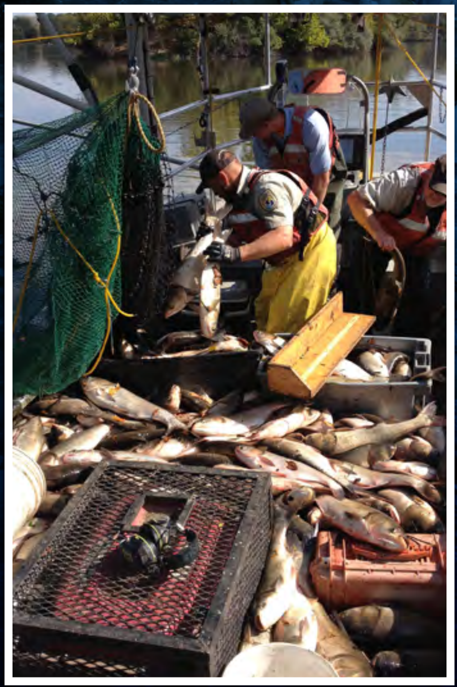
2015
Asian Carp Monitoring and Response Plan



Interim Summary Report

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

Table of Contents

ACKNOWLEDGEMENTS

The Asian Carp Monitoring and Response Plan Interim Summary Report was created by a team of biologists, scientists, managers, and administrators from state and federal agencies and includes technical input from government, university, and the private sector specialists. The original plan released in May 2010 was developed by S. Finney, R. Simmonds, S. Pescitelli, S. Shults, J. Mick, G. Sass, and R. Maher. This and earlier versions of the plan have benefitted from reviews by participants of the Monitoring and Response Work Group, Great Lakes state's natural resource agencies, non-governmental organizations, and staff from the Illinois Department of Natural Resources Division of Fisheries, U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service. K. Irons, J. Dettmers, K. Baerwaldt, J. Davis M. Shanks, N. Barkowski, E.Monroe, R. Simmonds, S. Finney, J. Stewart, N. Bloomfield, E. Pherigo, R. Neeley, M. O'Hara, T. Widloe, B. Caputo, B. Bushman, J. Widloe, L. Nelson, J. R. Haun, R. Young, M. Brey, S. Butler, M. Diana, S. Collins, and D. Wahl contributed project write-ups for the plan. USFWS, IDNR, and INHS provided pictures for the cover.

GLOSSARY

TERM	DEFINITION
°C	Degrees centigrade
°F	Degrees Fahrenheit
µS/cm	microSiemen per centimeter
A	Amps
ACRCC	Asian Carp Regional Coordinating Committee
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
ANS	Aquatic Nuisance Species
CAWS	Chicago Area Waterway System
CERL	Construction Engineering and Research Laboratory
cm	Centimeter
cm^2	Square centimeters
CPO	Conservation Police Officers
CPUE	Catch per unit effort
CSSC	Chicago Sanitary and Shipping Canal
dB	Decibels
DC	Direct current
DIDSON	Dual Frequency Identification Sonar
Diploid	Fish with the natural number of reproductive chromosomes; are capable of reproducing
ECALS	eDNA Calibration Study
eDNA	Environmental DNA
FWCO	Fish and Wildlife Conservation Office
g	Grams
GLFC	Great Lakes Fisheries Commission
GLMRIS	Great Lakes Mississippi River Interbasin Study
GPS	Global Positioning System
GSI	Gonadosomatic index
HACCP	Hazard Analysis and Critical Control Points
IDNR	Illinois Department of Natural Resources
INHS	Illinois Natural History Survey
IPC	Internal positive control
ISU	Invasive Species Unit
IWW	Illinois Waterway
kg	Kilogram
kHz	Kilohertz
km	Kilometer
km/hr	Kilometers per hour

GLOSSARY

TERM	DEFINITION
LOQ	Limit of quantification
LTRMP	Long-Term Resource Monitoring Protocols
m	Meter
m^2	Square meters
m^3	Cubic meters
ml	Milliliter
mm	Millimeter
MRP	Asian Carp Monitoring and Response Plan
MRWG	Monitoring and Response Work Group
MVN	Multivariate Normal Distribution
MWRD	Chicago Metropolitan Water Reclamation District
Ploidy	Measurement of number of chromosomes, triploid fish are sterile
QAPP	Quality Assurance Project Plan
RM	River Mile
SD	Standard deviation
SIM	Seasonal Intensive Monitoring
SIUC	Southern Illinois University Carbondale
TL	Total length
Triploid	Fish that have genetically modified to have an extra reproductive chromosome, rendering them sterile
-TS	Target Strength
UMESC	USGS Upper Midwest Environmental Sciences Center
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
V	Volts
v/cm	Volts per centimeter
V/in	Volts per inch
VHS	Viral Hemorrhagic Septicemia
W	Watts
WGL	Whitney Genetics Laboratory
yd	Yard
YOY	Young of year

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 23 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 2015, and provides recommendations for next steps for each project.

This ISR builds upon prior plans developed in 2011, 2012, 2013, and 2014. More specifically, it is intended to act as an update to the 2014 ISR that was developed in 2015. This 2015 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 2016 Asian Carp Monitoring and Response Plan (MRP), has also been completed by the MRWG. The 2016 MRP presents each project's plans for activities to be completed in 2016. Similar to the ISR, the MRP is intended to function as a living document, and will be updated at least annually. In conjunction, the 2016 MRP and 2015 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 2015 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 2015 results for 23 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 five general categories:

1) Monitoring Projects
2) Removal Projects and Evaluation
3) Barrier Effectiveness Evaluation
4) Gear Development and Effectiveness Evaluation
5) Alternative Pathway Surveillance.

A summary of the highlights of each project is presented below, intended to provide a brief snapshot of project accomplishments during 2015.

MONITORING 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 2015
- Estimated 2,280 person-hours were spent to complete 106 hours of electrofishing, set 74.4 km (46.2 mi) of trammel/gill net, 2.2 km (1.4 mi) of commercial seine and 16 net-days. Across all locations and gears in 2015, sampled 35,728 fish representing 60 species and 2 hybrid groups.
- Since 2010, an estimated 21,533 person-hours were spent to complete 875.4 hours of electrofishing, set 599 km (372.2 mi) of gill/trammel net and 6 km (3.7 mi) of commercial seine and 41.2 net-days

- A total of 314,719 fish representing 71 species and 6 hybrid groups were sampled, including 1,323 Banded Killifish (state threatened species) from 2010-2015
- Examined 99,314 YOY Gizzard Shad since 2010 and found no Asian carp
- Since 2010, 17 non-native species have been captured accounting for 14% of the total fish caught and 22% of the total species
- No Bighead Carp or Silver Carp have been captured or observed since 2011 (one Bighead Carp in Lake Calumet in 2010).
- 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 Monitoring 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.

CAWS Monitoring:

- One eDNA comprehensive sampling event took place in the CAWS at four regular monitoring sites in 2015, resulting in 240 samples collected and analyzed.
- Results: zero positive detections for either species of Asian carp DNA. One sample was inhibited, but clean up procedures removed inhibition and the sample was still negative.
- Since 2013, 1,160 samples have been collected and processed. 51 samples were positive for Silver Carp and 1 sample was positive for Bighead Carp.

Below the Electric Dispersal Barrier Monitoring:

- Two eDNA sampling events took place in the Illinois River along a gradient from Lower Lockport Pool to the Marseilles Pool and the lower portion of the Kankakee River in April and June of 2015.
- 362 samples were collected pre-spawn in April: 79 samples were positive for Silver Carp DNA and 60 samples were positive for Bighead Carp DNA. 42 of the positive samples were positive for both species. None of the samples were inhibited.
- 358 samples were collected the week prior to direct observation of carp spawning in June: 12 samples were positive for Silver Carp DNA and 5 samples were positive for Bighead Carp DNA, none positive for both species. 22 samples were inhibited, but clean up procedures removed inhibition and the samples were still negative.
- Measurement of mean DNA quantity in each positive sample was only above the limit of quantification (LOQ; 10 copies) in some samples from the April sampling event, all of the detections in the June event were below the LOQ, although they were above the limit of detection.

***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.

- Over 550 larval fish samples were collected from 12 sites across the length of the Illinois Waterway during April – October, 2015, capturing over 79,000 larval fish, including 62,170 larval Asian carp. Additionally, over 71,000 Asian carp eggs were collected in ichthyoplankton samples in 2015. These are the highest numbers of Asian carp larvae observed in the Illinois Waterway in six years of sampling.
- Asian carp eggs were collected in the LaGrange, Peoria, Starved Rock, and Marseilles pools during 2015. Asian carp larvae were identified from the LaGrange, Peoria, and Dresden Island Pools. Prior to this year, no Asian carp eggs or larvae had been collected at any location upstream of Henry (Peoria pool). These observations confirm that Asian carp reproduction occurs in some years in the upper Illinois River.
- An early spawn in May was evident from the presence of Asian carp eggs in the LaGrange pool, but the bulk of eggs and larvae were collected in association with the flooding that occurred in the Illinois River during June and July 2015. The presence of Asian carp eggs and larvae in the Illinois River appears to be associated with rising water levels when water temperatures are above 20°C.

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.

- Sampled for young Asian carp from 2010 to 2015 throughout the CAWS, Des Plaines River, and Illinois River between river miles 83 and 334 by incorporating sampling from several existing monitoring projects.
- Sampled with active gears (Trawls, pulsed-DC electrofishing, small mesh purse seine, cast net, and beach seine) and passive gears (small mesh gill nets, and mini-fyke nets) in 2015.
- Completed 1,691 hours of electrofishing across all years and sites.
- Examined 241,311 Gizzard Shad <152 mm (6 in) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam from 2010-2015 and found only 2 young Asian carp in Marseilles Pool and none upstream of that.
- High catches of young-of-year Asian carp in 2014 and moderate numbers in 2015 in the LaGrange Pool indicate two consecutive successful recruitment years despite limited to no recruitment in 2010-2013.
- Farthest upstream catch was two young-of-year Silver carp in the Marseilles pool near Morris, IL, (river mile 256.4) in 2015 which expands the range juveniles have been detected.
- Recommend continued monitoring for young Asian carp.

Distribution and Movement of Small Asian 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.

- A total of 89,857 fish were collected and analyzed
- Two juvenile Silver Carp (mentioned above in the "Young-of-year and Juvenile Asian Carp Monitoring" project summary) were collected in Marseilles Pool near river mile 256.4 representing the furthest upstream any juvenile Asian carp have been collected.

Fixed and Random Site Monitoring Downstream of the Dispersal Barrier – This project includes monthly standardized monitoring with electrofishing 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.

- From 2010-2015, an estimated 12,041.5 person-hours were spent sampling at fixed, random, targeted and additional sites downstream of the Electric Dispersal Barrier.
- A total of 549 hours were spent electrofishing, 923 km (573.5 miles) of trammel and gill nets were deployed and 1,180 net nights of hoop netting and mini-fyke netting were conducted.
- A total of 176,192 fish were captured, representing 97 species and 8 hybrid groups.
- No Bighead or Silver Carp were captured in Lockport and Brandon Road pools in all years sampled, but were collected in Dresden and Marseilles pools (n=1,250 and n=1,787, respectively), with the highest densities collected in Rock Run Rookery and Mobil Bay (Figure 3).
- Detectable population front of Asian carp located just north of I-55 Bridge (river mile 280; 47 miles from Lake Michigan). No appreciable change in upstream location of the population front in past six years.
- Recommend continued sampling below the Electric Dispersal Barrier, utilizing electrofishing, hoop netting, mini-fyke netting and gill and trammel netting with the addition of one commercial fishing boat to increase efforts.

REMOVAL PROJECTS AND EVALUATION

***Response Actions in the CAWS* –** This project uses a threshold framework to support decisions for response actions to remove any Asian carp from the CAWS upstream of the Electric Dispersal Barrier with conventional gear or rotenone.

- Based on the criteria of the Rapid Response Matrix there were no rapid response actions utilized in the CAWS in 2015. Alternatively two Seasonal Intensive Monitoring (SIM) events were conducted in 2015 yielding no Bighead Carp or Silver Carp being captured or observed. Refer to the Seasonal Intensive Monitoring report for comprehensive results.
- A total of 240 early detection monitoring samples (250 ml each) were collected upstream of the dispersal barrier, centrifuged in the mobile lab, and analyzed at WGL. All samples were negative for both species of Asian carp DNA
- From 2010-2012, eleven rapid response actions with conventional and experimental gears in the CAWS upstream of the Electric Dispersal Barrier. Eight of the response actions were triggered by positive detections of Asian carp eDNA.
- We recommend contingency planning for the upper Illinois Waterway to be developed for future responses.

***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 supported one clearing action on 18-19 November 2015.
- A total of 51 fish from 11 species were removed using pulsed DC-electrofishing, electrified paupier trawling and deep water gill net sets.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on 3 November indicating low fish abundance and no fish over 300 mm. Weekly scans below Barrier 2A were conducted throughout the sampling season which also contributed to characterizing risk of Asian carp presence.
- No Asian carp were captured or observed during fish suppression operations

***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.

- Contracted commercial fishers deployed 1,579.2 miles (2,541 km) of gill/trammel net, 5.3 miles (8.5 km) of commercial seine, and 204 hoop nets set in the upper IWW from 2010- 2015.
- A total of 79,077 Bighead Carp, 325,096 Silver Carp, and 2,558 Grass Carp were removed by contracted commercial fisherman from 2010-2015. The total weight of Asian carp removed was 1,971 tons.
- Recommend increased targeted harvest of Asian carp in the upper IWW with contracted commercial fishers and assisting IDNR biologists. Potential benefits include reduced Asian carp abundance at and near the detectable population front and the possible prevention of further upstream movement of populations toward the Electric Dispersal Barrier and Lake Michigan.

***Identifying Movement Bottlenecks and Changes in Population Characteristics of Asian Carp in the Illinois River* –** 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.

- Standardized electrofishing surveys indicated Asian carp abundance in the lower pools of the Illinois River increased in 2015.
- The presence of YOY individuals indicated spawning occurred in the lower river.
- Bighead and Silver Carp remained a large portion (by abundance and biomass) of the overall fish community throughout the Illinois River.
- Asian carp appear to be responding to harvest efforts in the upper pools, with densities decreasing in Dresden Island pool from 2012 to 2014.

BARRIER EFFECTIVENESS EVALUATION

***Telemetry Monitoring Plan* –** 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, we have acquired 20.2 million detections from 532 tagged fish.
- No live tagged fish have crossed the Electric Dispersal Barriers in the upstream direction
- Highest detection rates of tagged Common Carp in Lower Lockport Pool occurs in shallow backwater sites and immediately below the Electric Dispersal Barriers
- Tagged Common Carp utilize the full water column at the Electric Dispersal Barriers and mean depth at detection did not significantly differ from downstream control sites
- Inter-pool movement of tagged fish was observed in both directions between all pools within the study area in 2015 (Lockport, Brandon, Dresden Island and Marseilles)

- Tagged Common Carp utilize the full water column within the Brandon Road Lock chamber during lock operations but stay near the bottom of the lock chamber during periods between lock operations
- Bighead Carp were detected moving as far upstream as the Wilmington Dam on the Kankakee River during a rise in the hydrograph
- Total movement distance of Common Carp did not significantly differ from those of Bighead or Silver Carp in the Dresden Island Pool

Understanding Surrogate Fish Movement with Barriers - This project monitors the movements of tagged surrogate species in Dresden Island, Brandon Road and Lockport pools and Rock Run Rookery to assess fish movement between barriers and structures (i.e. the Electric Dispersal Barrier and locks and dams). Obtaining information on recapture rates of surrogate species helps verify sampling success using multiple gear types.

- Multiple agencies and stakeholders cooperated in successfully tagging 2,273 fish in Lockport pool, Brandon Road pool, Dresden Island pool and Rock Run Rookery (Between March 11, 2015 and December 11, 2015)
- A total of 158 fish were recaptured using pulsed DC-electrofishing, gill nets, trammel nets and 6 foot diameter hoop nets
- A total of 78 recaptures had tags but showed no movement between barrier structures, 65 recaptures where observed due to caudal fin clip but had no tag to show movement and 15 recapture showed movement through barrier structures and Lock and Dam Structures
- No recaptured fish with a floy tag showed upstream movement through a barrier structure
- Recommend continued tagging of Common Carp, Bigmouth Buffalo, Smallmouth Buffalo, Black Buffalo and Common Carp x Goldfish hybrid using pulsed DC-electrofishing, gill nets, trammel nets and 6 foot diameter hoop nets to monitor fish movement between barrier structures.

Monitoring Fish Abundance, Behavior, and Barge Interactions at the Electric Dispersal Barrier, Chicago Sanitary and Ship Canal, Illinois – This project uses split-beam hydroacoustics, side-scan SONAR, DIDSON, and other monitoring tools to assess the ability of fish the pass through the Electric Dispersal barrier. In 2015, the project focused on assessing the possibility for barge movement to allow fish to pass through the Electric Dispersal Barrier due to entrainment.

- Evaluated the potential of barge movement to transport fish through the Electric Dispersal Barrier and throughout the IWW. Results will be published pending peer review.

Monitoring Fish Abundance and Spatial Distribution in Lockport, Brandon Road, and Dresden Island Pools and the Associated Lock and Dam Structures – 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.

- There were significantly greater mean total densities of fish (non-Asian carp) observed immediately below the Electric Dispersal Barrier during the summer than in spring or winter.
- High relative densities of fish (non-Asian carp) were shown to be present within the Brandon Road Lock structure during both summer and fall.

***Monitoring Fish Abundance and Behavior at the Electric Dispersal Barrier* –** This project performs detailed monitoring of fish at the Electric Dispersal Barrier to analyze conditions that could allow fish to pass through the barrier. Work focused on identifying sizes of fish that can pass through the barrier, and evaluating the impact of passing barges on the strength of the electric field.

- Schools of small fish (non-Asian carp) were able to breach the narrow array of Barrier IIB frequently during 2013 (passage in 61% (n= 44 of 72) of samples; Only Barrier IIB active; water temp. = 22.8-26.8°C)
- No fish were observed crossing the IIB narrow array during October 2014 (Barrier IIA and IIB active; water temp. = 15.8-17.4°C)
- Schools of small fish (non-Asian carp) were able to breach the narrow array of Barrier IIB during 2015 (passage observed in 11.3% (n=41of 362) of samples, Barrier IIA and IIB active; water temp. = 21.0-25.1°C); however, we observed large schools of medium sized juvenile Gizzard Shad (72-102 mm) that did not appear to be able to breach the narrow array.
- During the passage of commercial barge tows the electrical field at Barrier IIB was reduced (mean=16.7% at center of narrow array).
- During the passage of commercial barge traffic in the downstream direction, large schools of fish (non-Asian carp) were able to move upstream through the entire narrow array at Barrier IIB in 66% of samples (n=9).

***Des Plaines River and Overflow 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 that may be transported to the CSSC via laterally flowing Des Plaines River floodwaters passing through the barrier fence.

- Collected 6,656 fish representing 53 species and 3 hybrid groups from 2011-2015 via electrofishing (45.03 hours) and gill netting (131 sets; 16,084 yards).
- No Bighead or Silver Carp have been captured or observed through all years of sampling.
- One Grass Carp was captured in 2015. Analysis indicated it was triploid. All six Grass Carp tested since 2013 have been triploid.

GEAR DEVELOPMENT AND EFFECTIVENESS EVALUATION

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 10 sites in the Illinois River, lower Des Plaines River, and CAWS that have varying carp population densities. Results will inform decisions on appropriate levels of sampling effort and monitoring regimes, and ultimately improve Asian carp monitoring and control efforts.

- Catches of juvenile Silver Carp were substantially lower in 2015 than in 2014. Sampling during high water periods appeared to be particularly unproductive, as juvenile Asian carp densities were lower, gear effectiveness was reduced, or some combination of these factors occurred. Catches of juvenile Asian carp increased during fall 2015 as water levels normalized.
- Catch rates of mini-fyke nets, beach seines, purse seines, and pulsed-DC electrofishing were all higher in main channel habitats than in backwater lakes during 2015. Gill nets were more effective for juvenile Silver Carp in backwater lakes.
- Mini-fyke nets appear to consistently capture the highest total numbers of juvenile Silver Carp across years, and were the only gear to capture juvenile Bighead Carp in 2015. However, on average, pulsed-DC electrofishing provided higher catch rates per sample, particularly during flood conditions. Beach seines and purse seines produced similar lower catch rates, but captured different size groups of juvenile Asian carp. No age-0 Asian carp were captured in gill nets or cast nets during 2015, although gill nets did capture age-1 Silver Carp.
- Asian carp appear to shift from nearshore habitats to deeper areas as they increase in size during their first two years of life. Beach seines that sample shoreline areas captured the smallest sizes of juvenile Silver Carp (mean = 37 mm), whereas offshore sampling with purse seines (mean = 53 mm), pulsed-DC electrofishing (mean = 61 mm), and gill nets (mean = 153 mm) collected larger individuals.

Exploratory Gear Development - Innovative techniques are being developed and evaluated for their ability to detect, monitor, and remove invasive carp of all sizes in varying habitats. If effective, gears may be used in place of rotenone for removal actions in the CAWS, for commercial fishing in the lower Illinois River, and incorporated into risk assessment and management plans of these nuisance fish.

- Standardizing the anode configuration for the paupier allows for determination of the electrofishing capabilities under varying environmental conditions.
- Longer towlines result in a wider net spread for surface trawling which enables a larger volume of water to be sampled.
- The dozer trawl is an inexpensive modification to standard fishing boats that can sample shallow habitats and a variety of water velocities.

- Testing of a modified purse seine shows promise for capture of invasive carps.
- Videos of electrified paupier provide a method to estimate densities of Silver Carp and behavioral responses to electrofishing settings in all seasons.

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.

- 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 sound stimuli for attracting/deterring Asian carp. They are being used by IDNR in the upper IWW as part of monitoring and control activities.
- Pound nets are capable of capturing large numbers of fish, and produce substantially higher catch rates of Asian carp than traditional entrapment gears in backwater habitats.
- Estimation of the effort required to deploy, maintain, and retrieve various entrapment gears indicates that pound nets are the most cost effective gear type for capturing Asian carp in backwater lake habitats due to their high catch rates relative to the labor hours invested.

Monitoring Adult Asian Carp Using Netting with Supplemental Capture Techniques – The purpose of this project is to evaluate the use of supplemental techniques to improve the effectiveness of net gears for capturing Asian carp. Electrofishing and sound are being evaluated as supplemental capture techniques.

- 802 fish were caught using gill and trammel nets
- 33,650 yards of gill or trammel net were fished
- Gill and trammel nets yielded an overall CPUE of 2.38 fish per 100 yards of net
- A total of 15 different species were captured in gill and trammel nets
- 451 Asian carp were captured via gill or trammel nets
- Overall Asian carp CPUE using gill and trammel nets was 1.34 fish per 100 yard of net
- The furthest upstream Asian carp was collected at 41.39611; -88.22886 in Dresden Island
- CPUE for capture technique was statically different in the Peoria Pool analysis
- Electrofishing was the most proficient supplemental capture technique
- Electrofishing yielded a CPUE of 6.12 fish per 100 yards of net for all fish
- Electrofishing yielded a CPUE of 4.33 fish per 100 yards of net for Asian carp
- Directional sound yielded a CPUE of 0.75 fish per 100 yards of net for all fish
- Directional sound yielded a CPUE of 0.19 fish per 100 yards of net for Asian carp
- Non-directional sound yielded a CPUE of 0.82 fish per 100 yards of net for all fish

- Non-directional sound yielded a CPUE of 0.05 fish per 100 yards of net for Asian carp
- 444 fish were collected using the supplemental electrofishing capture technique
- 332 Asian carp were collected using the supplemental electrofishing capture technique

An Assessment of Water Guns to Deter Asian Carp – This project focused on determining whether water guns, which shoot high-pressure jets of water into the water column, could act as an effective means for controlling Asian carp.

- Field tests of water gun arrays were tested with wild Asian carp
- Asian carp did not appear to be deterred by water guns, likely limiting their utility as a control method.

ALTERNATIVE PATHWAY SURVEILLANCE

Alternative Pathway Surveillance in Illinois – Law Enforcement - This project creates a more robust and effective enforcement component of IDNR's invasive species program by increasing education and enforcement activities at bait shops, bait and sport fish production/distribution facilities, fish processors, and fish markets/food establishments known to have a preference for live fish for release or food preparation. A second component conducts surveys at urban fishing ponds in the Chicago Metropolitan area included in the IDNR Urban Fishing Program as well as ponds with positive detections for Asian carp eDNA using conventional gears (electrofishing and trammel/gill nets) in an effort to remove potential accidentally stocked Bighead or Silver Carp.

- The Invasive Species Unit organized an operation to simultaneously inspect two fish trucks from a non-resident aquatic life dealer at two separate delivery locations. The detail involved four uniformed CPOs and the Invasive Species Unit. Information received by the Unit indicated the company was importing live Grass Carp and VHS susceptible species without permits. A testing protocol and a course of action to get any illegally imported fish to a testing facility was developed prior to the operation. The company did not have any illegal species in the shipments that were inspected.
- ISU initiated an investigation and identified an out-of-state resident illegally selling live Rusty Crayfish in Illinois.
- ISU conducted random commercial inspections of five aquaculture facilities in Northern Illinois. Five additional illegal aquaculture facilities were found to be raising live Tilapia. A total of 11 violations were documented.
- The Invasive Species Unit inspected a fish truck delivering live fish in Chicago's Chinatown. The company had previously been cited for importing Grass Carp (diploid) without a restricted species permit, selling aquatic life without a non-resident aquatic life dealer's license, and importing VHS susceptible species without permits. The owner of the company received a citation for selling aquatic life without a non-resident aquatic life dealer's license for the second time.

- The Invasive Species Unit initiated an investigation into an out-of-state company importing live Asian Swamp Eels into Chicago without a restricted species transportation permit and VHS import permits. The company was also importing live American Eels without a threatened species permit, and the company did not have the required non-resident aquatic life dealer's license.
- The Invasive Species Unit documented the first reported sale of Snakeheads in Chicago. Although the Snakeheads were frozen, they were not eviscerated which raised concerns of whether they were being imported alive or dead. Snakeheads are on the Federal and State injurious species list, which means they cannot be possessed alive. The grocery store where ISU observed the Snakeheads was given a written warning for not having an aquatic life dealer's license. ISU worked with the USFWS to determine shipping information for the Snakeheads.

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.

- Thirty-two 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.
- Eighteen 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.
- An attempt will be made to sample Elliot Lake in 2016, which is the last remaining pond that needs to be sampled.

INTRODUCTION

The 2015 Interim Summary Report (ISR) presents a comprehensive accounting of project results from activities completed by the Asian carp Monitoring and Response Workgroup in 2015. 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 6 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 2015 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 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.

MONITORING PROJECTS

Seasonal Intensive Monitoring in the CAWS

Justin Widloe, Tristan Widloe, Blake Bushman, Brennan Caputo, David Wyffels, Luke Nelson, Matthew O'Hara and Kevin Irons, Blake Ruebush
(Illinois Department of Natural Resources)

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

ADDITIONAL INFORMATION
- Link to mapping tool - Link to 2016 plan

Introduction and Need: Detections of Asian carp eDNA upstream of the Electric Dispersal Barrier in 2009 initiated 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 to increase the chance of encountering Asian carp in the CAWS beyond the designated fixed sites. Based on the extensive sampling upstream of the Electric Dispersal Barrier from 2010 through 2013 (682 hours of electrofishing, 445.8 km [277 miles] of gill/trammel net, 2.2 km [1.4 miles] of commercial seine hauls) and because only one Bighead Carp was collected in Lake Calumet in 2010, fixed site and random area sampling effort was reduced upstream of the barrier to two Seasonal Intensive Monitoring (SIM) events starting in 2014. The reduction in effort upstream of the Electric Dispersal Barrier will allow for increased monitoring downstream of the barrier. The increase in sampling downstream of the Electric Dispersal Barrier will focus 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 toward 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 in the event they are captured or observed.

Objectives:

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

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

Project Highlights:

- Completed two 2-week SIM events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier in 2015.

Seasonal Intensive Monitoring in the CAWS

- Estimated 2,280 person-hours were spent to complete 106 hours of electrofishing, set 74.4 km (46.2 miles) of trammel/gill net, 2.2 km (1.4 miles) of commercial seine, and 16 net-days.
- Across all locations and gears in 2015, sampled 35,728 fish representing 60 species and 2 hybrid groups.
- Since 2010, an estimated 21,533 person-hours were spent to complete 875.4 hours of electrofishing, set 599 km (372.2 miles) of gill/trammel net and 6 km (3.7 miles) of commercial seine and 41.2 net-days
- A total of 314,719 fish representing 71 species and six hybrid groups were sampled, including 1,323 Banded Killifish (state threatened species) from 2010 to 2015.
- Examined 99,314 YOY Gizzard Shad since 2010 and found no Asian carp
- Since 2010, 17 non-native species have been captured accounting for 14 percent of the total fish caught and 22 percent of the total species
- No Bighead Carp or Silver Carp have been captured or observed since 2011 (one Bighead Carp in Lake Calumet in 2010).
- 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, tandem trap nets, and a commercial seine were used to monitor for Asian carp in the CAWS upstream of the Electric Dispersal Barrier (Figure 1). Trammel and gill nets were 3 meters (10 feet) deep x 91.4 meters (300 feet) long in bar mesh sizes ranging from 88.9 to 108 mm (3.5 to 4.25 inches). Deep water gill nets were 9.1 meters (30 feet) deep x 91.4 meters (300 feet) long with bar mesh sizes ranging from 69.9 to 88.9 mm (2.75-3.5 inches).

Seasonal Intensive Monitoring in the CAWS

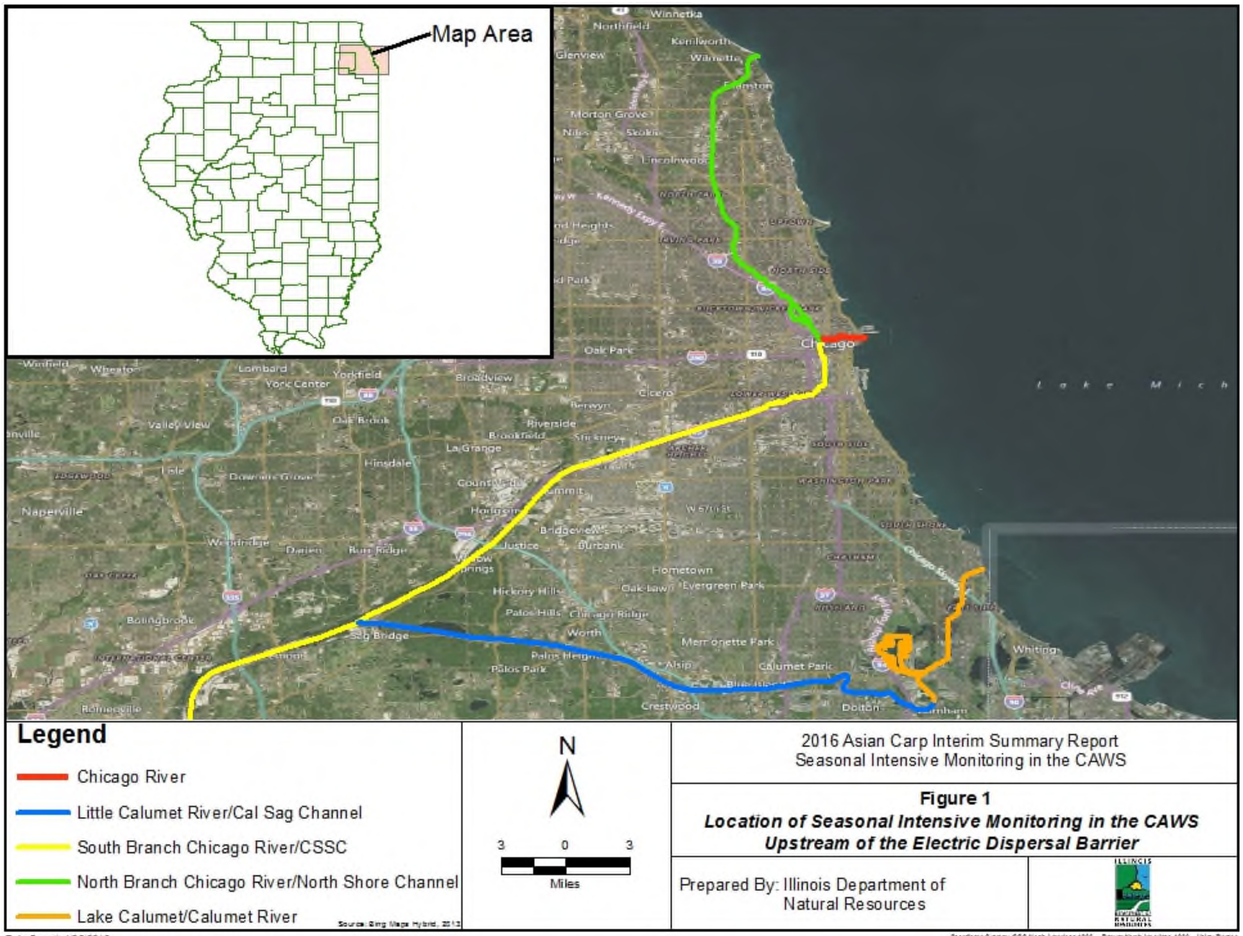


Figure 1. *Location of SIM in the CAWS upstream of the Electric Dispersal Barrier.*

The commercial seine was 9.1 meters (30 feet) deep x 731.5 meters (2,400 feet) long and had a cod end made of 50.8 mm (2.0 inch) bar mesh netting. The goal was to complete a minimum of 150 electrofishing runs and 150 net sets (trammel/gill nets and deep water gill nets) during each 2-week event.

Electrofishing Protocol – Each boat used pulsed DC-electrofishing with two dip-netters to collect stunned fish. Location of each electrofishing transect were 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, placed in a holding tank, and then identified and counted, after which they were be returned live to the water. Because of similarities in appearance and habitat use, YOY Gizzard Shad < 152.4 mm (6 inches) 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 (for example, plungers on the water surface, pounding on boat hulls, or revving trimmed up motors). In Lake Calumet, a 731.5 meter (2,400 feet) 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.

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 and netting gear). 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 percent 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 are used for monitoring efforts upstream of the Electric Dispersal Barrier.

Results and Discussion: SIM took place during the weeks of June 9, June 16, September 15, and September 22, 2015, 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).

The reduced sampling effort protocols established in 2014 upstream of the barrier (CAWS) were followed in 2015 to continue to focus additional monitoring effort on the leading edge of the Asian carp population below the Electric Dispersal Barrier (Figure 2). Effort in 2015 was 106 hours of electrofishing (422 transects) with an estimated 990 person-hours, 74.4 km (46.2 miles) of trammel/gill netting (441 sets), 2.2 km (1.4 miles) of commercial seine and four tandem trap nets, with an estimated 1,125, 135 and 30, person-hours utilized (Table 1). Across all locations and gears, 35,728 fish representing 60 species and two hybrid groups were sampled in 2015 (Table 1). Gizzard Shad, Common Carp, Freshwater Drum, and White Sucker were the predominant species, comprising 66 percent of all fish sampled. Thirteen non-native species were also sampled, which included Common Carp and Common Carp x Goldfish hybrids, Round Goby, Alewife, Goldfish, White Perch, Oriental Weatherfish, Grass Carp, Threadfin Shad, Chinook Salmon, Coho Salmon, Tilapia, and Rainbow Trout. Non-native species made up 21 percent of the total species collected and 17 percent of the total fish in 2015. Two hundred seventeen Banded Killifish, a state threatened species, were also collected. They were identified and returned to the water alive. No Bighead Carp or Silver Carp were captured or observed during SIM in 2015. In addition, we examined 11,535 YOY Gizzard Shad and found no YOY Asian carp.

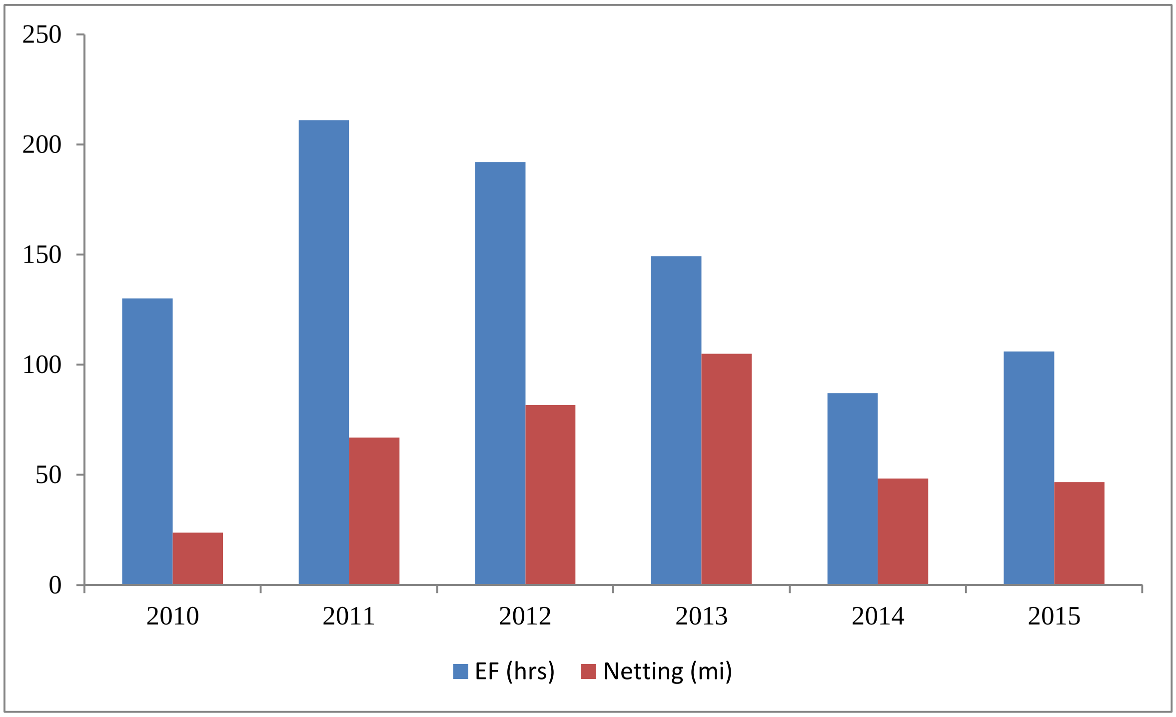


Figure 2. *Total electrofishing and trammel/gill netting effort at fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier, 2010-2015.*

Since 2010, an estimated 21,533 person-hours were expended monitoring fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier. Total effort was 875.4 hours of electrofishing (3,486 transects), 599 km (372.2 miles) of gill/trammel net (3,140 sets), 6 km (3.7 miles) of commercial seine hauls, and 41.2 net-days of hoop and trap nets (15 sets) from 2010 to 2015 (Table 2). The use of hoop nets and trap nets was suspended after 2013 based on the low gear efficiency. A total of 314,763 fish representing 71 species and three hybrid groups have been sampled since 2010 (Table 4). Gizzard Shad, Common Carp, Bluegill, Largemouth Bass, Bluntnose Minnow, and Pumpkinseed were the predominant species sampled, accounting for 77 percent of all fish collected. Since 2010, 17 non-native species have been caught, which include Common Carp and Common Carp x Goldfish hybrids, Alewife, Goldfish, White Perch, Round Goby, Oriental Weatherfish, Threadfin Shad, Rainbow Trout, Grass Carp, Brown Trout, Chinook Salmon, Coho Salmon, Tilapia, Rainbow Smelt, Silver Arrowana, and Threespine Stickleback. Non-native species constitute 14 percent of the total fish caught and 24 percent of the total species. Banded Killifish, a state threatened species, have been routinely collected during our monitoring efforts in the CAWS. To date, 1,323 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 to 2015. One Bighead Carp was caught in a trammel net in Lake Calumet in 2010.

Furthermore, 99,314 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.

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, 2015.*

	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)	142	75	78	10	117	422
Electrofishing hours	35.5	19.0	19.5	2.5	29.5	106.0
Electrofishing Catch						
All fish (*N*)	6,374	8,480	6,273	313	7,109	28,549
Species (*N*)	46	48	36	10	38	60
Hybrids (*N*)	1	0	2	0	1	2
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	179.5	446.3	321.7	125.2	241.0	262.7
Netting Effort						
Estimated person-hours	345	230	254	35	261	1,125
Samples (net sets)	127	90	89	24	111	441
Miles of net	15.1	9.9	10.2	1.4	10.0	46.6
Netting Catch						
All fish (*N*)	452	172	174	175	72	1,062
Species (*N*)	11	10	3	1	2	13
Hybrids (*N*)	0	1	0	1	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)	1.7	1.0	1.0	2.9	0.4	1.4
Seine Effort						
Estimated person-hours	135	-	-	-	-	135
Samples (seine hauls)	3	-	-	-	-	3
Miles of seine	1.4	-	-	-	-	1.4
Seine Catch						
All fish (*N*)	5,989	-	-	-	-	5,989
Species (*N*)	14	-	-	-	-	14
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	1996.3	-	-	-	-	1,996.3

Table 1. *Continued.*

	Lake Calumet/Calumet River	Little Calumet River/Cal Sag	S. Branch Chi. River/CSSC	Chicago River	N. Branch Chi. River/N. Shore	Total
Tandem Trap Net						
Estimated person-hours	30	-	-	-	-	30
Samples	4	-	-	-	-	4
Trap Net Catch						
All fish (*N*)	172	-	-	-	-	172
Species (*N*)	16	-	-	-	-	16
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	10.75	-	-	-	-	10.75

Table 2. *Summary of effort and catch data for all fixed and random site monitoring in the CAWS upstream of the Electric Dispersal Barrier, 2010-2015.*

	2010	2011	2012	2013	2014	2015	Total
Electrofishing Effort							
Estimated person-hours	1,280	2,180	4,330	1,528	945	990	11,253
Samples (transects)	519	844	765	588	348	422	3,486
EF (hrs)	130.0	211.0	192.0	149.3	87.1	106.0	875.4
Electrofishing Catch							
All fish (*N*)	33,688	52,385	97,510	45,443	24,492	28,549	282,067
Species (*N*)	51	58	59	56	56	61	69
Hybrids (*N*)	3	3	3	2	2	2	6
Bighead Carp (*N*)	0	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0	0
CPUE (fish/hr)	259.1	248.3	507.9	304.4	281.2	269.3	322.2
Netting Effort							
Estimated person-hours	885	1,725	3,188	1,932	1,125	1,125	9,980
Samples (net sets)	208	389	699	959	440	441	3,136
TRA/GIL (mi)	23.8	67.0	81.7	104.9	48.2	46.6	372.2
Netting Catch							
All fish (*N*)	2,439	4,923	3,060	4,195	1,461	1,062	17,140
Species (*N*)	17	20	20	30	18	13	32
Hybrids (*N*)	1	1	1	1	1	1	1
Bighead Carp (*N*)	1	0	0	0	0	0	1
Silver Carp (*N*)	0	0	0	0	0	0	0
CPUE (fish/100 yds of net)	5.8	4.2	2.1	2.3	1.7	1.3	3.0
Seine Effort							
Estimated person-hours	-	-	-	135	135	135	270
Samples (seine hauls)	-	-	-	3	2	3	7
Miles of seine	-	-	-	1.4	0.9	1.4	2.3
Seine Catch							
All fish (*N*)	-	-	-	7,577	1,725	5,989	9,302
Species (*N*)	-	-	-	15	11	14	16
Hybrids (*N*)	-	-	-	1	0	0	1
Bighead Carp (*N*)	-	-	-	0	0	0	0
Silver Carp (*N*)	-	-	-	0	0	0	0
CPUE (fish/seine haul)	-	-	-	2,525.7	862.5	1,996.3	1,328.9

Table 2. *Continued.*

	2010	2011	2012	2013	2014	2015	Total
Hoop/Trap Net/Tandem Trap Net							
Estimated person-hours	-	-	-	-	-	30	-
Samples (sets)	-	-	-	11	-	4	15
Net-days	-	-	-	25.2	-	16	41.2
Hoop/Trap Net/Tandem Trap Net Catch							
All fish (*N*)	-	-	-	93	-	172	265
Species (*N*)	-	-	-	17	-	17	17
Hybrids (*N*)	-	-	-	0	-	0	0
Bighead Carp (*N*)	-	-	-	0	-	0	0
Silver Carp (*N*)	-	-	-	0	-	0	0
CPUE (fish/net-day)	-	-	-	3.7	-	10.75	6.4

Table 3. *Total number of fish captured with electrofishing, trammel/gill nets and commercial seine in the CAWS upstream of the Electric Dispersal Barrier during Seasonal Intensive Monitoring, 2015. I = introduced species, ST = state threatened species.*

	Lake Calumet/ Calumet River				**Little Calumet River/Cal Sag**		**S. Branch Chi River/CSSC**		**Chicago River**		**N. Branch Chi River/N. Shore**		
Species	Electro-fishing	Trammel/Gill Net	Commercial Seine	Tandem Trap Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	All Sites
Gizzard Shad < 6 in	107				5018		3,455		191		2,764		11,535
Common Carp I	784	200	2	39	1272	134	1,531	171	37	68	878	141	5,257
Gizzard Shad > 6 in	300	7	2,762	8	289	1	455		40		448	1	4,311
Freshwater Drum	75	156	2,285	19	58	11	1	3			2		2,610
White Sucker	88				33		9				1,456		1,586
Largemouth Bass	639	1	8	6	236	1	103		23		291		1,308
Pumpkinseed	458			34	480		163				107		1,242
Yellow Perch	896			4	52						125		1,077
Channel Catfish	42	12	831	21	48	1	10				16		981
Bluntnose Minnow	403				146		64				103		716
Golden Shiner	86				120		209				272		687
Bluegill	159		1	12	111		120		10		166		579
Smallmouth Bass	457		7		8								472
Alewife I	295				1						66		362
Emerald Shiner	108				215		5		1		11		340
Rock Bass	289			1	5								295
Black Bullhead	183				18		3				37		241
Green Sunfish	120				18		23				64		225
Banded Killifish ST	162				43		9				3		217
Smallmouth Buffalo	114	21	58		3	5							201
Round Goby I	166				17		3		2		3		191
Fathead Minnow	141				26		5				12		184
Goldfish I	12			1	50		26	1			33		123
Yellow Bullhead	23				19		44				29		115
Black Crappie	25		5	9	6		1		4		63		113
Spotfin Shiner	31				30		2				47		110
White Bass	28		4	12	36						5		85
Spottail Shiner	24				5		1				45		75

Table 3. *Continued.*

	Lake Calumet/ Calumet River				Little Calumet		S. Branch Chi		Chicago River		N. Branch Chi		
Species	Electro-fishing	Trammel/Gill Net	Commercial Seine	Tandem Trap Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	All Sites
Black Buffalo	3	36	19			16							74
White Perch I	16			3	28				4		3		54
Brook Silverside	24				20								44
Brown Bullhead	36			1			1				1		39
Quillback	35	2	2										39
White Crappie	1			1	5		1				10		18
Bigmouth Buffalo	1	13	2		1								17
Common Shiner					2		3				11		16
Carp x Goldfish hybrid I						1	4			4		3	12
Blackstripe Topminnow							9				2		11
Creek Chub					8		3						11
River Shiner					1						10		11
Bowfin	5				3						2		10
Coho Salmon I	10												10
Oriental Weatherfish I					2		3				5		10
Rainbow Trout I	9										1		10
Silver Redhorse					9						1		10
River Carpsucker	7					1							8
Walleye	1			1	5						1		8
Flathead Catfish	1	2	3			1							7
Golden Redhorse					7								7
Grass Pickerel					5		2						7
Hybrid Sunfish	1										5		6
Orangespotted Sunfish	1				4		1						6
Bullhead Minnow					5		1						6
Chinook Salmon I	4						1						5
Grass Carp I		2			1	2							5
Mimic Shiner					5								5
Tilapia I									1		4		5
Yellow Bass	2				1						1		4

Table 3. *Continued.*

Species	Lake Calumet/ Calumet River				Little Calumet		S. Branch Chi		Chicago River		N. Branch Chi		
	Electro-fishing	Trammel/Gill Net	Commercial Seine	Tandem Trap Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	All Sites
Central Mudminnow	1				1						1		3
Channel Shiner					3								3
Skipjack Herring											3		3
Unidentified Salmonid	1						1						2
Log Perch					1								1
Longnose Gar											1		1
Unidentified Madtom							1						1
Threadfin Shad I											1		1
Total fish	6,372	439	5,987	171	8,472	174	6,269	175	313	72	7,087	145	35,728
Species (*N*)	47	11	14	16	48	10	36	3	10	1	64	5	60
Hybrids (*N*)	1	-	-	-	-	1	2	-	-	1	-	1	2

Table 4. *Total number of fish captured in the CAWS upstream of the Electric Dispersal Barrier, 2010-2015. I = introduced species, ST = state threatened species.*

Species	2010	2011	2012	2013	2014	2015	All Years
Gizzard Shad < 6 in	11,834	13,897	36,315	15,896	9,837	11,535	99,314
Gizzard Shad > 6 in	5,277	7,978	19,272	16,756	2,740	4,311	56,334
Common Carp I	7,061	7,956	7,699	6,703	4,379	5,257	39,055
Bluegill	1,105	4,703	6,966	4,012	522	579	17,887
Largemouth Bass	2,890	3,304	3,778	1,639	2,422	1,308	15,341
Bluntnose Minnow	1,165	3,556	5,954	2,005	1,153	716	14,549
Pumpkinseed	807	3,458	4,087	1,553	947	1,242	12,094
Freshwater Drum	229	1,261	568	1,650	539	2,610	6,857
Golden Shiner	739	1,474	2,708	639	492	687	6,739
Spotfin Shiner	628	1,565	1,548	1,317	332	110	5,500
White Sucker	514	993	708	365	698	1,586	4,864
Emerald Shiner	873	831	2,021	413	191	340	4,669
Brook Silverside	396	959	1,845	311	110	44	3,665
Green Sunfish	147	784	1,243	264	163	225	2,826
Yellow Perch	340	292	303	179	395	1,077	2,586
Channel Catfish	122	186	121	898	164	981	2,472
Smallmouth Bass	103	148	365	133	792	472	2,013
Western Mosquitofish	3	168	1,614	92	11	-	1,888
Alewife I	73	674	221	348	124	362	1,802
Banded Killifish ST	3	58	409	465	171	217	1,323
Rock Bass	42	74	154	195	410	295	1,170
Goldfish I	287	286	249	110	79	123	1,134

Table 4. *Continued.*

Species	2010	2011	2012	2013	2014	2015	All Years
Black Buffalo	251	497	79	111	51	74	1,063
Yellow Bullhead	87	229	312	143	95	115	981
White Perch I	234	205	166	154	33	54	846
Smallmouth Buffalo	145	182	98	88	121	201	835
Round Goby I	32	57	183	168	173	191	804
Black Bullhead	45	75	115	92	78	241	646
Spottail Shiner	72	150	188	38	95	75	618
Fathead Minnow	121	82	30	20	25	184	462
White Bass	77	70	51	76	62	85	421
Quillback	43	213	52	37	31	39	415
Blackstripe Topminnow	8	144	178	44	17	11	402
Black Crappie	54	80	40	61	47	113	395
Hybrid Sunfish	31	82	117	15	8	6	259
Orangespotted Sunfish	19	92	112	14	15	6	258
Oriental Weatherfish I	12	70	89	33	13	10	227
Carp x Goldfish hybrid I	41	71	50	24	15	12	213
Bigmouth Buffalo	18	36	38	77	15	17	201
Bullhead Minnow		89	51		25	6	171
Yellow Bass	85	40	25	10	1	4	165
Brown Bullhead	2	33	79	8	15	39	176
Chinook Salmon I	23	26	41	41	3	5	139
White Crappie	23	31	20	30	6	18	128
Creek Chub	3	23	68	14	1	11	120
Threadfin Shad I	13		89		4	1	107
River Carpsucker		8	37	8	1	8	62

Table 4. *Continued.*

Species	2010	2011	2012	2013	2014	2015	All Years
Central Mudminnow	20	14	9		10	3	56
Rainbow Trout I	1	16	18	2	2	10	49
Flathead Catfish	5	12	5	6	7	7	42
Grass Carp I	3	12	7	1	5	5	33
Age-0 fish			26		5		31
Bowfin	2	3	4	2	7	10	28
Walleye	4	7	3	5	1	8	28
Coho Salmon I	4	1	3	3		10	21
Common Shiner			1		4	16	21
Warmouth		5	9	6			20
Brown Trout I	1	6	1	11			19
Northern Pike	2	6	1	7	2		18
Sand Shiner	2	7	3		6		18
Unidentified Salmonid		12	4			2	18
Grass Pickerel		7	3			7	17
Silver Redhorse					3	10	13
River Shiner						11	11
Tilapia I				1	3	5	9
White Perch x Yellow Bass Hybrid			8	1			9
Ghost Shiner	4	3					7
Golden Redhorse						7	7
Spotted Sucker		2	4				6
Mimic Shiner						5	5
Unidentified Buffalo				5			5
Lake Trout		1		2			3

Table 4. *Continued.*

Species	2010	2011	2012	2013	2014	2015	All Years
Channel Shiner						3	3
Skipjack Herring						3	3
Unidentified Minnow		3					3
Unidentified Sunfish			3				3
Burbot				2			2
Largescale Stoneroller				2			2
Rainbow Smelt I		1		1			2
Log Perch						1	1
Longnose Gar						1	1
Unidentified Madtom						1	1
Bighead Carp I	1						1
Central Stoneroller					1		1
Johnny Darter				1			1
Mottled Sculpin			1				1
Non-Carp minnow spp.	1						1
Silver Arrowana I				1			1
Spotted Gar					1		1
Threespine Stickleback I			1				1
Total fish	38,137	59,319	102,582	59,321	29,692	37,743	314,719
Species (N)	54	58	60	58	57	61	71
Hybrids (N)	2	2	3	3	2	2	3

Strategy for eDNA Monitoring in the CAWS and Temporal eDNA Quantification Below the Electric Dispersal Barrier

Kelly Baerwaldt, Emy Monroe, Jenna Merry, and Nicholas Bloomfield
(US Fish and Wildlife Service)

Participating Agencies: U.S. Fish and Wildlife Service (Carterville, Wilmington sub-station, Columbia, and La Crosse Fish and Wildlife Conservation Offices, Whitney Genetics Laboratory) (lead), and Illinois Department of Natural Resources (field support).

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction and Objectives:

As outlined in the 2015 Monitoring and Response Plan, eDNA as a surveillance tool was used to monitor for the genetic presence of Bighead and Silver Carp as a complementary monitoring tool in the CAWS. The prescribed objectives of eDNA sampling were to:

(1) Monitor Asian carp DNA in strategic locations in the CAWS to potentially inform the status of Asian carp;

(2) Detect Asian carp DNA in areas that have been monitored since 2009 to maintain annual data collection that may inform future work in the CAWS.

Project Highlights

CAWS Monitoring:

- One eDNA comprehensive sampling event took place in the CAWS at four regular monitoring sites in 2015, resulting in 240 samples collected and analyzed.
- Results: zero positive detections for either species of carp DNA; one sample was inhibited, but cleanup procedures removed the inhibition and the sample was still negative.
- Since 2013, 1,160 samples have been collected and processed. During this time, 51 samples were positive for Silver Carp and one sample was positive for Bighead Carp.

Below the Electric Dispersal Barrier Monitoring:

- Two eDNA sampling events took place in the Illinois River along a gradient from Lower Lockport pool to the Marseilles pool and the lower portion of the Kankakee River in April and June 2015.
- 362 samples were collected pre-spawn in April: 79 samples were positive for Silver Carp DNA and 60 samples were positive for Bighead Carp DNA; 42 of them were positive for both species. None of the samples was inhibited.
- 358 samples were collected the week prior to direct observation of carp spawning in June: 12 samples were positive for Silver Carp DNA and five samples were positive for Bighead Carp DNA; none were positive for both species. 22 samples were inhibited, but cleanup procedures removed the inhibition and the samples were still negative.

Strategy for eDNA Monitoring in the CAWS and Temporal eDNA Quantification Below the Electric Dispersal Barrier

- Measurement of mean DNA quantity in each positive sample was above the limit of quantification (LOQ; 10 copies) only in some samples from the April sampling event; all of the detections in the June event were below the LOQ, although they were above the limit of detection.

Methods:
The CAWS was sampled for eDNA of Bighead and Silver Carp on one occasion in June 2015. Sampling immediately preceded Seasonal Intensive Monitoring in the CAWS. The Illinois River was sampled twice in April and June. The timing of the June event was targeted to coincide with visual observation of spawning behavior, but timing of other monitoring efforts and the extra barrier monitoring work resulting from increased concern and effort regarding small Asian carp forced eDNA sampling to take place the week before actual observed spawning events. Similarly, the third event below the barrier failed to occur because of the increased efforts that were required for other MRWG projects.

Similar to previous years, sample collection and processing followed the Quality Assurance Project Plan (http://www.fws.gov/midwest/fisheries/eDNA/documents/QAPP.pdf). New in 2015, an internal positive control (IPC) was added to all eight replicate reactions in the assay using the ACTM markers, which screen for both species in one reaction. The internal positive control measures inhibition of the polymerase chain reaction, which is one cause of false negative results. Inhibition can be removed from the sample extract with cleanup procedures, and the sample can be re-amplified to determine if the target DNA is present. Also new in 2015 is a change in water sampling techniques. A study comparing detection of carp DNA in 2-L filtered samples to 250-mL centrifuged samples indicated better DNA detection in low-carp density water with the centrifuged samples. Reports summarizing study results for both the IPC and centrifugation are appended to the QAPP.

USFWS crews collected 240 samples (including field blanks) in four reaches of the CAWS: 60 samples each from North Shore Channel, South Branch Chicago River to the Chicago Lock, Little Calumet River downstream of O'Brien Lock and Dam, and Lake Calumet. USFWS crews also collected 362 samples in April and 358 samples in June from the below the Electric Dispersal Barrier along a carp density gradient from Lower Lockport pool to the Marseilles pool and the lower portion of the Kankakee River. All samples were procedurally collected and centrifuged in a mobile eDNA trailer according to the QAPP; samples were preserved with ethanol until they were delivered Whitney Genetics Laboratory (WGL) for analysis. Sampling below the barrier differed from normal early detection efforts because carp occupancy is generally known. Each sample consisted of only 50 mL of water compared with 250 mL of water in CAWS, and sampling effort was spread along the length of the river reach instead of concentrated in any single area. 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 (CAWS) were then posted on line. Results from the Illinois River are provided in this report and will not be posted on line.

Results and Discussion:

CAWS:

A total of 240 early detection monitoring samples (250 mL each) were collected upstream of the dispersal barrier, centrifuged in the mobile laboratory, and analyzed at WGL. All samples were negative for both species of carp DNA. All eDNA results are available at: http://www.fws.gov/midwest/fisheries/eDNA/Results-chicago-area.html. All extraction and PCR positive control samples were positive, and none of these samples was inhibited as indicated by the IPC. All (100 percent) negative results should not be that surprising, considering eDNA was monitored only once, and a detection of zero is not that different from eight positive results (of 240 total samples) in the June event in 2014. Low detection rates have been observed in previous monitoring years and could be a result of seasonal effects on the eDNA signal in the water. Numbers of positive results for CAWS samples collected at different times of the year fluctuated; for example, in 2012, the June event had 18 positive results compared with only three in November. In 2013, the June event had eight positive results compared with 23 in October. Alternatively, it could be related to other monitoring efforts in the CAWS by state and federal crews as well as commercial fishing contractors. In the past (2009 to 2011), bi-weekly monitoring by government crews and commercial fishermen could have provided a regular loading of carp eDNA in the system (ACRCC 2013, 2014). The change to clean nets by commercial fishers in 2013 and an overall reduction in monitoring efforts by government agencies and commercial fishers over the last few years could have greatly reduced eDNA loading to the system.

Below the Electric Dispersal Barrier:

A total of 720 samples (50 mL each) were collected along a carp population density gradient below the Electric Dispersal Barrier, including the lower Kankakee River. Samples were collected in April and June (Figures 1 to 5). Results were consistent (positive reaches were still positive) between months in all but the Kankakee River (Figure 4), where there were no positive samples in the June event (Table 1). The low number of positive samples in June, relative to April, seems strange, considering fish were observed during sample collection. Sampling or processing errors can be ruled out because of the large number of controls, both positive and negative, used at each step in the process (QAPP) that turned out as expected. However, total discharge in the system varied nearly three-fold: flow during the week of 20 April ranged from 3,600 to 4,580 cubic feet per second (CFS) and during the week of 1 June it was 11,000 to 13,400 CFS. (Stream gauging data from the Wilmington, IL station on the Kankakee River downloaded from http://rivergages.mvr.usace.army.mil/WaterControl/shefgraph-historic.cfm?sid=WLMI2.) Perhaps the eDNA signal was diluted by higher volumes of water moving through the system, although there are no studies available in the literature to support this hypothesis.

Table 1. *Number of environmental DNA (eDNA) samples positive for Silver, Bighead, or both species of invasive carp in areas sampled below the Electric Dispersal Barrier in April and June, 2015. Total samples collected per reach are indicated, but results will not sum to that total, since some samples were positive for only one species, and others positive for both species.*

	April				June			
River Reach	N	Silver	Bighead	Both	N	Silver	Bighead	Both
Lockport Pool	57	0	0	0	55	0	0	0
Brandon Road Pool	55	0	0	0	58	0	0	0
Dresden Island Pool)	105	19	13	9	109	2	3	1
Kankakee River	54	2	5	2	49	0	0	0
Marseilles Pool	84	39	61	35	87	10	2	2

Recommendations:

To maintain vigilance within the CAWS, it is recommended to continue to monitor the four sites outlined above, with at least one sampling event per year. Information from other project results in this report may drive changes in eDNA sampling plans in the CAWS, but should certainly drive efforts below the barrier in 2016. Based on detections of small Asian carp farther upstream in 2015, eDNA sampling should be focused and repeated more than once in Lockport and Brandon Road pools to provide rapid and simple monitoring closer to the barrier. Repeated sampling is possible because of laboratory efficiency that has been realized over the last few years, and samples could be processed within a week or two after they were collected so that results can be available as soon as possible.

References:

Asian Carp Regional Coordinating Committee. 2013. Environmental DNA Calibration Study, Second Interim Technical Review Report. Kelly Baerwaldt, editor. 112 pages. Available at http://www.asiancarp.us/

Asian Carp Regional Coordinating Committee. 2014. Environmental DNA Calibration Study, Interim Technical Review Report. Kelly Baerwaldt, editor. 234 pages. Available at http://www.asiancarp.us/

http://rivergages.mvr.usace.army.mil/WaterControl/shefgraph-historic.cfm?sid=WLMI2. Accessed 17 Dec 2015.

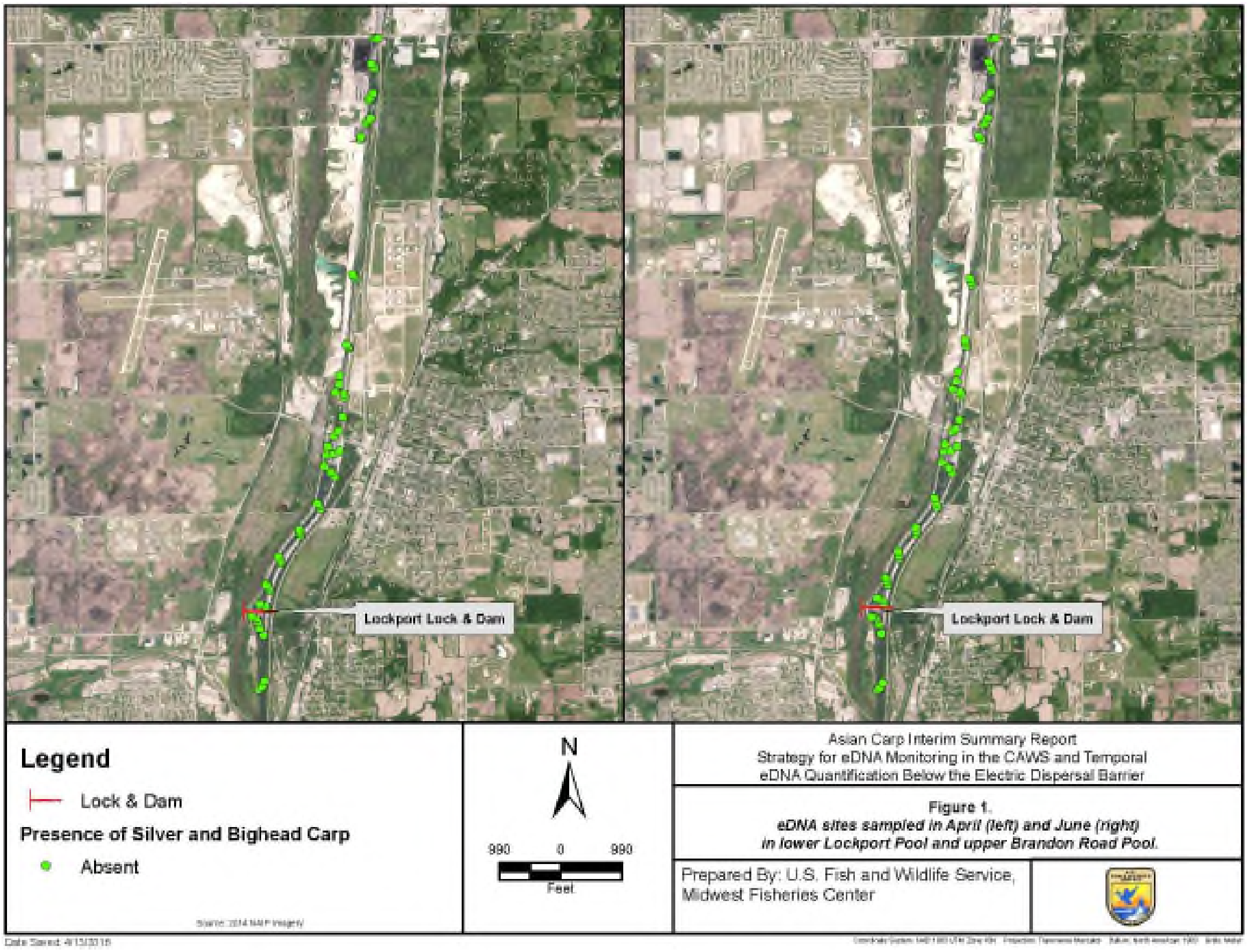


Figure 1. *eDNA sites sampled in April (left) and June (right) in lower Lockport Pool and upper Brandon Road Pool.*

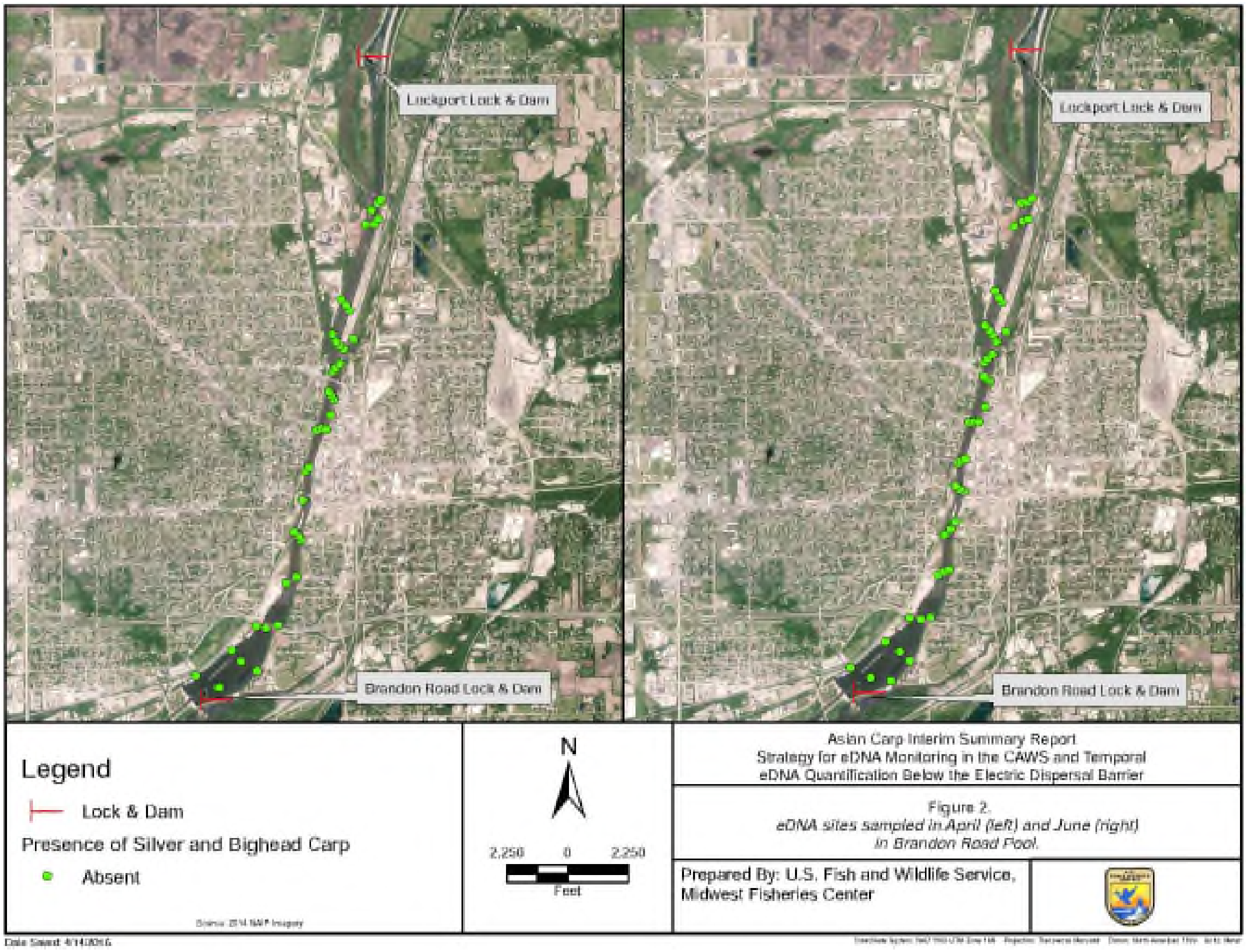


Figure 2. *eDNA sites sampled in April (left) and June (right) in Brandon Road pool.*

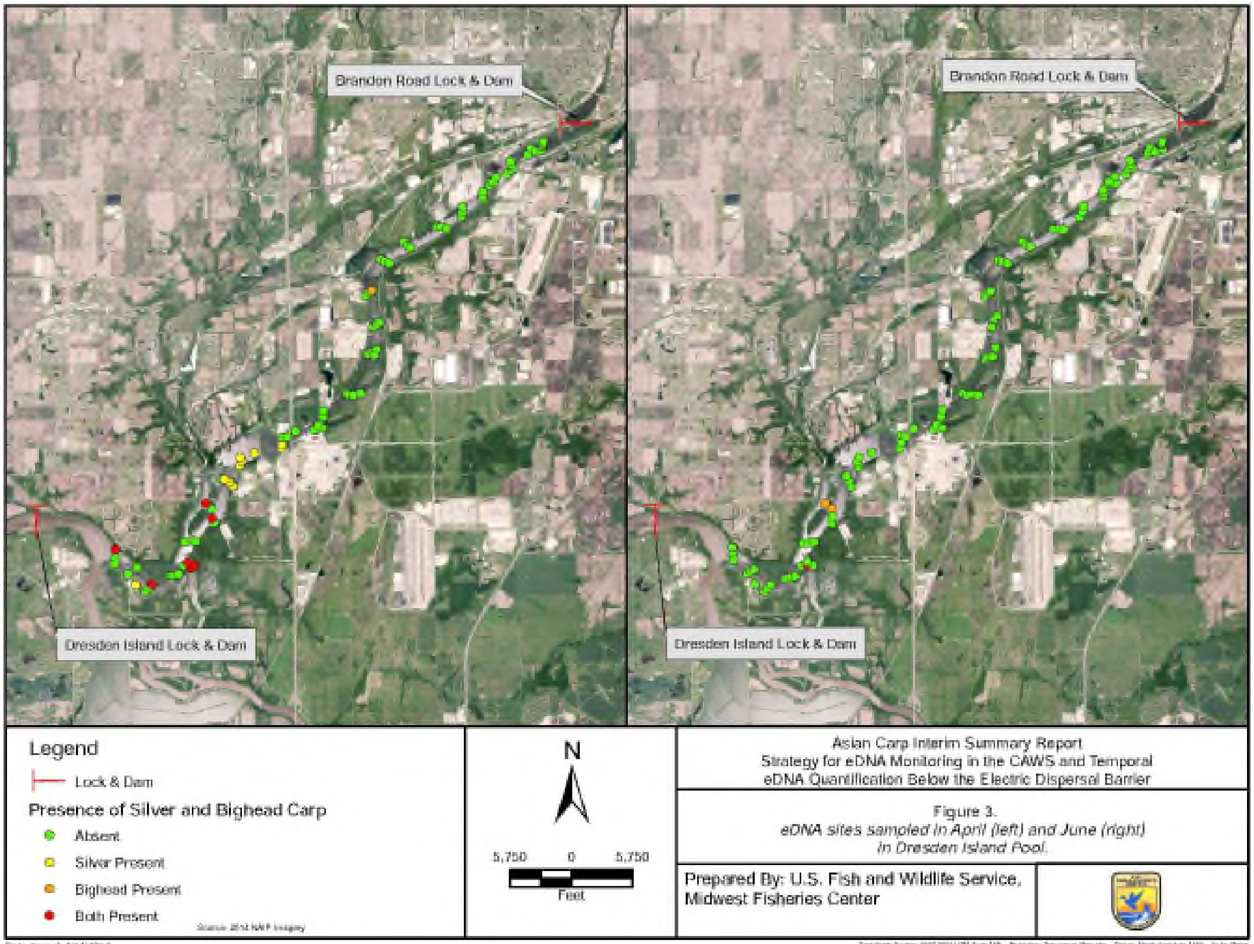


Figure 3. *eDNA site sampled in April (left) and June (right) in Dresden Island pool.*

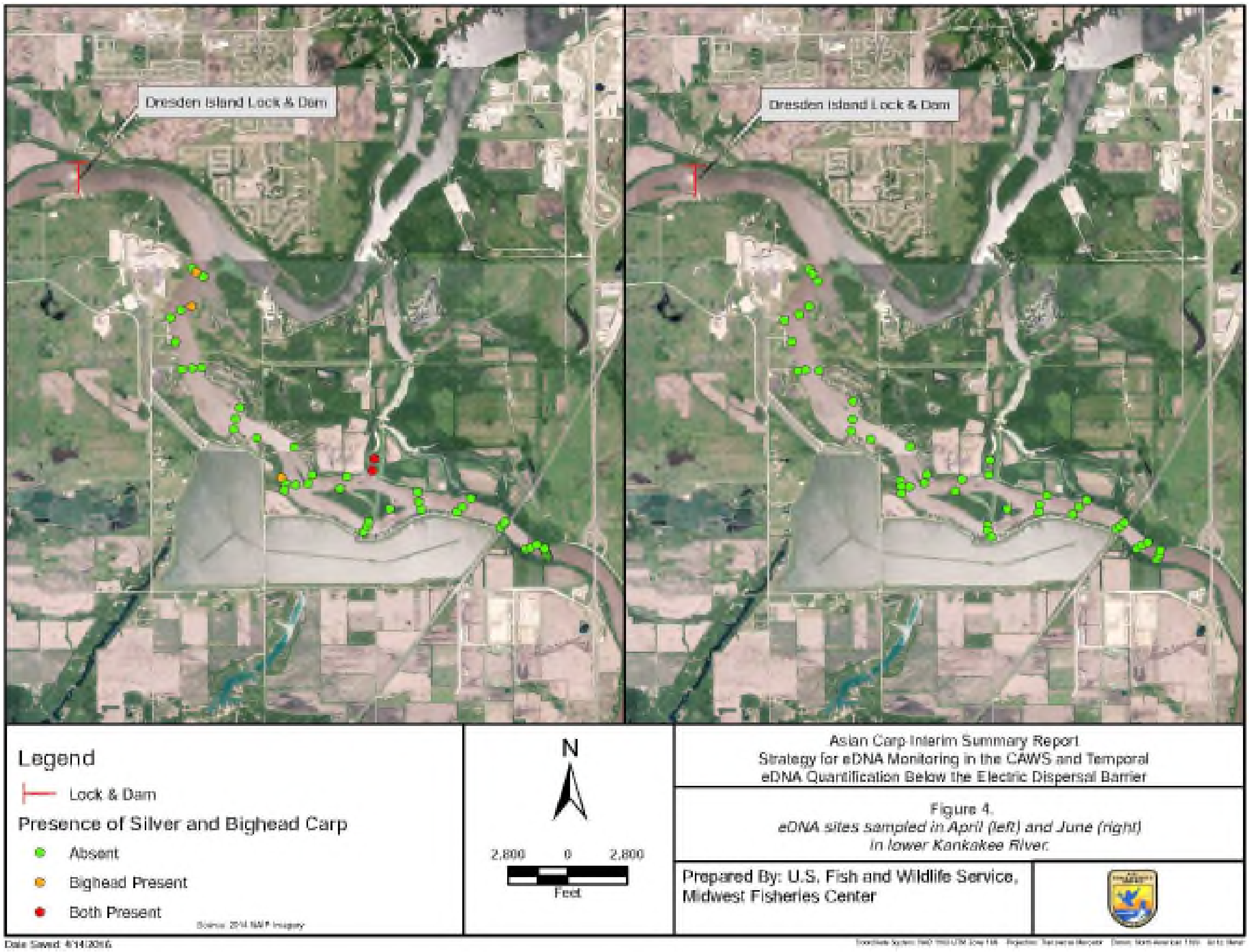


Figure 4. *eDNA sites sampled in April (left) and June (right) in lower Kankakee River.*

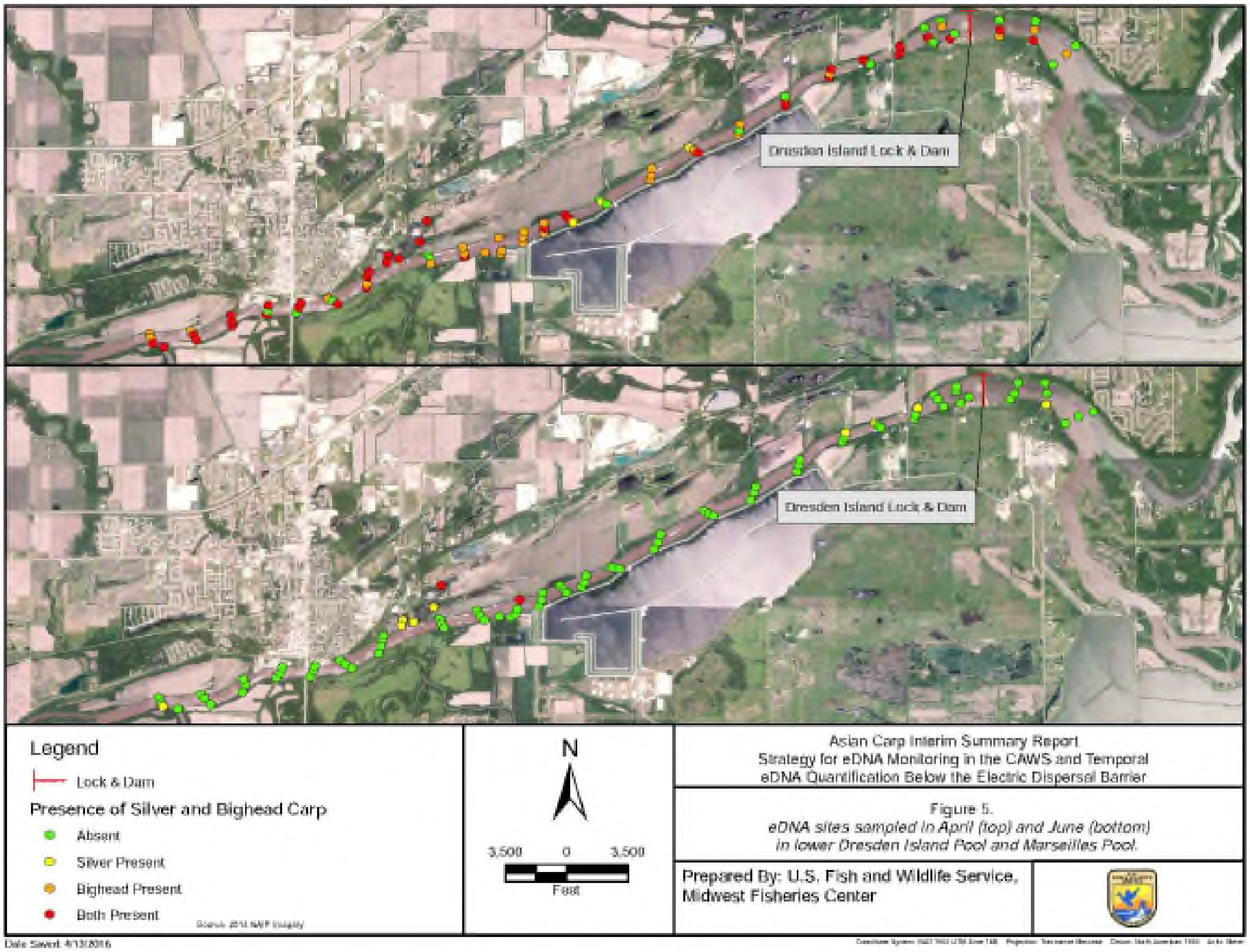


Figure 5. *eDNA sites sampled in April (top) and June (bottom) in lower Dresden Island pool and Marseilles pool.*

Larval Fish Monitoring in the Illinois Waterway

Steven E. Butler, Matthew J. Diana, Scott F. Collins, David H. Wahl
(Illinois Natural History Survey)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Participating Agencies: Illinois Natural History Survey (lead)

Introduction: Silver Carp and Bighead Carp are highly fecund, capable of producing hundreds of thousands of eggs, which are semibuoyant and drift in river currents for approximately a day before hatching. Larval Asian carp have previously been collected in the Alton, LaGrange, and Peoria Pools of the Illinois River, but reproduction appears to be highly variable among years. Information on the distribution of larval Asian carp is needed to identify adult spawning areas, determine reproductive cues, and characterize relationships between environmental variables and survival of young Asian carp. This information 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 early life history.

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 the abundance of Asian carp eggs and larvae.

Project Highlights:

- Over 550 larval fish samples were collected from 12 sites across the length of the Illinois Waterway during April – October, 2015, capturing over 79,000 larval fish, including 62,170 larval Asian carp. Additionally, over 71,000 Asian carp eggs were collected in ichthyoplankton samples in 2015. These are the highest numbers of Asian carp larvae observed in the Illinois Waterway in six years of sampling.
- Asian carp eggs were collected in the LaGrange, Peoria, Starved Rock, and Marseilles Pools during 2015. Asian carp larvae were identified from the LaGrange, Peoria, and Dresden Island Pools. Prior to this year, no Asian carp eggs or larvae had been collected at any location upstream of Henry (Peoria Pool). These observations confirm that Asian carp reproduction occurs in some years in the upper Illinois River.
- An early spawn in May was evident from the presence of Asian carp eggs in the LaGrange Pool, but the bulk of eggs and larvae were collected in association with the flooding that occurred in the Illinois River during June and July 2015. The presence of Asian carp eggs and larvae in the Illinois River appears to be associated with rising water levels when water temperatures are above 20°C.

Larval Fish Monitoring in the Illinois Waterway

Methods: Larval fish sampling is occurring at 12 sites throughout the Illinois Waterway (Figure 1). Sampling is occurring at approximately bi-weekly intervals from April to October, but with more frequent sampling taking place during periods when Asian carp spawning activity has been observed or when larval fish and eggs are considered likely to be present (May – early July). Four larval fish samples are being collected at each site on each sampling date. Sampling transects are 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 Service Pit in Marseilles Pool), samples are being collected at both backwater and adjacent main channel locations. Samples are collected using a 0.5 m-diameter ichthyoplankton push net with 500 um mesh. To obtain each sample, the net is pushed upstream using an aluminum frame mounted to the front of the boat. Boat speed is adjusted to obtain 1.0 – 1.5 m/s water velocity through the net. Flow is measured using a flow meter mounted in the center of the net mouth and is used to calculate the volume of water sampled. Fish eggs and larvae are collected in a meshed tube at the tail end of the net, transferred to sample jars, and preserved in 90-percent ethanol. Larval fish are being identified to the lowest possible taxonomic unit in the laboratory. Fish eggs are 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 are being calculated as the number of individuals per m^3 of water sampled.

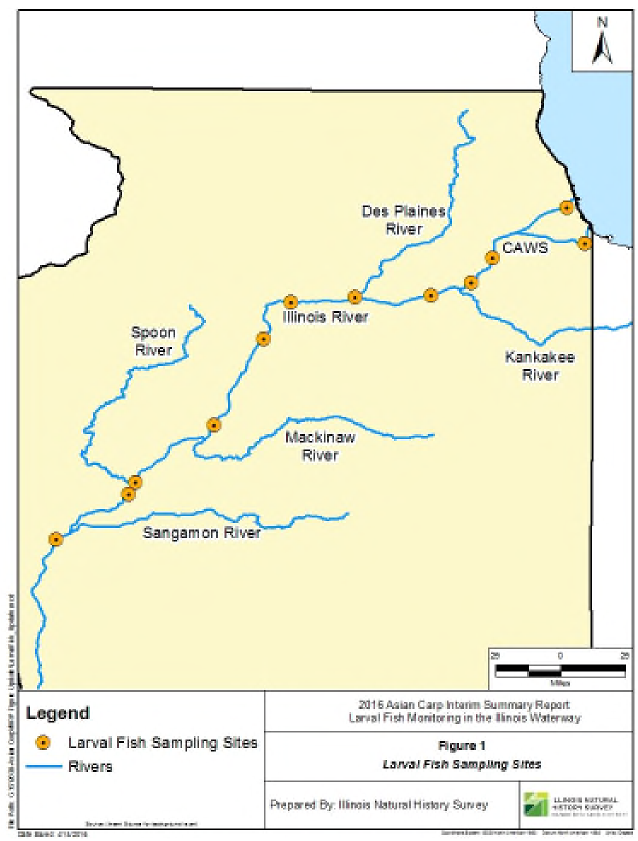


Figure 1. *Map of larval fish sampling sites in the Illinois Waterway. Sites on the main channel and backwaters of the Illinois Waterway are represented by circles.*

Larval Fish Monitoring in the Illinois Waterway

Results and Discussion: In 2015, a total of 558 larval fish samples were collected from main channel and backwater sites of the Illinois Waterway. From these, over 79,000 larval fish have been identified, including over 62,000 larval and early post-larval Asian carp. Additionally, over 71,000 Asian carp eggs have been identified from 2015 ichthyoplankton samples. These numbers of Asian carp eggs and larvae are substantially higher than those observed in previous study years (Table 1), suggesting that conditions may have been more suitable for successful spawning during 2015.

