Asian Carp Regional Coordinating Committee

Monitoring and Rapid Response Workgroup

2014 Asian Carp Monitoring and Response Plan Interim Summary Reports

June 2015

ACKNOWLEDGEMENTS

This compilation of interim summary reports for projects included in the 2014 Asian Carp Monitoring and Response Plan was created by a team of biologists, scientists, and managers from state and federal agencies implementing the plan. Although too numerous for individual recognition here, we would like to acknowledge everyone in the Illinois Department of Resources, US Army Corps of Engineers, US Fish and Wildlife Service, US Geological Survey, US Environmental Protection Agency, US Coast Guard, Illinois Natural History Survey, Southern Illinois University, Western Illinois University, Michigan Department of Natural Resources, Northern Illinois University, Fisheries and Oceans Canada, Hansen Material Service and Metropolitan Water Reclamation District of Greater Chicago for supporting or assisting with field work during 2014 Asian carp monitoring, removal, and response efforts. This and earlier versions of this document have benefitted from reviews by K. Baerwaldt, K. Irons, R. Simmonds, S. Finney, and B. Ruebush. M. O'Hara, provided pictures for the cover. M. O'Hara assembled this compilation of interim reports.

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EXECUTIVE SUMMARY

The latest version of the Asian Carp Monitoring and Response Plan (MRP) (formerly the Monitoring and Rapid Response Plan (MRRP)) was prepared by the Monitoring Response Workgroup (MRWG) and released by the Asian Carp Regional Coordinating Committee (ACRCC) in May 2014. It included 21 individual project plans detailing tactics and protocols to achieve the specific goal of preventing Asian carp from establishing populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. The term 'Asian carp' will refer 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*) for the purpose of this document. Projects in the MRP were classified geographically as occurring either upstream or downstream of the electric dispersal barrier system in Romeoville, Illinois and grouped into five categories: Monitoring Projects, Removal Projects, Barrier Effectiveness Evaluations, Gear Effectiveness Evaluations and Development Projects, and Alternative Pathway Surveillance.

To foster an adaptive management approach to Asian carp monitoring and removal, the 2014 MRP recommended completion of project interim reports summarizing the previous year's monitoring and removal efforts. These reports would be used to inform modifications and enhancements to projects included in an updated Monitoring and Response Plan.

This document is a compilation of interim reports for the 21 individual projects found in the 2014 MRP. The reports include summaries of activities completed during the 2014 and, in some cases previous results from 2010-14 data collection. Most reports are preliminary in nature and contain initial data summaries, analyses, and interpretations. Whereas results and conclusions may change as additional data is collected and analyses are refined over time, they still provide a scientific foundation for proposed modifications to the 2015 MRP and related field activities.

Individual report details, including data summary tables and figures, can be found herein and are marked by a page number in parentheses next to the project name. A brief summary of individual project highlights follows.

MONITORING PROJECTS

Seasonal Intensive Monitoring in CAWS (2) – This project represents a modification to response actions and Planned Intensive Surveillance in the CAWS and target areas that have been previously monitored through response actions. These efforts have the benefit of advanced planning and are in locations where the repeated detection of e DNA in previous years indicates the potential presence of Asian Carp in the waterway.

- Completed 2-two week SIM events with conventional gears in the CAWS upstream of the electric dispersal barrier in 2014
- Estimated 2,205 person-hours were spent to complete 87.1 hours of electrofishing, set 77.7 km (48.3 mi) of trammel/gill net and 2.2 km (1.4 mi) of commercial seine in 2014
- Across all locations and gears in 2014, sampled 27,678 fish representing 57 species and 2 hybrid groups
- Captured a Spotted Gar in the North Branch of the Chicago River in 2014. It is the first-ever recorded in the CAWS, and the western-most occurrence associated with Lake Michigan
- Since 2010, an estimated 19,388 person-hours were spent to complete 769.4 hours of electrofishing, set 524 km (325.6 mi) of gill/trammel net and 3.7 km (2.3 mi) of commercial seine
- A total of 278,991 fish representing 72 species and 6 hybrid groups were sampled, including 1,106 Banded Killifish (state threatened species) from 2010-2014
- Examined 87,779 YOY Gizzard Shad since 2010 and found no Asian carp
- Since 2010, 17 non-native species have been captured accounting for14% of the total fish caught and 22% of the total species
- No Bighead Carp or Silver Carp have been captured or observed since 2010 (1 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 and Upper Des Plaines River (11) – This project continues eDNA monitoring in strategic locations in the CAWS that will be used to inform on the status of Asian carp.

- Two eDNA comprehensive sampling events took place in the CAWS at four regular monitoring sites in 2014, resulting in 456 samples collected and analyzed.
- June event: seven positive detections for Silver Carp DNA, one positive detection for Bighead Carp DNA
- October event: 23 positive detections for Silver Carp DNA, zero positive detections for Bighead Carp DNA
- Comparative analysis of cPCR methods used prior to 2014 with qPCR methods employed in 2014

Larval Fish and Productivity Monitoring (19) – This information will aid in evaluating the potential for Asian carp 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.

- Over 500 larval fish samples were collected from 11 sites across the length of the Illinois Waterway during April – September, 2014, capturing over 18,000 larval fish, including 5,231 larval Asian carp.
- Larval Asian carp were only collected in the LaGrange and Peoria Pools in 2014. No Asian carp larvae were observed from the upper Illinois Waterway.
- Multiple peaks in larval Asian carp abundance were observed during June and July 2014, coinciding with a period of rising water levels and water temperatures consistently above 20°C. Low numbers of Asian carp larvae continued to be collected into August, indicating that spawning continued to occur during this time, although at much lower levels.
- Over 180 larval fish samples were collected from four Illinois River tributaries (Spoon, Sangamon, Salt Fork of the Sangamon, and Mackinaw Rivers) from April – October, 2014, capturing over 4,700 larval fish. Processing and identification of these samples is ongoing and results will be reported once available.

Young-of-Year and Juvenile Asian Carp Monitoring (25) – Monitoring for the presence of young-of-year Asian carp in the Illinois River, Des Plaines River, and CAWS occurred through sampling planned by other projects in the MRP and targeted a segment of the Asian carp population typically missed with adult sampling gears.

- Sampled for young Asian carp from 2010 to 2014 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 (pulsed-DC electrofishing, small mesh purse seine, cast net, and beach seine) and passive gears (small mesh gill nets, and mini-fyke nets) in 2014.
- Completed 1,401 hours of electrofishing across all years and sites.
- Examined 127,007 Gizzard Shad <152 mm (6 in) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam from 2010-2014 and found no young Asian carp.
- High catches of young-of-year Asian carp in 2014 in the LaGrange Pool indicate a high recruitment year despite limited to no recruitment in 2010-2013.
- Farthest upstream catch was a post larval Asian carp in the Peoria pool near Henry, Illinois (river mile 190) in 2012 and 2014, over 100RM downstream from the electric dispersal barrier.
- Recommend continued monitoring for young Asian carp to determine the farthest upstream young fish are recruited into the population.

Distribution and Movement of Small Asian Carp in the Illinois Waterway (31) - The purpose of this study was to establish where young (YOY to age 2) Asian carp occur in the IWW through intensive, directed fish sampling which targets these life stages.

- A total of 39,409 fish specimens were collected and examined.
- Eighty-three species were identified along with two hybrid combinations.
- Two Illinois State threatened species were sampled.
- One Illinois State endangered species was sampled.
- No YOY Asian carp were sampled.
- The lack of YOY Asian carp in our samples suggests that the uppermost limit of these fish is still downstream of the Starved Rock Lock and Dam in the Peoria pool.

Fixed Site Monitoring Downstream of the Dispersal Barrier (35) – This project included monthly standardized monitoring with pulsed-DC electrofishing gear and contracted commercial fishers at four fixed sites downstream of the Dispersal Barrier in Lockport Pool and downstream from the Lockport, Brandon Road, and Dresden Island locks and dams. It provides information on the location of the Asian carp detectable population front and upstream progression of populations over time.

- Estimated 10,224.5 person-hours spent sampling at fixed, random, and additional sites and netting locations downstream of the electric dispersal barrier from 2010-2014.
- 409 hours spent electrofishing and 439 km (273 miles) of trammel/gill net deployed.
- Sampled 146,882 fish, representing 97 species and seven hybrid groups.
- No Bighead or Silver Carp were captured by electrofishing or netting in Lockport and Brandon Road pools.
- Seventy-nine Bighead Carp and 19 Silver Carp were collected in the Dresden Island Pool
  during, fixed, random, and additional commercial netting from 2010-2014.
- Twenty-nine Bighead Carp were captured in a single hoop net in the Dresden Island Pool.
- One Bighead Carp and no Silver Carp were captured at Dresden Island Pool while electrofishing from 2010-2013, with none being captured in 2014.
- Detectable population front of mostly Bighead Carp located just north of I-55 Bridge at river mile 280 (76 km (47 miles from Lake Michigan)). No appreciable change in upstream location of the population front in past five years.
- Recommend to continue current sampling plan below the electric dispersal barrier with electrofishing, hoop netting, mini-fyke netting, and gill and trammel netting.

REMOVAL PROJECTS and Evaluations

Response Actions in the CAWS (45) – This project uses a threshold framework to support decisions for response actions to remove any Asian carp from the CAWS upstream of the Dispersal Barrier with conventional gear or rotenone.

- Based on the criteria of the Response Matrix there were no rapid response actions utilized in the CAWS in 2014. Alternatively two Seasonal Intensive Monitoring (SIM) events were conducted in 2014 yielding no Bighead Carp or Silver Carp being captured or observed. Refer to the Seasonal Intensive Monitoring Interim report for complete results.
- From 2010-2012, eleven rapid response actions occurred 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.
- Estimated 11,330 person-hours were spent to complete 170 hours of electrofishing, set 80.8 km (50.2 mi) of trammel/gill net, treat approximately 4 km (2.5 mi) (70 ha (173 acres)) of river with rotenone, made seven-0.7 km (800 yd) long commercial seine hauls, and deployed six tandem trap nets, 10 hoop nets and two Great Lake pound nets equal to 52.8 net-days of effort.
- Across all response actions and gears, sampled over 137,875 fish representing 57 species and 2 hybrid groups.
- Sampled 398 state threatened Banded Killifish
- No Bighead Carp or Silver Carp were captured or observed during rapid response actions.

Barrier Maintenance Fish Suppression (51) – This project provides a fish suppression plan to support US Army Corps of Engineers maintenance operations at the Dispersal Barrier. The plan includes fish sampling to detect juvenile or adult Asian carp presence in the Lockport Pool downstream of the electric dispersal barriers, surveillance of the barrier zone with split-beam hydroacoustics, side-scan sonar and DIDSON imaging sonar, and operations to clear fish from between barriers by 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 two clearing actions on 27 May and 9 June 2014.
- A total of 34 fish from 8 species were removed using pulsed DC-electrofishing, with 8 fish > 12 inches in length.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on 15 January which precluded the need for further clearing actions.
- **No Asian carp were captured or observed during fish suppression operations**

Barrier Defense Asian Carp Removal Project (55) – This program was established to reduce the numbers of Asian carp downstream of the electric dispersal barrier through controlled commercial fishing. We anticipate that reducing Asian carp populations will lower propagule pressure and the chances of Asian carp gaining access to waters upstream of the barrier. Primary areas fished include Dresden Island, Marseilles, and Starved Rock pools.

- Contracted commercial fishers deployed 1359.2 miles(2186.9km) of gill/trammel net, 3.1 miles (5.0km) of commercial seine, and 196 hoop nets set in the upper Illinois Waterway from 2010- 2014.
- A total of 70,882 Bighead Carp, 191,031 Silver Carp, and 1,718 Grass Carp were removed by contracted commercial fisherman from 2010-2014. The total weight of Asian carp removed was 1493.94 tons
- Recommend continued targeted harvest of Asian carp in the upper Illinois Waterway with contracted commercial fishers and assisting IDNR biologists. Potential benefits include reduced 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: (63) - This project encompasses multiple studies with the goal of determining estimates of Asian carp abundance, biomass, size structure, demographics (e.g., growth and mortality), natal origin, and rates of hybridization in the Alton, LaGrange, Peoria, Starved Rock, Marseilles, and Dresden Island pools of the Illinois and Des Plaines Rivers.

- Asian carp abundance in the lower river (i.e. below Starved Rock Lock and Dam) appears to have increased compared to 2012 and 2013. Captures of YOY Asian carp also indicate relatively successful recruitment, likely due to high river discharge during the early spawning period in 2014 (compared to 2011–2013).
- Although data processing is ongoing for 2014, upper river hydroacoustic estimates suggest population changes (decreases in abundance, biomass and fish size) between 2012 and 2013.
- Definite separation patterns between the lower and upper river (at Starved Rock Lock and Dam) were observed in 2014. Fish tended to move as far as the Peoria pool, and then return back downstream. Movement in the upper river tended to be in the downstream direction through the Marseilles lock in 2014 and into and out of the HMS pits.
- Continued contract harvest in the upper Illinois River (above Starved Rock) plus intensive commercial harvest in the lower Illinois River may reduce density, potential recruitment, and perhaps immigration of Asian carp towards the electric dispersal barrier.

BARRIER EFFECTIVENESS EVALUATIONS

Telemetry Monitoring Plan (68) – 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 system and pass through navigation locks in the upper Illinois Waterway. An array of stationary acoustic receivers and mobile tracking was used to collect information on Asian carp and surrogate species movements.

- 15.1 million detections from 432 tagged fish have been acquired since 2010
- The electric dispersal barriers have been effective at preventing upstream passage of free swimming tagged fish > 300 mm
- Since 2011, two transmitters implanted into Common carp downstream of the Barriers were located upstream although no detections were observed at barrier receivers. The most plausible explanation being assisted passage via barge entrainment; both transmitters were either expelled or the host had expired
- Fish approaching the Dispersal Barriers spend a greater amount of time challenging the barriers with increased discharge rates
- Common Carp over 415 mm in total length are repelled by electric field strengths as low as .1 to .5 V/in
- Inter-pool movement of tagged fish was observed in both directions between all pools within the study area in 2014 (Lockport, Brandon, Dresden Island and Marseilles)
- Asian Carp are consistently using the Kankakee River and Rock Run Rookery with little movement detected surrounding the Brandon Road Lock and Dam
- A probability model for tagged Asian carp presence/absence has been generated for the Rock Run Rookery and the Kankakee River within the Dresden Island Pool based on temperature and discharge rates

Understanding Surrogate Fish Movement with Barriers (68) – 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 structures (i.e. electric dispersal barriers and lock and dams). Obtain information on recapture rates of surrogate species to help verify sampling success using multiple gear types.

- Multiple agencies and stakeholders cooperated in successfully tagging 1,654 fish in Lockport Pool, Brandon Road Pool, Dresden Island Pool and Rock Run Rookery (Between April 1 and December 11)
- A total of 18 fish were recaptured using pulsed DC-electrofishing, gill nets, trammel nets and 6 foot diameter hoop nets.
- A total of 14 recaptures had tags but showed no movement between barrier structures, 3 recaptures where observed due to caudal fin clip but had no tag to show movement and 1 recapture showed movement from Dresden Island Pool downstream through the Dresden Island Lock and Dam into the Marseilles Pool.
- 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 Fish-Barge Interactions at the Barrier (81) – This project uses split-beam hydroacoustics, side-scan SONAR, Dual-Frequency Identification SONAR (DIDSON), and caged fish experiments to assess fish abundances and behavior at the electric dispersal barrier system designed to prevent fish passage between the Mississippi River and Great Lakes Basins. This is an updated plan that includes protocols for monitoring fish at the electric barrier system area.

- No fish were observed crossing the electric dispersal barrier's IIB narrow array during October 2014.
- Reverse flows in the canal at the electric dispersal barrier site were common and could not be identified from the USGS Lemont IL stream gauge.
- Median size of YOY fish (<150 mm) present in Lower Lockport Pool the week following 2013 DIDSON sampling was 62.2 mm.
- Fish density and congregation directly below the electric dispersal barriers was significantly greater during summer 2013 data collections than during fall 2014 data collections.

Evaluating Asian Carp Detection Techniques with SONAR (87) - This project evaluates the use of multiple hydroacoustic SONAR frequencies in order to assess whether live Asian carp can be specifically identified apart from any other fish species. These identifications could significantly reduce the amount of water targeted for future response efforts.

- There were significantly greater mean total densities of fish observed immediately below the electric dispersal barrier during the summer than in spring or fall.
- During spring both large and small mean fish densities were significantly greater directly below the barrier at night than during daytime or crepuscular periods.
- We observed differences in fish density patterns between study reaches that could be indicative of between reach migrations.
- High relative densities of fish were shown to be present within the Brandon Rd. Lock structure during both summer and fall.
- Acoustic remote sensing was used to communicate the presence of suspect ANS fish targets to state agencies that subsequently successfully captured Asian carp in the area.

Des Plaines River and Overflow Monitoring (82) – 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 52 species and 3 hybrid groups from 2011-2014 via electrofishing (38.65 hours) and gill netting (111 sets; 10,501 meters).
- IDNR basin survey completed 3.75 hours of electrofishing in 2014.
- No Bighead or Silver Carp have been captured or observed through all years of sampling.
- Two Grass Carp were captured in 2014. Analysis indicated both were triploid. Three Grass Carp tested in 2013 were also triploid. All Grass Carp were captured in the Des Plaines River.

GEAR EFFECTIVENESS EVALUATIONS AND DEVELOPMENT PROJECTS

Asian Carp Gear Efficiency and Detection Probability Study (86) – 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.

- Large numbers of juvenile Asian carp were captured in the LaGrange and Peoria Pools during 2014, but none were captured or observed upstream of the Peoria Pool. All juvenile Asian carp observed during 2014 were silver carp. No juvenile bighead carp were identified.
- Mini-fyke nets captured by far the highest number of juvenile silver carp in 2014. Beach seines and purse seines were also moderately effective. Pulsed-DC electrofishing and cast nets captured smaller numbers of juvenile silver carp. No juvenile Asian carp were captured in gill nets.
- Beach seines captured the smallest sizes of juvenile Asian carp (mean = 38 mm), whereas purse seines captured larger average sizes (mean = 53 mm). Cast nets (mean = 41 mm), pulsed-DC electrofishing (mean = 48 mm), and mini-fyke nets (mean = 49 mm) captured more intermediate sizes. However, electrofishing was the only gear that consistently captured juvenile Asian carp larger than 90 mm.
- Tributary sites were sampled with pulsed-DC electrofishing gear in the Spoon, Sangamon, Salt Fork of the Sangamon, and Mackinaw Rivers during 2014. A total of 796 adult Asian carp (6 bighead carp, 790 silver carp) were captured from tributaries. No juvenile Asian carp were observed in tributaries during electrofishing sampling.

Exploratory Gear Development Project (91) – A professional net designer has been consulted to develop and build enhanced purse seines, trawls, and gill nets for more effective harvest of Asian carp. Enhanced gears will be evaluated in areas known to have abundant Asian carp populations. If effective, gears may be used in place of rotenone for removal actions in the CAWS and for commercial fishing in the lower Illinois River or other Asian carp infested waterways.

- The paupier captures juvenile carp without electricity.
- The surface trawls capture juvenile carp.
- All sizes of Silver Carp were readily captured throughout the year in all habitats sampled.
- Juvenile invasive carp occupy lower reaches of tributary stream habitats of large rivers in the early life stages.
- YOY invasive carps transition to occupy shallow, still water habitats in the fall.

Unconventional Gear Development Project (95) –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.

- Driving fish into surface-to-bottom gill nets resulted in higher catch rates of all fish species and of silver carp than control sets. The highest catch rates were obtained by driving fish using a pulsed-DC electrofishing boat.
- The majority of fish species, including silver carp, were more vulnerable to smaller mesh sizes (6.4 – 7.6 cm) of surface-to-bottom gill nets, whereas bighead carp appear to be more vulnerable to larger mesh sizes (7.6 – 10.2 cm).
- Pound nets captured large numbers of fish, primarily consisting of Asian carp, and produced substantially higher catch rates of Asian carp than traditional entrapment gears in backwater habitats.
- Pound nets captured larger sizes of bighead carp than hoop nets or fyke nets, but sizes of captured silver carp did not differ among these gear types.

Water Gun Development and Testing (137) – Pneumatic water guns that emit high pressure underwater sound waves have potential to deter fishes or kill them if they are in close enough proximity to the wave source. This technology is being evaluated to determine their efficacy as a tool to modify Asian carp behavior and act as a barrier that can support maintenance of the electric dispersal barrier.

- Evaluated two $100in^3$ water guns firing every ten seconds as a barrier in an open water field setting.
- Behavioral responses of Asian carp and native fishes were observed with sonar and acoustic telemetry under controlled conditions. Initial results indicate fish passed through the water gun barrier during operation.
- Evaluated the behavioral and physiological effects of firing a $100in^3$ water gun on three species of native mussels
- Results indicate that native mussels did not alter their behavior in response to 100 firing of a 100in3 water gun.

- Results indicated that 100 firing of a 100in^3 water gun did not affect the shell of any of the mussels or cause mortality; even the thin-shelled mussels placed near the water gun.

ALTERNATIVE PATHWAY SURVEILLANCE

Alternate Pathway Surveillance in Illinois (107) – 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.

Law Enforcement:

- January 2014 - Sweetwater Spring Fish Company and owner each pled guilty to importing live VHS susceptible species without permits and paid a fine of $25,400.00 which was deposited in the Illinois Conservation Police Operations Assistance Fund.
- In August 2014, an Indiana bait dealer arrested for selling minnows and grass carp in Illinois without an aquatic life dealer's license, VHS permits, or a restricted species permit pled guilty and paid a $4000 fine which was deposited in the Illinois Conservation Police Operations Assistance Fund.
- November 2014 – A commercial fisherman targeted in an ISU investigation was arrested for the unlawful sale of 1,800 pounds of Bighead and Silver Carp – Class 3 Felony. His brother was arrested for possession of live Bighead and Silver Carp – Class A Misdemeanor.
- On December 01, 2014, Farm Cat Fish Transportation Company and the owner pled guilty to importing VHS susceptible species w/o permits and paid a $2,500 fine and $22,500 to the Illinois Conservation Police Operations Assistance Fund. They were also arrested for selling aquatic life without a license.
- Operation JabberJaw in Chinatown identified retail markets illegally selling shark fin. The operation resulted in the issuance of 8 citations for selling aquatic life without a license and 12 citations for illegally selling shark fin. A total of 80 shark fin violations were documented and 33 shark fin items seized. $3700 was awarded to the Illinois Conservation Police Operations Assistance Fund.
- A Commercial Fisherwoman was charged by ISU with 11 counts of falsifying roe harvester reports, 5 counts of fraudulently obtaining commercial device tags, 2 counts of fraudulently obtaining resident roe harvester permits, 2 counts of fraudulently obtaining resident commercial fishing licenses, 57 counts of unlawful commercialization of sturgeon roe, and 1 count of fraudulently obtaining a resident sport fishing license. On

December 2014, she pled guilty to 3 counts falsifying records, paid $5000 to the Illinois Conservation Police Operations Assistance Fund and a $300 fine.

Urban Fishing Pond Surveys:

- Thirty-two Bighead Carp have been removed from five Chicago area ponds using electrofishing and trammel/gill nets since 2011.
- Sampled four ponds with electrofishing and trammel/gill nets during 2013.
- Estimated 165 person-hours were spent sampling Chicago area ponds in 2013.
- Sampled 179 fish representing 5 species and 1 hybrid group.
- Six Bighead Carp were removed from Humboldt Park and Flatfoot Lake; a replica of the carp from Flatfoot Lake has been made for outreach and educational events.
- Recommend additional sampling of ponds from which Bighead Carp have been removed, as well as repeat sampling of ponds yielding positive results for Asian carp eDNA.

2014 Monitoring and Response Plan Interim Summary Reports

June 2015

INTRODUCTION

The Asian Carp Regional Coordinating Committee (ACRCC) was established in 2009 to provide coordinated communication and response to accomplish the goal of preventing Asian carp from becoming established in the Great Lakes. 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*) for the purpose of this document. To facilitate the accomplishment of the overarching goal, the ACRCC formed multiple work groups, including the Monitoring and Rapid Response Work Group (MRRWG). In 2013 the MRRWG decided to evolve based on the findings and the recommendation from the agency members of MRRWG. The MRRWG then became the Monitoring and Response Work Group (MRWG) based upon an adaptive management approach. The group decided that eDNA would not be used as a rapid response trigger, and to utilize a planned surveillance approach. Portions of the rapid response framework were used to develop a "Seasonal Intensive Monitoring" and "Barrier Maintenance and Fish Clearing" plan. Although eDNA results are not used as a response trigger within the response matrix, eDNA is still used as a tool within the Monitoring and Response Plan. As with most research projects it requires multiple years to obtain useable results, although most of the projects are continuations from previous plans and most are "modified" based on current findings. Case in point the 2013 Planned Intensive Surveillance plan was redeveloped into the 2014 Seasonal Intensive Monitoring Plan based on prior results and recommendations from the MRWG. Also, to gather critical or missing information within the CAWS additional plans are developed such as the Understanding Surrogate Fish Movement with Barriers plan that investigates the movement of surrogate fish near barriers such as the Electrical Dispersal Barrier and Brandon Road Lock and Dam. The MRWG is co-led by the Illinois Department of Natural Resources (IDNR) and the Great Lakes Fishery Commission (GLFC) and is comprised of liaisons from key state and federal agencies as well as independent technical specialists (see Appendix A for membership). Guided by the ACRCC Framework (ACRCC 2010), the MRWG was assigned the task of developing and implementing a Monitoring and Response Plan (MRP) for Asian carp that were present or could gain access to the Chicago Area Waterway System (CAWS).

The previous version of the MRP was released in April 2014. It included 21 individual project plans with over 70 project objectives detailing tactics and protocols to identify the location and abundance of Asian carp in the CAWS, lower Des Plaines River and upper Illinois River, and initiate appropriate response actions to address such findings (MRRWG 2012). This plan was used to guide and coordinate 2014 action agency efforts to accomplish strategic objectives and achieve the specific goal of preventing Asian carp from establishing populations in the CAWS and Lake Michigan. Projects were classified geographically as occurring either upstream or downstream of the Dispersal Barrier in Romeoville, Illinois and grouped into five categories: Monitoring Projects, Removal Projects, Barrier Effectiveness Evaluations, Gear Effectiveness Evaluations and Development Projects, and Alternative Pathway Surveillance (MRWG 2014).

The workgroup has adopted an adaptive management approach to Asian carp monitoring and removal and considers the MRP to be a working document that is continually open to modification and enhancement. To foster an adaptive management approach, the 2014 plan recommended completion of interim project summary reports for the previous year's monitoring and removal efforts. These reports could include preliminary data summaries or more in-depth data analysis and interpretation, and they would be used to inform modifications and enhancements to projects included in the updated MRP for the coming year.

This document is a compilation of summary reports covering each of the 21 project plans included in the 2014 MRP. It should be viewed as a companion document to 2014 MRP. Reports include summaries of activities completed during the 2014 or, for most projects, data collected beginning in 2010 and through 2014 field seasons. Also included are highlights of past activities and recommended updates to monitoring and removal actions that will be considered for the 2015 MRP. Most are interim reports with data summaries, analyses, and interpretations that are preliminary in nature but still offer a scientific basis for 2014 project updates and field activities. Results and conclusions may change as more data is collected and analyses are refined over time.

Seasonal Intensive Monitoring in the CAWS

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

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

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

Objectives:

1) Remove Asian carp from the CAWS upstream of the electric dispersal barrier when warranted; and
2) Determine Asian carp population abundance through intense targeted sampling efforts at locations deemed likely to hold fish.

Methods:

Pulsed DC-electrofishing, trammel and gill nets, deep water gill 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 m (10 ft) deep x 91.4 m (300 ft) long in bar mesh sizes ranging from 88.9-108 mm (3.5-4.25 in). Deep water gill nets were 9.1 m (30 ft) deep x 91.4 m (300 ft) long with bar mesh sizes ranging from 69.9-88.9 mm (2.75-3.5 in). The commercial seine was 9.1 m (30 ft) deep x 731.5 m (2400 ft) long and had a cod end made of 50.8 mm

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

(2.0 in) bar mesh netting. The goal was to complete a minimum of 150 electrofishing runs and 150 net sets (trammel/gill nets, deep water gill nets) during each two week event.

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

Netting Protocol – Contracted commercial fishers were used for net sampling at fixed and random sites. Sets were of short duration and include driving fish into the nets with noise (e.g., plungers on the water surface, pounding on boat hulls, or revving tipped up motors). In Lake Calumet, a 731.5 m (2400 ft) commercial seine was also used. Nets were attended at all times.

Locations for each net set were located and identified with GPS coordinates. Captured fish were identified to species, enumerated and released.

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

Results and Discussion: SIM took place during the weeks of June 9th, June 16th, September 15th and September 22nd 2014 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).

In order to focus additional monitoring effort on the leading edge of the Asian carp population below the electric dispersal barrier, sampling effort in the CAWS upstream of the barrier was reduced in 2014 (Figure 2). Effort in 2013 was 149.3 hours of electrofishing (588 transects), 168 km (104.9 mi) of trammel/gill netting (959 sets) and 2.2 km (1.4 mi) of commercial seine hauls (Table 1). In 2014, an estimated 2,205 person-hours were utilized to complete 87.1 hours of electrofishing (348 transects), set 77.7 km (48.3 mi) of trammel/gill net (440 sets) and 1.4 km (0.9 mi) of commercial seine. Across all locations and gears, 27,678 fish representing 57 species and 2 hybrid groups were sampled in 2014 (Table 3). Gizzard Shad, Common Carp, Largemouth Bass, Bluntnose Minnow and Pumpkinseed were the predominant species, comprising 78% of all fish sampled. Eleven non-native species were also sampled, which included Common Carp and hybrids, Round Goby, Alewife, Goldfish, White Perch, Oriental Weatherfish, Grass Carp, Threadfin Shad, Chinook Salmon, Tilapia and Rainbow Trout. Non-native species made up 19% of the total species collected and 17% of the total fish in 2014. One hundred seventy-one (171) Banded Killifish, a state threatened species, were also collected. They were identified and returned to the water alive. Also of note, was the capture of one Spotted Gar in the North Branch of the Chicago River. It is the first-ever recorded in the CAWS, and the western-most occurrence associated with Lake Michigan. No Bighead Carp or Silver Carp were captured or observed during SIM in 2014. In addition, we examined 9,837 YOY Gizzard Shad and found no YOY Asian carp.

Since 2010, an estimated 19,388 person-hours were expended monitoring fixed and random sites in the CAWS upstream of the electric dispersal barrier. Total effort was 769.4 hours

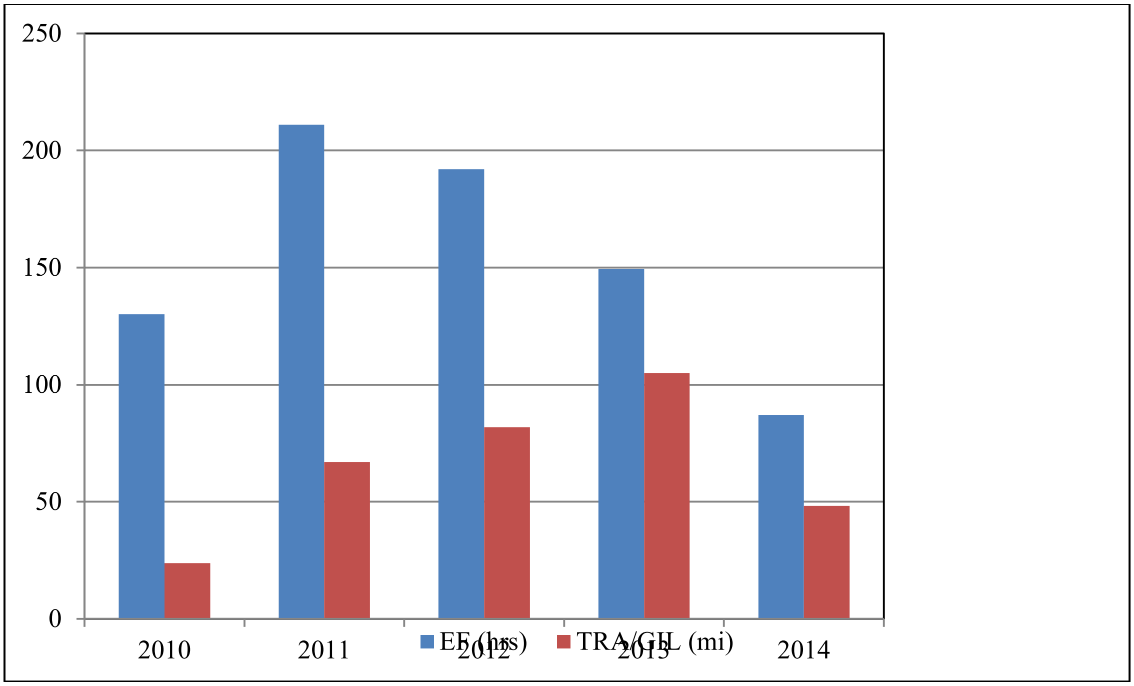

Figure 2. Total electrofishing and trammel/gill netting effort at fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier, 2010-2014.

of electrofishing (3,064 transects), 524 km (325.6 mi) of gill/trammel net (2,695 sets), 3.7 km (2.3 mi) of commercial seine hauls and 25.2 net-days of hoop and trap nets (11sets) from 2010-2014 (Table 1). The use of hoop nets and trap nets was suspended after 2013 due to low gear efficiency. A total of 278,991 fish representing 72 species and 6 hybrid groups have been sampled since 2010 (Table 4). Gizzard Shad, Common Carp, Bluegill, Largemouth Bass, Bluntnose Minnow, Pumpkinseed were the predominant species sampled, accounting for 82% of all fish collected. Since 2010, 17 non-native species have been caught, which include Common Carp and hybrids, Alewife, Goldfish, White Perch, Round Goby, Oriental Weatherfish, Chinook Salmon, Threadfin Shad, Rainbow Trout, Grass Carp, Brown Trout, Coho Salmon, Tilapia, Rainbow Smelt, Silver Arrowana and Threespine Stickleback. Non-native species constitute14% of the total fish caught and 22% of the total species. Banded Killifish, a state threatened species, have been routinely collected during our monitoring efforts in the CAWS. To date, 1,106 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 2011-2014. One Bighead Carp was caught in a trammel net in Lake Calumet in 2010. Furthermore, 87,779 YOY Gizzard Shad have been examined since 2014 with no YOY Asian carp being identified.

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

Project Highlights:

- Completed 2-two week SIM events with conventional gears in the CAWS upstream of the electric dispersal barrier in 2014
- Estimated 2,205 person-hours were spent to complete 87.1 hours of electrofishing, set 77.7 km (48.3 mi) of trammel/gill net and 2.2 km (1.4 mi) of commercial seine in 2014
- Across all locations and gears in 2014, sampled 27,678 fish representing 57 species and 2 hybrid groups
- Captured one Spotted Gar in the North Branch of the Chicago River in 2014. It is the first-ever recorded in the CAWS, and the western-most occurrence associated with Lake Michigan
- Since 2010, an estimated 19,388 person-hours were spent to complete 769.4 hours of electrofishing, set 524 km (325.6 mi) of gill/trammel net and 3.7 km (2.3 mi) of commercial seine
- A total of 278,991 fish representing 72 species and 6 hybrid groups were sampled, including 1,106 Banded Killifish (state threatened species) from 2010-2014
- Examined 87,779 YOY Gizzard Shad since 2010 and found no Asian carp
- Since 2010, 17 non-native species have been captured accounting for14% of the total fish caught and 22% of the total species
- No Bighead Carp or Silver Carp have been captured or observed since 2010 (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

Table 1. Summary of effort and catch data for all fixed and random site monitoring in the CAWS upstream of the Electric Dispersal Barrier, 2010-2014.

	2010	2011	2012	2013	2014	Total
Electrofishing Effort						
Estimated person-hours	1,280	2,180	4,330	1,528	945	10,263
Samples (transects)	519	844	765	588	348	3,064
Electrofishing hours	130.0	211.0	192.0	149.3	87.1	769.4
Electrofishing Catch						
All fish (*N*)	33,688	52,385	97,510	45,443	24,492	253,518
Species (*N*)	51	58	59	56	56	69
Hybrids (*N*)	3	3	3	2	2	6
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	259.1	248.3	507.9	304.4	281.2	329.5
Netting Effort						
Estimated person-hours	885	1,725	3,188	1,932	1,125	8,855
Samples (net sets)	208	389	699	959	440	2,695
Miles of net	23.8	67.0	81.7	104.9	48.2	325.6
Netting Catch						
All fish (*N*)	2,439	4,923	3,060	4,195	1,461	16,078
Species (*N*)	17	20	20	30	18	32
Hybrids (*N*)	1	1	1	1	1	1
Bighead Carp (*N*)	1	0	0	0	0	1
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/100 yds of net)	5.8	4.2	2.1	2.3	1.7	2.8
Seine Effort						
Estimated person-hours	-	-	-	135	135	270
Samples (seine hauls)	-	-	-	3	2	5
Miles of seine	-	-	-	1.4	0.9	2.3
Seine Catch						
All fish (*N*)	-	-	-	7,577	1,725	9,302
Species (*N*)	-	-	-	15	11	16
Hybrids (*N*)	-	-	-	1	0	1
Bighead Carp (*N*)	-	-	-	0	0	0
Silver Carp (*N*)	-	-	-	0	0	0
CPUE (fish/seine haul)	-	-	-	2,525.7	862.5	1,860.4
Hoop/Trap Net Effort						
Estimated person-hours	-	-	-	-	-	-
Samples (sets)	-	-	-	11	-	11
Net-days	-	-	-	25.2	-	25.2
Hoop/Trap Net Catch						
All fish (*N*)	-	-	-	93	-	93
Species (*N*)	-	-	-	17	-	17
Hybrids (*N*)	-	-	-	0	-	0
Bighead Carp (*N*)	-	-	-	0	-	0
Silver Carp (*N*)	-	-	-	0	-	0
CPUE (fish/net-day)	-	-	-	3.7	-	3.7

Table 2. Summary of effort and catch data for Seasonal Intensive Monitoring in the CAWS upstream of the Electric Dispersal Barrier, 2014.

	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	443	81	182	22	217	945
Samples (transects)	163	30	67	8	80	348
Electrofishing hours	40.8	7.5	16.8	2.0	20.0	87.1
Electrofishing Catch						
All fish (*N*)	8,673	4,648	3,194	322	7,655	24,492
Species (*N*)	44	36	29	11	38	56
Hybrids (*N*)	1	0	0	0	1	2
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/hr)	212.6	619.7	190.1	161.0	382.8	281.2
Netting Effort						
Estimated person-hours	345	230	254	35	261	1,125
Samples (net sets)	130	87	98	17	108	440
Miles of net	14.8	9.9	10.9	1.5	11.2	48.3
Netting Catch						
All fish (*N*)	413	129	272	123	524	1,461
Species (*N*)	13	6	3	3	9	18
Hybrids (*N*)	0	1	1	0	1	1
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	0	0	0	0	0	0
CPUE (fish/100 yds of net)	1.6	0.7	1.4	4.7	2.7	1.7
Seine Effort						
Estimated person-hours	135	-	-	-	-	135
Samples (seine hauls)	2	-	-	-	-	2
Miles of seine	0.9	-	-	-	-	0.9
Seine Catch						
All fish (*N*)	1725	-	-	-	-	1,725
Species (*N*)	11	-	-	-	-	11
Hybrids (*N*)	0	-	-	-	-	0
Bighead Carp (*N*)	0	-	-	-	-	0
Silver Carp (*N*)	0	-	-	-	-	0
CPUE (fish/seine haul)	862.5	-	-	-	-	862.5

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, 2014. 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	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	2,769			3,427		1,354		180		2,107		9,837
Common Carp I	1,047	196	3	300	109	649	269	64	121	1,124	497	4,379
Gizzard Shad > 6 in	363	10	1,374	4	1	214		18	1	754	1	2,740
Largemouth Bass	630		1	162		138		34		1,456	1	2,422
Bluntnose Minnow	541			118		126				368		1,153
Pumpkinseed	340			73		310		2		222		947
Smallmouth Bass	786	1	1	2		1				1		792
White Sucker	21			18		8				648	3	698
Freshwater Drum	102	97	305	18	8	3		2		1	3	539
Bluegill	87			66		142		2		225		522
Golden Shiner	89			87		80				236		492
Rock Bass	404							4		2		410
Yellow Perch	364			31								395
Spotfin Shiner	183			111						38		332
Emerald Shiner	101			25		19				46		191
Round Goby I	154			1		1		3		14		173
Banded Killifish ST	138			20		4				9		171
Channel Catfish	54	17	20	11	1	8	1			48	4	164
Green Sunfish	30			26		17		1		89		163
Alewife I	64					1		11		48		124
Smallmouth Buffalo	80	26	10		1				1	3		121
Brook Silverside	64			46								110
Spottail Shiner	22			17		18				38		95
Yellow Bullhead	18			5		45				26	1	95
Goldfish I	12			20		10	1			32	4	79
Black Bullhead	54	1		1		7				15		78
White Bass	29		6	8		4				14	1	62
Black Buffalo	1	43	2		5							51
Black Crappie	8		2	6		1		1		29		47
White Perch I	13			4		7				9		33
Quillback	24	7										31

Table 3. Continued.

Species	Lake Calumet/Calumet River Electro-fishing	Lake Calumet/Calumet River Trammel/ Gill Net	Lake Calumet/Calumet River Commercial Seine	Little Calumet River/Cal Sag Electro-fishing	Little Calumet River/Cal Sag Trammel/ Gill Net	S. Branch Chi River/CSSC Electro-fishing	S. Branch Chi River/CSSC Trammel/ Gill Net	Chicago River Electro-fishing	Chicago River Trammel/ Gill Net	N. Branch Chi River/N. Shore Electro-fishing	N. Branch Chi River/N. Shore Trammel/ Gill Net	All Sites
Bullhead Minnow	23									2		25
Fathead Minnow	15			8						2		25
Blackstripe Topminnow				5		3				9		17
Bigmouth Buffalo	8	7										15
Brown Bullhead	3					3				9		15
Carp x Goldfish hybrid I					4		1			1	9	15
Orangespotted Sunfish	13			2								15
Oriental Weatherfish I						5				8		13
Western Mosquitofish						11						11
Central Mudminnow				10								10
Bowfin	1			1		1				4		7
Flathead Catfish	3	4										7
Hybrid Sunfish	1					2				4		7
Sand Shiner										6		6
White Crappie	2			2						2		6
Grass Carp I	1	2		2								5
Age-0 fish	5											5
Common Shiner				4								4
Threadfin Shad I	1			3								4
Chinook Salmon I	1	2										3
Silver Redhorse				3								3
Tilapia I										3		3
Northern Pike						2						2
Rainbow Trout I	1									1		2
Creek Chub	1											1
Central Stoneroller				1								1
Green Sunfish hybrid	1											1
River Carpsucker			1									1
Spotted Gar										1		1
Walleye	1											1
Yellow Bass										1		1
Total fish	8,673	413	1,725	4,648	129	3,194	272	322	123	7,655	524	27,678
Species (*N*)	44	13	11	36	6	29	3	11	3	38	9	57
Hybrids (*N*)	1	-	-	-	1	-	1	-	-	1	1	2

Table 4. Total number of fish captured with electrofishing, trammel/gill nets, hoop nets, trap nets and commercial seine in the CAWS upstream of the Electric Dispersal Barrier, 2010-2014. I = introduced species, ST = state threatened species.

	2010		2011		2012		2013					2014			
Species	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Commercial Seine	Hoop Net	Trap Net	Electro-fishing	Trammel/ Gill Net	Commercial Seine	All Years
Gizzard Shad <6 in	11,834		13,897		36,315		15,896					9,837			87,779
Gizzard Shad	5,271	6	7,812	166	19,256	16	10,863	411	5,475	7		1,353	13	1,374	52,023
Common Carp I	5,202	1,859	5,406	2,550	5,279	2,420	3,468	2,748	479	1	7	3,184	1,192	3	33,798
Bluegill	1,104	1	4,703		6,965	1	4,012	0				522			17,308
Largemouth Bass	2,888	2	3,298	6	3,776	2	1,628	1	6		4	2,420	1	1	14,033
Bluntnose Minnow	1,165		3,556		5,954		2,005	0				1,153			13,833
Pumpkinseed	807		3,458		4,087		1,544	1			8	947			10,852
Golden Shiner	739		1,474		2,708		639					492			6,052
Spotfin Shiner	628		1,565		1,548		1,317					332			5,390
Emerald Shiner	873		831		2,021		413					191			4,329
Freshwater Drum	144	85	120	1,141	179	389	81	728	812	21	8	126	108	305	4,247
Brook Silverside	396		959		1,845		311					110			3,621
White Sucker	514		993		707	1	363	1			1	695	3		3,278
Green Sunfish	147		784		1,243		264					163			2,601
Mosquitofish	3		168		1,614		92					11			1,888
Smallmouth Bass	89	14	145	3	363	2	122	7	3		1	790	1	1	1,541
Yellow Perch	340		292		303		179	0				395			1,509
Channel Catfish	75	47	80	106	102	19	130	51	715	2		121	23	20	1,491
Alewife I	71	2	674		221		348					124			1,440
Banded Killifish ST	3		58		409		465					171			1,106
Goldfish I	285	2	259	27	230	19	83	25	2			74	5		1,011
Black Buffalo	3	248	33	464	51	28	7	98	3	3		1	48	2	989
Rock Bass	42		74		154		195					410			875
Yellow Bullhead	87		229		312		136	3	1		3	94	1		866
White Perch I	234		204	1	166		137	1	7		9	33			792
Smallmouth Buffalo	35	110	28	154	26	72	64	14	6	4		83	28	10	634
Round Goby I	32		57		183		168					173			613
Spottail Shiner	72		150		188		38	0				95			543
Black Bullhead	45		75		114	1	88	1			3	77	1		405
Blackstripe Topminnow	8		144		178		44					17			391
Quillback	35	8	32	181	28	24	13	24				24	7		376
White Bass	77		69	1	50	1	63	2	6		5	55	1	6	336

Table 4. Continued.

Species	2010 Electro-fishing	2010 Trammel/ Gill Net	2011 Electro-fishing	2011 Trammel/ Gill Net	2012 Electro-fishing	2012 Trammel/ Gill Net	2013 Electro-fishing	2013 Trammel/ Gill Net	2013 Commercial Seine	2013 Hoop Net	2013 Trap Net	2014 Electro-fishing	2014 Trammel/ Gill Net	2014 Commercial Seine	All Years
Black Crappie	54		80		40		57	1	3			45		2	282
Fathead Minnow	121		82		30		20					25			278
Orangespotted Sunfish	19		92		112		14					15			252
Oriental Weatherfish I	12		70		89		33					13			217
Sunfish hybrid			80		113		13					7			213
Carp x Goldfish hybrid I	7	34	8	63	11	39	11	13				1	14		201
Bigmouth Buffalo	7	11	4	32	26	12	8	13	56			8	7		184
Bullhead Minnow			89		51							25			165
Yellow Bass	85		40		25		10					1			161
Brown Bullhead	2		33		79		3	1			4	15			137
Chinook Salmon I	23		25	1	38	3	13	28				1	2		134
White Crappie	23		31		20		27		2		1	6			110
Creek Chub	3		23		68		14					1			109
Threadfin Shad I	13				89							4			106
River Carpsuker			3	5	33	4	8							1	54
Central Mudminnow	20		14		9							10			53
Rainbow Trout I	1		15	1	17	1	2					2			39
Flathead Catfish		5	2	10	1	4	1	4		1		3	4		35
Age-0 fish					26							5			31
Bluegill x Green Sunfish hybrid	30														30
Grass Carp I		3	3	9	5	2		1				3	2		28
Walleye	3	1	7		3		2	3				1			20
Warmouth			5		9		6								20
Brown Trout I	1		5	1	1		3	8							19
Bowfin	2		3		4		2					7			18
Northern Pike	2		6		1		7					2			18
Sand Shiner	2		7		3							6			18
Unidentified Salmonid			12		4										16
Coho Salmon I	4		1		3		3								11
Grass Pickerel			7		3			0							10
White Perch x Yellow Bass hybrid					8				1						9
Ghost Shiner	4		3												7

Table 4. Continued.

	2010		2011		2012		2013					2014			
Species	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Electro-fishing	Trammel/ Gill Net	Commercial Seine	Hoop Net	Trap Net	Electro-fishing	Trammel/ Gill Net	Commercial Seine	All Years
Green Sunfish x Bluegill hybrid					4		2								6
Spotted Sucker			2		4										6
Common Shiner					1							4			5
Unidentified Buffalo								5							5
Tilapia I							1					3			4
Lake Trout				1				2							3
Silver Redhorse												3			3
Unidentified Minnow			3												3
Unidentified Sunfish					3										3
Burbot							2								2
Green Sunfish x Pumpkinseed hybrid			1									1			2
Largescale Stoneroller							2								2
Pumpkinseed x Bluegill hybrid	1		1												2
Rainbow Smelt I			1				1								2
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	33,688	2,439	52,385	4,923	97,510	3,060	45,443	4,195	7,577	39	54	24,492	1,461	1,725	278,991
Species (*N*)	51	17	58	20	59	20	56	30	15	7	12	56	18	11	72
Hybrids (*N*)	3	1	3	1	3	1	2	1	1	0	0	2	1	0	6

Strategy for eDNA Monitoring in the CAWS

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Participating Agencies: US Fish and Wildlife Service (Carterville, Columbia, and La Crosse Fish and Wildlife Conservation Offices, Whitney Genetics Lab) (lead), and Illinois Department of Natural Resources (field support).

Project Highlights

- Two eDNA comprehensive sampling events took place in the CAWS at four regular monitoring sites in 2014, resulting in 456 samples collected and analyzed.
- June event: seven positive detections for Silver Carp DNA, one positive detection for Bighead Carp DNA
- October event: 23 positive detections for Silver Carp DNA, zero positive detections for Bighead Carp DNA
- Comparative analysis of cPCR methods used prior to 2014 with qPCR methods employed in 2014

Introduction and Objectives:

As outlined in the 2014 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 Chicago Area Waterway System (CAWS). The prescribed objectives of eDNA sampling were to:

1) Monitoring Asian carp DNA in strategic locations in the CAWS could be used to inform status of Asian carp;
2) Detect Asian carp DNA in areas that have been monitored since 2009 to maintain annual data collection which may inform future work in the CAWS.

Methods:

The CAWS was sampled for eDNA of Bighead and Silver Carp three occasions in 2014 (June, September, and October sampling events). Sampling is scheduled to immediately precede Seasonal Intensive Monitoring in the CAWS. Heavy rains during the September event prevented sample collection from the South Branch of the Chicago River. Therefore, samples collected in September were archived and sample collection was rescheduled for October. Similar to previous years, sample collection and processing followed the Quality Assurance Project Plan (http://www.fws.gov/midwest/fisheries/eDNA/QAPP-eDNA-2014.pdf). New in 2014, an improved marker was used for each species. For both the June and October events, FWS crews collected 240 samples (including 12 cooler 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. All samples were filtered in a mobile filtering trailer stationed at T.J. O Brien Lock and Dam. Samples were preserved on dry ice until they were delivered overnight to the FWS Whitney Genetics Lab (WGL) for analysis. The state of Illinois was notified of results following our Communication Protocol (http://www.fws.gov/midwest/fisheries/eDNA/QAPP-eDNA-2014.pdf) after sample processing was complete. Results were then posted online.

