allowing commercial fishers to choose their netting locations increasing the likelihood of capturing a Bighead or Silver Carp.

Electrofishing Protocol

Fixed and random electrofishing samples occurred bi-weekly from March to November 2018. All electrofishing used pulsed-DC current and included one or two netters (two netters were preferred). Electrofishing was conducted in a downstream direction in waterway channels (including following the shoreline into off-channel areas) or in a clockwise direction in backwater sloughs. Electrofishing runs were 15 minutes in length and generally parallel to shore. The operator was encouraged to switch the pedal on and off at times to prevent pushing fish in front of the boat and to increase the chances of catching an Asian carp. Common Carp were counted without capture, while all other fish were netted and placed in a tank to be identified and counted, after which they were returned live to the water (native fish only). Young-of-year

(YOY) Gizzard Shad were examined closely for the presence of Asian carp and counted to provide an assessment of any young Asian carp in the waterway. All field data were entered into a Microsoft Access Fish App database.

Gill and Trammel Netting Protocol

In 2018, IDNR contracted commercial fishers (3 fishers per week) deployed gill/trammel nets at fixed and targeted sampling locations downstream the Electric Dispersal Barrier in Lockport, Brandon Road and Dresden Island pools (including Rock Run Rookery) bi-weekly from March to December. An IDNR/INHS biologist was aboard each commercial netting boat to monitor operations, record data, and check for ultrasonic- or jaw-tagged Bighead or Silver carp (left pelvic/anal fin clips or telemetry surgery wounds on the left ventral area of the fish, posterior to the pelvic fin and anterior to the anus). Targeted site locations were selected based upon the discretion of commercial fishers. Deployed nets were attended at all times. Net sets were a short duration utilizing noise to drive fish into the nets (i.e., “pounding” with plungers on the water surface, banging on boat hulls or revving trimmed-up motors). Netting effort was standardized as 15- to 20-minute long sets with “pounding” no further than 137 m (150 yards) from the net. Captured fish were identified to species, counted and recorded on data sheets. All captured Asian carp were harvested and bycatch were returned to the water unharmed. All field data were entered into a Microsoft Access Fish App database.

Hoop and Mini-Fyke Netting Protocol

In 2018, IDNR/INHS biologists conducted hoop and mini-fyke net sampling at fixed sites downstream the Electric Dispersal Barrier. Fixed site sampling took place 1 week per month from April to November in Lockport, Brandon Road, Dresden Island, and Marseilles pools.

Hoop nets were composed of seven fiberglass hoops with 64 mm (2.5 inch) bar mesh (1.8 meters [6 feet] in diameter, 6.7 meters [7.3 yards] in length). An anchor was attached to the cod end of the net with a 15.2 meter (16.6 yard) anchor line. Typically, nets were kept open by the water current but sometimes required a bridle and weight on the downstream end of the net during low water velocities. Nets were set in main channel borders and below locks and dams in waters ≥1.8 meters (6 feet) deep. Hoop nets were set for 48 hours (two net nights). Captured fish were identified to species, counted, and recorded on data sheets. All captured Asian carp were harvested, and bycatch were returned to the water unharmed. All field data were entered into a Microsoft Access Fish App database.

Mini-fykes were a Wisconsin-type net composed of a lead 0.6 meter (2 feet) in height, 5 meters (5.5 yards) in length, rectangular frame and cab 3 meters (3.3 yards) in length with 3 mm (0.1 inch) nylon-coated mesh. Mini-fyke nets were set in main channel borders or backwater areas perpendicular to shore. Mini-fyke nets were set for 24 hours (one net night). Captured fish were identified to species, counted, and recorded on data sheets. All field data were entered into a Microsoft Access Fish App database.

Monitoring Efforts Downstream the Electric Dispersal Barrier

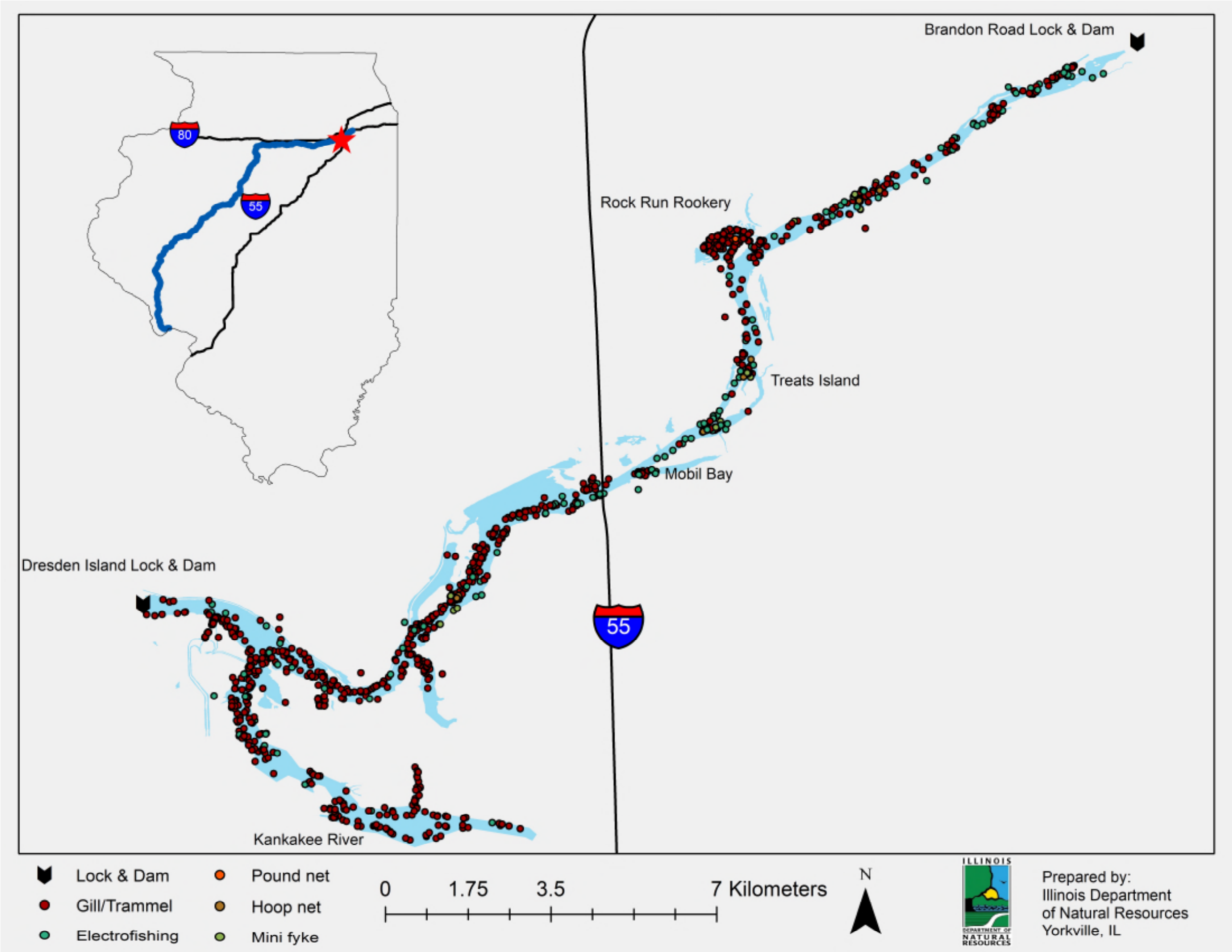

Figure 1. *Fixed, random, targeted, and additional sampling locations for all gear types (electrofishing, hoop/mini-fyke netting, and commercial netting) used to monitor Asian carp populations in Dresden Island Pool in 2018.*

Results and Discussion:

Electrofishing Effort and Catch

From 2010-2018, an estimated 9007.5 person-hours were expended completing 997.5 hours of electrofishing. A total of 233,486 fish were sampled representing 97 species and seven hybrid groups at fixed and random electrofishing sites downstream the Electric Dispersal Barrier (Table 1). Fixed site catch-per-unit-effort (CPUE) in 2018 was 276.34 fish/hour, a decrease from the 2017 fixed site CPUE (333.86 fish/hour; Table 2). Random site CPUE in 2018 was 192.16 fish/hour, a slight decrease from the 2017 random site CPUE (235.12 fish/hour; Table 2). Decreases in fixed site CPUE in 2018 are likely attributed to a decrease in Gizzard Shad detection (n = 6,363 in 2018 compared to n = 8,489 in 2017). Decreases in random site CPUE in 2018 are also likely attributed to a decrease in Gizzard Shad detection (n = 9,879 in 2018 compared to n = 12,567 in 2017. Fixed site Asian carp CPUE was 1.01 fish/hour (4.75 fish/hour in 2017) and random site Asian carp CPUE was 1.32 fish/hour (2.70 fish/hour in 2017). No

Bighead Carp or Silver Carp were sampled by electrofishing in Lockport or Brandon Road pools for any year sampled. In Dresden Island Pool, Asian carp fixed site CPUE was 0.36 fish/hour (0.32 fish/hour in 2017) and Asian carp random site CPUE was 0.30 fish/hour (0.96 fish/hour in 2017). In Marseilles Pool, Asian carp fixed site CPUE was 3.53 fish/hour (18.55 fish/hour in 2017) and Asian carp random site CPUE was 4.88 fish/hour (10.09 fish/hour in 2017). A total of 13,356 Gizzard Shad ≤ 152 mm (6 inches) were examined at fixed and random sites downstream of the Electric Dispersal Barrier in 2018 with no Asian carp YOY detected. This has been consistent for all years sampled. In 2018, species with the greatest overall abundance were Gizzard Shad (45.6%), Emerald Shiner (13.1%), Bluegill (5.7%), Largemouth Bass (4.4%), and Common Carp (3.6%) for random and fixed site electrofishing in all pools sampled (Table 2).

Gill and Trammel Netting Effort and Catch

From 2010-2018, 1,783 km (1,107.9 miles) of gill/trammel net were deployed at fixed, random, targeted and additional sampling locations downstream the Electric Dispersal Barrier. From 2010-2018, 14,138 person-hours were expended monitoring Asian carp; commercial netting yielded 44,561 fish representing 43 species and three hybrid groups. In 2018, 351.9 km (218.7 miles) of gill/trammel net were deployed at fixed and targeted sites in Lockport, Brandon Road, and Dresden Island pools. Commercial netting yielded 12,828 fish representing 32 species and two hybrid groups, of which Common Carp (14%) and Smallmouth Buffalo (63%) comprised 77% of the total catch and Bighead (3%) and Silver (10%) Carps comprised 13% of the total catch (Table 3). No Asian carp were captured in Lockport or Brandon Road pools, but were captured at fixed and targeted sites in Dresden Island Pool (n = 1,612); Table 2). Catches of Bighead and Silver Carps in the Dresden Island pool were higher at fixed and targeted sites sampled in 2018 (n = 393 and n = 1,219, respectively) than from fixed and targeted sites sampled in 2017 (n = 297 and n = 502, respectively; Table 2). Differences in Asian carp catches may be attributed to an increase in effort in 2018 from 2017 (351.8 km compared to 338.4 km respectively). The increase in effort was the result of the Unified Fishing Method that occurred in Dresden Island Pool in October 2018 and the continued use of three commercial fishers. Additionally, biologists were allowed access to the warm water discharge canal at the Dresden Nuclear Power Station (which comprised 60% of our Asian Carp catch). Gill/trammel netting CPUE (number of fish/100 yards of net) for all fish species was 4 fish/100 yards at targeted sites and 0.8 fish/100 yards at fixed sites in 2018 (Table 2), compared to 2.9 fish/100 yards at targeted sites and 0.5 fish/100 yards at fixed sites in 2017. CPUE of Bighead Carp was 0.13 fish/100 yards at targeted sites and 0.0 fish/100 yards at fixed sites in 2018 (Table 2), compared to 0.09 fish/100 yards at targeted sites and 0.0 fish/100 yards at fixed sites in 2017. CPUE of Silver Carp was 0.41 fish/100 yards at targeted sites and 0.003 fish/100 yards at fixed sites in 2018 (Table 2), compared to 0.15 fish/100 yards at targeted sites and 0.003 fish/100 yards at fixed sites in 2017.

Hoop and Mini-Fyke Netting Effort and Catch

From 2012 to 2018 an estimated 4,223 person hours were expended setting and running 967 hoop nets and 787 mini-fyke nets (1,922 hoop net nights and 635 mini-fyke net nights) downstream the Electric Dispersal Barrier. Hoop netting yielded 5,163 fish representing 24 species and two hybrid groups (Table 4). Smallmouth Buffalo comprised the largest proportion of the catch (43.7%; n = 2,256), followed by Channel Catfish (25.7%; n = 1,327) and Common Carp (14.2%; n = 731). Mini-fyke netting yielded 63,012 fish representing 70 species and one hybrid group (Table 5). Bluegill constituted the largest proportion of the catch (37%; n = 23,332) followed by Bluntnose Minnow (18%; n = 11,358) and Pumpkinseed (5.9%; n = 3,716).

In 2018 hoop netting yielded 614 fish representing 17 species and one hybrid group, with Smallmouth Buffalo comprising most of the catch (37%; n = 227), followed by Common Carp (27.4%; n = 168), and Channel Catfish (20.7%; n = 127; Table 4). No Asian carp were captured in Lockport or Brandon Road pools but were captured at fixed sites in Dresden Island Pool (1 Bighead Carp) and at fixed sites in Marseilles Pool (2 Bighead Carp, 1 Grass Carp and 27 Silver Carp; Table 4). Catches of Bighead Carp were lower in 2018 (n = 3) compared to 2017 (n = 12), and catches of Silver Carp were also lower in 2018 (n = 27) compared to 2017 (n = 45). Hoop netting CPUE (number of fish/net night) of all fish species was 2.8 at fixed sites in 2018 (Table 2), compared with 4.2 at fixed/additional sites in 2017. Bighead Carp hoop netting CPUE was 0.014 at fixed sites in 2018, compared with 0.022 at fixed/additional sites in 2017. Silver Carp hoop netting CPUE was 0.122 at fixed sites in 2018, compared with 0.084 at fixed/additional sites in 2017. Total catches of Asian carp were lower in 2018, compared with 2017, but CPUE of Silver Carp was slightly higher in 2018.

In 2018, mini-fyke netting yielded 5,367 fish representing 48 species and one hybrid group. Most of the catch was comprised of Bluntnose Minnow (22.4%; n = 1,201), followed by Bluegill (21.3%; n = 1,144), and Banded Killifish (7%; n = 375), which is a state threatened species (Table 5). Mini-fyke netting CPUE (number of fish/net night) of all species captured was 48.4 at fixed sites in 2018 (Table 2), less than in 2017 (CPUE = 73). No Asian carp were captured in mini-fyke nets.

Recommendation:

Extensive monitoring and removal efforts have allowed us to characterize and manage the risk of Asian carp populations moving upstream toward the Electric Dispersal Barrier and Lake Michigan. Similar patterns in Asian carp abundance among sampling gears (electrofishing and gill/trammel netting) and monitoring/removal projects (*see* Barrier Defense Removal report) add confidence to the finding that the relative abundance of Asian carp has decreased with upstream location in the Upper Illinois Waterway. Continued sampling efforts will provide invaluable real-time information about the detectable population front. Therefore, we recommend continued sampling below the Electric Dispersal Barrier using electrofishing, hoop netting, mini-fyke netting, and gill/trammel netting using the same protocols as in 2018.

Table 1. *Fixed and random electrofishing catch summary for 2018, including 2010-2018 in pools below the Electric Dispersal Barrier.*

Species	2018 Fixed Electrofishing						2018 Random Electrofishing						2010-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap	Percent	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap.	Percent	Captured	Percent
Alewife	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	47	0.02%
American eel	0	0	0	1	1	0.01%	0	0	0	0	0	0.00%	5	0.00%
Banded darter	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	6	0.00%
Banded killifish	60	12	99	175	346	2.25%	67	26	131	117	341	1.69%	1,447	0.62%
Bighead carp	0	0	1	0	1	0.01%	0	0	2		2	0.01%	37	0.02%
Bigmouth buffalo	0	0	2	13	15	0.10%	0	0	9	9	18	0.09%	577	0.25%
Black buffalo	0	0	1	1	2	0.01%	0	0	0	4	4	0.02%	202	0.09%
Black bullhead	0	14	1	1	16	0.10%	1	0	0	0	1	0.00%	36	0.02%
Black crappie	0	2	6	3	11	0.07%	0	0	2	2	4	0.02%	190	0.08%
Black redhorse	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	16	0.01%
Blacknose dace	0	0	0	0	0	0.00%	0	0	4	0	4	0.02%	6	0.00%
Blackside darter	0	0	1	0	1	0.01%	0	0	4	0	4	0.02%	13	0.01%
Blackstripe topminnow		1	2	2	5	0.03%	0	1	0	0	1	0.00%	79	0.03%
Blue catfish	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	1	0.00%
Bluegill	27	27	642	225	921	5.98%	11	12	943	144	1110	5.49%	12,948	5.55%
Bluegill x Green sunfish hybrid	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	30	0.01%
Bluntnose minnow	39	5	409	160	613	3.98%	42	18	407	199	666	3.29%	5,515	2.36%
Bowfin	0	0	4	0	4	0.03%	0	0	0	0	0	0.00%	44	0.02%
Brassy minnow	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	6	0.00%
Brook silverside	25	1	7	39	72	0.47%	6	2	60	3	71	0.35%	421	0.18%
Brook stickleback	0	0	2	0	2	0.01%	0	0	0	2	2	0.01%	4	0.00%
Brown bullhead	0	0	0	0	0	0.00%	0	0	1	0	1	0.00%	15	0.01%
Bullhead minnow	0	0	26	10	36	0.23%	0	0	111	16	127	0.63%	1,404	0.60%
Carp x goldfish hybrid	1	0	0	0	1	0.01%	0	0	0	0	0	0.00%	60	0.03%
Central mudminnow	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	4	0.00%
Central stoneroller	0	0	0	3	3	0.02%	0	0	3	0	3	0.01%	17	0.01%
Channel catfish	6	23	19	11	59	0.38%	1	9	43	50	103	0.51%	1,472	0.63%
Channel shiner	0	0	0	1	1	0.01%	0	0	0	0	0	0.00%	83	0.04%
Common carp	288	129	205	22	644	4.18%	71	117	356	77	621	3.07%	11,528	4.94%
Common shiner	0	0	0	0	0	0.00%			1	4	5	0.02%	35	0.01%
Creek chub	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	6	0.00%
Emerald shiner	841	286	300	917	2,344	15.21%	259	276	404	1,433	2,372	11.73%	18,278	7.83%
Fathead minnow	1	0	1	2	4	0.03%	0	2	0	0	2	0.01%	47	0.02%
Flathead catfish	0	0	0	1	1	0.01%	0	0	2	6	8	0.04%	117	0.05%
Freshwater drum	4	14	24	38	80	0.52%	3	8	59	53	123	0.61%	2,115	0.91%
Gizzard shad	1,119	1,039	3,009	1,196	6,363	41.30%	1,084	1,477	2,388	4,930	9,879	48.85%	121,313	51.96%

Species	2018 Fixed Electrofishing						2018 Random Electrofishing						2010-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap	Percent	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap.	Percent	Captured	Percent
Golden redhorse	0	0	17	41	58	0.38%	0	0	65	51	116	0.57%	1,573	0.67%
Golden shiner	8	4	63	10	85	0.55%	3	2	45	11	61	0.30%	996	0.43%
Goldeye	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	30	0.01%
Goldfish	18	18	4		40	0.26%	1	13	16	0	30	0.15%	672	0.29%
Grass carp	0	0	0	4	4	0.03%	0	0	2	4	6	0.03%	109	0.05%
Grass pickerel	4	1	1	1	7	0.05%	2	3	0	0	5	0.02%	60	0.03%
Greater redhorse	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	5	0.00%
Green sunfish	14	2	63	24	103	0.67%	8	9	48	21	86	0.43%	2,662	1.14%
Greenside darter	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	7	0.00%
Highfin carpsucker	0	0	0	4	4	0.03%	0	0	1	5	6	0.03%	58	0.02%
Hornyhead chub	0	0	0	0	0	0.00%	0	0	0	1	1	0.00%	4	0.00%
Hybrid Sunfish	0	1	52	0	53	0.34%	0	0	14	1	15	0.07%	388	0.17%
Johnny darter	0	0	0	0	0	0.00%	0	0	2	0	2	0.01%	23	0.01%
King salmon	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	1	0.00%
Largemouth bass	71	38	550	110	769	4.99%	25	47	650	70	792	3.92%	7,785	3.33%
Logperch	0	1	14	50	65	0.42%	0	0	30	32	62	0.31%	359	0.15%
Longear sunfish	0	0	19	2	21	0.14%	0	0	5	0	5	0.02%	84	0.04%
Longnose gar	3	2	29	27	61	0.40%	1	0	53	16	70	0.35%	1,395	0.60%
Mimic shiner	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	23	0.01%
Mooneye	0	0	0	1	1	0.01%	0	0	0	0	0	0.00%	12	0.01%
Mud darter	0	0	0	1	1	0.01%	0	0	0	0	0	0.00%	1	0.00%
Muskellunge	0	0	0	0	0	0.00%	0	0	1	0	1	0.00%	19	0.01%
Northern hog sucker	0	0	0	14	14	0.09%	0	0	0	4	4	0.02%	99	0.04%
Northern pike	1	11	2	1	15	0.10%	0	4	3	0	7	0.03%	100	0.04%
Orangespotted sunfish	0	0	7	2	9	0.06%	0	0	20	0	20	0.10%	248	0.11%
Oriental Weatherfish	15	1	0	0	16	0.10%	13	3	0	0	16	0.08%	262	0.11%
Paddlefish	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	1	0.00%
Pallid shiner	0	0	0	0	0	0.00%	0	0	0	1	1	0.00%	1	0.00%
Pumpkinseed	50	18	194	2	264	1.71%	18	20	238	1	277	1.37%	2,935	1.26%
Pumpkinseed x bluegill hybrid	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	15	0.01%
Quillback	0	0	6	9	15	0.10%		2	22	9	33	0.16%	670	0.29%
Red shiner	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	3	0.00%
Redear sunfish	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	23	0.01%
River carpsucker	0	0	21	63	84	0.55%	0	0	35	67	102	0.50%	1,875	0.80%
River redhorse	0	0	0	4	4	0.03%	0	0	2	0	2	0.01%	19	0.01%
River shiner	0	0	2	5	7	0.05%	0	0	2	4	6	0.03%	45	0.02%
Rock bass	0	11	6	1	18	0.12%	0	1	8	1	10	0.05%	150	0.06%
Round Goby	0	2	18	4	24	0.16%	2	8	7	47	64	0.32%	261	0.11%

Species	2018 Fixed Electrofishing						2018 Random Electrofishing						2010-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap	Percent	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap.	Percent	Captured	Percent
Sand shiner	0	0	2	109	111	0.72%	0	1	19	94	114	0.56%	499	0.21%
Sauger	0	12	0	0	12	0.08%	0	2	1	1	4	0.02%	69	0.03%
Shorthead redhorse	0	0	19	27	46	0.30%	0	0	8	19	27	0.13%	653	0.28%
Shortnose gar	0	0	1	5	6	0.04%	0	0	2	6	8	0.04%	139	0.06%
Silver carp	0	0	5	46	51	0.33%	0	0	4	127	131	0.65%	2,478	1.06%
Silver chub	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	2	0.00%
Silver redhorse	0	0	2	7	9	0.06%	0	0	11	6	17	0.08%	297	0.13%
Silverjaw minnow	0	0	0	0	0	0.00%	0	0	0	1	1	0.00%	1	0.00%
Skipjack herring	3	0	0	2	5	0.03%	1	1	1	0	3	0.01%	71	0.03%
Slenderhead darter	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	7	0.00%
Smallmouth bass	1	125	83	86	295	1.91%	1	75	102	217	395	1.95%	3,005	1.29%
Smallmouth buffalo	0	1	86	178	265	1.72%	0	2	194	531	727	3.59%	9,290	3.98%
Spotfin shiner	6	1	9	84	100	0.65%	0	0	30	265	295	1.46%	3,630	1.55%
Spottail shiner	0	17	109	139	265	1.72%	0	0	362	282	644	3.18%	2,652	1.14%
Spotted gar	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	8	0.00%
Spotted sucker	0	0	2	0	2	0.01%	0	0	3	2	5	0.02%	52	0.02%
Stonecat	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	1	0.00%
Striped bass x white bass hybrid	0	2	1	6	9	0.06%	0	0	0	1	1	0.00%	46	0.02%
Striped Shiner	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	3	0.00%
Suckermouth Minnow	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	4	0.00%
Tadpole madtom	0	0	4	0	4	0.03%	0	0	0	0	0	0.00%	8	0.00%
Threadfin shad	372	49	377	1	799	5.19%	213	24	166	28	431	2.13%	6,936	2.97%
Trout perch	0	0	0	15	15	0.10%	0	0	1	0	1	0.00%	23	0.01%
Unidentified Catostomid	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	44	0.02%
Unidentified Cyprinidae	0	0	0	18	18	0.12%	0	0	0	8	8	0.04%	31	0.01%
Unidentified Moronid	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	3	0.00%
Unidentified Percid	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	1	0.00%
Walleye	0	3	1	1	5	0.03%		1	2	2	5	0.02%	82	0.04%
Walleye x Sauger hybrid	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	1	0.00%
Warmouth	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	17	0.01%
Western mosquitofish	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	78	0.03%
White bass	1	0	4	16	21	0.14%	0	1	2	41	44	0.22%	747	0.32%
White crappie	2	0	5	1	8	0.05%	0	0	2	0	2	0.01%	126	0.05%
White perch	0	3	0	2	5	0.03%	0	2	3	2	7	0.03%	46	0.02%
White perch hybrid	0	0	0	0	0	0.00%	0	0	0	0	0	0.00%	1	0.00%
White sucker	0	26	9	0	35	0.23%	0	27	13	2	42	0.21%	618	0.26%
Yellow bass	0	0	0	3	3	0.02%	0	0	4	2	6	0.03%	68	0.03%
Yellow bullhead	6	3	18	0	27	0.18%	7	3	17		27	0.13%	613	0.26%

Species	2018 Fixed Electrofishing						2018 Random Electrofishing						2010-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap	Percent	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Cap.	Percent	Captured	Percent
Yellow perch	0	0	2	0	2	0.01%	0	4	4	0	8	0.04%	39	0.02%
Total Caught	**2,986**	**1,905**	**6,568**	**3,947**	**15,406**	**100.00%**	**1,840**	**2,203**	**7,150**	**9,032**	**20,225**	**100.00%**	**233,486**	**100.00%**
Species	**27**	**36**	**57**	**61**	**76**		**23**	**34**	**63**	**54**	**77**			
Hybrid Groups	**1**	**2**	**2**	**1**	**3**		**0**	**0**	**1**	**1**	**1**			

Table 2a. *Fixed electrofishing effort from March 27 – November 8, 2018 with catch summaries for 2018 in pools below the Electric Dispersal Barrier.*

	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Total
Estimated person-hours	160	130	137.5	130	557.5
Electrofishing hours	16	13	13.75	13	55.75
Samples (transects)	64	52	55	52	223
All Fish (*N*)	2,986	1,905	6,568	3,947	15,406
Species (*N*)	27	36	57	61	76
Hybrids (*N*)	2	2	1	1	3
Bighead Carp (*N*)	0	0	1	0	1
Silver Carp (*N*)	0	0	5	46	51
CPUE (fish/hour)	186.63	146.54	477.67	303.62	276.34

Table 2b. *Random electrofishing efforts from March 27 to November 8, 2018 with catch summaries for 2018 in pools below the Electric Dispersal Barrier.*

	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Total
Estimated person-hours	262.5	260	270	260	1,052.5
Electrofishing hours	26.25	26	27	26	105.25
Samples (transects)	105	104	108	104	421
All Fish (*N*)	1,840	2,203	7,150	9,032	20,225
Species (*N*)	23	34	63	54	77
Hybrids (*N*)	0	1	0	1	1
Bighead Carp (*N*)	0	0	2	0	2
Silver Carp (*N*)	0	0	4	127	131
CPUE (fish/hour)	70.10	84.73	264.81	347.38	192.16

Table 2c. *Fixed Gill and Trammel Netting Efforts from March 13 to November 5, 2018 with catch summaries for 2018 in pools below the Electric Dispersal Barrier.*

	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Total
Estimated person-hours	50	52	53	0	155
Samples (net sets)	50	52	53	0	155
Total miles of net	6.02	6.5	6.5	0	19.02
All Fish (N)	19	38	181	0	238
Species (N)	1	5	10	0	16
Hybrids (N)	0	0	0	0	0
Bighead Carp (N)	0	0	0	0	0
Silver Carp (N)	0	0	1	0	1
CPUE (No. fish/100 yards of net)	0.19	0.37	1.71	0	0.77

Table 2d. *Targeted gill and trammel netting efforts from March 13 to November 5, 2018 with catch summaries for 2018 in pools below the Electric Dispersal Barrier.*

	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Total
Estimated person-hours	321	303	845	0	1,469
Samples (net sets)	321	303	845	0	1,469
Total miles of net	37.7	37.6	124.43	0	199.73
All Fish (N)	59	294	11,259	0	11,612
Species (N)	3	7	32	0	42
Hybrids (N)	1	1	2	0	4
Bighead Carp (N)	0	0	393	0	393
Silver Carp (N)	0	0	1,218	0	1,218
CPUE (No. fish/100 yards of net)	0.09	0.49	6.66	0	3.95

Table 2e. *Fixed hoop netting efforts from April 16 to November 16, 2018 with catch summaries for 2018 in pools below the Electric Dispersal Barrier.*

	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Total
Est. person-hours	70	70	68	70	278
Net nights	56	56	54	56	222
Samples (net sets)	28	28	27	28	111
All Fish (*N*)	52	50	276	236	614
Species (*N*)	4	4	11	13	17
Hybrids (*N*)	1	0	1	0	1
Bighead Carp (*N*)	0	0	1	2	3
Silver Carp (*N*)	0	0	0	27	27
CPUE (No. fish/net night)	0.93	0.89	5.11	4.21	2.77

Table 2fa. *Mini-fyke netting efforts from April 16 to November 16, 2018 with catch summaries for 2018 in pools below the Electric Dispersal Barrier.*

	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	Total
Est. person-hours	70	68	70	70	278
Net nights	28	27	28	28	111
Samples (net sets)	28	27	28	28	111
All Fish (*N*)	2,070	458	1,338	1,501	5,367
Species (*N*)	27	22	33	28	48
Hybrids (*N*)	1	1	1	1	1
Bighead Carp (*N*)	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0
CPUE (No. fish/net night)	73.93	16.96	47.79	53.61	48.35

Table 3. *Fixed and targeted contracted commercial netting catch summary for 2018, including 2010-2018 in pools below the Electric Dispersal Barrier.*

Species	Fixed Gill and Trammel Netting Catch-2018					Targeted Gill and Trammel Netting Catch-2018					2010-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	No. Captured	Percent (%)	Lockport Pool	Brandon Pool	Dresden Pool	No. Captured	Percent	No. Captured	Percent (%)
Bighead carp	0	0	0	0	0.00	0	0	393	393	3.12	2,612	5.86
Black buffalo	0	0	3	3	1.26	0	0	65	65	0.52	460	1.03
Black Bullhead	0	0	0	0	0.00	0	0	0	0	0.00	1	0.00
Black crappie	0	0	0	0	0.00	0	0	1	1	0.01	2	0.00
Bluegill	0	0	0	0	0.00	0	0	0	0	0.00	1	0.00
Bigmouth buffalo	0	0	4	4	1.68	0	0	368	368	2.92	2,003	4.49
Bowfin	0	0	0	0	0.00	0	0	2	2	0.02	4	0.01
Common carp	19	30	90	139	58.40	53	237	1,307	1,597	12.68	13,038	29.26
Carp x goldfish hybrid	0	2	0	2	0.84	1	12	3	16	0.13	160	0.36
Channel catfish	0	4	5	9	3.78	5	20	204	229	1.82	837	1.88
Flathead catfish	0	0	0	0	0.00	0	0	30	30	0.24	123	0.28
Freshwater drum	0	1	1	2	0.84	0	6	389	395	3.14	902	2.02
Goldeye	0	0	0	0	0.00	0	0	0	0	0.00	3	0.01
Goldfish	0	1	0	1	0.42	0	2	0	2	0.02	66	0.15
Golden redhorse	0	0	0	0	0.00	0	0	7	7	0.06	10	0.02
Grass carp	0	0	0	0	0.00	0	1	51	52	0.41	148	0.33
Gizzard shad	0	0	0	0	0.00	0	0	6	6	0.05	17	0.04
Largemouth bass	0	0	0	0	0.00	0	0	12	12	0.10	43	0.10
Longnose gar	0	0	2	2	0.84	0	0	105	105	0.83	261	0.59
Mooneye	0	0	0	0	0.00	0	0	2	2	0.02	2	0.00
Muskelunge	0	0	0	0	0.00	0	0	0	0	0.00	2	0.00
Northern pike	0	0	0	0	0.00	0	0	3	3	0.02	15	0.03
Quillback	0	0	1	1	0.42	0	0	0	0	0.00	50	0.11
River carpsucker	0	0	1	1	0.42	0	0	21	21	0.17	234	0.53
River redhorse	0	0	0	0	0.00	0	0	1	1	0.01	1	0.00
Striped bass x white bass hybrid	0	0	0	0	0.00	0	0	8	8	0.06	13	0.03
Striped bass	0	0	0	0	0.00	0	0	1	1	0.01	1	0.00
Sauger	0	0	0	0	0.00	0	0	1	1	0.01	2	0.00
Smallmouth buffalo	0	0	73	73	30.67	0	16	8,024	8,040	63.86	21,230	47.64
Smallmouth bass	0	0	0	0	0.00	0	0	1	1	0.01	1	0.00
Shorthead redhorse	0	0	0	0	0.00	0	0	0	0	0.00	2	0.00
Shortnose gar	0	0	0	0	0.00	0	0	6	6	0.05	8	0.02
Spotted gar	0	0	0	0	0.00	0	0	1	1	0.01	9	0.02
Silver carp	0	0	1	1	0.42	0	0	1,218	1,218	9.67	2,266	5.09
Silver carp x Bighead carp hybrid	0	0	0	0	0.00	0	0	0	0	0.00	1	0.00
Silver redhorse	0	0	0	0	0.00	0	0	0	0	0.00	6	0.01
Skipjack herring	0	0	0	0	0.00	0	0	0	0	0.00	4	0.01
Unidentified catostomid	0	0	0	0	0.00	0	0	0	0	0.00	4	0.01
Walleye	0	0	0	0	0.00	0	0	2	2	0.02	6	0.01
White bass	0	0	0	0	0.00	0	0	2	2	0.02	4	0.01
White Crappie	0	0	0	0	0.00	0	0	0	0	0.00	1	0.00
White sucker	0	0	0	0	0.00	0	0	2	2	0.02	3	0.01
Yellow bullhead	0	0	0	0	0.00	0	0	1	1	0.01	5	0.01
Total Captured	**19**	**38**	**181**	**238**	**100.00**	**59**	**294**	**11,259**	**12,590**	**100.00**	**44,561**	**100.00**
No. Species	**1**	**5**	**10**			**3**	**7**	**32**			**43**	
No. Hybrid Groups	**0**	**0**	**0**			**1**	**1**	**2**			**3**	

Table 4. *Fixed and additional hoop netting catch summary for 2018, including 2012-2018 in pools below the Electric Dispersal Barrier.*

Species	**Hoop Netting Catch 2018**						**2012 - 2018**	
	Lockport Pool	**Brandon Pool**	**Dresden Pool**	**Marseilles Pool**	**No. Captured**	**Percent**	**No. Captured**	**Percent**
Bighead Carp			1	2	3	0.49%	175	3.39%
Bigmouth Buffalo			2		2	0.33%	18	0.35%
Black Buffalo					0	0.00%	13	0.25%
Black Crappie					0	0.00%	8	0.15%
Channel Catfish	3	15	78	31	127	20.68%	1,327	25.70%
Common Carp	45	29	63	31	168	27.36%	731	14.16%
Common Carp x Goldfish Hybrid	2		1		3	0.49%	8	0.15%
Flathead Catfish			3	10	13	2.12%	123	2.38%
Freshwater Drum	1	5	3	18	27	4.40%	220	4.26%
Gizzard Shad					0	0.00%	1	0.02%
Golden Redhorse					0	0.00%	4	0.08%
Goldfish					0	0.00%	4	0.08%
Grass Carp				1	1	0.16%	4	0.08%
Largemouth Bass			1		1	0.16%	2	0.04%
Longnose Gar				1	1	0.16%	2	0.04%
Quillback					0	0.00%	2	0.04%
River Carpsucker			2	3	5	0.81%	57	1.10%
Shorthead Redhorse			1		1	0.16%	3	0.06%
Silver Carp				27	27	4.40%	179	3.47%
Silver Redhorse					0	0.00%	4	0.08%
Smallmouth Bass				1	1	0.16%	4	0.08%
Smallmouth Buffalo			119	108	227	36.97%	2,256	43.70%
Striped Bass x White Bass Hybrid					0	0.00%	3	0.06%
Walleye		1		2	3	0.49%	4	0.08%
White Bass	1			1	2	0.33%	6	0.12%
White Crappie			2		2	0.33%	5	0.10%
Total Captured	**52**	**50**	**276**	**236**	**614**	**100.00%**	**5,163**	**100.00%**
No. Species	**4**	**4**	**11**	**13**	**17**		**24**	
No. Hybrid Groups	**1**	**0**	**1**	**0**	**1**		**2**	

Table 5. *Minnow fyke netting catch summary for 2018, including 2012-2018 in pools below the Electric Dispersal Barrier.*

Species	Minnow Fyke Netting Catch - 2018						2012-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Captured	Percent	No. Captured	Percent
Banded Darter					0	0.00%	1	0.00%
Banded Killifish	308	39	10	18	375	6.99%	2,304	3.66%
Black Buffalo					0	0.00%	1	0.00%
Black Bullhead			1		1	0.02%	8	0.01%
Black Crappie				4	4	0.07%	41	0.07%
Blackstripe Topminnow		1	2	8	11	0.20%	338	0.54%
Bluegill	261	128	651	104	1,144	21.32%	23,332	37.03%
Bluntnose Minnow	666	42	386	107	1,201	22.38%	11,358	18.03%
Bowfin					0	0.00%	1	0.00%
Brook Silverside				3	3	0.06%	49	0.08%
Brown Bullhead					0	0.00%	1	0.00%
Bullhead Minnow				19	19	0.35%	384	0.61%
Central Mudminnow	1		1		2	0.04%	8	0.01%
Central Stoneroller			1		1	0.02%	1	0.00%
Channel Catfish	23	1		2	26	0.48%	118	0.19%
Channel Shiner					0	0.00%	14	0.02%
Common Carp	9	10	3	2	24	0.45%	1,149	1.82%
Common Shiner					0	0.00%	7	0.01%
Creek Chub					0	0.00%	21	0.03%
Emerald Shiner	13	1	12	340	366	6.82%	1,146	1.82%
Fathead Minnow					0	0.00%	4	0.01%
Flathead Catfish					0	0.00%	6	0.01%
Freshwater Drum			1	1	2	0.04%	9	0.01%
Gizzard Shad					0	0.00%	757	1.20%
Gizzard Shad < 6"	11	14	14	31	70	1.30%	823	1.31%
Glass Shrimp					0	0.00%	37	0.06%
Golden Shiner	25		2		27	0.50%	199	0.32%
Goldfish					0	0.00%	21	0.03%
Grass Pickerel					0	0.00%	5	0.01%
Green Sunfish	288	40	33	4	365	6.80%	3,491	5.54%
Hybrid Sunfish	13	1	28	3	45	0.84%	358	0.57%
Johnny Darter		1		2	3	0.06%	27	0.04%
Largemouth Bass	26	45	29	20	120	2.24%	535	0.85%
Logperch				5	5	0.09%	19	0.03%
Longear Sunfish			25		25	0.47%	34	0.05%
Longnose Gar			1		1	0.02%	19	0.03%
Northern Pike		1			1	0.02%	3	0.00%

Species	Minnow Fyke Netting Catch - 2018						2012-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Captured	Percent	No. Captured	Percent
Orangespotted Sunfish	8	12	4	3	27	0.50%	1,205	1.91%
Oriental Weatherfish	51	5	2		58	1.08%	376	0.60%
Pumpkinseed	102	58	65		225	4.19%	3,716	5.90%
Redear Sunfish	1				1	0.02%	1	0.00%
River Carpsucker		1			1	0.02%	1	0.00%
River Shiner					0	0.00%	24	0.04%
Rock Bass			7		7	0.13%	50	0.08%
Round Goby	43	17	3	11	74	1.38%	1,624	2.58%
Sand Shiner		9	4	28	41	0.76%	682	1.08%
Sauger					0	0.00%	15	0.02%
Shorthead Redhorse					0	0.00%	2	0.00%
Shortnose Gar					0	0.00%	11	0.02%
Silver Chub					0	0.00%	11	0.02%
Skipjack Herring					0	0.00%	1	0.00%
Slenderhead Darter					0	0.00%	1	0.00%
Smallmouth Bass				3	3	0.06%	19	0.03%
Smallmouth Buffalo			1		1	0.02%	9	0.01%
Spotfin Shiner	2		7	77	86	1.60%	3,549	5.63%
Spottail Shiner	2	5	27	100	134	2.50%	965	1.53%
Stonecat					0	0.00%	1	0.00%
Striped Shiner			1		1	0.02%	4	0.01%
Suckermouth Minnow				1	1	0.02%	2	0.00%
Tadpole Madtom	5	2	2		9	0.17%	107	0.17%
Threadfin Shad			1		1	0.02%	7	0.01%
Trout Perch				2	2	0.04%	2	0.00%
Unidentified Catostomid		1		2	3	0.06%	18	0.03%
Unidentified Centrarchid			1	587	588	10.96%	638	1.01%
Unidentified Cyprinid		4	4	3	11	0.20%	21	0.03%
Unidentified Darter		1			1	0.02%	2	0.00%
Unidentified Ictiobus					0	0.00%	3	0.00%
Unidentified Moronid					0	0.00%	1	0.00%
Unidentified Notropis					0	0.00%	35	0.06%
Walleye	1		1		2	0.04%	3	0.00%
Warmouth	3	1	1		5	0.09%	33	0.05%
Western Mosquitofish	2			1	3	0.06%	1,845	2.93%
White Bass	11			1	12	0.22%	18	0.03%
White Crappie	2		3	7	12	0.22%	64	0.10%
White Perch					0	0.00%	13	0.02%

Species	Minnow Fyke Netting Catch - 2018						2012-2018	
	Lockport Pool	Brandon Pool	Dresden Pool	Marseilles Pool	No. Captured	Percent	No. Captured	Percent
White Sucker					0	0.00%	45	0.07%
Yellow Bass	2		2		4	0.07%	38	0.06%
Yellow Bullhead	160	18	2	2	182	3.39%	1,180	1.87%
Yellow Perch	31				31	0.58%	41	0.07%
Total Captured	2,070	458	1,338	1,501	5,367	100.00%	63,012	100.00%
No. Species	27	22	33	28	48		70	
No. Hybrid Groups	1	1	1	1	1		1	

Telemetry Interim Summary Report

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(US Army Corps of Engineers – Chicago District)

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

Introduction and Need:

Acoustic telemetry has been identified within the Asian Carp Regional Coordinating Committee (ACRCC) Control Strategy Framework as one of the primary tools to assess the efficacy of the electric dispersal barrier system. The following report summarizes methods and results from implementing a network of acoustic receivers supplemented by mobile surveillance to track the movement of Bighead Carp, *Hypopthalmichthys nobilis*, and Silver Carp, *Hypopthalmichthys molitrix*, in the Dresden Island Pool and associated surrogate fish species (locally available non-Asian carp fish species which most similarly mimic body shape and movement patterns) in the area around the electric dispersal barriers in the Upper Illinois Waterway (IWW). This network was installed and is maintained through a partnership between the U.S. Army Corps of Engineers and other participating agencies as part of the Monitoring and Response Workgroup's (MRWG) monitoring plan (MRWG, 2017).

Objectives:

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

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

- **Objective** Monitor the movements of tagged fish in the vicinity of the Electric Dispersal Barrier System using receivers placed immediately upstream and immediately downstream of the barriers.
- **Objective** Establish real-time receiver locations upstream of strategic control points and develop a reporting protocol to provide quality controlled information to resource managers in an efficient and timely manner.
- **Objective** Support barrier efficacy and mitigation studies through supplemental data collection of tagged fish in the vicinity during controlled experimental trials.

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

- **Objective** Monitor the movements of tagged fish at Dresden Island, Brandon Road, and Lockport Locks and Dams using stationary receivers (N=6) placed above and below 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 and Silver Carp invasion front;

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

Additional objectives of the telemetry monitoring plan:

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

Project Highlights:

- To date, USACE has acquired 29.1 million detections from 636 tagged fish.
- No live tagged fish have crossed the Electric Dispersal Barriers in the upstream direction.
- A high percentage of tagged surrogate fish in the Lower Lockport Pool continue to be detected near the Electric Dispersal Barrier System.
- There were three upstream lock passages by Common Carp from Brandon Road Pool into Lockport Pool.
- One Grass Carp and one Common Carp moved from Brandon Road Pool to Dresden Island Pool.
- Asian carp continue to be detected throughout the Dresden Island Pool with the majority of detections occurring near the Harborside Marina and Dresden Island Lock.
- Up to 90% of transmitters within Dresden Island Pool were detected near Harbor Side Marina at the Kankakee River confluence, but only accounted for 18.1% of the total detections in the pool in that season and overall for 36% of the detections in pool for the year.

Methods:

Based on MRWG expert opinion, it was recommended that a total of 200 active transmitters in fish be maintained within the study area for telemetry monitoring. At the end of the 2017 season there were approximately 97 tagged fishes (V16 Vemco transmitters) that remained active and only two of these transmitters were scheduled to expire within calendar year 2018. Additional tagging was required to sustain the recommended levels of the target sampling size as battery life expired and mortalities occurred in previously tagged fish. Because increases in transmitters deployed also increase the burden to stationary receivers for detection, the USACE decided to limit the amount of new tags to be implanted within certain high detection zones of the study area. A total of 11 transmitters (V16; 69 kHz) were implanted into surrogate species in 2018 to maintain adequate transmitter saturation within the Lower Lockport Pool and downstream of the electric dispersal barrier system. An additional 25 Silver Carp and 8 Bighead Carp were implanted with transmitters within the Dresden Island Pool (V16; 69 kHz). This increased the number of transmitters to 142 that were active for at least a portion of calendar year 2018. A combination of prioritized response activities, reduced staffing resources, and delayed funding prevented additional transmitter implementation.

Tagged surrogate fishes have been released below the Electric Dispersal Barrier System; however, no tagged Asian carp were released above the Brandon Road Lock. It was determined that no Asian carp caught in Lockport or Brandon Road pools would be tagged and returned as these areas are above the known upstream extent of the invasion front. Most fish captured in Brandon Road or Dresden Island pools were released at or near point of capture only after they were deemed viable and able to swim under their own power. All except one of the surrogate fishes released within Lower Lockport Pool were originally captured from the Upper Lockport Pool in an effort to induce higher approaches to the Dispersal Barrier through site fidelity. It has been observed that displaced fishes attempt to return to their original capture location and has been found to increase barrier approaches. Table 1 identifies all fishes containing active transmitters within the winter of 2017 and the field season of 2018 along with their release point within the system.

Table 1: *Active Fishes and Release Points within the Study Area in 2018.*

Release Location	Species Implanted	Number of Fish Implanted
Between Barriers	Common Carp	1
Lower Lockport Pool (Downstream of Barriers)	Common Carp	57
Lower Lockport sub-total		**58**
Brandon Rd Pool	Common Carp	14
Brandon Road sub-total		**14**
Dresden Island Pool	Common Carp	1
	Bighead Carp	34
	Silver Carp	34
	Silver-Bighead hybrid	1
Dresden Island sub-total		**70**
Total		**142**

Methods for transmitter implantation, stationary receiver deployment and downloads as well as mobile tracking were maintained from previous years effort. Data retrieval occurred bi-monthly throughout the season by downloading stationary receivers and supplementing with mobile tracking techniques as necessary. A detailed description of methods can be found in the MRRP Interim Summary Report (2012) with surgical implant procedures adapted from DeGrandchamp (2007), Summerfelt and Smith (1990) and Winter (1996). A portion of stationary receivers removed for winter in November 2017 were redeployed in March 2018 with revisions to the layout of receiver positions within the study area based off of lessons learned from previous data collected. USACE receiver coverage within the Dresden Island Pool decreased from 14 in 2017 to 11 in 2018. Receiver coverage was reduced within the Dresden Island Pool at the mouth of the DuPage River below the Channahon Dam, in the backwater area behind Moose Island, and within Hickory Creek (n=3). Additionally, one receiver was not placed in Upper Lockport, approximately 3.4 miles upstream of the dispersal barrier. The revised study area was covered by 27 USACE stationary receivers extending for approximately 33.5 river miles from the Calumet-Saganashkee Channel in Worth to the Dresden Island Lock on the Illinois River (Appendix A – Receiver Network Maps). All stationary receiver locations were identified by a station name. Station names were labeled with a two to three letter indicator of either pool or tributary location (i.e. LL for Lower Lockport or RR for Rock Run Rookery) and numbered from upstream to downstream in the main channel and downstream to upstream within the tributaries. Station identifications allow the database to track all detections made at a single location regardless of the unique receiver ID that may have been deployed at that location at any given time. Finally, there are five real-time receivers that have been installed in previous years by USGS in the area of coverage. One located above and below Brandon Road Lock and Dam, one upstream and downstream of the barrier system, and one upstream of Dresden Island Lock and Dam. The receivers upload detections to a USGS maintained website, providing real-time results and are part of a larger inter-agency effort to strategically cover the Illinois Waterway with this new data transmission technique.

The Dresden Island Pool was also included within the telemetry receiver networks for concurrent studies led by USGS, SIUC and USFWS. USGS maintains two real-time receivers within the pool; one at the approach channel to the Brandon Road Lock and one at the mouth of the Kankakee River just upstream of the Dresden Island Lock. SIUC maintains two stationary receivers within the upper pool in proximity to the lock and dam. One receiver was located within the tail waters of the dam and the remaining was positioned in the main channel within 1.5 miles of the lock. Finally, USFWS maintains four stationary receivers within the Dresden Island Pool and one receiver within the Brandon Road Pool. The USFWS receivers in the Dresden Island Pool were focused on the backwater areas of Treats Island and the Brandon Road Pool receiver was located within the I&M backwater just upstream of the Ruby Street Bridge. Data were shared between agencies to allow for continuous tracking of transmitters across the system as a whole. These additional receivers bring the total within the Dresden Island Pool to nineteen.

Barrier Efficacy – Barrier efficacy was assessed through a system of eleven stationary receivers with four upstream and seven downstream of the Electric Dispersal Barrier System within the Lockport Pool. Receivers were placed at the lock entrance, in areas offering shallow habitat, in proximity to the Electric Dispersal Barrier System and at the confluence of the CSSC and Cal-Sag Channel (Appendix A). Receiver data were analyzed for individual fish detections that would indicate an upstream or downstream passage through the Electric Dispersal Barrier

System. Additionally, data were analyzed to assess temporal and spatial distribution patterns within the Lower Lockport Pool. Mobile tracking utilizing the VR100 supplemented the stationary receiver data as needed throughout the year. Mobile tracking was used to track individual fish or areas of interest that were not covered by the stationary receiver network. All detections were recorded and compiled into the detection data set.

As of 1 January 2018, there were a total of 47 tagged surrogate fish (Common Carp) within the Lower Lockport Pool (mean ± SD; 618.9 ± 89.8 mm). In order to maintain a similar number of tagged fish within the Lower Lockport Pool across years, an additional 11 Common Carp (616.6 ± 84.8 mm) were tagged and released in 2018 to increase transmitter density bringing the total up to 58. These additional Common Carp were tagged using Vemco V16 transmitters with an estimated battery life of 2,176 days. These Common Carp were captured from Upper Lockport Pool (n=11) and released at the Cargill boat launch within the Lower Lockport Pool downstream of the Electric Dispersal Barrier System. Fish captured above and released below the barriers increase the likelihood of barrier interaction as they attempt to return to their point of capture.

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

Detection data were compiled for all stations within the Lower Lockport Pool by the number of detections for all transmitters and the total number of transmitters detected. The total number of detections was calculated for each of the seven stations from the Electric Dispersal Barrier System to the Lockport Lock for the full year and by season. Seasons were defined by monthly data with December to February representing winter, March to May for spring, June to August for summer, and September to November for fall. Each station detection sub-total was then summed across the pool to calculate the total number of detections in 2018 and then further detailed by season. Similarly, the total number of transmitters was recorded for each station independently. Detection data for all stations combined was also reviewed to determine the total number of transmitters detected annually. This process was repeated for each season to obtain total number of detections by station and totaled for the entire pool.

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

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

Asian carp Movement Analysis – A total of 69 USACE tagged Asian carp (Bighead and Silver Carp) were within the Dresden Island Pool at the end of 2018. All Asian carp were tagged following the same methods previously mentioned. Movement of individual fish were tracked via Vemco VR2W stationary receivers (Appendix A) strategically placed throughout the Des Plaines and Kankakee Rivers. VR2W detections were then uploaded into Vemco VUE. Each station detection sub-total was then summed across the pool to calculate the percent of total detections in 2018 and then further detailed by season. Detections of tags were recorded and percent tags detected at each station was calculated for each season of winter (Dec- Feb), spring (Mar-May), summer (June-Aug) and fall (Sept-Nov). Total tags and total detections at each receiver by season were used to observe any movement patterns. Detections for each tag detected were individually analyzed to determine if any fish potentially died during 2018. Fish that demonstrated only downstream movement after tagging or were detected at a single receiver at a consistent rate over several months, were removed from the analysis.

Results and Discussion:

The results discussed in this section will address the three goals of the study. As of November 2018, 29.1 million detections from 636 tagged fish have been recorded within the study area since the telemetry monitoring system was established in 2010. Results to date have shown that zero live fish have crossed the Electric Dispersal Barrier System in the upstream (northward) direction. Two transmitters that were implanted into Common Carp released below the barriers that were detected upstream of the barriers as was reported in previous reports (2014 MRP

Interim Summary, 2015) are no longer detectable as they have reached their expected lifespan. These transmitters had been presumed to be either expelled from the host fish or the host fish had experienced mortality due to lack of movement on the detected transmitters. The following sections provide new results from data collected in the 2018 sampling season in which 120 transmitters were detected system wide for a total of 3.5 million data points from 29 November 2017 through 19 November 2018.

Goal 1: Determine if fish approach and/or penetrate the electric dispersal barrier system (Barrier Efficacy)

There were a total of 58 tagged surrogate fishes with batteries still active in 2018 between Lockport Lock and the Electric Dispersal Barrier System. Seven stationary receivers (VR2W) detected movement on 41 of the tagged surrogate fishes throughout the pool in 2018. There were a total of just over 1.62 million detections within Lower Lockport Pool and zero detections in the Upper Lockport Pool indicating no tagged fish passage through the barriers.

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

Residency time was lowest in straight channel sections of the canal with deep water which best characterizes station LL03a (~1% of annual detections). Residency time increased in areas with shallow water habitat (LL03 with 19%, and LL05 with 25%). Barriers to movement such as the Electric Dispersal Barrier System (EDBS, LL01) and the Lockport Lock (LL06) experienced mid-level detection amounts, each with ~11% of annual detections. Among detections at the EDBS, the number of detections was highest in the fall months. Alternatively, detections decreased at the barrier to the fewest detections for the year, but at LL02 (0.5 miles downstream) experienced an increase in winter where 37% of the station's detections happened in this season (Figure 2). Many of the fish that were detected during this time were likely overwintering at or near the barriers and it is unlikely they were regularly approaching the barriers given their lack of detections on other receivers. It should be noted that during the winter months there were just four of the full seven receivers were deployed during the winter months of this period of analysis and it is uncertain if these fish were in areas of no coverage when not detected at the barrier.

Transmitter detection rates were high at all sites within the pool during the summer and fall months. This suggests the population of tagged fish was most active during these seasons. Spring detection ranges were also high at most sites with decreased levels only observed a half mile below the dispersal barrier (LL02). Sixty-two percent of tagged fish detected in winter months were still observed in the vicinity of the barrier during those months, but did not spend much time in that detection range when they appeared (~12% winter detections).

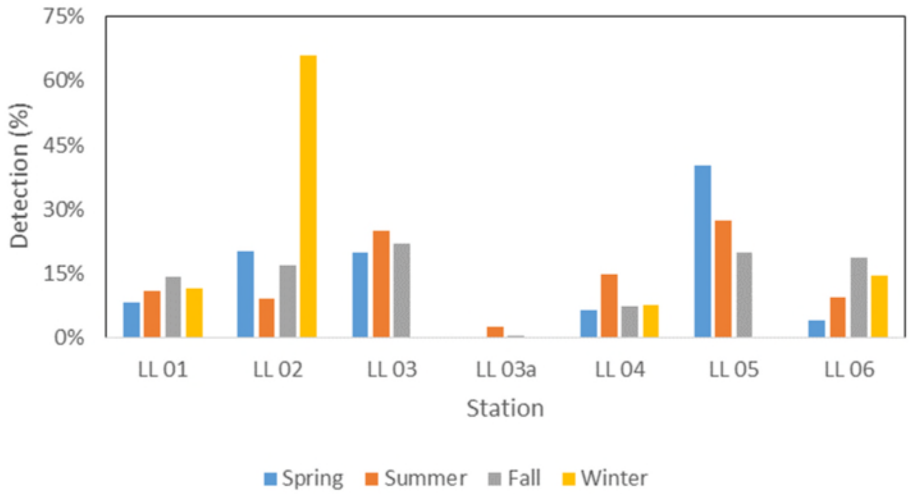

Figure 1*: Percentage of the Lockport Pool's total seasonal detections shown across receivers in 2018.*

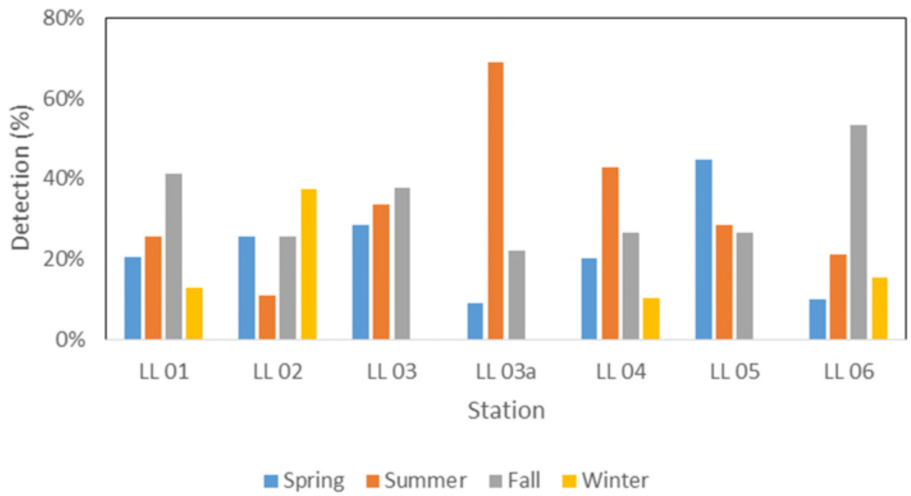

Figure 2*: Percentage of a receiver's total number of detections that occurred within a given season within the Lockport Pool in 2018.*

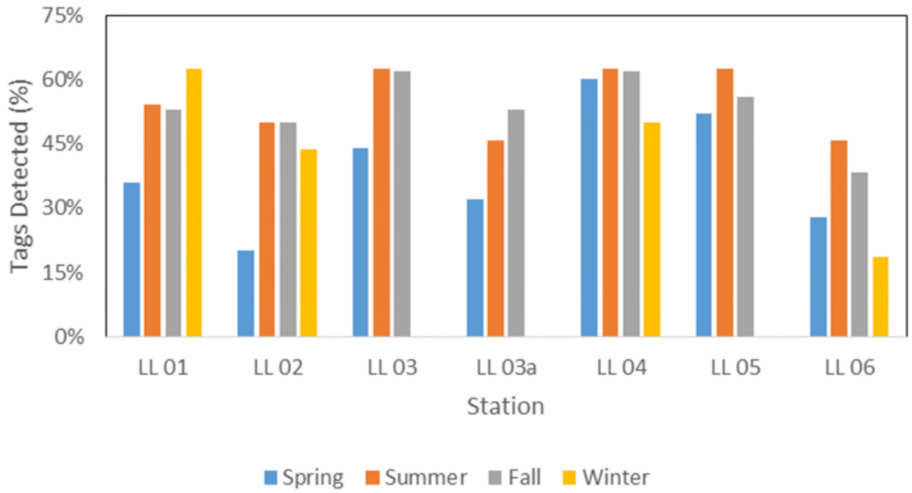

Figure 3*: Percentage of the total number of tags detected on a receiver in a season within the Lockport Pool in 2018.*

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

There were five occurrences of inter-pool movement by tagged fishes in calendar year 2018. Three of the movements consisted of tagged Common Carp moving from Brandon Road Pool to Lockport Pool. These three fish were all initially tagged and released in Lower Lockport Pool and had migrated to Brandon Road before 2018. To get back to Lockport Pool the three fish had to have traveled through the Lockport Lock. The first instance occurred between January 4th and February 25th, 2018. The fish was last detected on the receiver below Lockport lock on January 4th and detected above Lockport lock on February 25th. During this time a total of 171 downstream lockages and 186 upstream lockages occurred. Based on the delay in detections, it is not possible to determine exactly when the fish locked through and upstream into Lockport Pool. The second instance occurred on June 5, 2018. Differences in detection from a receiver upstream of Lockport Lock and a detection downstream in Brandon Road was approximately 55 minutes in the same day. During the 55 minute difference in detection time, only one 55 minute upstream lockage occurred and the fish likely made it through during that time period. The third instance occurred on June 18th, 2018 with a difference in detection time from below to above Lockport Lock of 1hr 42 minutes. During that time there was one, 98 minute upstream lockage that occurred where the fish likely moved through at that time.

The additional two fish that had migrated from Brandon Road Pool to Dresden Island Pool were a Grass Carp and Common Carp. The Common Carp was detected above the lock on October 4, 2018 and detected in the approach channel below the lock on October 6, 2018, but was not detected within the lock chamber. During this time there were 13 upstream and 11 downstream lockages. The Grass Carp was detected on June 21, 2018 above the lock and was detected on the 22nd of June approximately 2.75 miles downstream of the lock without being detected in the lock chamber or the lock approach channel. It is possible that both of these fish did not use the lock as a means to get to Dresden Island Pool, but instead went through the dam when the gates were open. It is also possible that barge noise masked the ping train of the transmitter while these fish were within detection range of the receiver, thus not allowing them to be recorded on one or both of these receivers.

From 2010 to 2018, there have been 67 occurrences of tagged fish moving downstream and 35 occurrences of upstream movement between navigation pools by a total of 83 individual tagged fish (Table 2). Inter-pool movement was greatest between the Lockport and Brandon Road pools accounting for 58% (n=59) of all inter-pool movements (upstream n=16; downstream n=43). The majority of downstream movement into the Brandon Road Pool occurred through the Lockport Controlling Works spillway approximately two miles upstream of the Lock (46%; n=30). Movement between the Dresden Island and Marseilles Pools comprised 35% (n=30) of all inter-pool movement (upstream n=14; downstream n=16). The lowest inter-pool movement occurred through the Brandon Road Lock and Dam accounting for 13% (n=13) of the total. Additionally, all upstream movement through the Brandon Road Lock has occurred by Common Carp originally captured within the Brandon Road Pool and released within the Dresden Island Pool. This method was used to increase the number of upstream lock passage attempts by fishes in the Dresden Island Pool and is not representative of the population originating from the Dresden Island Pool.

Table 2: *Tagged fish inter-pool movement from 2010 to 2018. Downstream is defined as DS and upstream is defined as US.*

Interpool Movement Data			
	US	DS	Total
Lockport	16	13	29
Lockport Spillway	0	30	30
Brandon Road	5	8	13
Dresden Island	14	16	30

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

A total of 46 out of 71 USACE tagged Asian Carp were detected within the Dresden Island Pool throughout 2018 resulting in a 65% detection of tagged fish. The 46 tagged Asian carp consisted of 17 Bighead Carp (Mean TL ± SD; 969 ± 88 mm), 28 Silver Carp (794 ± 57 mm), and 1 hybrid (878 mm) which were tagged between 2016 and October of 2018. In addition, 6 (4 Bighead, 2 Silver) active tags from Southern Illinois University and 10 USFWS tagged Grass Carp were detected throughout Dresden Island Pool and used within this analysis.

In total, the receivers placed in Dresden Island and the adjacent tributaries collected 238,126 detections from a total of 53 tagged Asian Carp, 10 grass carp, and one common carp. The percent of total detections at each receiver ranged from 0 to 36%. The stations that had the greatest percent of total detections included DI09a (36%), DI10 (30%), RR01 (14%), and KR01 (7%). In Figure 4 and Figure 5 it shows the percentage of the pool's total number of detections that occurred within a season and the percentage of a receiver's total number of detections that occurred within a season respectively for Dresden Island Pool. The clustering of fish in the lower end of the pool is not surprising as Asian Carp are consistently captured by contracted commercial fishermen in this area. The station at Rock Run Rookery (RR01) has consistently captured a large portion of detections over the past several years. The location of this receiver detects fish as they move in and out of the backwater and would likely have increased detections if it were strategically placed within the lake. Station DI10 is located upstream of the Dresden Island lock. The placement of DI09a was a new placement in 2016 and once again had the majority of the detections within Dresden Island. As indicated in the 2016 and 2017 interim summary, a myriad of habitat types within and adjacent to station DI09a combined with the constriction point in the river may help explain for the increased number of detections. The receiver is near shallow vegetated habitat, side channel habitat, backwater habitat (harbor slips) and close to an outfall from the I&M Canal. These habitat types may be an attractant to Asian carp, and the placement allows for fish to be detected as they move from the upper portion of the pool to the lower pool as well. Further investigations of fish detections at station DI09a, showed some fish tended to move through the area with only a few detections, other fish seemed to stage in the area for several days before moving up or downstream, and some fish appeared to use the area for a majority of the year and make minor movements into the Kankakee or upstream before returning to the area.