Table 1. *Dates, effort, and number of larval fish captured during ichthyoplankton sampling activities on the Illinois Waterway during 2010 – 2015.*

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

Asian carp appear to have had multiple spawning events in 2015, as indicated by the timing and location of eggs and larvae (Figure 2). Asian carp eggs were first observed at main channel sites in the LaGrange Pool during mid-May, after water temperatures had reached approximately 20°C and following a small rise in the hydrograph, but sampling during late May did not detect any Asian carp eggs or larvae at any sites. Following a rapid rise in water levels in early June, extremely high numbers of Asian carp eggs were collected at multiple sites as far upstream as the Marseilles Pool, with the highest densities observed in the Starved Rock and Peoria Pools. Shortly thereafter, large numbers of Asian carp larvae were collected at all sites in the LaGrange Pool, with lower numbers found in the lower Peoria Pool. Three Asian carp larvae (8.5 – 10.0 mm TL; developmental stages 41 - 43) were also identified in a sample collected upstream of the I-55 bridge in the Dresden Island Pool on June 18. Asian carp eggs continued to be collected in the upper Peoria and Starved Rock Pools, and larvae in the LaGrange and lower Peoria Pools through early July. Ichthyoplankton sampling continued to occur throughout the Illinois Waterway through October, but no Asian carp eggs or larvae were collected at any site after July 9. No Asian carp eggs were collected upstream of the Marseilles Pool during 2015, and no Asian carp larvae were collected upstream of the Dresden Island Pool. Subsamples of presumed Asian carp eggs and larvae, along with known bighead carp larvae (hatchery source; positive controls) and non-Asian carp larvae (negative controls) were sent to the USFWS Whitney Genetics Lab and the USGS Upper Midwest Environmental Sciences Center for genetic confirmation. These analyses identified one of the larvae collected in the Dresden Island Pool as a Silver Carp, and all but one presumed Asian carp egg (determined to be Grass Carp) as either Silver Carp or Bighead Carp. Overall, 94 percent of all presumed Asian carp eggs and 100 percent of all Asian carp larvae that were submitted for genetic analyses were confirmed to be *Hypophthalmichthys* spp.

Larval Fish Monitoring in the Illinois Waterway

Collectively, these data indicate that Asian carp had a successful spawning year in 2015, producing large numbers of larvae, at least some of which survived to the juvenile life stages (see Young-of-Year and Juvenile Asian Carp Monitoring summary). Numbers of Asian carp larvae observed in 2014 and 2015 were substantially higher than in previous years (2010 – 2013). Determining what conditions were associated with this high reproductive output in 2014 and 2015 that were absent in previous years of low spawning success is important to understanding factors that contribute to Asian carp reproduction and recruitment in the Illinois Waterway. Asian carp spawning is thought to be linked to a rising hydrograph during periods of appropriate water temperatures. The largest numbers of eggs and larvae collected in both 2014 and 2015 were indeed associated with prolonged periods of rising water levels. A more detailed analysis of all six years of sampling data, examining the relationships of temperature, water levels, and other environmental factors to the occurrence and densities of Asian carp eggs and larvae will likely help clarify differences in the reproductive output of Asian carp among years.

Asian carp eggs and larvae have not been observed in the upper Illinois Waterway in any study year prior to 2015, although Asian carp spawning activity has previously been observed in the Marseilles Pool. The presence of Asian carp eggs in the Starved Rock and Marseilles Pools confirms observations of spawning activity in the upper Illinois River, and indicates that some Asian carp reproduction takes place in the upper Illinois Waterway when conditions are conducive to spawning. However, other than the three larvae collected in the Dresden Island Pool, all Asian carp larvae found to date have been collected at or downstream of Henry (Peoria Pool). This suggests that even if spawning occurs in the upper Illinois River, the majority of eggs probably are transported downstream of the Starved Rock Lock and Dam before hatching. Some eggs still might be retained, hatch, and survive to juvenile stages above Starved Rock, but the abundance of these fish, or their contribution to the larger population, remains uncertain. The origin of the three Asian carp larvae collected in the Dresden Island Pool is also unknown. The high flows present in the Illinois Waterway during the time they were collected would make it unlikely that they originated in the CAWS. Eggs spawned within the Dresden Island Pool could possibly have been retained and hatched in off-channel areas, or eggs or larvae could have been entrained by barges and transported upstream. Further monitoring will be required to better understand the true distribution of Asian carp spawning activity, patterns of egg and larvae transport, and the potential survival of juvenile Asian carp in the upper Illinois Waterway.

Recommendations: Ichthyoplankton sampling should continue in future years in order to monitor for Asian carp reproduction, particularly upstream of the Peoria Pool. The high reproductive output and survival to juvenile stages that was observed in 2014 and 2015 contrasts with the pattern of little to no reproductive output observed in previous years. Additional sampling will be required to adequately understand factors that contribute to Asian carp reproduction and eventual recruitment, and to sufficiently characterize the potential for these species to reproduce in upstream reaches. Larval fish sampling in tributary rivers (Sangamon, Spoon, and Mackinaw 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. Additionally, with the confirmation of Asian carp spawning in the upper Illinois River, sampling in the Fox and Kankakee Rivers should be conducted to determine if Asian carp reproduction occurs in these systems. Analysis of egg and larval fish drift is warranted to determine the origin of Asian carp eggs and larvae that have been sampled from throughout the Illinois River.

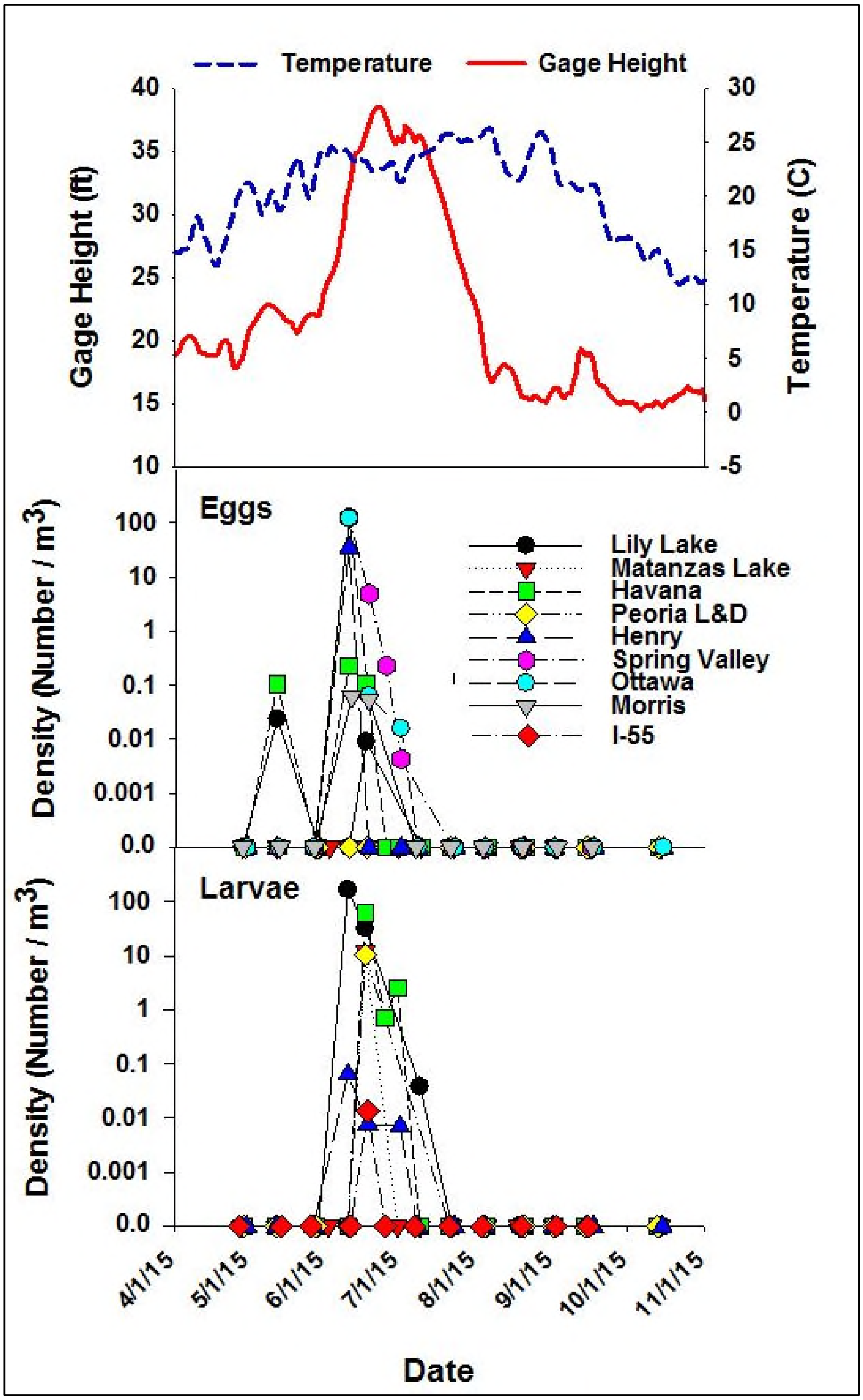


Figure 2. *Mean daily gage height (ft) and water temperature (° C) of the Illinois River during April – October 2015 (top panel), and densities (number / m^3; note log scale) of Asian carp eggs (middle panel) and larvae (bottom panel) collected from sites throughout the Illinois Waterway during 2015. Gage height and temperature data were obtained from USGS hydrograph 5586300 at Florence, IL.*

Young-of-year and Juvenile Asian Carp Monitoring

Brennan Caputo, David Wyffels, Tristan Widloe,
John Zeigler, Blake Ruebush, Matt O'Hara ,and
Kevin Irons (Illinois Department of Natural Resources)
Steven E. Butler, Matthew J. Diana, and David H. Wahl
(Illinois Natural History Survey)

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

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction: Bighead and Silver Carp are known to spawn successfully in larger river systems where continuous flow and moderate current velocities transport their semi-buoyant eggs during early incubation and development. Spawning typically occurs at water temperatures between 18 and 30ºC during rising water levels. Environmental conditions suitable for Asian carp spawning may be available in the CAWS and nearby Des Plaines River, particularly during increasingly frequent flooding events.

Successful reproduction is considered an important factor in the establishment and long-term viability of Asian carp populations. The risk that Asian carp will establish viable populations in Lake Michigan increases if either species is able to successfully spawn in the CAWS. Successful spawning in the upper Des Plaines River also could pose a threat because larval fish may be washed into the CSSC upstream of the Electric Dispersal Barrier during extreme flooding. Larvae can be transported to the CSSC despite installation of concrete barrier and fencing between the waterways because larval fish are small enough to pass through the 6.4-mm (0.25-inch) mesh fencing used for the separation project. Larvae washed into the CSSC would likely be transported downstream past the Electric Dispersal Barrier during flooding; these fish might become established in the lower Lockport pool, recruit to the juvenile life stage, and challenge the Electric Dispersal Barrier.

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

(1) Determine whether Asian carp young-of-year or juveniles are present in the CAWS, lower Des Plaines River, and Illinois River; and

Young-of-year and Juvenile Asian Carp Monitoring

(2) Determine the uppermost waterway reaches where young Asian carp are successfully recruiting.

Project Highlights:

- Sampled for young Asian carp from 2010 to 2015 throughout the CAWS, Des Plaines River, and Illinois River between river miles 83 and 334 by incorporating sampling from several existing monitoring projects.
- Sampled with active gears (trawls, pulsed-DC electrofishing, small mesh purse seine, cast net, and beach seine) and passive gears (small mesh gill nets and mini-fyke nets) in 2015.
- Completed 1,691 hours of electrofishing across all years and sites.
- Examined 241,311 Gizzard Shad <152 mm (6 in) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam from 2010 to 2015 and found only two young Asian carp in Marseilles Pool and none upstream.
- High catches of young-of-year Asian carp in 2014 and moderate numbers in 2015 in the LaGrange Pool indicate two consecutive successful recruitments year despite limited to no recruitment in 2010 to 2013.
- Farthest upstream catch was a two young-of-year Silver Carp in the Marseilles Pool near Morris, Illinois (river mile 263) in 2015, which expands the range where juveniles have been detected.
- Recommend continued monitoring for young Asian carp.

Methods: As in the past, 2015 sampling for young-of-year and juvenile Asian carp took place through other projects of the MRRP. Young fish were targeted in the following projects: Larval Fish and Productivity Monitoring, Fixed Site Monitoring Downstream of the Dispersal Barrier, Gear Efficiency and Detection Probability Study, Seasonal Intensive Monitoring (SIM) in the CAWS, Des Plaines River and Overflow Monitoring Project, and Barrier Maintenance Fish Suppression Project. See individual project summary reports and the 2015 MRP for specific locations of sampling stations.

Pulsed-DC electrofishing and mini fyke netting were the principal gears used to monitor for young Asian carp. Monthly fixed site monitoring in the CAWS upstream of the barrier was discontinued in 2014, with monitoring for all fish (adults and juveniles) conducted over two SIM sampling events that took place in June and September. This intensive event was coordinated and intensive and used efforts from multiple agencies (IDNR, INHS, USFWS, and USACE); all data are presented here. A total of 105.5 hours of electrofishing (422 transects) was completed over four SIM events in 2015. In past segments, fixed site monitoring occurred monthly from March to December at five stations and included 30 15-minute transects. Random site monitoring occurred in four reaches that encompassed the entire 122.3 km (76 miles) of the CAWS upstream of the barrier and averaged approximately 160 15-minute electrofishing transects per year (Tables 1 to 3).

Young-of-year and Juvenile Asian Carp Monitoring

Electrofishing and fyke netting at fixed sites downstream of the Electric Dispersal Barrier occurred monthly from March to November in 2015 at four sites in each of the Lockport, Brandon Road, Dresden Island, and Marseilles pools (16 15-minute transects and 4 net nights per month). Random site monitoring occurred in all four pools as well, for a total of 16 15-minute electrofishing runs per month. Standard electrofishing protocols were modified such that schools of small fish <152 mm (6 inches) long (typically Gizzard Shad) were subsampled by netting a portion of each school encountered during each electrofishing run. Netted small fish were placed in a holding tank and examined individually for the presence of Asian carp, counted, and then returned to the waterway alive. Counting Gizzard Shad < 152 mm (6 inches) long provided an estimate of the relative abundance of young Asian carp, if present, in each sample of small fish.

In addition to fixed and random monitoring below the barrier, the gear efficiency study targeted young Asian carp using pulsed DC-electrofishing, mini-fyke nets, small mesh gill nets, beach seines, cast nets, bottom electrified trawls, and small mesh purse seines. DC electrofishing was conducted every other week after larval Asian carp were detected in ichthyoplankton pushes. Sites were sampled with all gears in the LaGrange Pool in two backwaters and two main channel locations in August and again in September. Each site visit included four 15-minute DC electrofishing transects, four 4-hour gill net sets, eight mini-fyke net-nights, four beach seine hauls, four cast net throws, and four small mesh purse seine sets (see Gear Efficiency Report).

U.S. Fish and Wildlife juvenile sampling was conducted monthly in the Dresden, Marseilles, and Starved Rock Pool. Sampling included monthly mini fyke netting, electrofishing, and push trawl sampling. This sampling targeted areas off the main channel, including backwaters, isolated pools, side channels, side channel borders, and tributary mouths. For detailed methods, see the project report for "Distribution and Movement of Small Asian Carp in the Illinois Waterway." In addition, USFWS deployed trawling gears monthly in the Dresden, Marseilles, Starved Rock, Peoria, and LaGrange Pools. These gears included Paupier trawls, Dozer trawls, surface trawls, and push trawls. The types and numbers of trawls varied by sampling location and date, depending on the presence of Asian carp. For detailed methods, see the project report for "Distribution and Movement of Small Asian Carp in the Illinois Waterway."

Results and Discussion: Young Asian carp were targeted with six gears in 2010, eight gears in 2011, 10 gears in 2012, six gears in 2013, six gears in 2014, and 11 gears in 2015, which included both active gears, (trawling, electrofishing, purse seining, cast netting, and beach seining) and passive gears, (small mesh gill nets and mini-fyke nets). The DC electrofishing was conducted in all segments of the Illinois River, Upper Des Plaines River, and CAWS in 2015, and mini fyke net monitoring was conducted heavily downstream of the electric barrier from the Lockport to the LaGrange Pools. In 2015, large numbers of young-of-year Asian carp were detected in the LaGrange (n =1040) and reduced numbers were found in the Peoria (n = 152) and Starved Rock (106) Pools. No young-of-year Asian carp were collected upstream of the Starved

Rock Pool and only two 6 to 12 inch Silver Carp were collected in the Marseilles Pool, which is consistent with the absence of larval fish and is currently understood to be the farthest upstream successful reproduction of Asian carp has been documented. Spawning behavior and egg loss were observed the Marseilles pool, but no successful production of young-of-year fish was documented. All but nine (eight bighead and one hybrid) of the juvenile Asian carp collected were identified as Silver Carp in the field (Table 5) with. The greatest numbers of young-of-year Silver Carp were collected in various trawls (n = 1140), with Paupier trawls having the highest catch rates (663), followed by mini fyke nets (84) and DC electrofishing (29), with low catch rates for other gears.

High level of effort was spent on DC electrofishing, which accounted for 289.8 hours in all pools and mini-fyke nets with 478 net-nights (Table 5). A substantial effort was expended with various trawling efforts totaling 221,657 m of trawling. Sampling effort varied among pools and among gears from site to site, but adequately covered the CAWS upstream of the Electric Dispersal Barrier and all pools downstream. Although electrofishing did not produce the greatest numbers of Asian carp, it was able to detect them when they were present. Electrofishing, mini-fyke net, and trawl monitoring should be used together to adequately monitor for the presence of young-of-year Asian carp.

No juvenile Asian carp <305 mm (12 in) long were captured in 2010 and 2013, and low catches were reported in 2011 and 2012 (Table 1 and Table 2). These results are consistent with those from larval fish monitoring (see Larval Fish and Productivity Report), which may reflect poor Asian carp recruitment in the waterway over these past 4 years. The year 2014 is the first with substantial abundances of young-of-year Asian carp since this monitoring project began in 2010. Six hundred and thirty four juveniles 152 to 305 mm were detected in gears in 2015 in the Starved Rock, Peoria, and LaGrange Pools. Only two of this sized fish Asian carp were detected in the Marseilles Pool, and none of these fish were found upstream of the Marseilles Pool. Overall, we examined 241,311 Gizzard Shad <152 mm (6 inches) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam from 2010 to 2015 and found no young Asian carp.

Recommendations: We used multiple gears coordinated throughout several projects to monitor for young Asian carp in the CAWS, Des Plaines River, and Illinois River from 2010 to 2015. We found no Asian carp juveniles upstream of Starved Rock Lock and Dam. In 2015, we observed high numbers of young-of-year Silver Carp in the LaGrange pool as well as successful reproduction in the Peoria Pool and Starved Rock Pools. Numbers were not as high as 2014, and only very low numbers of Asian carp had been detected upstream of the Starved Rock Lock and Dam prior to 2014. We detected more Asian carp in the Starved Rock Pool than in past segments, but this increase may be the result of increased sampling efforts in this pool after they were first detected in 2014. While these results are encouraging in our efforts to prevent Asian carp from establishing populations in the CAWS and Lake Michigan, they are only temporary and may quickly change if conditions limiting recruitment success (for example, flow, water quality, competition for food and space, and abundance of spawning stock) improve in the future. We recommend continued vigilance in monitoring for juvenile Asian carp in the CAWS and Illinois Waterway through existing monitoring projects and enhanced efforts. A development that will benefit the understanding of Asian carp recruitment demographics is preparation of a white paper on the distribution of small Asian carp in the Mississippi Basin. This cooperative effort by IDNR, USACE, and USFWS will gather data on Asian carp spawning and the distribution of young Asian carp from researchers and management biologists across the basin. These data will be summarized and made available in a living document that can be used to identify data gaps and track 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. River miles are in parentheses.*

			Number collected						
Year and location	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 (296-334)	DC electrofishing	208 hours	0	0	0	0	0	0	12,746
Barrier to Marseilles Pool (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 (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 (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 (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

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					
Year/location	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.
2012	DC electrofishing	268 hours	0	0	0	0	0	42,448
CAWS upstream	Mini-fyke net	48 net-nights	0	0	0	0	0	22
of barrier	Small mesh gill net	336 hours	0	0	0	0	0	5
(296-334)	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	DC electrofishing	94 hours	0	0	0	0	0	14,439
to Starved Rock	Mini-fyke net	239 net-nights	0	0	0	0	0	642
Pool (240-296)	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	DC electrofishing	40.5 hours	0	0	0	0	0	755
La Grange and	Mini-fyke net	181 net-nights	4	0	0	0	0	3,867
Peoria Pools	Small mesh gill net	752 hours	0	0	0	0	0	76
(83-190)	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							
Location	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.	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

Young-of-year and Juvenile Asian Carp Monitoring

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.*

Location	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.*

Location	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	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

Table 5 Cont.

Young-of-year and Juvenile Asian Carp Monitoring

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

Young-of-year and Juvenile Asian Carp Monitoring

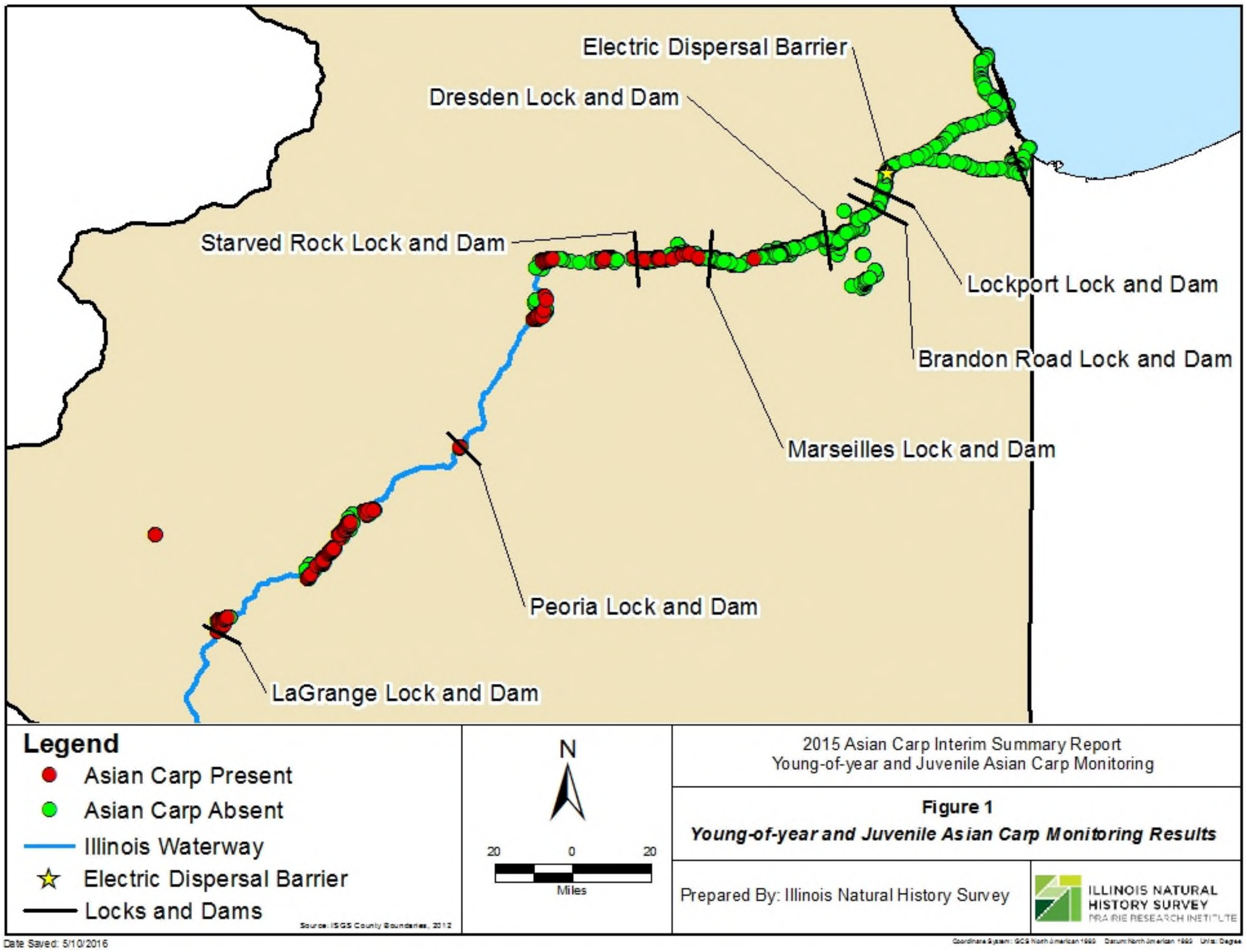


Figure 1: *Location of all juvenile sampling sites conducted by INHS, IDNR and USFWS in the Illinois River and CAWS in 2015.*

Distribution and Movement of Small Asian Carp in the Illinois Waterway

Kjetil Henderson, Jeff Steward, Rebecca Neeley, Samuel Finney, and Robert Simmonds Jr. (USFWS Carterville, Wilmington Substation)
Emily Pherigo (USFWS Columbia)

Participating Agencies:
USFWS Carterville Fish and Wildlife Conservation Office Wilmington Substation (lead), USFWS Columbia Fish and Wildlife Conservation Office (field support)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Location:
Known populations of adult Asian carp exist in all pools of the IWW downstream of Brandon Road Lock and Dam. In 2015, USFWS personnel surveyed for small Asian carp within the Dresden Island, Marseilles, Starved Rock, Peoria, and La Grange pools. As of January 2016, the farthest upstream small Asian carp (≤300 mm TL) have been recorded was in Moody Bayou (Gundy County) at Illinois River mile 256.4. These two Silver Carp (168 and 171 mm) were collected on October 22, 2015 (USFWS unpublished data).

Introduction:
An Electric Dispersal Barrier operated by the USACE in Lockport pool is intended to block the upstream passage of Asian carp through the CSSC. Laboratory tests have shown the operational parameters used at the barrier are sufficient for stopping large-bodied fish from passing through (Holliman 2009). However, testing of operational parameters using small Bighead Carp (51 to 76 mm TL) revealed these parameters may be inadequate for blocking small fish passage (Holliman 2011). USFWS research showed that Golden Shiner (*Notemigonus crysoleucas*) can be entrained in barge junction gaps upstream through the electric barrier (Davis et al. 2016). Other USFWS research, using a pair of Dual Frequency Identification Sonar units (DIDSON), showed that small fish (unknown species observed on sonar) are able to move upstream through the Electric Dispersal Barrier (Parker et al. 2013). If Asian carp are present near the barrier, these species may be capable of breaching the electric barrier. As such, there is a critical need to determine the small Asian carp distribution and demographic characteristics below the barrier. Additionally, there is an ongoing need to understand the reproduction of these species in the IWW so managers might better target small fish for eradication or other future management actions.

The purpose of this study is to establish where young Asian carp ≤ 300 mm occur in the IWW through intensive, directed fish sampling targeting these life stages. For this study, fish specimens ≤ 300 mm TL are considered "small fish" based on previously published estimates of age-one and age-two Bighead Carp (Shrank and Guy 2005) and Silver Carp (Williamson and Garvey 2005). Traditional and novel sampling techniques were used in 2015, including small-mesh fyke nets, DC boat electrofishing, and surface, mid-water, and benthic trawls. Irons et al. (2011) evaluated daytime electrofishing and mini-fyke nets as effective gears for detecting and collecting small Asian carp. These two gears have been shown to provide complementary information when employed in shallow water areas (Ruetz et al. 2007). USFWS sampling data indicate that trawls complement these methods by sampling deeper open water habitats.

Objectives:

1) Determine the distribution, abundance, and age structure of small Asian carp in the middle and upper IWW.
2) Use distribution and abundance data to characterize the risk of small Asian carp entry into the Great Lakes via the Chicago Area Waterway System.

Methods:

Sampling sites were identified as backwaters, isolated pools, main channel border, side channels, side channel borders, marinas, or tributary mouths. Physical, water quality, and habitat measurements were made at each collection site. Physical measurements included: depth, Secchi depth, and substrate (boulder, cobble, gravel, sand, silt, and clay). Water quality measurements included: temperature, salinity, specific conductance, dissolved oxygen, and pH; these were taken with an analytical instrument (YSI Professional Series multi-meter). Habitat measurements were recorded at the time of each sampling event. GPS coordinates were recorded for all net sets, beginning and end of electrofishing runs and trawl hauls.

All Bighead Carp, Silver Carp, Grass Carp, and up to 25 Gizzard Shad per sample were measured for total lengths. Most other fish were counted and released. Fish not easily identifiable in the field, including some young-of-year fish, were preserved in formalin for laboratory identification to the lowest possible taxonomic level. Effort was quantified as net nights (mini-fykes), minutes electrofishing (boat and paupier butterfly frame trawl), and meters sampled (paupier, push trawl, dozer trawl, and surface trawl). The dozer trawl and paupier butterfly trawl were developed and used by the USFWS Columbia office, and data for this sampling are included in this report only as summary data.

Fyke netting **—** Wisconsin type mini-fyke nets were set 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, 1/8-inch mesh, and 2-inch openings.

Electrofishing **–** Daytime electrofishing was conducted for approximately 15-minute periods. Pulsed DC (60 pulses/second) with approximately 16 to 22 A of electricity were used for all electrofishing sampling.

Push trawl **–** Daytime trawls sampled water depths of 0.5 meter to 2.0 meter. Target lengths of trawl hauls were between 25 and 100 meters but varied with the amount of fishable habitat present per location. The push-trawl employed had a skate balloon trawl net of 4-mm mesh, 1.8-meter body length, 0.76-meter x0.38-meter otter boards, 2.4-meter foot rope, and an effective net fishing width of 1.8-meters across.

Dozer trawl **–** A 35-mm mesh net at the opening reducing to 4-mm mesh in the cod attached to a 2-meter by 1-meter rigid frame that is mechanically raised and lowered to fish depths of up to 1-meter. The net extends approximately 2.5 meters back as it is pushed off the front of the boat. The target habitat is open water >0.6-meter deep (with up to medium flows) but can be utilized in a variety of conditions. The system can be electrified or not. Length and duration of trawl depends on site characteristics.

Paupier butterfly trawl **–** Contains one 3.7-meter x1.5-meter rigid frame on either side of a flat bottomed boat with 35-mm mesh in the body reducing to 4-mm mesh in the cod. Frames can be fished 0.5- to 3-meters. The system can be electrified or not. Target habitat includes open water ≥0.6 meter deep. Length and duration of trawl is dependent on site characteristics.

Surface trawl **–** The 10.7-meter-long surface trawl net has 35-mm mesh in the body reducing to 4-mm mesh in the cod. Towlines extend 38-meters to floating otter boards that spread the net to an approximate 6.5 meters wide. Able to fish up to 1 meter depth, target habitats include open water ≥1-meter with no to low flows. Length and duration of trawl is dependent on site characteristics.

Results and Discussion:

The two Silver Carp (168 and 171 mm) collected on October 22 represent the farthest upstream juvenile Asian carp have been sampled in the Illinois River. Much of the 2015 sampling efforts were conducted in the Starved Rock and Marseilles pools as a result of the detection of a substantial age-0 Silver Carp year class, and IWW flooding making some sites less accessible. Future sampling efforts will be shifted upstream to include increased sampling efforts in Dresden Island pool.

Novel trawling gears, developed by USFWS Columbia FWCO, were incorporated in 2015. Recruitment of age-0 Silver Carp captured in Starved Rock and Marseilles pools is displayed from August through November 2015 (Figure 1).

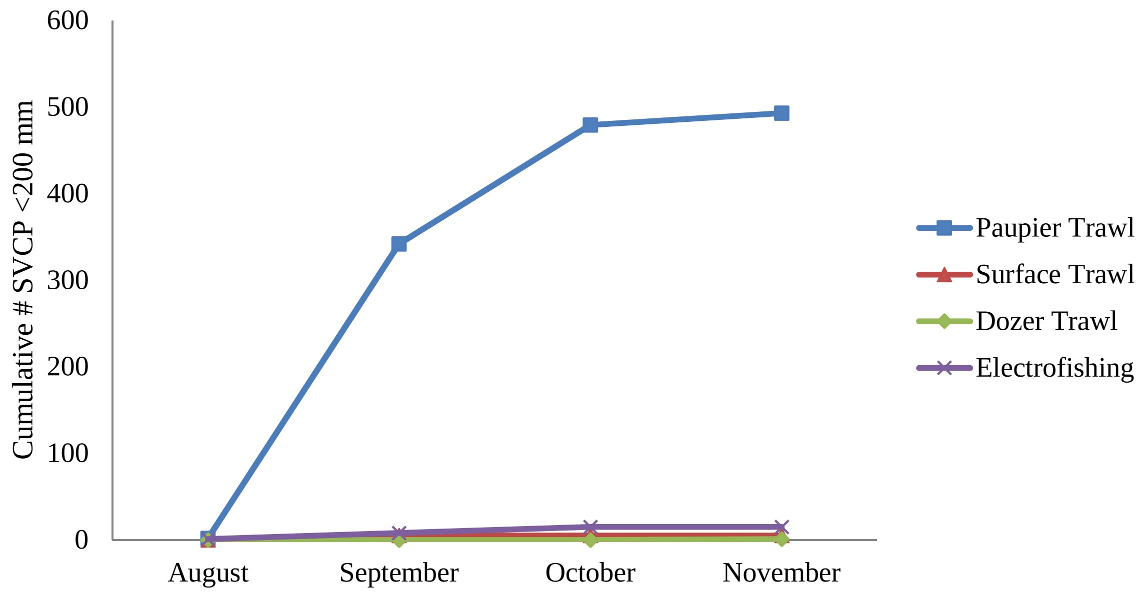


Figure 1. *Cumulative Silver Carp (≤153mm) captured in Starved Rock and Marseilles Pools using paupier trawl, surface trawl, dozer trawl, and electrofishing during August through November 2015.*

The paupier trawl caught the most Asian carp (≤153 mm) of the six gears (Table 1 and Table 2). This trawl can effectively fish deeper water than the other trawls, or electrofishing. Mini-fyke nets captured a few very small Asian carp (mean TL = 85 mm, n = 9). Boat electrofishing (mean TL = 150 mm, n = 17), and particularly the electrified paupier (mean TL = 150 mm, n = 1,141), is effective once fish recruit to these gears.

Table 1. *Bighead and Silver Carp (≤153mm) caught by USFWS personnel in 2015 by gear and pool.*

	Electrofishing	Mini-fyke	Push trawl	Surface trawl	Dozer trawl	Paupier trawl
Dresden Island	-	-	-	-	-	-
Marseilles	-	-	-	-	-	-
Starved Rock	8	-	-	4	-	96
Peoria	2	9	2	94	8	38
La Grange	212	-	46	71	112	536
Total	222	9	48	169	120	670

Table 2. *Summary of small Silver Carp (≤200mm) caught by electrofishing, mini-fyke, push trawl, surface trawl, dozer trawl, and paupier trawl in La Grange, Peoria, Starved Rock, Marseilles, and Dresden Island pools.*

	Electrofishing	Mini-fyke	Push trawl	Surface trawl	Dozer trawl	Paupier trawl
Mean (mm)	150	85	110	106	99	141
N	17	9	50	313	121	1141
Std. deviation	25.7	18.8	15.1	23.7	16.9	33.5
Range	95-195	54-112	55-146	33-195	51-171	24-198
Dates caught	4/16; 8/19-10/22	4/14; 6/9	4/9-4/29; 8/13	4/7-9/3	4/28-11/4	4/8-11/17

The USFWS small Asian carp project has grown considerably since 2012. More electrofishing, push trawl, and mini-fyke sampling efforts were made in 2015 (Table 3, Table 4, and Table 5) than in 2014 (2,085 minutes electrofishing, 205 mini-fyke net nights, and 20,657m push trawled).

Table 3. *Total USFWS 2015 sampling effort by pool and gear.*

	Dresden Island	Marseilles	Starved Rock	Peoria	La Grange
Paupier Trawl (meters)	-	17,215	44,171	11,109	19,042
Dozer Trawl (meters)	1,338	15,252	6,246	14,179	16,154
Surface Trawl (meters)	-	4,669	11,473	9,528	13,549
Push Trawl (meters)	3,333	6,841	10,483	5,955	11,120
Electrofishing (minutes)	545	1,586	721	78	-
Mini-fyke (night sets)	68	61	75	41	9

Table 4. *Total 2015 electrofishing (events/minutes) by pool and month for small fish project (no June sampling).*

Pool	April	May	July	August	September	October	November	Total
La Grange	-	-	-	-	-	-	-	-
Peoria	5/78	-	-	-	-	-	-	5/78
Starved Rock	-	-	42/388	10/76	12/124	9/133	-	73/721
Marseilles	-	5/75	21/192	16/136	4/34	77/860	20/289	143/1586
Dresden Island	-	-	6/82	-	13/171	-	22/292	41/545

Table 5. *Total 2015 push trawls (events/meters) by pool and month for small fish project.*

Pool	April	May	June	July	August	September	Total
La Grange	27/6254	-	7/615	-	15/4251	-	49/11120
Peoria	12/4353	-	9/982	10/620	-	-	31/5955
Starved Rock	21/4218	-	11/1831	21/2955	8/753	8/726	69/10483
Marseilles	-	19/2620	13/1679	21/2030	4/512	-	57/6841
Dresden Island	-	-	21/2641	8/692	-	-	29/3333

All 2015 sampling occurred between the dates of April 14 and November 18. Thisperiod represents the longest field season in the 4 years of the project. A total of 93 species and 89,857 fish were identified to species within the Starved Rock, Marseilles, and Dresden Island (including the Des Plaines River) pools. Electrofishing efforts in 2012 were more substantial than either 2013 or 2014, with 3,135 minutes electrofishing, while mini-fyke (184 net nights), and push trawling (88 events) were slightly less. Sampling efforts by pool and gear are provided (Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, and Table 9).

Table 6. *Total 2015 mini-fyke overnight sets by pool and month for small fish project.*

Pool	April	May	June	July	August	September	October	Total
La Grange	-	-	9	-	-	-	-	9
Peoria	23	-	8	10	-	-	-	41
Starved Rock	20	16	-	-	24	15	-	75
Marseilles	-	19	-	10	21	1	10	61
Dresden Island	-	19	28	-	-	10	11	68

Table 7. *Total 2015 surface trawls (events/meters) by pool and month for small fish project.*

Pool	April	May	June	July	August	September	October	Total
La Grange	20/3029	-	-	-	27/10520	-	-	47/13549
Peoria	19/7187	-	-	7/2441	-	-	-	26/9528
Starved Rock	8/2250	-	7/1943	13/5392	-	6/1888	-	34/11473
Marseilles	-	-	7/1980	5/2689	-	-	-	12/4669
Dresden Island	-	-	-	-	-	-	-	-

Table 8. *Total 2015 dozer trawls (events/meters) by pool and month for small fish project.*

Pool	April	May	June	July	August	September	October	November	Total
La Grange	-	-	-	-	46/16154	-	-	-	46/16154
Peoria	9/3250	-	-	28/10929	-	-	-	-	37/14179
Starved Rock	-	-	-	12/3182	-	2/427	15/2099	3/538	32/6246
Marseilles	-	8/1596	-	15/5131	-	7/1015	-	28/7510	58/15252
Dresden Island	-	-	-	-	-	5/1338	-	-	5/1338
Lockport	-	-	-	15/5131	-	-	-	-	15/5131

Table 9. *Total 2015 paupier trawls (events/meters/minutes) by pool and month for small fish project.*

Pool	April	May	June	July	August	September	October	November
La Grange	28/5756/107	-	-	-	27/10687/182	-	11/2599/56	-
Peoria	11/6373/84	-	-	9/3172/63	-	-	6/1564/23	-
Starved Rock	7/2840/49	19/5317/84	9/4691/60	14/5402/90	1/178/5	24/10840/173	50/13851/314	7/1052/113
Marseilles	-	-	6/2973/45	4/1889/24	-	17/4813/103	4/1055/24	10/6485/85
Dresden Island	-	-	-	-	-	-	-	-

Summary information and capture locations are provided for all small Silver Carp (≤ 153 mm) captured in Starved Rock and Marseilles pools (Table 10, Figure 2).

Table 10. *Juvenile Silver Carp (≤200mm) caught by USFWS using boat electrofishing, surface trawl, paupier trawl, and dozer trawls in Starved Rock and Marseilles pools in 2015.*

Pool	Dates	TL range (mm)	SVCP
Starved Rock	August 19	140	1
	August 28	128-133	2
	September 2-4	130-200	99
	September 30-October 2	137-200	321
	October 6-7	140-200	74
	November 4	171	1
	November 17	150-195	14
Marseilles	October 22	168-171	2

Juvenile Silver Carp aging was conducted by the U.S. Geological Survey – Columbia Environmental Research Center (USGS – CERC) using multiple hard structures including pectoral spines and vertebrate. Four year classes were identified measuring less than 300 mm (Figure 2, Duane Chapman and Joe Deters, personal communication).

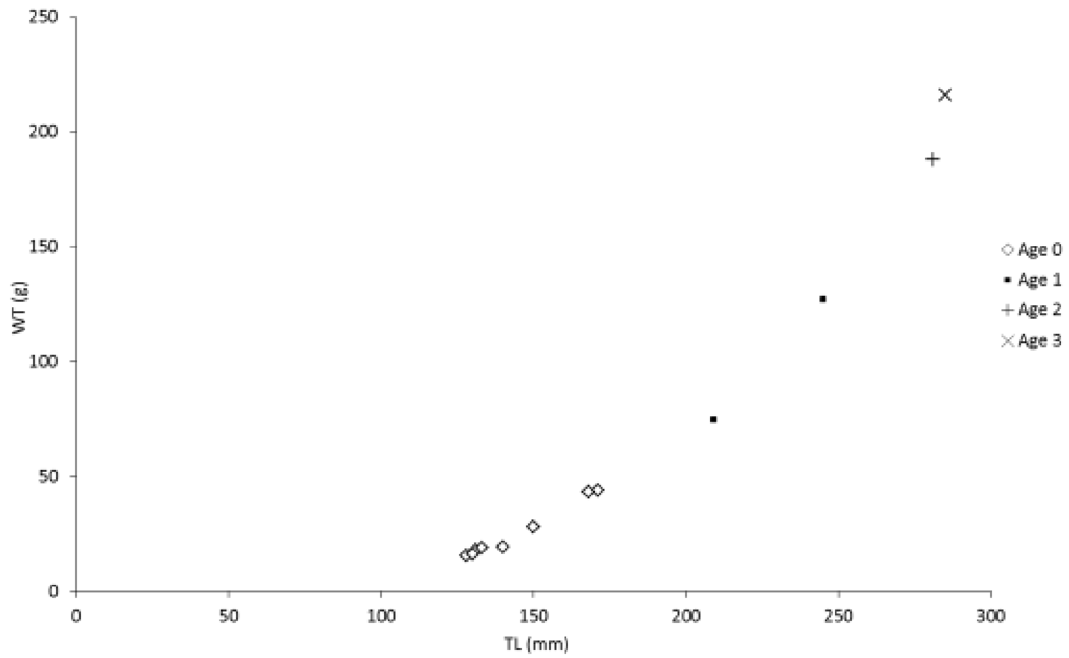


Figure 2. *Length and weight relationship for Silver Carp caught in Starved Rock pool from July 7-September 2, 2015. Aging was completed by USGS Columbia Environmental Research Center.*

Both Silver Carp (168 and 171 mm) collected on October 22, 2015, in Marseilles pool were confirmed to be young-of-year fish (Figure 3, Duane Chapman and Joe Deters, personal communication).

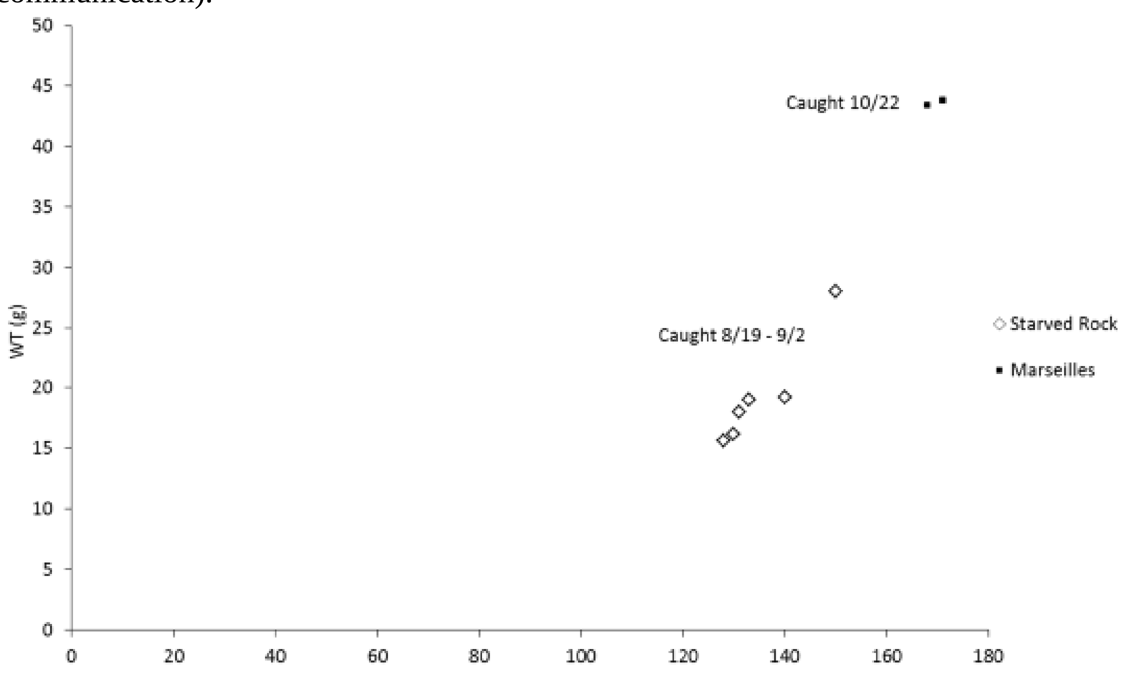


Figure 3. *Length-weight relationship for age-zero Silver Carp caught in Starved Rock and Marseilles pools from August through October 2015. Aging was completed by USGS Columbia Environmental Research Center.*

Distribution and Movement of Small Asian Carp in the Illinois Waterway

A length histogram is provided for Silver Carp captured in Starved Rock Pool during two sampling events from September 2 to 4 and September 30 to October 2 (Figure 4). The Electric Dispersal Barrier is less effective for fish <200 mm (Holliman et al. 2015). The potential of small Asian carp to reach the barrier varies by year class strength, time of spawn, and small fish growth rates to 200 mm.

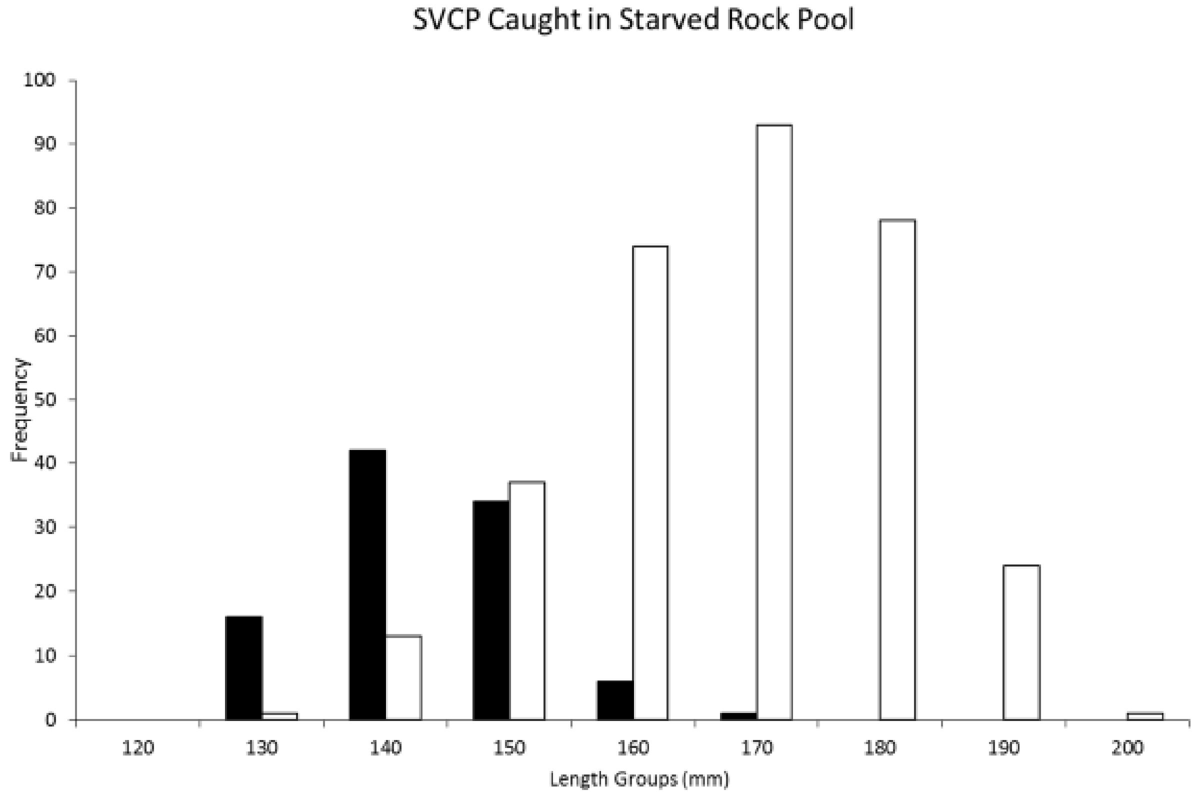


Figure 4. *Length histogram of Silver Carp caught from September 2-4 (black bars; $\bar{x} = 147$, $s = 8.3$, $n = 99$), and September 30-October 2 (white bars; $\bar{x} = 172$, $s = 12.5$, $n = 321$) in Starved Rock Pool.*

Identifying habitats (backwaters and marinas) used by small Asian carp (≤153 mm) throughout the Illinois River was one of the goals described in the 2015 study plan. Backwaters and main channel borders were identified by field personnel as 60 percent and 12 percent of all sites selected (Table 11).

Table 11. *Habitat types identified in 2015, and proportion of each containing small Silver Carp (≤153mm) by all pools and gears (N=1,256).*

Habitat	# of sites identified	% of total samples	% of samples with Silver Carp
Backwater	758	60	13
Isolated Pool	19	2	21
Main Channel Border	153	12	1
Marina	69	5	13
Tributary	101	8	11
Side Channel	105	8	10
Side Channel Border	51	4	0

Small Silver Carp were present in 13 percent of backwaters sampled, yet only 1 percentof main channel borders. The 21 percent of isolated pools containing small Silver Carp represent four different sampling events in Lake Chautauqua. Overall, backwaters were likely an overrepresented habitat because of the substantial flooding observed during the 2015 field season and the suitability of sampling techniques to habitat. Main channel borders are the habitats closest to the navigation channel, and these locations rarely (1 percent) contain small Silver Carp. Carp..

References:

Burr, B.M., D.J. Eisenhour, K.M. Cook, C.A. Taylor, G.L. Seegert, R.W. Sauer, and E.R. Atwood. 1996. Nonnative fishes in Illinois waters: What do the records reveal? Transactions of the Illinois State Academy of Science 89:73–91.

Chapman, D.C., and M.H. Hoff. 2011. Introduction in D.C. Chapman and M.H. Hoff, editors. Invasive Asian Carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18:117–143.

Conover, G., R. Simmonds, and M. Whalen, editors. 2007. Management and control plan for bighead, black, grass, and silver carps in the United States. Asian Carp Working Group, Aquatic Nuisance Species Task Force, Washington, D.C. 190 pp.

Davis, J.J., P.R. Jackson, F.L. Engel, J.A. Zinger, R.N. Neeley, S.T. Finney, and E.A. Murphy. 2016. Entrainment, retention, and transport of freely swimming fish in junction gaps between commercial barges through lock structures and the Electric Dispersal Barrier system on the Chicago Sanitary and Ship Canal. Journal of Great Lakes Research. In review.

DeGrandchamp, K.L. 2003. Habitat selection and movement of Bighead Carp and Silver Carp in the lower Illinois River. Master's Thesis. Southern Illinois University at Carbondale, Illinois. 47 pp.

DeGrandchamp, K.L., J.E. Garvey, and R.E. Colombo. 2008. Movement and Habitat Selection by Invasive Asian Carps in a Large River. Transactions of the American Fisheries Society 137:45–56.

Freeze, M. and S. Henderson. 1982. Distribution and status of the Bighead Carp and Silver Carp in Arkansas. North American Journal of Fisheries Management 2:197–200.

Garvey, J.E., K.L. DeGrandchamp, and C.J. Williamson. 2006. Life History Attributes of Asian Carps in the Upper Mississippi River System. ERDC/TN ANSRP-06-__ November 2006.

Holliman, F.M. 2009. Determination of optimum performance parameters for electric barriers on the Chicago Ship Canal: a pilot study April 2009. Report by Smith-Root, Inc.

Holliman, F.M. 2011. Operational protocols for electric barriers on the Chicago Sanitary and

Ship Canal: Influence of electrical characteristics, water conductivity, fish behavior, and water velocity on risk for breach by small silver and bighead carp. Report by Smith Root, Inc.

Holliman, F.M., K.J. Killgore, and C. Shea. 2015. Development of Operational Protocols for Electric Barrier Systems on the Chicago Sanitary and Ship Canal: Induction of Passage-Preventing Behaviors in Small Sizes of Silver Carp. Available: http://el.erdc.usace.army.mil/elpubs/pdf/ansrp15-1.pdf.

Irons, K.S., G.G. Sass, M.A. McClelland, and T.M. O'Hara. 2011. Bigheaded Carp Invasion of the La Grange Reach of the Illinois River: Insights from the Long Term Resource Monitoring Program. Pages 31-50 in D.C. Chapman and M.H. Hoff, editors. Invasive Asian Carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland.

Kolar, C.S., D.C. Chapman, W.R. Courtenay, Jr., 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.

Maceina, M.J., and S.M. Sammons. 2006. An evaluation of different structures to age freshwater fish from a northeastern U.S. river. Fisheries Management and Ecology 13:237–242.

Minchin, P.R. 1987. An evaluation of the relative robustness of techniques for ecological ordination. Vegetation 69:89–107.

O'Connell, M.T., A.U. O'Connell, and V.A. Barko. 2011. Occurrence and Predicted Dispersal of bighead carp in the Mississippi River system: development of a heuristic tool. Pages 51–71 in D.C. Chapman and M.H. Hoff, editors. Invasive Asian Carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland.

Parker, A.D. et al. 2013. Preliminary results of fixed DIDSON evaluations at the electric dispersal barrier in the Chicago Sanitary and Ship Canal. Department of the Interior, U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, 11 pp.

Peters, L.M., M.A. Pegg, and U.G. Reinhardt. 2006. Movements of adult radio-tagged bighead carp in the Illinois River. Transactions of the American Fisheries Society 135:1205–1212.

Petticrew, E.L. and J. Kalff. 1991. Calibration of a gypsum source for freshwater flow measurements. Canadian Journal of Fisheries and Aquatic Science 48: 1244–1249.

Ruetz III, C.R., D.G. Uzarski, D.M. Kruger, E.S. Rutherford. 2007. Sampling a littoral fish assemblage: comparison of small-mesh fyke netting and boat electrofishing. North American Journal of Fisheries Management 27:825–831.

Shrank, S.J., and C.S. Guy. 2002. Age, growth and gonadal characteristics of adult bighead carp, *Hypophthalmichthys nobilis*, in the lower Missouri River. Environmental Biology of Fishes 64:443–450.

Sparks, R.E., T.L. Barkley, S.M. Creque, J.M. Dettmers, and K.M. Stainbrook. 2011. Occurrence and Predicted Dispersal of bighead carp ion the Mississippi River system: development of a heuristic tool. Pages 51-71 in D.C. Chapman and M.H. Hoff, editors. Invasive Asian Carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland.

Summerfelt, R.C., and L.S. Smith. 1990. Anesthesia, Surgery, and Related Techniques. Pages 213–272 in C.B. Schreck and P.B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Williamson, C.J., and J.E. Garvey. 2005. Growth, fecundity, and diets of newly established Silver Carp in the Middle Mississippi River. Transactions of the American Fisheries Society 134:1423–1430.

Monitoring Efforts Downstream of the Electric Dispersal Barrier

Ryan Young, Rebekah Haun, Clinton Morgeson (Illinois Natural History Survey)
Blake Bushman, Brennan Caputo, Luke Nelson, Justin Widloe, David Wyffels, Tristan Widloe, Matt O'Hara and Kevin Irons (Illinois Department of Natural Resources)

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, Columbia, and La Crosse Fish and Wildlife Conservation Offices (field support); and U.S. Army Corps of Engineers – Chicago District (field support)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction: Standardized sampling can provide useful information to managers tracking population growth and range expansion of aquatic invasive species. Information gained from regular monitoring (such as presence, distribution, and population abundance of target species) is essential to understanding the threat of possible Asian carp invasion upstream of the Electric Dispersal Barrier. We used electrofishing, hoop netting, minnow fyke netting, and contracted commercial fishers to sample for Asian carp in four pools downstream of the Electric Dispersal Barrier. The primary goal of this monitoring effort was to identify the location of the detectable population front of advancing Asian carp in the Upper Illinois Waterway and track changes in distribution and relative abundance of leading populations over time. ("Detectable population" 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.) Monitoring data from 2010 to 2015 have contributed to our understanding of Asian carp abundance and distribution downstream of the Electric Dispersal Barrier and the potential threat of upstream movement toward the Electric Dispersal Barrier.

Objectives: Standardized sampling with conventional gears was used to:

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

(2) Determine the 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 (for example, the Asian Carp Barrier Defense Project and Telemetry Master Plan); and

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

Project Highlights:

- From 2010 to 2015, an estimated 12,041.5 person-hours were spent sampling at fixed, random, targeted, and additional sites downstream of the Electric Dispersal Barrier.

Monitoring Efforts Downstream of the Electric Dispersal Barrier

- A total of 549 hours were spent electrofishing, 923 km (573.5 miles) of trammel and gill nets were deployed, and 1,180 net nights of hoop netting and mini-fyke netting were conducted.
- A total of 176,192 fish were captured, representing 97 species and eight hybrid groups.
- No Bighead or Silver Carp were captured in Lockport and Brandon Road pools in all years sampled, but were collected in Dresden and Marseilles pools (N=1,250 and N=1,787, respectively), with the highest densities collected in Rock Run Rookery and Mobil Bay (Figure 3).
- Detectable population front of Asian carp located just north of I-55 Bridge (river mile 280; 47 miles from Lake Michigan). No appreciable change has been found in the upstream location of the population front in the past 6 years.

Recommend continued sampling below the Electric Dispersal Barrier, using electrofishing, hoop netting, mini-fyke netting, and gill and trammel netting with the addition of one commercial fishing boat to increase efforts.

Methods: The sampling design included electrofishing, gill and trammel netting, hoop netting, and minnow fyke netting at fixed, random, targeted, and additional sites in four pools downstream of the Electric Dispersal Barrier (Lockport, Brandon Road, Dresden Island, and Marseilles pools). The fixed sites (four sites/pool) were located primarily in the upper portions of each pool below lock and dam structures and in habitats where Asian carp are likely to be found (such as backwaters and side-channels). Electrofishing random sites were selected in main-channel habitats. In 2015, targeted commercial netting replaced random netting (employed from 2010 to 2014) to increase catches of Bighead and Silver Carp.

Electrofishing Protocol – In 2015, electrofishing surveys were conducted at fixed and random sites downstream of the Electric Dispersal Barrier. Sampling took place 2 weeks per month from April through November in Lockport, Brandon Road, Dresden Island, and Marseilles pools. All electrofishing was pulsed-DC current and included one or two netters. Electrofishing runs were 15-minute transects, oriented parallel to shore (moving in a downstream direction) and in areas with moderate current velocity, including shoreline and off-channel areas. Common Carp were counted without capture. All captured fish were placed in a holding tank, identified to species, enumerated, and returned to the water alive. Gizzard Shad were closely examined to verify they were not in fact Asian carp YOY. All field data were entered into a Microsoft Access Fish App database.

Gill and Trammel Netting Protocol – In 2015, contracted commercial fishers assisted IDNR biologists with net sampling at fixed and targeted sites downstream of the Electric Dispersal Barrier. Commercial netting took place 2 weeks per month from March through December in Lockport, Brandon Road, and Dresden Island pools (including Rock Run Rookery). In addition to commercial netting, IDNR biologists set 1,097 meters (1,200 yards) of gill net in the Army Pond (adjacent to Mobil Bay; Figure 1) in the Dresden Island pool on 21 July and 23 July.

Monitoring Efforts Downstream of the Electric Dispersal Barrier

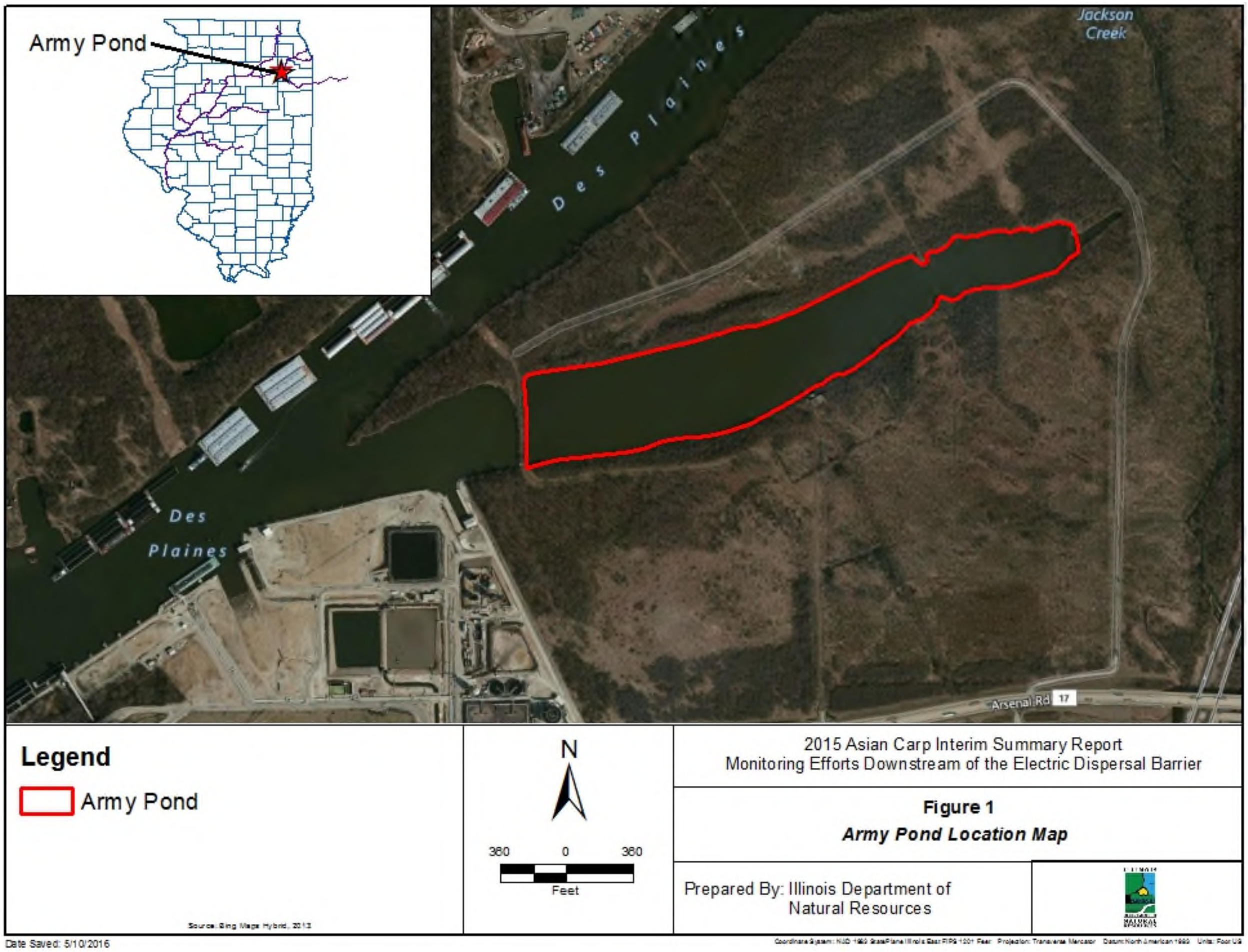


Figure 1. *Map of the Army Pond (adjacent to Mobil Bay) in the Dresden Island pool where additional gill netting was conducted on 21 July and 23 July 2015.*

Fishing gears utilized included large mesh (76 to 102 mm [3 to 4 inch]) trammel or gill nets (2.4 meter [8 feet] in height, 91 to 183 meters (100 to 200 yards) in length). An IDNR/INHS biologist was aboard each commercial net boat to monitor operations, record data, check for ultrasonic- or jaw-tagged Bighead or Silver Carp (left pelvic fin clips or telemetry surgery wounds on the left ventral area of the fish, posterior to the pelvic fin and anterior to the anus), and Floy tag all *Buffalo* spp. and Common Carp (*see* Surrogate Fish Movement With Barriers interim report). To increase catches in 2015, we moved from computer-generated random sites to targeted sites, which were left to the discretion of the commercial fishers. Nets were attended at all times. Net sets were short duration and used noise to drive fish into nets ("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 meters (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 alive. All field data were entered into a Microsoft Access Fish App database.

Monitoring Efforts Downstream of the Electric Dispersal Barrier

Hoop and Minnow Fyke Netting Protocol – In 2015, IDNR biologists conducted hoop netting and minnow fyke netting at fixed sites downstream of the Electric Dispersal Barrier. Netting took place 1 week per month from March through October 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 alive. All field data were entered into a Microsoft Access Fish App database.

Minnow fykes were a Wisconsin-type net (mini-fyke) composed of a lead 0.6 meter (2 feet) in height, 5 meters (5.5 yard) 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 on 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.

Results and Discussion: *Electrofishing Effort and Catch* – From 2010 to 2015, an estimated 4,510 person-hours were expended conducting 549 hours of electrofishing at fixed and random sites downstream of the Electric Dispersal Barrier. Electrofishing yielded 118,218 fish representing 97 species and eight hybrid groups (Table 1).

In 2015, electrofishing yielded 17,307 fish representing 75 species and 3 hybrid groups, of which Gizzard Shad, Emerald Shiner and Smallmouth Buffalo comprised 57 percent of the total catch (Table 1). No Asian carp were captured in Lockport or Brandon Road pools, but carp were captured at fixed and random sites in Dresden Island and Marseilles pools (n=3 and n=276; Table 1). Catches of Bighead Carp were higher at fixed and random sites sampled in 2015 than for those sampled in 2014 (n=5 and n=3). Catches of Silver Carp were lower at fixed and random sites sampled in 2015 than those sampled in 2014 (n=274 and n=358). Electrofishing catch-per-unit-effort (CPUE; No. fish/hour) of all fish species was 168.792 at fixed sites and 100.054 at random sites in 2015 (Table 2), compared with 262.096 at fixed sites and 108.774 at random sites in 2014. No Asian carp YOY were detected.

Gill and Trammel Netting Effort and Catch – From 2010 to 2015, an estimated 6,353 person-hours were expended setting and running 923 km (573.5 miles) of gill and trammel nets at fixed, random, targeted, and additional sites downstream of the Electric Dispersal Barrier. Commercial netting yielded 14,464 fish representing 27 species and two hybrid groups (Table 3).

In 2015, commercial netting and additional sampling yielded 6,036 fish representing 17 species and two hybrid groups, of which Common Carp, Smallmouth Buffalo, and Bigmouth Buffalo comprised 84 percent of the total catch (Table 3). No Asian carp were captured in the Lockport or Brandon Road pools, but were captured at fixed and targeted sites in the Dresden Island pool (*N*=427; Table 3). Catches of Bighead and Silver Carp in the Dresden Island pool were higher at fixed and targeted sites sampled in 2015 (*N*=262 and *N*=165) than fixed and random sites sampled in 2014 (*N*=49 and *N*=17). Differences in Asian carp catches may be attributed to an increase in effort in 2015 (281 km [174.7 miles]) of net fished in 2015 (Table 2), compared with 203 km (126.1 miles) of net fished in 2014. Elevated river stages during the weeks of 22 June and 6 July prevented barrier defense sampling in the Marseilles and Starved Rock pools. As a result, the barrier defense netting effort for those weeks was moved to Lockport, Brandon Road, and Dresden Island pools. Furthermore, increased catches may also be attributed to the change from computer-generated random sites to targeted sites selected by commercial fishers in 2015. Gill and trammel netting CPUE (No. fish/100 yards of net) of all fish species was 2.152 at targeted sites and 0.603 at fixed sites in 2015 (Figure 2, Table 2), compared with 1.069 at random sites and 0.504 at fixed sites in 2014 (Figure 2). CPUE of Bighead Carp was 0.096 at targeted sites and 0.008 at fixed sites in 2015 (Figure 2, Table 2), compared with 0.029 at random sites and 0.003 at fixed sites in 2014 (Figure 2). CPUE of Silver Carp was 0.059 at targeted sites and 0.019 at fixed sites in 2015 (Figure 2, Table 2), compared with 0.01 at random sites and 0 at fixed sites in 2014 (Figure 2).

Hoop and Mini-Fyke Netting Effort and Catch – From 2012 to 2015, an estimated 2,048 person hours were expended setting and running 460 hoop nets and 272 mini-fyke nets (908 net nights hoop and 272 net nights mini-fyke) downstream of the Electric Dispersal Barrier. Hoop netting yielded 2,092 fish representing 21 species and two hybrid groups (Table 4). Mini-fyke netting yielded 41,418 fish representing 50 species and one hybrid group (Table 5).

In 2015, hoop netting yielded 1,625 fish representing 20 species and two hybrid groups, of which Smallmouth Buffalo, Channel Catfish, and Common Carp comprised 87 percent of the total catch (Table 4). No Asian carp were captured in the Lockport or Brandon Road pools, but were captured at fixed and additional sites in Dresden Island and Marseilles pools (n=17 and n=114; Table 4). Catches of Bighead Carp were higher at fixed and additional sites sampled in 2015 than at fixed sites sampled in 2014 (n=102 and n=1), while catches of Silver Carp remained the same (n=29). Hoop netting CPUE (No. fish/net night) of all fish species was 5.276 at fixed and additional sites in 2015 (Table 2), compared with 0.844 at fixed sites in 2014. CPUE of Bighead Carp was and 0.331 at fixed and additional sites in 2015 (Table 2), compared with 0.004 at fixed sites in 2014. CPUE for Silver Carp was 0.094 at fixed and additional sites in 2015 (Table 2), compared with 0.113 at fixed sites in 2014.

In 2015, mini-fyke netting yielded 4,420 fish representing 44 species and one hybrid group, of which Bluntnose Minnow, Round Goby, and Bluegill comprised 53.4 percent of the total catch (Table 5). Mini-fyke netting CPUE (No. fish/net night) of all species captured was 34.531 at fixed sites in 2015 (Table 2), compared with 77.156 in 2014. No Asian carp were captured.

Results of standardized sampling revealed patterns of Asian carp distribution and relative abundance in the Upper Illinois Waterway. Based on monitoring results to date, we characterized abundance of Bighead and Silver Carp as absent in Lockport pool (river mile 291-296) and Brandon Road pool (river mile 286-291) downstream of the Electric Dispersal Barrier. The detectable adult population front to date is located in the Dresden Island pool at Treats Island just north of the I-55 Bridge where it crosses over the lower Des Plaines River (river mile 280). This location is about 47 miles from Lake Michigan (Chicago Harbor; river mile 327). The USACE first identified a small population of Bighead Carp in Dresden Island pool near Moose Island in 2006 (river mile 276; Kelly Baerwaldt, personal communication). For reasons unknown, the detectable population front has made little upstream progress.

The Marseilles Pool (river miles 245-272) contained moderately abundant populations of both Bighead and Silver Carp relative to downstream locations (such as at Starved Rock pool; *see* Barrier Defense Removal Report). Populations of adults were located within 55 miles of Lake Michigan and showed potential for spawning — gravid females and males were observed running ripe in the Marseilles Pool from 2010 to 2012. Spawning activity was observed on 22 May 2013 by B. Ruebush and J. Zeigler in the Marseilles pool (river mile 269.5). Increased commercial fishing efforts were directed to the Starved Rock pool when catch rates were low in the Marseilles pool. In 2015, juvenile Asian carp (>6 inches) were detected by USFWS at two sites in in Peoria pool (above Henry; river mile 190), two sites in the Starved Rock pool, and one site in the Marseilles pool (*see* Young-of-year and Juvenile Asian Carp Monitoring).

Recommendations: Extensive monitoring and removal efforts have allowed us to characterize and manage the risk of Asian carp populations moving upstream toward the CAWS and Lake Michigan. Similar patterns in abundance among sampling gears (electrofishing and gill and trammel netting) and monitoring/removal projects (*see* Barrier Defense Removal report) add confidence to the finding that the relative abundance of Asian carp decreased with upstream location in the Upper Illinois Waterway. Continued sampling efforts will provide invaluable up-to-date information about the detectable population front. In 2016, we will continue sampling with the addition of one commercial fishing boat to increase efforts below the Electric Dispersal Barrier.

Monitoring Efforts Downstream of the Electric Dispersal Barrier

Table 1. *Fixed and random electrofishing catch summaries for 2015, including catches from 2010-2015 in pools below the Electric Dispersal Barrier. Common Carp were counted without collection.*

	Fixed Electrofishing Catch - 2015						Random Electrofishing Catch - 2015						2010-2015	
	Pool						Pool							
Species	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	No. Captured	Percent
Alewife													10	<0.1%
American Eel													2	<0.1%
Banded Darter													3	<0.1%
Banded Killifish	19	7	5	6	37	0.5%	11	9	6	18	44	0.5%	161	0.1%
Bighead Carp			1		1	<0.1%			1	3	4	<0.1%	26	<0.1%
Bigmouth Buffalo		2	2	26	30	0.4%			2	25	27	0.3%	432	0.4%
Black Buffalo			1		1	<0.1%			3		3	<0.1%	185	0.2%
Black Bullhead	2				2	<0.1%	2				2	<0.1%	15	<0.1%
Black Crappie		1		8	9	0.1%			5	3	8	0.1%	107	0.1%
Black Redhorse													6	<0.1%
Blacknose Dace			1		1	<0.1%							2	<0.1%
Blackside Darter													6	<0.1%
Blackstripe Topminnow		2	3		5	0.1%		1	6	1	8	0.1%	50	<0.1%
Blue Catfish													1	<0.1%
Bluegill	43	24	154	53	274	3.4%	10	14	196	120	340	3.7%	8,206	6.9%
Bluegill x Green Sunfish Hybrid													30	<0.1%
Bluntnose Minnow	12	6	40	38	96	1.2%	6	10	169	28	213	2.3%	3,402	2.9%
Bowfin		1		2	3	<0.1%							20	<0.1%
Brassy Minnow													6	<0.1%
Brook Silverside				46	46	0.6%			7	26	33	0.4%	225	0.2%
Brown Bullhead													14	<0.1%
Bullhead Minnow				6	6	0.1%				7	7	0.1%	1,037	0.9%
Central Mudminnow								1			1	<0.1%	3	<0.1%
Central Stoneroller										1	1	<0.1%	7	<0.1%
Channel Catfish	6	27	26	18	77	1.0%	4	4	45	53	106	1.2%	883	0.7%
Common Carp	272	144	179	76	671	8.3%	39	166	297	84	586	6.4%	7,385	6.2%
Common Carp x Goldfish Hybrid			3		3	<0.1%		2			2	<0.1%	53	<0.1%
Common Shiner				1	1	<0.1%							29	<0.1%
Creek Chub							1				1	<0.1%	4	<0.1%
Emerald Shiner	26	146	315	482	969	12.0%	5	2	101	476	584	6.3%	8,638	7.3%
Fathead Minnow			1		1	<0.1%	1		2		3	<0.1%	18	<0.1%
Flathead Catfish				3	3	<0.1%			1	5	6	0.1%	43	<0.1%
Freshwater Drum	2	14	21	41	78	1.0%		1	60	117	178	1.9%	1,057	0.9%
Gizzard Shad	632	593	1,448	619	3,292	40.6%	671	594	1,486	922	3,673	39.9%	55,686	47.1%
Golden Redhorse			8	55	63	0.8%			31	70	101	1.1%	872	0.7%
Golden Shiner	21	7	14	9	51	0.6%	6	4	60		70	0.8%	492	0.4%
Goldeye			1		1	<0.1%							3	<0.1%
Goldfish	4	6	3	3	16	0.2%	8	26	32	1	67	0.7%	434	0.4%
Grass Carp		2		1	3	<0.1%			1	11	12	0.1%	40	<0.1%
Grass Pickerel	1	3			4	<0.1%		4	8		12	0.1%	37	<0.1%
Greater Redhorse				1	1	<0.1%							3	<0.1%
Green Sunfish	42	9	47	11	109	1.3%	27	18	83	39	167	1.8%	2,262	1.9%
Greenside Darter													6	<0.1%
Highfin Carpsucker			1		1	<0.1%							39	<0.1%

Table 1 *(Continued)*

	Fixed Electrofishing Catch - 2015						Random Electrofishing Catch - 2015						2010-2015	
	Pool						Pool							
Species	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	No. Captured	Percent
Hornyhead Chub													2	<0.1%
Johnny Darter				1	1	<0.1%				1	1	<0.1%	12	<0.1%
King Salmon													1	<0.1%
Largemouth Bass	66	31	129	89	315	3.9%	15	46	319	56	436	4.7%	3,950	3.3%
Logperch			1	4	5	0.1%			4	5	9	0.1%	130	0.1%
Longear Sunfish			2		2	<0.1%			2		2	<0.1%	18	<0.1%
Longnose Gar	7	1	30	54	92	1.1%		1	72	29	102	1.1%	773	0.7%
Mimic Shiner				6	6	0.1%				1	1	<0.1%	19	<0.1%
Mooneye													5	<0.1%
Muskellunge										1	1	<0.1%	2	<0.1%
Northern Hog Sucker				13	13	0.2%			9	4	13	0.1%	59	<0.1%
Northern Pike	3	3	1		7	0.1%		3	4		7	0.1%	46	<0.1%
Orangespotted Sunfish			1	5	6	0.1%		2	1	1	4	<0.1%	200	0.2%
Oriental Weatherfish	32		1		33	0.4%	10	7			17	0.2%	173	0.1%
Paddlefish													1	<0.1%
Pumpkinseed	25	17	81	3	126	1.6%	9	21	59	3	92	1.0%	1,853	1.6%
Pumpkinseed x Bluegill Hybrid													1	<0.1%
Pumpkinseed x Green Sunfish Hybrid													6	<0.1%
Quillback			8	26	34	0.4%			21	39	60	0.7%	447	0.4%
Red Shiner				1	1	<0.1%							3	<0.1%
Redear Sunfish													8	<0.1%
River Carpsucker			7	104	111	1.4%			33	181	214	2.3%	991	0.8%
River Redhorse				1	1	<0.1%				1	1	<0.1%	9	<0.1%
River Shiner				2	2	<0.1%				1	1	<0.1%	30	<0.1%
Rock Bass		2	2		4	<0.1%			6	1	7	0.1%	80	0.1%
Round Goby		5	3	1	9	0.1%		7	8	6	21	0.2%	134	0.1%
Sand Shiner	1	1		14	16	0.2%			1	15	16	0.2%	250	0.2%
Sauger		1			1	<0.1%				3	3	<0.1%	27	<0.1%
Shorthead Redhorse			5	54	59	0.7%			14	18	32	0.3%	307	0.3%
Shortnose Gar			1	9	10	0.1%			5	3	8	0.1%	82	0.1%
Silver Carp			1	181	182	2.2%				92	92	1.0%	925	0.8%
Silver Chub													2	<0.1%
Silver Redhorse				8	8	0.1%			8	9	17	0.2%	111	0.1%
Skipjack Herring				5	5	0.1%			1		1	<0.1%	48	<0.1%
Slenderhead Darter													2	<0.1%
Smallmouth Bass	2	57	94	57	210	2.6%	1	13	29	92	135	1.5%	1,339	1.1%
Smallmouth Buffalo		1	133	280	414	5.1%			206	756	962	10.5%	4,705	4.0%
Spotfin Shiner		1	2	83	86	1.1%	1	1	31	88	121	1.3%	2,831	2.4%
Spottail Shiner	1		107	51	159	2.0%			246	34	280	3.0%	1,098	0.9%
Spotted Gar													6	<0.1%
Spotted Sucker			1		1	<0.1%			4	2	6	0.1%	22	<0.1%
Stonecat													1	<0.1%
Striped Bass x White Bass Hybrid				4	4	<0.1%				1	1	<0.1%	14	<0.1%
Striped Shiner													2	<0.1%

Table 1 *(Continued)*

	Fixed Electrofishing Catch - 2015						Random Electrofishing Catch - 2015						2010-2015	
	Pool						Pool							
Species	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	No. Captured	Percent
Suckermouth Minnow													3	<0.1%
Sunfish Hybrid			10	2	12	0.1%			9	6	15	0.2%	305	0.3%
Tadpole Madtom										1	1	<0.1%	3	<0.1%
Threadfin Shad	3	2	189	18	212	2.6%		3	56	1	60	0.7%	3,807	3.2%
Trout Perch													4	<0.1%
Unidentified Catostomid									1		1	<0.1%	21	<0.1%
Unidentified Cyprinid									1		1	<0.1%	4	<0.1%
Unidentified Moronid		1			1	<0.1%							3	<0.1%
Unidentified Percid													1	<0.1%
Walleye			3	1	4	<0.1%			11	3	14	0.2%	37	<0.1%
Walleye x Sauger Hybrid													1	<0.1%
Warmouth	1				1	<0.1%							11	<0.1%
Western Mosquitofish													37	<0.1%
White Bass	1	1	7	25	34	0.4%			6	78	84	0.9%	439	0.4%
White Crappie				6	6	0.1%			7	2	9	0.1%	68	0.1%
White Perch	1				1	<0.1%			1		1	<0.1%	22	<0.1%
White Perch Hybrid													1	<0.1%
White Sucker		27	7	3	37	0.5%		53	9	3	65	0.7%	299	0.3%
Yellow Bass									2		2	<0.1%	40	<0.1%
Yellow Bullhead	5	3	7		15	0.2%	10	4	16		30	0.3%	439	0.4%
Yellow Perch		1			1	<0.1%							8	<0.1%
Total Captured	1,230	1,149	3,107	2,616	8,102	100.0%	837	1,017	3,804	3,547	9,205	100.0%	118,218	100.0%
No. Species	26	33	45	50	69		19	26	52	50	68		97	
No. Hybrid Groups			2	2	3			1	1	2	3		8	

Table 2. *Fixed and random electrofishing, fixed and targeted gill and trammel netting, hoop netting and minnow fyke netting efforts and catch summaries for 2015 in the pools below the Electric Dispersal Barrier.*

Fixed Electrofishing Effort - 2015

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample dates	13 Apr - 25 Nov				
Person-days	12	12	24	24	72
Est. person-hours	90	90	180	180	540
Electrofishing hours	11	11	13	13	48
Samples (transects)	44	44	51	52	191
All Fish (N)	1,230	1,149	3,107	2,616	8,102
Species (N)	26	33	45	50	69
Hybrids (N)	0	0	2	2	3
Bighead Carp (N)	0	0	1	0	1
Silver Carp (N)	0	0	1	181	182
CPUE (No. fish/hour)	111.818	104.455	239	201.231	168.792

Random Electrofishing Effort - 2015

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample dates	13 April - 25 Nov				
Person-days	12	12	24	24	72
Estimated person-hours	90	90	180	180	540
Electrofishing hours	22	18	26	26	92
Samples (transects)	88	72	104	104	368
All Fish (N)	837	1,017	3,804	3,547	9,205
Species (N)	19	26	52	50	68
Hybrids (N)	0	1	1	2	3
Bighead Carp (N)	0	0	1	3	4
Silver Carp (N)	0	0	0	92	92
CPUE (No. fish/hour)	38.045	56.5	146.308	136.423	100.054

Fixed Gill and Trammel Netting Effort - 2015

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample dates	17 Mar - 3 Dec				
Person-days	20	23	19	0	62
Est. person-hours	90	104	86	0	279
Samples (net sets)	58	64	54	0	176
Total miles of net	6.8	7.8	6.6	0	21.2
All Fish (N)	17	10	198	0	225
Species (N)	2	4	11	0	12
Hybrids (N)	0	0	2	0	2
Bighead Carp (N)	0	0	3	0	3
Silver Carp (N)	0	0	7	0	7
CPUE (No. fish/100 yards of net)	0.142	0.073	1.707	0	0.603

Targeted Gill and Trammel Netting Effort - 2015

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample dates	17 Mar - 3 Dec				
Person-days	20	23	19	0	62
Est. person-hours	150	173	143	0	465
Samples (net sets)	346	336	421	0	1,103
Total miles of net	41.1	41.1	71.3	0	153.5
All Fish (N)	100	1,440	4,271	0	5,811
Species (N)	3	6	19	0	20
Hybrids (N)	1	1	1	0	1
Bighead Carp (N)	0	0	259	0	259
Silver Carp (N)	0	0	158	0	158
CPUE (No. fish/100 yards of net)	0.138	1.992	3.406	0	2.152

Hoop Netting Effort - 2015

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample dates	30 Mar - 30 Oct				
Person-days	16	16	30	16	78
Est. person-hours	60	60	113	60	293
Net nights	64	64	116	64	308
Samples (net sets)	32	32	58	32	154
All Fish (N)	11	16	1,368	230	1,625
Species (N)	1	3	17	9	20
Hybrids (N)	0	1	1	0	2
Bighead Carp (N)	0	0	16	86	102
Silver Carp (N)	0	0	1	28	29
CPUE (No. fish/net night)	0.172	0.25	11.793	3.594	5.276

Mini Fyke Netting Effort - 2015

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample dates	30 Mar - 30 Oct				
Person-days	16	16	16	16	64
Est. person-hours	60	60	60	60	240
Net nights	32	32	32	32	128
Samples (net sets)	32	32	32	32	128
All Fish (N)	627	1,532	1,283	978	4,420
Species (N)	21	27	33	29	44
Hybrids (N)	1	1	1	0	1
Bighead Carp (N)	0	0	0	0	0
Silver Carp (N)	0	0	0	0	0
CPUE (No. fish/net night)	19.594	47.875	40.094	30.563	34.531

Table 3. *Fixed and targeted gilla and trammel netting catch summaries for 2015, including 2010-2015 catches in pools below the Electric Dispersal Barrier.*

	Fixed Gill and Trammel Netting Catch - 2015					Targeted Gill and Trammel Netting Catch - 2015					2010-2015	
	Pool					Pool						
Species	Lockport	Brandon	Dresden	No. Captured	Percent	Lockport	Brandon	Dresden	No. Captured	Percent	No. Captured	Percent
Bighead Carp			3	3	1.3%			259	259	4.5%	1,083	7.5%
Bigmouth Buffalo			3	3	1.3%			305	305	5.2%	688	4.8%
Black Buffalo			4	4	1.8%	1		135	136	2.3%	270	1.9%
Bluegill											1	<0.1%
Channel Catfish		2	16	18	8.0%		14	97	111	1.9%	326	2.3%
Common Carp	16	6	64	86	38.2%	94	1375	834	2,303	39.6%	5,992	41.4%
Common Carp x Goldfish Hybrid			4	4	1.8%	4	28	15	47	0.8%	118	0.8%
Flathead Catfish			1	1	0.4%		1	16	17	0.3%	47	0.3%
Freshwater Drum		1	11	12	5.3%		9	75	84	1.4%	251	1.7%
Gizzard Shad								2	2	<0.1%	4	<0.1%
Goldeye											3	<0.1%
Goldfish							3	2	5	0.1%	43	0.3%
Grass Carp								8	8	0.1%	97	0.7%
Largemouth Bass								15	15	0.3%	22	0.2%
Longnose Gar			1	1	0.4%			22	22	0.4%	75	0.5%
Muskellunge											1	<0.1%
Northern Pike	1			1	0.4%			2	2	<0.1%	7	<0.1%
Quillback								5	5	0.1%	19	0.1%
River Carpsucker			2	2	0.9%			41	41	0.7%	89	0.6%
Shortnose Gar											1	<0.1%
Silver Carp			7	7	3.1%			158	158	2.7%	802	5.5%
Silver Redhorse								2	2	<0.1%	3	<0.1%
Skipjack Herring											4	<0.1%
Smallmouth Buffalo		1	81	82	36.4%		10	2,277	2,287	39.4%	4,505	31.1%
Spotted Gar											1	<0.1%
Striped Bass x White Bass Hybrid			1	1	0.4%						3	<0.1%
Unidentified Catostomid											4	<0.1%
Walleye											2	<0.1%
White Crappie								1	1	<0.1%	1	<0.1%
Yellow Bullhead						1			1	<0.1%	2	<0.1%
Total Captured	17	10	198	225	100.0%	100	1,440	4,271	5,811	100.0%	14,464	100.0%
No. Species	2	4	11	12		3	6	19	20		27	
No. Hybrid Groups			2	2		1	1	1	1		2	