Results and Discussion:

A total of 456 samples along with 24 control samples were collected upstream of the dispersal barrier, filtered in the mobile lab, and analyzed at WGL (Table 1). The June event had seven positive detections for Silver Carp and one positive detection for Bighead Carp (Figure 1). The October event had 23 positive detections for Silver Carp and zero positive detections for Bighead Carp (Figure 2). All eDNA results are available at: http://www.fws.gov/midwest/fisheries/eDNA/Results-chicago-area.html.
In 2014, FWS began using new markers for Bighead Carp and Silver Carp designed to reduce false negative results by being less sensitive to inhibition (qPCR). Samples were also analyzed via the technique used from 2009-2013 (cPCR) to compare against the historical dataset and the new technique. The results from this analysis are included in Table 1. Across the year, there were 17 cPCR detections and 30 qPCR detections for Silver Carp from 456 samples. For Bighead Carp, there were zero cPCR detections out of 228 samples and one qPCR detection from 456 samples. Samples were not analyzed via cPCR for Bighead Carp during the October event because there were no qPCR detections.

Recommendations:

In order to maintain vigilance within the CAWS, it is recommended to continue to monitor the four sites outlined above, but with only one sampling event per year. The remainder of the effort would be reallocated to sites below the Dispersal Barrier over multiple sampling events. The objectives of the sampling would be to: 1) identify baseline data over a gradient of population densities along the invasion front, and 2) identify spikes that may be correlated with spawning movements and/or population advances.

Table 1. Summary table for all samples collected during two eDNA monitoring events in the CAWS at four sites above the electric barrier.

Location	Samples Collected	June Event				October Event			
		Silver Carp		Bighead Carp		Silver Carp		Bighead Carp	
		Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
North Shore Channel	57 (60*)	56	1	56	1	51	6	57	0
Chicago River	57 (60*)	55	2	57	0	52	5	57	0
Lake Calumet	57 (60*)	53	4	57	0	49	8	57	0
Little Calumet River	57 (60*)	57	0	57	0	53	4	57	0
Total	228 (240*)	221	7	227	1	205	23	228	0

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

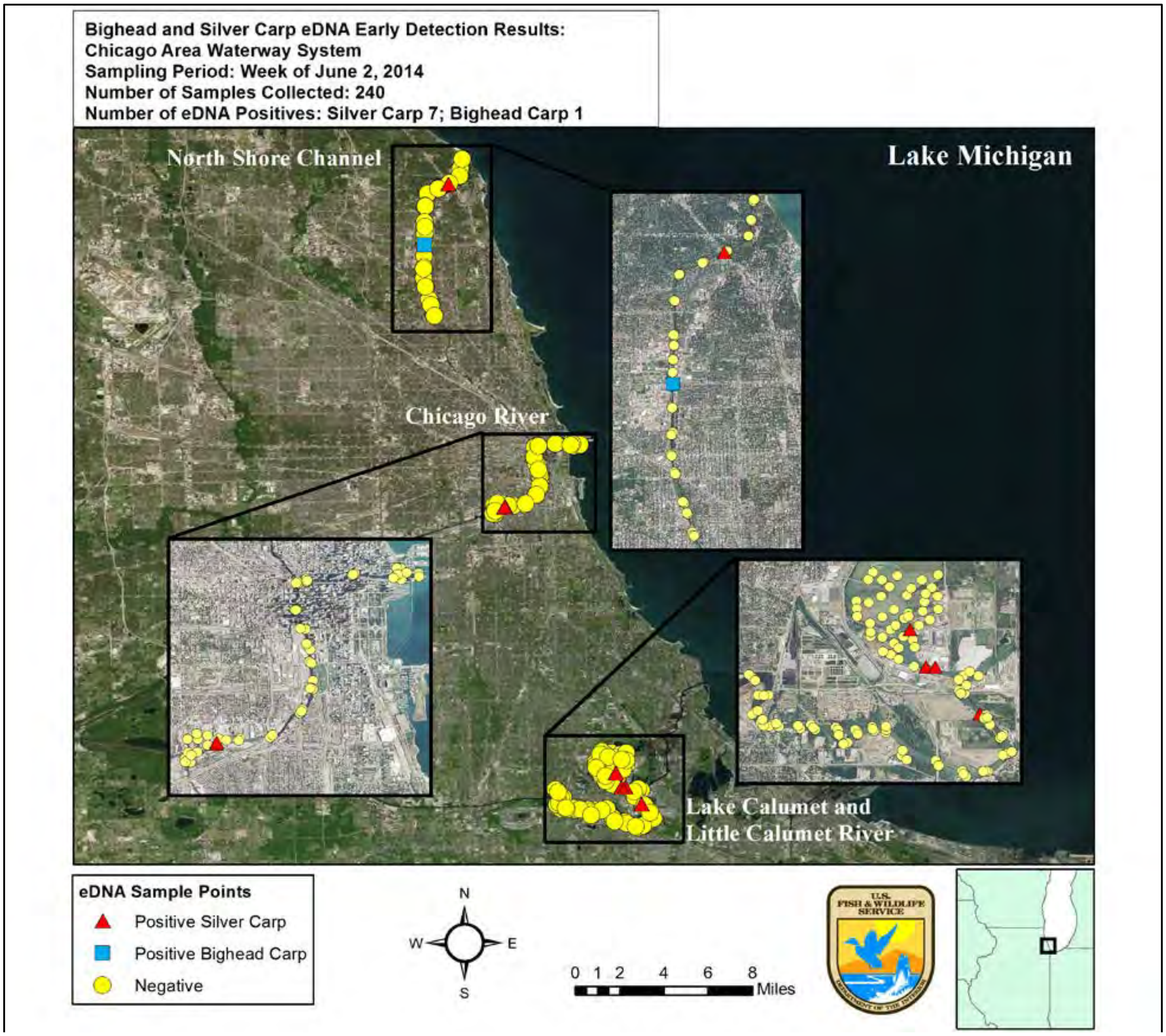

Figure 1. Geo-referenced sampling locations within each of four reaches of the CAWS during June 2014.

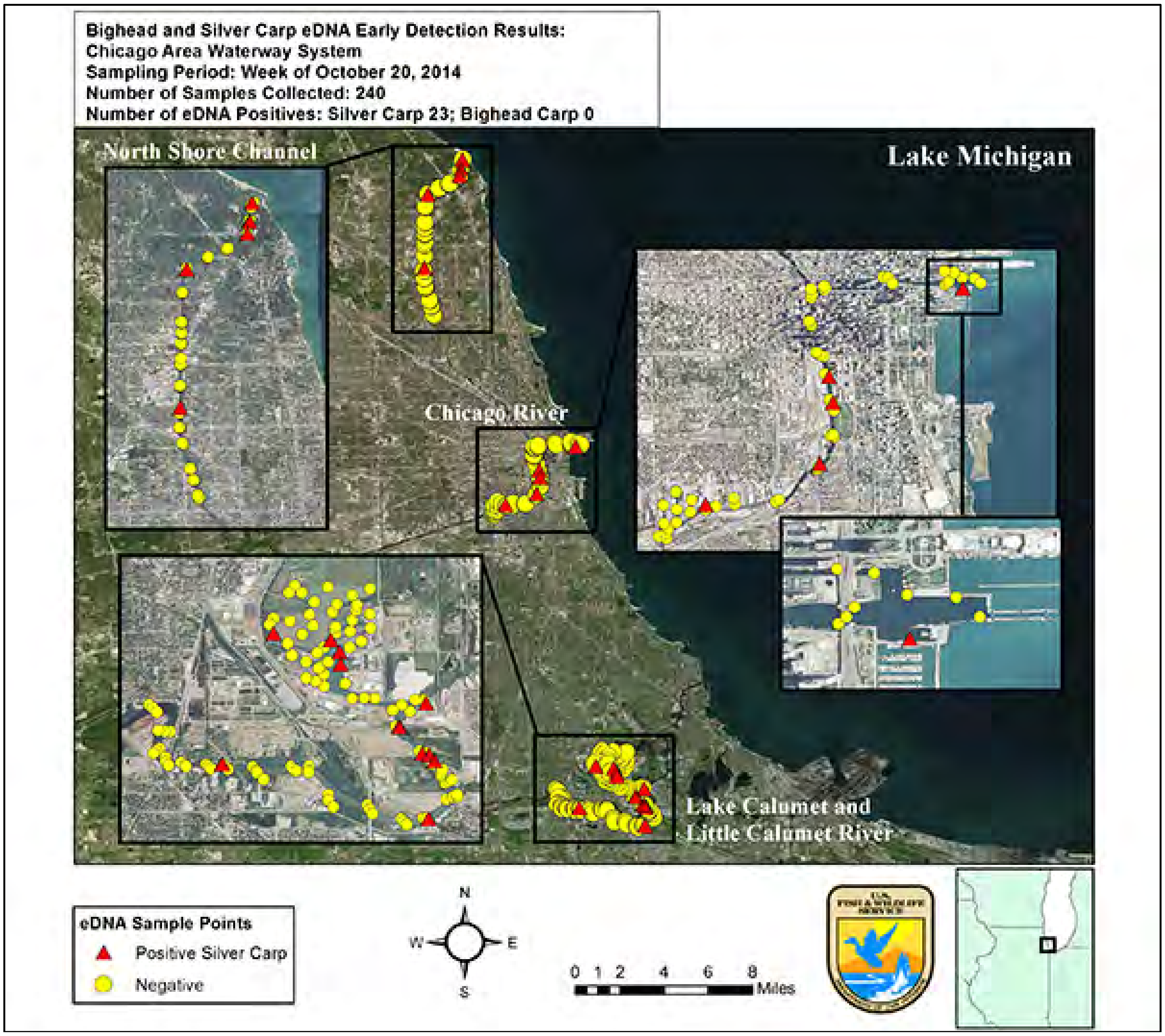

Figure 2. Geo-referenced sampling locations within each of four reaches of the CAWS during October 2014. Only Silver Carp eDNA results are represented because all samples were negative for Bighead Carp.

Larval Fish Monitoring in the Illinois Waterway

Steven E. Butler, Matthew J. Diana, Scott F. Collins, David H. Wahl (Illinois Natural History Survey), Robert E. Colombo, Clint W. Morgeson (Eastern Illinois University)

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

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 recruitment 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.

Methods: Larval fish and productivity sampling is occurring at 11 sites throughout the Illinois Waterway (Figure 1). Additional sampling is taking place in four tributary rivers (Spoon, Sangamon, Salt Fork of the Sangamon, and Mackinaw Rivers) at downstream sites near the confluence of each tributary with the Illinois River. 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. 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. Samples are collected using a 0.5 m-diameter ichthyoplankton push net with 500um 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. The presence of any eggs is being noted and all eggs are being retained for future analyses. Larval fish are being identified to the lowest possible taxonomic unit in the laboratory. Larval fish densities are being calculated as the number of individuals per m^3 of water sampled.

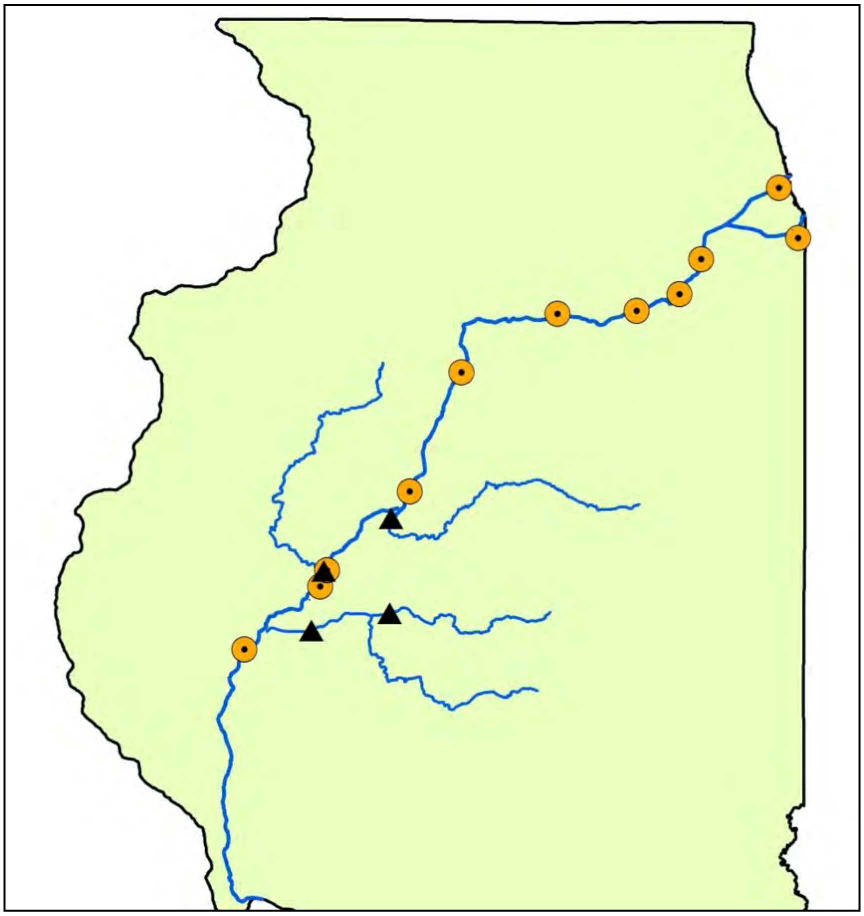

Figure 1. Map of larval fish sampling sites in the Illinois Waterway and four tributary rivers. Sites on the main channel and backwaters of the Illinois Waterway are represented by circles. Tributary sites are represented by triangles.

Results and Discussion: In 2014, a total of 558 larval fish samples were collected from main channel and backwater sites of the Illinois Waterway. From these, over 18,000 larval fish have been identified, including over 5,000 larval and early post-larval Asian carp. Clupeids dominated the ichthyoplankton drift at most sites, although Cyprinids (excluding Asian carp), Sciaenids, Catostomids, and Centrarchids were also abundant in larval fish samples. Large numbers of Asian carp larvae were observed in the LaGrange (n = 2,573) and Peoria (n = 2,658) Pools, but none were observed upstream of the Peoria Pool. The numbers of Asian carp larvae observed in 2014 were substantially higher than in previous years of ichthyoplankton sampling (Table 1), suggesting that Asian carp reproductive output was much higher in 2014 than in 2010 – 2013. Asian carp appear to have had multiple spawning events in 2014, as indicated by the timing of larval occurrences (Figure 2). The first observations of significant numbers of Asian carp larvae occurred at multiple sites in the LaGrange Pool on June 18. None were collected at these same sites during the week of June 23. However, at that time, extremely large numbers of

Table 1. Dates, effort, and number of larval fish captured during ichthyoplankton sampling activities on the Illinois Waterway during 2010 – 2014.

Year	Sampling Dates	# Samples	# Larval Fish	# Asian Carp Larvae

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

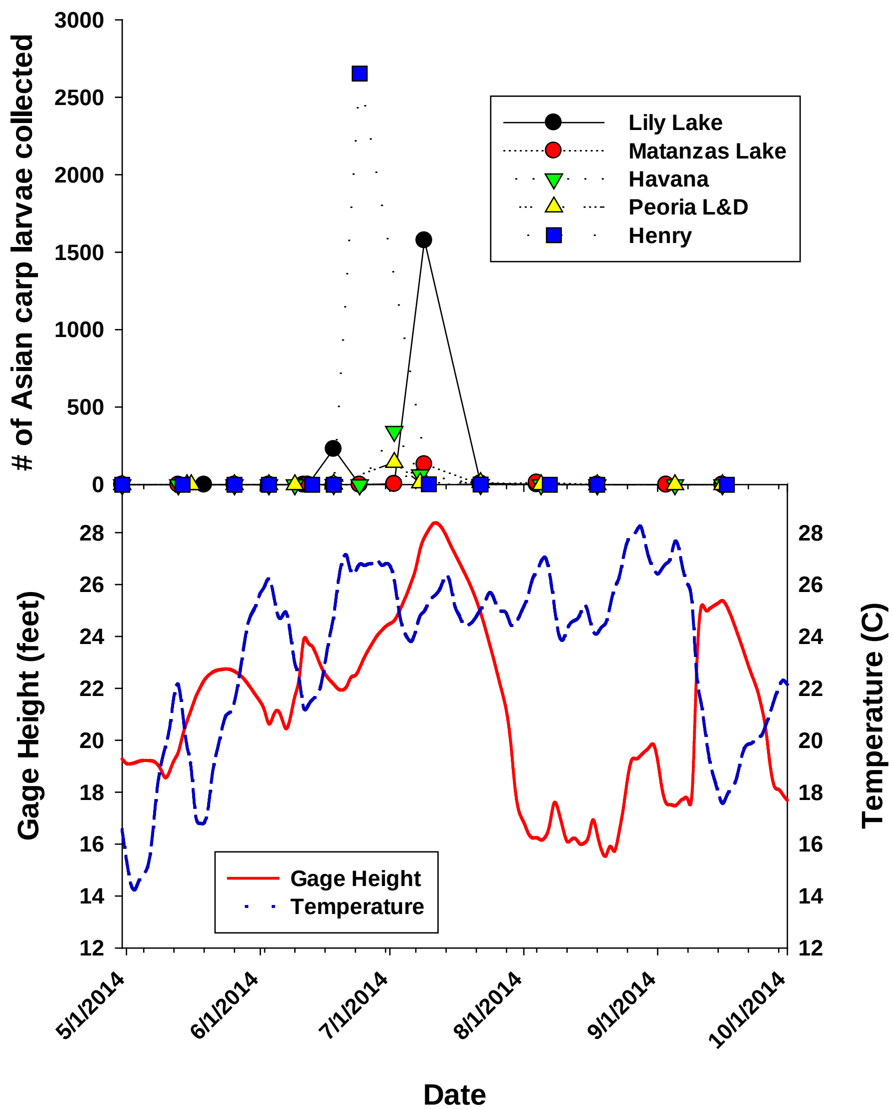

Figure 2. Numbers of Asian carp captured from sites in the LaGrange (Lily Lake, Matanzas Lake, Havana, Peoria L&D) and Peoria Pools (Henry) during 2014 (top panel), and mean daily gage height and water temperature of the Illinois River during this time (bottom panel). Gage height and temperature data were obtained from USGS hydrograph 5586300 at Florence, IL.

Asian carp larvae appeared in the Peoria Pool. During the following week (June 30 – July 4), large numbers of Asian carp larvae were again collected from main channel sites in the LaGrange Pool, and then large numbers of Asian carp larvae appeared in LaGrange Pool backwater sites during the week of July 7. These occurrences of Asian carp larvae coincided with three distinct rises in the hydrograph that occurred between mid-June and mid-July, as well as water temperatures continuously above 20°C (Figure 2). The continued presence of small numbers of Asian carp larvae from mid-July to early August in both the LaGrange and Peoria Pools suggests that additional, although less prolific spawning activity continued to occur during the summer in 2014. Few larval fish of any taxa were collected after August. In addition to the large numbers of Asian carp larvae collected in 2014, over 19,000 potential Asian carp eggs have been tentatively identified. Subsamples of potential Asian carp eggs have been sent to the USFWS Whitney Genetics Lab for genetic confirmation and results of egg collections will be reported once questions regarding egg identification have been clarified. Sampling in tributaries collected a total of 185 larval fish samples in 2014, collecting over 4,700 larval fish and over 1,800 eggs. Processing and identification of these samples is ongoing and results will be reported once available. Collectively, these data indicate that Asian carp had a successful spawning year in 2014, producing large numbers of larvae that then recruited to the juvenile life stages (see Young-of-Year and Juvenile Asian Carp Monitoring summary). Determining what conditions were associated with this high reproductive output in 2014 that were absent in previous years of low spawning success is important to understanding factors that contribute to Asian carp recruitment in the Illinois Waterway. Even though reproduction was considerably higher in 2014, larval and juvenile Asian carp were still only observed downstream of the Starved Rock Lock and Dam. As no Asian carp larvae or juveniles have been observed upstream of this point in over five years of sampling, it seems likely that Asian carp populations in the upper Illinois Waterway are composed largely of immigrants from downstream rather than from local sources. However, Asian carp spawning activity has been observed in the Marseilles Pool, and eggs and larvae may have drifted considerable distances before being sampled. Additional investigation to determine where Asian carp spawning is occurring is therefore warranted.

Recommendations: Larval fish 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 recruitment to juvenile stages that was observed in 2014 contrasts with the pattern of little to no reproductive output observed in previous years. The data collected in 2014 will therefore be important to eventually understanding factors that contribute to Asian carp reproduction and recruitment, but is not sufficient by itself to make strong inferences regarding these relationships. Additional sampling during other high recruitment years will be required to adequately understand factors that contribute to Asian carp reproduction and recruitment, and to sufficiently characterize the potential for these species to reproduce in upstream reaches. Continued larval fish sampling in tributary rivers (Sangamon, Salt Fork of the 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. Analysis of egg and larval fish drift is warranted to determine the origin of Asian carp eggs and larvae that have been sampled from the LaGrange and Peoria Pools.

Project Highlights:

- Over 500 larval fish samples were collected from 11 sites across the length of the Illinois Waterway during April – September, 2014, capturing over 18,000 larval fish, including 5,231 larval Asian carp.

- Larval Asian carp were only collected in the LaGrange and Peoria Pools in 2014. No Asian carp larvae were observed from the upper Illinois Waterway.
- Multiple peaks in larval Asian carp abundance were observed during June and July 2014, coinciding with a period of rising water levels and water temperatures consistently above 20°C. Low numbers of Asian carp larvae continued to be collected into August, indicating that spawning continued to occur during this time, although at much lower levels.
- Over 180 larval fish samples were collected from four Illinois River tributaries (Spoon, Sangamon, Salt Fork of the Sangamon, and Mackinaw Rivers) from April – October, 2014, capturing over 4,700 larval fish. Processing and identification of these samples is ongoing and results will be reported once available.

Young-of-year and Juvenile Asian Carp Monitoring

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

Introduction: Bighead Carp 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 periods of 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. The transport of larvae to the CSSC can occur despite the installation of concrete barrier and fencing between the waterways because larval fish are small enough to pass through the 6.4 mm (0.25 in) 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. An additional threat may occur if juvenile Asian carp from spawning events in downstream pools migrate to the Lockport pool via navigation locks. Even though there has been no evidence of successful Asian carp reproduction in the CAWS, Des Plaines River, or upper Illinois River, targeting young-of-year and juvenile Asian carp in monitoring efforts is needed because these life stages may not be detected in conventional sampling geared toward adults.

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

Methods: As in the past, 2014 sampling for young-of-year and juvenile Asian carp took place through other projects of the MRP. 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 2014 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 were discontinued in 2014, with monitoring for all fish (adults and juveniles) being conducted over two SIM sampling events that took place in June and September. This intensive event was a coordinated and intensive one that used efforts from multiple agencies (IDNR, INHS, USFWS, USACE), all data is presented here. A total of 88 Eight hours of electrofishing was completed over the two SIM events in 2014. In past segments, fixed site monitoring occurred monthly from March-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 1-3).

Electrofishing and fyke netting at fixed sites downstream of the electric dispersal barrier occurred monthly from March-November in 2014 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. Finally, two barrier maintenance fish suppression runs were conducted in the Lockport pool in 2014. Electrofishing for these events totaled 0.5 hours of sampling in the electric dispersal barrier.

Standard electrofishing protocols were modified such that schools of small fish <152 mm (6 in) 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 in) 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 and small mesh purse seines. DC electrofishing was conducted every other week following the detection of larval Asian carp in ichthyoplankton pushes. Sites were sampled with all gears in the LaGrange Pool (n = 4), Peoria Pool (n = 1) and the Marseilles Pool (n = 2) in August and the LaGrange Pool sites (n = 4) were sampled again in September. Each site visit included 4 15-minute DC electrofishing transects, 4 4-hour gill net sets, 8 mini-fyke net-nights ,4 beach seine hauls, 4 cast net throws, and 4 small mesh purse seine sets (see Gear Efficiency Report).

US Fish and Wildlife 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/or tributary mouths. For detailed methods see the project report for "Distribution and Movement of Small Asian Carp in the Illinois Waterway". In addition INHS sampling was conducted in 5 tributaries and tributary mouths to determine in Asian carp juveniles were present in these systems.

Results and Discussion: Young Asian carp were targeted with six gears in 2010, eight gears in 2011, ten gears in 2012, 6 gears in 2013, and 6 gears in 2014 which included both active gears, (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 2014 and mini fyke net monitoring was conducted heavily downstream of the electric barrier from the Lockport to the LaGrange Pools. Large numbers of young-of-year Asian carp were detected in the LaGrange (n = 69,114) and reduced numbers were found in the Peoria Pool (n = 49). No Asian carp were collected upstream of the Peoria Pool which is consistent with the absence of larval fish and is currently understood to be the furthest upstream successful reproduction of Asian carp has been documented. There was spawning behavior and egg loss observed the Marseilles pool, but no successful production of juvenile fish was documented. All of the juvenile Asian carp collected were identified as silver carp in the field (Table 4). The greatest numbers of young-of-year silver carp were collected in mini fyke nets (n = 56,054) followed by beach seines (n = 7,240) and DC electrofishing (n = 4,140). Although catch rates were variable, purse seines also captured large numbers of young-of-year silver carp (n = 4,060). Small mesh gill nets did not capture any young Asian carp, but did capture gizzard shad in the 6-12 inch range which was larger than the size of the Asian carp found in other gears at the time of sampling.

The highest level of effort was spent on DC electrofishing in all pools accounted for 328.6 hours of sampling followed by mini-fyke nets with 306 net-nights and beach seine with 44 hauls (Table 3). 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 and mini-fyke net 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 four years. 2014 is the first year with substantial abundances of young-of-year Asian carp since this monitoring project began in 2010. Overall, we examined 125,772 Gizzard Shad <152 mm (6 in) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam from 2010 to 2014 and found no young Asian carp. Additionally, sampling conducted by the USGS during the IPM sampled large numbers of gizzard shad and there were no young-of-year Asian carp detected.

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 2010-2014. We found no Asian carp juveniles upstream of Starved Rock Lock and Dam. In 2014, we observed high numbers of young-of-year silver carp in the LaGrange pool as well as successful reproduction in the Peoria Pool. In past years, only very low numbers of Asian carp had been detected downstream of the Starved Rock Lock and Dam. 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 (e.g., 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 the 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. This 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.

Project Highlights:

- Sampled for young Asian carp from 2010 to 2014 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 (pulsed-DC electrofishing, small mesh purse seine, cast net, and beach seine) and passive gears (small mesh gill nets, and mini-fyke nets) in 2014.
- Completed 1,401 hours of electrofishing across all years and sites.
- Examined 127,007 Gizzard Shad <152 mm (6 in) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam from 2010-2014 and found no young Asian carp.
- High catches of young-of-year Asian carp in 2014 in the LaGrange Pool indicate a high recruitment year despite limited to no recruitment in 2010-2013.
- Farthest upstream catch was a post larval Asian carp in the Peoria pool near Henry, Illinois (river mile 190) in 2012 and 2014, over 100RM downstream from the electric dispersal barrier.
- Recommend continued monitoring for young Asian carp to determine the farthest upstream young fish are recruited into the population.

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

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

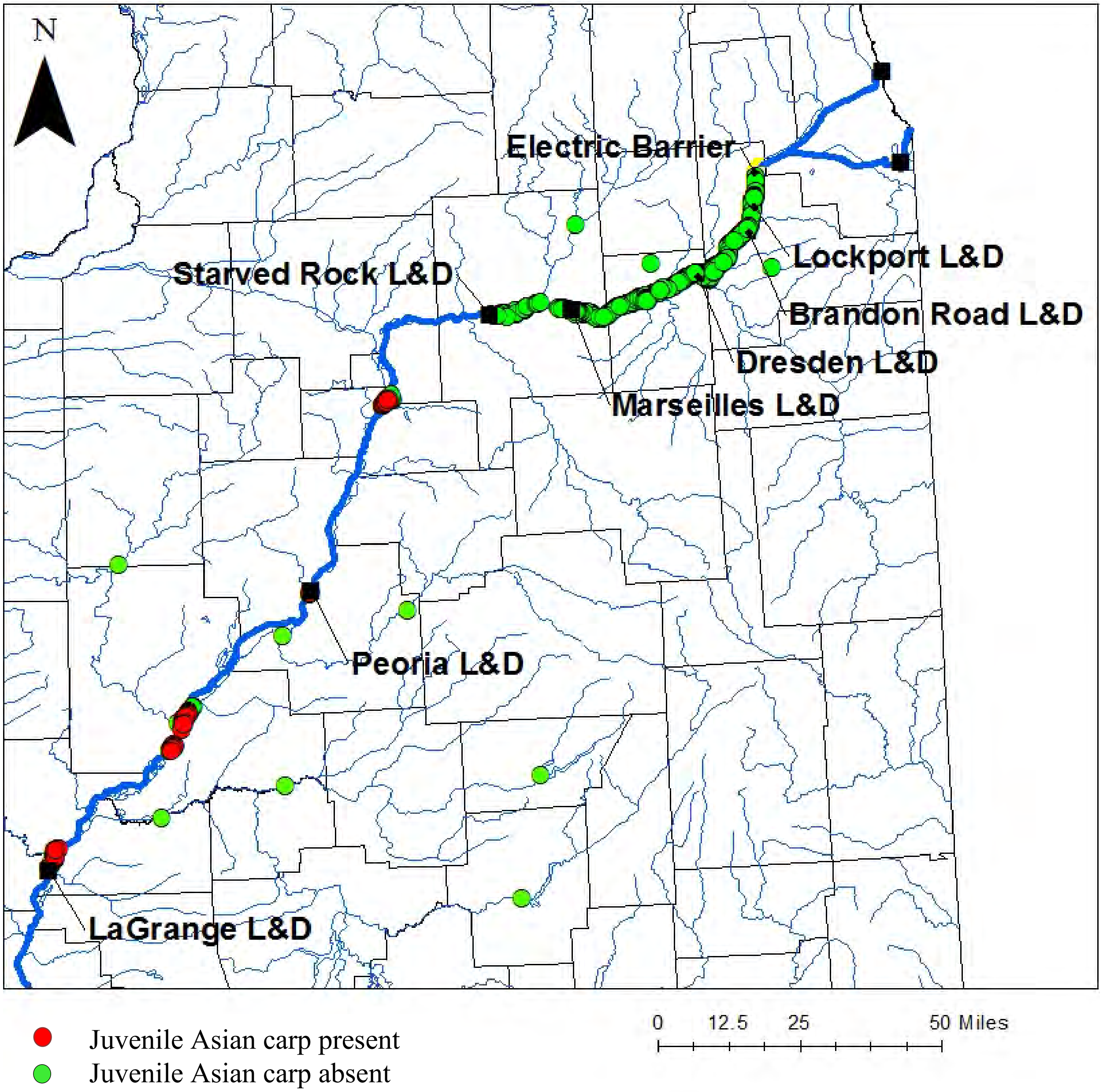

Figure 1: Location of all juvenile sampling sites conducted by INHS, IDNR and FWS below the electric barrier in the Illinois River in 2014.

Distribution and Movement of Small Asian Carp in the Illinois Waterway

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

Location:
Areas sampled were within the Starved Rock, Marseilles, and Dresden Island pools. Known populations of adult Asian carp exist in all pools of the Illinois River Waterway (IWW) from Dresden Island downstream. As of 2014, the farthest upstream extent of small (≤ 300mm TL) Asian carp recorded in the Illinois River has been near the town of Henry, Illinois (Peoria County) at river mile 194 where young-of-year (YOY) Silver Carp were collected in June 2012 and 2014 (USFWS unpublished data).

Introduction:
The bigheaded carps herein referred to as Asian carp, include the Silver Carp (*Hypophthalmichthys molitrix)* and Bighead Carp (*H. nobilis)* as well as hybrids between these species. Populations of these two introduced aquatic nuisance species are spreading throughout the Mississippi River Basin (Conover et al. 2007; Chapman and Hoff 2011; O'Connell et al. 2011). Kolar et al. (2007) rated the probability of Silver Carp and Bighead Carp spreading to previously uncolonized areas as "high" and assigned this rating a "very certain" degree of certainty. Asian carp are highly invasive species that have been expanding their range in the U.S. since the early 1980's when they first began to appear in public waters (Freeze and Henderson 1982; Burr et al 1996). Populations of Asian carp have grown exponentially because of their rapid growth rates, short generation times, and dispersal capabilities (DeGrandchamp 2003; Peters et al. 2006; DeGrandchamp et al. 2008). Asian carp have been shown to exhibit very high reproductive potential with high fecundity and the potential for a protracted spawning period (Garvey et al. 2006). Garvey et al. (2006) stated that high reproductive capacity of both species, in particular Silver Carp ensure that attempts to exclude or remove individuals will require a massive undertaking that targets young small-bodied fish as well as adults.

Populations of Asian carp have become well established in the lower and middle reaches of the Illinois River. Because of the connection of the upper IWW to Lake Michigan, natural resource managers are concerned about the potential invasion of Asian carps into the Great Lakes (Conover et al. 2007). If Asian carp gain entry into Lake Michigan they could pose a significant threat to fisheries by competing with established, economically and recreationally important species for limited plankton resources (Sparks et al. 2011). Kolar et al. (2007) noted that the most probable pathway for gaining access to the Great Lakes is through the Chicago Sanitary and Shipping Canal (CSSC). Therefore, the CSSC is also the key to stopping large numbers of Asian carp from expanding their range into Lake Michigan and the Great Lakes (Conover et al. 2007).

At present an electric dispersal barrier operated by the U.S. Army Corps of Engineers (USACE) is intended to block the upstream passage of Asian carp through the CSSC. Laboratory testing has shown that the operational parameters currently in use at the barrier are sufficient to stop large bodied fish from passing through (Holliman 2009). However, recent testing of operational parameters using small Bighead Carp (51 to 76 mm total length) revealed that operational parameters may be inadequate for blocking small fish passage (Holliman 2011). Recent work by USFWS has shown that tethered Gizzard Shad (*Dorosoma cepedianum*) can be entrained by barges and transported upstream through the electric dispersal barrier (Parker and Finney 2013). Additionally, work completed in 2013 by USFWS 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). For this reason there exists some concern that small sized Asian carp, if present, might represent a threat to breach the electric barrier. This highlights the need to better define the distribution and demographic characteristics of small Asian carp in the middle and upper IWW allowing us to fully characterize and assess the risk they may pose to the barriers. Additionally, there is an ongoing need to understand the reproduction of these species in the IWW so that managers might better target small sized fish for eradication or other management actions in the future.

The purpose of this study was to establish where young (YOY to age 2) Asian carp occur in the IWW through intensive, directed fish sampling which targets these life stages. For the purposes of this study, fish specimens less than 300mm total length were 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). Sampling employed the best known methods for detection and collection of Asian carp (Irons et al. 2011). Gears used included small-mesh fyke nets, DC boat electrofishing, and benthic push trawls. The use of small-mesh fyke nets and boat electrofishing has been shown to provide complimentary information when employed in shallow water areas (Ruetz et al. 2007). Results from 2012 and 2013 sampling indicate that trawls provide complimentary information to the above methods.

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 that small Asian carp pose to the Great Lakes via the Chicago Area Waterway System.

Methods:

Fish Capture

Site/Habitat Selection - Sites selected were in areas off of the navigation channel. These areas included backwaters, isolated pools, side channels, side channel borders, and/or tributary mouths. Efforts were made to sample areas which are difficult to sample using traditional fisheries boats (traditional fisheries boats are already collecting small fishes on other projects in the area). Shallow backwaters and isolated pools disconnected from the main channel, except during flooding events are areas that small Asian carp likely occupy but are rarely, if ever sampled. Sample sites were determined from analysis of LTRMP GIS data. Final in-field site selection was left ultimately to the discretion of the biologist in the field subject to on-site realities (e.g. a given site was dry so an alternative nearby site was chosen instead).

Fyke Netting - Nets used were Wisconsin type mini-fyke nets set and fished overnight. Mini-fyke nets were set in both single and tandem configurations depending on site characteristics. Single nets were set with the end of the lead staked against the shoreline or some other obstruction to fish movement. Tandem nets (with leads attached end to end) were fished in open water areas.

Electrofishing - Fifteen minute daytime pulsed DC electrofishing samples were made. Asian carp specific electrofishing settings were used with the Midwest Lakes Electrofishing System Infinity control box. All fish were collected and at the end of each 15 minute run fish were processed. Common Carp and adult Silver Carp observed were counted but not netted.

Push-trawl Sampling – Push trawl sampling was employed concurrently with netting and electrofishing sampling. Trawls were performed in shallow water (0.5m to 2.0m water depth habitats). Target lengths of trawl hauls were between 25 and 100 meters but varied with the amount of fishable habitat present at a given location. The push-trawl employed had a skate balloon trawl net of 4mm mesh, 1.8m body length, 0.76x0.38m otter boards, 2.4m foot rope, and an effective net fishing width 1.8 m across.

Fish Identification and Archiving - All fish other than Asian carp collected were identified to species, counted, and most native fish released. Large collections of small bodied fishes were necessarily preserved and returned to the laboratory for identification and enumeration.

Habitat Measurements - Macro habitat information was recorded for each sampling location (e.g. backwater, side channel border, tributary mouth). Physical and chemical habitat measurements were made at each collection site. Habitat measurements were recorded at the time of each net retrieval, electrofishing run, or push trawl. Global Positioning System (GPS) coordinates were recorded for all net sets, beginning and end of electrofishing runs and trawl hauls. Physical measurements included: depth, Secchi depth, and substrate composition (i.e. mud, sand, silt, vegetation, gravel, etc.). Water quality measurements included: temperature, salinity, specific conductance, dissolved oxygen, and pH. Water quality measurements were taken with an analytical instrument (YSI Professional Series multi-meter).

Data Analyses - Descriptive statistics such as presence/absence and mean counts from fish capture data are presented. Graphs of raw numbers of Asian carp caught using the different gear types will be used to determine which method is most effective at capturing small fish.

Fish Sampling Frequency and Effort - Sampling occurred during the months of May through September. One week per month per gear was spent sampling areas which are difficult to access with traditional fisheries boats but can be sampled with our shallow drive (mud motor) boat. Nets were set in the afternoon and run in the morning (overnight sets). Electrofishing and trawling were performed throughout the day.

Results and Discussion:
Sampling for small Asian carp occurred between the dates of 28 May and 18 September, 2014. A total of 327 sites were sampled throughout the Starved Rock, Marseilles, and Dresden Island Pools of the IWW. Samples taken included 139 15-minute electrofishing runs (34.75 hours of total shock time), 120 mini-fyke net nights, and 90 push trawls (5.926 kilometers trawled). All sites sampled in 2014 were in contiguous backwaters and side channels.

A total of 39,409 individual fish were collected in 2014. Eighty-three species and two hybrid combinations were identified including eight non-native species, three of which were Asian carp species, two Illinois state threatened species, and one Illinois state endangered species (Table 1). Young-of-year fish specimens that were not identified to species were keyed out to the lowest possible taxonomic level (Table 2). No YOY Asian carp or Asian carp <300mm were collected in 2014.

The absence of YOY Asian carp in the 2014 samples suggests there was little to no reproduction occurring within or upstream of our sampling reaches. Asian carp spawning was visually verified in our sampling reaches in 2013 by the Illinois Department of Natural Resources but not in 2014. No Asian carp larvae or juveniles have been collected upstream of Illinois River Mile 194 near Henry, IL. In 2014 we collected 14 more species than in 2013. We feel that our sampling regime is thorough enough that if juvenile Asian carp were present in our sampling reaches we would be likely to detect them. Mini-fyke nets and push trawling proved to be especially effective at sampling YOY fishes.

Recommendations:
Continued monitoring of the IWW for the uppermost limits of YOY and juvenile Asian carp is needed. Small bodied fish remain the biggest threat to breaching the electric dispersal barrier that separates the Great Lakes and Mississippi River Basins. Tracking the uppermost limits of small bodied Asian carp will provide valuable information to managers about the risk of these fish reaching the electric dispersal barrier in the CSSC.

Telemetry of Asian carp less than 300mm in length should be conducted to determine movements of juvenile fish which may have the ability to swim upstream and potentially breach the electric dispersal barrier. To date, this action has been hampered by our ability to capture the appropriate sized fish.

Table 1. Total numbers of fish species sampled with pulsed-DC electrofishing, mini-fyke netting, and push trawling at random sites in the Starved Rock, Marseilles, and Dresden Island pools of the Illinois Water Way. (*) Illinois State Threatened Species, (**) Illinois State Endangered Species, (***) Non-native fish species, (**BOLD**) Asian carp species.

Species	Total	Species	Total
Alewife***	2	Mooneye	1
Banded Darter	16	Mosquitofish	3
Banded Killifish*	84	Northern Hogsucker	3
Bighead Carp***	2	Northern Longear Sunfish	22
Bigmouth Buffalo	30	Northern Pike	6
Black Buffalo	4	Orangespotted Sunfish	259
Black Crappie	135	Orangethroat Darter	3
Black Redhorse	2	Pumpkinseed	470
Blacknose Shiner**	2	Quillback	11
Blackside Darter	17	Red Shiner	4
Blackstripe Topminnow	2	Redfin Shiner	1
Bluegill	1,755	River Carpsucker	112
Bluegill x Green Sunfish	2	River Redhorse*	1
Bluntnose Darter	34	Rock Bass	8
Bluntnose Minnow	2,757	Round Goby***	165
Brook Silverside	12	Sand Shiner	24
Brown Bullhead	1	Sauger	56
Bullhead Minnow	1,649	Shorthead Redhorse	3
Central Mudminnow	1	Shortnose Gar	59
Central Stoneroller	47	**Silver Carp*****	3,934
Channel Catfish	34	Silverband Shiner	10
Channel Shiner	62	Skipjack Herring	15
Common Carp***	638	Slenderhead Darter	1
Common Carp x Goldfish ***	3	Slender Madtom	1
Common Shiner	3	Smallmouth Bass	59
Creek Chub	5	Smallmouth Buffalo	717
Emerald Shiner	1,459	Spotfin Shiner	1,575
Fathead Minnow	14	Spottail Shiner	1,052
Flathead Catfish	15	Spotted Gar	8
Freshwater Drum	134	Spotted Sucker	3
Ghost Shiner	18	Striped Shiner	1
Gizzard Shad	2,642	Suckermouth Minnow	3
Golden Redhorse	67	Tadpole Madtom	21
Golden Shiner	663	Threadfin Shad	419
Goldfish***	67	Walleye	12
Grass Carp***	48	White Bass	55
Grass Pickeral	1	White Crappie	144
Green Sunfish	205	White Perch***	6
Highfin Carpsucker	4	White Sucker	37
Johnny Darter	109	Yellow Bass	9
Largemouth Bass	1,278	Yellow Bullhead	53
Logperch	64	Yellow Perch	3
Longnose Gar	13		

Table 2. Numbers of young-of-year fish that could not be identified to species. Fish were sampled with pulsed-DC electrofishing, mini-fyke netting, and push trawling at random sites in the Starved Rock, Marseilles, and Dresden Island pools of the Illinois Water Way.

Family	Total	Genus	Total
Centrarchidae	11,170	*Ictiobus sp.*	22
Clupeidae	72	*Lepisosteus sp.*	5
Cyprinidae	28	*Lepomis sp.*	3,645
Ictiluridae	2	*Moxostoma*	7
Ictiobinae	278	*Notropis sp.*	76
Moronidae	2	*Pimephales sp.*	568
Percidae	2	*Pomoxis sp.*	11

Project Highlights:

- A total of 39,409 fish specimens were collected and examined.
- Eighty-three species were identified along with two hybrid combinations.
- Two Illinois State threatened species were sampled.
- One Illinois State endangered species was sampled.
- No YOY Asian carp were sampled.
- The lack of YOY Asian carp in our samples suggests that the uppermost limit of these fish is still downstream of the Starved Rock Lock and Dam in the Peoria pool.

Fixed Site Monitoring Downstream of the Dispersal Barrier

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Illinois Department of Natural Resources

Participating Agencies: Illinois Department of Natural Resources (lead); US Fish and Wildlife Service – Carterville, Columbia, and La Crosse Fish and Wildlife Conservation Offices and US Army Corps of Engineers – Chicago District (field support).

Introduction: Standardized sampling can provide useful information to managers tracking population growth and range expansion of aquatic invasive species. Information gained from regular monitoring (e.g., 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 system. We used pulsed-DC electrofishing, hoop and mini-fyke netting, and contracted commercial netters to sample for Asian carp in the four pools downstream of the electric dispersal barrier. The primary goal of this monitoring effort is to identify the location of the detectable population front of advancing Asian carp in the Illinois Waterway and track changes in distribution and relative abundance of leading populations over time. The detectable population front is defined as the farthest upstream location where multiple Bighead Carp 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 through 2014 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 system.

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 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 (e.g., Asian Carp Barrier Defense Project and Telemetry 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.

Methods: The sample design included intensive electrofishing and netting at four fixed sites in each of four pools below the electric dispersal barrier (Lockport, Brandon Road, Dresden Island and Marseilles Pools). The fixed sites were located primarily in the upper portions below lock and dam structures, and in habitats where Asian carp are likely to be located (backwaters and side-channels). In 2014, randomly generated sites were sampled with electrofishing and commercial netting in each of the four pools.

Electrofishing Protocol – Fixed and random electrofishing samples in 2014 occurred twice per month from March through November. All electrofishing was pulsed-DC current and included one or two netters (two netters were preferred). Electrofishing was conducted in a downstream direction in areas with noticeable current velocity. Electrofishing runs were 15 minutes in length and generally parallel to shore (including following shoreline into off channel areas). The operator was encouraged to switch the pedal on and off at times to prevent pushing fish in front of the boat and increasing the chance of catching an Asian carp. Common Carp were counted without capture and all other fish were netted and placed in a tank where they were identified and counted, after which they were returned live to the water. Gizzard Shad YOY were examined closely for the presence of Asian carp and counted to provide an assessment of any young Asian carp in the waterway.

Gill and Trammel Netting Protocol – In 2014, commercial netting took place once per month from April through December in all four pools. Contracted commercial fishers were used for net sampling at all sites. Gear included large mesh (76-102 mm (3-4 in)) trammel or gill nets 2.4 m (8 ft) high and in lengths of 91 or 183 m (100 or 200 yd). An IDNR biologist was assigned to each commercial net boat to monitor operations, record data, and check for ultrasonically-tagged and jaw-tagged Asian carp and Common Carp (left pelvic fin clips or telemetry surgery wounds on the ventral left area of the fish, posterior to the pelvic fin and anterior to the anal opening), as well as Floy tag all Buffalo species and Common Carp sampled in the Lockport, Brandon Rd, and Dresden Island Pools (*see* Surrogate Fish Movement With Barriers interim report). Nets were attended at all times. Netting locations within each fixed site were left to the discretion of the commercial fishers. Net sets were short duration and included driving fish into the nets with noise (e.g. "pounding" with plungers on the water surface, banging on boat hulls, or racing tipped up motors). Netting effort was standardized as 15- to 20-minute long sets with "pounding" no further than 137m (150 yd) from the net. Captured fish were identified to species, enumerated, and recorded on data sheets.

Hoop and Minnow Fyke Netting Protocol – Hoop and minnow fyke netting were added to the sampling protocol in 2012 and continued during the 2014 field season. In 2014, nets were deployed at four fixed sites within each of the target pools, once per month, starting in April and concluding in November. All netting was conducted by IDNR biologists at all fixed sites.

Hoop nets were 1.8 m (6 ft) in diameter, composed of 7 hoops, with 64-mm (2.5-in) bar mesh and when extended were 6.7 m (22 ft) long. An anchor, followed by a 15.2 m (50 ft) foot line was connected to the cod end of the net. Water current kept the nets open, but when water velocities were too slow a bridle and block were used on the downstream end of the net. Nets were set in main-channel borders and below locks and dams in ≥ 1.8 m (6 ft) of water. Hoop nets were set for 48 hours (2 net nights). Upon retrieval, captured non target fish were identified, enumerated and released. All captured Asian carp were enumerated and euthanized.
A Wisconsin-type minnow fyke net (mini-fyke), composed of a lead, frame, and cab were used for mini-fyke netting. Netting material was 3 mm (0.12 in) in diameter and was nylon coated with green dip. A 5 m (16 ft) long, by 0.6 m (2 ft) high lead was connected to the cab. When fully extended the cab was 3 m (10 ft) long, making the entire net 7.6 m (25 ft) long. Mini-fyke nets were set on main-channel borders or backwater areas near hoop net sets. Mini-fyke nets were fished for 24 hours (1 net night). Upon retrieval, captured non target fish were identified, enumerated and released.

Results and Discussion: *Electrofishing Effort and Catch* – Fixed site electrofishing catch-per-unit-effort (CPUE) in 2014 (CPUE = 261.1 fish/hour) decreased from 2013 (CPUE = 359 fish/hour) as well as from 2012 (CPUE = 466.5 fish/hour), and 2011 (CPUE = 384.4 fish/hour) (Table 1). Random site electrofishing had a CPUE of 108.8 fish/hour, also a decrease from 2013 random sites (CPUE = 109.7 fish/hour) (Table 1). Fixed sites were chosen based on habitats likely preferred by Asian carp, while many of the random electrofishing sites were distributed on main-channel border habitat and which yielded lower catches. No Bighead Carp or Silver Carp were sampled by electrofishing in Lockport or Brandon Road pools for all years sampled, also no Bighead Carp and no Silver Carp were captured at any Dresden Island Pool sites in 2014. In contrast, fixed electrofishing sites in Marseilles Pool yielded 1 Bighead Carp and 212 Silver Carp while random electrofishing sites yielded 2 Bighead Carp and 146 Silver Carp in 2014. A total of 12,649 Gizzard Shad ≤ 152 mm (6 in) were examined at fixed and random electrofishing sites downstream of the electric dispersal barrier system and no Asian Carp YOY were detected in 2014, this has been consistent for all years sampled

An estimated 3,970 person-hours were expended completing 409 hours of electrofishing, capturing 100,914 fish representing 97 species, and seven hybrid groups at fixed and random sites downstream of the electric dispersal barrier from 2010-2014 (Table 2). Gizzard Shad, Emerald Shiner, Common Carp, Smallmouth Buffalo, Threadfin Shad, Spotfin Shiner, Largemouth Bass, Bluegill, Bluntnose Minnow, Smallmouth Bass, Spottail Shiner, Pumpkinseed Sunfish, Silver Carp, Freshwater Drum, and Channel Catfish accounted for over 90% percent of the total catch in 2014 for all pools combined.

Gill and Trammel Netting Effort and Catch – An estimated 5,609 person-hours were expended setting and running 642 km (399 miles) of net at fixed, random sites and additional netting locations downstream of the electric dispersal barrier from 2010-2014 (Table 1). Netting yielded 8,438 fish representing 29 species (Table 3). Common Carp, Bigmouth Buffalo Smallmouth Buffalo, Bighead Carp, and Silver Carp accounted for over 90% of the total catch in 2014.