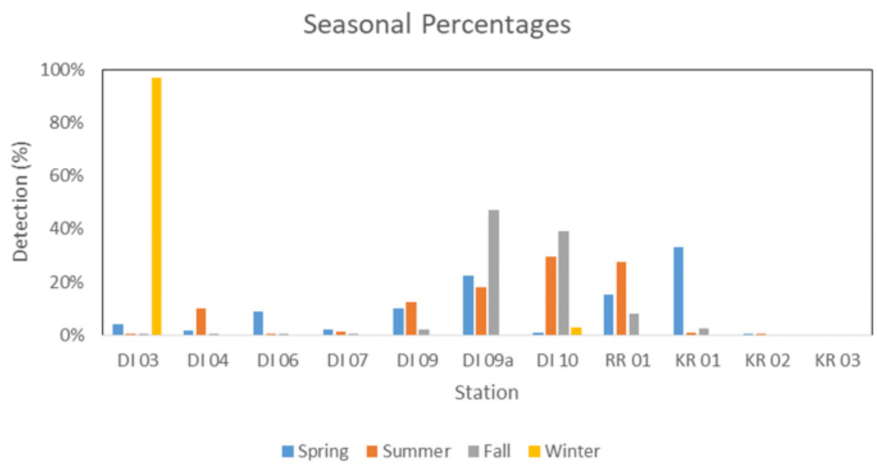

Figure 4: *Percentage of the Dresden Island Pool's total seasonal detections shown across receivers in 2018.*

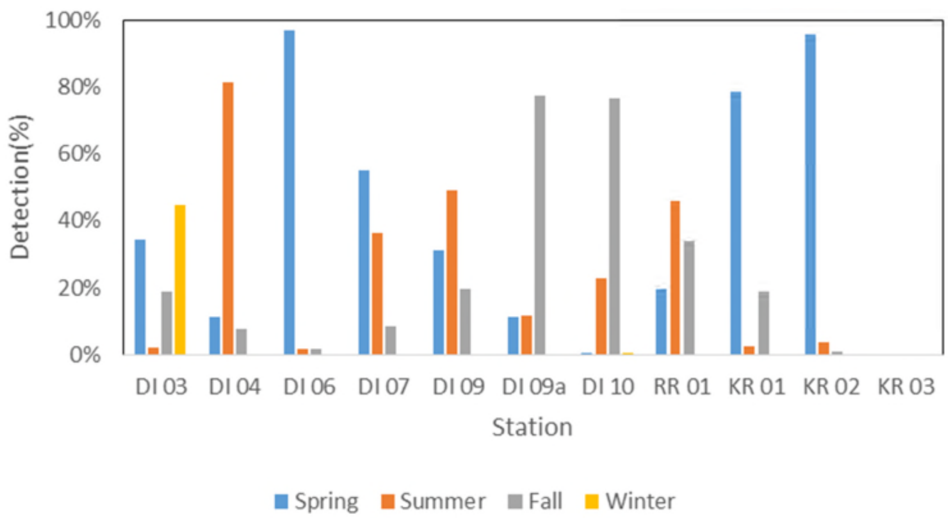

Figure 5: *Percentage of a receiver's total number of detections that occurred within a given season within the Dresden Island Pool in 2018.*

Total percent active tags detected at each receiver and the percent of total detections were used in conjunction to acquire inferences of seasonal fish movement within the Dresden Island Pool. Percent of active Asian carp tags detected seasonally ranged from 0 to 90% throughout the Dresden Island Pool (Figure *6*) (0-81% overall). Winter detections were low due to the decreased number of receivers within the pool. During the winter, a limited number of receivers are left in the pool to prevent loss from ice. In summer, DI10 had the greatest percent of total detections followed by RR01 (Figure 4). In fall, DI09a had the greatest percent of total detections.

Additionally, the greatest percentage of the pool's tags detected in spring occurred at DI09a followed by DI07 (Figure *6*). A total of 85% of the active tags were detected in fall with 47% of the pool's fall detections occurring at DI09a and 39% at DI10. This is likely because there was a large tagging effort that took place in the fall in the vicinity of these two receivers and might not accurately reflect Asian Carp movements at this time. Similarly, 40% of the active tags were detected during spring with 33% of the spring detections occurring at KR01 and 23% at DI09a. Finally, 31% of active tags were detected in summer with 30% of the detections occurring at DI10, 28% detections at RR01, and 18% of the detections occurring at DI09a (Figure *6*). These data continue to support the importance of DI09a as potential habitat and potential transition zones for Asian Carp movement between Kankakee River and the upper portions of the pool. Finally, KR 03 did not detect any fish during the 2018 season. This receiver is located approximately 0.5 mile downstream of Wilmington dam. Under normal conditions, there is approximately 5.5 miles of shallow, rocky waters and is not typical habitat where Asian Carp are expected to be found. They would likely not be drawn to this location in large numbers under normal conditions as they would be expected for areas such as backwaters or low flow side channels. This is also evident by the low number of detections at KR02, at the start of the rocky section of KR03. Under higher flow conditions, when Asian Carp are known to travel up the Kankakee River, it is possible that carp are indeed in the area. This is suggested by the majority of transmitters being detected during spring at KR02, when there is traditionally higher flows. However, the additional movement of water though this area may be creating enough noise to mask any transmitter noise and therefore giving the appearance of no fish being present. USACE is exploring other receiver placement options for the 2019 season that can give the desired detection coverage to monitor for fish that may be approaching Wilmington Dam.

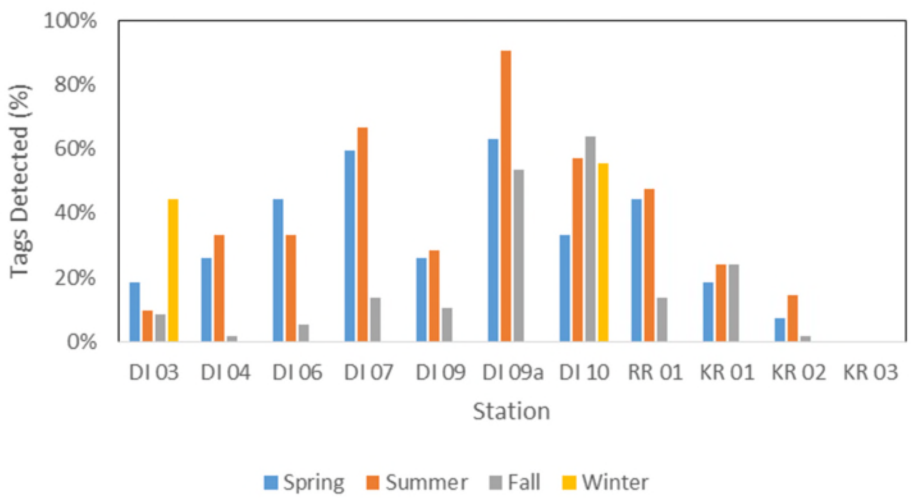

Figure 6: *Percentage of active tags within Dresden Island Pool and tributaries detected by each station across seasons in 2018.*

Due to ongoing work at Brandon road Lock and Dam, additional emphasis has been placed on Asian carp movements within and around the lock. In 2016, a single Bighead Carp was detected on the receiver within the Brandon Road approach channel in the Dresden Island Pool. This fish was first detected in the approach channel on 9 August at 14:15 and remained near the receiver for approximately 7 hours. This fish then heads downstream (2.8 miles) and is detected just upstream of Rock Run Rookery before returning to the approach channel at 10:01 on 10 August. The Bighead Carp then stages within the approach channel for close to 7 hours again before returning downstream. Another Bighead Carp had a single detection at the lock in 2017 on September 3rd at around 2 am. The fish was previously detected on DI04 and RR01 but was last detected at DI03. Due to the single detection, the fish likely moved back downstream to an area that is not covered by telemetry network. A download in March of 2018 of the overwinter network did not indicate the location of this fish, neither did subsequent downloads of the network throughout the year. If this fish is still present in the pool, it is likely in an area not covered by the network.

Temperature and Depth Analysis

Six Asian Carp (five Silver, one Bighead) have been implanted with depth and temperature transmitters in the Dresden Island Pool between the 2017 and 2018 seasons. The intent was to determine where fish have a tendency of staging in the water column to better inform targeted removal efforts in areas of variable habitat types. The number of depth and temperature detections and number of fish that produced those detections are indicated in Table 3. Figure 7 depicts the range of temperatures and depths that were detected at each station and the fish that produced those detections.

Overall, many of the detections can be found at less than two meters of water depth. Detections at greater than four meters are rare and a possible indication that these fish don't regularly use the bottom of main shipping channel and instead reside in the mid water column or in shallow portions of the river. At RR01 many of the detections are less than one meter which is a possible indication that the fish are utilizing and residing in or around the small, shallow connecting channel that joins Rock Run Rookery to the Des Plaines River. Stations DI06 and DI07 have a more even spread across depths, an indication that fish are actively migrating between shallow and deep water within the detection zones of these receivers. The receiver at DI09a also indicates that fish are actively moving between habitat types, but there is a small clustering in the shallower portions. The receiver itself is near shallow vegetated habitat, side channel habitat, backwater habitat (harbor slips) and close to an outfall from the I&M Canal. All these are habitat types that are likely favored by Asian Carp and explain the tendency for shallow water detection. Additionally, this location is a pinch point for carp moving between the upper and lower portions of the pool and the deeper detections are likely an indication of fish moving within that main channel as they traverse to other locations.

Table 3: *Number of detections for each tag type at Dresden Island Stations*

Station	Depth Detections	Temperature Detections	Number of Fish
DI 04	92	96	1
DI 06	111	109	3
DI 07	73	62	3
DI 09a	284	273	4
DI 10	38	44	5
KR 01	48	54	1
RR 01	1101	1061	3

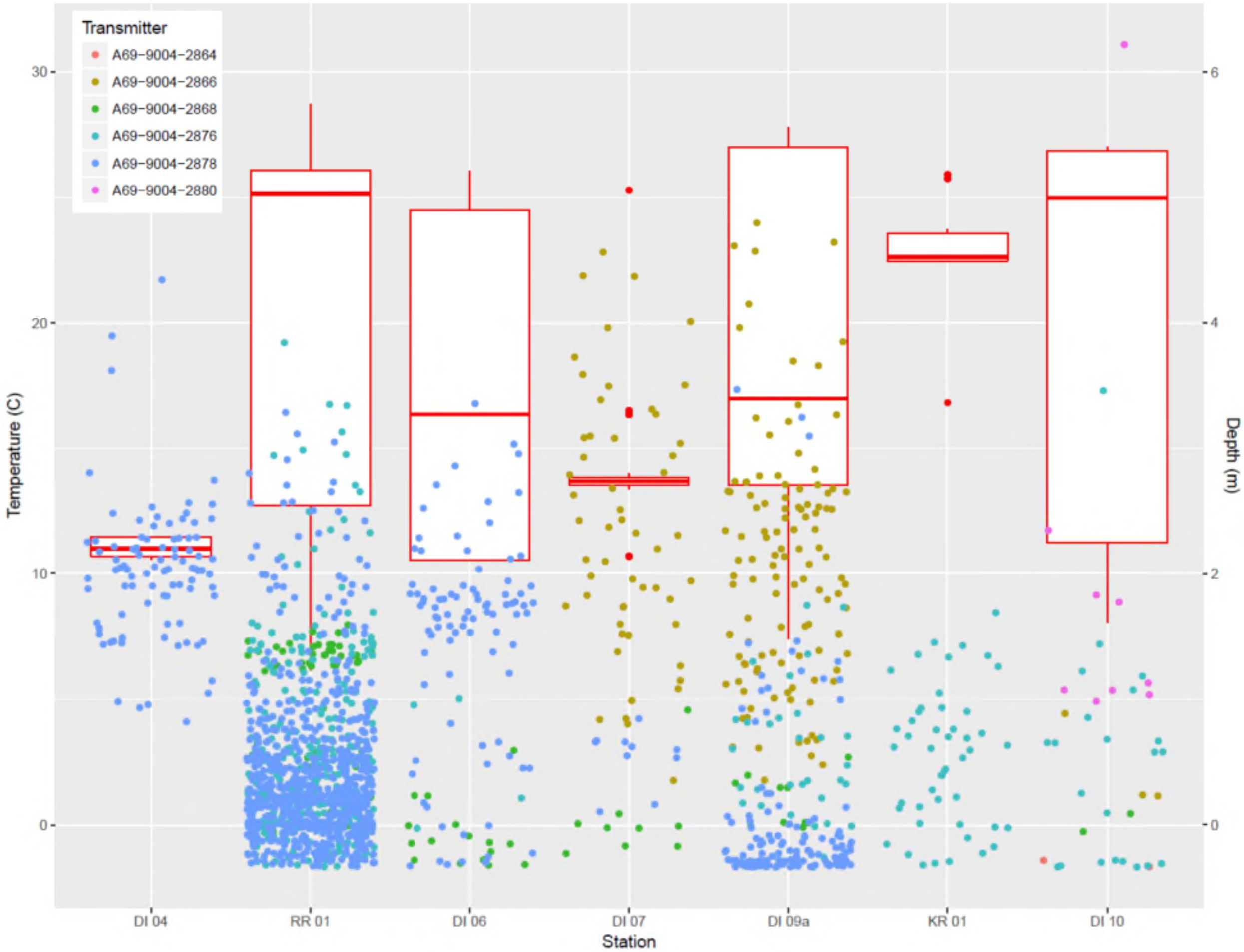

Figure 7: *Combined depiction temperature and depth analysis of five silver and one bighead carp in Dresden Island Pool. Bars indicate temperature and points indicate depth detections of the six fish.*

Finally, of the seven stations, only two received detections from just one fish, the remaining saw detections of at least three (Table 3). This indicates that fish are actively moving within the system and utilizing different depths and with the exception of Rock Run, are not residing at a location for large lengths of time before moving to another portion of the system. Moving forward with this type of analysis would require implantation of additional depth/temperature tags to further support or refute the previously indicated findings and to determine if there are any daily, monthly, or seasonal variations in where fish are located in the water column.

Recommendations:

USACE recommends continuation of the telemetry program and maintaining the target level of surrogate species tags within the system by replacing expired tags within the Lower Lockport Pool in early 2019. The number of Asian carp currently tagged within Dresden Island Pool should also be maintained with supplemental and replacement transmitters for these species. USACE will continue to collaborate with MRWG partners to maximize our understanding of Asian carp movement and biology within the Dresden Island Pool. USACE recommends continued collaboration with SIUC to perform comparisons of surrogate species to Bighead and Silver Carp. Understanding of how well Common Carp and other surrogates represent the behavior of bigheaded carps is important in determining the usefulness of the data collected from those surrogate species near the Electric Dispersal Barrier System. USACE will also continue to investigate the large expanse of data collected over the last 7 years to examine study area wide movement and habitat use for both Asian carp and surrogate species.

Continued analysis should occur at the Brandon Road Lock chamber for the telemetry program and continue the collaboration with partner agencies performing parallel studies. Continued collaboration with MRWG partners has helped fill in receiver coverage. USACE recommends continued collaboration with these partners to further investigate knowledge gaps in fish movement and behavior throughout the Upper Illinois River and the Chicago Area Waterway System.

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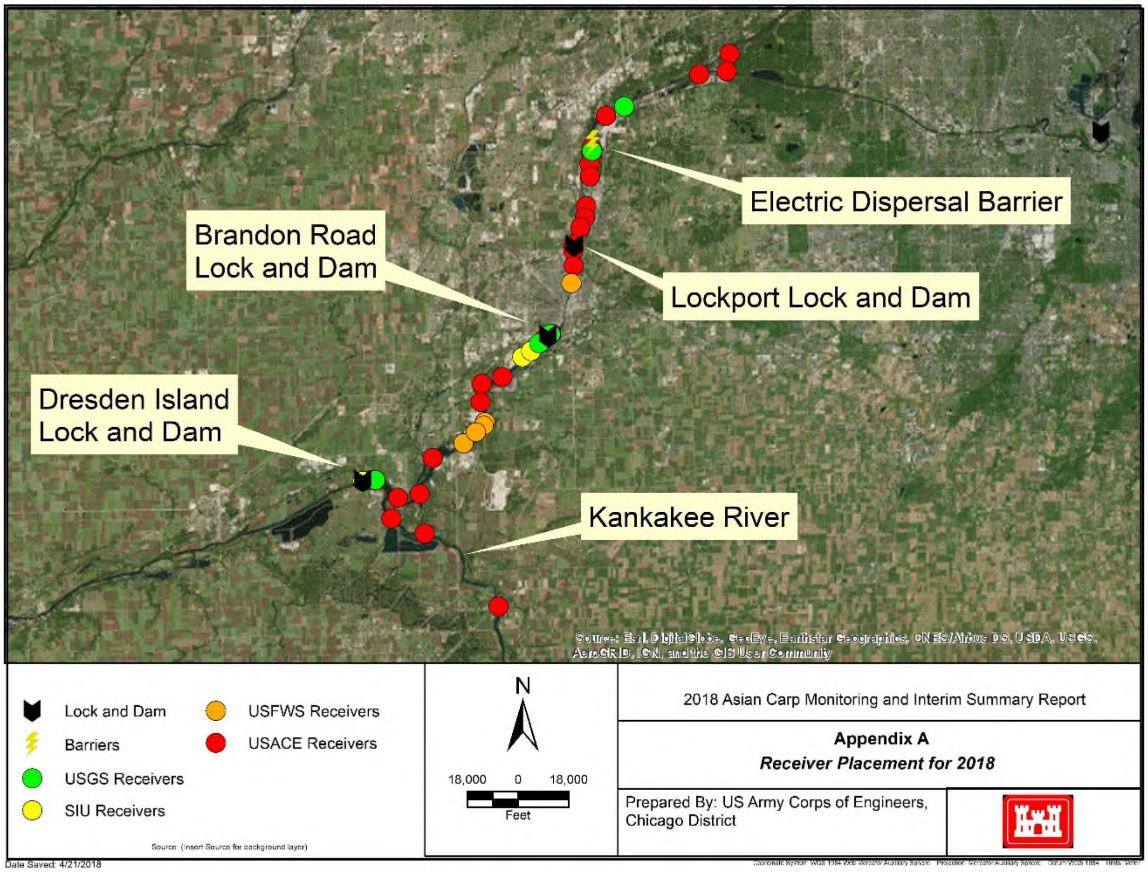
Appendix A


Electric Dispersal Barrier
Brandon Road Lock and Dam
Lockport Lock and Dam
Dresden Island Lock and Dam
Kankakee River
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Lock and Dam
Barriers
USGS Receivers
SIU Receivers
USFWS Receivers
USACE Receivers
N
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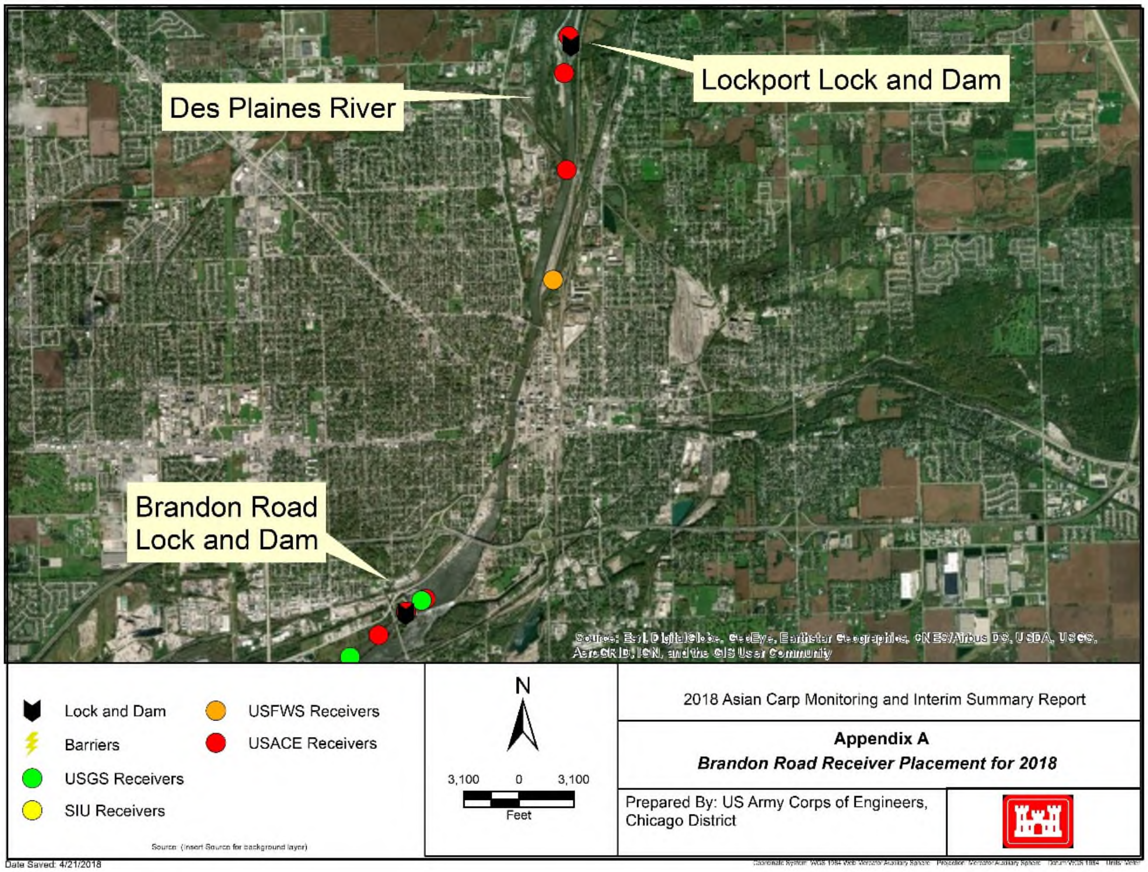
2018 Asian Carp Monitoring and Interim Summary Report
Appendix A
Receiver Placement for 2018
Prepared By: US Army Corps of Engineers, Chicago District
Date Saved: 4/21/2018


Lockport Lock and Dam
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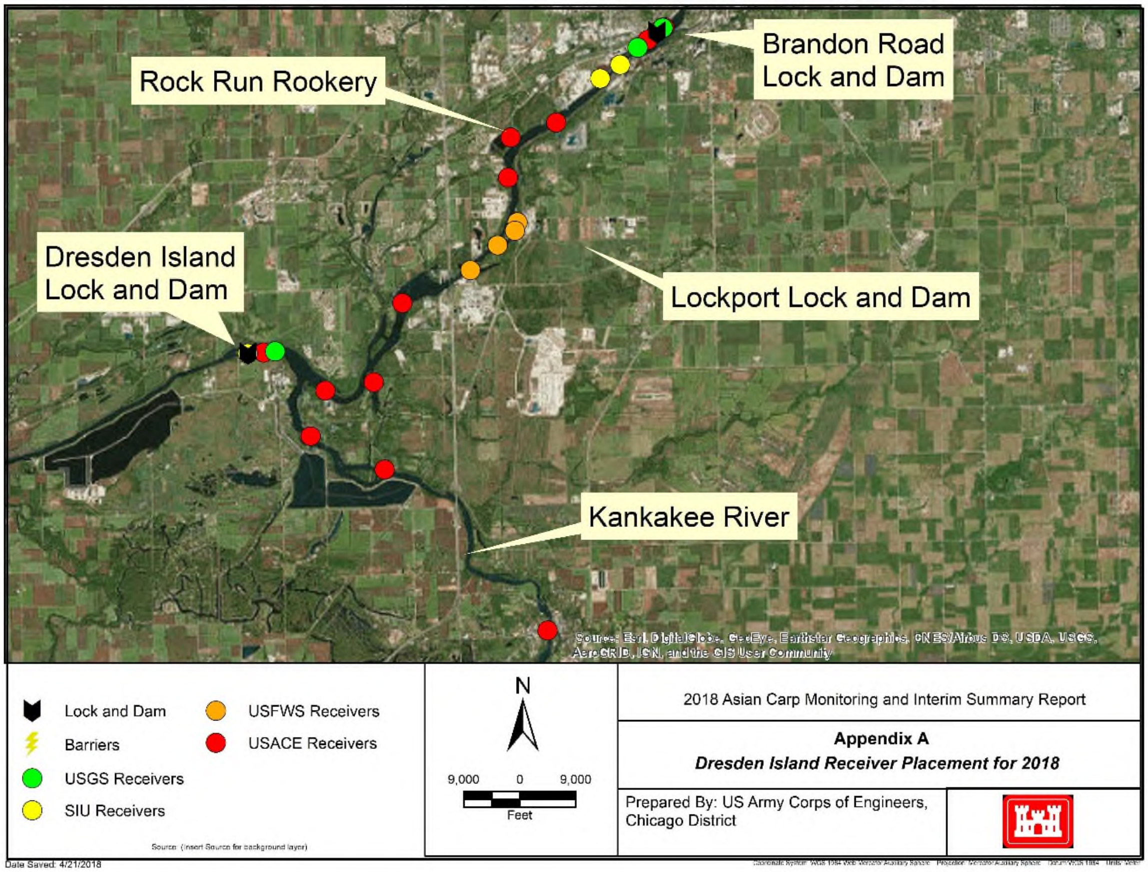
2018 Asian Carp Monitoring and Interim Summary Report
Appendix A
Brandon Road Receiver Placement for 2018
Prepared By: US Army Corps of Engineers,
Chicago District
Date Saved: 4/21/2018



Brandon Road
Lock and Dam
Rock Run Rookery
Dresden Island
Lock and Dam
Lockport Lock and Dam
Kankakee River
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Lock and Dam
Barriers
USGS Receivers
SIU Receivers
USFWS Receivers
USACE Receivers
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2018 Asian Carp Monitoring and Interim Summary Report
Appendix A
Dresden Island Receiver Placement for 2018
Prepared By: US Army Corps of Engineers,
Chicago District
Date Saved: 4/21/2018

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

Nathan Evans and Rebecca Neeley, USFWS Carterville FWCO
Wilmington

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

Pools Involved: Lockport, Brandon Road, and Dresden Island

Introduction and Need:

The Electric Dispersal Barrier located within the Chicago Sanitary and Ship Canal (CSSC) operates with the purpose of preventing inter-basin transfer of invasive fish species between the Mississippi and Great Lakes basins. Observational evidence from previous studies suggests that fish congregate below the Electric Dispersal Barrier at different times throughout the year, primarily during the summer and fall (Parker et al. 2015). How fish interact with the Electric Dispersal Barrier over varying temporal scales (e.g., diel to seasonal) is not well understood. Having a greater understanding of the temporally varying densities and spatial distributions of fish below the Electric Dispersal Barrier is important to barrier management, as it allows operational and maintenance decisions to be made in sync with potential risk factors. To determine these periods of elevated risk, split-beam hydroacoustic surveys were performed on a bi-weekly to monthly basis throughout 2018. Additionally, supplemental surveys were conducted weekly during December 2018 while maintenance was being performed on the Electric Dispersal Barrier. Moreover, split-beam hydroacoustic surveys of the Lockport, Brandon Road, and Dresden Island navigation pools of the Illinois Waterway were completed in the upper Illinois Waterway during spring and summer 2018. This work allowed for a greater understanding of the changes in fish densities and size distributions of the fish community in these study areas. Understanding fish community dynamics throughout the upper Illinois Waterway will allow the findings from a range of other research activities at the Electric Dispersal Barrier to be put into a system-wide context. This will then enable more refined interpretations of results and allow mangers to make better informed decisions. Additionally, identification of areas of high fish density may facilitate ongoing Asian carp removal efforts.

Objectives:

1) Evaluate the density of the fish community directly below the Electric Dispersal Barrier throughout the year.
2) Determine the density and distribution of fish in upper navigation pools within the Illinois Waterway throughout the year.

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

Project Highlights:

- Fish densities directly below the Electric Dispersal Barrier were similar across the majority of the 2018 hydroacustic surveys.
- Fish densities directly below the Electric Dispersal Barrier were releativly low with the majority of surveys indicating mean densities < 4 individual per 100,000 m^3 (annual mean = 2.46 individuals per 100,000 m^3).
- Fish densities ≥ 4 individuals/100,000 m^3 were observed during only three surveys: May 14 (survey mean = 9.09 individuals per 100,000 m^3), August 8 (survey mean = 7.46 individuals per 100,000 m^3) and September 26, 2018 (survey mean = 5.32 individuals per 100,000 m^3).
- Fish densities were greater in the summer and in the downstream pools. The greatest fish density was observed during the summer survey of Dresden Island Pool. The lowest fish density was observed during the spring survey of Lockport Pool.

Methods:

Acoustic Fish Surveys below the Electric Dispersal Barrier System

A series of side-looking split-beam hydroacoustic and side-scan sonar surveys were conducted below the CSSC Electric Dispersal Barrier System to assess fish density and distribution patterns near the barrier on a fine temporal scale. Surveys below the Electric Dispersal Barrier took place between February and November 2018 on a bi-weekly to monthly basis. Survey transects began approximately 500 m below the Electric Dispersal Barrier at 41º 38.200 N, 88º 03.664 W. The survey vessel traversed a path close to the west wall traveling north with the side-looking hydroacoustic transducers aimed towards the east wall. Each transect continued through the Electric Dispersal Barrier, paused briefly to allow bubbles and wake to disperse, turned south, and then traveled closely along the east wall back to 41º 38.200 N. Three consecutive replicate hydroacoustic samples took place on each survey date. Weekly surveys were conducted during December while maintenance was being performed on the Electric Dispersal Barrier. These surveys were performed using modified methods that involved not sampling above Barrier IIB and not pausing prior to southbound sampling while work was being conducted on the barriers. Due to the modified methods and the associated smaller sampling area, the results of the December surveys are not included in the analyses of this report.

The hydroacoustic survey equipment consisted of a pair of Biosonics® 200 kHz split-beam transducers and a 4125 Edge Tech ultra-high resolution side scan unit. The two split-beam hydroacoustic transducers were mounted in parallel on the starboard side of the research vessel 0.15 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. One hydroacoustic transducer was set to -3.2˚ and the other to -9.6˚ below parallel from the water surface. When necessary, due to boat movement, the rotators we manually repositioned to maintain optimal orientation. Split beam acoustic data was collected using Visual Acquisition v.6® from 1.15 – 50 m from the transducer face, at a ping rate of 5.0 pings per second, and a 0.40 ms pulse duration. Data collection was set to begin at 1.15 m from the transducer face in order to avoid near-field interference. To compensate for the effect of water temperature on two-way transmission loss via its effect on the speed of sound in water, temperature was recorded with a YSI® environmental meter and input into Visual Acquisition v.6® prior to all data collections. The split-beam acoustic transducers were calibrated on-axis with a tungsten carbide calibration sphere before sampling following Foote et al. (1987).

Split-beam hydroacoustic data were post-processed in Echoview® v. 9.0. Data was loaded into a mobile survey template. The A mobile survey template was used to identify and estimate the size and location of single fish targets based on angular position and target strength (TS). Data post processing followed standard methods (Glover et al. unpublished data). Data that were collected outside of the analysis bounds (between 41º 38.200 N and the IIA Electric Dispersal Barrier's lower parasitic structure) were removed from further analysis, a bottom line was digitized by hand, areas of bad data caused by air bubbles were removed, single targets were identified using a threshold of > -70 dB for target acceptance, fish tracks were identified using algorithms within the Echoview Fish Tracking Extension®, and single target -TS was converted from -dB to target length using equations derived from Love (1977). The settings applied in Echoview ® v. 9.0 were to only detect fish 12 inches or larger (≥ 30.5 cm total length) based on side-aspect TS. Calculation of target density within the canal was performed using the wedge volume sampled method whereby the number of targets encountered was divided by the total volume of water in a wedge encompassing the survey transect for each transducer (T. Jarvis, personal communication 4-7-2014). Each individual target and fish track was also spatially located within the water column using the split-beam transducers capabilities and assigned X, Y, and Z positional coordinates. Methods for processing the side-scan sonar data are currently being developed. Side-scan sonar results will be presented in the future.

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

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

Illinois Waterway Pool Surveys

To quantify the density and spatial distribution of the fish community in the upper Illinois Waterway, a series of hydroacoustic remote sensing surveys were conducted throughout the Lockport, Brandon Road, and Dresden Island navigation pools in spring (May) and summer (July and August) 2018. The surveys were conducted using the same equipment, collection techniques, and analysis methods as were employed during the hydroacoustic surveys at the Electric Dispersal Barrier. Within the navigation channel, each pool was surveyed by maneuvering the research vessel on clockwise transects around the pool near the channel margin. In areas where the navigation channel was wider than the range of the survey equipment (approximately 50 m) several concentric transects were conducted.

Results and Discussion:

Fish Surveys below the Electric Dispersal Barrier

Results from the hydroacoustic surveys conducted directly below the Electric Dispersal Barrier suggested that fish density was relatively low (annual mean = 2.46 individuals/100,000 m^3, SE = 0.63, n = 17) throughout the year (Kruskal-Wallis $P = 0.06$; Figure 1). Only three surveys illustrated mean fish densities ≥ 4 individuals/100,000 m^3: May 14 (survey mean ± SD = 9.09 ± 2.16 individuals/100,000 m^3), August 8 (survey mean ± SD = 7.46 ± 12.40 individuals/100,000 m^3) and September 26, 2018 (survey mean ± SD = 5.32 ± 4.61 individuals/100,000 m^3). These spikes in fish density may indicate periods of short-term elevated fish abundance that are not significantly different from the annual trend due to high variablity among the sample replicates. However, high variablity among the sample replicates during the surveys typically indicates compromised survey quality caused by factors such as weather, barge traffic, and floating debris.

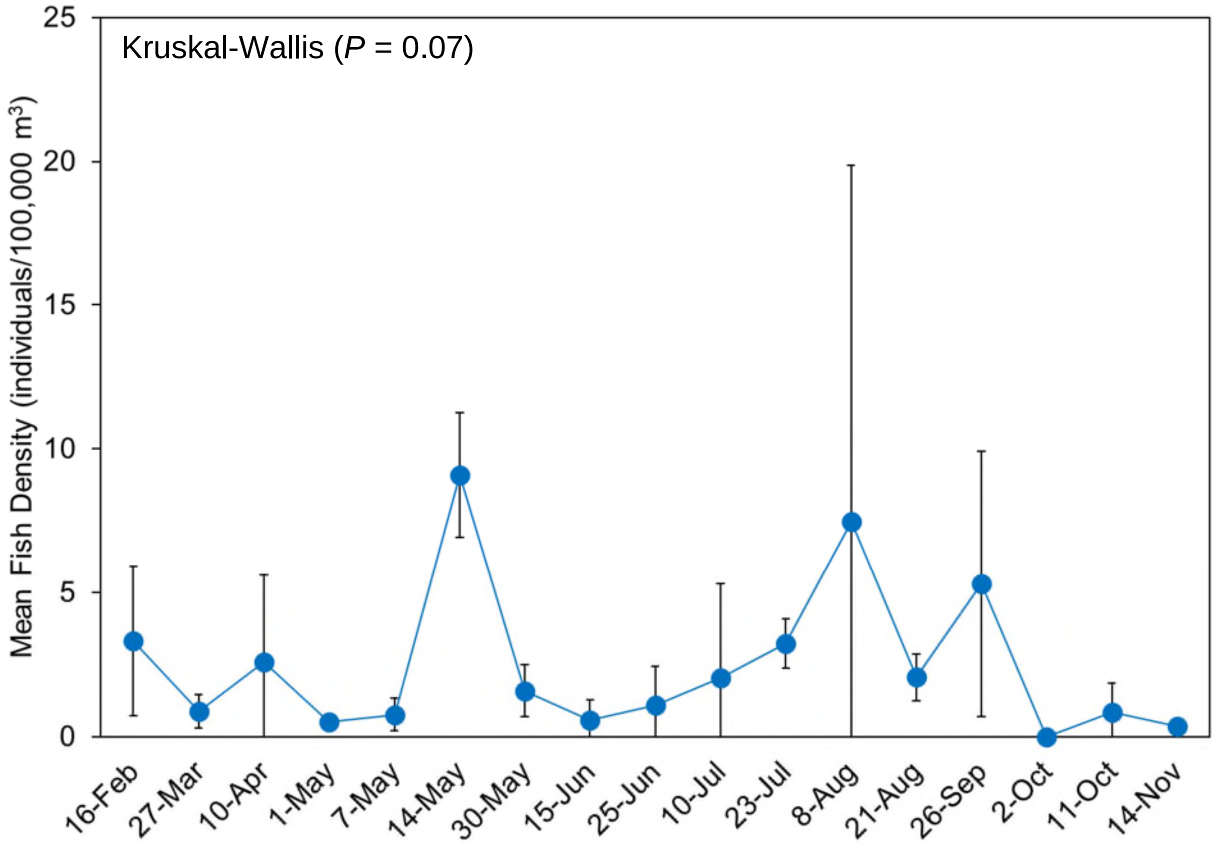

Figure 1. *Mean fish density (individuals/100,000 m^3) observed from the downstream edge of the barrier IIA parasitic structure to 500 m below) during split-beam hydroacoustic surveys conducted during 2018. Error bars represent ± 1 SD.*

Illinois River Pool Surveys

Results from the spring and summer hydroacoustic surveys conducted in Dresden Island, Brandon Road, and Lockport Pools illustrated greater mean fish densities during the summer surveys relative to the spring surveys (Figure 2). This difference in seasonal fish density was greatest for Brandon Road Pool where the mean density of the summer survey was approximately 4X greater than during the spring survey. Similarly, the mean fish density of the Lockport Pool summer survey was approximately 3X greater than the spring survey. The mean fish density of the Dresden Island Pool summer survey was approximately 1.2X greater than the spring survey. These increases in summer fish density are likely driven by young of year recruitment. Overall, fish densities decreased moving upstream with the greatest densities observed in Dresden Island, followed by Brandon Road, and the lowest densities observed in Lockport Pool.

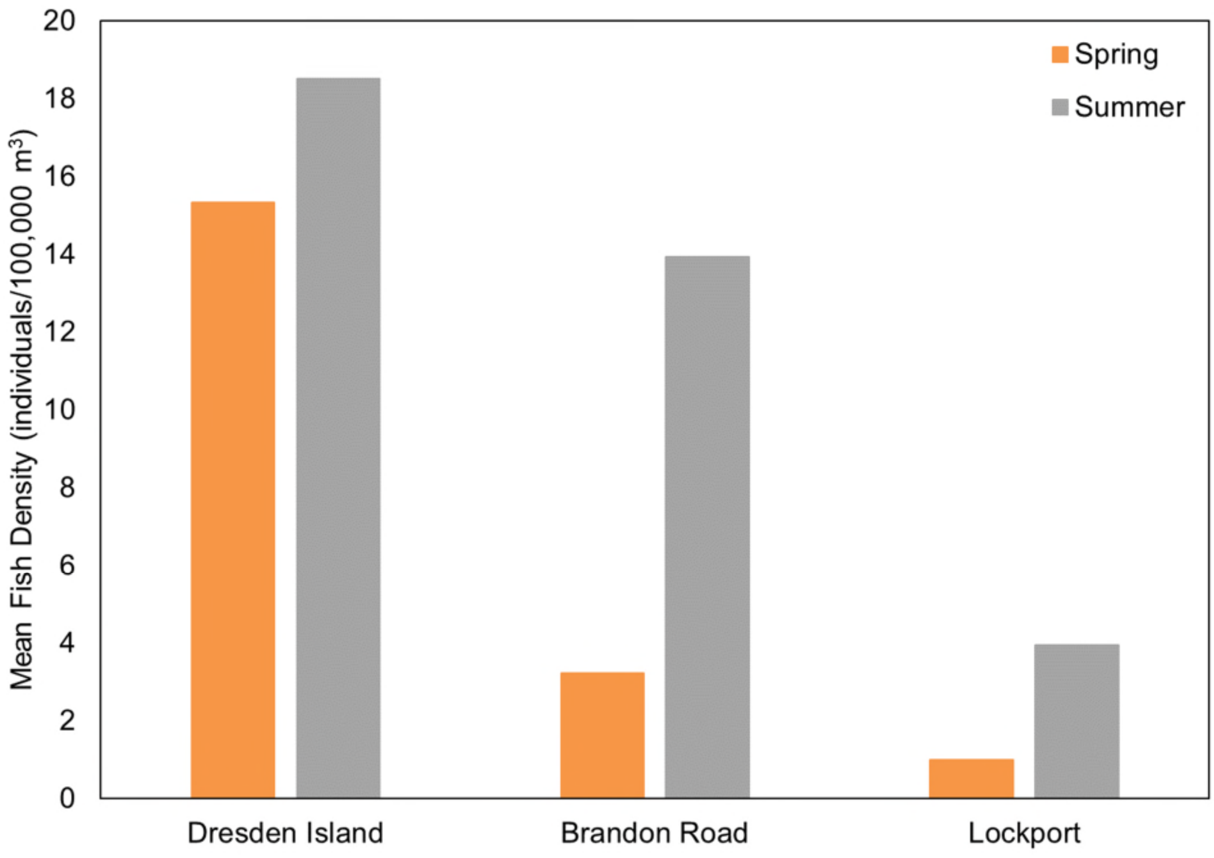

Figure 2. *Mean fish density (individuals/100,000 m^3) observed during spring (orange) and summer (gray) split-beam hydroacoustic surveys conducted during 2018 in Dresden Island, Brandon Road, and Lockport Pools. Surveys were conducted once per season in each of the three navigation pools.*

Conclusion

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

Recommendations:

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

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

(3) Increase the temporal frequency of pool surveys to improve statistical power and scope of inference about observed changes in fish density.

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Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

Seth Love, Nate Lederman, Tristan Widloe, Rebekah Anderson, Brennan Caputo, Kevin Irons, Matthew O'Hara, Justin Widloe (Illinois Department of Natural Resources), Eric Hine, Eli Lampo, Andrew Mathis (Illinois Natural History Survey), and Dr. Greg Whitledge (Southern Illinois University at Carbondale).

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

Introduction and Need:

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

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

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

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

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

Objectives:

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

Project Highlights:

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

Methods:

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

Results and Discussion:

A total of 43 Bighead Carp and one Silver Carp have been removed from nine ponds (Table 1). Fifty-seven hours of electrofishing and 12 miles of gill/trammel net were utilized to sample 24 Chicago area fishing ponds, resulting in 34 Bighead Carp removed from five ponds since 2011. Additionally, eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have been removed since 2008. Lastly, one Bighead Carp was incidentally caught by a fisherman in 2016. The lagoons at Garfield and Humboldt Park have had Bighead Carp removed following both natural die-offs and sampling. All ponds yielding positive eDNA detections and 18 of the 21 IDNR urban fishing ponds have been sampled. Lincoln Park South was not sampled because it was drained in 2008, resulting in three Bighead Carp being removed, and is no longer a source of Asian Carp as a result. Auburn Park was too shallow for boat access but had extremely high visibility. Therefore, the pond was visually inspected with no large bodied fish observed. Elliot Lake had banks too steep to back a boat in on a trailer. Lastly, Jackson Park and Garfield Park were drained in 2015 and, similar to Lincoln Park South, are no longer a source of Asian Carp. A map of all the Chicago area fishing ponds that were sampled or inspected as part of this project can be found in Figure 1.

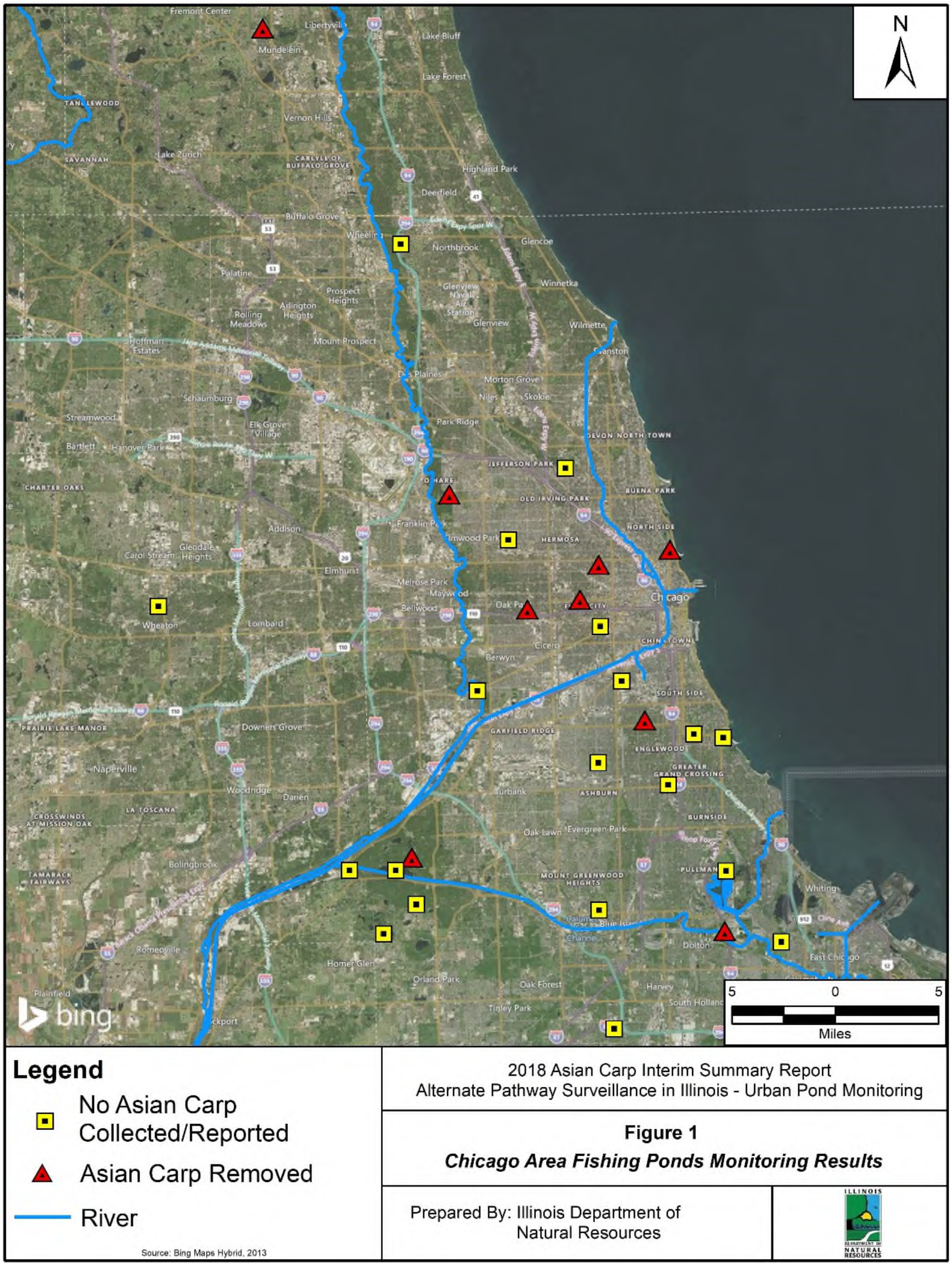

Figure 1. *Chicago area fishing ponds from which Asian carp have been removed (red) and those from which no Asian carp have been collected or reported (yellow).*

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

Recommendation:

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

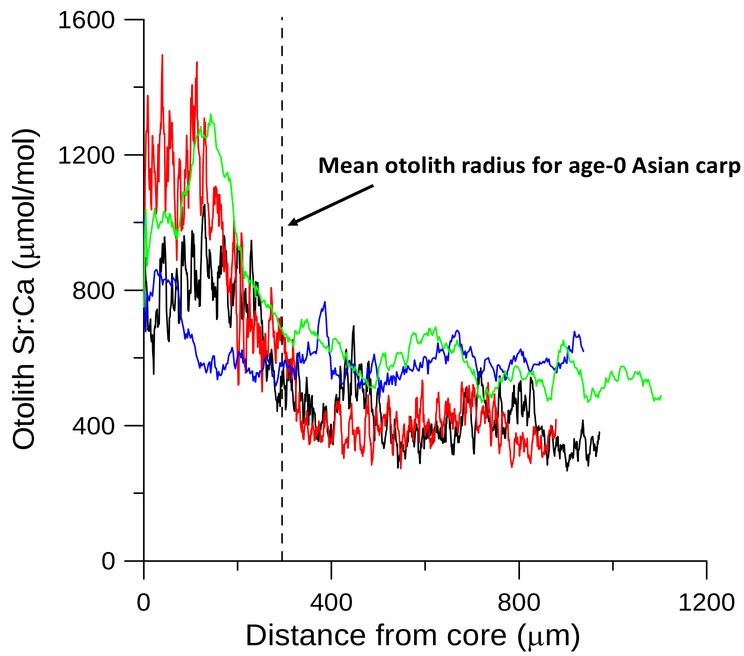

Figure 2. *Example of laser ablation transects for four Chicago pond Bighead Carp otoliths. The dashed line represents the mean otolith radius for age-0 Asian carp taken from nearby rivers.*

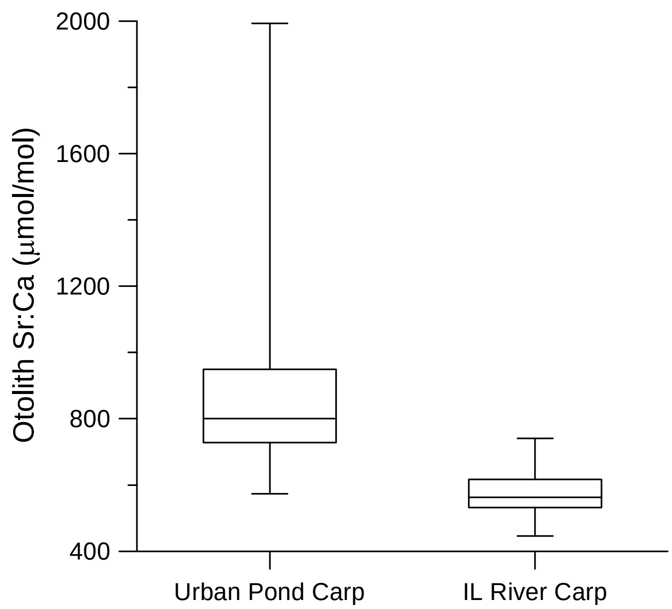

Figure 3. *Boxplots of otolith core Sr:Ca for Chicago pond (N = 24) and Illinois River (N = 81) Asian Carp. The minimum value for urban pond carp represents the Silver Carp collected from Sherman Park.*

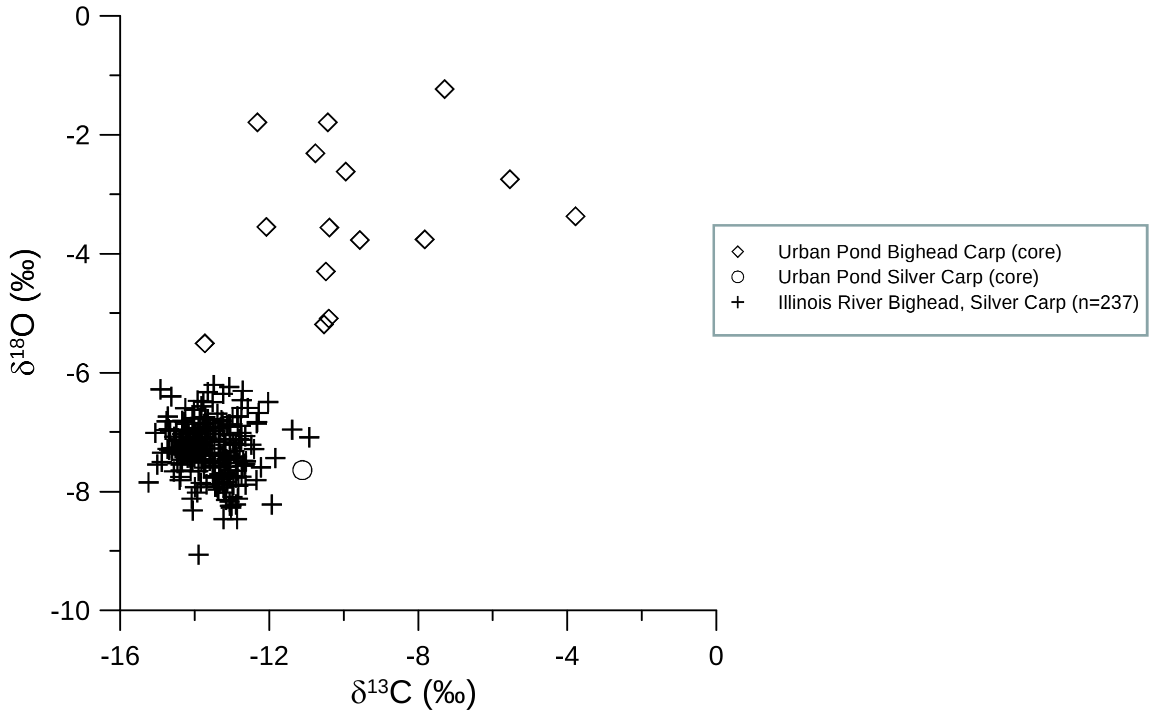

Figure 4. *Otolith Core $\delta^{18}O$ and $\delta^{13}C$ comparing Urban Pond and Illinois River Bighead and Silver Carps.*

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

	Sampling Results					
Location	Electrofishing (hrs.)	Gill/trammel netting (miles)	Sampling events (*N*)	Bighead carp (*N*)	Silver carp (*N*)	Asian carp collected post die-off, rotenone rehab or incidental take
Cermak Quarry	1.0	-	1	-	-	-
Columbus Park	0.8	0.1	1	-	-	3
Commissioners Park	0.5	0.1	1	-	-	-
Community Park	0.5	0.1	1		-	1
Douglas Park	0.8	0.2	1	-	-	-
Flatfoot Lake[1]	20.0	3.6	7	20	-	-
Garfield Park	3.6	0.1	1	2	-	1
Gompers Park	0.3	-	1	-	-	-
Harborside Golf Course Lake[2]	2.8	0.9	1	-	-	-
Horsetail Lake[2]	1.0	0.3	1	-	-	-
Humboldt Park	2.3	0.5	2	8	-	1
Jackson Park[1]	4.3	1.8	3	-	-	-
Joe's Pond [2]	0.5	0.3	1	1	-	-
Lake Owens	1.0	0.3	1	-	-	-
Lake Shermerville	1.0	0.3	1	-	-	-
Lincoln Park South	-	-	-	-	-	3
Marquette Park	1.3	0.4	1	-	-	-
McKinley Park	1.0	0.3	1	-	-	-
Powderhorn Lake[2]	2.0	0.7	1	-	-	-
Riis Park	0.2	-	1	-	-	-
Sag Quarry West[2]	0.6	0.3	1	-	-	-
Saganashkee Slough[3]	2.0	0.6	1	-	-	-
Schiller Pond	2.0	-	1	3	-	-
Sherman Park*	1.0	0.3	1	-	-	1
Tampier Lake[2]	5.5	0.6	1	-	-	-
Washington Park	1.5	0.3	1	-	-	-
Totals	57.2	12.1	34	34	0	10

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Young-of-year and Juvenile Asian Carp Monitoring

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Participating Agencies: Illinois Department of Natural Resources and Illinois Natural History Survey (co-leads); US Fish and Wildlife Service – Wilmington, Columbia, and La Crosse Fish and Wildlife Conservation Offices and US Army Corps of Engineers – Chicago District (field support).

Introduction and Need:

Successful reproduction and recruitment are crucial to the establishment and long-term viability of Asian carp populations in invaded waterways. Currently, large numbers of Asian carp inhabit the Illinois River, which is hydrologically connected to Lake Michigan and the broader Laurentian Great Lakes. The risk that Asian carp invade the Great Lakes and establish viable populations increases as Asian carp advance further up the Illinois River and its connected waterways. Although there is no current evidence of successful Asian carp reproduction in the CAWS or Des Plaines River, it is necessary to continually monitor and track the numbers of young-of-year and juvenile Asian carp among navigational pools to assess potential advancement and to describe inter-annual fluctuations in the numbers of small Asian carp. Such information informs agencies about the potential advancement of Asian carp populations through the Illinois Waterway towards the Great Lakes.

Objectives: Multiple gears suitable for sampling small fish were used to:

1) Determine whether young-of-year or juvenile Asian carp are present in the CAWS, lower Des Plaines River, and Illinois River; and
2) Determine the uppermost waterway reaches where young Asian carp are present in detectable numbers.

Project Highlights:

- Young Asian carp were sampled from 2010 to 2018 throughout the CAWS, Des Plaines River, and Illinois River between river miles 83 and 334 through sampling from existing monitoring projects.
- Sampling was conducted with active gears (trawls, pulsed-DC electrofishing, and beach seine) and passive gears (mini-fyke nets) in 2018. Mini-fyke nets caught the most Silver Carp <152 mm (i.e., <6 in.). Trawling captured more Silver Carp between 152-304 mm (i.e., 6-12 in.).
- Multiple agencies have completed 2,713 total hours of electrofishing across all years and pools.

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- Large numbers of Gizzard Shad <152 mm (6 in) were sampled along the Illinois Waterway during 2018, with catches within the range captured in previous years.
- Catches of small Asian carp in 2014 and 2018 were orders of magnitude higher than other years, suggesting stark differences between strong and weak recruitment years.
- The farthest upstream catch of young Asian carp in 2018 was one Silver Carp (152-304 mm) in the Starved Rock Pool.
- Given that the numbers of small Asian carp sampled differ by orders of magnitude among years, it is recommended that monitoring of small Asian carp be continued to examine recruitment fluctuations and identify abiotic and biotic factors that lead to recruitment success/failure.

Methods:

As in the past, 2018 sampling for young-of-year and juvenile Asian carp took place through other projects of the MRP. Projects included in this summary were: *Monitoring Efforts Downstream the Electric Dispersal Barrier*; *Seasonal Intensive Monitoring in the CAWS*; *Evaluation of Gear Efficiency and Asian Carp Detectability*; *Asian Carp Demographics*; *Distribution and Movement of Small Asian Carp in the Illinois Waterway*. See individual 2018 interim summary reports for additional information concerning sampling locations, specifics of fisheries gears, detailed sampling methods, and other protocols.

Sampling for small Asian carp consisted of a combination of active and passive gears. Effort was reported for each gear. Because effort varies by gear type, values are reported in terms of time (hours sampled), net-night deployments, or seine-hauls. Trawling, pulsed-DC electrofishing, seine hauls, and mini-fyke nets were the principal gears used to monitor for young Asian carp throughout the Illinois Waterway during 2018. Counts of small Gizzard Shad < 152 mm (6 in.) are included to track the relative abundance of a common native planktivore with similar vulnerabilities as young Asian carp across pools and through time. The intensive monitoring effort was the product of sampling by multiple agencies (IDNR, INHS, USFWS, USACE), and a summation of all catch and sampling effort from 2010-2018 is presented here.

Results and Discussion:

Young Asian carp were targeted with seven fisheries gears in 2018. Notably, numerous small Silver Carp, but no small Bighead Carp, were collected. Such a pattern has been observed in previous years. An overwhelming majority (99%) of all small Silver Carp were collected in the LaGrange Pool (n =51,657; Table 8). The remaining individuals (<1%) were collected in the Peoria Pool (n = 24) and the Starved Rock Pool (n = 1). In previous years (2015, 2016), a low number of small Asian carp were collected in the Marseilles Pool; the uppermost pool where small Asian carp have been documented as part of this ongoing project (see Tables 5, 6). However, in 2017 and 2018, no small Asian carp were detected by any agency in the Marseilles

Pool (Tables 7, 8). Finally, a total of 86,292 small Gizzard Shad were collected along the Illinois River (Table 8), and the catch was within range of previous years (range: 15,354 to 466,955; Tables 1-7).

Consistent with previous years, the greatest numbers of small (<6 in.) Silver Carp were collected in mini-fyke nets (n = 35,640; 199 net nights), followed by beach seining (n = 8,021; 35 hauls), dozer trawls (n = 5,697), and electrofishing (n = 2,300; 265 effort hours) (Table 8). Silver Carp between 152 and 304 mm (6 to 12 inches) were captured only in dozer trawls (n = 24) or by electrofishing (n = 1). Sampling effort during 2018 was consistent with other years. Overall, sampling effort varied among pools and among gears, but considerable effort was applied across a broad spatial area, from the CAWS upstream of the Electric Dispersal Barrier to the LaGrange Pool in the lower Illinois River.

Over the duration of this project, numbers of small Asian carp have varied from year to year by orders of magnitude. A total of 51,682 small (<304 mm) Silver Carp were collected during 2018 across the entire Illinois Waterway. Compared to previous years, 2018 had the second highest numbers of small Silver Carp (Figure 1). Total numbers of Silver Carp from 2018 were 4 orders of magnitude higher than 2010-2013 and 1-2 orders of magnitude higher than 2015-2017. Such stark differences in Silver Carp abundances suggest inconsistent recruitment among years. Using abundance of small Asian carp as a course index of recruitment, and comparing values among years, some inferences can be made about the population of Silver Carp in the Illinois River. Based on 8 years of data, a presumably strong recruitment year like 2014 was followed by three years of weak recruitment, and then followed by another strong recruitment year. Because these data reflect the summation of multiple projects, interannual variation in the numbers of Silver Carp can result from natural population dynamics as well as changes in sampling effort by contributing agencies. Consequently, inferring differences among low abundance years (e.g., 2010-2013 and 2015-2017) is not recommended. However, stark differences between high (2014, 2018) and low (2010-2013 and 2015-2017) abundances of Silver Carp are less likely to be affected by sampling effort, and differences between markedly high and low years likely reflects the drivers of strong and weak recruitment. Additional analyses are needed to identify the biotic and abiotic factors that drive differences between years in order to better understand the population dynamics of Silver Carp in the Illinois River.

Young-of-year and Juvenile Asian Carp Monitoring

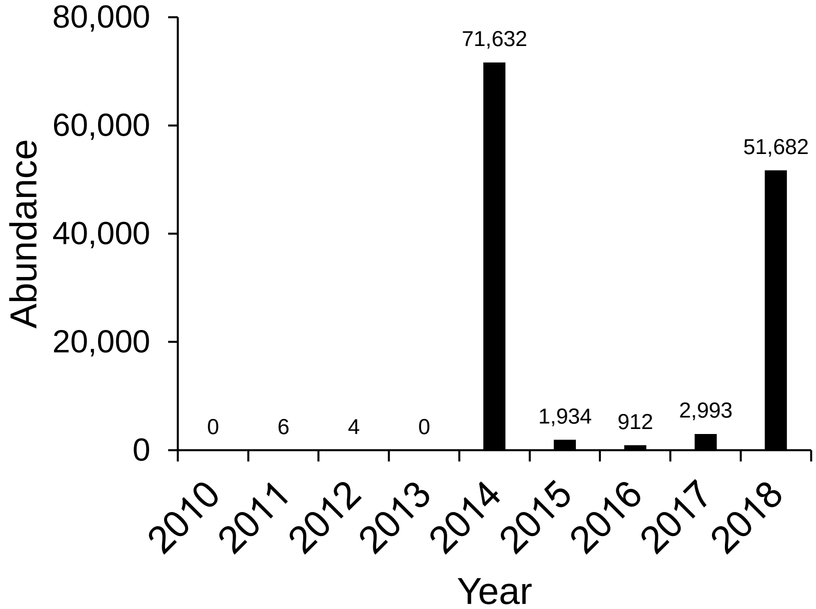

Figure 1. *Total abundance of small Silver Carp collected from a range of gears in the Illinois River from 2010 to 2018.*

Recommendation:

The use of multiple gears was coordinated throughout several projects to monitor for young Asian carp in the CAWS, Des Plaines River, and Illinois River from 2010-2018. We recommend continued vigilance in monitoring for juvenile Asian carp in the Illinois Waterway through existing monitoring projects. Sampling via a combination of mini-fykes, trawls, electrofishing, and seines provides suitable coverage and flexibility in sampling the diverse habitats/conditions of the Illinois Waterway. This cooperative effort by INHS, IDNR, USACE, and USFWS should continue in order to gather and synthesize data concerning the catches and locations of small Asian carp in the Illinois Waterway. These data will be summarized and made available in a living document that can be used to identify data gaps and track the ongoing status of the Asian carp invasion.