Table 4. *Fixed and additional hoop netting catch summary for 2015, including 2012-2015 catches in pools below the Electric Dispersal Barrier.*

	Hoop Netting Catch - 2015						2012-2015	
	Pool							
Species	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	No. Captured	Percent
Bighead Carp			16	86	102	6.3%	141	6.7%
Bigmouth Buffalo				1	1	0.1%	1	<0.1%
Black Buffalo			2		2	0.1%	7	0.3%
Black Crappie			1		1	0.1%	1	<0.1%
Channel Catfish		5	571	5	581	35.8%	657	31.4%
Common Carp	11	6	181	12	210	12.9%	342	16.3%
Common Carp x Goldfish Hybrid			4		4	0.2%	4	0.2%
Flathead Catfish			11	3	14	0.9%	32	1.5%
Freshwater Drum			13	4	17	1.0%	32	1.5%
Goldfish		3			3	0.2%	4	0.2%
Golden Redhorse			2		2	0.1%	2	0.1%
Grass Carp			1		1	0.1%	1	<0.1%
Largemouth Bass			1		1	0.1%	1	<0.1%
Longnose Gar							1	<0.1%
Quillback			2		2	0.1%	2	0.1%
River Carpsucker			24		24	1.5%	28	1.3%
Silver Carp			1	28	29	1.8%	60	2.9%
Silver Redhorse				1	1	0.1%	1	<0.1%
Smallmouth Bass			1		1	0.1%	1	<0.1%
Smallmouth Buffalo			532	90	622	38.3%	766	36.6%
Striped Bass x White Bass Hybrid		2			2	0.1%	2	0.1%
White Bass			2		2	0.1%	3	0.1%
White Crappie			3		3	0.2%	3	0.1%
Total Captured	11	16	1,368	230	1,625	100.0%	2,092	100.0%
No. Species	1	3	17	9	20		21	
No. Hybrid Groups		1	1		2		2	

Table 5. *Minnow fyke netting catch summary for 2015, including 2012-2015 catches in pools below the Electric Dispersal Barrier.*

	Minnow Fyke Netting Catch - 2015						2012-2015	
	Pool							
Species	Lockport	Brandon	Dresden	Marseilles	No. Captured	Percent	No. Captured	Percent
Banded Killifish	15	12	14	5	46	1.0%	283	0.7%
Black Buffalo	1				1	<0.1%	1	<0.1%
Black Bullhead							6	<0.1%
Black Crappie			2	4	6	0.1%	28	0.1%
Blackstripe Topminnow	1	3	5	4	13	0.3%	274	0.7%
Bluegill	151	178	169	63	561	12.7%	16,950	40.9%
Bluntnose Minnow	36	74	675	225	1,010	22.9%	5,932	14.3%
Brook Silverside				20	20	0.5%	35	0.1%
Bullhead Minnow			1		1	<0.1%	363	0.9%
Central Mudminnow		1	2		3	0.1%	4	<0.1%
Channel Catfish	22	1	3		26	0.6%	78	0.2%
Common Carp	5	302	13	22	342	7.7%	722	1.7%
Emerald Shiner	2	12	2	142	158	3.6%	545	1.3%
Fathead Minnow		1			1	<0.1%	4	<0.1%
Freshwater Drum				5	5	0.1%	6	<0.1%
Gizzard Shad	5	11	18	15	49	1.1%	515	1.2%
Golden Shiner	8		1	1	10	0.2%	91	0.2%
Goldfish	2	1	1	1	5	0.1%	19	<0.1%
Grass Pickerel			1		1	<0.1%	3	<0.1%
Green Sunfish	261	73	138	22	494	11.2%	2,570	6.2%
Johnny Darter		5	1	9	15	0.3%	19	<0.1%
Largemouth Bass	5	8	15	2	30	0.7%	285	0.7%
Logperch							14	<0.1%
Longear Sunfish							7	<0.1%
Longnose Gar			2		2	<0.1%	6	<0.1%
Northern Pike		1			1	<0.1%	1	<0.1%
Orangespotted Sunfish	1	3	1	3	8	0.2%	1,167	2.8%
Oriental Weatherfish	31	5			36	0.8%	126	0.3%
Pumpkinseed	7	42	57	7	113	2.6%	3,111	7.5%
Rock Bass		5	4		9	0.2%	26	0.1%
Round Goby		744	28	13	785	17.8%	1,192	2.9%
Sand Shiner	19		12	57	88	2.0%	523	1.3%
Shorthead Redhorse			1	1	2	<0.1%	2	<0.1%
Shortnose Gar			1	2	3	0.1%	9	<0.1%
Smallmouth Bass		2	3	1	6	0.1%	14	<0.1%
Smallmouth Buffalo			1	1	2	<0.1%	3	<0.1%
Spotfin Shiner			18	230	248	5.6%	3,365	8.1%
Spottail Shiner		7	49	104	160	3.6%	524	1.3%
Stonecat	1				1	<0.1%	1	<0.1%
Sunfish Hybrid	14	12	22		48	1.1%	136	0.3%
Tadpole Madtom							83	0.2%
Threadfin Shad		3			3	0.1%	6	<0.1%
Unidentified Catostomid							15	<0.1%
Unidentified Cyprinid							10	<0.1%
Unidentified Moronid							1	<0.1%
Unidentified Notropis							35	0.1%
Warmouth							18	<0.1%
Western Mosquitofish			4		4	0.1%	1,674	4.0%
White Bass				2	2	<0.1%	2	<0.1%
White Crappie	5	3	6	8	22	0.5%	41	0.1%
White Perch	1			1	2	<0.1%	10	<0.1%
White Sucker		9	1		10	0.2%	42	0.1%
Yellow Bass		1			1	<0.1%	30	0.1%
Yellow Bullhead	34	13	12	8	67	1.5%	485	1.2%
Yellow Perch							6	<0.1%
Total Captured	627	1,532	1,283	978	4,420	100.0%	41,418	100.0%
No. Species	21	27	33	29	44		50	
No. Hybrid Groups	1	1	1		1		1	

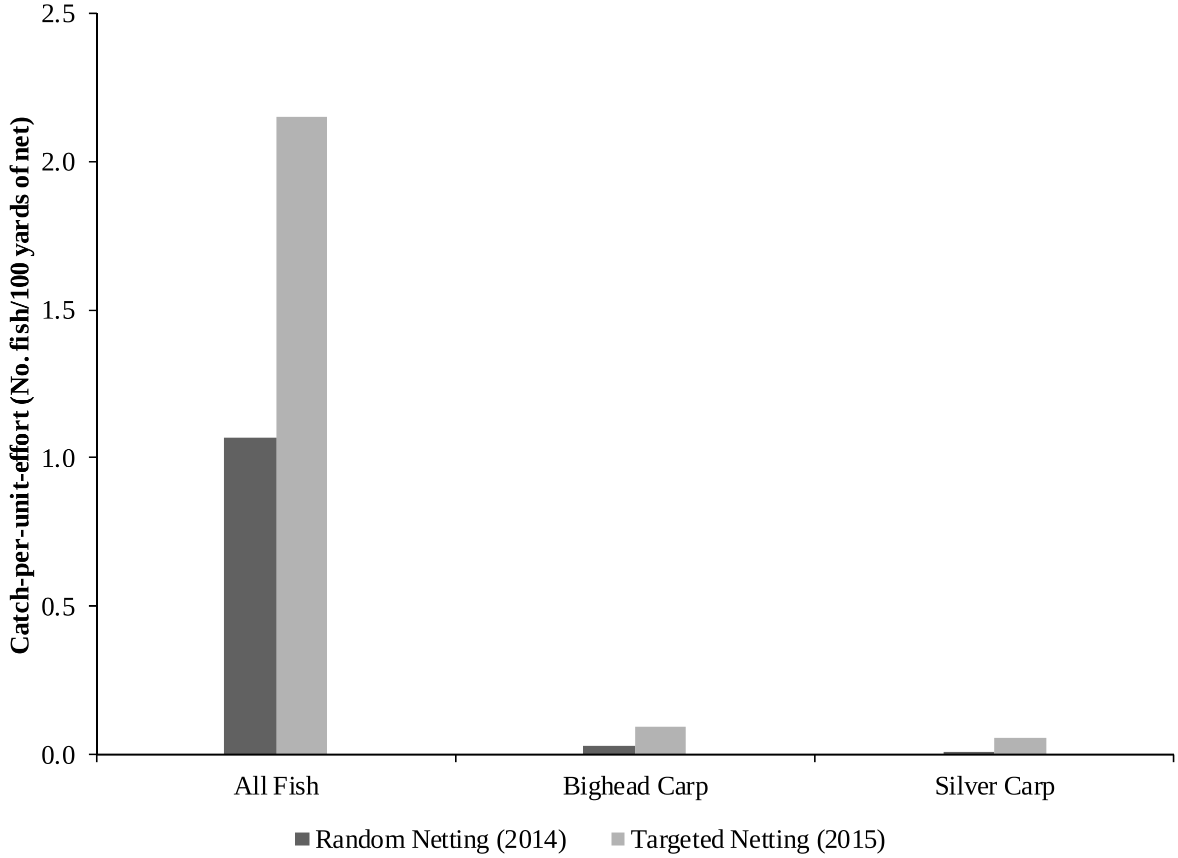


Figure 2. *Gill and trammel netting CPUE (No. fish/100 yards of net) of all fish, Bighead and Silver Carp captured at random sites in 2014 and targeted sites in 2015.*

Monitoring Efforts Downstream of the Electric Dispersal Barrier

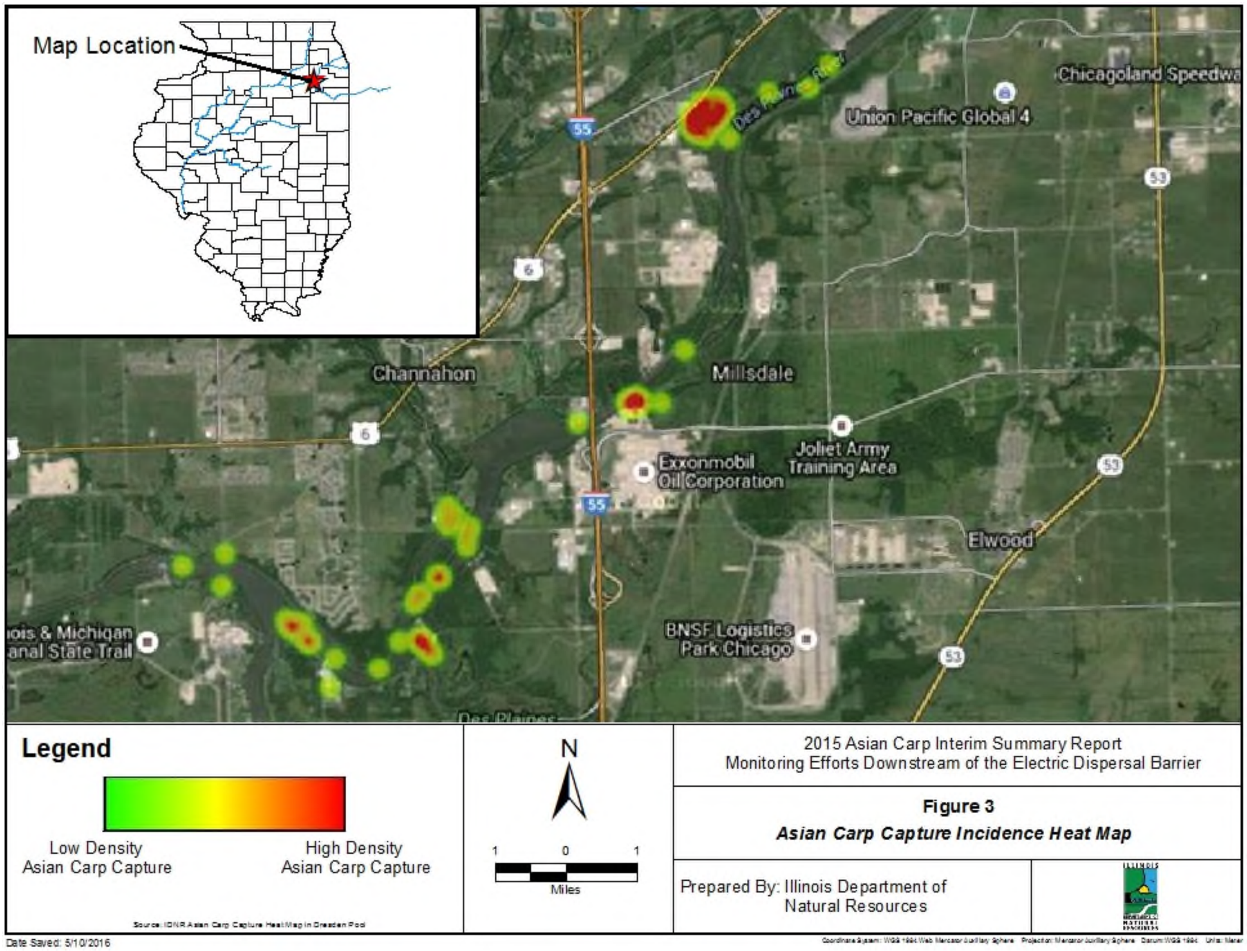


Figure 3. *Heat map showing capture incidents of Bighead (n=280) and Silver Carp (n=167) via electrofishing, gill and trammel netting, and hoop netting in the Dresden Island pool in 2015. Red indicates high densities of capture.*

REMOVAL PROJECTS AND EVALUATION

Response Actions in the CAWS

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Participating Agencies: IDNR (lead); INHS, USFWS, and USACE (field support), USCG (waterway closures when needed), USGS (flow monitoring and dye tracking when needed), MWRD (waterway flow management and access), USEPA and GLFC (project support)

Introduction: Preventing Asian carp from gaining access to Lake Michigan via the CAWS requires monitoring to detect and locate potential invaders and removal efforts to reduce population abundance and the immediate risk of invasion. Removal actions that capture or kill Asian carp once their location is known may include the use of conventional gears (e.g., electrofishing, nets, and commercial fishers), experimental gears (e.g., Great Lake pound nets and deep water gill nets), and chemical piscicides (e.g., rotenone), or all strategies. Decisions to commence removal actions, and particularly rotenone actions, are often difficult because of the high labor, equipment, and supply costs. Furthermore, a one-size-fits-all formula for rapid response actions is not possible in the CAWS because characteristics of the waterway (e.g., depth, temperature, water quality, morphology, and habitat) are highly variable. A threshold framework for response actions with conventional gear or rotenone was developed in the 2011 MRRP. Proposed thresholds were meant to invoke consideration of removal actions by the MRWG and were not intended to be rigid triggers requiring immediate action. Final decisions to initiate response actions and the type and extent of each action were ultimately based on the best professional judgment of representatives from the involved action agencies.

Objectives: The plan objectives are:

(1) Remove Asian carp from the CAWS upstream of Lockport Lock and the Power Station when warranted; and

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

Project Highlights:

- Based on the criteria of the Rapid Response Matrix, no rapid response actions were utilized in the CAWS in 2015. Alternatively, two Seasonal Intensive Monitoring (SIM) events were conducted in 2015, yielding no Bighead Carp or Silver Carp captured or observed. Refer to the Seasonal Intensive Monitoring report for comprehensive results.
- A total of 240 early detection monitoring samples (250 mL each) were collected upstream of the dispersal barrier, centrifuged in the mobile laboratory, and analyzed at WGL. All samples were negative for both species of Asian carp DNA.

Response Actions in the CAWS

- From 2010-2012, 11 rapid response actions were conducted with conventional and experimental gears in the CAWS upstream of the Electric Dispersal Barrier. Eight of the response actions were triggered by positive detections of Asian carp eDNA.
- We recommend contingency planning for the upper Illinois Waterway to be developed for future responses.

Methods: The tools used for response actions are combinations of conventional gears, experimental gears, or rotenone to capture and remove Asian carp from the CAWS upstream of Lockport Lock and Power Station. Each response action will be unique to location, perceived severity of the threat, and likelihood of successfully capturing an Asian carp. For example, observation of a live Asian carp from a credible source at the shallow North Shore Channel might elicit a 2- to 3-day conventional gear response with two electrofishing and netting crews. Capture of a live Asian carp at the same location might initiate a 2-week response with five to 10 sampling crews and additional types of gear. Furthermore, capture or credible observations of multiple Asian carp in a deep-draft channel, such as the Little Calumet River below O'Brien Lock, might call for an emergency rotenone action to eradicate the local population. In general, small-scale removal actions will require fewer sampling crews and gear types than larger events, although all events will include multiple gears for more than 1 day of sampling and participation by commercial fishers, if available.

New methods to drive, capture, and kill Asian carp are constantly being developed and evaluated as part of the ACRCC Framework (see water gun, gear evaluation, and alternative gear projects in this plan and pheromone research outlined in the 2014 framework). Such techniques may allow biologists to drive or attract Asian carp to barge slips or other backwater areas, where they can be captured more easily or killed. We will incorporate new technologies in response actions when they have been sufficiently vetted and shown to be of practical use.

Threshold Framework

Data from ECALS have revealed the uncertainty of eDNA positive detections originating from a live, free swimming fish, and several vectors have been identified as potential sources in addition to a live fish. No Asian carp have been observed or captured during intensive sampling over the past 2 years, including response actions triggered by detection of Asian carp DNA. At present, the detection of eDNA evidence within a sampled reach cannot verify whether live Asian carp are present, whether the DNA may have come from a dead fish, or whether water containing Asian carp DNA may have been transported from other sources such as boat hulls, storm sewers, sediment, piscivorous birds, or nets used by contracted commercial fishers. It is also not fully understood how environmental variables (such as temperature, conductivity, and pH) impact the detection rate, degradation rate, or persistence of DNA in the environment. In light of this information, the MRWG proposes a new framework to guide management decisions on response actions in the CAWS where eDNA is no longer a response trigger. Therefore, the observation or capture of a live Asian carp by a credible source would be the lone trigger for initiating a response.

The proposed thresholds for response actions with conventional gears and rotenone apply to monitoring efforts in the CAWS upstream of Lockport Lock and Power Station. Again, this threshold framework is meant to inform decisions to initiate response actions and guide the level of sampling effort put forth during such actions. Actual decisions to respond and the type, duration, and extent of response actions will be made by agency representatives with input from the MRWG. Action agencies also may conduct targeted response actions at selected locations in the CAWS outside the rapid response threshold framework when information gained from such actions may benefit monitoring protocols, research efforts, or Asian carp removal and control efforts.

The threshold framework includes three levels of response triggers and a feedback loop that advises for continued sampling or an end to the action (Figure 1). The first threshold level (Level 1) includes the observation of live Asian carp by a credible source (fisheries biologist or field technician). A suggested response for Level 1 might include two to four electrofishing boats and crews and one to two commercial fishing boats and crews sampling for 2 to 3 days.

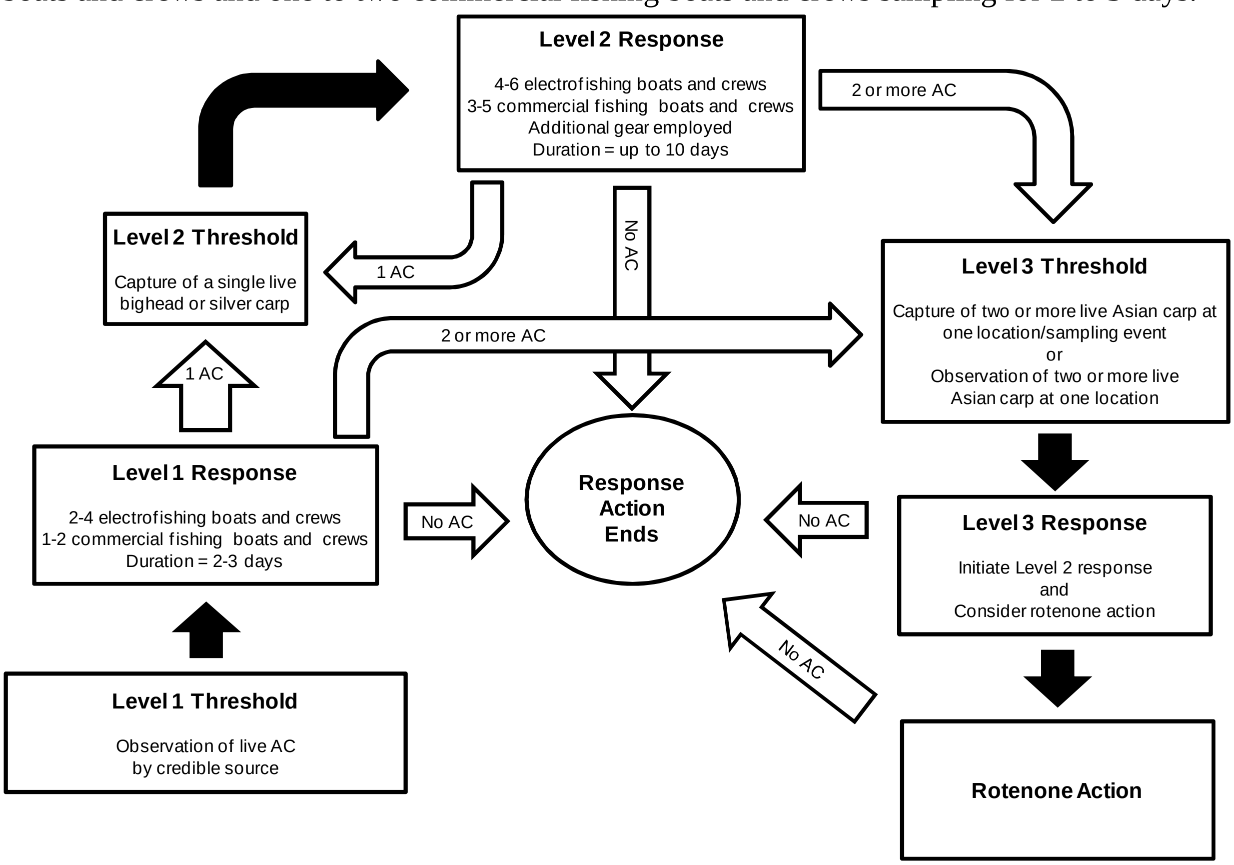


Figure 1. *Thresholds for Asian carp (AC) response actions with conventional gears and rotenone.*

Response Actions in the CAWS

A Level 2 threshold would include the capture of a single live Bighead or Silver Carp. A Level 2 response might employ four to six electrofishing boats and crews, three to five commercial fishing boats and crews, and additional gears (hydroacoustics, commercial seines, and trap or fyke nets). Level 2 events might last up to 10 days. The capture of two or more Asian carp from a single sampling event-location or the credible observation of two or more Asian carp at one location would signify a Level 3 threshold. Crossing the Level 3 threshold would trigger an immediate Level 2 conventional gear response action and consideration of a rotenone response. Where feasible (such as in non-navigation reaches, barge slips, and backwater areas), block nets will be used in an attempt to keep Asian carp in the area being sampled. The final decision to terminate a response will rely on best professional judgment of the participating biologists, managers, and agency administrators.

Results and Discussion: In 2015, no "Response" actions were initiated in the CAWS based on the established thresholds put forth in the 2015 MRP. However, two Seasonal Intensive Monitoring events were completed in the CAWS. Each of these events was strategically planned and developed according to the area sampled and its unique habitat characteristics. The results and details of these seasonal intensive monitoring events are summarized in this report in the Seasonal Intensive Monitoring section.

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 and netting gear). Efforts were taken in in the last 3 years above the Electric Dispersal Barrier to minimize the potential for eDNA contamination, and the MRWG has developed a Hazard Analysis and Critical Control Points (HACCP) plan to address the transport of eDNA and unwanted aquatic nuisance species. The 2015 decontamination protocol included the use of hot water pressure washing and chlorine washing (10% solution) of boats and potentially contaminated equipment. Additionally, IDNR and contracted commercial netters used netting gear that was site-specific to the CAWS and was only used for monitoring efforts above the Electric Dispersal Barrier.

A total of 240 early detection monitoring samples (250 ml each) were collected upstream of the dispersal barrier, centrifuged in the mobile lab, and analyzed at WGL. All samples were negative for both species of carp DNA. The "*Strategy for eDNA Monitoring*" section summarizes the events from 2015 and the results from these events are available at: http://www.fws.gov/midwest/fisheries/eDNA/Results-chicago-area.html

Recommendation: With the results from 2014 and 2015 Seasonal Intensive Monitoring events and several previous response actions, we would recommend continuing the seasonal intensive monitoring approach in the CAWS. This approach is considered a hybrid of the previous Fixed and Random Site Monitoring Upstream of the Dispersal Barrier and Planned Intensive Surveillance in the CAWS plans. The plan would continue monitoring intensively during a 2-

week period in the spring and fall using conventional and experimental gears that have been utilized during previous years and events. Ongoing monitoring results demonstrate that no fish were captured in the Lockport and Brandon Road pool, and the data suggest Asian carp abundance are either nonexistent or extremely low upstream of the Electric Dispersal Barrier system. With these two pools acting as a critical buffer, the Lockport and Brandon Road Pool areas have been integrated within the current response matrix. This integration will allow responses to be executed within these pools when the response criteria are met. Also, we recommend contingency planning for the upper Illinois Waterway to be developed for future responses. This response will be developed in light of additional information of small fish downstream within Starved Rock Pool and possible small fish entrainment scenarios.

Barrier Maintenance Fish Suppression

Brennan Caputo, Tristan Widloe, Kevin Irons, Matt O'Hara, David Wyffels, John Zeigler, Blake Ruebush (Illinois Department of Natural Resources)
Jeremiah Davis, Samuel Finney (USFWS – Carterville)
Matthew Shanks, Nicholas Barkowski (U.S Army Corps of Engineers)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

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

Introduction: The U.S. Army Corps of Engineers (USACE) operates three electric aquatic invasive species dispersal barriers (Demonstration Barrier and Barriers, 2A and 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 (about 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 on line 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 volt per centimeter or fish greater than 63 mm long at a setting of 0.91 volt 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 will be capable of increased operational settings in comparison to Barriers 2A and 2B and is expected to be commissioned in late 2017.

Barriers 2A and 2B 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 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 Maintenance Fish Suppression

Barrier 2B operated as the principal barrier from the time it was brought on line and tested in April 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 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 clear fish 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. Locking through happens if an outage were experienced at Barrier 2A. This outage would allow fish present just downstream to move up to Barrier 2B. If Barrier 2A were to then come back on line, 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. A more detailed description of the suppression plan is outlined in the methods section below.

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

(1) Remove fish >300 mm (12 inches) in total length between Barrier 2A and 2B before maintenance operations are initiated at Barrier 2B or after maintenance is completed at Barrier 2A 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 Barrier 2A and 2B 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 used in support of this effort.

(3) Assess the results of fish clearing operations by reviewing the physical captures and surveying the area between Barrier 2A and 2B 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 the presence of this size class upstream of Brandon Road Lock and Dam.

Barrier Maintenance Fish Suppression

Project Highlights:

2015 Barrier Maintenance Fish Suppression

- 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 supported one clearing action on 18 and 19 November 2015.
- A total of 51 fish from 11 species were removed using pulsed DC-electrofishing, electrified paupier trawling, and deep water gill net sets.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on 3 November, indicating low fish abundance and no fish larger than 300 mm. Weekly scans below Barrier 2A were conducted throughout the sampling season, which also contributed to characterizing risk of Asian carp presence.
- **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. The MRWG was notified as soon as possible by the USACE at the occurrence of any barrier outage and convened with key agency contacts to discuss the need for a barrier clearing action. The decision to perform a clearing action resulting from a barrier outage was based on factors related to the likelihood that Asian carp would pass 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, however, if small Asian carp are detected upstream of the Brandon Road Lock and Dam. The MRWG believes that either the wide or narrow array of each barrier provides a minimally effective short-term barrier for juveniles or adults. This conclusion is 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 Barriers 2A and 2B. 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 more than 3 years of sampling in the Lockport pool with no indication of any young of the 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 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 concluded 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.

A key factor to any response is risk of Asian carp being at or in the barrier. 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 electric barriers 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.

Initially, a clearing action will use split-beam hydroacoustics 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. If one or more fish targets over 300 mm are present, the MRWG recommends clearing the area between the affected barriers. Initial response (remote sensing) should occur within a week of an outage; after this survey is complete, fish detections, sizes, and locations will help formulate timely clearing efforts. Additional clearing actions can range from nearly "instantaneous" response with electrofishing to combined netting and electrofishing, or any combination of water gun or other efforts that may or may not require U.S. Coast Guard (USCG) closures of the canal and waterway. The USCG generally requires at least 45 days' notice for requests to restrict navigation traffic in the waterway.

Results and Discussion:

During 2015, Barrier 2A was the primary barrier within the Electric Dispersal Barrier system to fish passage in the upstream direction. Barrier 2A experienced a loss of power in water at both arrays for an extended duration (min =1.5 hour; max=370 hours; avg=63.0 hours) a total of eight times (Table 1). Barrier 2B was operational during each of Barrier 2A's outages and effectively served as the secondary barrier to upstream fish passage. The risk for Asian carp presence at the barrier and the likelihood that fish would move upstream to Barrier 2B was discussed with the MRWG at each primary barrier outage. For the majority of these incidences, the MRWG determined further clearing actions between the barriers were not required based on a very low risk of Asian carp presence. Extreme cold temperatures, seasonal movement patterns of Asian carp, and sufficient evidence from downstream sampling were all factors that 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 hindered 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. Additionally, the USFWS deployed side-scan sonar and split-beam hydroacoustics to assess the risk of fish greater than 300 mm between the barriers on 3 November 2015 and on a weekly basis from Barrier IIA to a point 500 meters downstream. The results from these scans in combination with known seasonal movement patterns and water temperatures precluded the need for further clearing actions for the majority of primary barrier outages.

There was one occasion when a multi-agency response team was deployed in an attempt to capture fish that may have moved upstream during a Barrier 2A loss of power in water. The clearing action was taken on 18 and 19 November and included two surface, pulsed DC electrofishing boats (USACE – Chicago District and IDNR), one electrified, pulsed DC paupier trawling boat (USFWS – Columbia), one side-scan sonar boat (USFWS – Wilmington), and two deep water gill net boats (IDNR/Contracted Fishermen). Two IDNR contracted commercial fishing vessels deployed 2,300 yards of 30-foot-deep gill nets within the Lower Lockport pool downstream of the Electric Dispersal Barriers. One vessel spread effort over the entire pool, while the second vessel focused efforts immediately south of the 135th Street Bridge to Hansen Material Services. Netting efforts captured a total of two fish from two species (Table 1). The USFWS Columbia crew performed three mid-channel, open water runs with a discrete deployment between Barriers IIA and IIB from 10:00 to 11:15. These electrified paupier trawls did not capture any fishes. The IDNR electrofishing crew performed three 15-minute electrofishing surveys along both canal walls in the area between Barriers IIA and IIB in conjunction with the USACE/USFWS electrofishing crew. Electrofishing runs captured a total of 48 fishes under 6 inches total length from nine species. No Asian carp were captured or identified in the effort. As in previous capture attempts between the barriers, the majority of fishes were collected from crevices in the canal wall where bedrock had deteriorated, leaving small pockets of habitat.

After physical clearing methods, a crew from the Carterville FWCO Wilmington Substation conducted an acoustic survey using a pair of side looking 200 kHz split beam transducers and a 1,600 kHz side scan sonar system at the Electric Dispersal Barrier system. The survey focused on the area between the Barrier IIA narrow array and the Barrier IIB narrow array. Five replicate survey transects were conducted. Each transect ensonified a mean volume of 13,595.8 m^3 (SD. = 1,322.8) of water within the study area. The total volume of water between the narrow arrays of the two barriers is approximately 45,000m^3. Results of the survey suggested that fish density between the two barriers was very low. The mean density of fish track targets observed during each replicate transect was 0.832 fish/ 1,000m^3 (SD. = 0.166). No fish track targets had estimated lengths > 150 mm based on target strength returns.

Barrier Maintenance Fish Suppression

Table 1: *Loss of power to the water at the primary active Barrier 2A in 2015; the secondary Barrier 2B was in full operation at each of the time and dates listed below.*

Barrier	Date	Outage time (hours)
2A	1-Jun-15	81.5
2A	22-Sep-15	370
2A	8-Oct-15	10
2A	23-Oct-15	9
2A	26-Oct-15	3
2A	12-Nov-15	3
2A	15-Dec-15	26.5
2A	18-Dec-15	1.5

Table 2: *Fish captured during multi-agency clearing event between the barriers on 18-19 November 2015 in response to Barrier 2A loss of power in water.*

Species ***(Scientific name)***	Individuals Captured
Common Carp *(Cyprinus carpio)*	*1*
Gizzard Shad *(Dorosoma cepedianum)*	3
Freshwater Drum *(Aplodinotus grunniens)*	*1*
Bluegill *(Lepomis macrochirus)*	20
Green Sunfish *(Lepomis cyanellus)*	9
Bluntnose Minnow *(Pimephales notatus)*	*1*
White Perch *(Morone Americana)*	*1*
Banded Killifish (*Fundulus diaphanous*)	12
Fathead Minnow *(Pimephales promelas)*	*1*
Yellow Bullhead *(Ameiurus natalis)*	*1*
Mosquitofish *(Gambusia affinis)*	*1*
Total	51

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 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, and hull banging). 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 based on 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, and complex noise generation.

Barrier Defense Asian Carp Removal Project

Blake Bushman, Tristan Widloe, Justin Widloe, Brennan Caputo, Luke Nelson, David Wyffels, Kevin Irons, Matt O'Hara Blake Ruebush
(Illinois Department of Natural Resources)
Rebekah Haun, Clint Morgeson, Ryan Young
(Illinois Natural History Survey)

Participating agencies: Illinois Department of Natural Resources – Aquatic Nuisance Species Division (lead), Illinois Natural History Survey

ADDITIONAL INFORMATION
- Link to mapping tool - Link to 2016 plan - Link to IDNR video

Introduction: This project uses controlled commercial fishing to reduce the number of Asian carp in the upper Illinois and lower Des Plaines Rivers downstream of the Electric Dispersal Barriers. By decreasing Asian carp numbers, we anticipate decreased migration pressure toward the Electric Dispersal Barriers and reduced chances that Asian carp will gain access to upstream waters in the CAWS and Lake Michigan. Trends in harvest data over time may also contribute to our understanding of Asian carp abundance and movement between pools of the upper Illinois Waterway. The removal project was initiated in 2010 and is ongoing, using 10 contracted commercial fishing crews to remove Asian carp primarily with large mesh (3.0 to 5.0 inch (76.2mm to 127mm)) gill nets and trammel nets. However, now that the program has identified efficiencies, additional gears are being fished, such as commercial seines, modified hoop nets, and Great Lakes trap nets.

Objectives: Ten commercial fishing crews will be contracted to:

(1) Harvest as many Asian carp as possible in the area between Starved Rock Lock and Dam and the Electric Dispersal Barrier. Harvested fish will be transported and used by private industry for purposes other than human consumption; and

(2) Gather information on Asian carp population abundance and movement in the Illinois Waterway downstream of the Electric Dispersal Barrier, as a supplement to fixed site monitoring.

Project Highlights:

- Contracted commercial fishers deployed 1,579.2 miles (2541 km) of gill/trammel net, 5.3 miles (8.5 km) of commercial seine, and 204 hoop nets set in the upper Illinois Waterway from 2010 to 2015.
- A total of 79,077 Bighead Carp, 325,096 Silver Carp, and 2,558 Grass Carp were removed by contracted commercial fisherman from 2010 to 2015. The total weight of Asian carp removed was 1971 tons.
- Recommend increased targeted harvest of Asian carp in the upper Illinois Waterway with contracted commercial fishers and assisting IDNR biologists. Potential benefits include

reduced Asian carp abundance at and near the detectable population front and the possible prevention of further upstream movement of populations toward the Electric Dispersal Barrier and Lake Michigan.

Methods: Contracted commercial fishing occurred in the target area of Dresden Island, Marseilles, and Starved Rock pools. Dresden Island Pool is located on the Illinois River from RM 271 to 286, Marseilles Pool RM 245 to 271, and Starved Rock Pool RM 231 to 245; each pool is located downstream of the electric dispersal barrier 10, 24 and 51 river miles (Figure 1).

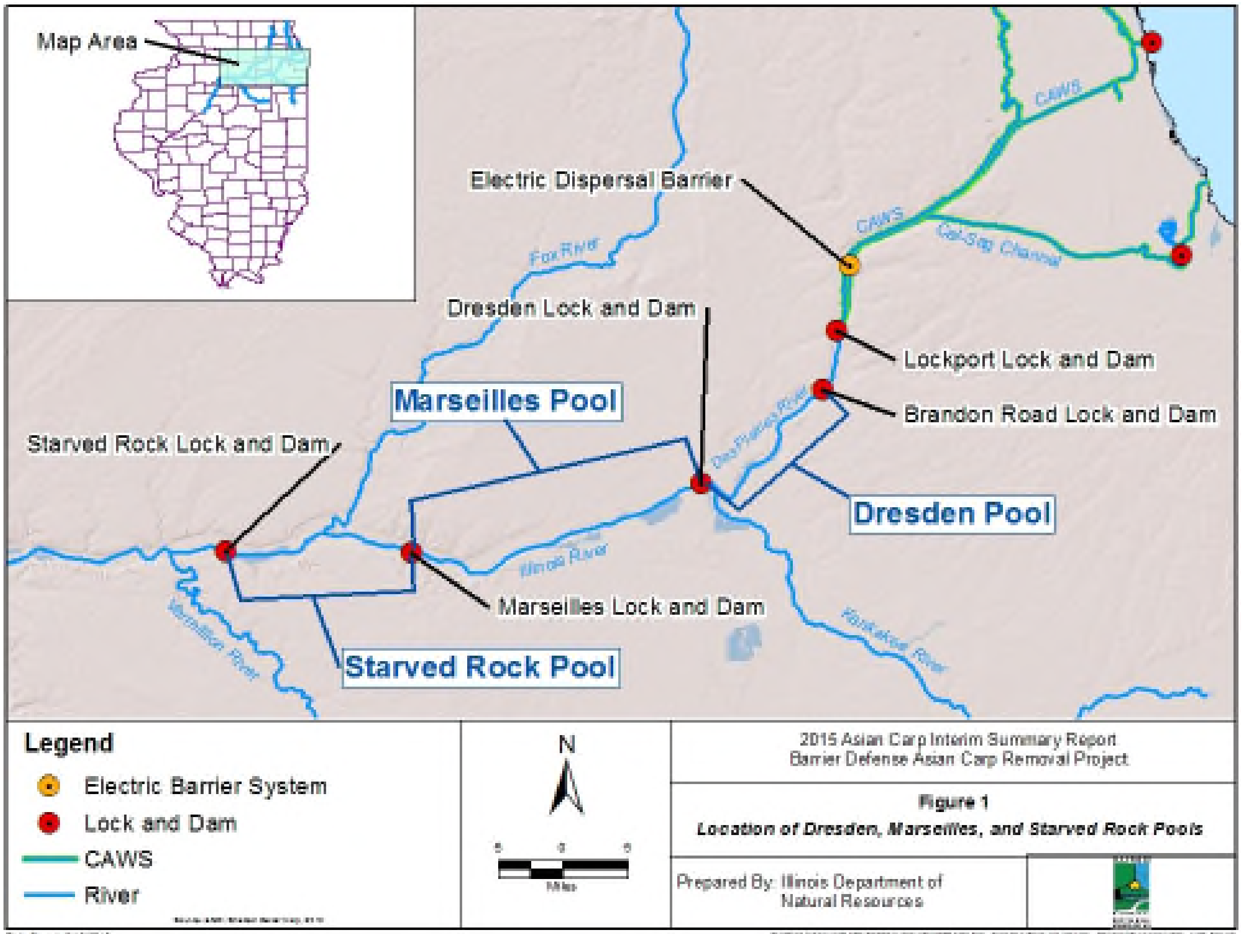


Figure 1: *Location of Dresden, Marseilles and Starved Rock pools on the Illinois River.*

This target area is closed to commercial fishing by Illinois Administrative Rule: Part 830 Commercial Fishing and Musseling in certain water of the state; Section 830.10(b) Waters open to commercial harvest of fish; therefore, an IDNR biologist is required to accompany commercial fishing crews in this portion of the river. Contracted commercial fishing took place from June through September 2010, April through December 2011, March through December 2012, March through December 2013, March through December 2014 and March through December 2015. Commercial Fishing also occurred December 2012 through March 2013 as part of a winter harvest project (*see* 2013 Monitoring and Response Plan Interim Summary Report). Five to six commercial fishing crews per week fished 4 days of each scheduled week. Fishing weeks were scheduled 1 or 2 weeks each month during the field season. Since fishing pressure was driving fish out of areas and greatly reducing catches, fishing weeks were scheduled at every-other-week intervals to allow fish to repopulate preferred habitats between events. Fishing occurred in backwater, main channel, and side channel areas which are favored Asian carp habitats. Specific netting locations were at the discretion of the commercial fishing crew with input from the IDNR biologist assigned to each boat. Large mesh (3.0 to 5.0 inch, 76.2 to 127mm) gill and trammel nets were typically used and set 20 to 30 minutes with fish being driven toward nets by the commercial fishing boats with noise (such as pounding on boat hulls, hitting the water surface with plungers, or running with motors tipped up). Occasionally, nets were set overnight off the main channel in non-public backwaters with no boat traffic. Beginning in 2014, hoop nets (2.0 to 8.0 feet (0.60 to 2.44 m) in diameter) and commercial seines (300 to 800 yards (0.27 to 0.73km) in length) were used in addition to the gill and trammel nets. Biologists on board identified, enumerated, and recorded Asian carp and bycatch to species. Asian carp and common carp were checked for ultrasonic tags. Fish implanted with ultrasonic tags, along with all bycatch, were returned to the water alive. Harvested Asian carp were transferred to a refrigerated truck and subsequently delivered to a processing plant and utilized for non-consumptive purposes (for example, converted to liquid fertilizer). During each harvest event, a representative subsample of 30 Bighead Carp and 30 Silver Carp from each pool were measured in total length (mm) and weighed (g) to provide estimates of total weight harvested.

Results and Discussion:

An estimated 4,140 person-hours in 2010, 6,750 person-hours in 2011, 7,650 person-hours in 2012 and 2013, 7,312 person-hours in 2014, and 7,650 person-hours in 2015 have been spent netting Asian carp during barrier defense removal efforts. A total of 1,578.7 miles (2,540.7 km) of gill/trammel net, 5.3 miles (8.5 km) of commercial seine, and 204 hoop net sets have been deployed in the upper Illinois Waterway since 2010 (Table 1). The total weight of Asian carp caught and removed from 2010 to 2015 was 3,941,940 pounds (1,971 tons) (Table 1). Silver Carp, Bighead Carp, and Grass Carp accounted for 63.8 percent (Silver), 35.9 percent (Bighead), and 0.3 percent (Grass) of the total tons harvested since 2010.

The combined catch of Asian carp (Bighead Carp, Silver Carp, and Grass Carp) since 2010 was 406,731 individuals (Table 1). Bighead Carp accounted for 82.0 percent of all Asian carp harvested in 2010, 56.3 percent in 2011, 39.4 percent in 2012, 20.1 percent in 2013, 11.5 percent in 2014, and 5.7 percent in 2015. Silver Carp accounted for 17.7 percent of all Asian carp harvested in 2010, 43.4 percent in 2011, 63.0 percent in 2012, 79.4 percent in 2013, 88.0 percent in 2014, and 93.7 percent in 2015. Grass Carp accounted for 0.3 percent of all Asian carp harvested in 2010, 0.4 percent in 2011, 0.6 percent in 2012, 0.5 percent in 2013, 0.5 percent in 2014, and 0.6 percent in 2015. The total harvest of Asian carp 2010-2015 consisted of 79.9 percent Silver Carp, 19.4 percent Bighead Carp, and 0.6 percent Grass Carp.

Barrier Defense Asian Carp Removal Project

The annual gill/trammel catch per unit effort for Asian carp (CPUE; No fish/1000 yards of net) of all pools combined was higher in 2015 (316.9) than in 2014 (121.7), 2013 (97.0) 2012 (87.6) and 2011 (86.9). Monthly gill/trammel CPUE for all pools combined demonstrates an increasing trend since 2011 (Figure 2).

Catch of Asian Carp within Pools –

Dresden Island Pool:

The Dresden Island pool was not fished as part of the Barrier Defense Project in 2015 because of the increased effort in the Fixed Site Monitoring downstream of the Dispersal Barrier Project. A total of 440 Asian carp were removed from the Dresden Island Pool in 2015. Monthly gill/trammel CPUE for Asian carp captured in the Dresden Island pool from 2011 to 2014 can be found in Figure 3. Further detail on monitoring efforts in the Dresden Island pool in 2015 can be found in the Fixed Site Monitoring downstream of the Dispersal Barrier section of this report.

Marseilles Pool:

Commercial fisherman removed Asian carp in the Marseilles pool from March through December in 2015. A total of 249,390 yards (228 km) of gill/trammel net, 1.1 miles (1.8 km) of commercial seine, and eight hoop nets were deployed in 2015. A total of 68,909 Silver Carp, 5,298 Bighead Carp, and 216 Grass Carp were harvested in 2015 (Table 1). The commercial seine hauls yielded 7,641 Silver Carp and 1,005 Bighead Carp. Silver Carp dominated the catch (92.6 percent) in 2015, (78.2 percent) in 2014 and 2013 (58.5 percent). Hoop nets caught 83 Silver Carp and 32 Bighead Carp. Prior to 2013, Bighead Carp was the dominate species caught in the Marseilles pool (Table 1). The annual CPUE of Asian carp from gill/trammel nets in the Marseilles Pool was an all-time high in 2015 of 248 Asian carp per 1,000 yards. Monthly gill/trammel CPUE for Asian carp captured in the Marseilles pool from 2011 to 2015 can be found in Figure 3.

Starved Rock Pool:

Commercial fisherman removed Asian carp in the Starved Rock Pool March through December in 2015. A total of 137,880 yards (126.1 km) of gill/trammel net, 0.5 miles (0.8 km) of commercial seine, and 84 hoop nets were deployed in 2015. A total of 65,156 Silver Carp, 2,897 Bighead Carp, and 624 Grass Carp were harvested in 2015 (Table 1). Hoop nets accounted for 1,873 Silver Carp and 217 Bighead Carp, while the commercial seine haul accounted for 4,942 Silver Carp and 146 Bighead Carp. Silver Carp were the dominate species harvested in 2015 (94.9 percent). Annual gill/trammel CPUE of Asian carp increased from 174.4 Asian carp per 1,000 yards in 2011 to 221.9 Asian carp per 1,000 yards of net in 2012 and 246.19 Asian carp per 1,000 yards of net in 2013, decreased in 2014 to 205.6 then increased in 2015 to 441.5 Asian carp per 1,000 yards of net. Monthly gill/trammel CPUE for Asian carp captured in the Starved Rock pool from 2011 to 2015 can be found in Figure 3.

Catch of Bycatch Species –

Gill and Trammel nets:

A total of 155,896 fish representing 36 species and one hybrid group were caught in gill\trammel nets during the 2015 Asian carp removal effort (Table 2). Asian carp (Bighead Carp, Silver Carp, and Grass Carp) made up 79.2 percent of the catch while *Ictiobus* spp. (Bigmouth Buffalo, Smallmouth Buffalo, and Black Buffalo) along with Common Carp made up an additional 18.7 percent of the total catch. A total of 978 fish from 12 species and one hybrid species made up the game fish species captured in 2015. Game fish represented 0.6 percent of the total catch in 2015, similar to 2014, when game fish represented 0.9 percent. Similar to previous years, Flathead and Channel Catfish were the most dominant game fish captured in 2015, accounting for 86.8 percent of the game fish captured.

Hoop Nets: A total of 3,544 fish representing 16 species were caught in hoop nets in 2015. Asian carp (Bighead Carp, Silver Carp, and Grass Carp) made up 62.4 percent of the catch, while *Ictalurus* spp. (Channel Catfish and Flathead Catfish) made up an additional 21.3 percent of the total catch.

Commercial Seine:

A total of 15,418 fish representing 22 species were caught in commercial seines in 2015. Asian carp (Bighead Carp, Silver Carp, and Grass Carp) made up 89.1 percent of the catch, while *Ictiobus* spp. (Smallmouth Buffalo, Bigmouth Buffalo, and Black Buffalo) and Common Carp made up an additional 7.3 percent of the total catch. Game fish represented 1.2 percent of the catch, with *Moronidae* spp. making up 89 percent of the game fish captured.

Great Lakes Pound Net:

A total of 8,812 fish representing 22 species and one hybrid group were caught in pound nets in 2015. Asian carp (Bighead Carp, Silver Carp, and Grass Carp) made up 38.2 percent of the catch, while *Ictiobus* spp. (Smallmouth Buffalo, Bigmouth Buffalo, and Black Buffalo) and Common Carp made up an additional 18.4 percent. Game fish represented 17.9 percent of the catch, with White Bass making up 73.7 percent of the game fish captured. The remainder of the species collected consisted of Freshwater Drum, River Carpsucker, Yellow Bass, Gizzard Shad, Quillback, Longnose Gar, Shorthead Redhorse, and Highfin Carpsucker.

Recommendations: We recommend increased Asian carp removal in the upper Illinois Waterway to reduce carp abundance at and near the detectable population front and prevent further upstream movement of populations toward the Electric Dispersal Barrier and Lake Michigan. Utilizing contracted commercial fishing crews with assisting IDNR biologists has been a successful approach for Asian carp removal in areas of the waterway not open to permitted commercial fishing. Multiple years of harvest data will provide insight into tracking and modeling changes in relative abundance of Asian carp populations over time and between pools in the upper Illinois Waterway. This information will assist in assessing the risk of further upstream invasion of Asian carp and challenges to the barrier. There is also a need to assess the effects of the removal program on actual Asian carp population densities and patterns of immigration and emigration at the population front.

Table 1: Asian Carp removal effort and harvest of Asian carps from Dresden, Marseilles and Starved Rock pools during 2010-2015 using contracted commercial fisherman.

	Effort						Harvest							
Year and River	Net Sets (*N*)	Miles of Net	Seine Hauls (*N*)	Miles of Seine	Hoop net Sets (*N*)	Pound Net Nights	Bighead Carp (*N*)	Silver Carp (*N*)	Grass Carp (*N*)	Total (*N*)	Bighead Carp (tons)	Silver Carp (tons)	Grass Carp (tons)	Total (tons)
2010														
Dresden Island	138	7.9					93	1	16	110	1.00	0.01	0.18	1.19
Marseilles	1,316	74.8					4,888	1,075	0	5,963	53.11	8.11	0.00	61.22
Starved Rock														
All pools	1,454	82.7					4,981	1,076	16	6,073	54.11	8.12	0.18	62.41
2011														
Dresden Island	56	9.2					66	13	5	84	0.78	0.10	0.02	0.90
Marseilles	671	213.6					20,087	7,023	34	27,144	229.39	46.00	0.16	275.55
Starved Rock	151	44.6					2,964	10,730	132	13,826	21.36	53.32	0.65	75.33
All pools	878	267.4					23,117	17,766	171	41,054	251.53	99.42	0.83	351.78
2012														
Dresden Island	74	19.3					76	13	1	90	0.53	0.10	>0.01	0.63
Marseilles	599	211.8					12,126	8,744	75	20,945	110.38	54.42	0.02	164.82
Starved Rock	198	62.1					4,358	19,875	233	24,466	24.67	94.23	0.18	119.08
All pools	871	293.2					16,560	28,632	309	45,501	135.58	148.75	0.20	284.53
Winter Harvest 2012-2013														
Dresden Island	37	11.9					240	45	5	290	2.90	0.30	0.10	3.30
Marseilles	151	41.8	4	1.8			2,378	3,588	284	6,250	23.80	22.20	2.00	48.00
Starved Rock	61	15.9					34	2,671	106	2,811	0.20	9.90	0.70	10.80
All pools	249	70	4	1.8			2,652	6,304	395	9,351	26.90	32.40	2.80	62.10
2013														
Dresden Island	141	54.5					849	45	3	897	9.68	0.29	0.03	10.00
Marseilles	457	193.9					7,134	10,154	76	17,364	66.17	49.06	0.33	115.56
Starved Rock	236	93.3					3,794	36,398	224	40,416	21.69	159.76	1.00	182.44
All pools	834	341.8					11,777	46,597	303	58,677	97.54	209.11	1.36	308.00
2014														
Dresden Island	32	9.0					26	8	0	34	0.26			0.26
Marseilles	488	204.4	3	1.1			7,549	27,516	108	35,173	69.33	112.29	0.05	181.67
Starved Rock	290	91.0	1	0.2	196.0		4,220	63,132	416	67,768	19.74	222.73	0.72	243.19
All pools	810	304.5	4.0	1.3	196.0		11,795	90,656	524	102,975	89.33	335.02	0.77	425.12
2015														
Marseilles	422	141.7	14	1.62	8		5,298	68,909	216	74,423	39.42	236.48		275.90
Starved Rock	226	78.3	4	0.53	84		2,897	65,156	624	68,677	13.14	187.99		201.13
All Pools	648	220	18	2.15	92		8195	134,065	840	143,100	52.56	424.47		477.03
2010-2015														
Dresden Island	478	112	0	0			1,350	125	30	1,505	15	1	0	16
Marseilles	4,104	1,082	21	4.5	8	24	59,460	127,009	793	187,262	592	529	3	1,123
Starved Rock	1,162	385	5	1	196		18,267	197,962	1,735	217,964	101	728	3	832
All pools	5,744	1579.2	26	5.3	204.0	24.0	79,077	325,096	2,558	406,731	707.55	1257.29	6.14	1970.97

Barrier Defense Asian Carp Removal Project

Table 2: Asian carp and by-catch captured with trammel and gill nets in the Dresden Island , Marseilles and Starved Rock Pools of the upper Illinois waterway in 2011 -2015. All Species other than Asian carp and Common Carp were returned to the River immediately after capture.

	2011		2012		2013		2014		2015	
Species	Number Captured	Percent %	Number Captured	Percent %	Number Captured	Percent %	Number Captured	Percent %	Number Captured	Percent %
Bighead Carp	23117	43.68%	16560	28.36%	11777	15.67%	10625	11.15%	6318	4.05%
Silver Carp	17776	33.59%	28632	49.03%	46597	62.01%	57302	60.15%	116411	74.67%
Smallmouth Buffalo	3853	7.28%	3749	6.42%	7397	9.84%	12717	13.35%	23989	15.39%
Bigmouth Buffalo	3850	7.27%	5043	8.64%	3567	4.75%	4670	4.90%	3174	2.04%
Common Carp	2574	4.86%	2386	4.09%	2685	3.57%	6699	7.03%	1819	1.17%
Freshwater Drum	573	1.08%	689	1.18%	1055	1.40%	1091	1.15%	1510	0.97%
Flathead Catfish	313	0.59%	299	0.51%	417	0.55%	301	0.32%	233	0.15%
Channel Catfish	201	0.38%	137	0.23%	321	0.43%	430	0.45%	616	0.40%
Black Buffalo	188	0.36%	262	0.45%	432	0.57%	318	0.33%	133	0.09%
Grass Carp	171	0.32%	299	0.51%	303	0.40%	524	0.55%	823	0.53%
Paddlefish	78	0.15%	51	0.09%	37	0.05%	37	0.04%	31	0.02%
River Carpsucker	61	0.12%	26	0.04%	105	0.14%	229	0.24%	467	0.30%
Quillback	37	0.07%	46	0.08%	49	0.07%	84	0.09%	134	0.09%
Largemouth Bass	28	0.05%	22	0.04%	28	0.04%	26	0.03%	34	0.02%
Sauger	19	0.04%	31	0.05%	12	0.02%	11	0.01%	31	0.02%
Shortnose Gar	16	0.03%	37	0.06%	44	0.06%	13	0.01%	29	0.02%
White Bass	13	0.02%	11	0.02%	40	0.05%	23	0.02%	14	0.01%
Longnose Gar	11	0.02%	25	0.04%	68	0.09%	91	0.10%	40	0.03%
Walleye	9	0.02%	12	0.02%	7	0.01%	5	0.01%	15	0.01%
Skipjack Herring	9	0.02%	14	0.02%			6	0.01%	6	< 0.01%
Blue Catfish	8	0.02%	7	0.01%	8	0.01%	2	< 0.01%	5	< 0.01%
Gizzard Shad	6	0.01%	22	0.04%	5	0.01%	3	< 0.01%	4	< 0.01%
Yellow Bass	3	0.01%	5	0.01%	9	0.01%	9	0.01%	4	< 0.01%
Hybrid Striped Bass	2	< 0.01%	7	0.01%	2	< 0.01%	5	0.01%	12	0.01%
White Crappie	1	< 0.01%	2	< 0.01%	1	< 0.01%	4	< 0.01%	7	< 0.01%
Bluegill			1	< 0.01%			1	< 0.01%	1	< 0.01%
Black Crappie	1	< 0.01%	1	< 0.01%	2	< 0.01%	4	< 0.01%	7	< 0.01%
Shorthead Redhorse		< 0.01%	1	< 0.01%			4	< 0.01%	1	< 0.01%
Golden Redhorse			2	< 0.01%	6	0.01%	30	0.03%	5	< 0.01%
River Redhorse	1	< 0.01%					1	< 0.01%	1	< 0.01%
Rock Bass			1	< 0.01%						
Muskellunge	1	< 0.01%			2	< 0.01%	1	< 0.01%	2	< 0.01%
Northern Pike	1	< 0.01%	1	< 0.01%	2	< 0.01%			1	< 0.01%
Common Carp x Goldfish Hybrid	1	< 0.01%	4	0.01%	2	< 0.01%				
Mooneye			6	0.01%	3	< 0.01%	1	< 0.01%	8	0.01%
Goldeye	1	< 0.01%							3	< 0.01%
Goldfish					20	0.03%			2	< 0.01%
Unidentified Buffalo Species					137	0.18%				
White Perch					1	< 0.01%				
Bowfin					4	0.01%			3	< 0.01%
Silver Redhorse							1	< 0.01%	3	0.00%
Total all Species	52924		58391		75145		95268		155896	

Barrier Defense Asian Carp Removal Project

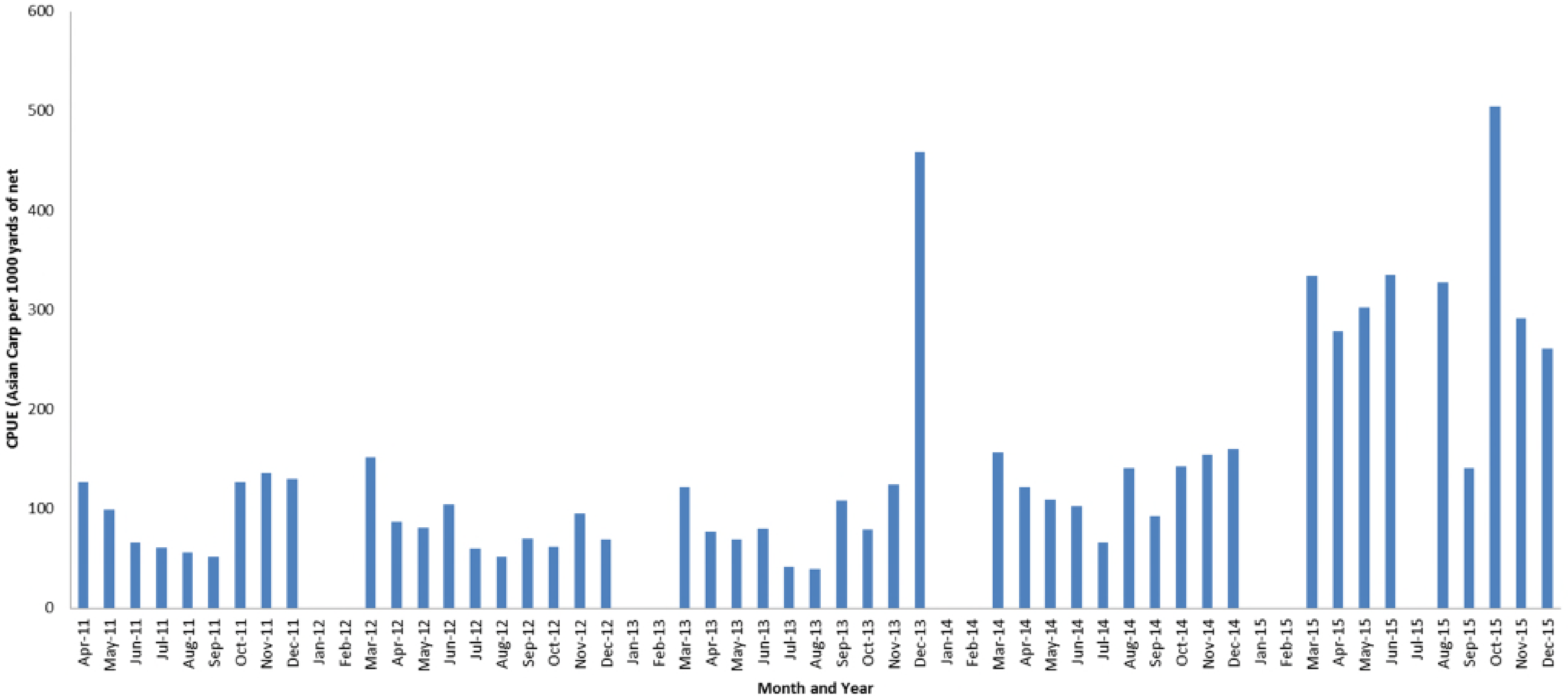


Figure 2: *Monthly Catch per unit effort (CPUE; Asian carp/1000 yards of gill/trammel net) for all pools combined in 2011- 2015.*

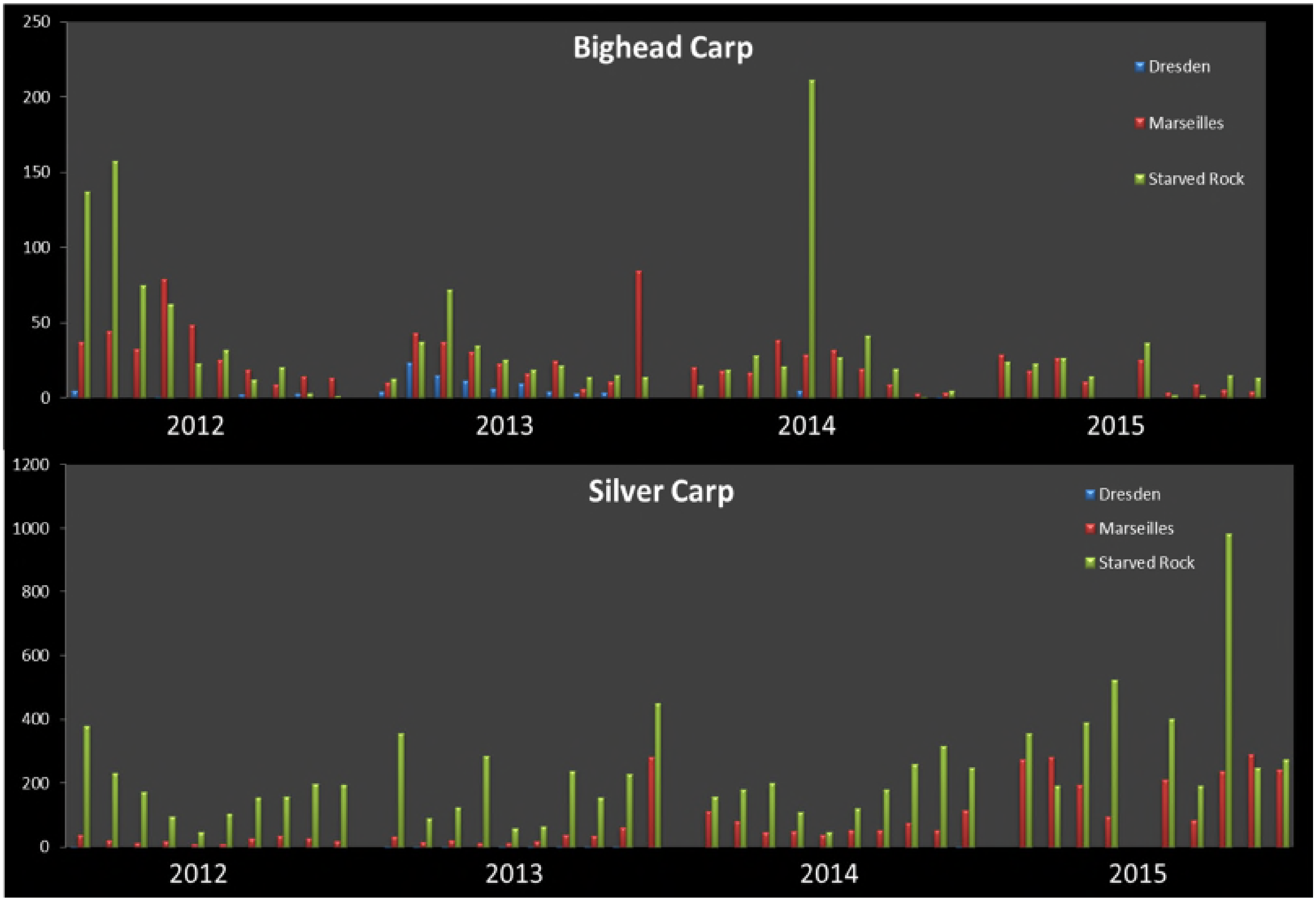


Figure 3. *Yearly trends in Catch per unit effort (CPUE; Asian carp/1,000 yards of gill/trammel net) in 2011-2015*

Identifying Movement Bottlenecks and Changes in Population Characteristics of Asian Carp in the Illinois River

David P. Coulter, Alison A. Coulter, Ruairi MacNamara, Marybeth K. Brey, James E. Garvey, Greg Whitledge, Matt Lubejko, Andrea Lubejko, Justin Seibert (SIU Carbondale)
Jahn Kallis, David Glover (The Ohio State University)
Jim Lamer (Western Illinois University)

Participating Agencies: Southern Illinois University Carbondale (lead); Western Illinois University (support), The Ohio State University (support), Illinois Department of Natural Resources (field support), U.S. Army Corps of Engineers–Chicago District (field support), US Geological Survey (support), Illinois Natural History Survey (support).

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Project Goal: Evaluate and monitor how harvest and other control methods affect the density, demographics, and movement of Asian carp in the Illinois River. Provide management recommendations for reducing the proximity of Asian carp to the CAWS. Ultimately, develop a predictive model of Asian carp dispersal in the Illinois River as a function of density, demographics, environment and harvest that can be applied to other rivers.

Introduction: Bighead Carp, Silver Carp, and their hybrids invaded the Illinois River 15 years ago. Asian carp recruit regularly in the lower Mississippi River (Lohmeyer and Garvey 2009). Once detected in the Illinois River, the density of these fish increased rapidly, and the fish have neared the CAWS, which forms a hydrological connection between the Great Lakes and Mississippi basins. For the past several years, it appears the Asian carp population front has remained in the Dresden Island reach of the Illinois River, approximately 55 miles from Lake Michigan. Current research efforts have focused on monitoring the population dynamics of these invasive species throughout the Illinois River since 2010.

Commercial harvest of Asian carp is occurring in the lower Illinois River, while contracted control fishing is ongoing (since 2010) above Starved Rock Lock and Dam (the upper Illinois River). These factors affect population dynamics, patterns of movement, and the risk that Asian carp will establish in the reaches directly below the electric barrier separating the Illinois River from the CAWS. Our group is collaborating with other researchers to quantify density, demographics, and movement throughout the Illinois River. A host of techniques (electrofishing surveys, split-beam hydroacoustics, and telemetry) are needed to generate robust data for the entire river. Ultimately, this information will be integrated into a population model to evaluate various harvest scenarios and inform effective control strategies.

Identifying Movement Bottlenecks and Changes in Population Characteristics of Asian Carp in the Illinois River

Methods: Standardized fish sampling in the lower river, hydroacoustic surveys, and acoustic telemetry were all used to quantify the efficiency of harvest and other control methods of Asian carp in the Illinois River.

Demographics in the Illinois River (Chapter 1). Standardized fish sampling was conducted along the main channel of the Illinois River at fixed locations within each of the three lower reaches (Alton, La Grange, and Peoria) including several adjacent backwaters in August 24 to 26, 2015 (Chapter 1.1, Table 1.1). A pulsed-DC electrofishing transect following USGS Long-Term Resource Monitoring Protocols (LTRMP) was conducted at each main channel and backwater site. Asian Carp biological information, including catch per unit effort, mean length-at-age, length-weight relationships, indices of spawning condition, sex ratios, and molecular identification (species or interspecies), were determined.

Acoustics (Chapter 2). Each fall from 2012 to 2015, standardized hydroacoustic surveys were undertaken in the main channel and associated side channels, backwater lakes, tributaries, and harbors along the Illinois and Des Plaines Rivers from the confluence with the Mississippi River to Brandon Road Lock and Dam. Hydroacoustic-derived targets within each reach were integrated with SIU standardized sampling and commercial fishing data to determine length-specific proportional abundance of Asian carp to other fishes. Reach-specific length-weight regressions were calculated for each group of fishes to estimate total biomass. Density (expressed in terms of abundance and biomass) of Asian carp and other fishes was then calculated based on the ensonified water volume.

Movement (Chapter 3). Since 2012, with assistance from IDNR-contracted commercial fishermen and INHS, 965 acoustic transmitters have been implanted in Asian carp in the Illinois River or Pool 26 of the Mississippi River. A network of 51 Vemco stationary receivers have been deployed and monitored in the Illinois River by SIUC since 2012 to monitor movement of acoustically tagged Asian carp. VR2Ws were downloaded every 2 to 4 months to record fish detections. Multiple stationary receivers were placed around lock chambers and the Hanson Material Service pits. Movements were then evaluated temporally and related to water temperature and river gage height. Movements of individuals tagged above and below Starved Rock Lock and Dam were also compared.

Spatially explicit population model (Chapter 4). Asian carp demographic parameters (growth, mortality, condition, and maturation schedule) were estimated along with their uncertainty using Bayesian hierarchical models. Current efforts are focused on estimating a stock-recruitment relationship using a combination of data sources (acoustics data and data from the USGS Long-Term Resource Monitoring Program). Updated demographic parameters will be used in a spatially explicit Asian carp population model for the Illinois River waterway (from the confluence with the Mississippi River to Lockport pool) that incorporates inter-reach movement probabilities. Finally, the newly developed model will be used to predict the number of Asian carp that would be expected to reach the Electric Dispersal Barrier under various harvest scenarios.

Results and Discussion (Overview):

Demographics in the Illinois River (Chapter 1). CPUE estimates of Asian carp increased from 2014 to 2015. In 2015, CPUE appeared similar among pools but, for all standardized sampling years combined, CPUE was greatest in the Peoria pool. CPUE can vary with environmental conditions, gear selectivity, fish behavior, fishing activity, and many other factors. Therefore, hydroacoustic estimates (Chapter 2) likely provide a more representative indicator of population status. Age-0 Silver Carp were collected in all three lower pools sampled but not as many as were collected in 2014 during standardized sampling. In 2015, gonadosomatic index was also lower than in 2014. Genetic testing of individuals collected in 2014 yielded very few Bighead Carp and Bighead Carp backcross individuals, but this low number may have resulted because most individuals were obtained via electrofishing. Genetic testing of fin clips collected in 2015 are currently being processed by Western Illinois University. Post-cleithra collected from Silver Carp during 2015 standardized sampling are currently being used to estimate age of individuals collected.

Hydroacoustics (Chapter 2). Hydroacoustic surveys since 2012 used side-looking, split-beam and side-scan sonar techniques in both main channel and backwater habitats. Analysis completed to date for the three upper reaches (2012 to 2014) has confirmed the high biomass of Asian carp in these reaches relative to native fishes (accounting for 40 to 60 percent of the fish community biomass). Between-year comparisons (2012 to 2014), however, suggest that the Asian carp population may be responding to commercial fishing; mean Asian carp density in the Dresden Island pool has steadily decreased through time and size structure in Dresden remains larger than in lower pools. Hydroacoustic surveys indicated that targeted harvest actions successfully reduced Asian carp densities in the short term (24 hours), however, densities rebounded to similar or higher levels over longer periods (2 weeks at some sites).

Movement (Chapter 3). Seasonal movement patterns were evident for both Bighead and Silver Carp, although Bighead Carp appeared to show more annual variability than did Silver Carp. In general, individuals moved more from May and August. Individuals usually move upstream from March to May and downstream from June to August, indicating the potential importance of spawning migrations. As suggested in previous SIUC reports, individuals tagged above Starved Rock Lock and Dam moved less overall compared with to those tagged downstream. The overall distances traveled by those tagged above Starved Rock Lock and Dam were reduced compared with those downstream. Downstream of Starved Rock Lock and Dam, Bighead and Silver Carp appeared to be more migratory than above, which could result from differences in fish behavior (such as transient/resident individuals), overall higher fish densities in the lower pools producing a density-dependent response, the location and proximity of spawning sites, the types of dams in the upper versus lower Illinois River, or other potential environmental differences. Tagged individuals appeared to use similar areas of the river in consecutive years and to not appear to shift their ranges upstream, with the exception of Silver Carp between 2012 and 2013. Fish movement through the channel connecting the Hanson Material Service pits to the Illinois River were significantly correlated with water temperature and river gage height, although the relationships were not strong. The interaction of gage height, temperature, or the interaction of these two variables did not produce any good generalized linear models. However, spawning did appear to occur with a rise in water level and temperatures > 18ºC, as movement in the Hanson Material Service pits connecting channel increases and then ceases. Estimates from the program MARK multi-state model show that there was a relatively low likelihood that fish would move more than one pool away from their starting pool. Transitions among the upper pools (Starved Rock, Marseilles, and Dresden Island) were lower than transition probabilities among the lower pools (Alton, La Grange, and Peoria). Currently, pool transition estimates are only pool specific and do not vary with time. Multi-state models are being constructed with seasons to better incorporate seasonal variation into the population model (Chapter 4).

Spatially explicit population model (Chapter 4). Asian carp demographic parameters (growth, mortality, condition, and maturation schedule) were estimated along with their uncertainty using Bayesian hierarchical models. Ages of fish ranged from 0 to 12 and 0 to 19 for Silver and Bighead Carp, with Bighead Carp exhibiting slower growth rates than Silver Carp. Allometric relationships between length and weight, along with the error around these relationships, were determined for both species. Maturation schedules demonstrated that Silver Carp mature at younger ages than Bighead Carp, and Silver Carp grow at higher rates and mature at smaller sizes.

Major Finding and Recommendation: Standardized electrofishing surveys indicated that Asian carp abundance in the lower pools of the Illinois River increased in 2015, and the presence of YOY individuals indicated that spawning did occur in the lower river. Bighead and Silver Carp remained a large portion (by both abundance and biomass) of the overall fish community throughout the Illinois River. However, both species appear to be responding to harvest in the upper pools, especially the Dresden Island pool, where densities decreased from 2012 to 2014. Standardized hydroacoustic surveys confirmed that contracted harvest events successfully reduce Asian carp densities. However, the effects were short lived, with densities rebounding within as little as 2 weeks. Low transition probabilities, lower densities, and reduced movements by Asian carp in the upper river pools indicated that frequent removal efforts may be most effective at controlling Asian carp in these reaches.

Identifying Movement Bottlenecks and Changes in Population Characteristics of Asian Carp in the Illinois River

Literature Cited:

Lohmeyer AM, Garvey JE. 2009. Placing the North American invasion of Asian carp in a spatially explicit context. Biological Invasions 11: 905-916.

Chapter 1:
Standardized sampling on the lower Illinois River
David P. Coulter, Alison A. Coulter, Ruairi MacNamara, Matt Lubejko, Andrea Lubejko, Marybeth K. Brey and James E. Garvey;
(Southern Illinois University Carbondale)

Participating Agencies: Southern Illinois University Carbondale (lead), Western Illinois University (subcontract for genetic testing)

Introduction: Periodic standardized sampling of aquatic invasive species can provide useful information for tracking changes in the demographics of a population over time. These data provide a baseline from which to assess the impacts of commercial fishing and harvest of Asian carp in the Illinois River. Although Asian carp have been detected in the lower Illinois River (from the confluence with the Mississippi to the Starved Rock Lock and Dam) since the early 1990s, monitoring downstream populations is essential for predicting changes in upstream population growth and further movement of Asian carp toward the CAWS. In addition, information collected via standardized sampling will allow us to parameterize predictive models and better forecast population dynamics in the future, in turn facilitating effective decision-making on control strategies. Finally, collecting genetic vouchers on an annual basis can provide additional information on hybridization of individuals in the lower reaches of the Illinois River. Hybridization may influence the movement, spawning, and feeding ecology of fish, with implications for invasibility in the CAWS and the Great Lakes. Here, the population dynamics of Asian carp in main channel and backwater areas of the lower Illinois River were assessed.

Objectives: Conduct standardized fish sampling along the three lower reaches (Alton, La Grange, and Peoria) of the Illinois River to:

(1) Determine demographic changes in the Asian carp populations and possible responses to commercial fishing, including condition, sex ratios, hybridization, and indices of spawning condition.

(2) Collect fish assemblage data (species and size composition) for incorporation into hydroacoustic estimates of density and size structure.

Project Highlights

- Silver Carp CPUE (Alton – Peoria pool combined) increased in 2015 compared with previous years.
- YOY Silver Carp were collected in each of the three pools: Alton – 37, La Grange – 11, Peoria – 17.
- Length-weight relationships indicated that Alton pool Silver Carp were heavier at a given length than those from La Grange and Peoria pool

- Interannual changes were evident in many of the population traits examined, and it is therefore important to continue to follow and search for temporal trends that could be exploited to better manage Asian carp.

Methods:

Fish collection

Standardized fish sampling has been conducted by SIUC from 2011 to 2015 occurred along the main channel of the Illinois River at four fixed locations within each of the three lower reaches, as well as nearby backwater areas (backwater lake, side channel, or tributary) between 24 and 26 August 2015 (Table 1.1). Sampling followed protocols outlined in the Long Term Resource Monitoring Program (LTRMP; Gutreuter et al. 1995). Three replicate, 15-minute pulsed-DC electrofishing transects (Smith-Root GPP 5.0 electrofisher), with two netters, were conducted parallel to shore along each main channel and backwater site during the day at a power goal of 3,000 W based on conductivity and temperature.

All fish species captured were identified, weighed, and measured (batch weights were taken when large quantities of age-0 fish were captured). Asian carp were retained and biological information including sex and gonad weight (nearest 0.1 g) was collected. Post-cleithra were removed for age determination and are currently being processed. Fin clips were also collected to determine maternal contribution of parental Silver Carp, Bighead Carp, and their hybrids. Genetic identification was also performed for select Asian carp that were used for acoustic telemetry (Chapter 3) in the lower river. DNA extraction, genotyping, and data processing are currently under way at Western Illinois University for 2015 samples. The 2014 genetic results presented in this report were assigned genotypes using the NewHybrids algorithm (Anderson and Thompson 2002) modified according to Lamer et al. (2015). Resulting products included genetic identification, allele frequency, and maternal contribution (early generation hybrids only) of up to 400 Asian carp per year.

Catch per unit effort

Electrofishing catch per unit effort (CPUE; number of fish per hour) was calculated for adult Silver Carp; CPUE included only fish that were netted, and not those that jumped into the boat. In previous years (2011 to 2013), electrofishing using two protocols was undertaken: the LTRMP protocol and an experimental protocol designed to maximize the capture of Asian carp. Only LTRMP electrofishing was performed in 2014 and 2015. The 2015 CPUE was adjusted to reflect both electrofishing methods to ensure meaningful comparisons of CPUE across years by applying a correction factor derived from the 3-year dataset of both electrofishing protocols. (IN other words, the experimental protocol captured on average 2.2 times more Silver Carp than the LTRMP protocol during 2011 to 2013.) A two-way ANOVA was used to compare Silver Carp CPUE among years, among pools, and among years within pools.

Chapter 1:
Standardized sampling on the lower Illinois River

Length-weight relationships
Length-weight relationships were developed for Silver Carp populations within each reach as well as all reaches combined after $\log_{10}$-transforming length and weight data. Outliers within the data were identified and removed if they could not be rectified from original data sheets and were not biologically reasonable. The slope and intercept parameters of the length-weight relationships were then compared among reaches and years using an analysis of covariance (ANCOVA).

Indices of spawning condition
Although Asian carp were collected after the spawning period, data from Pool 26 of the Mississippi River suggested that post-spawn gonadosomatic index (GSI) is much higher in spent female Silver Carp than in immature females (unpublished data). As such, changes in GSI as a function of length for female Silver Carp was tested using a two-dimensional Kolmogorov-Smirnov test (Garvey et al. 1998) to determine the length at which variation in GSI increases such that the probability of having a higher GSI increases, which indicates the potential size at maturation.

Sex ratio of Asian carp
Sex ratios of Asian carp populations were investigated within and among reaches. A chi-squared goodness of fit test was conducted to determine whether overall sex ratios differed from 1:1, and a chi-squared test of independence was used to test whether the sex ratios differed spatially among reaches.

Results and Discussion: The proportional abundance of Silver Carp varied slightly by pool but were not significantly different (ANOVA; $F_{2,14} = 0.30$, $P = 0.75$). Overall, Silver Carp comprised 32 percent (± 5 percent SE) of the standardized sampling catch.

Catch per unit effort
No Bighead Carp were captured during standardized sampling of the lower Illinois River. Silver Carp CPUE significantly differed by reach and year (ANOVA; $P = 0.001$). When pools are combined, Silver Carp CPUE did not change from 2011 to 2014 but significantly increased in 2015 ($P = 0.006$; Figure 1.1). Likewise, Silver Carp CPUE differed among pools when years were combined ($P = 0.002$). CPUE was higher in the Peoria pool (mean CPUE: 139) than in the Alton pool (mean CPUE: 61), with intermediate CPUE in the La Grange pool (mean CPUE: 101) that was similar to Alton and Peoria. The interaction between year and pool was not significant ($P = 0.69$), indicating that Silver Carp CPUE among years within pools were similar. Further monitoring is warranted to determine whether CPUE will continue to increase in the lower pools. CPUE also appears less variable across pools in 2015 compared with previous years, which may indicate a more even distribution of Silver Carp among pools.

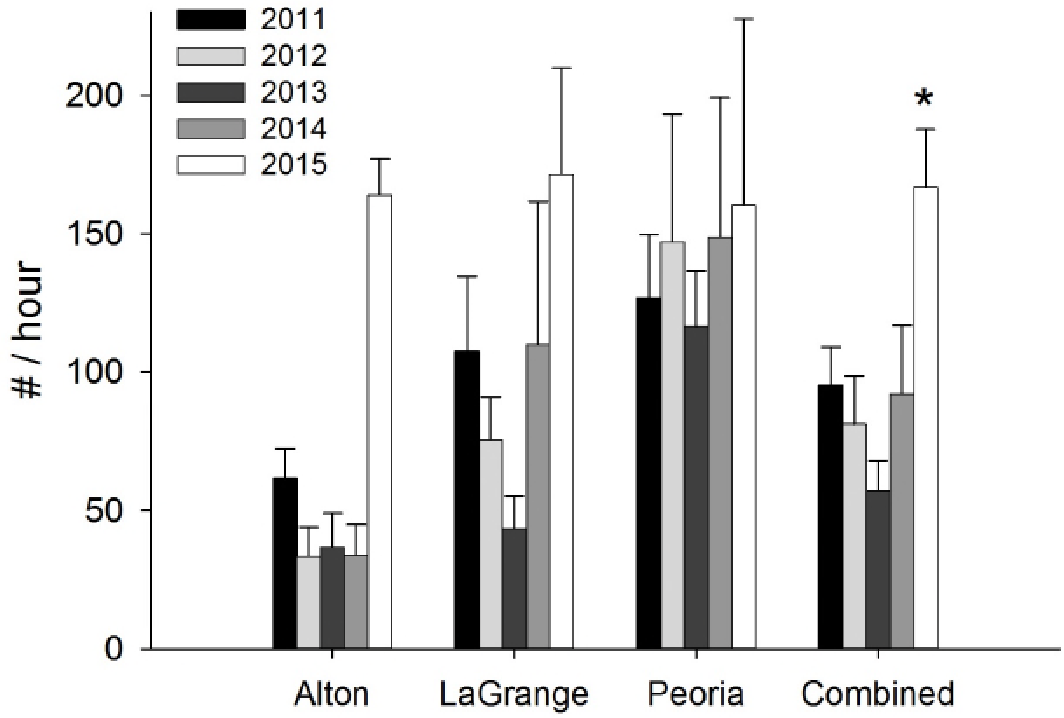


Figure 1.1. *Mean (±SE) Silver Carp catch per unit effort from standardized sampling in the lower pools of the Illinois River and all pools combined. The asterisk denotes a significantly higher CPUE in 2015 when the lower three pools are combined (Combined).*

Length-weight relationships

Length-weight relationships were significantly different among pools in 2015 (ANCOVA; $P <$ 0.001, $P_{slope} = 0.001$, $P_{Intercept} < 0.001$; Table 1.1). Pairwise comparisons indicated that the intercept of the Peoria pool was significantly different from Alton ($P = 0.01$) and La Grange ($P <$ 0.001) pools, but Alton and La Grange pool intercepts were not different from each other ($P =$ 0.42). Alton pool length-weight relationship had a significantly different slope from La Grange ($P = 0.01$) and Peoria ($P < 0.001$) pools but La Grange and Peoria pools were not significantly different in slope ($P = 0.10$). This finding indicates that, for a given length, Silver Carp from the Alton pool tended to weigh more than Silver Carp from the La Grange and Peoria pools. Silver Carp from La Grange had a slightly larger slope than those from Peoria pool, although not significantly so, indicating a slight trend of decreasing weight at length in the upstream direction. All slopes in 2015 were smaller than in 2014 (all $P < 0.001$), indicating individuals tend to weigh less at a given total length than the previous year. The intercept was only different between 2014 and 2015 for Peoria pool ($P < 0.001$).

Table 1.1. *Parameter values from the length-weight relationships ($\log_{10}mass = a' + b \cdot \log_{10}TL$) of Silver Carp collected from the lower three pools of the Illinois River in 2014 and 2015 by electrofishing. Parameter estimates with different letters indicate significantly different values between reaches ($P < 0.05$) within a year as determined by ANCOVA. Parameter estimates with different numbers indicate significantly different values ($P < 0.05$) between years for a given reach.*

Reach	*a'*	SE	*b*	SE	R^2	*P*	*N*
2014							
Alton	-4.534[ab1]	0.470	2.833[a1]	0.171	0.881	< 0.001	39
La Grange	-4.386[b2]	0.310	2.784[a2]	0.113	0.849	< 0.001	110
Peoria	-4.707[a4]	0.379	2.896[a4]	0.140	0.789	< 0.001	116
Combined	-4.828	0.162	2.942	0.059	0.903	< 0.001	265
2015							
Alton	-5.163[a2]	0.021	3.055[a1]	0.008	0.998	< 0.001	166
La Grange	-5.275[b3]	0.036	3.096[a2]	0.013	0.997	< 0.001	179
Peoria	-5.343[b5]	0.047	3.130[b5]	0.018	0.997	< 0.001	84
Combined	-5.218	0.018	3.076	0.007	0.998	< 0.001	429

Indices of spawning condition

Variation in female Silver Carp GSI was statistically similar across total lengths in Peoria (P = 0.79) and Alton (P = 0.45) pools but was different in La Grange (P = 0.001; Figure 1.2). Variation in GSI for La Grange pool females increased above 577 mm in total length. Overall, female GSI appeared less variable in 2015 than in 2014. Mean female Silver Carp GSI for 2015 was 0.011 (±0.0005 SE). Sampling in 2015 occurred several weeks later than in 2014, which may have influenced GSI. Annual variation in climatic conditions may have also influenced the timing of spawning and the subsequent GSI differences.