No Bighead or Silver Carp were caught by netting in the Lockport or Brandon Road pools for all years sampled. Catches of Bighead Carp and Silver Carp at fixed and random sampling sites increased downstream of the Brandon Road Lock and Dam. Forty-nine Bighead Carp and seventeen Silver Carp were collected in the Dresden Island Pool during fixed and random commercial netting in 2014. Total catch of Bighead Carp in the Marseilles Pool in 2014 (N = 88) were greater than 2013 (N = 58). Silver Carp were captured at both fixed sites (N = 134) and random sites (N = 71) in the Marseilles Pool in 2014. Fixed site netting CPUE decreased from 2011 (CPUE = 4.80 fish / 100 yards of net) to 2012 (CPUE = 1.87 fish / 100 yards of net) and from 2013 (CPUE = 0.014 fish / 100 yards of net) to 2014 (CPUE 0.011 fish / 100 yards of net).

Hoop and Mini-Fyke Netting Effort and Catch – Hoop and mini-fyke nets were set at four fixed sites in each of the four pools downstream of the electric dispersal barrier (Lockport, Brandon Road, Dresden Island, and Marseilles) starting in 2012. From 2012-2014 an estimated 1,755 person hours were expended setting and retrieving 306 hoop nets and 144 mini-fyke nets for 600 and 308 net nights, respectively.

Hoop netting captured 467 fish, representing 12 species from 2012-2014 (Table 4). In 2014, 218 fish from 9 species (Table 4) were collected in hoop nets. Catches from the previous year were higher by total catch (N = 249) and species diversity (N = 11). Common Carp, Smallmouth Buffalo, and Bighead Carp accounted for over 80% of the 2014 hoop net catches. No Asian carp were captured in hoop nets in the Lockport or Brandon Road Pools in 2012-2014. In 2014, 29 Bighead Carp were captured in the Dresden Island Pool. A total of one Silver Carp and two Bighead Carp were captured in hoop nets in the Marseilles Pool in 2014.

Mini-fyke netting captured 37,067 fish, representing 67 species and 3 hybrid groups from 2012-2014 (Table 5).In 2014, Mini-fyke nets captured 9,786 fish, representing 46 species and one hybrid group (Table 5). Bluegill, Bluntnose Minnow, Green Sunfish, Pumpkinseed, and Spotfin Shiner accounted for over 70% of the 2014 mini-fyke net catches. No YOY or adult Bighead or Silver Carp were captured in mini-fyke nets in any pool from 2012 - 2014.

Results of electrofishing and net sampling with contracted commercial fishers revealed patterns of Asian carp distribution and relative abundance in the Upper Illinois Waterway. Based on monitoring results to date, we would characterize abundance of Bighead and Silver Carp as rare in Lockport Pool below the electric dispersal barrier (river mile 291-296) and in Brandon Road Pool (river mile 286-291). The detectable adult population front 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 near river mile 280. This location is approximately 76 km (47 miles) from Lake Michigan (Chicago Harbor = river mile 327). Also Asian carp are routinely harvested from Rock Run Rookery Lake which is located near river mile 280. The US Army Corps of Engineers 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 still being determined, the detectable Asian carp population front has made little upstream progress.

The Marseilles Pool (river mile 245-272) contained moderately abundant populations of both Bighead and Silver Carp relative to downstream locations (e.g., Starved Rock Pool; see Barrier Defense Removal Report). These populations of mature adults were located within 89 km (55 miles) of Lake Michigan and showed a potential for spawning; we observed gravid females and males in Marseilles Pool during 2010 through 2012. Spawning activity was observed on 22 May 2013 by IDNR biologists at River Mile 269.5 in the Marseilles Pool. For this reason and to reduce propagule pressure on the electric dispersal barrier, located just 24 miles upstream, contracted commercial fishers directed most of their netting effort and removed the greatest quantity of Asian carp from the Marseilles Pool from 2010-2014. Increased commercial fishing efforts were directed to the Starved Rock Pool when catch rates were low in the Marseilles Pool. Although Asian carp populations in the Marseilles Pool exhibited spawning activity, we have no evidence in recent years that any successful reproduction has occurred in this or in other reaches of the Upper Illinois Waterway or CAWS. Extensive monitoring from 2010-2014 detected no Asian carp larvae upstream of Peoria Lock and Dam (river mile 158) and no juveniles above Henry, Illinois (river mile 190; over 100 miles from the electric dispersal barrier).

Recommendations: Extensive monitoring and removal efforts have allowed us to begin 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 trammel/gill netting) and monitoring/removal projects (also see Barrier Defense Removal report) adds confidence to the finding that relative abundance of Asian carp decreased with upstream location in the waterway.

We propose some minor changes in removing the Marseilles pool from the current monitoring plan of Asian carp populations at fixed and random sites downstream of the electric dispersal barrier with hoop contracted commercial fishers. We also propose the following for the contracted commercial fishing; fish for a predetermined number of hours with no minimum yardage, each fisherman fishes in a different pool each day, fisherman select site locations instead of using computer generated sites to focus on areas with high catch potential, and fish at Rock Run Rookery on Fridays. We recommend continuing the current mini-fyke netting and electrofishing monitoring plan. If deployed in late spring or early summer, these gears should increase our effectiveness at capturing adult Bighead Carp and juveniles of both species, should successful spawning take place. Continuing sampling efforts in the Upper Illinois Waterway will provide more information about the detectable population front.

Project Highlights:

- Estimated 10224.5 person-hours spent sampling at fixed, random, and additional sites and netting locations downstream of the electric dispersal barrier from 2010-2014.
- 409 hours spent electrofishing and 439 km (273 miles) of trammel/gill net deployed.
- Sampled 146,882 fish, representing 97 species and seven hybrid groups.
- No Bighead or Silver Carp were captured by electrofishing or netting in Lockport and Brandon Road pools.
- Seventy-nine Bighead Carp and 19 Silver Carp were collected in the Dresden Island Pool during fixed, random, and additional commercial netting from 2010-2014.
- Twenty-nine Bighead Carp were captured in a single hoop net in the Dresden Island Pool.
- One Bighead Carp and no Silver Carp were captured at Dresden Island Pool while electrofishing from 2010-2013, with none being captured in 2014.
- Detectable population front of mostly Bighead Carp located just north of I-55 Bridge at river mile 280 (76 km (47 miles from Lake Michigan)). No appreciable change in upstream location of the population front in past five years.
- Recommend to continue current sampling plan below the electric dispersal barrier with electrofishing, hoop netting, mini-fyke netting, and gill and trammel netting.

Table 1. Fixed and random electrofishing, fixed and random gill and trammel netting, hoop netting, and minnow fyke netting efforts and catch summaries for 2014 sample sites below the Electric Dispersal Barrier.

Fixed Electrofishing Effort - 2014

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	18 Mar - 27 Nov				
Person-days	33	21	45	90	189
Estimated person-hours	247.5	157.5	337.5	675	1417.5
Electrofishing hours	15	15	15.75	16.75	62.5
Samples (transects)	60	60	63	67	250
All Fish *(N)*	2189	1991	4357	7844	16,381
Species *(N)*	30	37	54	58	76
Hybrids *(N)*	2	2	2	1	3
Bighead Carp *(N)*	0	0	0	1	1
Silver Carp *(N)*	0	0	0	212	212
CPUE (fish/hour)	145.9	132.7	276.6	468.3	262.1

Random Electrofishing Effort - 2014

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	18 Mar - 27 Nov				
Person-days	33	21	45	90	189
Estimated person-hours	247.5	157.5	337.5	675	1417.5
Electrofishing hours	28	31.75	31.25	33	124
Samples (transects)	112	127	125	132	496
All Fish *(N)*	1893	2985	3959	4651	13,488
Species *(N)*	25	37	61	59	77
Hybrids *(N)*	1	3	3	1	4
Bighead Carp *(N)*	0	0	0	2	2
Silver Carp *(N)*	0	0	0	146	146
CPUE (fish/hour)	67.6	94.0	126.7	140.9	108.8

Fixed Gill and Trammel Netting Effort - 2014

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	1 Apr - 11 Dec				
Person-days	30	30	30	26	116
Estimated person-hours	225	225	225	195	870
Samples (net sets)	60	60	60	52	232
Total miles of net	6.8	6.8	6.8	5.9	26.3
All Fish *(N)*	10	19	152	328	509
Species *(N)*	1	1	12	13	15
Hybrids *(N)*	0	0	0	0	0
Bighead Carp *(N)*	0	0	1	69	70
Silver Carp *(N)*	0	0	0	134	134
CPUE (fish/100 yard of net)	0.001	0.002	0.013	0.032	0.011

Random Gill and Trammel Netting Effort - 2014

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	1 Apr - 11 Dec				
Person-days	30	30	46	26	132
Estimated person-hours	225	225	225	195	870
Samples (net sets)	212	208	351	58	829
Total miles of net	24.1	23.6	45.5	6.6	99.8
All Fish *(N)*	59	167	1527	153	1906
Species *(N)*	1	6	15	10	15
Hybrids *(N)*	0	3	1	0	1
Bighead Carp *(N)*	0	0	48	19	0
Silver Carp *(N)*	0	0	17	71	88
CPUE (fish/100 yard of net)	0.001	0.004	0.019	0.013	0.011

Hoop Netting Effort - 2014

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	28 Apr - 5 Nov				
Person-days	16	16	16	16	64
Estimated person-hours	60	60	60	60	240
Net Nights	64	64	64	64	256
Samples (net sets)	32	32	32	32	128
All fish *(N)*	4	28	124	60	216
Species *(N)*	1	3	7	6	10
Hybrids *(N)*	0	0	0	0	0
Bighead Carp *(N)*	0	0	0	1	1
Silver Carp *(N)*	0	0	0	29	29
CPUE (fish/net)	0.1	0.9	3.9	1.9	1.7

Minnow Fyke Netting Effort - 2014

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	28 Apr - 26 Nov				
Person-days	16	16	16	16	64
Estimated 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)*	3,158	1,636	3,130	1,952	9,876
Species *(N)*	20	22	35	38	45
Hybrids *(N)*	1	1	1	1	1
Bighead Carp *(N)*	0	0	0	0	0
Silver Carp *(N)*	0	0	0	0	0
CPUE (fish/net)	98.7	51.1	97.8	61.0	77.2

Table 2. Total number of fish captured and percentage of total catch from 2014 fixed and random electrofishing and 2010-2014 totals for fixed and random site electrofishing below the dispersal barrier. Common Carp were counted by observation

	2014 Fixed						2014 Random						2010-2014	
	Pool				Number		Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Gizzard Shad	1221	684	2776	4093	8774	53.6%	1284	1535	1702	589	5110	37.9%	48721	48.3%
Bluegill	38	60	145	112	355	2.2%	83	31	205	103	422	3.1%	7592	7.5%
Emerald Shiner	51	317	149	992	1509	9.2%	23	163	72	857	1115	8.3%	7085	7.0%
Common Carp	469	302	310	92	1173	7.2%	200	414	419	79	1112	8.2%	6128	6.1%
Threadfin Shad	49	120	123	290	582	3.6%	59	366	185	34	644	4.8%	3535	3.5%
Smallmouth Buffalo		1	115	357	473	2.9%		1	143	772	916	6.8%	3329	3.3%
Largmouth Bass	82	69	117	119	387	2.4%	19	96	261	50	426	3.2%	3199	3.2%
Bluntnose Minnow	55	27	109	87	278	1.7%	47	65	134	195	441	3.3%	3093	3.1%
Spotfin Shiner	8	5	4	286	303	1.8%			44	593	637	4.7%	2624	2.6%
Green Sunfish	26	21	54	34	135	0.8%	40	26	25	51	142	1.1%	1986	2.0%
Pumkinseed	85	59	36	15	195	1.2%	77	58	35	10	180	1.3%	1635	1.6%
Bullhead Minnow			17	47	64	0.4%	3		26	89	118	0.9%	1024	1.0%
Smallmouth Bass	2	70	20	109	201	1.2%	3	35	61	171	270	2.0%	994	1.0%
Freshwater Drum	4	29	31	85	149	0.9%	3	32	48	120	203	1.5%	801	0.8%
Golden Redhorse			10	118	128	0.8%			17	120	137	1.0%	708	0.7%
Channel Catfish	23	57	27	20	127	0.8%	3	24	60	66	153	1.1%	700	0.7%
River Carpsucker			6	109	115	0.7%			17	119	136	1.0%	666	0.7%
Spottail Shiner		6	66	84	156	1.0%		7	181	94	282	2.1%	659	0.7%
Silver Carp				212	212	1.3%				146	146	1.1%	651	0.6%
Longnose Gar	5		37	156	198	1.2%	2	2	41	9	54	0.4%	579	0.6%
Yellow Bullhead	9	20	17		46	0.3%	8	11	18	1	38	0.3%	394	0.4%
Bigmouth Buffalo			2	42	44	0.3%			2	17	19	0.1%	375	0.4%
Golden Shiner	10	7	29	18	64	0.4%	1	7	70	5	83	0.6%	371	0.4%
Quillback			5	38	43	0.3%			17	32	49	0.4%	353	0.3%
Goldfish	5	14	35		54	0.3%	2	26	80	4	112	0.8%	351	0.3%
White Bass		1	6	27	34	0.2%		1	4	76	81	0.6%	321	0.3%
Hybrid Sunfish	2		35	2	39	0.2%	16	1	9		26	0.2%	278	0.3%
Sand Shiner	1	1		35	37	0.2%		1	2	25	28	0.2%	218	0.2%
Shorthead Redhorse			6	28	34	0.2%			6	25	31	0.2%	216	0.2%
White Sucker		62	1		63	0.4%		29	5	4	38	0.3%	197	0.2%
Orangespot Sunfish		8	2	17	27	0.2%		3		8	11	<0.1%	190	0.2%
Black Buffalo			4	10	14	<0.1%			7	14	21	0.2%	181	0.2%
Brook Silverside			2	30	32	0.2%		1	4	16	21	0.2%	146	0.1%
Oriental Weatherfish	13	4			17	0.1%	5	1			6	<0.1%	123	0.1%
Logperch			1	42	43	0.3%			5	31	36	0.3%	116	0.1%
Round Goby	2	8	9		19	0.1%	1	20	1	16	38	0.3%	104	0.1%
Black Crappie			1	6	7	<0.1%				1	1	<0.1%	90	<0.1%
Silver Redhorse			2	21	23	0.1%			3	26	29	0.2%	86	<0.1%
Banded Killifish	14	7	2	2	25	0.2%	11	10	3	2	26	0.2%	80	<0.1%
Rock Bass		7	6	3	16	<0.1%		3		1	4	<0.1%	69	<0.1%
Shortnose Gar				20	20	0.1%				5	5	<0.1%	64	<0.1%
White Crappie	1		1	6	8	<0.1%			1	1	2	<0.1%	53	<0.1%
Common Carp x Goldfish Hybrid	1	2	1		4	<0.1%		1	1		2	<0.1%	48	<0.1%
Skipjack Herring	1	1		6	8	<0.1%		1	1	8	10	<0.1%	42	<0.1%
Highfin Carpsucker			2	6	8	<0.1%			3	6	9	<0.1%	38	<0.1%
Yellow Bass				3	3	<0.1%			2	4	6	<0.1%	38	<0.1%
Blackstrip Topminnow		1	4		5	<0.1%		2	2	3	7	<0.1%	37	<0.1%
Mosquitofish													37	<0.1%
Flathead Catfish		1	1	2	4	<0.1%			2	6	8	<0.1%	34	<0.1%
Northern Hogsucker				3	3	<0.1%						<0.1%	33	<0.1%
Northern Pike	1	2	1	1	5	<0.1%		2	1		3	<0.1%	32	<0.1%
Bluegill x Green Sunfish Hybrid													30	<0.1%
Common Shiner			4	20	24	0.1%				2	2	<0.1%	28	<0.1%
River Shiner				2	2	<0.1%				2	2	<0.1%	27	<0.1%
Grass Carp				2	2	<0.1%			4	6	10	<0.1%	25	<0.1%
Sauger		3		1	4	<0.1%			1	3	4	<0.1%	23	<0.1%
Grass Pickerel		5	6	6	17	0.1%		3	1		4	<0.1%	21	<0.1%
Bighead Carp				2	2	<0.1%				1	1	<0.1%	21	<0.1%
White Perch	1	1			2	<0.1%	1	1		2	4	<0.1%	20	<0.1%
Walleye			3	2	5	<0.1%			4	3	7	<0.1%	19	<0.1%
Unidentified Catastomid			2	5	7	<0.1%			2	8	10	<0.1%	18	<0.1%
Bowfin		2	1	2	5	<0.1%		2	2		4	<0.1%	17	<0.1%
Spotted Sucker									5		5	<0.1%	15	<0.1%
Fathead Minnow	8	1			9	<0.1%	1	1			2	<0.1%	14	<0.1%
Longear Sunfish				2	2	<0.1%			2	1	3	<0.1%	14	<0.1%
Brown Bullhead													14	<0.1%
Mimic Shiner													12	<0.1%
Black Bullhead			4		4	<0.1%	1		1		2	<0.1%	11	<0.1%
Johnny Darter				4	4	<0.1%				3	3	<0.1%	10	<0.1%
Warmouth	1				1	<0.1%						<0.1%	10	<0.1%
Alewife													10	<0.1%
Striped Bass x White Bass Hybrid		5	1		6	<0.1%		2	4		3	<0.1%	9	<0.1%
Redear Sunfish													8	<0.1%
Yellow Perch	1		1		2	<0.1%		1	1		2	<0.1%	7	<0.1%
River Redhorse				2	2	<0.1%				1	1	<0.1%	7	<0.1%
Spotted Gar			4		4	<0.1%			2		2	<0.1%	6	<0.1%
Central Stoneroller			2		2	<0.1%				3	3	<0.1%	6	<0.1%
Greenside Darter				4	4	<0.1%				1	1	<0.1%	6	<0.1%
Black Redhorse										2	2	<0.1%	6	<0.1%
Blackside Darter													6	<0.1%
Brassy Minnow													6	<0.1%
Pumpkinseed x Green Sunfish Hybrid													6	<0.1%
Mooneye										5	5	<0.1%	5	<0.1%
Trout Perch													4	<0.1%
Creek Chub			1		1	<0.1%			1	1	2	<0.1%	3	<0.1%

Table 2. Continued

	2014 Fixed						2014 Random						2010-2014	
	Pool				Number		Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Unidentified Notropis									1		1	<0.1%	3	<0.1%
Banded Darter													3	<0.1%
Suckermouth Minnow													3	<0.1%
Red Shiner				2	2	<0.1%						<0.1%	2	<0.1%
Unidentified Moronid		1			1	<0.1%			1		1	<0.1%	2	<0.1%
Greater Redhorse				1	1	<0.1%						<0.1%	2	<0.1%
Horneyhead Chub				1	1	<0.1%						<0.1%	2	<0.1%
Tadpole Madtom			1		1	<0.1%						<0.1%	2	<0.1%
American Eel													2	<0.1%
Central Mudminnow													2	<0.1%
Goldeye													2	<0.1%
Silver Chub													2	<0.1%
Slenderhead Darter													2	<0.1%
Striped Shiner													2	<0.1%
Muskellunge									1		1	<0.1%	1	<0.1%
Stonecat									1		1	<0.1%	1	<0.1%
Unidentified Carpsucker				1	1	<0.1%						<0.1%	1	<0.1%
Unidentified Darter										1	1	<0.1%	1	<0.1%
Unidentified Redhorse										1	1	<0.1%	1	<0.1%
Walleye x Sauger Hybrid										1	1	<0.1%	1	<0.1%
Blue Catfish													1	<0.1%
King Salmon													1	<0.1%
Paddlefish													1	<0.1%
Pumpkinseed x Bluegill Hybrid													1	<0.1%
White Perch Hybrid													1	<0.1%
Total Caught	2189	1991	4357	7844	16381	1	1893	2985	3959	4651	13488	1	100910	1
Species	30	37	55	58	77		25	37	61	62	78		97	
Hybrid groups	2	2	2	1	3		1	3	3	1	4		7	

Table 3. Total number of fish captured and percentage of total catch from 2014 fixed and random gill and trammel netting and 2010-2014 totals for fixed and random gill and trammel netting below the dispersal barrier.

	2014 Fixed						2014 Random						2010-2014	
	Pool				Number		Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Bighead Carp			1	69	70	13.8%			48	19	67	3.5%	821	9.7%
Black Buffalo			4	2	6	1.2%			14	1	15	0.8%	130	1.5%
Bigmouth Buffalo			3	30	33	6.5%			84		84	4.4%	380	4.5%
Common Carp	10	19	64	14	107	21.0%	59	157	374	5	595	31.2%	3,603	42.7%
Common Carp x Goldfish Hybrid								3	1		4	0.2%	67	0.8%
Channel Catfish			7	4	11	2.2%		2	30	2	34	1.8%	197	2.3%
Flathead Catfish				1	1	0.2%			8	1	9	0.5%	29	0.3%
Freshwater Drum			9	7	16	3.1%		1	41	2	44	2.3%	155	1.8%
Goldfish								1	1		2	0.1%	38	0.5%
Grass Carp			2	8	10	2.0%				12	12	0.6%	89	1.1%
Largemouth Bass			1		1	0.2%			1		1	<0.1%	7	<0.1%
Longnose Gar			3	5	8	1.6%			20	3	23	1.2%	52	0.6%
Northern Pike				1	1	0.2%					0	<0.1%	4	<0.1%
Quillback			2	2	4	0.8%			2		2	0.1%	14	0.2%
River Carpsucker			1		1	0.2%			15		15	0.8%	46	0.5%
Smallmouth Buffalo			55	51	106	20.8%		3	871	37	911	47.8%	2136	25.3%
Silver Carp				134	134	26.3%			17	71	88	4.6%	637	7.5%
Skipjack Herring						<0.1%						<0.1%	4	<0.1%
Unidentified Catostomid						<0.1%						<0.1%	4	<0.1%
Goldeye						<0.1%						<0.1%	3	<0.1%
Gizzard Shad						<0.1%						<0.1%	2	<0.1%
Striped Bass x White Bass Hybrid						<0.1%						<0.1%	2	<0.1%
Walleye						<0.1%						<0.1%	2	<0.1%
Bluegill						<0.1%						<0.1%	1	<0.1%
Muskie						<0.1%						<0.1%	1	<0.1%
Shortnose Gar						<0.1%						<0.1%	1	<0.1%
Silver Redhorse						<0.1%						<0.1%	1	<0.1%
Spotted Gar						<0.1%						<0.1%	1	<0.1%
Yellow Bullhead						<0.1%						<0.1%	1	<0.1%
Total Caught	10	19	152	328	509	100.0%	59	167	1,527	153	1906	100.0%	8,438	100.0%
Species	1	1	12	13	15		1	6	15	10	15		29	
Hybrid groups								1	1		1		2	

Table 4. Total number of fish captured and percentage of total catch from 2012-2014 fixed hoop neting downstream of the Electrical Dispersal Barrier.

	2014						2012-2014	
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Common Carp	2	22	24	3	51	23.4%	132	28.3%
Channel Catfish	0	3	8	2	13	6.0%	76	16.3%
Smallmouth Buffalo	0	0	93	7	100	45.9%	144	30.8%
Silver Carp	0	0	0	1	1	0.5%	31	6.6%
Bighead Carp	0	0	29	2	30	13.8%	39	8.4%
Flathead Catfish	0	0	9	3	12	5.5%	18	3.9%
Freshwater Drum	0	3	3	2	8	3.7%	15	3.2%
White Bass	0	1	0	0	1	0.5%	1	0.2%
River Carpsucker	0	0	2	0	2	0.9%	4	0.9%
Black Buffalo	0	0	0	0	0	0%	5	1.1%
Goldfish	0	0	0	0	0	0%	1	0.2%
Longnose Gar	0	0	0	0	0	0%	1	0.2%
Total Caught	2	29	167	20	218	100%	467	100%
Species	1	4	7	7	9		12	
Hybrid groups	0	0	0	0	0		0	

Table 5. Total number of fish captured and percentage of total catch from 2012-2014 fixed minnow fyke netting downstream of the Electric Dispersal Barrier

	2014 Mini Fyke							
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Bluegill	1042	638	1773	287	3740	38.0%	16389	44.21%
Bluntnose Minnow	326	134	454	358	1272	12.9%	4922	13.28%
Green Sunfish	396	199	147	11	753	7.7%	2076	5.60%
Pumpkinseed Sunfish	162	83	336	3	584	5.9%	2998	8.09%
Spotfin Shiner	9		41	471	521	5.3%	3117	8.41%
Common Carp	326	9	31	1	367	3.7%	380	1.03%
Round Goby	59	269	16	3	347	3.5%	407	1.10%
Sand Shiner	1	2	6	331	340	3.5%	435	1.17%
Yellow Bullhead	273	51	10		326	3.3%	418	1.13%
Gizzard Shad	222	80	11	37	314	3.2%	466	1.26%
Spottail Shiner			145	131	276	2.8%	364	0.98%
Banded Killifish	207	10	5	5	227	2.3%	237	0.64%
Largemouth Bass	56	82	57	20	215	2.2%	255	0.69%
Bullhead Minnow				106	106	1.1%	362	0.98%
Emerald Shiner		3	13	66	82	0.8%	387	1.04%
Oriental Weatherfish	29	16		1	46	0.5%	90	0.24%
Channel Catfish	26	1		2	29	0.3%	52	0.14%
White Sucker		22	6		28	0.3%	32	<0.1%
Hybrid Sunfish	8	2	16	1	27	0.3%	88	0.24%
Golden Shiner	5	11	8	1	25	0.3%	81	0.22%
Blackstripe Topminnow	1	9	2	6	18	0.2%	261	0.70%
Orangespotted Sunfish	1	6	2	6	15	0.2%	1159	3.13%
Unidentified Catastomid			1	14	15	0.2%	15	<0.1%
Black Crappie		2	10	2	14	0.1%	22	<0.1%
Logperch			4	10	14	0.1%	14	<0.1%
White Crappie			7	4	11	0.1%	19	<0.1%
Unidentified Cyprinid				10	10	0.1%	10	<0.1%
Yellow Bass	2	5	3		10	0.1%	29	<0.1%
Rock Bass			6	1	7	0.1%	17	<0.1%
Goldfish	4		2		6	0.1%	14	<0.1%
Smallmouth Bass			4	2	6	0.1%	8	<0.1%
Tadpole Madtom		1	3	1	5	0.1%	83	0.22%
Black Bullhead			1	2	3	<0.1%	6	<0.1%
Johnny Darter				3	3	<0.1%	4	<0.1%
Shortnose Gar			1	2	3	<0.1%	6	<0.1%
Yellow Perch			3		3	<0.1%	6	<0.1%
Fathead Minnow				2	2	<0.1%	3	<0.1%
Grass Pickerel			2		2	<0.1%	2	<0.1%
Longnose Gar				2	2	<0.1%	4	<0.1%
Warmouth			1	1	2	<0.1%	18	<0.1%
White Perch	2				2	<0.1%	8	<0.1%
Brook Silverside				1	1	<0.1%	15	<0.1%
Central Mudminnow	1				1	<0.1%	1	<0.1%
Freshwater Drum			1		1	<0.1%	1	<0.1%
Longear Sunfish				1	1	<0.1%	7	<0.1%
Smallmouth Buffalo			1		1	<0.1%	1	<0.1%
Threadfin Shad			1		1	<0.1%	3	<0.1%
Unidentified Moronid				1	1	<0.1%	1	<0.1%
Unidentified Notropis				1	1	<0.1%	35	<0.1%
Mosquitofish							1670	4.51%

Response Actions in the CAWS

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, particularly rotenone actions, often are difficult due to 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 involved action agencies.

Objectives: The plan objectives are:

1) Remove Asian carp from the CAWS upstream of Lockport Lock and Power Station when warranted; and
2) Determine Asian carp population abundance through intense targeted sampling efforts at locations deemed likely to hold fish.

Methods: The tools utilized for response actions are conventional gears, experimental gears and/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 5-10 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 one 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 has 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. Intensive sampling over the past two years, including response actions triggered by detection of Asian carp DNA, has resulted in no Asian carp being observed or captured. 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 (e.g. temperature, conductivity, pH, etc.) 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 (i.e., fisheries biologist or field technician). A suggested response for Level 1 might include 2-4 electrofishing boats and crews and 1-2 commercial fishing boats and crews sampling for 2-3 days. A Level 2 threshold

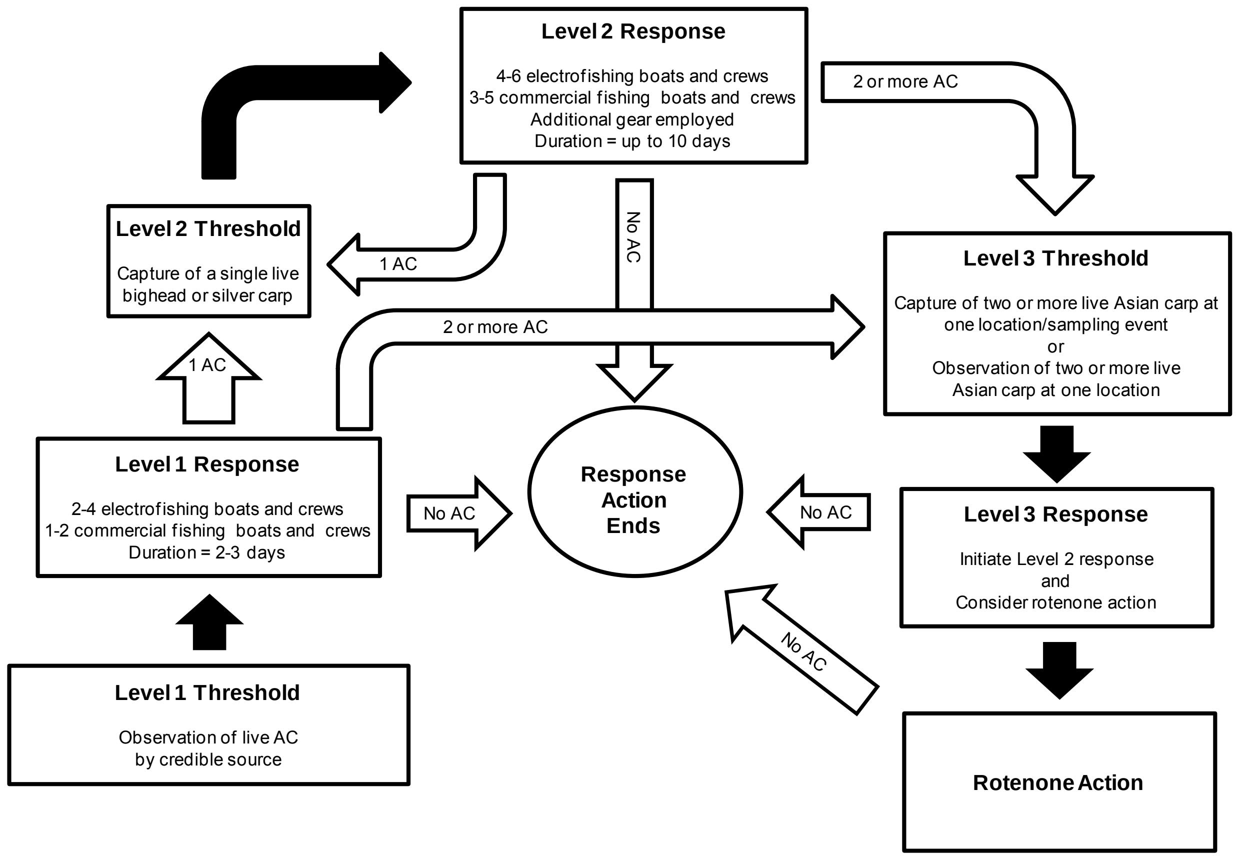

Figure 1. Thresholds for Asian carp (AC) response actions with conventional gears and rotenone.

would include the capture of a single live Bighead or Silver Carp. A Level 2 response might employ 4-6 electrofishing boats and crews, 3-5 commercial fishing boats and crews, and additional gears (e.g., 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 (e.g., non-navigation reaches, barge slips, 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 participating biologists, managers, and agency administrators.

Results and Discussion: In 2014 no "Response" actions were utilized in the CAWS based on the established thresholds put forth in the 2014 MRP. However two Seasonal Intensive Monitoring events were completed in the CAWS. Each of these events were 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 within 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, netting gear, etc.). Efforts were taken in in the last two 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 2014 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 456 samples along with 24 control samples were collected upstream of the dispersal barrier, filtered in the mobile lab, and analyzed at Whitney Genetics Lab. The June event had seven positive detections for Silver Carp and one positive detection for Bighead Carp. The October event had 23 positive detections for Silver Carp and zero positive detections for Bighead Carp. The "*Strategy for eDNA Monitoring*" section summarizes the events from 2014 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 2013 Planned Intensive Surveillance, 2014 Seasonal Intensive Monitoring events and previous Rapid 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 two week period in the spring and fall using conventional and experimental gears that have been utilized during previous years and events. Currently monitoring results demonstrate no fish captured in the Lockport and Brandon Road pool we feel that Asian carp abundance are either nonexistent or extremely low upstream of the electric dispersal barrier. With this two pools acting as a critical buffer, we propose adding Lockport and Brandon Road Pool areas to the response matrix. This will allow responses to be executed when the response criteria is met. Also we do recommend continued additional monitoring effort and fish sampling techniques be applied in Lockport, Brandon Road and Dresden Island pools to evaluate the potential risk of Asian carp breaching the electric dispersal barrier and develop a leading edge scenario of Asian carp invasion in the Upper Illinois Waterway and/or CAWS.

Project Highlights:

- Based on the criteria of the Rapid Response Matrix there were no rapid response actions utilized in the CAWS in 2014. Alternatively two Seasonal Intensive Monitoring (SIM) events were conducted in 2014 yielding no Bighead Carp or Silver Carp being captured or observed. Refer to the Seasonal Intensive Monitoring report for comprehensive results.

- 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.
- Estimated 11,330 person-hours were spent to complete 170 hours of electrofishing, set 80.8 km (50.2 mi) of trammel/gill net, treat approximately 4 km (2.5 mi) (70 ha (173 acres)) of river with rotenone, make seven-0.7 km (800 yd) long commercial seine hauls, and deploy six tandem trap nets, 10 hoop nets and two Great Lake pound nets equal to 52.8 net-days of effort.
- Across all response actions and gears, sampled over 137,875 fish representing 57 species and 2 hybrid groups.
- Sampled 398 state threatened Banded Killifish
- No Bighead Carp or Silver Carp were captured or observed during rapid response actions.
- We recommend continuation of the Seasonal Intensive Monitoring approach to evaluate the potential for Asian carp above the electric dispersal barrier in the Chicago Area Waterway.

Barrier Maintenance Fish Suppression

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

Introduction: The US Army Corps of Engineers operates three electric aquatic invasive species dispersal barriers (Demonstration Barrier, 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 online in April 2011. Both Barrier 2A and 2B can operate at parameters shown to repel or stun juvenile and adult fish greater than 137 mm long at a setting of 0.79 volts per centimeter or fish greater than 63 mm long at a setting of 0.91 volts per centimeter (Holliman 2011). The higher setting has been in use since October 2011.

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/or clearing operations at the barrier site. Fish suppression can vary widely in scope and may include application of a piscicide such as rotenone to keep fish from moving upstream past the barriers when they are down. Rotenone was used December 2009 in support of Barrier 2A maintenance, before Barrier 2B was constructed. With Barrier 2A and 2B now operational, fish suppression actions will be smaller in scope because one barrier can remain on while the other is taken down for maintenance.

Barrier 2B operated as the principal barrier from the time it was brought on line and tested in April 2011 through December 2013. During that time, Barrier 2A was held in warm standby mode (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 system. 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 in total length between Barrier 2A and 2B before maintenance operations are initiated at 2B or after maintenance is completed at 2A by collecting or driving fish into nets or 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; and
2) Assess the success of fish clearing operations by surveying the area between Barrier 2A and 2B with remote sensing gear (split-beam hydroacoustics and side-scan sonar). Success is defined as no fish >300 mm in total length 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.

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. At the occurrence of any barrier outage, the MRWG was notified as soon as possible by the USACE and convened with key agency contacts to discuss the need for a barrier clearing action. The decision to perform a clearing action based on a barrier outage was based on factors related to the likelihood of Asian carp passing the barrier, under the conservative assumption that they may be present in Lockport Pool and near or at the barriers. There has been no evidence of live Asian carp near the barriers. The MRWG currently expects only juvenile or adult fish (> 300 mm) to be to be the size most capable of reaching that area. 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, the MRWG believes that either the wide or narrow array of each Barrier provides a minimally effective short-term barrier for juveniles or adults. Thus, the MRWG views a total outage of both wide and narrow arrays as a situation of increased risk for Asian carp passing a given barrier. The MRWG decision to initiate a clearing action at the barriers was made only during heightened risk of Asian carp passage based on the most up to date monitoring results and current research.

A cut-off of 300 mm in total length was selected for fishes to be removed from the barriers area when a clearing action was recommended by the MRWG. By selecting a cut-off of 300 mm, sub adult and adult Asian carp were targeted and young-of-year fish were excluded. Excluding young-of-year Asian carp from the assessment was based on over three 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. Additionally, eggs, larvae, or young-of-year have not been observed upstream of Starved Rock Lock and Dam in nearly a decade.

A key factor to any response is risk of Asian carp being near 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.

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 2A and 2B 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 affected barriers. Initial response (remote sensing) should occur within a week of an outage; upon completion of this survey, 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 US Coast Guard (USCG) closures of the Canal/Waterway. The USCG generally requires at least 45 days notice for requests to restrict navigation traffic in the waterway.

Results and Discussion:

During 2014 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 hr; max=239 hrs; avg=53.2 hrs) a total of 11 times (Table 1). Barrier 2B was operational during each of 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 of fish moving 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 due to 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 which supported the conclusion that Asian carp were likely not in the vicinity of the barriers during the reported losses of power. Safety and fishing gear availability were additional factors in the decision to not perform clearing actions. Extreme cold temperatures or abnormally high flow within the canal restrained 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 15 January 2014. The results from that scan in combination with known seasonal movement patterns and water temperatures precluded the need for further clearing actions. There were two occasions in which an electrofishing response team was deployed in an attempt to capture fish that may have moved upstream during a Barrier 2A loss of power in water. One USACE boat with three crew members performed surface electrofishing with pulsed-DC power between Barrier 2A and the Demonstration Barrier on 27 May and between Barriers 2A and 2B on 9 June. No Asian carp were captured or observed during each clearing event. A combined total of 34 naturalized or native fish from eight species were collected during both events (Table 2) which ranged in size from 41 to 786 mm in total length. 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.

Table 1: Loss of power to the water at the primary active Barrier 2A in 2014; the secondary Barrier 2B was in full operation at each of the time and dates listed below.

Barrier	Date	Off Time (hours)
2a	1-5 Jan	108
2A	29-Mar	7
2A	2-Apr	4
2A	29-Apr	4.25
2A	6-May	3
2A	12-20 May	200
2A	29 May - 8 June	239
2A	19-Jun	13
2A	8-Sep	3
2A	10-Sep	3
2A	11-Nov	1

Table 2: Fish captured during pulsed-DC electrofishing sampling between the barriers on 27 May and 9 June 2014 in response to Barrier 2A loss of power in water.

Sampling Date	Species - Common Name	Scientific Name	Total Length (mm)	Sample location
27-May-14	Common Carp	Cyprinus carpio	786	Between 2A and Demo
27-May-14	Common Carp	Cyprinus carpio	579	Between 2A and Demo
27-May-14	Common Carp	Cyprinus carpio	495	Between 2A and Demo
27-May-14	Common Carp	Cyprinus carpio	548	Between 2A and Demo
27-May-14	Common Carp	Cyprinus carpio	482	Between 2A and Demo
27-May-14	Common Carp	Cyprinus carpio	476	Between 2A and Demo
27-May-14	Common Carp	Cyprinus carpio	573	Between 2A and Demo
27-May-14	Common Carp	Cyprinus carpio	626	Between 2A and Demo
27-May-14	Bluegill	Lepomis macrochirus	112	Between 2A and Demo
27-May-14	Coho Salmon	Oncorhynchus kisutch	152	Between 2A and Demo
9-Jun-14	Green Sunfish	Lepomis cyanellus	90	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	65	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	59	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	58	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	60	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	72	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	50	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	57	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	41	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	53	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	54	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	55	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	52	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	57	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	57	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	52	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	58	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	53	Between 2A and 2B
9-Jun-14	Bluntnose Minnow	Pimephales notatus	61	Between 2A and 2B
9-Jun-14	Fathead Minnow	Pimephales promelas	41	Between 2A and 2B
9-Jun-14	Fathead Minnow	Pimephales promelas	60	Between 2A and 2B
9-Jun-14	Spotfin Shiner	Cyprinella spiloptera	71	Between 2A and 2B
9-Jun-14	Spotfin Shiner	Cyprinella spiloptera	62	Between 2A and 2B
9-Jun-14	Banded Killifish	Fundulus diaphanus	62	Between 2A and 2B

Recommendations:

The MRWG agency representatives should continue to assess the risk of Asian carp presence for each loss of power in the water at the primary downstream barrier. The group should take into consideration the most recent downstream monitoring data, known locations of Asian carp (adults and juveniles) and other biotic and abiotic factors relative to Asian carp movement and dispersal patterns. This summary also recommends continued use of hydroacoustics to survey in between the Demonstration Barrier and Barrier 2A for fish greater than 300 mm in total length (12 inches) as a primary means of identifying risk for potential Asian carp presence prior to any other clearing action. Clearing actions that address removal of fish from between the barriers should include surface, pulsed DC-electrofishing and noise scaring tactics (tipped up motors, push plungers, hull banging, etc). Deep water gill net sets and other submerged bottom deployed gears are not recommended for further use between the barriers as a removal action due to safety concerns for personnel. Additionally, this summary recommends continued research and deployment of novel fish driving and removal technologies such as water cannons, low dose piscicides, complex noise generation, etc.

Project Highlights:

2014 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 two clearing actions on 27 May and 9 June 2014.
- A total of 34 fish from 8 species were removed using pulsed DC-electrofishing, with 8 fish > 12 inches in length.
- Split-beam hydroacoustics and side-scan sonar assessed the risk of large fish presence between the barriers on 15 January which precluded the need for further clearing actions.
- **No Asian carp were captured or observed during fish suppression operations**

Barrier Defense Asian Carp Removal Project

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Illinois Department of Natural Resources

Participating agencies: Illinois Department of Natural Resources – Division of Fisheries (lead).

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 towards the electric dispersal barriers and reduced chances of carp gaining 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, utilizing ten contracted commercial fishing crews to remove Asian carp primarily with large mesh (3.0 - 5.0 inch, 76.2mm-127mm) gill nets and trammel nets, however, with the program identifying efficiencies additional gears are being fished such as commercial seines and modified hoop 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.

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 respectively (Figure1). 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-September 2010, April-December 2011, March-December 2012, March-December 2013 and March-December 2014. 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. Due to fishing pressure 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 in 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 – 5.0 inch, 76.2-127mm) gill and trammel nets were typically used and set 20-30 minutes with fish being driven towards nets by the commercial fishing boats with noise (e.g., pounding on boat hulls, hitting the water surface with plungers, running with motors tipped up). Occasionally nets were set overnight off the main channel, and non-public backwaters with no boat traffic. In 2014, hoop nets (2.0-8.0 feet, 0.60m -2.44m in diameter) and commercial seines, 300-800 yards, 0.27-0.73km, in length, were used in addition to the gill and trammel nets. Biologists on board identified, enumerated and recorded Asian carp and by-catch to species. Asian carp and common carp were checked for ultrasonic tags, these fish along with all by catch were returned live. Harvested Asian carp were transferred to a refrigerated truck and trucked to a processing plant and utilized for non-consumptive purposes (e.g., converted to liquid fertilizer). During each harvest event a representative sample of 30 Bighead, Silver, and Grass Carp from each pool was 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, and 7,312.5 person-hours in 2014 have been spent netting Asian carp during barrier defense removal efforts. A total of 1,359.2 miles (2186.9km) of gill/trammel net, 3.1 miles (5.0km) of commercial seine and 196 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 2010-2014 was 2,987,880 pounds or 1493.94 tons (Table 1). Silver Carp, Bighead Carp, and Grass Carp accounted for 55.8%, 43.8%, and 0.4% of the total tons harvested since 2010 respectively.

The combined catch of Asian carp (Bighead, Silver, and Grass Carp) since 2010 was 263,631 (Table 1). Bighead Carp accounted for 82.0% of all Asian carp harvested in 2010, 56.3% in 2011, 39.4% in 2012, 20.1% in 2013, and 11.5% in 2014. Silver Carp accounted for 17.7% of all Asian carp harvested in 2010, 43.4% in 2011, 63.0% in 2012, 79.4% in 2013, and 88.0% in 2014. Grass Carp accounted for 0.3% of all Asian carp harvested in 2010, 0.4% in 2011, 0.6% in 2012, 0.5% in 2013 and 0.5% in 2014. The total harvest of Asian carp 2010-2014 consisted of 72.5% Silver Carp, 26.9% Bighead Carp, and 0.6% Grass Carp.

The annual gill/trammel catch per unit effort for Asian carp (CPUE *N*/1000 yards of net) of all pools combined was higher in 2014 (121.7) than in 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 –

<u>Dresden Island Pool:</u>

The Dresden Island pool was only fished during the months of July and December in 2014 because of changes in to the Barrier Defense Asian carp Removal plan for 2014(See 2014 Monitoring and Response Plan). In July, Rock Run Rockery, an 83 acre backwater located at river mile 278, was fished and 28 Bighead Carp were removed. In December commercial fishing in the Dresden Island pool main stem yielded two Bighead Carp and eight Silver Carp. A total of 15,900 yards (14.5km) of gill/trammel net were deployed in 2014 (Table 1). Results from monthly gill/trammel netting CPUE for Asian carp captured in the Dresden Island pool from 2011 -2014 can be found in Figure 3.

<u>Marseilles Pool:</u>

Commercial fisherman removed Asian carp in the Marseilles pool from March through early December in 2014. A total of 359,800 yards (329km) of gill/trammel net and 1.1 miles (1.8km) of commercial seine were deployed in 2014. A total of 27,516 Silver Carp, 7,549 Bighead Carp, and 108 Grass Carp were harvested in 2014 (Table 1). The commercial seine hauls yielded 4,393 Silver Carp and 726 Bighead Carp. Silver Carp dominated the catch (78.2%) in 2014 and 2013 (58.5%). In previous years Bighead Carp was the dominate species caught in the Marseilles pool. The annual CPUE of Asian carp from gill/trammel nets in the Marseilles Pool was an all time high in 2014 of 83.2 Asian carp per 1000 yards. The increase in the annual CPUE can be attributed to the boost in Silver Carp catches in 2014. Monthly gill/trammel CPUE for Asian carp captured in the Marseilles pool from 2011-2014 can be found in Figure 4.

<u>Starved Rock Pool:</u>

Commercial fisherman removed Asian carp in the Starved Rock Pool March through December in 2014. A total of 184,600 yards (146.5km) of gill/trammel net were deployed in 2014 also hoop nets were utilized to assist catching fish during periods of high flow. Additionally one 300 yard (0.3km) commercial seine haul was made in the Starved Rock pool. A total of 67,768 Asian carp were harvested in 2014, an increase of 40.4% from 2013 (Table 1). Hoop nets accounted for 5,792 Silver Carp and 196 Bighead Carp, while the commercial seine haul accounted for 21,763 Silver Carp and 9 Bighead Carp. Silver Carp were the dominate species harvested in 2014 (93.2%) (N=63,132) (Table 1). Annual gill/trammel CPUE of Asian carp increased from 174.4 Asian carp per 1000 yards in 2011 to 221.9 Asian carp per 1000 yards of net in 2012 and 246.19 Asian carp per 1000 yards of net in 2013 and then decreased in 2014 to 205.6 Asian carp per 1000 yards of net. Monthly gill/trammel CPUE for Asian carp captured in the Starved Rock pool from 2011-2014 can be found in Figure 5.

Catch of By-Catch Species –

Gill and Trammel nets:
A total of 95,268 fish representing 33 species and 1 hybrid groups were caught in gill\trammel nets during the 2014 Asian carp removal effort (Table 2). Asian carp (Bighead, Silver, and Grass Carp) made up 71.2% of the catch while *Ictiobus* spp. (Bigmouth Buffalo, Smallmouth Buffalo, and Black Buffalo) along with Common Carp made up an additional 25.6% of the total catch. A total of 842 fish from 11 species and 1 hybrid species made up the game fish species captured in 2014. Game fish represented 0.9 % of the total catch in 2014, similar to 2013 when game fish represented 1.1%. Similar to previous years Flathead and Channel Catfish were the most dominate game fish captured in 2014 accounting for 87.6 % of the game fish captured.
Hoop Nets:
A total of 7,541 fish representing 15 species and 1 hybrid groups were caught in hoop nets in 2014. Asian carp (Bighead, Silver, and Grass Carp) made up 71.2% of the catch while *Ictiobus* spp. (Bigmouth Buffalo, Smallmouth Buffalo, and Black Buffalo) and Common Carp made up an additional 9% of the total catch. A total of 542 fish from 5 species made up the total game fish species captured in 2014. Game fish represented 7.2 % of the total catch in 2014 with Flathead and Channel Catfish being the most dominate game fish captured accounting for 98.3 %.
Commercial Seine:
No by-catch data was enumerated in 2014 to reduce mortality on non-target species present in the seine. Species were noted in gear comments. By observation, Smallmouth Buffalo were the most common species captured during all three seine hauls in 2014.

Recommendations: We recommend continued Asian carp removal in the upper Illinois Waterway to reduce carp abundance at and near the detectable population front and prevent further upstream movement by 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. Additional multi-seasonal 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 determining 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 carp population densities and patterns of immigration and emigration at the population front.

Project Highlights:

- Contracted commercial fishers deployed 1359.2 miles(2186.9km) of gill/trammel net, 3.1 miles (5.0km) of commercial seine, and 196 hoop nets set in the upper Illinois Waterway from 2010- 2014.
- A total of 70,882 Bighead Carp, 191,031 Silver Carp, and 1,718 Grass Carp were removed by contracted commercial fisherman from 2010-2014. The total weight of Asian carp removed was 1493.94 tons

- Recommend continued targeted harvest of Asian carp in the upper Illinois Waterway with contracted commercial fishers and assisting IDNR biologists. Potential benefits include reduced 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.

Figure 1: Location of Dresden, Marseilles and Starved Rock pools on the Illinois River. Red line indicates location of the Electric Dispersal Barriers

Table 1: Asian Carp removal effort and harvest of Asian carps from Dresden, Marseilles and Starved Rock pools during 2010-2014 using contracted commercial fisherman.

	Effort					Harvest							
Year and river Pool	Net Sets (*N*)	Miles of Net	Seine Hauls (*N*)	Miles of Seine	Hoop net Sets (*N*)	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
2010-2014													
Dresden Island	478	112	0	0		1,350	125	30	1,505	15	1	0	16
Marseilles	3,682	940	7	2.9		54,162	58,100	577	112,839	552	292	3	847
Starved Rock	936	307	1	0	196	15,370	132,806	1,111	149,287	88	540	3	631
All pools	5,096	1359.2	8	3.1	196.0	70,882	191,031	1,718	263,631	654.99	832.82	6.14	1493.94

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 -2014. All Species other than Asian carp and Common Carp were returned to the River immediately after capture.