Young-of-year and Juvenile Asian Carp Monitoring

Table 1. *Number of juvenile Bighead Carp, Silver Carp, hybrid Bighead Carp x Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2010 and 2011.*

		Number Collected						
Gear	**Effort**	**Bighead Carp <6 in.**	**Bighead Carp 6-12 in.**	**Silver Carp <6 in.**	**Silver Carp 6-12 in.**	**Hybrid Carp <6 in.**	**Hybrid Carp 6-12 in.**	**Gizzard Shad <6 in.**
2010 **CAWS Upstream of Barrier (River Mile 296-334)**								
DC electrofishing	208 hours	0	0	0	0	0	0	12,746
Barrier to Marseilles Pool (River Mile 265-296)								
DC electrofishing	34 hours	0	0	0	0	0	0	3,655
Mini-fyke net	40 net-nights	0	0	0	0	0	0	65
Trap net	8 net-nights	0	0	0	0	0	0	2
Small mesh gill net	1,950 yards	0	0	0	0	0	0	77
Purse seine	10 hauls	0	0	0	0	0	0	0
Midwater trawl	10 tows	0	0	0	0	0	0	0
2011 **CAWS Upstream of Barrier (River Mile 296-334)**								
DC electrofishing	330.5 hours	0	0	0	0	0	0	15,655
Mini-fyke net	48 net-nights	0	0	0	0	0	0	6
Trap net	70 net-nights	0	0	0	0	0	0	0
Small mesh gill net	192 hours	0	0	0	0	0	0	6
Purse seine	24 hauls	0	0	0	0	0	0	3
Midwater trawl	24 tows	0	0	0	0	0	0	0
Beach seine	24 hauls	0	0	0	0	0	0	4
Cast net	48 throws	0	0	0	0	0	0	0
Upper Des Plaines River								
DC Electrofishing	10.5 hours	0	0	0	0	0	0	4
Dispersal Barrier to Starved Rock Pool (River Mile 240-296)								
DC electrofishing	50 hours	0	0	0	0	0	0	7,191
Mini-fyke net	72 net-nights	0	0	0	0	0	0	13
Trap net	72 net-nights	0	0	0	0	0	0	1
Small mesh gill net	288 hours	0	0	0	0	0	0	10
Purse seine	36 hauls	0	0	0	0	0	0	60
Midwater trawl	36 tows	0	0	0	0	0	0	153
Beach seine	36 hauls	0	0	0	0	0	0	14
Cast net	144 throws	0	0	0	0	0	0	18
Illinois River La Grange and Peoria Pools (River Mile 83-190)								
DC electrofishing	22 hours	0	0	0	1	1	0	77
Mini-fyke net	96 net-nights	0	0	0	0	0	0	22,773
Trap net	96 net-nights	0	1	0	0	0	0	1
Small mesh gill net	480 hours	0	0	1	3	0	0	23
Purse seine	60 hauls	0	0	0	1	0	0	108
Midwater trawl	60 tows	0	0	0	0	0	0	11
Beach seine	60 hauls	0	0	0	0	0	0	307
Cast net	96 throws	0	0	0	0	0	0	14

Young-of-year and Juvenile Asian Carp Monitoring

Table 2. *Number of juvenile Bighead Carp, Silver Carp, hybrid Bighead Carp x Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2012. River miles are in parentheses*

		Number Collected					
Gear	**Effort**	**Unidentified Asian Carp <6 in.**	**Bighead Carp <6 in.**	**Bighead Carp 6-12 in.**	**Silver Carp <6 in.**	**Silver Carp 6-12 in.**	**Gizzard Shad <6 in.**
CAWS Upstream of Barrier (River Mile 296-334)							
DC electrofishing	268 hours	0	0	0	0	0	42,448
Mini-fyke net	48 net-nights	0	0	0	0	0	22
Small mesh gill net	336 hours	0	0	0	0	0	5
Purse seine	48 hauls	0	0	0	0	0	6
Midwater trawl	2 hours	0	0	0	0	0	0
Beach seine	24 hauls	0	0	0	0	0	106
Cast net	24 casts	0	0	0	0	0	3
Fyke Net	48 net-nights	0	0	0	0	0	0
Upper Des Plaines River							
DC electrofishing	12.6 hours	0	0	0	0	0	6
Dispersal Barrier to Starved Rock Pool (River Mile 240-296)							
DC electrofishing	94 hours	0	0	0	0	0	14,439
Mini-fyke net	239 net-nights	0	0	0	0	0	642
Push trawls	55 runs	0	0	0	0	0	157
Small mesh fyke net	28 net-nights	0	0	0	0	0	1527
Small mesh gill net	464 hours	0	0	0	0	0	37
Purse seine	72 hauls	0	0	0	0	0	107
Midwater trawl	3 hours	0	0	0	0	0	0
Beach seine	36 hauls	0	0	0	0	0	2,708
Cast net	36 casts	0	0	0	0	0	24
Fyke Net	72 net-nights	0	0	0	0	0	1
Illinois River, LaGrange and Peoria Pools							
DC electrofishing	40.5 hours	0	0	0	0	0	755
Mini-fyke net	181 net-nights	4	0	0	0	0	3,867
Small mesh gill net	752 hours	0	0	0	0	0	76
Push trawls	33 runs	0	0	0	0	0	49
Small mesh fyke net	24 net-nights	0	0	0	0	0	288
Purse seine	120 hauls	0	0	0	0	0	71
Midwater trawl	2 hours	0	0	0	0	0	0
Beach seine	60 hauls	0	0	0	0	0	2,331
Cast net	60 casts	0	0	0	0	0	17
Fyke Net	72 net-nights	0	0	0	0	0	2

Table 3. *Number of juvenile Bighead Carp, Silver Carp, hybrid Bighead Carp x Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2013.*

		Number Collected							
Gear	**Effort**	**Bighead Carp <6 in.**	**Bighead Carp 6-12 in.**	**Silver Carp <6 in.**	**Silver Carp 6-12 in.**	**Hybrid Carp <6 in.**	**Hybrid Carp <6 in.**	**Gizzard Shad <6 in.**	**Gizzard Shad 6-12 in.**
CAWS									
DC Electrofishing	9 hours	0	0	0	0	0	0	23	109
Small Mesh Gill Nets	96 hours	0	0	0	0	0	0	3	25
Mini-Fyke Nets	48 net-nights	0	0	0	0	0	0	9	3
Beach Seines	24 hauls	0	0	0	0	0	0	16	1
Pound Nets	18 net-nights	0	0	0	0	0	0	0	9
Dresden Pool									
DC Electrofishing	3 hours	0	0	0	0	0	0	0	8
Small Mesh Gill Nets	32 hours	0	0	0	0	0	0	1	5
Mini-Fyke Nets	16 net-nights	0	0	0	0	0	0	533	1
Beach Seines	8 hauls	0	0	0	0	0	0	0	3
Marseilles Pool									
DC Electrofishing	4 hours	0	0	0	0	0	0	34	73
Small Mesh Gill Nets	32 hours	0	0	0	0	0	0	1	16
Mini-Fyke Nets	16 net-nights	0	0	0	0	0	0	38	3
Beach Seines	10 hauls	0	0	0	0	0	0	10	0
Pound Nets	46 net-nights	0	0	0	0	0	0	0	61
Starved Rock Pool									
DC Electrofishing	4 hours	0	0	0	0	0	0	0	11
Small Mesh Gill Nets	32 hours	0	0	0	0	0	0	0	3
Mini-Fyke Nets	16 net-nights	0	0	0	0	0	0	1	0
Beach Seines	10 hauls	0	0	0	0	0	0	0	0
Peoria Pool									
DC Electrofishing	4 hours	0	0	0	0	0	0	0	2
Small Mesh Gill Nets	32 hours	0	0	0	0	0	0	2	31
Mini-Fyke Nets	16 net-nights	0	0	0	0	0	0	5326	0
Beach Seines	10 hauls	0	0	0	0	0	0	39	0
Purse Seines	3 hauls	0	0	0	0	0	0	4	2
LaGrange Pool									
DC Electrofishing	13 hours	0	0	0	0	0	0	4471	5
Small Mesh Gill Nets	128 hours	0	0	0	0	0	0	18	55
Mini-Fyke Nets	48 net-nights	0	0	0	0	0	0	4019	0
Beach Seines	34 hauls	0	0	0	0	0	0	364	0
Pound Nets	8 net-nights	0	0	0	0	0	0	0	16

Table 4. *Number of juvenile Bighead Carp, Silver Carp, hybrid Bighead Carp x Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2014.*

Gear	Effort	Number Collected						
		Bighead Carp <6 in.	Bighead Carp 6-12 in.	Silver Carp <6 in.	Silver Carp 6-12 in.	Hybrid Carp <6 in.	Hybrid Carp 6-12 in.	Gizzard Shad
CAWS								
DC Electrofishing	88.25 hours	0	0	0	0	0	0	9837
Lockport Pool								
DC Electrofishing	43 hours	0	0	0	0	0	0	2505
Mini Fyke	28 net nights	0	0	0	0	0	0	222
Brandon Road								
DC Electrofishing	46.75 hours	0	0	0	0	0	0	2219
Mini Fyke	28 net nights	0	0	0	0	0	0	78
Dresden Pool								
DC Electrofishing	58.75 hours	0	0	0	0	0	0	4478
Mini Fyke	64 net nights	0	0	0	0	0	0	11
Push Trawls	30 pushes	0	0	0	0	0	0	NA
Marseilles Pool								
DC Electrofishing	64.25 hours	0	0	0	0	0	0	4734
Beach Seine	8 hauls	0	0	0	0	0	0	57
Cast Net	8 throws	0	0	0	0	0	0	9
Mini Fyke	83 net nights	0	0	0	0	0	0	72
Small Mesh Gill Nets	16 hours	0	0	0	0	0	0	5
Purse Seine	8 sets	0	0	0	0	0	0	190
Push Trawls	30 pushes	0	0	0	0	0	0	NA
Starved Rock Pool								
DC Electrofishing	12.75 hours	0	0	0	0	0	0	NA
Mini Fyke	32 net nights	0	0	0	0	0	0	NA
Push Trawls	30 pushes	0	0	0	0	0	0	NA
Peoria Pool								
DC Electrofishing	4 hours	0	0	36	0	0	0	305
Beach Seine	4 hauls	0	0	0	0	0	0	56
Cast Net	4 throws	0	0	0	0	0	0	0
Mini Fyke	8 net nights	0	0	11	0	0	0	670
Small Mesh Gill Nets	16 hours	0	0	0	0	0	0	2
Purse Seine	4 sets	0	0	2	0	0	0	0
LaGrange Pool								
DC Electrofishing	10.75 hours	0	0	4,104	0	0	0	1831
Beach Seines	32 hauls	0	0	7,240	0	0	0	329
Cast Net	32 throws	0	0	135	0	0	0	5
Mini Fyke	63 net nights	0	0	56,043	0	0	0	4643
Small Mesh Gill Nets	96 hours	0	0	0	0	0	0	84
Purse Seine	32 sets	0	0	4,060	1	0	0	591

Table 5. *Number of juvenile Bighead Carp, Silver Carp, hybrid Bighead Carp x Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2015.*

Gear	Effort	Number Collected						
		Bighead Carp <6 in.	Bighead Carp 6-12 in.	Silver Carp <6 in.	Silver Carp 6-12 in.	Hybrid Carp <6 in.	Hybrid Carp 6-12 in.	Gizzard Shad
CAWS								
Electrofishing (hours)	105.5	0	0	0	0	0	0	11,535
Brandon Road								
Electrofishing (hours)	29	0	0	0	0	0	0	925
Mini Fyke (Net Nights)	32	0	0	0	0	0	0	11
Lockport								
Electrofishing (hours)	33	0	0	0	0	0	0	656
Mini Fyke (Net Nights)	32	0	0	0	0	0	0	5
Dresden Island								
Electrofishing (hours)	47.83	0	0	0	0	0	0	6,722
Mini-fyke (night sets)	100	0	0	0	0	0	0	40
Dozer Trawl (meters)	1,338	0	0	0	0	0	0	0
Paupier Trawl (meters)	0	0	0	0	0	0	0	0
Push Trawl (meters)	3,333	0	0	0	0	0	0	101
Surface Trawl (meters)	0	0	0	0	0	0	0	0
5/8" mesh seine (pulls)	3	0	0	0	0	0	0	69
Bottom Electrified Trawls (pulls)	3	0	0	0	0	0	0	0
Marseilles								
Electrofishing (hours)	68.70	0	0	0	2	0	0	6,079
Mini-fyke (night sets)	93	0	0	0	0	0	0	121
Dozer Trawl (meters)	15,252	0	0	0	0	0	0	1,610
Paupier Trawl (meters)	17,215	0	0	0	0	0	0	4,250
Push Trawl (meters)	6,841	0	0	0	0	0	0	269
Surface Trawl (meters)	4,669	0	0	0	0	0	0	187
5/8" mesh seine (pulls)	5	0	0	0	0	0	0	82,959
Bottom Electrified Trawls (pulls)	3	0	0	0	0	0	0	0
Starved Rock								
Electrofishing (hours)	18.27	0	0	8	5	0	0	552
Mini-fyke (night sets)	75	0	0	0	0	0	0	159
Dozer Trawl (meters)	6,246	0	0	0	1	0	0	321
Paupier Trawl (meters)	44,171	0	1	94	438	0	0	4,561
Push Trawl (meters)	10,483	0	0	0	0	0	0	251
Surface Trawl (meters)	11,473	0	0	4	1	0	0	27
Bottom Electrified Trawls (pulls)	3	0	0	0	0	0	0	0

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Gear	Effort	Number Collected						
		Bighead Carp <6 in.	Bighead Carp 6-12 in.	Silver Carp <6 in.	Silver Carp 6-12 in.	Hybrid Carp <6 in.	Hybrid Carp 6-12 in.	Gizzard Shad
Peoria								
Electrofishing (hours)	4.9	0	0	2	0	0	0	86
Mini-fyke (night sets)	41	0	0	9	0	0	0	19
Dozer Trawl (meters)	14,179	0	0	8	0	0	0	12
Paupier Trawl (meters)	11,109	0	0	38	5	0	0	49
Push Trawl (meters)	5,955	0	0	2	0	0	0	12
Surface Trawl (meters)	9,528	0	0	93	2	0	0	31
Bottom Electrified Trawls (pulls)	5	0	0	0	0	0	0	0
La Grange								
Electrofishing (hours)	15.6	0	0	19	6	0	0	432
Mini Fyke (Net Nights)	105	1	2	75	0	0	0	1136
Dozer Trawl (meters)	16,154	0	0	112	0	0	0	1,228
Paupier Trawl (meters)	19,042	5	2	531	136	1	0	4,968
Push Trawl (meters)	11,120	0	0	118	0	0	0	579
Surface Trawl (meters)	13,549	2	0	140	8	0	0	326
Cast Net (sets)	16	0	0	0	0	0	0	0
Purse Seine (sets)	48	0	0	19	3	0	0	143
1/8" Mesh Seine (Pulls)	44	0	0	1	0	0	0	195
Small Mesh Gill Nets (hours)	36	0	0	7	24	0	0	323
Bottom Electrified Trawls (pulls)	5	0	0	9	0	0	0	0

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Table 6. *Number of juvenile Bighead Carp, Silver Carp, hybrid Bighead Carp x Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2016.*

Gear	**Effort**	**Number Collected**						
		Bighead Carp <6 in.	**Bighead Carp 6-12 in.**	**Silver Carp <6 in.**	**Silver Carp 6-12 in.**	**Hybrid Carp <6 in.**	**Hybrid Carp 6-12 in.**	**Bighead Carp <6 in.**
CAWS								
Electrofishing (hours)	101.5	0	0	0	0	0	0	6941
Brandon Road								
Electrofishing (hours)	36.1	0	0	0	0	0	0	784
Mini Fyke (net nights)	32.0	0	0	0	0	0	0	69
Lockport								
Electrofishing (hours)	35.7	0	0	0	0	0	0	1854
Mini Fyke (net nights)	32.0	0	0	0	0	0	0	179
Dresden Island								
Electrofishing (hours)	86.2	0	0	0	0	0	0	13511
Mini-fyke (night sets)	40.0	0	0	0	0	0	0	5
Dozer Trawl (hours)	2.8	0	0	0	0	0	0	332
Paupier Trawl (hours)	0.9	0	0	0	0	0	0	11
Push Trawl (hours)	0.0	0	0	0	0	0	0	0
Surface Trawl (hours)	0.0	0	0	0	0	0	0	0
5/8" mesh seine (pulls)	3.0	0	0	0	0	0	0	4780
Bottom Electrified Trawls (pulls)	0.0	0	0	0	0	0	0	0
Marseilles								
Electrofishing (hours)	88.2	0	0	0	1	0	0	8158
Mini-fyke (night sets)	32.0	0	0	0	0	0	0	1
Dozer Trawl (hours)	11.6	0	0	0	3	0	0	9445
Paupier Trawl (hours)	4.8	0	0	0	0	0	0	17350
Push Trawl (hours)	0.0	0	0	0	0	0	0	0
Surface Trawl (hours)	7.1	0	0	0	0	0	0	13922
5/8" mesh seine (pulls)	9.0	0	0	0	0	0	0	25269
Bottom Electrified Trawls (pulls)	0.0	0	0	0	0	0	0	0
Starved Rock								
Electrofishing (hours)	6.4	0	0	0	1	0	0	499
Mini-fyke (night sets)	19.0	0	0	0	0	0	0	17
Dozer Trawl (hours)	7.0	0	0	0	2	0	0	411
Paupier Trawl (hours)	3.2	0	0	0	0	0	12	612
Push Trawl (hours)	0.0	0	0	0	0	0	0	0
Surface Trawl (hours)	0.6	0	0	0	1	0	0	8
Bottom Electrified Trawls (pulls)	0.0	0	0	0	0	0	0	0

Young-of-year and Juvenile Asian Carp Monitoring

Gear	Effort	Number Collected						
		Bighead Carp <6 in.	Bighead Carp 6-12 in.	Silver Carp <6 in.	Silver Carp 6-12 in.	Hybrid Carp <6 in.	Hybrid Carp 6-12 in.	Bighead Carp <6 in.
Peoria								
Electrofishing (hours)	0.0	0	0	0	0	0	0	0
Mini-fyke (night sets)	0.0	0	0	0	0	0	0	0
Dozer Trawl (hours)	0.4	0	0	4	14	0	0	60
Paupier Trawl (hours)	0.0	0	0	0	0	0	0	0
Push Trawl (hours)	0.0	0	0	0	0	0	0	0
Surface Trawl (hours)	0.0	0	0	0	0	0	0	0
Bottom Electrified Trawls (pulls)	0.0	0	0	0	0	0	0	0
La Grange								
Electrofishing (hours)	7.5	0	0	0	32	0	0	200
Mini Fyke (net nights)	42.0	0	0	328	0	0	0	240
Dozer Trawl (hours)	13.5	0	1	7	142	0	0	2799
Paupier Trawl (hours)	7.0	1	0	81	232	0	0	7663
Push Trawl (hours)	0.0	0	0	0	0	0	0	0
Surface Trawl (hours)	6.8	1	0	38	5	0	0	537
Cast Net (sets)	0.0	0	0	0	0	0	0	0
Purse Seine (sets)	0.0	0	0	0	0	0	0	0
1/8" Mesh Seine (Pulls)	32.0	0	0	6	0	0	0	14
Small Mesh Gill Nets (hours)	0.0	0	0	0	0	0	0	0
Bottom Electrified Trawls (pulls)	0.0	0	0	0	0	0	0	0

Young-of-year and Juvenile Asian Carp Monitoring

Table 7. *Number of juvenile Bighead Carp, Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2017.*

Gear	Effort	Number Collected				
		Bighead Carp <6 in.	Bighead Carp 6-12 in.	Silver Carp <6 in.	Silver Carp 6-12 in.	Gizzard Shad
CAWS						
Electrofishing (hours)	203.9	0	0	0	0	15022
Brandon Road						
Electrofishing (hours)	32.5	0	0	0	0	2089
Mini Fyke (net nights)	29.4	0	0	0	0	178
Dozer Trawl (hours)	1.1	0	0	0	0	27
Paupier Trawl (hours)	0	0	0	0	0	0
Lockport						
Electrofishing (hours)	31.3	0	0	0	0	2451
Mini Fyke (net nights)	28.4	0	0	0	0	30
Dozer Trawl (hours)	0.65	0	0	0	0	0
Paupier Trawl (hours)	0	0	0	0	0	0
Dresden Island						
Electrofishing (hours)	54.5	0	0	0	0	8972
Mini-fyke (night sets)	34.8	0	0	0	0	560
Dozer Trawl (hours)	1.7	0	0	0	0	269
Paupier Trawl (hours)	0.2	0	0	0	0	322
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
5/8" mesh seine (pulls)	4	0	0	0	0	1557
Bottom Electrified Trawls (pulls)	0	0	0	0	0	0
Marseilles						
Electrofishing (hours)	70	0	0	0	0	18966
Mini-fyke (night sets)	41	0	0	0	0	10
Dozer Trawl (hours)	8.5	0	0	0	0	28891
Paupier Trawl (hours)	23.5	0	0	0	0	278339
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
5/8" mesh seine (pulls)	5	0	0	0	0	52453
Bottom Electrified Trawls (pulls)	0	0	0	0	0	0

Young-of-year and Juvenile Asian Carp Monitoring

Gear	Effort	Number Collected				
		Bighead Carp <6 in.	Bighead Carp 6-12 in.	Silver Carp <6 in.	Silver Carp 6-12 in.	Gizzard Shad
Starved Rock						
Electrofishing (hours)	24	0	0	0	1	3044
Mini-fyke (night sets)	50	0	0	0	0	38
Dozer Trawl (hours)	3.7	0	0	0	0	1419
Paupier Trawl (hours)	2.9	0	0	0	0	728
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
Bottom Elec. Trawls (pulls)	0	0	0	0	0	0
Peoria						
Electrofishing (hours)	7	0	0	3	11	123
Mini-fyke (night sets)	13	0	0	0	0	1
Dozer Trawl (hours)	5.1	0	0	0	11	87
Paupier Trawl (hours)	0.5	0	0	0	0	25
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
Bottom Elec. Trawls (pulls)	0	0	0	0	0	0
La Grange						
Electrofishing (hours)	7.7	0	0	0	0	1190
Mini Fyke (net nights)	42	0	0	2855	0	0
Dozer Trawl (hours)	13.9	0	0	6	5	14059
Paupier Trawl (hours)	8.5	0	0	28	70	36105
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
Cast Net (sets)	0	0	0	0	0	0
Purse Seine (sets)	0	0	0	0	0	0
1/8" Mesh Seine (Pulls)	32	0	0	3	0	0
Small Mesh Gill Nets (hours)	0	0	0	0	0	0
Bottom Elec. Trawls (pulls)	0	0	0	0	0	0

Table 8. *Number of juvenile Bighead Carp, Silver Carp, and Gizzard Shad sampled with various gears in the CAWS and Illinois Waterway during 2018. BHC = Bighead Carp; SCP = Silver Carp*

Gear	Effort	Number				
		BHC <152mm	BHC 152-304mm	SCP <152mm.	SCP 152-304mm	Gizzard Shad
CAWS						
Electrofishing (hours)	104	0	0	0	0	8,602
Commercial Seine (pulls)	3	0	0	0	0	2,584
Brandon Road						
Electrofishing (hours)	1	0	0	0	0	172
Mini Fyke (Net Nights)	27	0	0	0	0	14
Lockport						
Electrofishing (hours)	1	0	0	0	0	338
Mini Fyke (Net Nights)	29	0	0	0	0	11
Dresden Island						
Electrofishing (hours)	49	0	0	0	0	3,761
Mini-fyke (night sets)	24	0	0	0	0	14
Dozer Trawl (hours)	0	0	0	0	0	0
Paupier Trawl (hours)	0	0	0	0	0	0
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
5/8" mesh seine (pulls)	0	0	0	0	0	0
Bottom Electrified Trawls (pulls)	0	0	0	0	0	0
Marseilles						
Electrofishing (hours)	61	0	0	0	0	12,746
Mini-fyke (night sets)	37	0	0	0	0	2,216
Dozer Trawl (hours)	4	0	0	0	0	11,717
Paupier Trawl (hours)	0	0	0	0	0	0
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
5/8" mesh seine	0	0	0	0	0	0
Bottom Electrified Trawls (pulls)	0	0	0	0	0	0
Starved Rock						
Electrofishing (hours)	13	0	0	0	1	1,198
Mini-fyke (night sets)	23	0	0	0	0	2
Dozer Trawl (hours)	4	0	0	0	0	2,817
Paupier Trawl (hours)	0	0	0	0	0	0
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
Bottom Electrified Trawls (pulls)	0	0	0	0	0	0

Young-of-year and Juvenile Asian Carp Monitoring

Gear	Effort	Number				
		BHC <152mm	BHC 152-304mm	SCP <152mm.	SCP 152-304mm	Gizzard Shad
Peoria						
Electrofishing (hours)	0	0	0	0	0	21
Mini-fyke (night sets)	14	0	0	0	0	324
Dozer Trawl (hours)	9	0	0	0	24	1,109
Paupier Trawl (hours)	0	0	0	0	0	0
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
Bottom Electrified Trawls (pulls)	0	0	0	0	0	0
La Grange						
Electrofishing (hours)	8	0	0	2,299	0	987
Mini Fyke (Net Nights)	46	0	0	35,640	0	35,912
Dozer Trawl (hours)	11	0	0	5,697	0	909
Paupier Trawl (hours)	0	0	0	0	0	0
Push Trawl (hours)	0	0	0	0	0	0
Surface Trawl (hours)	0	0	0	0	0	0
Cast Net (sets)	0	0	0	0	0	0
Purse Seine (sets)	0	0	0	0	0	0
1/8" Mesh Seine (Pulls)	32	0	0	8,021	0	838
Small Mesh Gill Nets (hours)	0	0	0	0	0	0
Bottom Electrified Trawls (hours)	0	0	0	0	0	0

Des Plaines River Monitoring

Participating Agencies: US Fish and Wildlife Service- La Crosse Fish and Wildlife Conservation Office (lead); US Fish and Wildlife Service- Carterville Fish and Wildlife Conservation Office Wilmington Substation; Southern Illinois University, Metropolitan Water Reclamation District of Greater Chicago, US Army Corps of Engineers and Illinois Department of Natural Resources (field support)

Introduction and Need:

The upper Des Plaines River rises in Southeast Wisconsin and joins the Chicago Sanitary and Shipping Canal (CSSC) in the Brandon Road Pool immediately below Lockport Lock and Dam. Asian carp have been observed in this pool up to the confluence with the Des Plaines River, and have free access to enter the upper Des Plaines River. In 2010 and 2011, Asian carp eDNA was detected in the upper Des Plaines River (no samples were taken in 2012 – 2018). It is possible that Asian carp present in the upper Des Plaines River could gain access to the CSSC upstream of the Electric Dispersal Barrier during high water events when water flows laterally from the upper Des Plaines River into the CSSC. A physical barrier to reduce the likelihood of this movement was constructed in the fall of 2010 by the US Army Corps of Engineers (USACE). The barrier 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. Although the purpose of the barrier is to stop adult and juvenile Asian carp from infiltrating the CSSC, it will allow Asian carp eggs and fry to pass. Overtopping events in 2011 and 2013 created breaches in the barrier that were passable. Breach sites and other low-lying areas were later reinforced with chicken wire buried in gravel and/or cement to prevent scouring during future overtopping events. One low-lying area was reinforced with a large berm. It is important to monitor and understand the current Asian carp population status (including reproduction) and determine effectiveness of the physical barrier to help inform management decisions, evaluate risk during overtopping events, and direct removal actions.

Objectives:

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

(2) During high flow events when water moves laterally from the Des Plaines River into the CSSC, monitor for eggs and larvae around the physical barrier and monitor the effectiveness of the barrier against fishes.

Project Highlights:

- Collected 11,830 fish representing 62 species and 3 hybrid groups from 2011-2018 via electrofishing (64.02 hours) and gill netting (21,316 yards).

Des Plaines River Monitoring

- No Bighead Carp or Silver Carp have been captured or observed through all years of sampling (2011-2018).
- Ten Grass Carp have been collected, of which six were submitted for ploidy analysis. All six were determined to be triploid.
- Three overtopping events since 2011 have resulted in several improvements to the barrier fence.
- No high-water events occurred in 2018 so there were no times when the barrier was overtopped, therefore ichthyoplankton sampling was not conducted in 2018.

Methods:

In 2018, sampling was conducted in the upper Des Plaines River from Romeoville, Illinois upstream to near Burr Ridge, Illinois (Figure 1). Sampling was performed using pulsed-DC electrofishing and short term top to bottom gill net sets. Electrofishing runs included one or two dippers and proceeded for 15 minutes or until the backwater shoreline was completed. Gill net sets included 3 inch, 3.5 inch, 4 inch, 4.25 inch, and 5 inch bar mesh. Fish were driven to the nets using electrofishing boats and/or pounding. Sampling was performed in backwaters and channel habitat that were accessible near launch locations using gill nets and electrofishing gear. Grass Carp were removed. All other fish species were identified and released.

Potential overtopping events were investigated to determine if surface water reached the CSSC, to locate any breaches, and if so, to sample for fish/eggs/larvae that may have passed the barrier fence. Crews drove or walked along the fence and inspected areas where water reached the fence. Ichthyoplankton samples are collected when overtopping events occur at water temperatures conducive to spawning (>18° C) (Kolar et al. 2007). This did not occur in 2018 so no ichtyhoplankton sampling was conducted.

In years when overtopping of the barrier occurs and water temperatures > 18° C, icthyoplankton samples are taken at three locations: Willow Springs Road via bridge, at the confluence with the CSSC via boat, and above the confluence in the CSSC via boat. Samples are collected using 500 µm mesh and a 0.5 m diameter hoop. At each site, three replicates are collected for five minutes each. Samples are collected just beneath the surface, stationary from the bridge or towed slowly upstream from the boat. Samples are transferred to 95% ethanol and later processed in a laboratory where larval fish are identified to family and genus and eggs are identified as Asian carp or non-Asian carp.

Results and Discussion:

During the eight years of sampling (2011-2018), 64.02 hours of electrofishing and 21,316 yards of gill net resulted in a total catch of 11,830 fish. Sixty-two species and three hybrid groups have been collected with Common Carp being the most commonly collected species, followed by Gizzard Shad and Bluegill.

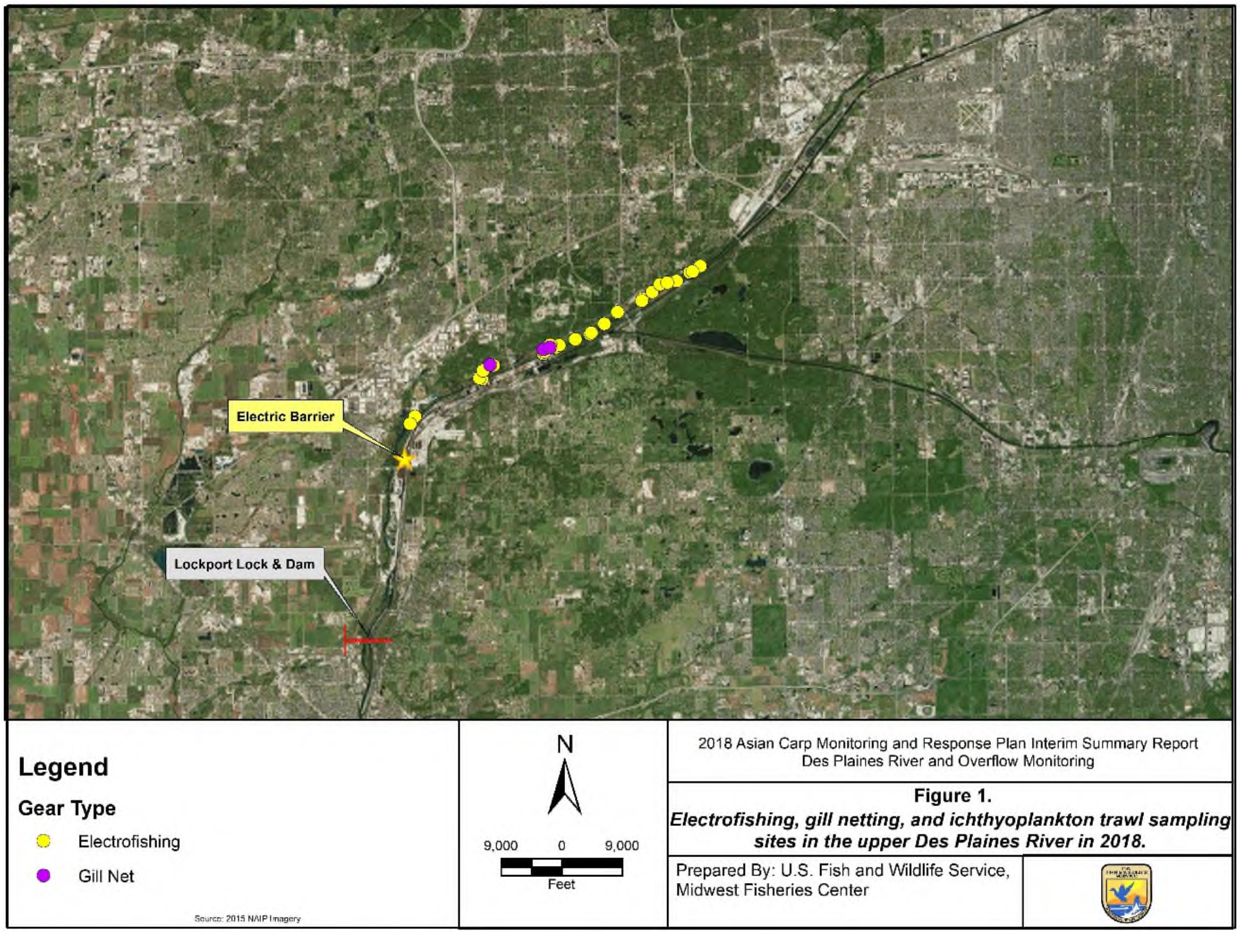

Figure 1: *Electrofishing and gill netting sampling sites in the upper Des Plaines River in 2018.*

Three Grass Carp were collected in 2018. To date, six Grass Carp have been tested for ploidy out of 10 total collections (Figure 2). All six tested were determined to be triploid, or sterile. The three collected in 2018 were not tested. Collection occurred under high ambient temperatures and transport logistics prevented preservation of samples suitable for analysis. However, one specimen was a ripe male while the other two did not have enlarged gonads.

There were no overtopping events resulting in transfer of surface water from the Des Plaines River to the CSSC. Therefore, no ichthyoplankton samples were collected in 2018.

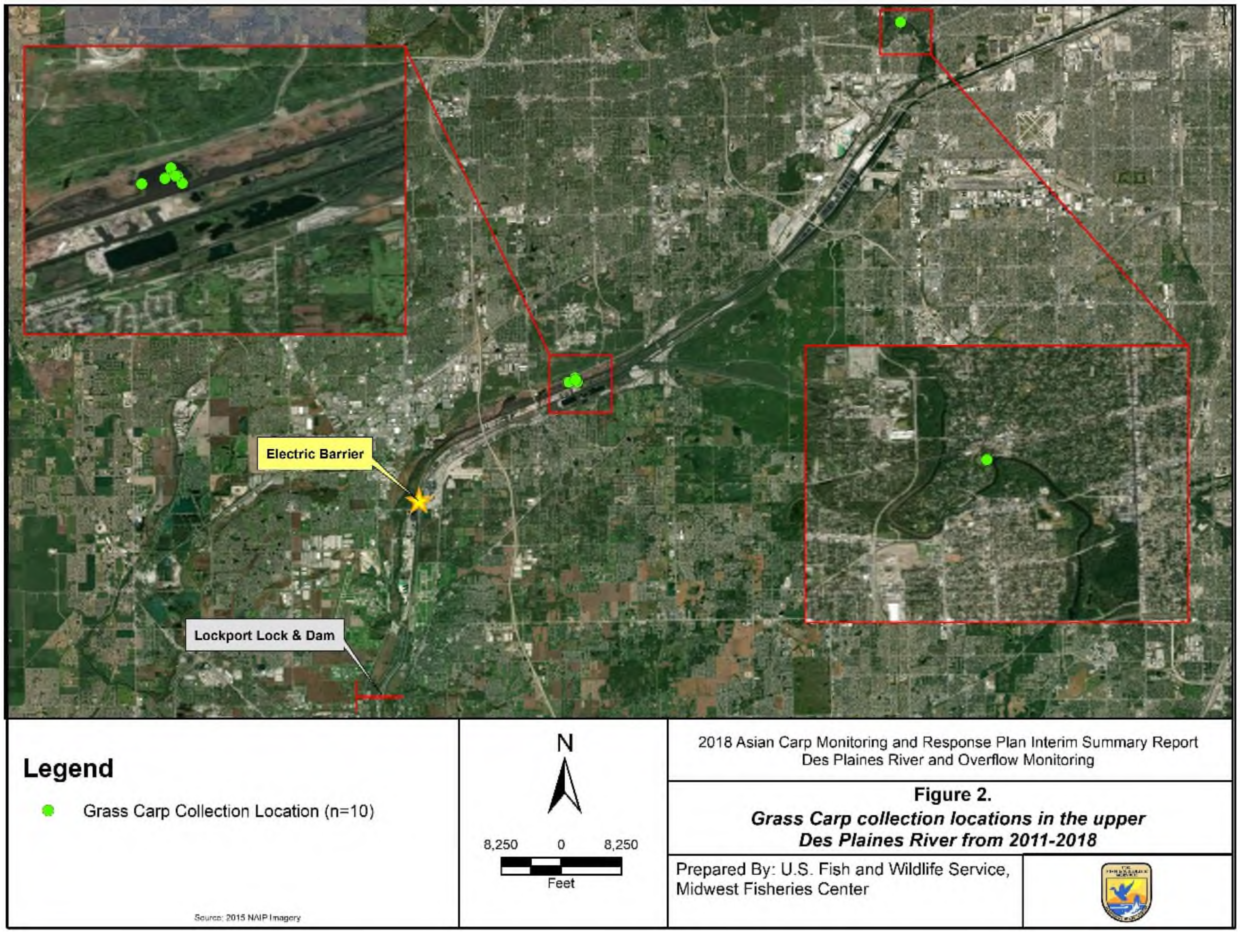

Figure 2: *Grass Carp collection locations in the upper Des Plaines River from 2011-2018.*

Recommendation:

Continue gill netting and electrofishing for adult and juvenile Bighead Carp and Silver Carp in the upper Des Plaines River with emphasis on backwater habitat. Continue to monitor Des Plaines River stage during heavy rainfall events and conduct investigations of the physical barrier, as needed, in areas where overflow has occurred. Investigate detection probabilities for current icthyoplankton sampling methods, and if acceptable, continue to collect icthyoplankton samples during potential overflow events when temperatures are conducive for reproduction.

References:

Kolar, C.S., D.C. Chapman, W.R. Courtenay, C.M. Housel, J.D. Williams, and D.P. Jennings. 2007. Bigheaded carps: a biological synopsis and environmental risk assessment. American Fisheries Society, Special Publication 33, Bethesda, Maryland.

USGS Support for Implementation of MRP

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

Introduction and Need:

Intensified surveillance in the Upper Illinois River between Starved Rock Lock and Dam and the Electric Dispersal Barriers using advanced and traditional telemetry methods (e.g., transmitter data from passive receivers in near real-time, enhanced acoustic arrays, manual tracking, and satellite-capable transmitters) will provide a greater understanding of the movements, habitats, and behaviors of Asian carp in areas of intense management that will allow for better application of control and containment tools. An abundance of data has been and is currently being collected in the upper Illinois waterways, however, limited support exists to bring this information together to support management objectives and to inform further research and data collection. There is a need for development of databases, decision support tools, and targeted analyses of existing data to help maximize data and information usefulness for adaptive and integrated management of Asian carp in the intensive management zone.

Mass harvest of bigheaded carp (i.e., Silver Carp and Bighead Carp) is challenging primarily due to their strong net avoidance behaviors. Evaluation of innovative capture gear and techniques (e.g., the Unified Method for bigheaded carps; hereafter Unified Method) across a variety of habitat types is important to identify the most effective methods for removing large quantities of carps. Herding techniques such as underwater sound are also being tested and assessed. The FluEgg model is a multi-purpose risk assessment tool that is being used to assess Asian carp spawning and recruitment success, as well as to help identify high risk locations for barge entrainment of small fish. There is also a continuous need for hydraulic data and information to support control and containment efforts, assessment of barrier locations such as Brandon Road Lock and Dam, and other waterway actions.

Objectives:

(1) Implement and evaluate new strategies for monitoring, surveillance, risk assessment, control and containment of bigheaded carp.

(2) Develop databases and related decision support tools in support of bigheaded carp control.

Project Highlights:

- Two additional real-time telemetry recievers were deployed to inform removal efforts and contingency actions. One was deployed near Romeoville, Illinois, just downstream of the electric dispersal barrier and the other was deployed near Morris, Illinois, in the west pit of Hanson Material Services.

- A new version of FishTracks telemetery database was released with online upload/download capabilities and enhanced data visualization tools.
- The Illinois River Catch Database (ILRCdb) was released with online upload/download capabilities and automated report generation features.
- Decision support tools to inform removal of adult bigheaded carp and mitigate for bigheaded carp egg/larvae entrainment moved toward completion.
- USGS-CERC has developed a simple, inexpensive procedure for automated processing of side-scan and 360 sonar imagery recorded by recreational "fish finder" systems. The process takes a folder of side-scan image tiles or 360 screenshots and produces a spreadsheet of fish counts per image in seconds or minutes, depending on the number of images. This method provides a quick way to visualize fish counts generated from side-scan data in ESRI ArcMap so that users can identify spatial distributions and determine relative fish abundance.
- An experimental Unified Method for bigheaded carp was conducted at Creve Coeur near St. Louis, Missouri that removed about 240,000 pounds of Asian carp. The controlled design, telemetry and accurate geospatial tracking of efforts will facilitate analyses on driving and capturing techniques that will inform modifications to improve effectiveness.
- Trap nets tested for efficacy on invasive carp include the Merwin trap, the Iruka trap, and pound nets, and the effect of algal attractants to enhance trap net catch was tested.
- Successful deployment of an acoustic barrier in the Chicago Area Waterways (CAWs) provided added protection during electric dispersal barrier maintenance.
- Study plans for the evaluation of experimental acoustic deterrents at Barkley Dam and a backwater in the Wabash River are complete or nearly complete. These studies will provide the large-scale testing needed to inform more permanent deployment of acoustic deterrents at strategic locations.
- Three manuscripts have been submitted for publication regarding the response of fishes to sound including the response of native fishes to a 100hp boat motor sound, deterrence of fishes at Emiquon Preserve in response to a 100hp boat motor sound, and Black Carp auditory evoked potentials. All these efforts are critical to informing the deployment of acoustic deterrents to control Asian carp.
- The FluEgg model was redeveloped from the ground up and ported from Matlab to Python software. The redevelopment was necessary to improve functionality and ease of use, allow for easier integration with hydraulic models and web applications, and improve code structure and documentation for developers.

Methods:

Real time telemetry, telemetry database, and visualization tools

- Install additional real time receivers in the upper Illinois waterways at key removal areas and bring them online for use by Illinois DNR removal crews.

USGS Support for Implementation of MRP

- Monitor, maintain, test and download data from real time receivers and provide timely summaries and alerts to removal crews and key decision makers.
- With management agencies, identify additional sites for placement of automated real-time receivers to support removal efforts and contengency planning.
- Complete development and release a new version of the telemetry database and visualization tool to collaborating management and research agencies.
- Continue email summaries of river discharge, temperature, and "real-time" telemetry detections at key locations on the Illinois River to inform removal efforts and contengency planning.

Bigheaded carp habitat mapping, modeling and removal dashboard:

- Collect high resolution bathymetry in off-channel areas of Starved Rock and Marseilles pools, including Morris pits, Dresden Island and Brandon Road pools and serve data as GIS layers for use in management action planning and Bighead/Silver Carp habitat modeling.
- Work with Illinois DNR and USFWS to build a conceptual model of an Asian carp removal dashboard (i.e., GIS visualization and decision support tool) and habitat models to inform fish removal actions.

Database and decision support tools actions

- Continue the development of an Asian carp commercial catch and monitoring database (ILRCdb) to house monitoring and assessment data for the Upper Illinois River. Includes data from Illinois DNR, USACE, and USFWS.
- Complete development of a decision support tool to inform mitigation measures to minimize the entrainment of Asian carp eggs and larvae by barge traffic.
- Continue development of a habitat suitability decision support tool for Asian carp using 2D hydrologic and water quality data.

_*Mass Harvest and Unified Method*

- Identify site-appropriate mass removal gears (Lampara Seine, tributary Iruka Trap, Paupier, Purse Seine, effluent trap) and refine prototype gear to minimize limitations and maximize efficiency.
- Use above techniques with the Unified Method to maximize harvest of Asian carp in a 2-week event in Creve Coeur Lake in Missouri (January or February 2018). Conduct hydroacoustic surveys, use DIDSON, and tag and implant transmitters in Silver Carp to observe fish behavior.

Underwater Sound Technology (USGS/USACE)

- In response to the planned winter maintenance of the Electric Dispersal Barrier, Illinois DNR requested, through the ACRCC, operation of a temporary acoustic deterrent in the CAWS (February 2018 through the end of Electric Dispersal Barrier maintenance) to serve as a risk reduction measure.
- Continue pond experiments of newly screened potential sounds specifically designed to deter Asian carp and limit impacts on native fishes.

- Select a set of non-proprietary sounds to be used in the field to deter Asian carp (based on pond trials (see above). Test these sounds in a field setting on wild fish in Wabash River. Parameterize a sound propagation model at Brandon Road lock approach with these new sounds.
- Initiate design, installation and evaluation of 1–3 acoustic deterrent systems with multi-agency science and management teams. Barkley Dam, Kentucky Dam, Lock & Dam 19, and Starved Rock Lock and Dam are potential sites for deployment, but additional or alternative site selection may occur.
- Refine sound propagation model for designing acoustic deterrent systems in locks and navigation channels.
- Reports on fish hearing damage, potential for sound habituation, and effectiveness of herding strategies in tributaries with high Bighead and Silver Carp densities.

Barge Entrainment

- Entrainment mitigation technology refinement with USFWS, USACE, USGS, and USCG builds on previous research and will include risk assessment modeling using the FluEgg simulation model and ship tracking data to identify high entrainment risk locations and time periods.

FluEgg Model to assess spawning and recruitment

- Complete a USGS software release of FluEgg including a user's manual.
- Conduct phase 2 lab flume experiments to characterize swim speeds and mortality in flowing water (USACE/USGS).
- Present a webinar targeted toward managers to explain capabilities of FluEgg which simulates egg and larvae transport from spawning grounds.
- Work with MRWG to use the Illinois Waterway (IWW) forecasted hydraulic conditions and the FluEgg model to predict where eggs and larvae will be after spawning.

Assessment of hydraulic and water quality influences on waterways

- Publish continuous 2017 water quality data for Illinois River main channel and backwater sites and continue velocity and bathymetry mapping of selected river reaches and spawning documentation activities in coordination with Illinois DNR and other agencies.
- Analyze 2015 fish tissue for anthropogenic bioactive compounds (ABCs; USGS/U of IL), review historic Illinois Natural History Survey data for fish tissue analyses, and coordinate fish tissue sampling with Illinois DNR and commercial fishers.
- Draft a USGS manuscript on results of study relating the Asian carp movement and water-quality data.

USGS Support for Implementation of MRP

Results and Discussion:

Real time telemetry, telemetry database, and visualization tools:

This project was initiated in 2015 and currently includes deployment and maintenance of seven real-time receivers in the Upper Illinois Waterways. An automated alert system for key personnel was established in 2017 for detections of tagged bigheaded carp in strategic locations to alert management agencies and inform contingency actions. That alert system was continued in 2018. As well, USGS made data from all real-time receivers in the network available online continuously. USGS monitored, maintained and downloaded data from these receivers and provided timely summaries to partners via MRWG monthly updates and FishTracks telemetry database (FishTracks DB). USGS deployed and maintained receivers annually as needed and conducted range testing on all receivers to establish detection capabilities and limitations. Consultations in 2018 with partner agencies resulted in plans for deployment of 3 additional receivers in the east and west pits of the Hanson Material Service (HMS) site (for harvest decision support) in the Marseilles pool and one new receiver below the electric dispersal barrier (to inform contingency actions and barrier evaluation). In HMS, consultations called for one receiver on each side of the culverts separating east and west pits, and another near the entrance from the main channel into east pit. Two new real-time telemetry receivers were deployed in the Upper Illinois Waterway in 2018, one in the west pit of Hanson Materials and another below the Dispersal Barrier near Romeoville, IL.

The latest version of the FishTracks telemetry database and visualization tool was released to collaborating management and research agencies. Updates include new data management features that allow users to import data and specify their desired levels for sharing permissions of their submitted data. The web visualization tool now includes a profiler for viewing real-time fish movements and related environmental conditions (e.g. water temperature and discharge) at the time of movement. The profiler tool allows users to tie environmental conditions to fish habitat affinity and analyze fish behavior. An update was made to the data collection feature, to allow for maintainable and long-term data archiving by including metadata utilities. All data and application software continues to be actively maintained.

Bigheaded carp habitat mapping, modeling and removal dashboard:

High resolution bathymetry data has been collected in priority areas of Starved Rock, Marseilles, Dresden Island, and Brandon Road pools. These data have been processed into GIS data layers (sonar mosaics and bathymetry) for use in management action planning, and visualization and decision support tool development. Developing, processing, and serving data layers based on a benthic habitat classification for the Illinois River continues.

Development of an online visualization tool to inform Asian carp removal efforts (i.e. GIS visualization and decision support tool) has been initiated, using the La Grange reach of the Illinois River as the test area. The habitat mapping visualization tool includes Asian carp-related data layers, including the Stainbrook, Dettmers, & Trudeau, 2007 habitat suitability models. Development and expansion of this visualization tool will continue, incorporating additional data layers (e.g. water temperature and discharge web services, catch data from the Illinois River Catch Database, and high-resolution bathymetric and benthic data) and adding analysis tool capabilities to identify areas with similar environmental conditions.

Database and decision support tools actions:

The latest version of the Illinois River Catch database (ILRCdb) and visualization tool has been updated to include additional interactive and static reports requested by users. Users can now request a formatted, emailed report (monthly, annual, etc.) that summarizes data queries tailored to the user's needs, eliminating the effort previously needed to manually filter the data records, format the results, and generate a report. All data and application software continues to be actively maintained.

A library of FluEgg spawning simulation results was generated for a range of flow scenarios and water temperatures in the Illinois River System. This library was provided to the FluEgg model development group at the USGS Central Midwest Water Science Center for integration with NAIS shiptrack data for continued risk assessment of egg and larvae entrainment by barge movement. Initial data processing of NAIS shiptrack data has been completed, and will be combined with a library of FluEgg spawning simulation results covering a range of flow scenarios and water temperatures in the Illinois River System to model risk assessment of egg and larvae entrainment by barges at particular locations and/or time periods.

Mass Harvest and Unified Method

A procedure for the automated processing of recreational sonar imagery was developed in 2018. This process greatly reduces the amount of time for generating fish abundance estimates, and these estimates could be used for population monitoring and to measure the success of removal efforts. In 2019, research will continue to improve the method by testing it against research-grade equipment estimates and conducting a field validation. Additional work to standardize sonar data acquisition methods to better facilitate post-processing will also be conducted. These methods will also be useful to estimate carp abundance in areas where experimental gears are being tested.

To evaluate the effectiveness of various trap nets with and without algal attractants, four weeks of passive net sets were completed in the Illinois River; 2 weeks in Lily Lake and 2 weeks in the Hansen Materials Pits. Each week, the Merwin trap and pound net were set in the same water body on Monday and removed on Friday, and fish were removed and enumerated every 24 hours. Two weeks of net sets were completed where an algal food attractant was applied over the trap nets to determine if capture would be enhanced. Work in 2019 will focus on whether herding methods can enhance capture by the Merwin Trap, pound net, and Iruka net. New trap nets may also be tested.

Several different sounds and boat electro-fisher settings and configurations were tested in 2018 to identify the best stimuli and settings for motivating carps to move downstream. Those stimuli and others were further tested in a replicated field study in a tributary. Future work, in 2019 will focus primarily on applying and further testing these techniques in other water bodies and water body types in Illinois and developing methods for herding carps into trap nets using the stimuli found to be most effective.

A Unified Method harvest was completed in FY2018 at Creve Coeur Lake in Missouri. Approximately 240,000 pounds of bigheaded carp were removed from the lake. Catch per unit effort with Paupier electrofishing, quantitative eDNA, and acoustic methods indicate that more than half the carp were removed from the lake. DIDSON work showed that bigheaded carp avoided the Iruka trap net when used as deployed at Creve Coeur, and the fish were captured primarily by seining. No gill nets were used in the Creve Coeur operation. Data analysis, presentations and publications from this work will continue in 2019.

Additional data collections on fish behavior associated with deployments of an Iruka net are continuing in the first half of calendar 2019. These collections with a DIDSON sonar will build on our data from the Unified Method operation at Creve Coeur to better understand fish avoidance behavior to improve harvest. Additional work by USGS in 2019 will include collections of fish behavior data associated with Unified Method activities at Morris, IL, development of manuscripts on previous applications of the Unified Method, a workshop on the Unified Method in Kentucky for application in the Ohio River Basin, and further testing of driving and capture techniques used during Unified Method applications to enhance effectiveness.

Underwater Sound Technology (USGS/USACE)

The USGS, with USACE partners, installed a five-speaker underwater Acoustic Deterrent System (ADS) in the CAWS during the planned winter maintenance of the Electric Dispersal Barrier. The system operated from February–April 2018 in response to a request from the IL DNR/MRWG and the ACRCC. No system outages occurred during the deployment period in 2018. To monitor fish in the area, hydroacoustic scans were completed by the USFWS and telemetry receivers were monitored by the USACE. In addition to field deployments, testing of two new non-proprietary acoustic deterrent sounds was completed in ponds in Columbia, Missouri. Pond testing of two new deterrent sounds, specifically designed to deter Asian carp and limit impacts on native fishes, were tested against the 100 hp boat motor sound (that has previously been shown to elicit deterrence) and no sound. Data are currently being analyzed to inform field studies that will occur in 2019. Additional sounds continue to be screened by the USACE ERDC lab in Vicksburg, Mississippi. USGS has also continued to participate in the study design for evaluation of a BioAcoustic Fish Fence (BAFF) at Barkley Lock and Dam. Planning regarding testing of a second deterrent system was initiated in 2018 and will continue in 2019. Finally, three manuscripts have been submitted for publication regarding the response of fishes to sound including the response of native fishes to a 100hp boat motor sound, deterrence of fishes at Emiquon Preserve in response to a 100hp boat motor sound, and Black Carp auditory evoked potentials. Manuscripts will be released to partners when accepted for publication. Lock & Dam 19, and Starved Rock Lock and Dam are potential sites for deployment, but additional or alternative site selection may occur.

Barge Entrainment

This project provides follow up investigations to barge entrainment and fish interaction studies conducted during 2015, 2016, and 2017. Those published studies showed that freely swimming small fish could become entrained within barge junction gap spaces and subsequently transported upstream. Surrogate fish were transported upstream through the Electric Dispersal Barrier System (EDBS), through upstream lockage operations, and over long distances (9.6 river miles). Studies conducted during FY 2017 provided preliminary evaluations of potential mitigation management strategies and technologies. Results from the 2017 mitigation field trials are in the process of being published. No additional mitigation field trails were completed in FY 2018; however, the multiagency team continues to evaluate mitigation options for both entrainment and non-entrainment pathways for fish passage of the Electric Dispersal Barrier System associated with transiting of commercial barge tow traffic. Finally, a related analysis of historical Asian carp spawning events and commercial ship track data on the Illinois River was started in FY 2018. The analysis, to be completed in FY 2019, will identify potential zones of high entrainment risk where egg density is likely to be high and the incidence of spatial overlap with commercial traffic is also likely to occur.

FluEgg Model to assess spawning and recruitment

The FluEgg model simulates egg and larvae transport from Asian carp spawning grounds. Model results can help in determining reach length required for successful egg hatching or the location of nursery habitat. The model can also be used in "reverse-time" mode to estimate spawning location from the location of sampled eggs. Starting in 2018, the FluEgg model was redeveloped from the ground up and ported from Matlab to Python. The redevelopment was necessary to improve functionality and ease of use, allow for easier integration with hydraulic models and web applications, and improve code structure and documentation for developers. The redeveloped FluEgg will be released in 2019 as a USGS software release with the executable, source code, and user's manual. Associated FY 2018 research includes: (1) the completion of an Illinois Waterway FluEgg forecast model to predict where eggs and larvae will be following a spawning event (was scheduled to go online in FY 2019, but funding was cut) and (2) phase 2 of laboratory flume experiments characterizing the settling velocities, drifting response, and survival rate of Grass carp eggs and larvae under complex bed morphologies. Phase 1 of the experiments, completed in FY 2017, was published in 2018 in a peer-reviewed journal (https://doi.org/10.1371/journal.pone.0208326).

Assessment of hydraulic and water quality influences on waterways

This project investigates the influence of habitat stimuli, such as river hydraulics and water-quality, on the population range, movement, and spawning and recruitment success of Asian carp. Intensive sampling by Illinois DNR has shown that the leading edge of the bigheaded carp population front has been stalled in the Dresden Island Pool of the Illinois Waterway (IWW) since at least 2008. In 2015, this study established baseline water chemistry conditions in the IWW with four rounds of water-quality sampling. In FY 2018, the study identified several anthropogenic bioactive compounds (ABCs) that correlate with the stalled population front and the results will be published in a peer-reviewed journal article in 2019. Also, in FY 2018, an initial round of metabolomic analyses of fish tissue samples collected by the University of Illinois at multiple locations in the IWW (in 2015) was completed. The results of the metabolomic analyses were compared to the 2015 water chemistry results to target specific ABCs. Commercial fishers collected fish from Rock Run Rookery (population front) in 2018 for analysis of specific ABCs in tissue. This fish tissue analysis will be completed in FY 2019 and will help define if environmental ABCs are contributing to the stalled movement of the leading edge of carp populations and how to use the information to control the population front. Finally, this project also covers the operation and maintenance of two continuous water-quality monitoring stations on the IWW, one in the main channel (USGS Site No: 05543010; https://waterdata.usgs.gov/usa/nwis/uv?05543010) and one in a backwater of the of IWW in the Marseilles Pool (USGS Site No: 411955088280601; https://waterdata.usgs.gov/nwis/uv?site_no=411955088280601).

MANAGE AND CONTROL PROJECTS

Comprehensive Asian Carp Removal Summary

Participating Agencies: Illinois Department of Natural Resources, Illinois Natural History Survey, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers

Introduction and Need:

This is a comprehensive summary of Asian carp removal efforts occurring in the upper Illinois and lower Des Plaines Rivers downstream of the Electric Dispersal Barrier since 2010 (Figure 1). Additional details about Asian carp removal can be found in the IDNR Barrier Defense Project, USFWS Barrier Defense Project, and Monitoring Efforts Downstream of the Electric Dispersal Barrier sections of this report.

Objectives:

(1) Exploit Asian carp removal to maximum potential. Harvested Asian carp will be reserved for private companies to use for purposes other than human consumption (e.g., fertilizer, pet treats, chum bait, ect).
(2) Gather information on Asian carp population dynamics in the Illinois Waterway downstream of the Electric Dispersal Barrier.

Project Highlights:

- Since 2010, contracted fisher and agency staff efforts in the upper Illinois Waterway included: 2,754 miles (4,432.1 km) of gill/trammel net, 22 miles (35.4 km) of commercial seine, 260 pound net nights, 4,963.2 hoop net nights, 550.8 electrofishing hours, and 68.7 electrified paupier hours.
- From 2010-2018, a total of 93,947 Bighead Carp, 868,967 Silver Carp, and 6,216 Grass Carp were removed, totaling 3,880.32 tons.

Methods:

Further details regarding Asian Carp removal methodologies may be found in the IDNR Barrier Defense Project, USFWS Barrier Defense Project, and Monitoring Efforts Downstream of the Electric Dispersal Barrier sections of this report.

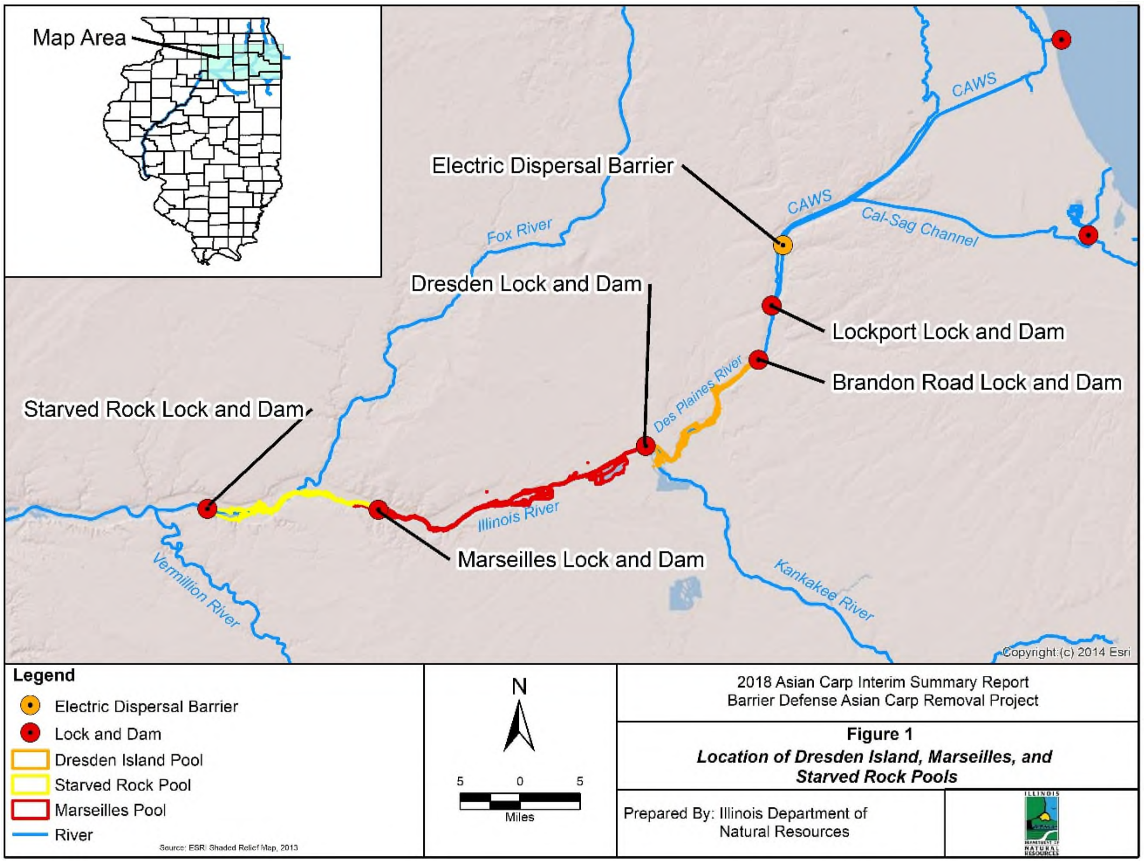

Figure 1. *Locations of Asian carp removal efforts downstream of the Electric Dispersal Barrier.*

Results and Discussion:

Since 2010, contracted fisher and agency staff efforts in the upper Illinois Waterway included: 2,754 miles (4,432.1 km) of gill/trammel net, 22 miles (35.4 km) of commercial seine, 260 pound net nights, 4,963.2 hoop net nights, 550.8 electrofishing hours, and 68.7 electrified paupier hours (Table 1). From 2010-2018, 7,760,640 lbs (3,880.32 tons) of Asian carp were removed (Table 1). Silver Carp, Bighead Carp, and Grass Carp accounted for 73.7%, 21.0%, and 5.3% of total tons harvested, respectively. The combined catch of Asian carp (Bighead Carp, Silver Carp, and Grass Carp) was 969,130 individuals (Table 1). Silver Carp, Bighead Carp, and Grass Carp accounted for 89.7%, 9.7%, and 0.7% of the total number of Asian carp harvested, respectively. Since 2010, the proportion of Asian carp captured by gear type was as followed: gill/trammel nets: 82.1% (788,905 individuals), electrified paupier: 7.1% (67,910 individuals), commercial seine: 6.6% (63,068 individuals), hoop nets: 3.3%, pound nets: 0.5% (5,190 individuals), and electrofishing: 0.4% (3,636 individuals; Figure 2). The proportion of Asian carp weight (tons) removed by gear types was as followed: gill/trammel nets: 84.8% (3,352.3 tons), commercial seine: 6.7% (265.4 tons), electrified paupier: 4.8% (189.9 tons), hoop nets: 2.8% (109.4 tons), pound nets: 0.5% (21.5 tons), and electrofishing: 0.4% (15.5 tons; Figure 3).

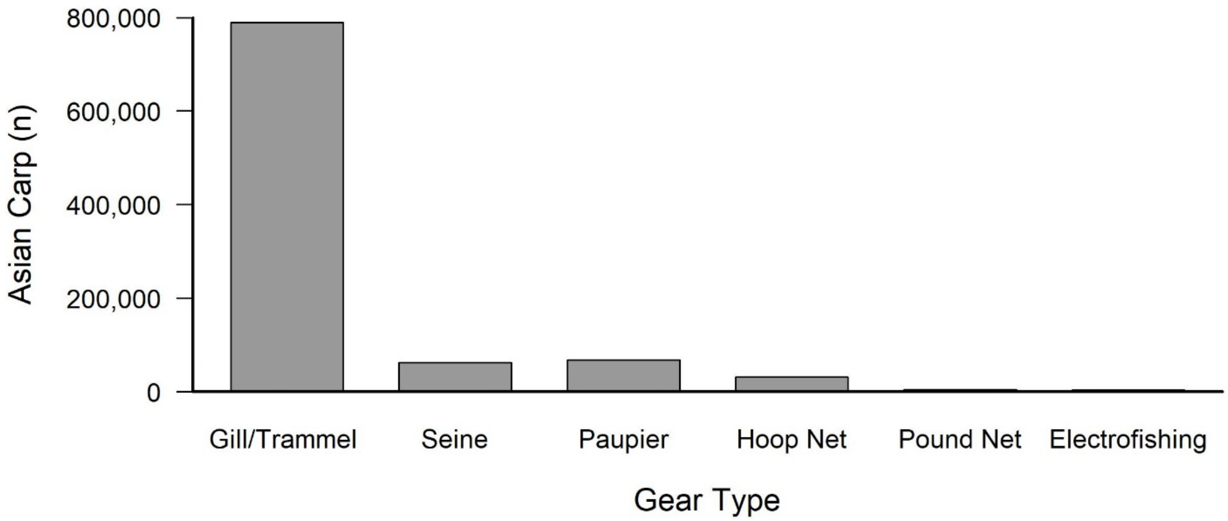

Figure 2. *Total number of Asian carp captured by gear type from Dresden Island, Marseilles, and Starved Rock pools from 2010 to 2018.*

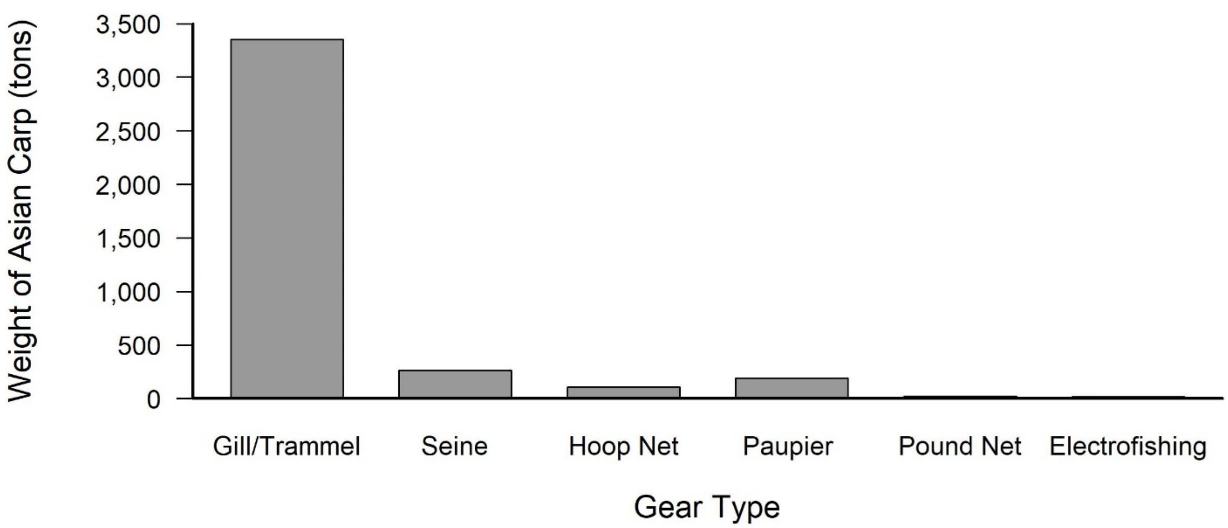

Figure 3. *Total weight of Asian carp (tons) removed from Dresden Island, Marseilles, and Starved Rock pools by gear type from 2010 to 2018.*

Comprehensive Asian Carp Removal Summary

Catch of Asian carp within pools –

Dresden Island pool:

Since 2010, contracted fisher and agency staff efforts in the Dresden Island pool included: 471.6 miles (759.0 km) of gill/trammel net, 674 hoop net nights, 12 pound net nights, 5.6 electrified paupier hours, and 294.8 electrofishing hours. Since 2010, 2,537 Bighead Carp, 2,334 Silver Carp, and 131 Grass Carp were harvested in Dresden Island pool (Table 1).

Marseilles pool:

Since 2010, contracted fisher and agency staff efforts in the Marseilles pool included: 1,554.8 miles (2,502.2 km) of gill/trammel net, 700.9 hoop net nights, 248 pound net nights, 0.4 electrified paupier hours, and 256 electrofishing hours. Since 2010, 68,470 Bighead Carp, 265,467 Silver Carp, and 1,086 Grass Carp were harvested in Marseilles pool (Table 1).

Starved Rock pool:

Since 2010, contracted fisher and agency staff efforts in the Starved Rock pool included: 727.6 miles (1,171.0 km) of gill/trammel net, 3,588.3 hoop net nights, and 62.7 electrified paupier hours. Since 2010, 22,940 Bighead Carp, 601,166 Silver Carp, and 4,999 Grass Carp were harvested in Starved Rock pool (Table 1).