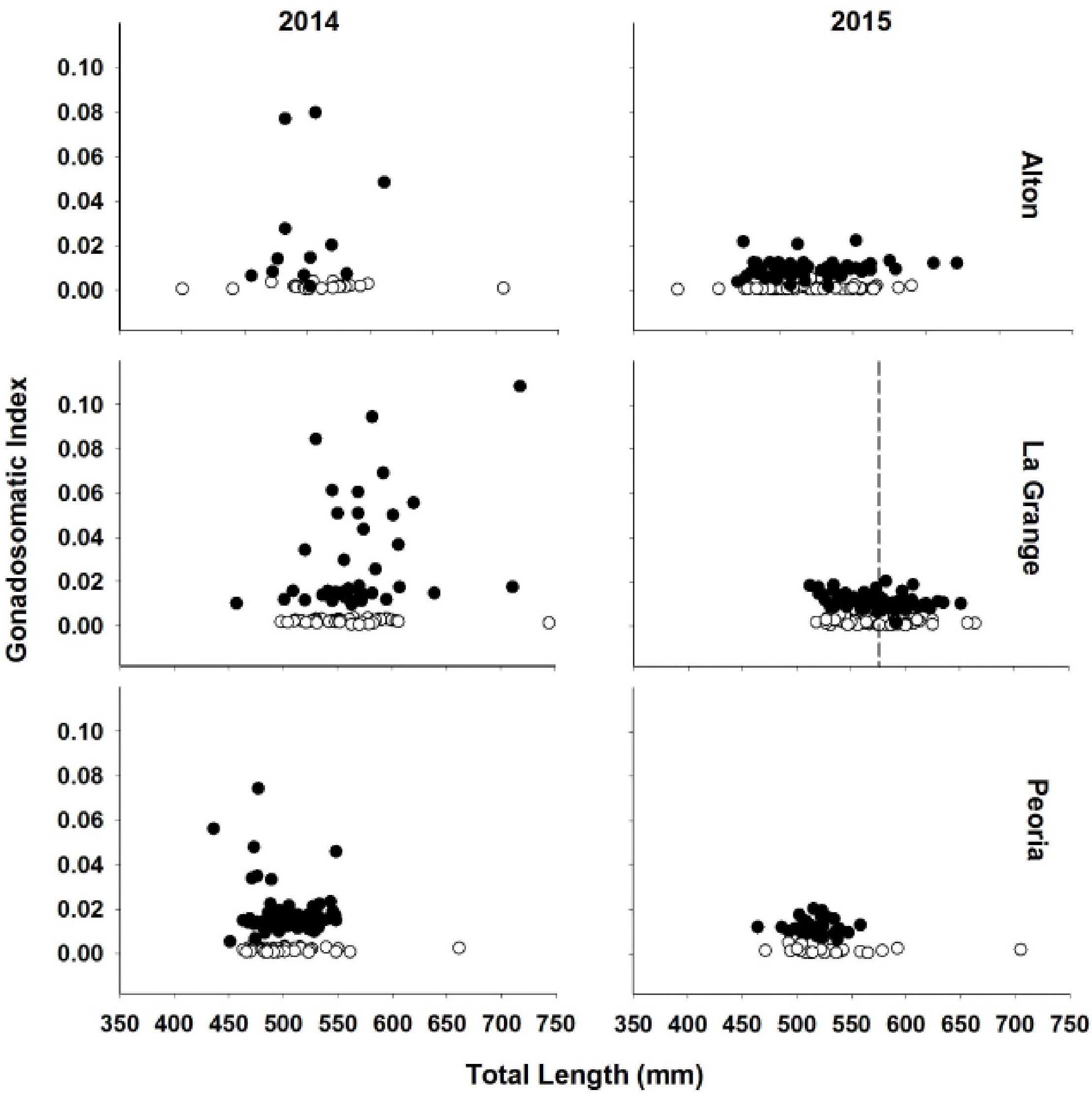


Figure 1.2. *Gonadosomatic index (GSI) of Silver Carp plotted by total length for each sex for the three lower reaches of the Illinois River. The dashed vertical line shows the total length at which variation in GSI increases for female Silver Carp as determined by a two-dimensional Kolmogorov-Smirnov test.*

Sex ratio of Asian carp

Sex ratios of Silver Carp collected in 2015 were not significantly different from 1:1 at the pool level (P = 0.25), or for all pools combined (P = 0.15), with 189 males and 162 females collected among all three lower pools. Data collected during 2012, coincident with the SIU fishing experiment where nearly 3 million pounds of carp were removed from the lower river, indicated that the sex ratio had shifted away from 1:1 (observed in 2011), with 17 percent more males overall in 2012. Silver Carp sex ratio had returned to 1:1 in 2013 and remained at this ratio in 2014 and 2015. It will be important to continue monitoring Asian carp sex ratios in the future to make inferences about the potential intrinsic rate of increase of Asian carp abundance.

Chapter 1:
Standardized sampling on the lower Illinois River

Molecular identification of Asian carp

Genotyping is still under way for 281 tissue samples collected in 2015 and should be completed by early 2016. Summary data for the 341 Asian carp individuals genotyped in 2014 are given in Table 1.2. "Pure" Bighead and Silver Carp accounted for 0.6 percent and 37 percent of the sampled fish. The low numbers of Bighead Carp collected may have resulted from most effort coming via electrofishing, which is known to be biased against Bighead Carp. Silver Carp individuals were the most common of the genetic identifications. As found in 2014, fourth generation Silver Carp backcross (Bx4SC) was common, accounting for 37 percent of all sampled individuals, suggesting high rates of hybridization in the Illinois River Asian carp population (ACRCC 2015). Only one first generation hybrid (F1) was found, indicating that hybridization may still occur but that it may be uncommon. Continued monitoring of genetic contributions of Bighead and Silver Carp is important because hybrids may have a different reproductive potential and have different impacts on ecosystem structure and function. This information is critical for predicting invasion potential into the CAWS and the Great Lakes. Additional analyses are under way to determine if hybrid individuals have different movement patterns and rates than pure individuals in the Illinois River.

Recommendations: The results of this ongoing monitoring continuously serve as baseline information for determining the effects of commercial fishing on Asian carp populations. It will be necessary to continue monitoring to determine how these factors will influence factors such as growth rates, condition, and reproductive success. This information will increase knowledge of how Asian carp respond to annual differences such that predictive models can better forecast population dynamics in the future to facilitate decisions concerning control measures. In addition, given that hydroacoustics must have some form of paired sampling, the data garnered from field collections concerning species-specific proportional abundance and changes in length-weight relationships among fishes is critical for interpretation of hydroacoustics data (Chapter 2).

Literature Cited:

Asian Carp Regional Coordinating Committee (ACRCC). 2015. 2014 Asian Carp Monitoring and Response Plan Interim Summary Reports. June 2015, 242 pp.

Anderson, .E.C, and Thompson, E.A. 2002. A Model-Based Method for Identifying Species Hybrids Using Multilocus Genetic Data. Genetics 160: 1217–1229.

Lamer, J.T., Ruebush, B.C., Arbieva, Z.H. et al. 2015. Diagnostic SNPs reveal widespread introgressive hybridization between introduced bighead and silver carp in the Mississippi River Basin. Molecular Ecology 24: 3931–3943.

Garvey, .J.E, Marschall, E.A., and Wright, R.A. 1998. From star charts to stoneflies: detecting relationships in continuous bivariate data. Ecology 79: 442-447.

Chapter 1:
Standardized sampling on the lower Illinois River

Gutreuter, S., Burkhardt, R., and Lubinsk, J K. 1995. Long-term resource monitoring program procedures: fish monitoring. National Biological Service. Environmental Management Technical Center, Onalaska, Wisconsin.

Table 1.2. *Genetic identification of 341 Asian carp between the Alton and Peoria pools on the Illinois River in 2014. BH = Bighead Carp, BxBH = first generation Bighead Carp backcross, Fx = complex late generation backcross [homozygous for both Bighead and Silver Carp], F1 = first generation cross between parental Bighead Carp and parental Silver Carp, FxSC = Likely late generation Silver Carp backcross x late generation Silver Carp backcross, Bx2SC = second generation Silver Carp backcross, Bx3SC = third generation Silver Carp backcross, Bx4SC = fourth generation Silver Carp backcross, SC* = undetermined late generation Silver Carp backcross x late generation Silver Carp backcross, SC = Silver Carp.*

	Genetic Results												% Pure	
Pool	BH	Bx4BH	BxBH	Fx	F1	FxSC	Bx2SV	Bx3SV	Bx4SV	SC*	SC	**Total**	BH	SC
Alton						2	3	1	30		33	69	0.0	47.8
La Grange		6		1	1	12		9	40	5	35	109	0.0	32.1
Peoria	2	12	1			13		13	55	8	59	163	1.2	36.2
Total	2	18	1	1	1	27	3	23	125	13	127	341	0.6	37.2

Chapter 2:

Hydroacoustic population estimates of Asian carp in the Illinois River

David Coulter, Ruairí MacNamara, Andrea Lubejko, James E. Garvey
(Southern Illinois University Carbondale)

Participating Agencies: Southern Illinois University at Carbondale (lead); Illinois Department of Natural Resources (field support); The Ohio State University (support); Illinois Natural History Survey (support).

Introduction: Hydroacoustics provide a unique, fishery-independent monitoring tool that is now being extensively utilized in freshwater systems (see for example Parker-Stretter et al. 2009). In total, 4 years of fall surveys have now been completed (2012 to 2015), which provide robust estimates of Asian carp density and size structure in the upper Illinois River.

Information derived from the annual hydroacoustic surveys are used in a number of ways. Firstly, the impact of commercial harvest on the Asian carp population in the lower pools is evaluated. In the upper pools, where IDNR harvest is attempting to decrease the probability of Asian carp progression upstream toward the Great Lakes, hydroacoustic monitoring provides important information for assessing and guiding these ongoing efforts. Asian carp population size data have also been incorporated into predictive models (Chapter 4) that will in turn facilitate decision-making in terms of appropriate control strategies.

Objectives: SIUC conducted annual (2012 to 2015) hydroacoustic surveys to:

(1) Estimate the pool-specific density and size structure of Silver and Bighead Carp in six pools of the Illinois River, from the confluence of the Mississippi River upstream to Brandon Road Lock and Dam (Alton – Dresden Island pools).

(2) Determine the relative density among the main channel and associated habitats, including backwater lakes, side channels, tributaries, and harbors.

(3) Determine whether densities of Silver and Bighead Carp have changed in response to harvest.

Project Highlights

- Four years of standardized hydroacoustic surveys (fall 2012 to 2015) have been completed throughout the Illinois River to provide long-term trends in Silver and Bighead Carp densities. Protocols have been developed and refined so that surveys are analyzed in a comparable fashion to provide replicate annual Asian carp population estimates.
- Asian carp densities remain low in the uppermost pools surveyed. In the Dresden Island pool (the farthest upstream pool sampled), both numerical and biomass densities of Asian carp continuously decreased from 2012 to 2014.
- Shifts in Asian carp size structure, generally consistent with the removal of larger individuals, were also apparent in the three upper reaches.
- Asian carp densities decreased immediately following harvest events but rebounded or exceeded initial levels over longer periods ($\geq$ 2 weeks).

Chapter 2:
Hydroacoustic population estimates of Asian carp in the Illinois River

Methods:

Hydroacoustic surveys

Hydroacoustic surveys took place annually (2012 to 2015) in the six pools of the Illinois River (and portions of the Kankakee and Des Plaines River) between the confluence of the Mississippi River and Brandon Road Lock and Dam. Almost all accessible habitat was surveyed in the upper three pools (Starved Rock, Marseilles and Dresden Island), whereas several 6.4 km stretches of main channel and associated side channels, backwater lakes, tributaries, and harbors were surveyed in each of the lower three pools (Alton, La Grange, and Peoria).

Mobile hydroacoustic surveys were undertaken using two side-looking, split-beam transducers (BioSonics DT-X) on a SIUC research vessel. The upper acoustic beam extended parallel to the water surface, and the second beam was offset to ensonify the water column directly below the first beam. For all surveys, hydroacoustic data were collected to a maximum distance of 50 meters, with a ping rate of 5 per second and a 0.40 ms pulse duration. Various transducer combinations were deployed during each field season (70 kHz and 70 kHz, 70 kHz and 208 kHz, and 201 kHz and 208 kHz). Transducers were individually calibrated on axis with the appropriate tungsten carbide sphere (Foote et al. 1987).

Survey transects in the main channel consisted of a loop following the nearshore ~1.5 meter depth contour, with the acoustic beams pointing toward the mid-channel. A second loop was performed inside the first, closer to the mid-channel. Only one loop was generally required in side channels and tributaries. The first loop began at the ~1.5 meter depth contour in backwaters lakes and harbors and was repeated progressively closer to the center at intervals that would limit overlap while ensuring as complete coverage as possible. Vessel speed was approximately 6.5 km/hr for all transects.

Post-processing

Hydroacoustic data were processed using Echoview 5.4 software. A bottom line was manually drawn to separate the river bed from the water column. Areas where acoustic targets could not be reliably distinguished from the river bed, or areas of high interference, were excluded. Only data > 1 meter from the transducers (to account for the near-field distance; Simmonds and MacLennan 2005) and before the bottom line were analyzed further. Target strength was compensated for two-way signal loss, as it is affected by range from the transducer, the speed of sound in water, signal absorption, and angle at which echoes are received. Background noise was filtered by removing target strength-compensated acoustic signals less than -60 dB.

Fish targets were identified using Echoview's "split-beam single target detection (method 2)" algorithm following Parker-Stetter et al. (2009). Echoview's "fish track detection" algorithm was then used to group targets originating from a single fish. All fish tracks were then manually inspected. The mean acoustic target strength (in dB) of each fish track was then converted to fish length using Love's (1971) fish length–target strength equation. This widely used, multispecies equation can be applied to a range of transducer frequencies. (SIUC variously used 70 kHz, 201 kHz and 208 kHz transducers.) Only acoustic targets corresponding to a fish > 30 cm were included in the analysis.

Paired sampling

As species identification is not possible using split-beam hydroacoustics, some form of paired sampling was necessary to inform species composition and size structure. To ensure as complete a representation as possible of the Illinois River fish community (that is, to limit size- and gear-selectivity sampling biases), data derived from a combination of standardized pulsed-DC electrofishing surveys (conducted by SIUC in the lower three pools [Chapter 1] and by INHS in the upper three pools [LTRMP]), and gill/trammel net data (from IDNR- and SIUC-monitored commercial fishing) were used. Fish collected were identified, measured (total length, to the nearest mm) and weighed (to the nearest g).

Density

Using the ground-truth data, fish > 30 cm were separated into three categories (Silver Carp, Bighead Carp, and other fish species) within each pool, and the numbers of fish in each 2 cm length-class were determined. Pool-specific proportions of Silver and Bighead Carp and all other species were then linearly interpolated for each 0.1 cm length increment. A 120 cm cut-off was used; if the largest fish captured was < 120 cm, then a 100 percent Bighead Carp composition was assumed for the remaining length increments (based on SIUC field observations in the Illinois River). Acoustically derived fish lengths were extrapolated according to total fish abundance, and the length-specific proportions of each fish category were then applied to estimate the total number of Silver Carp, Bighead Carp, and other fish species. Length-specific biomass was estimated by multiplying fish weight (determined for each fish category by log-transformed length-weight regressions from the paired sampling data) by total estimated abundance for every 0.1 cm length increment in each fish category. Finally, species-specific total biomass was determined by summing length-specific biomass. Density (abundance and mass per 1,000 m^3) was calculated following protocols outlined in ACRCC 2015 (pp 97-98).

Hydroacoustic surveys to assess harvest impacts

In addition to the fall surveys described above, key locations in the upper river in 2014 and 2015 were surveyed to determine whether Asian carp densities changed in relation to harvest efforts. Specifically, these surveys were conducted in: the Brandon Road pool; immediately below Brandon Road Lock and Dam; Rock Run Rookery in the Dresden pool; and the Hanson Material Service East and West Pits in the Marseilles pool. Most surveys were coordinated so that they occurred directly before and after (within 24 hours) IDNR Barrier Defense contracted commercial fishing efforts. Field crews aboard the commercial fishing boats measured length and weight from subsamples of all species captured.

Chapter 2:
Hydroacoustic population estimates of Asian carp in the Illinois River

Results and Discussion: Each year, more than 225 kilometers of Illinois River main channel were surveyed, in addition to 16 side channels and tributaries and 10 other backwaters (lakes, harbors, and bays) of varying sizes (Table 2.1). The hydroacoustic data from 2015 fall surveys are currently being processed at SIUC.

Asian carp density

Density estimates are presented either in terms of abundance or biomass (number or kg of fish per 1,000 m^3 of water sampled). Silver Carp remained at similar numerical densities within the Starved Rock, Marseilles, and Dresden Island Pools from 2013 to 2014 (based on pairwise interval estimation; Figure 2.1). Silver Carp mean biomass density, however, decreased by 24 percent at Starved Rock from 2013 to 2014, remained constant at Marseilles, and increased by 34 percent in 2014 at Dresden Island (Figure 2.2). In contrast, Bighead Carp densities displayed different patterns than Silver Carp between 2013 and 2014. Numerical and biomass densities of Bighead Carp increased at Starved Rock and Marseilles (Figure 2.1), whereas both density measures decreased in 2014 at Dresden Island (60 percent decrease in numerical density and 56 percent decrease in biomass density). When assessed by habitat type, Asian carp densities in backwater habitats (side channels, backwater lakes, and harbors combined) were relatively high compared with the main channel in all pools.

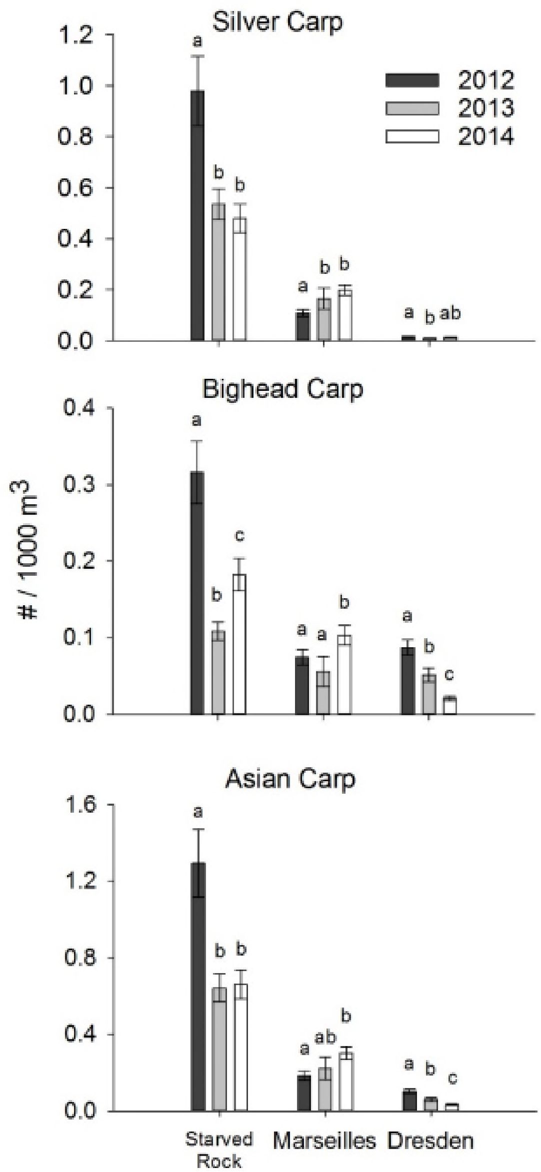


Figure 2.1. *Mean density (expressed as numbers of fish per 1,000 m^3) and associated 95 percent confidence intervals for Silver Carp, Bighead Carp, and Asian carp combined in the upper Illinois River. Different letters represent statistically different ($P < 0.05$) densities among years within a pool.*

Main channel density decreased from 2013 to 2014 in the Dresden Island pool, increased at Marseilles, and did not change at Starved Rock (Figure 2.3). Backwater densities did not change from 2013 to 2014 in these pools, although a non-significant decreasing trend was present at Dresden Island. Both numerical and biomass densities displayed similar patterns. While environmental conditions, especially river discharge, affect Asian carp demographics, contracted harvest may be playing a role in density and biomass trends, especially in the Dresden Island pool, where numerical and biomass densities at a pool-wide scale remain low and have been decreasing through time.

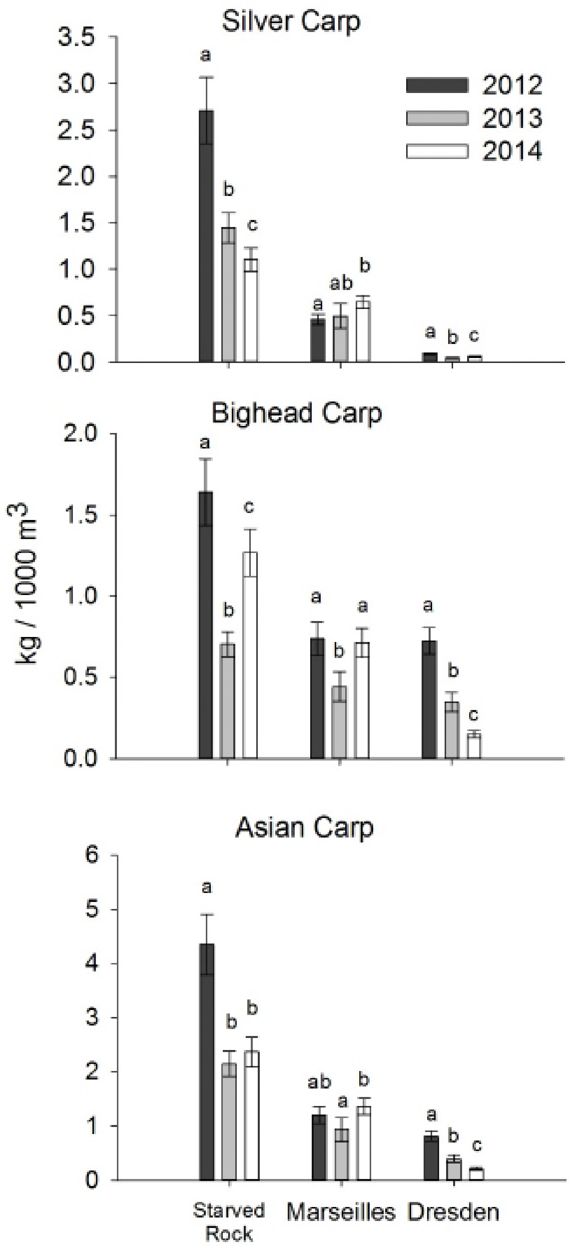


Figure 2.2. *Mean density (expressed as biomass of fish per 1,000 m^3) and associated 95 percent confidence intervals for Silver Carp, Bighead Carp, and Asian carp combined in the upper Illinois River. Different letters represent statistically different (P < 0.05) densities among years within a pool.*

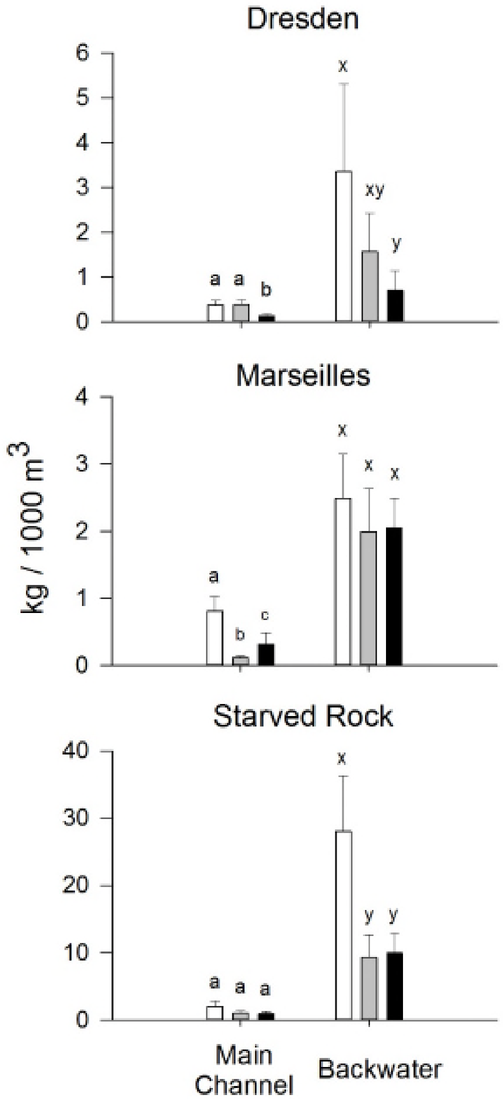


Figure 2.3. *Biomass density of Asian carp (Bighead and Silver Carp combined) by habitat type. Backwater habitats include side channels, backwater lakes, and harbors in the Illinois River. Different letters indicate statistically different densities across years within a pool-specific habitat type (P < 0.05).*

Asian carp size structure

As a result of the relatively low density of Asian carp in the upper Illinois River, data from different habitat types (main channel, side channel, backwaters, and harbors) were combined for each pool. A Kruskal-Wallis test indicated that the size of Asian carp was significantly different among reaches in 2012, 2013, and 2014 (all $P < 0.001$; Figures 2.4 and 2.5). Asian carp sizes increased going upstream from Starved Rock to Dresden Island in all years (*post-hoc*, all $P < 0.001$). The extent that these patterns are attributable to species-specific upstream dispersal or other density-dependent mechanisms is not clear.

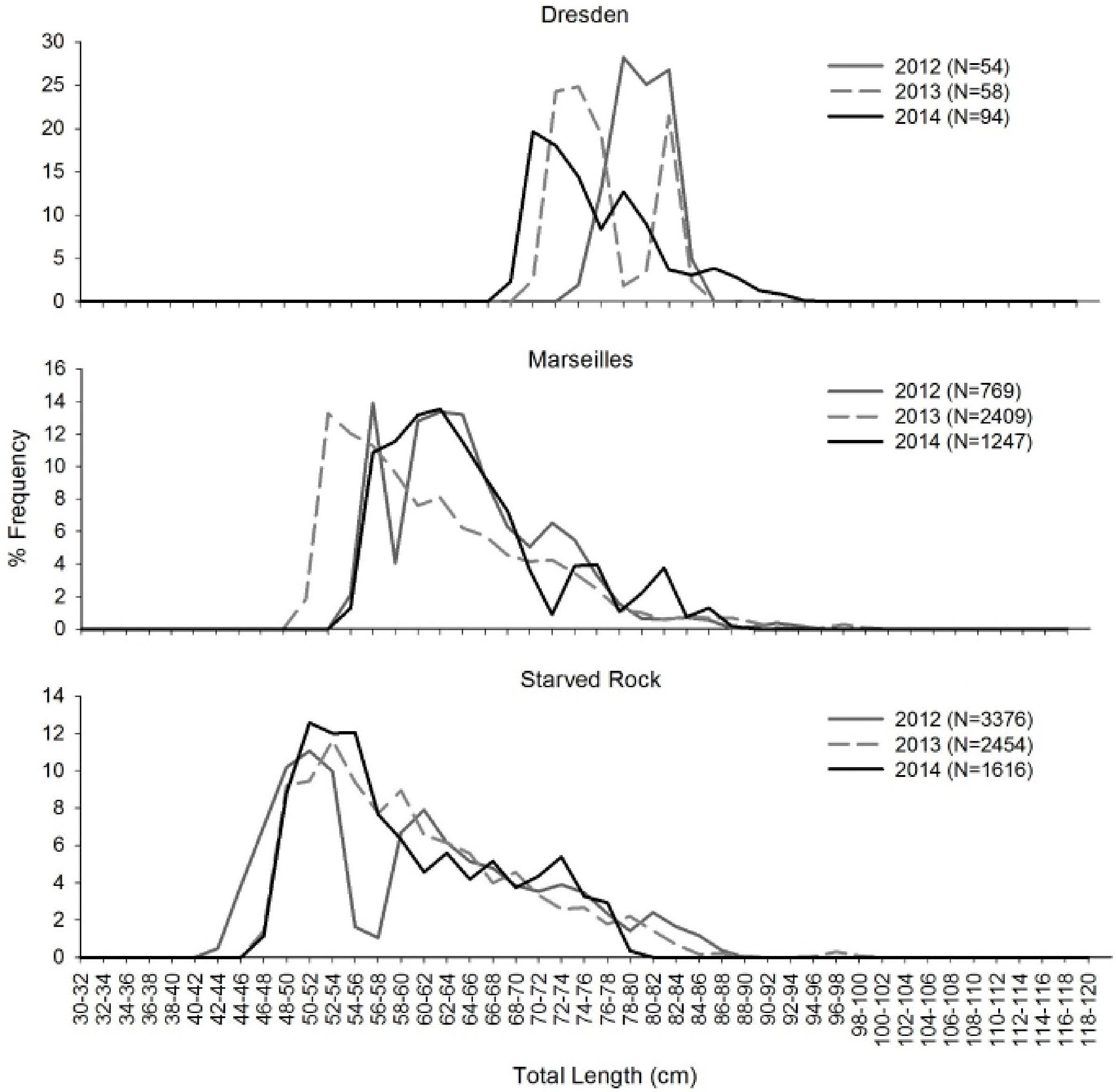


Figure 2.4. *Silver Carp size distributions in the Starved Rock, Marseilles, and Dresden Island pools of the Illinois River based on hydroacoustic surveys from 2012 to 2014.*

It also remains to be seen if the inter-annual variability in size structure observed within a particular reach reflects natural trends (for example, strong year-class) or is harvest-induced through gear selection for a particular species or size class (Irons et al. 2011; Tsehaye et al. 2013).

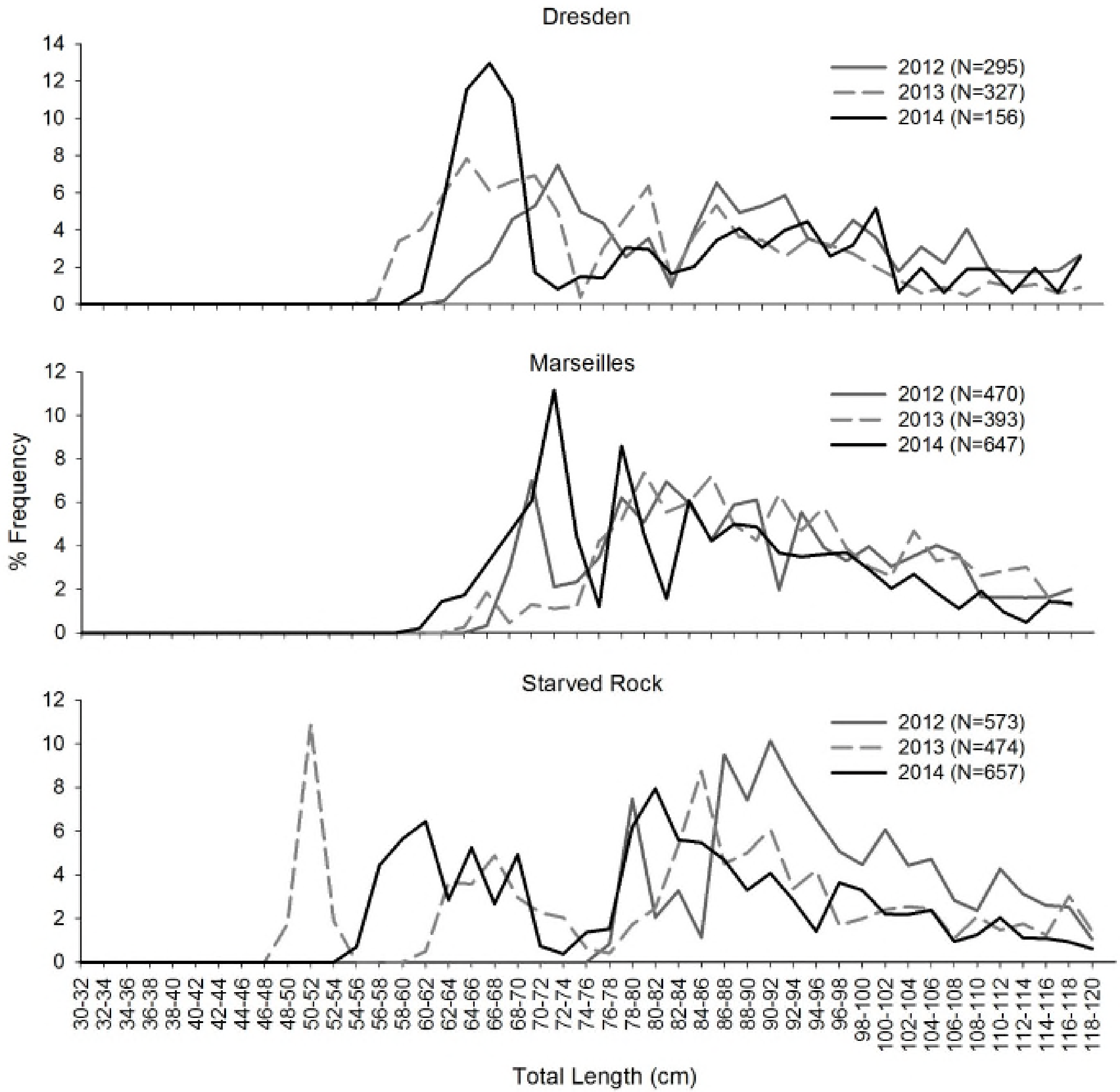


Figure 2.5. *Bighead Carp size distributions in the Starved Rock, Marseilles, and Dresden Island pools of the Illinois River based on hydroacoustic surveys from 2012 to 2014.*

Asian carp density response to harvest

Hydroacoustic sampling of backwaters occurred on ten occasions before harvest events and eight occasions after harvest between 2014 and 2015. Harvest events successfully reduced Asian carp densities at most locations by, on average, 32-64 percent (Figure 2.6). However, these reductions occurred within 24 hours of harvest, and densities rapidly rebounded. Multiple harvest events occurred at three backwater sites where densities returned to or exceeded initial levels within as little as 2 weeks of the commercial harvest.

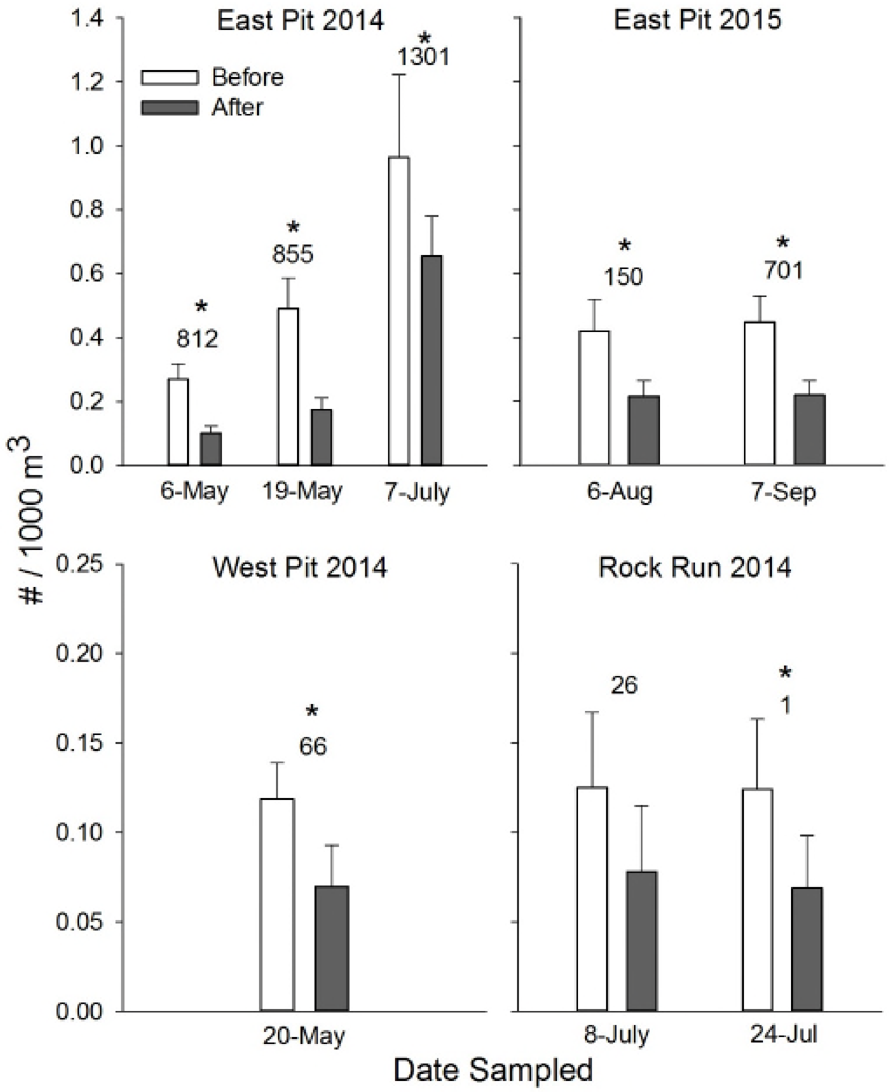


Figure 2.6. *Mean density (± 95 percent confidence intervals) of Asian carp (Silver and Bighead Carp combined) before and after contracted commercial fishing harvest in backwater lakes in the Marseilles (East and West Pits) and Dresden Island pools (Rock Run). Asterisks denote significantly (P < 0.01) different densities before and after harvest and numbers represent the number of Asian carp harvested on each sampling date.*

Rebound rate is an important metric for evaluating targeted harvest (Frazer et al. 2012), and it appears that — at least in these locations — some features or conditions are continually attracting Asian carp propagules (for example, Cuddington et al. 2015). An integrated pest management approach (Koehn et al. 2000; ACRCC 2015) involving removal of individuals present (harvest) and prevention of recolonization by new individuals (for example, by behavioral barriers at strategic locations or manipulation of water levels) may therefore be a rational management approach.

Chapter 2:
Hydroacoustic population estimates of Asian carp in the Illinois River

Recommendations: Results from hydroacoustic surveys thus far indicate just how prevalent Asian carp are in the upper reaches of the Illinois River (accounting for ~40 to 60 percent of the fish community biomass), but may suggest that the Asian carp population is showing signs of a response to commercial fishing (deceases in mean density and shifts in size structure). Contracted commercial harvest immediately reduced densities in backwaters, but densities rebounded over longer periods (≥ 2 weeks). Coupling regular harvest events in upper pools with actions that reduce propagule pressure coming from lower reaches may be necessary to maintain low densities in upper pools. Continuing annual standardized hydroacoustic surveys will establish long-term patterns of Asian carp densities that will be useful in understanding population-level responses to harvest programs.

Literature Cited:

Asian Carp Regional Coordinating Committee (ACRCC). 2015. 2014 Asian Carp Monitoring and Response Plan Interim Summary Reports. June 2015, 242 pp.

Cuddington, K., Hull, Z.T., Currie, W.J., and Koops, M.A. 2015. Landmarking and strong Allee thresholds. Theoretical Ecology 8: 333–347.

Frazer, T.K., Jacoby, C.A., Edwards, M.A., Barry, S.C., and Manfrino, C.M. 2012. Coping with the lionfish invasion: can targeted removals yield beneficial effects? Reviews in Fisheries Science 20: 185–191.

Foote, K.G., Knudsen, H.P., Vestnes, G, .MacLennan, D.N., and Simmonds, E.J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Cooperative Research Report, No. 144.

Irons, K.S., Sass, G.G., McClelland, M.A., and O'Hara, M. 2011. Bigheaded carp invasion of the La Grange reach of the Illinois River: insights from the Long Term Resource Monitoring Program In: Chapman, D.C., Hoff, M.H. (eds) Invasive Asian carps in North America. American Fisheries Society Symposium 74. Bethesda, Maryland, pp 31–50.

Koehn, J., Brumley ,A, and Gehrke, P. 2000. Managing the impacts of carp. Bureau of Rural Sciences (Department of Agriculture, Fisheries and Forestry – Australia), Canberra.

Love, R.H. 1971. Measurements of fish target strength: a review. Fishery Bulletin 69: 703-715.

Parker-Stretter, S.L., Rudstam, L.G., Sullivan, P.J., and Warner, D.M. 2009. Standard operating procedures for fisheries acoustic surveys in the Great Lakes. Great Lakes Fisheries Commission Special Publication 09-01.

Simmonds, J., and MacLennan, D. 2005. Fisheries acoustics: theory and practice. Blackwell, Oxford.

Tsehaye, I., Catalano, M., Sass, G., Glover, D., Roth, B. 2013. Prospects for fishery-induced collapse of invasive Asian carp in the Illinois River. Fisheries 38: 445-454.

Chapter 2:
Hydroacoustic population estimates of Asian carp in the Illinois River

Table 2.1. *Locations sampled with hydroacoustics in each reach of the upper and lower river during annual fall surveys from 2012 to 2015 (rkm = river km). Habitat type codes: BW = backwater lake; CL = contiguous shallow lake; HB = harbor/marina; MC = main channel; SC = side channel; and TR = tributary.*

Site	Habitat type	Location (rkm)
Upper river		
Dresden		
Illinois River and Des Plaines River	MC	436.9-460.3
Treats Island	SC	449-450.9
Mobile Oil Corp. Bay	BW	447.7
Breezy Harbor Marina	HB	440.3
Kankakee River (~1st mile)	TR	439.3
Marseilles		
Illinois River	MC	395.4-436.9
Hanson Material Service East pit	BW	421.6
Hanson Material Service West pit	BW	421.8
Sugar Island	SC	418.9-420.4
Starved Rock		
Illinois River	MC	371.8-397.5
Heritage Harbor Marina	HB	389.9
Bulls Island and Scherer Island	SC	386.2-388.8
Fox River (~1st mile)	TR	385.8
Hitt Island and Mayo Island	SC	381.4-384.6
Sheehan Island	SC	378.5-380.4
Lower River		
Peoria		
Illinois River (near Ogelsby)	MC	226.3-231.0
Illinois River (near Spring Valley)	MC	215.0-219.0
Clark Island	SC	215.1-215.6
Illinois River (near Hennepin)	MC	208.0-212.0
Illinois River (near Henry)	MC	196.0-200.0
Illinois River (near Chillicothe)	MC	181.0-185.0
Illinois River (near Upper Peoria Lake)	MC	167.0-173.0
Upper Peoria Lake	CL	166.6-177.4
Illinois River (near Peoria Lake)	MC	162.0-166.0
Peoria Lake	CL	163.0-166.1

Table 2.1 continued. *Locations sampled with hydroacoustics in each reach of the upper and lower river during annual fall surveys from 2012 to 2015 (rkm = river km). Habitat type codes: BW = backwater lake; CL = contiguous shallow lake; HB = harbor/marina; MC = main channel; SC = side channel; and TR = tributary.*

Site	Habitat type	Location (rkm)
La Grange		
Illinois River (near Pekin)	MC	253.6-247.2
Illinois River (near Copperas Creek)	MC	218.1-224.5
Illinois River (near Havana)	MC	190.7-197.1
Spoon River (1st 0.4 mile)	TR	193.9
Quiver Island	SC	194.4-196.3
Illinois River (near Bath)	MC	169-175.4
Bath Chute	SC	171.7-182.5
Illinois River (near Browning)	MC	156.1-162.5
Chain Lake	BW	158.8
Illinois River (near Frederick)	MC	144.8-151.3
Illinois River (near La Grange)	MC	130.4-136.8
Lily Lake	BW	133.7
Alton		
Illinois River (near Beardstown)	MC	122.6-129.1
Illinois River (near Meredosia)	MC	110.2-116.7
Illinois River (near Florence)	MC	90.14-96.6
Big Blue Island	SC	92.5-96.2
Illinois River (near Bedford)	MC	74-80.5
Buckhorn Island	SC	73.9-74.5
McEvers Island	SC	77.9-79.8
Illinois River (near Kampsville)	MC	51.5-57.9
Illinois River (near Hardin)	MC	35.4-41.8
Diamond Island (Dark Chute)	SC	36.7-41
Macoupin Creek (1st 0.8 mile)	TR	37.2
Illinois River (near Grafton)	MC	0-6.4
Grafton Harbor	HB	3.4

Chapter 3:
Asian Carp Movement in the Illinois River

Alison A. Coulter, Marybeth Brey, Matthew Lubejko, James E. Garvey
(Southern Illinois University Carbondale)

Participating Agencies: Southern Illinois University-Carbondale (lead), U.S. Geological Survey, U.S. Army Corps of Engineers (field support), Illinois Department of Natural Resources (field support).

Introduction: Analysis of Asian carp movement through the Illinois River has the potential to reveal important information about the timing and extent of the dispersal of these invasive fishes. Movements can be used to target control efforts and predict when Asian carp may challenge barriers, including the Electric Dispersal Barrier or lock and dam structures. Telemetry data can be used to monitor the probability of Asian carp transitioning among Illinois River pools, which will be vital in accurately parameterizing the spatially-explicit population model (Chapter 4). Therefore, general seasonal trends in movements throughout the Illinois River could prove important for management, and information collected over the multiple years Asian carp have been tracked by SIU will be used to quantify movement probabilities among pools.

Telemetry can reveal areas where Asian carp may congregate that can help direct removal efforts. Mass movements, such as those related to spawning, could increase propagule pressure in specific areas and deserve special consideration. Asian carp are thought to utilize backwater habitats, such as Hanson Material Service pits, during the majority of the year and as potential staging locations prior to mass spawning movements. In 2014, movements into and out of Hanson Material Service were correlated with water levels. Therefore, movements into and out of Hanson Material Service pits and how those movements relate to temperature and discharge were examined.

Objectives:

(1) Monitor and examine temporal patterns of Asian carp movement in the Illinois River.

(2) Relate discharge and water temperature to potential spawning behavior of Asian carp, especially mass movements into and out of backwater habitats, including the Hanson Material Service pits.

(3) Quantify transition probabilities for Asian carp among Illinois River pools and when and in what direction pool-to-pool transitions occur.

Project Highlights

- Bighead and Silver Carp exhibited seasonal trends in movements where individuals move more in the summer, usually move upstream from March to May and downstream from June to August.
- Individuals tagged above Starved Rock Lock and Dam moved less than those tagged below.
- Through time, Bighead and Silver Carp did not appear to be moving progressively farther upstream in consecutive years.

- There were relatively weak correlations between spawning movements, river gage height, and water temperature. However, there is evidence of spawning movements at the first big rise in water level once river temperatures were > 18 ºC.
- Pool-specific transition probabilities indicate a relatively small chance that Bighead and Silver Carp will move among upper river pools, or move more than one pool away from their original pool.

Methods:

Basic telemetry

SIU maintains an array of Vemco stationary receivers throughout most pools on the Illinois River. As a result of an additional telemetry project around Starved Rock Lock and Dam, additional stationary receivers have been placed around this structure. This addition resulted in the following distribution of 51 stationary receivers that are still actively maintained: Alton = 7, La Grange = 8, Peoria = 16, Starved Rock = 11, Marseilles = 8, Dresden = 1.

Seasonal trends in movements

Detections from stationary receivers were first reduced to one detection per location per day for each individual to observe seasonal trends in movement. Then, the distance and direction (upstream vs. downstream) between consecutive detections in Illinois River kilometer were determined. Net movement of each individual over each month was calculated such that positive values indicate upstream movements and negative values indicate downstream movements. These values were then averaged across individuals. Total movements were also calculated for each month and were the total of all movements regardless of direction. Total and net movements were then averaged by month for each year (2012 to 2015). Net and total movements were grouped into individuals tagged above Starved Rock Lock and Dam and those tagged below Starved Rock Lock and Dam. As noted in previous reports by SIUC (ACRCC 2015), individuals above Starved Rock Lock and Dam appear to move less than those found below Starved Rock Lock and Dam.

Bighead and Silver Carp are known to make large upstream and downstream movements, which could lead to their colonization of new habitats. In an effort to determine whether tagged individuals are consistently moving upstream or downstream, changes in mean Illinois River kilometer and maximum Illinois River kilometer for each study year were determined, and then the annual changes in these values from the previous year were calculated. Mean Illinois River kilometer was determined for each tagged individual for each year they were involved in the study, and then each mean Illinois River kilometer from the previous year was subtracted from the current year (for example 2013 – 2012) so that negative values indicated a downstream dispersal. The annual differences were then averaged across individuals. Additionally, the maximum upstream river km where each tagged individual was detected in the previous year was subtracted from the current year and then averaged across individuals.

Chapter 3:
Asian Carp Movement in the Illinois River

Spawning movements

As noted in previous SIUC reports, Bighead and Silver Carp appear to engage in spawning runs, exiting the Hanson Material Service pits, linked with appropriate spawning temperatures and rises in water level. In addition, 2013 yielded a significant correlation between river gage height and individuals detected, but this relationship was not as evident in 2014. To evaluate these previous observations further, numbers of tagged Bighead and Silver Carp detected on a stationary receiver located in the channel connecting the Hanson Material Service pits to the Illinois River were determined for each day of 2015 for which data were available (January 2015 through August 2015). Water temperature and river gage height were obtained from a USGS real-time river gage at Seneca, Illinois (USGS gage # 05543010) and were averaged for each day. Initially, Spearman rank correlations were performed between river temperature and the number of tagged fish in the Hanson Material Service pits channel, as well as river gage height and the number of tagged fish in the Hanson Material Service pits channel. Generalized linear models were used to evaluate potential relationships to further examine potential links among temperature, gage height, and the interaction of temperature and gage height with numbers of fish entering/exiting the Hanson Material Service pits. The full interactive model was used and evaluated as well as the additive model, and separate models with temperature or gage height. Models were evaluated using chi-squared goodness-of-fit tests that examined model deviance and degrees of freedom. A significant result of this test ($P < 0.05$) indicates poor model performance.

Pool transition probabilities

Numbers of transitions among pools were examined seasonally, spatially, and for direction of transition. Telemetry data of Asian carp from 2012 to 2015 were compiled and parameterized for use in a robust multi-state model in program MARK. Fish with known fates (those harvested) were used, but those whose tags expired could not be used because their fate was unknown. As a result data were used from 2012 to 2014 as this period encompassed the time when data from the most fish were available. Input data were developed on a monthly basis, meaning the capture history for each individual used by program MARK indicated the pool the fish was residing in at the end of each month for capture histories, with a total of 36 recapture events. States in the multi-state model were the Illinois River pools and the multi-state model allowed for estimation of transition probabilities among pools as well as pool-specific survival and detection probability estimates. For this report, pool transition probabilities were allowed to vary spatially (from pool to pool) but did not vary temporally. Transitions were also examined for direction (upstream vs. downstream) and timing to evaluate temporal trends in directionality and frequency. These temporal trends will be used in the future to assess the temporal scale at which pool transitions should be examined.

Results and Discussion: Seasonal trends in movement were examined using telemetry data collected from 2012 to 2015 from Bighead and Silver Carp. As a result of this approach, movements were available for 213 Bighead and 441 Silver Carp, although the number of individuals detected varied annually (Bighead Carp: 2012 = 68; 2013 = 116; 2014 = 104; 2015 = 52; Silver Carp: 2012 = 65; 2013 = 267; 2014 = 217; 2015 = 110). Individuals that were detected only once during the study were not included in the above counts and were not included in analysis of movements. Information on the new fish tagged in 2015 and a map of stationary receiver locations are included in the report from the grant to SIUC: "Assessing Population, Movement, and Behavior of Asian Carp to Inform Control Strategies."

Seasonal trends in movements

Both Bighead and Silver Carp displayed increased total movements during summer (April to August; Figure 3.1; Figure 3.2). Bighead Carp moved upstream from March through May and then downstream from May through August, although there was considerable variation around these trends. In general, seasonal movement patterns in Silver Carp exhibited less inter-annual variation in both net movement and total movement. Silver Carp tended to move upstream from April to May and moved downstream from June to August, with the most movement occurring from April to August. Overall, these findings fit with previous SIUC research showing that the majority of Bighead and Silver Carp move upstream in the spring, likely for spawning, and then move back downstream over the summer months. Bighead Carp do not appear to move as far as Silver Carp and appear less consistent in their movement patterns from year to year, making it potentially more difficult to manage and predict the movements of this species, although about half as many Bighead Carp have been tagged compared with Silver Carp.

When Bighead and Silver Carp tagged above and below Starved Rock Lock and Dam were compared, the greatest apparent difference in movement occurred from March to– May for both species (Figure 3.3; Figure 3.4). Fish tagged below Starved Rock Lock and Dam tended to move more than those above Starved Rock Lock and Dam. Less movement of individuals tagged above Starved Rock Lock and Dam may indicate that movement is more restricted in these upper reaches, potentially due to the gate style lock and dam structures. Additionally, individuals residing below Starved Rock Lock and Dam may be more transient, exploiting a greater area of the Illinois River and, potentially, the Mississippi River, as was suggested in previous SIUC reports (ACRCC 2015).

Tagged Bighead Carp did not appear to be dispersing farther upstream in consecutive years, while Silver Carp appeared to move upstream from 2012 to 2013, slightly downstream from 2013 to 2014, and used approximately the same areas from 2014 to 2015 (Figure 3.5). The upstream migration in 2013 may have been because most individuals in 2012 were tagged in the lower Illinois River. It appears that individuals used similar areas of the Illinois River and did not necessarily move farther upstream each year.

Chapter 3:
Asian Carp Movement in the Illinois River

Spawning movements

In previous years, mass spawning movements were documented where Bighead and Silver Carp entered and exited the Hanson Material Service pits. In addition, the number of fish moving through the channel connecting the Hanson Material Service pits to the Illinois River main channel had shown some correlation to river gage height (in 2013 but not 2014). All available data from 2015 (January to mid-August) were used to examine possible relationships among water temperature and water levels to numbers of Asian carp in the Hanson Material Service channel. Both Illinois River temperature and river gage height were significantly correlated with numbers of Asian carp in the Hanson Material Service channel (temperature: $r_s = 0.24$, $P = 0.001$; gage: $r_s = 0.22$, $P = 0.003$) in 2015. However, statistical significance may have resulted from the large sample size used in these correlations (>170 days of data). Generalized linear models (temperature-gage height interactive model, additive model, temperature model, and gage height model) all had poor model fits and high deviance (chi-squared goodness-of-fit, all $P < 0.001$). There were several apparent trends that indicate spawning movements. An increase in Bighead and Silver Carp exiting the Hanson Material Service pits followed by several days of little to no entrances or exits that occur in conjunction with appropriate spawning temperatures and a rise in water level (Figure 3.6).

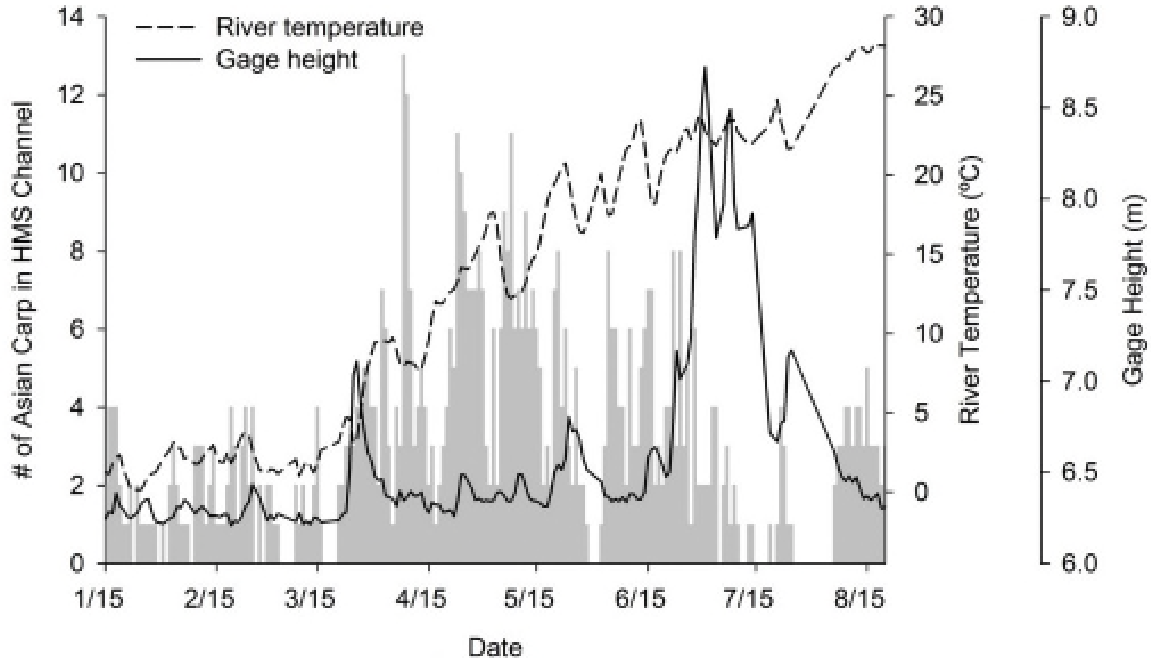


Figure 3.6. *Numbers of different tagged Asian carp (gray bars) entering and exiting Hanson Material Service pits (Hanson Material Service) in 2015. Water levels, as indicated by river gage height, and water temperature in the Illinois River were obtained from the USGS river gage at Seneca, IL*

As documented in previous years, Bighead and Silver Carp exited the Hanson Material Service pits at appropriate spawning temperatures and then during the potential spawning event; there was little movement between the Hanson Material Service pits and the Illinois River main channel.

Pool transition probabilities

Pool transition probabilities were extremely low. The likelihood that carp would move more than one pool away from an individual's current pool had the lowest probabilities. The highest transition probabilities for both Bighead and Silver Carp had a > 50 percent chance that fish found in La Grange pool in 1 month would be found in the Alton pool the next (Table 3.1; Table 3.2).

Table 3.1. *Pool-specific transition probabilities (SE) for Bighead Carp in the Illinois River calculated in program MARK (a robust multi-state model) using telemetry data from 2012-2014. Survival and detection probability also varied by pool in this model. Transition probabilities approaching 0 are listed as < 0.0001 and no standard error is provided as these estimates were also < 0.0001.*

			End Pool			
Original Pool	Dresden	Marseilles	Starved Rock	Peoria	LaGrange	Alton
Dresden	-	0.074 (0.015)	0.006 (0.005)	< 0.0001	< 0.0001	< 0.0001
Marseilles	0.138 (0.028)	-	0.031 (0.011)	< 0.0001	< 0.0001	< 0.0001
Starved Rock	0.032 (0.020)	0.009 (0.009)	-	0.088 (0.036)	< 0.0001	< 0.0001
Peoria	< 0.0001	< 0.0001	0.030 (0.021)	-	0.007 (0.007)	0.009 (0.009)
LaGrange	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	0.541 (0.06)
Alton	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.035 (0.01)	-

Table 3.2. *Pool-specific transition probabilities (SE) for Silver Carp in the Illinois River calculated in program MARK (a robust multi-state model) using telemetry data from 2012-2014. Survival and detection probability also varied by pool in this model.*

			End Pool			
Original Pool	Dresden	Marseilles	Starved Rock	Peoria	LaGrange	Alton
Dresden	-	< 0.0001	0.014 (0.014)	< 0.0001	< 0.0001	< 0.0001
Marseilles	< 0.0001	-	0.034 (0.009)	0.006 (0.005)	< 0.0001	0.011 (0.008)
Starved Rock	< 0.0001	< 0.0001	-	0.140 (0.030)	< 0.0001	0.013 (0.012)
Peoria	< 0.0001	< 0.0001	0.007 (0.007)	-	0.074 (0.025)	0.020 (0.019)
LaGrange	< 0.0001	< 0.0001	< 0.0001	0.029 (0.020)	-	0.610 (0.044)
Alton	< 0.0001	0.004 (0.002)	0.002 (0.002)	0.006 (0.004)	0.029 (0.007)	-

Most pool transition probabilities were slightly higher among the three pools below Starved Rock Lock and Dam (Peoria, La Grange, and Alton). Estimated probabilities for Silver Carp to move into Dresden pool from any other pool were approaching 0 percent, while Bighead Carp originating above Starved Rock Lock and Dam showed a slight chance of moving into Dresden pool. This estimate indicates that removal of biomass from areas above Starved Rock Lock and Dam may prove most effective at reducing propagule pressure along the population front because these populations are likely replenished at a slow rate. Silver Carp originating in Alton pool appear to be an exception to many of these trends, with a 0.01 percent chance of moving to any pool except for Dresden. Analyses of movement patterns of Silver Carp tagged below Starved Rock Lock and Dam indicate the potential for greater movements, especially upstream, and the transition probabilities among these lower pools are some of the higher pool transition probabilities. More research on potential barriers to upstream movement may be especially helpful in deterring these transient, highly mobile individuals because Silver Carp originating in the lower Illinois River appear to be the most likely to move farther upstream. Transitions among pools appear to follow a similar seasonal trends when compared with the movements (Figure 3.7). These seasonal changes in movement transitions will be used to parameterize the population model (Chapter 4).

Recommendations: Telemetry observations of Bighead and Silver Carp continue to provide the best estimates of the potential dispersal capabilities of these species. Additionally, telemetry observations allow for the observations of movement patterns that could be exploited to better manage these species. These findings are vital for correct parameterization of a population-specific model (Chapter 4). Pool transition probabilities will likely vary through time, and so the robust multi-state models will be rerun with different seasons and evaluated based on model fits. Given that backwater areas typically have higher densities of Bighead and Silver Carp and that individuals typically move in and out of these backwaters to spawn, passages out of backwaters could be managed via block nets or barrier technology to reduce the spawning populations in the main channel. There is additional need for more movement observations from smaller individuals, as most fish tagged in this study were > 50 cm in total length. Smaller and immature fish may exhibit different movement patterns that may offer additional opportunities to exploit or manage Bighead and Silver Carp in the Illinois River. Additionally, it is vital to continue to monitor individuals in multiple pools, as it is evident from the patterns presented here that there may be differences among these pools.

Literature Cited:

Asian Carp Regional Coordinating Committee (ACRCC). 2015. 2014 Asian Carp Monitoring and Response Plan Interim Summary Reports. June 2015, 242 pp.

Chapter 3:
Asian Carp Movement in the Illinois River

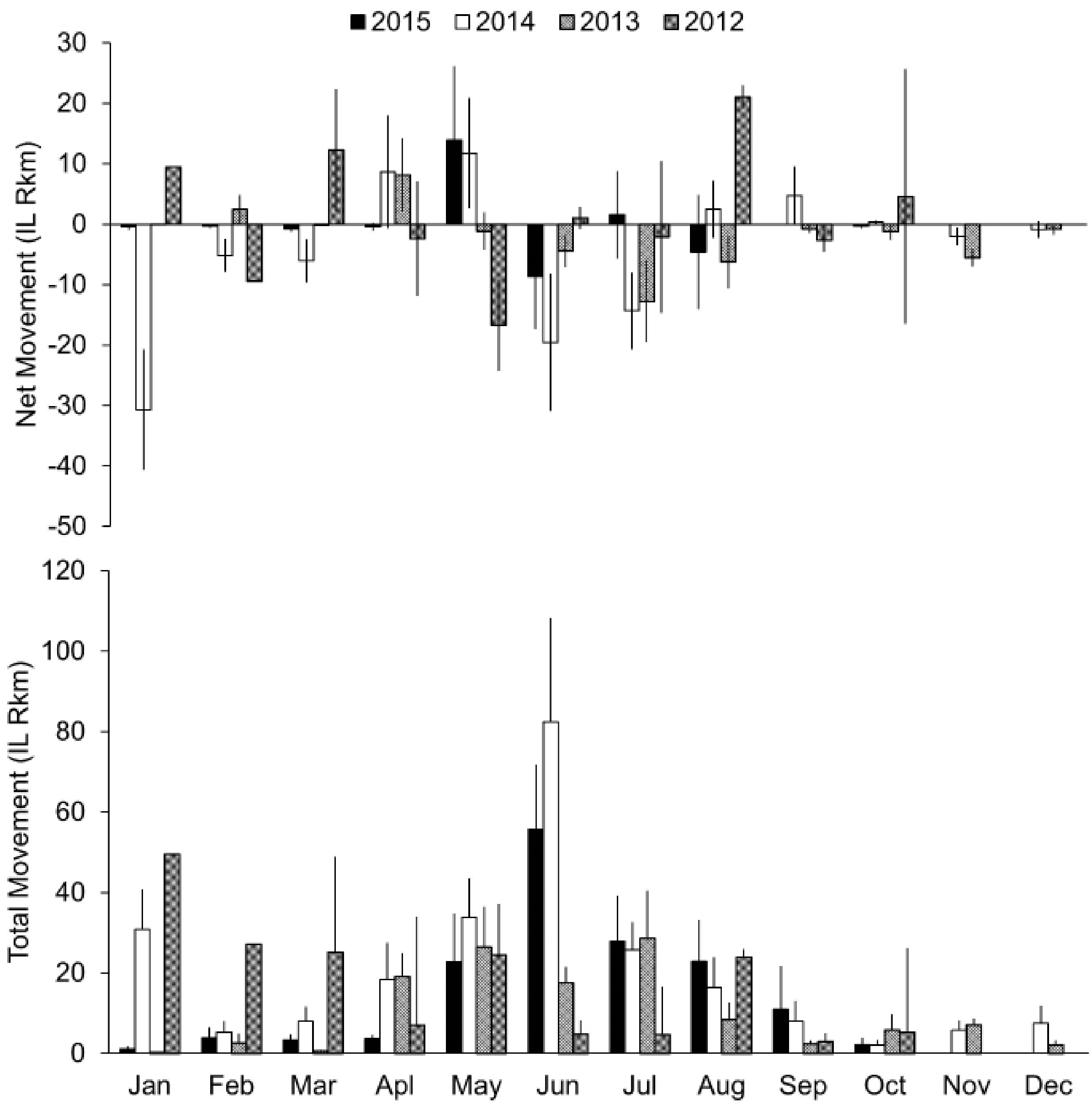


Figure 3.1. *Mean monthly net and total movement (±SE) for Bighead Carp in the Illinois River. Downstream net movements have negative values while upstream movements are positive. Movements for each month were then summed and averaged across individuals. Total movement is the sum of all distance traveled in a month, averaged across individuals, regardless of whether the movement was upstream or downstream.*

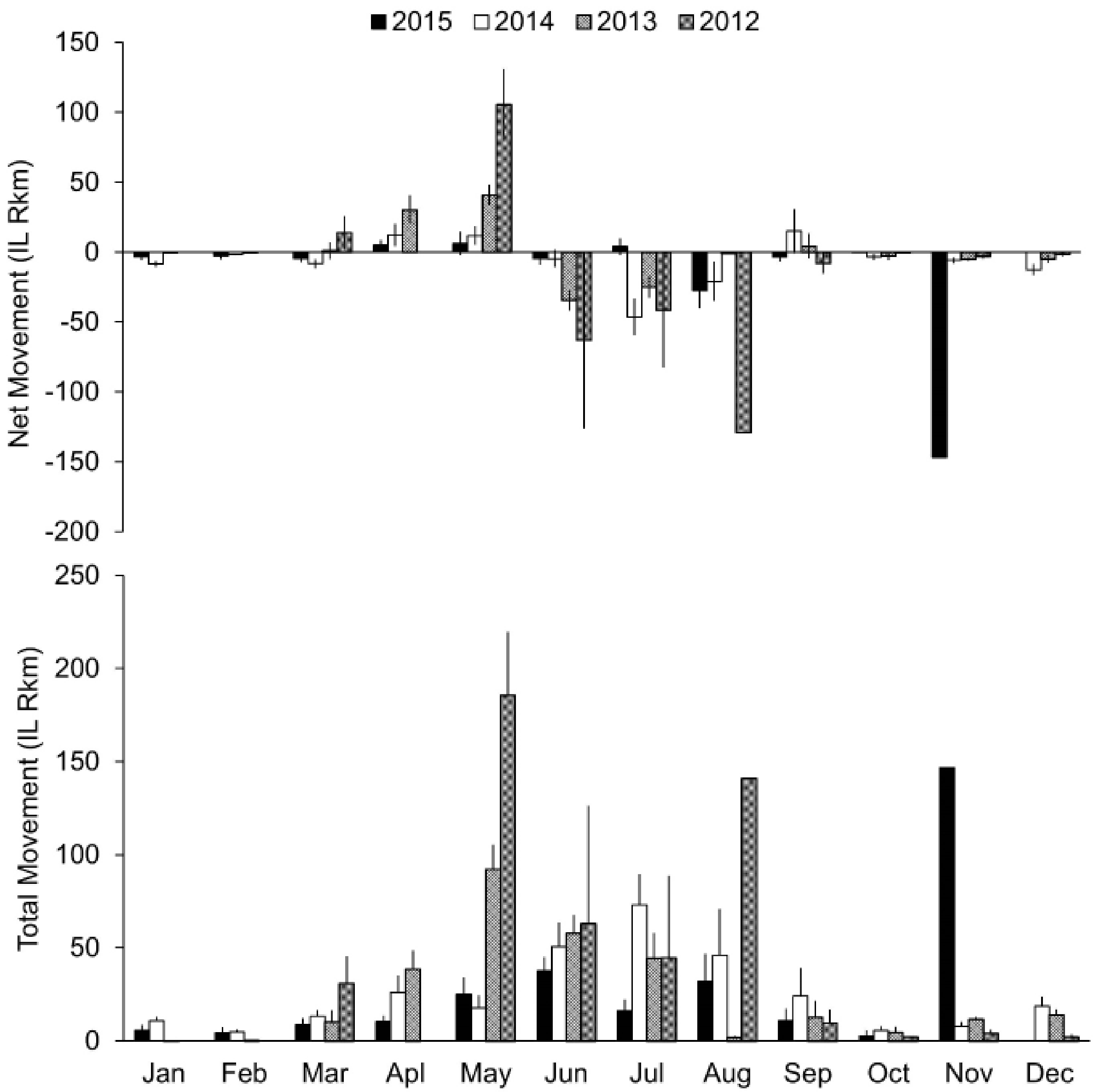


Figure 3.2. *Mean monthly net and total movement (±SE) of Silver Carp in the Illinois River. Downstream net movements have negative values while upstream movements are positive. Movements for each month were then summed and averaged across individuals. Total movement is the sum of all distance traveled in a month, averaged across individuals regardless of whether the movement was upstream or downstream.*

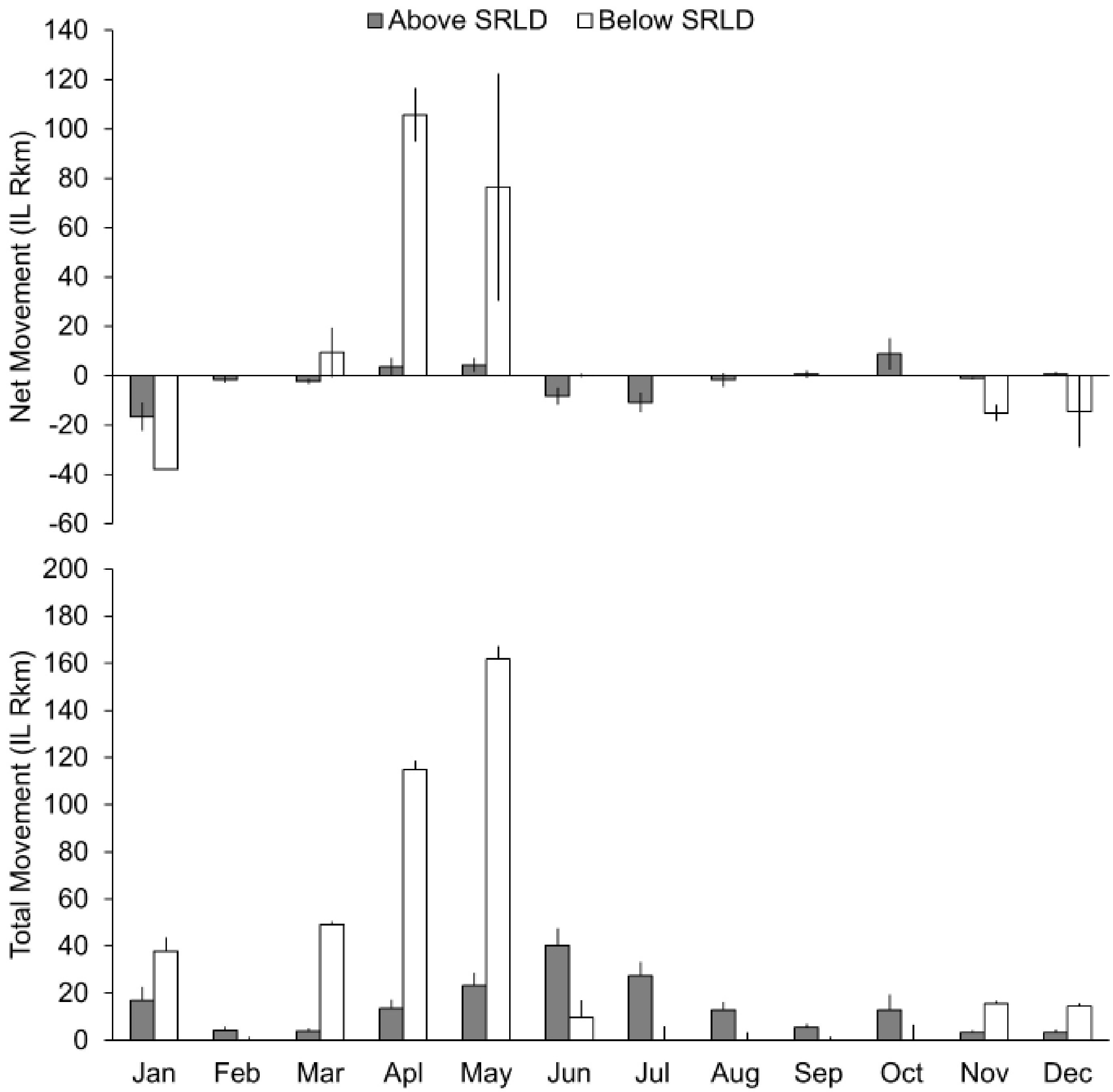


Figure 3.3. *Mean monthly movements of Bighead Carp in the Illinois River (tagged above or below Starved Rock Lock and Dam; Starved Rock Lock and Dam). Downstream net movements have negative values while upstream movements are positive. Movements for each month were then summed and averaged across individuals. Total movement is the sum of all distance traveled in a month, averaged across individuals regardless of the direction of movement.*

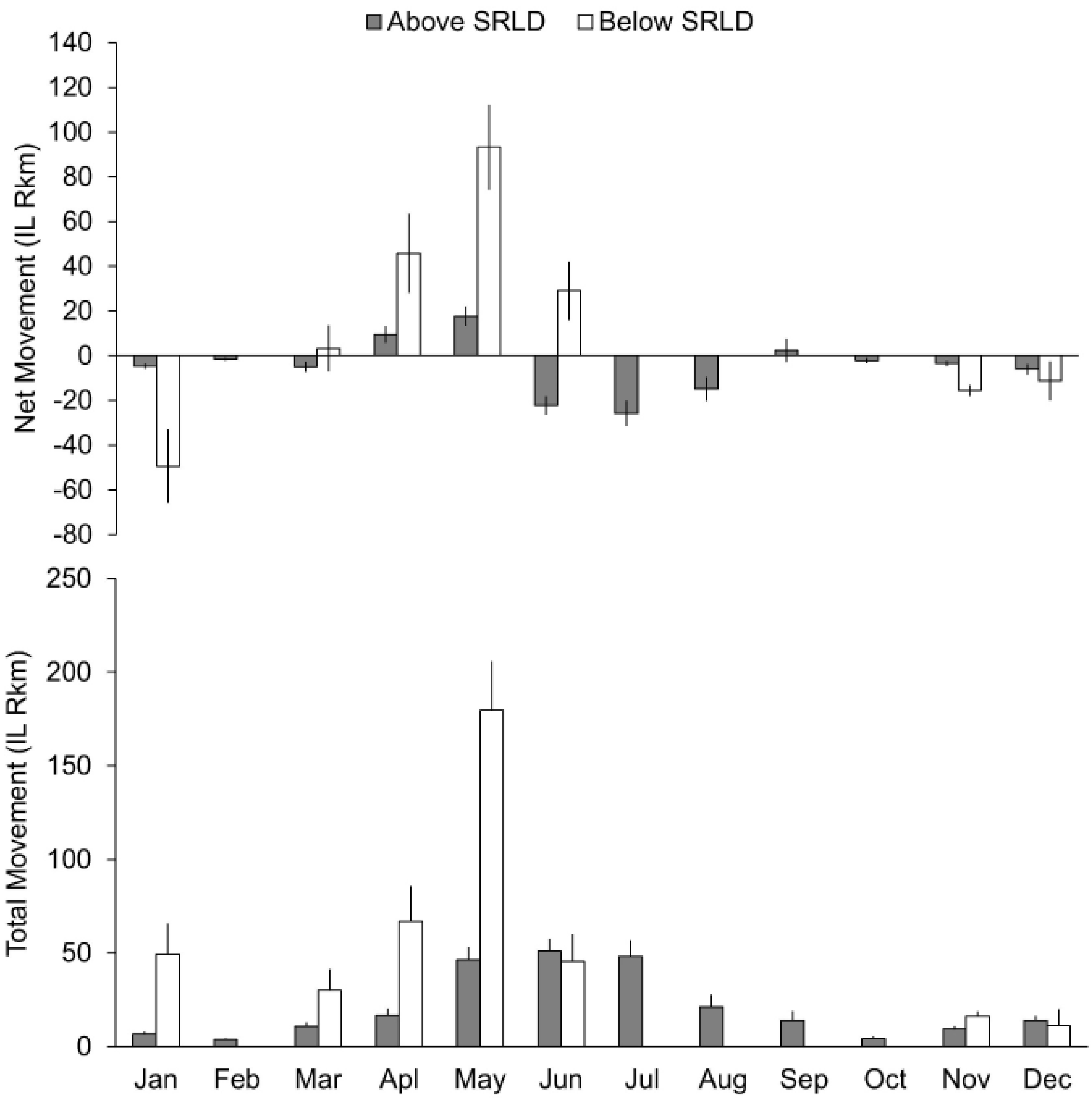


Figure 3.4. *Mean monthly movements of Silver Carp in the Illinois River that were tagged either above or below Starved Rock Lock and Dam (Starved Rock Lock and Dam). Downstream net movements have negative values while upstream movements are positive. Movements for each month were then summed and averaged across individuals. Total movement is the sum of all distance traveled in a month, averaged across individuals, regardless of the direction of movement.*

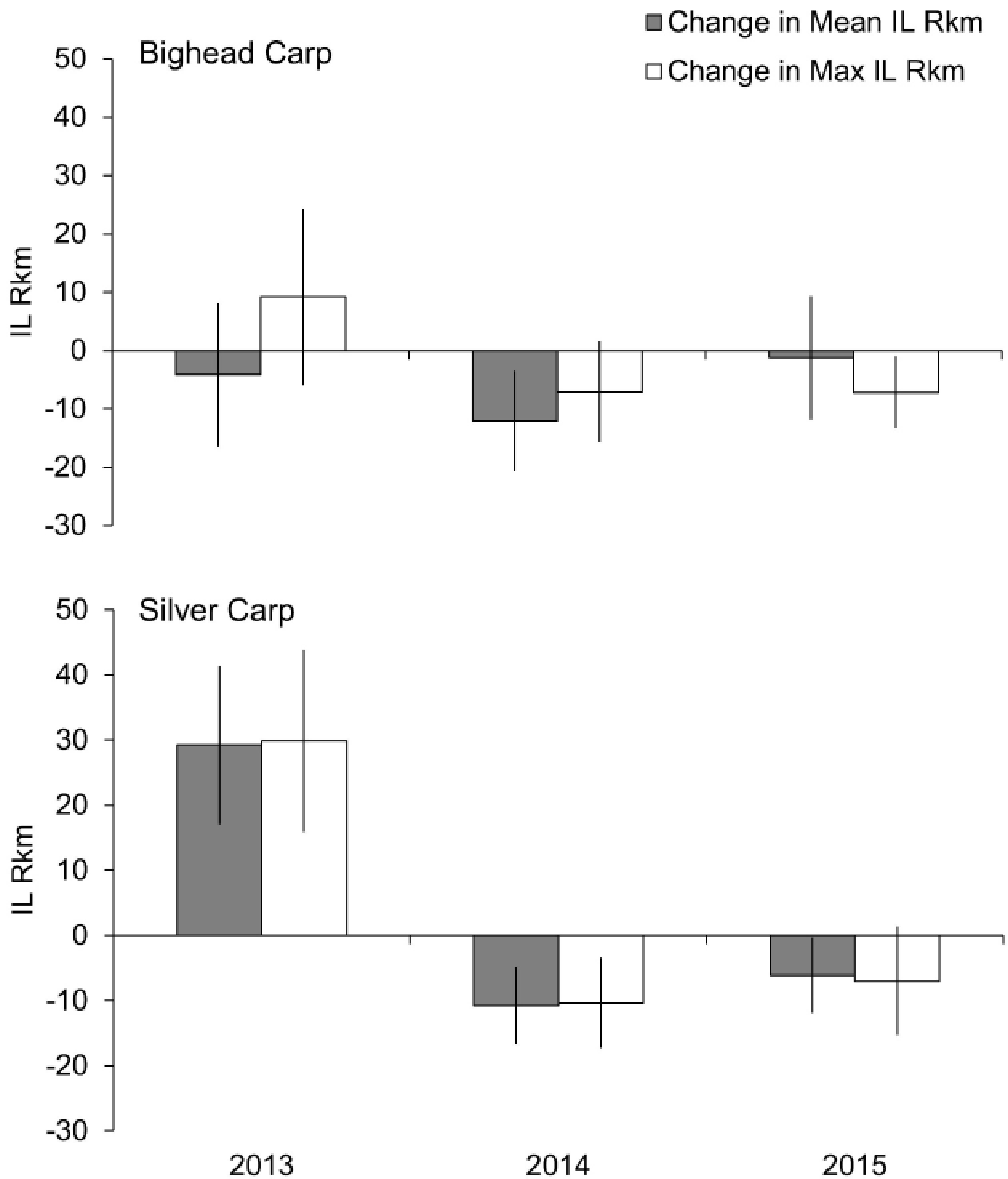


Figure 3.5. *Annual differences in mean (SE) annual Illinois River km (Illinois River kilometer; annual mean Illinois River kilometer of detections – annual mean IL RKM of detections from previous year) and maximum annual Illinois River kilometer (most upstream detection in a year – previous year's most upstream detection) for Bighead and Silver Carp. Mean and maximum Illinois River kilometer were determined for each tagged individual first and then averaged for each year.*

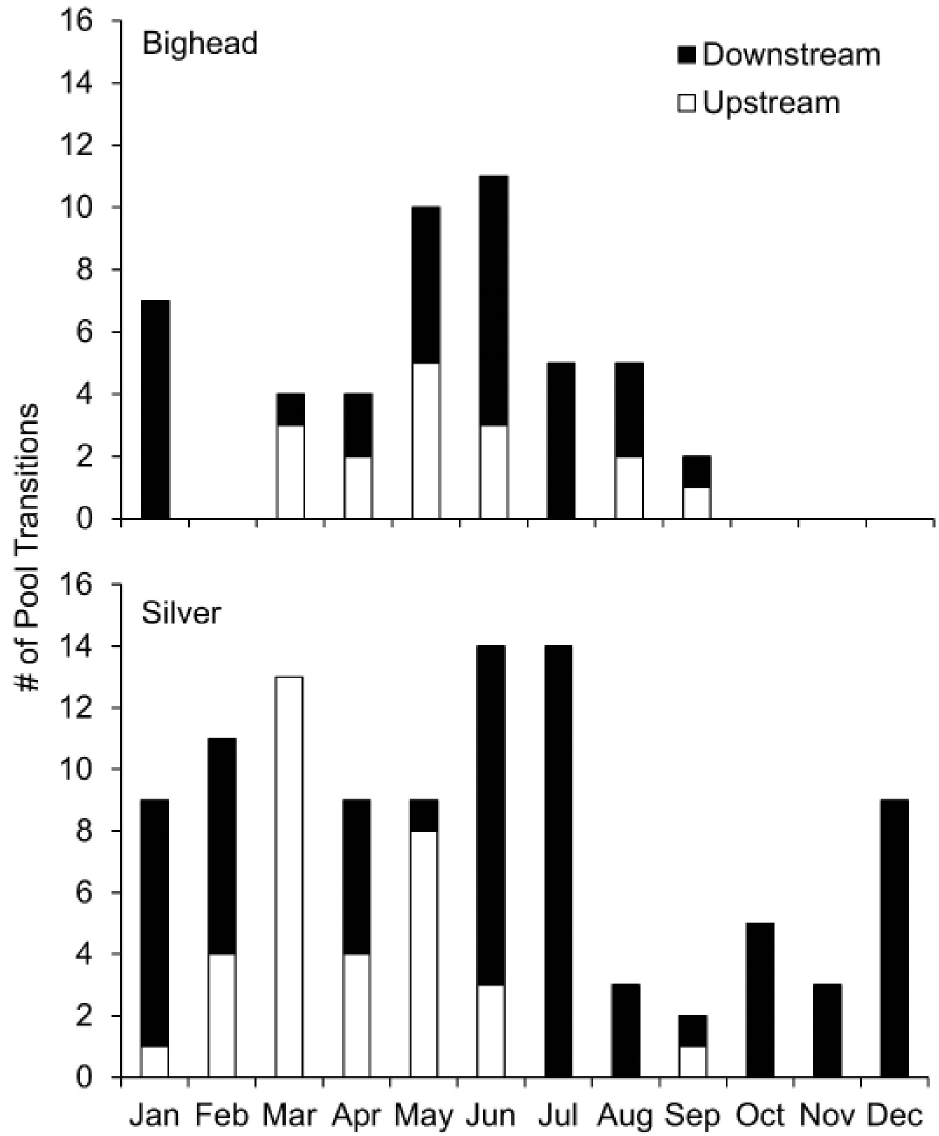


Figure 3.7. *Number, timing, and direction of pool transitions for Bighead and Silver Carp in the Illinois River. Only transitions made by Bighead and Silver Carp used in MARK multi-state model (2012 – 2014) are shown.*

Chapter 4:
Spatially Explicit Population Model
Jahn Kallis and David Glover
(The Ohio State University)

Participating Agencies: The Ohio State University (lead), Southern Illinois University-Carbondale (support).

Introduction: Recent evidence has suggested that the Electric Dispersal Barrier may not be as effective as once thought and other weaknesses are becoming evident (see for example Parker et al. 2013, 2015). Although the risk of an Asian carp breach is currently considered to be because of the purported absence of Asian carp near the Electric Dispersal Barrier, harvest of Asian carp downstream of the electric barrier may help to reduce the probability that Asian carp will challenge the barrier. It is currently unknown, however, the extent to which the intensive efforts of Asian carp removal are curtailing the probability of upstream movement.

A previously developed Asian carp population model (Tsehaye et al. 2013) provided a reasonable first step at assessing the efficacy of Asian carp harvest as a control option. The results from this model suggested requirements of an exploitation rate of 70 percent on all sizes of Asian carp (both Bighead and Silver Carp) to overfish the population to functional extinction within the lower three reaches of the Illinois River (Alton, La Grange, and Peoria pools). The results from recent commercial harvest experiments conducted by Southern Illinois University suggest that these requirements are not being met, at least in terms of size selectivity (past reports). Despite the observed size selectivity, field information collected in intensively harvested areas has yielded promising results that are consistent with demographic changes expected to occur in heavily fished populations.

There is a need to address the inadequacies of the previous Asian carp population model (Tsehaye et al. 2013) to make it more useful in terms of decision making relative to the spatial allocation of harvest to minimize propagule pressure on the Electric Dispersal Barrier. For example, a goal of functional extinction in the previous model was likely highly conservative toward minimizing upstream movement of Asian carp. As such, an updated model is needed that includes necessary spatially explicit components that incorporate empirically derived probabilities of movement across the entire Illinois Waterway.