	2011		2012		2013		2014	
Species	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%
Silver Carp	17776	33.59%	28632	49.03%	46597	62.01%	57302	60.15%
Smallmouth Buffalo	3853	7.28%	3749	6.42%	7397	9.84%	12717	13.35%
Bigmouth Buffalo	3850	7.27%	5043	8.64%	3567	4.75%	4670	4.90%
Common Carp	2574	4.86%	2386	4.09%	2685	3.57%	6699	7.03%
Freshwater Drum	573	1.08%	689	1.18%	1055	1.40%	1091	1.15%
Flathead Catfish	313	0.59%	299	0.51%	417	0.55%	301	0.32%
Channel Catfish	201	0.38%	137	0.23%	321	0.43%	430	0.45%
Black Buffalo	188	0.36%	262	0.45%	432	0.57%	318	0.33%
Grass Carp	171	0.32%	299	0.51%	303	0.40%	524	0.55%
Paddlefish	78	0.15%	51	0.09%	37	0.05%	37	0.04%
River Carpsucker	61	0.12%	26	0.04%	105	0.14%	229	0.24%
Quillback	37	0.07%	46	0.08%	49	0.07%	84	0.09%
Largemouth Bass	28	0.05%	22	0.04%	28	0.04%	26	0.03%
Sauger	19	0.04%	31	0.05%	12	0.02%	11	0.01%
Shortnose Gar	16	0.03%	37	0.06%	44	0.06%	13	0.01%
White Bass	13	0.02%	11	0.02%	40	0.05%	23	0.02%
Longnose Gar	11	0.02%	25	0.04%	68	0.09%	91	0.10%
Walleye	9	0.02%	12	0.02%	7	0.01%	5	0.01%
Skipjack Herring	9	0.02%	14	0.02%			6	0.01%
Blue Catfish	8	0.02%	7	0.01%	8	0.01%	2	< 0.01%
Gizzard Shad	6	0.01%	22	0.04%	5	0.01%	3	< 0.01%
Yellow Bass	3	0.01%	5	0.01%	9	0.01%	9	0.01%
Hybrid Striped Bass	2	< 0.01%	7	0.01%	2	< 0.01%	5	0.01%
Spotted Gar	1	< 0.01%						
White Crappie	1	< 0.01%	2	< 0.01%	1	< 0.01%	4	< 0.01%
Bluegill			1	< 0.01%			1	< 0.01%
Black Crappie	1	< 0.01%	1	< 0.01%	2	< 0.01%	4	< 0.01%
Shorthead Redhorse		< 0.01%	1	< 0.01%			4	< 0.01%
Golden Redhorse			2	< 0.01%	6	0.01%	30	0.03%
River Redhorse	1	< 0.01%					1	< 0.01%
Rock Bass			1	< 0.01%				
Muskellunge	1	< 0.01%			2	< 0.01%	1	< 0.01%
Northern Pike	1	< 0.01%	1	< 0.01%	2	< 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%
Goldeye	1	< 0.01%						
Goldfish					20	0.03%		
Unidentified Buffalo Species					137	0.18%		
White Perch					1	< 0.01%		
Bowfin					4	0.01%		
Silver Redhorse							1	< 0.01%
Blue Sucker					1	< 0.01%		
Total all Species	52924		58391		75146		95268	

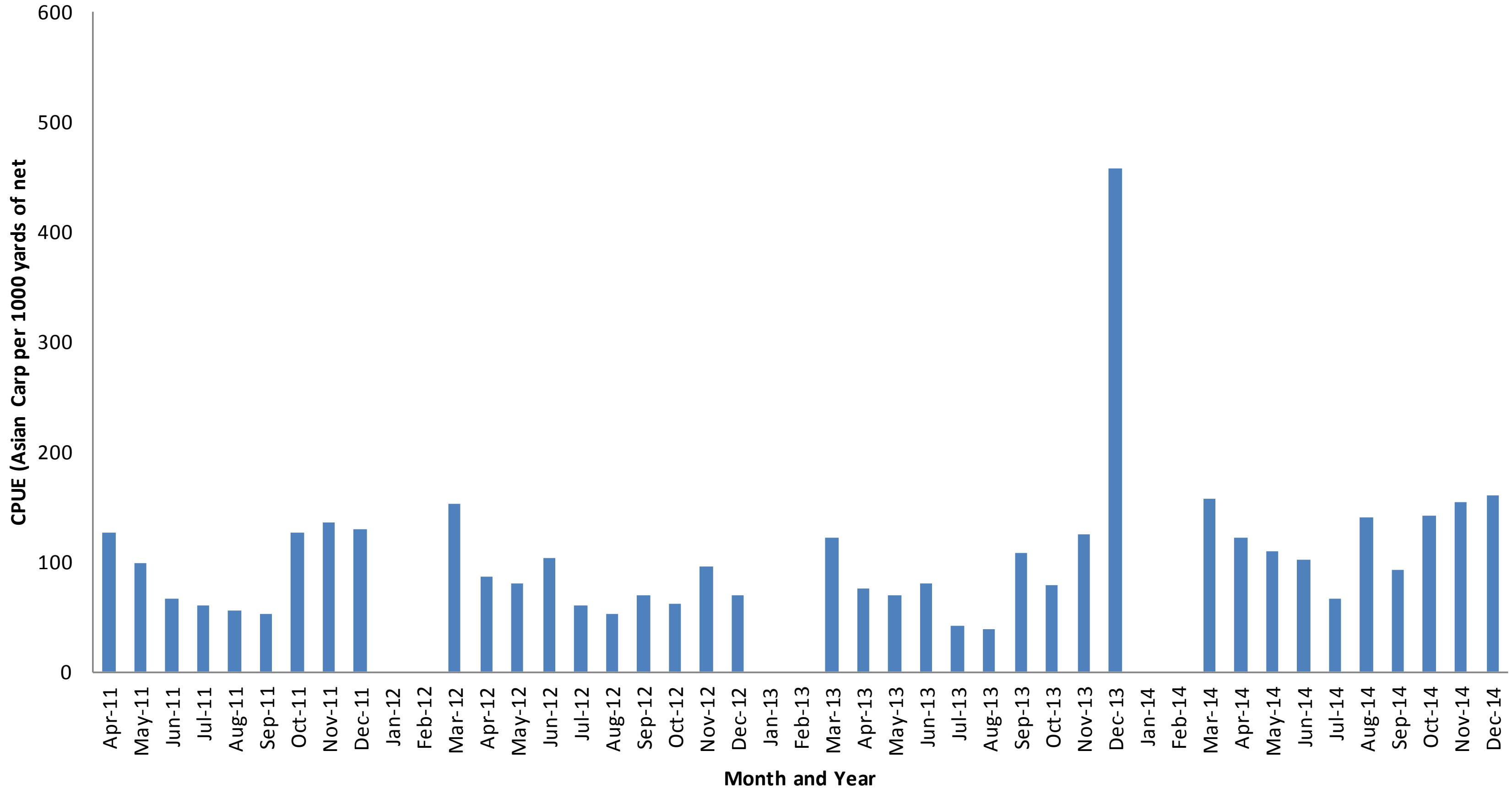

Figure 2: Monthly Catch per unit effort (CPUE; Asian carp/1000 yards of gill/trammel net) for all pools combined in 2011- 2014.

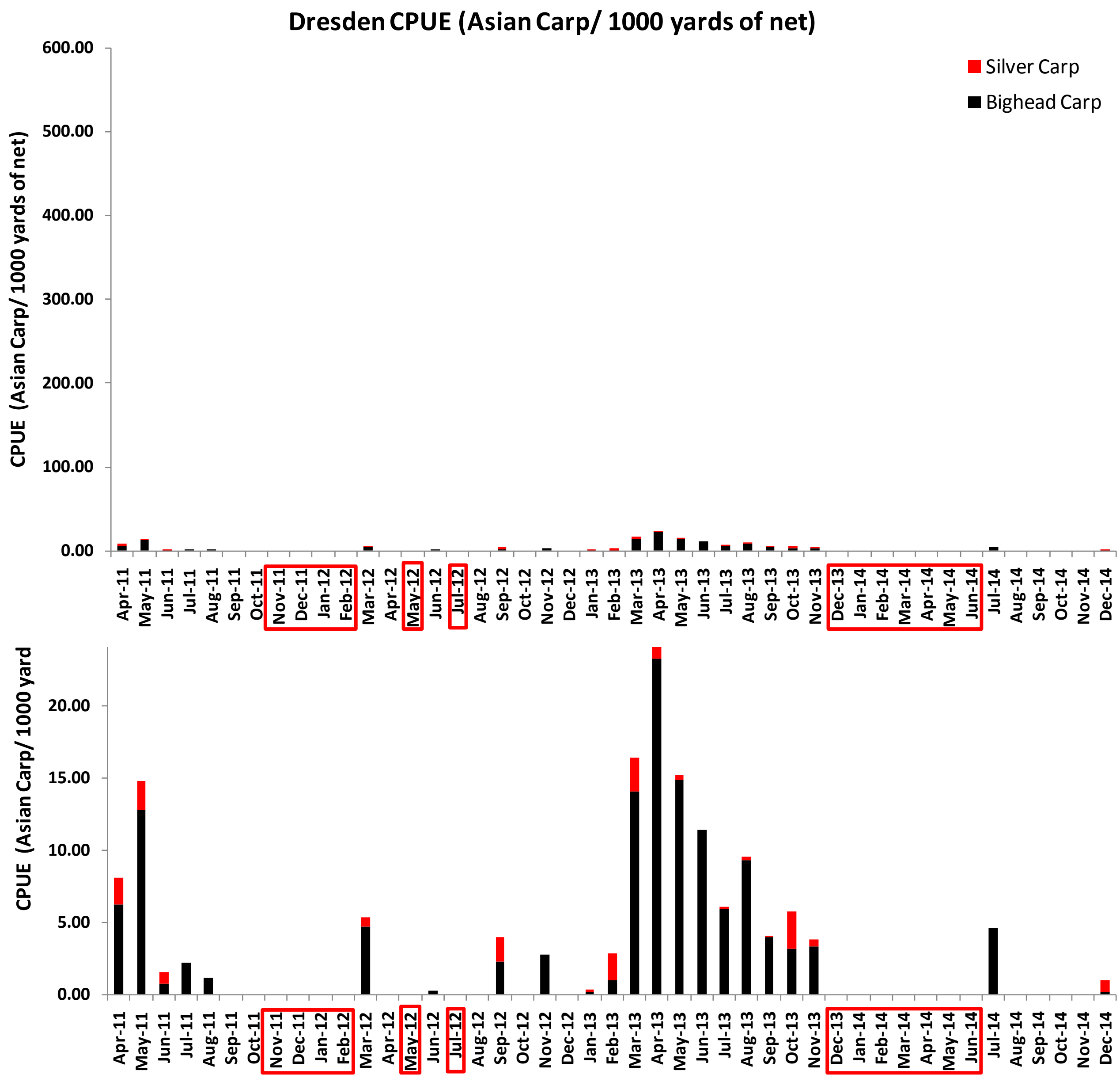

Figure 3: Monthly Asian carp gill/trammel netting CPUE for the Dresden Island pool. Red boxed months are months in which no fishing took place. Upper graph is on a 600 scale for comparison to Figure 4 and 5.

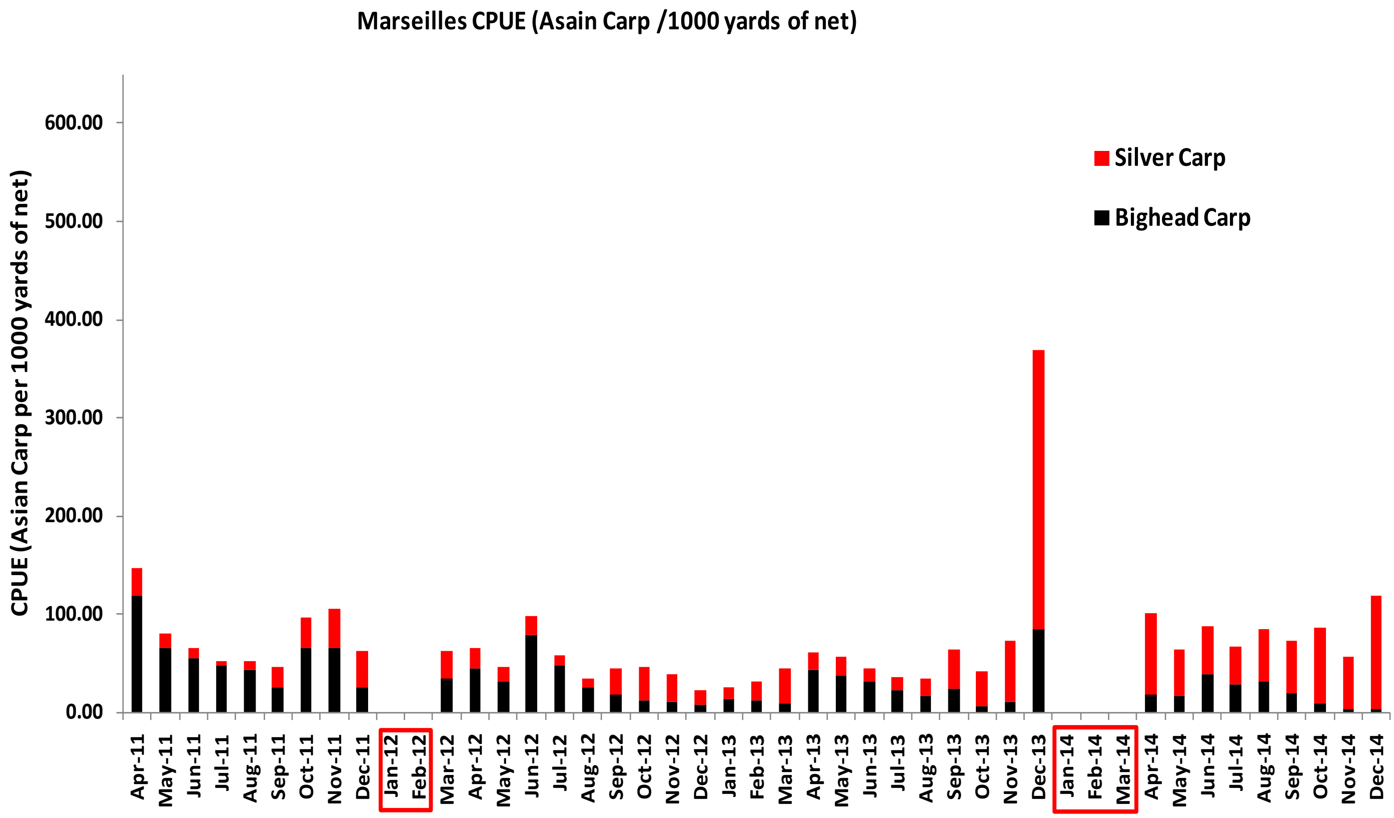

Figure 4: Monthly Asian carp gill/trammel netting CPUE for the Marseilles pool. Red boxed months are months in which no fishing took place.

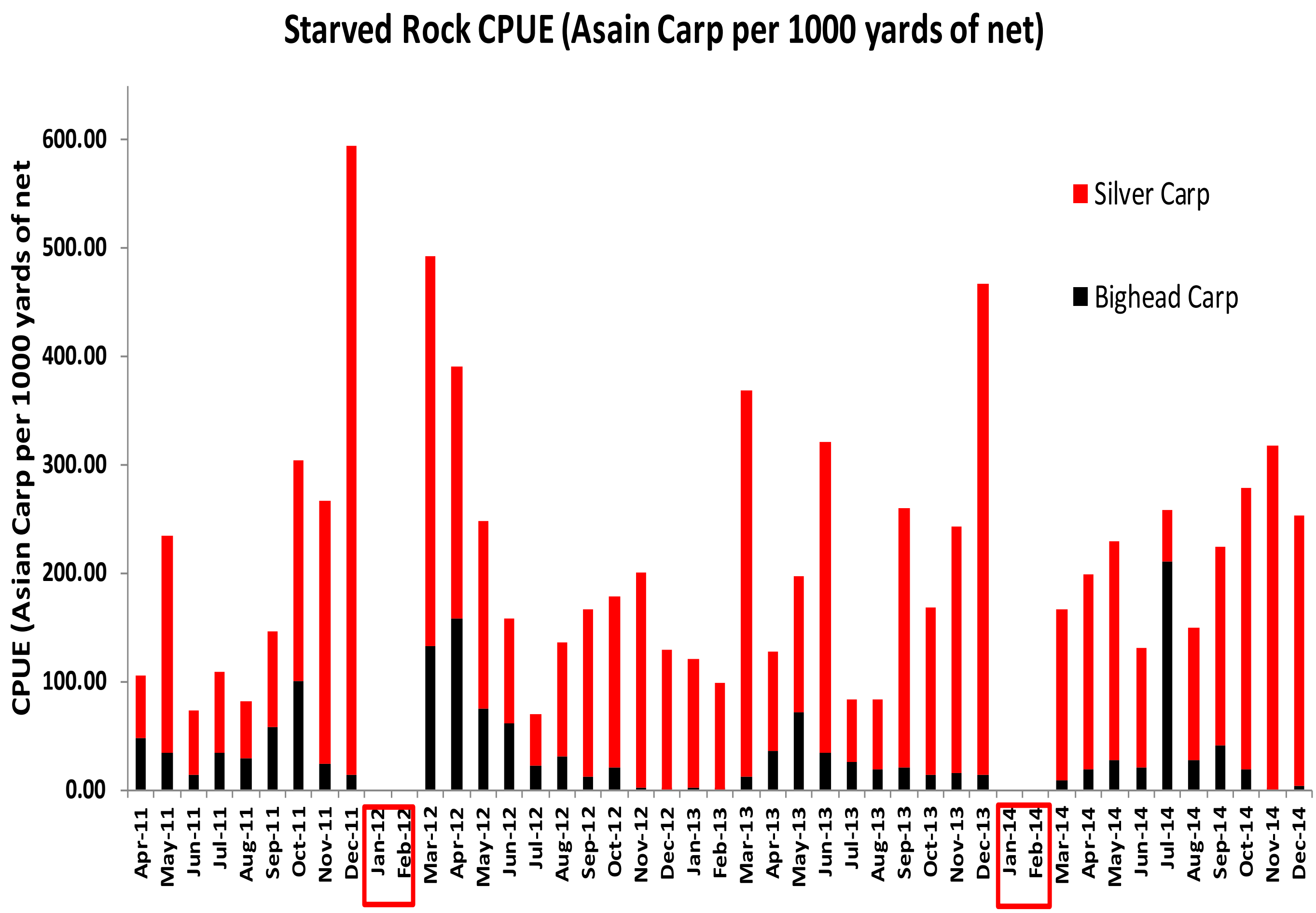

Figure 5: Monthly Asian carp gill/trammel netting CPUE for the Starved Rock pool. Red boxed months are months in which no fishing took place.

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

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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).

Project Goal: Evaluate 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 Chicago Area Waterway System. 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 and Need: Silver Carp, Bighead carp, and their hybrids invaded the Illinois River at least 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 Chicago Area Waterway System (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 reach of the Illinois River, approximately 55 miles from Lake Michigan. Our research efforts have focused on monitoring the population dynamics of these invasive species throughout the Illinois River since 2010.

In the lower Illinois River, commercial harvest of Asian carp is occurring, while contracted control fishing is ongoing (since 2010) above Starved Rock Lock and Dam (i.e. the upper Illinois River). These factors affect population dynamics, patterns of movement, and the risk of Asian carp establishing 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.

Methods and Materials: 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 four fixed locations within each of the three lower reaches, as well as nearby backwater areas (e.g., backwater lake, side channel, or tributary) from August 4–13, 2014 (Chapter 1, Table 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 ratio, and molecular identification (i.e., species or interspecies), were determined.

Acoustics (Chapter 2). In the fall of 2012, 2013 and 2014, 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 (Chapter 1) and commercial fishing data to determine length-specific proportional abundance of Asian carp to other fishes. Reach-specific length-weight regressions were determined 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. In addition, repeat hydroacoustic surveys of specific locations were conducted periodically throughout summer 2014. During all surveys, side-scan sonar was used in conjunction with split-beam hydroacoustic gear to provide additional coverage and help pinpoint fish aggregations in real-time, to assist targeted commercial removal.

Movement (Chapter 3). Since 2012, with assistance from IDNR-contracted commercial fishermen and Illinois Natural History Survey (INHS), 965 acoustic transmitters have been implanted in Asian carp in the Illinois River or Pool 26 of the Mississippi River. In addition, 300 carp were tagged in pool 26 of the Mississippi River in 2010 to determine immigration to the Illinois River. In 2014, 256 Asian carp were implanted with acoustic transmitters (2013 N = 337; 2012 N = 372). A network of 39 Vemco® VR2W receivers has been deployed and monitored in the Illinois River by SIUC since 2012 to monitor movement of acoustically tagged Asian carp. VR2Ws are downloaded every 2-4 months to record fish detections. Receivers have been placed in and around each lock chamber and near major tributaries to track large-scale movements within and among reaches, though five receivers have now been specifically placed within the HMS pits to better understand the factors affecting Asian carp immigration and emigration within this area. Average daily temperature and river discharge are continuously monitored to correlate with fish movement.

Spatially explicit population model (Chapter 4). A simulation modeling approach will be used to evaluate the efficacy of harvest to minimize the propagule pressure on the electric dispersal barrier located in the Chicago Sanitary and Ship Canal. Reach-specific Asian carp demographic parameters (i.e., abundance, age and size distribution, growth, survival, condition, maturation schedule, stock-recruitment relationships) along with their variability and uncertainty will be estimated using Bayesian methods via JAGS. We will use this information to develop 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, we will use the newly developed model to predict the number of Asian carp that would be expected to reach the electric dispersal barrier under various harvest scenarios.

Results and Discussion (See Appendix for chapters and additional details):

Demographics in the Illinois River (Chapter 1). Catch per unit effort (CPUE) estimates in late summer 2014 suggest that relative abundance of Silver Carp has increased to levels comparable with 2011 (Chapter 1, Fig.1). Silver Carp CPUE was highest in Peoria reach: this may be due to the large amount of shallow-water areas and higher catch rates rather than actual density in this reach. Catch per unit effort can vary with environmental conditions, fish behavior, fishing activity, and many other factors. Split-beam and side-scan hydroacoustic estimates will likely provide a more consistent indicator of population status for the lower three reaches, which we anticipate becoming available in the coming year. A total of 380 age-0 Asian Carp were collected in 2014, indicating significant recruitment occurred in the Illinois River-a strong 2014 year class can be anticipated in coming years. In 2014, Silver Carp recruited in 2009 represented the predominant year-class (aside from YOY). Silver carp condition and GSI were generally higher in 2014. The results of genetic testing in 2013 revealed that ‘pure’ silver carp and bighead carp comprised 31.3% and 28.8% of those examined; the remainder of fish caught were hybrids of various backcross combinations (Chapter 1, Table 5). Caudal fin clips were obtained from 320 fish in 2014 and are currently being processed at Western Illinois University for identification of Bighead Carp, Silver Carp, and hybrids.

Acoustics (Chapter 2). Initial hydroacoustic surveys during 2010 through 2011 in main channel habitat have been expanded since 2012 to include side-looking split-beam and side-scan sonar techniques in both main channel and backwater habitats. Three years of annual repeat surveys throughout the Illinois River have now been undertaken. Analysis completed to date for the three upper reaches in 2012 and 2013 has confirmed the high biomass of Asian carp in these reaches relative to native fishes (i.e., accounting for 43.8–65.5% of the fish community biomass). Between year comparisons (2012 vs. 2013), however, suggests that the Asian Carp population may be responding to commercial fishing; mean Asian Carp density has decreased by 32.5–54.8% (abundance) and by 53.5–60.6% (biomass) (Chapter 3, Fig. 1 & 2), and size structure shifts generally indicate fish were smaller in 2013 (Chapter 3, Fig. 3–5). Additional data from 2014, including new survey locations and repeat surveys, as well as the incorporation of complementary project components such as telemetry (Chapter 3), will bolster our capacity to infer the Asian carp population response and inform future control strategies.

Movement (Chapter 3). Fish detections in lock and dams during 2014 were generally higher than in 2013, and more downstream movement was observed. We tagged additional fish in the lower river last year, accounting for some of the change in patterns. Fourteen fish attempted to pass through the Dresden Island Lock and Dam. We were only able to confirm that two of those fish succeeded in passage downstream (late July and late August). Eight fish were detected by the receiver in the Marseilles lock chamber. Two fish likely passed upstream on 11 and 19 May 2014 and two passed downstream on 2 April and 15 May 2014. Thirteen fish were detected in the Starved Rock lock chamber, with five making successful downstream passages. A total of 14 fish moved through the Peoria lock chamber, while 18 made it through the La Grange lock chamber. The updated (as of 2014) redetection rate of fish tagged in 2012 was 32.6%, 73.1% for fish tagged in 2013, and 8.3% for fish tagged in 2014.

Definite separation patterns between the lower and upper river (at Starved Rock Lock and Dam) were observed in 2014. Fish tended to move as far as the Peoria pool, and then return back downstream. Movement in the upper river tended to be in the downstream direction through the Marseilles lock in 2014 and into and out of the HMS pits. In addition, fish tended to spend longer periods of time moving upstream or downstream in the upper river; whereas, fish in the lower river moved long distances in shorter periods of time (less time detected at each receiver). Still, no fish that were tagged below Starved Rock Lock and Dam have ever been detected moving upstream through that lock chamber. Although we are currently working at discerning what variables account for these differences in movement patters, we recommend additional fish be tagged (both with jaw tags and acoustic transmitters) near this area (especially in the upper Peoria pool) to determine when and where (e.g., chamber or gates) fish are passing.

Movement within the HMS pits and between the HMS pits and the main channel were also analyzed for 2014. Similar to 2013, increased movement occurred out of the HMS pits (corresponding with low commercial CPUE) in mid-May when temperatures reached 18^{o}C and river discharge spiked. Fish movement into and out of the HMS pits was not as pronounced in 2014 as in other years. Fish may have spent more time in the main channel due to elevated river discharge over a longer portion of the year. Movement between the east HMS pit and the west HMS pit was greatest in April, although a large block net was in place between the east and west pits for much of the summer, and we were unable to determine movement during that time period.

Spatially explicit population model (Chapter 4). A flexible, Asian carp age-structured dynamic simulation model has been coded using the program R that forecasts abundance in each of the seven pools of the Illinois River over a 25 year period. Sub-routine models (e.g., growth, movement, annual survival, spawner-recruit) are under development as additional data is being accumulated from various sources. As such, we sought to capture the general structure of the model and code it in such a way that updated parameter estimates and sub-routines can be added later as they become available. Also during 2014 we developed stock-recruit relationships for Silver and Bighead carp using catch per unit effort data from the LTRMP using similar methodology as Hoff et al. (2011). Catchability between adults and recruits are highly likely to be different and further, the spawner-recruit relationships proved to be highly variable. These concerns lead us to explore alternatives to a simple spawner-recruit relationship. Given that there are several plausible approaches for estimating a stock-recruitment relationship for Asian carp, we will likely conduct and present harvest simulations using various stock-recruitment relationships to determine how they vary.

Major Finding and Recommendation: Asian Carp abundance appears to have increased in 2014, particularly in the La Grange reach, and successful recruitment was also apparent. However, analysis is ongoing, and the additional hydroacoustic and telemetry data collected in 2014 will enable us to more accurately determine the population status, and ultimately parameterize the population model. Initial results in the upper River are positive, hence continued contract harvest (above Starved Rock Lock and Dam) plus intensive commercial harvest in the lower Illinois River may reduce density, potential recruitment, and perhaps immigration of Asian carp and their hybrids toward the electric dispersal barrier in Lockport Pool.

Chapter 1:

Standardized sampling on the lower Illinois River

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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 (i.e. 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 towards the Chicago Area Waterway System (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, we assess the population dynamics of Asian carp in main channel and backwater areas of the lower Illinois River.

Objectives: SIUC will carry out 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, in terms of changes in relative abundance, growth, condition, sex ratios, hybridization, and indices of spawning condition.
2) Provide length-specific proportions of Asian carp relative to other species, for incorporation into hydroacoustic estimates of density and size structure.

Materials and Methods

Fish collection

Standardized fish sampling was conducted 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 (e.g., backwater lake, side channel, or tributary) between 4–13 August, 2014 (Table 1.1). A fifteen minute pulsed-DC electrofishing transect (Smith-Root GPP 5.0 electrofisher), with two netters, was conducted along each main channel and backwater site during the day at a power goal of 3,000 W based on conductivity and temperature (Burkhardt and Gutreuter 1995). Within each backwater and main channel site, a transect was conducted parallel to the shoreline, with the driver maintaining a constant speed such that an area approximately 200m x 30m was covered in the allotted 15 minutes, as per the Long Term Resource Monitoring Program (LTRMP) protocols (Gutreuter et al. 1995).

During electrofishing runs, Asian Carp that jumped into the boat while current was being applied to the water were kept and processed to increase sample size and confidence in certain population metrics (e.g. age, condition, etc.); however, these fish were not included in electrofishing catch per unit effort calculations. Although a power goal of 3,000 watts was established, Smith-Root GPP electrofishers do not provide the necessary read-out information to calculate true output while operating in the field. A comparison of outputs of six different Smith-Root units with an oscilloscope has shown maximum average outputs at low range (500 V) to be between 1,864 and 2,486 W, and at high range (1,000 V) between 5,684 and 7,019 W (Pope et al., 2001), although the conductivities in this study were roughly an order of magnitude higher than those typically seen in the Illinois River. Our electrofisher settings of 8-12 amps, 60 pulses per second, and at least 50% power should achieve the power goal.

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 stored in coin envelopes with date, location, species, and identification number.

Asian Carp fin clips, to identify, quantify and determine maternal contribution of parental Silver Carp, Bighead Carp, and their hybrids were collected during standardized sampling in 2014. In addition, tissue samples were collected from fish that were used for acoustic telemetry (Chapter 3) in the lower river (30 from the Alton reach, and 50 each from the La Grange and Peoria reaches). Samples were placed in 75% ethanol and sent to Western Illinois University for processing. DNA extraction, genotyping, and data processing are currently underway for 2014 samples using 60 SNP nuclear DNA assays for parental and hybrid assignment and one mitochondrial SNP to determine maternal contribution to the hybrids and the effect of hybridization on movement.

Data Analysis

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, not those that jumped into the boat. In previous years (2011–2013), 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. Thus, to ensure meaningful between-year comparison of CPUE, 2014 data were adjusted to reflect both electrofishing methods. This was done by applying a correction factor derived from the three year dataset of both electrofishing protocols (i.e. the experimental protocol captured on average 2.2 times more Silver Carp than the LTRMP protocol during 2011–2013). Changes in the annual Silver Carp CPUE from 2011 to 2014 were compared for the whole river, and by each reach using Analysis of Variance (ANOVA). Tukey's Highly Significant Difference (HSD) test was used to test for differences in CPUE by reach and year.

Mean length-at-age

Post-cleithra were sectioned transversely across the center with a diamond-blade isomet saw (Johal et al. 2000). Sections were read by two independent readers using bottom illumination from a compound microscope; if disagreements between readers could not be resolved, the age was omitted from analyses. A half year was added to ages to compensate for collection during the summer. Silver Carp mean length-at-age was compared among reaches and years using ANOVA for all age classes 3.5 to 6.5. Age classes less than 3.5 and greater than 6.5 were not represented in all reaches and were therefore omitted from analyses. If the *F*-test detected significant differences, post-hoc *t*-tests were conducted to determine where differences existed.

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; Strange 1996) is much higher in spent female Silver Carp than immature females (unpublished data). As such, we tested for changes in GSI as a function of TL for female Silver Carp using a two-dimensional Kolmogorov-Smirnov test (Garvey et al. 1998) to determine the size at which variation in GSI increases such that the probability of having a higher GSI increases, which is indicative of 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.

Molecular identification of Asian carp

All genotypes will be assigned by posterior probabilities computed by NewHybrids hybrid assignment algorithm. Resulting products are genetic identities, allele frequencies, and maternal contributions of up to 400 Asian carp per year.

Results and Discussion

Fish collection

Electrofishing effort at 19 sites resulted in the collection of 1,983 fishes, including 29 different species (Table 1.2). Of the 265 adult Silver Carp collected, 58 jumped into the boat during electrofishing. No Bighead Carp were collected in 2014. Age-0 Asian Carp were collected in the Alton (N = 327) and La Grange reaches (N=53) in 2014, indicating a high level of successful spawning activity this year; only 4 age-0 Silver Carp were collected in 2013 (in Alton), and none in 2011 or 2012. The noted difference in river discharge during the early spawning period in 2014 (compared to 2011–2013) was the likely driver of a successful 2014 spawn.

Catch per unit effort

Silver Carp CPUE differed significantly by reach (ANOVA; $P < 0.001$), with greater catches in the Peoria reach ($P \leq 0.033$) compared to the Alton or La Grange reaches (Figure 1.1). Following two years of consecutive declines (2012 and 2013), Silver Carp mean CPUE in 2014 was comparable with 2011 levels; however, no significant difference between years was apparent ($P = 0.454$). Likewise, there was no significant interaction between reach and year ($P = 0.807$). Lack of interaction between reach and year is probably related to the high variability in CPUE among sites and years. Silver Carp CPUE among reaches for all years combined was significantly different ($P < 0.001$). Tukey's HSD indicated that Silver Carp CPUE in Peoria was significantly higher ($P \leq 0.028$) than in Alton or La Grange. There were no significant differences detected among years for Silver Carp CPUE for all reaches combined ($P = 0.385$), likely due to the high variability in CPUE among years. High Silver Carp CPUE in 2014 was primarily driven by increased catches in the La Grange reach (mean CPUE increased from 44 to 110 fish per hour between 2013 and 2014).

The lack of Bighead Carp captures in 2014 was likely due to sampling and gear inefficiencies. In spring 2012, 45% of the 2.88 million pounds of Asian carp harvested in the lower Illinois River for conversion to fishmeal was composed of Bighead Carp according to subsamples taken at the fish processor. Likewise, subsampling at American Heartland Fish Products Ltd. in Grafton, IL during summer 2014 indicated that Bighead Carp numerically accounted for 27% of the commercial catch in the lower River. Therefore it is clear that Bighead Carp continue to make up a large proportion of the fish community, and continued monitoring of commercial fishing catches in the lower river (i.e. at processing plants, and commercial fishermen specifically contracted by SIU for surveying work) will provide a better indication of the Bighead Carp population status.

Mean length-at-age

In 2014, 327 age-0 Asian Carp were collected in the Alton reach, with a mean total length of 45.2 mm (SE = 0.37 mm). Main channel sampling sites accounted for 96.9% of captures. In the La Grange reach, 53 age-0 Asian Carp were collected with a mean total length of 68.5 mm (SE = 1.52 mm). La Grange captures were approximately equal between main channel (49.1%) and backwater sampling sites (50.9%). River mile 120 (Havana, IL) was the furthest upstream point of capture for age-0 Asian Carp. No age-1.5 Silver Carp were collected in any reach, and only a single age-2.5 Silver Carp was collected, in the Peoria reach. Mean length-at-age for age-3.5 to age-6.5, by year and reach, is given in Figure 1.2. The mean length of age-3.5 Silver Carp has remained relatively unchanged in the La Grange and Peoria reaches; data for the single age-3.5 Silver Carp collected in Alton is shown in Figure 1.2 but not included in statistical analysis. In 2014, the mean length of age-3.5 Silver Carp was significantly higher in La Grange than Peoria ($P = 0.028$). For age-4.5 Silver Carp, mean length-at-age has not changed significantly across years in the La Grange reach, but fluctuations across years in the Alton and Peoria reaches are apparent (Figure 1.2). For the second consecutive year, Silver Carp in the Peoria reach had a significantly lower mean length compared to those in the Alton and La Grange reaches (both $P < 0.001$); there are at least two possible explanations for this. First, there are too many fish in this pool causing intraspecific competition. Second, increased commercial fishing has removed the larger individuals of each age-class leaving the smaller ones in the population. Given that overall condition of the fish (see below) has increased in the Peoria pool (between 2013 and 2014) a combination of the two scenarios and will need to be teased apart further. Silver Carp age-5.5 had similar mean total lengths in 2014 compared to the previous year in Alton and Peoria, but mean total length in La Grange was significantly higher ($P = 0.013$). Peoria also had shorter age-5.5 Silver Carp compared to Alton and La Grange in 2014 (both $P < 0.001$; Figure 1.3). Age-6.5 Silver Carp mean length-at-age has remained relatively unchanged in the Alton and La Grange reaches over the last three and four years, respectively; Asian carp may have reached their carrying capacity in these reaches. Data for a single age-6.5 collected in Peoria are shown in Figure 1.2 but not included in statistical analysis.

Detecting trends in mean age-at-length between separate reaches and years is complex, but by combining annual mean length-at-age data of electrofishing-sampled Silver Carp for the lower three reaches, we see that mean lengths-at-age have increased for most age classes since 2013 (Figure 1.3). Comparing age-3.5 to age-6.5 Silver Carp reveals that mean lengths are higher in 2014 than 2013 for all ages, but only significantly so for ages-4.5 and ages-5.5. Aside from YOY, the 2009 year class was the most prevalent in all reaches in 2014 (Figures 1.4 & 1.5). The observed trend in mean total length at age across multiple ages and years may be indicative of variation in habitat conditions or resource availability among years, and emigration or immigration among reaches or river systems. Additional data will be necessary to collect before it is possible to make any strong conclusions about these observed changes in size-at-age.

Length-weight relationships

Adult Silver Carp length–weight relationships were analyzed by ANCOVA. Length-weight relationships were significantly different among reaches in 2014 (ANCOVA; slope: $P > 0.05$; intercept: $P = 0.023$; Table 1.3). Because slopes were similar, it appears that the rate at which weight increases per unit of body length is relatively uniform among reaches. Pairwise comparisons indicated that the intercepts of the length-weight relationships were similar between Alton and Peoria ($P > 0.05$) and Alton and La Grange ($P > 0.05$), but significantly different between La Grange and Peoria ($P = 0.019$); Silver Carp in the La Grange reach tended to be heavier at a given body length than those in the Peoria reach. This was also the case for Silver Carp in the La Grange reach compared to those in the Alton reach, although not significantly so.

Trends in the overall length–weight relationship of adult Silver Carp captured by the LTRMP protocol between 2013 and 2014 were significantly different (ANCOVA; slope: $P > 0.05$; intercept: $P < 0.001$). When analyzed on a reach-specific basis, the intercept of the length–weight relationship changed significantly between years in Alton ($P = 0.012$), La Grange ($P < 0.001$), and Peoria ($P = 0.007$). Therefore, while the rate at which weight increased per unit of body length has remained relatively constant between years, Silver Carp in all three reaches were heavier at a given body length in 2014. The observed shift in the intercepts of the length–weight relationships from 2013 to 2014 indicates that Silver Carp are in better condition, possible evidence of an increase in food availability or less intra- and inter-specific competition.

Indices of spawning condition

Variation in female Silver Carp gonadosomatic index (GSI) was statistically homogenous across TL for each reach (all $P > 0.05$), and for all reaches combined ($P = 0.072$) (Figure 1.6). Mean GSI ± SE for female Silver Carp ranged from 0.0184 ± 0.0016 to 0.0289 ± 0.004 across reaches (Table 1.4). Mean GSI values generally increased in 2014 compared to 2013. However, the trends observed in previous years (i.e. lower mean GSI values in Alton reach than in La Grange or Peoria) were not apparent for female fish in 2014. Comparisons of GSI values among years should be made with caution, given that GSI may be affected by multiple variables such as time of year, temperature, or river conditions. Continued monitoring of GSI in Asian carp populations in the Illinois River will be important in determining trends in reproductive success. It may also be useful to monitor GSI during pre-spawn, spawn, and post-spawn time periods to better understand fluctuations of GSI over time, and to better identify timing of spawning events.

Sex ratio of Asian carp

Sex ratios of Silver Carp collected in 2014 were not significantly different from 1:1 at the reach level ($P = 0.056$), or for all reaches combined ($P = 0.075$), with 147 males and 118 females. 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% more males overall in 2012. Silver Carp sex ratio had returned to 1:1 in 2013, and our data in 2014, though only marginally non-significant and of a smaller sample size, does not differ from 1:1. 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.

Molecular identification of Asian carp

Genotyping is still underway for 320 tissue samples collected in 2014, and should be completed by early 2015. Summary data for the 281 Asian carp individuals genotyped in 2013 are given in Table 1.5. Both "pure" Bighead Carp and "pure" Silver Carp were well represented in the sample accounting for 22.8% and 31.3% of the sample respectively. Interestingly, the fourth generation Silver Carp backcross (Bx4SV) was most common, accounting for 55% of all crosses identified, suggesting high rates of hybridization in the Illinois River Asian carp population. First generation backcrosses (F1) were still observed, suggesting that hybridization is ongoing. 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 underway to determine whether hybrid individuals have different movement patterns and rates than pure individuals in the Illinois River.

Recommendations:

The results of this ongoing monitoring continually serve as baseline information for determining the effects of commercial fishing on Asian carp populations. Demographic changes, particularly related to increased relative abundance and high recruitment, were apparent in 2014. It will be necessary to continue monitoring to determine how these will influence factors such as growth rates, condition, and reproductive success. This information will increase our knowledge of how Asian carp respond to fishing pressure 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 our hydroacoustics data (Chapter 2).

Project Highlights:

- Changes in Silver Carp relative abundance and size structure were evident in lower Illinois River during 2014 compared to previous years.
- Silver Carp CPUE differed significantly by reach, with greater catches in the Peoria reach compared to the Alton or La Grange reaches. Following two years of consecutive declines (2012 and 2013), Silver Carp mean CPUE increased in 2014 to levels comparable with 2011.
- Young-of-year Silver Carp were collected in the Alton (N=253) and La Grange reaches (N=37) in 2014. Since standardized sampling began in 2011, only four YOY Silver Carp have been collected (all in 2013), indicating highly successful spawning in the Illinois and/or Mississippi Rivers in 2014.

- Analysis of length-weight relationships indicates that in 2014, Silver Carp are in better condition in La Grange than the other reaches, and that overall, Silver Carp are in better condition in 2014 than 2013.

Table 1.1. Standardized sampling locations and effort for the three lower reaches of the Illinois River, 2014. Main channel (MC) and backwater (BW) sites were sampled in each reach, electrofishing effort was reported as total amount of pedal time (min).

			Electrofishing (min)		
Reach Code	Location name	Habitat type	LTRMP	Latitude	Longitude
Alton					
A-MC1	Grafton	Main channel	15	38°58'14.19"N	90°27'42.26"W
A-MC2	Hardin	Main channel	15	39° 9'23.29"N	90°36'47.83"W
A-BW2	Mortland Island	Side channel	15	39°7'39.04"N	90°36'48.17"W
A-MC3	Florence	Main channel	15	39°37'42.20"N	90°36'26.60"W
A-BW3	Big Blue Island	Side channel	15	39°39'34.14"N	90°37'21.09"W
A-MC4	Meredosia	Main channel	15	39°49'55.62"N	90°33'58.36"W
A-BW4	Meredosia Lake	Backwater lake	15	39°52'57.27"N	90°32'44.18"W
LaGrange					
L-MC1	MC near Lilly Lake	Main channel	15	39°58'42.00"N	90°30'44.12"W
L-BW1	Lilly Lake	Backwater lake	15	39°59'16.39"N	90°30'29.33"W
L-MC2	Frederick	Main channel	15	40° 7'29.25"N	90°22'3.85"W
L-BW2	Wood slough	Backwater lake	15	40° 4'52.82"N	90°22'46.42"W
L-MC3	Havana	Main channel	15	40°20'12.76"N	90° 2'57.76"W
L-BW3	Quiver Lake	Backwater lake	15	40°20'10.72"N	90° 2'45.20"W
L-MC4	Peoria Lock and Dam	Main channel	15	40°37'21.76"N	89°38'12.47"W
Peoria					
P-MC1	Upper Peoria Lake	Main channel	15	40°47'34.08"N	89°33'43.45"W
P-MC2	Chillicothe	Main channel	15	40°55'3.85"N	89°28'42.78"W
P-MC3	Henry	Main channel	15	41° 6'18.07"N	89°21'26.53"W
P-BW3	Senachwine Lake	Backwater lake	15	41° 9'35.61"N	89°20'12.00"W
P-MC4	Hennepin	Main channel	15	41°15'30.63"N	89°20'54.70"W

Table 1.2. Common name, scientific name, species code, and total number of fish collected for each species by reach from the Illinois River in 2014.

Common name	Scientific name	Code	Alton	La Grange	Peoria
Black buffalo	*Ictiobus niger*	BKBF	2	0	12
Black crappie	*Pomoxis nigromaculatus*	BKCP	0	5	0
Bluegill	*Lepomis macrochirus*	BLGL	3	12	1
Bluntnose Minnow	*Pimephales notatus*	BNMW	1	2	0
Bigmouth buffalo	*Ictiobus cyprinellus*	BMBF	2	2	23
Common carp	*Cyprinus carpio*	CARP	14	16	23
Channel catfish	*Ictalurus punctatus*	CNCF	13	13	4
Emerald shiner	*Notropis atherinoides*	ERSN	14	33	3
Flathead catfish	*Pylodictis olivaris*	FHCF	5	1	0
Freshwater drum	*Aplodinotus grunniens*	FWDM	12	26	7
Green Sunfish	*Lepomis cyanellus*	GNSF	0	1	0
Grass carp	*Ctenopharyngodon idella*	GSCP	3	3	1
Gizzard shad	*Dorosoma cepedianum*	GZSD	187	666	3
Largemouth bass	*Micropterus salmoides*	LMBS	0	2	1
Longear Sunfish	*Lepomis megalotis*	LESF	0	2	0
Longnose gar	*Lepisosteus osseus*	LNGR	0	1	0
Orangethroat darter	*Etheostoma spectabile*	OTDR	0	2	0
Quillback	*Carpiodes cyprinus*	QLBK	0	4	1
River carpsucker	*Carpiodes carpio*	RVCS	0	2	0
River redhorse	*Moxostoma carinatum*	RVRH	0	6	0
Sauger	*Stizostedion canadense*	SGER	0	3	4
Shorthead redhorse	*Moxostoma macrolepidotum*	SHRH	0	0	1
Skipjack herring	*Alosa chrysochloris*	SJHR	7	6	0
Smallmouth buffalo	*Ictiobus bubalus*	SMBF	4	11	8
Shortnose gar	*Lepisosteus platostomus*	SNGR	6	1	0
Spotted Gar	*Lepisosteus oculatus*	STGR	0	1	0
Spottail shiner	*Notropis hudsonius*	STSN	0	0	1
Silver Carp	*Hypopthalmichthys molitrix*	SVCP	39	110	116
Silver Carp YOY	*Hypopthalmichthys molitrix*	SVCP YOY	327	53	0
White bass	*Morone chrysops*	WTBS	74	73	4
Total fish sampled			**713**	**1,057**	**213**

Table 1.3. Parameter values from the length-weight relationships ($\log_{10}\text{mass} = a' + b \cdot \log_{10}\text{TL}$) of Silver Carp collected from the lower three reaches of the Illinois River in 2013 and 2014 by LTRMP electrofishing. Parameter estimates with different letters indicate significantly different values between reaches ($P < 0.05$) as determined by ANCOVA.

Reach	*a'*	SE	*b*	SE	R^2	*P*	*N*
2013							
Alton	-4.730	0.429	2.899	0.157	0.857	< 0.001	59
La Grange	-4.879	0.480	2.953	0.176	0.881	< 0.001	39
Peoria	-4.311	0.289	2.744	0.108	0.868	< 0.001	101
Combined	-4.495	0.161	2.813	0.060	0.919	< 0.001	199
2014							
Alton	-4.534[ab]	0.470	2.833[a]	0.171	0.881	< 0.001	39
La Grange	-4.386[b]	0.310	2.784[a]	0.113	0.849	< 0.001	110
Peoria	-4.707[a]	0.379	2.896[a]	0.140	0.789	< 0.001	116
Combined	-4.828	0.162	2.942	0.059	0.903	< 0.001	265

Table 1.4. Mean gonadosomatic index (GSI) for Silver Carp by reach and sex in the Illinois River, 2013 and 2014.

Year	Sex	*N*	Mean GSI	SE
		Alton		
2013	F	42	0.0098	0.0008
	M	51	0.0016	0.0004
2014	F	12	0.0261	0.00794
	M	26	0.0018	0.0002
		La Grange		
2013	F	54	0.0172	0.0024
	M	53	0.0018	0.0002
2014	F	40	0.03004	0.00405
	M	51	0.00268	0.00017
		Peoria		
2013	F	57	0.0122	0.001
	M	62	0.0026	0.0004
2014	F	59	0.01873	0.00155
	M	52	0.00232	0.00016
		Combined		
2013	F	153	0.013	0.001
	M	166	0.002	0.0002
2014	F	111	0.0236	0.00193
	M	129	0.00236	0.0001

Table 1.5. Genetic identification of 281 Asian carp collected between Alton and Dresden on the Illinois River in 2013. BH = Bighead Carp, Bx2BH = second generation Bighead Carp backcross, Bx2SV = second generation Silver Carp backcross, Bx3BH = third generation Bighead Carp backcross, Bx3SV = third generation Silver Carp backcross, Bx4BH = fourth generation Bighead Carp backcross, Bx4SV = fourth generation Silver Carp backcross, BxBH = first generation Bighead Carp backcross, BxBH*= Likely late generation Bighead backcross x late generation Silver backcross, BxSV = first generation Silver Carp backcross, F1 = first generation cross between parental Bighead Carp and parental Silver Carp, F2 = second generation cross between parental Bighead Carp and parental Silver Carp, FxBH = Likely late generation Bighead backcross x late generation Bighead backcross, FxSV = Likely late generation Silver backcross x late generation Silver backcross, SV = Silver Carp.