	Effort						Harvest							
Year and Pool	**Miles of Net**	**Electro-fishing Hrs**	**Miles of Seine**	**Hoop Net Nights**	**Pound Net Nights**	**Paupier Hrs**	**Bighead Carp (N)**	**Silver Carp (N)**	**Grass Carp (N)**	**Total (N)**	**Bighead Carp (tons)**	**Silver Carp (tons)**	**Grass Carp (tons)**	**Total (tons)**
2010														
Dresden	1.8	6					2			2	0.01			0.01
Marseilles	75.5	6					4,894	1,139		6,033	53.11	8.11		61.22
Starved Rock														
All pools	77.3	12					4,896	1,139		6,035	53.12	8.11		61.23
2011														
Dresden	4.8	9					8			8	0.06			0.06
Marseilles	219.2	9					20,087	7,023	34	27,144	229.39	46	0.16	275.55
Starved Rock	44.6						2,964	10,730	132	13,826	21.36	53.32	0.65	75.33
All pools	268.6	18					23,059	17,753	166	40,978	250.81	99.32	0.81	350.94
2012														
Dresden	9.8	9		32			120	36	3	159	0.87	0.04	0.28	1.2
Marseilles	235.6	9	0.9	32			13,971	11,074	160	25,205	126.07	64.39	0.67	191.13
Starved Rock	67.3						3,994	20,589	243	24,826	22.42	99.98	1.39	123.79
All pools	312.7	18	0.9	64			18,085	31,699	406	50,190	149.36	164.41	2.34	316.12
2013														
Dresden	16.4	32		56			1,095	93	13	1,201	13.5	0.17	0.73	14.4
Marseilles	237.8	32	0.9	48			7,746	11,747	378	19,871	74.05	59.38	2.67	136.1
Starved Rock	104.1						3,938	38,666	369	42,973	21.93	1.97	168.14	192.04
All pools	358.2	64	0.9	104			12,779	50,506	760	64,045	109.48	61.52	171.54	342.54
2014														
Dresden	52.3	47		64			104	25	5	134	1.04	0.07	0.2	1.3
Marseilles	216	50	1.1	64			7,553	27,903	108	35,564	69.33	112.29	0.05	181.67
Starved Rock	91		0.2	421.7			4,220	63,132	416	67,768	19.74	222.73	0.72	243.19
All pools	359.3	97	1.3	549.7			11,877	91,060	529	103,466	90.11	335.09	0.97	426.16
2015														
Dresden	77.9	39		116			272	150	11	433	2.36	0.15	0.96	3.47
Marseilles	141.2	39	1.6	86.5	24		5,387	69,105	216	74,708	38.9	236	1.2	276.1
Starved Rock	78.3		0.5	141.2			2,908	68,681	641	72,230	13.2	198.1	3.7	215
All pools	297.4	78	2.2	343.7	24		8,567	137,936	868	147,371	54.46	434.25	5.86	494.57
2016														
Dresden	79.8	55					232	263	21	516	2.31	0.28	1.46	4.05
Marseilles	203.1	39	8.1	85.7	128	0.4	5,943	62,565	76	68,584	46.86	251.4	0.4	298.66
Starved Rock	88.3		2.1	683.1		15.4	2,065	94,486	613	97,164	9.65	259.88	3.5	273.02
All pools	371.2	94	10.2	768.8	128	15.8	8,240	157,314	710	166,264	58.81	511.55	5.36	575.73

	Effort						Harvest							
Year and Pool	**Miles of Net**	**Electro-fishing Hrs**	**Miles of Seine**	**Hoop Net Nights**	**Pound Net Nights**	**Paupier Hrs**	**Bighead Carp (N)**	**Silver Carp (N)**	**Grass Carp (N)**	**Total (N)**	**Bighead Carp (tons)**	**Silver Carp (tons)**	**Grass Carp (tons)**	**Total (tons)**
2017														
Dresden	98	45		352	4		307	537	25	869	5.28	0.33	4.25	9.86
Marseilles	139.9	33	2.8	104.7	74		1,489	42,344	70	43,903	13.56	176.7	0.3	190.56
Starved Rock	113.7		1.3	938.6		14	1,170	151,455	1,134	153,759	4.9	413.9	6.5	425.3
All pools	351.7	78	4.1	1,395.30	78	14	2,966	194,336	1,229	198,531	23.74	590.93	11.05	625.72
2018														
Dresden	130.9	52.8		54	8	5.6	397	1,230	53	1,680	4.96	10.21	0.54	15.71
Marseilles	86.5	39	2.4	280	22		1,400	32,567	44	34,011	13.33	149.53	0.22	163.08
Starved Rock	140.2			1,403.70		33.3	1,681	153,427	1,451	156,559	8.21	493.29	7.02	508.52
All pools	357.6	91.8	2.4	1,737.70	30	38.9	3,478	187,224	1,548	192,250	26.5	653.03	7.78	687.31
2010-2018														
Dresden	471.6	294.8		674	12	5.6	2,537	2,334	131	5,002	30.38	11.24	8.43	50.05
Marseilles	1,554.80	256	17.8	700.9	248	0.4	68,470	265,467	1,086	335,023	664.6	1103.8	5.67	1774.07
Starved Rock	727.6		4.2	3,588.30		62.7	22,940	601,166	4,999	629,105	121.41	1743.17	190.97	2056.19
All pools	2,754.00	550.8	22	4,963.20	260	68.7	93,947	868,967	6,216	969,130	816.39	2858.2	205.07	3880.32

Barrier Defense Asian Carp Removal Project

Rebekah Anderson, Justin Widloe, Brennan Caputo, Nathan Lederman, Seth Love, Blake Bushman, Tristan Widloe, Kevin Irons, Matt O'Hara, Nate Grider (Illinois Department of Natural Resources)
Eli Lampo, Eric Hine, Andrew Mathis (Illinois Natural History Survey)

Participating Agencies: Illinois Department of Natural Resources, Illinois Natural History Survey.

Pools Involved: Dresden Island, Starved Rock, Marseilles

Introduction and Need:

This project utilizes IDNR contracted fishers to reduce the numbers of Bighead Carp, Silver Carp, and Grass Carp (referred to as Asian carp herein) in the upper Illinois and lower Des Plaines Rivers downstream of the Electric Dispersal Barrier. By decreasing Asian carp numbers, we anticipate reduced migration pressure to the barrier and decreased probability of carp gaining access to waters upstream the Electric Dispersal Barrier (e.g., CAWS and Lake Michigan). Trends in long-term harvest data are important to our understanding of Asian carp population abundance and movement between pools of the Illinois Waterway. This project was initiated in 2010 and is ongoing. Nine contracted fishers remove Asian carp using large mesh [2.5 - 5.0 inch (63.5 – 127mm)] trammel nets and gill nets, and occasionally other gears (e.g., seines, pound nets, and hoop nets).

Objectives:

Nine contracted fishers are employed to:

(1) Reduce Asian carp populations, lessening migration pressure to the Electric Dispersal Barrier, and thus decreasing the chances of Asian carp accessing upstream reaches (e.g., CAWS and Lake Michigan).
(2) Exploit Asian carp removal to maximum potential. Harvested Asian carp will be reserved for private companies to use for purposes other than human consumption (e.g., fertilizer, pet treats, chum bait, ect).
(3) Gather information on Asian carp population dynamics in the Illinois Waterway downstream of the Electric Dispersal Barrier.

Project Highlights:

- Since 2010, contracted fishers' efforts in the Upper Illinois Waterway include: 2,283 miles (3,674km) of gill/trammel net, 22 miles (35km) of commercial seine, 184 pound net nights, and 3,970 hoop net nights.
- A total of 91,204 Bighead Carp, 786,401 Silver Carp, and 5,999 Grass Carp were removed by contracted fishermen from 2010-2018. The total weight of Asian carp removed was 3,639 tons.

Barrier Defense Asian Carp Removal Project

- We propose to increase Asian carp harvest using contracted fishers in the upper Illinois Waterway in 2019 (+45 harvest weeks; 109 weeks in 2018 vs 154 in 2019). Since 2010, this program has been successful at managing the Asian carp population in the upper Illinois River. Adding harvest weeks will allow us to remove more Asian carp in 2019 than in previous years, further reducing Asian carp abundance at and near the detectable population front and possibly preventing further upstream movement of populations toward the Electric Dispersal Barrier and Lake Michigan.

Methods:

Since 2010, contracted fishing has occurred in Dresden Island (RM 271-286), Marseilles (RM 245 to 271), and Starved Rock (RM 231 to 245) pools. Pools are located 10, 24, and 51 river miles downstream of the Electric Dispersal Barrier, respectively (Figure 1). This area is 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 IDNR biologist is required to accompany contracted fishers in this section of the river. Most years, contracted fishing took place March – December, excluding 2010 (June – September), 2011 (April – December), 2013 (January– December), and 2017 (February – December). Six contracted fishing crews deployed gears effective for capturing Asian carp four days each week of the field season (March – December 2018). Scheduled weeks occurred 1-4 times each month. Harvest weeks were generally scheduled every other week to allow Asian carp the opportunity to repopulate the targeted habitats between harvest weeks. Fishing occurred in backwater, main channel, and side channel habitats where Asian carp are known to congregate. Biologists provided general fishing locations, but specific areas were ultimately determined by contracted fishers. Large mesh [2.5 - 5.0 inch (63.5 -127 mm)] gill and trammel nets were typically used and set 20-30 minutes with fish being driven to the nets with noise (e.g., pounding on boat hulls, hitting the water surface with plungers, running with motors tipped up). Occasionally nets were set overnight along the main channel shorelines or in backwaters with no public access. Beginning in 2014, hoop nets [2.0-8.0 feet (0.60-2.44 m) in diameter] and commercial seines [300-800 yards (0.27-0.73 km) in length] were used in addition to gill and trammel nets. Great Lakes pound nets were added in 2015. The biologist assigned to each boat identified to species, enumerated, and recorded Asian carp and bycatch captured in gear types utilized by the contracted fisher. Asian and Common Carps were examined for ultrasonic tags, and bycatch and tagged fish were returned to the water unharmed. Harvested Asian carp were transferred to a refrigerated truck and subsequently utilized for non-consumptive purposes (e.g., converted to liquid fertilizer, chum, etc.). Each harvest week, a representative sample ≤ 30 of each Asian carp species from each pool (Starved Rock and Marseilles) were measured in total length (mm), weighed (g), and sexed (identifying the presence/absence of pectoral fin ridges) to gather morphometric data on harvested carps overtime.

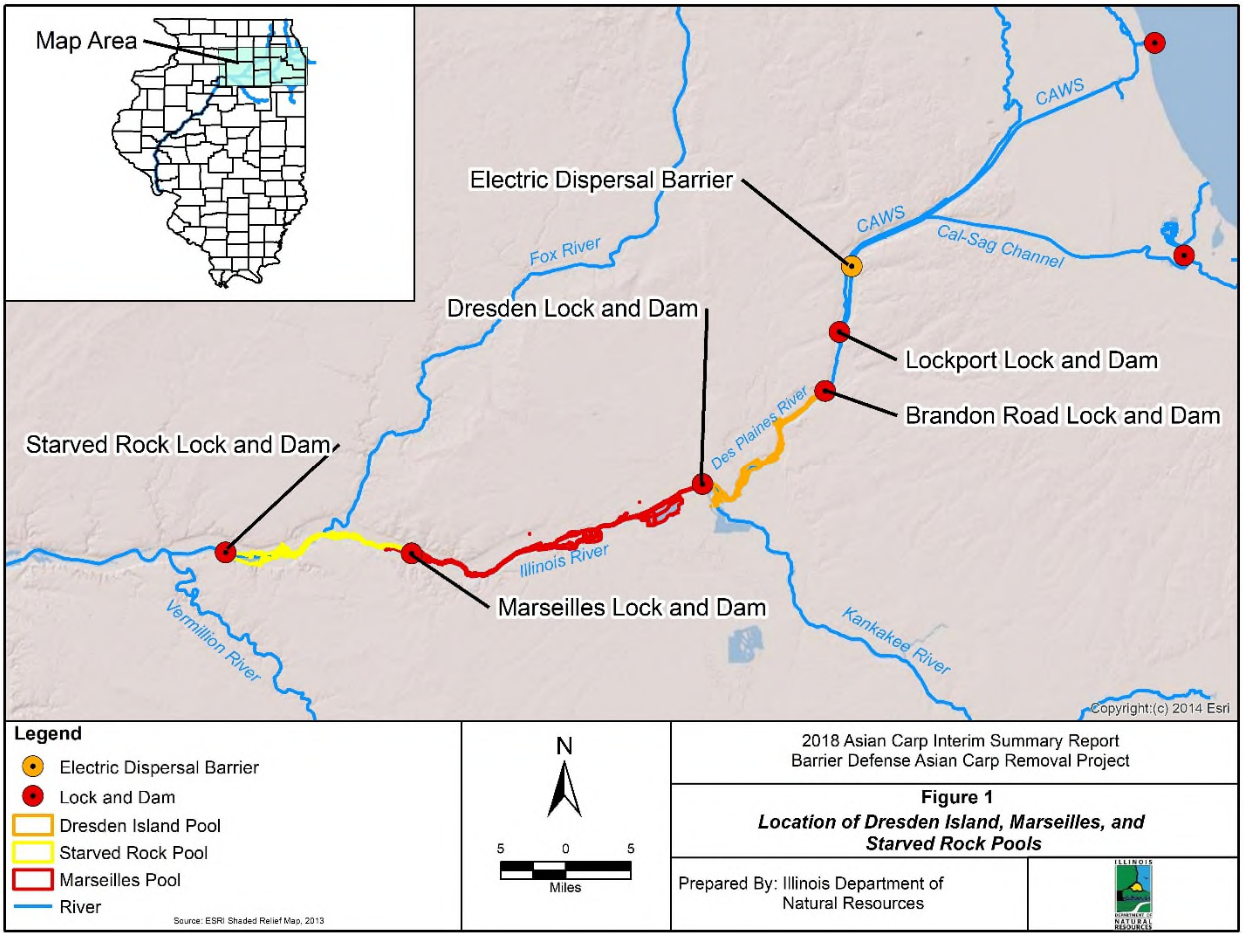

Figure 1. *Locations of Barrier Defense Asian carp removal downstream of the Electric Dispersal Barrier.*

Results and Discussion:

An estimated 11,880 person-hours were expended harvesting Asian carp for the Barrier Defense Removal Project in 2018. Previously 10,463 person-hours in 2017, 10,980 person-hours in 2016, and 7,650 person-hours in 2015 were expended. For details regarding estimated person-hours prior to 2015, see that respective year's Interim Summary Report (MRRP 2011-2014). A total of 2,283 miles (3,674 km) of gill/trammel net, 22 miles (35 km) of commercial seine, 184 pound net nights and 3,970 hoop net nights have been deployed in the upper Illinois Waterway since 2010 (Table 1). The total weight of Asian carp caught and removed 2010-2018 was 7,262,000 pounds (3,631 tons; Table 1). Silver Carp, Bighead Carp, and Grass Carp accounted for 73.1%, 21.6%, and 5.4% of the total tons harvested since 2010, respectively.

Since 2010, the combined catch of Asian carp was 883,604 individuals (Table 1). The total harvest of individuals from 2010-2018 consisted of 89.0% Silver Carp, 10.3% Bighead Carp, and 0.7% Grass Carp. Since 2010, Bighead Carp relative catch has decreased by 80.0% (Bighead Carp accounted for 82.0% of Asian carp harvested in 2010 and only 2.0% in 2018). Silver Carp relative catch has increased by 79.4% (Silver Carp accounted for 17.7% of Asian carp harvested in 2010 and 97.1% in 2018). Grass Carp relative catch has increased by 0.5% (Grass Carp accounted for 0.4% of Asian carp harvested in 2010 and 0.9% in 2018).

The 2018 gill/trammel net catch per unit effort (CPUE; number of fish/1,000 yards of net) of Asian carp for all pools combined was the highest to date at 368.8. Asian carp CPUE in 2018 increased 9% from 2017 (338.3) and 324% from 2011 (86.9). For details regarding gill/trammel CPUE of Asian carp for all pools combined from other years, see those years' respective Interim Summary Reports (MRRP 2012-2016). The gill/trammel CPUE for all pools combined demonstrates an increasing trend overtime (Figure 2).

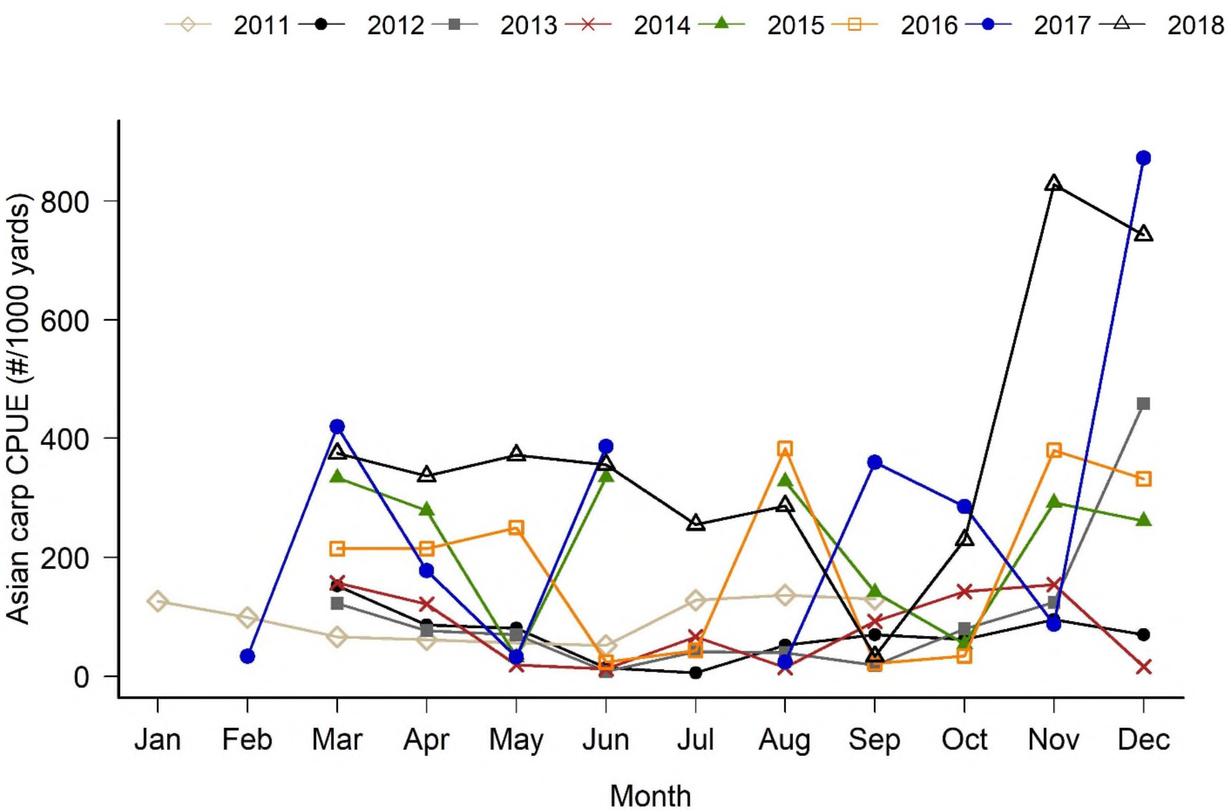

Figure 2. *Monthly catch per unit effort (CPUE; number of fish per 1,000 yards of gill/trammel net) of Asian carp for Dresden Island (2011-2015), Marseilles (2011-2018), and Starved Rock (2011-2018) pools combined. In 2015, Asian carp removal efforts in Dresden Island pool transitioned to the Fixed Site Monitoring Downstream the Dispersal Barrier Project.*

Catch of Asian carp within Pools

Dresden Island Pool:

Asian carp removal efforts in Dresden Island pool were documented in the 2018 Fixed Site Monitoring Downstream of the Dispersal Barrier ISR (effective 2015). Dresden Island pool occurs within the zone of the upper Illinois River designated to monitoring below the Electric Dispersal Barrier. Asian carp abundance is relatively low in Dresden Island pool, and monitoring is essential because the leading edge of the Silver and Bighead Carp population occurs there. Briefly, a total of 1,663 Asian carp (14.2 tons) were removed from the Dresden Island Pool (including Rock Run Rookery and the Dresden Nuclear Power Station warm water discharge). Asian carp relative catch increased 98% from 2017 (840 Asian carp). This is due to increased effort in Dresden Island pool in 2018 (additional sampling days), and IDNR biologists and contracted fishers gaining access to the Dresden Nuclear Power Station's warm water discharge area (60% of Asian carp removed from Dresden Island pool came from the Dresden Nuclear Power Station's warm water discharge area). For further details, see the 2018 Fixed Site Monitoring Downstream of the Dispersal Barrier ISR.

Marseilles Pool:

In 2018, 22% of the total harvested Asian carp came from Marseilles pool. Asian carp removal efforts included: 151,900 yards (138.9 km) of gill/trammel net, 2.4 miles (3.9 km) of commercial seine, 224.46 hoop net nights, and 22 pound net nights. A total of 32,367 Silver Carp; 1,397 Bighead Carp; and 35 Grass Carp were harvested from Marseilles pool in 2018 from all gear types (Table 1). We captured 920 Silver Carp and 127 Bighead Carp using the commercial seine, and 88 Silver Carp, 2 Bighead Carp, and 7 Grass Carp using hoop nets. Silver Carp dominated the relative catch of Asian carp in the Marseilles pool in 2018 (96%), as per the past five years. Prior to 2013, Bighead Carp was the dominant Asian carp species caught in the Marseilles Pool (>55%). In 2018, the relative catch of Bighead carp was only 4% (Table 1). The 2018 gill/trammel net CPUE of Asian carp for Marseilles pool was 214.0, an 29% increase from 2017 (166.0). Gill/trammel net CPUE of Asian carp captured in Marseilles Pool since 2012 can be found in Figure 3.

Starved Rock Pool:

In 2018, 78% of the total harvested Asian carp came from Starved Rock pool. Asian carp removal efforts included: 246,700 yards (225.5 km) of gill/trammel net and 1403.7 hoop net nights. A total of 115,848 Silver Carp, 1,648 Bighead Carp, and 1,406 Grass Carp were harvested from Starved Rock pool in 2018 from all gear types (Table 1). We captured 4,129 Silver Carp, 84 Bighead Carp, and 186 Grass carp using hoop nets. Silver Carp dominated the relative catch of Asian carp in Starved Rock pool in 2018 (97%), as per usual. The 2018 gill/trammel net CPUE of Asian carp for Starved Rock pool was 464.1, an 18% decrease from 2017 (549.8). Gill/trammel net CPUE of Asian carp captured in Starved Rock pool since 2012 can be found in Figure 3.

Catch of Bycatch Species

Gill and Trammel nets:

A total of 186,317 fishes representing 36 species and 2 hybrid groups were captured in gill/trammel nets in the 2018 Asian carp removal efforts (Table 2). Asian carp occupied 78.9% of the total catch, *Ictiobus spp.* (i.e., Bigmouth, Black, and Smallmouth Buffaloes) occupied 17.1% of the total catch, and Common Carp occupied 2% of the total catch. A total of 1,147 fishes representing 13 species and 1 hybrid group considered game fishes (i.e., *Pomoxis spp.*, *Micropterus spp.*, Ictalurids, Esocids, Percids, Moronids), were captured in gill/trammel nets in 2018. Game fishes occupied 0.6% of the total catch of fishes captured in gill/trammel nets in

2018. Similar to previous years, Flathead and Channel Catfishes were the most dominant game fishes captured in 2018, occupying 82.5% of the total game fishes captured in gill/trammel nets.

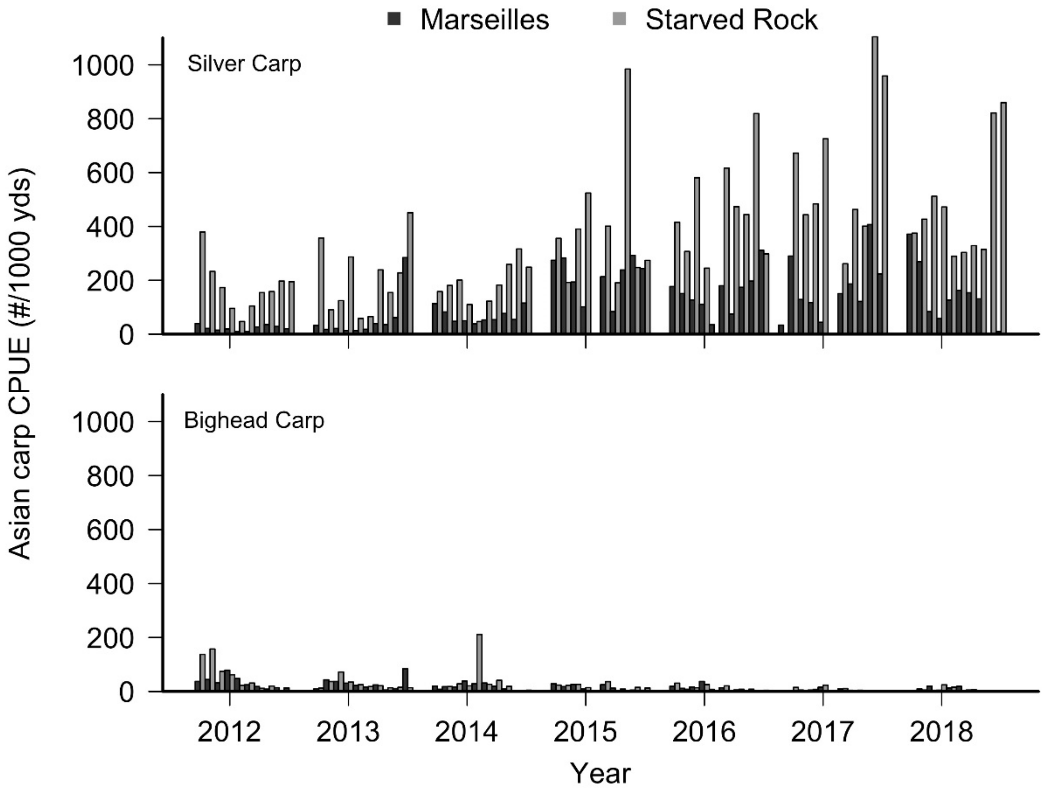

Figure 3. *Trends in catch per unit effort (CPUE) of Silver and Bighead Carp (number of Asian carp per 1,000 yards of gill/trammel net) in Marseilles and Starved Rock pools, 2012-2018. Each bar pair (or lack thereof) represents a single month.*

Hoop Nets:

A total of 7,864 fishes representing 16 species and one hybrid group were captured in hoop nets in the 2018 Asian carp removal efforts. Asian carp occupied 57.1% of the total catch, *Ictiobus spp.* (Smallmouth and Black Buffaloes) occupied 24.3%, and species considered game fishes (i.e., Black Crappie, Ictalurids, Walleye, and Moronids) occupied 2.7% of the total catch.

Commercial Seine:

A total of 5,144 fishes representing 16 species were captured in a commercial seine in the 2018 Asian carp removal efforts. Gizzard Shad occupied 38.9% of the total catch, Asian carp occupied 20.3%, Catostomids (i.e., River Carpsucker and Big and Smallmouth Buffaloes) occupied 20.2%, and game fishes (i.e., *Pomoxis spp.*, Ictalurids, Moronids, and *Micropterus spp.)* occupied 14% of the total catch.

Great Lakes Pound Net:

A total of 3,083 fishes representing 14 species were captured in Great Lakes pound nets in the 2018 Asian carp removal efforts. Gizzard Shad occupied 60% of the total catch, Freshwater Drum occupied 19.1%, Asian carp occupied 5%, and game fishes (i.e., *Pomoxis spp.*, Bluegill, Ictalurids, Largemouth Bass, and Yellow Bass) occupied 4.5% of the total catch.

Barrier Defense Asian Carp Removal Project

Recommendation:

We propose to increase Asian carp harvest using contracted fishers in the upper Illinois Waterway in 2019 (+45 harvest weeks; 109 weeks in 2018 vs.154 weeks in 2019). Since 2010, this program has been successful at managing the Asian carp population in the upper Illinois River. Adding harvest weeks will allow us to remove more Asian carp in 2019 than in previous years, further reducing Asian carp abundance at and near the detectable population front and possibly preventing further upstream movement of populations toward the Electric Dispersal Barrier and Lake Michigan. Long term harvest data provides information necessary to model changes in Asian carp relative abundance and population demographics among pools of the upper Illinois Waterway in future years. Additionally, research has identified the Barrier Defense Asian Carp Removal Program has benefited Gizzard Shad (Love *et al.* 2017), although other research determining how native species are responding to the reduction of Asian carp in the Upper Illinois River is lacking.

Table 1. *Contracted fishers' removal efforts by gear type and harvest numbers of Asian carp from Marseilles and Starved Rock pools, years 2010-2018.*

	Effort						Harvest							
Year and River Pool	**Net Sets (*N*)**	**Miles of Net**	**Seine Hauls (*N*)**	**Miles of Seine**	**Hoop Net Nights (*N*)**	**Pound Net Nights (*N*)**	**Bighead Carp (*N*)**	**Silver Carp (*N*)**	**Grass Carp (*N*)**	**Total (*N*)**	**Bighead Carp (tons)**	**Silver Carp (tons)**	**Grass Carp (tons)**	**Total (tons)**
2010														
Marseilles	1,316	75.5	0	0	0	0	4,888	1,075	0	5,963	53.11	8.11	0	61.22
Starved Rock	0	0	0	0	0	0			0				0	
All pools	1,316	75.5	0	0	0	0	4,888	1,075	0	5,963	53.11	8.11	0	61.22
2011														
Marseilles	671	219.2	0	0	0	0	20,087	7,023	34	27,144	229.39	46	0.16	275.55
Starved Rock	151	44.6	0	0	0	0	2,964	10,730	132	13,826	21.36	53.32	0.65	75.33
All pools	822	263.8	0	0	0	0	23,051	17,753	166	40,970	250.75	99.32	0.81	350.88
2012														
Marseilles	599	235.6	2	0.9	0	0	13,962	11,018	160	25,140	126.07	64.39	0.67	191.13
Starved Rock	198	67.3	0	0	0	0	3,994	20,589	243	24,826	22.42	99.98	1.39	123.79
Total	797	302.9	2	0.9	0	0	17,956	31,607	403	49,966	148.49	164.37	2.06	314.92
2013														
Marseilles	457	237.8	2	0.9	0	0	7,742	11,633	378	19,753	74.05	59.38	2.67	136.10
Starved Rock	236	104.07	0	0	0	0	3,938	38,666	369	42,973	21.93	1.97	168.14	192.04
Total	693	341.87	2	0.9	0	0	11,680	50,299	747	62,726	95.98	61.35	170.81	328.14
2014														
Marseilles	488	216	3	1.1	0	0	7,549	27,516	108	35,173	69.33	112.29	0.05	181.67
Starved Rock	290	91	1	0.2	421.7	0	4,220	63,132	416	67,768	19.74	222.73	0.72	243.19
Total	778	307	4	1.3	421.7	0	11,769	90,648	524	102,941	89.07	335.02	0.77	424.86
2015														
Marseilles	420	141.2	14	1.62	22.5	24	5,298	68,804	216	74,318	38.90	236.00	1.23	276.13
Starved Rock	225	78.3	4	0.53	141.2	0	2,908	68,681	641	72,230	13.20	198.10	3.64	214.94
Total	645	219.5	18	2.15	163.7	24	8,206	137,485	857	146,548	52.10	434.10	4.86	491.06

	Effort						Harvest							
Year and River Pool	**Net Sets (*N*)**	**Miles of Net**	**Seine Hauls (*N*)**	**Miles of Seine**	**Hoop Net Nights (*N*)**	**Pound Net Nights (*N*)**	**Bighead Carp (*N*)**	**Silver Carp (*N*)**	**Grass Carp (*N*)**	**Total (*N*)**	**Bighead Carp (tons)**	**Silver Carp (tons)**	**Grass Carp (tons)**	**Total (tons)**
2016														
Marseilles	553	203.1	37	8.1	85.7	64	5,924	62,490	76	68,490	46.86	251.30	0.43	298.59
Starved Rock	291	88.3	14	2.1	683.1	0	2,048	83,790	606	86,444	9.60	232.03	3.44	245.06
Total	844	291.43	51	10.2	768.8	64	7,972	146,280	682	154,934	56.46	483.33	3.87	543.65
2017														
Marseilles	488	139.9	12	2.8	48.7	74	1,486	41,775	51	43,312	13.56	176.70	0.29	190.55
Starved Rock	442	113.7	3	1.3	938.6	0	1,151	121,264	1,128	123,543	4.80	361.09	6.40	372.28
Total	930	253.7	15	4.1	987.3	74	2,637	163,039	1,179	166,855	18.36	537.78	6.69	562.83
2018														
Marseilles	423	86.5	10	2.4	224.5	22	1,397	32,367	35	33,799	13.3	148.3	0.2	161.6
Starved Rock	597	140.2	0	0	1403.7	0	1,648	115,848	1,406	118,902	8	383.9	6.8	391.9
Total	1,020	226.7	10	2.4	1,628.2	22	3,045	148,215	1,441	152,701	21.3	532.2	7	553.5
2010-2018														
Marseilles	6,054	1,555	80	18	381	184	68,333	263,701	1,058	333,092	665	1,102	6	1,773
Starved Rock	2,491	728	22	4	3,588	0	22,871	522,700	4,941	550,512	121	1,553	191	1,859
Total	8,545	2,282	102	22	3,970	184	91,204	786,401	5,999	883,604	786	2,656	197	3,631

Table 2: *Asian carp and bycatch captured by contracted fishers using gill and trammel nets in the Dresden Island (2011-2014), Marseilles (2011-2018), and Starved Rock (2011-2018) pools of the upper Illinois Waterway. In 2015, Asian carp removal efforts in Dresden Island pool transitioned to the Fixed Site Monitoring Downstream the Dispersal Barrier Project.*

	2011		2012		2013		2014		2015		2016		2017		2018	
Species	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**
Bighead Carp	23,117	43.68%	16,560	28.36%	11,777	15.67%	10,625	11.15%	6,318	4.05%	7,962	3.62%	2,402	1.33%	2,832	1.49%
Silver Carp	17,776	33.59%	28,632	49.03%	46,597	62.01%	57,302	60.15%	116,411	74.67%	145,790	66.29%	147,472	81.45%	142,924	75.08%
Smallmouth Buffalo	3,853	7.28%	3,749	6.42%	7,397	9.84%	12,717	13.35%	23,989	15.39%	31,588	14.36%	22,349	12.34%	28,429	14.93%
Bigmouth Buffalo	3,850	7.27%	5,043	8.64%	3,567	4.75%	4,670	4.90%	3,174	2.04%	3,707	1.69%	3,292	1.82%	3,344	1.76%
Common Carp	2,574	4.86%	2,386	4.09%	2,685	3.57%	6,699	7.03%	1,819	1.17%	3,137	1.43%	2,119	1.17%	3,702	1.94%
Grass Carp	171	0.32%	299	0.51%	303	0.40%	524	0.55%	823	0.53%	681	0.31%	1,150	0.64%	1,248	0.66%
Freshwater Drum	573	1.08%	689	1.18%	1,055	1.40%	1,091	1.15%	1,510	0.97%	11,685	5.31%	736	0.41%	948	0.50%
River Carpsucker	61	0.12%	26	0.04%	105	0.14%	229	0.24%	467	0.30%	2,028	0.92%	616	0.34%	1,485	0.78%
Channel Catfish	201	0.38%	137	0.23%	321	0.43%	430	0.45%	616	0.40%	1,679	0.76%	307	0.17%	773	0.41%
Flathead Catfish	313	0.59%	299	0.51%	417	0.55%	301	0.32%	233	0.15%	331	0.15%	225	0.12%	173	0.09%
Black Buffalo	188	0.36%	262	0.45%	432	0.57%	318	0.33%	133	0.09%	81	0.04%	110	0.06%	85	0.04%
Largemouth Bass	28	0.05%	22	0.04%	28	0.04%	26	0.03%	34	0.02%	61	0.03%	33	0.02%	57	0.03%
Silver Redhorse	0	0	0	0	0	0	1	< 0.01%	3	<0.01%	8	<0.01%	33	0.02%	22	0.01%
Quillback	37	0.07%	46	0.08%	49	0.07%	84	0.09%	134	0.09%	497	0.23%	31	0.02%	15	0.01%
Walleye	9	0.02%	12	0.02%	7	0.01%	5	0.01%	15	0.01%	35	0.02%	25	0.01%	57	0.03%
Longnose Gar	11	0.02%	25	0.04%	68	0.09%	91	0.10%	40	0.03%	110	0.05%	23	0.01%	29	0.02%
Shortnose Gar	16	0.03%	37	0.06%	44	0.06%	13	0.01%	29	0.02%	36	0.02%	15	0.01%	13	<0.01%
Golden Redhorse	0	0	2	< 0.01%	6	0.01%	30	0.03%	5	< 0.01%	30	0.01%	14	0.01%	15	<0.01%
Sauger	19	0.04%	31	0.05%	12	0.02%	11	0.01%	31	0.02%	65	0.03%	13	0.01%	16	<0.01%
White Bass	13	0.02%	11	0.02%	40	0.05%	23	0.02%	14	0.01%	505	0.23%	13	0.01%	21	1.10%
Gizzard Shad	6	0.01%	22	0.04%	5	0.01%	3	< 0.01%	4	< 0.01%	2,193	1.00%	12	0.01%	29	1.52%
Paddlefish	78	0.15%	51	0.09%	37	0.05%	37	0.04%	31	0.02%	27	0.01%	9	<0.01%	22	1.16%
Shorthead Redhorse	0	< 0.01%	1	< 0.01%	0	0	4	< 0.01%	1	< 0.01%	15	0.01%	9	<0.01%	13	<0.01%
White Crappie	1	< 0.01%	2	< 0.01%	1	< 0.01%	4	< 0.01%	7	< 0.01%	65	0.03%	8	<0.01%	11	<0.01%
Blue sucker	0	0	0	0	0	0	0	0	0	0	0	0	5	<0.01%	2	<0.01%
Black Crappie	1	< 0.01%	1	< 0.01%	2	< 0.01%	4	< 0.01%	7	< 0.01%	133	0.06%	4	<0.01%	13	<0.01%
Northern Pike	1	< 0.01%	1	< 0.01%	2	< 0.01%	0	0	1	< 0.01%	5	<0.01%	4	<0.01%	1	<0.01%
Blue Catfish	8	0.02%	7	0.01%	8	0.01%	2	< 0.01%	5	< 0.01%	3	<0.01%	3	<0.01%	2	<0.01%

	2011		2012		2013		2014		2015		2016		2017		2018	
Species	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**	**Catch (*N*)**	**Percent %**
Hybrid Striped Bass	2	< 0.01%	7	0.01%	2	< 0.01%	5	0.01%	12	0.01%	12	0.01%	3	<0.01%	15	<0.01%
Yellow Bass	3	0.01%	5	0.01%	9	0.01%	9	0.01%	4	< 0.01%	157	0.07%	3	<0.01%	4	<0.01%
Carp x Goldfish	1	< 0.01%	4	0.01%	2	< 0.01%	0	0	0	0	2	<0.01%	2	<0.01%	0	0
Highfin Carpsucker	0	0	0	0	0	0	0	0	0	0	2	<0.01%	2	<0.01%	0	0
Skipjack Herring	9	0.02%	14	0.02%	0	0	6	0.01%	6	< 0.01%	39	0.02%	2	<0.01%	2	<0.01%
Alligator Gar	0	0	0	0	0	0	0	0	0	0	0	0	1	<0.01%	0	0
Bowfin	0	0	0	0	4	0.01%			3	< 0.01%	5	<0.01%	1	<0.01%	2	<0.01%
Greater Redhorse	0	0	0	0	0	0	0	0	0	0	0	0	1	<0.01%	0	0
Mooneye	0	0	6	0.01%	3	< 0.01%	1	< 0.01%	8	0.01%	3	<0.01%	1	<0.01%	0	0
American Brook Lamprey	0	0	0	0	0	0	0	0	0	0	1	<0.01%	0	0	0	0
Black Bullhead	0	0	0	0	0	0	0	0	0	0	2	<0.01%	0	0	0	0
Bluegill	0	0	1	< 0.01%	0	0	1	< 0.01%	1	< 0.01%	10	<0.01%	0	0	0	0
Gizzard Shad <6 in	0	0	0	0	0	0	0	0	0	0	375	0.17%	0	0	0	0
Goldeye	1	< 0.01%	0	0	0	0	0	0	3	< 0.01%	0	0	0	0	0	0
Goldfish	0	0	0	0	20	0.03%	0	0	2	< 0.01%	0	0	0	0	0	0
Hybrid Sunfish	0	0	0	0	0	0	0	0	0	0	8	<0.01%	0	0	0	0
Muskellunge	1	< 0.01%	0	0	2	< 0.01%	1	< 0.01%	2	< 0.01%	0	0	0	0	1	<0.01%
River Redhorse	1	< 0.01%					1	< 0.01%	1	< 0.01%	4	<0.01%	0	0	0	0
Rock Bass	0	0	1	< 0.01%	0	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0	0	0	11	0.01%	0	0	3	<0.01%
UI Buffalo Spp.	0	0	0	0	137	0.18%	0	0	0	0	3,446	1.57%	0	0	0	0
UI Carpsucker	0	0	0	0	0	0	0	0	0	0	470	0.21%	0	0	0	0
UI Catostomid	0	0	0	0	0	0	0	0	0	0	2,062	0.94%	0	0	0	0
UI Moronid	0	0	0	0	0	0	0	0	0	0	865	0.39%	0	0	0	0
White Perch	0	0	0	0	1	< 0.01%	0	0	0	0	4	<0.01%	0	0	0	0
White Sucker	0	0	0	0	0	0	0	0	0	0	1	<0.01%	0	0	6	<0.01%
Northern Hogsucker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<0.01%
Spotted Gar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<0.01%
Silver x Bighead Carp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<0.01%
Total All Species	52,924	0	58,391	0	75,145	0	95,268	0	155,896	0	219,936	0	181,048	0	190,353	0

Barrier Maintenance Fish Suppression

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

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

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

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

Objectives: The IDNR will work with federal and local partners to:

(1) Remove fish >300 mm (12 inches) in total length from between applicable barrier arrays before maintenance operations are initiated at upstream arrays and after maintenance is completed at downstream arrays by collecting or driving fish into nets from the area with mechanical technologies (surface noise, surface pulsed-DC electrofishing and surface to bottom gill nets) or, if needed, a small-scale rotenone action.
(2) Assess fish assemblage <300 mm (12 inches) in total length between applicable barrier arrays, if present, for species composition to ensure Asian carp juvenile or young of year individuals are not present. Physical capture gears focused on small bodied fishes such as electrified paupier surface trawls and surface pulsed-DC electrofishing could be utilized in support of this effort.
(3) Assess the results of fish clearing operations by reviewing the physical captures and surveying the area between barrier arrays with remote sensing gear (split-beam hydroacoustics and side-scan sonar). The goal of fish clearing operations is to remove as many fish (>300 mm in total length) as possible between the barriers, as determined with remote sensing gear or until the Monitoring and Response Workgroup (MRWG) deems the remaining fish in the barrier as a low risk. Fishes <300 mm in total length at the Barriers are deemed a low risk to be Asian carp until further evidence from downstream monitoring suggests a change in the known population front for this size class of invasive Asian carps.

Project Highlights:

- The MRWG agency representatives met and discussed the risk level of Asian carp presence at the Electric Dispersal Barrier System at each primary barrier loss of power to water and determined that no barrier clearing actions were required.
- Three 15 minute electrofishing run were completed between Barriers 2A and 2B to supplement existing data in support of the MRWG clearing decision.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on a bi-weekly basis, both below and within the EDBS indicating low fish abundance and no fish over 300 mm.
- An acoustic deterrent system was installed approximately a half mile downstream of the Electric Dispersal Barrier System between February 14 and May 7, 2018 and between November 19, 2018 and April 3, 2019 in support of annual maintenance operations.
- **No Asian carp were captured or observed during fish suppression operations.**

Methods:

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

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

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

Initial clearing action is likely to use split beam hydroacoustics and side scan SONAR imaging to determine if fish are present in the target area of the electric barrier array, including the area between Barrier IIA and IIB or between the active barrier array and the demonstration barrier, to identify the number of fish over 300 mm. This sonar scan may be completed upon request or the MRWG may decide to utilize the most recent data available as USFWS continues bi-weekly surveillance of the vicinity. If one or more fish targets over 300 mm are present, the MRWG will convene and decide if a clearing action is warranted for the area between affected barriers. Initial response to any loss of power to the water should occur within a week of the outage; upon completion of the sonar survey, fish detections, sizes, and locations will help formulate timely clearing efforts if deemed necessary. Additional clearing actions can range from nearly “instantaneous” response with electrofishing to combined netting and electrofishing, or any combination of other deterrent technologies that may or may not require US Coast Guard (USCG) closures of the Canal/Waterway. The USCG generally requires at least a 45 day notice for requests to restrict navigation traffic in the waterway.

Results and Discussion:
During 2018, Barrier 2A and 2B were the primary barrier to fish passage in the upstream direction within the EDBS at various points during the year. During periods when Barrier 2A was designated as the primary barrier, it experienced a loss of power in water at both arrays for an extended duration (minimum = 1 minutes; maximum = 26 days and 23 hours) a total of 12 times (**Table 1**). Over the course of six 2A outage events, there were 19 instances when Barrier 2B also went down (minimum = 20 minutes, maximum = 10 days, 8 hours). Of those, 18 of them were during annual maintenance events and a separate acoustic barrier was established downstream during this time period (February – May) in addition to the demonstration barrier being active. The first 2B outage occurred between January 9 and 19, 2018, before the acoustic barrier was installed and lasted 10 days, 8 hours. The full list and duration of 2B outages can be found in **Table 2**. During the remaining six 2A outages (minimum = 1 minute, maximum = 11 days, 21 minutes) barrier 2B was operational. Three of those six events encompassed an annual maintenance period in December of 2018, at which time an acoustic deterrent system was established downstream of the barrier. The risk for Asian carp presence at the barrier and the likelihood of fish moving upstream was communicated to the MRWG at each primary barrier outage. The MRWG determined formal clearing actions between the barriers were not required due to a very low risk of Asian carp presence. There were three occasions in which additional electrofishing monitoring actions were taken at the Electric Dispersal Barrier System to further support the MRWG decision. Extreme cold temperatures, seasonal movement patterns of Asian carp and sufficient evidence from downstream sampling were all factors which supported the conclusion that Asian carp were likely not in the vicinity of the barriers during the reported losses of power. Safety was an additional factor in the decision to not perform clearing actions. Extreme cold temperatures or abnormally high flow within the canal restrain the ability of the workgroup to effectively deploy clearing teams. During such instances, the workgroup relied on best professional judgment, downstream sampling efforts and telemetry results to assess the risk of breach.

The three monitoring actions performed at the Electric Dispersal Barrier System utilized DC electrofishing. The monitoring actions were taken on July 11, August 14, and August 29 in response to a prior barrier outage at 2A. USACE completed these 15 minute electrofishing runs. These were not designated as clearing actions, but rather to help assess the risk for Asian carp presence during routine monitoring activities of the Lockport Pool. No Asian carp were captured, but other fish species were. On July 11 one Freshwater Drum at 207mm was collected. On August 14 several fish under 200mm were captured, species included Gizzard Shad (8), Largemouth Bass (2), Green Sunfish (1), Bluntnose Minnow (6), Emerald Shiner (8), Spottail Shiner (2), and Banded Killifish (21). On August 29 three species were captured during the electrofishing run, and all fish were under 300 mm. The species were Largemouth Bass (1), Emerald Shiner (6), Gizzard Shad under six inches (29), and Gizzard Shad over 6 inches (1). Additional monitoring actions were undertaken by USWFS using hydroacoustic sonar scans. The monitoring responses were conducted by USFWS Wilmington sub-office. They completed a sonar scan between the barriers on a bi-weekly to monthly basis between February and November 2018 and on a weekly basis in December during maintenance activities. Results from these scans indicated fish abundance was low between the barriers and no large fish were observed. These scans were part of normal monitoring activities of the EDBS and were not specifically requested by the MRWG, but they helped further assess the risk for fish presence between Barriers 2A and 2B. Results from these scans indicated no large fish and low abundance of small fish between Barriers 2A and 2B.

Several of the early 2018 outages were coordinated by USACE with the MRWG as a planned outage event at Barriers 2A and 2B in March and April of 2018. A concurrent shutdown of Barrier 2A and 2B was needed to support dive operations and inspection and replacement of the in-water component at those barriers. USACE planned this outage to occur at a time of the year when fish activity and water temperatures are expected to be the lowest. The Demonstration Barrier was also operated continuously during the planned outages. The MRWG convened a call on November 21, 2017 to discuss the risk for Asian carp presence and the need for clearing actions. It was determined that USACE would complete a download of data from telemetry receivers in the vicinity of the barriers and that USFWS would complete a sonar scan to supplement existing monitoring data. USFWS performed bi-weekly sonar scans in advance of the dive operations. The results indicated there were no large fish in vicinity of the barriers and a low abundance of small fish. USACE telemetry data was downloaded on 11 and 15 January at the Romeoville Road Bridge. Telemetry data indicated low activity of tagged fish as well.

Table 1. *Loss of power to the water at the primary active Barrier 2A in 2018; the Demonstration Barrier was in full operation at each of the time and dates listed below.*

Barrrier	Start Date	End Date	Outage Duration
IIA	23-Dec-17	9-Jan-18	17d 21h 10 min
IIA	28-Jan-18	30-Jan-18	2d 2h 27min
IIA	7-Mar-18	3-Apr-18	26d 23h 28min
IIA	10-Apr-18	10-Apr-18	27min
IIA	10-Apr-18	10-Apr-18	6 min
IIA	24-Apr-18	2-May-18	8d 7h 35 min
IIA	1-Jul-18	1-Jul-18	1 min
IIA	3-Jul-18	3-Jul-18	1 min
IIA	20-Aug-18	20-Aug-18	2h 36 min
IIA	10-Dec-18	18-Dec-18	8d 21h 49min
IIA	19-Dec-18	20-Dec-18	1d 1h 7 min
IIA	26-Dec-18	8-Jan-19	11d 21h 33 min

Table 2. *Loss of power to the water at the primary active Barrier 2B in 2018; the Demonstration Barrier was in full operation at each of the time and dates below.*

Barrrier	Start Date	End Date	Outage Duration
IIB	9-Jan-18	19-Jan-18	10d 8h 2 min
IIB	7-Mar-18	9-Mar-18	Avg daily 7h 41 min
IIB	12-Mar-18	12-Mar-18	10h 5 min
IIB	15-Mar-18	16-Mar-18	Avg daily 10h 16 min
IIB	19-Mar-18	23-Mar-18	Avg daily 9h 47 min
IIB	26-Mar-18	30-Mar-18	Avg daily 9h 30 min
IIB	2-Apr-18	2-Apr-18	7h 51 min
IIB	24-Apr-18	24-Apr-18	20 min

Recommendations:

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

Barrier Defense Removal of Asian Carp Using Novel Gear

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

Introduction and Need:

Barrier Defense was initiated in 2010 to reduce propagule pressure on the electric dispersal barriers in the Chicago Sanitary and Ship Canal by targeting mass removal efforts in areas of the Illinois River where there are high densities of Asian carp (Bushman et al. 2015). The Columbia Fish and Wildlife Conservation Office (FWCO) has contributed to the Illinois Department of Natural Resources's (IDNR) Asian carp mass removal efforts in the Starved Rock pool of the upper Illinois River beginning with an exploratory effort in 2015 using an electrified butterfly frame trawl (paupier; Doyle et al. 2015). The paupier was officially incorporated into the removal project in 2016 and was able to remove over 11,000 Silver Carp (Ridgway et al. 2016). Experience and several gear improvements led to an increase in yield in 2017 to over 19,000 Silver Carp removed (Ridgway and Pherigo 2017). Efforts continued through 2018 with additional improvements designed to further increase the total catch of Asian carp and increase the efficiency as measured by Asian carp biomass per labor hour.

Objectives:

(1) Remove adult and juvenile Asian carp from the Starved Rock pool of the Illinois River with the paupier, a tender boat, and an on-site processor.

(2) Track and assess efficiency in terms of Asian carp biomass per labor hour to inform future harvest.

Project Highlights:

- Fourteen days of effort removed an estimated 37,657 Asian Carp (approximately 109 tons), 99.6% of which were Silver Carp, from the Starved Rock pool of the upper Illinois River. Asian carp were removed at a rate of 7.8 tons/day (tons/d) in 2018, compared to 4.8 tons/d in 2017.
- The proportion of non-target fish in the total catch was similar between the two years, with 9% in 2017 and 10% in 2018.
- The percentage of time spent electrofishing increased from 24% in 2017 to 29% in 2018.
- The addition of a second tender boat, redesign of the fish unloading process, inclusion of hydroacoustic technology, and adjustment of the subsample protocol likely contributed to an increase in harvest during 2018.

Methods:

Gear, 2017–2018

Modeled after shrimp trawlers in the Gulf of Mexico, the paupier has metal frames measuring 3.7 meters (m) wide by 1.5 m tall extending off the port and starboard with 52 millimeter (mm) bar mesh nets attached to the frames tapering back approximately 7 m towards the stern to a 20 mm (2017) or a 38 mm (2018) bar mesh cod end. Three cable dropper anodes were affixed to booms 3–4 m in front of the paupier frames. An 18 centimeter (cm) diameter hemisphere anode was suspended in each paupier frame approximately 1 m back from the net opening (Figure 1). Anodes were powered with a 82-amp ETS box. Duty cycle and frequency (pulses per second) were 15% and 30 hertz, respectively. Power output was adjusted based on ambient conductivity and the observed immobilization of Silver Carp.

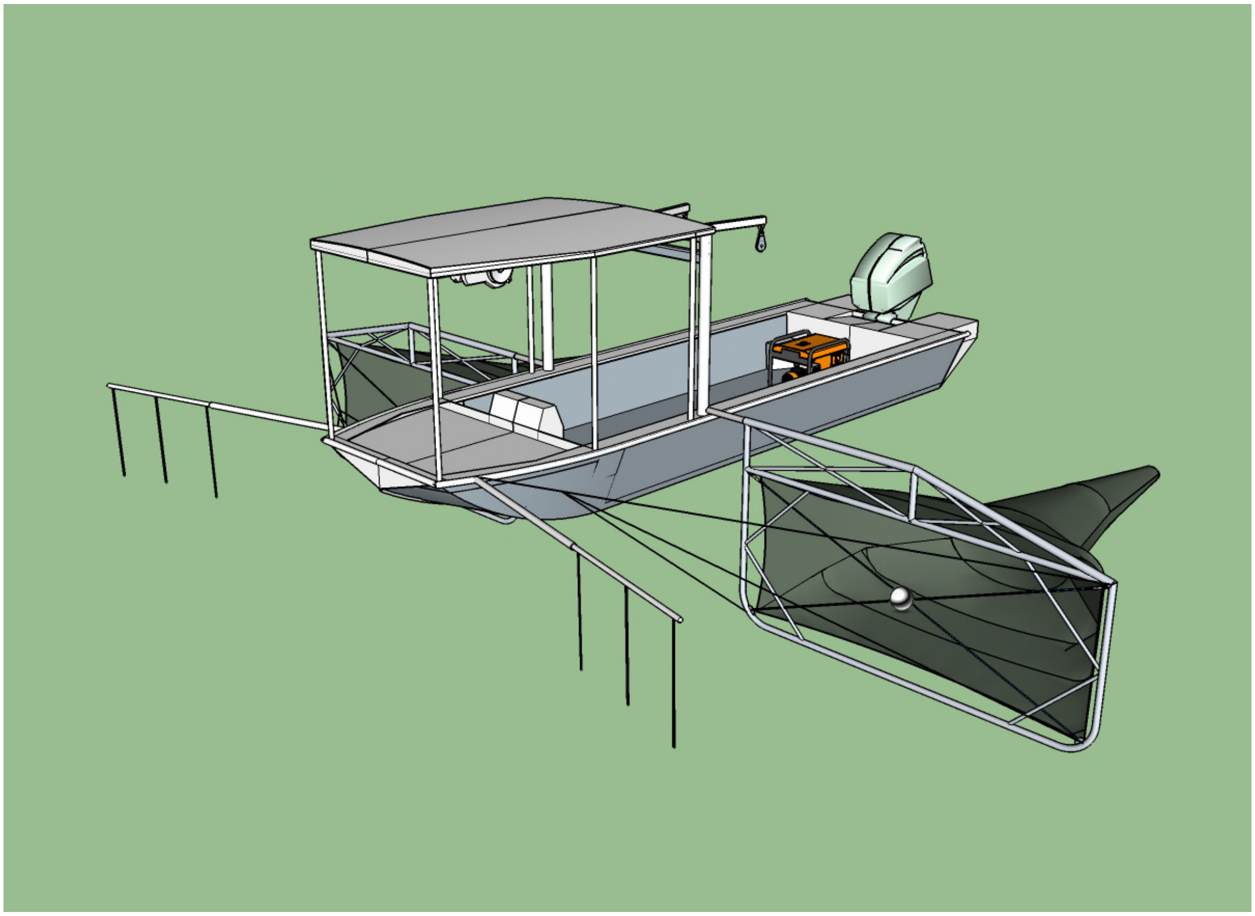

Figure 1. *Mockup of the electrified paupier used in Barrier Defense efforts June through September 2018, depicting booms attached to each corner of the bow with cable dropper anodes, a hemisphere anode in each frame (port-only shown here), and conical nets.*

Data collection, 2017

Mass removal efforts took place from August to November 2017 in the Starved Rock pool of the upper Illinois River using the paupier, one tender boat, and a fish hauling trailer. Mechanical winches allowed the paupier crew to empty cods into the tender boat, which was used to hold and transport fish from the paupier to the boat ramp.

Crews consisted of six or seven people, depending on staff availability. Asian carp aggregations were located using boat-mounted sonar (i.e., Humminbird 1100 Series and Humminbird 360ssi). Flowing habitats (i.e., tributaries, side channels, and channel borders) were targeted because these areas have been shown to have less non-target fish compared to backwaters (Ridgway et al. 2016). Transect length and electrofishing time varied depending on habitat availability and net capacity. All Asian carp were identified and enumerated. Total lengths and weights were recorded for a random 10% subsample of the Silver Carp and for all Bighead and Grass carp. Asian carp were hauled to the IDNR processor-disposal station at the end of each day. Non-target fish were identified, enumerated, and released at point of capture.

In addition to fish biological data, the electrofishing (i.e., pedal) time, crew size, and time spent on the water were recorded daily. This data, along with mean weight of subsampled fish was used to calculate the estimated biomass of Silver Carp for each day.

Data collection, 2018

From June to September 2018, the Columbia FWCO conducted removal efforts in the Starved Rock pool of the upper Illinois River using the paupier (with the same mechanical improvements introduced in 2017), one or two tender boats (depending on availability), and a IDNR contracted commercial processor located on shore near the collection sites. The addition of the processor located near the collection site allowed the paupier fishing crew to focus on catching Silver Carp capture rather than transport of the catch. Additionally, the second tender boat enabled efficient offloading of the paupier catch while the first tender boat transported a load to the processor, The unloading process was also updated in 2018 with the addition of “speed bags”, which minimized handling of individual fish and allowed fish to be removed from tender boats with a forklift, reducing crew fatigue (Figure 2).

Figure 2. *Beginning in 2018, fish were emptied from cods directly into speed bags (A), reducing handling of individual fish by allowing them to be offloaded from tender boats with a forklift (B).*

Crews varied between six and eleven people depending on number of tender boats and staff available. Habitats with known aggregations of invasive carp were targeted similar to the previous year, with the addition of telemetry and hydroacoustics further informing the 2018 efforts. Telemetry provided information on Silver Carp movement trends and habitats frequented. Hydroacoustic technology provided maps identifying aggregations ofAsian carp. These maps highlighted potential new areas to fish while boat-mounted sonar allowed verification of the presence of schools before fishing efforts began. Transect length and electrofishing time varied depending on available habitat and net capacity.

Due to the increased number of fish compared to 2017, total lengths and weights were recorded for a random 10% subsample of all Asian carp to calculate biomass. Similar to 2017, electrofishing time, crew size, and time spent on the water were recorded daily and used with the biological data to calculate the estimated biomass of Silver, Bighead, and Grass carp for each day.

Results and Discussion:

Summary, 2017–2018

Eleven days and 392 labor hours were expended in 2017, with 1.3 ± 0.5 hrs (mean ± standard deviation) of daily electrotrawling time (23.7% of each day). In 2018, effort increased to 14 days and 1,098 labor hours, with 2.38 ± 0.6 hrs of daily electrotrawling time (28.5% of each day; Table 1). A total of 19,124 Asian carp (52.8 tons) were removed in 2017, 99.9% of which was

Silver Carp. The catch nearly doubled in 2018 to an estimated 37,657 Asian carp (109.0 tons), 99.6% of which was Silver Carp.

Table 1. *Summary of the sampling effort and Asian carp catch of the electrified paupier during Barrier Defense efforts in the Starved Rock pool of the upper Illinois River, 2017–2018. Labor hours were defined as crew size multiplied by time spent on the water.*

	2017	2018
Number of Days on Water	11	14
Crew Size	6–7	6–11
Hours on Water	58.9	116.9
Labor Hours	392	1,098
Electrotrawling Hours	14.0	33.4
Silver Carp Count	19,116	37,579
Bighead Carp Count	2	33
Grass Carp Count	6	45
Silver Carp Biomass (lbs)	105,484	217,186
Bighead Carp Biomass (lbs)	19	298
Grass Carp Biomass (lbs)	58	478
CPUE (SVCP count/electrotrawling hour)	1,365	1,128
CPUE (SVCP biomass/electrotrawling hour)	7,535	6,537
CPUE (SVCP biomass/labor hour)	269	198

Paupier catch, 2017–2018

The proportion of Asian carp in the total catch was similar over the two years: 91% and 90% in 2017 and 2018, respectively. Non-target fish were dominated by Gizzard Shad (*Dorosoma cepedianum*) and Smallmouth Buffalo (*Ictiobus bubalus*) in both years. The weight (Table 2) and length distribution (Figure 3) of all Asian carp species captured in 2017 and 2018 were similar.

Table 2. *Summary statistics for the weight of the Silver, Bighead, and Grass carp captured as part of the Barrier Defense removal efforts in 2017 and 2018. SD = standard deviation*

Species	Year	Sample Size	Weight (lbs)	
			Mean (SD)	Range
Silver Carp	2017	2,042	5.5 (1.3)	1.9–14.5
	2018	4,931	5.8 (1.2)	1.9–17.7
Bighead Carp	2017	2	-	6.6–12.8
	2018	17	9.1 (2.1)	5.5–12.2
Grass Carp	2017	5	9.6 (2.5)	7.2–13.1
	2018	21	8.7 (2.0)	4.5–12.2

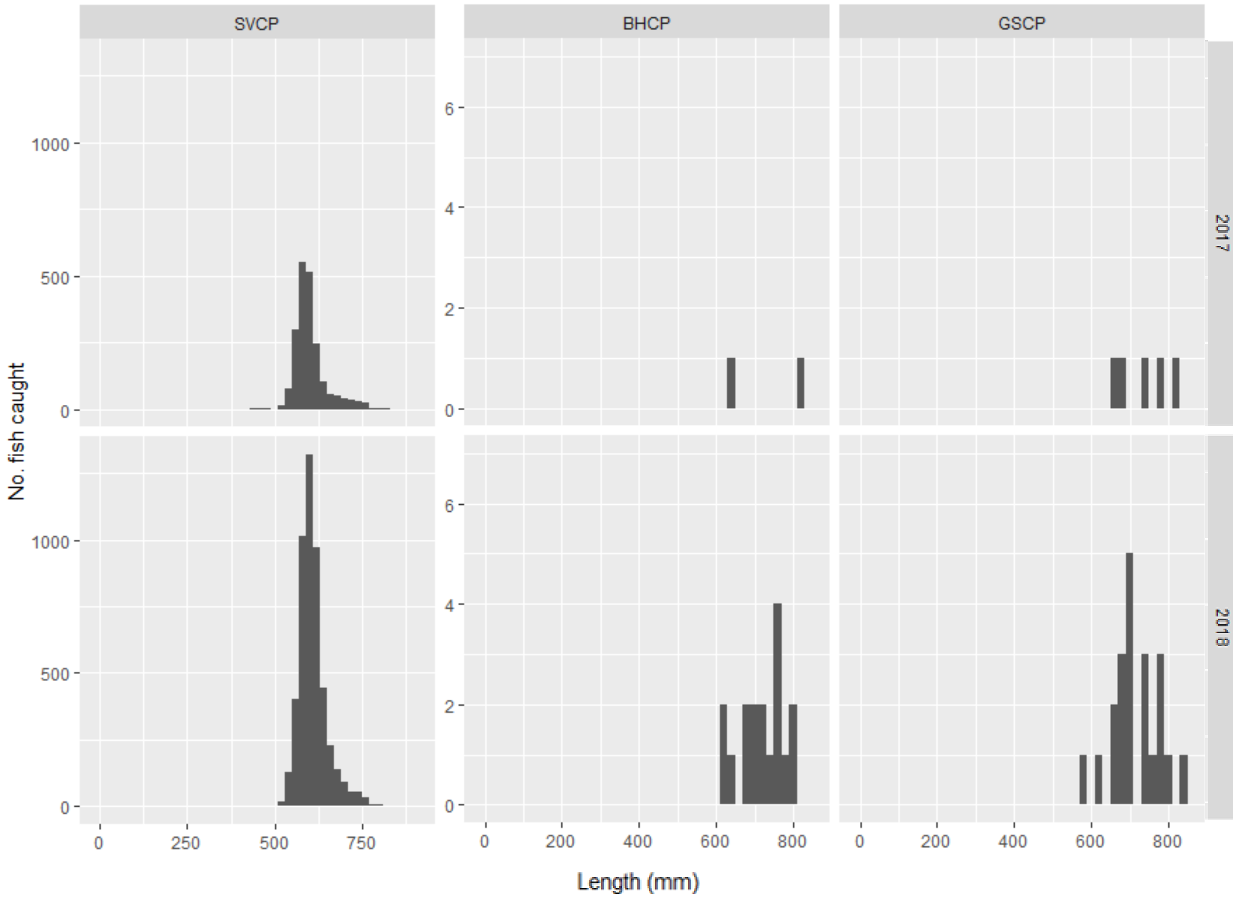

Figure 3. *Length frequency histograms of Silver Carp (SVCP), Bighead Carp (BHCP), and Grass Carp (GSCP) captured in 2017 (top row) and 2018 (bottom row) as part of the Barrier Defense removal efforts. Note the different y-axis range for Silver Carp compared to Bighead and Grass Carp.*

Efficiency, 2017–2018

The average Silver Carp removal increased to 7.8 tons/d in 2018 compared to 4.8 tons/d in 2017. With the addition of hydroacoustic and telemetry data, the paupier and tender boat crews were able to spend less time searching for fish and more time electrotrawling. The addition of a second tender boat similarly allowed for more time to be spent electrotrawling by eliminating the need for the paupier to hold and transport fish. These changes, along with an increase in the number of sampling days, resulted in an increase in the time spent electrotrawling from 14.0 hours (24% of each day) in 2017 to 33.4 hours (29% of each day) in 2018 and resulted in doubling the number of Asian carp removed with the paupier from the Starved Rock Pool in 2018.