Several assumptions regarding the demography of Asian carp were necessary in the Tsehaye et al. (2013) model as a result of data limitations and the concern over the use of previous stock-recruitment relationships that were based on CPUE of spawners and recruits (for example, Hoff et al. 2010) as opposed to spawning stock biomass and total number of recruits. As such, a more refined model should make use of all available demographic data that have been collected from various sources, including investigating the use of LTRMP data and other standardized sampling programs to develop stock-recruitment relationships for Bighead and Silver Carp.

Chapter 4:
Spatially Explicit Population Model

Objectives:

(1) Update reach-specific Asian carp demographic parameter estimates (abundance, age and size distribution, growth, survival, condition, maturation schedule) using Bayesian methodology.

(2) Refine Bighead and Silver Carp stock-recruitment relationships; the uncertainty in the stock-recruitment relationships was found to be the largest source of variation in the Tsehaye et al. (2013) model.

(3) Develop a spatially-explicit Asian carp population model for the Illinois River waterway that incorporates inter-reach movement probabilities.

(4) Use the newly developed model to predict the number of Asian carp that would reach the Electric Dispersal Barrier on the Chicago Sanitary and Ship Canal under various harvest scenarios.

Project Highlights:

- Asian carp demographic parameter estimates (abundance, age and size distribution, growth, and maturation schedule), and the uncertainty around these estimates, were derived using Bayesian methodology.
- Field data are needed to test whether a stock-recruitment relationship exists for Illinois River Asian carp.
- The spatially explicit population model will be used to predict the number of Asian carp that would be expected to reach the Electric Dispersal Barrier under various harvest scenarios.

Methods: The spatially-explicit length-based population model will be parameterized using updated demographic rates estimated from all possible data sources (state and federal agencies and universities). Demographic rates for Bighead and Silver Carp were estimated using Bayesian hierarchical models and data collected from the Illinois and Mississippi rivers. River pool was treated as the random effect in all models.

Growth rate was estimated by fitting a von Bertalanffy growth function to individual length at age data:

$$L_{i,j} = L_{\infty j}\left(1 - e^{-K_j(a_{ij} - t_{0j})}\right) + \varepsilon_{ij}$$
$$\varepsilon_{i,j} = N(0, \sigma^2)$$
$$log\begin{pmatrix} L_{\infty,j} \\ K_j \\ t_{0,j} + 10 \end{pmatrix} \sim MVN(\mu, \Sigma)$$
$$\mu = \log(\bar{L}_\infty, \bar{K}, \bar{t}_0),$$

where $L_{i,j}$ is the total length and $a_{i,j}$ is the estimated age for fish *i* from pool *j*. The model parameters $L_{\infty,j}$, K_j, and $t_{0,j}$ represent the asymptotic length, the growth coefficient, and the theoretical age at which size equals 0. Age- and pool-specific random errors representing individual variation in length at age are indicated by $\varepsilon_{i,j}$. The random errors were assumed to be independently and identically distributed as $N(0, \sigma^2)$, whereas the natural log of the von Bertalanffy model parameters were assumed to follow a multivariate normal distribution (MVN) with a population mean μ and variance-covariance $\sum$. The population mean μ contains L_∞, K, and t_0, which are the population-averaged parameters that describes the mean growth curve among pools. Though estimates of t_0 are typically negative, the log of negative values is not possible. Thus, to facilitate with model fitting, a value of 10 was added to t_0, and subsequently subtracted, before evaluating on the original scale (Kimura 2008).

Probability of maturity was modelled as a function of female length using a binomial logit model:

$$logit(p_{ij}) = \beta_j L_{ij} + \alpha_j + \varepsilon_{ij}$$
$$\varepsilon_{i,j} = N(0, \sigma^2)$$
$$(\alpha_j, \beta_j) \sim MVN(\mu, \Sigma)$$
$$\mu = (\mu_\alpha, \mu_\beta)$$

where $p_{i,j}$ is the probability of maturity and $L_{i,j}$ is the total length for fish i from pool j. Parameters β_j and α_j are pool specific slope and intercept parameters. The structure of random errors and correlations between parameters in the maturity models were treated similarly to the approach used in growth models. Maturity was assigned using either macroscopic visual inspection or the gonadosomatic index (100 x Ovary weight/Somatic weight). Females that were not visually inspected were considered mature when GSI was greater than 1 percent and immature otherwise (Tsehaye et al. 2013). Analysis was limited to data collected during May through August when gonads are at their largest and, thus, most easily detected.

Condition was estimated by fitting a linear regression to individual length-at-weight data:

$$Y_{ij} = \beta_j L_{ij} + \alpha_j + \varepsilon_{ij}$$
$$\varepsilon_{i,j} = N(0, \sigma^2)$$
$$(\alpha_j, \beta_j) \sim MVN(\mu, \Sigma)$$
$$\mu = (\mu_\alpha, \mu_\beta),$$

where Y_{ij} is the weight and L_{ij} is the length of fish i in pool j. Parameters β_j and α_j are the slope and intercept estimates for pool j.

For most models, the prior probability distributions for σ were diffuse uniform, whereas the distributions for μ and ∑ were diffuse normal. However, because Asian carp grow rapidly during their first year of life and relatively few age-0 or age-1 fish were captured, the data provided poor estimates for t_0, which led to unrealistic estimates of L_∞ and K as a result of the strong correlation among parameters. Consequently, a prior probability distribution was included on t_0 using available data (Silver Carp: mean = -0.05; sd = 0.18; Bighead Carp: mean = -0.04, sd = 0.22; fishbase.org). Variance-covariance ∑ was modelled using the scaled inverse-Wishart distribution (Gelman and Hill, 2007). Posterior distributions were compiled by running three concurrent

Markov chains beginning each chain with different values. Chains were run for a total of 500,000 iterations, with the first 200,000 discarded for burn-in. The remaining data were further thinned by retaining every third sample, leaving a total of 100,000 values for analysis. Final posterior distributions were assessed visually and Brooks-Gelman-Rubin statistic R-hat with values <1.1 indicated convergence. No values <1.1 were observed. All analyses were implemented from within R (R Core Team 2014), using JAGS (Version 3.4.0) and the rjags package (Plummer 2013).

Annual natural mortality was estimated using indirect methods that relate mortality to demographic parameters and environmental conditions (Pauly 1980; Jensen 1996). Although many estimators of natural mortality exist, Pauly's and Jensen's are recommended and can work well for species that do not exhibit certain characteristics (for example, short adult lives after rapid juvenile growth; Kenchington 2014). Uncertainty in natural mortality estimates was derived from variation in the demographic parameters L_∞ and K that fed into the empirical relationships.

Results and Discussion: Asian carp demographic parameters were updated using existing data from all possible sources (state and federal agencies and universities). The final dataset included records from the Alton, La Grange, Peoria, Starved Rock, and Marseilles pools of the Illinois River and pools 22, 24, 26, and 27 of the Mississippi River. Although we had intended to parametrize the population model using pool-specific estimates, data from all pools were not always available. Consequently, posterior distributions for the population estimates from the full dataset in the simulation model will be used.

Ages of fish ranged from 0 to 12 and 0 to 19 for Silver and Bighead Carp. Both species of carp exhibited high growth during the first years of life and slower growth at older ages (Figures 4.1 and 4.2). Consistent with previous findings, Bighead Carp grew more slowly but reached greater ages and sizes than Silver Carp (Figures 4.1 and 4.2).

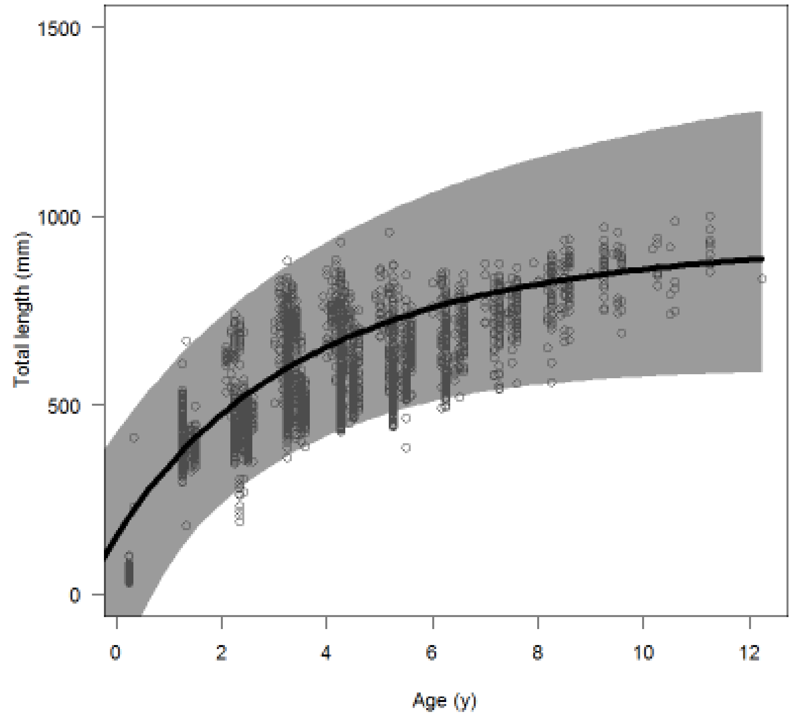


Figure 4.1. *Total length plotted against age for Silver Carp collected from the Illinois and Mississippi rivers. The line is the posterior mean estimate and the shaded area represents the 95 percent credible interval.*

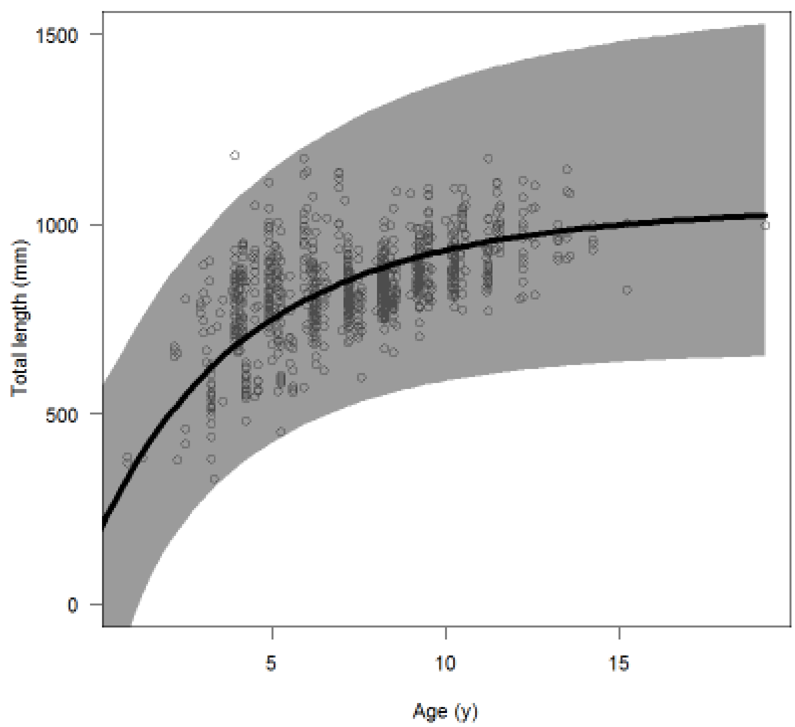


Figure 4.2. *Total length plotted against age for Bighead Carp collected from the Illinois and Mississippi rivers. The line is the posterior mean estimate and the shaded area represents the 95 percent credible interval.*

Chapter 4:
Spatially Explicit Population Model

Stock-recruit relationships typically express spawning potential as a function of spawning stock biomass. A length-weight relationship was estimated to convert fish length to biomass. Results from log transformed data indicated that for both species of carp, weight increased allometrically with length. Similar to previous studies, weight at a given length was greater for Bighead Carp than for Silver Carp (Figures 4.3 – 4.4).

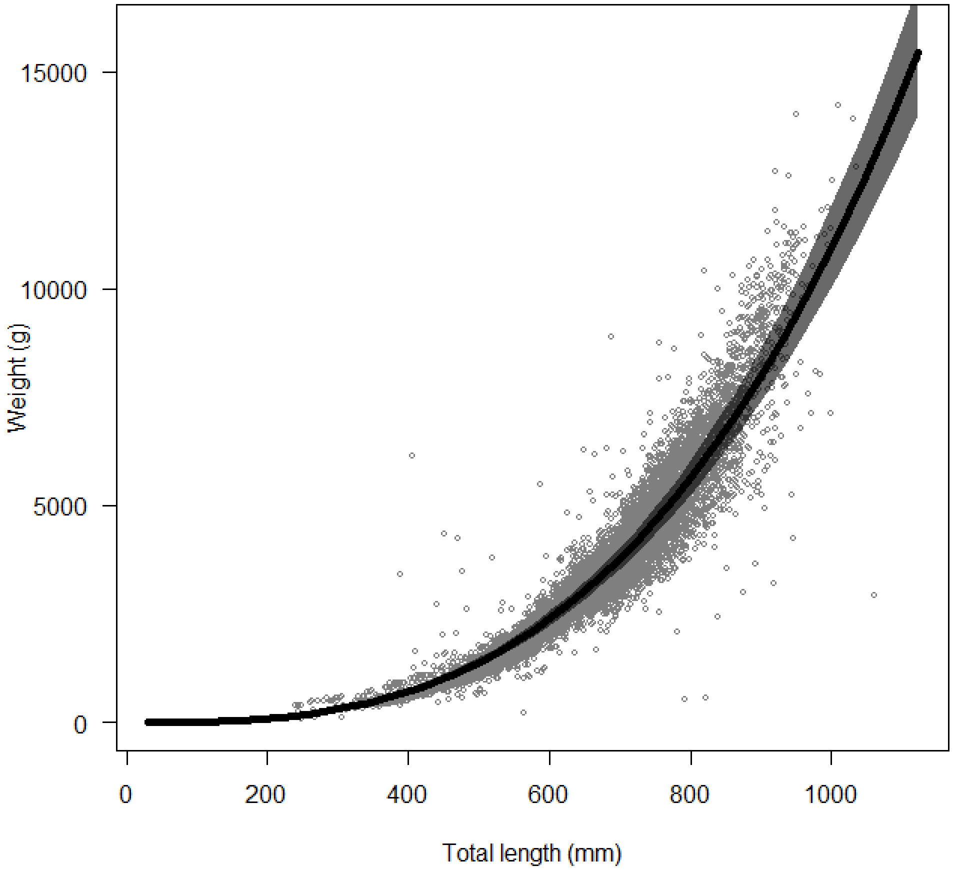


Figure 4.3. *The length-weight relationship for Silver Carp collected from the Illinois and Mississippi rivers. The line is the posterior mean estimate and the shaded area is the 95 percent credible interval.*

Maturity schedules for Bighead and Silver Carp were estimated to assign reproductive status to individuals in the simulation model. Silver Carp begin maturing at a smaller size than Bighead Carp (Figure 4.5). Size at maturity, growth, and density dependence in the stock-recruitment relationship strongly influence how fish populations respond to harvest pressure. Growth and maturity results indicated that Silver Carp mature at younger ages than Bighead Carp, and that Silver Carp grow at higher rates and mature at smaller sizes. Consequently, Silver Carp populations would be expected to be more robust against overexploitation relative to Bighead Carp.

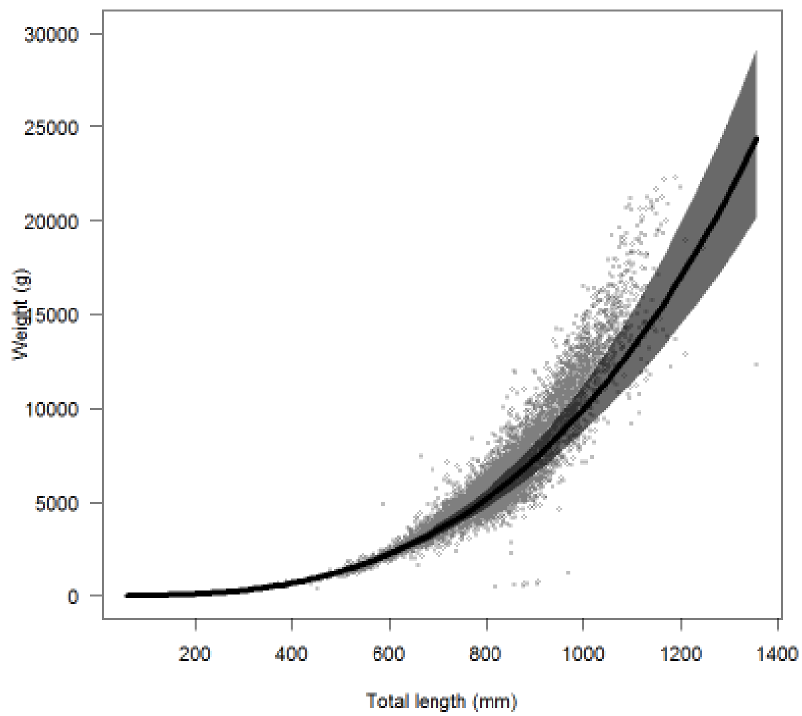


Figure 4.4. *The length-weight relationship for Bighead Carp collected from the Illinois and Mississippi rivers. The line is the posterior mean estimate whereas the shaded area is the 95 percent credible interval.*

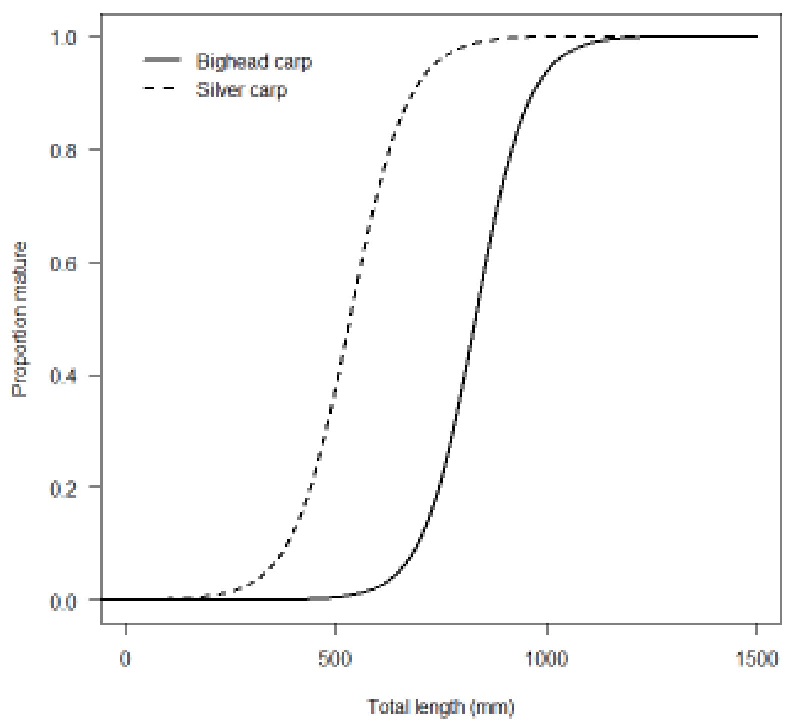


Figure 4.5. *Probability of maturity as a function of total length of Bighead Carp (solid line) and Silver Carp (dashed line) collected from the Illinois and Mississippi rivers. Lines represent the posterior mean estimate.*

Chapter 4:
Spatially Explicit Population Model

Recommendations: Using available data to estimate a stock-recruitment relationship for Illinois River Asian carp and running simulations using the population model with updated parameters represent the next steps for this research. Determining the stock-recruitment relationship for Illinois River Asian carp and the degree of density dependence in successful recruitment is critical for understanding how these populations will respond to intense harvest. Empirical abundance estimates will be used from a combination of acoustic data and relative abundance data from the USGS LTRMP to estimate the stock-recruitment relationship. Analysis will be limited to ages or sizes that have recruited to the gear and assumptions regarding annual natural mortality rates will be used to hind-cast abundance at early ages and, therefore, recruitment to account for differences in catchability among adults and recruits in the LTRMP data. This approach will introduce additional variation into the stock-recruitment relationship and increase uncertainty in predicting how Asian carp will respond to intense harvest. Consequently, collecting field data necessary to test whether a stock-recruitment relationship exists for Illinois River Asian carp or whether there are other proxies for predicting recruitment should be a high priority for future research.

Literature Cited:

Gelman, A., and Hill, J. 2007. Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge.

Hoff, M.H., Pegg, M.A., and Irons, K.S. 2011. Management implications from a stock-recruit model for bighead carp in portions of the Illinois and Mississippi Rivers. Pages 5-14 in D.C. Chapman and M.H. Hoff, editors. Invasive Asian carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland.

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences 53: 820 – 822.

Kenchington, T.J. 2014. Natural mortality estimators for information-limited fisheries. Fish and Fisheries 15: 533 – 562.

Kimura, D. 2008. Extending the von Bertalanffy growth model using explanatory variables. Canadian Journal of Fisheries and Aquatic Sciences 65: 1879 – 1891

Parker, A.D. et al. 2013. Preliminary results of fixed DIDSON evaluations at the Electric Dispersal Barrier in the Chicago Sanitary and Ship Canal. Department of the Interior, U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, 11 pp.

Parker, A.D., Glover, D.C., Finney, S.T., Rogers, P.B., Stewart, J.G., and Simmonds Jr.. R.L. 2015. Direct observations of fish reactions to a large electrical fish barrier in the Chicago Sanitary and Ship Canal. Journal of Great Lakes Research 41: 396-404.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil 39: 175 – 192.

Plummer, M. 2013. rjags: Bayesian Graphical Models Using MCMC.

R Core Team. 2013. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Tsehaye, I., Catalano, M., Sass, G., Glover, D., and Roth, B. 2013. Prospects for fishery-induced collapse of invasive Asian carp in the Illinois River. Fisheries 38: 445-454.

BARRIER EFFECTIVENESS EVALUATION

Telemetry Interim Summary Report

Matthew Shanks, Nicholas Barkowski (US Army Corps of Engineers – Chicago District)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

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

Introduction: 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 (USACE) and other participating agencies as part of the Monitoring and Response Workgroup's (MRWG) monitoring plan (MRWG, 2013).

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: Determine if fish are able to approach and/or penetrate the electric dispersal barrier system (Barrier Efficacy);

- **Objective** Monitor the movements of tagged fish in the vicinity of the electric dispersal barrier system using receivers (N=8) placed immediately upstream, within, and immediately downstream of the barriers, in addition to mobile tracking.
- **Objective** Utilize depth sensor transmitters in surrogate species at the barriers to further refine the understanding of barrier challenges and the efficacy of clearing actions between the barriers utilizing traditional (i.e. electrofishing, driving fish with noise) and/or non-traditional methods (i.e. water guns, deep water electrofishing)
- **Objective** Analyze behavior and movement patterns of fish near the barriers as they interact with barge traffic.

Telemetry Interim Summary Report

Goal 2: Determine if and how Asian carps and surrogate species pass 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=8) placed above and below and within each lock.
- **Objective** Release Common Carp with depth sensor transmitters within the Brandon Road Lock as a surrogate fish to analyze movement within the water column under various lock operations

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

- **Objective** Determine if the leading edge of the Asian carp invasion (currently RM 281.5) has changed in either the up or downstream direction.
- **Objective** Describe habitat use and movement in the areas of the Upper IWW and tributaries where Asian carp have been captured and relay information to the population reduction program undertaken by IDNR and commercial fishermen.
- **Objective** Further develop and refine a presence/absence model for tagged Asian carp in the Kankakee River and Rock Run Rookery backwater

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, we have acquired 20.2 million detections from 532 tagged fish.
- No live tagged fish have crossed the Electric Dispersal Barriers in the upstream direction
- Highest detection rates of tagged Common Carp in Lower Lockport Pool occurs in shallow backwater sites and immediately below the Electric Dispersal Barriers
- Tagged Common Carp utilize the full water column at the Electric Dispersal Barriers and mean depth at detection did not significantly differ from downstream control sites
- Inter-pool movement of tagged fish was observed in both directions between all pools within the study area in 2015 (Lockport, Brandon, Dresden Island and Marseilles)
- Tagged Common Carp utilize the full water column within the Brandon Road Lock chamber during lock operations but stay near the bottom of the lock chamber during periods between lock operations
- Bighead Carp were detected moving as far upstream as the Wilmington Dam on the Kankakee River during a rise in the hydrograph
- Total movement distance of Common Carp did not significantly differ from those of Bighead or Silver Carp in the Dresden Island Pool

Telemetry Interim Summary Report

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 2014 season there were approximately 179 tagged fishes (V16 Vemco transmitters) that remained active and 74 of these transmitters were scheduled to expire within calendar year 2015. 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 increases 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 106 transmitters (Vemco transmitters V13 (n=30) and V16 (n=76); 69 kHz) were implanted into both Asian carp and surrogate species in 2015 to maintain adequate transmitter saturation within each pool between the Cal-Sag Channel and the Dresden Island lock and dam. This supplement of tagged fish brought the running total of active fish in the system to 285. With 74 previously deployed tags set to expire within 2015, the minimum number of active tags was 211 within the system during the sampling season. Tagged surrogates have been released both above and below the 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 and could interfere with eDNA surveillance. Most fish were released at or near point of capture only after they were deemed viable and able to swim under their own power. A portion of the surrogate fishes released within Dresden Island pool were originally captured from the Brandon Road pool in an effort to induce higher approaches to the Brandon Road Lock through site fidelity as those displaced fishes attempt to return to their original capture location. This method was used in previous years at the electric dispersal barriers location and was found to increase barrier approaches. Table 1 identifies all fishes containing active transmitters within the winter of 2014 and the field season of 2015 along with their release point within the system.

Table 1: *Active Fishes and Release Points within the Study Area in 2015*

Release Location	Species Implanted	Number of Fish Implanted
Upper Lockport Pool (Upstream of Barriers)	Common Carp	15
Between Barriers	Common Carp	10
Lower Lockport Pool (Downstream of Barriers)	Common Carp	58
	Freshwater Drum	1
Brandon Road Pool	Common Carp	44
Brandon Road Lock	Common Carp	6
Dresden Island Pool	Bighead Carp	65
	Silver Carp	16
	Silver-Bighead Hybrid	3
	Smallmouth Buffalo	13
	Common Carp	23
Marseilles Pool	Bighead Carp	16
	Silver Carp	15
Total		**285**

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 mobile tracking techniques and downloading stationary receivers. 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). Stationary receivers removed for winter in 2014 were redeployed in mid March, 2015 with revisions to the layout of receiver positions within the study area based off of lessons learned from previous data collected. Receiver coverage within the Dresden Island pool increased from six in 2013, eleven in 2014 and thirteen in 2015. New coverage within the Dresden Island pool has allowed for more detailed measurements of tagged fish movement and habitat use at the leading edge of the invasion front. New receiver locations included additional backwater areas within the pool, extended coverage within the Kankakee River and around the Brandon Road Lock and Dam. The revised study area was covered by 39 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 (Figure A – Receiver Network Maps).

Barrier Efficacy – Barrier efficacy was assessed by observing both the long range and fine scale movements of tagged fishes located within the Lockport pool. Long range movements were assessed utilizing 11 stationary VR2W receivers strategically placed up and downstream of the electric dispersal barriers (n=6 upstream and n=7 downstream). These receivers were placed at the lock entrance, in areas of suitable habitat, in proximity to the electric dispersal barriers and at the confluence of the CSSC and Cal-Sag Channel (Figure A). Receiver data was analyzed for individual fish detections that would indicate an upstream or downstream passage through the electric dispersal barriers. Bi-monthly mobile tracking utilizing the VR100 supplemented the stationary receiver data. Mobile tracking occurred within the main channel of the waterway at .3

mile intervals throughout the study area. All detections were recorded and compiled into the detection data set.

Fine scale movement patterns were assessed within the electric dispersal barriers through a network of eight VR4 receivers which compose a Vemco Positioning System (VPS). The VPS is capable of producing two dimensional fish positions for detections of tagged fish within the VR4 receiver array. This data was evaluated to determine the frequency of occurrence of tagged fish approaching the barriers in relation to temporal and environmental parameters. Descriptive statistics were used to determine the number of fish that approached the barriers and the resulting percentage of the total available tagged fish population in Lower Lockport pool. For each fish that approached the barriers additional data were considered including residency time and the closest distance to the first active barrier. Residency time within the VPS was calculated for any fish that had two or more positions not separated by greater than 120 minutes. Positions separated by greater than 120 minutes were assumed to be generated by separate approaches. Residency time is thus defined as the amount of time an individual fish spent challenging the barrier per approach. Environmental parameters were measured for each barrier approach and include hourly mean discharge, temperature and conductivity. Temperature and conductivity data were provided by onsite data loggers directly at the barrier location. Hourly mean discharge data was determined using a US Geological Survey stream gauge approximately 3.5 miles upstream of the barriers (05536890-Chicago Sanitary and Shipping Canal at Lemont, IL). Historical data from this gauge at its previous location at the barriers indicate that discharge rates between the Electric Dispersal Barriers System and Lemont are comparable. Linear regression analysis was used to determine significant relationships between barrier approaches, residency time or distance to active barrier in comparison to the three environmental parameters discussed above.

As of 1 January 2015, there were a total of 47 tagged surrogate fishes (Common carp and Freshwater drum) active within the Lower Lockport Pool (mean ± SD; 564 ± 61 mm). In order to maintain a similar number of tagged fish within the Lower Lockport pool across years, an additional 22 Common carp (561 ± 56 mm) were tagged and released in 2015 to increase transmitter density bringing the total up to 69. These additional Common carp were tagged using Vemco V13P pressure sensor transmitters capable of providing a depth at time of detection. These Common carp were then released either immediately below the barrier system (n=12) or between the active barriers (n=10). To increase chances of interaction with the Electric Dispersal Barriers these additional fish were all captured upstream of the Barriers and released downstream. A T-test was used to compare difference in average depth of water column used by tagged fish within the electric dispersal barriers to those detected in similar habitat downstream and outside of the influence of an electrical field.

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 barriers. 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 which are separated by the electric dispersal barriers. The remaining pools include the Brandon Road pool of the CSSC 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 was retrieved for each passage where a specific time of occurrence could be determined.

Greater emphasis was placed on the Brandon Road Lock as this is the first barrier to upstream migration of Asian carp from the known invasion front. Previous years efforts have increased the receiver coverage surrounding the Brandon Road Lock to better understand fish behavior during an approach in the upstream direction. In 2015, depth sensor transmitters were introduced to the system and implanted into 9 Common carp. These fish were released in groups of three within and below the Brandon Road Lock Chamber. Three fish were released during a downstream lockage within the lock chamber, three fish were released within the approach channel downstream of the lock chamber and the final three fish were released within the lock chamber during an upstream lockage. In order to increase the likelihood of these fish attempting to move back upstream through the Brandon Road lock, all fish were captured from the Brandon Road Pool. Average depths at detection for these fish were recorded during lock filling, lock emptying and steady state lock operations (no active lock operations at both upper and lower elevations). Additionally, average depths were recorded during barge presence and barge absence within the lock chamber and within the approach channel.

In addition to the depth sensor tagged Common Carp mentioned above, a total of fifty one Asian carp (40 Bighead, 10 Silver and 1 Hybrid) were tagged. These fish were captured with the help of IDNR and commercial fishermen as part of the Barrier Defense Removal and Fixed Site Sampling projects. Asian carp were released back into the Dresden Island Pool near their respective collection sites at either Big Basin Marina (n=15) or Rock Run Rookery (n=36).

Asian carp Movement Analysis – From 2013 to 2015 73Asian carp (Bighead and Silver) and 20 Common Carp were tagged with Vemco ultrasonic tags as previously described within the Dresden Island pool. Each fish was captured via electrofishing or gill/trammel net, placed into a recirculating livewell with added salt to account for lost electrolytes. Movement of individual fish were tracked via Vemco VR2w stationary receivers (Figure 1) strategically placed throughout the Des Plaines and Kankakee Rivers. VR2w detections were then uploaded into Vemco Vue. Detections for each tag were exported into an excel file and ArcMap 13.2 was used to track the total distance (km) traveled by each fish. The total distance was then divided by the total number of days the tag was active to standardize the data to km/d. Fish tracks that only resulted in downstream movements and tags that were only detected on one receiver with no detections elsewhere were considered to be dead and were not used in this analysis. A t-test was used to determine if any statistically significant differences in the total distance traveled existed between species.

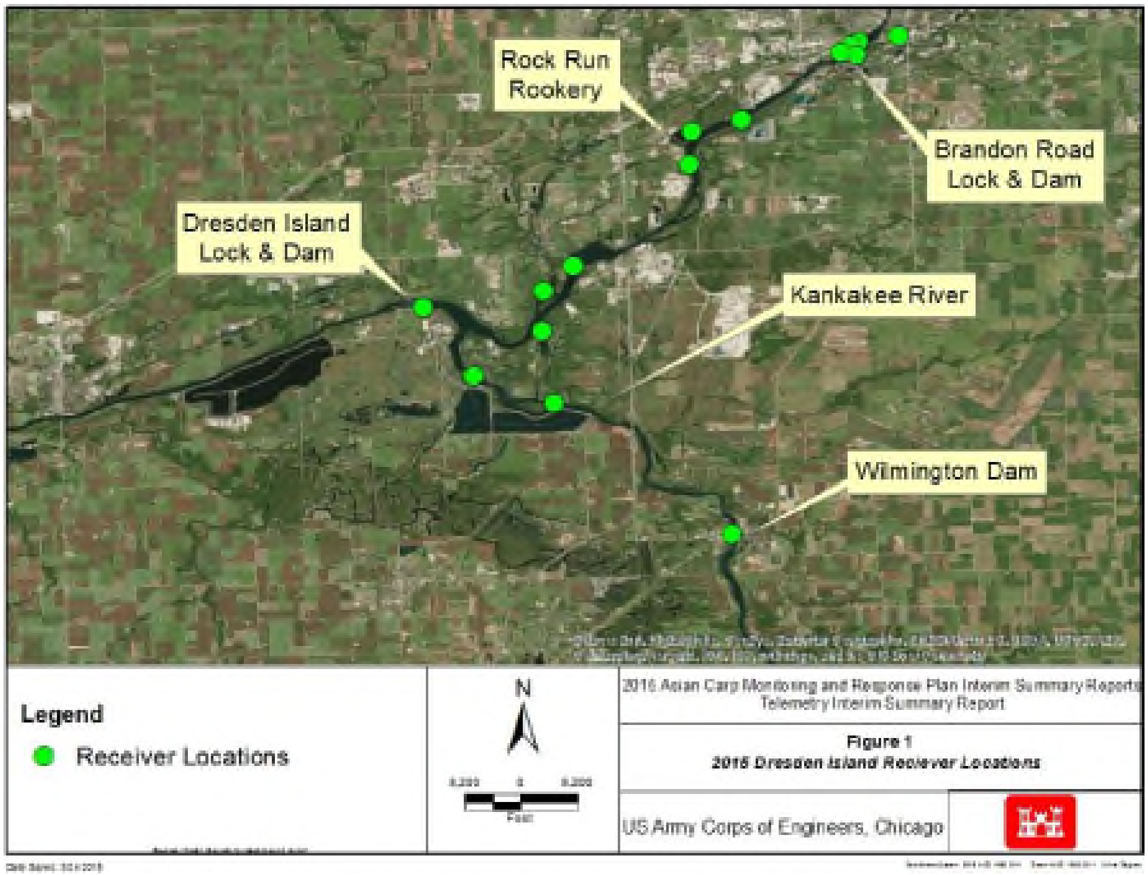


Figure 1: *Dresden Island Pool Receiver Locations*

Results and Discussion: The results discussed in this section will address the three goals of the study. As of December 2015, 20.2 million detections from 532 tagged fish have been recorded within the study area. 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 were detected upstream of the barriers as was reported in previous reports (2014 MRP Interim Summary, 2015). These transmitters had been presumed to be either expelled from the host fish or the host fish had expired due to lack of movement on the detected transmitters. The following sections provide new results from data collected in the 2015 sampling season in support of the three project goals: barrier efficacy, lock passage and leading edge status.

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

Large Fish Testing above barriers: No fishes were tagged or released within the Upper Lockport pool during the 2015 field season. There were 14 active transmitters in live fish above the barriers in 2015. These fish included Common Carp captured from the Cal-Sag Channel which were tagged in November 2013 and released at a barge slip approximately 3.5 miles upstream of the barriers. Two of these fish (Common Carp; TL 543 & 696 mm) were detected at the barriers in 2015. The first fish approached the barriers encountering Barrier IIB on 12 March 2015 and returned upstream after 6 hours and 20 minutes of detections on barrier receivers. This same fish approached Barrier IIB again on 14 March 2015 and was presumed to have died upon prolonged exposure to the barrier system. This fish was detected on barrier receivers for 7 days, 13 hours and 23 minutes before exiting the Electric Dispersal Barrier System in the downstream direction. Subsequent stationary receiver detections only occurred in the downstream direction following passage further supporting the fish had perished or expelled the transmitter. The second fish approached Barrier IIB from the north on 19 April 2015. This approach was detected on barrier receivers for 18 hours and 22 minutes before returning upstream.

There have been a total of three approaches to the barriers from the upstream direction since 2013 in which fish have returned back upstream. The average time spent challenging the barriers before returning upstream was 10 hours and 5 minutes. The average canal discharge at the time of first barrier detection was 2681 cubic feet per second (cfs). This was similar to the average discharge at time of first detection for the two fish that passed downstream through the barriers (2800 cfs) since 2013. Regardless of barrier passage or returning upstream there have been a total of five approaches to the barriers from the upstream detection. One approach occurred in winter (December) and the remaining four have occurred in the spring (March-April). All approaches that occurred in the spring were within 24 hours of a maximum discharge of at least 5300 cfs while the winter approach occurred within 24 hours of a maximum discharge of 3461 cfs (Table 2).

Table 2: *Common Carp Downstream Approaches to the Electric Dispersal Barrier System*

Date of Approach	Downstream Passage	Residency Time (min)	Discharge at time of Approach (cfs)	Daily Average Discharge (cfDaily)	Max Discharge (cfs)	Season	Alive	1st Active Barrier
12-Mar-15	No	380	3727	3991	6105	Spring	Yes	2B
14-Mar-15	Yes	10883	3440	3292	5307	Spring	No	2B
19-Apr-15	No	1102	2436	2976	5800	Spring	Yes	2B
2-Dec-13	No	332	1881	1953	3461	Winter	Yes	Demo
24-Apr-14	Yes	60	2159	2787	5376	Spring	Yes	Demo

Large Fish Testing at and below barriers: There were 69 tagged surrogate fishes active within the Lower Lockport pool in 2015 between Lockport Lock and the Electric Dispersal Barrier System. Six stationary receivers (VR2W) detected movement on 68 percent (n=47) of the tagged surrogate fishes throughout the pool in 2015. There were a total of 1.8 million detections within Lower Lockport Pool January through December. The greatest number of detections occurred within the Hanson Material Services mooring slip approximately 0.8 miles downstream of the Electric Dispersal Barrier System, accounting for 29 percent of all detections. The lowest number of detections occurred at the Lockport Lock accounting for only 1.7 percent of detections. The receiver located immediately downstream of the Electric Dispersal Barrier System detected the most individual transmitters of all receivers within the pool (n=32, Table 3). This indicates that 68 percent of active fish within the Lower Lockport Pool were detected within at least 0.5 miles of the Electric Dispersal Barrier System.

Table 3: *Surrogate Fish Detections between Lockport Lock and the Electric Dispersal Barriers*

Station	Total	Percent Total	Transmitters
LL01	343233	18.37	32
LL02	297545	15.92	24
LL03	542775	29.05	27
LL03a	121187	6.49	25
LL04	215187	11.52	25
LL05	316304	16.93	23
LL06	32271	1.73	21

Positional data on fish movements within the VPS at the Electric Dispersal Barriers has been retrieved and analyzed for detected positions from 1 November 2014 through 13 October 2015. During this period of analysis, 24 individual fish (51.1 percent of active fish detected within Lower Lockport Pool) were detected actively moving within the VPS array allowing positional data to be acquired. All fish that were observed approaching the barriers were Common Carp between 455 mm and 740 mm (566 ± 73 mm). These fish approached the Barriers a total of 944 times during the period of analysis. No fish were observed to cross over an active barrier in the upstream direction. Tagged fish were observed to approach Barrier IIA when active and Barrier IIB during periods of maintenance outages at Barrier IIA. The number of approaches to the Electric Dispersal Barrier System per fish ranged from a single approach to a maximum of 218 times for a single fish. The average number of approaches per fish was 41 within the period of analysis.

There was 100 percent mortality of Common Carp implanted with depth sensor transmitters and released between active Barriers IIA and IIB (n=6). These fish were immediately exposed to an electrical field upon release which may have contributed to the high mortality rate. An additional three Common Carp with depth sensors were released between Barrier IIB and the Demonstration Barrier of which there was only one mortality. One Common Carp was found to have moved downstream through Barriers IIB and IIA and remains alive and active following this downstream passage. The final Common Carp was found to move upstream past the Demonstration Barrier approximately one week after release when the Demonstration Barrier was turned off for maintenance.

There were 13 active Common Carp with depth sensor transmitters downstream of the Electric Dispersal Barriers inclusive of the one Common Carp that was found to pass downstream through the Barriers. All of these fish were observed to approach the Electric Dispersal Barrier System numerous times throughout the 2015 sampling season. Common Carp were found to utilize the full water column, from canal bottom to the surface, in proximity to the electrified water. Within the VPS, from 6 meters upstream of Barrier IIB to 52 meters downstream of Barrier IIA, the mean depth for all fish detections was 3.68m (SD±1.92). Depth at positions within the VPS were further refined to include only those positions upstream of the wide electrode array of Barrier IIA. This step filtered out any fish positions which may have been within the VPS but downstream of an electric field influence. The mean depth of fish positions upstream of the Barrier IIA wide array was 2.74m (SD±1.11). A t-test did not show any significant difference in the mean depth per detection for the full VPS versus those detections within the VPS upstream of the Barrier IIA wide array (P=0.29). Additionally, further t-tests did not show any significant difference in mean depth of habitat use within the VPS in comparison to two downstream sites of similar canal morphology outside of the barrier's electrical influence (VPS-LL03a, P=0.56 and VPS-LL02, P=0.19). Site LL02 and LL03a were located approximately 0.5 miles and 1.5 miles downstream of the Electric Dispersal Barrier System respectively (Figure A – Receiver Network Maps). Mean depth at site LL02 was 3.39m (SD±0.92) and mean depth at site LL03a was 3.11m (SD±1.26).

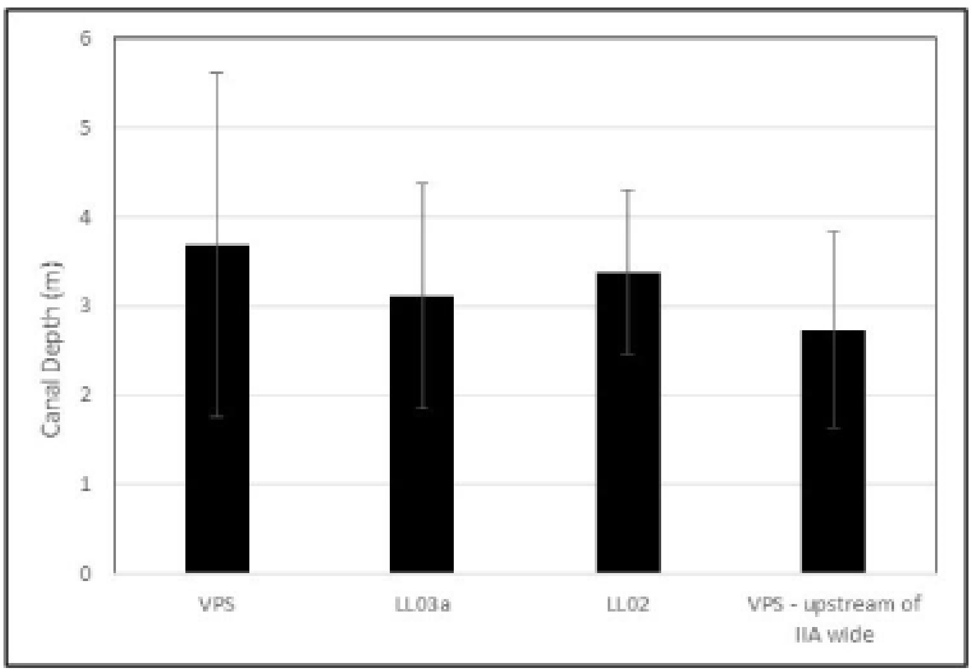


Figure 2: *Mean depth at time of detection for Common Carp at the Electric Dispersal Barriers and two locations within the Lower Lockport Pool with similar canal morphology. VPS refers to those detections within the Vemco Positioning System at the Electric Dispersal Barriers. This area was further divided into the full VPS and those detections within the VPS upstream of the Barrier IIA wide array. T-tests resulted in no significant differences.*

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

From 2010 to 2015, there have been 52 occurrences of tagged fish moving downstream and 31 occurrences of upstream movement between navigation pools by a total of 67 individual tagged fish (Table 2). Inter-pool movement was greatest between the Lockport and Brandon Road pools accounting for 53 percent (44/83) of all inter-pool movements. Of the 44 transfers recorded between these two pools, 31 occurred in the downstream direction and 13 upstream. Downstream movement into the Brandon Road Pool occurred through two pathways, the Lockport Lock and through the Lockport Controlling Works spillway approximately two miles upstream of the Lock. Lockport Controlling Works is managed by the Metropolitan Water Reclamation District of Greater Chicago (MWRD) and is used to lower the river stage in Lockport pool in advance of large storm events in the drainage basin. There have been 20 occurrences of tagged Common Carp passing through this spillway into the Des Plaines River. All twenty fish were detected moving within the Des Plaines River and into the Brandon Road Pool where they continued to display activity. Movement between the Dresden Island and Marseilles Pools comprised 34.9 percent (29/83) of all inter-pool movement with approximately equal movement upstream and downstream (upstream n=14; downstream n=15). All upstream movement from the Marseilles to the Dresden Island Pool is assumed to pass through the lock chamber. Downstream movement from Dresden Island to the Marseilles Pool is primarily over the dam however with only 20 percent (3/15) downstream movement through the lock chamber. The lowest inter-pool movement occurred through the Brandon Road Lock and Dam accounting for 12 percent (10/83) 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 those fishes originating from the Dresden Island Pool.

Table 4: *Tagged fish inter-pool movement from 2010 to 2015. Downstream is defined as DS and Upstream is defined as US.*

Interpool Movement Data			
	US	DS	Total
Lockport	13	11	24
Lockport	0	20	20
Brandon Road	4	6	10
Dresden Island	14	15	29

The mean total length of the nine Common Carp implanted with depth sensor tags at Brandon Road Lock was 642 ± 92 mm with a range of 564 to 859 mm. Movement analysis of the six fish released within the lock chamber revealed one mortality within the lock chamber, two upstream passages into the Brandon Road Pool and three downstream passages into the Dresden Island

Pool. The mean time to exit the lock in the downstream direction was 190 ± 129 minutes ranging from 43 to 283 minutes. The mean time to exit the lock in the upstream direction was 671 ± 185 minutes with a range from 540 to 801 minutes. The two fish passages into the Brandon Road Pool occurred during downstream lockage of barge traffic. Fish passing through the upstream gates also missed more opportunities to leave the lock chamber (mean = 5.5) than those fish passing through the downstream gates (mean = 1.6). Figure 3 provides the mean depths recorded across each fish within the lock chamber under various lock operations with barge presence and barge absence. T tests were used to compare the means of each set of data. The only significant difference that was observed was the mean depths recorded at the upper pool elevation with the gates closed (10.34 ± 2.58 m) compared to the lower pool elevation with the gates closed in the absence of a barge (4.28 ± 0.87 m; P=0.003). This same situation was also analyzed during the presence of a barge but was not found to be significantly different (P=0.054) as there was additional variance in the data (figure 3). The lock chamber depth at the upper and lower pool elevations is approximately 15 m and 4.7 m respectively. This would indicate that during times of no lock operations tagged fish were utilizing the bottom of the chamber at the lower pool elevation but approximately 5 meters off of the bottom at the upper pool elevation. During periods of lock operation, including filling and emptying of the lock chamber or active movement of tow and barge vessels within the chamber, fish were more active throughout the full water column with mean depths ranging from 6.15 to 7.35 m. The range of depths utilized during these active lock operations included surface of the water to the bottom of the lock chamber.

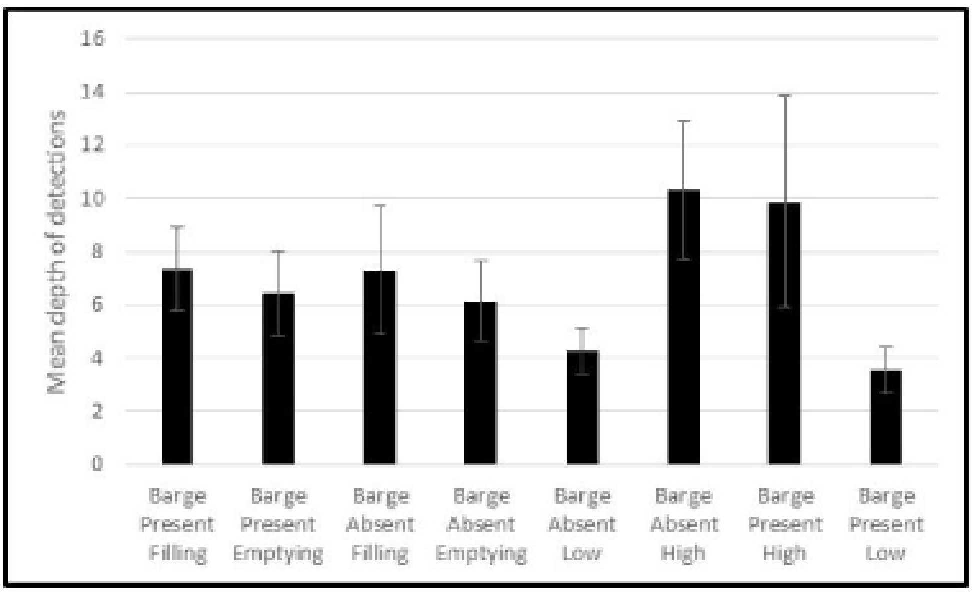


Figure 3: *Mean depths of detections within the Brandon Road Lock chamber under various lock operations and in the presence or absence of barge traffic. Filling and emptying operations were recorded from the time between gates closed to gates open. 'High' refers to the upper pool elevation and 'Low' refers to the lower pool elevation.*

All three of the Common Carp released within the approach channel downstream of Brandon Road Lock were observed to exit the approach channel in the downstream direction. The average time in which these fish initially stayed within the approach channel following release was 11 hours and 24 minutes. Six Common Carp were detected within the approach channel inclusive of the three fish that were released in the lock chamber and passed downstream. All six of these fish were found to exit the approach channel and return multiple times through 10 December 2015. The furthest downstream detection of these fish occurred approximately 3 miles from the lock. One of these Common Carp also detected within the connecting Hickory Creek tributary. Mean depths recorded within the approach channel remained within the top meter of the water column (Figure 4) regardless of lock emptying, filling or steady state operations.

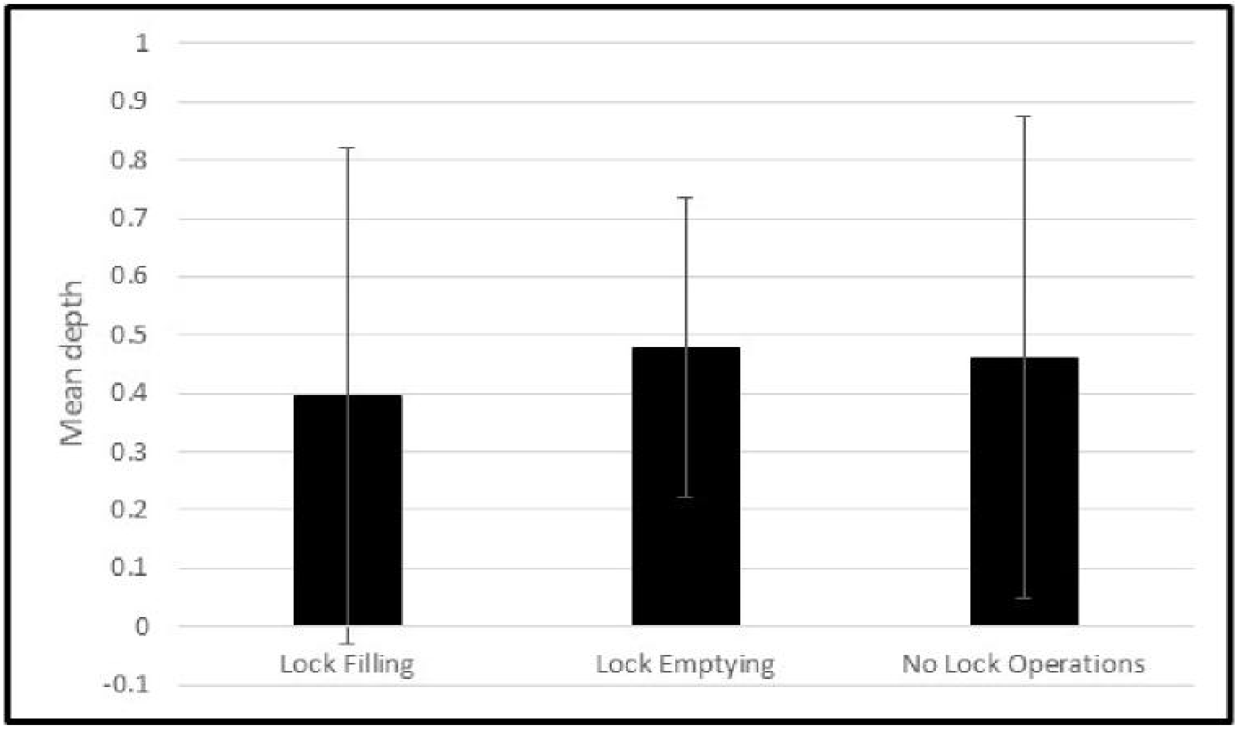


Figure 4: *Mean depth of Common Carp detected within the approach channel to the Brandon Road Lock during lock emptying, filling and steady state operations. (Negative standard deviation is a result of Vemco V13P pressure sensors containing an error of plus or minus 1.7 m.)*

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

A total of 3 Common Carp and 21 Asian Carp were not included in the analysis as they appeared to succumb to post-release mortality. Through this assumption, post-release mortality was determined to be 15 percent for Common Carp and 29 percent for Asian carp. As a result of post-release mortality, a total of 51 Asian carp (Silver Carp; n=7, Bighead Carp; n= 43, silver x bighead hybrid; n=1; TL ± SD; 907 ± 92.8 mm) and 17 Common Carp (590 ± 68.6 mm) were included in this analysis and were used to compare distance traveled amongst species. Previous analysis

(2013 MRP Interim Summary, 2014) demonstrated that Silver Carp and Bighead Carp move similarly, so both species were grouped together for analysis. Common Carp showed ranges of daily movements between 0.09 to 1.85 km/d with a mean of 0.51 ± .0.45 km/d and Asian carp had daily movements ranging from 0.16 to 2.06 km/d with a mean of 0.71 ± 0.39 km/d. Total distances traveled across species was not statistically significant (p=0.11; Figure 5).

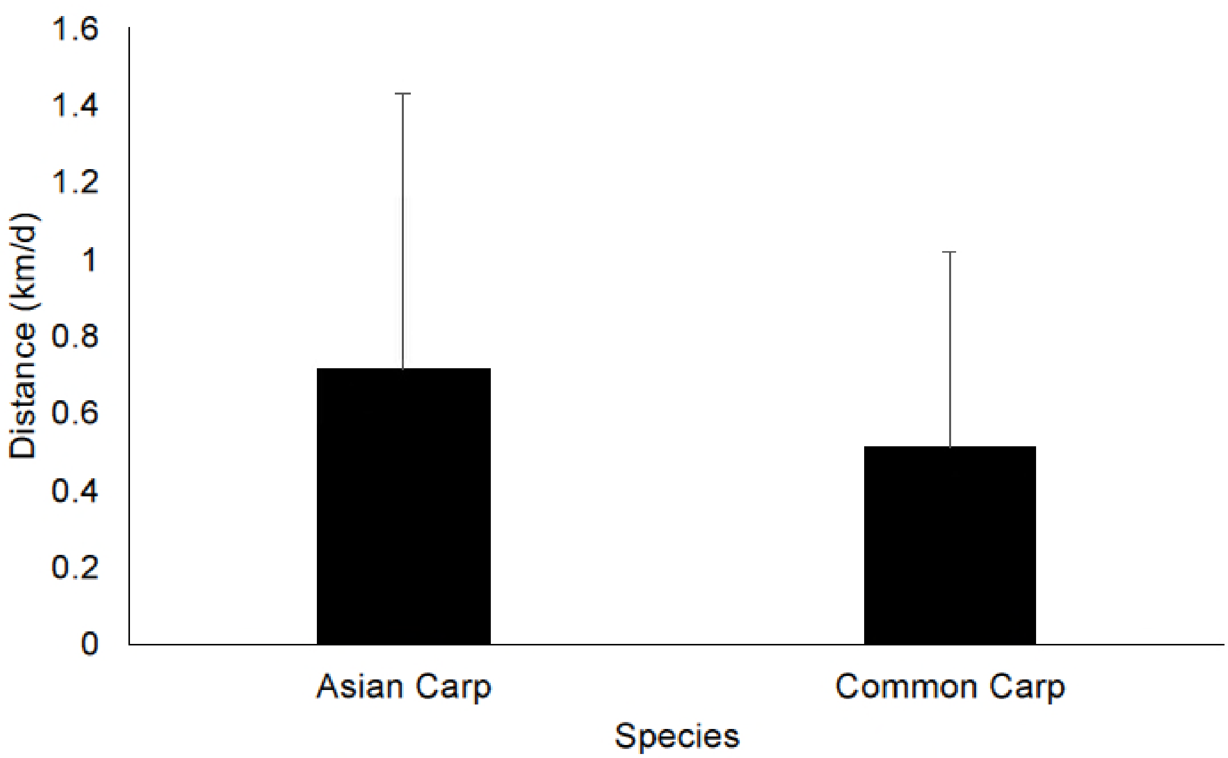


Figure 5. *Mean ± SD distance (km/d) traveled by tagged Asian carp and Common Carp within the Dresden Island pool of the Upper Illinois Waterway. A t-test resulted in no significant differences (p=0.11)*

Based on total movement, these data suggest that Common Carp may be effective surrogates for Asian carp studies within the upper Illinois River. While total distances are not significant, further analysis is required to investigate potential seasonal movement patterns and habitat use differences between Asian carp and Common Carp.

In addition to the aforementioned analysis, detections of tagged Asian carp were observed further upstream of the Kankakee River than previous sampling seasons. In the past, the furthest upstream an Asian carp was detected occurred at the Des Plaines Dolomite Prairies Land and Water Reserve. This year 10 tagged Asian carp were detected just downstream of the Wilmington Dam, approximately 10 km further upstream. While Asian carp have been captured upstream of the Wilmington Dam, the events that occurred around the detections are to be considered. The Kankakee River was in flood stage for approximately xx days, xx days more than the previous years. During the flood pulse (Figure 6) approximately 85 detections from 12

Asian carp were detected. This type of response may suggest the potential attempts of spawning within the Kankakee River. The Wilmington Dam has a bypass channel that Asian carp can likely swim through under high flows since they have been found upstream of the dam in the past. The next upstream impediment is the Kankakee Dam, which is approximately 22 miles further upstream and provides a much greater distance for potential hatching of Asian carp eggs. With the finding of larval Asian carp in Dresden Island in 2015, the Kankakee River should be monitored more heavily at the best of the MRWG's ability.

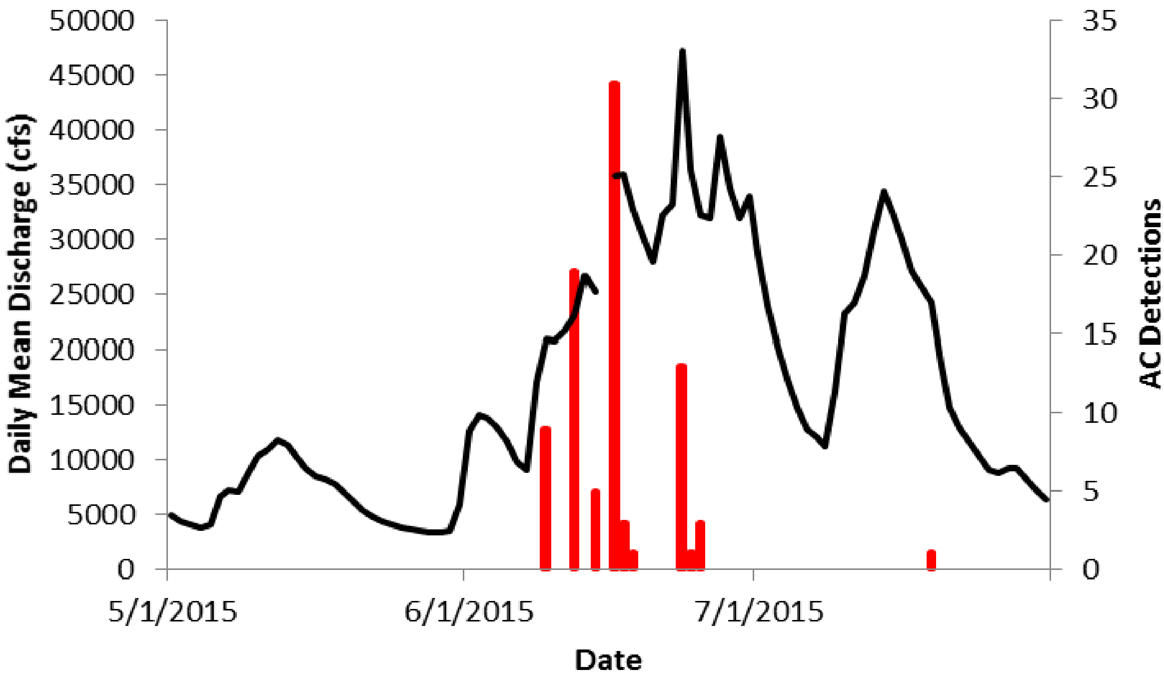


Figure 6. *Daily mean discharge (cfs) of the Kankakee River at Wilmington with detections of tagged Asian carp during the 2015 sampling season at the VR2w receiver located just downstream of the Wilmington Dam. A total of 85 detections were observed at the Wilmington Dam from 12 tagged Asian carp.*

Recommendations:

USACE recommends continuation of the telemetry program and maintaining the current level of surrogate species tags within the system. The number of Asian carp currently tagged within Dresden Island Pool should also be maintained but supplemental and replacement transmitters for these species should include depth and temperature sensors to improve our current data on habitat use. In addition, temperature data loggers should be maintained within the area of the receiver network from the Lockport Pool to Dresden Island Lock and Dam.

In regards to the Electric Dispersal Barriers, this report recommends continued analysis of barge entrainment and detection probability of transmitters within the safety zone of the regulated navigation area. Further analysis of existing data will be ongoing and telemetry techniques should be used to supplement and support future barge entrainment work by partner agencies. The results from depth sensor analysis reported here indicate that agency efforts to clear fish between the barriers should be comprehensive and include the full depth of the canal within the safety zone. Efforts to clear fish between the barriers that focus exclusively on the surface of the canal may exclude those fishes at the bottom of the canal even in those areas with an electrical field. VR4 receiver battery life will expire in spring of 2016 and future monitoring of fish passage at the Electric Dispersal Barrier should be focused on utilizing a long term deployment of hydroacoustic monitoring.

Continued analysis should occur at the Brandon Road Lock chamber for the telemetry program and continue the collaboration with partner agencies performing parallel studies. USACE recommends collaborating with SIUC in the positioning of additional receivers in and around the Brandon Road Lock and Dam to maximize efficiency of receiver detections.

Literature Cited

DeGrandchamp, K. L., J. E. Garvey, and L. A. Csoboth. 2007. Linking reproduction of adult invasive carps to their larvae in a large river. Transactions of the American Fisheries Society 136:1327-1334.

Monitoring and Rapid Response Workgroup, 2012. Monitoring and Rapid Response Plan for Asian Carp in the Upper Illinois River and Chicago Area Waterway System. http://www.asiancarp.us/documents/2012mrrp.pdf [Accessed 7 Jan 2013].

Monitoring and Rapid Response Workgroup, 2012. 2011 Asian Carp Monitoring and Rapid Response Plan Interim Summary Reports. http://www.asiancarp.us/documents/MRRPInterimSummaryReports.pdf [Accessed 7 Jan 2013].

Smith, B. B., Sherman, M., Sorensen, P., and Tucker, B. (2005). Current-flow and odour stimulate rheotaxis and attraction in common carp. South Australian Research and Development Institute (Aquatic Science), SARDI Publication Number RD04/0064–3, Adelaide.

Summerfelt, R. C. and L. S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213-263 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

USACE. 2013. Summary of Fish-Barge Interaction Research and Fixed DIDSON Sampling at the Electric Dispersal Barrier in Chicago Sanitary and Ship Canal. U.S. Army Corps of Engineers, Chicago District.

Winter, J. D. 1996. Underwater biotelemetry. Pages 371-395 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

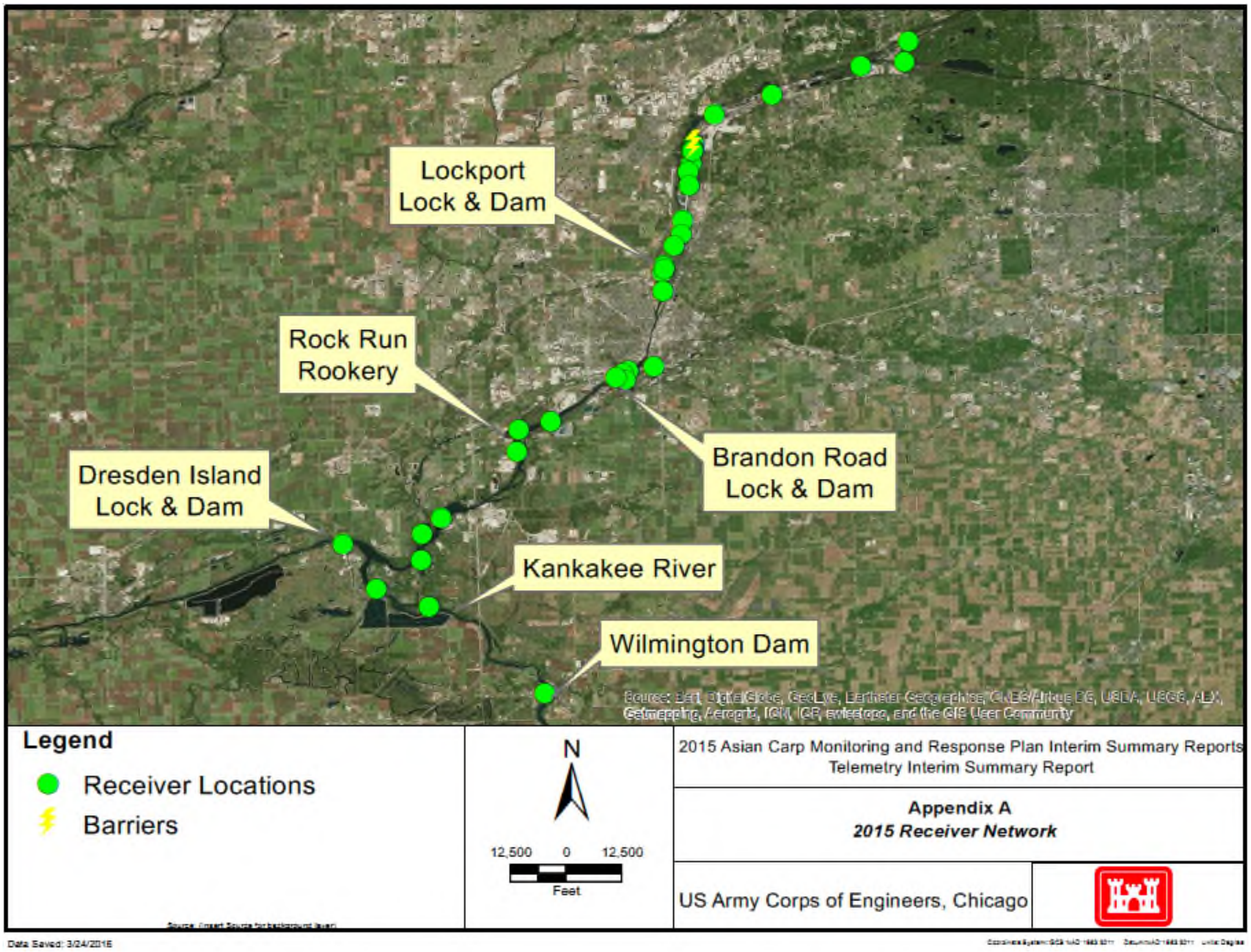


Figure A. *Telemetry Receiver Network*

Understanding Surrogate Fish Movement with Barriers

Brennan Caputo, Clint Morgeson, Tristan Widloe, Rebekah Haun, Ryan Young, Justin Widloe, David Wyffels, Blake Bushman, Luke Nelson, Matthew O'Hara, and Kevin Irons (Illinois Department of Natural Resources)
Nick Bloomfield and Jenna Merry (USFWS– Carterville)
Mathew Shanks and Nicholas Barkowski (US Army Corps of Engineers)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Participating Agencies: Illinois Department of Natural Resources (lead); U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Illinois Natural History Survey, and the Forest Preserve District of Will County.

Location: Sampling will take place in the Lockport Pool downstream of the Electric Dispersal Barrier, Brandon Road pool, Dresden Island pool, and Rock Run Rookery.

Introduction: Based on the results of extensive monitoring using traditional fishery sampling techniques (electrofishing, trammel nets, gill nets, hoop nets, and fyke nets), Asian carp are rare to absent in the area between the Electrical Dispersal Barrier and the Brandon Road Lock and Dam. Based on monitoring data, the most upstream an Asian carp has been caught or observed is in Dresden Island pool near River Mile 278, which is 18 river miles downstream of the Electric Dispersal Barrier. Given the close proximity, Asian carp pose a real threat to the Electric Dispersal Barrier. The goal of this project is to use surrogate species to assess the potential risk of Asian carp movement through barriers (lock chambers and the Electric Dispersal Barrier). In addition, recapture rates of surrogate species will be used to assess sampling efficiency in the area between the Electric Dispersal Barrier and the Dresden Island Lock and Dam. Surrogate species will be tagged in the Rock Run Rookery, Dresden Island, Brandon Road, and Lockport pools to test the potential risk of Asian carp movement through barriers. Common Carp (*Cyprinus carpio*), Black Buffalo (*Ictiobus niger*), Smallmouth Buffalo (*Ictiobus bubalus*), and Bigmouth Buffalo (*Ictiobus cyprinellus*) will be used as surrogate species because they are naturalized and widespread throughout the CSSC and the upper Illinois River. Common Carp are known to migrate relatively long distances and grow to large sizes that are approximate to those achieved by invasive carps (Dettmers and Creque 2004). Based on these characteristics, Common Carp should provide a good indicator of how Asian carp would respond to the various barriers if they were present. Similarly, *Ictiobus* spp. (Smallmouth, Bigmouth, and Black) make good surrogates based on their migration pattern and large body sizes (Becker 1983).

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

(1) Monitor the movements of tagged surrogate species in Dresden Island, Brandon Road, and Lockport pools and Rock Run Rookery to assess fish movement between barrier structures; and

(2) Obtain information on recapture rates of surrogate species to help verify sampling success using multiple gear types.

Project Highlights:

- Multiple agencies and stakeholders cooperated in successfully tagging 2,273 fish in Lockport pool, Brandon Road pool, Dresden Island pool, and Rock Run Rookery (between March 11, 2015, and December 11, 2015)
- A total of 158 fish were recaptured using pulsed DC-electrofishing, gill nets, trammel nets, and 6-foot-diameter hoop nets
- A total of 78 recaptures had tags but showed no movement between barrier structures, 65 recaptures where observed based on a caudal fin clip but had no tag to show movement, and 15 recapture showed movement through barrier structures and Lock and Dam Structures
- No recaptured fish with a floy tag showed upstream movement through a barrier structure
- Recommend continued tagging of Common Carp, Bigmouth Buffalo, Smallmouth Buffalo, Black Buffalo, and Common Carp x Goldfish hybrid using pulsed DC-electrofishing, gill nets, trammel nets, and 6-foot-diameter hoop nets to monitor fish movement between barrier structures.

Methods: Sampling for Common Carp, Bigmouth Buffalo, Smallmouth Buffalo, and Black Buffalo will be obtained through Fixed and Random Site Monitoring Downstream of the Barrier and Barrier Maintenance Fish Suppression projects (see Monitoring and Response Plan for Asian Carp in the Upper Illinois River of Chicago Area Waterway 2014). The sample design includes electrofishing at four fixed sites and 12 random sites in each of the three pools below the Electric Dispersal Barrier. Contracted commercial netting will include four fixed sites in each pool along with targeted sampling determined by the commercial fisherman in Brandon Road, Lockport, and Dresden Island pools sampled each week. Contracted commercial netting will also include targeted sampling in Rock Run Rookery each week sampled from March to December. Hoop and minnow fyke netting will take place at four fixed sites in each pool once per month. The fixed sites in each of the three pools are located primarily in the upper end of each pool below lock and dam structures, in habitats where Asian carp are likely to be located (backwaters and side-channels), or both. Random electrofishing and contracted commercial fishing sites occur throughout each pool, including the lower portions of each pool as well as in the Kankakee River, from the Des Plaines Fish and Wildlife Area boat launch downstream to the confluence with the Des Plaines River.

Floy tagging and external marking procedure – Floy tags will be anchored to all Common Carp, Bigmouth Buffalo, Smallmouth Buffalo, and Black Buffalo collected. The length of each fish will be recorded in millimeters along with date, location, coordinates, and an individual tag reference number. Floy tags will be anchored by inserting the tag gun needle into a fleshy area below the dorsal fin on the left side of the fish. The needle should be inserted at an acute angle to the body, angling the needle towards the anterior portion of the fish to allow the tag to lie along the side of the fish. The needle should pass the midline of the body but not penetrate the opposite side of the fish. If the T-bar is only held in by the fish's skin, the tag will be removed and the fish will be retagged. A secondary mark on the caudal fin will be given to all fish collected in case of a floy tag malfunction. A fin clip will be given to all fish in the lower portion of the caudal fin at an angle to increase recognition when it is recaptured. In the event of a recapture, fish species and tag number will be recorded. If a floy tag is missing from a recaptured fish possessing a fin clip, a new tag will be inserted and the new number will be recorded.

Results and Discussion: Between March 16, 2015, and December 11, 2015, a total of 2,273 Common Carp, Smallmouth Buffalo, Bigmouth Buffalo, Black Buffalo, and Common x Goldfish hybrids were tagged in Lockport pool, Brandon Road pool, Dresden Island pool, and Rock Run Rookery. Of the total 3,927 fish tagged in 2014 and 2015, 177 were recaptured, which gave a recapture percentage of 4.51 percent (Table 1). Individual recapture percentages were 4.14 percent for Lockport pool, 7.80 percent for Brandon Road pool, 2.56 percent for Dresden Island pool, and 8.84 percent for Rock Run Rookery (Table 1). Of the 158 recaptures in 2015, 15 showed movement from the original pool where they were captured (Table 2). One Common Carp (605 mm) was initially captured and tagged in Lockport pool on May 12, 2015, and was recaptured the next day, May 13, 2015, in Brandon Road pool. This fish travelled 6.72 miles downstream from the tagging location through the Lockport Lock and Dam. Another recaptured fish, a Common Carp (594 mm), was tagged April 29, 2014, in Dresden Island pool and then travelled downstream through the Dresden Island Lock and Dam and the Marseilles Lock and Dam before it was recaptured in Starved Rock Pool May 21, 2015 (Table 2). These surrogate fish demonstrated the ability for movement downstream through the Lockport Lock and Dam, Dresden Island Lock and Dam, and the Marseilles Lock and Dam structures. Thirteen of the 15 recaptured fish that travelled through a barrier structure travelled through the Dresden Island pool and Rock Run Rookery connection. Of these 13 recaptures, four of the recaptured fish moved from Rock Run Rookery into Dresden Island pool, and nine of the recaptured fish moved from the Dresden Island pool into Rock Run Rookery (Table 2). The hydrological data between April 1, 2015, and June 1, 2015, at Dresden Island Lock and Dam showed three spikes in flow that were above the 2015 average of 10,722 cubic feet per second (Figure 1).

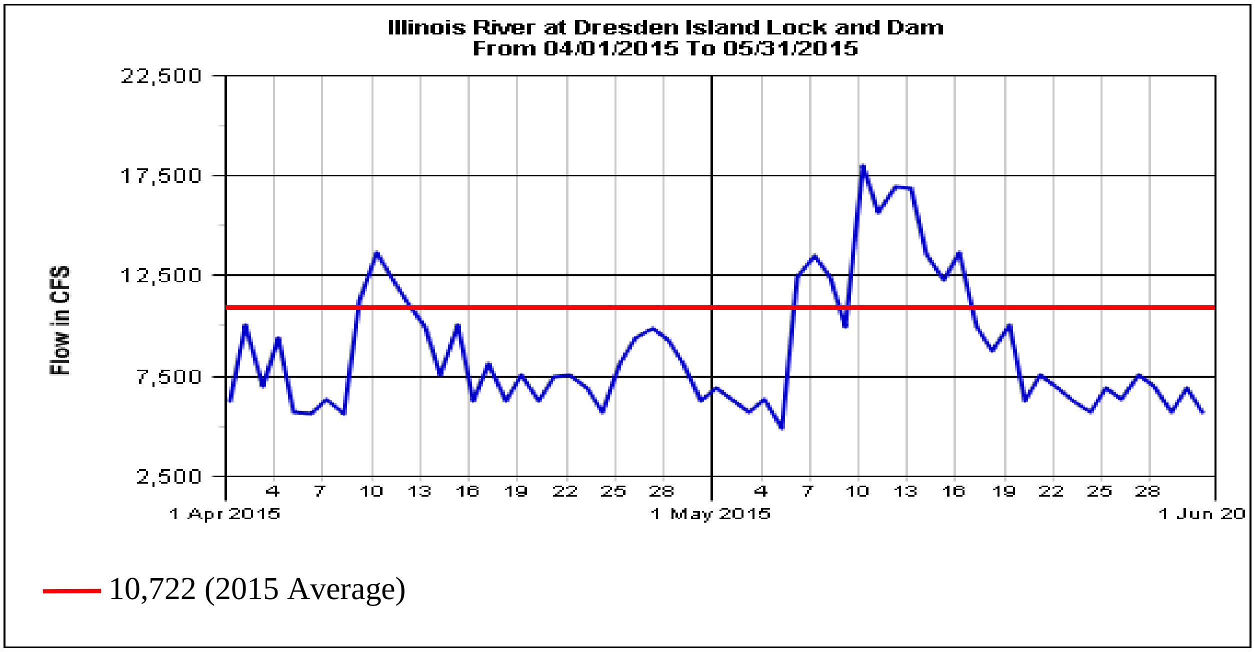


Figure 1: *Dresden Island Lock and Dam flow rates in cubic feet per second (CFS) between the time 3 out of the four recaptured species moved from Rock Run Rookery into Dresden Island Pool and one Common Carp moved from Dresden Island pool downriver to Starved Rock pool*

The spikes in flow might have attributed to the recaptured species moved from Rock Run Rookery moving into Dresden Island pool and 1 Common Carp moved from Dresden Island pool downriver to Starved Rock pool. The hydrological data between July 15, 2015, and December 15, 2015, at Dresden Island Lock and Dam showed one very large spike in flow in early July and then five smaller spikes that were above the 2015 average of 10,722 cubic feet per second (Figure 2). This large spike in flow followed by relatively low flow rates after might have attributed to the recaptured species move from Dresden Island pool into Rock Run Rookery. With the 158 recaptured fish in 2015, we feel floy tag retention has met expectations. Common Carp showed to be the most predominant fish in Lockport and Brandon Road pools, with population estimates of 3,408 in Lockport pool and 4,703 in Brandon Road pool (Table 3). Smallmouth Buffalo showed to be the most predominant fish in Dresden Island pool and Rock Run Rookery, with population estimates of 26,250 in Dresden Island Pool and 2,090 in Rock Run Rookery (Table 3).

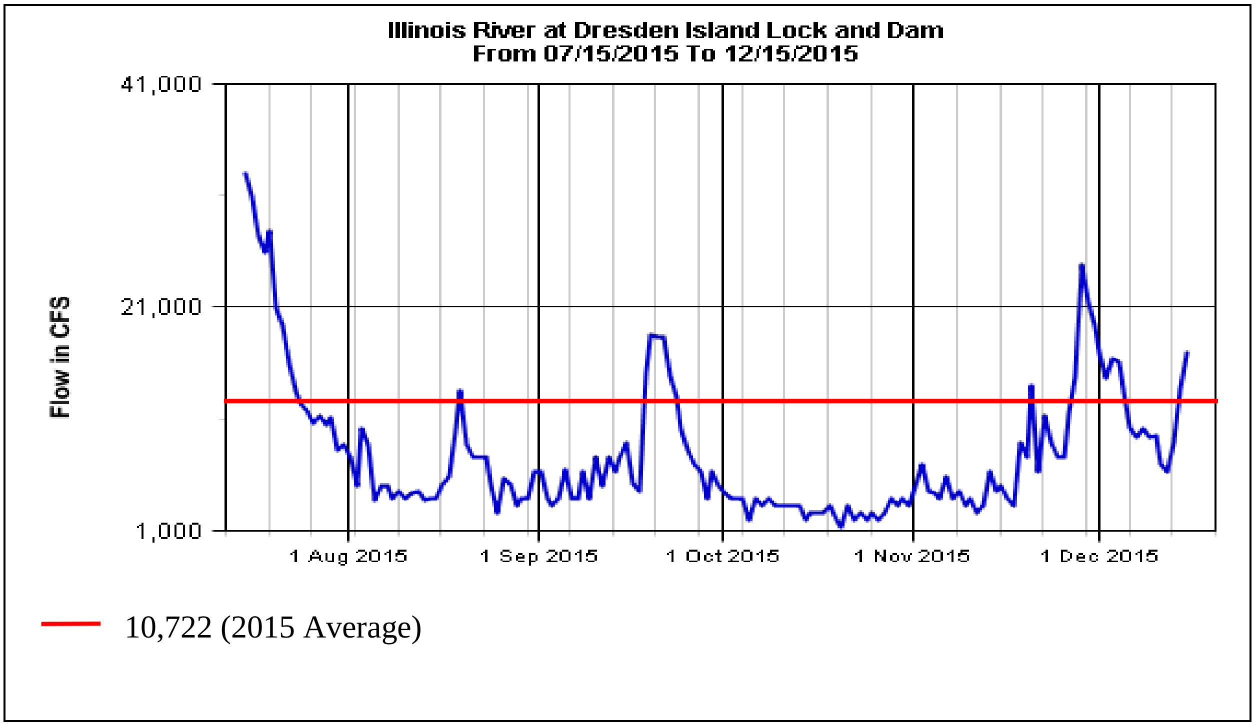


Figure 2: *Dresden Island Lock and Dam flow rates in cubic feet per second (CFS) between the time all recaptured species moved from Dresden Island pool into Rock Run Rookery and one Smallmouth Buffalo moved from Rock Run Rookery into Dresden Island pool.*

Recommendations: The continuation of this project will help us better understand the threat of Asian carp movement through barrier structures. With more data, we will also be able to determine if there is a correlation between fish movement and hydrological data. We recommend the continuation of floy tagging surrogate species through electrofishing, hoop nets, and commercial fishing for all sampling projects in Lockport pool, Brandon Road pool, Dresden Island pool, and Rock Run Rookery. Data collected on surrogate species movement and recapture rates will provide valuable information on how Asian Carp may move through barrier structures.

Literature Cited:

Guy, C. S., H.L. Blankenship, and L.A. Nielsen. 1996. Tagging and Marking. Pages 353-383 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Dettmers, J.M. and S.M. Creque. 2004. Field assessment of an electric dispersal barrier to protect sport fishes from invasive exotic fishes. Annual Report to the Division of Fisheries, Illinois Department of Natural Resources, Illinois Natural History Survey, Center for Aquatic Ecology and Conservation.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison, Wisconsin. 1052 pages.

Understanding Surrogate Fish Movement with Barriers

Table 1: *Number Of Fish Floy Tagged and Recaptured For Areas Sampled in 2014 and 2015*

	Fish Tagged 2014	**Fish Tagged 2015**	**Recapture 2014**	**Recapture 2015**	**Recapture %**
Lockport Pool					
Common Carp	177	130	3	10	
Smallmouth Buffalo	1	0	0	0	
Bigmouth Buffalo	0	0	0	0	
Black Buffalo	0	0	0	0	
Common X Goldfish Hyb.	2	4	0	0	
Total	**180**	**134**	**3**	**10**	**4.14%**
Brandon Road Pool					
Common Carp	276	440	7	48	
Smallmouth Buffalo	4	14	0	4	
Bigmouth Buffalo	0	0	0	0	
Black Buffalo	0	0	0	0	
Common X Goldfish Hyb.	5	17	0	0	
Total	**285**	**471**	**7**	**52**	**7.80%**
Dresden Island Pool					
Common Carp	466	510	1	24	
Smallmouth Buffalo	565	737	4	28	
Bigmouth Buffalo	24	20	1	2	
Black Buffalo	16	29	0	1	
Common X Goldfish Hyb.	1	14	0	0	
Total	**1072**	**1310**	**6**	**55**	**2.56%**
Rock Run Rookery					
Common Carp	9	26	0	4	
Smallmouth Buffalo	86	261	2	28	
Bigmouth Buffalo	21	53	0	5	
Black Buffalo	1	18	0	3	
Common X Goldfish Hyb.	0	0	0	0	
Total	**117**	**358**	**2**	**40**	**8.84%**
Marseilles Pool					
Smallmouth Buffalo			1		
Total			**1**		
Starved Rock Pool					
Common Carp				1	
Total				**1**	
Overall Total	**1654**	**2273**	**19**	**158**	**4.51%**

Table 2: *Distance Recaptured Fish Travelled in Miles Through a Barrier System*

Understanding Surrogate Fish Movement with Barriers

Movement	Species	Date Captured	Area Recaptured	Distance Travelled (miles)
Rock Run Rookery to Dresden Island Pool	Smallmouth Buffalo	4/3/2015	Dresden Pool	0.67
	Bigmouth Buffalo	5/27/2015	Kankakee	N/A
	Smallmouth Buffalo	11/5/2015	Dresden Pool	2.12
	Smallmouth Buffalo	4/27/2015	Dresden Pool	1.85
Dresden Island Pool to Rock Run Rookery	Smallmouth Buffalo	8/14/2015	Rock Run	1.84
	Common Carp	8/21/2015	Rock Run	8.55
	Common Carp	10/16/2015	Rock Run	0.35
	Smallmouth Buffalo	10/16/2015	Rock Run	1.71
	Smallmouth Buffalo	10/16/2015	Rock Run	0.48
	Bigmouth Buffalo	10/16/2015	Rock Run	4.15
	Smallmouth Buffalo	12/9/2015	Rock Run	3.94
	Common Carp	8/21/2015	Rock Run	0.58
	Bigmouth Buffalo	7/17/2015	Rock Run	0.66
Dresden Island Pool to Starved Rock Pool	Common Carp	5/21/2015	Starved Rock	35.71
Lockport Pool to Brandon Road Pool	Common Carp	5/13/2015	Brandon Pool	6.72

Table 3: *Population Estimates of Common Carp, Bigmouth Buffalo, Black Buffalo, and Smallmouth Buffalo with a 95% Confidence Interval*

	SPECIES	Fish Tagged	Fish Recaps	Population Estimate	95% LCI	95% UCI
Lockport Pool	Common Carp	363	17	3408	2174	5627
	Bigmouth Buffalo	0	0	0	0	0
	Black Buffalo	1	0	0	0	0
	Smallmouth Buffalo	1	0	0	0	0
Brandon Road Pool	Common Carp	768	56	4730	3741	6432
	Bigmouth Buffalo	0	0	0	0	0
	Black Buffalo	0	0	0	0	0
	Smallmouth Buffalo	22	4	36	16	86
Dresden Island Pool	Common Carp	999	25	18282	12540	27670
	Bigmouth Buffalo	55	3	341	140	843
	Black Buffalo	46	1	484	147	945
	Smallmouth Buffalo	1332	31	26250	18666	38074
Rock Run Rookery	Common Carp	39	4	115	51	276
	Bigmouth Buffalo	80	5	448	212	1026
	Black Buffalo	22	3	38	15	93
	Smallmouth Buffalo	373	28	2090	1462	3092

Overview: Barge Fish Interaction Trials in the Illinois Waterway

Jeremiah J. Davis, Rebecca N. Neeley, and Samuel T. Finney.
(USFWS Carterville Conservation Office, Wilmington Substation)
P. Ryan Jackson, Frank L. Engel, Jessica Zinger, and Elizabeth A. Murphy
(U.S. Geological Survey, Illinois Water Science Center)

Participating agencies: U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, Wilmington Substation (lead), U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office (lead), U.S. Geological Survey, Illinois Water Science Center (lead), USACE-Chicago District (field/logistical support), USACE-Rock Island District (field/logistical support)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction: Previous research has shown that there may be a warping effect on the electrical field produced by the Electric Dispersal Barrier, located in the CSSC within the CAWS, which is induced by the passage of large steel hulled vessels (Dettmers et al. 2005; Sparks et al. 2010). These studies raised concerns that fish passage at the Electric Dispersal Barrier system could be possible in conjunction with commercial barge traffic. A study conducted by USACE suggested that the electrical field was seriously degraded (-93.4 percent) within the junction gap area between a boxed stern barge and a raked bow barged (rake-to-box junction) when barges configured in that manner crossed the Electric Dispersal Barrier (USACE 2013).