																	% Pure	
Reach	**BH**	**Bx2BH**	**Bx2SV**	**Bx3BH**	**Bx3SV**	**Bx4BH**	**Bx4SV**	**BxBH**	**BxBH***	**BxSV**	**F1**	**F2**	**FxBH**	**FxSV**	**SV**	**Total**	**BH**	**SV**
Alton	12	1	1		6	1	11	1							15	48	25.0%	31.3%
Peoria	6				2		14								29	51	11.8%	56.9%
Starved Rock	6			1	6		18		1	2					18	52	11.5%	34.6%
Marseilles	16	1	3		8		28		1	1	1		1	5	26	92	17.4%	28.3%
Dresden	24	4		3		2		1				1	2	1		38	63.2%	0.0%
Total	**64**	**6**	**4**	**4**	**22**	**3**	**71**	**3**	**2**	**3**	**1**	**1**	**3**	**6**	**88**	**281**	**22.8%**	**31.3%**

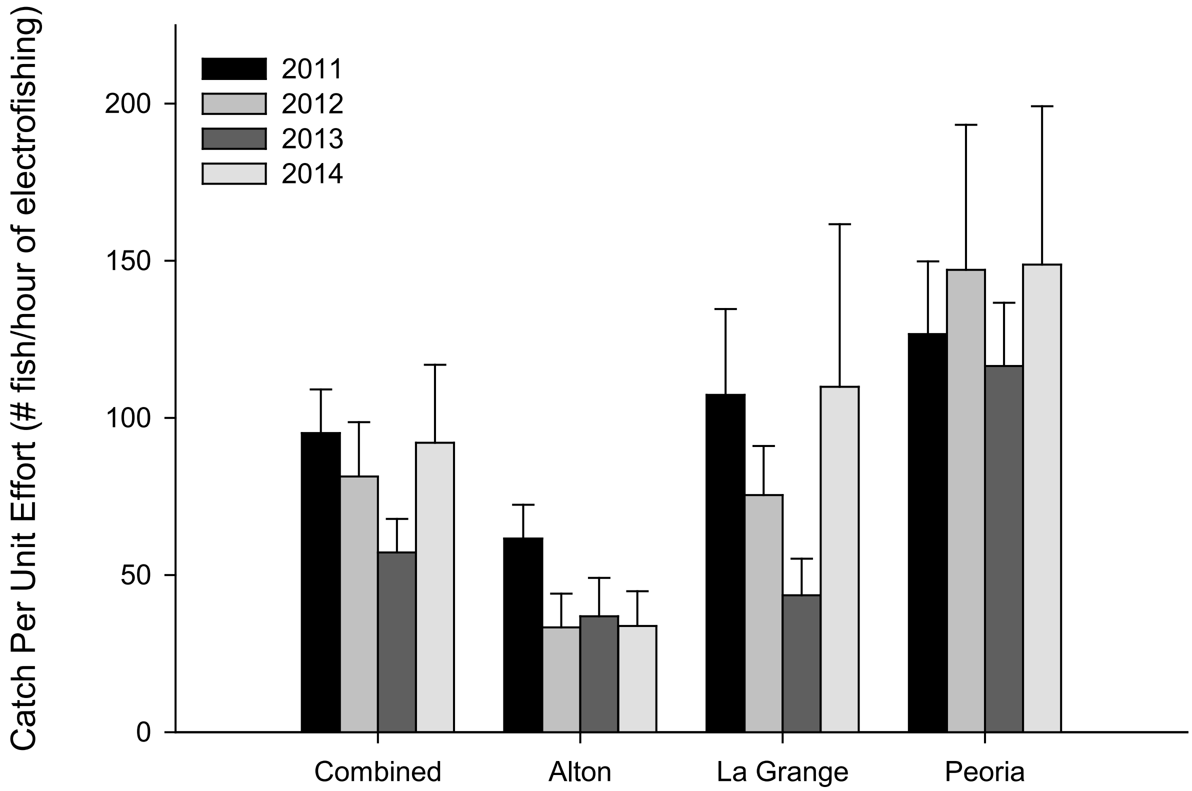

Figure 1.1. Mean catch per unit effort of Silver Carp with associated standard errors from standardized fish sampling conducted in 2011, 2012, 2013, and 2014 for each reach of the lower the Illinois River, and all three reaches combined.

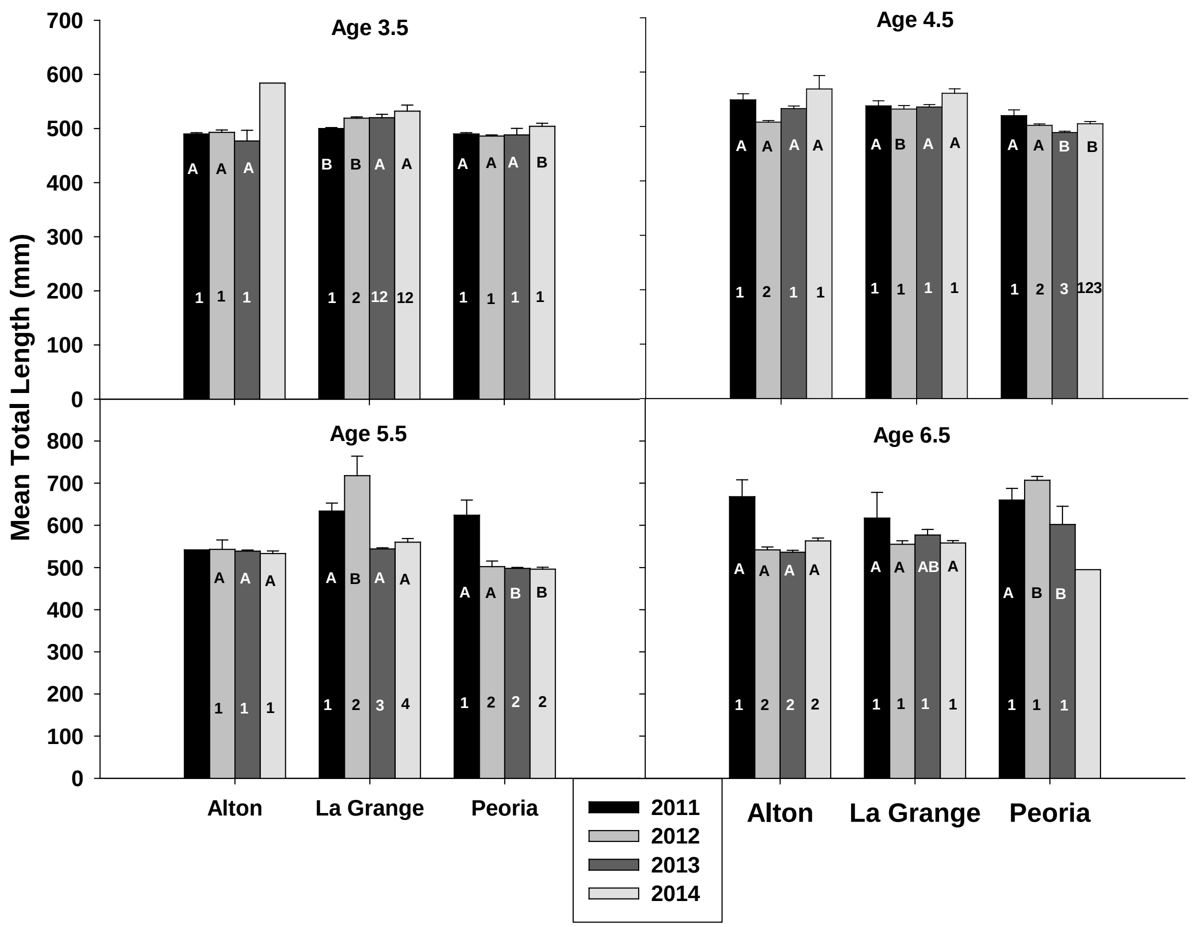

Figure 1.2. Mean length-at-age with associated standard error for Silver Carp in the three lower reaches of the Illinois River collected in 2011, 2012, 2013 and 2014; different numbers denote a significant difference in mean total length among years, within a reach, different letters indicate significantly different mean total lengths among reaches within a year ($P \leq 0.05$), as determined by ANOVA. Note different scales on the Y-axis.

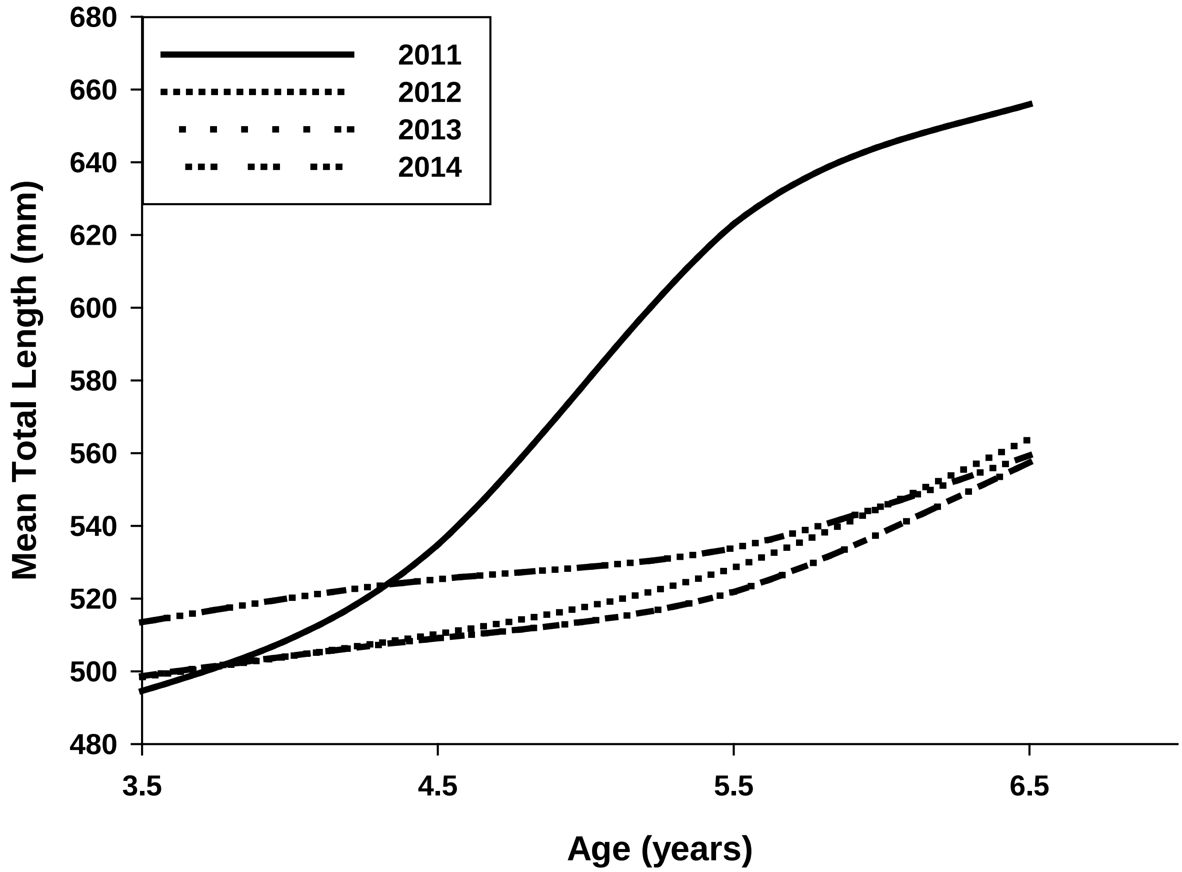

Figure 1.3. Mean length-at-age of Silver Carp collected from the lower three reaches of the Illinois River combined, 2011, 2012, 2013 and 2014.

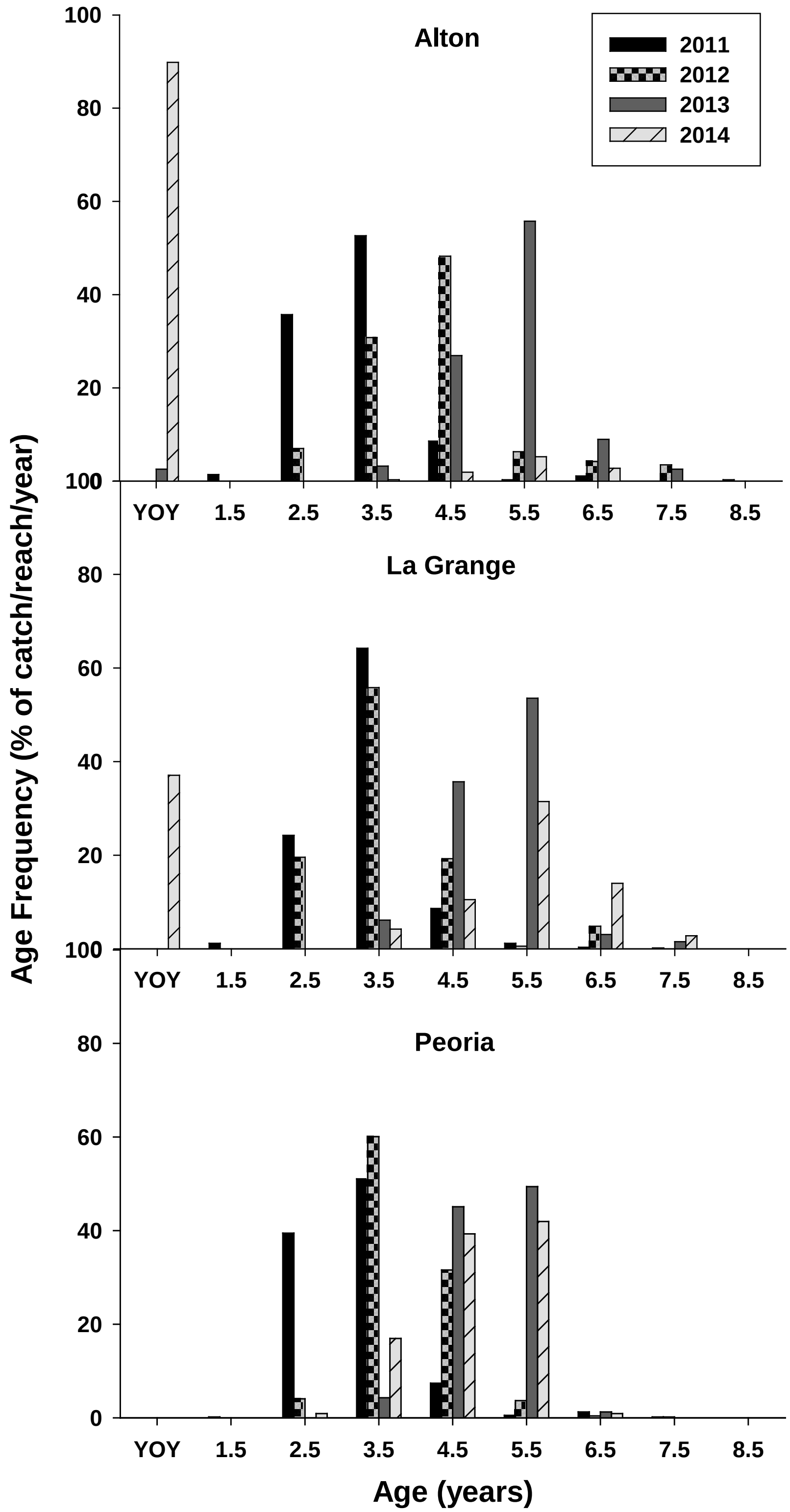

Figure 1.4. Age frequency for Silver Carp by reach of the lower Illinois River for 2011–2014, collected by electrofishing.

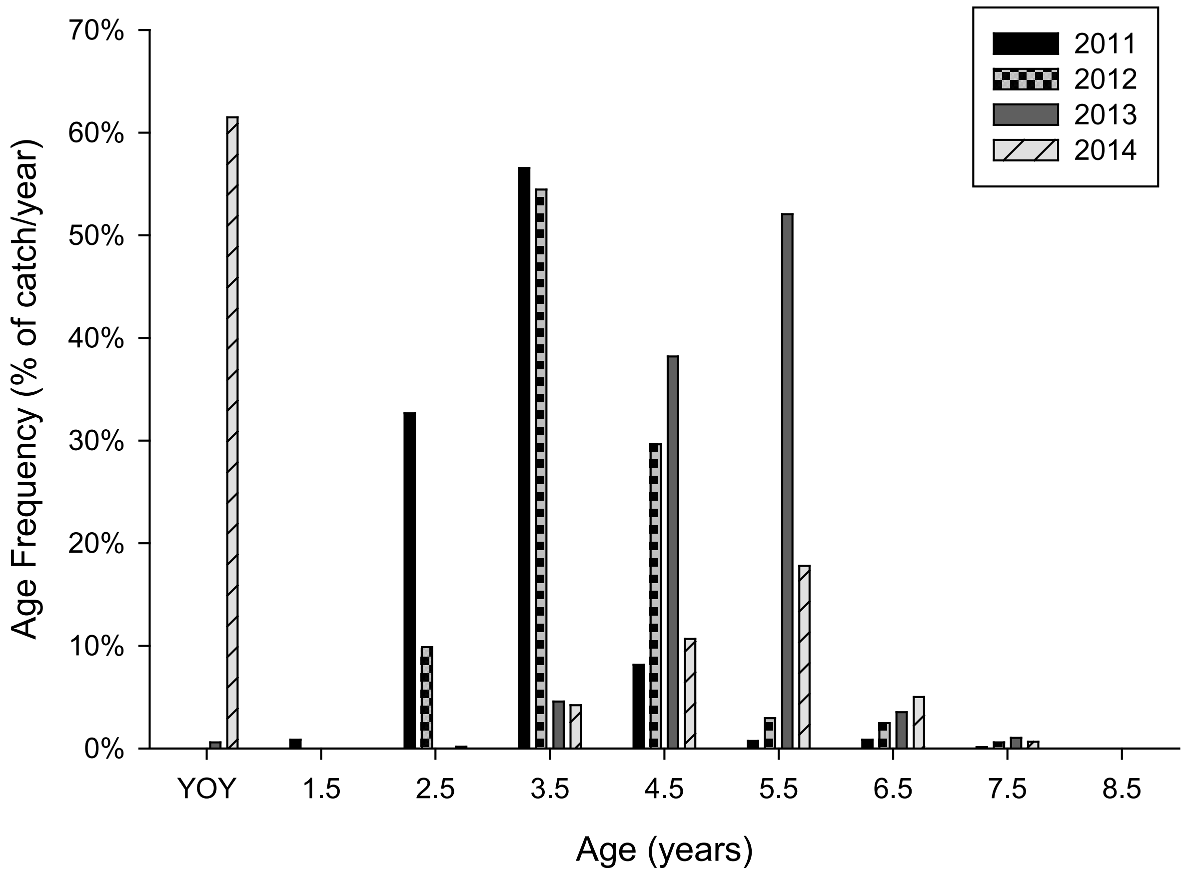

Figure 1.5. Age frequency of Silver Carp, for the lower three reaches of the Illinois River combined, for 2011–2014, collected by electrofishing.

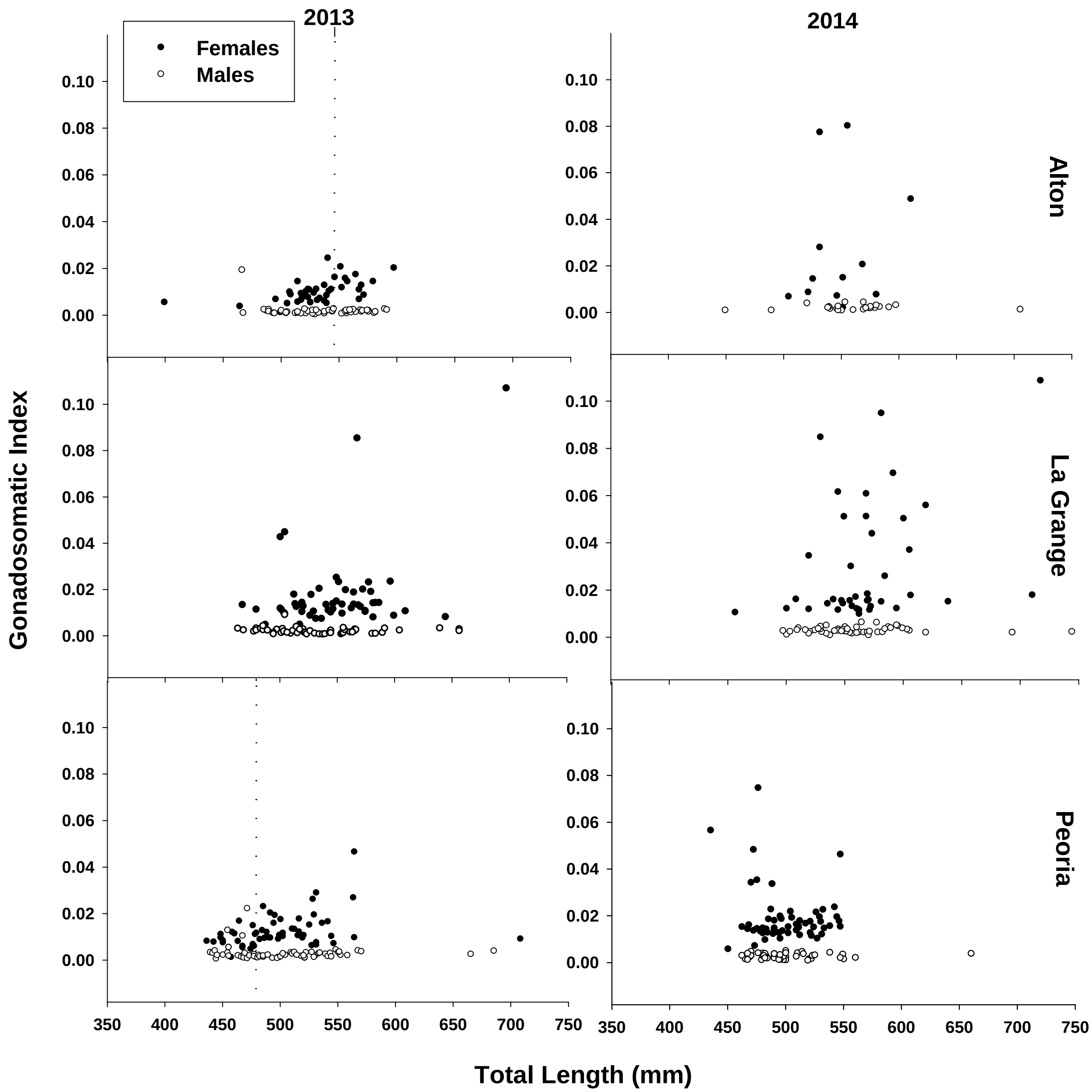

Figure 1.6. Gonadosomatic index (GSI) of Silver Carp plotted by total length for each sex for the three lower reaches of the Illinois River, 2013 and 2014. The dashed vertical line shows the total length at which variation in GSI increases for female Silver Carp as determined by a two-dimensional Kolmogorov Smirnov test (P < 0.0054 for Alton and Peoria reaches, 2013; P > 0.05 for all reaches, 2014).

Chapter 2:

Hydroacoustic population estimates of Asian carp in the Illinois River

SIU CARBONDALE Ruairí MacNamara, James E. Garvey; Southern Illinois University at 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 (e.g. Parker-Stretter et al. 2009). Since 2010, Southern Illinois University at Carbondale (SIUC) researchers have been developing hydroacoustic surveying protocols to assess Asian carp population dynamics in the Illinois River. Initial surveys (during 2010/2011) used down-looking split-beam transducers in main channel habitat as a first attempt at quantifying the population size. Since 2012, the addition of side-looking split-beam transducers and side-scan sonar in main channel and backwater habitat has increased the survey coverage (i.e. volume of water ensonified) by approximately two orders of magnitude. Three years of fall surveys have now been completed (2012, 2013 and 2014), which will provide robust estimates of Asian carp density and size structure in the Illinois River.

Information derived from the annual hydroacoustic surveys will be used in a number of ways. Firstly, the impact that commercial harvest is having on the Asian carp population in the lower reaches will be evaluated. In the upper reaches, where Illinois Department of Natural Resources (IDNR) harvest is attempting to decrease the probability of Asian carp progression upstream toward the Great Lakes, hydroacoustic monitoring will provide important information to assess and guide these ongoing efforts. Finally, Asian carp population size data will be incorporated into predictive models (Chapter 4) that will in turn facilitate decision-making in terms of appropriate control strategies.

Objectives: SIUC will conduct and analyze annual (2012–2014) hydroacoustic surveys to:

1) Estimate the reach-specific density and size structure of silver carp and bighead carp in the six reaches of the Illinois River, from the confluence of the Mississippi River upstream to Brandon Road Lock and Dam.
2) Determine the relative density among the main channel and associated habitats including backwater lakes, side channels, tributaries, and harbors.
3) Determine whether density and size structure of Silver Carp and Bighead Carp have changed in response to harvest.

Methods and Materials:

Hydroacoustic surveys

Hydroacoustic surveys took place annually (2012–2014) in the six reaches 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. In the upper three reaches (Starved Rock, Marseilles and Dresden), almost all accessible habitat was surveyed, whereas several four mile stretches of main channel and associated side channels, backwater lakes, tributaries, and harbors were surveyed in each of the lower three reaches (Alton, La Grange and Peoria).

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

Survey transects in the main channel consisted of a loop following the nearshore ~1.5 m depth contour, with the acoustic beams pointing towards 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. In backwaters lakes and harbors, the first loop began at the ~1.5 m depth contour and was repeated progressively closer to the center, at intervals that would limit overlap while ensuring as complete coverage as possible. Vessel speed was kept constant at 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 m from the transducers (*i.e.* to account for the near-field distance; Simmonds and MacLennan 2005) and before the ‘bottom’ line were analyzed further. Target strength (TS) 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 TS-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 manually inspected and edited to ensure accuracy. The mean acoustic target strength (in dB) of each fish track was then converted to fish length using Love’s (1971) fish length–TS equation. This widely-used, multispecies equation can be applied to a range of transducer frequencies (*i.e.* we variously used

70 kHz, 201 kHz and 208 kHz transducers). Only acoustic targets corresponding to a fish > 30 cm were included in the analysis.

Ground-truth data
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 (*i.e.* to limit size- and gear-selectivity sampling biases), we used data derived from a combination of standardized pulsed-DC electrofishing surveys [conducted by SIUC in the lower three reaches (Chapter 1) and by Illinois Natural History Survey in the upper three reaches (Long-Term Resource Monitoring Program)], and gill / trammel net data (from IDNR- and SIUC-monitored commercial fishing). Fish collected were identified, measured (total length, to the nearest mm) and weighed (to the nearest g).

Density

Following the protocols developed by Scheaffer *et al.* (1996) and Parker-Stetter *et al.* (2009), main channel transects were separated into two strata (*i.e.,* the first strata consisted of the nearshore loop and the second strata consisted of the loop closer to the mid-channel). Each 0.5 nautical mile (nmi) sampled along these strata represented replicates of the strata. In smaller waterbodies (*i.e.* side channels, tributaries, backwaters and harbors), 0.25 nmi replicates were used. Backwaters may have up to 4 strata. Strata-specific density ($\bar{\rho}_h$) and associated within-strata variance ($s^2_{\rho_h}$) was calculated as:

$$\bar{\rho}_h = \frac{1}{n_h}\sum_{i=1}^{n_h} \rho_{h,i}$$

$$s^2_{\rho_h} = \frac{1}{n_h - 1}\sum_{i=1}^{n_h}\left(\rho_{h,i} - \bar{\rho}_h\right)^2$$

where n_h is the number of replicates in stratum h, and $\rho_{h,i}$ is the mean density of replicate *i* within stratum *h*. The mean density ($\bar{\rho}$) for a specific waterbody was calculated using:

$$\bar{\rho} = \frac{1}{A}\sum_{h=1}^{L} A_h \cdot \bar{\rho}_h$$

where L is the total number of strata, A is the volume of sampled water (*i.e.* between the near-field and 'bottom' lines; estimated by the 'wedge volume sampled' method in Echoview) for all strata combined, and A_h is the volume of sampled water for strata h, such that the mean density is weighted by the sampled volume in each strata. The standard error of the estimated mean density ($SE(\rho)$) was calculated using:

$$SE(\rho) = \sqrt{\sum_{h=1}^{L} \left(\frac{A_h}{A}\right)^2 \left(\frac{s_{\rho_h}^2}{n_h}\right)}$$

following the variable nomenclature defined above. Mean fish abundance (N) was estimated by multiplying $\bar{\rho}$ by the volume of sampled water. The standard error for mean fish abundance ($SE(N)$) was estimated by multiplying $SE(\rho)$ by the volume of sampled water. Density (fish per 1000 m^2) was then calculated by dividing fish abundance by the volume of sampled water and multiplying by 1000.

From the ground-truth data, fish > 30 cm were separated into three categories (*i.e.* silver carp, bighead carp, and other fish species) within each reach, and the numbers of fish in each 2 cm length-class were determined. Reach-specific proportions of Silver Carp, Bighead Carp and all other species were then linearly interpolated for each 0.1 cm length increment. A cut-off point of 120 cm was used; if the largest fish captured was < 120 cm, then a 100% Bighead Carp composition was assumed for the remaining length increments (based on our 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 ground-truth 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 (kg per 1000 m^2) was calculated as described above.

Additional hydroacoustic surveys at specific locations

In addition to the fall surveys described above, we undertook a series of surveys during summer 2014 at key locations in the upper river. Specifically these were in: the Brandon Road reach; immediately below Brandon Road Lock and Dam; Rock Run Rookery in the Dresden reach; and the HMS East and West Pits in the Marseilles reach. Most surveys were coordinated so that they occurred directly before and after IDNR Barrier Defense commercial fishing efforts. SIU field crews aboard the commercial fishing boats took length and weight measurements of subsamples of all species captured.

Results and Discussion:

Each year, over 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 1). Echoview processing of the hydroacoustic data obtained is currently being undertaken by a team at SIUC; the ‘bottom’ line is drawn to define the water column, the ‘fish-track detection’ algorithm is run and manually edited, and finally fish track and volume of water sampled are exported to Excel format. After this, data are assigned to appropriate strata and replicates, and combined with the annual reach-specific ground-truth data to estimate Asian carp density.

While Echoview is a powerful tool for processing hydroacoustic data, many of its automated procedures are designed for application in deep waters such as seas or lakes, and hence cannot reliably be performed on our data from a relatively shallow, highly noisy river system. We are working to develop scripting which will help streamline some of the procedures, but much of the processing is complex and has to be done by hand. This, along with the sheer amount of data, leads to the long processing time. To date, Echoview analysis has been completed for the three reaches of the upper River (Starved Rock, Marseilles and Dresden) for 2012–2014, and completed density estimates are available for 2012 and 2013 (2014 analysis will be completed once ground-truth data becomes available, which is expected in early February 2015). Processing of much of the lower River (Alton, La Grange and Peoria) is partially completed and density estimates are expected to become available during the coming year. For the purposes of this report, we present completed analysis of Asian carp density and size structure in the three upper river reaches in 2012 and 2013. Data are presented for fish in the size range 30–120 cm in the following categories: silver carp, bighead carp, silver and bighead carp combined (*i.e.* Asian carp combined), and all other fish species.

Asian carp density

Density estimates are presented either in terms of abundance (number of fish per 1000 m^3 of water sampled) or biomass (kg of fish per 1000 m^3 of water sampled). Between 2012 and 2013, Silver Carp, Bighead Carp and Asian carp mean density (numbers of fish) decreased in each reach of the upper Illinois River (Fig. 1). Specifically, Silver Carp mean density decreased by 49.3% (Dresden), 6.5% (Marseilles) and 55.7% (Starved Rock). Bighead Carp mean density decreased by 48.8% (Dresden), 75.0% (Marseilles) and 49.5% (Starved Rock), while the mean density of Asian carp combined decreased by 48.9% (Dresden), 32.5% (Marseilles) and 54.8% (Starved Rock). Mean densities for each location surveyed within a reach (Table 2.1) were compared with paired *t*-tests, and significant differences for each fish category are indicated in Figure 2.1. Between 2012 and 2013, Silver Carp, Bighead Carp and Asian carp mean density (biomass of fish) also decreased in each reach of the upper Illinois River (Figure 2.2); by 58.4% (Dresden), 23.1% (Marseilles) and 56.1% (Starved Rock) for Silver Carp; by 52.9% (Dresden), 74.7% (Marseilles) and 67.4% (Starved Rock) for Bighead Carp; and by 53.5% (Dresden), 54.8% (Marseilles) and 60.6% (Starved Rock) for Asian carp combined. Significant differences within reaches for each fish category are shown in Figure 2.2.

Asian carp size structure

Due to the relative low density of Asian carp in the upper Illinois River, we have combined data from different habitat types (*i.e.* main channel, side channel, backwaters and harbors) to be representative of the Asian carp population of each entire reach. The lower river reaches, where Asian carp densities are higher and more replicates of each habitat type were surveyed (Table 2.1), will facilitate a detailed examination of habitat-specific Asian carp demographics.

Hydroacoustically derived Silver Carp and Bighead Carp size structure are given by reach and year in Figures 2.3–2.5. A Kruskal-Wallis test indicated that the size of Silver Carp was significantly different among reaches in 2012 ($P < 0.001$) and 2013 ($P < 0.001$). Pairwise post-hoc comparisons showed Silver Carp increased in size in each reach from downstream to upstream in both years (all $P < 0.001$). Similarly, the size of Bighead Carp was different among reaches in 2012 ($P < 0.001$) and 2013 ($P < 0.001$). In 2012, the size of Bighead Carp increased in each reach from upstream to downstream (all $P \leq 0.012$), while in 2013, Bighead Carp were largest in Marseilles compared to Dresden or Starved Rock reaches (both $P < 0.001$). Bighead Carp in Starved Rock were larger than those in Dresden ($P < 0.001$).

In terms of within-reach comparisons, Silver Carp were significantly larger in 2012 than 2013 in the Dresden reach (Mann-Whitney *U*-test; $P < 0.001$; Figure 2.3a) and the Marseilles reach ($P < 0.001$; Figure 2.4a), but the opposite was observed (i.e. larger in 2013) in Starved Rock ($P < 0.001$; Figure 2.5a). Bighead Carp were significantly larger in 2012 than 2013 in the Dresden ($P < 0.001$; Figure 2.3b) and Starved Rock ($P < 0.001$; Figure 2.5b) reaches, but the opposite was observed (*i.e.* larger in 2013) in the Marseilles ($P < 0.001$; Figure 2.4b) reach.

The observed population changes, though limited to just two years at this stage, may suggest signs of a possible response to contract fishing, though environmental / hydrological conditions may also play a role. Mean densities of Silver Carp, Bighead Carp and Asian carp combined were lower in all three reaches in 2013 compared to 2012. Analysis of size structure further suggests that contract fishing is successfully removing larger individuals; Silver Carp size decreased from 2012 to 2013 in Dresden and Marseilles. In Starved Rock, though Silver Carp mean density declined significantly, fish were larger in 2013. It is possible that immigration from the downstream Peoria reach could be a factor (preliminary hydroacoustic estimates suggest Asian carp density is almost 4 times higher in Peoria). Bighead Carp were smaller in 2013 in the Dresden and Starved Rock reach. In Marseilles, though Bighead Carp were larger in 2013, their density declined significantly. Removal of such large, highly fecund individuals is likely to affect potential reproductive success, but as previous modelling work has shown, harvest must not be size- or species-specific for population collapse to occur (Tsehaye et al., 2013).

Density and size structure in relation to other fish species

Asian carp numerically accounted for relatively similar proportions of the upper Illinois River fish community in 2012 (14.3–28.7%) and 2013 (11.4–29.2%). In biomass terms, Asian carp accounted for 51.1–63.9% of the fish community in 2012 and 43.8–65.5% in 2013. Reflective of the population progression upstream to the population front (which has remained in the Dresden reach for several years), Asian carp density (relative to other fish species) was highest in Starved Rock and lowest in Dresden.

Hydroacoustic surveys in specific habitats

Additional hydroacoustic surveys were undertaken during summer 2014 at a number of locations considered to be of particular importance to ongoing Asian carp management and research efforts. The HMS East and West Pits in the Marseilles reach are semi-enclosed backwaters with relatively high numbers of Asian carp and regular harvest efforts as part of the IDNR Barrier Defense program. Both lakes are important experimental sites that provided an ideal setting to determine the accuracy of hydroacoustic population estimates at a local-scale (i.e. by reference to harvest CPUE), and also for assessing seasonal populations changes (i.e. reflective of different hydrological conditions, fishing pressure, etc.). Repeat surveys were also undertaken at Rock Run Rookery in the Dresden reach in 2014, to provide a low-density contrast to the HMS Pits surveys. Rock Run Rookery Lake was not surveyed prior to 2014, so its inclusion this year will also facilitate more accurate Asian carp population estimates for the Dresden reach. In previous years, very large Bighead Carp individuals have been removed from this lake by commercial fishermen, which may possibly explain the observed spatial trends in Bighead Carp size (*i.e.* larger Bighead Carp in the reaches downstream). Information on the location of fish aggregations (observed from the split-beam and side-scan sonar) during surveys in the HMS Pits and Rock Run Rookery were relayed to IDNR biologists and commercial fishermen to facilitate targeted removal.

The Brandon Road reach was also surveyed in 2014. This reach was not originally included in the fall surveys, as traditional sampling gears have not indicated the presence of Asian carp upstream of the Dresden reach (i.e. hydroacoustics rely on Asian carp captures from paired sampling, hence the estimated number of Asian carp would be zero). However, hydroacoustic data collected in 2014 are currently being analyzed to determine the presence of fish targets larger than the species captured by gill nets, which could be indicators of potential Asian carp targets. We also performed three surveys in May 2014 immediately below the Brandon Road Lock and Dam, in support of the USGS water gun trial at this site.

Recommendations:

Hydroacoustic estimates of Asian carp density and size structure intrinsically depend on the background data from which they are derived (*e.g.* ground-truth sampling, fish length–TS equation). When combined with large-scale monitoring programs, reliable information can be obtained from hydroacoustic surveys, which will serve as a baseline to determine the effects of commercial fishing on Asian carp throughout the Illinois River and inform future control strategies. Our initial results thus far indicate just how prevalent Asian carp are in the upper reaches of the Illinois River (accounting for 43.8–65.5% 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). Additional data from 2014, including new survey locations and repeat surveys, as well as the incorporation of complementary project components such as telemetry (Chapter 3), will bolster our capacity to infer the Asian carp population response in the upper river.

Project Highlights:

- Three years of hydroacoustic surveys (fall 2012, 2013 and 2014) have been completed throughout the Illinois River. Protocols have been developed and refined so that surveys are analyzed in a comparable fashion, to provide replicate annual Asian carp population estimates.
- Analysis completed to date indicates that between 2012 and 2013, the mean density of Asian carp (expressed in terms of abundance and biomass per 1000 m^3 of water sampled) decreased in all three reaches of the upper Illinois River.

- During the same period, shifts in Asian carp size structure to smaller fish, generally consistent with the removal of larger individuals, were also apparent in the upper Illinois River.
- The observed population changes, though limited to just two years at this stage, may suggest signs of a response to commercial fishing. Inclusion of 2014 data will allow stronger conclusions to be made regarding the effect of harvest on the Asian carp population.

Table 2.1. Locations sampled with hydroacoustics in each reach of the upper and lower river during fall surveys in 2012, 2013 and 2014. The habitat type and approximate river mile (RM) are indicated. Habitat type codes are as follows: BW = backwater lake, CL = contiguous shallow lake, HB = harbor/marina, MC = main channel, SC = side channel, and TR = tributary.

Location	Habitat type	Approximate location (RM)
	Upper river	
Dresden		
Illinois River and Des Plaines River	MC	271.5-286.0
Treats Island	SC	279.0-280.2
Mobile Oil Corp. Bay	BW	278.2
Breezy Harbor Marina	HB	273.6
Kankakee River (~1st mile)	TR	273.0
Marseilles		
Illinois River	MC	245.7-271.5
Hanson Material Service East pit	BW	262.0
Hanson Material Service West pit	BW	262.1
Sugar Island	SC	260.3-261.2
Starved Rock		
Illinois River	MC	231.0-247.0
Heritage Harbor Marina	HB	242.3
Bulls Island and Scherer Island	SC	240.0-241.6
Fox River (~1st mile)	TR	239.7
Hitt Island and Mayo Island	SC	237.0-239.0
Sheehan Island	SC	235.2-236.4

Table 2.1 continued. Locations sampled with hydroacoustics in each reach of the upper and lower river during fall surveys in 2012, 2013 and 2014. The habitat type and approximate river mile (RM) are indicated. Habitat type codes are as follows: BW = backwater lake, CL = contiguous shallow lake, HB = harbor/marina, MC = main channel, SC = side channel, and TR = tributary.

Location	Habitat type	Approximate location (RM)
	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
La Grange		
Illinois River (near Pekin)	MC	157.6-153.6
Illinois River (near Copperas Creek)	MC	135.5-139.5
Illinois River (near Havana)	MC	118.5-122.5
Spoon River (1st 0.4 mile)	TR	120.5
Quiver Island	SC	120.8-122.0
Illinois River (near Bath)	MC	105.0-109.0
Bath Chute	SC	106.7-113.4
Illinois River (near Browning)	MC	97.0-101.0
Chain Lake	BW	98.7
Illinois River (near Frederick)	MC	90.0-94.0
Illinois River (near La Grange)	MC	81.0-85.0
Lily Lake	BW	83.1
Alton		
Illinois River (near Beardstown)	MC	76.2-80.2
Illinois River (near Meredosia)	MC	68.5-72.5
Illinois River (near Florence)	MC	56.0-60.0
Big Blue Island	SC	57.5-59.8
Illinois River (near Bedford)	MC	46.0-50.0
Buckhorn Island	SC	45.9-46.3
McEvers Island	SC	48.4-49.6
Illinois River (near Kampsville)	MC	32.0-36.0
Illinois River (near Hardin)	MC	22.0-26.0
Diamond Island (Dark Chute)	SC	22.8-25.5
Macoupin Creek (1st 0.8 mile)	TR	23.1
Illinois River (near Grafton)	MC	0.0-4.0
Grafton Harbor	HB	2.1

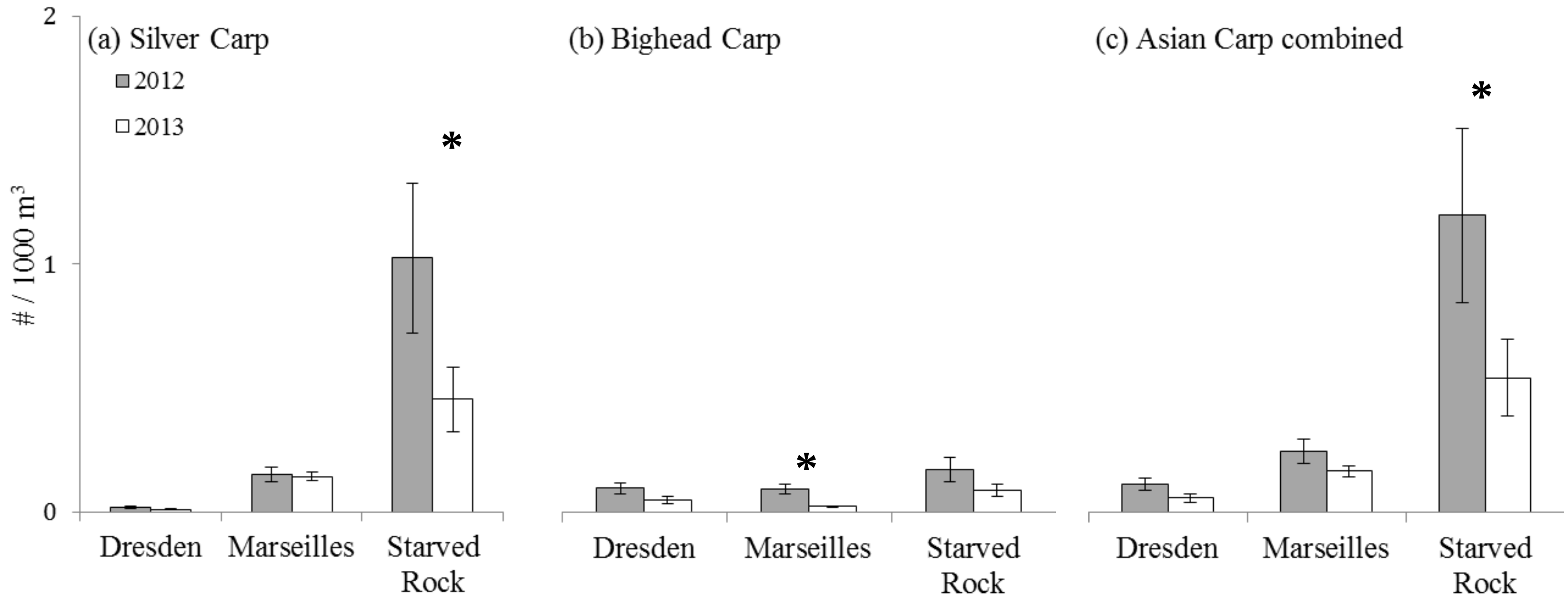

Figure 2.1. Mean density (expressed as numbers of fish per 1000 m^3) and associated 95% confidence intervals for (a) Silver Carp, (b) Bighead Carp and (c) Asian carp combined in the three reaches of the upper Illinois River in 2012 and 2013. Asterisks denote significant differences at the 0.05 level.

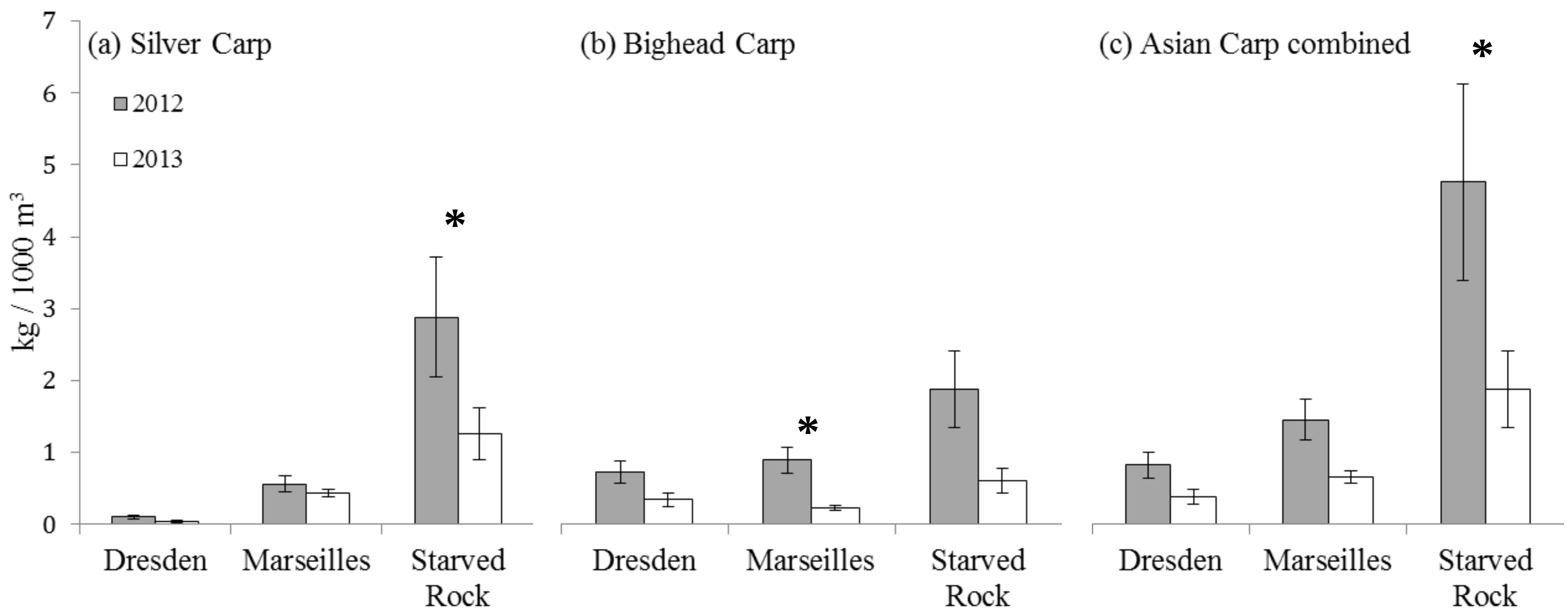

Figure 2.2. Mean density (expressed as kg of fish per 1000 m^3) and associated 95% confidence intervals for (a) Silver Carp, (b) Bighead Carp and (c) Asian carp combined in the three reaches of the upper Illinois River in 2012 and 2013. Asterisks denote significant differences at the 0.05 level.

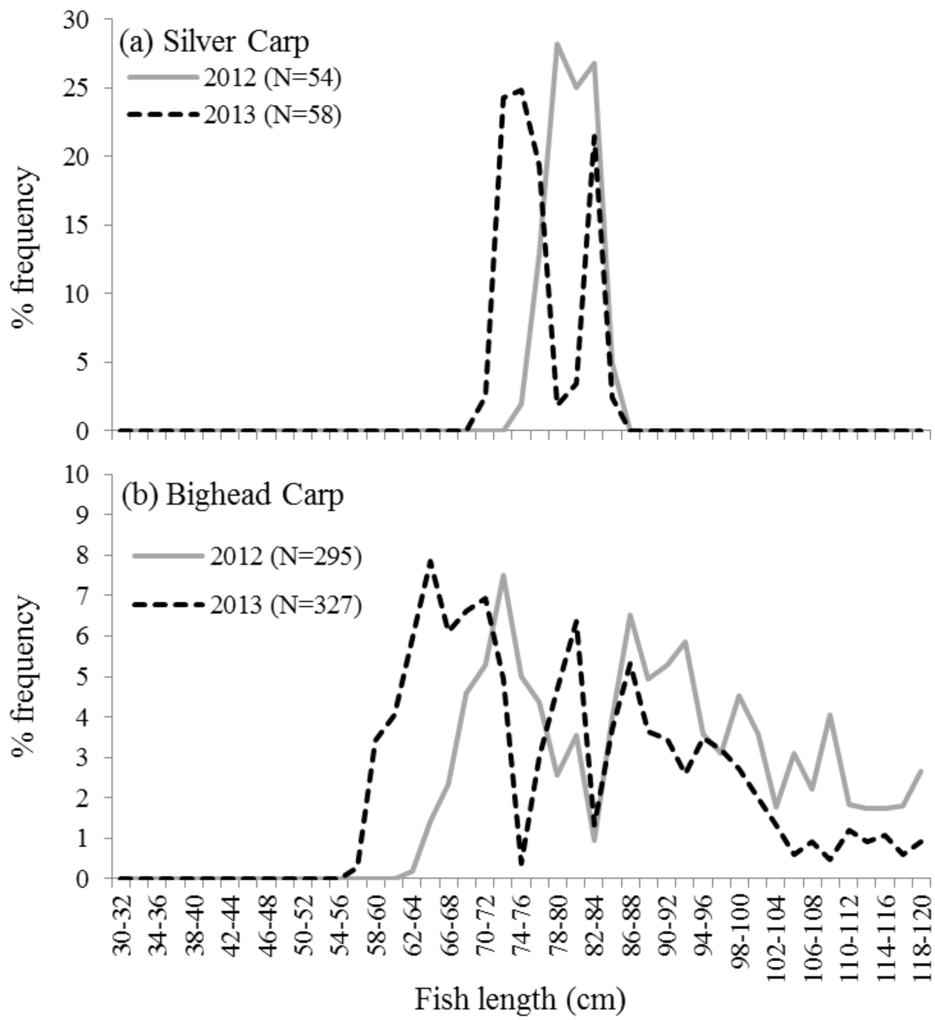

Figure 2.3. Size structure of (a) Silver Carp and (b) Bighead Carp in the Dresden reach in 2012 and 2013.