To achieve this increase in Silver Carp removed in 2018, we doubled our hours on the water (including three extra days of targeted removal), more than doubled our time spent electrotrawling, and nearly tripled our labor hours. Extra crew members were added for training or observation purposes on several sampling days leading to a substantial increase in labor hours.

As a result, Silver Carp biomass per labor hour decreased between the two years from 269 lbs per labor hour in 2017 to 198 lbs per labor hour in 2018. This 26% decrease in efficiency as measured by Silver Carp biomass per labor hour is likely influenced by the increase in crew. Future operations will seek to balance the crew size and labor time to increase Asian carp removed as well as maximize efficiency as measured by biomass per labor hour.

Silver Carp catch per electrotrawling hour decreased by 17% over the two years, from 1,365 fish per electrotrawling hour in 2017 to 1,128 fish per electrotrawling hour in 2018 (Table 1). Although harvest doubled from 2017 (105,484 lbs) to 2018 (217,186 lbs), the time spent electrotrawling in 2018 was almost two and half times what it was in 2017 (14.0 hrs in 2017 compared to 33.4 hrs in 2018). The increase in harvest was not enough to yield a similar or increased catch per unit effort of Silver Carp based on electrotrawling time, perhaps suggesting an increase in the percentage of time spent electrotrawling may lead to a larger harvest, but at the expense of efficiency. Another potential explanation for the 17% decrease in catch rate is simply a decrease in the biomass of Asian carp present in the Starved Rock pool between 2017 and 2018. This hypothesis may be evaluated using hydroacoustic estimates of fish density over the two years. Further refining when, where, and how much we deploy targeted fishing efforts in an area will help maintain high catch rates as well as contribute to increased biomass removed.

Recommendations:

- Silver Carp catch rates in terms of tons/d increased between 2017 and 2018, indicating there is a benefit to the most recent changes. These protocols should be further developed in the 2019 field season.
- Efficiency in terms of Silver Carp biomass per labor hour should be used to assess cost-effectiveness of the electrified paupier as a removal tool similar to the methods of Collins et al. (2015, 2017).
- Catch rates of Silver Carp should be compared to fish density estimated using hydroacoustics or other available data sources to inform the decrease in catch rate observed in 2018.
- Methods of optimizing the crew size to limit labor hours without sacrificing harvest should be explored.

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Optimization of Mass Removal Techniques

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Participating Agencies: USFWS-Columbia Fish and Wildlife Conservation Office (USFWS-CFWCO), USGS-Columbia Environmental Research Center (USGS-CERC; Collaborator)

Location: Missouri River tributaries and backwaters

Introduction and Need:

Mass removal techniques such as the Unified Method rely on herding fish to an end-point where harvest occurs with a beach seine. Evaluation of the effect and behavior of fish to herding methods is important for streamlining the event relative to days and personnel required to complete the harvest. Restricted physical habitats like small tributaries provide a natural confined environment to test Silver Carp response to herding methods and passive capture. Passive capture nets would provide a new method of harvest in areas where beach seines are impractical.

Electrified Paupier sampling and low-tech sonar can be effectively used as rapid assessment tools for pre-and post- mass harvest efforts in lake environments. Combined use of these methods can help mangers asses the available biomass, fish density, and species composition leading to an evaluation of cost and reward for conducting expensive removal efforts.

Electrofishing has become a widely used scientific and research technique since the 1950's (Reynolds and Kolz 2012). A version of electrofishing using a shrimp skimmer (collectively deemed the Paupier, which is French for butterfly), has been successful in Midwestern waters for Asian Carp. Within the Illinois River system, the Paupier's success is evidenced by Asian carp catch rates ranging from 1.7-4.8 tons/day in 2017 and up to 7.8 tons/day in 2018 during targeted sampling in the upper Starved Rock Pool (Ridgway and Pherigo 2017). The Paupier has been most effective in summer months in shallow water where fish are near the surface, but has shown utility for deep-water using a new design configuration. We developed a mapping tool to explain the Paupier's efficiencies and use that tool to modify the electrical configuration to fish over a wider range of water bodies and habitat types.

Objectives:

(1) Identify, develop, and evaluate herding and capture methods to optimize mass harvest.

(2) Validate low-cost methods using the Humminbird 360 sonar to identify and measure Silver Carp aggregations.

(3) Validate environmental variables predicting Silver Carp aggregations in tributaries to identify prime "Harvest Basins." (See USGS Report)

Optimization of Mass Removal Techniques

Objective 1: Identify, develop, and evaluate herding, and capture methods to optimize mass harvest.

Project Highlights:

- Collaborative efforts with USGS operated DIDSON and side-scan techniques to quantify the effects of herding methods (See USGS report)
- When herded, Silver Carp were highly averse to entering hoop or fyke trapping net, but would jump into an open-top ramp net.
- Silver carp were effectively herded at night using a method that combined bright lights with a flexible underwater curtain in a small tributary.
- New Paupier electrofishing anode designs were developed to enhance the gear's effectiveness over a wider range of conductivities, seasons, and water depths.
- Electrical field mapping showed that insignificant amounts of electricity existed deeper than 2 meters suggesting electrofishing as a herding, detection or capture method in deeper habitats may be largely ineffective without modification.
- The Paupier was used with deep-water wing deployment (3.5m) to target fish deep in the water column and to herd fish during Unified Method events.

Methods:

<u>Herding:</u>

Herding methods included: electricity, sound, bright lights with boat mounted scare curtain, towed scare curtain, and deep frame deployment using the Paupier. With the exception of the Paupier (where trials were conducted within a lake), novel herding methods occurred within tributaries approximately 20-30m in width. Herding effects using electricity and high intensity sound were evaluated in a separate USGS report.

Herding commenced 100-200m above a blocking net that contained the passive capture net and progressed until the boats reached the net. Trials were conducted mid-day with the exception of the bright light/boat scare curtain method, which was conducted at night. The "Scare Curtain" was conceived as a mobile physical and visual barrier that could push fish without becoming entangled in debris. The curtain was made of 200cm wide X 3m long strips of weighted white sun-shade fabric. The curtain was either boat mounted on 4m boat outriggers (Figure 2) or towed between two boats (Figure 3).

The towable scare curtain was attached to the bow of each of two boats that operated nearshore. The boats slowly pulled the curtain downstream while water pumps and plungers were used to deter fish near the shore. To understand fish avoidance to the towed curtain, Silver Carp were captured with the electrified Paupier, marked with floats, tethered to fishing line and a hook, and released into the treatment area.

The boat-mounted scare curtain was also used at night in conjunction with high-intensity LED lights that could be deployed under or above the water's surface.

Optimization of Mass Removal Techniques

In a separate effort from tributary herding, the Paupier was used in conjunction with sound and traditional electrofishing boats to push fish out of cells as part of a Unified Harvest Method on a 200-acre lake. The wings were deployed downward 3.5m at 45 degrees to the boat so that electricity and the net wings were 0.5 meters from the bottom of the 4m deep lake.

Optimized Harvest: Nets

Our goal was to create a new passive net capture method that could be used for quick and discrete mass-harvest of Silver Carp in confined environments like small tributaries. In collaboration with USGS, we deployed multiple fyke type traps and attempted to herd Silver Carp into the traps. We monitored the interaction behavior of Carp to several of the nets using DIDSON and Humminbird 360 sonars. Several funnels and large traps were deployed with the objective of capturing hundreds of Silver Carp in a driving effort. The determination to conduct comparative analytical trials of fyke designs was determined by observational success of the net in capturing a large proportion of the Silver Carp encountered.

Experimental funnels and trap nets were incorporated within block-nets that extended to the shoreline, while fish herding methods drove fish towards the net. Water depth was 2.5-3m in all trials. The fyke nets used for trials included:

1. Funnel trap with a mouth approximately 10m wide X 20m long extending into a containment cage with 1.7mX 2.6m entrance deployed in 2.5m depth
2. A flexible net that was 4m wide X 2.7m deep X 7m long with 2.3 internal hoop funnel leading to a standard 1.2m 7 ring hoop net
3. Rectangular frame 2m wide X 1m deep opening to an open coral
4. 1.8m hoop with a 2 m tapered funnel opening to .9m internal hoops
5. Vertical net with two 1.2m hoop nets at the center positioned at the surface and near the bottom
6. 1.2m hoop net at the side of the tributary tow
7. Multiple tapered hoops starting 2m and extending 20m deep with progressive restrictions
8. The ramp net consisted of a 12 m wide ramp X 4m high 32mm polyethylene netting extending 7m forward with a floor under the ramp. The ramp was weighted at the forward end and extended to a floating top edge. At the top edge of the ramp was a 1m opening connected to a walled backing of 74mm bar netting or to a large trawl that extended back approximately 20 meters to a funneled cod. The net was anchored to the shore’s edge and the top was supported with wood structure (Figure 3).

Optimized Harvest: Paupier

The non-electrified Paupier design construction and operation was based upon that described by Coale (1993) and Hines et al. (1995) for use in the commercial shrimp industry. Our Paupier is built around a semi-V plate boat measuring 7.3m (24ft) long by 1.8m (6.0ft) wide, and the net is attached to 4 x1.5m winch supported frames. The boat was electrified using traditional electrofishing forward mounted booms attached to 3 3/16inch stainless steel cables of proportionate lengths to allow the cables to drift about 1-meter in front of the frames when the boat is underway. Behind the frame is another electrified quadrant using a single hemisphere supported by rope (Figure 4). A Honda 7000 watt generator with an ETS 82Amp pulsator box was used to power the system. Due to power limitations, 30Hz with 15% duty cycle was used exclusively during operations. To determine the appropriate fishing threshold (similar to power goals), five peak amperes were applied to the forward anodes when fish conductivity matched the water conductivity. As water conductivity increased, so did the peak amps. Holliman (2011) estimated the effective conductivity (Cf) of Silver Carp to be 90 µS/cm by fitting fish threshold power density data to the power transfer model of Kolz (1989). Voltage gradients and electrical net size were calculated using the estimated Silver Carp's Cf as described by Dean (2018). One distinction from a traditional electrofisher, the Paupier uses four fields or quadrants of electricity so that the Amperage output from the pulsator is distributed across those quadrants and must be balanced and calculated independently to understand the effective field or impact on fish within each zone.

Kolz (1993) and Henry et al. (2001) found that conducting voltage gradient field-testing allowed for a comprehensive calibration of a boat's electrofishing design. Voltage gradients were measured to determine how electricity was being displaced for the Paupier's traditional configuration, a modified traditional design, and newly proposed "deep water" version. The method used to produce voltage gradient maps is described by Smith (2018).

We evaluated various anode to cathode design configurations to optimize the efficiency of capture with the Paupier. The gear is currently limited by power demands partitioned between four quadrants around the boat frames as well as function of the electrical field when the frames are deployed below the water surface. Voltage gradient maps were developed to evaluate the effective electrical field for the traditional Paupier design and modifications in the rear quadrant of that design comparing a single hemisphere to dual micro-arrays (Figure 5).

We address the need to conserve power and create an adaptive design that targets fish in the water column down to 3.5meters by cumulatively comparing the ENet (ENet- defined as the effective anodic influence area) across all designs. The traditional Paupier design relies on surface deployed boom anodes interacting with surface oriented fish. When cathodic frames are deployed downward, the electrical field becomes weak at the outside edge of the frames, which allows fish to escape or become aware of the field. To address this issue, we eliminated the forward anodes and affixed a wire anode to the frame's bridle support allowing for equidistant anode/cathode proximity as the frame moves (Figure 6). Subsequently, we mapped the new electrical field at the calculated amperage goal and at twice that goal to determine the appropriate amount of power needed to capture fish using a simplified design.

We also sought to better control the ENet within our anode and cathode arrays to address warping of the field. The appropriate balance of exposed metal needed on the frame was determined by removing all the insulating paint on one frame and comparing that to the field of a frame having only a 50cm exposed portion within the interior (traditional frame).

Using the information acquired through the voltage gradient mapping process, we developed and field tested a design with deep water application. We conducted 5-minute trawls with the frames extended as far downward to the bottom as possible without touching the substrate. We conducted DC pulsated 5-minute random surveys in a 200 acre lake with a hydro-acoustically estimated 20,000 silver carp in October, 2018. Additionally, we conducted four 5-minute samples using rectified AC pulsation in a large tributary of the Missouri River in December, 2018. Silver carp were subjectively observed on sonar to be at a high density and oriented toward the bottom of the river.

Results and Discussion:

<u>Herding</u>

The goal for herding was to move the majority of the encountered fish at least 100m with motivation to escape into a trap net. The lighted boat-mounted scare curtain was effective in August, but not in October. The boat towed scare curtain was never effective. Electricity and sound were evaluated within a separate USGS report.

For the lighted boat-mounted scare curtain used during August, we observed fish being deterred physically and visually from our curtain with a progressive accumulation of fish and high motivation to escape through the net (Figure 7). We saw different results in October where the fish did not readily move away from brush piles or deeper holes. The organization of the driving effort in terms of time of net deployment, disturbance to the environment, and speed of the drive, may be determining factors to success in herding operations. There is a likely application of this method in summer months within weir/trap designs in larger, shallow impoundments or within discrete tributary confluences or side channels of a river.

In our trials with the boat towed scare curtain, we observed buoy marked fish making short evasive movements (approximately 10m) as the curtain or boat approached, followed by evasion to deeper holes or brush piles. Carp were as likely to challenge the curtain as move away from it or underneath. Only two of the marked fish continued to travel the 100m distance downstream to our block net and only one fish entered the fyke net. The use of a water pump to deter fish appeared to work near shore and prevented fish from jumping when sprayed on the surface of the water. We surmise that fish could readily negotiate the gaps in our curtain and that there was insufficient weight to create bottom contact with the curtain. The process of towing created prop-wash that generated openings in the curtain which slowed down the overall the process.

Within a lake environment, the Paupier was used during a collaborative Unified Method harvest by deploying its 4m wings downward at a 45 degree angle near the bottom of the lake. This method of herding is unique in that, traditional surface deployed electricity creates a field with the boat hull that does not extend to the bottom of the lake, thereby not impacting bottom oriented fish. The Paupier framed nets create a visual and physical barrier in conjunction with electrical deterrence, which is likely important when fish are oriented at the bottom of the water column compared to other broadcast methods like sound, motors or surface electricity. We also used a standard electrofisher during this event, but based on our recent mapping of electrical fields and knowledge that electricity did not extend deep in the water, we used long (3m) insulated droppers with small exposed arrays near the benthos. Our boat was effective in moving fish out of deep holes when other surface "spider" array anodes showed no impact on the deep school. We recommend, during Unified Harvest Events, to change the anode configuration of electrofishing boats to deploy the electricity from bottom up using the method described to move fish when they are oriented near the bottom.

Optimized Harvest: Nets

The ramp net was the only method that proved successful in capturing large numbers of fish. There appeared to be a relatively small timeframe from when the boats entered the area to completion of the event when fish could be "controlled". As has been observed with other studies, Silver Carp readily jumped over a block net. With the ramp design, we capitalized on this behavior and used the ramp to bring the fish to the surface where they could easily jump over a float line into the trap. Once the fish were within the net, the top entry point was difficult to find again, which prevented escapement. More work needs to be done with this conceptual design, but Carp appeared to be less averse to interacting with a net that was underneath them compared to traditional trap devices where netting is vertical or overhead.

Silver Carp showed a high aversion to all other test trapping nets and funnels, despite being driven close to the opening. Numerous modifications of funnel designs, opening widths, tapers and use in day versus night did not change our ability to capture Silver Carp with large funnel type traps. Although commercial fishermen report high catches in 6ft hoop nets, we did not observe fish being willing to enter hoop funnels of any size. The difference in carp aversion to a similar type commercial hoop net may be explained by flowing versus static water conditions, but this was not evaluated

Optimized Harvest: Paupier

Voltage gradient (VG) mapping proved to be a valuable troubleshooting tool for advancing our understanding of electrofishing in relation to a novel gear. Although the Paupier has proven to be extremely effective in its many renditions over the last 7 years, we sought to continue to refine its' utility for Asian Carp sampling and mass harvest by challenging our assumptions, incorporating our observations, and striving to create a more user-friendly gear that can be deployed in a broad range of habitats. Previous attempts of VG mapping has not been achieved to the extent that our results document. In fact, unique tools had to be invented to physically detect electricity around the boat, to map the result, and to theorize a mathematical solution to refinement. We successfully detected deficiencies in the Paupier's design relative to anode/cathode design, proportional placement in the system, and overall power demands. The information is summarized to enable understanding of the system's operation and to propose a more effective and less complicated design.

Avoidance of Silver Carp to electrofishing is profound. In fact, it is rare that taxis is observed with this species compared to other traditionally electrofished species, where taxis is common. As such, Silver Carp must be taken quickly from free-swimming to immobilization to ensure capture. This gear is particularly effective, because it uses speed and net area to overcome avoidance, which is otherwise difficult with traditional electrofishing. Creating an effective ENet depends on creating a sharp VG with minimal radiance of a non-immobilizing field.

VG mapping results for the currently used a Paupier design, having 3 forward boom mounted anodes suggests an adequate forward quadrant ENet exists. However, the single hemisphere rear anode design insufficiently covered the rear quadrant compared to a design with two rear anodes suggesting there is probable escape of fish in the current design and an amplified effect of escape if the frame were to be deployed further downward away from the forward anodes (Figure 8). Also, no effective gradient was observed beyond the bottom of the frame. This provides insight into standard electrofishing operations and the perception that the electricity is extending to the bottom of the lake during fish driving efforts.

In the early iterations of the Paupier, a 50Amp pulsator box was used to power the system. The amperage was not sufficient to operate the gear as water conductivity increased and in an effort to decrease resistance and enable fishing over a wider range of habitat, the frame's exterior was coated with non-conductive paint. Since that time, we have installed an 82 Amp pulsator. In effect, the painted frame is a remnant of a past prototype, but it was unknown whether it had been a positive or negative addition to the design. VG maps comparing painted to unpainted frames show that a more effective field exists when Paupier frames are not painted (Figure 9). The VG maps also revealed a "warp" to the field, whereby the electricity was interacting with the hull of the boat instead of with the desired cathodic frames. We suggest that scrapes on the hull from trailering the boat can be relatively important to consistency and effectiveness of the operation. Without regular maintenance to the cathode (either through cleaning or painting) there could be confounding effects in data collection between boats or within the same boat over time.

The frame-support bridle array without the forward boom droppers was evaluated as an improved modification of the Paupier for deep-water deployment. The VG maps depict the Electrical Net increases from the Amperage "at fish match" goal to double the Amp goal (Figure 10). The mathematical function between the two thresholds can be used to determine the desired Enet size relative to power availability. The map also revealed that the Enet was dramatically warping toward the boat, suggesting exposed metal on the hull and excessive anode metal in close proximity to the boat were present. The mapped design used two rearward anodes and showed strong coupling with the forward anode field, compared to the traditional design where anode fields were discrete. This suggested that the rearward anodes may not be necessary if the Enet could be simply expanded by conserving power through a more effective design (Figure 11).

A new design configuration was conceived from the results of this study and is different in capability, simplicity and cost from the traditional design. The difference being that, unpainted frames produce a more attractive cathodic resistance to a closer proximal positioning of a new single support bridle anode. Rear anodes are thus eliminated resulting in a conservation of power that allows the system to operate at 1.75 x the amperage goal. The design then can operate within higher water conductivity (900uS) and use higher duty cycles consistent with LTRM protocols. Most importantly, since the ENet is unchanged as the frames are deployed (compared to a surface boom mounted array) this design will enable the Paupier to deploy its frames down to 3.5 meters and target carp oriented lower in the water column. This support bridle anode configuration produces an immobilization field well below the bottom edge of the frame (6ft) as well as into the frame (Figure 9), while the boom support design has no effective immobilization potential at the same depth (Figure 8). The extension of the Enet below the frame should increase the zone of capture and enhance catch rates, especially when fish and the frame are both near the substrate.

This new design was field tested as a deep frame deployment method within a tributary and lake. We conducted four 5- minute deep-water AC electrofishing sampling runs a large tributary of the Missouri River and captured an average of 16 silver carp per minute of electrotrawling. We conducted 36 five- minute deep-water DC electrofishing sampling runs in Creve Couer Lake, St. Louis, MO and captured 1.67 silver carp per minute of electrotrawling.

Use of new fishing gears and techniques are necessary to combat Asian Carp. The Paupier has application as a tool, in the hands of qualified professionals, to dramatically impact carp populations throughout the Midwest.

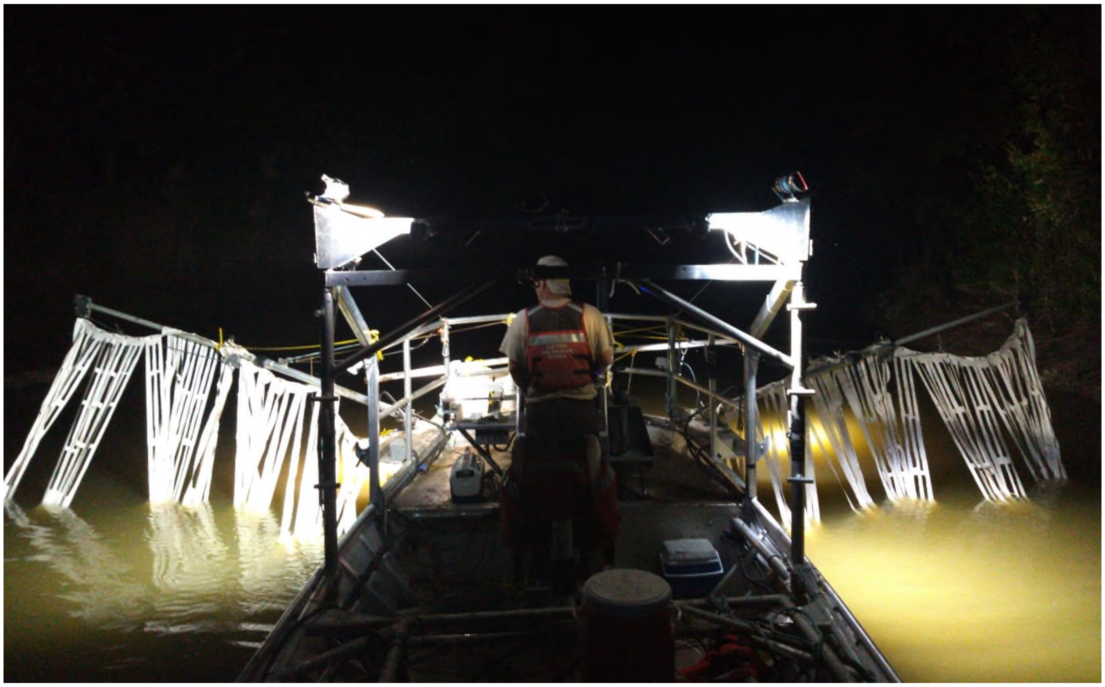

Figure 1. *Boom and front mounted flexible "Scare Curtain" used with high intensity LED lights in a small tributary*

Figure 2. *Flexible "Scare Curtain" being towed between two boats. White weighted 7inch strips of sun-shade fabric extend from the floats to the bottom of the tributary.*

Figure 3. *Ramp net prototype. Black netting is angled forward and anchored the bottom substrate. The black polyethylene netting floats creating a ramp to the surface where a 1m gap connects the green funnel net. The entire net is enclosed except for a gap at the top, which the fish jump in, and funnel bag to remove the fish.*

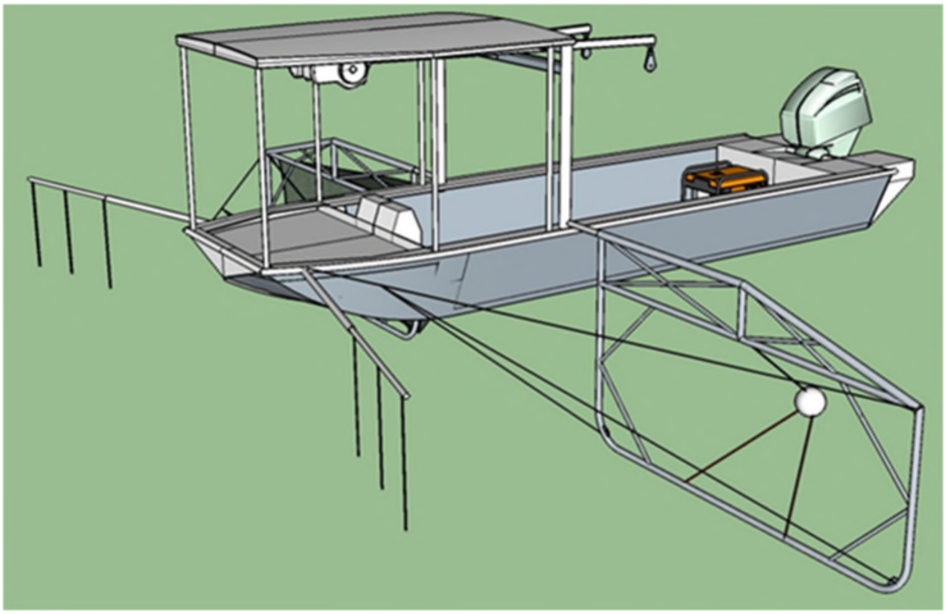

Figure 4. *Depicts the most commonly used Paupier configuration with one rearward hemisphere anode which is used to deter fish from escaping back out of the net (trawl net not shown). AutoCAD drawing by Kevin Drews, USFWS-Columbia FWCO.*

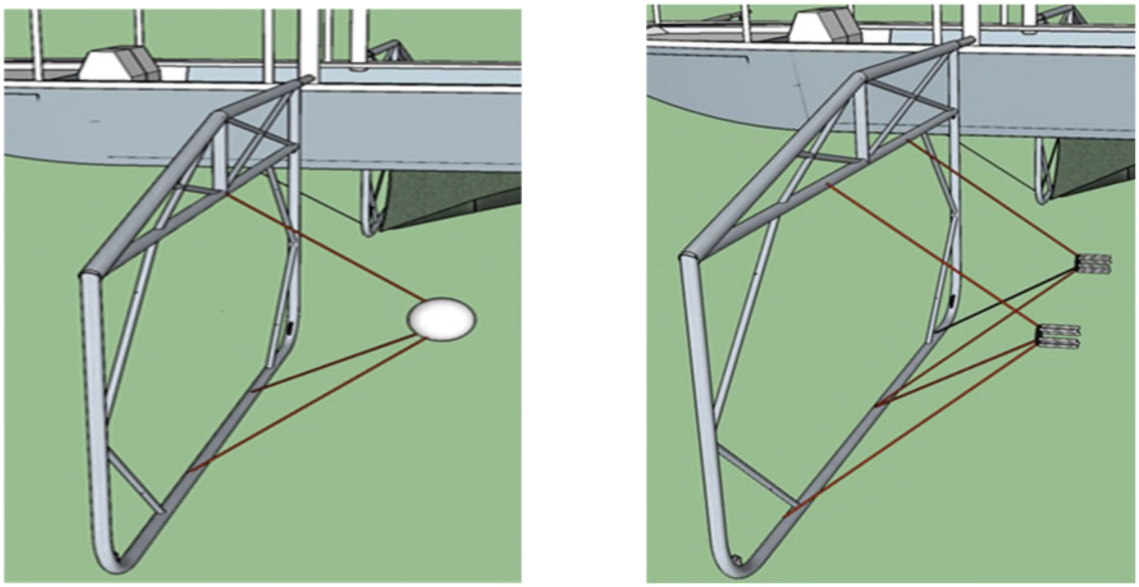

Figure 5. *Depicts the Paupier's second immobilization zone designs using two micro arrays (left) and a hemisphere (right). AutoCAD drawing by Kevin Drews, USFWS-Columbia FWCO.*

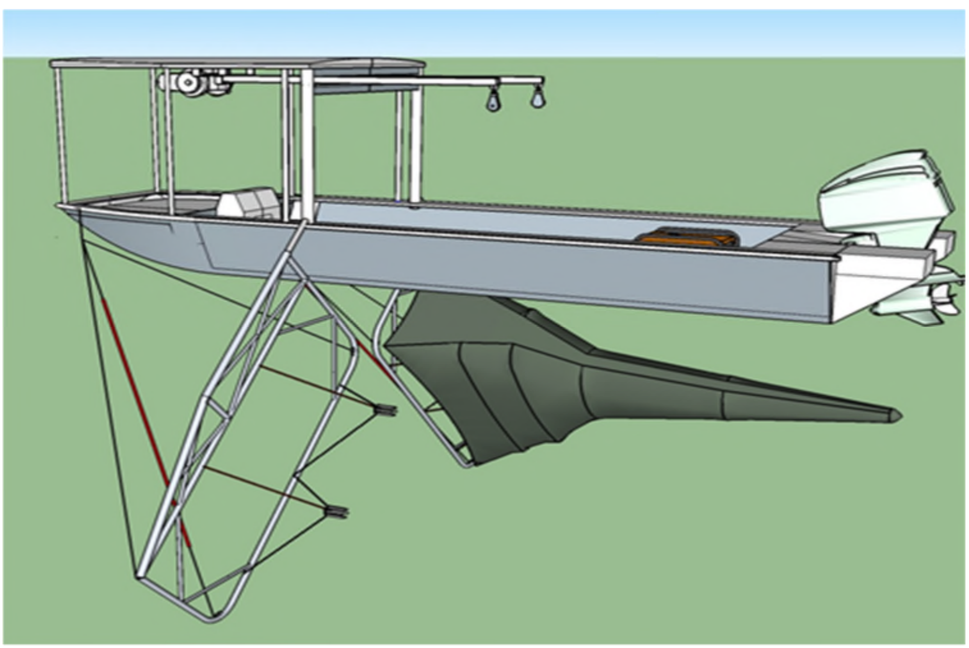

Figure 6. *Deep water design uses a stainless cable and was attached to the bottom support bridle line made of 1/4in ®Amsteel line (in bold red line). The frames can be deployed at the surface or below the boat based on fish orientation within the water column. This anode design allows for constant anode/ cathode position positioning when the frame moves. AutoCAD drawing by Kevin Drews, USFWS-Columbia FWCO.*

Figure 7. *Scare curtain driving fish up a ramp net into an opening on the surface. Net has a floor and back to prevent escape once fish enter. Lighted scare curtain deters fish from swimming back upstream.*

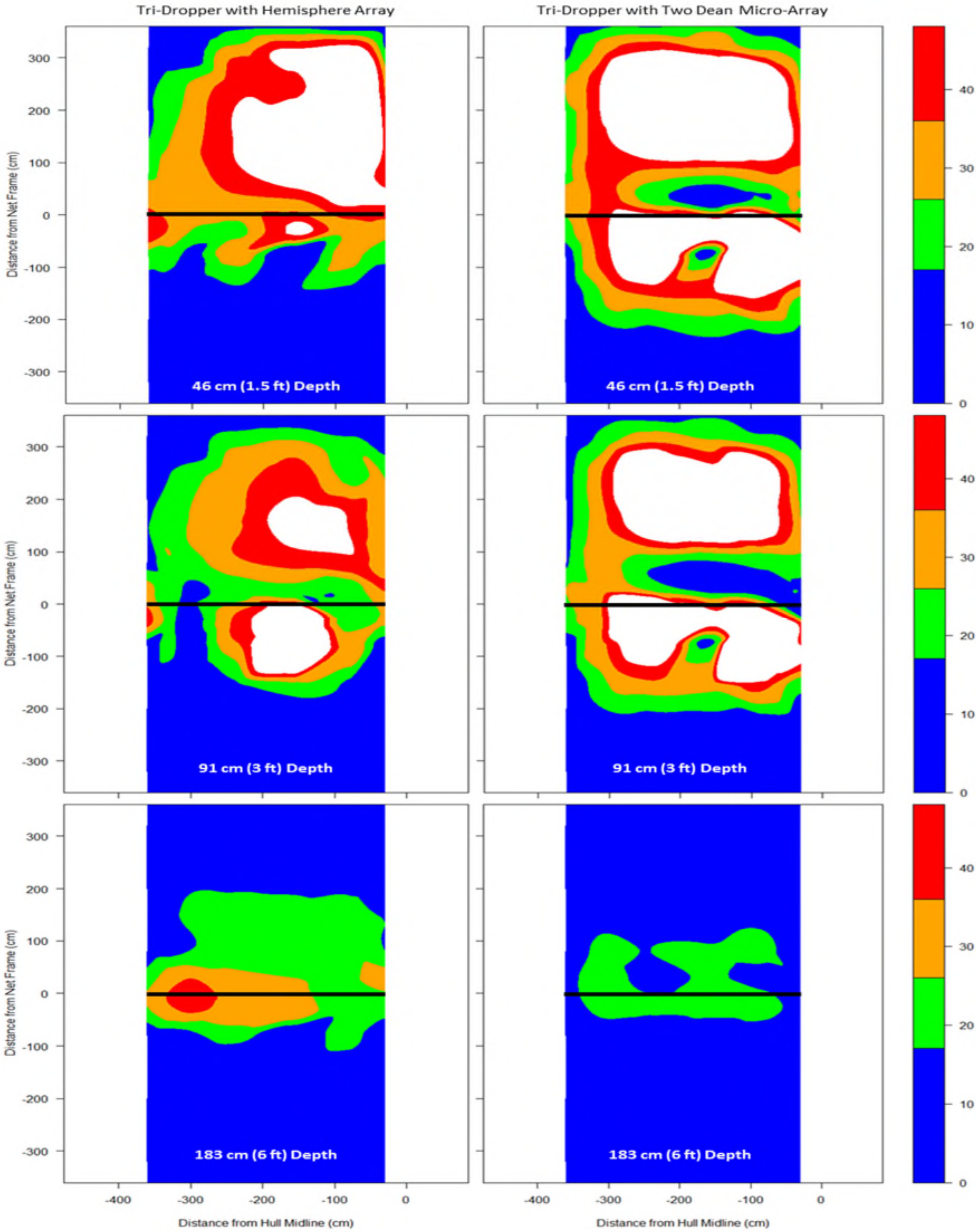

Figure 8. *Current density field intensity map at 1.5, 3.0 and 6.0ft depths for 3-dropper boom mounted surface anode design at target Amp goal comparing a single sphere holding array in the rear quadrant (left) to dual micro-arrays (right). The effective "Electrical Net" is represented by the most intense to minimal effective field (white-red-orange-yellow) with green representing avoidance.*

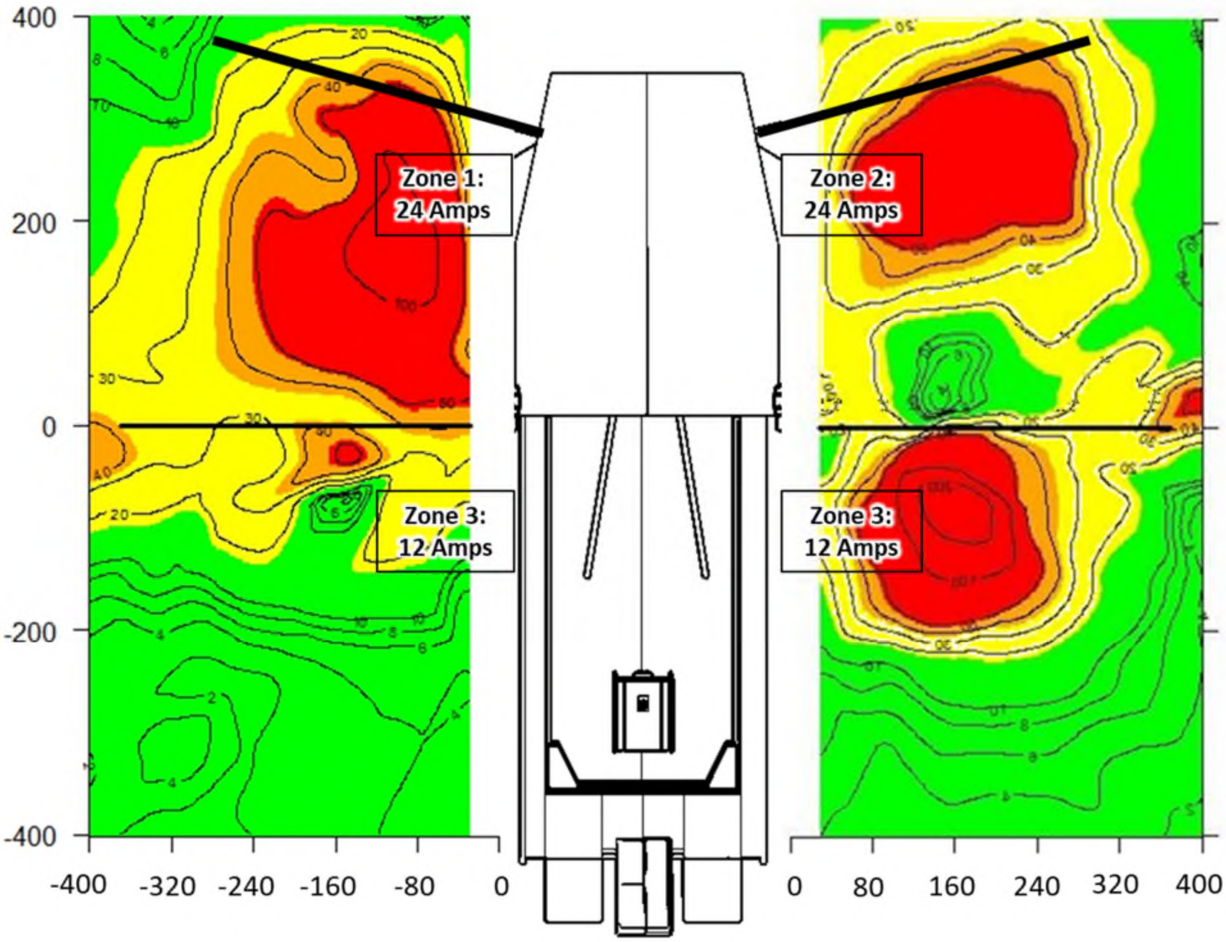

Figure 9. *Current Density Field Intensity map averaged from 1.5, 3 and 6 ft depth measurements for a 3-dropper boom mounted anode design with an uninsulated frame (left) verses insulated frame (right). The dark zero line represents the cathodic frames. Each zone receives a proportion of amperage if the Paupier were operated at 700 µs/cm³ based upon electrode shape, size and proximity to the cathode. The comparison offers an understanding of electrical field manipulation using metal proximity and surface area proportion of the anodes to cathode after removing insulating paint on the frame.*

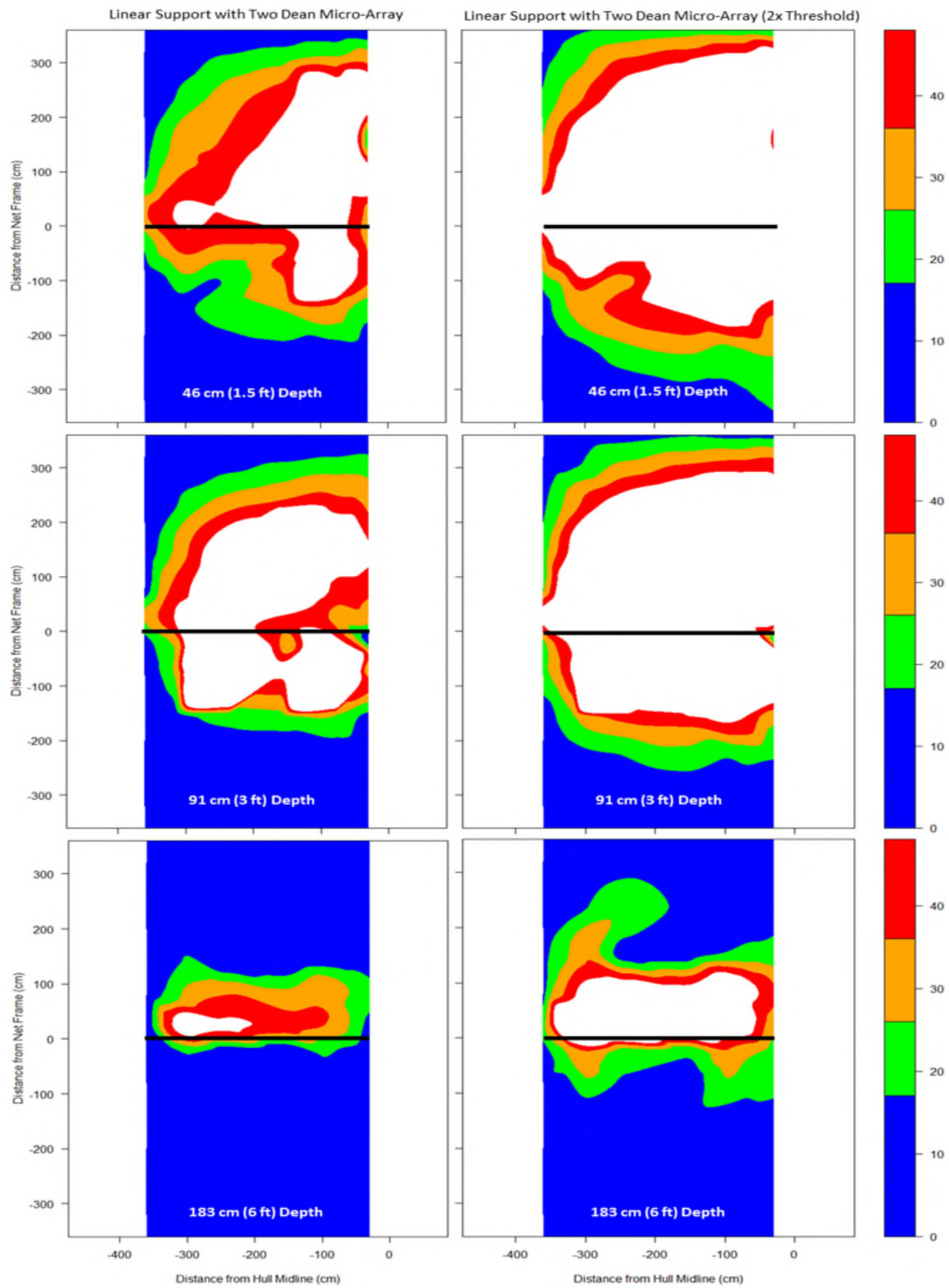

Figure 10. *Current density field intensity map at 1.5, 3.0 and 6.0ft depths for deep-water bridle support anode design at 2x target fishing threshold (right) and at fishing threshold (left) used in conjunction with rearward quadrant micro-arrays. The effective "Electrical Net" is represented by the most intense to minimal effective field (white-red-orange-yellow) with green representing an inhibited swimming zone. The comparison shows how the ENet size can be manipulated by increasing electrical output to twice the target fishing threshold.*

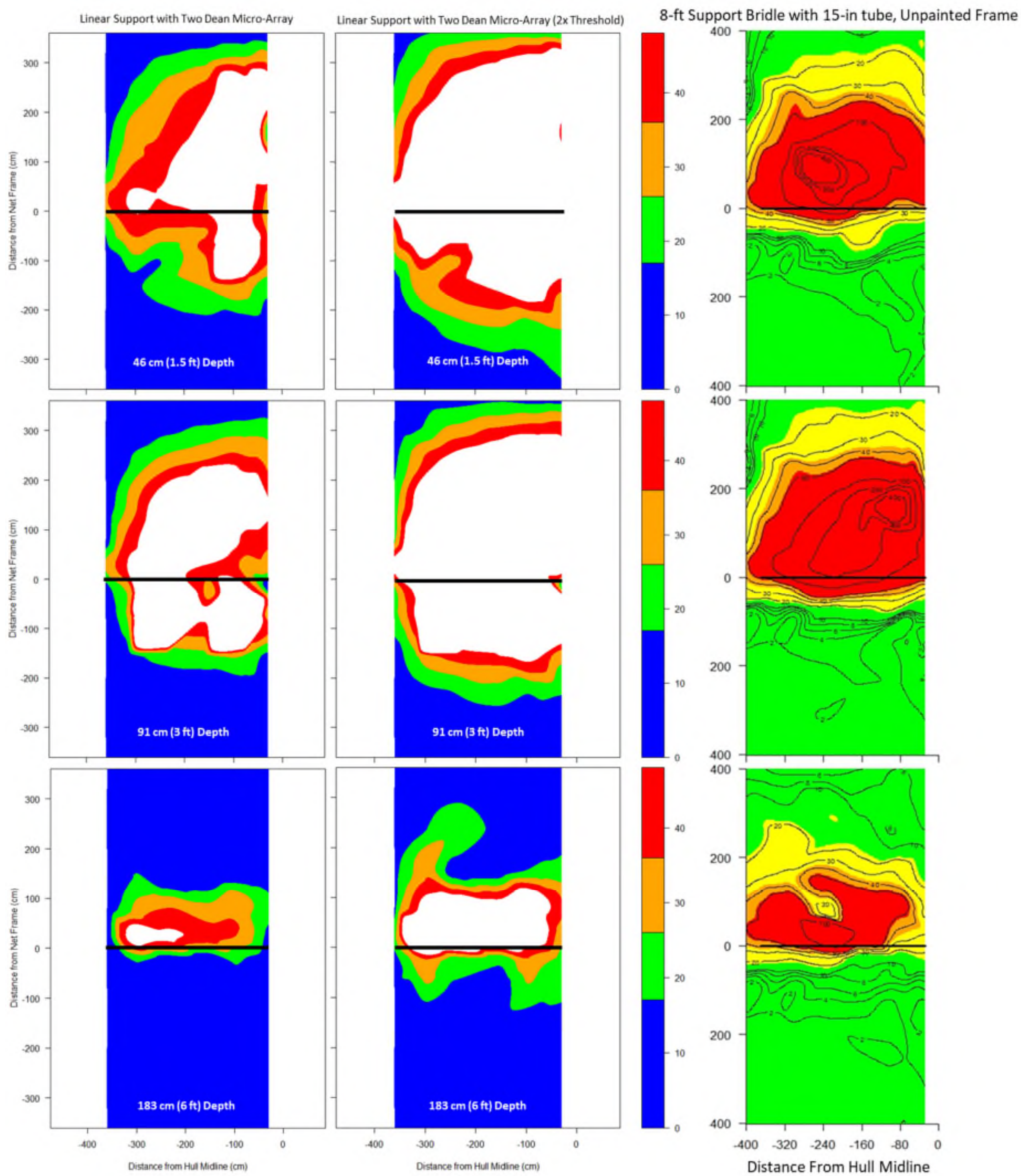

Figure 11. *Current density field intensity maps for a support bridle anode design with two rearward micro arrays and 80% painted frames (left and middle) compared to a forward bridle array with unpainted frames, no rear anodes operated at 1.75 Amp goal (right).*

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Optimization of Mass Removal Techniques

Objective 2: Validate low-cost methods using the Humminbird 360 sonar to identify and measure Silver Carp aggregations.

Introduction:

Waterfowl managers have successfully used visual estimation to assess bird populations (Koneff et al. 2008). Using inexpensive sonar technology such as side-scan or Humminbird 360 technology to assess fish densities in a given area could help determine the success of a mass removal event. The Columbia Fish and Wildlife Conservation Office used a Humminbird 360 and Electrified Paupier to assess fish density and estimate total population of a 200-acre backwater in St. Louis Missouri before and after a mass removal event that took place in the winter of 2018.

Objectives:

- To determine if a common waterfowl arial count method could be transferred to sonar visual counts for Asian Carp.
- Assess the overall success of a mass removal event using low tech sonar equipment.
- Compare sonar survey and mass removal with Paupier survey

Project Highlights-Sonar Survey:

- Precision of reader's estimates using real-time counts was high compared to actual laboratory counts
- Counts were relatively accurate when less than 100 fish appeared on the screen
- Schools of fish likely makeup larger portions of the population than anticipated, indicating caution should be exhibited when relying on 2D hydroacoustic measures when large schools exist.
- The use of traditional waterfowl counting methods may be applicable to carp population estimation when qualifiers for number and size of schools accompany the estimate.
- Very little reader training or computer processing was necessary to conduct precise visual sonar counts.

Methods-Sonar Survey:

A Humminbird 360 sonar was deployed on a 120 acre backwater lake in Missouri to assess a low-tech method of counting fish to gauge the success of Silver Carp harvest. A boat systematically conducted 200m transects within the lake before and after an estimated 48,000 fish removal event while two readers visually counted the number of fish observed on a Doppler type image. The speed of the boat (3mph) and timing of the sonar scan (30seconds) were calibrated to ensure no duplication of the fish image. The visual counts by the two readers were evaluated during post processing and summarized for relative error rate. The area of each image was converted to acres and extrapolated to the entire lake for a population estimate.

Results and Discussion-Sonar Survey:

An estimated 48,000 silver carp were removed during the harvest event. The sonar derived population estimates before and after removal was 20722 and 19619 respectively. Disagreement between readers varied little when less than 160 fish were encountered and disparity increased beyond that to 200 fish when schools were determined to be "unreadable". Due to the two-dimensional aspect of the sonar output, it is impossible to accurately count fish that may overshadow other fish with the 360 sonar, Thirteen schools with high densities were observed before the removal event and only 2 schools of smaller size were observed after the harvest. This suggests that knowledge of the school size and proportion of schools in an area may need to be an accompanying qualitative characteristic of a population estimate.

On the post removal assessment, two people individually estimated the number of fish as the image was captured. The results between the two estimates were similar, with one population estimate at 20722 and the other at 19619. The real-time estimations showed a tendency to underestimate the number of fish per screen especially as the number of fish per screen increases (Figure 1). The error is likely due to the discrepancy between the few images that had a large number of fish on the individual image. As stated above there is no accurate way to count the number of fish in a large school. The reader's tendency to over, or underestimate the population, is shown by the negative slope of the line from zero.

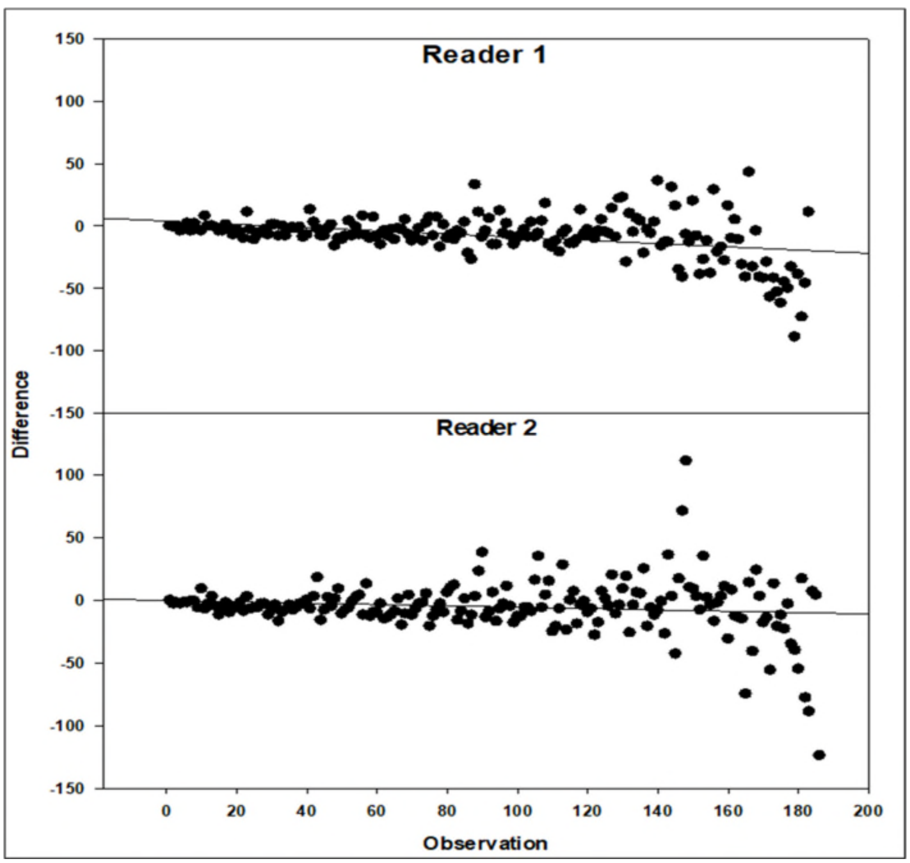

Figure 1. *Real-time estimates versus the actual count. Reader 1 and Reader 2 both tended to underestimate the number of fish per screen giving a conservative estimate.*

Pre vs Post assessment

The number of images with greater than 200 fish in the pre- assessment was significantly higher than the post assessment (Figure 2) likely contributing to an error of 40,000+ fish. A known number of fish were removed from this lake allowing for physical sampling to estimate school size with more research and application of this methodology.

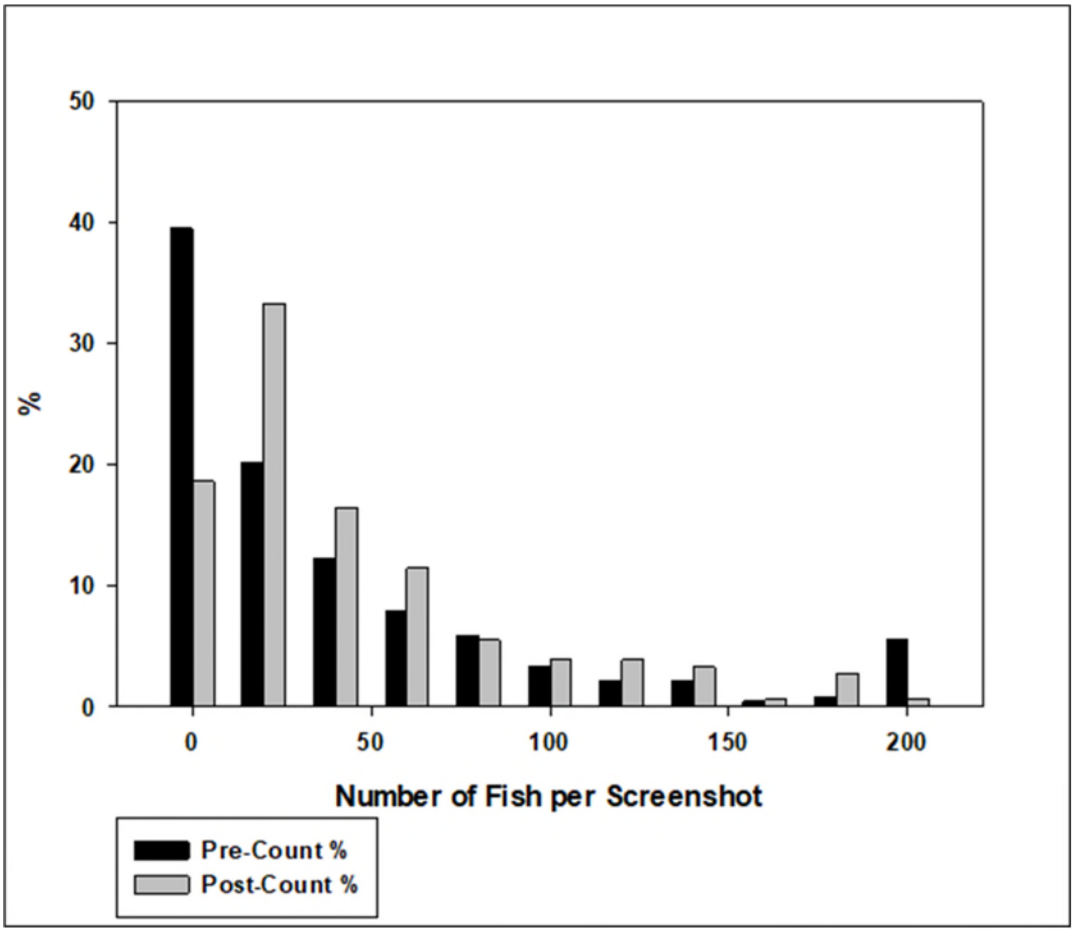

Figure 2. *Depicts a pre-and post- 360 Humminbird Sonar assessment for Silver Carp on Creve Coure Lake, St. Louis Missouri following the removal of approximately 48,000 Silver Carp. Counts were taken from screen shots collected in systematic transects across the lake. Population size increases exponentially for higher number screen shots. Differences between the assessments are evident in the number of schools detected before the removal event versus after.*

Although we have not found a way to use the Humminbird to count high densities accurately, we can count and estimate low and medium density images with precision. Our results suggest that impacts of removal events and relative abundance of fishes in a lake environment could be conducted with low cost and little training with only slight post-processing calibration needed.

Supplemental qualifiers of numbers of schools and proportional size of those schools appears to be necessary for quantified population estimates, in that 48,000 fish may exist within 11 schools on this particular lake. An expanded effort should be made to train more readers and further assess this type of technique for incorporation to make realtime assessments while boats are actively deployed on the water.

Literature Cited-Sonar Survey:

Mark D. Koneff, J. Andrew Royle, Mark C. Otto, James S. Wortham, John K. Bidwell, A Double-Observer Method to Estimate Detection Rate During Aerial Waterfowl Surveys. J. of Wildlife Management, 72(7):1641-1649 (2008).

Objective 2-Paupier Survey:

Project Highlights-Paupier Assessment:

The Paupier was used to document a 64% reduction in Silver Carp following a Unified Method that removed approximately 48,000 fish.

Methods-Paupier Assessment:

We conducted thirty 5-minute random trawls in each of three 2-night sampling events in October 2017, April 2018, and October 2018 on a 200-acre lake in St. Louis, MO to evaluate a Unified Method harvest event that took place in late January 2018. All fish species were enumerated and Silver Carp were measured and weighed.

Results and Discussion-Paupier Assessment:

Approximately 50,000 Asian Carp were removed during a Unified Method Harvest in late January, 2018 (citation/reference). Post assessments with the Paupier revealed a 64% decrease in Silver carp catch rates in October between years (Figure 1). Catch rates for Silver carp were 30 per 5-minute trawl in October, 2017, 5.5 in April, 2019 and 11 in October, 2019. Total Silver Carp sampled for the respective events were 1,083,164 and 367. Additionally, over 19 species were documented in each sampling event along with their relative availability. These results show that the Paupier can rapidly (2-nights per 200 acres/assessment) provide important pre-and post-assessments necessary for management. The Paupier can be used to determine proportional densities of the fish community and inform managers about biomass availability of Silver Carp priory to mass harvest events.

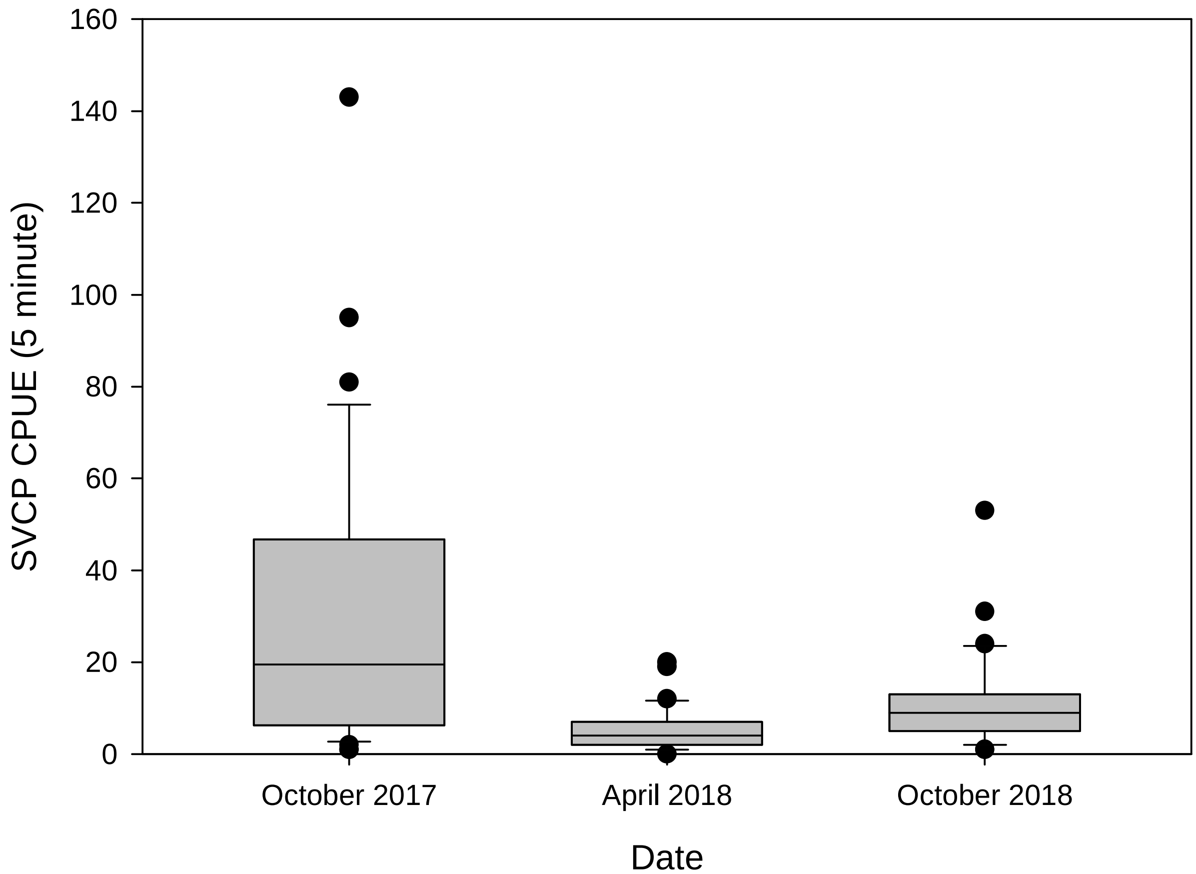

Figure 1. *Catch rates (Fish/5minute trawl) using an Paupier in Creve Coure Lake, St. Louis, MO after a removal of approximately 48,000 Silver Carp in January 2018.*

Using Long-term Asian Carp Abundance and Movement Data to Reduce Uncertainty of Management Decisions

David Coulter, Alison Coulter, Jen-Luc Abeln, Greg Whitledge, Jim Garvey (Southern Illinois University)

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

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

Introduction and Need:

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

Monitoring of bigheaded carp densities via hydroacoustic sampling throughout the Illinois River (Alton to Dresden Island pools) by Southern Illinois University (SIU) has been ongoing since 2012 and is a useful metric to evaluate long-term changes in bigheaded carp abundance. Broad-scale density estimates also help inform management actions in the upper river near the invasion front. Annual densities in the lower Illinois River have displayed relatively large annual fluctuations among years (Coulter et al. 2016), necessitating the need for continued assessments of bigheaded carp densities throughout the river. This will identify whether lower river population size has increased from the previous year and help determine whether harvest or surveillance in the upper river should be altered in anticipation of increased immigration from downstream pools. It is currently unclear whether, or the extent to which, bigheaded carp in the Illinois River exhibit density-dependent effects on reproduction, condition, growth, and movement. Collecting long-term data, particularly density and movement data, will help quantify these patterns which will better inform management decisions and improve models predicting population response to management actions. While hydroacoustic surveys have provided density estimates for large sections of the Illinois River since 2012, the relationship between other fisheries gears and hydroacoustic densities have not fully been explored (except contracted gill net CPUE and hydroacoustic density; MacNamara et al. 2016). Identification of such relationships will aid in understanding the results of various sampling gears relative to one another.

Using Long-term Asian Carp Abundance and Movement Data to Reduce Uncertainty of Management Decisions

Starved Rock Pool and other upper river pools are locations where removal efforts seek to reduce numbers of bigheaded carps near the population front. In comparison to Marseilles and Dresden Island pools, Starved Rock Pool has a high number and diversity of non-main channel habitats that bigheaded carp utilize. Identifying in more detail which specific main channel and non-main channel locations bigheaded carp use, knowing when they use these locations, and understanding environmental conditions associated with use of these habitats can help pinpoint locations to harvest in different seasons or under varying environmental conditions. The large number of acoustically tagged bigheaded carp and telemetry receivers located in Starved Rock Pool from previous research (Lubejko et al. 2017) is ideal for obtaining more information on bigheaded carp movements and habitat use within Starved Rock Pool.

A spatially-explicit population model of bigheaded carp in the Illinois River was recently developed to assess how bigheaded carp populations respond to a variety of management actions (e.g., location and intensity of harvest; location and effectiveness of deterrent technologies). One component of this population model is a multistate model which estimates movements of bigheaded carp among Illinois River pools (Coulter et al. 2018). Movement estimates were generated using data from 2012 – 2015 however, given the rarity and variability of dam passage events, collections and incorporation of additional years' data would help quantify movement estimates and variability around those estimates. For example, previous telemetry work by SIU has shown that passages of bigheaded carp through lock and dam structures can be variable among years (e.g., 0 passages in 2014 and > 10 passages in 2015 at Starved Rock Lock and Dam). Including additional years' worth of data to parameterize the model will better account for such annual variability in movement behavior, densities, and life history characteristics.

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

Road Lock and Dam and perhaps other lock and dam structures on native riverine fishes and also inform potential strategies to mitigate impacts of barrier enhancement on native fishes.

Objectives:

(1) Inform contracted removal efforts on changes in bigheaded carp spatial distributions in Marseilles and Dresden Island pools throughout the year using hydroacoustic surveys.

(2) Estimate density of bigheaded carp in the Illinois River in fall 2018 for comparison to long-term density trends.

(3) Explore relationships between hydroacoustic estimates of bigheaded carp densities and data from other sampling approaches.

(4) Assess bigheaded carp movements, patterns in habitat use, and environmental drivers of movements among habitats in Starved Rock Pool.

(5) Quantify bigheaded carp movement throughout the Illinois River, particularly determining number and timing of passages through lock and dam structures.

(6) Provide movement data to update the spatially-explicit population model for bigheaded carp in the Illinois River.

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

Project Highlights:

- Repeated hydroacoustic surveys in Dresden Island and Marseilles pools identified areas of high bigheaded carp density and how these locations change through time. These data helped direct contracted removal efforts throughout 2018.
- Bigheaded carp densities in Dresden Island and Marseilles pools during fall 2018 did not change from densities in the fall of 2017. Densities in Starved Rock Pool were slightly lower in fall 2018 compared to fall 2017.
- Fall 2018 bigheaded carp densities in Starved Rock, Marseilles, and Dresden Island pools were the lowest or as low as any densities observed in those pools since monitoring began in 2012.
- Hydroacoustic estimates of bigheaded carp densities were significantly, positively related to the number of acoustically tagged individuals detected by telemetry receivers. Change in hydroacoustic density estimates following unified method events in the HMS East and West pits were significantly related to the number of fish harvested.