USFWS has been investigating how fish and commercial barges may interact near the Electric Dispersal Barrier since 2012. The first set of experiments examined the effect of the Electric Dispersal Barrier on fish when the fish were placed within the rake-to-box junction gap of a loaded commercial barge in a non-conductive cage. The results of those experiments showed that fish (160 to 511 mm) that traversed the Electric Dispersal Barrier within the rake-to-box junction gap between barges were not incapacitated (Parker and Finney 2013). This finding raised concerns that fish passage could occur if fish were present within the rake-to-box junction gap during barge passage at the Electric Dispersal Barrier. Another set of experiments by USFWS used fish that were tethered to floats. Results from this study showed that when tethered fish encountered a barge tow moving upstream they could become entrained within flows around the barge and transported across the Electric Dispersal Barrier with the barge tow. Some of those fish were also entrained within the rake-to-box junction gap during passage (Parker and Finney 2013). During 2015, we initiated a series of experimental trials with the objective of quantifying entrainment rates, retention rates, and the potential for upstream transport of freely swimming (non-caged/non-tethered) fish within rake-to-box barge junction gaps. These experiments also investigated flow dynamics around moving barges and the impact of potential barriers to upstream dispersal on fish entrainment dynamics.

Overview: Barge Fish Interaction Trials in the Illinois Waterway

Objectives:

- Quantify flow velocity distributions near moving barges in the Illinois Waterway.
- Evaluate the potential for entrainment of freely swimming fish by barge tows.
- Determine the potential for entrained fish to be retained inside gap spaces in the barge junction and then transported upstream.
- Examine the effects of lockages and the Electric Dispersal Barrier system on entrainment and retention dynamics.

Methods:
A commercial barge tow consisting of a tow boat and four loaded barges was contracted for these experiments. The barge tow was configured so that a rake-to-box junction gap was located at the center of the tow. Inside this junction gap, a multi-beam sonar system (Sound Metrics ARIS 3000) was installed to track fish movements, and acoustic Doppler velocity meters (SonTek Argonaut SW ADVM) were installed to monitor flow velocities. 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 gap.

A series of mark capture experiments were conducted using hatchery reared Golden Shiners (*Notemigonus crysoleucas*) (63 to 122 mm). The Golden Shiners were marked with fin clips before each trial and stocked at different locations around the moving barge tow. The barge tow then traveled upstream through various reaches of the Illinois Waterway. Fish recapture events took place at the conclusion of each trial. 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.

These experimental trials took place at the Electric Dispersal Barrier, in the Lockport navigation pool, Brandon Road Lock, Lockport Lock, and within the Brandon Road navigation pool. One set of experiments looked at the potential for freely swimming fish that encountered a barge tow moving upstream to become entrained within the rake-to-box junction gap. Another set of trials assessed the retention of fish that were entrained within the gap as the barge tow traversed the Electric Dispersal Barrier and underwent upstream lockage operations at Brandon Road Lock. A third set of trials quantified retention rates of freely swimming fish over longer distances as the barge tow moved upstream through the Illinois Waterway. Results are summarized in Table 1.

Overview: Barge Fish Interaction Trials in the Illinois Waterway

Table 1. *Description of experimental trials completed during the 2015 barge fish interaction study*

Trial Type	Number of Trials	Physical Location	Fish Stocking Location	Fish Recapture Location	Distance Traveled (km)
Entrainment	6	Electric Dispersal Barrier	In front of tow	Rake-to-box junction	1.0 km
Retention	6	Electric Dispersal Barrier	Rake-to-box junction	Rake-to-box junction	1.0 km
Retention	3	Brandon Road Lock Location 1	Rake-to-box junction	Rake-to-box junction	0.38 km
Retention	3	Brandon Road Lock Location 2	Rake-to-box junction	Rake-to-box junction	0.9 km
Transport	2	Lockport Pool and Electric Dispersal Barrier	Rake-to-box junction	Rake-to-box junction	5.4 km and 7.6 km
Transport	1	Brandon Road Pool, Lockport Lock, Lockport Pool, Electric Dispersal Barrier	Rake-to-box junction	Rake-to-box junction	15.5 km

Results and Discussion:
The results of this study are pending final data processing and review as of January 13, 2015; once internal and peer review is completed, the full methods and results of this project will be provided as a peer reviewed manuscript and can be accessed here:

PDF. Link

Recommendations:

(1) The preliminary results of this project have raised many additional questions. We recommend that field trials continue in 2016 to address these new questions.

Overview: Barge Fish Interaction Trials in the Illinois Waterway

Literature Cited:

Dettmers, J.M., Boisvert, B.A., Barkley, T., Sparks, R.E., 2005. Potential impact of steel hulled barges on movement of fish across an electric barrier to prevent entry of invasive carp into Lake Michigan. October 2003 – September 2005. Completion Report for US FWS; INT FWS 301812J227

Parker, A.D., Finney, S.T., 2013. Preliminary Results of Fish-Barge Interactions at the Electric Dispersal Barrier in the Chicago Sanitary and Ship Canal. U.S. Fish and Wildlife Service Midwest Fisheries Program. Accessed November 30, 2015, at *http://www.fws.gov/midwest/fisheries/carterville/documents/barge.pdf*

Sparks, R.E., Barkley, T.L., Creque, S.M., Dettmers, J.M., Stainbrook, K.M., 2010. Evaluation of an Electric Fish Dispersal Barrier in the Chicago Sanitary and Ship Canal. In: Chapman, D.C., Hoff, M.H. (Eds.), Invasive Asian carps in North America. American Fisheries Society, Symposium 74, Bethesda, Maryland, pp. 139–161.

U.S. Army Corps of Engineers, 2013. Summary of Fish-Barge Interaction Research and Fixed Dual Frequency Identification Sonar (DIDSON) Sampling at the Electric Dispersal Barrier in Chicago Sanitary and Ship Canal, accessed December 1, 2015 at *http://www.lrc.usace.army.mil/Portals/36/docs/projects/ans/docs/Fish-Barge%20Interaction%20and%20DIDSON%20at%20electric%20barriers%20-%2012202013.pdf*

Monitoring of Fish Abundance and Spatial Distribution in Lockport, Brandon Road, and Dresden Island Pools and the Associated Lock and Dam Structures

Jeremiah J. Davis, Rebecca N. Neeley, Samuel T. Finney, and Robert L. Simmonds Jr.
(USFWS Carterville, Wilmington Substation)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

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

Introduction: The Electric Dispersal Barrier in the 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 barrier system at different times throughout the year, primarily during the summer and fall (Parker and Finney 2013). How fish interact with the Electric Dispersal Barrier over varying temporal scales (i.e. 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 system 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 remote sensing surveys were performed on a weekly to bi-weekly basis throughout the spring and summer of 2015. The results from these surveys are communicated to the ACRCC within one week of each survey so that managers have up to date information on fish density near the Electric Dispersal Barrier when making management decisions.

Additionally, split beam hydroacoustic remote sensing surveys of the Lockport, Brandon Road, and Dresden Island navigation pools were undertaken in the upper Illinois Waterway during spring, summer, and fall in 2014 and 2015. This work allowed for a greater understanding of the dynamics of temporally varying fish densities, patterns in spatial distribution within the study pools, and size frequency 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 more informed decisions. Additionally, identification of areas of high fish density may help to better target ongoing Asian carp removal efforts.

The Great Lakes Mississippi River Interbasin Study (GLMRIS) was released in January 2014 and presents a comprehensive range of options and technologies available to prevent the inter-basin transfer of ANS between the Great Lakes and Mississippi River Basins through aquatic pathways. A study of the feasibility of implementation of ANS control measures at Brandon Road Lock and Dam is being undertaken by USACE. Gaining a greater understanding of fish abundance, behavior, and movements in and adjacent to the Brandon Road Lock and Dam will help to inform potential GLMRIS actions at the Brandon Road Lock and allow for evaluations of the efficacy of any measures that are implemented. Preliminary hydroacoustic surveys within and near the Brandon Road Lock chamber were conducted to quantify the extent of fish utilization of the structure and evaluate the potential for lock chamber mediated fish dispersal between reaches. To further enhance monitoring at the Brandon Road Lock chamber and gain insights on patterns of fish movement near the lock chamber a stationary acoustic remote sensing system was deployed above the Brandon Road Lock chamber during summer 2015.

Objectives:

1) Evaluate the density and size structure of the fish community directly below the Electric Dispersal Barrier system throughout the year.
2) Determine the density and distribution of fish in upper navigation pools on the Illinois Waterway throughout the year.
3) Evaluate size structure of fish in the study reaches and quantify seasonal changes.
4) Determine the extent of fish utilization of the Brandon Road lock structure.
5) Identify trends in fish movement patterns into and out of the Brandon Road Lock chamber.
6) Identify large fish targets in the study pools suspected of being Asian carp to direct targeted sampling efforts at these fish for removal.

Project Highlights:

- There were significantly greater mean total densities of fish observed immediately below the Electric Dispersal Barrier during the summer than in spring or winter.
- High relative densities of fish were shown to be present within the Brandon Road Lock structure during both summer and fall.

Monitoring of Fish Abundance and Spatial Distribution in Lockport, Brandon Road, and Dresden Island Pools and the Associated Lock and Dam Structures

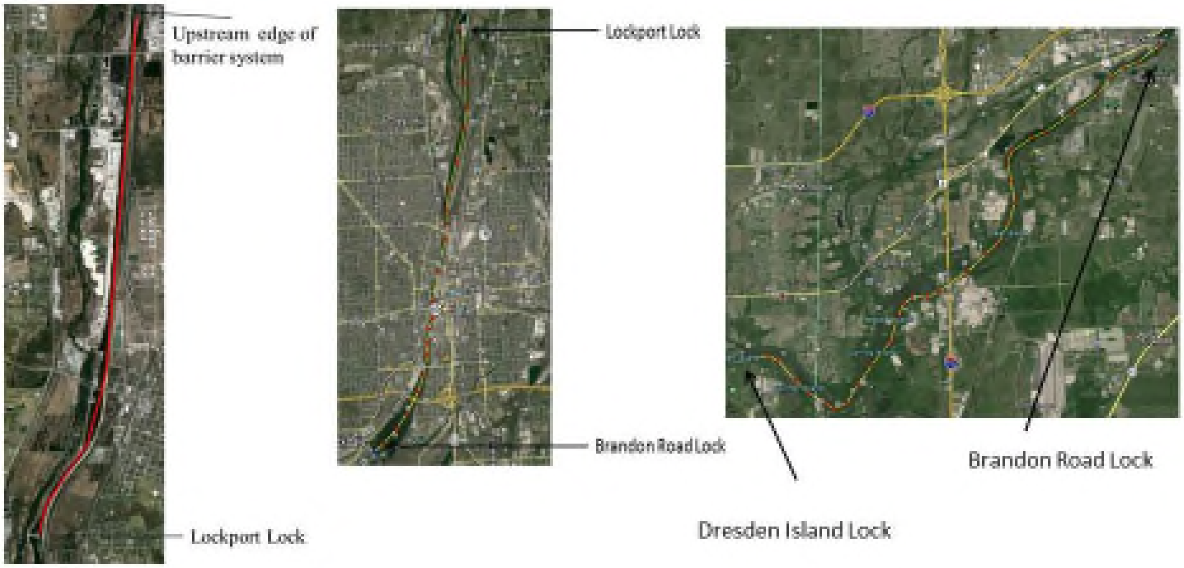


Figure 1. *Satellite photos of our study areas. (A) 5.4 mile stretch of the Lockport pool in the CSSC. (B) 4.8 mile stretch of the Brandon Rd. pool and (C) 14.5 mile stretch of Dresden Island pool where split beam hydroacoustic remote sensing surveys took place.*

Methods:

Acoustic Fish Surveys below the Electric Dispersal Barrier: A series of side-looking split beam hydroacoustic remote sensing 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 March and July 2015 on a weekly to bi-weekly basis. Survey transects began below the barrier system (≈ 300 m) at 41° 38.200 N, 88° 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 barrier system, turned south, and then traveled closely along the east wall back to 41° 38.200 N. Five consecutive replicate hydroacoustic surveys took place on each survey date.

The hydroacoustic survey equipment consisted of a pair of Biosonics® 200 kHz split-beam transducers. The two split-beam 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 rotators repositioned the transducers to preset positions every 45 seconds. One transducer was set to -3.3° and the other to -9.9° below parallel from the water surface. Split beam acoustic data was collected using Visual Acquisition v.6® from 1.15- 55 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 the near-field effect (Simmonds and MacLennon 2005; Garvey et al. 2011). 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 data collections. The split-beam acoustic transducers were calibrated on-axis with a 200 kHz tungsten carbide sphere before sampling following Foote et al. (1987).

Split beam hydroacoustics data were post-processed in Echoview® v. 6.0. After a calibration offset was applied to account for measured and theoretical target strength (-TS) response from each transducer, data were loaded into a mobile survey template. The template used angular position and -TS to identify and estimate the size and location of single fish targets. Data post processing followed standard methods (Glover et al. unpublished data). Data that were collected outside of the analysis bounds (between 41^0 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 and fish tracks were identified using algorithms within the analysis software and the Echoview Fish Tracking Extension®, and single target -TS was converted from -db to target length using equations derived from Love, 1977. 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.

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 normalized to meet assumptions of parametric tests where necessary using log10 transformations. One-way Analysis of Variance (ANOVA) with significance at $\alpha = 0.05$ was used to test for differences in mean densities between sampling dates with pairwise comparisons using the Holm-Sidak post-hoc test.

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 seasonally between 2013 and 2015. The surveys were conducted using the same equipment, collection techniques, and analysis methods as were employed during other hydroacoustic surveys. 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 (≈55 m) several concentric transects were conducted.

Brandon Road Lock Mobile Acoustic Surveys: Acoustic remote sensing surveys were conducted within and adjacent to the Brandon Road Lock structure on September 11 and November 5, 2014 using the same equipment and methods described for other hydroacoustic surveys. Data processing and analysis methods also remained consistent between surveys. Briefly, the research vessel entered the lock chamber from downstream with the lock chamber emptied (depth over sills ≈ 5 m). The vessel then conducted three replicate transects around the inside of the lock chamber in a clockwise fashion staying as close as possible to the wall while surveying the opposite side of the chamber. These surveys conducted during 2014, were done to answer a variety of preliminary questions. First, to what extent are fish utilizing the lock structures as habitat? Second, what effects do locking operations have on the abilities of acoustic remote sensing gears to quantify fish density and size? Third, what survey design will be best suited to quantify between reach movements of fish through the lock chambers in our study area.

Brandon Road Lock Stationary Acoustic Monitoring: A stationary acoustic remote sensing system was deployed approximately 40 meters upstream from the Brandon Road Lock chamber during 2015. This system utilized two transducers (120 kHz and 420 kHz) that were aimed across the approach channel in a side looking configuration. This configuration provided acoustic coverage from surface to bottom across approximately 20 m of the opposite canal wall when measured from the opposite canal wall (Figure 2).

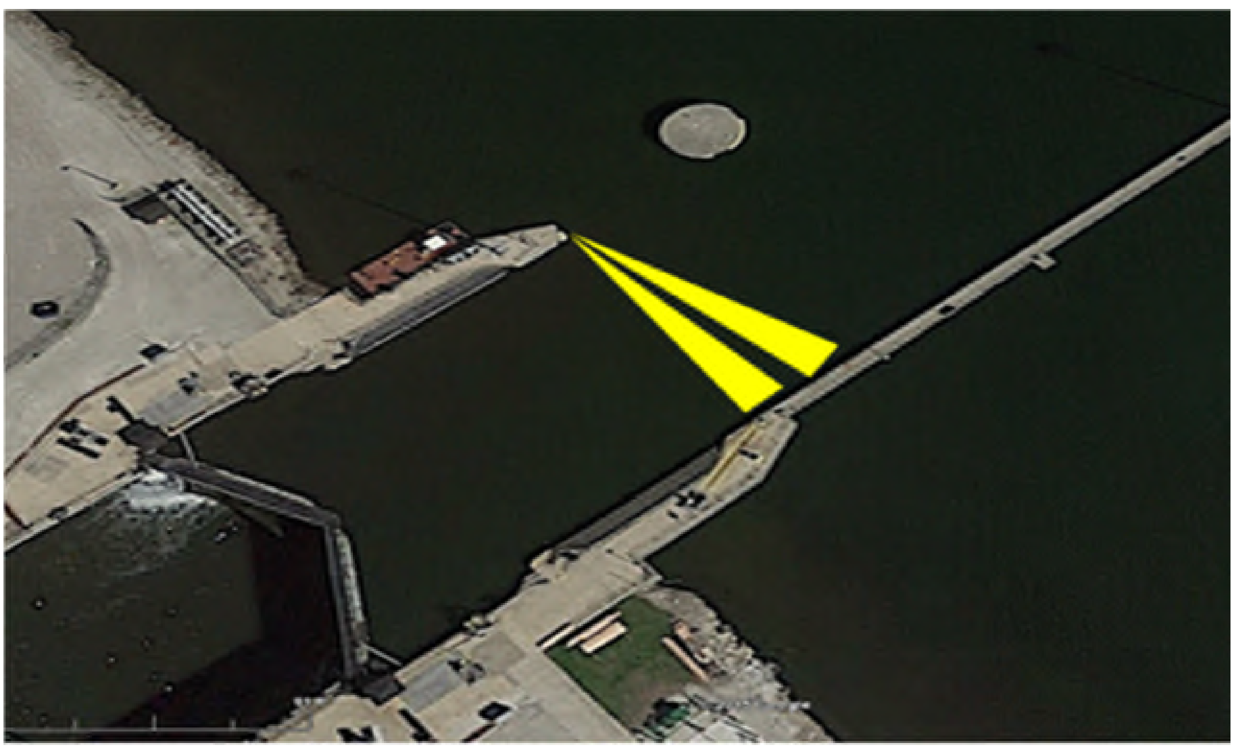


Figure 2. *An overhead view of the approach channel upstream of the Brandon Road Lock shows approximate acoustic beam coverage.*

The transducers were powered by a Biosonics DTX® echo sounder operating at 3.0 pings per second with a 0.40 ms pulse width. The echo sounder data was routed into a control module running Visual Acquisition v.6® and Auto Track® data acquisition and automated fish tracking software (Figure 3).

Monitoring of Fish Abundance and Spatial Distribution in Lockport, Brandon Road, and Dresden Island Pools and the Associated Lock and Dam Structures

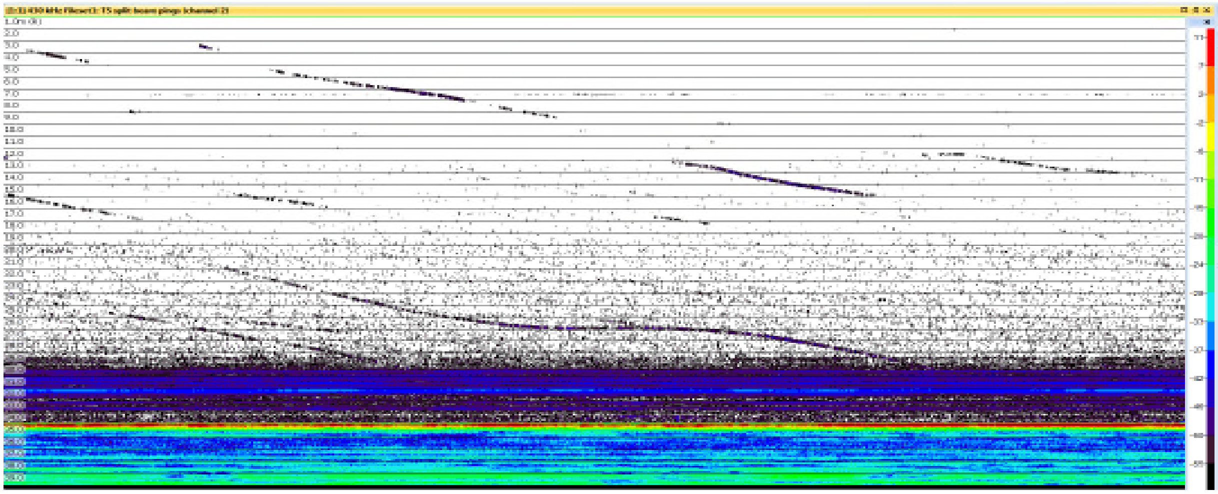


Figure 3. *Example of an echogram showing fish tracks collected as fish swam through the acoustic beam of the stationary monitoring system upstream of the Brandon Road Lock.*

This system allowed for continuous data collection and real time fish track data processing twenty four hours a day throughout the entire study period (June, 25-September, 29 2015). During the course of the stationary deployment over 2100 hours of acoustic data were collected and more than 1100 lockage operations took place. Given the large amount of data, a sub-sampling procedure was used to provide preliminary results. A random number generator was used to identify 35 random upstream lockages of interest from each month of data collections (July, August, and September). During these lockage operations, the period of time from when the upstream lock gates opened until the barge tow moved upstream past the monitoring system was analyzed. Additionally, the 15 minute period before the lock gates opened was analyzed to provide contrast in fish density and movement direction patterns between periods when the gates were and closed. Fish density was standardized to fish detected per minute and the number of fish detected that were moving in either the upstream or downstream directions was quantified.

Results and Discussion:

Fish Surveys below the Electric Dispersal Barrier: Results from acoustic surveys conducted directly below the Electric Dispersal Barrier during 2015 suggested that fish density during late winter was very low (mean = 0.071 fish/1000m^3 SD = 0.087, n=3). During the spring fish density below the Electric Dispersal Barrier increased (mean = 0.47 fish/1000m^3 SD = 0.50, n=12). In the summer, fish density below the Electric Dispersal Barrier peaked on June 22 at a mean density of 2.09 fish/1000m^3 (SD = 0.72, n=5) (Figure 4).

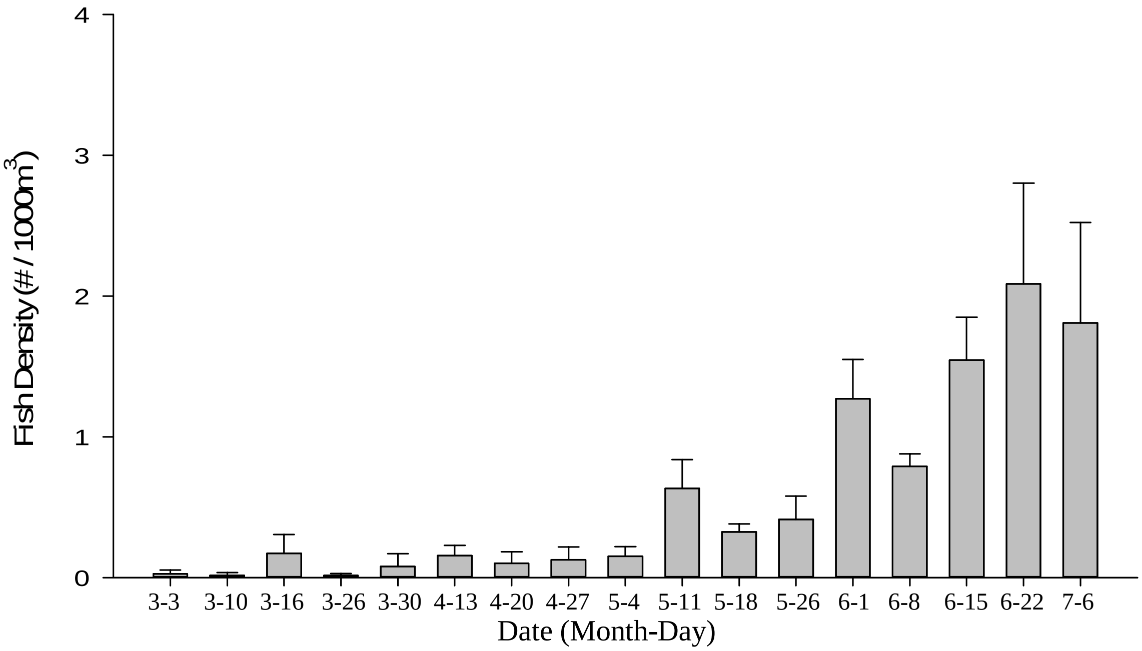


Figure 4. *Fish density (# / 1000m3) observed from the downstream edge of the barrier IIA parasitic structure to 500 m below (except during 6-1; from the downstream edge of barrier IIB) during weekly split beam hydroacoustic surveys conducted during 2015 . Error bars denote S.D.*

The fish targets encountered during the surveys were estimated to be primarily < 150 mm. However, several larger fish targets were observed during the surveys (up to 843 mm). These results follow trends that were previously observed in the Lockport navigation pool (Asian Carp Regional Coordinating Committee Monitoring and Rapid Response Workgroup, 2015). Increased fish density during the late spring and summer were likely driven by an influx of YOY fishes into the community.

Illinois River Pool Surveys: Results from the intensive acoustic remote sensing survey conducted in the Lockport navigation pool between 2013-2015 showed relatively stable and low fish densities throughout the winter and spring. Fish densities were then observed to increase in July and peak in August; this was followed by substantial declines as fall progressed. These trends remained consistent among years. Results from the 2014 surveys suggested that during the spring, total fish density was greater in the Brandon Road (0.56 fish / 1000 m^3) and Dresden Island (0.65 fish / 1000 m^3) pools than in the Lockport pool (0.16 fish / 1000 m^3). During summer, fish density in the Dresden Island Pool remained consistent with the density observed in the spring (0.63 fish / 1000 m^3) while fish densities in the Lockport and Brandon Road pools increased dramatically (1.75 and 3.52 fish / 1000 m^3, respectively). During 2015, surveys showed greater mean densities of fish in the spring throughout all study pools than were observed in 2014. Mean fish density during spring surveys in Lockport, Brandon Road, and Dresden pools were 1.92 fish/1000 m^3, 3.94 fish/1000 m^3 , and 2.77 fish/1000 m^3, respectively.

The lowest density of large fish was observed in the Brandon Road Pool (0.019 fish / 1000 m^3), followed by Lockport (0.046 fish / 1000 m^3), and Dresden Island (.074 fish / 1000 m^3). During summer, substantial increases in large fish density were observed in Lockport (0.22 fish / 1000 m^3) and Brandon Road (0.23 fish / 1000 m^3) pools while density remained consistent with spring levels within the Dresden Island Pool (0.060 fish / 1000 m^3). During fall surveys, large fish density in both Lockport (0.072 fish / 1000 m^3) and Brandon Road (0.16 fish / 1000 m^3) pools fell from summer levels while substantial increases in large fish density were observed in the Dresden Island Pool (0.52 fish / 1000 m^3). Although the majority of the increases in fish density appeared to be driven by YOY recruitment and potentially upstream migration of these recruits, substantial increases in the density of large fish were observed during the summer in the Lockport and Brandon Road pools and during the fall in Dresden Island Pool.

Brandon Road Lock Mobile Acoustic Survey: Results from surveys conducted inside the Brandon Road Lock structure answered the preliminary questions. First, fish are utilizing the Brandon Road Lock structure as habitat and were present at densities greater than were observed in the Lockport, Brandon Road, or Dresden Island study reaches during the same season, despite the lock doors being closed except to receive in-coming vessel traffic. Mean total fish densities in the Brandon Road Lock were observed during summer and were well above any densities observed throughout our remote sensing study (mean = 38.63 fish / 1000 m^3). During fall, densities decreased dramatically but remained higher than levels observed throughout the remainder of the study area (mean = 4.41fish / 1000 m^3) (Table 1). Second, the acoustic remote sensing gear proved very efficient at observing and quantifying fish density within the lock chambers both at the empty stage and at the full stage. It was also very efficient at surveying inside the lock during the emptying cycle. During the filling cycle air bubbles obscure the equipment for approximately ten minutes after filling when surveying inside the chamber. Air bubbles are also problematic during emptying when positioned outside of the chamber on the downstream side.

Table 1. *Mean total fish density (# / 1000 m^3) observed during summer and fall 2014 acoustic remote sensing surveys in the Upper Illinois River.*

Location	Summer (# fish / 1000 m^3)	Fall (# fish / 1000 m^3)
Brandon Rd. Lock	**38.63**	**4.41**
Lockport Pool	**1.75**	**0.44**
Brandon Rd. Pool	**3.52**	**1.57**
Dresden Pool	**0.63**	**2.27**

Brandon Road Lock Stationary Acoustic Monitoring: Results from initial data processing of stationary acoustic data collected above the Brandon Road Lock suggested that fish abundance varied greatly. During periods when the lock chamber doors were closed a mean of 27.81 fish/min. (SD = 19.61, n=105) were detected. The abundance of fish above the lock chamber was highly variable. A maximum of 88.87 fish/min were observed while the minimum number of fish detected per minute was 3.67. The median number of fish detected per minute during periods when the upstream lock gates were opened (23.96 fish/min.) was compared with periods when the lock gates were closed (23.93 fish/min.). There was no significant difference in fish abundance ($P = .601$, $n=105$). There was also no significant difference in the number of fish moving upstream ($P=0.125$) or downstream ($P= 0.419$) between treatments. Although these preliminary results do not show significant differences in fish abundance or behavior depending on whether the upstream lock gates are opened or closed, there is a large amount of data that has yet to be completely analyzed. Forthcoming analysis will quantify temporal trends in fish abundance near the lock chamber, describe changes in the size structure of the fish community present on a temporal scale, and further investigate changes in behavior and abundance that may occur as vessels exit the lock chamber.

Conclusion: These studies provided insights on the dynamics of fish communities throughout the upper portion of the Illinois Waterway that would be unattainable using traditional fisheries survey gear. These studies also allowed changes in density across large spatial areas and throughout multiple temporal scales to be examined and these insights will be useful for identifying risk and designing further studies. In addition, this study allowed the opportunity to refine techniques and challenge limitations of the acoustic remote sensing gear.

Recommendations:

1) Continue monitoring spatial and temporal dynamics in within the Illinois Waterway fish communities to detect changes in biomass or habitat utilization that could be indicative of changes in community structure.
2) Continue real time monitoring of survey data to inform management agencies of suspected ANS observations.

Literature Cited:

Foote, K.G., H.P. Knudsen, G. Vestnes, D.N. MacLennan, E.J. Simmonds. (1987). Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Cooperative Research Report, No. 144.

Garvey, J.E., G.G. Sass, J.Trushenski, D.C. Glover, P.M. Charlebois, J. Levengood, I. Tsehaye, M. Catalano, B.Roth, G. Whitledge, B.C. Small, S.J. Tripp, S. Secchi, W. Bouska. (2011). Fishing down the bighead and silver carps: reducing the risk of invasion to the Great Lakes. Final Report to the U.S. Fish and Wildlife Service and the Illinois Department of Natural Resources. 187 pp.

Jarvis, T. (2014) Personal Communication. Echoview Training Seminar. OSU. Columbus Ohio. April 7, 2014.

Love, R. H. (1977). Target strength of an individual fish at any aspect. The Journal of the Acoustical Society of America, 62(6), 1397-1403.

Parker, A.D., Finney, S.T., (2013). Preliminary Results of Fish-Barge Interactions at the Electric Dispersal Barrier in the Chicago Sanitary and Ship Canal. U.S. Fish and Wildlife Service Midwest Fisheries Program. Accessed November 30, 2015, at http://www.fws.gov/midwest/fisheries/carterville/documents/barge.pdf

Schultz, D. W. (2006). Quantifying Fish Movement between the Illinois River and an Associated Backwater. Thesis, Southern Illinois University, Carbondale, Illinois.

Shanks, M. and Barkowski, N. (2014). Telemetry Monitoring Plan. 2013 Report to the Monitoring and Rapid Response Workgroup of the Asian Carp Regional Coordinating Committee.

Simmonds, J. and D. MacLennon. (2005). Fisheries acoustics: theory and practice, 2nd edition. Blackwell Publishing, Oxford.

Stainbrook, K. M., Dettmers, J. M., and T.N. Trudeau. (2007). Predicting suitable Asian carp habitat in the Illinois waterway using geographic information systems.

Steidl, R. J., Hayes, J. P., & Schauber, E. (1997). Statistical power analysis in wildlife research. The Journal of Wildlife Management, 270-279.

Monitoring Fish Abundance and Behavior at the Electric Dispersal Barrier

Preliminary Results of Fixed DIDSON Evaluations at the Electric Dispersal Barrier in the Chicago Sanitary and Ship Canal

Jeremiah Davis, Rebecca Neeley, Samuel Finney, and Robert Simmonds, Jr.
(USFWS Carterville Wilmington Substation)

Participating agencies: U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office Wilmington Substation (lead), U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office (lead), U.S. Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office (field support), USACE-Chicago District (field/logistical support), USACE-Rock Island District (field/logistical support), USACE-Champaign Construction Engineering Research Laboratory (field/logistical support).

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction: Previous studies conducted by the Carterville FWCO have suggested that small fish congregate below the Electric Dispersal Barrier during the summer. Some of those data indicated that small fish were potentially present directly over the portion of the barrier system that produces the greatest in-water electrical field (Parker et al. 2015). To investigate these observations further, crews deployed a pair of Dual Frequency Identification Sonar (DIDSON) units from a shore based telescopic boom lift into the canal. The multi-beam sonar system made direct observations of fish behavior directly over the narrow array structure of Electric Dispersal Barrier IIB over the course of three field seasons (2013 to 2015). The DIDSON units used a series of 96 separate acoustic cones that are integrated to produce video-quality acoustic images. This sampling system produced real-time observations of fish behavior in the canal over the portion of Barrier IIB that exhibited the highest electrical field strength.

Objectives:

- Determine the behavior of fish near the Electric Dispersal Barrier system.
- Document any breaches of the narrow array at Barrier IIB
- Quantify the species and length frequency distribution of any fish that exhibit barrier passage.

Project Highlights:

- Schools of small fish were able to breach the narrow array of Barrier IIB frequently during 2013 (passage in 61 percent [n= 44 of 72] of samples; Only Barrier IIB active; water temperature = 22.8-26.8°C)
- No fish were observed crossing the Barrier IIB narrow array during October 2014 (Barrier IIA and IIB active; water temperature = 15.8-17.4°C)

Monitoring Fish Abundance and Behavior at the Electric Dispersal Barrier

Preliminary Results of Fixed DIDSON Evaluations at the Electric Dispersal Barrier in the Chicago Sanitary and Ship Canal

- Schools of small fish were able to breach the narrow array of Barrier IIB during 2015 (passage observed in 11.3 percent [n=41of 362] of samples, Barrier IIA and IIB active; water temperature = 21.0-25.1°C); however, we observed large schools of medium sized juvenile Gizzard Shad (72 to 102 mm) that did not appear to be able to breach the narrow array.
- During the passage of commercial barge tows, the electrical field at Barrier IIB was reduced (mean=16.7 percent at center of narrow array).
- During the passage of commercial barge traffic in the downstream direction, large schools of fish were able to move upstream through the entire narrow array at Barrier IIB in 66 percent of samples (n=9).

Methods:

Prior to shore-based sampling, two DIDSON units were deployed off of a boat within the narrow arrays. Through that initial work, it was determined that when two DIDSON units were deployed 3.7 meters apart (parallel to the western canal wall), and 10 meters east of the wall, the entire 9-meter width of the narrow array electrode at Barrier IIB could be ensonified (Figure1).

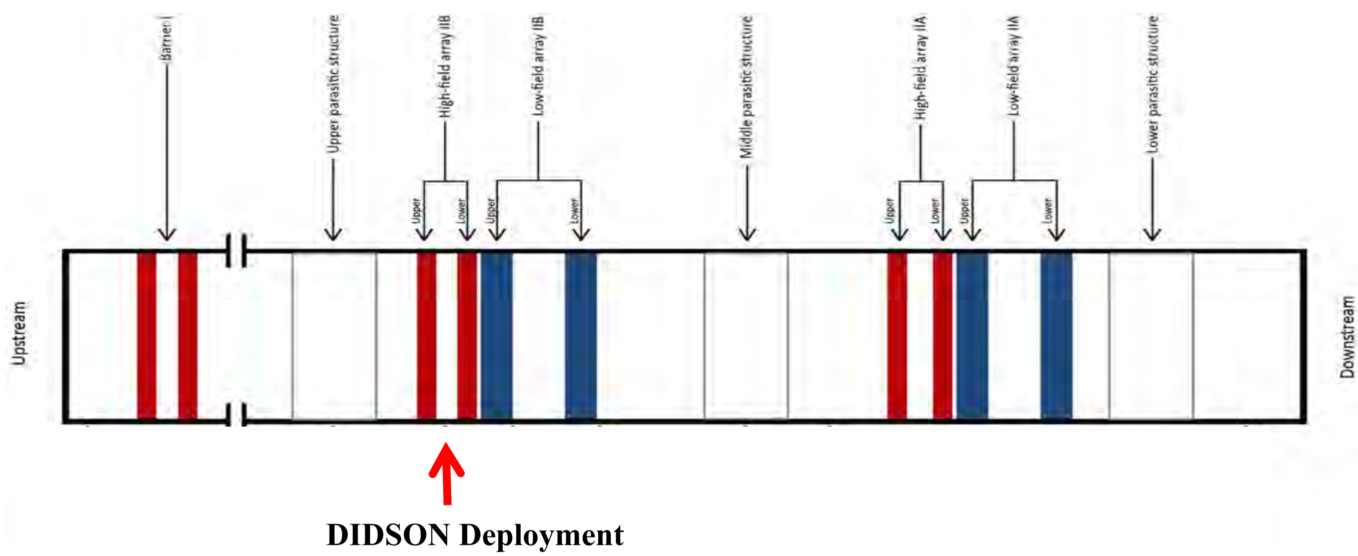


Figure 1. *Schematic diagram of the CSSC Electric Dispersal Barrier system showing the location of the DIDSON deployment. The red lines denote the locations of narrow electrode arrays (high-field) and the blue lines denote the locations of wide electrode arrays (low-field). DIDSON deployment took place over the Barrier IIB narrow array during all study years (2013-2015).*

The USACE Champaign Construction Engineering and Research Laboratory (CERL) identified the exact locations of the narrow array margins and the area of highest in-water voltage along the western canal wall to use as references for later sampling with the DIDSON units. A Trimble GeoXH (Trimble Navigation Limited, Sunnyvale, California) GPS unit, with a maximum margin of error of ± 0.1 meter, was used to mark the upstream margin of the lower narrow array and the downstream margin of the upper narrow array (Figure 2).

The location of the highest in-water voltage was determined using a Fluke model 124 industrial oscilloscope. These locations were permanently marked with marker plaques embedded into the concrete walkway. The markers were subsequently used as reference points to deploy reference markers into the canal. The reference markers were positioned directly over the upstream and downstream margins of the narrow array and in the center of the narrow array at the point of highest strength of the electrical field. These markers served as reference points that could be observed with the DIDSON units to ensure that the units were positioned correctly.

The two DIDSON units were deployed into the canal from the western canal wall using a mobile telescopic boom lift (Figure 2A-C). The DIDSON units were attached to custom-made mounts including a dielectric coupler that attached the DIDSON mount to the cage at the end of the boom. This coupler electrically isolated the boom lift from the electricity in the water. The DIDSON units were deployed 10 meters from the western canal wall, 0.5 meter below the water surface, and were aimed toward the western wall. Both of the DIDSON units were simultaneously operated from one computer (Figure 2D).

Figure 2. *Two DIDSON units being deployed into the CSSC using a telescopic boom lift (A-C) and the two DIDSON units being operated on one computer (D).*

The two DIDSON units were able to ensonify the entire width of the Barrier IIB narrow array. The DIDSON units were positioned so that the entire downstream array marker was clearly visible in the DIDSON cone to focus the study on fish that were swimming upstream. The middle marker denoting the area of the ultimate field strength was visible on both DIDSON cones. By positioning the DIDSON units this way, if fish were to swim immediately adjacent to the canal wall and past the ultimate field strength marker, they would be briefly ensonified within both the upstream and downstream DIDSON viewing cones before they proceeded farther upstream. However, only a portion of the upstream marker is visible within the upstream DIDSON viewing cone because the DIDSON units were positioned slightly downstream (Figure 4).

In addition to DIDSON data collections, surveys were conducted to characterize the fish community present directly downstream of the Electric Dispersal Barriers and quantify the length frequency distribution of each species present during study periods. Crews from the USFWS Columbia Fish and Wildlife Conservation Office conducted paupier and dozer trawling directly over and immediately downstream of the Electric Dispersal Barrier. During the barrier collections, the survey boat traveled downstream from above the barrier, deployed the trawl just above the Barrier IIB narrow array, trawled over the target area, and lifted the gear immediately after it exited the Electric Dispersal Barrier (Fig.3).

During 2014 and 2015, a Fluke 124 industrial oscilloscope with an x,y,z electrical probe was used to measure the electrical field that was present over Barrier IIB at the surface, near (< 0.1 meter) the western canal wall. Baseline measurements were taken at the point of highest field strength and at the upper and lower margins of the Barrier IIB narrow array daily. Measurements were also taken on a finer spatial scale (every 2.5 meters) over the entire wide array (n=2) and narrow arrays (n=6) at Barrier IIB on several occasions during the study.

During 2015, several additional data collection techniques were employed. To better characterize the environment in the canal during data collections, a Marsh McBirney mechanical flow meter was attached directly to the mount of the DIDSON units to quantify flow velocity during data collection periods. Additionally, underwater cameras were attached to the top of each DIDSON unit in an attempt to identify the species of fish that were being observed with the sonar equipment.

Also during 2015, several data collections were conducted concurrent with the passage of a loaded commercial barge tow. During these trials, the DIDSON units collected data using the same methods as all other data collections while the barge tow traversed the barrier in both the upstream (n=10) and downstream (n=9) directions (Figure 5). (For specifics on the barge tow configuration, see Preliminary Results of Barge Fish Interaction Trials in the Illinois Waterway, Asian Carp Regional Coordinating Committee Monitoring and Rapid Response Workgroup, Monitoring and Rapid Response Plan Interim and Summary Report 2015).

Figure 3. *Paupier butterfly trawl net deployment used to capture fish within the vicinity of the CSSC Electric Dispersal Barriers. The nets extend over the sides of the vessel and are lowered and raised into and out of the water at precise locations. Juvenile Gizzard Shad captured over the Electric Dispersal Barrier system during July 2015.*

Results and Discussion:

During 2013, results showed that of the 72 10-minute data collections that took place, 44 (61 percent) of them captured at least one occurrence of a school of fish crossing the entire width of the narrow array of Barrier IIB in an upstream direction. Twenty-seven (38 percent) data collections revealed multiple fish school breaches of Barrier IIB (Figure 1). The sizes of fish that breached the barrier were estimated to range from approximately 50 to 100 mm (2 to 4 inches) total length by using the fish measurement tool in the DIDSON software package. However, error ranges for these size estimates become greater with the distance of fish from the lens of the DIDSON unit (± ≈10 mm @ 2 m to ± ≈50 mm @ 10 m) because each cone of the acoustic array expands in size with increased range ($X= 2R \tan(\theta/2)$. All of the fish observed breaching the barrier did so in schools, further complicating size estimation procedures. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape, and the group expanded again after they breached. It was possible to then quantify the size frequency distribution of the fish population present near the Electric Dispersal Barrier with mobile split beam acoustic remote sensing surveys that were conducted below the Electric Dispersal Barrier the week after DIDSON data collections. Results from those data collections indicated that the median size of fish present in the Lockport navigation pool during August 2013 was 62.2 mm.

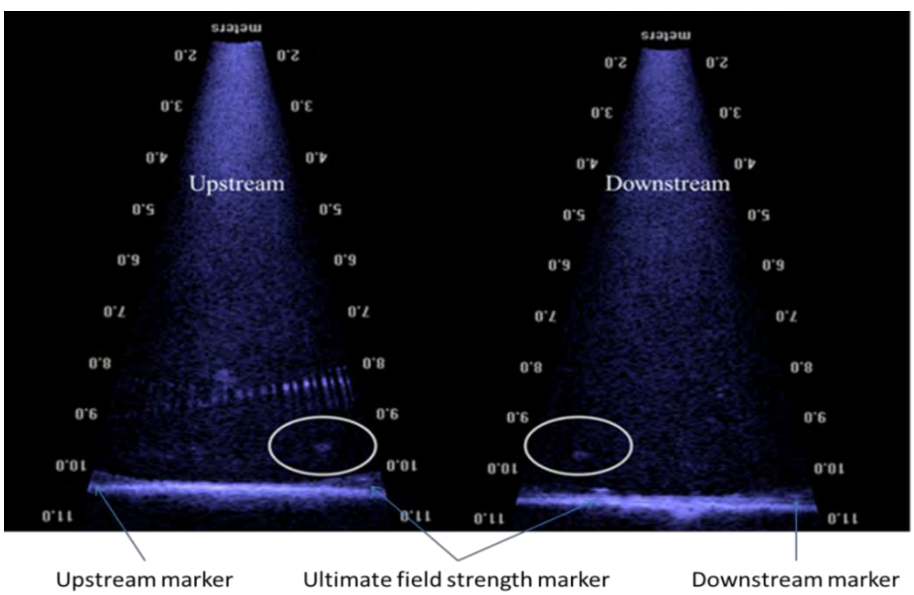


Figure 4. *Example of both the upstream and downstream DIDSON units ensonifying the same school of fish (in white circles) as it swims upstream past the ultimate field strength marker before swimming further upstream and out of the DIDSON view during data collections made on August 1, 2013*

Between, October 7 and 9 and October 21 and 23, 2014, DIDSON data collections consisting of 134 discrete 10-minute periods were obtained. No fish were observed crossing the Electric Dispersal Barrier's IIB narrow array during 2014. However, conditions were very different than those encountered during the 2013 study period, when fish were observed to cross the Barrier IIB narrow array frequently. Only Barrier IIB was operational during data collections in 2013; as a result, the first "in water" electricity encountered by fish as they moved upstream was from the Barrier IIB wide and narrow arrays, where all DIDSON data collections took place. Data collections that took place in 2014 were completed while both Barrier IIA (downstream barrier) and Barrier IIB (upstream barrier) were active. Therefore, fish moving upstream in the canal first encountered the electrical field from Barrier IIA, which is approximately 100 meters downstream from the sampling location over Barrier IIB. Additionally, delaying the data collections until October in 2014 resulted in lower water temperatures during the study period (15.8°C to 17.4°C in 2014 vs. 22.8°C to 26.8°C in 2013). Mobile acoustic remote sensing surveys also demonstrated that the mean density of YOY fish present in the Lockport navigation pool below the Electric Dispersal Barrier was significantly lower (ANOVA $F= 32.595$; d.f. = 57; $P< 0.001$) on November 4, 2014 (0.366 fish / 1,000 m^3) than on August 6, 2013 (2.08 fish / 1,000 m^3). Differences in density among locations within the Lockport Pool were also apparent. Fish were more densely congregated in the area directly below the barriers the week after DIDSON sampling in summer 2013 than during fall of 2014. These findings were further confirmed when the USFWS Columbia FWCO sampled fish both within the narrow arrays and directly below the Electric Dispersal Barrier system concurrently with DIDSON sampling in 2014 and also observed low fish abundance. Low numbers (< 10) of Gizzard Shad (*Dorosoma cepedianum*), Brook Silversides (*Labidesthes sicculus*), and Creek Chub (*Semotilus atromaculatus*) were captured in the Lockport navigation pool below the Electric Dispersal Barrier system.

Multi-beam sonar sampling continued over the narrow array of Barrier IIB during the summer of 2015. A total of 381 10-minute data collection periods occurred between July 14 and September 24. Three hundred and sixty-two of these data collections occurred during periods when no commercial vessel traffic was traversing the Electric Dispersal Barrier system. Commercial barge traffic did traverse the Electric Dispersal Barrier system concurrently with data collections on 19 occasions. Both Barrier IIA and Barrier IIB were operational during all collection periods that occurred in 2015. Fish were present directly below Barrier IIB in high densities throughout the study period, despite the fact that Barrier IIA was operational throughout the study period. Fish were observed challenging the narrow array of Barrier IIB during 64.6 percent (n=234) of data collections when no barge traffic was present. During those data collection events, 11.3 percent (n=41) contained at least one instance of a fish or school of fish passing the point of greatest electrical field strength and completely breaching the narrow array of Barrier IIB.

During some instances when fish interacting with the barrier was observed, video evidence captured by underwater cameras mounted on top of the sonar units observed schools of juvenile Gizzard Shad. Fish collection events confirmed this evidence. The fish population directly below Barrier IIB was composed primarily of juvenile Gizzard Shad in samples collected during the last week of July (72 to 105 mm TL; n=397, 97.1 percent). However, there was also representation within the population by much smaller juvenile Gizzard Shad (26 to 29 mm; n=7, 1.7 percent) (Figure 3).

While a substantial number of fish passages were observed (sonar data), there were also large numbers of Gizzard Shad present below the narrow array of Barrier IIB. These fish were challenging the barrier. However, they were not able to penetrate the narrow array of Barrier IIB to the point of greatest electrical field strength (sonar data and video data; estimated size from visual observation ≈ 60 to 100 mm TL). The location where the electrical field became too great for the majority of juvenile Gizzard Shad to further penetrate varied daily between approximately 5.0 meters and 10.0 meters downstream from the point of highest electrical field strength. Finding that larger juvenile Gizzard Shad were unable to cross the point of highest field strength at Barrier IIB suggests that the numerous instances of fish passage observed were committed by members of the population representing the smaller size classes, since the electrical field affects smaller fish to a lesser extent.

In response to the observation that larger juveniles were being repelled by the electrical field directly below Barrier IIB, the magnitude of the electrical field near the surface of the water was measured at approximately 0.1 meter from the edge of the western canal wall, at the location where the majority of the medium-sized juvenile Gizzard Shad were repelled by the electrical field. Results suggested that the majority of the Gizzard Shad present directly below Barrier IIB could penetrate the barrier to a point with an electrical field magnitude of 1.7 V/in before further penetration into the barrier was halted. Given this observation, the question was posed as to what circumstances may have led to the presence of these large schools of Gizzard Shad directly below Barrier IIB, since Barrier IIA was continuously operational (2.2V/in) during the entire study period.

One competing hypothesis was that the large schools of medium-sized juvenile Gizzard Shad may have breached Barrier IIA in conjunction with the passage of commercial vessel traffic. To test that hypothesis, continued collection of DIDSON data at Barrier IIB, using identical methods, during the passage of a commercial barge vessel is recommended (loaded two long by two wide, rake barge; n=10 upstream passages; n=9 downstream passages). Additionally, measurements of the magnitude of the electrical field near the western canal wall, both before and during passage of the vessel, were taken. Results indicated that the magnitude of the electrical field near the wall was reduced from 2.1 V/in to a mean of 1.75 V/in (SD = 0.109; n=12) during the passage of the barge vessel down the center of the channel. When the barge tow passed closer to the western wall, the magnitude of the electrical field was further decreased (minimum = 0.3 V/in at 5.5 m from wall). Furthermore, sonar data showed that there was a distinct change in flow within the canal during the passage of barge tows. During upstream passage, the current velocity in the downstream direction increased and no fish passage was observed. During downstream passage, the current in the canal changed directions and flowed upstream. In addition, large schools of fish were observed to breach the entire narrow array of Barrier IIB during downstream passage of the barge tow and proceed upstream during 66 percent of data collections (n=9). These results suggest that the combination of a reduction in the electrical gradient coupled with the upstream current produced by barge tow passage allowed the passage of large schools of medium sized juvenile Gizzard Shad through the Electric Dispersal Barrier during the downstream passage of barge tows at the Electric Dispersal Barrier (Figure 5).

Figure 5. *Northbound commercial barge tow traversing the Electric Dispersal Barrier while the DIDSON deployment continues to collect data.*

Recommendations:

(1) Conduct further research focusing on potential fish passage events associated with movement of barge traffic over the Electric Dispersal Barrier.

(2) Install instrumentation in close proximity to the electric dispersal barrier that can provide real-time alerts to management and operators when there is a reverse flow condition in the canal.

Literature Cited:

Parker, A. D., Glover, D. C., Finney, S. T., Rogers, P. B., Stewart, J. G., & Simmonds Jr, R. L. (2015). Fish Behavior and Abundance at the Electric Dispersal Barrier in the Chicago Sanitary and Shipping Canal at Reduced and Current Voltage Operating Parameters.

Des Plaines River and Overflow Monitoring

Nicholas Bloomfield (US Fish and Wildlife Service- La Crosse)

ADDITIONAL INFORMATION

- Link to Mapping Tool
- Link to 2016 Plan

Participating Agencies: U.S. Fish and Wildlife Service-La Crosse Fish and Wildlife Conservation Office (lead); Metropolitan Water Reclamation District of Greater Chicago, U.S. Army Corps of Engineers, and Illinois Department of Natural Resources (field support)

Introduction: The upper Des Plaines River rises in Southeast Wisconsin and joins the CSSC in the Brandon Road Pool immediately below the Lockport Lock and Dam. Asian carp have been observed in this pool up to the confluence 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 collected in 2012 through 2015.) 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. Construction of a physical barrier to reduce the likelihood of this movement was completed in the fall of 2010. The physical barrier was constructed by USACE and consists of concrete barriers and 0.25-inch mesh fencing built along 13.5 miles of the upper Des Plaines River where it runs adjacent to the CSSC. It is designed to stop adult and juvenile Asian carp from infiltrating the CSSC, although it will likely allow Asian carp eggs and fry to pass. Overtopping events in 2011 and 2013 created breaches in the fencing and allowed fish to pass. These areas and other low-lying areas were reinforced with chicken wire buried in gravel or cement to prevent scouring during future overtopping events. It is important to understand the Asian carp population status, monitor for any potential spawning events, and assess the effectiveness of the physical barrier to help inform management decisions and direct removal actions.

Objectives: There are two major objectives for this study:

(1) Monitor Bighead and Silver Carp and their spawning activities in the Des Plaines River above the confluence with the CSSC; and

(2) Monitor for Bighead and Silver Carp eggs and larvae around the physical barrier and monitor the effectiveness of the barrier during high flow events when water moves laterally from the Des Plaines River into the CSSC.

Project Highlights:

- Collected 6,656 fish representing 53 species and three hybrid groups from 2011 through 2015 via electrofishing (45.03 hours) and gill netting (131 sets; 16,084 yards).
- No Bighead or Silver Carp have been captured or observed through all years of sampling.
- One Grass Carp was captured in 2015. Analysis indicated it was triploid. All six Grass Carp tested since 2013 have been triploid.

Des Plaines River and Overflow Monitoring

Methods: In 2015, sampling was conducted in the upper Des Plaines River from Romeoville, Illinois, upstream to the Columbia Woods area near Willow Springs, Illinois. Sampling was performed using pulsed-DC electrofishing and short-term top to bottom gill net sets using 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 pounding. Sampling was performed during increased water levels to improve the accessibility to the sampling sites. Sampling was performed in backwaters using gill nets and electrofishing and in channel habitat with electrofishing gear. All fish were identified and released, with the exception of one Grass Carp that was dispatched.

Results and Discussion: During the 5 years of sampling (2011-2015), 45.03 hours of electrofishing and 131 sets covering 16,084 yards of gill net resulted in a total catch of 7,926 fish (Table 1). Fifty three species and three hybrid groups have been collected. Common carp have been the most commonly collected species, followed by Bluegill and Spotfin Shiner. In 2015, sampling occurred during 2 weeks while water levels were elevated: May 11, 2015, and December 7, 2015. Low flow conditions the remainder of the sampling season meant that targeted sampling areas of the river were largely inaccessible. Sampling effort in 2015 included 6.38 hours of electrofishing that resulting in 709 fish and 4,600 yards of gill net that resulting in 561 fish. The 2015 sampling yielded 29 species and one hybrid group. No Bighead or Silver Carp have been seen or captured during the 5 years of sampling. One Grass Carp was captured in a backwater area near Lemont, Illinois. Eyeballs were removed and transported to Whitney Genetics Laboratory for ploidy testing. Results indicated that the fish was triploid.

To date, six Grass Carp have been tested for ploidy. All six have been determined to be triploid, or sterile. Therefore, it is likely that Grass Carp captured in the upper Des Plaines were stocked escapees, as opposed to migrants from a breeding population on the Illinois River or from a breeding population from within the upper Des Plaines River.

No overtopping events, defined by water flowing laterally from the Des Plaines River to the CSSC, occurred in 2015.

Recommendations: Continue monitoring for adult and juvenile Bighead and Silver Carp in the upper Des Plaines River, with emphasis on backwater habitat. Given the limitations of the physical barrier, we will initiate young-of-year sampling via seine to document any potential spawning success. Gill netting and electrofishing in backwater habitat will continue when these areas are accessible. Additional electrofishing during normal flows will be attempted in the channel. Des Plaines River stage will continue to be monitored during heavy rainfall events and investigations of the physical barrier will be conducted, as needed, in areas where overflow has occurred.

Des Plaines River and Overflow Monitoring

Table 1. *Fish collected from the upper Des Plaines River from 2011-2015 via electrofishing and gill netting.*

Species	Electrofishing			Gill Netting			Grand Total
	2011-2014	2015	Total	2011-2014	2015	Total	
Common Carp	1,032	287	1,319	435	545	980	2,299
Bluegill	798	59	857	2		2	859
Spotfin Shiner	745	12	757				757
Gizzard Shad	615	9	624	8		8	632
Largemouth Bass	488	83	571	5		5	576
Bluntnose Minnow	465		465				465
Channel Catfish	305	13	318	31		31	349
Black Crappie	228	46	274	2		2	276
White Sucker	183	84	267	7		7	274
Green Sunfish	155	1	156				156
Spottail Shiner	145	3	148				148
Northern Pike	87	29	116	24	7	31	147
Sand Shiner	140	1	141				141
Orangespotted Sunfish	101		101				101
Golden Shiner	80	15	95				95
Bowfin	64	4	68	2		2	70
Sauger	54	2	56	2		2	58
Longnose Gar	45		45	4		4	49
Emerald Shiner	28	16	44				44
Blackstripe Topminnow	38	3	41				41
Fathead Minnow	36	4	40				40
Pumpkinseed	26	11	37				37
Smallmouth Bass	17	13	30	1		1	31
Yellow Bullhead	28	1	29				29
Round Goby	26		26				26
Spotted Sucker	24		24	2		2	26
Goldfish	11	8	19	2		2	21
Bigmouth Buffalo	2		2	16	2	18	20
Rock Bass	16	1	17	1		1	18
GoldfishXCarp Hybrid				13	3	16	16
Quillback	9		9	6		6	15
Smallmouth Buffalo	1		1	11	3	14	15
Blackside Darter	14		14				14
River Carpsucker	7	1	8	2		2	10
Black Bullhead	9		9				9
Walleye	7		7	1		1	8
Grass Carp	1		1	5	1	6	7
Warmouth	6		6				6
Hornyhead Chub	6		6				6
Creek Chub	6		6				6
Freshwater Drum	4		4				4
Central Stoneroller	3		3				3
Grass Pickerel	3		3				3
Western Mosquitofish	2		2				2
Yellow Perch	2		2				2
Oriental Weatherfish	2		2				2
Johnny Darter	2		2				2
Logperch	2		2				2
Central Mudminnow		2	2				2
Longear Sunfish	1		1				1
Hybrid Sunfish	1		1				1
White Crappie	1		1				1
White Perch	1		1				1
Muskellunge	1		1				1
StripedXWhite Bass Hybrid	1		1				1
Yellow Perch		1	1				1
Totals	**6,074**	**709**	**6,783**	**582**	**561**	**1,143**	**7,926**

GEAR DEVELOPMENT AND EFFECTIVENESS EVALUATION

Evaluation of Gear Efficiency and Asian Carp Detectability

ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Scott F. Collins, Steven E. Butler, Matthew J. Diana, David H. Wahl (Illinois Natural History Survey)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 Plan

Participating Agencies: Illinois Natural History Survey (lead)

Introduction: A variety of sampling gears are being used by various agencies to monitor and control Asian carp populations, but the relative efficiency of each of these gears — and the amount of effort required to detect Asian carp when they are present in low densities — has not previously been evaluated. Evaluating the ability of traditional and alternative sampling gears to capture both juvenile and adult Asian carp will allow managers to customize monitoring regimes and more effectively establish relative abundances of Asian carp. Data gathered from gear evaluations can also be used to model the probability that Asian carp will be detected with each sampling gear in different areas of the Illinois Waterway, which will allow for identification of appropriate levels of sampling effort and help improve the efficiency of monitoring programs. Results of this study will help improve Asian carp monitoring and control efforts in the Illinois River and the CAWS 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 each gear;
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 and CAWS to further assess gear efficiency and examine potential associations between Asian carp and native fishes.

Project Highlights:

- Catches of juvenile Silver Carp were substantially lower in 2015 than in 2014. Sampling during periods of high water appeared to be particularly unproductive, as juvenile Asian carp densities were lower, gear effectiveness was reduced, or some combination of these factors occurred. Catches of juvenile Asian carp increased during fall 2015 as water levels normalized.

Evaluation of Gear Efficiency and Asian Carp Detectability

- Catch rates of mini-fyke nets, beach seines, purse seines, and pulsed-DC electrofishing were all higher in main channel habitats than in backwater lakes during 2015. Gill nets were more effective for juvenile Silver Carp in backwater lakes.
- Mini-fyke nets appear to consistently capture the highest total numbers of juvenile Silver Carp across years and were the only gear to capture juvenile Bighead Carp in 2015. However, on average, pulsed-DC electrofishing provided higher catch rates per sample, particularly during flood conditions. Beach seines and purse seines produced similar (and lower) catch rates, but captured different size groups of juvenile Asian carp. No age-zero Asian carp were captured in gill nets or cast nets during 2015, although gill nets did capture age-1 Silver Carp.
- Asian carp appear to shift from nearshore habitats to deeper areas as they increase in size during their first 2 years of life. Beach seines that sample shoreline areas captured the smallest sizes of juvenile Silver Carp (mean = 37 mm), whereas offshore sampling with purse seines (mean = 53 mm), pulsed-DC electrofishing (mean = 61 mm), and gill nets (mean = 153 mm) collected larger individuals.

Methods: The high spawning success and subsequent survival of Asian carp to the juvenile life stage that occurred in 2015 (see Larval Fish Monitoring and Young-of-Year and Juvenile Asian Carp Monitoring summaries) provided the opportunity for continued evaluation of gears for capturing juvenile Asian carp. After larval Asian carp were detected by ichthyoplankton sampling during June and July, pulsed-DC electrofishing was conducted biweekly during July and August at sites in the LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island Pools of the Illinois Waterway to determine the extent of juvenile Asian carp occurrence. Experimental comparisons of juvenile gears were subsequently conducted during summer and fall at paired main channel and backwater sites within the LaGrange Pool of the Illinois River (Figure 1).

Evaluation of Gear Efficiency and Asian Carp Detectability

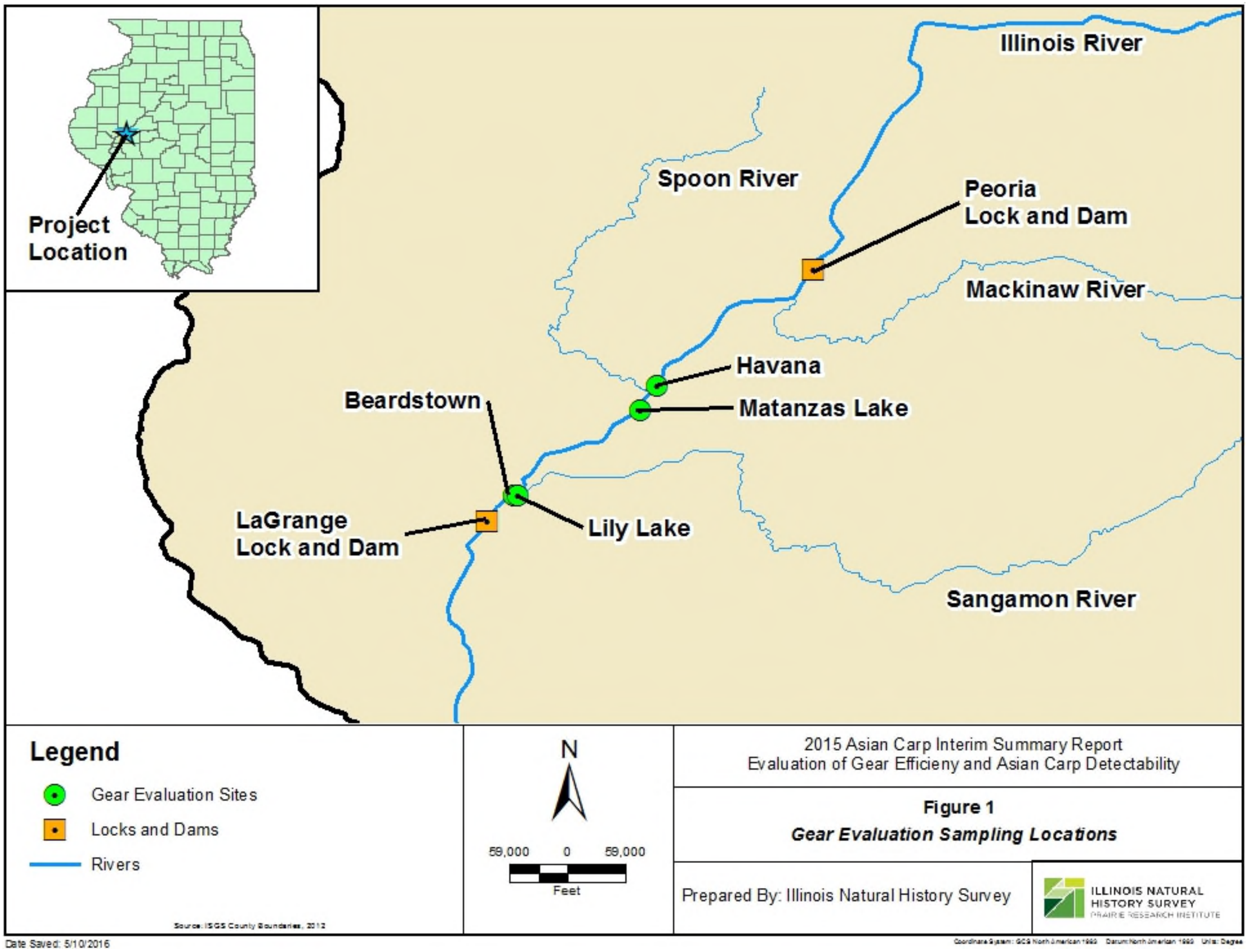


Figure 1. *Map of 2015 gear evaluation sampling locations in the LaGrange Reach of the Illinois Waterway. Navigation dams are represented by squares. Sampling sites are represented by circles.*

The 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 at river kilometer 186.7 for the backwater lake (Matanzas Lake) and 193.1 for main channel habitats (Havana). Gears used in 2015 were the same as those used in 2014 to provide multiple years of data for evaluations. Flooding during 2015 allowed us to evaluate these gears under high flow conditions, which differed from 2014 sampling (Figure 2). All fish captured were identified to species and measured for total length and weight. Subsamples of juvenile Asian carp were retained for later diet and age analysis.

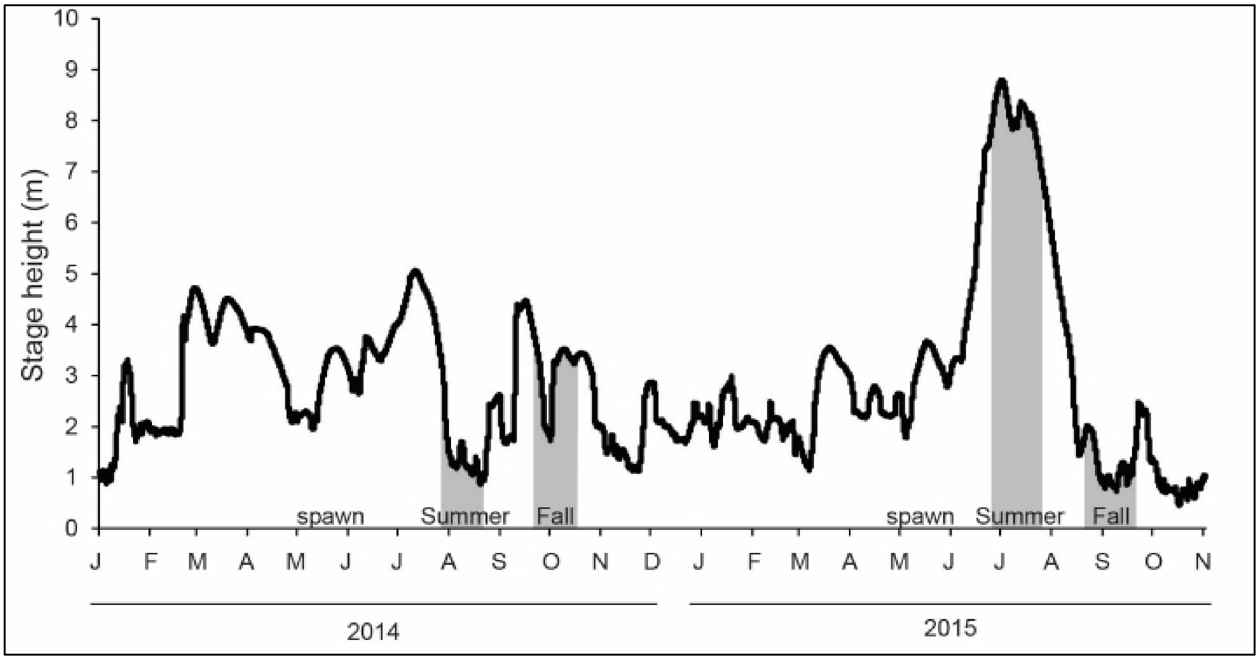


Figure 2. *Stage height of the Illinois River during 2014 and 2015. Vertical grey bars indicate sampling periods for each year. Stage height data was obtained from USGS Gaging Station 05585500 at Meredosia, Illinois.*

Gears used to target juvenile Asian carp in 2015 included:

- Pulsed-DC electrofishing (250 V, 8 – 10 A, varied pulse width; four 15-minute transects per site visit)
- Floating experimental gill nets (45.8 m long x 3.05 m deep, 1.9, 2.5, 3.2, 3.8, and 5.1 cm mesh panels; four 4-hour sets 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)
- Small-mesh purse seines (122 m x 3.05 m, with 2.5 cm mesh; minimum 4 hauls per site-visit)
- Cast nets (2 m radius, various mesh sizes; minimum 4 throws per site-visit)
- Hydroacoustic surveys, using a 200 kHz split-beam transducer mounted to the front of the boat and connected to a computer with acquisition software

Results and Discussion: Flooding in early 2015 resulted in stage heights of 5.83 ± 2.24 m, which were on average 3.8 times higher than the same sampling period from 2014 (Figure 2). Stage heights normalized during the fall 2015 sample period to 2.06 ± 0.38 m, which were similar to the previous year. Only small numbers of age-0 and age-1 Asian carp were captured by pulsed-DC electrofishing in the LaGrange and Peoria Pools, although field personnel reported that numerous age-0 Asian carp were observed in very shallow areas containing flooded vegetation where electrofishing boats were unable to access. No juvenile Asian carp were observed upstream of the Peoria Pool during this time. Evaluation of all juvenile gears during

2015 resulted in the capture of 39,358 fish, including 106 juvenile Silver Carp and three Bighead Carp. Catches of juvenile Silver Carp were substantially reduced during flood periods, despite the high numbers of larvae collected in June and July of 2015. Most juvenile Silver Carp were captured after the flooding had subsided (n = 10 during flooding, n = 99 post-flooding). In general, average catches for all gears, except gill nets, were higher in main channel habitats in comparison to backwater lakes (Table 1). Mini-fyke nets captured the highest numbers of juvenile Silver Carp (n = 60) and all three Bighead Carp in 2015. Electrofishing collected fewer Silver Carp (n = 39), but had a higher average catch rate per sample in main channel habitats. Beach seines (n = 1) and purse seines (n = 1) had similar average catches in main channel habitats. Both cast nets and gill nets failed to capture any age-0 Asian carp. However, gill nets did collect age-1 Silver Carp in backwater lake habitats (n = 8, average = 0.5 per set; Figure 3).

Table 1. *Mean ± SD catches of Silver Carp in juvenile gears during 2015. DC-EF = pulsed-DC electrofishing.*

Habitat	Mini-fyke	Beach seine	Purse seine	DC-EF	Gill net
Backwater	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.5 ± 2
Main channel	1.7 ± 4.0	0.06 ± 0.2	0.06 ± 0.2	2.3 ± 4.5	0 ± 0

Data from 2014 and 2015 were combined to describe the sizes of Silver Carp collected by each gear (Figure 3). Beach seines captured the smallest juvenile Silver Carp (mean = 37.0 mm), which occurred in shallow, nearshore locations. Mini-fyke nets collected, on average, larger Silver Carp and a greater range of sizes, particularly in main channel habitats (mean = 58.3 mm). Purse seines captured larger average sizes of juvenile Silver Carp (mean = 52.5 mm) in offshore locations, likely because they rarely captured any Silver Carp smaller than 40 mm. Pulsed-DC electrofishing collected a wide size distribution of Silver Carp (mean = 60.7 mm), including higher numbers of Silver Carp larger than 90 mm. Gill nets collected no age-0 Silver Carp, but did collect age-1 Silver Carp in backwater lakes (mean = 153.3 mm). Cast nets collected no Silver Carp in 2015.

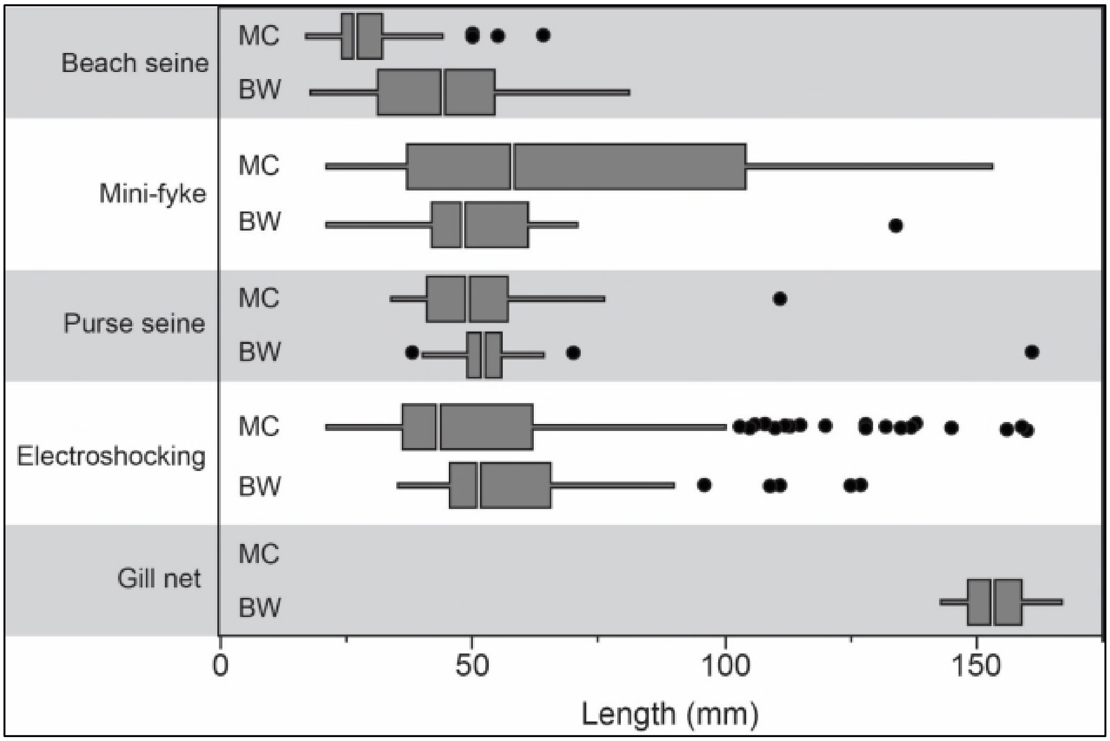


Figure 3. *Size distributions of juvenile Silver Carp captured by different gear types from the Illinois River during 2014 and 2015. MC = main channel, BW = backwater lake.*

Despite extremely high numbers of Asian carp larvae collected during ichthyoplankton sampling in 2015, considerably fewer juvenile Asian carp were captured than during the previous year. During the 2015 flooding, juvenile Asian carp may have been more widely dispersed in off-channel areas, where they were not vulnerable to sampling gears, or high water levels may have interacted directly with the functioning of the gears to render them less effective. Alternatively, despite the observed high reproductive output in 2015, survival to juvenile size classes may actually have been lower than in 2014, resulting in lower abundances of age-0 Asian carp and therefore lower catch rates. All but three juvenile Asian carp observed during gear evaluation sampling in 2015 were identified as Silver Carp based on gill raker morphology, coloration, and the presence of a ventral keel. The low numbers of juvenile Bighead Carp captured over 2 years of sampling prohibits any determination of the most effective gears for capturing juveniles of this species. Bighead Carp reproduction and recruitment may have been low in recent years, or the behavior and habitat use of this species may differ from that of Silver Carp during the juvenile stage, making them less vulnerable to the sampling gears being evaluated. Further study will be necessary to assess the vulnerability of juvenile Bighead Carp to various sampling gears and to evaluate patterns of Bighead Carp recruitment.

Mini-fyke nets captured the highest total numbers of juvenile Silver Carp during both 2014 and 2015 and were the only gear to collect juvenile Bighead Carp. This gear type is particularly useful in shallow-water and other near-shore areas and appears to be a consistently effective tool for targeting the smaller size groups of juvenile Asian carp. Beach seines were very ineffective at capturing juvenile Silver Carp during 2015, but were the second most productive gear in 2014. This disparity among years is very likely attributable to the high water of 2015, as beach seines were previously found to be effective primarily for the smallest size classes of Silver Carp when they occur along shoreline areas. These size classes would have been present during the peak of the flooding in 2015, when juvenile Silver Carp may have been widely dispersed, and when sampling flooded vegetation would be difficult with this gear. Purse seines were also largely ineffective during 2015, although they were effective at capturing larger size classes of juvenile Silver Carp in deeper water areas (2 to 4 m) in 2014. The cause of this difference among years is uncertain at this time. Gill nets were completely ineffective at capturing age-0 Asian carp in both years, but did produce age-1 individuals in 2015, suggesting that Asian carp may become vulnerable to this gear as they grow larger. We do not recommend this gear type for monitoring for Asian carp less than 150 mm. Further evaluation will be required to assess the effectiveness of these sampling gears for larger size groups of juvenile Asian carp. Additional years of sampling and differing offshore gears will be required to target age-1 and age-2 Asian carp from the 2014 and 2015 cohorts.

Recommendations: Evaluation of sampling gears targeting juvenile Asian carp was possible during both 2014 and 2015 because of the high reproductive output and subsequent recruitment to juvenile stages. However, based on very low catch rates during high flow conditions in 2015, additional data during other years of high Asian carp recruitment to the juvenile stages will be necessary to fully evaluate sampling gears. Additionally, based on our experiences in 2015, we recommend delaying sampling for juvenile Asian carp during periods of flooding. If sampling is required during such conditions, we recommend pulsed-DC electrofishing for its higher catch rates. Otherwise, mini-fyke nets appear to consistently produce the highest catches of juvenile Asian carp across years. Additional sampling is necessary to track the 2014 and 2015 cohorts to identify the associated habitats for these fish and the most effective gears for targeting these sizes. Because sampling data indicate that larger age-0 and age-1 Asian carp are unlikely to inhabit nearshore environments, tracking these cohorts in offshore areas may require differing gears. Additionally, Asian carp observed during 2015 were predominantly Silver Carp, with only three Bighead Carp captured. 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. Results of this future research will be reported as they become available to allow for adaptation of monitoring and control activities.

Exploratory Gear Development Project

Wyatt Doyle, Emily Pherigo, Amber Masters (USFWS-Columbia Fish and Wildlife Conservation Office)
Skyler Schlick, Kevin Drews, (DLH Corp, USFWS-Columbia Fish and Wildlife Conservation Office)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Participating Agencies: Columbia Fish and Wildlife Conservation Office (lead), Carterville Fish and Wildlife Conservation Office – Wilmington Field Station

Introduction: The USFWS-Columbia Fish and Wildlife Conservation Office (CFWCO) continued development and evaluation of innovative techniques to detect, monitor, and remove invasive carp of all sizes in varying habitats. Novel gears were incorporated into monitoring efforts for small Asian carp, hydroacoustic studies and sweeps at the Electric Dispersal Barrier, and removal of adult Asian carp in coordination with barrier defense efforts. A variety of trawls were evaluated in 2015, including paupier butterfly frame trawl, surface trawls, and a new design referred to as the dozer trawl. Exploratory gear application and efficacy was measured in a gear's ability to detect the targeted size classes in the targeted habitat. Silver Carp from 11 to 1000 mm were effectively collected in 2015. Analysis comparing exploratory gears with more traditional sampling techniques (boat electrofishing, mini fykes, and gill nets) is ongoing. This summary focuses on the development of exploratory gears for the capture of Asian carp. The process of developing sampling techniques and associated protocols that target invasive carp is integral to assessing the risk and developing plans to manage these nuisance fish.

Objectives: Develop new gears to:

1) Increase carp capture efficiency
2) Effectively sample various habitat types
3) Reduce carp populations
4) Detect presence of carp in areas of low density
5) Target all size classes of carp

Project Highlights:

- Standardizing the anode configuration for the paupier trawl allows for determination of the electrofishing capabilities under varying environmental conditions.
- Longer towlines result in a wider net spread for surface trawling, which enables a larger volume of water to be sampled.
- The dozer trawl is an inexpensive modification to standard fishing boats that can sample shallow habitats and a variety of water velocities.

- Testing of a modified purse seine shows promise for capture of invasive carps.
- Videos of electrified paupier trawl provide a method to estimate densities of Silver Carp and behavioral responses to electrofishing settings in all seasons.

Field Mapping of Electrified Paupier

Background

The paupier butterfly frame trawl is modeled after shrimp trawlers used in the Gulf of Mexico. It is designed to fish 2 to 10 feet deep in Midwestern waters with very little flow, including backwaters, reservoirs, tributary mouths, side channels, and channel borders. The paupier trawl is essentially two electrofishing boats operating in tandem. A 72-amp ETS (Wisconsin Box or Burke's box) powers up to four anodes: two boom anodes off the front of the boat and two spherical anodes located inside the rectangle frames on either side. The booms can be rotated from directly in front of the boat to parallel with the frames on either side. The frames act as the cathodes, concentrating the electric field between the boom anodes, the frame, and the spherical anodes inside the net. The spherical anodes inside the net are essential to prevent fish from swimming out of the net once they are behind the influence of the electrical field

Determining the electrical field by mapping the amount of electricity produced in the water by electrofishing boats and where the gradient loses effectiveness on a targeted species is an important part of standardization in programs using traditional electrofishing (Kolz 1993). This information allows electrical configurations to be adjusted for changing environmental conditions or target species. Mapping the electrical field of various anode configurations was an important step to standardization and to understand the capabilities and limitations of the technique. Based on results of previous years, the 72-amp ETS box was chosen as the standard electrofishing box for the paupier configuration because it provides the power needed to achieve the behavioral response necessary to capture Asian carp (specifically Silver Carp) in Midwestern waters.

Objectives

- Establish the electrical field (measured in volts per centimeter [V/cm]) in the water produced by various anode configurations.
- Determine a standard anode configuration for the electrified paupier.

Methods

The electrical fields of two anode configurations on the electrified paupier were mapped on December 16, 2014, in Perche Creek, a tributary of the Missouri River in central Missouri. Ambient conductivity was 481 µS/cm and water temperature was 8.4 °C. The ETS was used and standardized at 200 volts, 30 Hz, and 15 percent duty cycle. A directional probe connected to a Velleman oscilloscope collected measurements in volts per centimeter. Measurements were recorded at 15 different locations in a 9-feet-long by 12-feet-wide by 5-feet-deep grid around the setups (Figure 1).