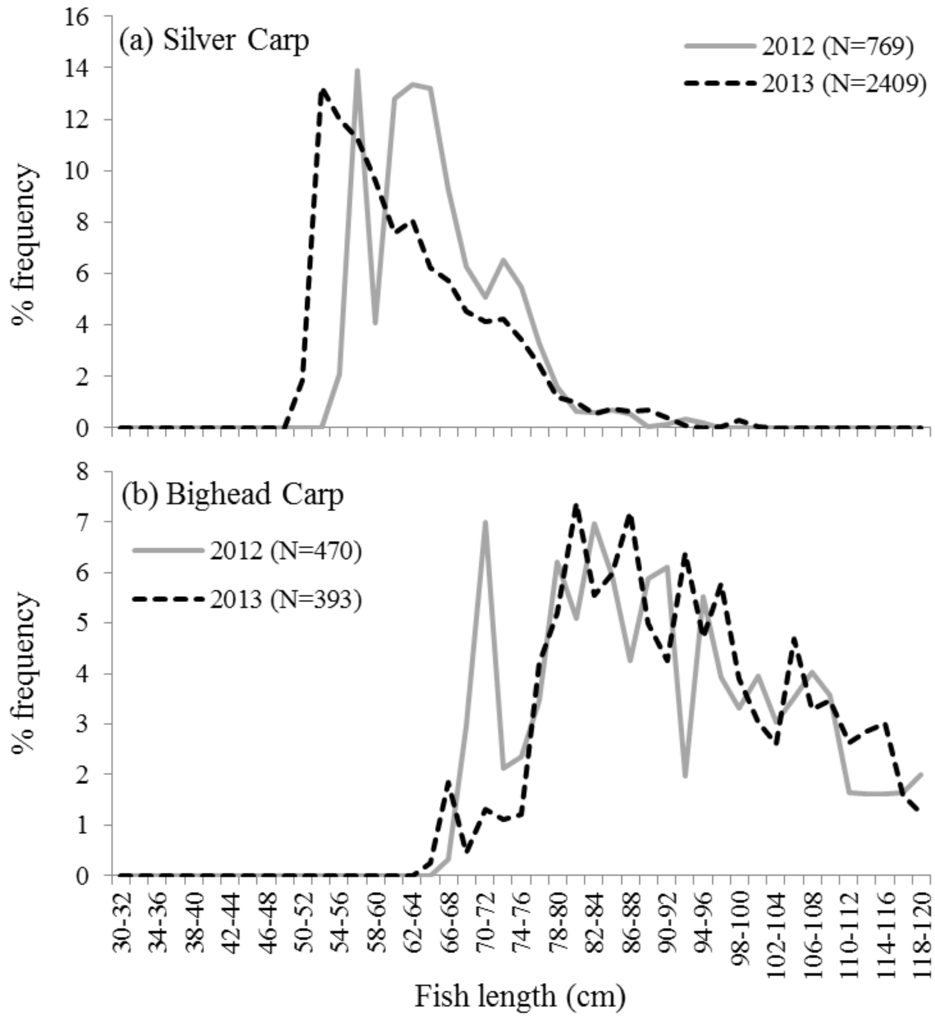

Figure 2.4. Size structure of (a) Silver Carp and (b) Bighead Carp in the Marseilles reach in 2012 and 2013.

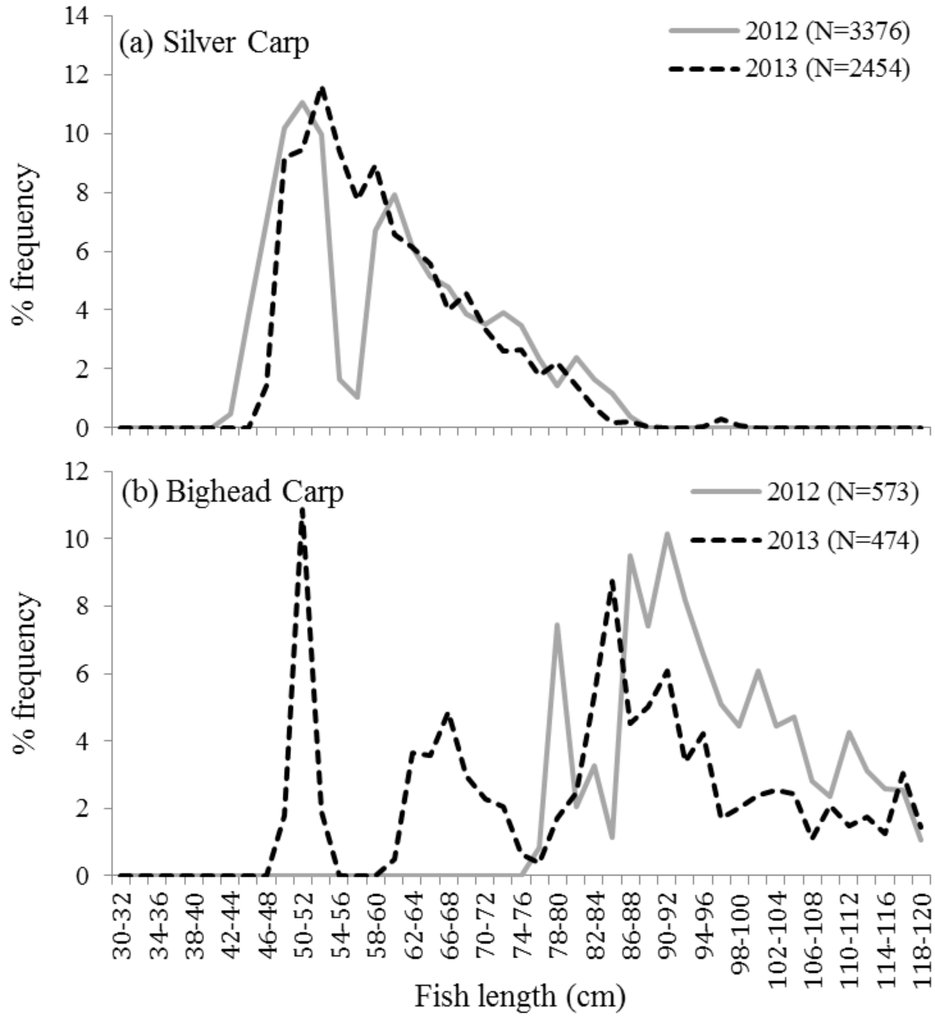

Figure 2.5. Size structure of (a) Silver Carp and (b) Bighead Carp in the Starved Rock reach in 2012 and 2013.

Chapter 3:

Asian Carp Movement in the Illinois River

Marybeth K. Brey, James E. Garvey; Southern Illinois University-Carbondale

Participating Agencies
Southern Illinois University-Carbondale (lead), US Army Corps of Engineers (field support), Illinois Department of Natural Resources (field support).

Introduction: Immigration and upstream movement of Asian carp were quantified with telemetry in 2010-2011, and indicated that 30% of Asian carp (tagged in the Mississippi River) immigrated into the Illinois River from the Mississippi River and subsequently made long distance trips up the Illinois River, but did not extend past Starved Rock Lock and Dam. Immigration and upstream movement corresponded with elevated flow in the river during spring through summer. However, many Asian carp that moved upstream, returned to downstream locations as water levels dropped in late summer. Examining how immigration and movement rates of Asian carp change in relation to seasonal and annual changes in river flow as well as determining how changes in Asian carp density affect these movement rates are important considerations for forecasting population responses to removal efforts and predicting how this will affect the probability of movement toward or away from the Chicago Area Waterway System (CAWS).

Multi-year data on movement will allow us to predict the river conditions (e.g., threshold discharge, temperature) that trigger mass movement of fish in the Illinois River. Periods of mass movement might be times when removal efforts need to be increased. If removal efforts are successful and movement is density dependent, then frequency of movement of fish toward the CAWS should decline through time. Even if movement is not density dependent but related solely to temperature and river discharge, successful removal efforts would reduce the number of fish that could potentially arrive at the CAWS. Tracking tagged fish over time may also allow us to locate areas that attract (or deter) Asian carp. Focus on these areas during commercial harvest events could have positive effects on decreasing the population growth rate of carp in the upper reaches.

Although further analyses need to be completed to determine if this is an artifact of the number of tags in the upper river versus the lower river, our data suggest that Asian carp that are resident in the upper reaches may have different movement behaviors (i.e., staying put) relative to the fish in the lower river. By dividing tagged fish between upper and lower river reaches, we will determine whether this is true. The alternate is that all fish in the upper reaches are transient "visitors" and will eventually be moving downstream. This effort also will allow us to test whether Asian carp frequently move past Starved Rock Lock and Dam and whether the route of movement is through the gates or the lock. If movement is concentrated through the lock, then control efforts may be directed toward these structures in the upper river. Lastly, determining how Asian carp interact with the locks and dams of the Illinois River is an important consideration for parameterizing spatially explicit models as the type of dam (e.g., wicket dams on the lower Illinois River compared to the gated lock and dams at Brandon Road) may affect the probability for successful passage.

Objectives:

1) Monitor and discern patterns of Asian carp movement throughout the entire Illinois River Discern fine scale patterns of movement of any Asian carp near the CAWS.
2) Determine differences between "immigrant" carp from the Mississippi and lower Illinois Rivers and "resident" carp in the upper Illinois River; providing a risk assessment for movement toward the CAWS and Great Lakes.
3) Relate total discharge, river gage height, and temperature in the Illinois River to movement patterns of Asian carp, and provide risk assessments for movement into the Great Lakes.
4) Relate carp movement to biomass estimates at the invasion front to determine whether movement is density dependent.

Methods:

Acoustic transmitters—tagging

Transmitters implanted in fish tagged in 2010 and 2012 expired during 2014, thus it was necessary to tag additional fish. During Fall 2014 (21-22 October and 10-13 November), 256 Asian carp were tagged with acoustic transmitters in the Alton (near Grafton; N = 30), La Grange (near Pekin, IL; N = 50), Peoria (near Lacon, IL; N = 50), Starved Rock (Starved Rock Marina; N = 50), and Marseilles pools (near Morris, IL; N = 50). Refer to Table 3.1 for a breakdown by species. An additional six fish were tagged in the HMSC west pit in May 2014 in conjunction with a USGS study in that area. We were unable to capture any fish for tagging in the Dresden Island pool in 2014 due to the low catches by commercial fishermen. All fish were also tagged with individually numbered $50 reward jaw tags (aluminum, size 1242-9C, National Band and Tag Co.) to provide incentives to fishermen not contracted by the IDNR to return transmitters. IDNR contracted fishermen have been instructed to return healthy fish back to the water as soon after capture as possible.

Receivers

A total of 39 Vemco® VR2W receivers have been maintained in the Illinois River to monitor movement of acoustically tagged Asian carp since 2012 (Alton = 8, Swan Lake = 1, LaGrange = 9, Peoria = 7, Starved Rock = 7, and Marseilles = 6; Dresden Island = 1; Figure 3.1). Two additional receivers were added to the HMS west pit in 2014 to add better coverage to that area and to monitor the effects of USGS water gun testing on Asian carp (Figure 3.2). We have continued to monitor receivers in each of the lock chambers (La Grange, Peoria, Starved Rock, Marseilles, and Dresden Island) and on each upstream and downstream side of the lock and dam, with the exception of Dresden Island lock (receivers maintained by the USACE) and Marseilles (only downstream; two receivers were lost/stolen). Additional receivers are located in main channel locations as well as near major tributaries to track large-scale movements within and among reaches. Three receivers were placed within the Hanson Material Service pits to better understand the factors affecting Asian carp immigration and emigration within that area.

Temperature loggers were also placed on all VR2W receivers to determine how movement relates to changes in water temperature. Movement and temperature data have been and will continue to be downloaded at 3-month intervals to determine how discharge and water temperature affect movement of Asian carp.

Minimal VR100 active tracking by boat using a Vemco® VR100 receiver was also completed in three areas during 2014. We surveyed a small stretch of the Fox River (Starved Rock pool), in the main channel of the Marseilles pool (from river mile 262-270), and within the HMS east pit (south of the connecting channel) on the 9-10 and 21-22 of October. Twenty two fish were detected during active tracking by boat using a Vemco® VR100 receiver near the Fox River (Starved Rock pool), in the main channel of the Marseilles pool, and within the HMS pits on the 9-10 and 21-22 of October. On 9 October 2014, four Bighead Carp, one Common Carp, and one Silver Carp were detected in the main channel of the Marseilles pool upstream of Morris, IL (at river miles 264.4-270.0), and one Silver Carp was detected at the mouth of Fox River on 10 October.

All telemetry, fish, and recapture data are maintained in an MS ACCESS database for all years acoustic receivers have been in the Illinois River. In addition to SIU data, VR2W and fish tagging data collected from the USACE, and fish data from the FWS and MO DOC are also included in this database.

Results and Discussion:

General movement

Over 3.5 million positive (known transmitter) detections have been recorded from 1 January 2014 to 19 December 2014 on passive VR2W receivers located along the Illinois River (from Grafton, IL to Dresden Island Lock and Dam). From these detections, 266 individual Asian carp have been identified (including fish tagged by USACE and SIU fish tagged from years prior). The updated (as of 2014) redetection rate of fish tagged in 2012 was 32.6%, 73.1% for fish tagged in 2013, and 8.3% for fish tagged in 2014 (Table 3.2). Most 2014 fish were tagged in the late fall, so their time at large is short, accounting for the low 2014 redetection rate. The short-term (< 6 months) redetection rate for Asian carp in the Illinois River has been very good; however, redetection of fish six months after tagging has been relatively low. Increased active tracking would be extremely valuable, albeit time consuming, and would likely increase our detection ability.

In general, long distance movements upstream and downstream occurred in the lower river (below the Peoria pool) in the spring (generally, May). Above the Peoria pool, fish movements tended to be shorter distances and fish had very high site fidelity. There was more downstream movement occurring in the upper river (especially through lock chambers) than previously observed.

Of the 348 Asian carp that were tagged in the Mississippi River by SIU in October/November 2010 (with active transmitters during this study), 61 have now been redetected in the Illinois River (Table 2). Three of those fish immigrated into Swan Lake, a backwater of the Alton reach located between RM 5 and RM 13. Four fish moved through the Peoria Lock and Dam and one fish moved into the Starved Rock pool. Three of those four fish made long distance migrations up to the Peoria pool then returned to the Mississippi River. Including the fish that moved into Swan Lake, the immigration rate from the Mississippi River to the Illinois River over ~4.5 years was 17.5%, compared to 13.5% immigration rate for a 2.5 year period (in 2013). Of the fish that were tagged in the Mississippi River (Pool 26) in fall 2012 (N = 148), twelve were redetected in the Illinois River (Alton = 3, La Grange = 3, Peoria = 3, Swan Lake = 3). Including the three fish last redetected in Swan Lake, the 2-year immigration rate for 2012 carp was 8.1%. Although we do not know the number of fish that died during this time period, this is a starting point from which to parameterize spatially explicit movement models for the river and gives us an idea of the proportion of fish immigrating from the Mississippi River into the Illinois River.

Spawning movements

Spawning aggregations were observed for the first time in the Marseilles reach in 2013 (22 May); however, no movements were observed in 2014. Nonetheless, spawning movements were distinguishable on acoustic receivers in the HMS pits and Sheehan Island in the Starved Rock pool. Fish detections and movement in the HMS backwater of the Marseilles reach were compared to temperature and river discharge (stage height used as a proximate measure of discharge in this reach) to determine what cues triggered spawning movements in carp. Because a receiver is located in the connecting channel between the main river channel and the backwater of the HMS pits (Figure 3.2), we were able to determine when fish were moving into or out of the pits. Net migration out of the pits was again observed in mid-May corresponding to elevated river discharge and river temperatures above 18°C. Although there was a significant, albeit weak, positive correlation between the number of fish detected and the stage height of the Marseilles reach (R = 0.16; $P = 0.001$) in 2013 suggesting that each rise in river stage height (elevated discharge) triggered a spawning movement, no such relationship was found in 2014. In both 2013 and 2014, the 8 May was the first date that water temperature rose above 18°C, a trigger for spawning movement in their native habitat (Yangtze River; Li et al. 2013). Net migration into the pits (around 30 May) corresponded with high catches by commercial fishermen and descending river stage (Figures 3.4 and 3.5). Discrete movement/spawning periods did not seem to be as clear as in 2013 in the Marseilles pool. This was likely due to the increased river discharge for longer periods in 2014.

Passage through locks and dams and between reaches

Fish detections in lock and dams during 2014 were greater than in 2013, and more downstream movement was observed (Figure 3.6). The increase in lock detection is partially due to the increased number of transmitters in the water in 2014 and will teased apart with further analyses. Fourteen fish attempted to pass through the Dresden Island Lock and Dam. We were only able to confirm that two of those fish (two Bighead Carp; 893 mm and 863 mm, tagged in 2013 in Dresden and Rock Run Rookery, respectively) actually succeeded. One fish moved from river mile 283 to river mile 244. This fish stayed near the lock for 2 months before moving downstream on 28 August 2014. The second fish moved through the lock on 21 July 2015 and continued into the HMS pits.

Eight fish were detected by the receiver in the Marseilles lock chamber. Two fish likely passed upstream on 11 and 19 May, but we were unable to confirm their exact location following passage. One Silver Carp moved downstream on 2 April from the HMS pits, one passed through (moving downstream) in mid-May, and one common carp passed downstream on 18 May. Interestingly, three additional fish attempted passage in late December and early January.

Until May 2014, thirteen fish were detected in the Starved Rock lock chamber. After May, one fish either died or shed a receiver in the lock chamber and that has been the only observed detection since that time. Five fish made a successful downstream passage. Passaged occurred from 28 December 2013 to 11 January 2014, 28 January (two Silver Carp 667 mm and 687 mm, respectively), 1 March (Bighead Carp, 722 mm), and 5 March (Silver Carp, 818 mm). No upstream passage was detected.

The wickets at the Peoria Lock and Dam were down for a large portion of 2014, yet, 14 fish moved through the lock chamber. Nearly all fish that moved through the lock did so during a long distance movement upstream and subsequent movement downstream. One of the longest movements occurred from 11-29 June. A Silver Carp from the Mississippi River migrated to the Peoria pool. In two weeks, this fish covered over 230 river miles (160 river miles to the Peoria pool and back out to the Mississippi River).

There was a distinct separation located between the Peoria pool and the Starved Rock pool observed in 2014. Fish that made long distance migrations (see example in Figure 3) tended to do so in the lower river, moving as far as the Peoria pool. Some fish stayed in this reach for months then moved back downstream in late summer or early fall. Other fish made migrations upstream in the spring and immediately returned to the lower river (in a two-week time period). Movement in the upper reaches was in much shorter distances and "migrations" were harder to determine. In 2014, more downstream movements were identified between pools both in the spring and in the fall/winter than in past years, suggesting that fish are either cuing on different environmental variables, or have different behavioral responses to river discharge, temperature, and turbidity than those in the lower river.

We have still never observed a fish that was tagged in the lower river moving through Starved Rock Lock and Dam to the upper river and have only ever confirmed two fish moving upstream through Starved Rock Lock and Dam. Both Silver Carp had been originally captured and tagged in the Starved Rock pool. They had moved downstream, then back upstream.

Recommendations:

We were able to monitor and discern patterns of Asian carp movement throughout the entire Illinois River, showing the general time periods that fish were moving. Asian carp have been detected by the USACE at the Brandon Road lock and dam, but no other Asian carp were detected near the CAWS, so no fine scale movement monitoring was necessary. Additional active tracking will be conducted to locate fish tagged in Peoria, Marseilles, and Starved Rock pools. Redetection rates are lower in the Starved Rock pool and we would like to determine where these fish are alive or if they are dead.

We were also able to determine differences between “immigrant” carp from the Mississippi and lower Illinois Rivers and “resident” carp in the upper Illinois River. Although fish from the Mississippi River were detected as far upstream as the Starved Rock pool, no “immigrant” fish were present further upstream. Carp from the Mississippi River are capable of making long distance migrations in a relatively short period of time (e.g., Alton pool to the Starved Rock pool in less than one month), however the immigration rate into the Illinois River was only measured at 13.5% over a 2.5-year period, suggesting that fish already present in the Illinois River are of greater concern than those in the Mississippi River

River discharge, gage height, and temperature in the Illinois River were related to movement patterns of Asian carp during 2013. Movement, at least in terms of distance moved in the lower river and the amount of passage through dams appeared to be greater in 2014 than in 2013 and 2012. River discharge was continuously higher over a longer portion of the year in 2014 compared to years prior. This increase could have triggered more fish to stay in the main channel habitat longer than in other years. Temperatures over 18°C and increases in river discharge during the month of May appeared to trigger spawning movements in the Marseilles reach. Increasing fishing pressure prior to such events (April) may help to decrease the number of spawning individuals when conditions become favorable.

Although we are not able to relate carp movement to fish density yet, we will continue to monitor Asian carp movement though the Illinois River in 2015 and make such comparisons as soon as hydroacoustic estimates become available (Chapter 2). We recommend increased effort to locate fish in side channels and backwater areas, as these may be important staging locations or barriers to movement for Asian carp, and more closely monitoring fine scale movements in those areas.

Highlights:

- In 2014, an additional 256 Asian carp were tagged with acoustic transmitters in the Illinois River (Marseilles = 73, Starved Rock = 50, Peoria = 50, La Grange = 50, Alton = 30).
- Of the 348 Asian carp that were tagged in the Mississippi River by SIU in October/November 2010, 61 have now been redetected in the Illinois River. The immigration rate from the Mississippi River to the Illinois River over ~4 years was 17.5%.
- Over 2.5 million positive (known transmitter) detections have been recorded from January 2014 to December 2014 on passive VR2W receivers located along the Illinois River. From these detections, 266 individual Asian carp have been identified.
- The updated (as of 2014) redetection rate of fish tagged in 2012 was 32.6%, 73.1% for fish tagged in 2013, and 8.3% for fish tagged in 2014
- Fish were detected in all lock chambers in 2014.
- In the Dresden Island lock chamber, 14 fish were detected, and two passed successfully downstream in late summer.

- Separation between the lower and upper river (at Starved Rock Lock and Dam) was delineated using acoustic telemetry. Fish tended to move as far as the Peoria pool, and then return back downstream. Movement in the upper river tended to be in the downstream direction through the Marseilles lock in 2014 and into and out of the HMS pits. We have never observed that was tagged in the lower river moving through Starved Rock and Dam to the upper river and have only ever confirmed two fish moving upstream through Starved Rock Lock and Dam. Both Silver Carp had been originally captured and tagged in the Starved Rock pool. They had moved downstream then back upstream.

Table 3.1. The number of bighead and silver carp tagged with acoustic transmitters, the number redetected (to date), and the redetection rate by reach for 2012 and 2013.

2012	Bighead carp	Silver carp	Total	Number redetected	Redetection rate
Pool 26	19	129	148	14	9.46%
Dresden Island	25	20	45[b]	5	16.67%
Marseilles	48	16	64[a]	40	62.50%
Starved Rock	56	103	159	66	41.51%
Total	148	268	401	125	31.17%

[a] Includes 30 USACE fish tagged in the east pits.

[b] Includes 17 USACE fish tagged in the Dresden Island Pool.

2013	Bighead carp	Silver carp	Total	Number redetected	Redetection rate
Rock Run Rookery	10		10	4	40.00%
Dresden Island	26	2	28	9	32.14%
Marseilles	2	54	56	0	0.00%
HMSC Pits	19	19	38	25	65.79%
Starved Rock	8	46	54	3	5.56%
Peoria	6	45	51	1	1.96%
La Grange	21	33	54	4	7.41%
Alton	13	33	46	45	97.83%
Total	105	232	337	91	27.00%

Table 3.2. Numbers and redetection rates (via VR2W stationary receivers) of Asian carp tagged in the Illinois River since 2008.

YEAR	USACE	SIU	RECAP	Redetection Rate
2008	1			
2009	12			
2010	17	380	196	49.4%
2012	46	371	136	32.6%
2013	25	291	231	73.1%
2014	3	250	21	8.3%
SUM/Average	104	1,292	584	40.8%

Table 3.3. Number of Asian Carp tagged with acoustic transmitter in each pool of the Illinois River in 2014.

	Bighead carp	Silver carp	Hybrid Asian carp
Marseilles	15	58	
Starved Rock	23	23	4
Peoria	15	23	12
La Grange	9	31	10
Alton		16	14

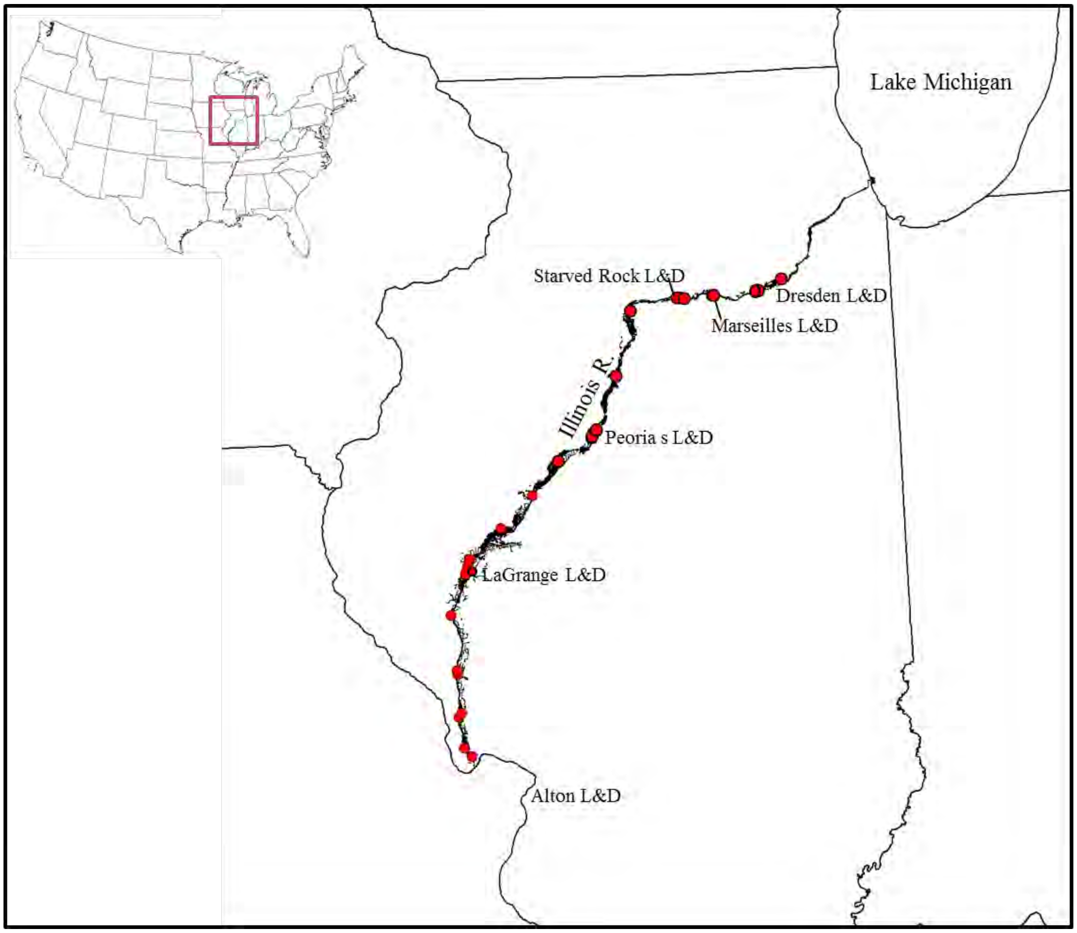

Figure 3.1. Locations of all active VR2W receivers along the Illinois River.

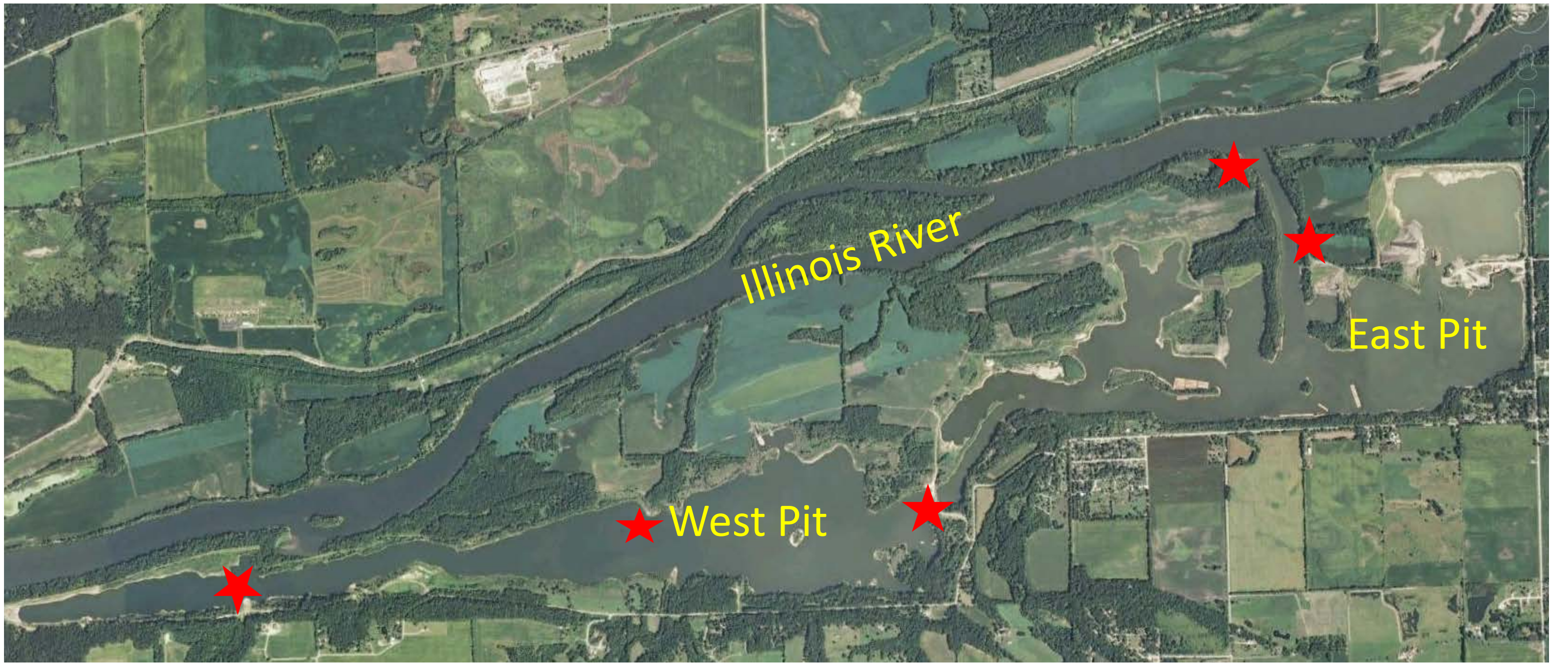

Figure 3.2. Map of Hanson Material Services Corporation (HMSC) backwater near Morris, IL indicating locations of VR2 receivers to quantify movement in/out of this backwater and between the west and east pits.

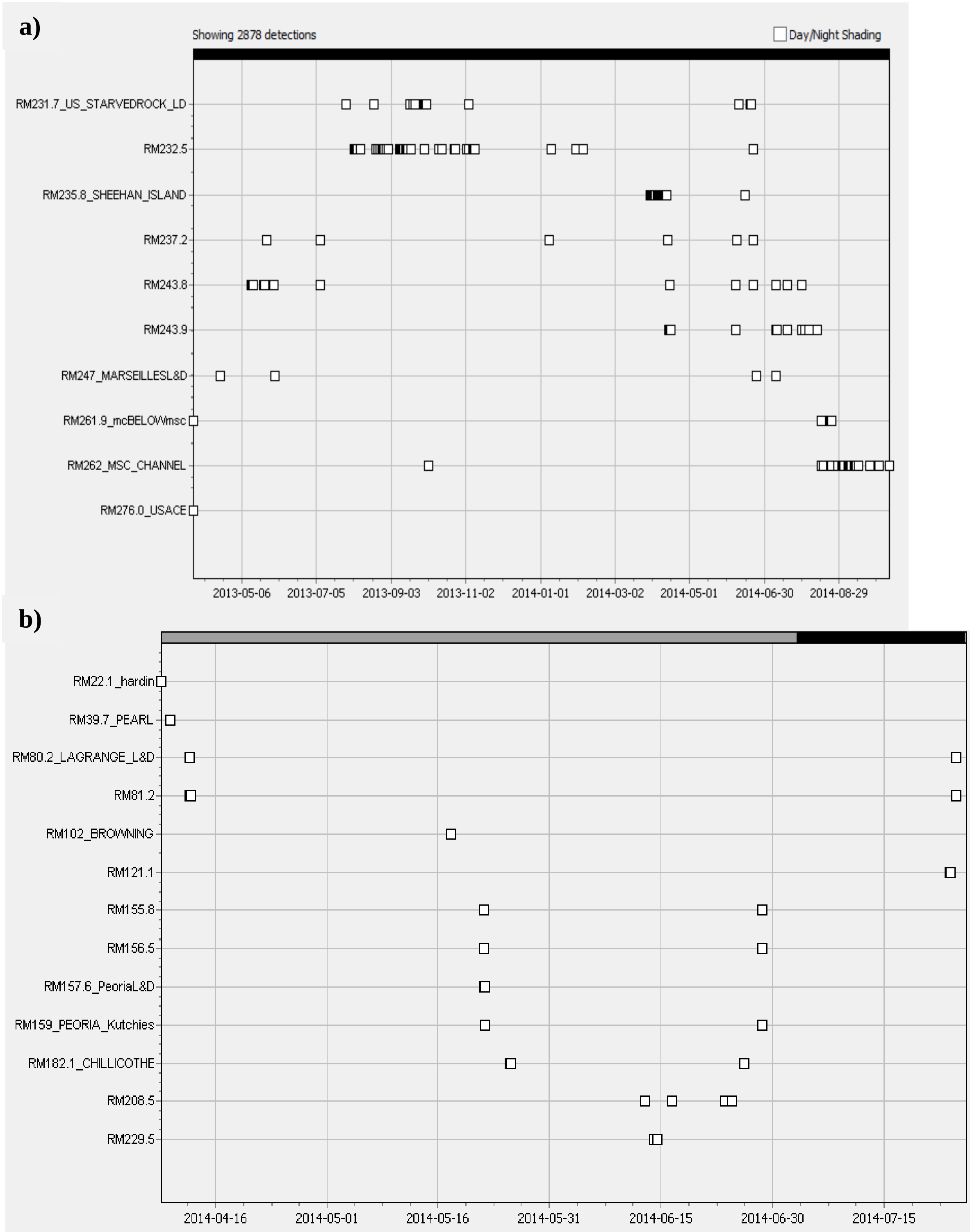

Figure 3.3. Examples of long-term movement patters of a) a 920 mm Bighead Carp (#45285, USACE) in the upper river and a Silver carp (733 mm) originally tagged in Pool 26 of the Mississippi River (# 44847, SIUC).

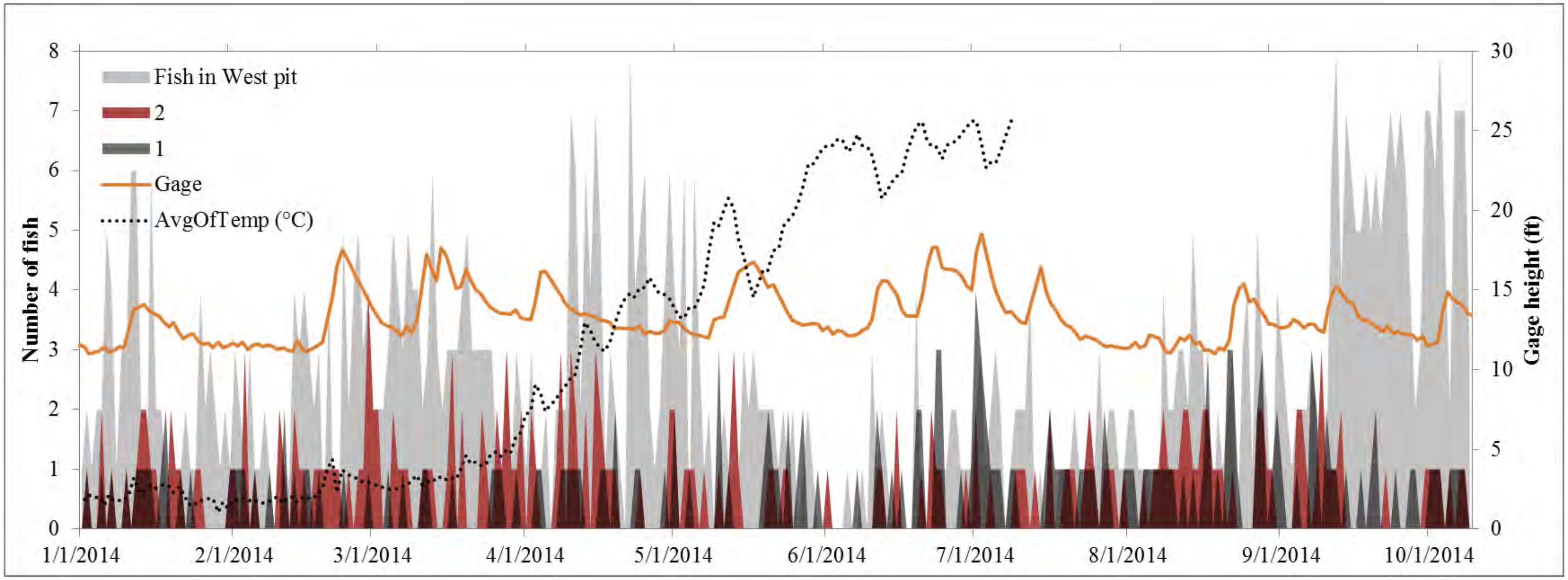

Figure 3.4. Detections of individual fish detected in the HMS West pit (grey), connecting channel of the HMS pits (2; red), and at the main entrance (main channel) of the HMS pits (1; black) with gage height (ft.) and temperature (^{o}C) for 2014.

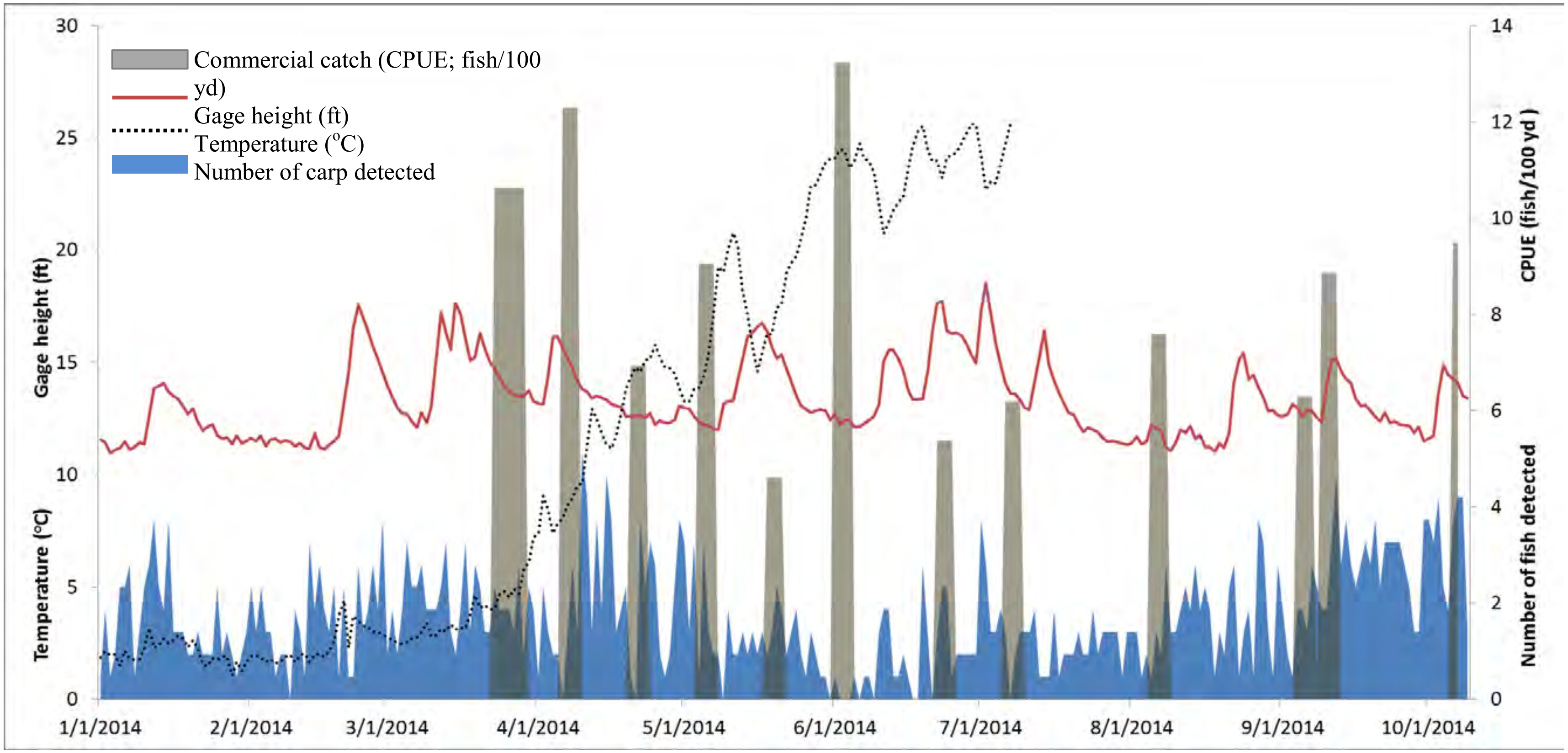

Figure 3.5. Total number of independent fish detected in the HMS pits (East and West pits) on stationary receivers (Figure 2) related to river gage height (ft.), temperature (^{o}C), and commercial fishing catch.

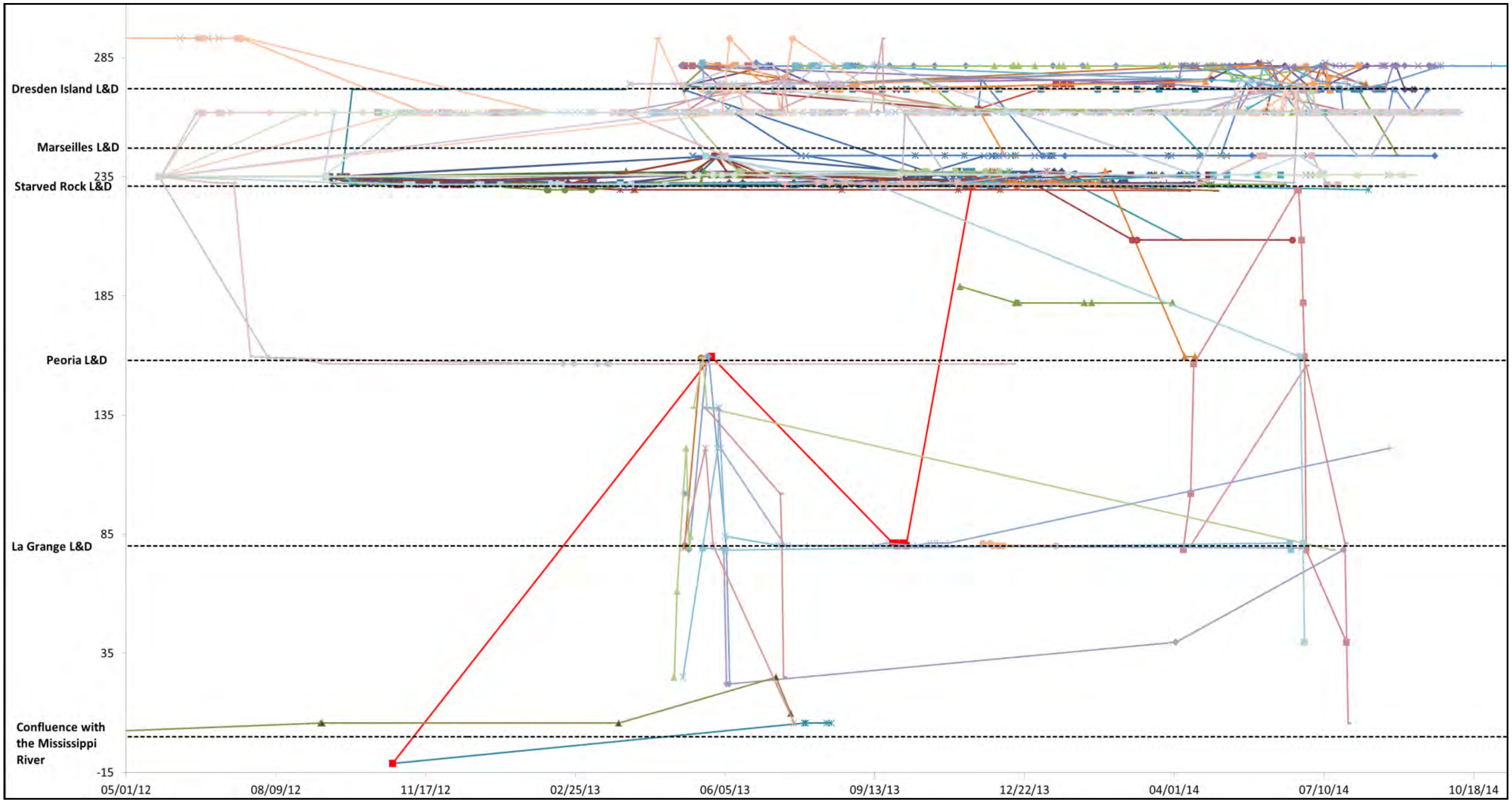

Figure 3.6. Movement of all redetected fish from 5/1/2012 to 10/18/2014 in the Illinois River and Pool 26 of the Mississippi River (river mile -15). Each colored line is an individual fish, and each dot represents a detection on a stationary VR2W receiver. All lock chambers are shown as a dashed line at their respective river mile.

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 (e.g., Parker et al. 2013) and other weaknesses are becoming evident. Although the risk of an Asian carp breach is currently considered to be low due to the purported absence of Asian carp in the electric dispersal barrier area, harvest of Asian carp downstream of the electric barrier may help to reduce the probability of Asian carp challenging the barrier during the chance event that would allow them to successfully breach 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 determining the efficacy of Asian carp harvest as a control option. The results from this model suggested requirements of an exploitation rate of 70% 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 (i.e., Alton, La Grange, and Peoria pools). The results from recent commercial harvest experiments conducted by Southern Illinois University suggest that we are not meeting these requirements, 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 probability of movement across the entire Illinois waterway.

Several assumptions regarding the demography of Asian carp were necessary in the Tsehaye et al. 2013 model, due to data limitations and the concern over the use of previous stock-recruitment relationships that were based on catch per unit effort of spawners and recruits (e.g., 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 has been collected from various sources, including investigating the use of Long Term Resource Monitoring

Program data and other standardized sampling programs to develop stock-recruitment relationships for silver and bighead carp.

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 silver and bighead carp stock-recruitment relationships; the uncertainty in the stock-recruitment relationships were 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.

Methods: Asian carp demographic parameters will be updated using existing Asian carp data from all possible sources (state and federal agencies and universities). Data from the Long Term Resource Monitoring Program and any other sources with reliable standardized approaches will be used to investigate the development of species-specific stock recruitment relationships. Catch per unit effort data may at the very least facilitate the scaling of stock-recruitment parameters. Additional explanatory variables, such as river discharge, will be evaluated in these relationships to explain additional recruitment variation. If the catch per unit effort data prove to be inadequate for the development of stock-recruitment relationships, an alternative approach would be to use a similar approach that was used in Tsehaye et al. 2013, but narrow the pool of stocks down to similar species rather than the all-encompassing approach previously used. If this approach is adopted, it will be necessary to explore varying the annual recruitment variability to capture the boom and bust nature of Asian carp recruitment patterns. Similar to the Tsehaye et al. 2013 model, a Bayesian approach will be used for parameter estimates to allow for the incorporation of individual variability and parameter uncertainty in model simulations.

The development of a spatially explicit Asian carp population model will be accomplished by applying the re-parameterized and refined population model to each reach (i.e., Alton, La Grange, Peoria, Starved Rock, Marseilles, Dresden, Brandon Road, and Lockport pools). The upper reaches (upstream of the Peoria pool) will be distinct in that adult Asian carp will be assigned a very low probability of successful reproduction such that this rare possibility is at least included in the model for conservative measures. Movement probabilities of Asian carp among all reaches based on empirical data will be incorporated and will likely include other explanatory variables regarding the probability of movement; including size, temperature, and hydrography (see Chapter 3).

Harvest scenarios evaluated will include, but will not be limited to: 1) a baseline strategy of no harvest, 2) harvest Asian carp from only the upper reaches, 3) harvest of Asian carp from only the downstream reaches, 4) harvest along the entire Illinois River waterway, 5) spatially dynamic strategy in which commercial fisherman are responding to changes in catch rates in an effort to maximize their catch per effort, 6) and optimization approach that can facilitate an adaptive management approach (i.e., the best place to fish may change seasonally). Other goals would be to define the exploitation levels or target density levels required to minimize movement probabilities of Asian carp to the electric barrier and how size-selectivity influences our results. Other reasonable harvest scenarios will be obtained through discussions with the Illinois Department of Natural Resources. Under each harvest strategy, the probability of Asian carp making it to Lockport pool will be determined with confidence bounds based on individual variability, environmental variability, and parameter uncertainty. An odds ratio approach will be adopted to examine the relative improvement of one strategy relative to others.

Results and Discussion:

A flexible, Asian carp age-structured dynamic simulation model has been coded using the program R that forecasts abundance in each of the seven pools of the Illinois River. We are still accumulating Asian carp demographic data to make parameter estimates as robust as possible. As such, our goal was to capture the general structure of the model and code it in such a way that updated parameter estimates and sub-models (e.g., stock-recruit, movement) can be added later as they become available. The model currently includes 25 annual and 2 seasonal (i.e., intra-annual) time steps. During the first seasonal time step the model simulates movement (net upstream), reproduction, growth, and mortality (natural and harvest). During the second seasonal time step the model simulates movement (net downstream) and mortality.

Results from version 1 of the Asian carp population model indicated that the spawner-recruitment relationship introduced a high amount of uncertainty into forecasted responses from harvest (Tsehaye et al. 2013); refining this relationship is therefore very important. A stock-recruitment relationship for Bighead Carp in the Illinois and Mississippi Rivers has been previously developed, but was not used in previous modeling simulations. Using LTRMP data collected in the La Grange reach of the Illinois River and Pool 26 of the Mississippi River, Hoff et al. (2010) found that adult relative abundance and river discharge were strong predictors of age-0 relative abundance ($R^2 = 0.84$). During the past quarter we updated Hoff's model by adding additional data (i.e., years) to the relationship. Further we developed a separate relationship for Silver Carp. Our findings suggest that stock-recruitment relationships for Silver and Bighead carp are more variable than originally indicated by Hoff et al. (2010). Moreover, the LTRMP data for Silver and Bighead carp are in units of standardized catch-per-unit-effort and the catchability between adults and recruits are highly likely to be different. As such, stock-recruitment parameter estimates are confounded with varying catchability coefficients between spawners and recruits, and possibly as a function of density. Therefore we will use different approaches for estimating the stock-recruitment relationship for Asian carps.