- Regardless of season, bigheaded carp more frequently used lateral habitats than main channel habitats in Starved Rock Pool. Increasing water temperatures were positively related to lateral habitat use as was increasing main channel discharge.
- Upstream passages at dams of greatest concern in the upper Illinois River continue to be limited with only three upstream passages detected in 2018 (one in Starved Rock; two in Dresden Island). These three passages all occurred through lock chambers.
- Results to date indicate some evidence of upstream passage by native fishes through Brandon Road Lock and Dam. Additional sampling will be used to refine estimates of the relative abundance of native fishes upstream of Brandon Road Lock and Dam that had previously been in the Illinois or Kankakee rivers.

Methods:

Hydroacoustic Surveys

Repeated hydroacoustic surveys in the upper Illinois River (Dresden Island and Marseilles pools) in 2018 were completed in March, May, and July. Final 2018 surveys in these pools and throughout other Illinois River (Starved Rock – Alton pools) were completed in fall of 2018. All hydroacoustic sampling methods, designs, and analyses followed those outlined in MacNamara et al. (2016).

Previously collected data were used to explore relationships between hydroacoustic estimates of bigheaded carp densities and data from other sampling approaches. These analyses build upon those already documented by MacNamara et al. (2016). First, bigheaded carp telemetry data from Starved Rock Pool was compared to density estimates. Nine telemetry receivers located in main channel and non-main channel habitats were examined for the number of unique silver carp detected on the day of hydroacoustic sampling in fall of 2017. The number of unique silver carp detected within 24 hours and within 48 hours of the hydroacoustic sampling event were separately related to bigheaded carp densities. The second dataset analyzed examined relationships between density estimates and harvest from unified methods. Bigheaded carp densities were estimated using hydroacoustic surveys before and after each unified method that occurred in the HMS East and West pits in 2016–2017. The mean change in density (i.e., mean effect size; densities before unified method compared to after unified method) was calculated for Silver Carp and Bighead Carp during each unified method. Regression analysis was used to relate the number of Silver Carp and Bighead Carp actually harvested during the unified methods to the species-specific change in density (effect size).

Habitat Use – Starved Rock Pool

An array of 20 Vemco 69 kHz stationary receviers were maintained and downloaded in Starved Rock Pool in 2017 and 2018 to evaluate residiency and habitat use by bigheaded carp. Ten stationary receivers were placed in main channel locations and 10 in lateral habitats of interest

(Abeln 2018), including: Fox River, Heritage Harbor, Sheehan Island side channel, Sheehan Island backwater, Delbridge Island side channel, Bull's Island side channel, and Mayo Island side channel. 50 bigheaded carp were surgically implanted with Vemco 69 kHz acoustic transmitters in spring 2017 within Starved Rock Pool following SIU's standard surgical procedures (Lubejko et al. 2017; Coulter et al. 2018). Environmental data were also collected at each location each week. The proportion of known hours per week an individual used a habitat was calculated and compared between lateral and main channel habitats, and was analyzed to determine whether this varied seasonally or was related to environmetnal conditions using a linear mixed effects model with AIC_C model selection.

Movement and Dam Passage

Utilizing an array of 71 Vemco 69 kHz stationary receivers maintained by SIU (Coulter et al. 2018; Abeln 2018) as well as stationary receviers maintained by partner agencies (USGS, USACE, USFWS, MDC), the movements of Silver Carp and Bighead Carp implanted by SIU with internal transmitters (Vemco V16 transmitters) were monitored from Alton Pool upstream through Dresden Island Pool. Additionally, other bigheaded carp, Grass Carp, and Common Carp implanted with 69 kHZ transmitters by other members of the Telemetry Working Group (MRWG) were also detected by this array. Stationary receivers were downloaded on 2 occasions in 2018. Downloaded data for 2018 were initially checked to remove false detections and data were analyzed to identify upstream and downstream passages through lock and dam structures in the study area (*sensu* Lubejko et al. 2017*)*. Route of passage through the lock and dam structure (i.e., lock chamber or through dam gates/wickets) was determined when possible.

Using fin ray microchemistry to evaluate native fish passage through Brandon Road Lock and Dam

Water samples were collected during 2017-2018 from the Des Plaines, Illinois, and Kankakee rivers to verify persistence of previously observed differences in water strontium:calcium ratio (Sr:Ca) among these rivers. Water samples for determination of Sr and Ca concentrations were collected using a syringe filtration technique (0.45 µm pore size) and analyzed using high resolution, inductively coupled plasma mass spectrometry (ICPMS). Native fishes (primarily catostomids, ictalurids, and *Micropterus* spp.) were collected from the Kankakee River, the upper Illinois River, and Des Plaines River upstream of Brandon Road Lock and Dam during 2017-2018. A leading pelvic fin ray was be removed from each fish at the base of the fin. A cross-section of the base of the fin ray from each fish was analyzed for Sr:Ca along a transect from the core to the edge of the fin ray using laser ablation-ICPMS. Fin ray edge (the portion of the structure reflecting recent growth) Sr:Ca of fish collected in the Kankakee, Illinois, and Des Plaines rivers was used to characterize Sr:Ca values indicative of fish residency in each river. Fin ray Sr:Ca data along the entire laser ablation transect from fin ray core to edge for fish captured in the Des Plaines River upstream of Brandon Road Lock and Dam were examined to identify individuals that had previously been in the Illinois or Kankakee rivers (and, therefore, must have passed upstream through Brandon Road Lock and Dam) based on the presence of Sr:Ca values reflective of Illinois or Kankakee river residency at one or more locations within the fin ray.

Results and Discussion:

Hydroacoustic Surveys

Mobile hydroacoustic surveys conducted every other month in Dresden Island and Marseilles pools identified locations where bigheaded carp aggregated and determined how these locations changed throughout the year (Figure 1). Density maps (Figure 1) were provided to MRWG members which helped direct contracted removal efforts.

Bigheaded carp densities in fall (October) 2018 were statistically similar to densities in fall 2017 in Dresden Island and Marseilles pools (Figures 2 and 3). Bigheaded carp densities in Dresden Island Pool in 2017 and 2018 were lower than all previous years (2012‒2016) since densities have been assessed (Figure 3). Similarly, bigheaded carp densities in Marseilles Pool remained stable from 2016‒2018. Densities in Starved Rock Pool significantly decreased from fall 2017 to fall 2018, where 2018 densities were the lowest since monitoring began in 2012 (Figure 2). Fall densities in the lower Illinois River (Alton‒Peoria Pools) were delayed due to unexpected equipment repairs. This caused lower river pools to be sampled in November when water temperatures were much lower than when these pools were sampled in October from 2012‒2017. Fish of all species in the lower river were much less abundant in main channel habitats compared to previous years, likely due to low water temperatures. Pool-wide bigheaded carp densities were, therefore, low in Alton‒Peoria pools (Figure 4) and not comparable to fall density estimates from previous years.

Analyses of existing data determined that bigheaded carp density estimates from mobile hydroacoustic surveys were related to bigheaded carp data from other sampling approaches. Silver carp density estimates in nine habitats in Starved Rock Pool during fall 2017 were significantly, positively related to the number of unique Silver Carp with acoustic transmitters detected in the same locations (Figure 5). Likewise, the change in density before versus after harvest (i.e., mean effect size) from unified methods in the HMS East and West pits in 2016 and 2017 were significantly, positively related to the number of Silver Carp and Bighead Carp harvested (Figure 5). These results show similar patterns as analyses by MacNamara et al. (2016), who demonstrated that bigheaded carp density estimates before contracted gillnetting were significantly, positively related to gillnet CPUE, and that the change in density after contracted netting (i.e., mean effect size) was significantly, positively related to contracted gillnet CPUE.

Using Long-term Asian Carp Abundance and Movement Data to Reduce Uncertainty of Management Decisions

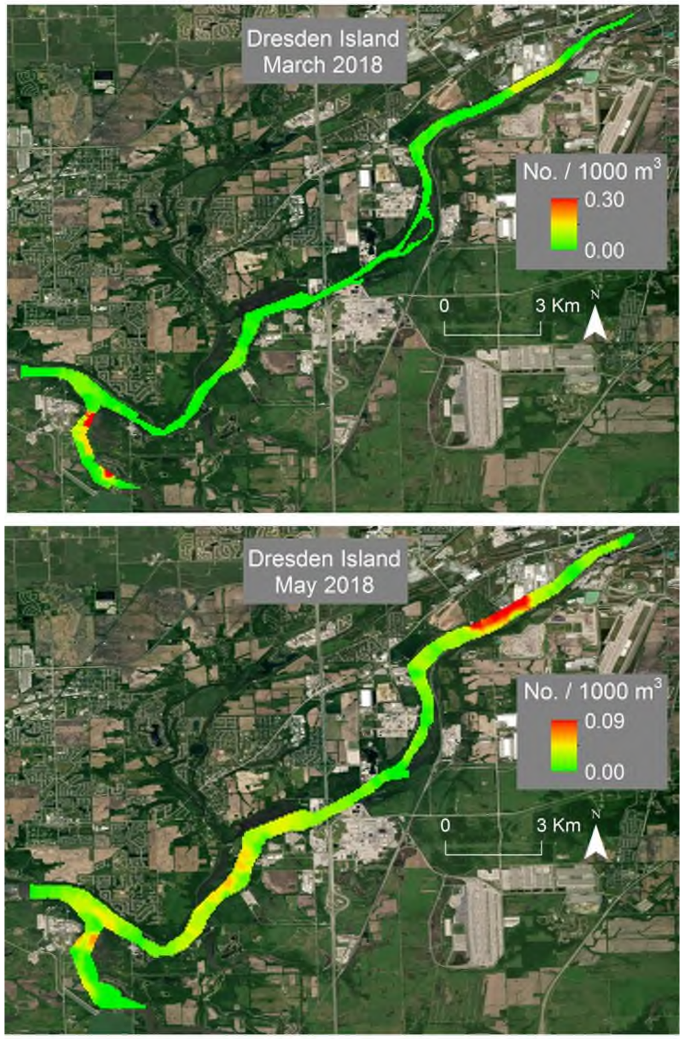

Figure 1. *Example of bigheaded carp spatial distributions, and variability in distributions through time, in the Dresden Island Pool. Density maps were used to direct contracted removal to high-density locations throughout 2018. Densities were observed using mobile hydroacoustic surveys.*

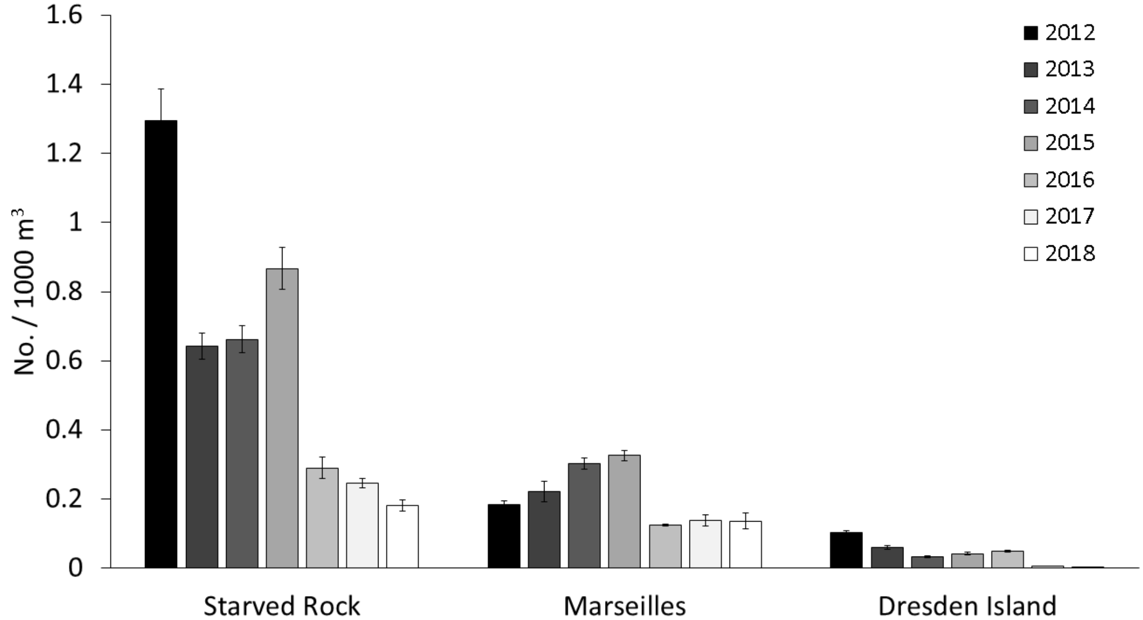

Figure 2. *Mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities estimated from fall hydroacoustic surveys conducted at standardized locations in the upper Illinois River. Densities in Marseilles and Dresden Island pools did not change from 2017, whereas 2018 Starved Rock densities slightly decreased from 2017.*

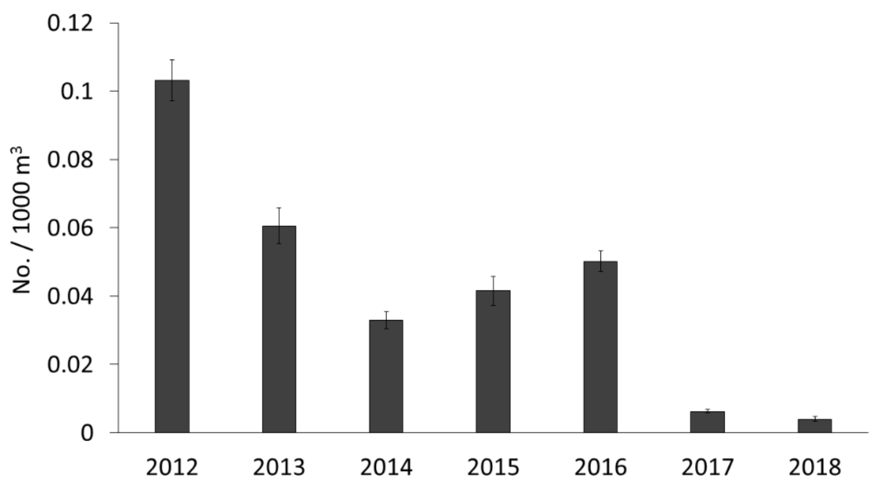

Figure 3. *Mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities estimated from fall hydroacoustic surveys in Dresden Island Pool. Densities in 2018 were similar to 2017 and both years were lower than densities from 2012–2016.*

Using Long-term Asian Carp Abundance and Movement Data to Reduce Uncertainty of Management Decisions

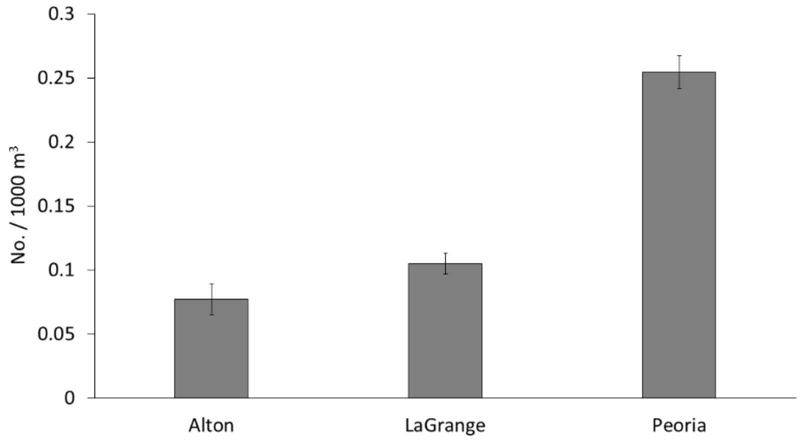

Figure 4. *Mean (SE) bigheaded carp (Bighead Carp and Silver Carp combined) densities from the lower Illinois River in 2018. Equipment repairs delayed sampling in these pools until November. Therefore, data from these pools in 2018 were not directly comparable to data from these pools collected in October 2012-2017.*

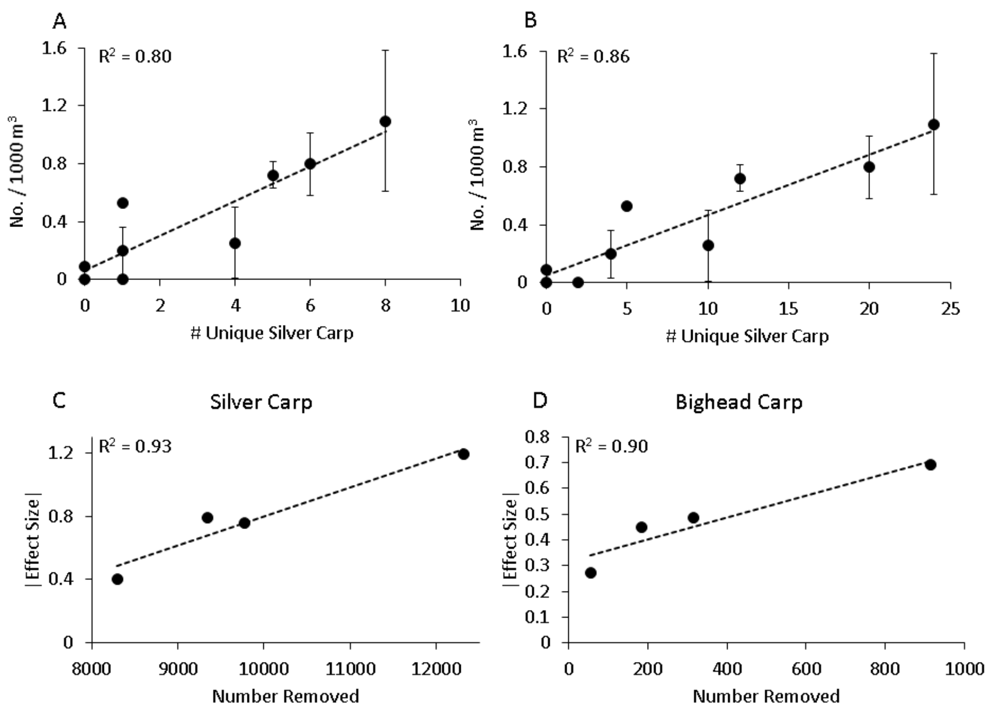

Figure 5. *Relationships between hydroacoustic density estimates and data from other sampling gears. Silver Carp densities were related to the number of unique Silver Carp with acoustic transmitters detected in a variety of habitats in Starved Rock Pool in fall 2017 on the same day as hydroacoustic sampling (panel A) or within 48 hours of hydroacoustic sampling(panel B). Reductions in Silver Carp and Bighead Carp densities (i.e., mean effect size) following unified method removal in the HMS East and West pits in 2016‒2017 were related to the number of individuals harvested (panels C and D).*

Habitat Use – Starved Rock Pool

Overall mean (± SD) proportional residency for all tagged bigheaded carp was 0.45 ± 0.40 in lateral habitats, 0.12 ± 0.25 in main channel habitats, and 0.43 ± 0.40 in undeterminable habitats. Detection histories of 63 total bigheaded carp were used throughout this study (fish tagged 19-June 2016 to 2-April 2018). Proportional residency differed between lateral and main channel habitats ($F_{1,3642}$ = 1798, $p < 0.001$) by season ($F_{3,3642}$ = 31, $p < 0.001$), and by their interaction ($F_{3,3642}$ = 29, $p < 0.001$). *Post-hoc* Tukey's pairwise comparisons showed lateral habitats were used significantly more than main channel habitats in all seasons (Figure 6). Sex did not influence lateral habitat use ($F_{1,2}$ = 0.3, p = 0.77).

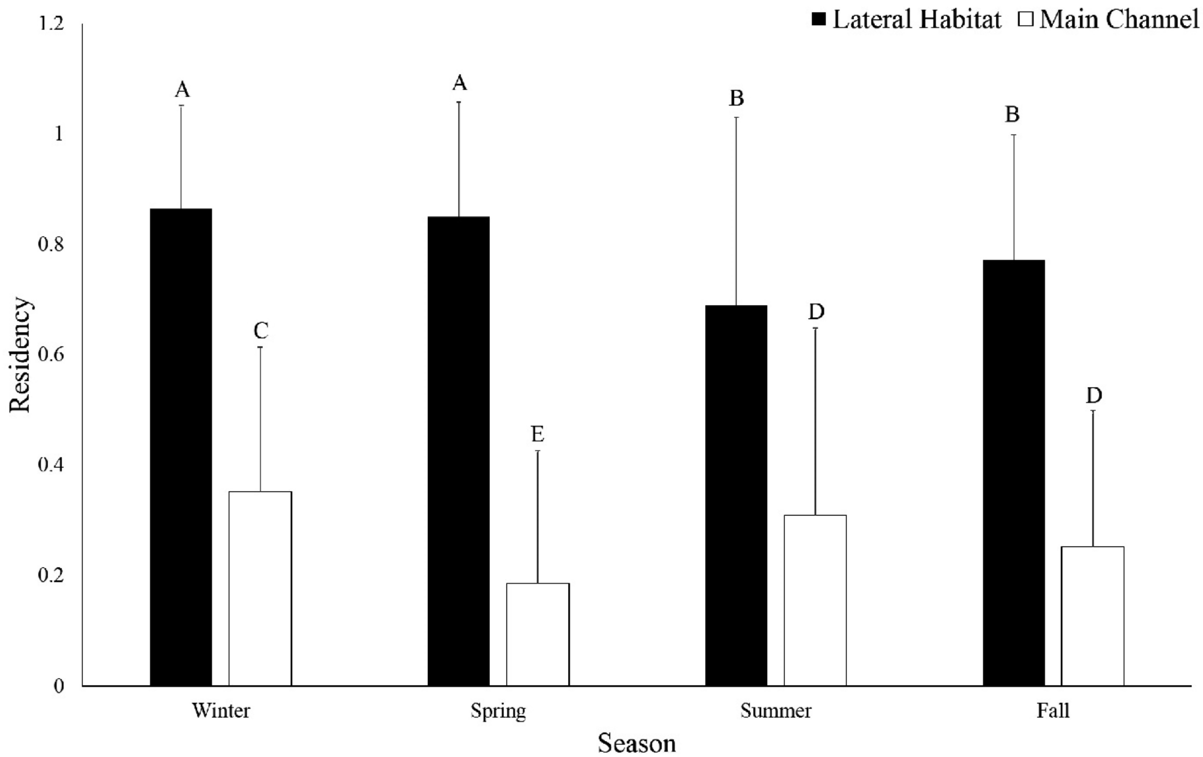

Figure 6. *Mean (± SD) residency (proportion of known hours per week an individual inhabited a habitat) of bigheaded carp in main channel and lateral habitats in Starved Rock Pool during winter (December-February), spring (March-May), summer (June-August), and fall (September-November) of 2017 and 2018. Different letters indicate significant differences (p < 0.05).*

Main channel residency was not influenced by main channel discharge ($F_{1,79}$ = 3.4, p = 0.07), but was significantly affected by main channel water temperature ($F_{1,54}$ = 78, $p < 0.001$) and the interaction between discharge and temperature ($F_{1,53}$ = 33, $p < 0.001$). Higher main channel water temperature was associated with higher main channel residency, while higher main channel discharge was associated with lower main channel residency.

The linear mixed effects model indicated a significant effect of lateral habitat on proportional residency ($F_{6,747}$ = 11, $p < 0.001$; Figure 7). Heritage Harbor and Bulls Island side channel had the highest average residencies, while the Fox River had the lowest average residency. Mayo Island side channel was not significantly different from any other lateral habitat. Generalized linear mixed models indicated that bigheaded carp habitat use was strongly and positively associated with water temperature, and that discharge was negatively related to main channel use (DeGrandchamp et al. 2008, Coulter et al. 2017). Although discharge was only marginally significant ($p < 0.1$), the interaction of discharge and temperature did influence proportional main channel residency. These results suggest that removal efforts would be most effectively focused in lateral habitats during periods prior to spawning (spring staging), lower temperature (overwintering), and during higher discharges. Additional project details, results, and discussion are available in Abeln 2018.

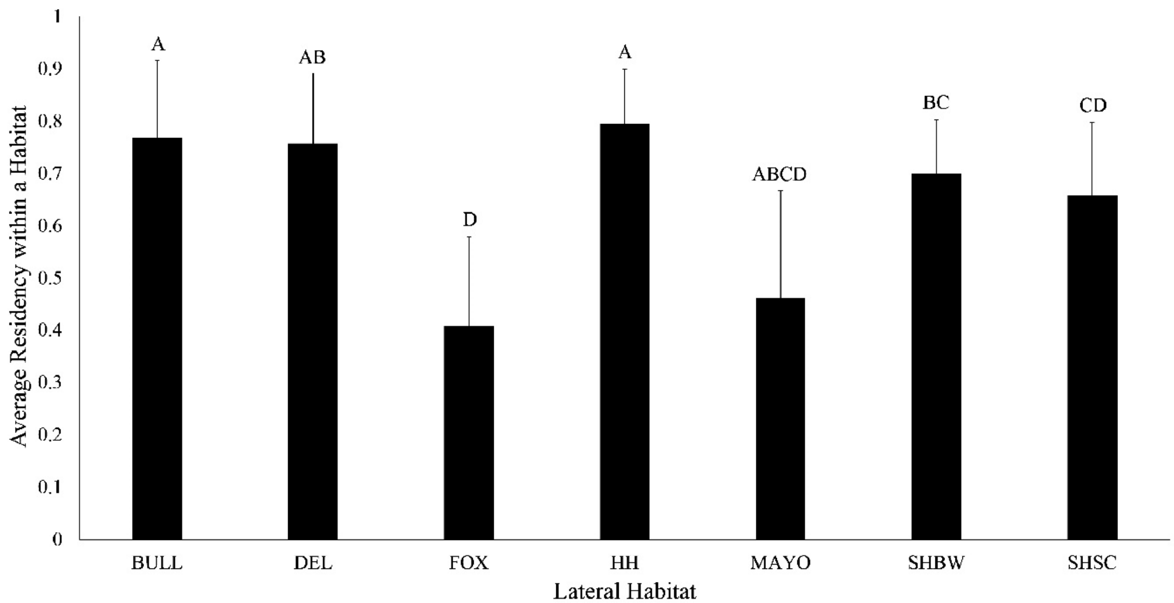

Figure 7. *Mean (± SD) residency of bighead carp in each of seven lateral habitats in Starved Rock Pool during June 2016–April 2018. Different letters indicate significant differences among locations ($p < 0.05$). HH = Heritage Harbor, SHBW = Sheehan Island backwater, BULLS = Bulls Island side channel, DEL = Delbridge Island side channel, FOX = Fox River, SHSC = Sheehan Island side channel, MAYO = Mayo Island side channel.*

Movement and Dam Passage

SIU stationary receivers collected 1,822,917 detections in 2018 with the majority of detections coming from 130 individuals. All detection data has been submitted for inclusion in the USGS-managed telemetry database. Detections of upstream passages towards the invasion front were limited to one upstream passage through Starved Rock Lock and Dam and two upstream passages through Dresden Island Lock and Dam in 2018 (Table 1). Upstream passage through Starved Rock Lock and Dam occurred on 2-June. The exact dates of upstream passage through Dresden Island Lock and Dam could not be determined. Detections of dam passages in the lower river were limited, as there were relatively few active transmitters in the lower Illinois River in 2018 compared to numbers in previous years.

Table 1. *Identified dam passages by bigheaded carps in the Illinois River in 2018. Table indicates direction of passage, which lock and dam (L&D) structure was passed, the route of passage (lock versus dam), the date or range of dates during which passage occurred, and the species making passages.*

Direction	L&D Structure	Route	Date or Date Range	Species
Upstream	Dresden	Lock	8/3/2017-5/4/2018	Bighead Carp
Downstream	Dresden	Lock	8/2/2017-2/24/2018	Bighead Carp
Upstream	Dresden	Lock	8/10/2018-10/19/2018	Bighead Carp
Downstream	Starved Rock	Dam	1/23/2018	Silver Carp
Downstream	Starved Rock	Dam	1/24/2018	Silver Carp
Downstream	Starved Rock	Dam	1/24/2018	Silver Carp
Downstream	Starved Rock	Dam	2/18/2018-2/20/2018	Silver Carp
Downstream	Starved Rock	Dam	2/20/2018	Silver Carp
Downstream	Starved Rock	Dam	2/20/2018-2/28/2018	Silver Carp
Downstream	Starved Rock	Dam	2/21/2018	Silver Carp
Downstream	Starved Rock	Dam	2/24/2018	Silver Carp
Downstream	Starved Rock	Dam	2/28/2018	Silver Carp
Downstream	Starved Rock	Dam	3/9/2018	Silver Carp
Downstream	Starved Rock	Dam	3/13/2018	Silver Carp
Downstream	Starved Rock	Dam	4/16/2018	Silver Carp
Downstream	Starved Rock	Dam	4/30/2018	Silver Carp
Downstream	Starved Rock	Dam	5/13/2018	Silver Carp
Downstream	Starved Rock	Dam	5/26/2018	Silver Carp
Upstream	Starved Rock	Lock	6/2/2018	Silver Carp
Upstream	LaGrange	Dam	4/30/2018-5/3/2018	Silver Carp
Upstream	LaGrange	Dam	5/6/2018-5/22/2018	Silver Carp
Upstream	LaGrange	Dam	5/14/2018-5/17/2018	Silver Carp
Upstream	LaGrange	Dam	5/15/2018-5/19/2018	Silver Carp
Downstream	LaGrange	Dam	7/13/2018-7/16/2018	Silver Carp
Downstream	LaGrange	Dam	7/23/2018-7/26/2018	Silver Carp
Downstream	LaGrange	Dam	7/26/2018-7/30/2018	Silver Carp
Downstream	LaGrange	Lock	9/10/2018	Silver Carp
Downstream	LaGrange	Lock	9/12/2018	Silver Carp

Using fin ray microchemistry to evaluate native fish passage through Brandon Road Lock and Dam

Water samples collected during 2017–2018 confirmed persistence of differences in water Sr:Ca among the Kankakee, Illinois, and Des Plaines Rivers; mean water Sr:Ca is lowest in the Kankakee River, intermediate in the Illinois River, and highest in the Des Plaines River.

Likewise, fin ray edge Sr:Ca is lowest among fish collected in the Kankakee River, intermediate for fish collected in the Illinois River, and highest for fish collected in the Des Plaines River. Fin ray Sr:Ca also differed among fish taxa within rivers. Thus, interpretation of fin ray Sr:Ca data must be done on a taxa-specific basis. Some overlap in ranges of fin ray edge Sr:Ca for fish collected from the Illinois and Des Plaines rivers is present within all taxa; thus, inter-river movement and Brandon Road Lock and Dam passaged is uncertain for fish whose fin ray Sr:Ca values fall entirely within this range of overlap. Results to date indicate that 5% of bass (*Micropterus* spp.) collected upstream of Brandon Road Lock and Dam had passed upstream through Brandon Road Lock and Dam, 29% showed no evidence of upstream passage, and 66% of individuals sampled may have passed upstream through Brandon Road Lock and Dam. For ictalurids sampled upstream of Brandon Road Lock and Dam, 48% had passed upstream through Brandon Road Lock and Dam, 49% showed no evidence of upstream passage, and 3% may have passed upstream through Brandon Road Lock and Dam. Among catostomids sampled from the Des Plaines River upstream of Brandon Road Lock and Dam, 30% had passed upriver through Brandon Road Lock and Dam, 44% showed no evidence of upstream passage through Brandon Road Lock and Dam, and 26% may have passed upriver through Brandon Road Lock and Dam.

Recommendations:

Hydroacoustic surveys are needed to inform (via spatial distribution maps) contracted removal and Unified Method events in the upper river as they can provide quite complete coverage of habitats. Bigheaded carp spatial distributions change through time and are not consistent across years, necessitating repeated surveys in Dresden Island and Marseilles pools in order to direct harvest efforts to appropriate locations. Standardized fall hydroacoustic surveys from Alton–Dresden Island pools are also needed to monitor long-term population trends that can indicate responses to environmental conditions, reproductive events, and harvest activities. Telemetry data from Starved Rock Pool indicated that removal efforts would be most effectively focused in lateral habitats during periods prior to spawning (spring staging), lower temperature (overwintering), and during higher discharges. Due to reduced numbers of active Vemco transmitters (69kHz), there is a need for additional transmitters to be deployed in bigheaded carps in the Illinois River in order to continue monitoring bigheaded carp dispersal towards the invasion front and collect dam passage data to improve the spatially-explicit carp population model (SEACarp). The telemetry working group currently plans to begin deploying additional transmitters in bigheaded carps in 2019 with the goal of at least 50 active tags per lower Illinois River pool. Evidence of upstream passage through Brandon Road Lock and Dam by some native fishes indicates a need for continued consideration of how any actions taken to minimize invasive species passage at Brandon Road Lock and Dam may impact non-target species.

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Evaluation of Gear Efficiency and Asian Carp Detectability

Steven E. Butler, Scott F. Collins, Joseph J. Parkos III, David H. Wahl (Illinois Natural History Survey)

Participating Agencies: Illinois Natural History Survey (lead)

Pools Involved: LaGrange Pool and adjacent backwater lakes

Introduction: Multi-agency monitoring and removal efforts using a variety of sampling gears are currently ongoing in the Illinois River and the CAWS to monitor and control populations of Asian carp. Sampling gears may vary widely in their ability to capture fish in proportion to their abundance, and may select for different sizes of fish. Evaluating the relative ability of traditional and alternative sampling gears to capture juvenile and adult Asian carp will help improve the efficiency of monitoring programs and allow managers to more effectively assess Asian carp relative abundance. Data gathered from effective gears can also be used to calculate detection probabilities for Asian carp, allowing for determination of appropriate levels of sampling effort and helping improve the design of existing monitoring regimes. Results of this gear evaluation study will help improve Asian carp monitoring and control efforts in the Illinois Waterway, and will contribute to a better understanding of the biology of these invasive species in North America.

Objectives: We are using a variety of sampling gears to:

(1) Evaluate the effectiveness of traditional and alternative sampling gears at capturing both juvenile and adult Asian carp;

(2) Determine site characteristics and sampling gears that are likely to maximize the probability of capturing Asian carp;

(3) Estimate the amount of effort required to detect Asian carp at varying densities with different gears;

(4) Supplement Asian carp sampling data being collected by other agencies; and

(5) Gather data on abundances of other fish species found in the Illinois River to further assess gear efficiency, and examine potential associations between Asian carp and native fishes.

Project Highlights:

- Summer catches of age-0 Silver Carp were higher during 2018 than in all previous study years except 2014. Fall catch rates of age-0 Silver Carp were intermediate compared to previous years. Differences in catches of juvenile Silver Carp among years and seasons may be attributable to variation in reproductive output, timing of reproduction, variable survival to juvenile life stages, and ontogenetic changes in habitat association by juvenile

Silver Carp. No juvenile Bighead Carp were captured during 2018, and haven't been observed since 2015.

- During 2018, mini-fyke nets collected the highest total numbers of age-0 Silver Carp. Mini-fyke nets have consistently produced higher catch rates of age-0 Silver Carp than all other sampling gears and are likely a preferred tool for monitoring for age-0 Silver Carp in floodplain rivers, especially during the summer months. Beach seines and dozer trawls captured intermediate numbers of age-0 Silver Carp, and may be useful for rapid monitoring purposes or for targeting specific habitats. Pulsed-DC electrofishing is not an effective method for monitoring for age-0 Silver Carp.

- Detection probability modelling using data from adult sampling gears indicates that a gear that produces the highest catches of a particular species may not necessarily be the most efficient gear for purposes of detection. Pulsed-DC electrofishing produces the highest detection probabilities for adult Silver Carp. Hoop nets, fyke nets, and trammel nets produce similar detection probability estimates for adult Bighead Carp, whereas electrofishing, fyke nets, or trammel nets provided the highest probability of detecting Grass Carp, depending on navigation pool. However, when the labor costs associated with each gear were accounted for, the most efficient gear for achieving a 95% cumulative detection probability for Silver Carp varied among pools, with hoop nets, fyke nets, and electrofishing each conveying minimum labor costs in different sections of the Illinois Waterway. Hoop nets and fyke nets provided very similar and low number of labor hours to reach a 95% cumulative probability of detecting Bighead Carp, whereas fyke nets were the most efficient gear for attaining a high cumulative detection probability for Grass Carp.

Methods:

During 2018, evaluation of sampling gears continued to focus on methods aimed at capturing juvenile Asian carp. Gears were deployed during summer (July) and fall (October) at paired main channel and backwater sites within the LaGrange Pool of the Illinois River (Figure 1). The first pair of sites was located at river kilometer 133.6, near Beardstown, Illinois, where gears were deployed in main channel (Beardstown) and backwater lake (Lily Lake) habitats. The second pair of sites was located at river kilometer 186.7 for the backwater lake (Matanzas Lake) and river kilometer 193.1 for main channel habitats (Havana). Gears used in 2018 were chosen based on experimental comparisons of multiple gears conducted in previous study years (Collins et al. 2017). All fish captured in 2018 were identified to species, and measured for total length (mm). Subsamples of juvenile Asian carp were retained for later diet and age analyses. Total catches, mean catch rates, and size distributions of captured age-0 Silver Carp and native fishes are being compared among years, seasons, habitats, and gear types. Cost effectiveness (catch per number of labor hours required to deploy and retrieve sampling gears) is being compared among sampling gears to identify the most efficient methods for monitoring for juvenile Asian carp (Collins et al. 2017).

Gears used to target juvenile Asian carp in 2018 included:

- Pulsed-DC electrofishing (250 V, 8 – 10 A, varied pulse width; four 15-minute transects per site-visit)
- Wisconsin-type mini-fyke nets (4.5 m x 0.6 m lead, 0.6 m x 1.2 m trap, 3 mm mesh; 8 net-nights per site-visit)
- Beach seines (various lengths, 3 mm mesh; minimum 4 hauls per site-visit)
- Dozer trawl (1 m x 2 m frame, 4 m long net, 3 mm mesh, minimum four 5-minute pushes per site-visit)

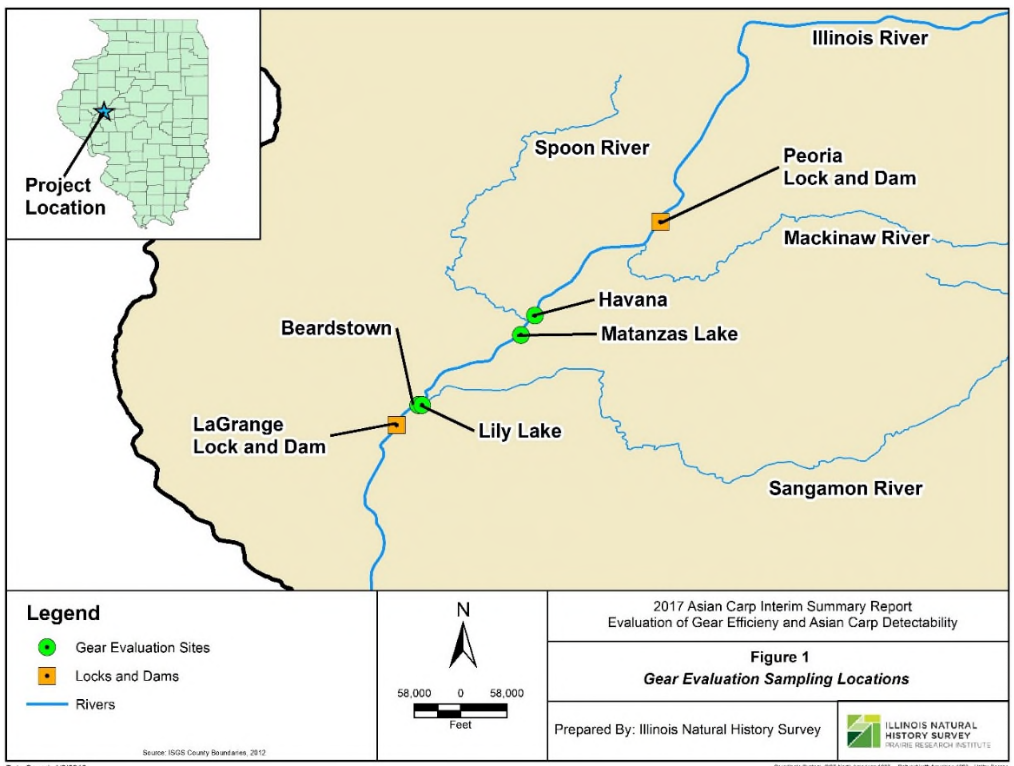

Figure 1. *Map of 2018 gear evaluation sampling locations in the LaGrange Reach of the Illinois Waterway. Navigation dams are represented by squares. Sampling sites are represented by circles.*

The probabilities of detecting Asian carp and several surrogate species in adult sampling gears that were evaluated in previous years were modelled using PRESENCE software (v. 12.16; Hines 2006). Sampling data from electrofishing, hoop nets, fyke nets, and trammel nets that were used for gear evaluation sampling during 2011 – 2013 were used to parameterize models to estimate detection probabilities for Silver Carp, Bighead Carp, Grass Carp, Bigmouth Buffalo, Smallmouth Buffalo, and Common Carp in each navigation pool. For each gear type, the number of samples required to achieve a 95% cumulative probability of detecting a species was calculated using the equation $N = \log_{(1-p)}(1 - F)$, where N is the sample size, p is the single-sample probability of detection, and F is the cumulative probability of detection. These estimates were then used to calculate the number of labor hours that would be required to reach a 95% cumulative detection probability with each gear type. Effort (labor hours) for each gear type was estimated based on the time required by a sampling crew to deploy and recover each gear multiplied by the number of people needed to effectively operate the gear (Collins et al. 2015, 2017).

Results and Discussion:

Evaluation of sampling gears targeting juvenile Asian carp during 2018 resulted in the capture of 131,928 fish, including 51,635 age-0 Silver Carp. Mini-fyke nets captured the highest numbers of all fish (July: n = 101,177; October: n = 3,703) and the most juvenile Silver Carp (July: n = 35,569; October: n = 71) during both sampling periods. Among the other sampling gears, total numbers of fish (all species) declined from beach seines (July: n = 12,359; October: n = 1,149) to dozer trawls (July: n = 8,834; October: n = 281) to pulsed-DC electrofishing (July: n = 3,804; October: n = 621). Numbers of juvenile Silver carp captured in July followed this same rank order (beach seine: n = 8,015; dozer trawl: n = 5,675; electrofishing: n = 2,299), but only beach seines captured age-0 Silver Carp in October (n = 6).

Relative abundances of age-0 Silver Carp captured in summer 2018 were high compared to all other study years except 2014, but fall catch rates were intermediate compared to previous years (Figure 2). Differences in catches of juvenile Silver Carp among years and seasons may be attributable to variation in reproductive output, timing of reproduction, variable survival to juvenile life stages, and ontogenetic changes in habitat association by juvenile Silver Carp. Asian carp reproductive output is highly variable among years, but egg and larval densities also do not correlate well with subsequent juvenile Silver Carp relative abundances (see Larval Fish Monitoring summary). Even in years when reproductive output is high, survival of offspring to juvenile stages may be poor. Survival of juveniles from summer to fall may also vary considerably depending on environmental conditions during summer months. Additionally, while early-spawned cohorts might be vulnerable to juvenile sampling gears during the summer sampling period, late-spawned cohorts may not appear in these gears until fall. However, Silver Carp relative abundances during fall sampling are often several orders of magnitude lower than during summer. Juvenile Silver Carp may use different habitats that are not effectively sampled by common littoral sampling gears during the fall period. Although some gears that target offshore habitats (gill nets, purse seines, pulsed-DC electrofishing) were used during earlier study years, these methods proved largely ineffective for capturing age-0 Silver Carp (Collins et al. 2017). Young Asian carp may not be particularly vulnerable to these gear types due to patchy distributions, avoidance behaviors, or simply low gear selectivity. Alternative methods that target larger sizes of age-0 as well as age-1 Asian carp in deeper water (trawls, unconventional electrofishing systems, small-mesh hoop nets, etc.) may be necessary to adequately sample for these fish.

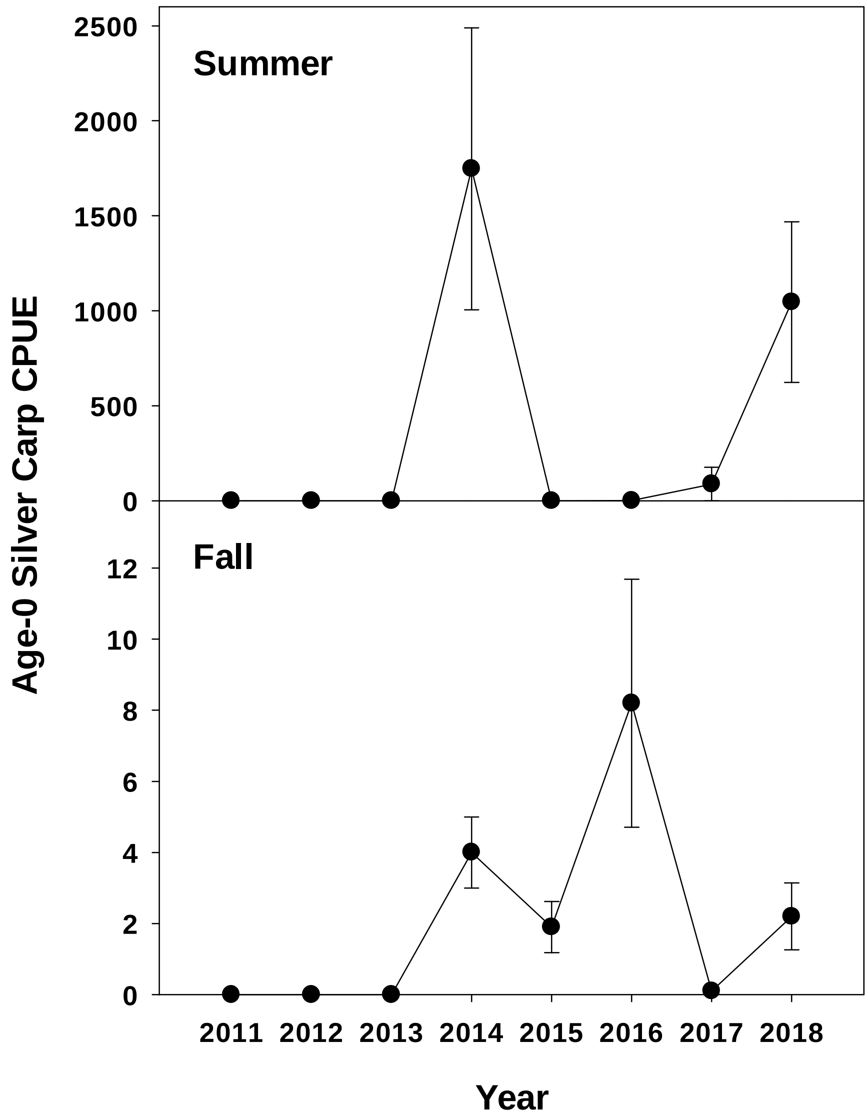

Figure 2. *Mean catch-per-unit effort (CPUE; number / net-night; ± SE) of age-0 Silver Carp captured in mini-fyke nets in the LaGrange Pool of the Illinois Waterway during summer (July – August; top panel) and fall (late September – October; bottom panel) sampling periods during 2011 – 2018.*

Despite the high variability in abundances of age-0 Silver Carp among years, several patterns are evident regarding the performance of various sampling gears for monitoring for juvenile Asian carp. Mini-fyke nets have consistently produced higher catch rates of small age-0 Silver Carp than all other sampling gears. This is likely a preferred tool for monitoring for age-0 Silver Carp in floodplain rivers, especially during the summer months. However, given the extremely high variation in catch rates observed in mini-fyke samples, consideration must be given to appropriate sample sizes needed to assess both spatial and temporal variation in age-0 Silver

Carp relative abundance. Beach seines have been less consistent at capturing juvenile Silver Carp, but may have some utility for Asian carp monitoring, as they have been found to have similar sampling efficiencies to mini-fyke nets in some years (Collins et al. 2017). Beach seines may be useful for rapid monitoring purposes when overnight gear sets are not practical, provided that water levels allow for access to open shoreline areas where beach seines can be effectively used. Dozer trawls have captured intermediate numbers of age-0 Silver Carp during the past two years, and may be useful for evaluating juvenile Asian carp densities in offshore habitats. Dozer trawls have been found to be particularly effective in backwater areas, but produce low catch rates in main channel habitats. Additional refinement of dozer trawls (adjustment of sampling depth, electrification, etc.) and other trawling methods is warranted to further enhance the utility of these tools for capturing juvenile Asian carp in offshore areas. Pulsed-DC electrofishing has been consistently found to perform poorly for capturing juvenile Asian carp. Although this gear is widely employed by a number of agencies for Asian carp monitoring, and may be a useful tool for sampling adult Silver Carp, the results of this study suggest that it is not an effective method for monitoring juvenile size classes. Because immobilization of fish by electric fields is related to body size, smaller Asian carp may not be vulnerable to the waveforms used for electrofishing by many agencies. Further assessment of electrofishing settings or alternative electrofishing configurations for targeting juvenile Asian carp may be warranted.

No juvenile Bighead Carp have been captured during gear evaluation sampling since 2015, when only three individuals were collected. Bighead Carp reproduction and recruitment to juvenile stages may have been low in recent years, or the behavior and habitat association of this species may differ from that of Silver Carp during the juvenile stage, making them considerably less vulnerable to the sampling gears that have been evaluated. Further study will be necessary to determine vulnerability of juvenile Bighead Carp to various sampling methods, and to evaluate patterns of Bighead Carp recruitment.

Previous evaluation of sampling gears targeting adult Asian carp that was conducted during 2011 – 2013 suggested that pulsed-DC electrofishing was the most effective gear for sampling Silver Carp, whereas hoop nets were the most effective gear for capturing Bighead Carp, based on total numbers of fish captured. Pulsed-DC electrofishing also produced the highest detection probabilities for Silver Carp across all Illinois Waterway navigation pools (Figure 3). However, after accounting for labor costs, the most efficient gear for achieving a 95% cumulative detection probability for Silver Carp varied among pools, with hoop nets, fyke nets, and electrofishing each conveying minimum labor costs in different sections of the Illinois Waterway (Figure 4). Electrofishing carried the lowest labor cost in the Starved Rock Pool, and was the only gear that detected Silver Carp in the Marseilles Pool, suggesting that this gear may perform better for detecting Silver Carp in areas of lower abundance. Modelled estimates for Bighead Carp indicate that several sampling gears may provide similar detection probabilities, with hoop nets, fyke nets, and trammel nets having broadly overlapping confidence intervals (Figure 3).

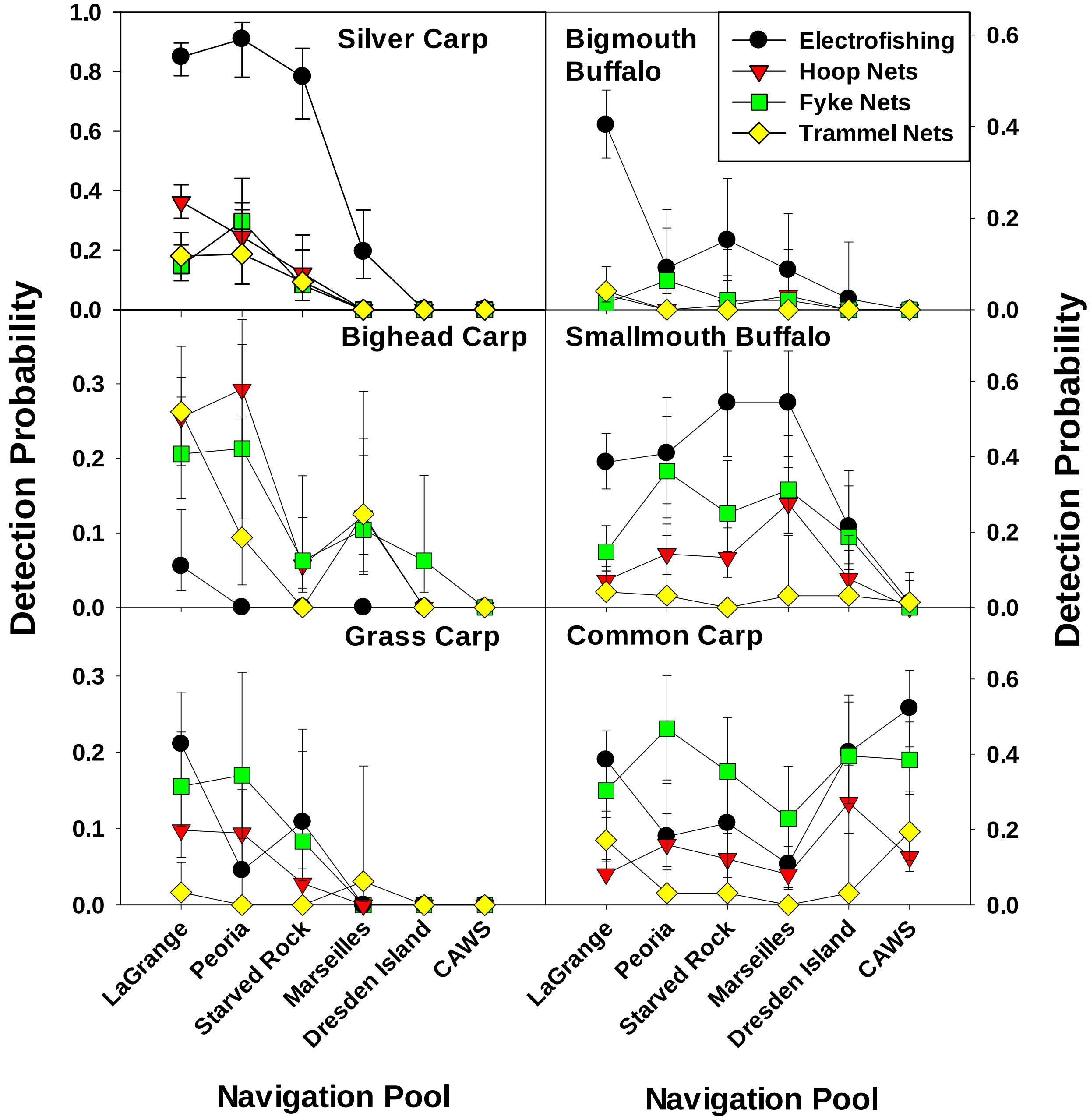

Figure 3. *Estimates and 95 percent confidence intervals of the mean probability of capturing at least one adult individual, given that the species is present, of 3 Asian carp species (Silver Carp, Bighead Carp, Grass Carp) and 3 surrogate species (Bigmouth Buffalo, Smallmouth Buffalo, Common Carp) using 4 common sampling gears (pulsed-DC electrofishing, hoop nets, fyke nets, trammel nets) in each navigation pool of the Illinois Waterway. Navigation pools are ordered from downstream (left) to upstream (right). Estimates are derived from models generated using PRESENCE (v.12.16) software on data collected during 2011 – 2013.*

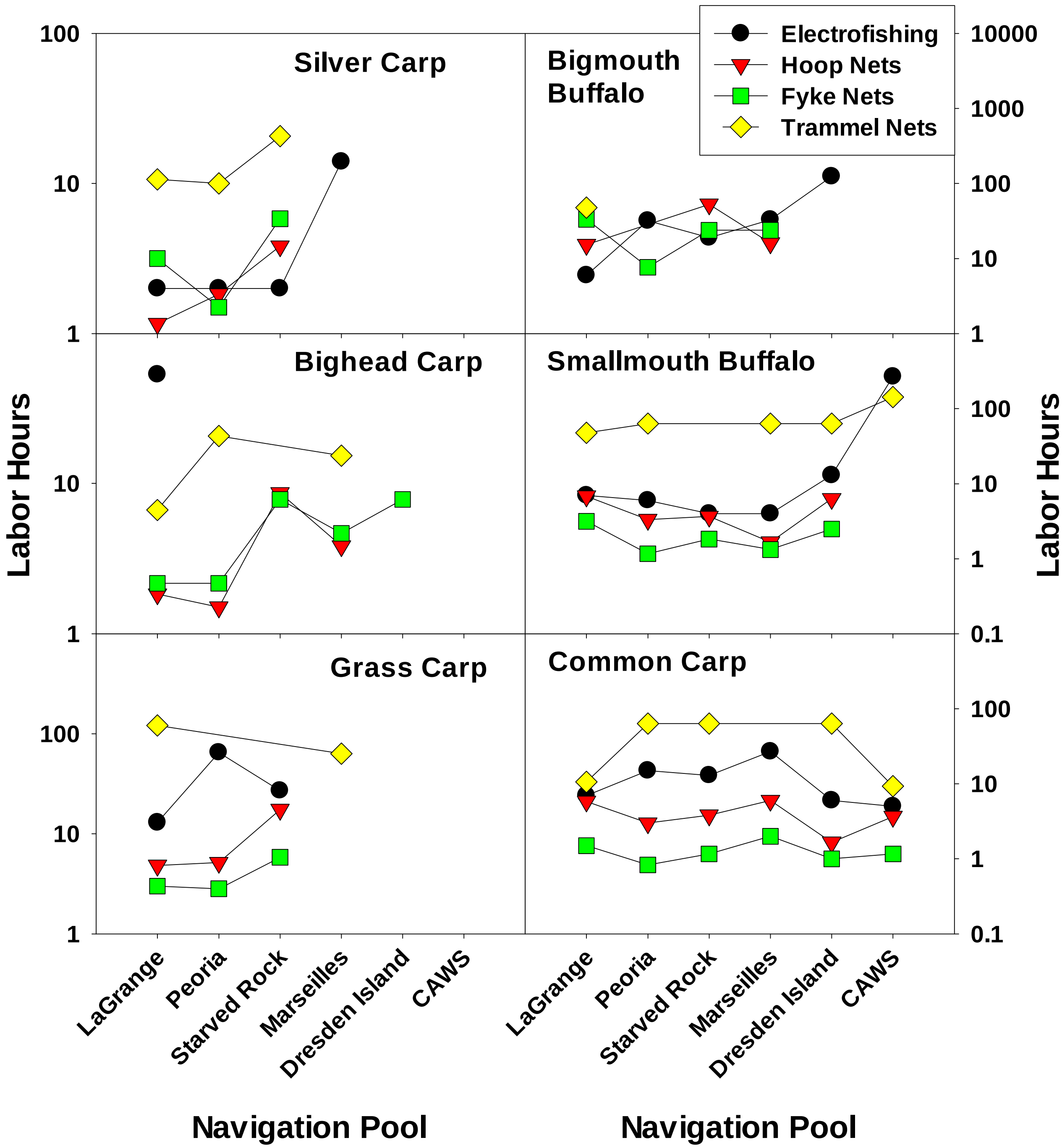

Figure 4. *Estimates of the labor costs (number of personnel hours; note log scale) required to achieve a 95% cumulative probability of detecting adults of 3 Asian carp species (Silver Carp, Bighead Carp, Grass Carp) and 3 surrogate species (Bigmouth Buffalo, Smallmouth Buffalo, Common Carp) using 4 common sampling gears (pulsed-DC electrofishing, hoop nets, fyke nets, trammel nets) in each navigation pool of the Illinois Waterway. Navigation pools are ordered from downstream (left) to upstream (right).*

Evaluation of Gear Efficiency and Asian Carp Detectability

Accounting for labor costs, hoop nets and fyke nets were very similar and required the lowest number of labor hours to reach a 95% cumulative probability of detecting Bighead Carp (Figure 4). Depending on navigation pool, electrofishing, fyke nets, or trammel nets produced the highest probability of detecting Grass Carp (Figure 3), but fyke nets were the most efficient gear for attaining a high cumulative detection probability with minimum labor expenditure (Figure 4). Detecting Bigmouth Buffalo and Smallmouth Buffalo was generally most feasible via electrofishing, although fyke nets produced similar estimates of detectability in some pools (Figure 3). However, no single sampling gear consistently achieved a minimum labor cost for Bigmouth Buffalo, but the lowest labor costs for realizing a 95% probability of detecting Smallmouth Buffalo were attained with fyke nets (Figure 4). Common Carp were generally most easily detected using fyke nets, although electrofishing produced similar or higher detection estimates in some pools (Figure 3). Due to lower labor costs, fyke nets were always the most efficient gear for reaching a high probability of detecting Common Carp (Figure 4).

These results indicate that a sampling gear that produces the highest catches of a particular species may not necessarily be the most efficient gear for purposes of detection. A gear that consistently captures at least small numbers of a species may be preferable for purposes of detection to a gear that captures large numbers of that species, but only in a small proportion of samples. Additionally, a gear that produces lower detection probabilities may be preferable to other gears if the effort needed to deploy and retrieve that gear is sufficiently low to minimize the labor costs needed to achieve a target probability of detection. For instance, we had previously discounted the usefulness of fyke nets for sampling Asian carp due to lower total catches compared to other sampling gears. However, because a high proportion of fyke net sets often contain at least one Asian carp, and fyke nets can be deployed and retrieved rapidly with a low number of personnel, this gear type was found to be an efficient tool for detection purposes, particularly for Bighead Carp and Grass Carp. These results highlight the need to explicitly define the purposes of a sampling program, whether it is to monitor for changes in the relative abundance of a species, to obtain representative samples for collecting demographic data, or to detect a species at the leading edge of its invasion front, as different sampling methods may be better suited for each of these purposes. The density of the target species in the environment and characteristics of the study area might also affect choice of sampling gears. The gear that produced the highest detection probability varied among navigation pools for some species. The probability of detecting any species will be in part a function of its abundance, but the slope of the relationship between abundance and detection probability may differ substantially among gear types. Additionally, habitat characteristics may affect both local abundances of the target species and the effectiveness of a sampling gear. Obviously, fyke nets would be of limited usefulness in the concrete-lined channels in much of the CAWS, whereas hoop nets would have little utility in shallow backwaters. The composition of different habitat types within a study area must be considered along with the relative efficiency of different gear types at detecting a target species when selecting the optimal mix of sampling methods to use at a given location.

Evaluation of Gear Efficiency and Asian Carp Detectability

Recommendations:

Mini-fyke nets appear to consistently capture higher numbers of age-0 Silver Carp than all other gear types, and are recommended for monitoring juvenile Asian carp in near-shore environments. Beach seines have been less consistent at capturing juvenile Silver Carp, but may have some utility for Asian carp monitoring, possibly as a rapid monitoring tool when overnight gear sets are not practical and water levels allow for access to open shoreline areas. However, some evidence indicates that larger age-0 and age-1 Asian carp are unlikely to inhabit nearshore habitats. Dozer trawls have been moderately successful for capturing age-0 Silver Carp in offshore habitats of backwater areas. Additional refinement of dozer trawls (adjustment of sampling depth, electrification, etc.) and other trawling methods may help to further enhance the utility of these tools for capturing juvenile Asian carp in offshore areas. Pulsed-DC electrofishing has been consistently found to perform poorly for capturing juvenile Asian carp. Although this gear is widely employed by a number of agencies for Asian carp monitoring, and may be a useful tool for sampling adult Silver Carp, the results of this study suggest that it is not an effective method for monitoring juvenile size classes. Further assessment of electrofishing settings or alternative electrofishing configurations for targeting juvenile Asian carp may be warranted. Numerous questions remain concerning Bighead Carp reproduction and recruitment, habitat use by juvenile Bighead Carp, and the most effective gears for targeting juvenile Bighead Carp. We are unable to provide recommendations for sampling for juvenile Bighead Carp at this time.

Previous assessments suggested that pulsed-DC electrofishing was the most effective gear for sampling adult Silver Carp, whereas hoop nets were the most effective gear for capturing adult Bighead Carp, based on total numbers of fish captured. However, hoop nets, fyke nets, and electrofishing each conveyed a minimum labor cost for attaining a 95% cumulative probability of detecting Silver Carp in different sections of the Illinois Waterway. Electrofishing carried the lowest labor cost in the Starved Rock Pool, and was the only gear that detected Silver Carp in the Marseilles Pool, suggesting that this gear may perform better for detecting Silver Carp in areas of lower abundance. Hoop nets and fyke nets were very similar and required the lowest number of labor hours to reach a 95% cumulative probability of detecting Bighead Carp, whereas fyke nets were the most efficient gear for attaining a high cumulative detection probability for Grass Carp. No single gear consistently achieved a minimum labor cost for Bigmouth Buffalo, but the lowest labor costs for realizing a 95% probability of detecting Smallmouth Buffalo and Common Carp were attained with fyke nets. Because these results indicate that a sampling gear that produces the highest catches of a particular species may not necessarily be the most efficient gear for purposes of detection, we recommend that careful consideration be given to the desired objectives of a sampling program, as different sampling methods may be better suited for various purposes. A mix of pulsed-DC electrofishing, fyke netting, and hoop netting may be the optimal combination of gears for monitoring for the presence of all species of Asian carp, with the actual composition of gear types used at a site determined after consideration of habitat conditions and sampling goals. Similar analyses of detection probabilities for juvenile sampling gears are being conducted and may also provide insight into methods that maximize the efficiency of detecting juvenile Silver Carp.

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Unconventional Gear Development

Steven E. Butler, Scott F. Collins, Anthony P. Porreca, Joseph J. Parkos III, David H. Wahl (Illinois Natural History Survey)

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

Pools Involved: LaGrange, Peoria, Starved Rock, and Marseilles Pools

Introduction and Need:

Traditional sampling gears vary widely in their ability to capture Asian carp. Many of these gears may have limited effectiveness for capturing and removing large numbers of Asian carp, or for detecting Asian carp in areas of low population density without expending extremely high levels of sampling effort. Evaluation of novel sampling gears and capture methods is warranted to enhance the efficiency of monitoring programs and increase capture rates of Asian carp for control efforts. Capture efficiency and size selectivity of these new methods are being evaluated and compared with selected traditional gears to determine the utility of these techniques for monitoring and controlling juvenile and adult Asian carp.

Objectives:

To enhance sampling success for low-density Asian carp populations, and increase harvest of Asian carp for control efforts, we are:

1) Investigating alternative techniques to enhance capture of Asian carp in deep-draft channels, backwater lakes, and other areas of interest for Asian carp monitoring and control purposes; and
2) Evaluating unconventional gears, capture methods, and combination system prototypes in areas with varying Asian carp population densities.

Project Highlights:

- Alternative configurations for setting pound nets produced highly variable catch rates and no apparent overall differences between parallel and perpendicular sets in open-water settings. Site-specific habitat conditions and local fish distribution may influence catch rates more than net configuration.
- Pound nets are being used for ongoing research, monitoring, and control efforts on the Illinois Waterway. Pound nets are being used in collaboration with USGS to test feeding attractants and evaluate other large entrapment gears.
- Herding fish into surface-to-bottom gill nets with sound or electrical stimuli increased catch rates and detection probabilities of Asian carp. These synergistic capture methods may provide a means of increasing catch rates and improving the probability of detecting

Asian carp, and may be useful for targeting both Silver Carp and Bighead Carp simultaneously.