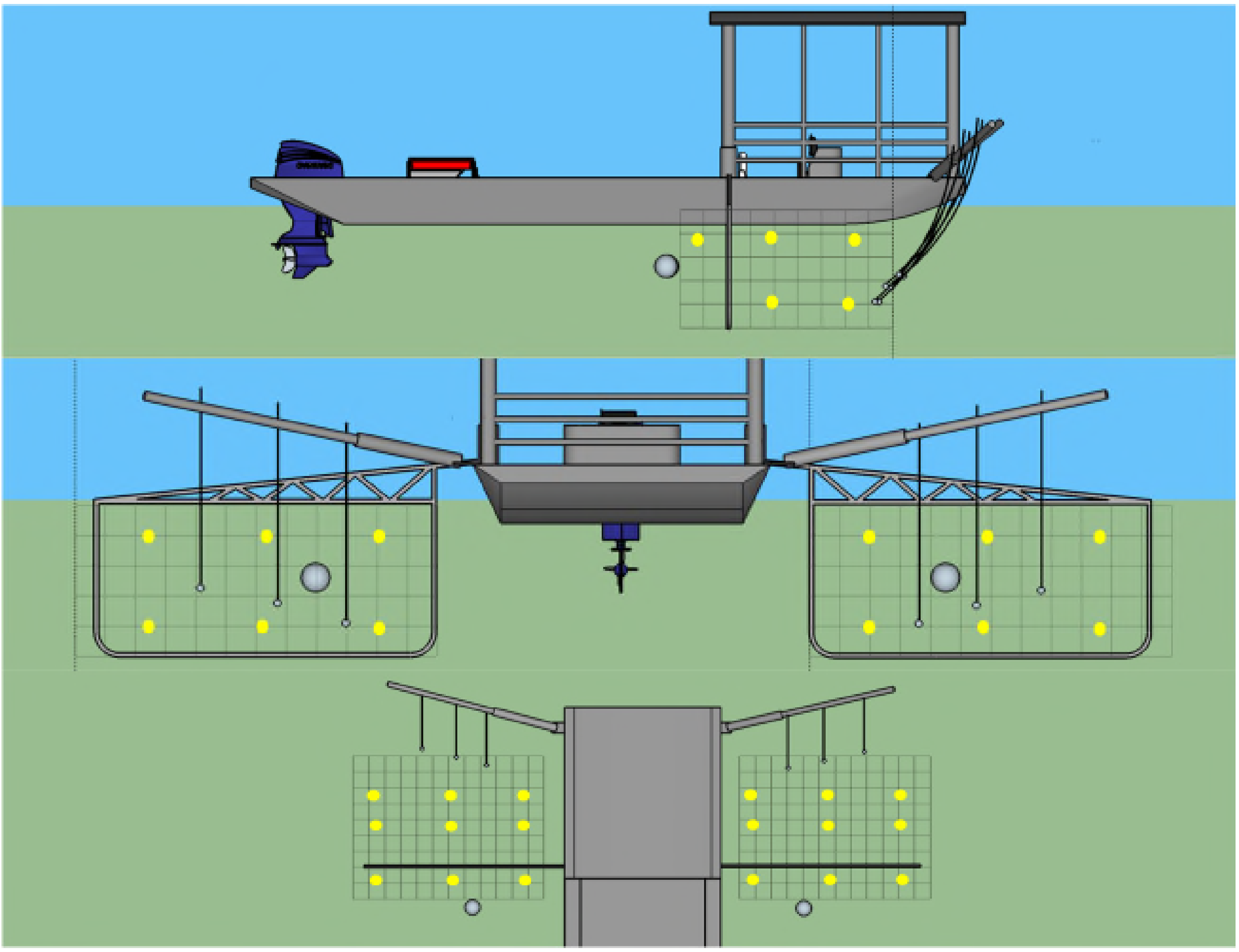


Figure 1. *The electrical gradient (volts/cm) was measured at 15 locations between the anodes and cathodes of the electrified paupier.*

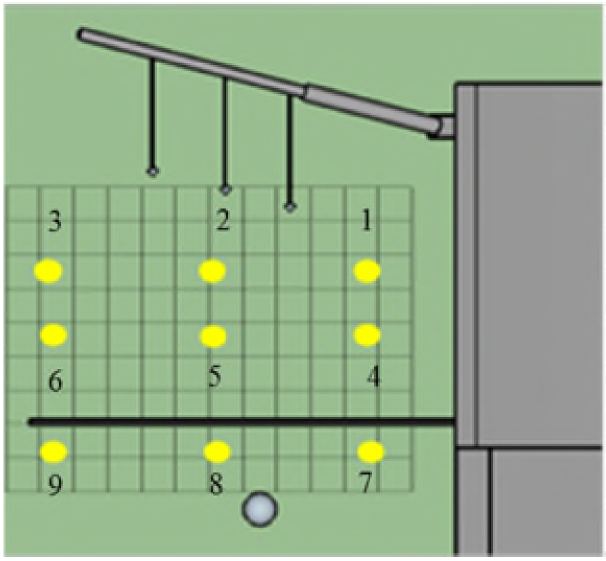
The two configurations mapped had spherical anodes behind the cathode frame, but the anodes connected to the front booms were different shapes and sizes, resulting in different surface areas (Table 1). The "cable" anode configuration consisted of three, 3/16-inch cables spaced evenly on the front boom extending into the water (Table 1, Figure 1). The "sphere" anode configuration consisted of two, 2 5/16 -inch solid steel balls and one, 7-inch steel hemisphere extending into the water. The sphere anode configuration was four times the amount of surface area as the cable configuration (Figure 1).

Table 1. *Description of anode configuration used in mapping electrical fields along with corresponding surface area.*

Anode Configuration	Anode Description (number of anodes)	Anode Surface Area (cm^2)
Cable	3/16" cable (3)	112
Sphere	2 5/16" sphere (2) and 7" hemisphere (1)	467

Results

The sphere configuration had more variation in the V/cm readings than the cable configuration (Figure 2). The spheres produced high V/cm close to the boom anodes (positions 1 and 2) and low V/cm behind the cathode frame in positions 8 and 9. The cables had more consistent V/cm readings between boom anodes and cathode, indicating a more uniform field.



	3/16" Cable ($112\ cm^2$)	two spheres, small bowl ($467\ cm^2$)
1	0.108	0.2915
2	0.154	0.3495
3	0.137	0.118
4	0.104	0.1995
5	0.129	0.1745
6	0.1375	0.1495
7	1.75	0.35
8	0.087	0.15
9	0.075	0.083

Figure 2. *Electrical gradient (V/cm) readings for two different anode configurations at nine locations within the electrical field. Measurements 1-6 are averages of two depths (2 feet and 4 feet).*

Discussion

A uniform electrical field for the electrified paupier trawl is preferred to ensure that fish in any part of the field experience an equal power density. For example, a high voltage gradient close to the boom anode would stun the fish, but it could become mobilized and escape as it drifts back toward the net. As a result, the fish needs to remain immobilized as it drifts past the frame and into the net. A spherical anode behind the cathode frame maintains an electrical field at the opening of the net, which prevents escape. The electrical field behind the cathode frame was not as strong as the field close to the boom anodes in the sphere configuration, thus increasing the risk of escape. The electrical field behind the frame was uneven in both configurations because the sphere was positioned closer to the boat side during mapping. This configuration allowed electricity to take the path of least resistance. During field sampling, the spherical anode behind the cathode frame is centrally located. The cable configuration was able to achieve a more uniform field in front of the frame while still maintaining a strong field behind the frame and was therefore chosen as the standard for paupier electrofishing. Now that a standard anode configuration is in place, power goals can be set based on varying conductivities and output from different EF boxes.

Exploratory Gear Development Project

Measuring the Effective Fishing Width of Surface Trawls:

Background

Preliminary testing has shown that mamou and scalene surface trawls are effective at catching Silver Carp <100 mm in backwater lakes and tributary mouths with low flow. Potential applications for these innovative techniques include monitoring year class production and removal of young-of-year Asian carp. The mean effective fishing width was measured using Sea Scan HDS Towed System side scan sonar borrowed from Southern Illinois University, Carbondale, to quantify the effort of two types of surface trawls. The effective fishing width is a measurement of the net opening while fishing (Ridenour et al. 2011). Knowing the effective fishing width under various trawling configurations can optimize sampling efficiency and be used to calculate volumetric sampling effort.

Objectives

- What is the effective fishing width of the mamou and scalene surface trawls?
- How does tow line length affect the spread of the otter boards and effective fishing width?

Methods

Two types of surface trawls were evaluated: the mamou and scalene. Both trawls are conical nets with wide openings pulled behind the boat using towlines extending from a fixed point approximately one-third back from the bow of the boat. The mamou head rope is 8.25 meters (27.25 feet) wide at the opening, 11.7 meters (38.5 feet) long from head rope to the end of the cod, and composed of 25 mm high density polyethylene (HDPE) mesh. The mamou samples 1 to 2 meters (3 to 6 feet) below the surface. The scalene has 38 mm HDPE nearest the opening and tapers to 25 mm HDPE mesh in the net-body. It is 7.93 meters (25.25 feet) wide at the head rope opening, 11.5 meters (37.6 feet) long from head rope to the end of the cod, and fishes the top 1 meter (3.25 feet) of the water column. Both trawls had a 6 mm mesh insert in the cod-ends to catch young-of-year and small-bodied fish.

The trawl doors (also known as otter boards) are 107 cm (42 inches) long by 53 cm (21 inches) high, weigh 18.6 kg (41 pounds), and have PVC floats on the top, which keeps the doors on the surface of the water. Water pressure on the trawl doors spread the net. Towing speeds are usually 1 to 3 miles per hour depending, on flow conditions.

Nets were deployed in the Osage River, a tributary of the Missouri River in central Missouri, on May 26, 2015. Each net was deployed twice: once with a towline of 22.86 meters (75 feet), and once with a tow line of 35.05 meters (115 feet), for a total of four configurations. After the trawl was deployed and fishing in the downstream direction, the boat with the sidescan sonar unit (Sea Scan HDS Towed System, Marine Sonic Technology) circled the trawl three times to record multiple images and views of each configuration. Post-processing was completed in the office where the program Sea Scan Survey was used to make six measurements of each configuration’s effective fishing width (Figure 3). The mean effective fishing width of each configuration was divided by the net head rope length to obtain the percent spread.

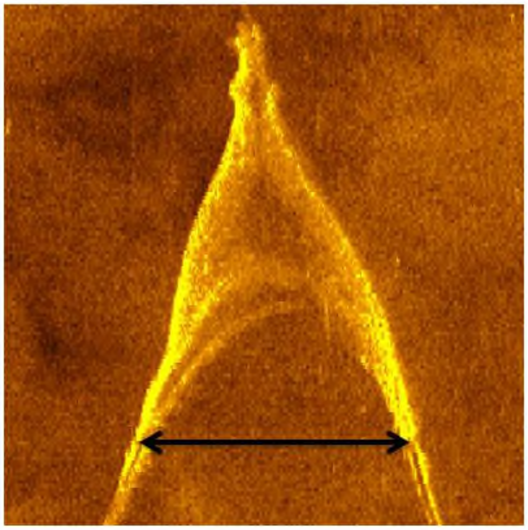


Figure 3. *Sidescan sonar image of surface trawl with arrow indicating location of effective fishing width measurement. Images were collected on four surface trawl configurations in the Osage River in central Missouri on May 26, 2015.*

Results

Longer towlines resulted in greater net spread for both net types. For the mamou, which has a slightly longer head rope at 8.25 meters, the 22.86 meter long towlines produced a 4.44 meter fishing width, creating a 54 percent net spread (Table 2). Similarly, the scalene net achieved a 52 percent spread with the 22.86 meter towlines. When towlines were extended to 35.05 meters, the percent spread increased to 62 percent for the mamou and 63 percent for the scalene.

Table 2. *Trawl net specifications, towline lengths, fishing width, and percent spread of two surface trawls measured via sidescan sonar in May 2015.*

Net	Mesh	Head rope length, meters	Towline Length, meters	Fishing Width, meters	% spread
Mamou	25 mm sapphire HPDE body mesh, 6 mm cod	8.25	22.86	4.44	54
			35.05	5.11	62
Scalene	35 mm dyneema HPDE fishing circle mesh, 25 mm green HPDE body mesh, 6 mm cod	7.93	22.86	4.15	52
			35.05	5.01	63

Discussion

Surface trawl towline length was standardized to 38 meters to maximize the effective fishing width. The goal of each trawl configuration is to attain a minimum net spread of 75 percent. Standardization of the surface trawl nets, otter boards, and operating procedures will be determined as evaluation of the surface trawl continues.

Using the mean effective fishing width, effort can be calculated as the area sampled (effective fishing width x distance trawled; m^2). Investigations into methods for calculating volumetric effort (m^3) are ongoing and will be useful in comparing fish densities across multiple trawling methods as well as hydroacoustic density estimates (Emmrich et al. 2010).

Dozer Trawl Developed to Sample Shallow Water

Background

Challenges in sampling shallow habitats in the Illinois River led to development of a new push trawl design called the dozer trawl. Following the same principle as the benthic push trawl, the dozer trawl is deployed in front of the boat and pushed along to sample up to 1 meter deep. The dozer trawl net is attached to a rigid, rectangular frame, unlike the benthic push trawl, which uses otter boards to spread the net along the bottom of the river. It is a simple, inexpensive adaptation to existing boats and can be used to sample small, shallow backwater habitats as well as swift main channel borders.

Objectives

- Develop an active sampling technique to effectively sample in a variety of flows.
- Develop a sampling technique to target small, shallow habitats.
- Develop an effective technique that can be employed with minor, inexpensive modifications to an existing sampling setup.

Gear Description

The dozer trawl consists of a 2.3-meter-wide by 0.64-meter-tall by 5-meter-long net attached to a rigid 2.13-meter-wide by 0.91-meter-tall frame extending off the front of a flat bottom jon boat. The trawl is pushed from the front of the boat, similar to the blade of a bulldozer. Also in imitation of this terrestrial grading machine, the dozer trawl can be raised directly upwards with two forward-protruding booms, which closes the mouth of the net at the end of each sample and allows access to the cod. This boom and net frame system can be quickly and easily attached to many existing boats to target the pelagic fish community. Without electricity, the majority of fish captured by the dozer trawl are small-bodied, however, the addition of electricity enables the capture of larger fish.

Application

The non-electrified dozer trawl was used for the majority of the 2015 sampling season. It was effective at catching juvenile Asian carp <150 mm in shallow backwater habitats and main channel borders (Figure 5). In November 2015, electricity was added to the configuration to catch a greater range of size classes. Similar to a traditional electrofishing boat setup, two booms with spider arrays were positioned off the front of the boat (Figure 4). Electrical field mapping revealed that the electrical gradient extended beyond the rigid frame. Reducing to one boom centrally positioned off the front of the boat in front of the rigid frame concentrated the field between the spider array anode and the frame. This configuration ensured that fish in front of the net were stunned and unlikely to escape. Preliminary trials suggest the electrified dozer trawl can be used to capture and remove juvenile Silver Carp (<400 mm) as well as adults (>399 mm; Figure 4).

Figure 4. *Silver Carp captured during preliminary testing of electrified dozer trawl in Perche Creek, a tributary of the Missouri River in central Missouri, fall 2015.*

Innovative Gears for the Mass Removal of Asian Carp

Background

Purse seines are an effective technique to capture large quantities of marine schooling fish such as sardines. After the methodology of this technique had been studied, a version of purse seine is in development to be used for the mass removal of invasive carp from areas of high population concentrations.

Objectives

- Develop a method to remove large numbers of Asian carp.
- Determine practical ability to safely and effectively deploy and retrieve purse seines using small boats in confined areas, such as riverine systems.
- Observe Asian carp behavioral response to the deployment and retrieval of the purse seine.

Gear Description

The purse seine is a 525-foot circumference net with an extruded conical bunt in the center and 200-foot wings on either side. A cinching "purse" line is run through rings attached to the bottom of the net, allowing the net to be pulled shut after it encircles a school of fish. The bunt was added to address the issue of Silver Carp jumping over the top of the net during pursing by allowing an escape route. The fish are hoisted into the boat with a winch and the net is emptied through the cod end.

Application

Deployment and retrieval methods were tested in Starved Rock Pool the week of December 8, 2015. The initial attempts with the purse seine did not produce the desired results in numbers of fish caught nor the predicted level of efficiency. However, these trials provided great insight for modifications and alternative techniques that can be employed to improve catch numbers, increase safety, and simplify deployment and retrieval procedures.

Development of a lampara seine, which is a small-mesh, lightweight purse seine targeting concentrations of juvenile Asian carp, begins in 2016. Many of the same concepts developed to operate the purse seine will be applied to deployment and retrieval of the lampara seine.

Application: Movement and Distribution of Small Asian Carp

Background

Novel and exploratory gears were incorporated into Asian carp monitoring efforts being conducted as a part of the Distribution and Movement of Small Asian Carp in the Illinois Waterway. Although these efforts targeted juvenile Asian carp <153 mm, all sizes of Silver Carp were captured. This multi-gear monitoring project allowed for investigation into the ability of traditional and novel gears to capture Silver Carp of varying size classes.

Objectives

- What size classes of Asian carp are captured by traditional sampling techniques compared to innovative sampling techniques?
- How does electricity change the sizes of Silver Carp captured?

Exploratory Gear Development Project

Methods

For a full discussion of sampling methods, refer to the Movement and Distribution of Small Asian Carp summary found elsewhere in this document. Efforts were spread throughout the LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools from April through November 2015. Length histograms were created for each sampling technique to illustrate the size classes captured by the various gears.

Results

In 2015, over 90% of the Silver Carp captured by non-electrified sampling methods were less than 153 mm. The non-electrified paupier captured 250 Silver Carp ranging from 62 to 700 mm and 93% were less than 153mm (Figure 5). The non-electrified dozer trawl captured 124 Silver Carp ranging from 51 to 750 mm, of which 97% were less than 153mm. The surface trawl captured 330 Silver Carp; 93% were less than 153 mm. Of the 48 Silver Carp captured by push trawl, all of them were less than 153mm. All but one of the ten Silver Carp captured in mini-fykes were less than 153mm.

Electrified methods captured Silver Carp in all size classes (Figure 5). The electrified paupier captured 3,506 Silver Carp measuring 24 to 1,000 mm. Of those, 12% were less than 153mm. Traditional boat electrofishing caught 779 Silver Carp ranging from 95 to 898 mm of which 1% was less than 153mm.

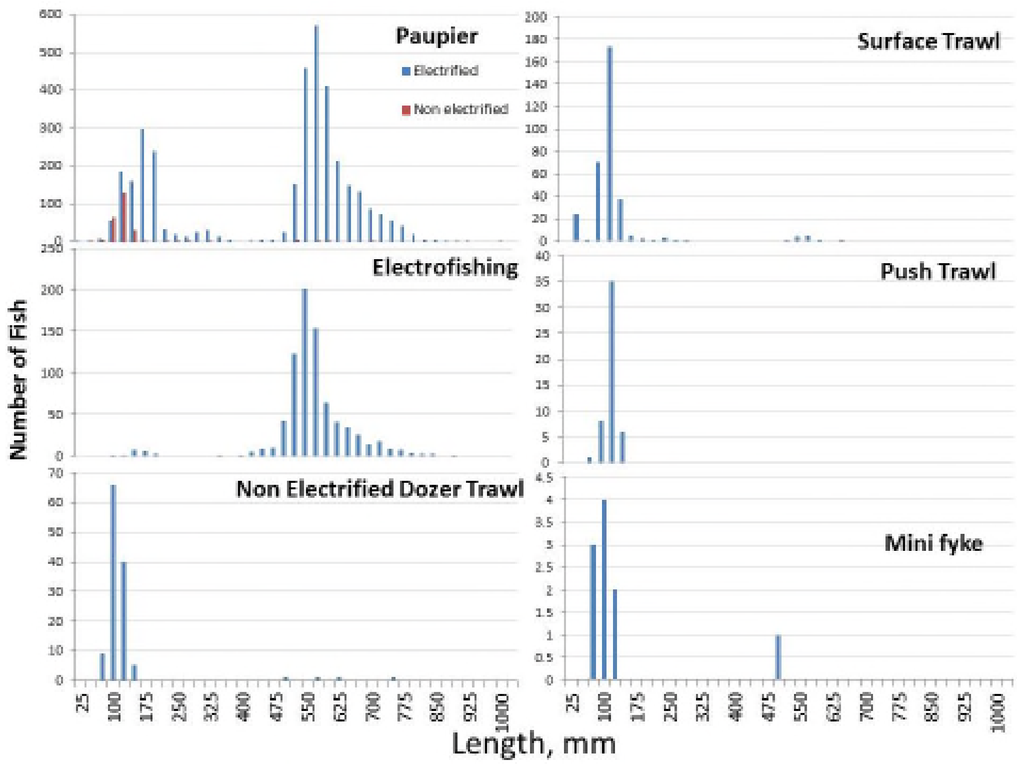


Figure 5. *Silver Carp length histograms for traditional (boat electrofishing and mini-fykes) and novel (paupier electrified and non-electrified, dozer trawl, surface trawl, and push trawl) sampling techniques in the Illinois River, April-November 2015.*

Exploratory Gear Development Project

Discussion

Sampling techniques using electricity captured the widest range of Silver Carp sizes in 2015. Non-electrified techniques detected Silver Carp <153 mm, but were less likely to detect a Silver Carp as it grew past this stage. In general, using a sampling technique that involves electricity appears to increase the likelihood of catching Silver Carp greater than 150 mm.

Many of the non-electrified sampling techniques (dozer trawl, surface trawl, and mini-fykes) captured adult Silver Carp. These were chance captures, and it is not suggested to use non-electrified sampling techniques to monitor Asian carp greater than 150 mm.

As monitoring efforts evolve, it would be prudent to develop protocols using gears at appropriate times for detecting the size classes of Asian carp present. For example, electrified sampling methods capture fish of all sizes and could therefore be incorporated into protocols throughout the year, whereas techniques targeting the earlier life stages should be focused on the time period associated with post-spawning. This post-spawn time period may be informed by observations of spawning activity, detection of larval Asian carp, or during a specific water temperature, discharge, or calendar date.

Application: Barrier Defense

Background

The electrified paupier partnered with commercial gill nets to remove adult Asian carp from the Starved Rock and Marseilles pools as part of barrier defense efforts in 2015. In an integrated effort to reduce a population, Columbia FWCO and commercial fishers targeted sites known to have high densities of Asian carp.

Objectives

- Does the paupier catch the same size Silver Carp as commercial fishing gill nets?

Methods

On November 4 and 5, 2015, Columbia FWCO partnered with a commercial fishing boat to remove adult Asian carp from Sheehan Island backwater (Starved Rock Pool) and Hansen Material Services West Pit (Marseilles Pool).

On November 4, the commercial fishermen blocked the entrance to Sheehan Island backwater with gill nets and then set additional nets in the open backwater. Meanwhile, the electrified paupier fished the closed-off backwater capturing fish and herding others into the gill nets. The paupier did seven runs averaging 11 minutes in approximately 4 hours of sampling in Sheehan Island Backwater. During that same time, the commercial fishers deployed and retrieved 1,000 yards of gill net.

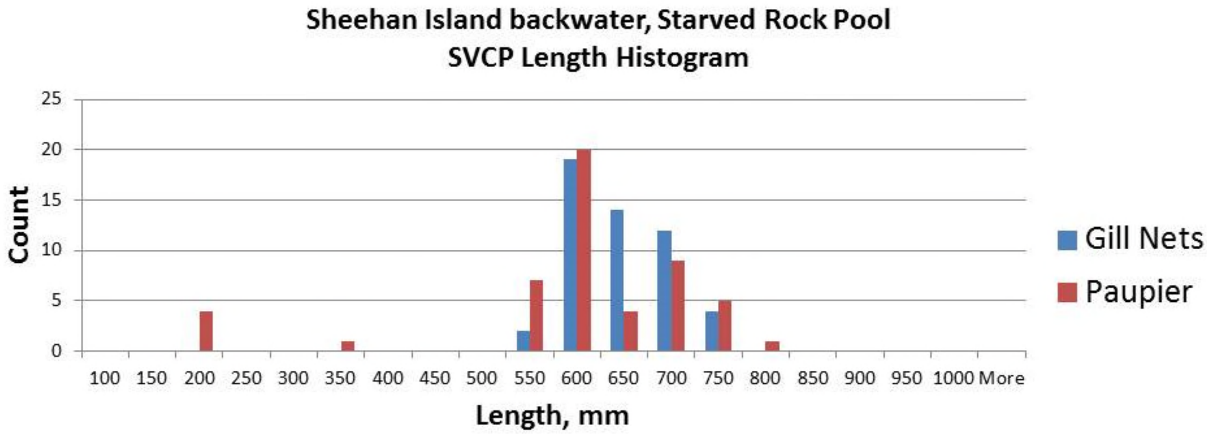
A similar method was used in the Hansen Material Services West Pit with gill nets blocking off an area of the backwater and the electrified paupier operating within the blocked off area. The paupier did five runs in Hansen Material Services West Pit averaging 10 minutes in approximately 4 hours of sampling. The commercial fishers deployed and retrieved 1,000 yards of gill net in that same time.

Following removal efforts, 50 Silver Carp were randomly chosen and measured from the total catch of each gear in both locations.

Results

The electrified paupier captured 439 Silver Carp and commercial gill nets captured 421 Silver Carp in Sheehan Island Backwater on November 4, 2015. The following day, the paupier captured 109 Silver Carp while commercial gill nets captured 530 Silver Carp in Hansen Material Services West Pit.

The mean total length of Silver Carp collected by electrified paupier (n=102, mean = 619.8 mm, SE=11.5) was significantly different from those collected by gill nets (n=102, mean = 656.1 mm, SE=5.6; two sample t-test $p<0.005$). This difference was the result of the wider range of Silver Carp sizes captured by electrified paupier, and specifically the capture of juvenile Silver Carp in Sheehan Island backwater (Figure 6). In Sheehan Island, the electrified paupier captured Silver Carp ranging 625 mm (175 to 800 mm) while gill nets covered a 201 mm range (540 to 741 mm). No juvenile Silver Carp were captured in Hansen Material Services West Pit; however, the electrified paupier captured a slightly wider range of Silver Carp sizes (542 to 783 mm) than commercial gill nets (584 to 782 mm).



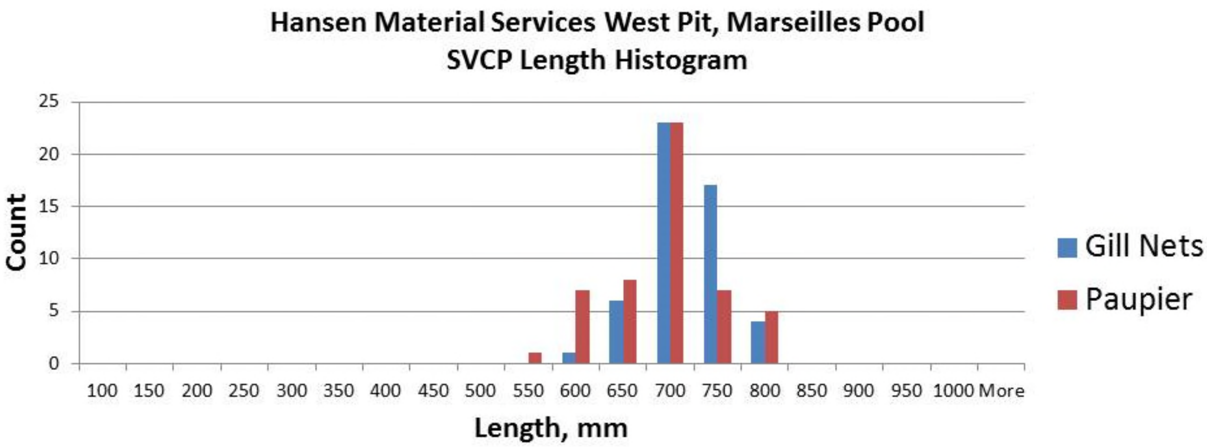


Figure 6. *Length histograms for Silver Carp captured by electrified paupier (top) and commercial gill nets (bottom) during barrier defense efforts in Starved Rock and Marseilles pools, November 4-5, 2015.*

A two sample t-Test revealed a significant difference (P<0.000) between the mean length of Silver Carp captured in the Sheehan Island backwater in Starved Rock Pool and those from the Hansen Material Services West Pit in the Marseilles Pool (Figure 7).

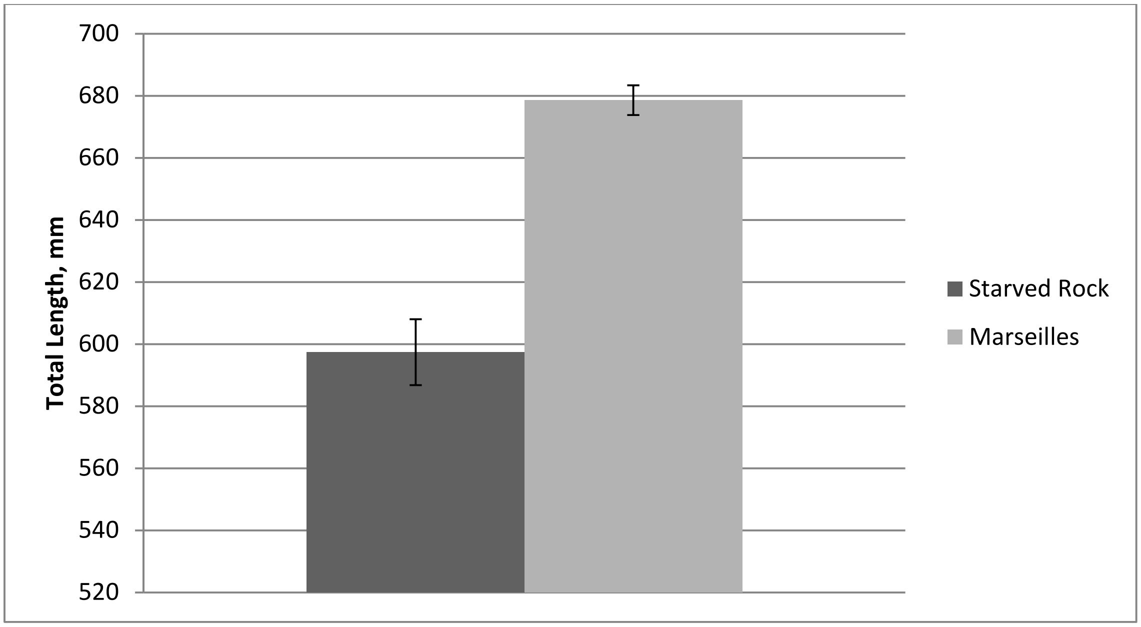


Figure 7. ***Mean length (mm) of Silver Carp captured by commercial gill nets and electrified paupier in the Starved Rock and Marseilles Pools, November 4-5, 2015.***

Discussion

This integrated approach facilitated removal of all sizes of Asian carp from a targeted area. Depending on the mesh, gill nets target a very specific size of fish. The electrified paupier is capable of capturing a wider range of Silver Carp size classes by combining electricity and the smaller net mesh. Regardless of the technique used, Silver Carp captured in the Hansen Material Services Pit were larger than those captured in Sheehan Island backwater in the Starved Rock Pool.

The electrified paupier and commercial gill nets captured nearly the same amount of Silver Carp during 4 hours of sampling in the Sheehan Island backwater of the Starved Rock Pool. However, commercial gill nets captured more fish than the electrified paupier in the Hansen Material Services West Pit in the Marseilles Pool. One factor that could have contributed to this discrepancy was depth; Hansen Material Services was approximately 0.6 meter (2 feet) deeper than Sheehan Island backwater. Although the paupier frames can be lowered to fish deeper water, this lower depth distorts the electrical field and may not be as efficient as when fished at the 1- to 1.5-meter range.

Use of Video Technology in Asian Carp Monitoring and Control Studies

Background

The amps are adjusted and observations of fish behavior are noted to determine species tolerance to amperage administered during electrofishing. The targeted response behavior is taxis, or forced swimming toward the anode. Another common response is complete immobilization. Neither response is often seen in Silver Carp. Instead, Silver Carp respond rapidly to boat motors and electricity by jumping out of the water and away from the perceived threat.

Exploratory Gear Development Project

Video of electrified paupier in multiple habitats and all seasons is used to observe Asian carp behavioral responses to electricity. By analyzing these videos thoroughly, sampling efforts can be refined to increase applications of electricity in further monitoring and removal efforts.

Objectives

- Analyze video of areas repeatedly sampled to estimate population densities.
- Determine Silver Carp response to various electrofishing settings.

Methods

Using GoPro cameras attached to either side of the paupier boat, the majority of paupier sampling was recorded in a variety of locations, habitats, and seasons. In 2015, spring began on May 20, summer on June 21, fall on September 23, and winter began on December 22. Videos were analyzed to record Asian carp reactions to various levels of electricity. The following behavioral responses were noted:

- Fish jumping
- Distance from paupier frame of fish jumping
- Taxis
- Immobilization
- Number of fish seen in the video

Behavioral responses were then linked to field sampling data for summary and analysis.

Results

Nearly 600 videos from all seasons and multiple water bodies have been recorded. Fall and summer data are still being analyzed. Initial observations have shown no differences in estimated densities of Silver Carp between winter and spring sampling events in the same location.

Preliminary results show a correlation between the electrofishing settings, specifically power (watts), and immobilization (Figure 8). Under 5,000 watts, immobilization is observed in only 10 percent of the videos where fish were noted. As power increases to 10,000 watts, immobilization is observed in 40 percent of the videos with Silver Carp. As power exceeds 11,000 watts, the proportion of videos showing immobilization decreases.

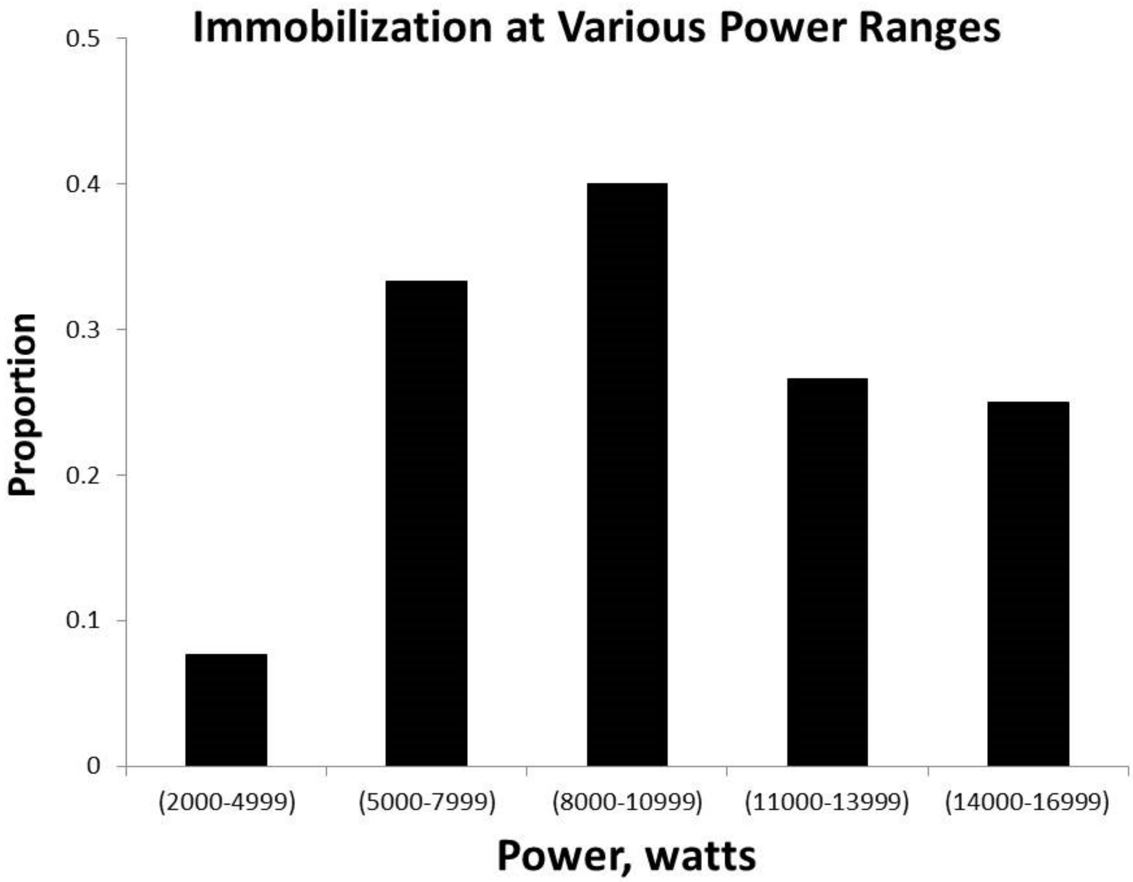


Figure 8. *Proportion of Silver Carp immobilized at various power settings during electrified paupier sampling, winter and spring 2015.*

Discussion

No difference in the densities of Silver Carp has been observed of the areas sampled repeatedly in winter and spring, suggesting that the population density is static during spring and winter in these locations. Analysis of summer and fall videos may show whether these habitats are used seasonally or if these areas support a stable population of carp year-round.

Many community sampling protocols' target power goals are standardized at less than 5,000 watts (Miranda 2009, Ratcliff et al. 2014). These goals may not achieve the capture rate necessary to measure Silver Carp response to management activities. To achieve 10,000 watts of power, traditional boat electrofishing set-ups will have to adjust duty cycle and pulse rate (frequency) settings. Even then, the overall design of the boat or a higher amp electrofishing box may be needed to achieve these goals.

Preliminary data suggest that high power outputs, over 11,000 watts, are not effective to immobilize Silver Carp. This observation may be the result of the relatively small sample size that has been analyzed up to this date. Another possibility is that the sensitive Silver Carp may sense the electricity in the water and therefore swim away before stunning, immobilization, and capture are possible.

Overall Discussion:

Developing standard sampling techniques for the capture and subsequent monitoring of Asian carp populations in the Illinois River is essential to measure the impacts of management activities. In 2015, the paupier (electrified and non-electrified), surface trawls, and dozer trawls were further standardized and incorporated into monitoring and response efforts. These efforts allowed for comparisons with traditional gears such as boat electrofishing, mini-fykes, and gill nets. These novel sampling techniques showed great success in capturing all sizes of Silver Carp. Gears without electricity successfully captured Silver Carp less than 153 mm but electricity was necessary to ensure capture as the fish grew. Video of electrified paupier sampling is used to evaluate Silver Carp behavioral response to electrofishing and estimate invasive carp population densities. In addition to the improvement of sampling techniques to detect and monitor Asian carp populations, modified purse seines are being developed for mass removal of invasive carp populations in a riverine environment.

Recommendations:

More investigations to understand Asian carp response to electrofishing settings are suggested to refine electrofishing sampling techniques and protocols targeting them. Further evaluating the ability of innovative and traditional sampling methods to capture all sizes of invasive carp in various habitats is suggested before large-scale protocols would be developed to monitor populations and assess risks associated with these nuisance species.

Literature Cited:

Emmrich, M., I.P. Hellend, S. Busch, S. Schiller, and T. Mehner. 2010. Hydroacoustic estimates of fish densities in comparison with stratified pelagic trawl sampling in two deep, coregonid-dominated lakes. *Fisheries Research*, 105: 3, 178-186.

Kolz, A. Lawrence. 1993. In-Water Electrical Measurements for Evaluating Electrofishing Systems. Fish and Wildlife Service Denver Co Denver Wildlife Research Center.

Miranda, L. E. 2009.Standardizing Electrofishing Power for Boat Electrofishing. Pages 223-230 *in* S. A. Bonar, W. A. Hubert, and D. W. Willis, editors. Standard Methods for Sampling North American Freshwater Fishes. American Fisheries Society, Bethesda, Maryland.

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

Ridenour, C. J., W. J. Doyle, and T. D. Hill. 2011. Habitats of Age-0 Sturgeon in the Lower Missouri River. *Transactions of the American Fisheries Society*, 140:5, 1351-1358.

Unconventional Gear Development

ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Steven E. Butler, Scott F. Collins, Matthew J. Diana, David H. Wahl (Illinois Natural History Survey)

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction: Traditional sampling gears vary widely in their ability to capture Asian carp. Many of these gears may have limited effectiveness for detecting Asian carp in areas of low population density without expending extremely high levels of sampling effort. Additionally, the conditions in the CAWS present numerous challenges that limit the ability of many types of gear to effectively sample for Asian carp. Sampling gears or combinations that are effective in such habitats or that substantially increase the probability that Asian carp will be detected in areas where they occur in low abundance are needed to enhance monitoring and control efforts. Capture efficiency and size selectivity of several new methods are being evaluated and compared with selected traditional gears to assess the utility of these techniques for monitoring and controlling Asian carp populations.

Objectives: To enhance sampling success for low-density Asian carp populations, we are:

(1) Investigating alternative techniques to enhance capture of rare Asian carp in deep-draft canals, such as in the CAWS; and

(2) Evaluating gear and combination system prototypes in areas with low to moderate Asian carp population densities.

Project Highlights:

- 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 sound stimuli for attracting and deterring Asian carp. They are being used by IDNR in the upper Illinois Waterway as part of monitoring and control activities.
- Pound nets are capable of capturing large numbers of fish and produce substantially higher catch rates of Asian carp than traditional entrapment gears in backwater habitats.
- Estimation of the effort required to deploy, maintain, and retrieve various entrapment gears indicates that pound nets are the most cost-effective gear type for capturing Asian carp in backwater lake habitats because of their high catch rates relative to the labor hours invested.

Unconventional Gear Development

Methods: In 2015, unconventional gear efforts focused on the use of Great Lakes trap (pound) nets in collaboration with IDNR and USGS partners to achieve various monitoring and research objectives. Pound nets (100 m lead, 6.1 x 3.0 x 3.0 m pot, 7.6-9.1 m wings, 3.8-6.4 cm mesh) were deployed for 2-week periods at the Lily Lake backwater (LaGrange Pool) during April, June, and August in collaboration with USGS to test the effectiveness of feeding attractants and sound stimuli for capturing and deterring Asian carp. During these trials, attractants were tested by deploying the attractant at one net and using a second net as a control. Pound nets were checked daily during each set, when all captured fish were removed from the pots for identification and measurement. INHS also assisted IDNR personnel using pound nets at the Hanson Material Service pit (Marseilles Pool) for monitoring and removing Asian carp during May.

Results and Discussion: Results of feeding attractant and sound stimuli trials will be reported by USGS. Catch totals from monitoring and removal activities in the upper Illinois Waterway will be reported by ILDNR. Findings from previous years' pound net evaluation were prepared, submitted, and accepted for publication during 2015 (see Collins et al. 2015). In summary, catch rates of Bighead Carp and Silver Carp by pound nets were typically one to three orders of magnitude higher than for fyke nets or hoop nets set in similar backwater habitats. Pound nets tend to capture larger Bighead Carp than fyke nets or hoop nets, but Silver Carp size distributions appear to be similar among gears. Estimation of the labor hours required to deploy, maintain, and retrieve various entrapment gears indicates that pound nets are considerably more cost effective for capturing Asian carp than fyke nets or hoop nets because of the high catch rates relative to the labor hours invested.

Recommendations: Pound nets appear to be highly effective for capturing large numbers of adult Asian carp in backwater habitats relative to traditional entrapment gears. Pounds nets are already proving useful for a variety of monitoring, control, and research purposes. The use of pound nets instead of traditional entrapment gears may increase efficiencies and help save natural resource agencies considerable personnel time. However, use of pound nets is limited to certain habitats, and areas with even moderate current or water level fluctuations may be unsuitable for their use. Frequent attendance of pound nets is recommended to ensure that pound nets are fishing effectively and to minimize mortality of native species.

Literature Cited:

Collins, S.C., 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.

Monitoring Adult Asian Carp through Netting with Supplemental Capture Techniques

Trevor Cyphers, Rebecca Neeley, Sam Finney, Robert Simmonds Jr.
(USFWS Carterville Fish and Wildlife Conservation Office – Wilmington Substation)

Participating Agencies: U.S. Fish and Wildlife Service Carterville Fish and Wildlife Conservation Office – Wilmington Substation (lead), Illinois Department of Natural Resources (project support).

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction

Asian carp have inhabited parts of the Illinois River Basin through rapid growth rates, short generation times, and dispersal capabilities; however, the overall leading edge of adult Asian carp has remained relatively unchanged since 2006. With established Asian carp populations in the lower and middle pools of the Illinois River, an increased monitoring effort has been taken on by federal, state, and private agencies within the upper Illinois River (waterway) and the CAWS. Monitoring effort has traditionally been conducted using traditional gears, such as gill netting, electrofishing, hoop nets, and pound nets to detect the presence of adult Asian carp.

This project was established to aid the current monitoring effort and potentially increase the probability that adult Asian carp will be detected in the pools closest to the USACE Electrical Dispersal Barriers. Trammel and gill nets were used in conjunction with supplemental capture techniques to potentially increase catch rates of adult Asian carp. Supplemental capture techniques included driving fish into nets through electrofishing, directional sound (mounted underwater speakers) and non-directional sound (pounding on the boat hull). Techniques were tested in the Peoria pool of the Illinois River to determine which techniques garnered the highest catch rates with regards to Asian carp and native species. After the most efficient techniques had been identified and a collection protocol established, efforts were focused on Dresden Island, Brandon Road, and Lockport pools.

Objectives:

(1) Increase monitoring effort in the upper pools of the Illinois River Basin and aid in understanding the current extent of the adult Asian carp population.

(2) Determine which supplemental capture techniques are most effective at capturing adult Asian carp and native species through analysis of CPUE.

Project Highlights

- 802 fish were caught using gill and trammel nets
- 33,650 yards of gill or trammel net were fished
- Gill and trammel nets yielded an overall CPUE of 2.38 fish per 100 yards of net

Monitoring Adult Asian Carp through Netting with Supplemental Capture Techniques

- A total of 15 different species were captured in gill and trammel nets
- 451 Asian carp were captured via gill or trammel nets
- Overall Asian carp CPUE using gill and trammel nets was 1.34 fish per 100 yard of net
- The farthest upstream Asian carp was collected at latitude 41.39611; longitude -88.22886 in Dresden Island
- CPUE for capture technique was statically different in the Peoria Pool analysis
- Electrofishing was the most proficient supplemental capture technique
- Electrofishing yielded a CPUE of 6.12 fish per 100 yards of net for all fish
- Electrofishing yielded a CPUE of 4.33 fish per 100 yards of net for Asian carp
- Directional sound yielded a CPUE of 0.75 fish per 100 yards of net for all fish
- Directional sound yielded a CPUE of 0.19 fish per 100 yards of net for Asian carp
- Non-directional sound yielded a CPUE of 0.82 fish per 100 yards of net for all fish
- Non-directional sound yielded a CPUE of 0.05 fish per 100 yards of net for Asian carp
- 444 fish were collected using the supplemental electrofishing capture technique
- 332 Asian carp were collected using the supplemental electrofishing capture technique

Methods

A combination of gill, trammel, and floating trammel nets were used in conjunction with supplemental capture techniques to monitor adult Asian carp in the Illinois River within Lockport, Brandon Road, Dresden Island, Marseilles, Starved Rock, and Peoria pools. Sampling events within the lower pools of the Illinois River (Peoria, Starved Rock, and Marseilles) were predominantly used to establish collection procedure and refine capture techniques in areas where Asian carp are readily available. Sampling events in the Upper Illinois River (Dresden Island, Brandon Road, and Lockport) were geared toward utilizing supplemental capture methods to aid in the detection of adult Asian carp (Silver Carp, Bighead Carp, and Grass Carp).

Nets used for this project consisted of gill nets 12, 16, or 24 feet deep by 100 yards long with bar mesh of 3, 3.5, 4, and 4.25 inches, trammel nets 12 feet deep by 200 yards long with bar mesh of 3, 3.5, or 4 inches, and floating trammel nets 12 feet deep by 100 yards long with bar mesh of 3.5 inches. Floating trammel nets were fished in main or side channel current without utilizing a capture technique. Nets were deployed in predetermined areas based on river current, topography, and suggestions from the IDNR and commercial fisherman contracted by the IDNR. When the nets were deployed, GPS coordinates were recorded and capture techniques were implemented. Asian carp collected in Dresden Island and above were measured for length (mm) and weight (kg), sex and lapilli otoliths were taken for aging and analysis of microchemistry, while native fish were enumerated and released.

Supplemental techniques included driving fish into nets by using electrofishing, directional sound, non-directional sound, or a combination of these techniques. Electrofishing involved using pulsed DC current around gill/trammel nets in an attempt to push fish into nets. Electrofishing runs were recorded for time and stunned fish were collected by dip-netters, with netting priority given to Asian carp over native fish species. Fish captured during electrofishing runs were enumerated to analyze CPUE of electrofishing during technique evaluation. Directional sound used a Lubell LL9162T acoustic underwater transducer with a Peavey amplifier attached to a dock line lowered 6 feet into the water column. Transducers were employed with an audio file of a 100 HP boat motor to startle fish. A DolphinEar DE200 series hydrophone was used to ensure transducers were functioning properly. Non-directional sound, a technique frequently used by commercial fishermen, involved driving fishing into nets by noise created from pounding on boat hulls with wrenches or mallets, using plungers on the surface of the water, and revving tilted boat motors. Combinations of capture techniques were evaluated to detect the possibility of using multiple techniques to increase the probability of detecting Asian carp. Technique utilization was often determined by gear and crew availability.

Supplemental capture techniques were analyzed for efficiency in Peoria pool by comparing techniques across three sites. Each technique was standardized by using the same trammel net configuration at each site and each capture technique to drive fish for 15 minutes. CPUE was determined for each technique and analyzed via one-way ANOVA to determine statistical differences ($\alpha = 0.05$).

Results and Discussion

Gill and trammel net overall catch – Sampling via gill or trammel netting was done from May 15, 2015, to October 28, 2015, and consisted of 241 net sets, 33,650 yards, 216.9 hours of netting time, with 802 total fish captured. This effort resulted in a total of 15 different species being captured with an overall CPUE of 2.38 fish per 100 yards of netting effort (Table 1).

Table 1. *Netting effort and netting catch based on pools within the Illinois River for the 2015 sampling season.*

	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	Total/ Avg
Netting Effort							
Net Sets	50	44	76	20	37	14	241
Distance (yds.)	6900	5400	10600	2800	5150	2800	33650
Time Fished (hrs.)	28.8	27.5	68.9	22.9	11.9	56.8	216.9
Netting Catch							
All Fish	14	38	126	153	319	152	802
Species	1	4	8	10	10	10	15
CPUE (fish/100 yds.)	0.20	0.70	1.19	5.46	6.19	5.43	2.38

Marseilles, Starved Rock, and Peoria pools had the highest CPUEs with 5.46, 6.19, and 5.43 fish per 100 yards of netting effort (Table 1). The upper pools (Dresden Island, Brandon Road, and Lockport) accounted for 68.1 percent of the total netting effort, but yielded only 22.2 percent of the total catch, a CPUE of 0.78 fish per 100 yards of net (Table 1). Most of the low yield can be attributed to Brandon Road and Lockport pools, where suitable habitat is hard to find and fish density is relatively low. Silver Carp, Common Carp, Smallmouth Buffalo, and Grass Carp were the predominant species, accounting for 88.9 percent of the total catch (Table 2).

Table 2. *Species captured and counts based on pool for gill/trammel netting within the Illinois River for the 2015 sampling season.*

Fish Species	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	Total
Bighead Carp	-	-	-	12	9	2	23
Bigmouth Buffalo	-	-	1	18	5	15	39
Channel Catfish	-	1	3	4	1	1	10
Common Carp	14	32	76	7	20	24	173
Flathead Catfish	-	-	1	2	1	-	4
Freshwater Drum	-	1	2	-	2	1	6
Grass Carp	-	-	-	1	17	56	74
Hybrid Striped Bass	-	-	-	-	-	1	1
Longnose Gar	-	-	2	-	-	-	2
Paddlefish	-	-	-	1	-	-	1
River Carpsucker	-	-	-	1	-	1	2
Silver Carp	-	-	4	56	245	49	354
Skipjack Hearing	-	-	-	-	1	-	1
Smallmouth Buffalo	-	4	37	51	18	2	112
Total	14	38	126	153	319	152	802

Asian carp catch - Asian carp captured in gill and trammel nets totaled 451 fish with a CPUE of 1.34 fish per 100 yards of netting effort, accounting for 56.2 percent of the total catch. Asian carp were captured only in the Dresden Island, Marseilles, Starved Rock, and Peoria pools of the Illinois River, with 70.7 percent of Asian carp being collected in Starved Rock (Table 3).

Table 3. *Netting catch and length of Asian carp based on pools within the Illinois River for the 2015 sampling season.*

	Dresden Island	Marseilles	Starved Rock	Peoria	Total/Avg.
All carp	4	69	271	107	451
Silver carp	4	56	245	49	354
Avg. Length (mm)	740.3	665.7	596.8	573.7	609.1
Bighead carp	-	12	9	2	23
Avg. Length (mm)	-	706.0	756.5	640.0	715.0
Grass carp	-	1	17	56	74
Avg. Length (mm)	-	880.0	703.2	737.7	735.6
CPUE (fish/100 yds.)	0.04	2.46	5.26	70.39	56.23

Dresden Island, Marseilles, Starved Rock, and Peoria pools had CPUEs of 0.04, 2.46, 5.26 and 3.82 Asian carp per 100 yards of netting effort (Table 3). Silver Carp were the most abundant Asian carp species, accounting for 78.5 percent of all Asian carp captured. Population dynamics data regarding Silver Carp indicated a statistical difference between total length and pool captured (Table 3, Figure 1).

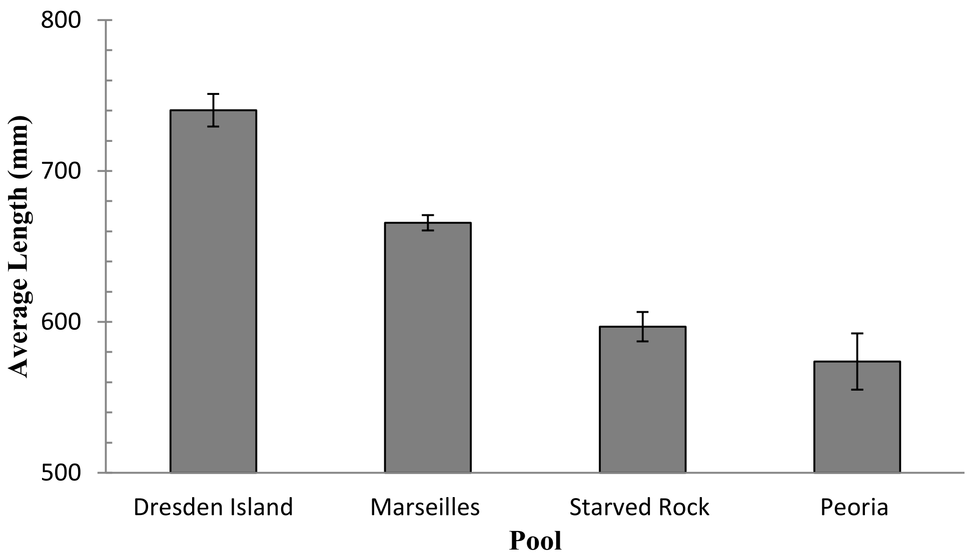


Figure 1. *Average total length of Silver Carp captured in gill/trammel nets based on pool captured within the Illinois River during the 2015 sampling season.*

The detection front of adult Asian carp during this project was Dresden Island Pool near river mile 275, southwest of Conroy Island (Figure 2), farther downstream than historical data from the IDNR.

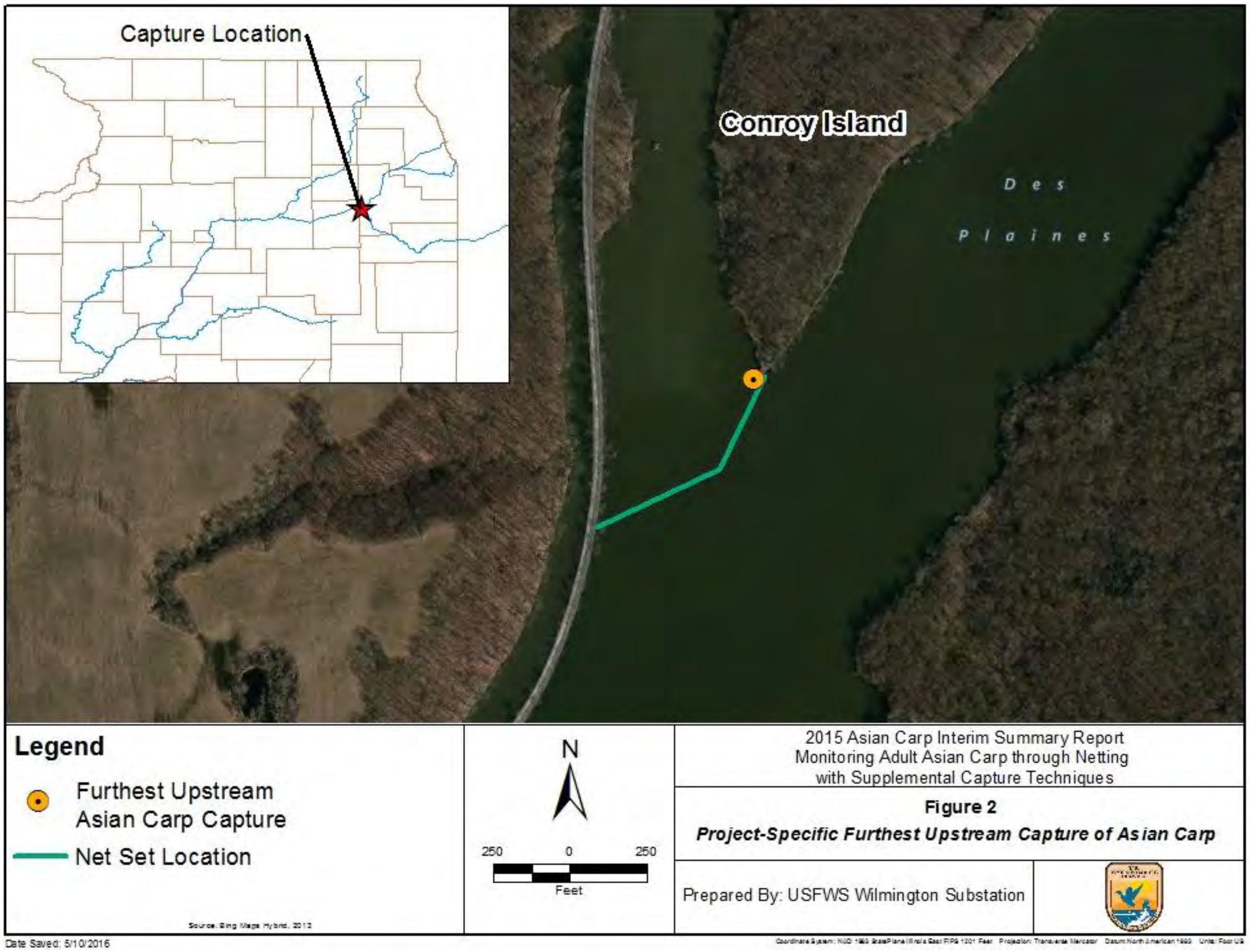


Figure 2. *Farthest upstream capture of a Silver Carp (this project) on the Illinois River for the 2015 sampling season.*

Although no Asian carp have been captured above Dresden Island Pool, continued monitoring efforts are warranted in Brandon Road and Lockport pools to verify that there are no Asian carp within these pools.

Analyzing supplemental capture techniques – Comparing supplemental techniques in Peoria pool indicated that electrofishing was the most effective capture technique of the three techniques analyzed, accounting for 88.8 percent of the total fish captured in gill or trammel nets with a CPUE of 10.88 fish per 100 yards of net. With regards to Asian carp, electrofishing was the most effective capture technique, accounting for 92.0 percent of all Asian carp captured and a CPUE of 10.00 Asian carp per 100 yards of net (Table 4, Figure 3). Statistical analysis (one-way ANOVAs) indicated a statistical difference between CPUE and capture techniques with regards to all fish and strictly Asian Carp.

Table 4. *Netting catch for all fish and Asian carp based on capture techniques that were used within Peoria Pool of the Illinois River for the 2015 sampling season.*

Site	Total Fish	CPUE (fish/100 yds.)	Total Asian Carp	CPUE (fish/100 yds.)
Electrofishing				
1	26.0	6.5	26.0	6.5
2	34.0	17.0	31.0	15.5
3	27.0	13.5	23.0	11.5
Total/Avg.	87.0	10.88	80.0	10
Directional Sound				
Site	Total Fish	CPUE (fish/100 yds.)	Total Asian Carp	CPUE (fish/100 yds.)
1	1.0	0.3	1.0	0.3
2	0.0	0.0	0.0	0.0
3	3.0	1.5	2.0	1.0
Total/Avg.	4.0	0.5	3.0	0.4
Non-Directional Sound				
Site	Total Fish	CPUE (fish/100 yds.)	Total Asian Carp	CPUE (fish/100 yds.)
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	7.0	3.5	4.0	2.0
Total/Avg.	7	0.88	4.0	0.5

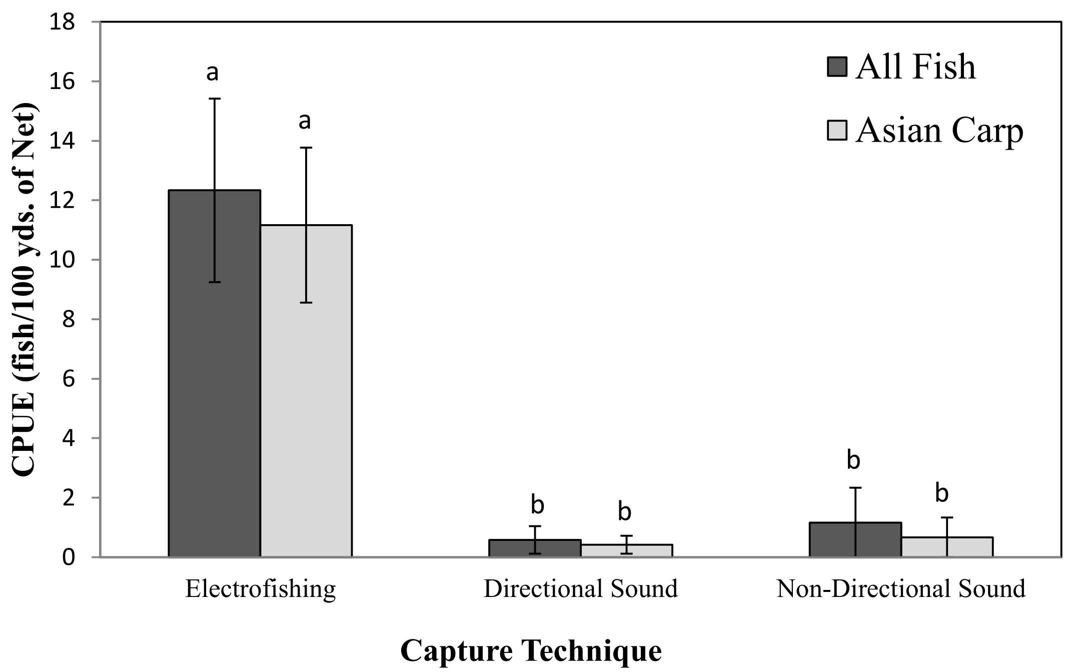


Figure 3. *Average CPUE of each supplemental capture technique evaluated in Peoria Pool based on all fish and strictly Asian carp.*

Supplemental capture techniques overall – Evaluating supplemental capture techniques from all netting effort indicated that electrofishing was the most successful technique at driving fish into gill or trammel nets. Electrofishing accounted for 63.0 percent of all fish captured while only accounting for 24.5 percent of the total effort. Electrofishing had the highest CPUE regarding all fish, with 6.12 fish per 100 yards of netting effort, with no supplemental technique having the second highest CPUE with 5.40 fish per 100 yards of netting effort (Table 5).

Table 5. *Netting catch of all fish and all Asian carp based on the capture technique that was used within the Illinois River for the 2015 sampling season.*

Technique	Net Sets	Total yards	All Fish	CPUE (fish/100 yds.)	Asian Carp	CPUE (fish/100 yds.)
Directional Sound	9	1600	12	0.75	3	0.19
Directional Sound, Non-Directional Sound	10	1600	12	0.75	-	-
Electrofishing	53	8250	505	6.12	357	4.33
Electrofishing, Non-Directional Sound	38	4400	82	1.86	37	0.84
No Technique	8	1000	54	5.40	46	4.60
Non-Directional Sound	123	16800	137	0.82	8	0.05
Total	241	33650	802	2.38	451	1.34

Electrofishing may have been the most effective means of driving fish because electricity typically drives fish better than sound. Non-directional sound was the most used capture technique, accounting for 49.9 percent of the total effort with a CPUE of 0.82 fish per 100 yards of netting effort. Directional sound was an ineffective means of driving fish into nets, resulting in a CPUE of 0.75 fish per 100 yards of net. One reason may be because most this effort was geared toward the upper pools of the Illinois River. Directional sound should be further evaluated to ensure that the most efficient sound levels and audio files are being used to push adult Asia carp. Focusing only on catch rates of Asian carp, no supplemental technique and electrofishing was the most effective, having CPUEs of 4.60 and 4.33 Asian carp per 100 yards of netting effort (Table 5).

Electrofishing Technique Catch – Electrofishing as a supplemental capture technique yielded a catch of 444 fish over 5.8 hours, resulting in a CPUE of 76.61 fish per hour of electrofishing. Asian carp accounted for 332 of the total fish, or 74.8 percent of the total catch with a CPUE of 57.29 Asian carp per hour of electrofishing (Table 6). Electrofishing resulted in collection of 17 unique species from the Illinois River. When electrofishing is used as a capture technique it allows for another viable means of collecting adult Asian carp.

Table 6. *Electrofishing effort and CPUE for all fish and Asian carp while driving gill/trammel nets during the 2015 sampling season.*

	Lockport	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	Total/Avg.
All Fish	0	65	33	17	232	97	444.0
Time Fished (hrs)	0.6	0.8	1.0	0.4	2.0	1.0	5.8
CPUE (fish/hr)	0.00	83.54	34.38	39.61	118.54	92.87	76.61
Asian Carp Total	-	-	-	17	230	85	332.0
AC CPUE (fish/hr)	-	-	-	39.61	117.51	81.38	57.29

Recommendations

- Sampling for adult Asian carp using different capture techniques should be continued within the Upper Illinois River to monitor the adult Asian carp presence front.
- Electrofishing should be used more frequently as a supplemental technique for driving fish into gill or trammel nets, as it has shown to yield the highest CPUE.

Table 7. *Species captured and counts based on pool/river using the electrofishing capture technique for the 2015 sampling season.*

Fish Species	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria	Total
Bluegill	-	3	-	-	-	3
Common Carp	-	5	-	-	8	13
Emerald Shiner	1	-	-	-	-	1
Freshwater Drum	-	1	-	-	-	1
Gizzard Shad < 6 inches	60	3	-	-	-	63
Gizzard Shad > 6 inches	-	5	-	-	-	5
Golden Redhorse	-	1	-	-	-	1
Golden Shiner	2	-	-	-	-	2
Goldfish	-	1	-	-	-	1
Grass Crap	-	-	-	3	6	9
Green Sunfish	-	1	-	-	-	1
Largemouth Bass	1	6	-	-	-	7
Longnose Gar	-	1	-	-	-	1
Pumkinseed	-	-	-	1	-	1
Silver Carp	-	-	17	227	79	323
Smallmouth Buffalo	-	-	-	1	4	5
Spottail Shiner	-	3	-	-	-	3
Yelllow Bullhead	1	3	-	-	-	4
Total	65	33	17	232	97	444

An Assessment of Water Guns to Deter Asian Carp

Jon J. Amberg, Aaron Cupp, Mark Gaikowski (USGS Upper Midwest Environmental Sciences Center)
Tyson Hatton, Nick Swyers (USGS Wester Fisheries Research Center)

Participating Agencies: USGS, Great Lakes Science Center

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction

The prevention of the movement of Asian carp from the Mississippi watershed into the Great Lakes currently rests on an Electric Dispersal Barrier installed in the CAWS. Additional barriers and supplements to the Electric Dispersal Barrier would improve the efficacy of deterring Asian carp movement into the Great Lakes and elsewhere. There is a *critical need* for redundant Asian carp deterrent systems, especially for deployment when the Electric Dispersal barrier must be deactivated for maintenance or repair.

Seismic technologies used in oil exploration create high-pressure underwater sound energy waves that may deter the movement of Asian carp. These sound energy waves may be produced by a variety of means ranging from chemical explosives to high-pressure air. Two pneumatic techniques, both involving high pressure air, are the air guns and water guns. Air guns release on command a specified volume of high-pressure air that produces a steep-fronted shock wave with several oscillations caused by the repeated collapse and expansion of the air bubble (USGS 2010a). Water guns use high-pressure air to drive a shuttle through the lower chamber of the water gun. The rapid expulsion of the water in the lower chamber by the shuttle creates a void that is rapidly filled by the collapse of water back into the void. The collapse of water into this void creates a pulsed sound energy or pressure wave whose frequencies range from 20 to 1,500 Hz (USGS 2010b). The frequency generated from firing a water gun is directly related to the pressure applied and inversely related to the chamber size. The pulse signature, created by a high-velocity water jet, is characterized by a large and rapid positive to negative (peak to peak) sound pressure wave that emits large amounts of energy with a stable repeatable pulse pattern in terms of frequency composition and amplitude (USGS 2010b). Seismic technologies employed as a barrier could deter movement of or drive Asian carp from an area, effectively supplementing existing barriers or by providing a stand-alone deterrent in other locations (such as locks and connecting waterways).

Even though water guns have previously been shown to cause damage to trout and northern pike, they seem to have limited utility in killing Asian carp. Only 11 percent of Asian carp were found to have ruptured swim bladders in a 2010 study. Ponds studies in 2012 at UMESC indicated that both Silver Carp and Bighead Carp will avoid the firing water guns. Subsequent field trials at Hanson Material Service in Morris, Illinois, in 2013 and 2014 had inconclusive results when the deployment enabled a two-gun array to fire every 10 seconds. Using hydroacoustics, fish appeared to stay more than 50 meters from the firing guns, but the telemetered fish in the same study breached the water gun barrier. It is generally thought that a 10-second interval between firings is too great and a decreased interval may yield more conclusive results.

Before seismic water guns are deployed in the Chicago Area Waterway System to prevent movement of Asian carp past critical points, it is crucial that the effectiveness of this technology to either repel or damage carp in the field be conducted and demonstrated conclusively. Behavioral responses of several fish species to seismic surveys in marine environments (Lokkeborg et al. 2012) suggest that seismic survey gear (such as air guns) cause increased fish movement (as evidenced by greater catch rates of marine fishes in gillnets [a gear that required fish to encounter it]) and decreased feeding (as evidenced by decreased catch using longline sets [a gear that requires active feeding] and decreased stomach contents). Movement response appears to vary with the habitat preference of the species: those with specific habitat preferences, such as gadoid species, did not move away from their home range during air-gun emissions (Wardle et al. 2001). Skalski et al. (1992) speculated that marine species using essentially featureless habitats may have greater dispersal responses to seismic survey technologies than species that inhabit more specific “rough” bottom habitats. Applying the hypothesis of Skalski et al. (1992) for marine species to fresh water suggests that the pelagic nature of Bighead Carp and Silver Carp may cause them to disperse in response to the sound and pressure pulse generated from water gun discharge. Therefore, the goal of this project was to determine if Asian carp modify their behavior in response to firing a six-gun array, where two guns fire simultaneously every 3 to 4 seconds.

Methods

A channel was constructed in the west pit of Hanson Material Service (HMS) near Morris, Illinois. This channel was approximately 30 meters long by 32 meters wide, with a depth of less than 5 meters. The walls of the channel were parallel to shore and constructed of block nets. These block nets extended perpendicular to and onto the nearest shore to ensure that fish can pass through only the artificial channel. Approximately 200 meters east and west of the midpoint of the channel, block nets were placed across the entire pond to create an enclosed area with a channel directly in the middle. Six 100-in^3 water guns were placed within the channel in three two-gun arrays. However, technicians could not maintain the operation of two water guns, so we conducted the test trails with a four-gun array. This array ensured that two guns fired simultaneously every 6 seconds. Each two-gun array was placed at the entrance of the channel. Guns in each two-gun array were in a line along a north/south gradient with a distance between guns that allowed for a pressure of at least 0.5 in^2 across the channel.

For each trial (control and test), 30 adult Asian carp (300 to 1,000 mm TL) were captured using gill nets by commercial fishers in the west pit of HMS and immediately placed in a holding tank supplied with oxygen. Once all 30 fish were captured, they were transported to the test site. There fish were sedated with 50 mg/L of AQUI-S®20E (5 mg/L eugenol) to minimize handling stress. Individual fish were measured and tagged with an acoustic tag. An external acoustic transmitter was injected posterior to the dorsal fin, 1 cm lateral of the midline on the left side in white muscle at approximately a 30-degree angle in each fish. All tags were programmed to have a battery life of approximately 8 days. Once tagged, fish were immediately released into both sides of the test area: eight fish were released from shore closest to the channel on both the west and east side of the test area, while another eight fish were released from shore approximately 50 meters to the west and east channel. A fish was released in the following pattern until all 30 fish were released: near east, near west, far east, then far west.

As a control to study the behavior of the fish within the enclosed area without stimulus, 30 fish were placed into the enclosed test area. These fish will be allowed to freely pass through the channel and constantly monitored for 24 hours. The block nets on the ends were then removed and fish allowed to leave the enclosed study area. After 48 hours, the block nets were placed back across the test area to create the enclosure for the test trial. We initiated firing of the water guns for the test trial and then placed 30 new fish into the enclosed test area and monitored them for the next 24 hours. The block nets on the ends were then removed and fish allowed to leave the enclosed study area.

We compared the number of individual fish that crossed between the control trail and the test trial to determine if fish behavior changed in response to the firing of water guns. Additionally, we compared the time of first cross, as well as the general swimming direction of the fish while they were within the channel.

Results and Discussion

Rather than a six-gun deployment, we were able to deploy only a four-gun array because two guns failed. Two seismic technicians, with more than 30 years of experience with water guns, were unable to efficiently maintain the operation of two guns. Both guns appeared to function if they were allowed to reset every 20 seconds rather than the 12-second reset time needed in this study.

Preliminary analysis of fish tracks suggests that multiple fish crossed the barrier while the guns were firing (Figure 1).

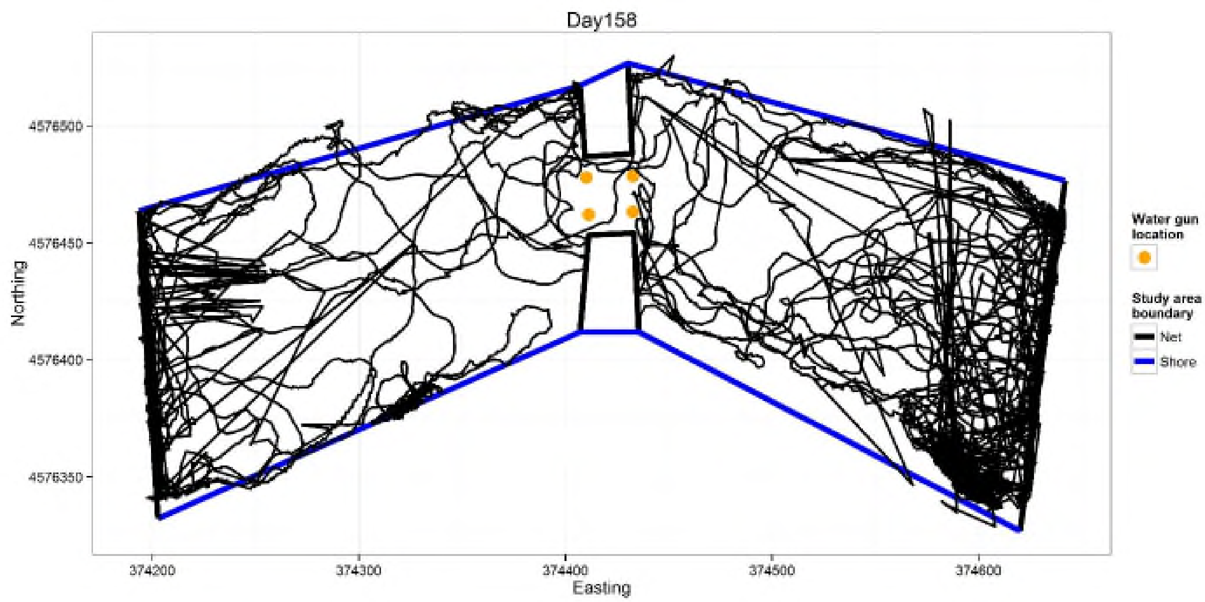


Figure 1. *An example of a single fish track during the 24 hours of operating the water gun array. This individual fish was released from the shore close to the east side of the channel and was observed crossing the channel three times.*

A total of 23 fish crossed the channel during the control period, while 19 fish crossed during the water gun testing. Many fish appeared to have crossed multiple times while water guns were fired. However, preliminary analysis of swimming direction suggests that Bighead Carp had a more directional swimming pattern while in the channel during water gun firings than during the control trial (Figure 2). This finding may be suggestive of the effect of sound as a stimuli and the minimal effect of the pressure wave produced by the cavitation of the water guns.

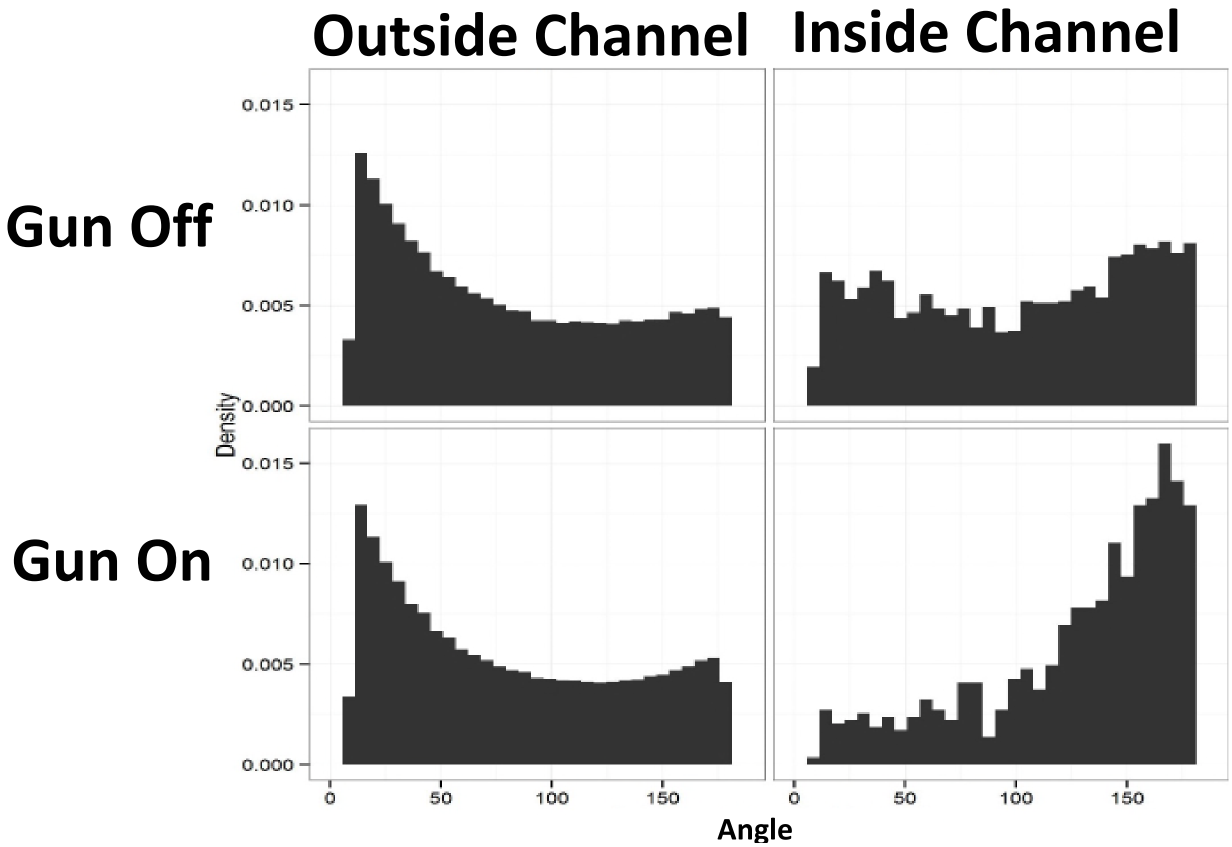


Figure 2. *Swimming direction of fish outside and inside the channel during the control period (Guns Off) and water gun testing period (Guns On).*

Table 1. *The total number of fish that did not cross the channel, entered the channel but did not cross, or crossed the channel during the control period (Guns Off) and water gun testing period (Guns On).*

	Gun Off	Gun Firing
Number of fish that did not cross channel	7	10
Number of fish that entered barrier but did not cross	2	3
Number of fish that crossed channel	23	19
Total number of fish	32	32

No additional trials with water guns will be conducted in 2016. Data for work conducted in 2015 are currently being summarized and will soon be submitted for peer-review for publication.

Literature Cited:

Løkkeborg, S., E. Ona, A. Vold, A. Salthaug. 2012. Sounds from seismic air guns: gear- and species specific effects on catch rates and fish distribution. Canadian Journal of Fisheries and Aquatic Sciences 69:1278-1291

Skalski, J.R., W.H. Pearson, C.I. Malme, C.I. 1992. Effects of sound from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (Sebastes spp). Canadian Journal of Fisheries Aquatic Sciences 49:1357–1365

USGS 2010a. http://woodshole.er.usgs.gov/operations/sfmapping/airgun.htm

USGS 2010b. http://woodshole.er.usgs.gov/operations/sfmapping/watergun.htm

Wardle, C.S., T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson, D. Mackie. 2001. Effects of seismic air guns on marine fish. Continental Shelf Research. 21:1005–1027.

ALTERNATIVE PATHWAY SURVEILLANCE

Alternate Pathway Surveillance in Illinois - Law Enforcement

Brandon Fehrenbacher and Heath Tepovich (Illinois Department of Natural Resources)

Participating Agencies: Illinois Department of Natural Resources (lead)

Introduction: The Illinois Department of Natural Resources Invasive Species Unit adds a specialized law enforcement component toward overall efforts in preventing the spread of invasive species. The Invasive Species Unit has demonstrated the ability and determination to successfully enforce laws that regulate the transportation, propagation, and trade of aquatic life throughout the region. Two fully dedicated Conservation Police Officers assigned to the unit have a combined 24-plus years of experience as Conservation Police Officers. The Invasive Species Unit continues to lead the way in conducting successful operations for detection and prosecution of violations of the invasive species law. The unit provides a necessary added layer of protection in the overall efforts of safeguarding the Great Lakes Basin and other water systems from the spread of invasive species, and the reputation of the unit has allowed for close working relationships with law enforcement agencies throughout the United States and Canada.

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Extensive efforts are under way to prevent Asian carp from advancing through Illinois by their own means. In addition, the pet trade, environmental terrorism, aquatic life industry, and recreational sports all pose potential risks for spreading Asian carp.

Objectives:

1) Develop and implement a training course that is annually updated to educate officers throughout the state on the positive impact of invasive species enforcement and teach the techniques necessary to prevent and interdict the illegal transportation of aquatic life.
2) Use the newly created Webcrawler system to expand the unit's ability to search for illegal sales of injurious species on the Internet.
3) Dedicate enforcement efforts focusing on the illegal sales or importation of invasive species within the bait industry and employ new technology as is comes available to search for contaminated bait stock (eDNA testing equipment).
4) Initiate commercial inspections of aquaculture facilities licensed in the state.
5) Conduct surveillance on commercial fishermen, transportation companies, and fish dealers who have been identified as potential risks based on the intelligence gathered.
6) Recognize new threats as they develop within the aquatic life industry and develop a quick response plan to eliminate the threat.

7) Seek out and complete training relevant toward invasive species enforcement to build the unit's capacity to conduct successful investigations.
8) Represent Illinois, the IDNR, and the Invasive Species Unit at various conferences, meetings, and seminars that discuss topics related to Asian carp and law enforcement's responses and experiences.

Project Highlights:

- The Invasive Species Unit organized an operation to simultaneously inspect two fish trucks from a non-resident aquatic life dealer at two separate delivery locations. The detail involved four uniformed CPOs and the Invasive Species Unit. Information received by the unit indicated the company was importing live Grass Carp and VHS susceptible species without permits. A testing protocol and a course of action to transport any illegally imported fish to a testing facility was developed prior to the operation. The company did not have any illegal species in the shipments that were inspected.
- ISU initiated an investigation and identified an out-of-state resident illegally selling live Rusty Crayfish in Illinois.
- ISU conducted random commercial inspections of five aquaculture facilities in Northern Illinois. Five additional illegal aquaculture facilities were found to be raising live Tilapia. A total of 11 violations were documented.
- The Invasive Species Unit inspected a fish truck delivering live fish in Chicago's Chinatown. The company had previously been cited for importing Grass Carp (diploid) without a restricted species permit, selling aquatic life without a non-resident aquatic life dealer's license, and importing VHS susceptible species without permits. The owner of the company received a citation for selling aquatic life without a non-resident aquatic life dealer's license for the second time.
- The Invasive Species Unit initiated an investigation into an out-of-state company importing live Asian Swamp Eels into Chicago without a restricted species transportation permit and VHS import permits. The company was also importing live American Eels without a threatened species permit, and the company did not have the required non-resident aquatic life dealer's license.
- The Invasive Species Unit documented the first reported sale of Snakeheads in Chicago. Although the Snakeheads were frozen, they were not eviscerated, which raised concerns of whether they were being imported alive or dead. Snakeheads are on the federal and state injurious species list, which means they cannot be possessed alive. The grocery store where ISU observed the Snakeheads was issued a written warning because it did not have an aquatic life dealer's license. ISU worked with the USFWS to establish shipping information for the Snakeheads.

Methods: Because they are sensitive, surveillance activities, operations, and specific arrest details cannot be discussed in this document. The ISU received and followed up on leads provided from field officers, other agencies, the public, and those involved with the aquatic life industry. The ISU utilized Internet database search tools, surveillance, and on-site observations to conduct the investigations. Commercial inspections and detailed records searches provided beneficial evidence and identified additional violations by individuals and businesses.

Results and Discussion: The Invasive Species Unit developed a lesson plan and taught the newly hired recruits invasive species laws and enforcement techniques. ISU developed and implemented an aquaculture facility inspection operations plan, including a testing protocol for seized fish. Field officers began taking the initiative to look for violations of the invasive species law without prompting.

The Webcrawler system was not up and running in 2015. ISU provided feedback to facilitate the implementation process, wrote a letter of recommendation in support of the project, and volunteered to be on the WebCrawler committee.

Bait truck and dealer inspections, including surveillance operations, identified the illegal importation of live Rusty Crayfish into Illinois.

Five licensed aquaculture facilities were inspected by as part of the random commercial inspection program, resulting in the discovery and inspection of five additional illegal aquaculture facilities in the Chicago area.

Surveillance targeted on previously identified potential threats and the discovery of new threats resulted in the seizure of live Oriental Weatherfish and Red Swamp Crayfish in a Korean market, which were exported from Korea into New York and then imported into Illinois. Market inspections in Chinatown revealed Goldfish being labeled and sold as live Crucian Carp. Snakeheads were found in a Korean market, but they were frozen. Live Asian Swamp Eels were confiscated after the ISU found them being illegally sold in a Chinatown market. ISU received information that live Barramundi, a restricted species, were being imported and sold in Chicago. ISU quickly reacted to a Craigslist advertisement where a uninformed commercial fisherman offered to sell live fish including Asian Carp from the Illinois River.

ISU successfully completed training certifications in Open Source Intelligence and Cell Phone Technology and displayed the ability to utilize the newly acquired skills in investigations. ISU attended and represented Illinois at the Association of Midwest Fish and Game Investigator's conference; the Great Lakes Law Enforcement Committee meeting; and the six-state border conference.

Recommendations: An annual review should be conducted of current regulations with an open discussion on any modifications needed. A strong emphasis should be maintained on ensuring the Illinois invasive species laws are readily available and understood among those involved in the aquatic life industry. ISU should continue to seek training and networking opportunities to improve the unit.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

Tristan Widloe, David Wyffels, Brennan Caputo, Justin Widloe, Blake Ruebush, Matthew O'Hara, Kevin Irons (Illinois Department of Natural Resources)
Greg Whitledge (Southern Illinois University at Carbondale)

ADDITIONAL INFORMATION

- Link to mapping tool
- Link to 2016 plan

Introduction: The IDNR fields many public reports of observed or captured Asian carp. All reports are taken seriously and investigated through phone and e-mail 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 pounds]) 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, verified reports at three additional ponds in the program of Bighead Carp from either pond rehabilitation with piscicide or natural die-offs (Columbus Park, Garfield Park, and Lincoln Park South) (Table 1). Reported sightings at one pond of Bighead Carp were not confirmed by sampling (McKinley Park). The distance from Chicago area fishing ponds to Lake Michigan ranges from 0.2 to 41.4 km (0.1 to 25.7 miles). The distance from these ponds to the CAWS upstream of the 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 the lake or CAWS upstream of the 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 2015respectively. 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 because of the potential for human transfers 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 and 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 (they may, for example, represent live or dead fish or result from sources other than live fish, such as DNA from the guano of piscivorous birds or boats and sampling gear used in Asian carp-infested waters), they should be examined for the presence of live Asian carp given the proximity to CAWS waterways.

Objective: Urban pond monitoring objective was to:

(1) Sample fishing ponds in the Chicago Metropolitan area included in the IDNR Urban Fishing Program as well as ponds with positive detections for Asian carp eDNA using conventional gears (electrofishing and trammel and gill nets) for the presence of Asian carp.

Project Highlights:

- Thirty-two Bighead Carp have been removed from five Chicago area ponds using electrofishing and trammel and 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.
- Eighteen 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.
- We will attempt to sample Elliot Lake in 2016, which is the last remaining pond that needs to be sampled.