To gain further insights on improving the stock-recruitment relationship we met with Dr. Matt Catalano (Auburn University). Dr. Catalano developed the stock-recruitment relationship in version 1 of the model and is adept at Bayesian analysis, a statistical framework that we will use to update parameter estimates. Given that there are several plausible approaches for estimating a stock-recruitment relationship for Asian carp, we will likely conduct and present harvest simulations using various stock-recruitment relationships to determine how they vary.

Recommendations:

Determining the stock-recruitment relationship for Asian carp and the degree of density dependence in successful recruitment is critical to understand relative to the response of population dynamics to intense harvest. Determining whether this function exists for Asian carp species or whether there are other proxies for predicting recruitment should be a high priority for future research.

Telemetry Interim Summary Report

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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 (large and small) 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** Analyze behavior and movement patterns of fish near the barriers as they interact with barge traffic.

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 each dam.

- **Objective** Determine the efficacy of receiver coverage within the Brandon Road Lock and increase receiver coverage below the Brandon Road Dam and within an adjacent downstream tributary

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.

Additional objectives of the telemetry monitoring plan:

- **Objective** Integrate information between 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.

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 2013 season there were approximately 171 fishes (n=123, n=48 V16 and V7 Vemco transmitters) that remained active into 2014. 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 56 transmitters (Vemco transmitters V7 and V16; 69 kHz) were implanted into both Asian carp and surrogate species in 2014 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 227. 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 2013 and the field season of 2014 along with their release point within the system.

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

Release Location	Species Implanted	Number of Fish Implanted
Upper Lockport Pool (Upstream of Barriers)	Common carp	27
	Largemouth Bass	12
Between Barriers (Demo and IIB)	Common carp	12
	Largemouth Bass	12
Lower Lockport Pool (Downstream of Barriers)	Common carp	46
	Freshwater Drum	1
Brandon Rd Pool	Common carp	20
Dresden Island Pool	Bighead Carp	25
	Silver Carp	6
	Silver-Bighead Hybrid	2
	Smallmouth buffalo	13
	Common carp	20
Marseilles Pool	Bighead carp	16
	Silver carp	15
Total		**227**

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), Sumerfelt and Smith (1990) and Winter (1996). Stationary receivers removed for winter in 2013 were redeployed in mid March, 2014 with revisions to the layout of receiver positions within the study area based off of lessons learned from previous data collected. The receiver network was removed in the Marseilles pool due to expanding network coverage by Southern Illinois University (SIU) receivers. It was determined that USACE receivers deployed within the Marseilles pool were overlapping coverage of the water way with SIU receivers and could be better utilized to increase coverage within the Dresden Island pool. Three receivers were removed from the Marseilles pool. Receiver coverage within the Dresden Island pool increased from six in 2013 to eleven in 2014. 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 35 stationary receivers extending for approximately 33.5 river miles from the Calumet-Saganashkee Channel in Worth to the Dresden Island Lock on the Illinois River (Appendix A – Receiver Network Maps).

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=5 downstream). These receivers were placed at the lock entrance, in high quality habitat, in proximity to the electric dispersal barriers and at the confluence of the CSSC and Cal-Sag Channel (Appendix 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 location indicate that discharge rates between the electric dispersal barriers 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 2014, there were a total of 46 tagged surrogate fishes (Common carp, Largemouth bass and Freshwater drum; Table 1). In order to maintain a similar number of tagged fish within the Lower Lockport pool across years, an additional 25 Common carp were tagged and released in late April 2014 to increase transmitter density bringing the total up to 71. These additional Common carp were released at the Hanson Material Service owned slip approximately 0.8 miles downstream of the barriers (n=15) and at the Cargill boat launch approximately 3.5 miles downstream of the 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.

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. Additionally, this lock is the only one within the study area in which upstream passage of tagged fish has not yet been detected in previous year's efforts. In addition to the standard up and downstream receivers around the lock, three more receivers were deployed to gain increased detection coverage. The additional receivers were placed within the lock chamber, below the dam and approximately 0.5 miles upstream of an adjacent connecting tributary, Hickory Creek. In order to increase the likelihood of fish interaction with the Brandon Road lock additional fish were tagged and released into the Dresden Island pool. A total of eight Asian carp (5 Bighead, 3 Silver) and eight Smallmouth Buffalo were tagged. These fish were captured with the help of IDNR and commercial fishermen as part of the Barrier Defense Removal project. An additional 15 Common Carp were captured from the Brandon Road pool by USACE electrofishing and tagged and released into the Dresden Island pool. These fish were transplanted across pools to take advantage of the site affinity displayed by Common Carp. This was done to maximize the probability of fish attempting to pass through the Brandon Road lock in the upstream direction.

Asian carp Movement Analysis – In 2013, 20 Bighead Carp (mean ± SD; 931± 79 mm), 3 Silver Carp (788 ± 18 mm), and 2 hybrids (837 ± 173 mm) were tagged in Dresden Island. An additional 5 Bighead Carp (832 ± 127 mm) and 3 Silver Carp (755 ± 81 mm) were tagged in 2014. Analysis of tag locations and movement identified 8 individual fish that are assumed to have suffered post-release mortality or were harvested shortly after tagging in 2013. These fish only demonstrated downstream movement and often consisted of only a few detections right after release and were not included in this analysis. In addition, 1 fish moved out of the study area (detected by SIU Receivers in Havana) and was not included in the analysis. By the fall of 2013, 4 fish were either harvested or suffered mortality and were included into the analysis. These 4 fish had approximately 1.5 to 3.0 months of detection data. Fish detections were passively obtained through an extensive VR2W receiver network established throughout the Dresden Island pool. Variation in network coverage varied among years (Figure 1, Figure 2).

Data analysis from 2013 demonstrated the need for greater understanding of Asian Carp usage of Dresden Island pool. Specifically, additional analysis was needed to determine frequency of use within the Kankakee River and the Lower Des Plaines near Brandon Road Lock and Dam. For both 2013 and 2014 the calendar year was split into weeks labeled 1 to 52 and weekly individual fish detections, mean weekly discharge, and mean weekly temperature were recorded. Discharge values for the Lower Des Plaines River near Brandon Road Lock and Dam were obtained from USGS station number 05537980 at Route 53 in Joliet and temperature was obtained from USGS Water Quality Station 05539670 near Channahon, Illinois. These two stations represent the closest monitoring sites for discharge and temperature for the area near Brandon Road Lock and Dam. Discharge for the Kankakee River was obtained from the USGS station number 05527500 just downstream of the Wilmington Dam in Wilmington, Illinois and temperature data was obtained from USGS Water Quality station 05527000 at Custer Park approximately 4 miles upstream of the Wilmington Dam. Discharge and temperature data have been graphed and are available for review within Appendix B. Receivers were labeled from 1 to 9 in the Lower Des Plaines River with 1 being the furthest upstream (just below Brandon Road Lock and Dam) and 9 the furthest downstream (just above Dresden Island Lock and Dam). Receivers 10 and 11 were placed approximately 1.5 and 4.2 miles upstream in the Kankakee River, respectively.

Figure 1.— United States Army Corps of Engineers VR2W receiver coverage in the Dresden Island Pool of the Upper Illinois Waterway in 2013. Green circles represent receiver locations and the labeled number is the station ID.

Figure 2.— United States Army Corps of Engineers VR2W receiver coverage in the Dresden Island Pool of the Upper Illinois Waterway in 2014. Green circles represent receiver locations and the labeled number is the station ID.

Individual fish detections were recorded at each station for each week. Since most of the VR2W receivers are removed for the winter, detections were only recorded from early to mid-March through mid-November for both years. Multiple regression was used to determine if weekly fish detections can be explained by temperature and discharge data at Rock Run Rookery (RRR) and the Kankakee River. An additional logistic regression was conducted on daily data to determine the probability of finding a tagged fish given specific temperature and discharge data for the Kankakee River, RRR, and Brandon Road Lock and Dam.

Results and Discussion: The results discussed in this section will address the three goals of the study. As of December 2014, 15.1 million detections from 432 tagged fish have been recorded within the study area. Results through 2014 have shown that only two of 148 tagged fish released within Lower Lockport pool have been detected upstream of the electric dispersal barriers. Although upstream movement was observed across the barriers by these two transmitters, the method of passage cannot be definitively stated. These fish and their detections are described in detail within the results of Goal 1 below.

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 2014 field season. Twelve Common Carp and twelve Largemouth Bass were released immediately upstream of the demonstration barrier in October 2013 and had batteries expire in late May and early April 2014. During the period of active battery life for these 24 fish, five Largemouth Bass (205 ± 55 mm) and two Common Carp (538 ± 46 mm) were found to cross the barriers in the downstream direction. Two of the Largemouth Bass that passed downstream through the barrier were later determined to be dead as all movement was downstream and then no movement occurred for extended periods before losing detections all together. Both Common carp that passed downstream through the barriers were found to be active within the Lower Lockport pool.

An additional 15 Common Carp captured from the Cal-Sag Channel were tagged in November 2013 and released at a barge slip approximately 3.5 miles upstream of the barriers. These fish were implanted with transmitters that were active throughout 2014 and to date 86.7% (13/15) have moved back upstream past the confluence of the Cal-Sag Channel. The remaining two fish made downstream movements following release and were detected at the electric dispersal barriers. One was able to turn back upstream to the confluence, while the other proceeded downstream through the barriers into Lower Lockport pool. This fish (688 mm) was alive after barrier passage and continued to challenge the barriers in the upstream direction without success.

Large Fish Testing at and below barriers: There have been 100 tagged fish (69 kHz, V16 transmitters) greater than 300 mm released between the Dispersal Barrier System and the Lockport Lock and Dam since 2010. These fish have been monitored within the vicinity of the barriers by a network of 8 VR4 receivers capable of producing positioning data for each tag as they are detected since May 2011. Data presented here has been retrieved and analyzed for detection positions from 13 May 2011 through 31 October 2014. During this period of analysis, 50 individual fish (50%) were detected within the VPS array allowing positional data to be acquired. All fish that were observed approaching the barriers were Common Carp between 415 mm and 740 mm (562 ± 67 mm). There was no significant difference between the mean total lengths of fish that approached the barrier compared to the mean total length of all tagged fish in Lower Lockport Pool. For all fish that approached the barriers, the furthest distance away from the active barrier that a fish turned back downstream was 190.8 meters. There was only one occasion on 19 November 2013 in which a fish was able to penetrate the wide array of Barrier IIB and was positioned 3.43 meters into the field from its downstream edge. This fish may have experienced electrical field strengths anywhere from .8-1.0 V/in prior to returning downstream. A two sample t-Test assuming equal variances revealed no significant difference (P=0.062) between the mean approach distance between Barriers 2A (n=22, 59.35 m) and2B (n=18, 50.01 m).

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. The mean residency time for fishes that approached the barriers was 252 minutes with a range from 0.5 to 7103 minutes. Mean residency times for individual fish were poorly correlated using linear regression (n=40, P=0.03, r^2=0.11) with mean hourly discharge (cubic feet per second, cfs) (Figure 3) at the time of initial approach with greater flows equating to longer time spent within the VPS array. Mean hourly discharge was used in place of mean daily discharge due to the inconsistent and flashy discharge rates within the engineered canal.

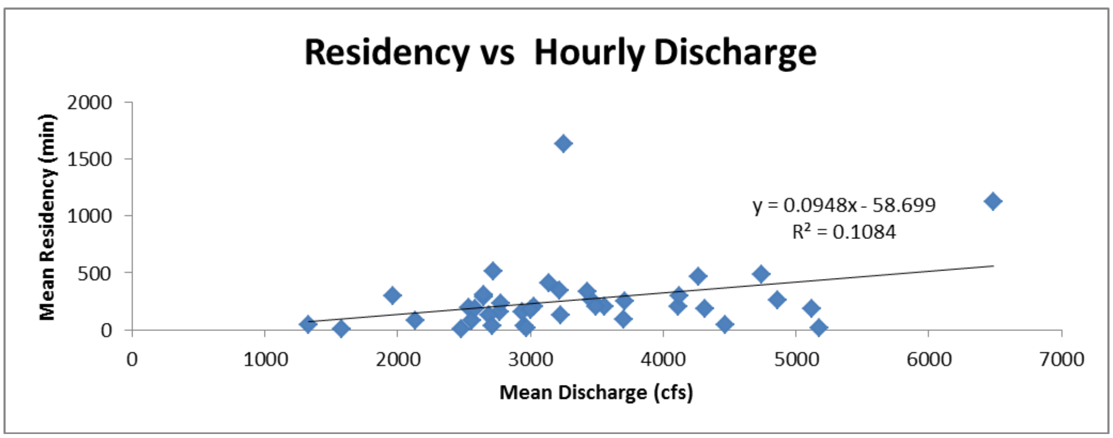


Figure 3: Mean residency period plotted against hourly discharge data for fishes approaching the Electric Dispersal Barrier System in Romeoville, IL (Significance F=0.03).

Through 2014, only two out of 148 tagged fish released within Lower Lockport Pool have been detected upstream of the electric dispersal barrier system. The two transmitters, 62042 and 26927, were implanted into Common Carp (TL=650 and 541mm) and released below the electric dispersal barriers in October 2010 and April 2014. Each transmitter was detected using mobile tracking in the Upper Lockport Pool approximately two and three miles upstream of the Barrier System. The area of detection was located in proximity to a heavily used commercial barge staging area near the I-355 overpass in Romeoville, IL (Figure 4). The transmitters were detected by mobile tracking on 16 August 2011 and 30 June 2014. Follow up tracking data along with specialized receiver placement in vicinity of the upstream detection locations indicated that both transmitters were no longer mobile and had either been expelled from the host fish or the fish died. In 2011, transmitter 62042 was not detected on 12 intermediate receivers between the last known detection downstream of the barriers to the upstream detection location. Transmitter 26927 was detected on only one intermediate receiver located 1.5 miles upstream of the Barrier System, two weeks before its detection via mobile tracking.

During analysis of these results, USACE identified potential reasons for a lack of detections on intermediate receivers in order to better understand a passage mechanism. Potential reasons may include masked transmission signal by increased ambient noise in the water column (vessel generated or high density of transmitters), temporary transmitter failure or a removal from the water over that area (predator, scavenger or human mediated). Although the exact mechanism for barrier passage has not been verified the following discussion provides an analysis of several pathways which coincide with these reasons for a lack of detections. Detections on receivers prior to and post passage were analyzed by the manufacturer (Vemco) for evidence of malfunction and revealed that both transmitters were behaving normally and provided no reason to believe they experienced any operating issues. The large sizes of the host fish would suggest that predator or scavenger mediated transport out of the water was unlikely but could still have been human mediated through catch and release. This also seems unlikely as recreational fishing pressure in Lower Lockport Pool is very low due to accessibility issues, poor habitat and the high commercial traffic of the canal. Masked transmissions seem the most likely cause for the lack of detections on these two fish over the barriers.

Two possible scenarios that were further investigated assuming the signal was masked and that the transmitter remained within the canal during passage.. The first is that the fish was able to swim through the electric dispersal barrier system by taking advantage of barrier outage times and 'locking' through the area. This could occur if the downstream barriers experienced outages allowing the fish to move successively upstream and eventually past the barrier system. Barrier outage records were reviewed and indicated that this could have happened prior to the upstream detection of 26927 with successive outages occurring at the three barriers. The problem with this hypothesis however arises from the explanation of a masked signal for the fish as it waits for barrier outages. The fish would have been entrained between the barriers for a period of 24 days and was not detected on any of the 11 receivers within detection range during that period. There were detections on those receivers of other transmitters in the area which suggest that ambient noise was not elevated enough throughout this period to mask the signal. The other potential scenario is that the fish were entrained by a moving vessel as it passed upstream through the barriers. Unfortunately, this scenario could not be verified by security cameras at the barriers as the recordings were unavailable at the time of review. Lockage data from the Lockport Lock was also reviewed which suggested at least one barge was admitted upstream on the days in question. In addition, there is local barge traffic that moves through the Dispersal Barrier System on a daily basis that would not have been documented by the lock reports. Transmitter 62042 remained at the original detection location throughout the remainder of the battery life before expiring. Transmitter 26927 remains active at the site of its original detection location upstream of the barriers.

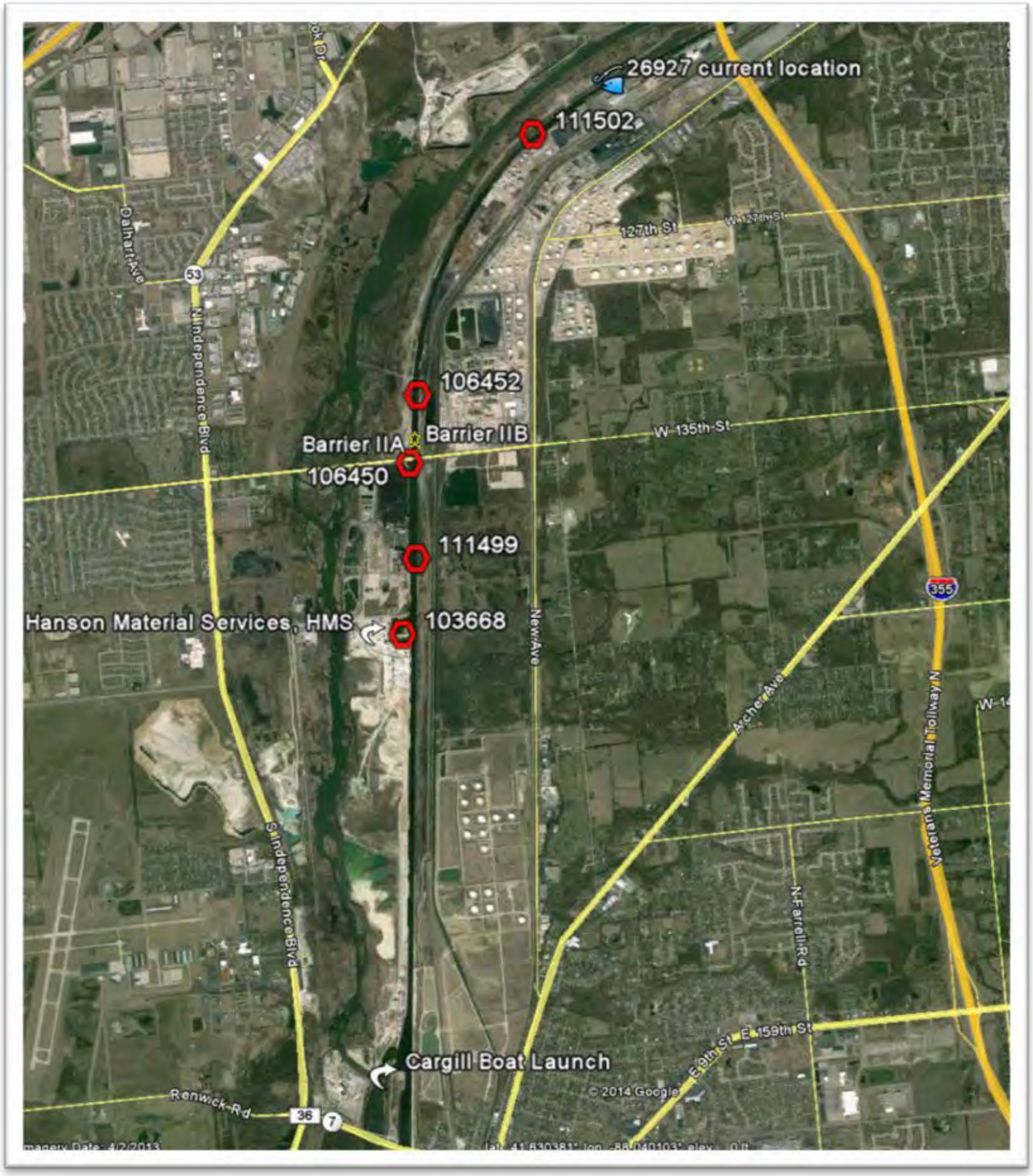


Figure 4: Vicinity map of barriers and key points in reference to analysis of transmitters which were located upstream of the barriers but released downstream of the barriers.

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

From 2010 to 2014, there have been 47 occurrences of tagged fish moving downstream and 16 occurrences of upstream movement between navigation pools by a total of 50 individual tagged fish (Table 2). Inter-pool movement was greatest between the Lockport and Brandon Road pools accounting for 61.9% (39/63) of all inter-pool movements. Of the 39 transfers recorded between these two pools, 29 occurred in the downstream direction and ten 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 18 occurrences of tagged Common Carp passing through this spillway into the Des Plaines River. All eighteen 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 25.4% (16/63) of all inter-pool movement with the dominant direction being downstream (75%). All movement between these two pools was made through the Dresden Island Lock chamber by a total of 10 Bighead Carp and two hybrid bighead/silver carp.

Table 02: Tagged fish inter-pool movement from 2010 to 2014. Downstream is defined as DS and Upstream is defined as US.

Interpool Movement Data			
	US	DS	Total
Lockport	10	11	21
Lockport Spillway	0	18	18
Brandon Road	2	6	8
Dresden Island	4	12	16

Brandon Road Lock and Dam was of particular interest in the 2014 sampling season due to having zero upstream passages through that lock from 2010 through 2013. In addition to the eight Asian carp and eight Smallmouth Buffalo captured, tagged and released within the Dresden Island Pool there were 15 Common Carp captured in the Brandon Road Pool and then tagged and released within the Dresden Island Pool. This was done to help increase the probability of tagged fish detection at the Brandon Road Lock. Additional receivers were also placed within the lock chamber, below the dam and approximately 1.5 miles upstream in an adjacent tributary, Hickory Creek. There were eight occurrences of inter-pool movement across the Brandon Road Lock and Dam from 2010 to 2014 by eight Common Carp with two moving upstream and six downstream. Both of the Common Carp to move upstream through the lock were originally captured from the Brandon Road Pool. The first upstream passage occurred on 15 May and was detected in the lock chamber on and off for four hours and 47 minutes. The second upstream passage occurred on 7 August and was again detected in the lock chamber sporadically over a period of four hours and 27 minutes. In both cases, the fish had staged within the lock chamber or just downstream through multiple lockage of vessels in the up and downstream directions before passing upstream. The combination of vessel generated noise, mechanical noise from the lock operation and turbulent waters could explain the sporadic detections within the lock chamber.

The receiver within Hickory Creek was deployed 17 March and retrieved for the winter months on 17 November 2014. There were 35 detections on this receiver on five separate days from 13 May to 15 July. Three tagged Common Carp (573 ± 71 mm) accounted for all detections with one fish originating from the Dresden Island Pool near the Kankakee Confluence and the other two fish originating from the Upper Lockport Pool. Detections on the Hickory Creek receiver indicate at least some use of this connecting tributary as fish approach the Brandon Road Lock and Dam. The receiver below the dam was deployed on 17 March and was retrieved for the winter on 17 November 2014. There were 193 detections on this receiver on five days from 10

April to 4 August 2014. Three tagged Common Carp (533 ± 16 mm) were detected on this receiver. Only one of these fish was also detected on the Hickory Creek receiver and had originally been captured and tagged within the Upper Lockport Pool. The other two fish originated from the mouth of the Kankakee River in Dresden Island Pool and near the I&M Canal within the Brandon Road Pool and were released within their pool of capture.

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

Weekly individual fish detections were significantly correlated to both flow and temperature in the Kankakee River (multiple regression; DF=68, F value= 12.56, p<0.0001). In addition, temperature was significantly correlated with weekly individual fish detections at RRR (df=82, f value= 24.61, p<0.0001). Only two detections since 2013 have been observed at Brandon Road Lock and Dam and the data were insufficient for statistical analysis. The number of individual fish observed at the Kankakee River was most driven by temperature. However, based on observations of tag data, fish appeared to visit the Kankakee River in early spring only after a rise in the hydrograph occurred. It is possible that these fish are attracted to the river in the spring by flows and then become increasingly active as the water temperature rises. At RRR, fish moved in and out of the area quite frequently. In many cases a fish can be observed leaving RRR, head downstream to the Kankakee River and then head back to RRR. In addition, detection data suggests some fish are over-wintering in RRR. The exact reason for the increase of AC in RRR is unknown. There are additional backwater habitats in Dresden Island that appear to be used by some fish, but not to the extent of RRR. Additional habitat and water chemistry of RRR is needed to increase our understanding of its use by Asian carps.

The logistic regression models to determine the probability of finding a tagged fish at the Kankakee River receiver and at the RRR were both significant. Both temperature (df=1, χ= 102.81, p=<0.0001) and flow (df=1,χ=12.04, p=0.0005) were significant for the Kankakee River. Probability for each observation was plotted against the model output value to create a model probability curve (Figure 5). By entering the current flow (m^3/s) and temperature (C°) into the model an estimated probability of finding a tagged fish at the location can be determined. In general, the model predicts the greatest probability of finding a tagged fish at the Kankakee River receiver under low to mid flows at higher temperatures. The model produced a maximum probability of 0.72 resulting in some issues for values beyond the predicted curve. Increases in tag detection may help increase the model fit and provide greater probabilities. An additional year of data collection and increases in tagged fish throughout the Dresden Island pool may help produce a more robust model.

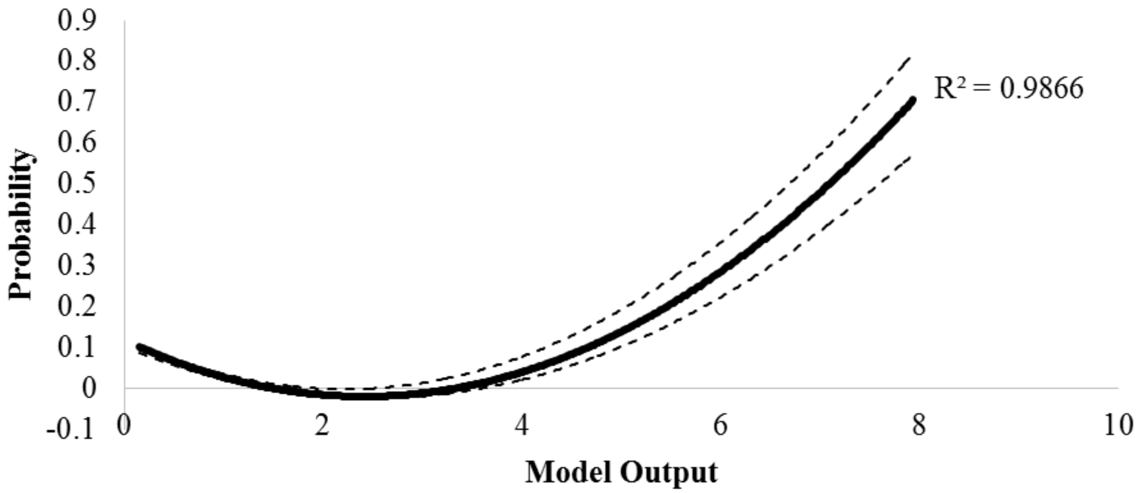


Figure 5.— Probability of a tagged Asian Carp in Kankakee River based on flow and temperature. The model output is the value acquired from y=(-7.2242+0.262(temp)+0.0031(flow))+7.

The probability model for RRR was also statistically significant with only flow as significant term (df=1,χ=17.85, p=<0.0001). However, through the course of 2 years, only 45 days were observed with no Asian Carp detections. As a result, the lowest probability of finding Asian Carp at RRR was 0.87. In order to better understand Asian Carp movement in Dresden Island, fine-scale temperature data and increased detections are needed. It will also be beneficial to develop a spatio-temporal probability model for the entire pool.

Only two detections of Asian Carp were found at Brandon Road. These data suggest that most tagged fish are not migrating that far upstream. While increased flows do occur at Brandon Road, fish appear to prefer the Kankakee under increased flows. Most fish during the spring move back and forth from RRR to the Kankakee River during increased flows. The reason for preference of the Kankakee River is unknown, however it is hypothesized that the overall flow rates and habitat are superior to that of Brandon Road.

Recommendations:

USACE recommends continuation of the telemetry program and maintaining the current level of surrogate species tags within the system while increasing the number of tagged Asian carp within the Dresden Island pool. In addition, temperature data loggers should be deployed across Dresden Island and Lower Lockport to effectively develop a spatio-temporal probability model for the presence/absence of tagged fish. This will provide quick reference for fish managers on the likelihood of fish being present throughout the system.

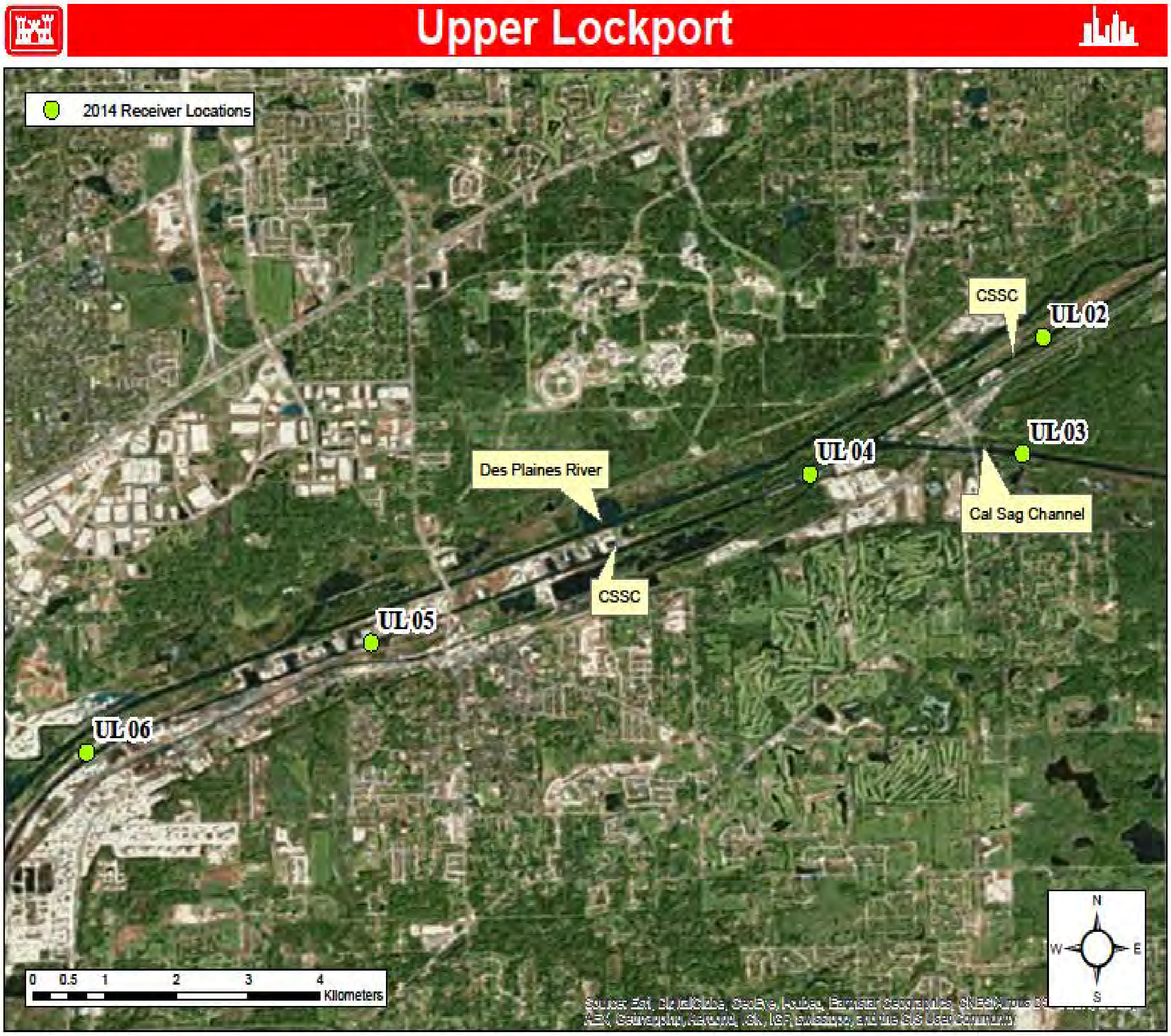
In regards to the electric dispersal barriers, this report recommends continued analysis of barge entrainment and detection probability of transmitters within the safety zone of the regulated navigation area. In light of the two transmitters that have been located upstream of the Barriers these two actions are warranted to further evaluate the hypothesis that entrainment could have been the method of transport. It is also imperative to maintain operation of the low electrical fields generated by the wide arrays of each barrier to reduce the chances of fish becoming incapacitated by first encountering the narrow (higher electrical field) array. Incapacitation at the Barriers may increase opportunities for barge entrainment in the upstream direction as stunned fish are unable to maneuver themselves away from vessel traffic.

USACE recommends continuation of the modified lock gate standard operating procedure at Brandon Road Lock which allows the minimum opportunity for fish passage. This SOP should also be adopted at other locks within the IWW to include Lockport and Dresden Island at a minimum. Continued analysis should occur at the Brandon Road Lock chamber for the telemetry program but increased collaboration with USGS and USFWS lead projects at the lock should occur in 2015.

Project Highlights:

- To date, we have acquired 15.1 million detections from 432 tagged fish.
- The electric dispersal barriers have been effective at preventing upstream passage of free swimming tagged fish > 300 mm.
- Since 2011, two transmitters implanted into Common Carp downstream of the Barriers have been located upstream although no detections were observed at barrier receivers. The most plausible explanation being assisted passage via barge entrainment; both transmitters were either expelled or the host had expired.
- Fish approaching the Dispersal Barriers spend a greater amount of time challenging the barriers with increased discharge rates.
- Common Carp over 415 mm in total length are repelled by electric field strengths as low as .1 to .5 V/in.
- Inter-pool movement of tagged fish was observed in both directions between all pools within the study area in 2014 (Lockport, Brandon, Dresden Island and Marseilles).
- Asian Carp are consistently using the Kankakee River and Rock Run Rookery with little movement detected surrounding the Brandon Road Lock and Dam.
- A probability model for tagged Asian carp presence/absence has been generated for the Rock Run Rookery and the Kankakee River within the Dresden Island Pool based on temperature and discharge rates.

Appendix A – Attached PDF



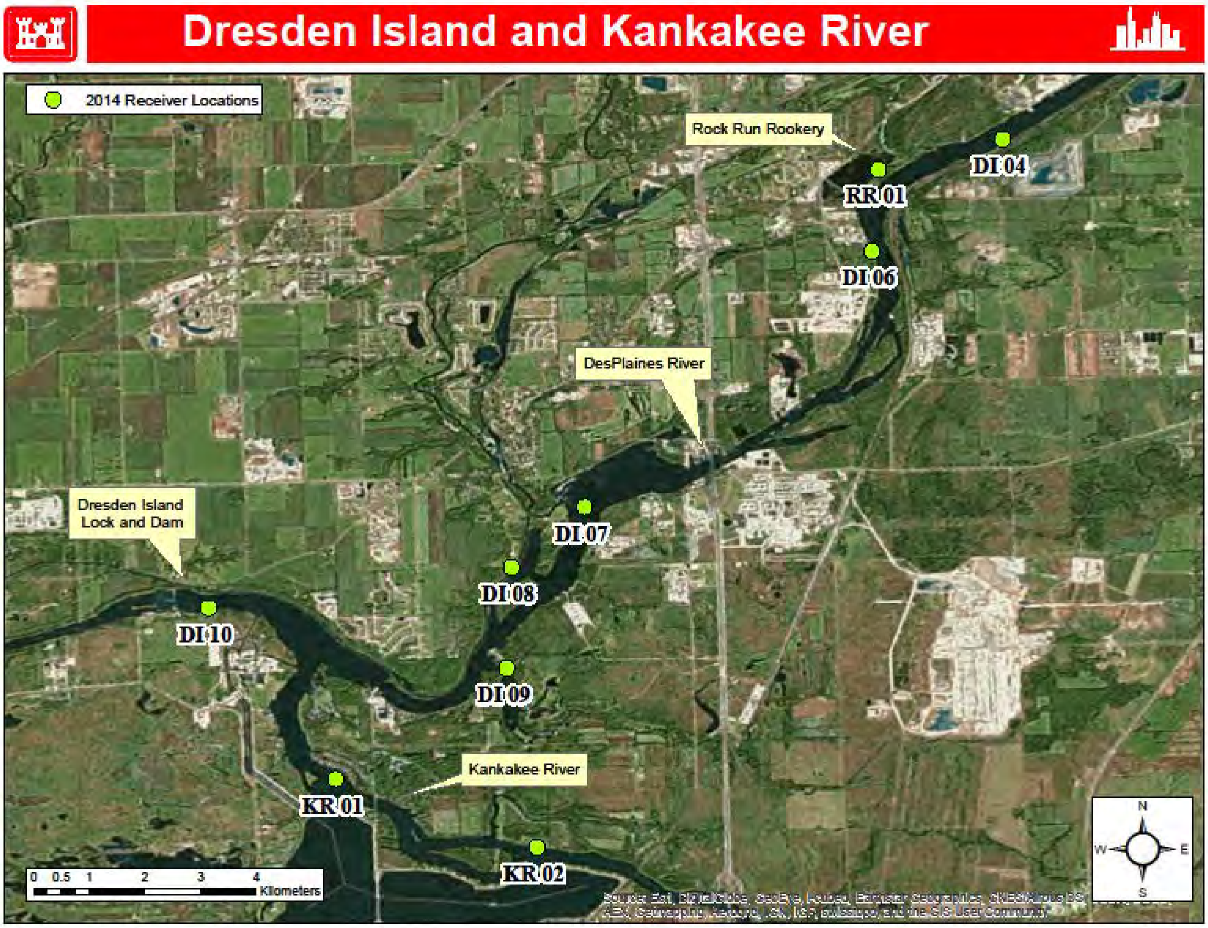
Barriers


2014 Receiver Locations
UL 07
Demo Barrier
VR4 01
VR4 05
2B Barrier
VR4 02
VR4 06
VR4 03
VR4 07
2A Barrier
VR4 04
VR4 08
LL 01
0 0.02250.045 0.09 0.135 0.18
Kilometers
N
W
E
S

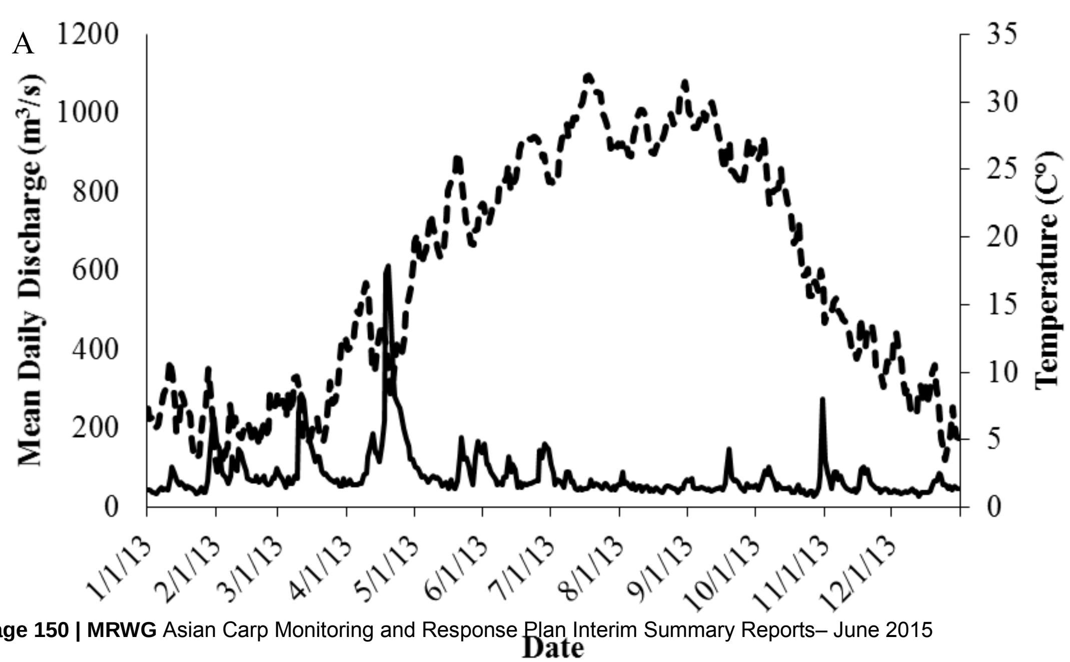
Lower Lockport

Lockport Lock


Brandon Rd Lock and Dam
2014 Receiver Locations
DesPlaines River
Brandon Lock
BR 03
BR 04
DI 02
DI 03
DI 01
Brandon Rd Dam
Hickery Creek
0 0.1 0.2 0.4 0.6 0.8
Kilometers
N
W
E
S

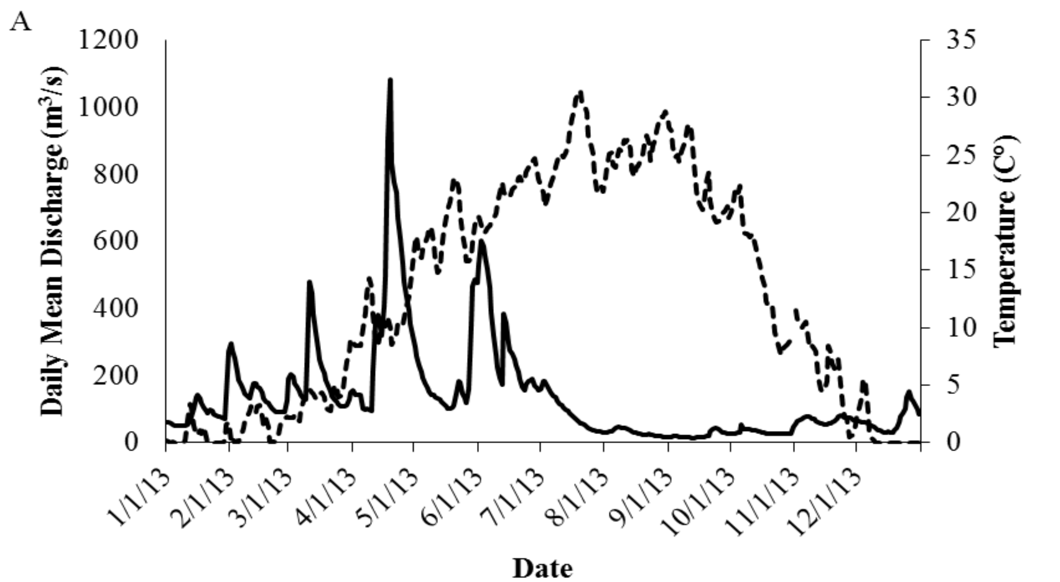


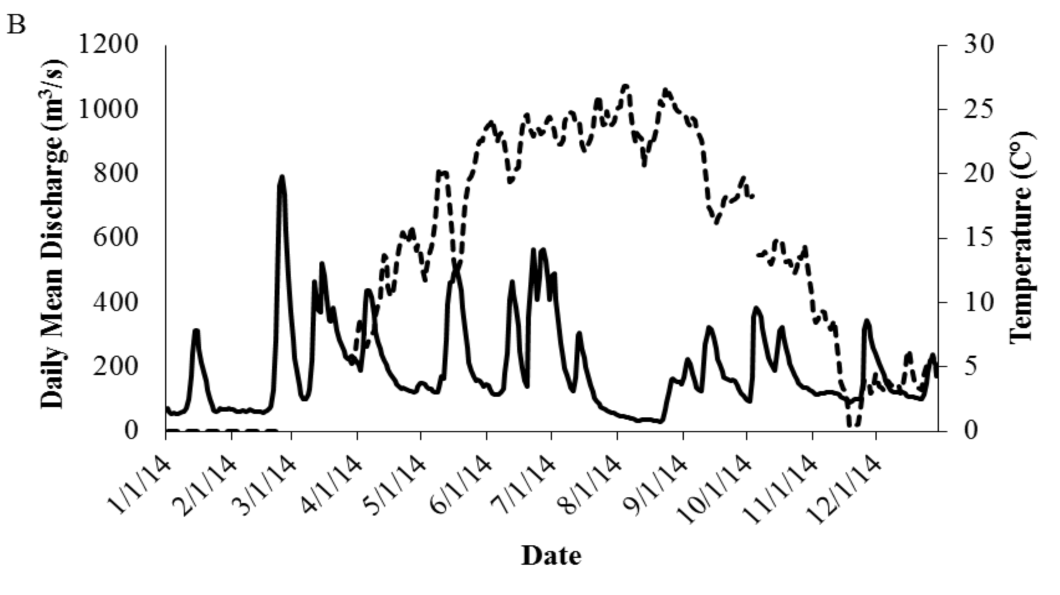
Appendix B: Temperature and Flow Data



Appendix A

Mean daily discharge (m^3/s) of the Lower Des Plaines River near Route 53 in Joliet, Illinos and mean daily temperature (C°) near Channahon, Illinois for 2013 (A) and 2014 (B). Discharge is indicated by the solid black lines and temperature is represented by the dashed lines. Data gaps exist in 2014 due to equipment malfunction and ice cover





Mean daily discharge (m^3/s) of the Kankakee River near Wilmington, Illinois and mean daily temperature (C°) at Custer Park for 2013 (A) and 2014 (B). Discharge is indicated by the solid black lines and temperature is represented by the dashed lines. Data gaps exist in 2014 due to equipment malfunction and ice cover.

Understanding Surrogate Fish Movement with Barriers

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and

Nick Bloomfield and Patricia Herman; US Fish and Wildlife Service – Carterville Fish and Wildlife Conservation Office
and

Mathew Shanks and Nicholas Barkowski: US Army Corps of Engineers

Participating Agencies: Illinois Department of Natural Resources (lead); US Fish and Wildlife Service, US Army Corps of Engineers, 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 and Need: 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 (i.e. lock chambers and the electric dispersal barrier). In addition, recapture rates of surrogate species will be used to determine sampling efficiency in the area between the electric dispersal barrier and the Dresden Island Lock and Dam. In order to test the potential risk of Asian carp movement through barriers, surrogate species will be tagged in the Rock Run Rookery, Dresden Island, Brandon Road and Lockport Pools. 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 Chicago Sanitary Ship Canal (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 due to 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.

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 eight random sites in each of the three pools below the electric dispersal barrier. Contracted commercial netting will include four fixed sites in each pool, twelve random sites in Brandon Road and Lockport Pools, and twenty four random sites in Dresden Island Pool each week sampled. Contracted commercial netting will also include two sets in Rock Run Rookery two times a month from March to November. 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 upper portion of the caudal fin at an angle to increase recognition upon recapture. 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 April 1 and December 11, 2014, a total of 1,654 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. Eighteen of the 1,654 fish tagged were recaptured, which is a recapture percentage of 1.09% (Table 1). Individual recapture percentages for Lockport Pool, Brandon Road Pool, Dresden Island Pool and Rock Run Rookery were 1.67%, 2.46%, .56% and 1.71%, respectively (Table 1). Of the 18 recaptures, 2 showed movement from the original pool from which they were captured

(Table 2). One Smallmouth Buffalo (532mm) was initially captured and tagged in Dresden Island Pool on August 19, 2014 (Figure 1). This fish travelled 10.65 miles downstream from the tagging location through the Dresden Island Lock and Dam. The fish was subsequently harvested on October 22, 2014 in the Marseilles Pool in the Hansen Material Services east pit near Morris Illinois by a contracted commercial fisherman. This surrogate fish demonstrated the ability for movement downstream through the Dresden Island Lock and Dam. The hydrological data between August 19 and October 22 at Dresden Lock and Dam, showed 4 spikes in flow that where above the 2014 average of 10,308 cubic feet per second (CFS(Figure 3)). The spikes in flow might have attributed to the Smallmouth Buffalo traveling downstream through the Dresden Island Lock and Dam. Also with the capture of this fish we feel floy tag retention has met expectations. The second recaptured fish, a Bigmouth Buffalo (562mm), was tagged August 8, 2014 in Dresden Island Pool then travelled upstream in the Kankakee River (Figure 2). The fish was harvested September 15, 2014 by a bow fisherman 9.15 miles from where it was tagged. The hydrological data between August 8 and September 15 at Dresden Lock and Dam showed 2 spikes in flow that where above the 2014 average of 10,302 CFS (Figure 4). The spikes in flow might have attributed to the Bigmouth Buffalo traveling upstream the Kankakee River. Although the Bigmouth Buffalo did not travel through a barrier structure, the distance travelled within a year demonstrated the potential for the species to travel long distances and the use of tributaries as a preferred habitat. This fish also provided insight on how they could be recaptured by alternate recreational methods.

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 with 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 r Asian Carp may potentially move through barrier structures.