Methods:

In 2018, unconventional gear efforts focused on the use of Great Lakes trap (pound) nets as part of an ongoing collaboration with IDNR and USGS partners to achieve various monitoring and research objectives. Previously, pound nets (100 m lead, 6.1 × 3.0 × 3.0 m pot, 7.6-9.1 m wings, 3.8-6.4 cm mesh) were deployed in a manner where the two wings from the net were angled to opposite banks, blocking the entirety of the waterway (Collins et al. 2015). However, in larger floodplain lakes, blocking from bank to bank is not possible. INHS has been experimenting with alternative configurations of pound nets to determine optimal methods for using this gear in larger waterbodies. Tests in the Marseilles Pool during 2017 produced very low catch rates, and low water levels prohibited testing at additional sites. In 2018, alternative pound net configurations were tested at the Chautauqua National Wildlife Refuge near Havana, IL. During these deployments, one pound net was set perpendicular to shore and another was set parallel to shore to compare catch rates and species composition between these two alignments. Pound nets were set in both the north and south pools at Chautauqua for 4 net nights each during April. Nets were attended daily, at which times all captured fishes were removed, measured, and weighed. Additional sites for alternative pound net deployments in the Alton, LaGrange, and Peoria Pools were investigated during 2018, but water levels were found to be unsuitable for the purposes of these tests at these locations. INHS also assisted USGS with the use of pound nets for testing feeding attractants and comparisons with other large entrapment gears at sites in the Marseilles and LaGrange Pools on multiple occasions during May to September 2018. Results of these tests will be reported by USGS. In 2018, INHS completed analyses of experiments examining the use of herding methods to increase catch rates of Asian carp in surface-to-bottom gill nets. Catch rates and detection probabilities of traditional sets where fish were not herded were compared with sets where either percussive sound or electrical stimuli were used to direct fish into the net.

Results and Discussion:

INHS evaluated alternative pound net configurations at Chautauqua National Wildlife Refuge during the weeks of April 9 and April 23, 2018. A total of 192 fish were captured from the north pool of Chautauqua, including 99 Silver Carp, and 161 total fish were captured from the south pool, including 117 Silver Carp, 13 Bighead Carp, and 7 Grass Carp. The parallel net configuration produced more fish in the north pool, averaging 21 Silver Carp per night versus 3.75 per night for the perpendicular set. However, the perpendicular configuration captured considerably more fish in the south pool, averaging 27.75 Silver Carp, 3.25 Bighead Carp, and 1.25 Grass Carp per night versus 1.5 Silver Carp, 0.5 Grass Carp, and no Bighead Carp in the parallel set. When examined together with catches from alternative configuration trials performed during 2017, no differences in catch rates of either all fishes or of Silver Carp were evident between parallel and perpendicular sets (Figure 1). Bighead Carp were only captured in perpendicular sets, but overall numbers were low (n = 16 total). Grass Carp were captured in both parallel and perpendicular sets, but overall numbers were also too low (n = 8 total) to warrant drawing any conclusions. Given the highly variable catches that different configurations of pound nets have produced, no strong recommendations can be provided regarding optimal configurations for capturing Asian carp with pound nets in open-water areas. Site-specific conditions and fish distribution may influence catch rates more than net configuration, and different sites may lend themselves better to a particular deployment strategy depending on waterbody dimensions, bathymetry, and presence of coarse woody habitat.

A number of new sites in the Alton, LaGrange, and Peoria Pools were examined for suitability for pound net deployments during 2018, but were found to be either too deep or too shallow to effectively fish pound nets at the water levels that were present during available deployment dates. This highlights a significant limitation of the use of Great Lakes-style pound nets, which have a fixed height and are therefore limited in the range of depths (approximately 1.5 – 2 m) that they can effectively fish for Asian carp. If they are set in water that is too shallow, the net walls and throat mesh will collapse, either restricting entry by fish into the pot or reducing pot volume, whereas if they are set in water that is too deep, many fish, especially Silver Carp, can swim over the lead and wings, also reducing the effectiveness of this gear. Coastal-style pound nets, which are used extensively by commercial fishers on the Atlantic and Gulf coasts, may provide a solution to this limitation, as they are designed to be used in systems where water depth fluctuates on a daily basis due to tides. Instead of mesh that is suspended by floats, coastal pound nets are supported by poles or pylons that are pounded into the sediment, and are therefore unaffected by changing water levels. Use of coastal pound nets in Illinois River backwaters might allow for capture of Asian carp across a wide range of water depths and therefore have more utility for management and research purposes, but would require further assessment to understand how water depth and seasonal changes in Asian carp densities in backwaters may influence catch rates.

An experiment testing the effectiveness of using percussive sound or electrical stimuli to herd Asian carp into surface-to-bottom gill nets demonstrated that herding methods increased catch rates and detection probabilities for most fish species (Butler et al. *In Press*). Catch rates of Silver Carp were over three times higher when sound stimuli was used to herd fish, and over six times higher when electrical stimuli were used relative to control trials. Catch rates of Bighead Carp were five times higher in sound stimuli trials and four times higher in electrical stimuli trials than in control trials. Herding methods also decreased the number of samples required to achieve a given detection probability for Asian carp. These synergistic capture methods may provide a means of increasing catch rates and improving the probability of detecting Asian carp, and may be useful for targeting both Silver Carp and Bighead Carp simultaneously. Commercial fishers already widely employ sound stimuli for herding Asian carp into nets, but such methods have not been widely adopted for monitoring purposes. Further examination of herding methods with entanglement or entrapment gears is warranted in order to improve confidence in monitoring programs occurring in areas of low Asian carp abundance.

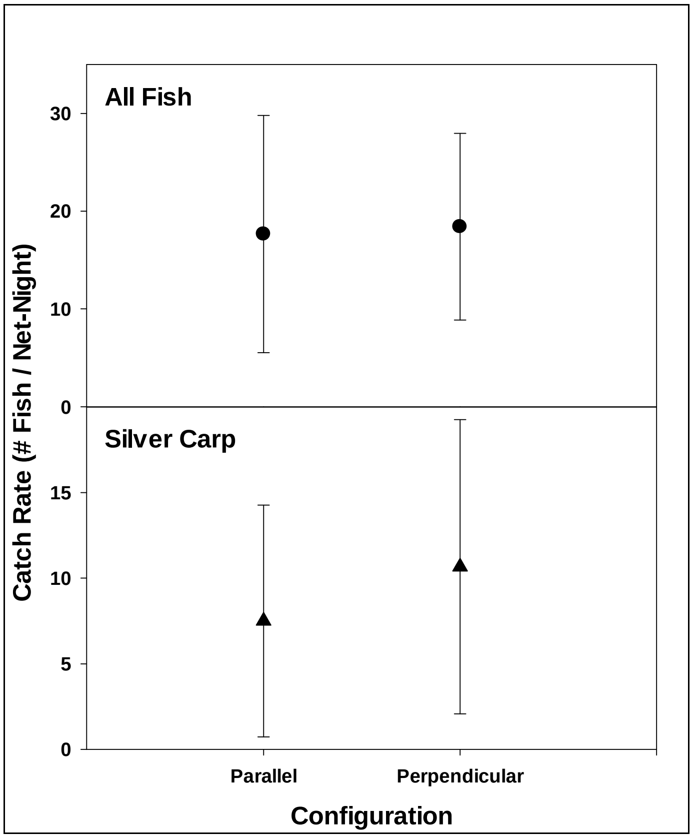

Figure 1. *Mean (± SE) catch rates of all fish (top panel) and Silver Carp (bottom panel) captured in parallel and perpendicular configurations of pound nets during 2017-2018.*

Recommendations:

The use of pound nets has proven useful for a variety of monitoring, control, and research purposes. The continued use of pound nets instead of traditional entrapment gears may increase efficiencies and help save natural resource agencies considerable personnel time (Collins et al. 2015). Given the high variability observed in catch rates between different configurations of pound nets set in open-water areas, neither deployment method can be recommended over the other. Site-specific conditions and fish distribution may influence catch rates more than net configuration, and an optimal deployment strategy may depend on local habitat features.

Water levels that are outside of the effective range for deploying Great Lakes-style pound nets frequently occur in Illinois River backwater lakes, and likely in other systems. Coastal-style pound nets may prove more useful for Asian carp monitoring and control purposes across a wide range of water depths. However, the utility of this style of pound net requires further evaluation to understand how water depth and seasonal variation in Asian carp densities in backwater lakes affect catch rates before this gear can be recommended for routine management or research purposes.

Herding fish into surface-to-bottom gill nets using both sound and electrical stimuli was found to increase capture rates and enhance detection probabilities for Asian carp. Commercial fishers already employ such methods for harvesting Asian carp, but the use of herding methods for monitoring purposes has not been widely adopted. Such synergistic capture methods should be further explored to develop and standardize enhanced sampling regimes, particularly in areas where Asian carp densities are low and/or where high uncertainty of capture exists.

References:

Butler, S.E., A.P. Porreca, S.F. Collins, J.A. Freedman, J.J. Parkos III, M.J. Diana, and D.H. Wahl. *In Press*. Does fish herding enhance catch rates and detection of invasive bigheaded carp? Biological Invasions. https://doi.org/10.1007/s10530-018-1857-2.

Collins, S.F., S.E. Butler, M.J. Diana, and D.H. Wahl. 2015. Catch rates and cost effectiveness of entrapment gears for Asian carp: a comparison of pound nets, hoop nets, and fyke nets in backwater lakes of the Illinois River. North American Journal of Fisheries Management 36:1219-1225.

Barge Entrainment and Asian Carp Interaction Study and Monitoring Barge Entrainment Dynamics and Assessment of Mitigation Protocols

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Participating Agencies: U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, Wilmington Substation

Pools Involved: La Grange and Peoria

Introduction and Need:

The Electric Dispersal Barrier 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. In an attempt to gain further understanding about the potential risk of fish passage associated with barge traffic at the Electric Dispersal Barrier the U.S. Fish and Wildlife Service (USFWS) and U.S. Geological Survey (USGS) conducted a series of experimental field trials during 2015-2017 that utilized a contracted commercial barge tow. Studies conducted during 2015-2016 investigated the potential for entrainment, retention, and transport of freely swimming fish within the rake to box junction gaps between barges and examined non-entrainment pathways for fish passage associated with barge traffic at the Electric Dispersal Barrier. Results of the barge entrainment studies demonstrated that small fish can become entrained by barges, retained within junction gaps, and transported over distances of at least 9.6 miles including upstream across the Electric Dispersal Barrier (Davis et al. 2016). Studies conducted during 2017 tested mitigation techniques to reduce or eliminate fish passage at the Electric Dispersal Barrier associated with passing tows.

Currently, juvenile Asian carp (< 6”) are not believed to be present near the Electric Dispersal Barrier or in the Illinois Waterway within 39.5 miles downstream from the Electric Dispersal Barrier System. This is based on extensive physical sampling efforts targeting juveniles. These observations highlight a need to understand the risks associated with barge entrainment and upstream transport of early life stages of Silver Carp in the Illinois Waterway. During FY 2018, a barge entrainment risk assessment tool will be developed using existing data and models to identify potential times and locations that may be “hotspots” for the inadvertent entrainment of early life stages of Asian carp.

Objectives:

(1) Gain further insights on barge entrainment, retention, and transport dynamics specifically regarding entrainment of juvenile Silver Carp.

(2) Determine potential upper size thresholds for entrainment of juvenile Silver Carp.

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Methods:

A commercial barge tow consisting of a tow boat and four loaded barges (200’ x 35’ each) were contracted for these experiments. The barge tow was configured so that there was a rake-to-box junction gap located at the center of the tow (Figure 1). Inside this junction gap, a multi-beam sonar system (Sound Metrics ARIS 3000) was installed to track fish movements. Additionally, a fish capture system was developed using a modified cast net that allowed crews to sample freely swimming fish inside the rake-to-box junction gaps.

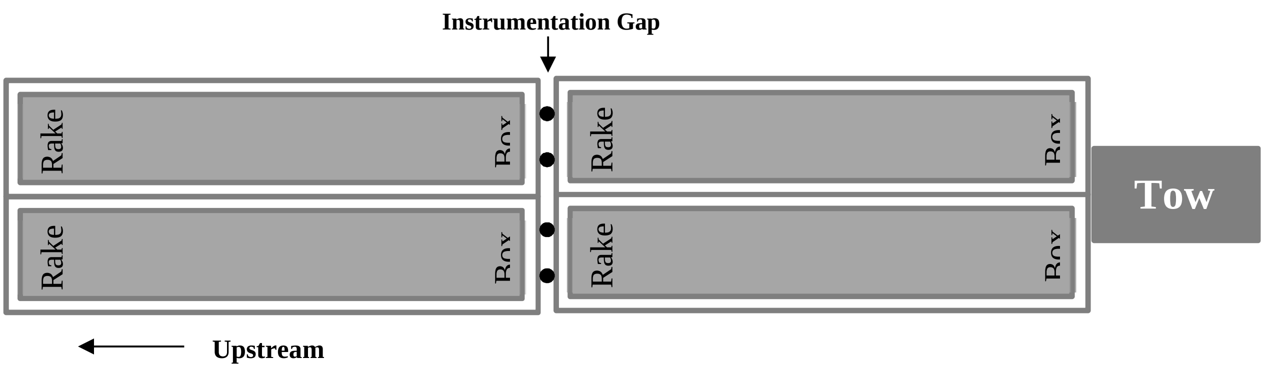

Figure 1. *Tow configuration used during 2018 Asian carp entrainment trials. Juvenile Asian carp were stocked either into the rake-box junction gap or off the front of the barge.*

A series of mark recapture experiments were conducted using USFWS reared age-0 Bighead, Grass and Silver Carp (56-180mmTL). The Asian carp were collected within the Peoria Pool in late June and early July of 2018. The fish were held at the National Great Rivers Research and Education Center at the Lewis and Clark Community College in Alton, IL. The captive Asian carp grew substantially (from an average of 10mm to an average of 87mm) during their time in captivity and appeared healthy at the time of the field trials. The Asian carp were marked with fin clips before each trial and stocked at the front, within the rake-to-box junction or both locations of the moving barge tow. The barge tow then traveled upstream towards the Peoria Lock and Dam, locking through the lock and moving upstream. At the conclusion of each trial, fish recapture events took place. These recapture events coupled with the addition of data from the fish observation sonar system, allowed researchers to quantify entrainment, retention, and transport distances for freely swimming fish that encountered the moving barge tow. Additional wild fish trails were conducted while traveling upstream to determine if wild fish could be entrained within the rake-to-box junction gap. During these runs, fish movement into and out of the rake-to-box junction was recorded using the ARIS. When a fish was detected on sonar an attempt was made to capture the individual(s) using the modified cast net system.

Barge Entrainment and Asian Carp Interaction Study and Monitoring Barge Entrainment Dynamics and Assessment of Mitigation Protocols

Water chemistry data was collected during the trial period. Using a YSI Pro Plus meter, temperature, ambient conductivity, pH and DO (mg/L) data were collected.

Results and Discussion:

In 2018, the second barge entrainment study looking at potential entrainment with free-swimming Asian carp was conducted. The Peoria Lock and Dam was used as a base instead of the La Grange Lock and Dam to reduce the handling and transport stress on the fish as a work station was set up alongside of the lock. During all juvenile entrainment trials, sonar observations were used, in addition to recapture events, to determine if small fish remained within the rake-box junction gap or were transported upstream. Ten trials were conducted over two weeks (Table 1). Delays due to issues at the Peoria Lock and Dam, the barges and having access to fewer fish reduced the number of runs that were conducted over the two week period.

Table 1. *Trial runs conducted by the USFWS during October 2018.*

Date	Wild Fish Runs	Asian Carp Trials	# of Fish Clipped	# of Asian Carp recaptured
10/17/2018	1	1	98	0
10/18/2018	1	1	386	0
10/19/2018	1	0	0	0
10/24/2018	0	2	600	2
10/25/2018	2	1	172	0
Total	5	5	1256	2

Five trials were conducted using live Asian carp and a total of 1256 fish were clipped and released in front of the barges, within the rake-to-box junction gap or both. Of the 1256 fish released only 2 were recaptured, one in the left gap and one in the right. However, sonar data from 2018 is still being processed and may provide further information on other entrained fish. In 2017, the average size of Silver Carp used in the downstream trials was 42mm TL, however, the average size Asian carp used in the 2018 study was 87mm TL. Additional data, still being processed, my provide further information as to the size threshold at which the swimming ability of Asian carp becomes strong enough to avoid or escape entrainment within barge junction gaps.

The difference in recapture and retention rates could also be due to the temperature at which the trials were conducted. Previous barge entrainment studies using Asian carp were conducted in

September where the average river temperature was 23.6°C However, the 2018 study was conducted in mid-October and the temperature average was 11.3°C.

Additional data will be provided to the MRWG when data analysis is complete. No studies are planned for 2019.

Asian Carp Population Modeling to Support an Adaptive Management Framework

US Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office and Columbia Fish and Wildlife Conservation Office; US Geological Survey Upper Mississippi Environmental Science Center

Introduction:

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

Management scenarios explored herein relate to 1) additive mortality of adult Asian carp in downstream pools (Alton, La Grange, Peoria) and upstream pools (Starved Rock, Marseilles, and Dresden Island) of the Illinois River, and 2) deterring upstream movement of Asian carp (all sizes) through existing bottlenecks at Starved Rock Lock and Dam, Marseilles Lock and Dam, or Dresden Island Lock and Dam. Note that additional mortality and deterrence of upstream movement can be achieved by a variety of tools or strategies and recommendations for achieving ideal levels are beyond the scope of this interim summary report.

Objectives:

1) Estimate demographic rates using the most current data available and incorporate results into the SEAcarP model
2) Conduct sensitivity analyses and develop a prioritized list of data and research needs based on results thereof
3) Recommend mortality benchmarks and fish passage deterrent locations with efficiency requirements
4) Use statistical catch-at-length models to estimate vulnerability to fishing as a function of fish size, exploitation rates, and immigration into the upper Illinois River Waterway.
5) Modify the length-based structure of the model; use integral projection models to define populations by a continuous variable instead of discrete length classes

Asian Carp Population Modeling to Support an Adaptive Management Framework

Project Highlights:

- Provided model results to inform management recommendations for reduction/elimination of Asian carp in Dresden Island pool over a 25 year period while accounting for uncertainty in our understanding of population dynamics. Recommendations relate to the minimum amount of additive mortality required in the upstream pools (Starved Rock, Marseilles, and Dresden Island) and downstream pools (Alton, La Grange, and Peoria) across varying levels of deterrence efficiency (measured as percent reduction in annual upstream movement rates) placed at either the Starved Rock Lock and Dam, the Marseilles Lock and Dam, or the Dresden Island Lock and Dam.
- Updated demographic parameters for Silver carp and Bighead carp across entire Illinois River and Upper Mississippi River and Ohio River systems (Erickson et al*. in review*.; code available at https://github.com/rerickson-usgs/CarpLifeHistoryModels); defining demographic rates in additional locations improves estimates of Illinois River demographics and also provides information on potential source populations that will hopefully be incorporated into the SEAcarP model in the future
- Developed and published findings from a simplified version of the SEAcarP model using Grass carp as the target species (Erickson et al. 2018). General conclusions regarding the effectivness of deterring upstream movement as well as additional mortlaity in downstream versus upstream locations relative to population control were consistent with SEAcarP model findings.
- Worked closely with MRWG technical workgroups to prioritize future data collections and research using the SEAcarP model assumptions and limitations as a decision support tool. These efforts ensure that field-related efforts are coordinated to reach management goals and provide maximum ability to test assumptions, aliviate limitations, and increase our general understanding of Asian carp population dynamics.

Methods:

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

Asian Carp Population Modeling to Support an Adaptive Management Framework

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

Uncertainty in Asian carp demographic rates were incorporated by repeating 25-year simulations for each management scenario using 1,000 iterations of growth, maturity, natural mortality, and condition parameters, randomly selected from Bayesian posterior distributions. Hence, the parameters drawn from the posterior distributions were time invariant over a given 25-year simulation period. Interannual variability in recruitment, however, was included using a Bernoulli distribution to simulate variability in reproductive success (i.e., frequent year class failure and occasional reproductive success). Specifically, for each time step the number of individuals estimated from the stock-recruitment function was added to the population with probability 0.5, which was estimated from the relative frequency of historically observed and successful reproduction in the La Grange pool of the Illinois River and quantified using 2000 – 2015 USGS Long-Term Resource Monitoring Program (LTRMP) data. Annual data was classified as successful when the catch of age-0 fish (i.e., < 250 mm total length [TL]) was greater than zero. Similar to previous Asian carp population modeling efforts (Tsehaye et al. 2013), a Ricker stock recruitment function (Ricker 1954) with an extremely high steepness value of 1 was used (Mangel et al. 2013). Higher steepness values are associated with a high resilience to additional mortality because of high recruitment rate potential even at low spawner abundance. Sensitivity of model results relative to the shape and steepness of the stock recruitment function and other model inputs (e.g., growth) are subjects of ongoing research (Objective 2).

Effects of additional mortality on Asian carp populations were evaluated at 10% intervals from 0 to 100% in the upstream pools (Starved Rock, Marseilles, and Dresden Island) and downstream pools (Alton, La Grange, and Peoria). The annual time step reduced our confidence in exploring pool-specific effects of additional mortality because finer-scale movement patterns (e.g., seasonal) are required to better understand varying levels of vulnerability to additional mortality across space. Additional mortality was limited to adult fish (i.e., ≥ 500 mm TL). Deterrence of upstream movement on Asian carp populations were evaluated in combination with additional upstream mortality. A range of different upstream movement deterrence efficiencies – proportional reduction (0 to 100% in 10% intervals) relative to observed values – and locations (i.e., Starved Rock Lock and Dam, Marseilles Lock and Dam, and Dresden Island Lock and Dam) were considered.

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

Model support for data-driven management decisions: Although the primary goal of the modeling effort is to inform the decision making process with respect to control via additional mortality of adults and deterring upstream movement, tools such as the SEAcarP model could be used to inform other management decisions such as prioritizing field collections and research. To accomplish this secondary goal, model results were dessiminated to managers via oral presenations (e.g., meetings of the ACRCC, MRWG, Missouri River Natural Resource Committee, Lower Mississippii River Natural Recource Committee). In addtion, the modeling workgoup collaborated with MRWG technical groups (e.g., telemetry team) to address key uncertainties and knowledge gaps identified during the model development process.

Results and Discussion:

Model updates and improvements: Updates and improvements to the SEAcarP model including revised demographic rates estimated using all available data (Objective 1; Erickson et al. in review; code available at https://github.com/rerickson-usgs/CarpLifeHistoryModels) and modifications to the length-based structure of the model (Objective 5) were completed during late 2018. The length-based structure of the population model was changed allowing Asian carp growth to be described as a continuous process using integral projection models (IPMs) rather than a discrete process based on length classes (e.g., Erickson et al. 2018). IPMs are preferable because they better capture continuous processes such as fish growth (Ellner and Rees 2006, Merow et al. 2014).

Simulation results

Graphical results of model simulations are presented for Silver carp (Figures 1 – 5; Table 1) and Bighead carp (Figures 6 – 10; Table 2) species. To minimize redundancy, results and discussion reported herein focus on Silver carp findings. Similar patterns were observed for Bighead carp, yet effects of additional mortality and upstream movement deterrence tended to be stronger for this species, which was attributed to this species relatively low population size, larger size at maturity, and higher natural mortality rates.

Model results from scenarios that focused only on additional mortality as a management tool suggest that additional mortality of adult-sized Silver carp can have profound effects on Dresden Island abundance (Figure 1). In general, additional downstream mortality was a more effective long-term control strategy than additional upstream mortality, a finding we attributed to effects associated with increased mortality on source populations (i.e., sources of successful recruitment and immigration; Erickson et al. 2018). Model results revealed that high reductions in Silver carp relative abundance (i.e., >90%) in Dresden Island Pool were not possible without additional downstream mortality, whereas the reverse was not true (Figure 1). For example, high reductions in Silver carp relative abundance were observed when additional downstream mortality rates were greater than 50% and this result was consistent across all levels of upstream mortality. In contrast, setting upstream mortality rates to an unrealistically high level (i.e., 100%) still required a minimum downstream mortality rate of 30-40% to reach high reduction levels. Regardless, we do not recommend eliminating upstream harvest efforts in the short term.

Silver carp scenarios involving the deterrence of upstream movement rates produced considerable reductions in Dresden Island relative abundance (Figures 2 – 4). In these simulations, we held additional adult mortality in the downstream pools to zero to allow for comparisons between effectiveness of adding either downstream mortality as a management strategy (Figure 1) or reductions in upstream movement (Figures 2 – 4). The magnitude of deterrence effects on reduction of Silver carp population abundance in the Dresden Island Pool was influenced by location. Specifically, the effectiveness of deterring upstream movement on population reduction in the upper Illinois River was strongest at Starved Rock Lock and Dam (Figure 4) in comparison to Marseilles Lock and Dam (Figure 3) and Dresden Island Lock and Dam (Figure 2). Strong effects of deterring upstream movement were realized at intermediate deterrence efficiency levels in scenarios that did not have any additional mortality. For example, deterring upstream movement at Dresden Island Lock and Dam by 50% resulted in a 20% reduction in Silver carp relative abundance and this effect increased as the location of deterrence moved downstream. Specifically, a similar 50% deterrence of upstream movement resulted in a 35% reduction in abundance when located at Marseilles Lock and Dam and 45% when located at Starved Rock Lock and Dam. As expected, combining additive upstream mortality and deterrence of upstream movement increased reductions in Silver carp relative abundance relative to deterrence-only strategies (Figures 2 – 4).

Management strategies may need to involve a combination of increased mortality in locations both upstream and downstream of Starved Rock Lock and Dam as well as reductions in upstream movement rates. Reducing upstream movement rates did result in substantial decreases in simulated abundance and these forecasts had less uncertainty than scenarios simulating only additional mortality. As such, even small reductions in upstream movement rates increase the effectiveness of additional mortality of Asian carp in pools downstream of Starved Rock Lock and Dam and reduce uncertainty in population forecasts.

Asian Carp Population Modeling to Support an Adaptive Management Framework

While determining combinations of strategies that result in the elimination of Asian carp from Dresden Island is the current goal of these modeling efforts, uncertainty in demographic parameter estimates led to some simulations being biologically unreasonable. Specifically, in a relatively few simulations it was impossible to eliminate all Silver carp despite high mortality rates (i.e., 100%) even in combination with strong reductions in movement rates, a finding we attributed to unreasonably low growth and natural mortality estimates. In short, fish in these simulations never reached 500 mm TL and therefore were invulnerable to additional size based mortality. In addition, they had extremely low natural mortality rates, which allowed them to persist beyond the 25 year simulation period. As such, using a strict criterion of eliminating Asian carp across all 1,000 simulations as an objective approach to providing management recommendations would lead to spurious conclusions regarding minimum requirements for achieving this goal. As noted, updated demographic parameter estimates have been completed (Objective 1) and other model limitations have been or are currently being addressed, which we expect will improve certainty in population forecasts and recommendations. Prior to making specific recommendations from updated simulations for minimum target mortality rates and upstream movement deterrence efficiency requirements for short-term and long-term control, additional discussions are needed to define desired levels of population reduction (e.g., >50% of simulations lead to elimination of Asian carp).

In summary, simulation results indicate that additional mortality in upstream and downstream pools can have a substantial effect on relative abundance of Silver carp in Dresden Island Pool. However, if the management objective is to eliminate Silver carp or reduce populations by greater than 65%, then additional mortality of downstream source populations must be included assuming an additional mortality-only control strategy. Simulations using deterrence of Silver carp upstream movement were highly effective at controlling population size in Dresden Island Pool and relative to mortality-based simulations, had greater certainty. Further, larger reductions in Silver carp relative abundance were realized by combining upstream movement deterrence with additional mortality in downstream and upstream pools. This result highlights the compounding benefits associated with using a multipronged strategy, but does not account for effects to species other than Silver carp.

Model support for data-driven management decisions: Key uncertainties and limitations identified during model development were used to inform the ACRCC, MRWG, and other decision makers regarding Asian carp data collections and research. For example, discussions among the modeling and telemetry technical workgroups led to the conclusion to increase tagging efforts on small immature fish located below Starved Rock Lock and Dam. These efforts will provide data to test the model assumption that movement is independent of fish size (i.e., all Asian carp move at similar rates regardless of size). Conversations between the modeling and telemetry technical workgroups also helped inspire development of a new multistate temporary emigration movement model (e.g., Kendall et al. 1997) that will be parameterized using Upper Mississippi River and Illinois River data, though future telemetry modeling efforts should include other source populations (e.g., Missouri River) as data become available. This model, which is in early stages of development, will address the SEAcarP model assumption that Illinois River is a closed system (i.e., immigration from other large rivers is assumed to be zero). The modeling workgroup also identified the paucity of growth data from small fish (< 300 mm TL) and variation associated with systematic aging errors as key sources of uncertainty in the SEAcarP model through their effects on growth. To address these concerns, USGS-CERC led an Asian carp age and growth workshop during August 2018 (MRP: Asian carp demographics; ACRCC 2018). The product of this effort will be a standard operating procedure for aging Asian carp, which is expected to reduce uncertainty in future Asian carp growth estimates. Likewise, USFWS-Columbia implemented a demographics project (MRP: Asian carp demographics; ACRCC 2018) designed to address other data gaps identified by the modeling workgroup including growth information on small fish (<300 mm TL) and size at maturity and sex ratio data. These collections were also supported by ILDNR contracted commercial fishers during a two-week intensive data collection effort during October of 2018 (MRP: Asian carp demographics; ACRCC 2018). Lastly, model-based results provided objective data-driven support for recent management decisions aimed at controlling Asian carp population growth. For example, consistent with modelling results, the ILDNR plans to expand contract fishing efforts into the lower pools of the Illinois River beginning with Peoria Pool while expanding current levels of effort by ~25% in the upstream pools. Similarly, evaluation of deterrents to upstream movement are moving forward in other basins (e.g., bio-acoustic fish fence at Barkley Lock and Dam located on the Cumberland River in Kentucky).

Recommendations:

- SEACarP modeling indicates that both additive mortality as well as deterrents to upstream movement, when strategically implemented, could have a significant impact on Asian Carp populations and therefore support shared long-term Asian Carp management goals. We recommend communicating model results to managers to help inform decision-making.
- Implement forthcoming Asian carp standard operating procedure for age determination developed by USGS-CERC during the 2018 age and growth workshop to specifically address uncertainty in model forecasts resulting from systematic aging errors (Erickson et al. *In review*).
- Support research designed to address key model assumptions and limitations such as density feedback loops, variation in the relation between size and age, factors influencing pool-to-pool movement probabilities, and size-dependent vulnerability to harvest.
- Hold coordination meeting to define acceptable levels of population reduction for model simulations and to determine desired management scenarios for future modeling efforts.

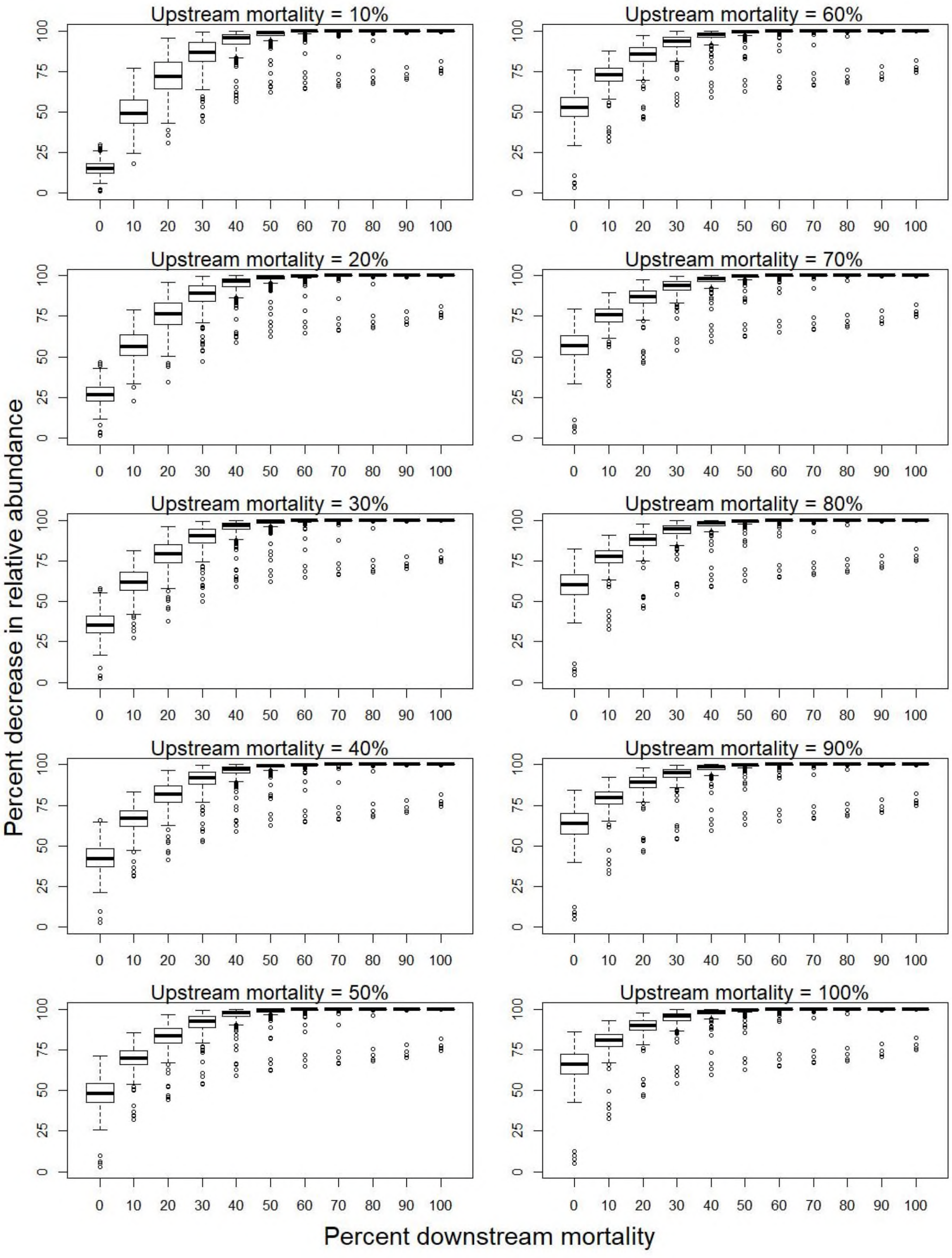

Figure 1. *Boxplots showing the distributions of percent decrease in Dresden Island Pool Silver carp abundance relative to the no-action scenario as a function of downstream and upstream mortality (i.e., additive mortality for Silver carp ≥500 mm TL). Mortality levels for the downstream pools (Alton, La Grange, and Peoria) increase from left to right along the x-axis and are held at a constant rate for each panel for upstream pools (Starved Rock, Marseilles, and Dresden Island). Distributions are based on 1,000 iterations per scenario.*

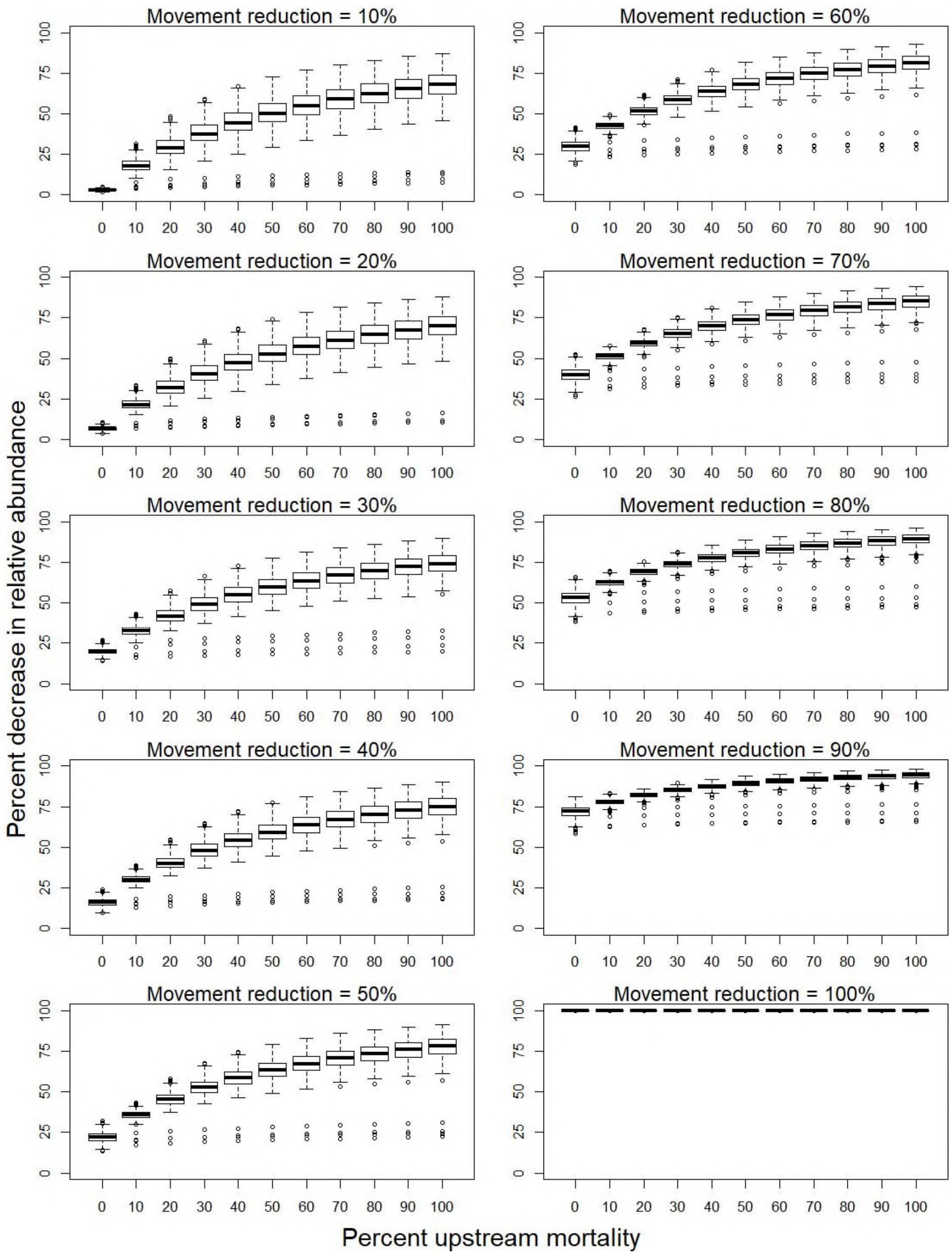

Figure 2. *Boxplots showing distributions of percent decrease in Dresden Island Pool Silver carp abundance relative to the no-action scenario as a function of upstream mortality (i.e., additive mortality for Silver carp ≥500 mm TL) and upstream movement deterrence at Dresden Island Lock and Dam under varying efficiency levels. Mortality levels for the upstream pools (Starved Rock, Marseilles, and Dresden Island) increase from left to right along the x-axis and deterrence efficacy is held at a constant rate for each panel. Additional mortality for downstream pools (Alton, La Grange, and Peoria) was set to zero for these simulations. Distributions are based on 1,000 iterations per scenario.*

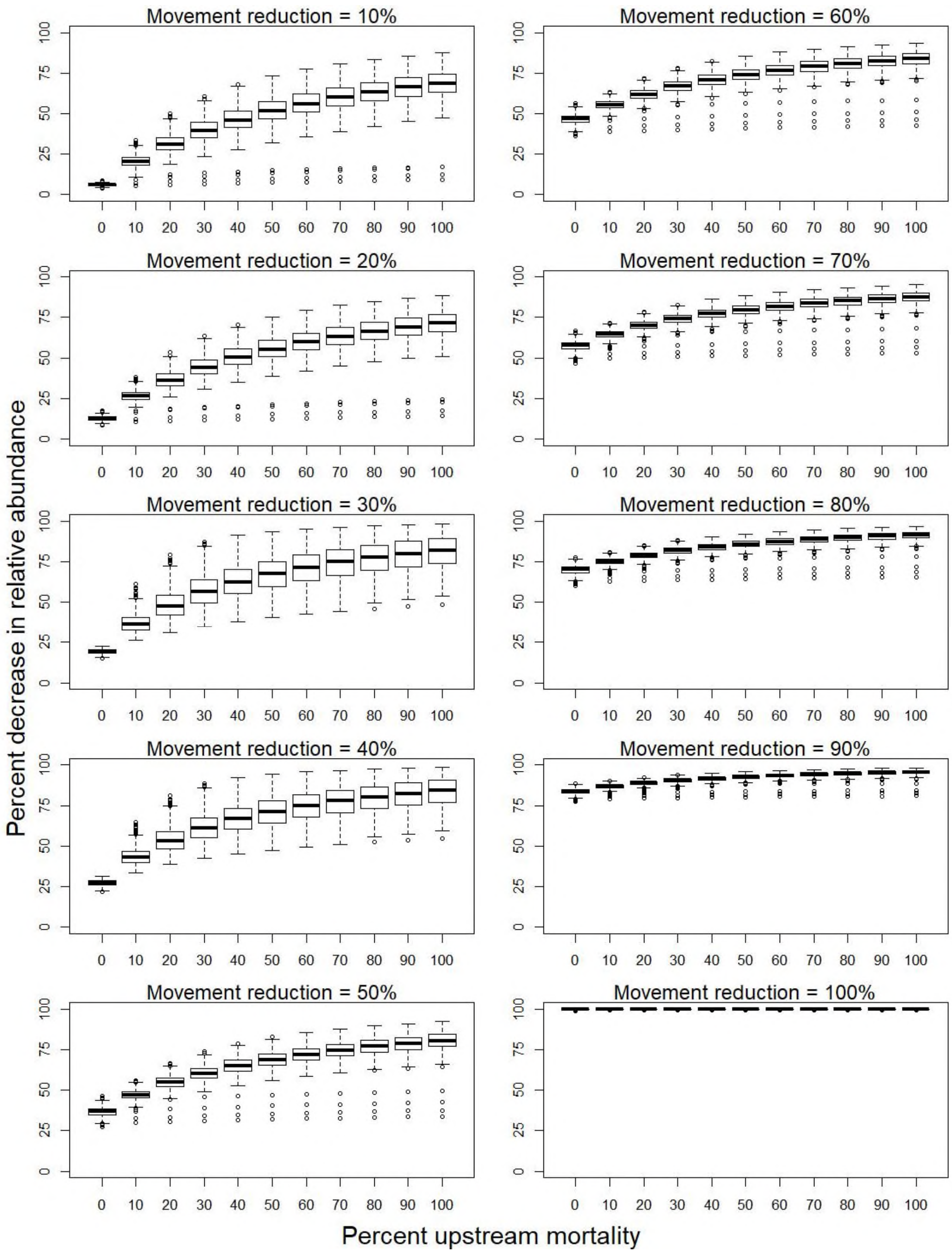

Figure 3. *Boxplots showing distributions of percent decrease in Dresden Island Pool Silver carp abundance relative to the no-action scenario as a function of upstream mortality (i.e., additive mortality for Silver carp ≥500 mm TL) and upstream movement deterrence at Marseilles Lock and Dam under varying efficiency levels. Mortality levels for the upstream pools (Starved Rock, Marseilles, and Dresden Island) increase from left to right along the x-axis and deterrence efficacy is held at a constant rate for each panel. Additional mortality for downstream pools (Alton, La Grange, and Peoria) was set to zero for these simulations. Distributions are based on 1,000 iterations per scenario.*

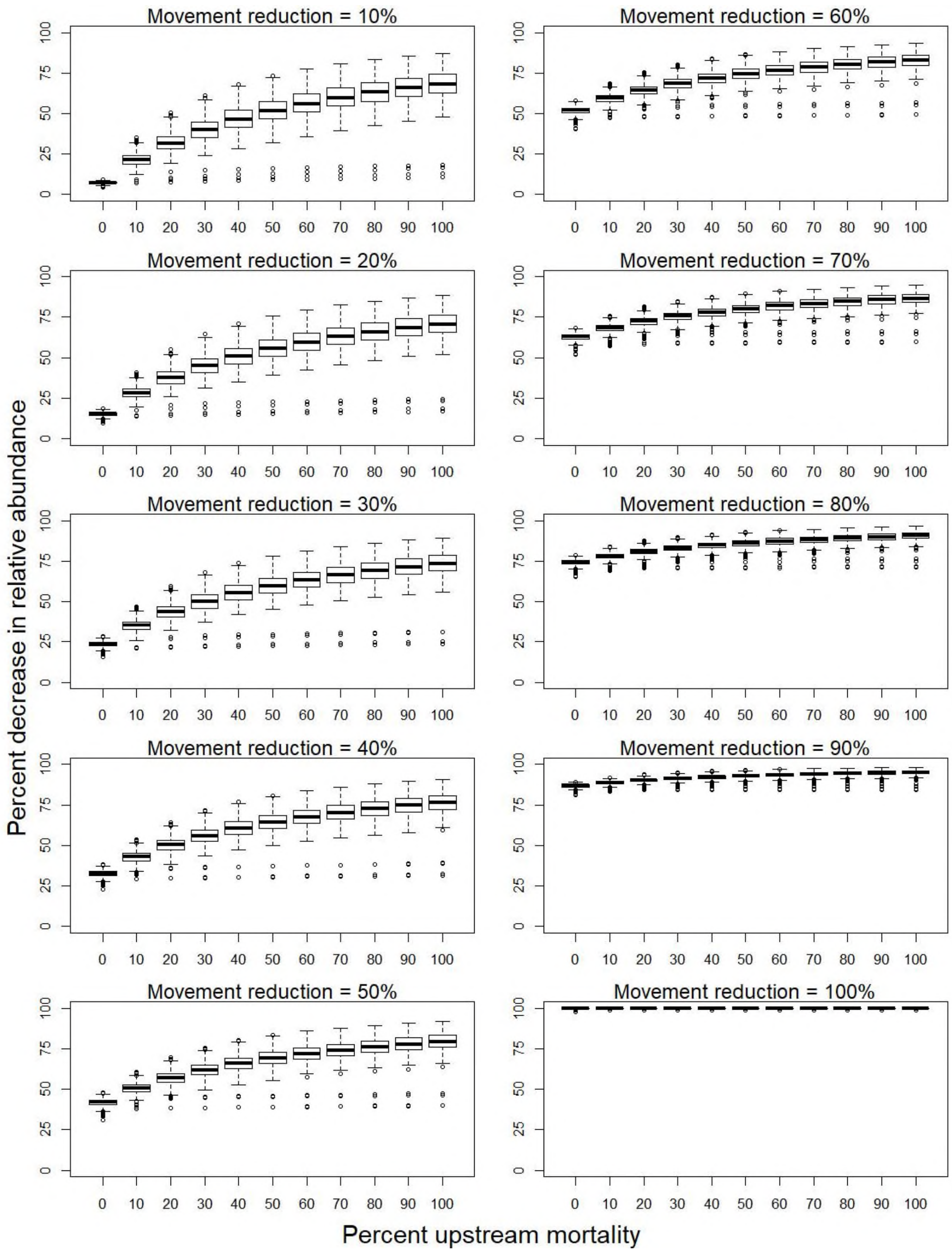

Figure 4. *Boxplots showing distributions of percent decrease in Dresden Island Pool Silver carp abundance relative to the no-action scenario as a function of upstream mortality (i.e., additive mortality for Silver carp ≥500 mm TL) and upstream movement deterrence at Starved Rock Lock and Dam under varying efficiency levels. Mortality levels for the upstream pools (Starved Rock, Marseilles, and Dresden Island) increase from left to right along the x-axis and deterrence efficacy is held at a constant rate for each panel. Additional mortality for downstream pools (Alton, La Grange, and Peoria) was set to zero for these simulations. Distributions are based on 1,000 iterations per scenario.*

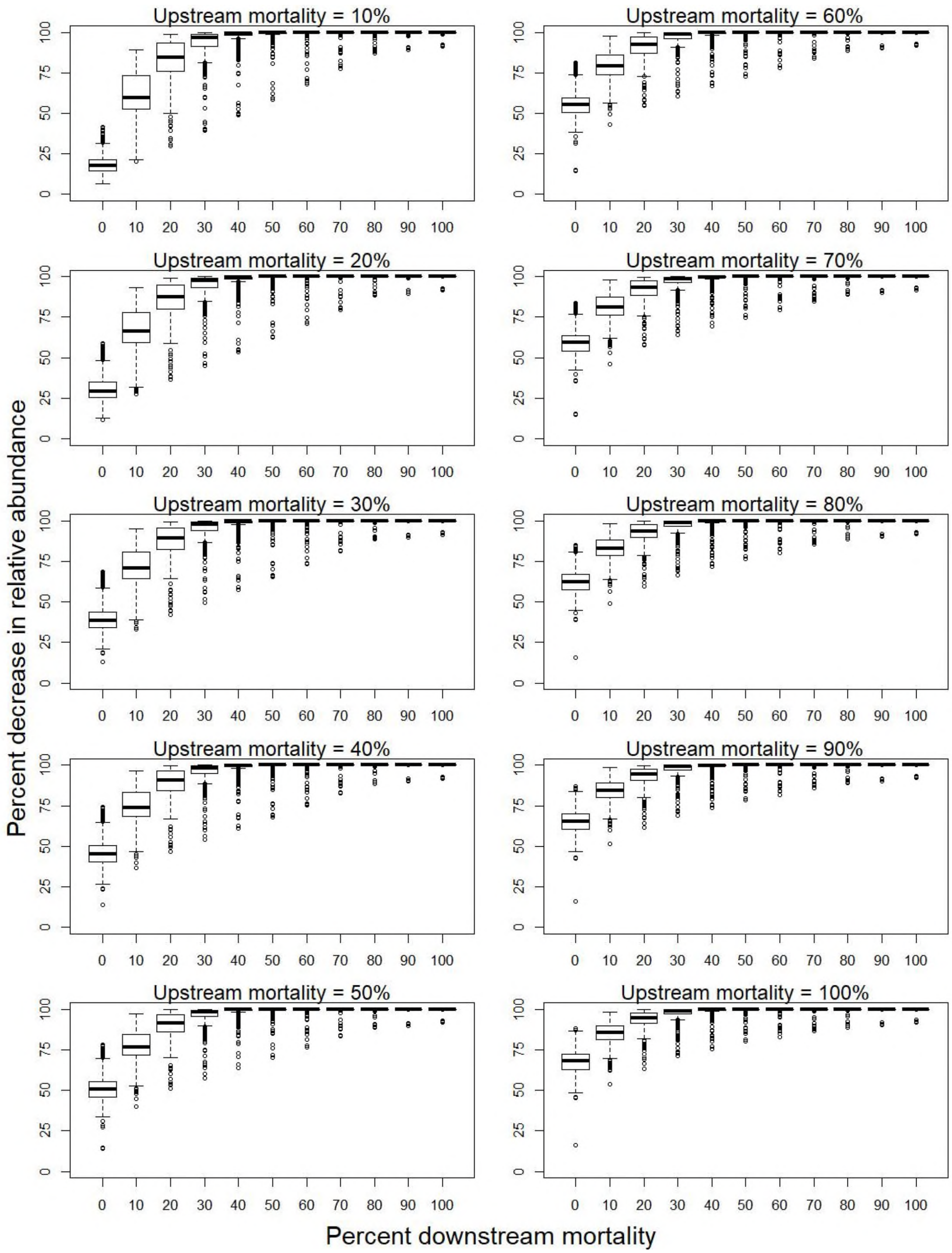

Figure 6. *Boxplots showing the distributions of percent decrease in Dresden Island Pool Bighead carp abundance relative to the no-action scenario as a function of downstream and upstream mortality (i.e., additive mortality for Bighead carp ≥500 mm TL). Mortality levels for the downstream pools (Alton, La Grange, and Peoria) increase from left to right along the x-axis and are held at a constant rate for each panel for upstream pools (Starved Rock, Marseilles, and Dresden Island). Distributions are based on 1,000 iterations per scenario.*

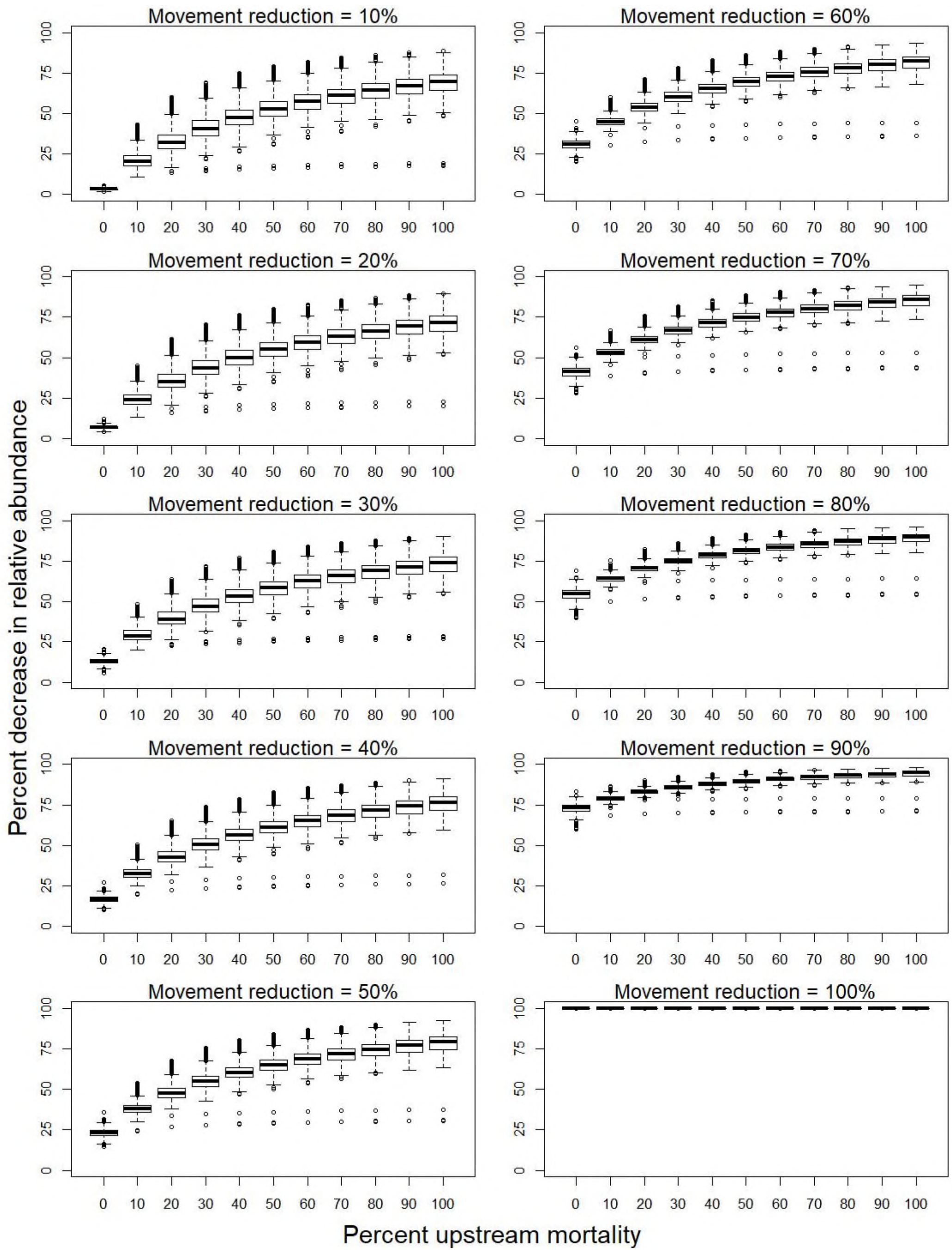

Figure 7. *Boxplots showing distributions of percent decrease in Dresden Island Pool Bighead carp abundance relative to the no-action scenario as a function of upstream mortality (i.e., additive mortality for Bighead carp ≥500 mm TL) and upstream movement deterrence at Dresden Island Lock and Dam under varying efficiency levels. Mortality levels for the upstream pools (Starved Rock, Marseilles, and Dresden Island) increase from left to right along the x-axis and deterrence efficacy is held at a constant rate for each panel. Additional mortality for downstream pools (Alton, La Grange, and Peoria) was set to zero for these simulations. Distributions are based on 1,000 iterations per scenario.*

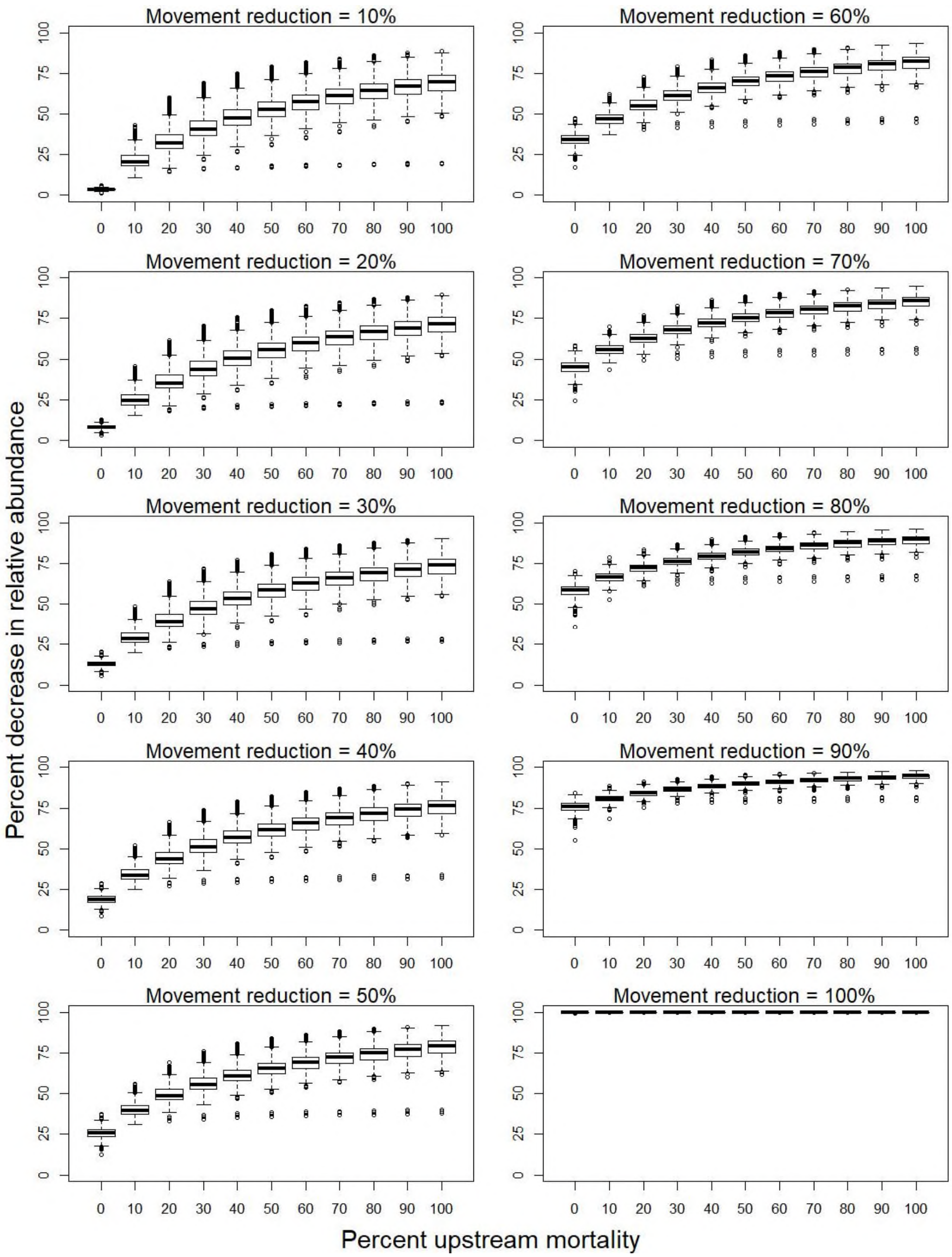

Figure 8. *Boxplots showing distributions of percent decrease in Dresden Island Pool Bighead carp abundance relative to the no-action scenario as a function of upstream mortality (i.e., additive mortality for Bighead carp ≥500 mm TL) and upstream movement deterrence at Marseilles Lock and Dam under varying efficiency levels. Mortality levels for the upstream pools (Starved Rock, Marseilles, and Dresden Island) increase from left to right along the x-axis and deterrence efficacy is held at a constant rate for each panel. Additional mortality for downstream pools (Alton, La Grange, and Peoria) was set to zero for these simulations. Distributions are based on 1,000 iterations per scenario.*

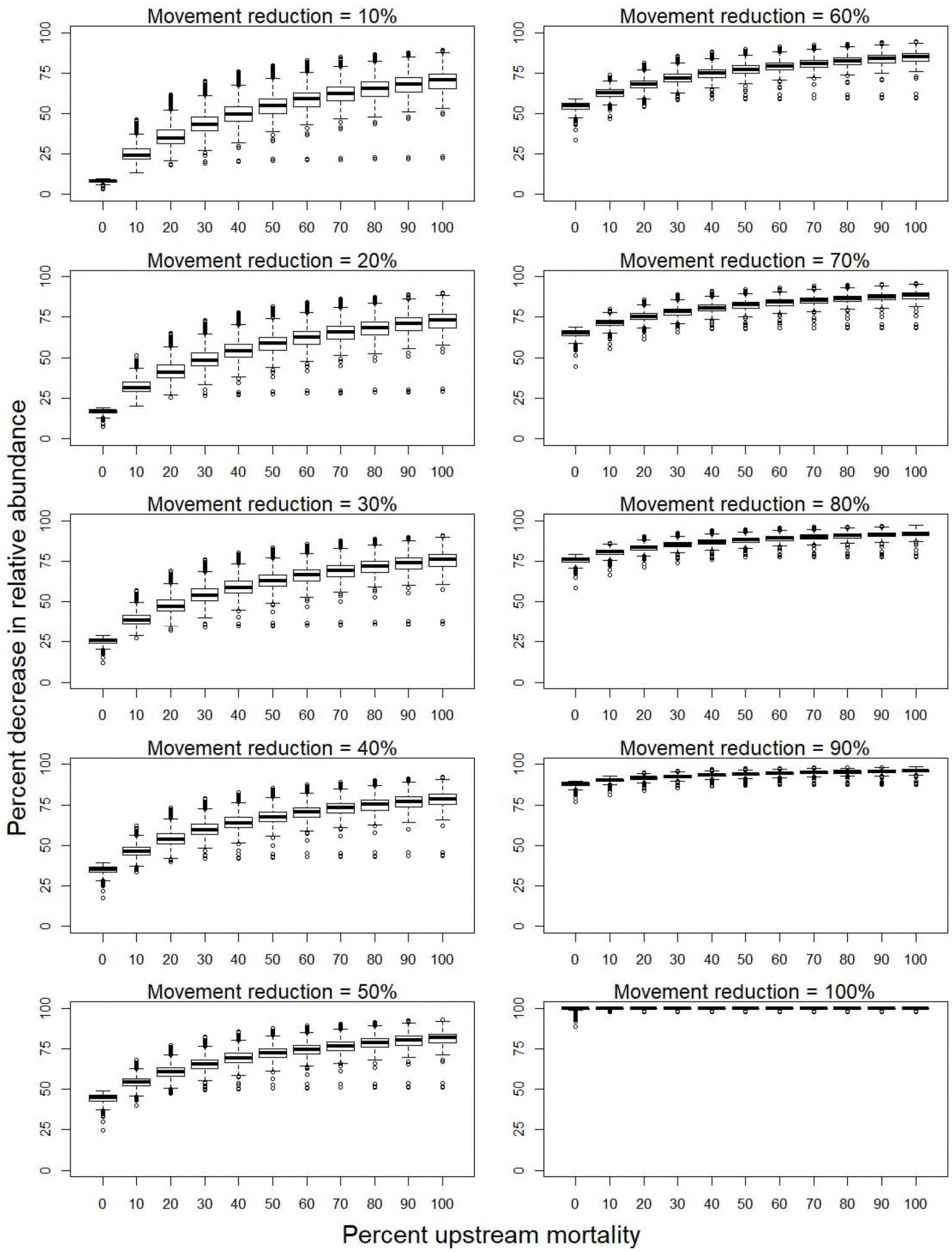

Figure 9. *Boxplots showing distributions of percent decrease in Dresden Island Pool Bighead carp abundance relative to the no-action scenario as a function of upstream mortality (i.e., additive mortality for Bighead carp ≥500 mm TL) and upstream movement deterrence at Starved Rock Lock and Dam under varying efficiency levels. Mortality levels for the upstream pools (Starved Rock, Marseilles, and Dresden Island) increase from left to right along the x-axis and deterrence efficacy is held at a constant rate for each panel. Additional mortality for downstream pools (Alton, La Grange, and Peoria) was set to zero for these simulations. Distributions are based on 1,000 iterations per scenario.*

Asian Carp Population Modeling to Support an Adaptive Management Framework

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

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

Pools Involved: Peoria

Introduction and Need:

Movement is the backbone of the Spatially explicit Asian carp population model (SEACarP) and is the primary driver for how researchers expect the population to respond to management strategies. The simulation model makes several assumptions associated with inter-pool and inter-basin movement. The current movement model provides pool-to-pool transition probabilities, but does not incorporate influential factors such as season, hydrology, fish density, and fish size. Harvest effects such as changes in fish density and size distributions likely impact movement and will thus influence our ability to predict population responses. Further, estimates from the movement model may be biased high and not directly transferable to small fish as initial tagging efforts focused on larger and more mobile individuals (i.e., fish >500 mm total length (TL) that passed one or more lock and dam complexes).

Small Silver and Bighead Carp represent a greater risk of breaching the Electric Dispersal Barrier than larger bodied adults due to the negative relationship between body size and electrical immobilization. Results of research conducted by the U.S. Fish and Wildlife Service (USFWS) have also highlighted passive entrainment of small bodied fishes by barges as a weakness of the Electric Dispersal Barrier. Traditional sampling gears have limitations, including habitat-specific gear efficiency and detection probability, changing environmental conditions, and sparse species distributions. Identifying habitat areas used by juvenile Asian carp will help to inform monitoring efforts by the USFWS and Illinois Department of Natural Resources (IDNR) focused on detecting juvenile Asian carp. Increased knowledge of the habitat usage and movement patterns of juvenile Asian carp, when related to environmental factors, are invaluable for future management actions.

Asian carp demographic information will also be collected throughout 2018 to further bolster the SEACarP. For more information on small Asian carp telemetry please refer to the USFWS Distribution and movement of small Asian carp in the Illinois Waterway using telemetry monitoring and response plan.

Objectives:

(1) Quantify movement frequency and distance of Asian carp,

(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,

(4) Determine macro-habitat selection based on periods of residency of juvenile Asian carp.

Project Highlights:

- 130 Asian carp were tagged within the Peoria Pool (Figure 1) ranging in size from 391-635mm TL.
- In addition, 81 small Asian carp (122mm-352mm TL) were tagged as part of the USFWS Distribution and movement of small Asian carp in the Illinois Waterway using telemetry project.