Methods:

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

Results and Discussion:

A total of 40 Bighead Carp and one Silver Carp have been removed from eight ponds (Table 1). Fifty hours of electrofishing and 11 miles of gill/trammel net were used to sample 24 Chicago area fishing ponds, resulting in 32 Bighead Carp removed from five ponds since 2011. Eight Bighead Carp and one Silver Carp killed by either natural die-off or pond rehabilitation with piscicide have been removed since 2008. Bighead Carp have been removed from the lagoons at both Garfield and Humboldt Park following natural die-offs and sampling. All ponds yielding positive eDNA detections and 18 of the 21 IDNR urban fishing ponds have been sampled. Lincoln Park South was not sampled because it was drained in 2008, resulting in three Bighead carp being removed, and is no longer a source of Asian carp as a result. Auburn Park was too shallow for boat access but had extremely high visibility. Therefore, the pond was visually inspected, with no large-bodied fish observed. Elliot Lake had banks too steep to back in a boat on a trailer. A boat will likely need to be lowered in using a wench, which will be attempted in 2016. 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.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

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). The CAWS upstream of the Electric Dispersal Barrier is highlighted in yellow.*

Approximately 80 percent of the Bighead Carp otoliths examined to date exhibited a decline in Sr:Ca from high values in the otolith core (750 to 1,900 µmol/mol, within 50 to 150 microns of the otolith center) to lower values (range 400 to 650 µmol/mol) toward the edge of the otolith (mean 618 µmol/mol within 50 microns of the otolith edge) (Figure 2).

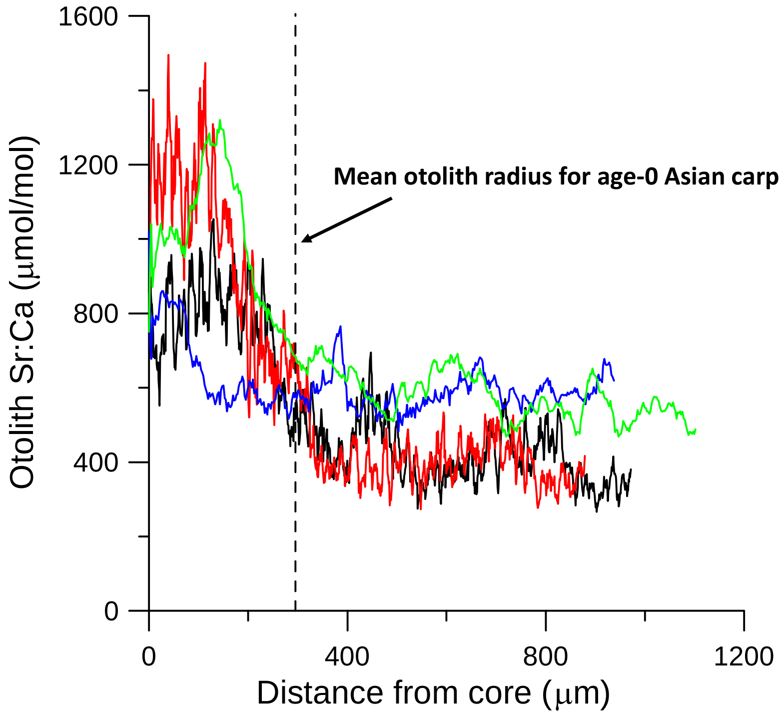


Figure 2. *Example of laser ablation transects for four Chicago pond Bighead Carp otoliths. The dashed line represents the mean otolith radius for age-0 Asian carp taken from nearby rivers.*

Mean otolith Sr:Ca of 618 µmol/mol near the otolith edge is consistent with expected otolith Sr:Ca for a resident fish in these Chicago fishing ponds based on Sr:Ca of water samples taken from these sites 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 waters 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 with that of Bighead Carp of Illinois River origin as well as other sites previously examined in northern Illinois (Figure 3) (Whitledge 2009).

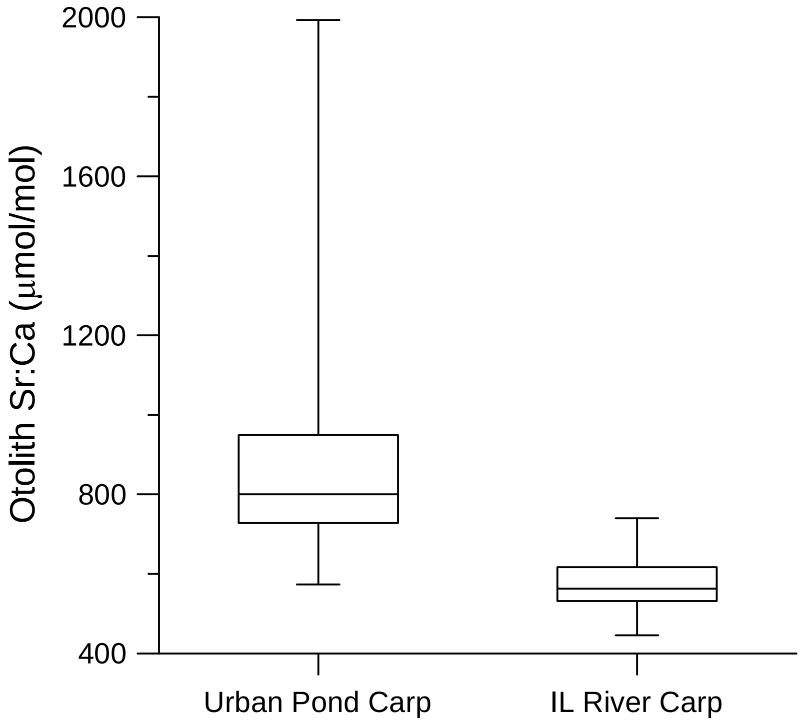


Figure 3. *Boxplots of otolith core Sr:Ca for Chicago pond (N = 24) and Illinois River (N = 81) Asian carp. The minimum value for urban pond carp represents the Silver Carp collected from Sherman Park.*

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).

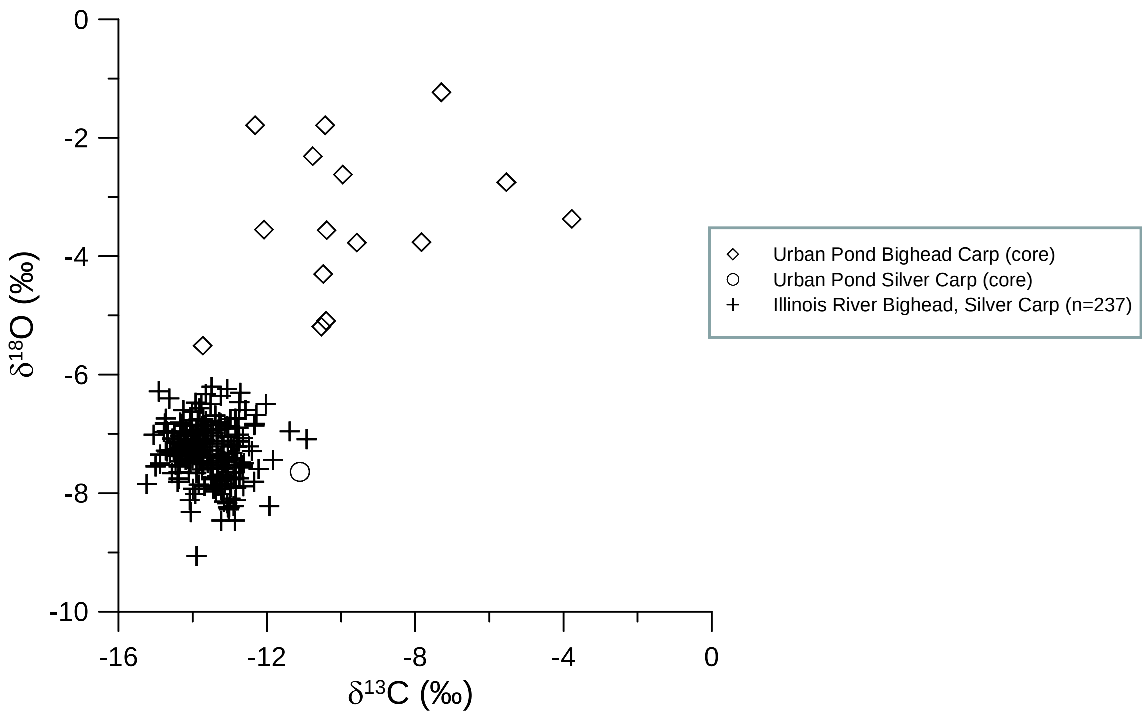


Figure 4. *Otolith Core $\delta^{18}O$ and $\delta^{13}C$ comparing Urban Pond and Illinois River Bighead and Silver Carps.*

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, it is 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 and 2003. This period 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).

Recommendations: We will investigate reports of Asian carp sightings in Chicago area ponds based on photographic evidence or reports from credible sources. We will also attempt to sample Elliot Lake in 2016, which is the last pond remaining that needs to be sampled.

Literature Cited

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

Kolar, C.S., D.C. Chapman, W.R. Courtenay, Jr., 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.

Whitledge, G.W. 2009. Otolith microchemistry and isotopic composition as potential indicators of fish movement between the Illinois River drainage and Lake Michigan. Journal of Great Lakes Research 35:101-106.

Table 1. *Sampling location, boat electrofishing effort (hrs.) and gill/trammel netting effort (miles), number of sampling events, number of Bighead Carp and Silver Carp collected, number of Asian carp removed following natural die-off or pond rehabilitation with rotenone. 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 or rotenone rehab (*N*)
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	-	-	-
Douglas Park	0.8	0.2	1	-	-	-
Flatfoot Lake[1]	13.0	2.7	6	18	-	-
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	50.2	11.2	33	32	0	9

APPENDICES

Investigation and Development of Novel Chemical Barriers to Deter the Movement of Asian Carp

Caleb Hasler, Jen Jeffrey, John Tix, Kelly Hannan, Cody Sullivan, Adam Wright, and Cory D. Suski (University of Illinois – Urbana-Champaign)

Participating Agencies: University of Illinois – Urbana-Champaign (lead), Illinois Department of Natural Resources (funding/field support), and U.S. Geological Survey (funding/field support).

Introduction: Our research group has been investigating the use of carbon dioxide gas (CO_2) as a non-physical barrier to prevent the movement of Asian carp for several years. Results to date have shown that exposure of fishes to approximately 30 mg/L CO_2 induces a suite of stress responses, including activation of "stress genes" and plasma ion imbalances, indicating discomfort when fish are placed in elevated CO_2 zones. More importantly, studies in field and laboratory settings have demonstrated that both small Asian carp (2 to 4 inches), as well as adult Asian carp, demonstrate active avoidance of CO_2 at approximately 70 to 100 mg/L CO_2 and will leave CO_2-rich areas. Together, this series of experiments has shown great potential for CO_2 to act as a novel barrier to deter the movement of Asian carp.

Despite the promise of CO_2 as a novel barrier technology to influence the movement of invasive carp, there are a number of unknowns and questions that must be addressed prior to full-scale implementation of a CO_2 barrier in a field setting. More specifically, using CO_2 as a non-physical barrier will entail injecting or infusing CO_2 into a natural water system and, as such, there is a need to better understand potential impacts to non-target species, along with the "behavior" of CO_2 when it is released. Knowing these details will assist practitioners with limiting potential negative consequences to non-target species and maximize the effectiveness of a CO_2 barrier should one be deployed. To this end, work in 2014 and 2015 has focused on assessments of CO_2 on non-target species, including freshwater mussels and fish, and on understanding how to scale-up CO_2 work to be functional in a larger, natural setting.

[1] Note that prior to 2014, concentrations were presented as mg/L. Concentrations for experiments conducted in 2015 and beyond will be presented in both mg/L and µatm (see: http://www.epoca-project.eu/index.php/huide-to-best-practices-for-ocean-acidification-research-and-data-reporting.html).

Investigation and Development of Novel Chemical Barriers to Deter the Movement of Asian Carp

Aim: The overall goal of the current series of studies is to define the potential impacts of elevated CO_2 on non-target species and improve our understanding how CO_2 can be deployed at a large scale as a non-physical barrier to fish.

Objective 1: Determine physiological and molecular responses of native freshwater mussels to elevated carbon dioxide

Freshwater mussels are among the most at risk taxa in North America. Should CO_2 be used as a barrier in natural environments, freshwater mussels have the potential to be exposed to elevated CO_2. The goal of this project was to quantify the short- and long-term effects of elevated CO_2 on physiological (such as calcium, sodium, and magnesium) and molecular (gene expression) variables of freshwater mussels to better understand potential consequences of using CO_2 in a natural environment.

Study 1: Acute and chronic exposure and recovery to elevated levels of CO_2

In fall, 2014, Wabash Pigtoe mussels (*Fusconaia flava*) were collected by benthic grab from Big Four Ditch, Paxton, Illinois, and transported to the Aquatic Research Facility at the University of Illinois, Champaign-Urbana, Illinois. Two series of experiments were subsequently conducted: (1) impacts of *short-term* CO_2 exposure on physiological properties of mussels, and (2) impacts of *long-term* (chronic) elevations of CO_2 on physiological properties of mussels. For the short-term study, individual mussels (n = 48) were placed in two closed, recirculating systems each containing eight 0.71 L containers. After a 24-hour acclimation period, compressed CO_2 gas was bubbled into a central basin to the target CO_2 concentration of either ~14,800 µatm (35 mg/L) or ~18,200 µatm (225 mg/L) for 6 hours, and a third set of mussels were held at ambient conditions (~275 µatm; 12 mg/L) as controls. Mussels were either sampled directly after the 6-hour CO_2 treatment (n = 8), or after an additional 6-hour recovery period at ambient CO_2 (n = 8). Sampling consisted of hemolymph being extracted from the anterior adductor muscle and flash frozen liquid nitrogen and stored at -80°C. Foot, gill, adductor muscle, and mantle tissue were additionally collected and stored in RNA. The chronic exposure study consisted of mussels (n = 48) housed in 128.7 L recirculating tank systems and exposed to either ambient (~980 µatm; 16 mg/L) or elevated (~22,700 µatm; 40 mg/L) CO_2 levels for up to 32 days. Mussels were sampled at 4, 8, or 32 days after the onset of the CO_2 treatment and were sampled as described above.

Hemolymph Cl^-, Mg^{2+}, and Na^+ levels significantly decreased with 6 hours CO_2 treatment and did not recover by 6 hours post-treatment. The ratio of RNA:DNA was significantly elevated in mussels exposed to short-term barrier level CO_2 and decreased below control levels during recovery. Further data related to the chronic exposures are being analyzed and will be shared in summer 2016. For enzymes and gene work, mussels initially exhibited an increase in chitin synthase (CS) following exposure to elevated pCO_2 levels for 6 hours, whereas long-term exposure resulted in a decrease in CS mRNA abundance, suggesting that mussels may invest less in shell growth during chronic exposure to elevated pCO_2 levels. In response to an acute elevation in pCO_2 levels, mussels increased the mRNA abundance of heat shock protein 70 (HSP70) in mantle and adductor muscle. A similar increase in HSP70 transcript levels was observed in the gill and adductor muscle of mussels exposed to chronically elevated levels of pCO_2. This overall increase in HSP70 mRNA levels in *F. flava* suggests that both acute and chronic exposure to elevated pCO_2 levels initiates activation of the stress response. Together, these results suggest that freshwater mussels respond to elevated pCO_2 levels by increasing the machinery necessary to "deal with" the stressor and that, over the long term, mussels may reduce their investment in processes such as shell growth.

Study 2: Chronic exposure to fluctuating levels of CO_2

Given that one option for the deployment of a CO_2 barrier may be to treat a navigational lock, or in an approach channel downstream of a barrier, it is likely that freshwater mussels may be exposed to fluctuating levels of elevated pCO_2. (CO_2 levels would go up when treated water is released downstream, but then would fall after the plume of CO_2 moves past.) To quantify the impact of fluctuating levels of pCO_2 in freshwater mussels, three species of adult freshwater mussels (*Amblema plicata*, *Lampsilis cardium*, and *Pyganodon grandis*) representing three different mussel tribes (shell thickness) were exposed to fluctuating (30 minutes on, 90 minutes off) levels of elevated pCO_2 (55,000 µatm) over a 28-day period. Mussels were repeatedly sampled for hemolymph at 24 hours and then every 7 days either before or after one CO_2 cycle. Results from these studies are currently being analyzed. There is some indication that freshwater mussels experienced physiological changes related to acid-base disturbance following CO_2 exposure, and there is evidence that species respond differently.

Study 3: Transcriptomic response to elevated CO_2

Results from collaborators at UMESC have indicated that lengthy exposure to elevated CO_2 has serious consequences for survival of juvenile freshwater mussels. Therefore, juvenile *L. siliquoidea* were exposed to either 24 hours or 96 hours of ambient or 55,000 µatm level CO_2 to further understand how mussels are being physiologically affected by elevated levels of CO_2. Using RNAseq, the transcriptomic response to elevated CO_2 levels will be assessed. To date, experimental treatments were completed in the fall of 2015. Samples are currently being processed for analysis. In addition, JD Jeffrey has completed a workshop at UIUC for the analysis of RNAseq data. Data are currently being analyzed and should be completed by summer or fall 2016.

Study 4: The interactive effects of temperature and CO_2 on juvenile freshwater mussels

Rarely are environmental stressors researched independently of each other, and with global warming expected, freshwater mussels will likely be affected by rising water temperatures as well as elevated levels of CO_2. In 2015, juvenile *L. siliquoidea* were exposed to 22, 25, 28, 31, or 34°C in addition to either ambient, 20,000, or 55,000 µatm levels of CO_2 for a period of 14 d. Over this period, mussels were assessed for survival and at the end of the 14 d period, surviving mussels were preserved for the assessment of physiological parameters (whole-body mRNA expression of HSP70 and regulators of acid-base and ion balance). Experimental treatments were completed in the fall/winter of 2015. Survival data are currently being analyzed and molecular assays to assess physiological parameters are being generated. In addition to survival and physiological indicators of stress and acid-base and ion regulation, the transcriptomic responses of mussels exposed to ambient conditions (22°C, ambient CO_2), heat-stress (34°C, ambient CO_2), elevated CO_2 (22°C, 55,000 µatm), and both heat-stress and elevated CO_2 (34°C, 55,000 µatm) will be assessed. These data will provide us with an overall view of the consequences of exposure to elevated CO_2 or heat stress across multiple physiological pathways.

Study 5: Gaping behavior of freshwater mussels exposed to elevated CO_2

Gaping behavior in mussels, or the opening and closing of their valves, often changes with respect to environmental variation and can influence survival in challenging environments. In late summer 2015, a study was conducted to monitor the gaping behaviors of three species of freshwater mussels (*Amblema plicata*, *Lampsilis cardium*, and *Pyganodon grandis*). Gape monitoring was measured using custom-built sensors and magnets attached to the mussel valves. Each mussel was then exposed to ambient CO_2 for 2 days (control), a period of elevated CO_2 for 2 days (exposure period), and lastly, a recovery period of 2 days where the pCO_2 was returned to ambient (recovery period). After several days, the same mussels were then exposed to a CO_2 challenge, whereby CO_2 was elevated every 5 minutes for approximately 2 hours to monitor when abrupt closure of the values occurs. Data analysis is ongoing and will be shared at a later date.

General Findings

Overall, elevated levels of CO_2 tended to elicit a physiological response in several measured variables, including ion concentrations and the expression of some genes. However, growth and condition do not appear to be negatively affected, at least in the short time frame of the studies completed. Further work on juvenile survivorship, adult transcriptomic response, and the interactive effects of temperature and CO_2 should assist with furthering our understanding of the physiological responses of freshwater mussel to elevated levels of CO_2.

Objective 2: Determine behavioral impacts of fish exposed to elevated CO_2

Recent studies in the marine environment have shown that small increases in CO_2, caused by climate change, even over short time spans, can have negative impacts on several aspects of fish behavior (impaired ability to detect predators and impaired ability to perform homing activities). To date, few studies have sought to quantify the impact of elevated CO_2 on freshwater fish behavior (particularly on non-target, native fishes), which is necessary before CO_2 can be used as a barrier in natural environments. To begin to understand the behavioral impacts of elevated CO_2 on freshwater fish, the responses to alarm cues of fish (Fathead Minnow and Silver Carp) were monitored, the effects on personality of Bluegill were tested, and post-release behaviors of Largemouth Bass were investigated. In general, assessment of these broadly defined behaviors will help to grow our understanding of the potential for a CO_2-barrier to influence freshwater fish ecology and populations.

Study 1- Alarm Cue Responses

Fathead Minnows were held in experimental tanks at the University of Illinois Aquatic Research Facility and exposed to ambient or elevated levels of CO_2. After exposure to experimental conditions for 5 to 12 days, single fish were placed into a choice arena and exposed to either water treated with alarm cues generated from tissue of conspecifics, or water containing Largemouth Bass (native predator of Fathead Minnow). The behavioral response of each fish was recorded using digital cameras and analyzed for several movement parameters (such as velocity, acceleration, and distance travelled) and alarm behaviors (for example, whether it darts or freezes). After 12 days, CO_2 elevated water was returned to ambient conditions and fish were allowed a 3-day recovery period, at which time a second group of fish were similarly tested. Preliminary analyses indicate that some “alarm” responses are inhibited by exposure to elevated levels of CO_2, but not all. In 2015, we also attempted to quantify the predator response to Fathead Minnow skin extracts using Largemouth Bass tagged with accelerometer tags. Analyses for this portion of the study are ongoing. Furthermore, early in 2016, a similar study will be conducted at the Upper Midwest Environmental Center (UMESC) in La Crosse, Wisconsin, to assess potential impairment of alarm cue responses of Silver Carp.

Study 2- Fish Personality

In 2015, an experiment was conducted to understand whether elevated CO_2 impacts personality in Bluegill. Specifically, boldness, anxiety, and lateralization were repeatedly quantified in a group of Bluegill that was exposed to various levels of CO_2. Briefly, individually tagged hatchery-reared Bluegill were acclimatized to laboratory conditions and tested for lateralization (turning preference test) and boldness/anxiety (novel object test). Fish were then exposed to elevated levels of CO_2 for 4 days and re-tested for both behaviors. Following the second test, fish were tested for a third time after a period of recovery at ambient CO_2 levels. Preliminary results suggest that elevated levels of CO_2 increase activity and velocity, but no changes in lateralization and other bold/anxiety behaviors were detected.

Study 3- Post-release Behaviors Following CO_2 Exposure

Adult Largemouth Bass were tagged with acoustic transmitters and held at either elevated levels of CO_2 or ambient CO_2 for 5 days at the University of Illinois Aquatic Research Facility. Fish were then released into a small pond that was equipped with a hydrophone array. Movement behaviors — including minimum distance travelled, space-use, swimming speed, nearest neighbor distance, and turning angle — were measured for each fish four times a day for 15 days.

Differences in behaviors between CO_2-treated fish and unexposed fish were assessed to understand if exposure to elevated levels of CO_2 altered post-release behaviors of adult fish. Preliminary analyses suggest that diel movement patterns between exposed and unexposed fish are conservatively altered for a period of 10 days after release. However, other variables, including space-use and nearest neighbor distance, were unaffected by exposure to elevated levels of CO_2.

General Findings

Though data analyses and interpretation are ongoing, general results suggest that exposure to elevated levels of CO_2 did influence the behaviors of freshwater fishes (such as alarm cue responses and diel movement patterns). However, in most cases, fish behaviors return to normal after only a few days after movement to ambient conditions, suggesting that fish have the potential to recover. Furthermore, though some behaviors changed, several other tested behaviors (for example, boldness/anxiety and space use) did not, and suggests that native freshwater fishes may be more robust to higher levels of CO_2 compared with marine species.

Objective 3: Explore the potential of Ozone to be used as a non-physical fish barrier

Several experiments were undertaken in 2015 to understand if ozone (O_3) could be used as a non-physical fish barrier. O_3 is a powerful oxidizer and is frequently used as a sanitizer in aquaculture facilities. O_3 could be used as a fish deterrent in water because of its high oxidative properties. One upside to using O_3 as a fish barrier is that it rapidly offgases from the treated water and does not cause secondary reactions, meaning fish not challenging the barrier will not be exposed to high concentrations of O_3. No research has been done on the use of O_3 as a deterrent, but other research has demonstrated the toxicity of ozone on fish and the associated mortality. At high concentrations, O_3 has a negative impact on gill function of fish, and O_3 impacts respiration and osmoregulation in freshwater fish. Despite some research with respect to O_3 exposure, further research is needed to determine if it is an effective fish deterrent. Overall, the focus of work in 2015 was to: (1) test whether it was possible to create high levels of dissolved O_3 in fresh water, and (2) explore the potential for behavioral and physiological responses of freshwater fish.

To complete Objective 1, two O_3 generators and two oxidative reduction potential (ORP) meters were purchased. Furthermore, best practices for dissolving O_3 into freshwater were researched. We tested our ability to dissolve O_3 in several sources of freshwater including de-ionized water, water from earthen-lined ponds, groundwater, and river water (from Sangamon River in Mahomet, Illinois). In general, O_3 levels of approximately 700 to 800 mV or 0.5 mg/L were reached, which is equivalent to what has been shown to cause toxic impacts for fish. However, our ability to dissolved O_3 was more difficult in pond water and river water than in dissolved and groundwater. Furthermore, the amount of O_3 that can be dissolved in water decreases exponentially as temperature rises, and the half-time of O_3 in solution is relatively short (< 30 minutes). For these reasons, maintaining elevated O_3 is difficult.

With respect to the potential for elevated levels of O_3 to cause behavioral and physiological changes in fish, Bluegill were exposed to either control water or elevated O_3 (870 mV or 0.5 mg/L) for 15-minute periods. Fish were monitored for ventilation rate, loss of equilibrium, and signs of distress (such as reflex). By and large, exposure to elevated O_3 did not result in any changes in the tested behaviors. Cortisol (a stress hormone in fish) was measured in a set of Bluegill exposed for 0.5, 1, or 2 hours to elevated O_3 and, again, no significant changes in cortisol were observed.

General Findings

In light of the difficulty with dissolving O_3 in water and keeping it in solution, combined with the lack of behavioral and physiological responses in Bluegill at the levels of O_3 maintained, it is likely that elevated O_3 is not an appropriate fish barrier. We are currently preparing a thorough report on the knowledge gained and the results of our two studies.

Objective 4: Understand the behavior of dissolved CO_2 to facilitate large-scale field deployment

Work to date on CO_2 has largely occurred in a laboratory setting using small-scale studies. Deployment of a CO_2 barrier in a field setting (such as river, shipping lock, and backwater area) necessitates a much larger scale deployment. The effective “scaling up” of laboratory work to a field setting will require an understanding of CO_2 behavior. This objective investigates the volume of CO_2 gas required to reach barrier levels across a range of tanks sizes, coupled with studies to define how CO_2 behaves in flowing water. (Will it sink, will it float, does it disperse evenly?)

Multiple sized tanks (76 L, 379 L, 1136 L [20, 100, and 300 gallons]) were filled with water from a 0.04 hectare natural, earthen-bottom pond. Tanks were either treated with compressed CO_2, compressed CO_2 coupled with aeration, or not treated (ambient/controls). CO_2 was added to the tank, and injection ended when a concentration of approximately 25,000 µatm was reached (approximate target concentration for a CO_2 barrier). The amount of compressed CO_2 required to reach barrier level was determined by recording the amount time and the rate of gas movement through a flow regulator. Tanks were also monitored to quantify the rate that CO_2 dissipated. Preliminary results indicate that the amount of CO_2 gas necessary to raise water CO_2 levels is proportional to the volume of water. Also, CO_2 dissipates from water faster when tanks are aerated, even slightly.

A subsequent study was completed to define how CO_2 behaves in flowing water. For this, a 300-gallon annular tank containing flowing water received CO_2-rich water at various depths, and the position of the CO_2-plume within the flowing water over time was defined. Data suggest that higher levels of CO_2 are found near the surface and that offgassing occurs much faster relative to static water. We are currently finalizing precise relationships and interpretation of the data.

Objective 5: Quantify effectiveness of CO_2 barrier at large scales

To better define the effectiveness of a CO_2 barrier at large scales, a CO_2 barrier was built at the Hanson Material Services gravel mine near Morris, Illinois. Telemetered Silver and Bighead Carp were used to determine how fish interact with a CO_2 barrier prototype and if the zone is an effective barrier in this setting. Lastly, a future component of this objective will be to assess the potential for CO_2 to be used as part of integrative pest management along with other potential tools to control Asian Carp movement (pulse-pressure water guns and netting).

This field experiment was conducted in collaboration with the Upper Midwest Environmental Science Center (UMESC) at Hanson Material Services gravel mine to define the effectiveness of a CO_2 barrier in deterring the movements of free-swimming Asian Carp. The study used telemetry equipment, design, and facilities generated by UMESC for studies to quantify the impact of pulse-pressure water guns on the movement and activity of carp. Briefly, a CO_2 infusion system, based on venturi principles, was built on site and used to create an enclosed area of elevated dissolved CO_2; the size of this elevated CO_2 zone was approximate to a shipping lock or approach channel to a shipping lock. Asian carp were externally tagged on the dorsal musculature with an acoustic transmitter to track and monitor fish movement (3-D) at sub-meter accuracy. Monitoring of movement and activity patterns occurred during a "control" period before CO_2 was infused. When the control period was complete, water flowing through the venturi system became supersaturated with CO_2 and was pumped into the enclosure through a discharge manifold. The elevated CO_2 area of the enclosure was maintained for a period of time, and fish monitoring continued. The CO_2 infusion system was then turned off allowing a post-injection monitoring period. The experiment was repeated several times.

In August 2015, UMESC, with assistance provided by us, built a CO_2-infuser that was deployed at the Morris pits. Several laboratory members traveled to the test barrier site near Morris, Illinois, on July 30 and from August 17 to 20 to assist with operations led by collaborators at UMESC. Drs. Suski and Hasler were able to provide logistical support for the CO_2 injection method. Other activities included measuring carp and affixing acoustic transmitters to the animals for use in the CO_2 barrier telemetry trials. At the site, a channel had been created using seine nets, into which CO_2 was injected to simulate the barrier and track fish movement. Additional time was spent assisting with general site maintenance and monitoring of the CO_2 injector system, when fish movement and water quality data were collected. Preliminary results suggest that a CO_2 plume with levels appropriate for use as a fish barrier was not maintained, and therefore future work is needed to further test the effectiveness of CO_2 at a large scale to deter Asian carp movement. For further details and preliminary results, see interim report prepared by UMESC.

Objective 6: CO_2 applications in flowing environments

Work to date that has documented the potential for CO_2 to act as a non-physical barrier to fishes has largely been conducted in a static water environment (tank or experimental pond). A field application of a CO_2 barrier would likely occur in a flowing water environment such as a river, canal, or navigational lock. We are therefore conducting a series of experiments to define not only how CO_2 behaves when released into a flowing water environment, but also how fish in a flowing water environment will respond to elevated CO_2.

Investigation and Development of Novel Chemical Barriers to Deter the Movement of Asian Carp

To date, preliminary studies have been completed to assess the behavior of fish in a flowing water environment when a plume of CO_2 is present and to determine if feeding and predatory behaviors of largemouth bass are altered by exposure to elevated CO_2. These studies are currently being refined and data analysis is ongoing.

Ecosystem Responses to Barrier Defense Asian Carp Removal Project

Collin J. Hinz, Jason A. DeBoer, Brian Zalay, Steven E. Butler, David H. Wahl, Andrew F. Casper (Illinois Natural History Survey)

ADDITIONAL INFORMATION

- Link to mapping tool

Introduction: Plankton are a major food source for both Asian carp (*Hypophthalmichthys* spp.) and native fish. Combined with rapid growth (days to weeks), this characteristic makes zooplankton an excellent rapid indicator of ecosystem response to the arrival of and reduction through commercial harvest of the planktivorous Asian carp. Plankton productivity is an important driver of fisheries in aquatic ecosystems like the Mississippi River and Great Lakes basins. High densities of newly arrived Asian carp are believed to exert a strong indirect negative impact on these types of ecosystems because they filter-feed on plankton. Thus, the thought is that any reductions in Asian carp numbers should produce a corresponding increase in zooplankton density and biomass. Controlled commercial fishing reductions of Asian carp were initiated in 2010 in an attempt to reduce migration pressure on the Electric Dispersal Barrier, thereby reducing the risk that Asian carp would enter the CAWS and Lake Michigan (see Barrier Defense Asian Carp Removal Project Description/Chapter). Short-term changes in plankton response could provide insight into any of Asian carp's lagged impact on the ecosystem.

Summary of Key Previous Results for 2011 - 2014:

- Total zooplankton abundance and biomass are significantly reduced since the establishment of large numbers of Asian carp in the lower river (Figures 2 and 3).
- The abundance and biomass of zooplankton was more equally divided among large-bodied and small-bodied zooplankton, prior to establishment of large numbers of Asian carp by 2000. However, after large numbers of Asian carp were established, the biomass of large-bodied zooplankton taxa was significantly reduced while the biomass of small-bodied rotifers was not as strongly affected (Figures 4 and 5).

Summary of New Results for 2015:

- Zooplankton abundance and biomass are reduced as Great Lakes water moves through the CAWS and into the high density of Asian carp in the upper Illinois River (Figure 6).
- An assessment of the effect of commercial harvest of Asian carp on plankton in both a single intensively harvest backwater and a spectrum of nine backwaters suggests that current harvest levels are not high enough to produce a detectable positive zooplankton response in the backwater areas (Figure 7 and 8)
- A companion data set supplied by DNR/INHS shows that Asian carp condition has been negatively affected since 2002. This finding suggests that higher densities of Asian carp are depleting zooplankton and likely limiting their own populations (Figure 9).

Ecosystem Responses to Barrier Defense Asian Carp Removal Project

Methods: Plankton sampling occurred monthly during the May to October season at 18 sites throughout the Illinois Waterway (Alton, La Grange, Peoria, Starved Rock, Marseilles, and Dresden reaches) from 2011 to 2014 and at a subset of six sites during 2009 and 2010 (Table 1). Three vertically integrated 55-µm 30-L sample replicates were obtained at each site-date combination by pumping water through 55-µm mesh. Captured zooplankton were then immediately preserved in a 12 percent sugar-buffered formalin solution in the field and with Rose Bengal stain later added after the sample was returned to the laboratory.

These field samples were concentrated to a known volume for microscopic analyses, from which a homogenized subsample (10 percent of the concentrated volume) was transferred to a counting wheel with a Hensen-Stemple pipette. Zooplankton were identified to the lowest possible taxonomic unit using a dissecting scope, and the resulting densities are given as the number of individuals per liter of water sampled. In addition to abundance and taxa composition, biomass was estimated with length-weight regressions using body lengths of the first 15 encounters of each species. This process is outlined in more detail in USEPA 2003. Historical samples from Illinois River Mile 121.1 (Havana, Illinois) collected using the same May to October period, field procedures, and sample volumes were also analyzed. Simple t-tests examined differences in average abundance and biomass between the pre-Asian-carp (1997-2000) and post-Asian-carp (2012-2014) samples to assess changes in the long-term zooplankton community composition since the establishment of Asian carp.

Productivity for 2011 through 2014 was evaluated by measuring total phosphorus and chlorophyll *a*. Two replicate water samples were collected 0.5 meter below the surface at each site-date combination. Chlorophyll-*a* concentrations were estimated by acetone extraction using standard fluorometric techniques. Total phosphorus concentrations were estimated by the ascorbic acid method after digestion with persulfate under acid conditions (Soballe and Fischer 2004). Asian carp commercial harvest data used are reported in Asian Carp Monitoring and Response Workgroup Interim Summary Report (Asian Carp Regional Coordinating Committee 2015).

Preliminary Results and Discussion:

Ecosystem (plankton) response to increasing abundance of Asian carp

There is a statistically significant reduction in total zooplankton abundance and biomass after the establishment of large numbers of Asian carp in the lower Illinois River (Figures 2 and 3, Table 2). The abundance and biomass of cladocerans, copepod adults, and nauplii declined strongly as Asian carp abundance increased (Figure 3). Although the large-bodied zooplankton (Copepods and Cladocerans) would logically be more susceptible to Asian carp planktivory, we also see that rotifers also declined significantly, though to a lesser extent than the large-bodied macrozooplankton (Figures 4 and 5, Table 2). Longitudinal downstream assessment of plankton abundance (Figure 6) shows significant shifts and declines in plankton moving from Lake

Michigan through the CAWS above River Mile 326 and into the upper Illinois River, where large numbers of planktivorous Asian carp are present by River Mile 265. Based on these results, we can conclude that:

- Abundance and biomass of all types of plankton in Lake Michigan and the CAWS, large-bodied strong swimmers like copepods as well as the more numerous small-bodied rotifers are strongly and negatively affected by the presence of Asian carp.
- This shift may also be a rapid diagnostic for invaded systems that cannot be monitored for Asian carp themselves.
- Establishment of large populations of Asian carp in the Great Lakes or any connecting waterways will likely cause a rapid and strong ecosystem shift. As plankton can be major drivers of water quality (grazing and filtration of algae and turbidity) and the productivity of both recreational and commercial fisheries (for example, they are a critical food resource for young fish), they are critically important components of most freshwater ecosystems.

Ecosystem (plankton) response to commercial harvest of Asian carp in the Upper River

An assessment of the impact of two consecutive commercial harvest events conducted in a single backwater owned by Hanson Material Services during late summer of 2014 (Figure 7) suggests:

- Backwaters have much higher amounts of plankton food that Asian carp feed on.
- The natural pattern of seasonal succession and decline in plankton potentially masked any increases of zooplankton in response to the 2 harvest events.

These findings imply that Asian carp may be having their strongest effects in backwaters rather than in the main channel of the river. This finding is also evidence that 2014 harvest rates were not great enough to generate a positive response strong enough to be measurable using our current sampling design.

A 2015 follow-up assessment conducted in multiple backwaters throughout the upper Illinois River (Figure 8) that each receives a spectrum of levels of commercial harvest during the late summer of 2015:

- Demonstrates that there is a great deal of variation in plankton abundance among the nine backwaters (a range of surface area, depth, and volume).
- Confirms that current harvest levels may not be great enough to produce a rapid positive response in abundance by the plankton.

Completion of the microscopy and analysis of samples from this nine backwater study is anticipated fall of 2016.

Potential density-dependent limits for Asian carp in the Upper Illinois River

The biomass of Silver Carp has increased substantially in the lower Illinois River since 2000. However, as biomass increased through time, Asian carp condition (relative weight, W_r) decreased, indicating a density-dependent relationship between biomass and condition (Figure

9). It is likely that as Silver Carp population biomass increased, zooplankton prey became limiting, and individual condition has consequently and unequivocally decreased. This pattern is clear in the lower river, where Asian carp abundances are substantially greater than close to the barrier in the upper river.

Next steps: More resolution on the question of ecosystem response (zooplankton, chlorophyll *a*, and phosphorus) will come with the completion of the remaining 2014 to 2015 samples from the main channel and from analysis of larger backwater harvest events (Study 1 above, Study 2 above). In addition, completion of the 2015 chlorophyll *a* and phosphorus analysis will help make a clearer conclusion about how quickly the potential benefits of commercial fishing to reduce Asian carp will benefit the Illinois River waterway and other afflicted regional river systems.

Recommendations for future study design: Monitoring of response of zooplankton and primary productivity should continue to contribute to a better understanding of the long-term ecosystem effects of controlled commercial removal of Asian carp. Removals could be conducted in intermediate connected backwaters that isolate from the main river during low water to increase the ability to detect ecosystem responses to removal efforts. After colonization by carp during high water, reductions of could occur during periods of isolation to account for carp immigration and emigration. Concurrent ecosystem monitoring could also be conducted at more frequent intervals around the removal events. In situ experimental enclosures or experimental ponds may also be beneficial to manipulate carp densities and initial ecosystem parameters (such as zooplankton, phytoplankton, and nutrients). A study of phytoplankton composition in areas of both high and low Asian carp densities may lend more insight to dynamic ecosystem responses to Asian carp.

Acknowledgments: Support for this research was contributed by the Illinois Department of Natural Resources Fisheries Division ANS Program and Asian carp team (Kevin Irons, Matt O'Hara, and Tristan Widloe), the USEPA's Great Lakes Restoration Initiative, and the INHS Long-term Electrofishing Program sponsored by the USFWS's Sportfish Restoration Fund (Dingell-Johnson Act).

References:

Asian Carp Regional Coordinating Committee. 2015. 2014 Asian Carp Monitoring and Response Workgroup Interim Summary Report (June 2015). Available online at http://www.asiancarp.us/documents/MRP2014-InterimSummary.pdf

Domaizon, I. and J. Dévaux. 1999. Impact of moderate silver carp biomass gradient on zooplankton communities in a eutrophic reservoir. Consequences for the use of silver carp in biomanipulation. Comptes Rendus De L Academie Des Sciences Serie Iii-Sciences De La Vie-Life Sciences. 322:621-628.

Li, M., P. Xie, H. Tang, Z. Shao, and L. Xie. 2002. Experimental study of trophic cascade effect of silver carp (*Hypophthalmichthys molitrix*) on in a subtropical lake, Lake Donghu: on plankton community and underlying mechanisms of changes of crustacean community. Hydrobiologia 487:19-31.

Soballe, D.M. and J.R. Fischer. 2004. Long Term Resource Monitoring Program Procedures: Water quality monitoring. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, March 2004. Technical Report LTRMP 2004-T002-1 (Ref. 95-P002-5). 73 pp. + Appendixes A

U.S. Environmental Protection Agency. 2003. Standard operating procedure for zooplankton analysis. LG403. In: USEPA, 2007. Sampling and analytical procedures for GLNPO's Open lake water quality survey of the Great Lakes. U.S. Environmental Protection Agency. Great Lakes National Program Office, Chicago, IL EPA 905-R-05-001.

Ecosystem Responses to Barrier Defense Asian Carp Removal Project

Table 1. *Inventory of site/date combinations for which zooplankton data have been collected. Sites include 55 and 20 µm zooplankton samples (macrozooplankton and microzooplankton respectively). Total phosphorus and chlorophyll a concentrations are also available at these site/date combinations.*

			2009		#						2011						2012						2013						2014						2015					
Site	**Pool**	**River Mile**	**6**	**7**	**6**	**7**	**8**	**9**	**10**	**11**	**5**	**6**	**7**	**8**	**9**	**10**	**5**	**6**	**7**	**8**	**9**	**10**	**5**	**6**	**7**	**8**	**9**	**10**	**5**	**6**	**7**	**8**	**9**	**10**	**5**	**6**	**7**	**8**	**9**	**10**
Grafton	**Alton**	**0.0**			*						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Hardin	Alton	21.1									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*												
Florence	**Alton**	**55.3**	*				*	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Meredosia	Alton	71.0										*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*												
Lily Lake MC	**La Grange**	**83.2**										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*		*	*	*	*
Lily Lake	**La Grange**	**83.7**				*	*				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*		*	*	*	*
Frederick	La Grange	96.2										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
Bath Chute	**La Grange**	**111.0**				*	*				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*		*	*	*	*
Matanzas Lake	**La Grange**	**115.0**										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Havana	**La Grange**	**121.1**	*		*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Peoria L&D	**La Grange**	**156.0**				*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Upper Peoria Lake	**Peoria**	**171.1**									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Chillicothe	Peoria	180.2	*				*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*												
Henry	**Peoria**	**197.0**			*	*	*	*				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Senachwine	Peoria	200.6																					*	*	*	*														
Hennepin	Peoria	207.5										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*												
Ottawa	**Starved Rock**	**239.8**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Morris	**Marseilles**	**263.5**	*	*			*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Channahon	**Dresden**	**279.0**	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Lockport L&D	**Brandon Rd**	**290.0**				*	*		*		*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CSSC / Cal-Sag	Lockport	303.0				*																																		
Worth	**Lockport**	**311.2**				*	*		*		*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Western Ave	**Lockport**	**320.0**			*	*	*		*		*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
O'Brien L&D	**Lockport**	**325.0**				*	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Lake Calumet	O'Brien	327.2			*	*	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*												
N. Branch Chicago Rvr	Lockport	-				*																																		
N. Shore Channel	Lockport	-				*																																		

Table 2. *Results (p-values) for t-tests comparing the mean abundance (Figure 1) and biomass (Figure 2) of the zooplankton classes between 1997-2000 (n = 77) and 2012-2014 (n = 52).*

Taxa	Abundance	Biomass
total zooplankton	<0.0001	<0.0001
copepod	<0.0001	<0.0001
nauplii	<0.0001	<0.0001
cladoceran	<0.0001	<0.0001
rotifer	<0.0001	<0.01

Ecosystem Responses to Barrier Defense Asian Carp Removal Project

Figure 1. *Reach and locations of sample sites of plankton and Asian carp (see Table 1 for site names and river mile). Red upward pointing triangle symbols show plankton monitoring 2011 – 2015. Yellow downward pointing triangles indicate locations of the backwaters used to evaluate plankton response to commercial harvest of Asian carp. Blue circles are locations of leveraged sampling by IL DNR Sportfish Restoration Fund sponsored monitoring of Asian carp abundances.*

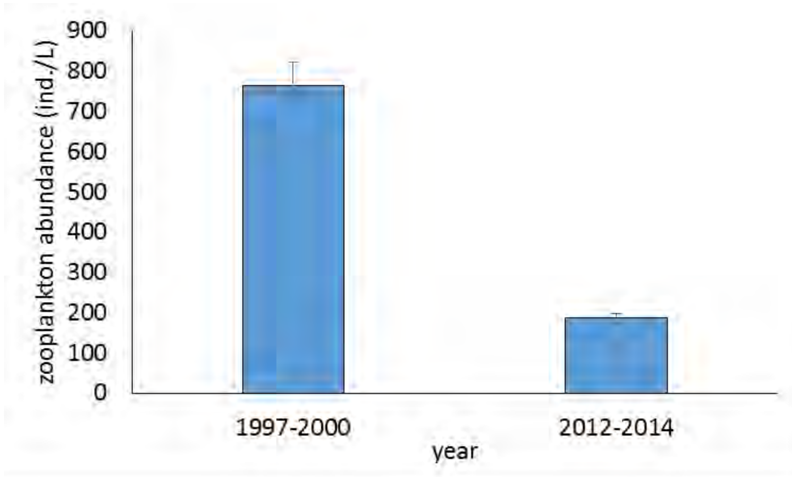


Figure 2. *Mean (± SE) total zooplankton density by year at Havana, IL (RM 121.1); 1997-2000 (pre Asian carp) and 2012-2014 (post Asian carp).*

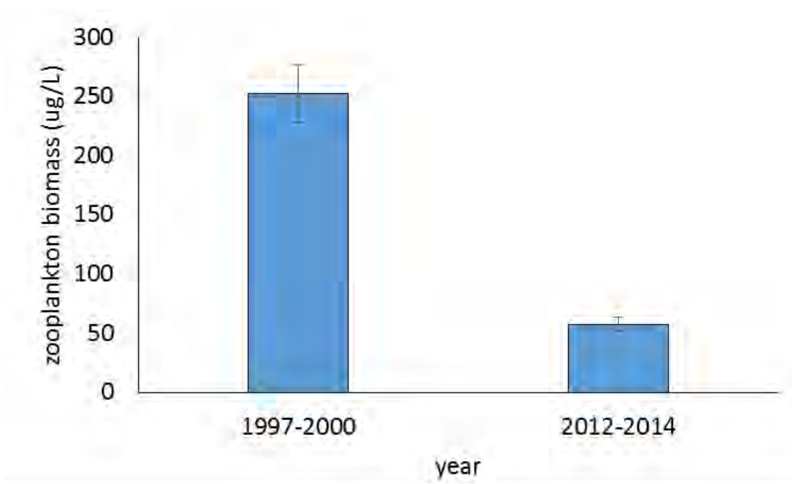


Figure 3. *Mean (± SE) total zooplankton biomass by year at Havana, IL; 1997-2000 (pre Asian carp) and 2014 (post Asian carp).*

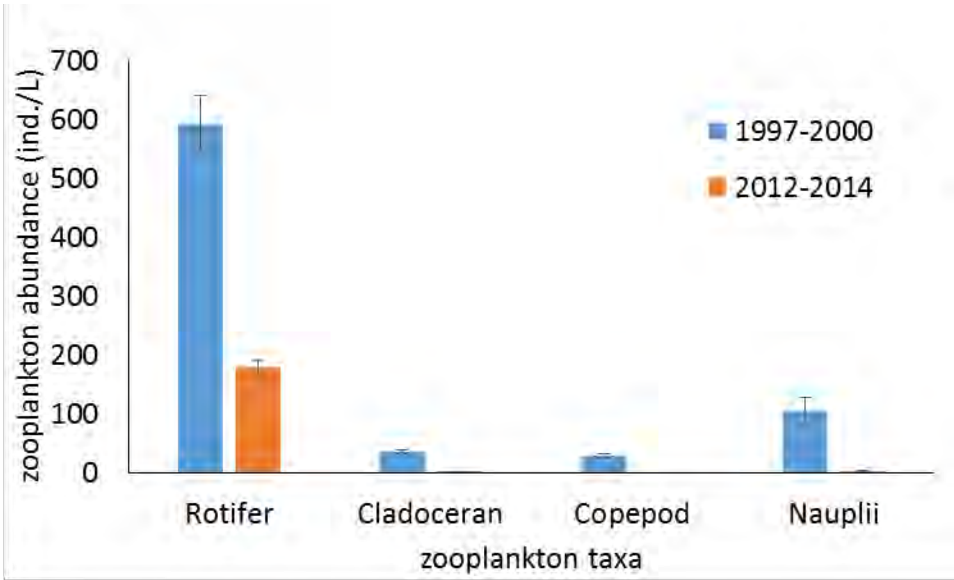


Figure 4. *Mean (± SE) zooplankton densities by taxa at Havana, IL for 1997-2000 (pre Asian carp) and 2014 (post Asian carp).*

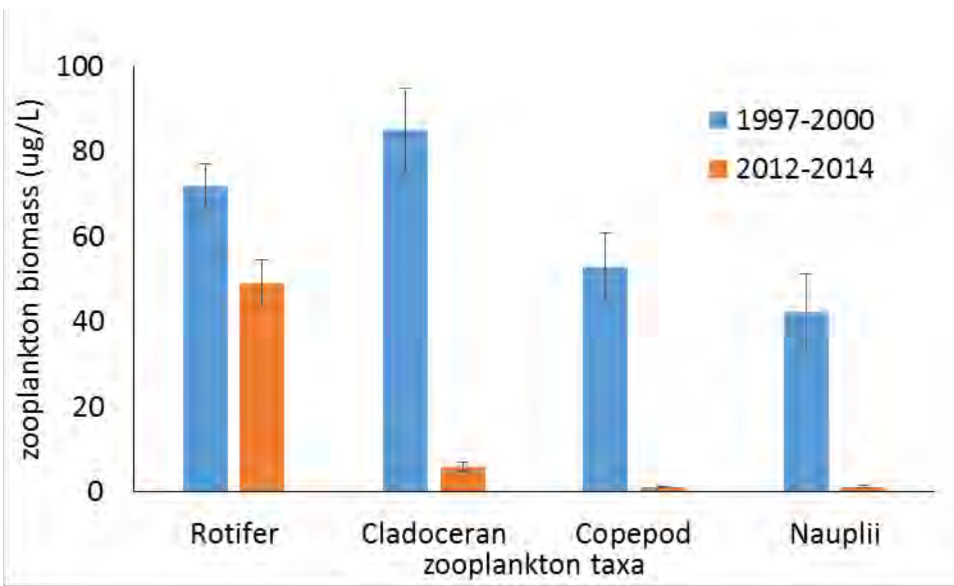


Figure 5. *Mean (± SE) zooplankton biomass by taxa at Havana, IL for 1997-2000 (pre Asian carp) and 2014 (post Asian carp).*

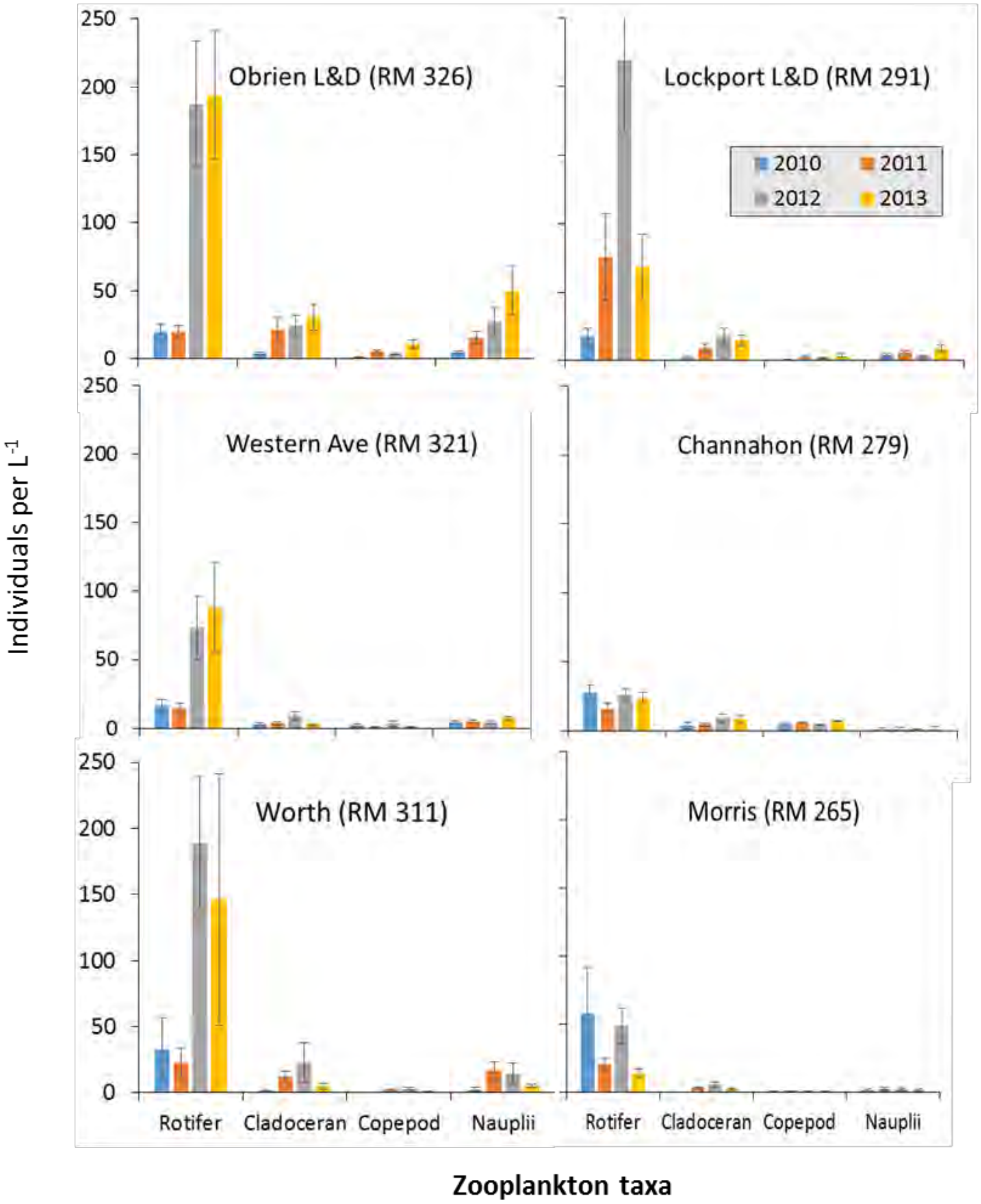


Figure 6. *Zooplankton abundance (individuals/L) by taxa for 2010-2013 at six sites in the upper Illinois River. The electric barrier at Brandon Rd occurs at river mile (RM) 297; no Asian carp have been detected above the barrier to date. Error bars represent standard error.*

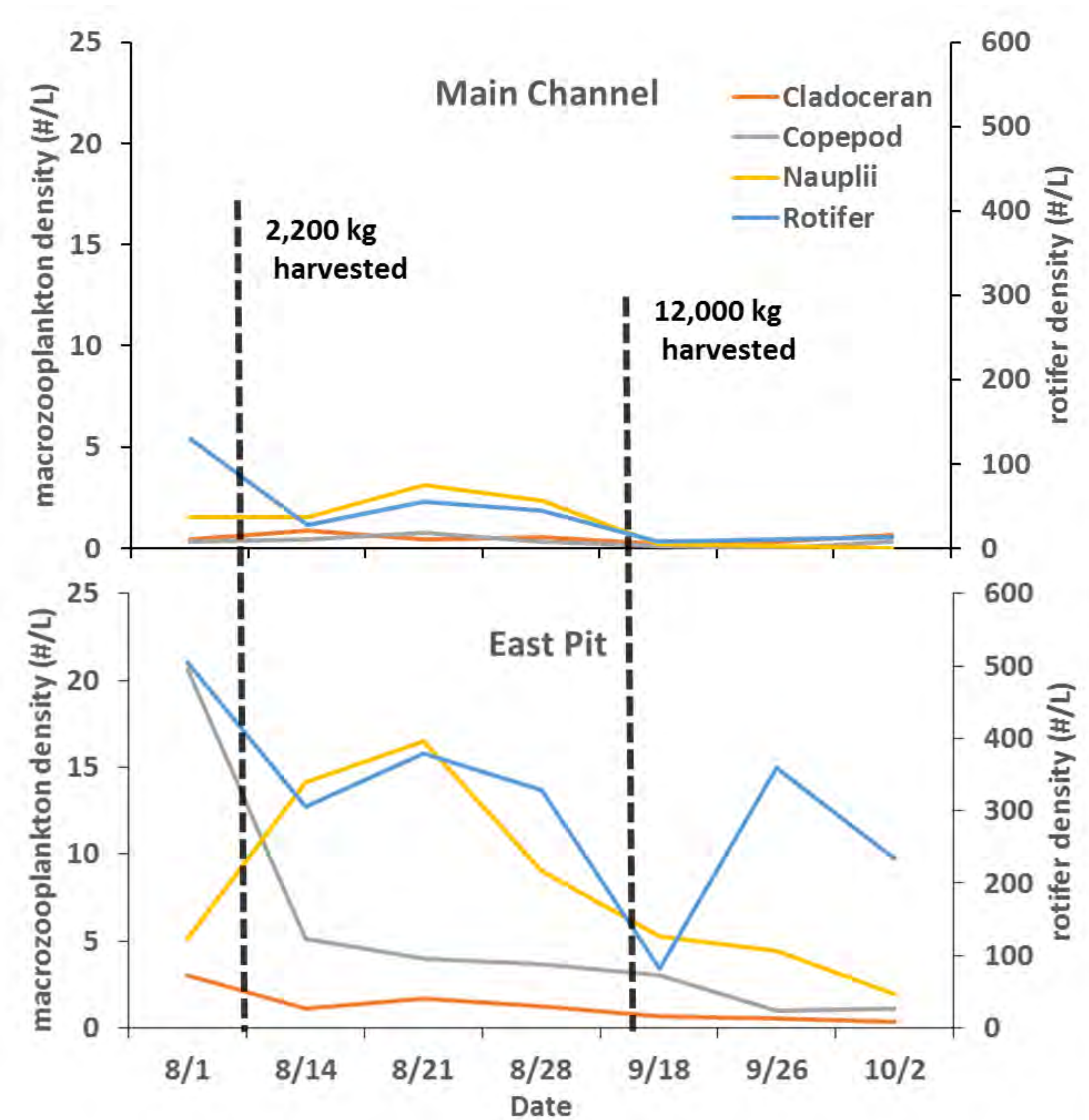


Figure 7. *Zooplankton response patterns during the August 1 to October 2 2014 period in which 2,200 kg of Asian carps were harvested on in the second week of August and 12,000 kg were harvested during the second week of September (dashed lines). The site is a backwater of the upper Illinois River, the east pit of Hanson Material Services, and in the main channel adjacent to its connection to the backwater at approximately river mile 261. Note: Rotifers are placed on their own secondary y-axis because of their higher densities.*

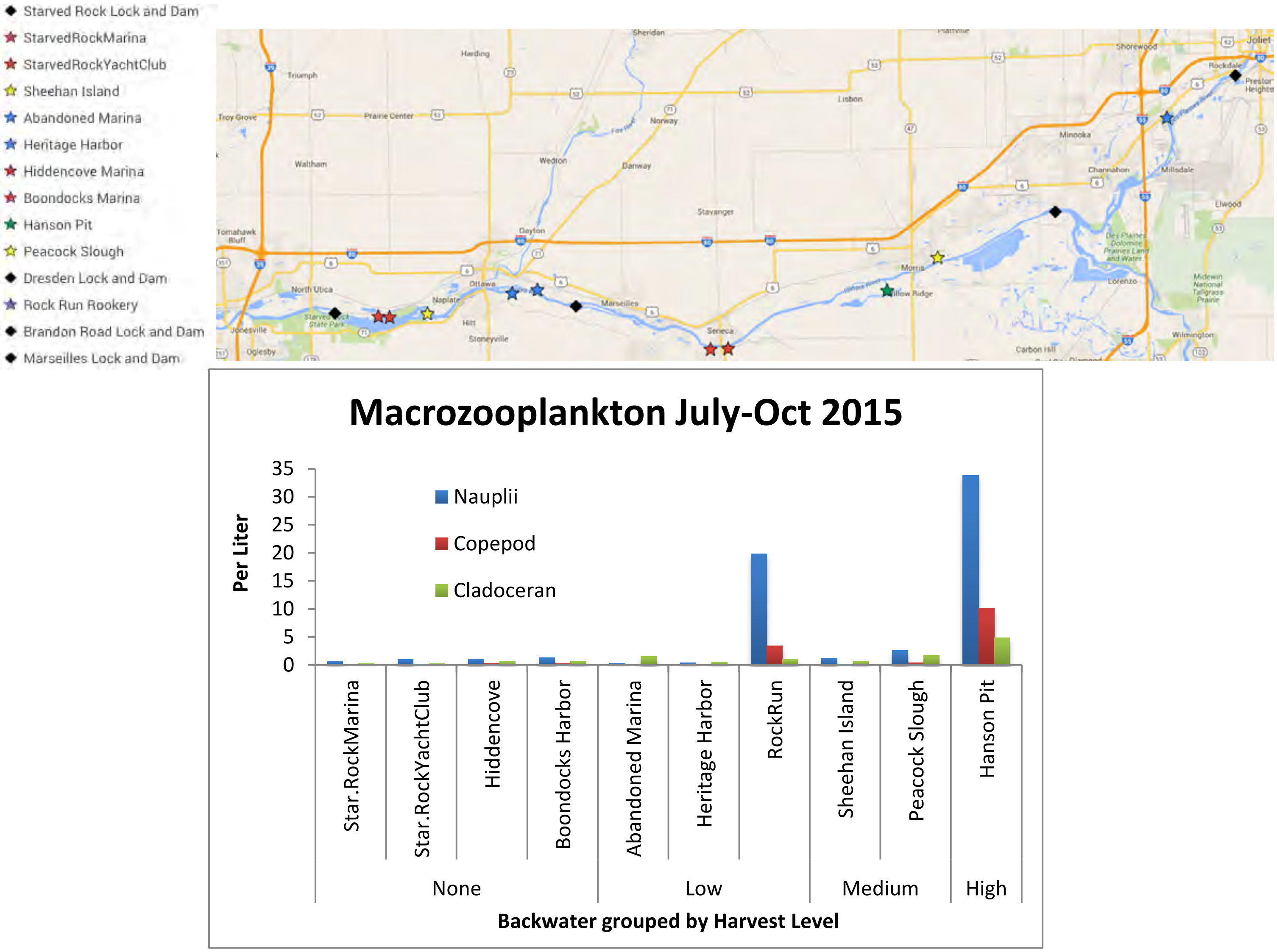


Figure 8. *Map and results of a 3-month assessment, August – October 2015, of zooplankton abundance in 9 backwaters grouped by level of commercial harvest targeting Asian carp.*

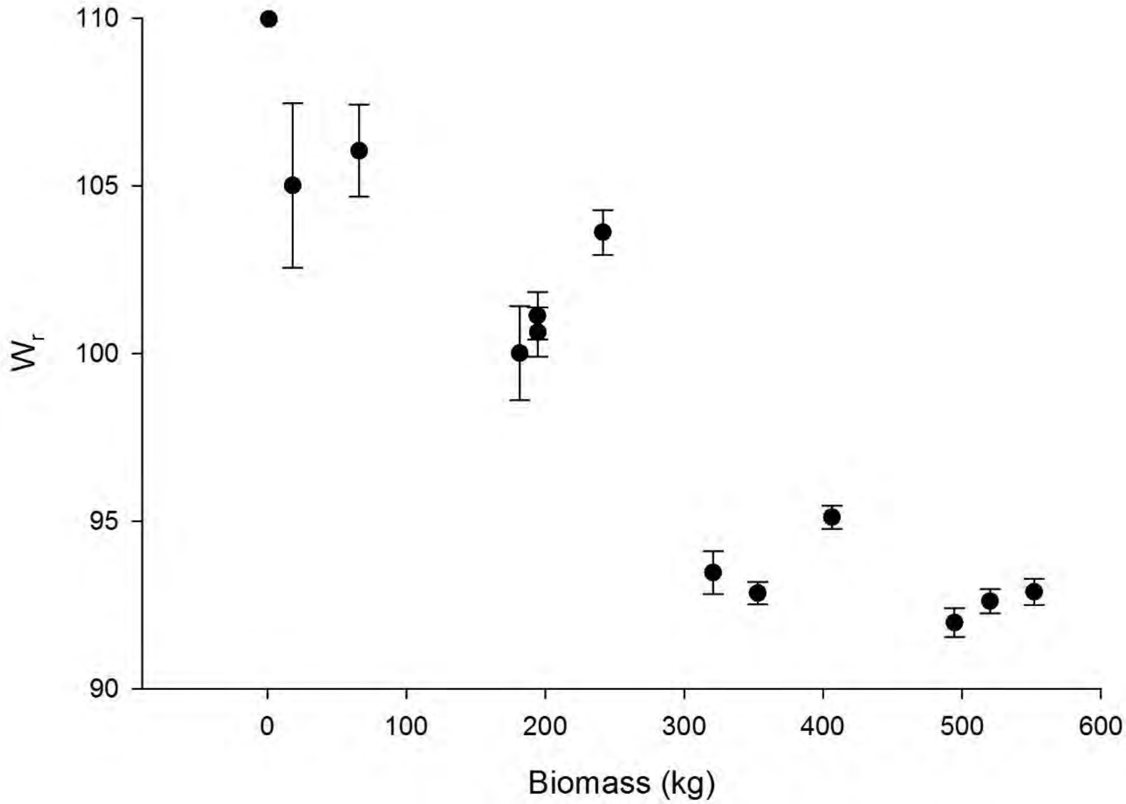


Figure 9. *Silver carp (Hypophthalmichthys molitrix) relative weight (W_r) as a function of total biomass collected in the LTEF monitoring program for the lower Illinois River (Peoria, LaGrange, and Alton pools) during 2001-2014.*

Assessing Population, Movement, and Behavior of Asian Carp to Inform Control Strategies

Matthew Lubejko, Alison Coulter, Greg Whitledge, James Garvey;
Southern Illinois University

Participating Agencies: Southern Illinois University-Carbondale (lead), U.S. Army Corps of Engineers (field and data support), Illinois Department of Natural Resources (field support).

Project Goal: Continue to monitor Asian carp demographics and abundance in the Illinois River. Monitor movements of Asian carp throughout the Illinois River and increase surveillance of Asian carp movements around Starved Rock Lock and Dam as well as Brandon Road Lock and Dam.

Introduction: Upstream movement of Asian carp through Starved Rock Lock and Dam (SRLD) was quantified with acoustic telemetry from 2013-2014. From these data, we determined only 1.2 percent (n=3) of Asian carp detected between river kilometers (Rkm) 0.0 and SRLD (Rkm 371.8) passed upstream through SRLD. Additionally, hydroacoustic surveys completed by SIUC from 2013 to 2014 indicated the density of Asian carp in the Illinois River was significantly greater in pools downstream of SRLD than in pools upstream of the dam. The low rate of upstream passage, coupled with reduced densities upstream, indicate SRLD may act as a partial barrier to upstream movement of Asian carp.

The navigation lock and tainter gates are possible avenues of passage at SRLD. Fish can use the lock chamber to lock through with vessels or pass through openings in the dam created when the tainter gates are raised. Ten tainter gates are used to maintain desired pool elevations. Each gate is 18.28 meters wide by 5.18 meters high, thereby creating 10 18.28 meters by 5.18 meters gaps in the dam when all tainter gates are lifted during high water events. Of the three upstream passages recorded from 2013 to 2014, we can verify only one occurred through the lock chamber. The other two passages likely occurred through the dam as there were no detections in the lock chamber. However, with the limited number of receivers located near SRLD in 2013 and 2014, we could not be certain passage occurred through the dam or when passage events occurred.

In 2015, we increased the number of tagged fish and receivers near SRLD to determine timing and avenue (lock vs. dam) of passage for Asian carp through SRLD. These data will be important for managing Asian carp and reducing their upstream movement through SRLD and other gated dams along the Illinois and Mississippi Rivers.

Objectives:

(1) Increase the number of acoustically tagged fish downstream of SRLD and acoustic receivers upstream and downstream of SRLD.

(2) Monitor and discern patterns of Asian carp movement through SRLD.

(3) Relate total discharge, water temperature, and gate openness to passage and attempted passage events.

Project Highlights

- 119 Asian carp were tagged within 20.3 Rkm downstream of SRLD (50 Bighead, 69 Silver Carp)
- Of the fish tagged in 2015, 14 percent were redetected within 3 Rkm of SRLD.
- Spawning downstream of SRLD was observed on 6/9 and coincided with the maximum number of challengers detected downstream of SRLD.
- We recorded the first upstream passages of Asian carp tagged downstream of SRLD.
- Passages through the dam occurred within a 12-day period.
- Four of five passages through the tainter gates occurred when the tainter gates were completely open.
- One fish passed through the tainter gates when the gates were no more than 1.83 meters open.
- 23 percent of all upstream migrating fish detected within 3 Rkm downstream of SRLD eventually passed upstream.
- Five of six fish which passed upstream through SRLD remained upstream (as of October 2015).

Methods:
Acoustic tagging

Prior to 2015, only 3 percent of Asian carp tagged downstream of SRLD were detected within 3 Rkm of SRLD. This could be a result of the distance fish were tagged downstream of the dam; Asian carp have never been tagged within 28 Rkm of SRLD. In 2015, tagging locations were selected to be as close to the downstream end of SRLD as possible, with the expectation that fish closer to the dam would be more likely to approach and pass through the dam than fish tagged farther downstream. Between March and October 2015, transmitters were surgically implanted into 119 Asian carp from SRLD up to 20.3 Rkm downstream (Rkm 351.5 to 371.6; Table 1). While we intended to tag Bighead Carp closer to SRLD, river conditions and capture effort required us to tag all Bighead Carp at Rkm 351.5, where densities were higher. On October 11, we hired commercial fishermen to collect Asian carp, specifically targeting individuals < 500 mm; however, this effort proved unsuccessful and we instead tagged 19 Silver Carp > 500 mm. All fish implanted with transmitters in 2015 were also marked with individually numbered, $50 reward jaw tags to provide incentives to fishermen not contracted by the IDNR to return transmitters. Fishermen contracted by IDNR have been instructed to immediately return healthy fish. Tagging methods were similar to those employed by SIUC in previous years. Individuals tagged in 2015 join additional Bighead and Silver Carp tagged from 2012 to 2014 by SIUC in the Illinois and Mississippi Rivers.

Table 1. *Date and location of Silver and Bighead Carp tagged with acoustic transmitters in 2015.*

Date	Rkm	Distance downstream of SRLD (Rkm)	Silver Carp	Bighead Carp	Total tagged
3/23/2015	364.5	7.3	2	0	2
4/6/2015	371.6	0.2	21	0	21
5/29/2015	364.5	7.3	14	0	15
5/29/2015	371.6	0.2	13[a]	0	12
5/30/2015	351.5	20.3	0	50[b]	50
10/11/2015	364.5	7.3	19	0	19
		Total	**69**	**50**	**119**

[a] Includes one tagging mortality.
[b] Includes two tagging mortalities.

Receivers

Five Vemco VR2W receivers, located within 3 Rkm upstream and downstream of SRLD, have been logging Asian carp movements near SRLD since 2013. In 2015, 12 additional receivers were added around SRLD (downstream = 9, upstream = 3) to increase detection probability and discern fine-scale movement patterns and better understand passage events. There are currently 17 receivers near SRLD (Figure 1). Movement data from an additional 34 receivers distributed throughout the Illinois River will be used to supplement data collected from the receivers near SRLD.

HOBO temperature loggers were attached to seven of the 17 receivers near SRLD. Temperature data will be used to determine if temperature differences exist among receiver locations and if Asian carp movement is influenced by water temperature.

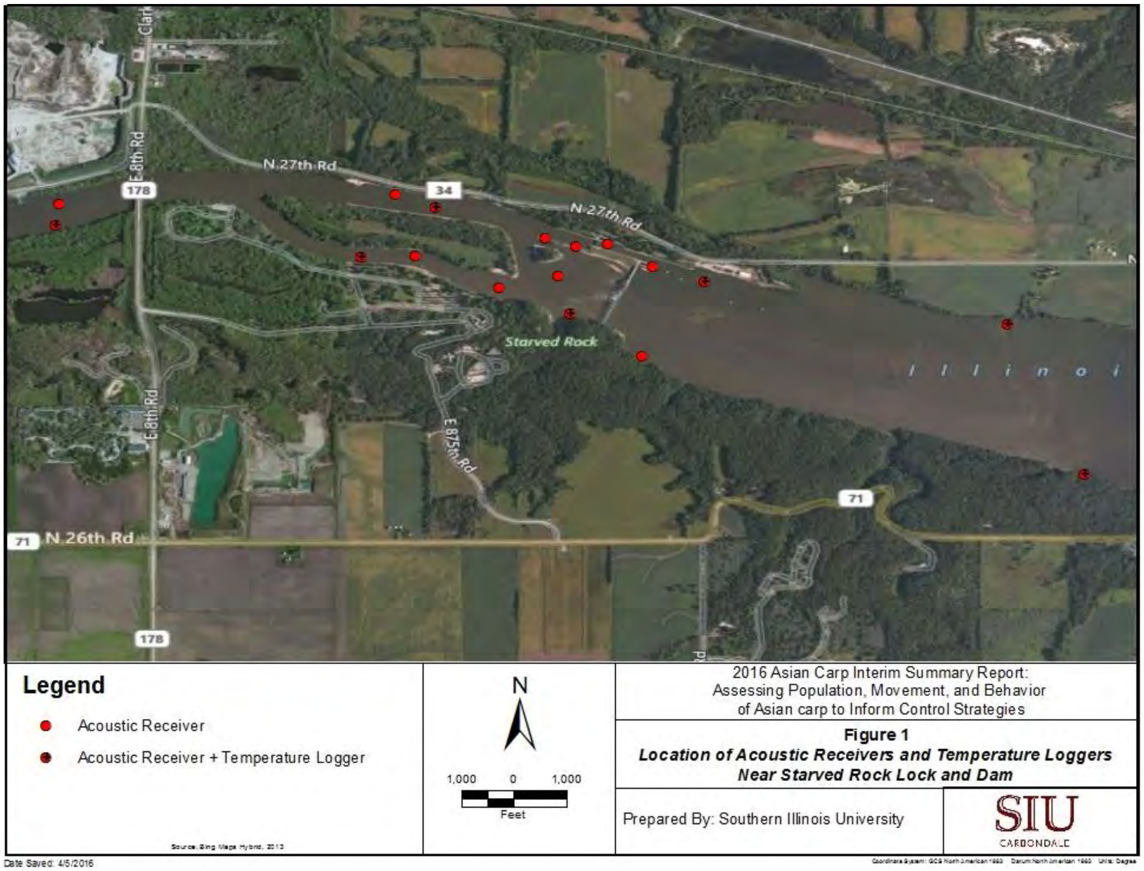


Figure 1. *Location of acoustic receivers and temperature loggers near Starved Rock Lock and Dam (2015).*

Results and Discussion:

Movement around SRLD – Fish tagged in 2015

Mean total length of the 69 Silver Carp tagged around SRLD was 553 mm (±8 SE; 802 – 465 mm), while the 50 Bighead Carp tagged averaged 669 mm (±8 SE; 840– 591 mm). Nineteen of the 119 Asian carp tagged for this project were tagged within 2 weeks of our final receiver download near SRLD and were excluded from analysis as a result of their lack of time at large in the river (data 2 weeks post-tagging were removed based on possible tagging impacts [winter 1996]). Of the remaining 100 Asian carp tagged in 2015, three died several days after transmitter implantation and, therefore, were also excluded from analysis.

The redetection rate of fish tagged in 2015 was 21 percent (Table 1). We anticipate, with additional time, the redetection rate will increase. Only 14 percent of fish were detected within 3 Rkm of SRLD, and 3 percent successfully passed upstream. Asian carp tagged closer to SRLD appeared more likely to approach and pass through SRLD than fish tagged farther downstream. Fish tagged close to the dam were also detected downstream (at least 35 Rkm) more than any other group of fish tagged in 2015. This finding suggests that Asian carp immediately downstream of SRLD are more likely to be actively migrating than Asian carp found farther downstream.

We detected only one Bighead Carp tagged in 2015 near SRLD. All Bighead Carp were tagged farther downstream of SRLD than Silver Carp, potentially limiting their likelihood of approaching the dam. Ideally, additional Bighead Carp would be tagged closer to SRLD, but these fish proved difficult to locate during 2015 sampling. Manual tracking will be conducted in 2016 to determine where Bighead Carp tagged in 2015 are located.

Table 1. *Detection summary of Asian carp tagged in 2015 around Starved Rock Lock and Dam (SRLD).*

Rkm Tagged	Number tagged*	% redetected	% detected ≤ 3 Rkm downstream of SRLD	% detected >35 Rkm downstream of SRLD	% passed upstream through SRLD
351.5	48	4%	2%	2%	0%
364.5	16	13%	6%	13%	0%
371.6	33	49%	36%	15%	9%
Total	**97**	**21%**	**14%**	**8%**	**3%**

*Excludes 19 fish tagged at Rkm 364.5 on 10/13/15 and three tagging mortalities (Rkm 351.5 = 2, Rkm 371.6 = 1). SRLD located at Rkm 371.8.

Spawning movements

On June 9, 2015, two SIUC researchers observed a widespread spawning event downstream of SRLD, which appeared to be mostly Silver Carp. Spawning was observed between SRLD and Rkm 362 and was often restricted to the northern half of the river (Figure 2). Spawning likely extended downstream of Rkm 362 but was not verified by the field crew.

Figure 2. *Approximate distribution (red) of spawning event below Starved Rock Lock and Dam witnessed on June 9, 2015.*

Spawning activity started around 10:00 (6/9) and was still occurring when the crew left the river at 20:00. The crew returned to the river on June 10, 2015, and noted very little spawning activity throughout the day. We detected 10 unique fish within three Rkm downstream of SRLD on June 9 and 10, much higher than the 2015 daily average of 1.7 fish/day (Figure 3).

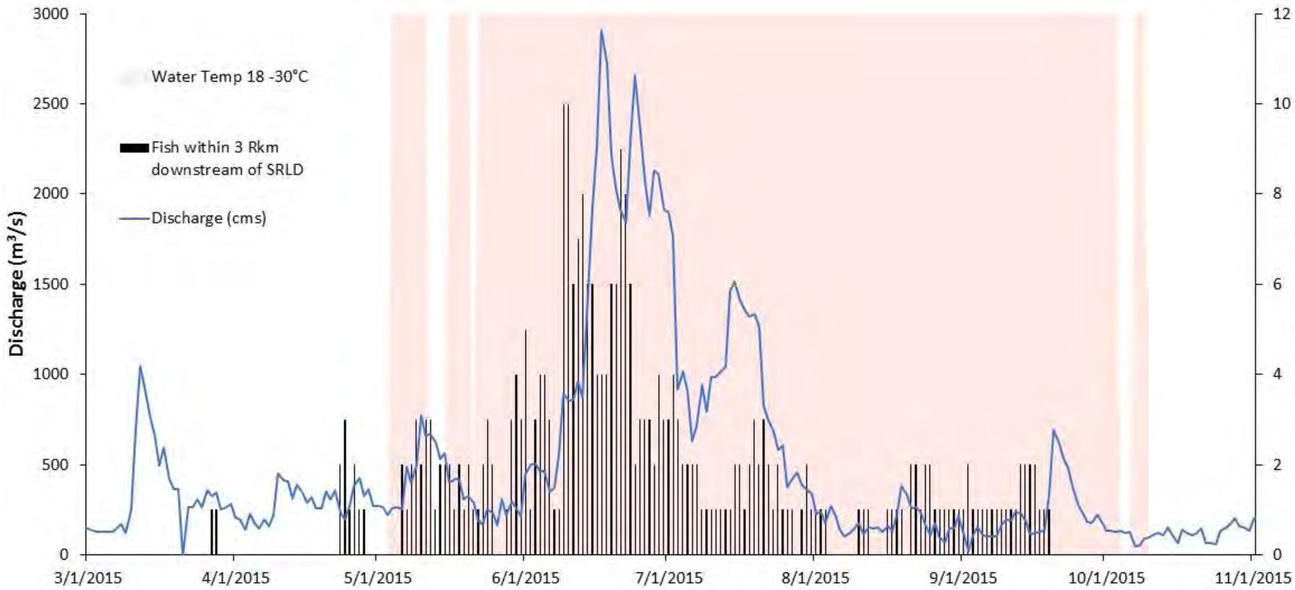


Figure 3. *Upstream migrating Asian carp detected within three Rkm downstream of Starved Rock Lock and Dam (SRLD) with discharge and water temperature for 2015. Discharge data were obtained from U.S. Army Corp of Engineers, Rock Island District.*

We also detected nine unique fish within three Rkm downstream of SRLD on June 21, 20154, potentially indicating another spawning event. Average water temperature on June 9 and June 21 was 22.5°C and 22.4°C, well within reported values of Asian carp spawning in North America (Deters et al. 2013).

Asian carp "challengers" to SRLD

Asian carp detected within 3 Rkm downstream of SRLD were considered "challengers" with an increased potential to immigrate into the Starved Rock Pool based on their proximity to the dam. In 2015, we detected 26 individuals immigrating to within 3 Rkm of SRLD (Figure 3). These fish were detected between 3/27 and 11/19 and included 18 Silver Carp and eight Bighead Carp. Some of these fish appeared to approach SRLD for spawning, as their appearance below SRLD occurred at the same time that spawning was directly observed. Challengers seemed to be influenced by temperature and discharge. Data collected in 2016 will be combined with 2015 data to further investigate the timing of challengers throughout the year.

Passage by Asian carp through SRLD

In 2015, we recorded six upstream and 17 downstream passages through SRLD. One upstream and one downstream passage occurred through the lock chamber, and all other passages were through the tainter gates. The single upstream lock passage occurred on July 24, 2015, when there were no tainter gates open more than 0.6 meter. This fish was detected immediately downstream of the dam before it entered the lock chamber, suggesting it would have passed through the dam if possible.

Of the five upstream passages though the dam gates, all but one occurred when the tainter gates were completely open (Figure 4). One fish passed upstream on July 3 when the tainter gates were 0.9 to 1.8 meters open. This detection demonstrates that SRLD is susceptible to passage by Asian carp when the gates are only partially open.

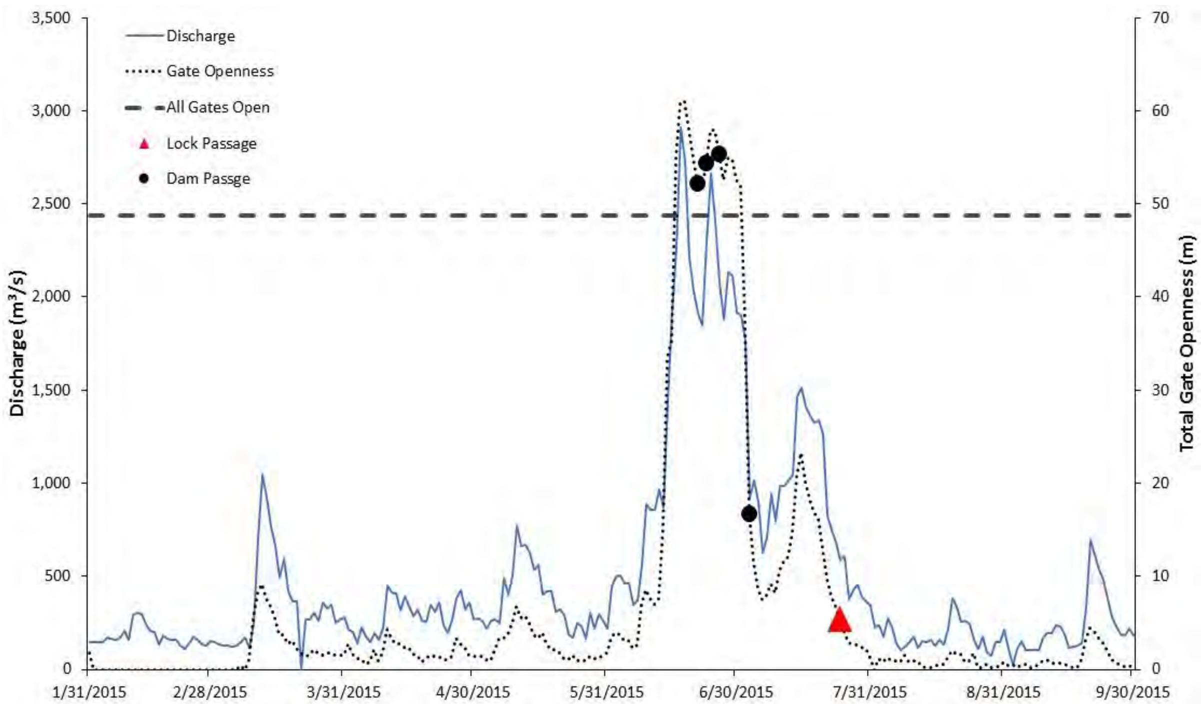


Figure 4. *Timing and conditions of passage events through Starved Rock Lock and Dam in 2015. Total of six passage events (two dam passages on 6/21).*

Prior to 2015, no fish tagged downstream of SRLD had successfully passed upstream through SRLD. In 2015, three of six upstream passages were from fish tagged 0.2 Rkm downstream of SRLD. Of these three fish, two remained upstream, and one returned downstream 27 days after upstream passage. In total, five fish remained upstream through the end of data collection in October 15. The number of fish that passed through the dam and remained upstream provides evidence of net immigration into the Starved Rock Pool. It appears that individuals immediately below SRLD may be more likely to pass through the dam, and so reduction of fish directly below the dam may prove effective at reducing passage events. We will continue to monitor these fish and any additional fish that pass upstream through SRLD to determine the rate of upstream immigration and to determine which environmental conditions are associated with passage.

Recommendations: Of the fish that were detected within three Rkm of SRLD (n=26), 23 percent successfully passed upstream. This relatively high rate of passage is evidence that SRLD is not a barrier to upstream movement of Asian carp but may inhibit movement somewhat, as 77 percent of challengers did not pass through SRLD. Even though upstream passage through the lock was recorded, it appears that the dam poses a greater threat as an avenue of upstream passage for Asian carp. As such, effort should be focused on limiting passage through the dam. Potential changes in dam management may also help to reduce passage as movement data from 2013 to 2015 suggest Asian carp do not begin to challenge SRLD until after discharge exceeds 850 m^3/s.

Targeted mechanical removal of Asian carp downstream of SRLD is another potential method to reduce upstream immigration. In addition, the number of challengers appears greatest when water temperature exceeds 18 °C. Therefore, mechanical removal may be most successful following the first annual rise in the hydrograph ($\geq$ 850 m^3/s) and when water temperatures are $\geq$ 18 °C.

These findings are the result of one dam and mostly larger (> 500 mm total length) Asian carp. Therefore, this study will expand during the next season to monitor another lock and dam (likely Brandon Road Lock and Dam) and will target Asian carp < 500 mm for tagging.

Literature Cited

Deters, J.E., Chapman, D.C., and McElroy, B. 2013. Location and timing of Asian carp spawning in the lower Missouri River. Environmental biology of fishes 96: 617-629.

Winter, J., Murphy, B., and Willis, D. 1996. Advances in underwater biotelemetry. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland: 555-590.