Methods

In addition to the juvenile Asian carp habitat project which is focused on tagging fish 300mm and below, staff will also tag all Asian carp collected that are 300-500mm. The Vemco V-5 tags currently used for the small fish telemetry project use 180 kHz receivers which is different than the 69 kHz array which is currently dispersed throughout the Illinois River. Work conducted in support of the SEACrP model will use Vemco V-9 and V-13 tags which are on the 69 kHz frequency. This will give biologists a better understanding of more 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.

FWS crews will tag an additional Asian carp in and around the Peoria Pool using Vemco V-9 and V-13 tags. This large scale tagging of adult and juvenile Asian carp will provide more information for the model to better estimate current levels of exploitation and to bolster estimates of large-scale pool to pool movement.

Asian carp will be captured using boat electrofishing and electrified dozer trawl from the Illinois River. 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.

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

The surgery site will be gently washed with several drops of betadine prior to making an incision. Using a #12 hook blade scalpel, a 1cm (Vemco -5 acoustic tags) or 2.5 cm (Vemco-9 or V-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, IL) 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 de-ionized 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 Illinois Waterway. Additional receivers will be placed in areas with reduced coverage and the MRWG Telemetry Working Group will be consulted prior to deployment.

For more information on the SEACarP Model, please refer to the SEACarP Modeling Interim Summary Report.

Results and Discussion:

Over a three month period in 2018, 130 large Asian carp (>300mm TL) were captured, tagged and released within the Peoria Pool (Figure 1 & Table 1). The tagged Asian carp ranged in size from 391-635mm TL. Sixty-four fish were tagged with V-9 tags and 66 with V-13 tags. Tags used were chosen based on the length of the fish, V-9 <450mm TL and V-13 >450mm TL. Four of the fish captured on August 16 were also tagged with Lotek radio tags (391-635mm TL). These radio tags are used as part of the USFWS Distribution and movement of small Asian carp in the Illinois Waterway using telemetry project. Prior to the fish being tagged and released, six additional acoustic receivers were placed throughout the Peoria Pool in addition to the already existing array. The MRWG Telemetry Working Group was consulted prior to deployment for optimal placement and coverage.

Processing of the tracking data is ongoing. Results will be transmitted to the Monitoring and Response Working Group when complete. This project will continue in 2019 and an additional 150 tags will be implanted. Distribution of tagged fish will, once again, be spread throughout the Peoria Pool.

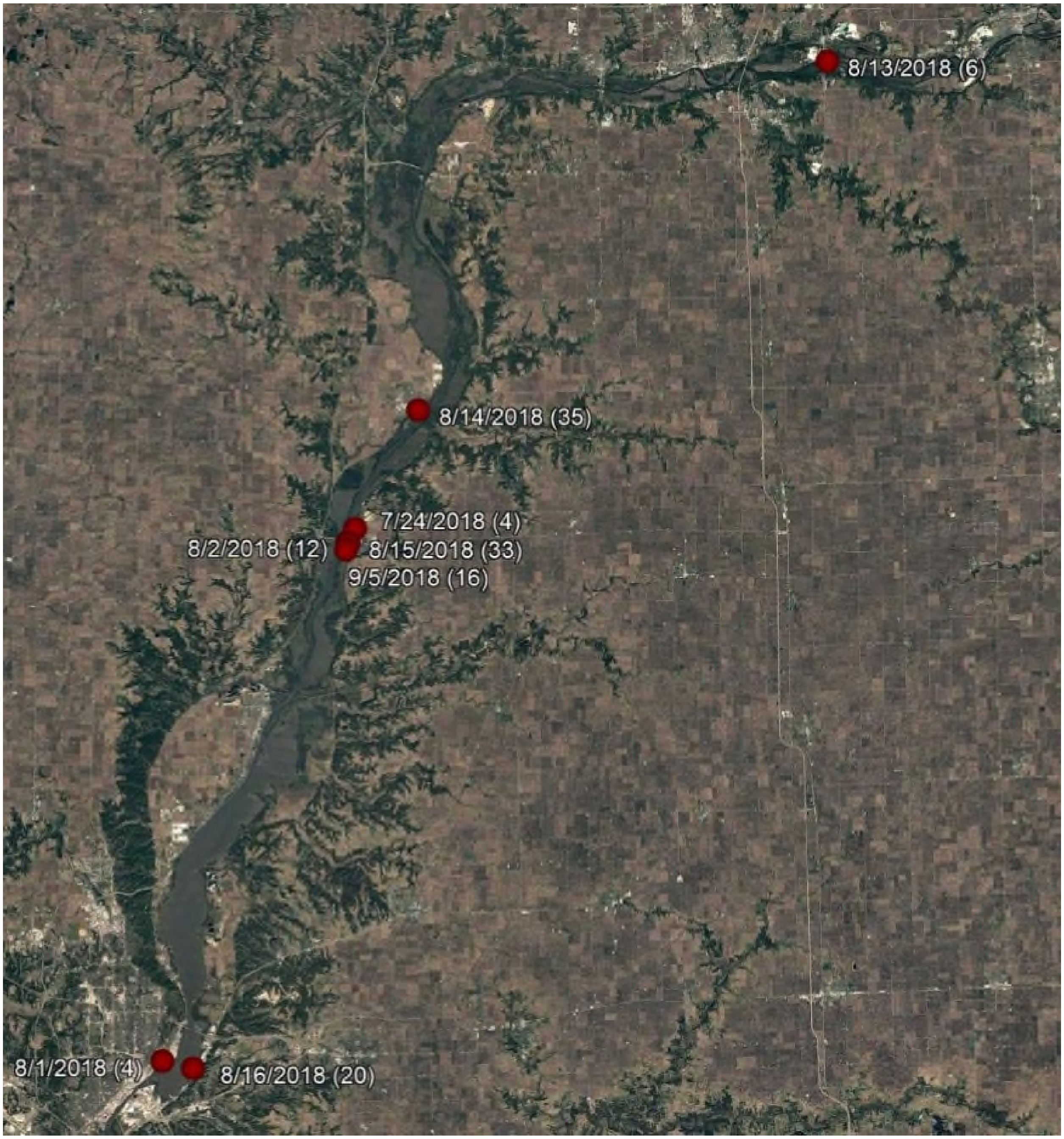

Figure 1. *Map of the Peoria Pool showing the locations tagged fish were released by date and number in 2018. (Google Earth)*

Table 1. *2018 Asian carp tagged in support of the SEACarP Model*

Date	Equipment used to capture AC	Number of AC tagged	Release location within Peoria Pool*
7/24/2018	Dozer	4	Middle
8/1/2018	Dozer	4	Lower
8/2/2018	Dozer	12	Middle
8/13/2018	Dozer	6	Upper
8/14/2018	Electrofishing	35	Middle
8/15/2018	Electrofishing	33	Middle
8/16/2018	Electrofishing	20	Lower
9/5/2018	Dozer	16	Middle

*See Figure 1 for map depiction of release locations.

Asian Carp Demographics

Jeremy Hammen, Jahn Kallis, and Eddie Sterling (US Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office); Jeff Jolley, Duane Chapman, Anne Herndon, and Joel Yeager (USGS Columbia Environmental Research Center)

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

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

Introduction and Need:

Management of invasive Asian carp in the Upper Illinois Waterway (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. Although the SEAcarP model represents one such tool, there remains great need to address data gaps identified by the modeling workgroup. In the Illinois River there are two sources of data: fisheries independent data collected through a standardized protocol and fishery-dependent data collected from commercial or recreational sources targeting fish. To address data gaps associated with the SEAcarP model, the US Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office (USFWS Columbia FWCO) collected fisheries-independent Silver Carp data from portions of the upper Illinois Water Way (IWW; Starved Rock and Marseilles pools) and from the lower IWW (Alton, LaGrange, and Peoria pools) for which there is a paucity of data. In addition, the USFWS coordinated with Illinois Department of Natural Resources (ILDNR) contracted fishermen to collect supplemental data during a fall removal effort in the Peoria, Starved Rock, Marseilles, and Dresden Island pools. This data will be used to determine Silver Carp spawner biomass, recruitment, age, and growth data

Development of data-driven tools for control of Asian carp requires a high level of accuracy and precision when aging Asian carps, but these fish can be difficult to age and opinions vary as to the best methods. Cyprinids as a whole are notoriously more difficult to age than some other families of fish. Asian carp growth rate can vary tremendously, depending on resources available. Asian carp can spawn any time that the water is the right temperature (Deters et al. 2013), therefore the first annulus can vary substantially in its location relative to the focus. Because Asian carp can be batch spawners, with more than one spawning effort in the same year, multiple spawn "checks" can occur at nearly any time during the warm months. Some of the more favored aging structures are prone to development of large lumens (Fischer and Koch 2017) that obscure multiple annuli. Published opinions on the value of otoliths for aging Silver Carp are varied, and varieties of hard structures have been used to age Silver Carp (Phelps et al. 2017). Publications that incorporate aging of Asian carp have had few or no "known age" validations of aging techniques used. There is a need for consensus and development of a "gold standard" aging method for these important invasive fishes, as well as a better understanding of the accuracy of that method. We describe here an effort to develop that gold standard and to define that accuracy.

Objectives:

(1) Quantify size and sex structure, length at maturity, and relative abundance during spring and fall in the lower five pools of the Illinois River.

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

(3) Work with ILDNR contracted fishers during a two-week intensive data collection effort during October 2018.

(4) Transfer Asian carp captured in the field to USGS for laboratory processing (e.g. aging) and inclusion in the USGS-led age and growth workshop during August 2018.

(5) Recruit team of acknowledged experts in aging fish, including but not limited to persons experienced with Asian carps.

(6) Extract, prepare, and image a suite of aging structures from available known-age Asian carp and Asian carp collected from the Illinois River.

(7) Convene workshop and generate a consensus "gold standard" methodology for aging Asian carps.

(8) Using that standard method, generate age and growth information for Illinois River Silver Carp.

Project Highlights:

- In spring and fall 2018, we completed a demographics protocol in five pools of the Illinois River in 4-5 weeks.
- Executing this standardized sampling method with the electrified dozer trawl to collect demographic data was time efficient and representative. Samples can be used to measure population responses to changes in management strategies.
- Approximately 2,800 Silver Carp measuring 40-872 mm were captured. Size classes varied across pools and seasons.
- Relative abundances of Silver Carp appeared to decrease moving upstream within the Illinois River.
- 25 small Silver Carp (< 153 mm) were captured: 22 in the LaGrange Pool measured 40 to 140 mm and two in the Alton Pool measured 50 to 76 mm.
- Collaborated with ILDNR staff and contract fishers, during a two-week intensive removal effort in Peoria, Marseilles, and Dresden Island to collect fishery-dependent demographic data.

  - Length, weight, and sex data was collected from Asian carp captured in the Dresden Island, Marseilles, Starved Rock, and Peoria pools
  - Aging structures were collected from 62 Silver Carp to supplement the standardized demographics data set. These were larger Silver Carp (650-912) that were less represented in the standard demographics sampling.
- USGS-CERC and USFWS Columbia FWCO convened a group of 12 experts in fish age estimation to develop a range-wide, standard protocol for aging techniques of Silver Carp.
- The USGS-CERC is facilitating a scientific approach for developing the "gold-standard" manual for aging Silver Carp, including the processing of structures and age estimation methods.

Methods:

In 2018, the USFWS Columbia FWCO collected fisheries-independent data on Silver Carp using a random design stratified by habitat type (i.e., backwaters, island side channels, main-channel borders) during spring (May - June) and fall (September – November) in the upper IWW (i.e., Starved Rock and Marseilles pools) and the lower IWW (Alton, LaGrange, and Peoria pools). Habitat classifications were based on aquatic area designations developed by the Habitat Needs Assessment II project (USACE 2017). Prior to each sampling event, collection sites were randomly selected from a Geographic Information System (GIS) that includes habitat data and an indexed 50- by 50-m grid. Fifty collection sites per pool were sampled by conducting 5-minute trawls at 4.8 kilometers per hour (calculated by GPS tracking) using the electrified dozer trawl. Trawl runs did not overlap. An initial sample size of 50 (5-minute trawls) per pool was selected because catch rate data from Illinois River backwaters (2014-2017 Template: Gear Evaluation for Removal and Monitoring of Juvenile Asian Carp) revealed that the precision associated with this amount of effort was within acceptable levels (i.e., 25% relative standard error; Koch et al. 2014). Fish length and weight was measured for all captured Bighead and Silver carp. Subsamples consisting of 10 small (≤ 300 mm total length) or five large (> 300 mm total length) individuals per 50 mm length class were targeted for laboratory analysis (i.e., age, sex, maturity status) by USGS. All by-catch were identified to species, enumerated, and released at point of capture. Silver Carp catch rates and size structures are reported.

The USFWS coordinated with ILDNR contracted commercial fishers during a two-week intensive data collection effort in October of 2018. Supplemental records including length, weight, and sex data and aging structures from a subset of fish were collected. These data will be used to 1) inform the population model on Asian carp demographics in the upper IWW and their vulnerability to harvest as a function of total length, and 2) provide data to incorporate into a statistical catch-at-length model that will provide a secondary source of information regarding immigration into upper pools and exploitation levels. Silver Carp aging structures were collected following a standard operating procedure developed during the fishery independent component of this project and sent to USGS-CERC for processing.

In August 2018, USGS hosted an aging workshop comprised of expert agers to develop an aging protocol for Silver Carp. They discussed structure processing, age assignments, and preferred structures that minimize bias in estimating fish ages. They evaluated several aging structures: lapilli otolith, postcleithra, primary dorsal fin ray, the leading and secondary process of the first pectoral fin ray, whole vertebrae, and sectioned vertebrae for a total of seven structure comparisons

All data collected as part of this project has been or will be transferred to the modeling workgroup for analyses associated with the SEAcarP model. Analyses conducted under this project will be used to determine if a single season sampling design sufficiently meets data needs regarding indices of spawner abundance and recruitment. A minimum of two years (2018-2019) of data are suggested under this protocol before a determination is made for long-term field data collection and data workflow.

Results and Discussion:

The USFWS Columbia FWCO conducted 50 electrified dozer trawl transects as part of a standardized protocol deployed in each of five pools of the Illinois River over 4-5 weeks in spring and fall 2018. Approximately 2,800 Silver Carp were captured and catch rates were similar between seasons in each pool except in the Alton and Marseilles pools where spring had lower catch rates (Figure 1). Silver carp catch rates were lower in the upper IWW (Starved Rock and Marseilles pools) compared to the lower IWW (Alton, LaGrange, and Peoria pools). The relative abundances of the different pools were indicative of the longitudinal pattern of Asian carp densities observed in the Illinois River with high densities observed in the downstream pools and lower densities in upstream pools.

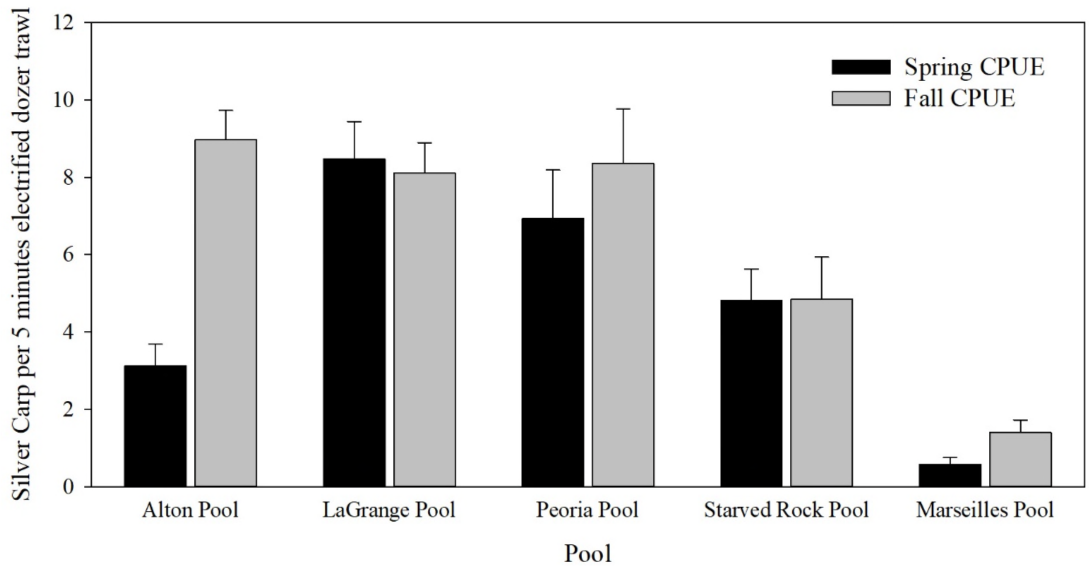

Figure 1. *Silver Carp catch per unit of effort (CPUE; fish/five minutes) in the Alton, LaGrange, Peoria, Starved Rock, and Marseilles pools of the Illinois River, Illinois, in spring and fall of 2018.*

The electrified dozer trawl captured Silver Carp measuring 40-878 mm across all pools and seasons. In total, 25 small Silver Carp (< 153 mm) were captured in the fall and those captures were limited to the Alton and LaGrange pools. There were 22 small Silver Carp captured in the LaGrange Pool that measured 38 to 140 mm and two in the Alton Pool that measured 51 and 76 mm (Figure 2). The larger Silver Carp were captured in the upper IWW (Starved Rock and Marseilles Pool) of the Illinois River (Figure 2, Table 1).

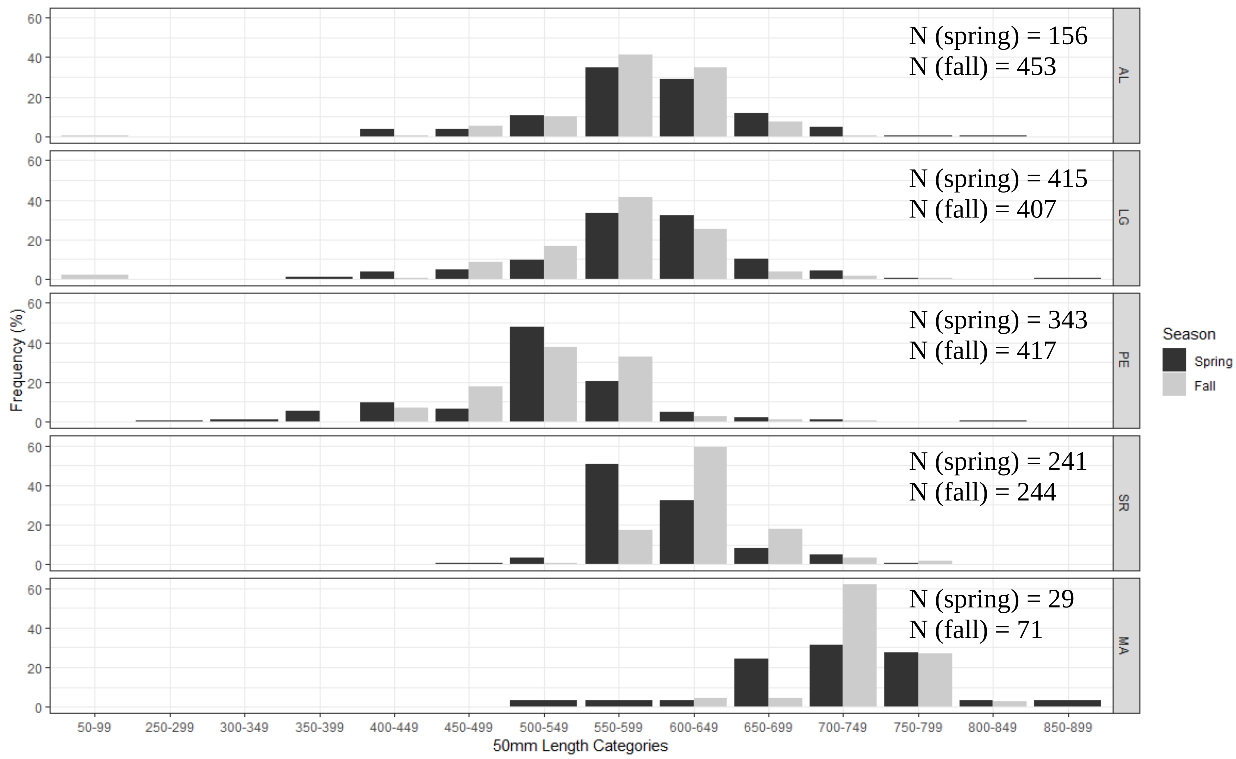

Figure 2. *Length-frequency histograms and total catch (N) for Silver Carp in each pool (Alton Pool [AL], LaGrange Pool [LG], Peoria Pool [PE], Starved Rock Pool [SR], Marseilles Pool [MA]) in spring and fall of 2018.*

Table 1. *Total Silver Carp catch at each length category in five pools of the Illinois River in spring and fall 2018 to determine the proportional size distribution described by Phelps and Willis (2013; substock [<250mm], stock [251 – 450 mm], quality [451 – 560 mm], preferred [561 – 740 mm], memorable [741 – 930 mm], and trophy [>930]). Percentage of total Silver Carp catch per pool is in parenthesis.*

Spring						
	Substock	Stock	Quality	Preferred	Memorable	Trophy
Alton Pool	0 (0)	6 (4)	30 (19)	117 (75)	3 (2)	0 (0)
LaGrange Pool	0 (0)	20 (5)	77 (19)	312 (75)	6 (1)	0 (0)
Peoria Pool	0 (0)	58 (17)	221 (64)	62 (18)	2 (<1)	0 (0)
Starved Rock Pool	0 (0)	0 (0)	18 (8)	222 (92)	1 (<1)	0 (0)
Marseilles Pool	0 (0)	0 (0)	2 (7)	16 (55)	11 (38)	0 (0)
Fall						
	Substock	Stock	Quality	Preferred	Memorable	Trophy
Alton Pool	3 (<1)	1 (<1)	96 (21)	352 (78)	1 (0)	0 (0)
LaGrange Pool	22 (5)	2 (<1)	119 (29)	263 (65)	1 (0)	0 (0)
Peoria Pool	0 (0)	31 (7)	273 (65)	112 (27)	1 (0)	0 (0)
Starved Rock Pool	0 (0)	0 (0)	5 (2)	234 (96)	5 (2)	0 (0)
Marseilles Pool	0 (0)	0 (0)	0 (0)	42 (59)	29 (41)	0 (0)

Energy allocation to reproduction strongly influences the relationship between length and weight. Consequently, we plotted spring and fall length-weight data separately. This analysis indicated that, with exception to Marseilles pool the rate at which Silver Carp increase in weight per unit length was similar across pools. Differences observed in Marseilles pool data appeared negligible.

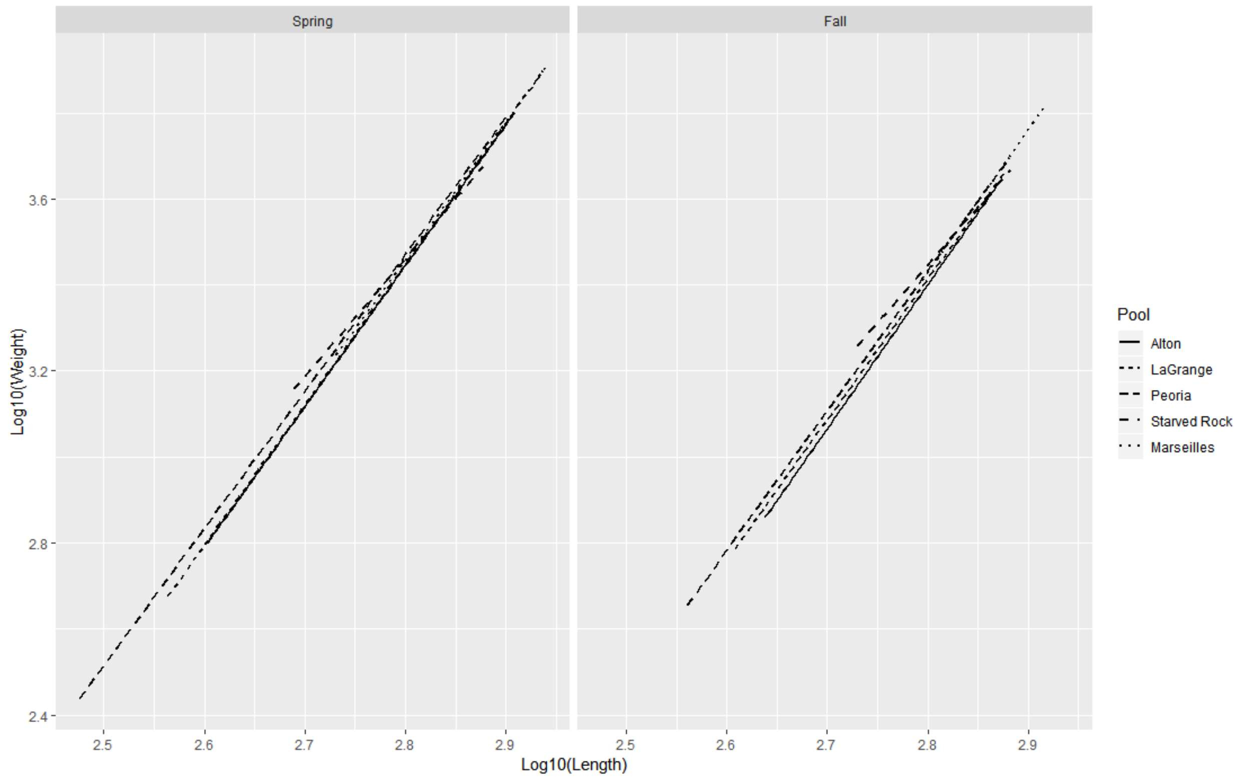

Figure 3. *Length vs. weight regressions for five pools (Alton Pool [AL], LaGrange Pool [LG], Peoria Pool [PE], Starved Rock Pool [SR], Marseilles Pool [MA]) in spring (top graph) and fall (bottom graph) 2018 in the Illinois River, Illinois.*

During October 2018, US Fish and Wildlife Service collected demographic data (i.e., length, weight, age structures, sex) from Silver Carp captured during contract fishermen targeted gill net efforts coordinated by ILDNR in the Dresden Island, Marseilles, Starved Rock and Peoria pools. Data from this effort was used to boost sample sizes relative to target numbers (i.e., 10 small (≤ 300 mm total length) or five large (> 300 mm total length) individuals per 50 mm length class). Aging structures were collected from 38 Silver Carp ranging from 650 to 912mm captured in Dresden Island Pool and 24 Silver Carp ranging from 750 to 900mm in the Peoria, Starved Rock and Marseilles pools. In addition, the number of Silver Carp females relative to the total number of Silver Carp captures was quantified using methods described by Wolfe et al. (2018). The proportion of females was substantially lower in Dresden Island pool (17%) relative to Marseilles (35%), Starved Rock (43%), and Peoria (40%) pools. Two possible explanations for this pattern include selective removal of female fish over consecutive years of harvest due to size-dependent differences in their vulnerability to fishing (e.g., Fenberg and Roy 2008) or alternatively higher net upstream movement of male fish relative to female fish. Underlying mechanisms that influence sex ratios in the Illinois River should be investigated given the potential for fishery-induced shifts toward male dominated populations to limit recruitment potential through its effects on total egg production.

In August 2018, the USGS - CERC hosted the group of experts in fish age estimation for a face-to-face workshop to discuss sample processing, age assignments, and preferred structures that minimize bias in estimating fish ages. Workshop attendees examined multiple aging structures (otoliths, dorsal and pectoral fin rays, vertebrae, and postcleithra) from 100 Silver Carp captured during the spring 2018 data collection in the Illinois River to determine which structures would be appropriate to use for aging analysis. Preliminary workshop results indicated high variability in aging precision for each structure with the coefficient of variation (CV) among age estimates by multiple readers always greater than 25%. Whole vertebrae and sectioned vertebrae were eliminated from consideration due to high CV and low reader confidence.

Since the workshop, the USGS-CERC has drafted proposed standard rules and utilized this guidance to begin aging Silver Carp collected by USFWS Columbia FWCO as part of the Silver Carp demographics project in the Illinois River. Preliminary reassessment of aging structures incorporating the standard rules revealed significant improvements in precision of age estimates among readers with minimum reduction in CV by 25%.

In 2019, a standard technique or “gold standard” manual and peer-reviewed publication will be developed based on the results of the workshop and subsequent efforts to determine the best practices for aging Silver Carp. From these efforts, USGS will assist USFWS with analysis and publication of a manuscript on age and growth of bigheaded carp captured from the lower five pools of the Illinois River. This information will be used to populate the SEAcarP Model.

Recommendations:

- Increase field sampling efficiency via updates to pool-specific sample sizes using power analyses based on 2018 data
- Implement results from the USGS-led age and growth workshop to future aging structure collections
- Investigate underlying causes that explain male dominated silver carp populations
- Evaluate the potential benefits and costs of using dozer trawl collections to inform hydroacoustics data in tandem or separately from currently used physical capture gears.

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RESPONSE PROJECTS

Contingency Response Plan Actions

Participating Agencies: IDNR, USFWS, USACE, USGS, INHS, USEPA, GLFC

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

Introduction and Need:

A Contingency Response Plan has been developed to guide response actions within the five navigation pools of the Upper Illinois Waterway (IWW) - Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock pools (river miles 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, the plan will be implemented to carry out response actions. The current status is presented in Figure 1.

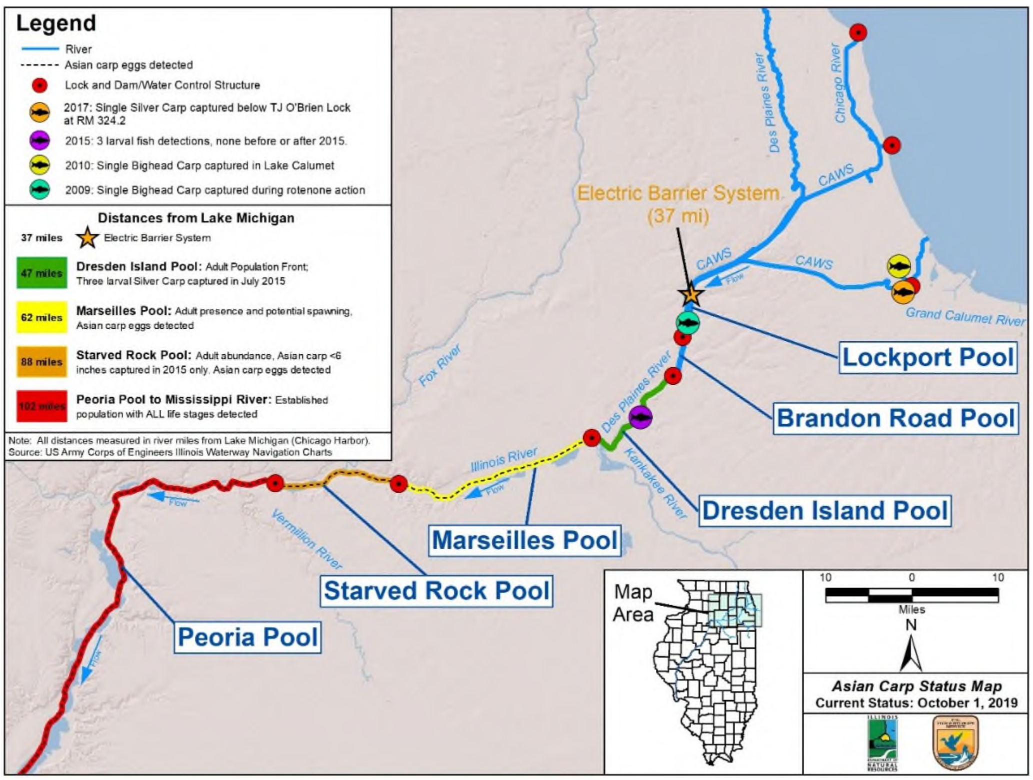

Figure 2. *Asian carp Status Map. Current Status: October 1, 2019.*

Results and Discussion:

There were no changes in the status of Asian carp that required the activation of the Contingency Response Plan during 2018. Planning was initiated to conduct a table-top exercise that will allow stakeholders to practice implementing the Contingency Response Plan, and will be used to evaluate the plan and identify potential improvements. Efforts were made to conduct the table-top exercise during 2018, but based on the availability of key stakeholders the exercise will be held during 2019.

APPENDICES

Appendix A: Using zooplankton to measure ecosystem responses to Asian carp barrier defense and removal in the Illinois River

Thomas M. Detmer, Anthony P. Porreca, Steven E. Butler, Joseph J. Parkos III, David H. Wahl (Illinois Natural History Survey)

Participating Agencies: Illinois Natural History Survey (lead)

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

Introduction: The arrival and establishment of large numbers of Asian carp in the Illinois Waterway poses a major ecological threat to the connected Great Lakes ecosystems. Due to their ability to efficiently filter large volumes of water and capture small particle sizes, Asian carp can deplete zooplankton densities and alter community composition, potentially competing with native fishes for food resources and altering flows of organic matter. The potential impacts of Asian carp on native fishes poses a substantial risk to recreational and commercial fisheries economies of several states, provinces, and tribes. Due to these risks, an aggressive Asian carp removal strategy has been implemented in the Illinois Waterway to limit further advances of Asian carp towards Lake Michigan. In addition to aiding in preventing the expansion of Asian carp towards the Great Lakes, this removal program may also benefit native fish assemblages in the Illinois Waterway by reversing some of the ecological impacts that Asian carp have had on this system. However, the extent and pace of potential ecosystem responses due to Asian carp removals are uncertain. This project will help determine the extent to which the removal strategy is working to reverse ecosystem impacts from Asian carp and continue long-term monitoring of zooplankton in the Illinois River. Previous data have shown that zooplankton dynamics are a relatively rapid index of ecosystem response because most riverine zooplankton taxa have relatively short generation times and high productivity rates, making these data an efficient tool for informing potential management strategies. Ultimately, this information will aid decision-making in the Great Lakes region as well as other aquatic systems that Asian carp have or may eventually invade.

Objectives: Zooplankton are being sampled throughout the Illinois Waterway and adjacent backwaters to:

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

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

3.) Identify changes in zooplankton assemblage composition and population dynamics of the Illinois River coinciding with the establishment of Asian carp.

Appendix A: Using zooplankton to measure ecosystem responses to Asian carp barrier defense and removal in the Illinois River

Project Highlights:

- A total of 210 zooplankton samples were collected from the Illinois Waterway during 2018. Preliminary analyses indicate considerable spatial and temporal variation among zooplankton assemblages within this system, with notable differences in assemblage structure, density, and biomass between the upper and lower Illinois Waterway, and between main channel and backwater locations.
- Ongoing analyses are assessing the influences of environmental factors and both short- and long-term changes in Asian carp densities on zooplankton assemblage metrics and establishing targets of ecosystem response for assessing the effectiveness of Asian carp removals.

Methods: Field sampling for assessment of zooplankton trends took place from March to October of 2018 at established sites to maintain consistency and data comparability. Zooplankton were collected by obtaining vertically-integrated water samples using a diaphragmatic pump. At each site, 90 L of water was filtered through a 55 μm mesh to obtain crustacean zooplankton and 10 L of water was filtered through a 20 μm mesh to obtain microzooplankton. Organisms were transferred to sample jars and preserved in either Lugols solution (4%; for macrozooplankton) or buffered formalin (10%; for rotifers).

In the laboratory, individual organisms are being identified to the lowest possible taxomomic unit, counted, and measured using a digitizing pad. Zooplankton densities are being calculated as the number of individuals per liter of water sampled. Biomass is being calculated using standard length-mass regressions for each taxa. Zooplankton responses to removal are being assessed by comparing densities, biomass, community composition, and demographic parameters (estimated birth rate, mortality rate, population growth rate) through time among sites with varying Asian carp densities and harvest levels. Similar assessments are being used to evaluate the overall effects of the Asian carp invasion using archived samples and historical data sets from before the establishment of Asian carp in the Illinois Waterway.

Results and Discussion: During 2018, a total of 210 zooplankton samples were collected from the Illinois Waterway. Sample processing is ongoing. Preliminary analyses indicate that sites in the lower Illinois River (downstream of Starved Rock L&D) displayed higher temporal variation in zooplankton assemblage structure than sites in the upper river during 2018 (Figure 1). Zooplankton assemblages of the upper and lower Illinois Waterway became more dissimilar from each other from spring into the summer months. Overall density and biomass of macrozooplankton (≥ 55 um) were considerably higher in the lower Illinois River (lower LaGrange and Alton Pools, river km 0 – 193) than at upstream locations during May, but peak

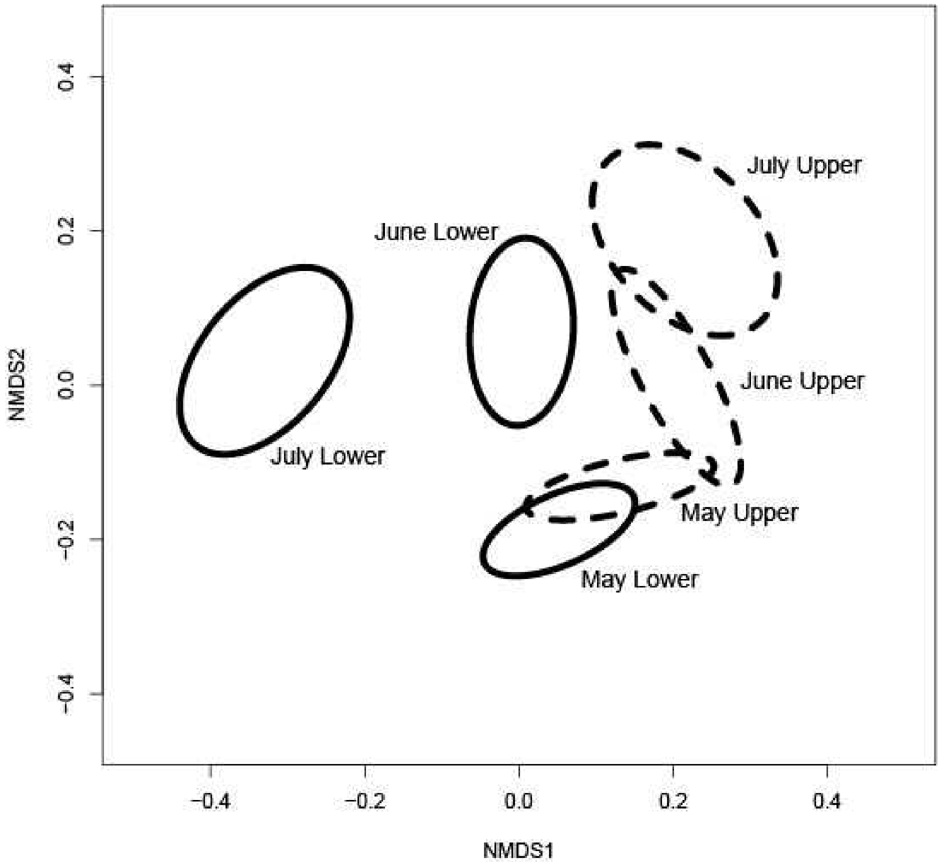

Figure 1. *Nonmetric multidimentional scaling (NMDS) ordination (Bray-Curtis similarities, 2D stress = 0.19) of zooplankton assemblage structure in different areas in the Illinois Waterway over three months of sampling in 2018. Upper and lower river designations describe areas upstream (Upper) and downstream (Lower) of Starved Rock L&D (river km 371.8). Each assemblage is delineated by its standard deviation ellipse.*

zooplankton abundance shifted farther upriver during June and July (Figure 2). These patterns were largely driven by the large rotifer taxa that comprised the majority of zooplankton collected in 55 µm samples. Cladoceran zooplankton density and biomass increased with distance upstream during May and June, with especially large increases at sites upstream of Starved Rock L&D during June. By July, this pattern reversed, with cladoceran density and biomass being highest in the lower Illinois River (Figure 3). Zooplankton abundances differed between backwater and main channel environments, with the Hanson Material Service backwater consistently containing substantially higher zooplankton density and biomass than the main channel of the Marseilles Pool. Total macrozooplankton densities and biomass in the main channel and backwaters of the LaGrange Pool broadly overlapped, although this pattern was driven by large rotifer taxa. In contrast, density and biomass of crustacean zooplankton was consistently higher in the main channel of the LaGrange Pool than in the backwaters.

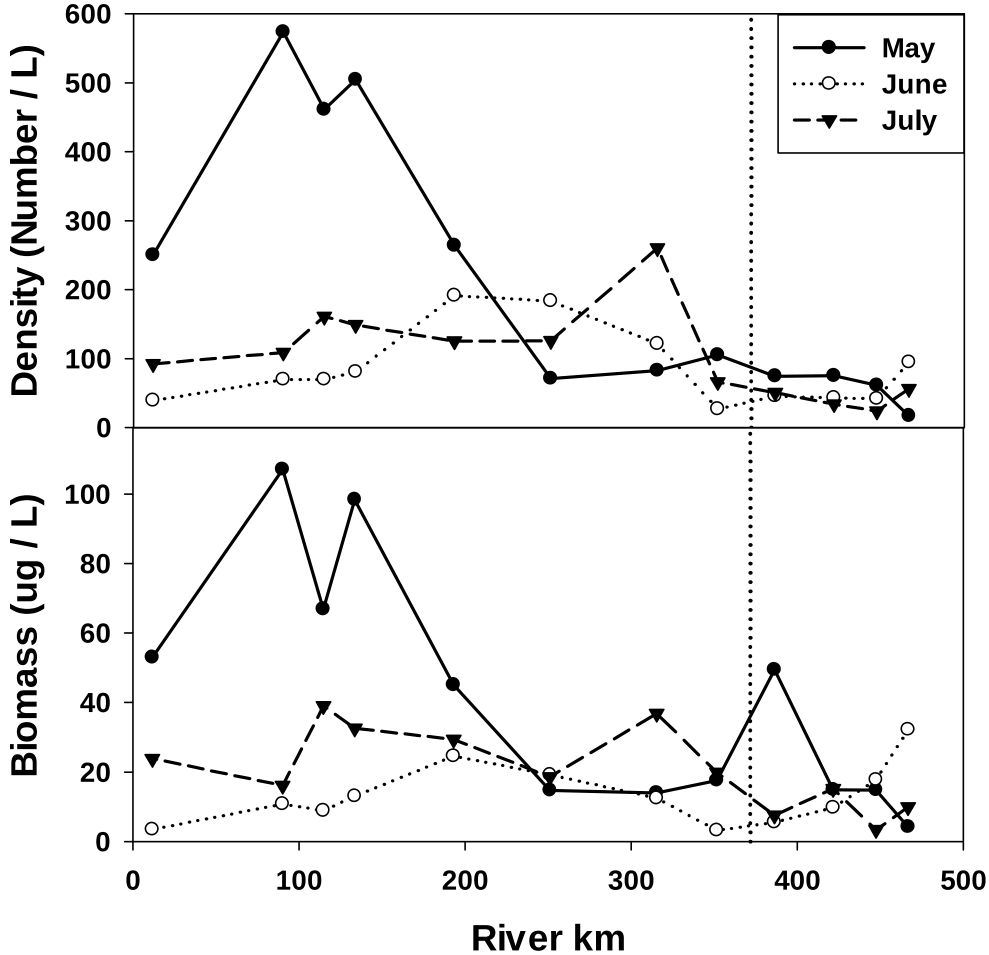

Figure 2. *Total macrozooplankton (≥ 55 µm) density (top panel) and biomass (bottom panel) across the Illinois Waterway from near Grafton (river km 11.7) to Lockport L&D (river km 466.7) during May - July 2018. The dotted vertical line represents the location of Starved Rock L&D (river km 371.8).*

These data indicate considerable spatiotemporal variation in zooplankton assemblage composition, density, and biomass within the Illinois Waterway, likely driven by seasonal environmental variation and spatial differences in temperature, water chemistry, and hydrology, and potentially varying Asian carp densities among various parts of this system. Underlying environmentally-driven variability in zooplankton metrics must be considered when evaluating the effects of planktivory by Asian carp and the responses of zooplankton to Asian carp removal. Data collected in 2018 will be incorporated into the long-term data set of zooplankton assemblages in the Illinois Waterway. Comparison of zooplankton data collected during 2011-2015 with pre-invasion zooplankton collections indicate that zooplankton abundance in the

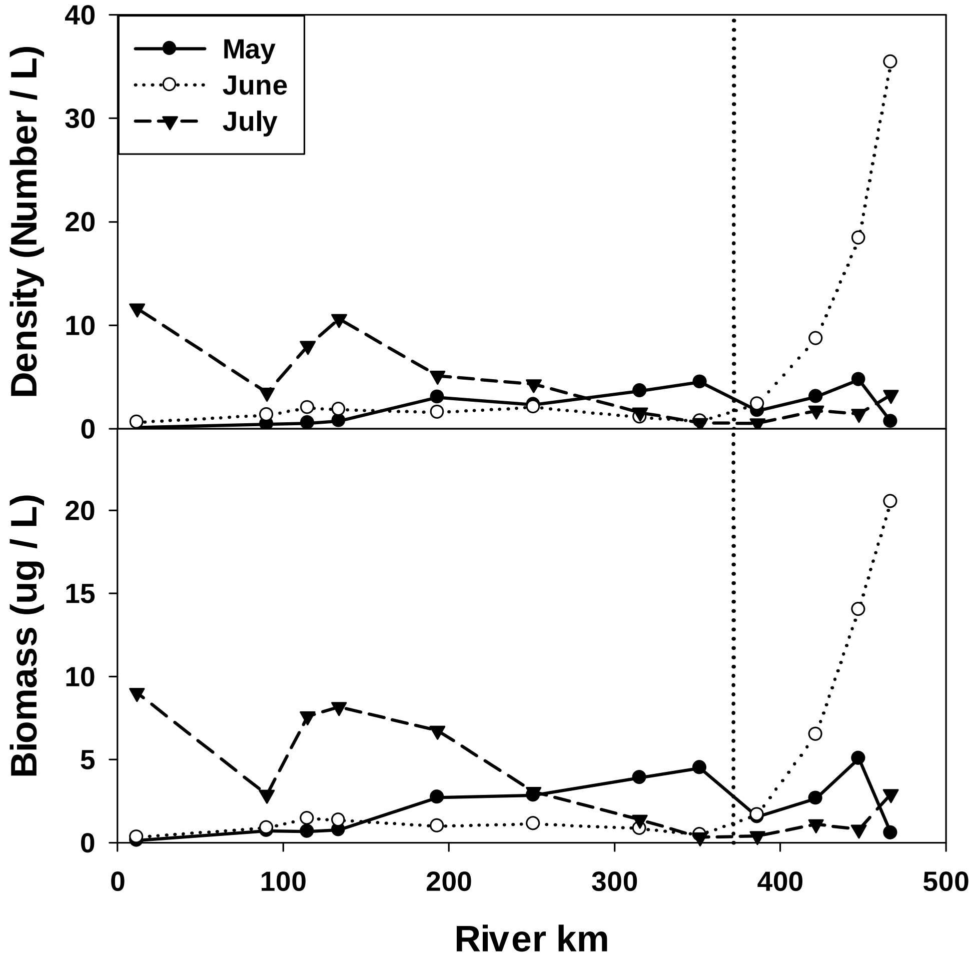

Figure 3. *Cladoceran density (top panel) and biomass (bottom panel) across the Illinois Waterway from near Grafton (river km 11.7) to Lockport L&D (river km 466.7) during May - July 2018. The dotted vertical line represents the location of Starved Rock L&D (river km 371.8).*

Illinois River has been significantly reduced since the establishment of Asian carp and that backwaters may experience greater fluctuations in plankton densities than main channel sites where Asian carp are established. Community composition has also been affected by the establishment of Asian carp, with shifts in both macrozooplankton and rotifers. Examination of all years of available zooplankton data will be necessary to separate the influences of environmental factors from both long- and short-term changes in Asian carp densities. Comparison of pre-establishment zooplankton assemblages to those from recent years will be needed to determine the effects of planktivory by Asian carp on zooplankton metrics and establish targets of ecosystem response for assessing the effectiveness of Asian carp removals. **Recommendations:** Continued monitoring and analyses of zooplankton data from the Illinois Waterway will assess the influence of environmental factors known to affect zooplankton communities in large rivers (turbidity, chlorophyll *a*, total phosphorus, temperature, discharge), as well as the effect of changing Asian carp densities in different pools of the Illinois Waterway. Short-term responses of zooplankton to Asian carp removal in specific backwater habitats will be assessed after accounting for seasonal environmental influences. To understand pool-wide responses of zooplankton to Asian carp removal, models of zooplankton indicators will be parameterized over conditions including pre- or early-invasion time periods, when Asian carp were absent or at very low abundance. Environmental values from the recent time periods will be entered into these models while holding carp abundance at zero to produce target values for zooplankton metrics (i.e., expected zooplankton values in the absence of carp but still under control of seasonal environmental conditions). A second set of predicted zooplankton values will be generated using observed carp abundances in combination with observed environmental values (i.e., full set of observed conditions during assessment period).

To characterize the effectiveness of Asian carp harvest, data from this project will be used to create an index of zooplankton responses. This index will provide a simple means of communicating the ecosystem responses of harvest efforts to a general audience (e.g., policy makers and the general public). A stoplight assessment report card will be developed for locations throughout the Illinois Waterway based on deviation of zooplankton performance measures from predicted management targets. The stoplight report will code locations as being impacted by Asian carp (red light) if the deviation (± 2 standard error) between observed and target predictions of zooplankton metrics falls outside of the deviation (± 2 standard error) between observed zooplankton values and predictions based on the full set of observed conditions (this deviation interval is known as the control limits of a given metric). Locations will be coded as warranting caution (yellow light) if zooplankton target intervals fall outside of the ± 1.5 standard error control limit. Locations where zooplankton targets fall within the ± 1.5 standard error control limit will be considered to not be impacted by Asian carp (green light).

Appendix B: Detection Using Novel Gear

Jeremy Hammen
(US Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office)

Participating Agencies: US Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office, Illinois Department of Natural Resources, and Illinois Natural History Survey

Pools Involved: Throughout Illinois River.

Introduction and Need:

Invasive species, like Silver Carp, are inherently difficult to manage and control because limited information exists for species in newly invaded areas. Many times the lack of information can be related to the inability to effectively capture the species. Effective sampling techniques that have a high probability to capture a species and correctly represent that species' population are crucial for biologists and managers to correctly manage and control any invasive species. Several projects have evaluated techniques used to capture Silver Carp in the Illinois River (Gear Evaluation for Removal and Monitoring of Asian Carp Species; Barrier Defense Using Novel Gear; Evaluation of Gear Efficiency and Asian Carp Detectability; Unconventional Gear Development; Monitoring Asian Carp Using Netting with Supplemental Capture Techniques). The results of these projects and information gained from multiple agencies working on Silver Carp will be compiled to help guide biologists and managers on how to capture Silver Carp at all sizes and densities to provide crucial information needed to effectively assess, manage, and remove bigheaded carp from the invaded waters.

Objectives:

(1) Develop a framework for techniques used to capture Silver Carp within the Illinois River.

Project Highlights:

- Agencies have been contacted to provide data on tools and techniques that have been used to capture Silver Carp of all sizes and catch rates
- Collaboration among multiple agencies compiling data and specifications on tools and techniques used to capture Silver Carp of all sizes in various habitats of the Illinois River occurred
- First draft of a manuscript is going through internal reviews
- Framework to support gear workshops highlighting tools and techniques available for Silver Carp capture is in development.

Methods:

This was a collaborative effort among several agencies that will require a thorough literature search and review for all tools and techniques used to capture Silver Carp. Biologists and managers from several agencies were asked to contribute data and gear specifications on tools and techniques they had used to sample Silver Carp.

Results and Discussion:

A manuscript is in development. Several tools throughout the Illinois River and Mississippi River basin were identified and researched to make available for the manuscript. A gear workshop is proposed for April 2019 by the Mississippi River Basin Panel where this document will provide knowledge on the past and current gears and techniques that have been used to capture Silver Carp. Continued support will be given to agencies working on the management and control of bigheaded carp.

Recommendations:

This document should be used as a guideline for agencies and managers working with Silver Carp by providing a framework to identify gears suitable for specific objectives. Additionally, an interactive web link needs to be pursued to provide this framework virtually so managers can access the most up-to-date gears and techniques being used to manage and control Silver Carp.

Appendix C: Horseshoe Lake Incident Response: Black Carp Round-Up

Nathan Lederman, Kevin Irons, Matt O'Hara, Justin Widloe, Brennan Caputo,
Rebekah Anderson, Seth Love, (Illinois Department of Natural Resources)
Andrew Mathis, Eli Lampo, Eric Hine, Illinois Natural History Survey

Participating Agencies: Illinois Department of Natural Resources (IDNR) (lead); Illinois Natural History Survey, US Fish and Wildlife Service (USFWS), Western Illinois University (WIU), and Southern Illinois University (SIU) (field support)

Introduction and Need:

Black Carp were brought into the United States in the early 1970's as contaminants of imported Grass Carp stocking. Black Carp then escaped confinement and were detected in the wild in 1994 (USGS 2019). Black Carp appear to be rare within their invaded range, but increased detections suggests an expanding distribution and potentially spawning success within the wild. Limited information exists about Black Carp success within their invaded habitat or their general distribution. Illinois Department of Natural Resources imposed a $100 bounty/reward for Black Carp in hopes of increasing the understanding of Black Carp distribution (ACRCC 2017). Ten Black Carp were reported captured in the Illinois River and 9 Black Carp were reported captured in Horseshoe Lake (37.140197 -89.350684, near Miller City, Illinois) since the bounty was imposed (United States Geological Survey 2019). Due increases in the number of Black Carp captured, the USFWS began a sampling endeavor for detecting Black Carp in Horseshoe Lake in June of 2018 (United States Geological Survey 2019). During those targeted sampling efforts, the US Fish and Wildlife Service captured 2 more Black Carp. In response to increased captures of Black Carp by commercial fishers and managing bodies a multiagency response action, Black Carp Round Up, was initiated in Horseshoe Lake.

Objectives:

(1) Remove Asian carp, targeting Black Carp specifically, from Horseshoe Lake as warranted.

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

Project Highlights:

- A one-week, multiagency (IDNR, INHS, USFWS, SIU, WIU) response utilizing a variety of conventional gears was completed at Horseshoe Lake.
- Four thousand one hundred and fifty fish representing 26 species and 1 hybrid group were collected with all gears combined.
- Thirteen Black Carp, 336 Bighead Carp, 11 Grass Carp, 1 Silver CarpXBighead Carp and 537 Silver Carp were removed from Horseshoe Lake during the Black Carp Round up.

Electrofishing:

- Crews from USFWS completed 5 electrofishing runs at targeted sites (5.25 hours total).

Appendix C: Horseshoe Lake Incident Response: Black Carp Round-Up

- Crews collected 2 Bighead Carp, 2 Grass Carp and 300 Silver Carp
- Bycaught species were not recorded
- No Black Carp where captured during electrofishing

Gill/trammel netting:
- Contracted commercial fishers along with assisting IDNR biologist, USFWS biologist, WIU students or SIU students set 19.2 km (11.9 mi) of gill net at targeted sites
- Crews captured 1,284 individual fish representing 18 species
- Six Black Carp, 281 Bighead Carp, 1 Grass Carp and 189 Silver Carp were captured with contracted commercial gill netting

Hoop netting:
- Crews from the IDNR and US Fish and Wildlife Service set and pulled 38 hoop nets at targeted sites totaling 87.8 net nights of sampling
- Crews captured 2,393 individual fish representing 22 species and 1 hybrid group
- Five Black Carp, 51 Bighead Carp, 7 Grass Carp, 1 Silver CarpXBighead Carp hybrid and 47 Silver Carp were captured with hoop netting

Tandem fyke netting:
- Crews from IDNR set and pulled four tandem fyke nets at targeted sites for a total of 9.4 net nights
- One hundred and seventy fish from 19 species were captured
- Two Black Carp, 2 Bighead Carp, and 1 Silver carp were captured with tandem fyke netting

Methods:

Description of Capture Gears — Pulsed DC-electrofishing, gill nets, hoop nets, and tandem fyke nets were used to monitor for Black Carp in Horseshoe Lake (Figure 1). Gill nets were 3.0 m (10.0 ft) deep x 91.4 m (300.0 ft) long in bar mesh sizes ranging from 82.6-127.0 mm (3.25-5.0 in). Hoop nets were composed of seven fiberglass or metal spring hoops 1.2 m (4.0 ft) to 1.8 m (6.0 ft) in diameter with 38.1 mm (1.5 in) to 63.5 mm (2.5 in) bar mesh measuring 6.7 meters (7.3 yards) in length. An anchor was attached to the cod end of the net with a 15.2-meter (16.6 yard) anchor line. Fyke net frames were constructed of two, 1.2 m (4.0 ft.) by 1.8 m (5.0 ft.) rectangular bars made of 8 mm (0.3 in.) black oil temper spring steel. Inner wings (vertical wall throats) of the frame extended from outer corners of the front rectangle to the middle of the rear rectangle. A 76.0 mm (3.0 in.) vertical gap existed on either side of lead between the wings and lead at middle of rear rectangle. A 1.2 m (4.0 ft.) webbing covered gap connected the cab and frame together. The cab was constructed of six, 0.9 m (3.0 ft.) diameter spring steel hoops spaced 61.0 cm (24.0 in.) apart from each other. Cab and frame together were 6.0 m (20.0 ft.) in total length. Extending from the mouth of the fyke net was a 15.2 m (50.0 ft) long by 1.4 m (4.5 ft.) deep lead.

Electrofishing Protocol – Each boat used pulsed DC-electrofishing with two dip-netters to collect Asian Carp fish. 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. Electrofishing transects occurred at targeted sites along the shoreline of Horseshoe Lake. Only Asian Carp were collected during sampling runs. Location of each electrofishing transect was identified with GPS coordinates.

Gill Netting Protocol – Contracted commercial fishers used gill nets at targeted sites. Sets were short duration and included driving fish into the nets with noise (e.g., plungers on the water surface, pounding on boat hulls, or revving trimmed up motors). Locations for each net set were identified with GPS coordinates and recorded. Captured fish were identified to species, enumerated, and released, except Asian Carp. Collected Asian carp were transferred to a refrigerated truck and subsequently utilized for nonconsumptive purposes (e.g., converted to liquid fertilizer, chum, etc.). Black Carp caught were transferred to Southern Illinois University personnel for further analysis.

Hoop Netting Protocol – Hoop nets were set at targeted sites in varying depths of water, typically around a depth 3 – 4 ft submerging the throats underwater but exposing part of the net to air. Hoop nets were baited with either cotton or clams and retrieved after ~48 hours (two net nights) of fishing. Locations for each net set were identified with GPS coordinates and recorded. Fish handling protocol followed those described in the gill netting protocol.

Tandem Fyke Netting Protocol – Two fyke nets were set in tandem, connected at the mouth with the leads. Tandem fyke nets were set by IDNR biologists at targeted sites conducive to effective sampling with the gear. Locations for each net set were identified with GPS coordinates and recorded. Fyke nets were checked once every 2 net nights by IDNR biologists. Fish handling protocol followed those described in the gill netting protocol.

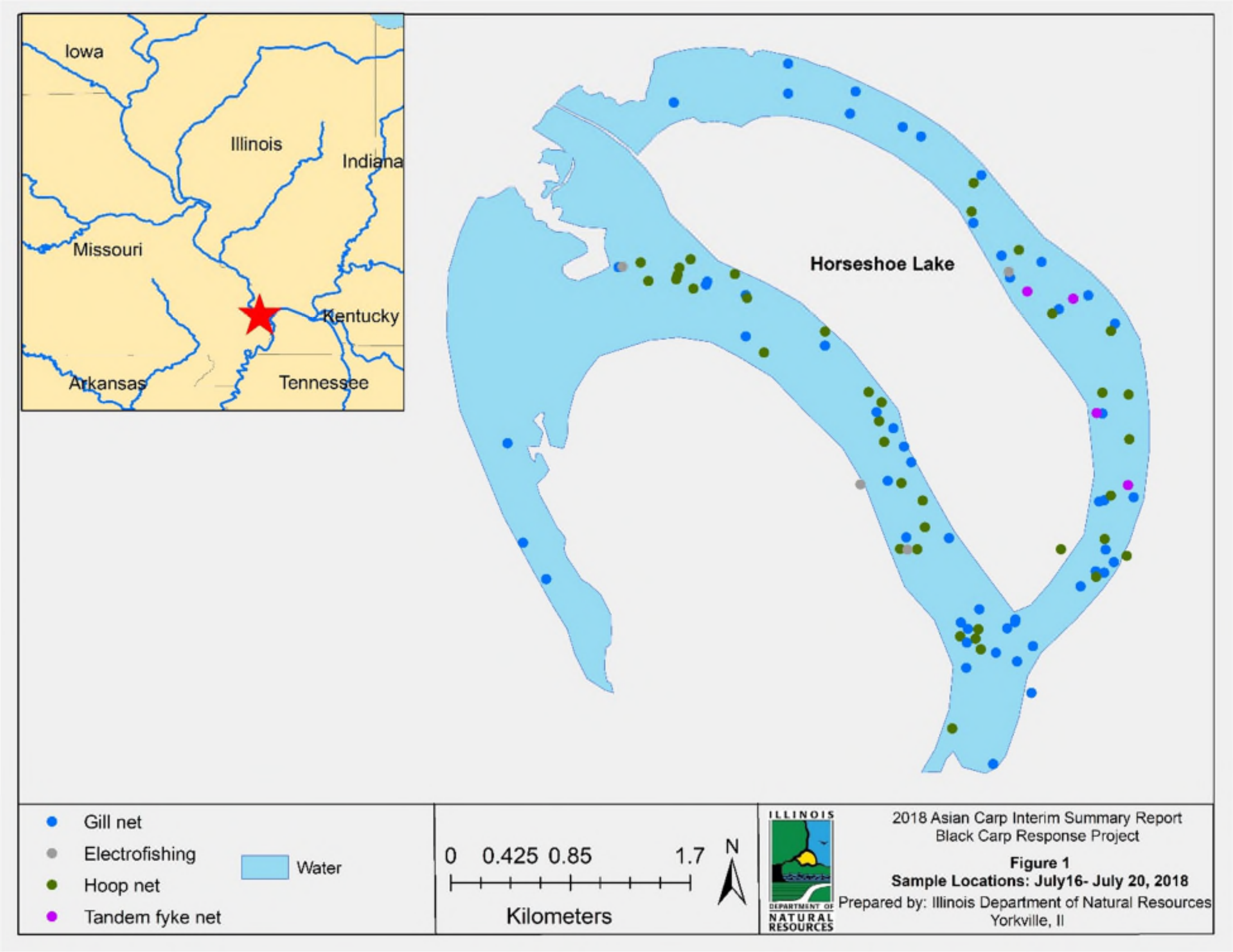

Figure 1. *Location of Black Carp Round Up event and sites sampled.*

Results and Discussion:

Black Carp Round Up took place 16 July 2018 to 20 July 2018. Sample effort included 5.25 hours of electrofishing (5 transects) requiring an estimated 72 person-hours, 19.2 km (11.9 mi) of trammel/gill netting (54 sets) requiring an estimated 216 person hours, 23 hoop nets fished for 87.8 net nights requiring an estimated 58 person-hours pound nets and 4 tandem fyke nets fished for 9.4 net nights requiring an estimated 8 person-hours (Table 1.). Across all gears, 4,150 fish representing 26 species and 1 hybrid groups were sampled from Horseshoe Lake (Table 2.) Bigmouth Buffalo was the predominant species captured, comprising 51.7% of all fish sampled. Four non-native species were also sampled, including Bighead Carp, Black Carp, Common Carp, and Silver Carp. Non-native species made up 22.8% of the total number of individuals collected. One Alligator Gar, a state threatened species being reintroduced, was also collected.

Appendix C: Horseshoe Lake Incident Response: Black Carp Round-Up

Recommendation:

The incident command system used during the Black Carp Round Up was useful in tracking resources and prompting communication among the multiple agencies involved. New insights on Black Carp habitats and gear biases within a backwater system was gained because of the Black Carp Round up. We recommend continued monitoring of commercial fishers catches of invasive species can allow for early detections and trends in catches providing opportunities for rapid management actions and is encouraged. We also recommend the continued Black Carp bounty to provide incentive for non-managing bodies to report captures of Black Carp. Additionally, continued use of the incident command system when coordinating response actions is recommended.

Table 1. *Summary of effort and catch data for the Black Carp Round up at Horseshoe Lake.*

	Gear Type			
	Electrofishing	**Gill net**	**Hoop net**	**Tandem fyke net**
Estimated person hours	72	216	58	8
Samples (number of sets/runs	5	54	23	4
Effort	5.25 hours	19.2 km	87.8 net nights	9.4 net nights
All Fish	304	1284	2392	170
Species	3	18	24	20
Hybrids	1	1	1	0
Bighead Carp	2	281	51	2
Black Carp	0	6	12	2
Grass Carp	2	1	7	1
Silver Carp	300	189	47	1
CPUE	1.0 fish/hour	6.1 fish/100 yards of net	27.2 fish/net night	18.1 fish/ net night

Appendix C: Horseshoe Lake Incident Response: Black Carp Round-Up

Table 2. *Total number of fish captured with electrofishing, gill nets, hoop net, and tandem fyke nets during the Black Carp Round up at Horseshoe Lake*

Species	Gear Type					
	Electrofishing	Gill Net	Hoot Net	Tandem Fyke Net	No. Captured	Percent
Alligator Gar		1			1	0.02%
Bighead Carp	2	281	51	2	336	8.10%
Black Buffalo		397	12	1	410	9.88%
Black Carp		6	5	2	13	0.31%
Black Crappie		1	5	7	13	0.31%
Blue Catfish		1	6		7	0.17%
Bluegill			10	28	38	0.92%
Bigmouth Buffalo		58	2,086	2	2,146	51.71%
Bowfin			1	1	2	0.05%
Common Carp		58	1	2	61	1.47%
Channel Catfish		2	56	11	69	1.66%
Flathead Catfish		3	1		4	0.10%
Freshwater Drum		17	8	2	27	0.65%
Grass Carp	2	1	7	1	11	0.27%
Gizzard Shad			1		1	0.02%
Largemouth Bass				1	1	0.02%
Longnose Gar		4	4	7	15	0.36%
Paddlefish		23	2		25	0.60%
Quillback		1			1	0.02%
River Carpsucker		2	10	6	18	0.43%
Silver Carp Bighead Carp Hybrid			1		1	0.02%
Smallmouth Buffalo		239	32	1	272	6.55%
Shortnose Gar			22	32	54	1.30%
Spotted Gar			11	6	17	0.41%
Silver Carp	300	189	47	1	537	12.94%
White Crappie			12	46	58	1.40%
Yellow Bass			1	11	12	0.29%
Total Captured	304	1,284	2,392	170	4,150	
No. Species	3	18	24	20	26	
No. Hybrid Group	0	0	1	0	0	

*Only Asian Carp were recorded during electrofishing samples

References:

Asian Carp Regional Coordinating Committee. 2017. Keep, Cool, Call: What to do if you capture a black carp. Council on Environmental Quality, Washington, D.C. https://www.asiancarp.us/Documents/KeepCoolCallHandout.pdf

United States Geological Survey. 2019. Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov, January 3, 2019.