Table 1. Number of fish tagged and recaptured in Lockport Pool, Brandon Road Pool, Dresden Island Pool and Rock Run Rookery in 2014

	Fish Tagged	Recaptures	Recapture %
Lockport Pool			
Common Carp	177	3	
Smallmouth Buffalo	1	0	
Bigmouth Buffalo	0	0	
Black Buffalo	0	0	
Common X Goldfish Hybrid	2	0	
Total	180	3	1.67%
Brandon Road Pool			
Common Carp	276	7	
Smallmouth Buffalo	4	0	
Bigmouth Buffalo	0	0	
Black Buffalo	0	0	
Common X Goldfish Hybrid	5	0	
Total	285	7	2.46%
Dresden Island Pool			
Common Carp	466	1	
Smallmouth Buffalo	565	4	
Bigmouth Buffalo	24	1	
Black Buffalo	16	0	
Common X Goldfish Hybrid	1	0	
Total	1072	6	0.56%
Rock Run Rookery			
Common Carp	9	0	
Smallmouth Buffalo	86	2	
Bigmouth Buffalo	21	0	
Black Buffalo	1	0	
Common X Goldfish Hybrid	0	0	
Total	117	2	1.71%
Grand Total	1654	18	1.09%

Table 2. Summary of recapture data for Floy Tag Project in 2014 through the use of pulsed DC electrofishing, gill nets, trammel nets, bow fishing and single line pole fishing

Species	Area Captured	Gear	Moved Through Barrier/Dam	Distance Travelled (mile/kilometers)
Common Carp	Brandon Road Pool	DCEF	No	0.59m/.95km
Common Carp	Brandon Pool	POLE	No	0.01m/.02km
Common Carp	Brandon Pool	GILL	No Tag	N/A
Common Carp	Brandon Pool	DCEF	No Tag	N/A
Common Carp	Brandon Pool	GILL	No	0.21m/.34km
Common Carp	Brandon Pool	GILL	N/A	N/A
Common Carp	Brandon Pool	GILL	No	2.00m/3.22km
Common Carp	Dresden Island Pool	DCEF	No	6.45m/10.38km
Smallmouth Buffalo	Dresden Pool	TRAM	No	0.14m/.23km
Smallmouth Buffalo	Dresden Pool	GILL	No	0.36m/.58km
Smallmouth Buffalo	Dresden Pool	GILL	No	0.23m/.37km
Bigmouth Buffalo	Kankakee	BOW	No	9.15m/14.73km
Common Carp	Lockport Pool	DCEF	No	N/A
Common Carp	Lockport Pool	DCEF	No	0.96m/1.54km
Common Carp	Lockport Pool	DCEF	No	0.45m/.72km
Smallmouth Buffalo	Marseilles Pool	GILL	Yes	10.65m/17.14km
Smallmouth Buffalo	Rock Run	GILL	No	0.27m/.43km
Smallmouth Buffalo	Rock Run	GILL	No	N/A

Figure 1. Movement of Smallmouth Buffalo (532mm) originated in Dresden Pool and moved through Dresden Lock and Dam downstream to Material Services in Marseilles Pool

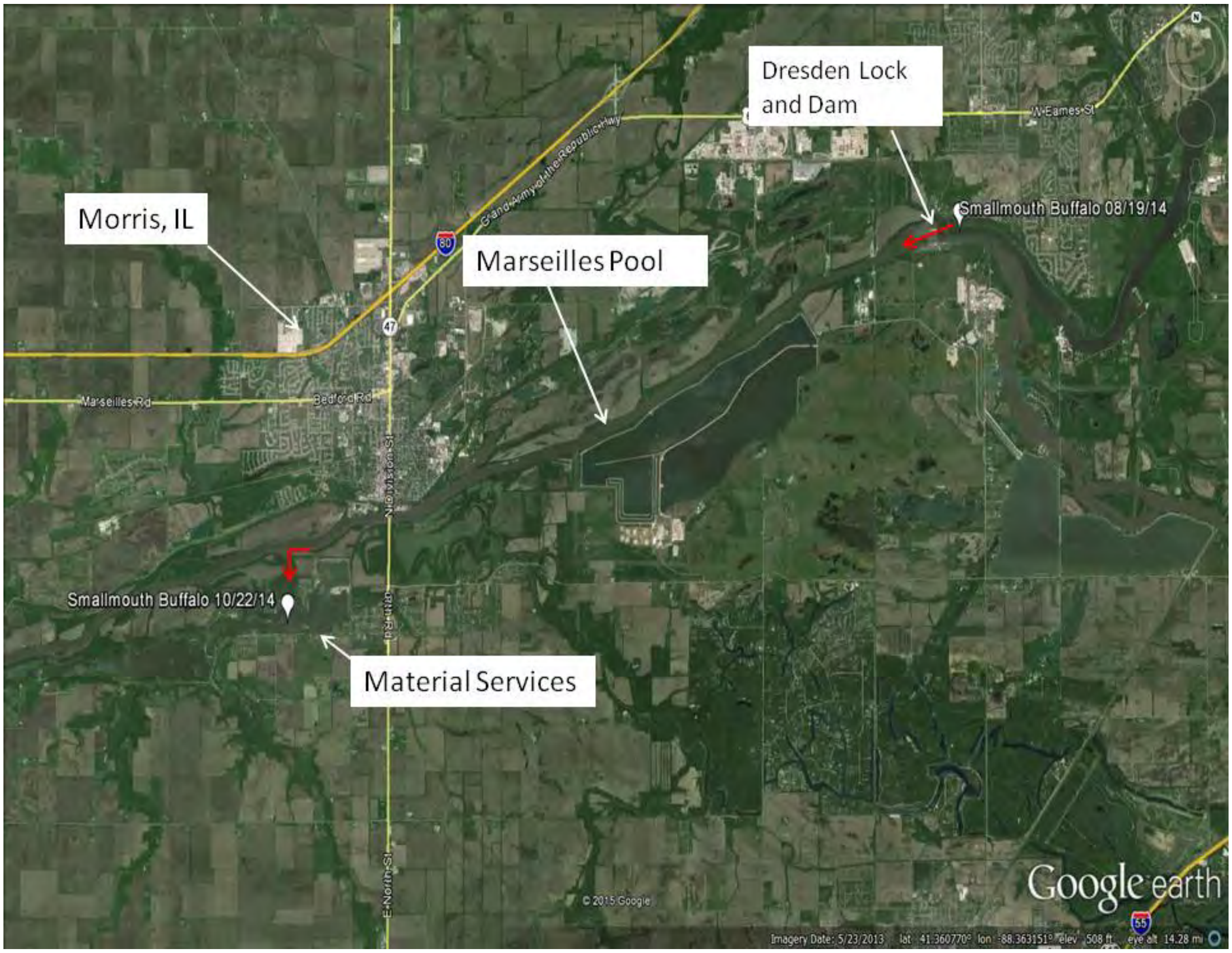


Figure 2. Movement of Bigmouth Buffalo (562mm) originated in Dresden Pool then swam 9.15 miles upstream the Kankakee River

Figure 3. Dresden Lock and Dam flow rates in cubic feet per second (CFS) between the time Smallmouth Buffalo (532mm) was first captured August 19 in Dresden Pool and recaptured October 22 in Material Services

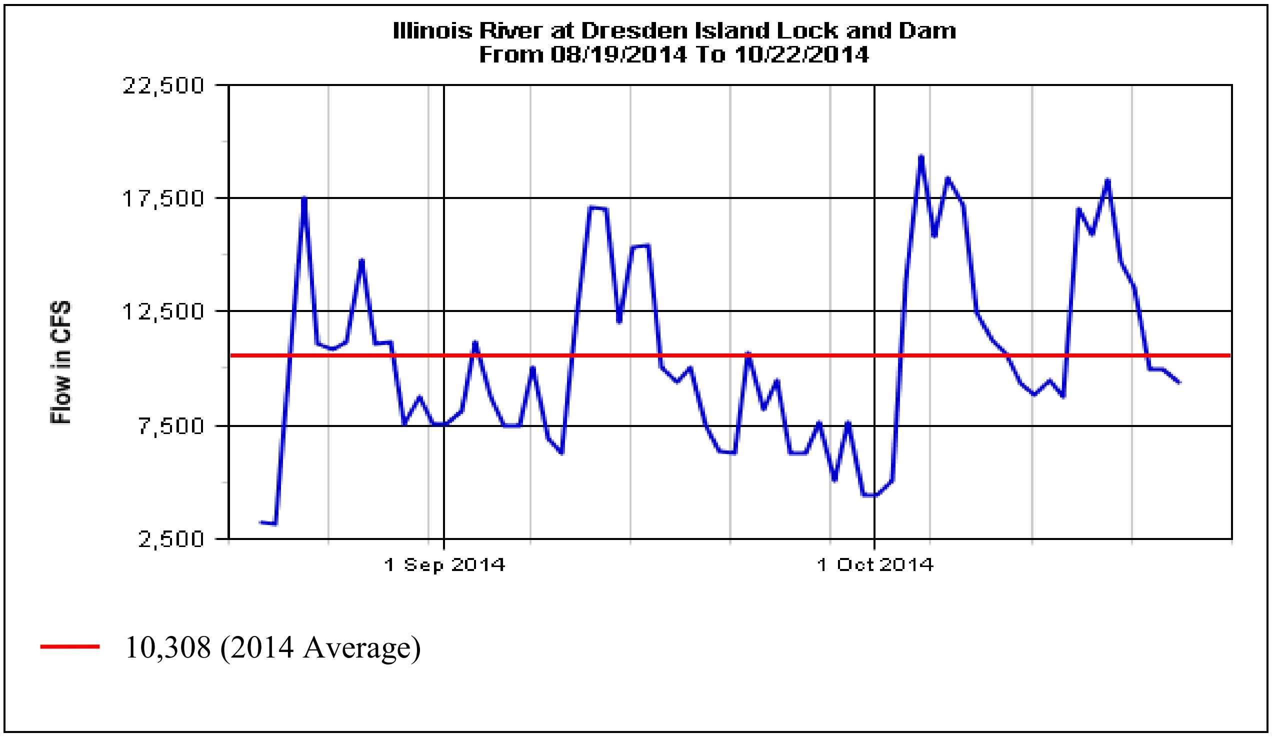
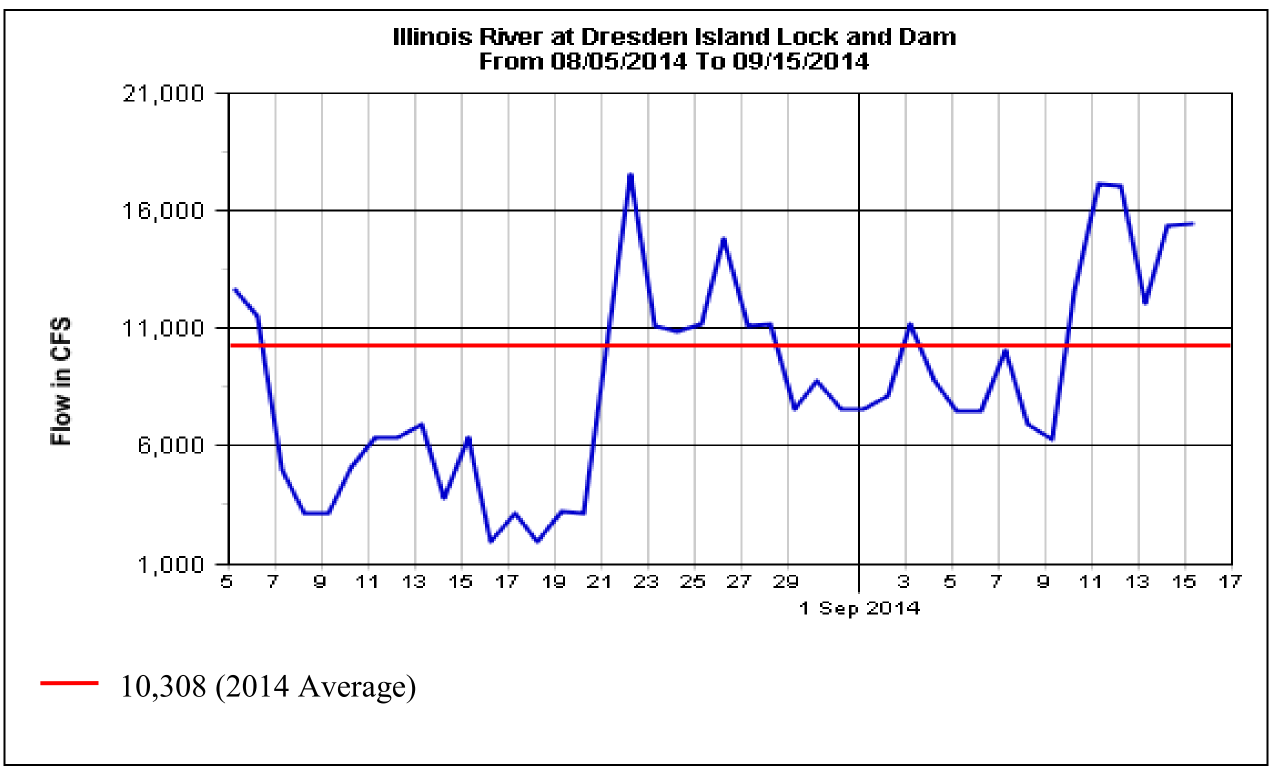


Figure 4. Dresden Lock and Dam flow rates in cubic feet per second (CFS) between the time Bigmouth Buffalo (562mm) was first captured August 5 in Dresden Pool and recaptured September 15 up stream in the Kankakee River



Project Highlights:

- Multiple agencies and stakeholders cooperated in successfully tagging 1,654 fish in Lockport Pool, Brandon Road Pool, Dresden Island Pool and Rock Run Rookery (Between April 1 and December 11)
- A total of 18 fish were recaptured using pulsed DC-electrofishing, gill nets, trammel nets and 6 foot diameter hoop nets.
- A total of 14 recaptures had tags but showed no movement between barrier structures, 3 recaptures where observed due to caudal fin clip but had no tag to show movement and 1 recapture showed movement from Dresden Island Pool downstream through the Dresden Island Lock and Dam into the Marseilles Pool.
- 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 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

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U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office, Illinois

Participating agencies: 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- Construction Engineering Research Laboratory (field/logistical support).

Introduction: Preliminary trials of a study designed to make direct observations of fish behavior at the CSSC electric dispersal barrier took place July 30- August 1, 2013. Previous studies suggested that small fish were congregating below the electric dispersal barrier during summer and some of those data indicated that small fish were potentially present directly over the portion of the barrier that produces the greatest in-water electrical field (USFWS unpublished data). To investigate these observations further, crews deployed a series of Dual Frequency Identification Sonar (DIDSON) units from a telescopic boom lift into the canal, directly over the narrow array structure of electric dispersal barrier IIB. The DIDSON units utilize a series of 96 separate acoustic cones that are integrated to produce video quality acoustic images. This sampling system allowed us to make real time observations of fish behavior in the canal, over the portion of the barrier that exhibited the highest electrical field strength. During the 2013 trials, barrier IIB was the furthest downstream barrier operating.

Results of these preliminary studies showed that of the 72, 10 minute data collection periods that took place, 44 (61%) of them captured at least one occurrence of a school of fish crossing the electric dispersal barrier in an upstream direction. 27 (38%) of data collections revealed multiple fish school breaches of the electric dispersal barrier (Fig. 1). The sizes of the fish that breached the barrier were estimated to range from approximately 50 to 100 mm (2 to 4 in) total length by using the fish measurement tool in the DIDSON software package. However, these size estimates have estimated error ranges (± ≈10 mm @ 2 m to ± ≈50mm @ 10 m) that become greater with the distance a fish is from the lens of the DIDSON unit. This is because each cone of the acoustic array expands in size with increased range (X= 2R tan (θ/2). All of the fish observed breaching the barrier did so in schools; this further complicated 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 after they breached, the group expanded again.

Although there were more replicate trials scheduled to take place during 2013, maintenance of barrier IIB caused further sampling in 2013 to be postponed. While barrier IIB was down, barrier 2A (located immediately downstream of barrier IIB) was the primary operating barrier. The telescopic boom lift used to deploy the DIDSON units cannot be deployed directly over barrier 2A because a storage building is located adjacent to the canal where the deployment would need to take place. During 2014, sampling was tentatively scheduled to take place in late summer; however, work could not take place until dive crews finished construction of underwater electrodes to be utilized by the new Permanent Barrier 1. This work was delayed by weather and we subsequently did not begin sampling until October 2014.

Objectives:

- Determine the frequency of electric dispersal barrier passage by fish in the CSSC.
- Quantify the species and length frequency distribution of any fish that are exhibiting barrier passage behavior.

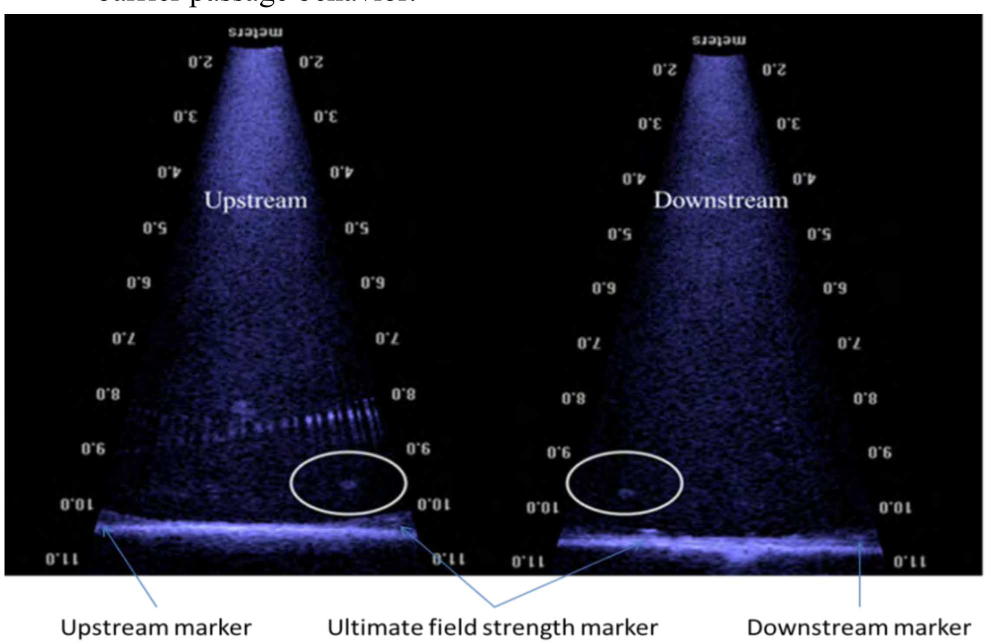


Figure 1. Example of both the upstream and downstream DIDSON units ensonifying the same school of fish (in white circles) as it swims upstream past the ultimate field strength marker before swimming further upstream and out of the DIDSON view during data collections made on August 1, 2013.

Methods: Prior to the shore-based sampling, a field reconnaissance mission occurred, in which two DIDSON units were deployed off of a boat within the narrow arrays. Through that initial work, we determined that when two DIDSON units were deployed 3.7 m apart (parallel to the western canal wall), and 10 m east of the wall, the entire 9 m width of the narrow array electrode could be ensonified (Fig.2). On the western bank along the canal, workers from the U.S. Army Corps of Engineers (USACE) Construction Engineering Research Laboratory (CERL) determined the exact locations of the inside narrow array margins and the area of highest in-water voltage to use as references for later sampling with the DIDSON units. A Trimble GeoXH (Trimble Navigation Limited, Sunnyvale, CA) GPS unit, with a maximum margin of error of ± 0.1 m, was used to mark the upstream margin of the lower narrow array and the downstream margin of the upper narrow array (Fig.2). The location of the highest in-water voltage was determined using a Fluke® model 124 industrial scope-meter. These locations were permanently marked with marker plaques embedded into the concrete walkway. The markers were subsequently used as reference points to deploy concrete marker blocks into the canal. The blocks were positioned directly over the upstream and downstream margins of the narrow array and directly in the center of the narrow array at a depth of ≈ 0.3 m. These served as reference points that could be observed with the DIDSON units to be sure that the units were positioned correctly. Throughout the time that the concrete markers were serving as reference markers, personnel periodically checked them to ensure that they were correctly aligned with the land markers.

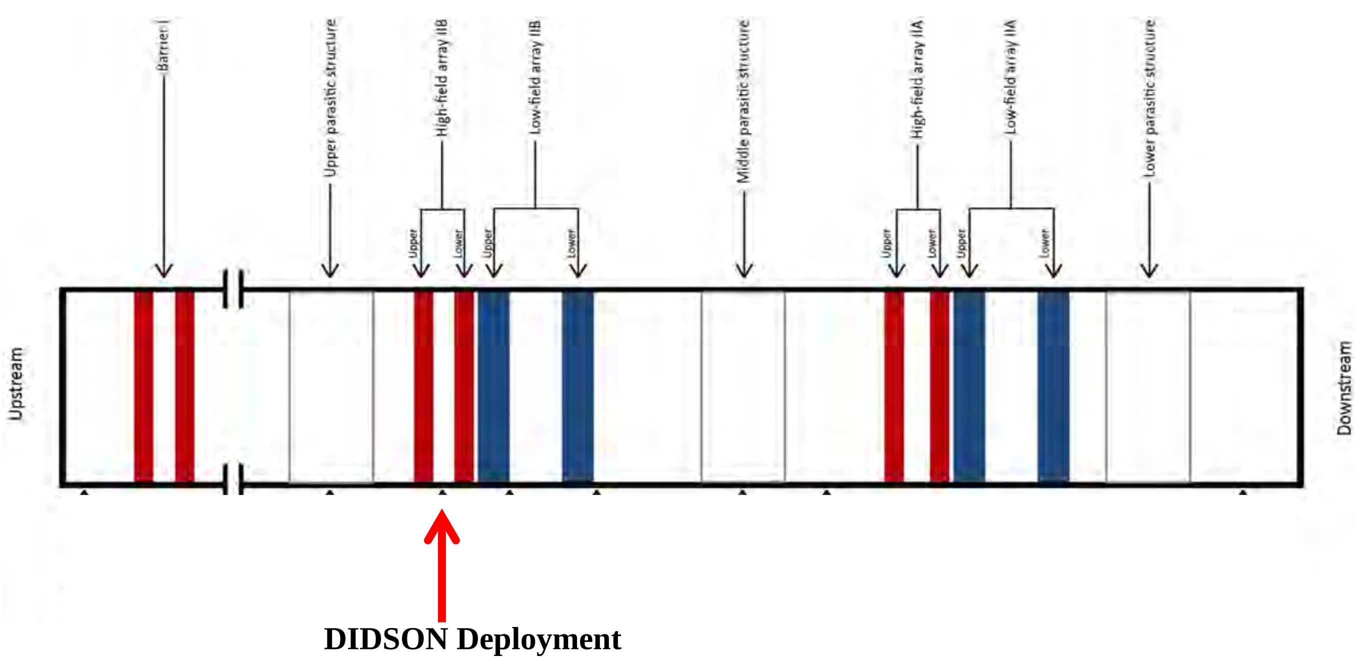


Figure 2. Schematic of the electric dispersal barrier system within the CSSC. The red lines denote the locations of narrow electrode arrays (high-field) and blue lines denote the location of wide electrode arrays (low-field). DIDSON deployment took place over the barrier IIB narrow array during both study years.

To deploy the DIDSON units into the canal from the western canal bank, a mobile telescopic boom lift was utilized (Fig.3A-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, thus electrically isolating the boom lift from the dispersal barrier electricity. The DIDSON units were deployed 10 m from the western canal wall, 1 m below the water surface, and were aimed towards the western wall. Both of the DIDSON units were simultaneously operated from one computer (Fig.3D).

The two DIDSON units were able to ensonify the entire width of the narrow array. To focus our study on fish that were swimming upstream, we positioned the DIDSON units so that the entire downstream array marker was clearly visible in the DIDSON cone, and so that the middle marker denoting the area of the ultimate field strength was visible in 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 proceeding further upstream. However, because the DIDSON units were positioned slightly downstream, only a portion of the upstream marker is visible within the upstream DIDSON viewing cone (Fig. 4). Unfortunately, mid-way through the first week of sampling during 2014 one of the DIDSON units developed a mechanical problem and was returned to the manufacturer for repair. Subsequent 2014 DIDSON data collections took place using one unit centered on the middle marker over the area of highest field strength (2.3V/in; 2.6 ms). This allowed coverage of a ≈5 m wide section of the canal at range = 10 m.

In addition to DIDSON data collections, we conducted a fish survey to characterize the fish community present directly downstream of the electric dispersal barriers and quantify the length frequency distribution of each species present. A crew from the USFWS Columbia Fish and Wildlife Conservation Office conducted Paupier butterfly trawling immediately downstream of the electric dispersal barrier and directly over the electric dispersal barrier. Briefly, during over the barrier collections, the survey boat traveled downstream from above the barrier, deployed the butterfly trawl just above the barrier IIB narrow array, trawled over the target area, and lifted the gear immediately after exiting the electric dispersal barrier (Fig.5).

Further, we performed split beam hydroacoustic data collections the week following DIDSON data collections in Lockport pool below the electric dispersal barrier to gain a greater understanding of spatial heterogeneity in fish density and to quantify the length frequency distribution of the fish community during both years. (For complete methods see: Monitoring of Fish Abundance and Spatial Distribution in Lockport, Brandon Road, and Dresden Island Pools and the Associated Lock and Dam Structures ; Monitoring and Response Work Group Interim Report 2015).

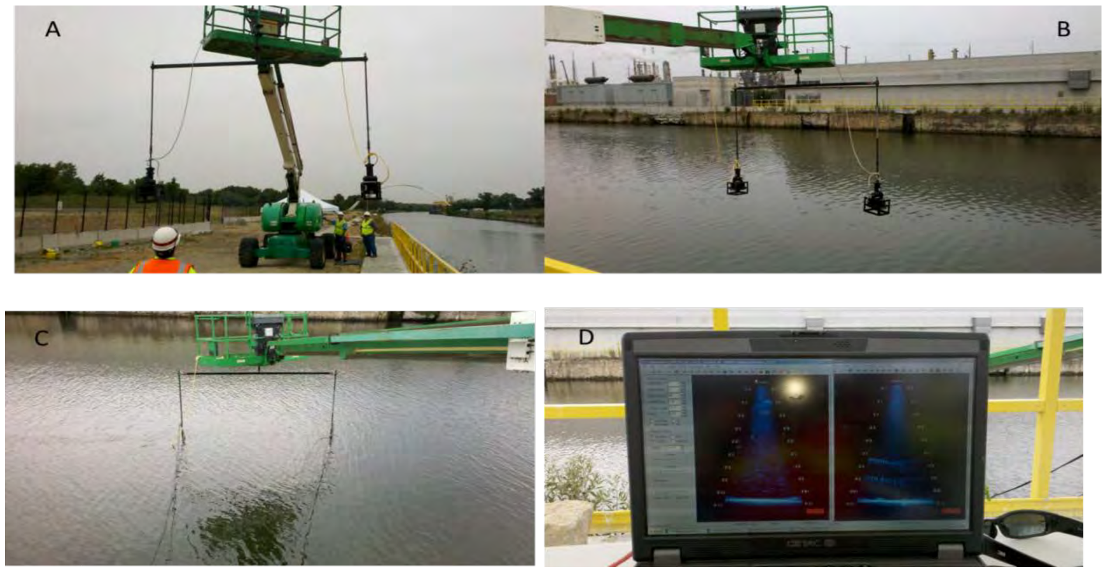


Figure 3. Two DIDSON units being deployed into the CSSC using a telescopic boom lift (A-C) and the two DIDSON units being operated on one computer (D).

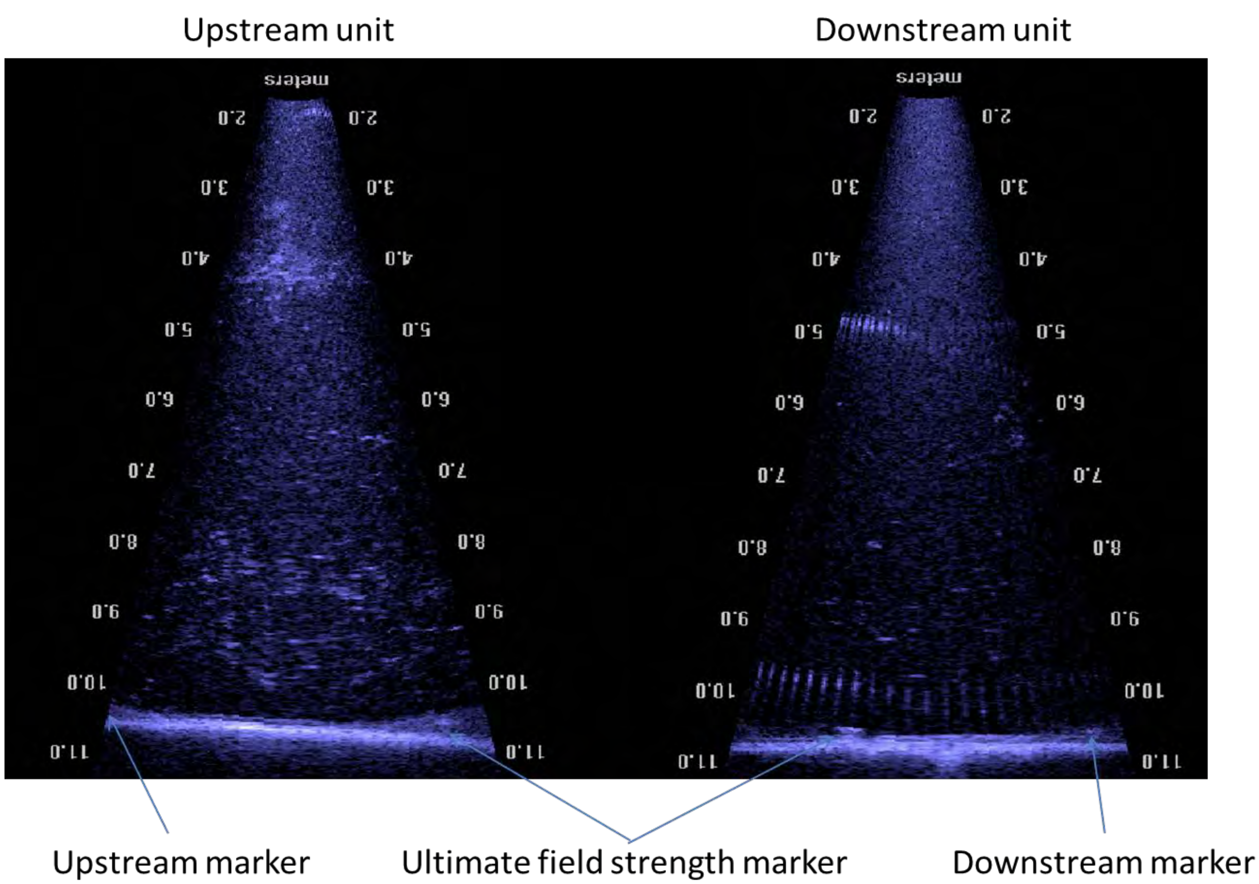


Figure 4. Viewing cones of the upstream and downstream DIDSON units and the three markers along the western canal wall

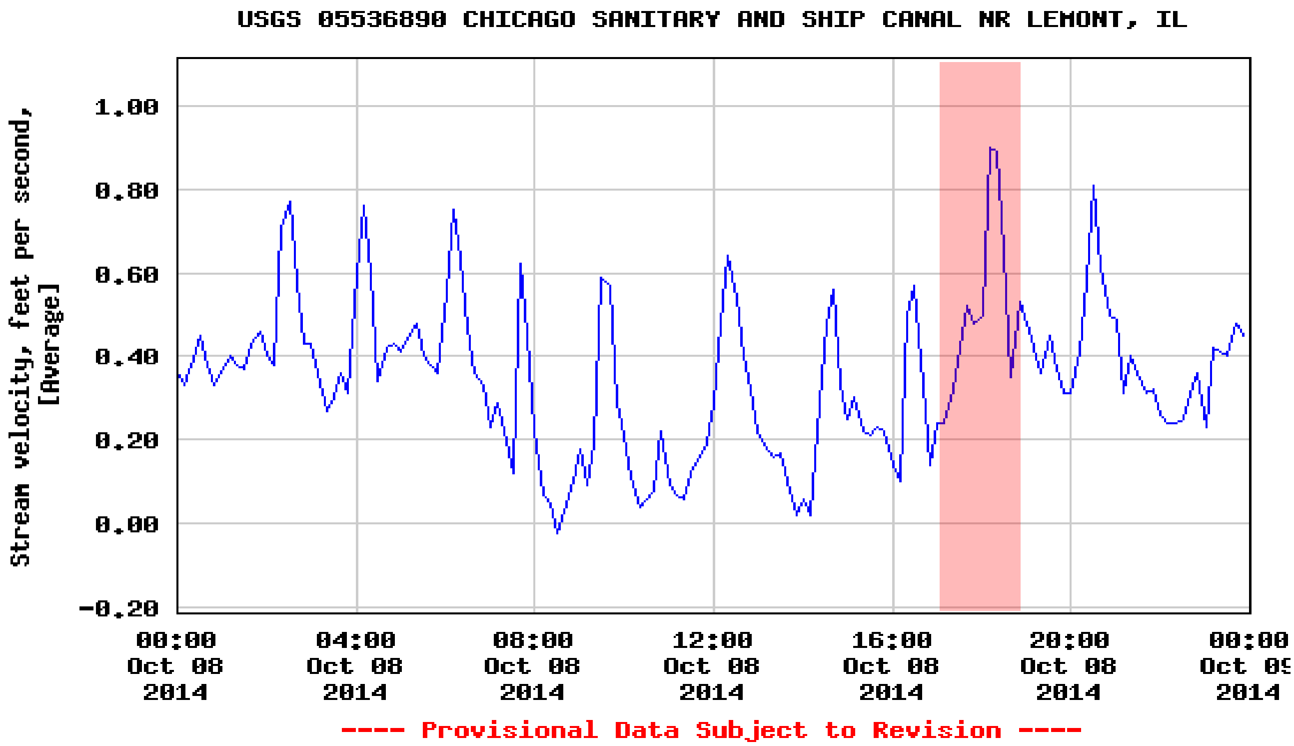
Figure 5. Paupier butterfly trawl net deployment used to capture fish within the vicinity of the CSSC electric dispersal barriers. The nets extend over the sides of the vessel and are lowered and raised into and out of the water at precise locations.

Results and Discussion: During Oct. 7-9 and Oct 21-23, 2014, we were able to obtain DIDSON data collections consisting of 134, discrete 10-minute periods. 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 IIB narrow array frequently. During data collections in 2013 only barrier IIB was operational; this means that 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. During data collections that took place in 2014 both barrier 2A (downstream barrier) and barrier IIB (upstream barrier) were active. This active barrier configuration was necessary due to concerns over barrier switching that would not be avoidable due to operational requirements of construction activities. Also, during 2013 all data collections took place during the day. Dive operations took place concurrently with our first week of data collections (Oct. 7-9). These operations required daily canal closures and the need to de-energize barrier IIB during the day for safety. Due to these limitations, data collection events took place only at night during the first week (sampling during the week of Oct. 21- Oct. 23 took place during the day). Delaying the data collections until October in 2014 also resulted in lower water temperatures during the study period (15.8^{0}C-17.4^{0}C in 2014 vs. 22.8^{0}C-26.8^{0}C in 2013). Additionally, the flow regimes we experienced during our 2014 data collections were different than those observed in 2013. Measured flow velocities at the electric dispersal barrier site in 2013 ranged from 0.06 - 0.20 m/s in the downstream direction. Although we did not measure flow velocities directly in 2014, it was clear from observing floating debris in the DIDSON data collections that reverse flows were common. During the first week of sampling (Oct 7-9), reverse flows occurred 24.1% of the time that we collected data. During the second week of the study (Oct. 21-23), we observed reverse flows during 15.5% of data collections. Interestingly, none of those reverse flow events were captured by the nearest USGS gauging station at Lemont; IL (Fig.6).

Results of acoustic remote sensing surveys conducted below the electric dispersal barrier in 2013, the week following DIDSON data collections, indicated that the median size of YOY (< 150 mm) fish present in the Lockport pool at that time was 62.2 mm (Fig.7). These surveys also demonstrated that the mean density of YOY fish present in the Lockport pool below the electric dispersal barriers was significantly lower (ANOVA F= 32.595; d.f. = 57; P< 0.001) on November 4, 2014 (0.366 fish / 1000 m^3) than on August 6, 2013 (2.08 / 1000 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 following DIDSON sampling in summer 2013 than during fall 2014 (Fig.8). In agreement with these findings, the USFWS Columbia FWCO sampled fish both within the narrow arrays and directly below the electric dispersal barrier concurrently with DIDSON sampling and also observed low fish abundance in 2014. Low numbers (< 10) of Gizzard Shad (*Dorosoma cepedianum*), Brook Silversides (*Labidesthes sicculus*), and Creek Chub (*Semotilus atromaculatus*) were captured in Lockport pool below the electric dispersal barrier.

The differences in fish behaviors we observed between the 2013 and 2014 sampling periods are likely the result of a combination of the factors mentioned previously. Although we are encouraged by the finding that fish passage of the electric dispersal barrier during our study period this year did not take place; we did make several important observations and formulate several recommendations that could reduce risk of fish passage. First, During our first week of data collections (Oct.7-9), barrier IIB power-up followed the conclusion of diving operations each day. At these times, we witnessed a large number of small (< 150 mm) clupeids (gizzard shad) become incapacitated and float to the surface in a state of narcosis. These fish were likely congregating over the arrays of barrier IIB when power-up was initiated. On Oct. 8 when that action took place the canal was in a reverse flow condition. Many of those fish that were shocked floated in the upstream direction (towards Lake Michigan) with the prevailing flow. We observed many of these fish subsequently regain swimming ability. The scene we witnessed is not particularly alarming because the small clupeids were likely on the upstream side of barrier IIB initially. However, If barrier 2A were shut-down for maintenance and fish were congregated over the arrays while power was applied to the barrier during a reverse flow condition; there is a possibility that fish in a state of narcosis could be swept upstream through the entire barrier system with the prevailing current. For these reasons, we suggest that barrier 2A not be reenergized after a maintenance event when the canal is under reverse flow conditions. Problematically, during the course of this study we have clearly shown that there are discrepancies between the stream velocity readings at the USGS Lemont IL gauging station and the actual flow conditions in the canal at the electric dispersal barrier.

On Oct. 22 we recorded a small fish swim from upstream of barrier IIB in a downstream direction against reverse flow into barrier IIB’s narrow array with the DIDSON unit. The fish penetrated the barrier to a point even with the downstream margin of the narrow array (41.64228 88.06037). The fish then surfaced in a state of narcosis; it was identified as a white perch (*Morone americana*) and size was estimated at 80-100 mm. The fish did not regain mobility before drifting out of sight. Again, this situation was not particularly alarming because the fish originated from upstream of the barrier. Both the 2A and 2B electric dispersal barriers are designed with both narrow (intense field; upstream) and wide array (gradual field; downstream) electrodes to discourage fish from entering the high intensity field well before they reach it. The fish we observed approached barrier IIB from the upstream side of the barrier system; it did not have the opportunity to experience a gradually increasing electrical field. Rather, it encountered the high intensity field of the IIB narrow array abruptly. If fish were to encounter a similar electrical field, in the same manner as the fish we observed, except from the downstream side and during a reverse flow event, there is a possibility that upstream transport of fish past the barrier system could occur. This situation would be more probable if the downstream active barrier was operating with only the narrow array energized. For these reasons, we suggest operating the downstream dispersal barrier with both the wide and narrow arrays energized whenever possible; especially during reverse flow events.



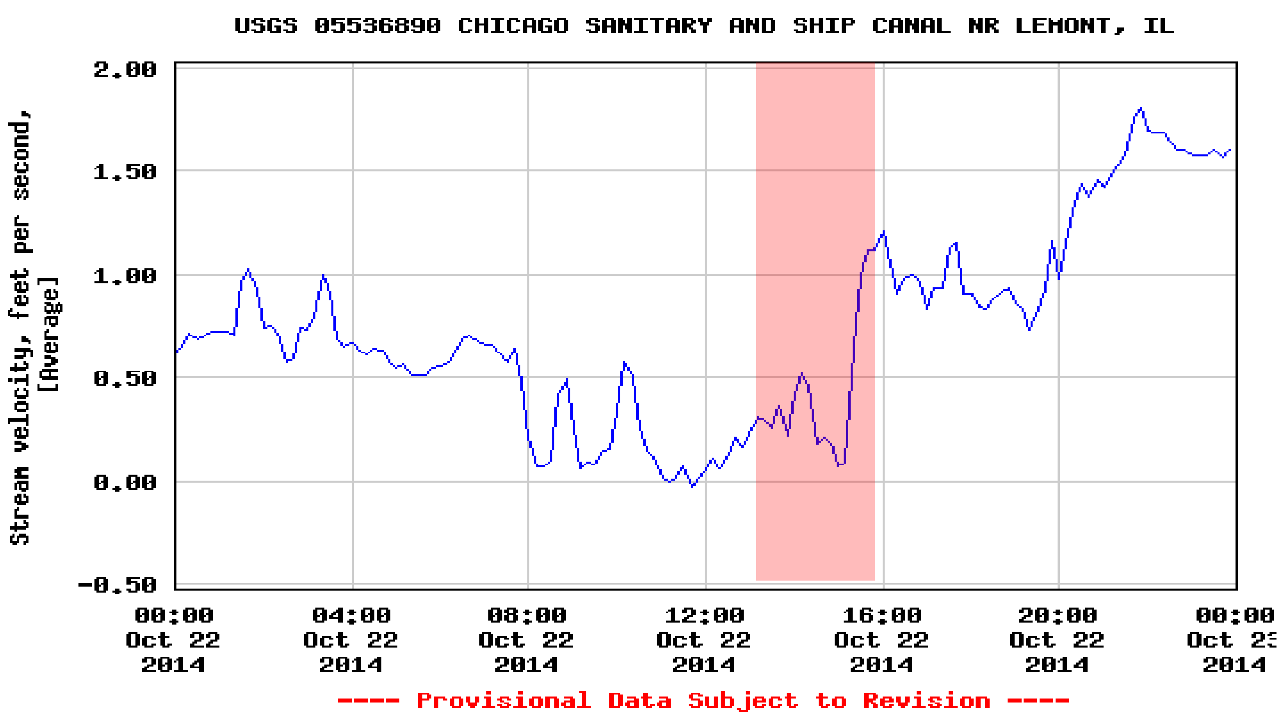


Figure 6. Provisional stream velocity (fps) data from the USGS Lemont IL stream gauge collected Oct. 8 and Oct. 22, 2014. Red shading indicates periods of reverse flow streamflow (toward Lake Michigan) that were observed during DIDSON data collections.

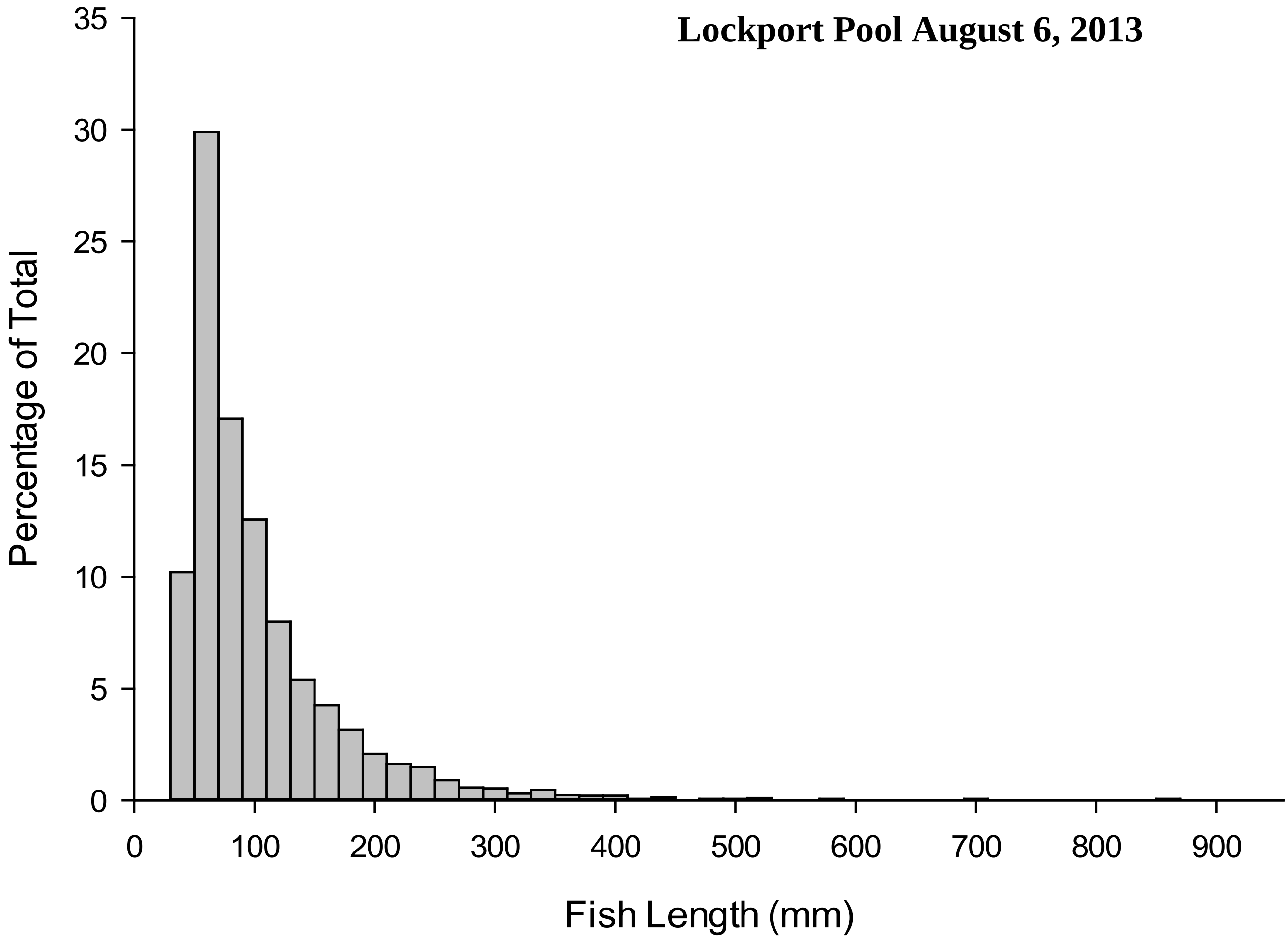
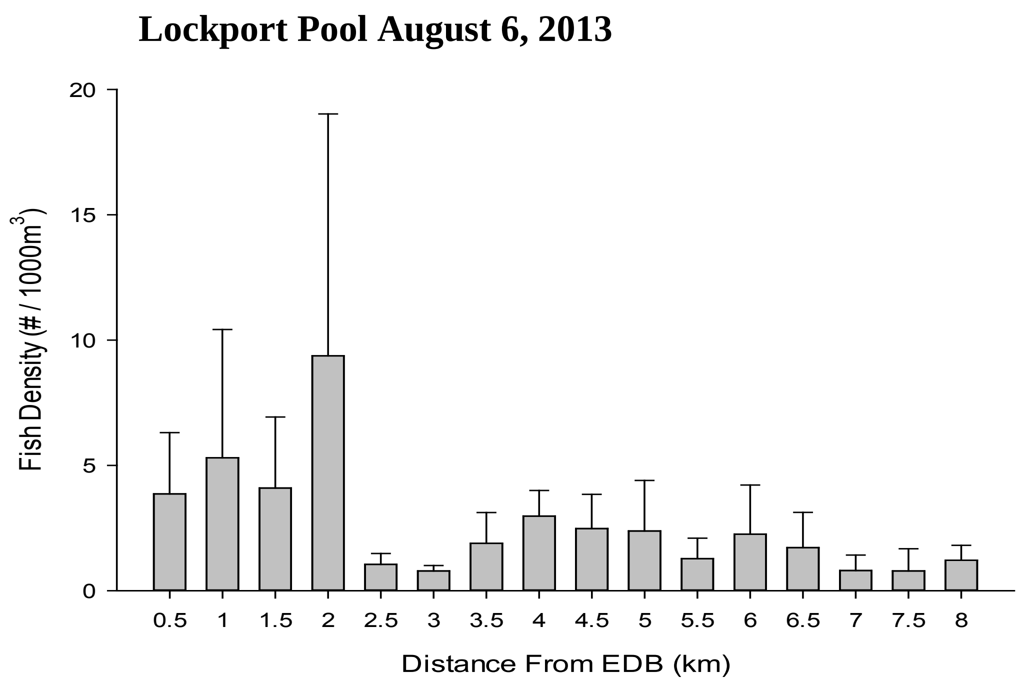


Figure 7. Histogram showing the length frequency distribution (20mm bins) of fish present downstream of the electric dispersal barrier in the Lockport pool of the Upper Illinois River during August 2013 (n= 2969). Data were collected with mobile split beam hydroacoustic remote sensing surveys. Length was estimated by converting -TS from the remote sensing surveys using equations from Love 1977.



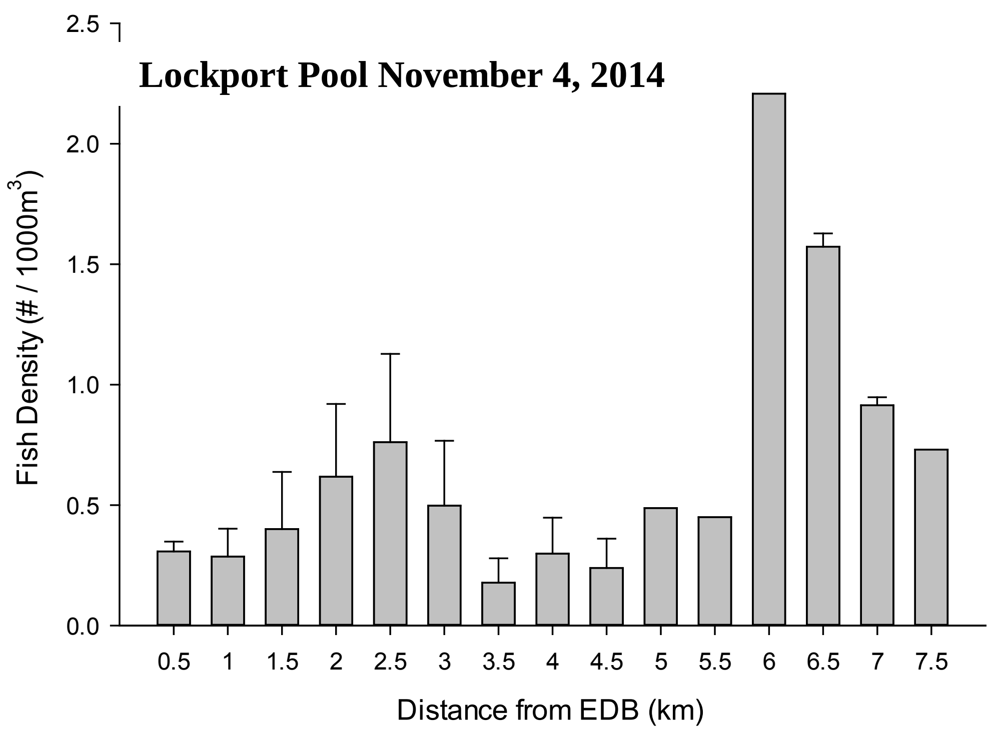


Figure 8. Bar graph of mean fish density (# / 1000 m^3) in Lower Lockport Pool collected with acoustic remote sensing gear the week following DIDSON data collections in 2013 and 2014. The study reach was split into 0.5 km sections below the electric dispersal barrier (EDB) to observe spatial heterogeneity in density patterns. In those sections where replicate samples were collected, n= 2 and error bars denote standard deviation. Note differences in scale on the Y-axis.

Recommendations:

1) We will continue to perform fixed DIDSON monitoring of the electric barrier using the telescopic boom lift in summer 2015, when abundances of small fish at the barrier are greatest (USFWS unpublished data).
2) We suggest not re-energizing barrier 2A following maintenance operations during periods of reverse flow.
3) We recommend that instrumentation be installed in close proximity to the electric dispersal barrier that can provide real-time alerts of the presence of a reverse flow condition in the canal to management and operators.
4) We suggest that the barriers be operated with both the narrow and wide arrays energized in sync whenever possible and especially during a reverse flow event.

Project Highlights:

- No fish were observed crossing the electric dispersal barrier's IIB narrow array during October 2014.
- Reverse flows in the canal at the electric dispersal barrier site were common and could not be identified from the USGS Lemont IL stream gauge.
- Median size of YOY fish (<150 mm) present in Lower Lockport Pool the week following 2013 DIDSON sampling was 62.2 mm.
- Fish density and congregation directly below the electric dispersal barriers was significantly greater during summer 2013 data collections than during fall 2014 data collections.

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

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

Introduction: The electric dispersal barrier in the Chicago Sanitary and Ship Canal (CSSC) operates with the purpose of preventing upstream fish migration from the Mississippi River Basin to Lake Michigan. 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 (USFWS unpublished data). Monthly maintenance, daily barge traffic, and other regular maintenance operations have been shown to have the potential to allow fish to pass the electric dispersal barrier (see http://www.fws.gov/midwest/fisheries/carterville/didson-barge.html for reports). If and 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 density and spatial distribution of fish below the electric dispersal barrier system is important to barrier management because it allows operational and maintenance decisions to be made in sync with potential risk factors. To determine these periods of elevated risk, we performed split beam hydroacoustic remote sensing surveys throughout 24 hour periods immediately downstream of the electric dispersal barrier during spring, summer, and fall 2014. In addition, we undertook split beam hydroacoustic remote sensing surveys of the Lockport, Brandon Rd., and Dresden Island navigation pools in the Upper Illinois River during spring, summer, and fall 2014. This work allowed us to gain 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 River 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 enables more refined interpretation of results and better informed management decisions. Additionally, identification of areas of high fish density may help to better target ongoing Asian carp removal efforts.

Further, 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 aquatic nuisance species (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 Rd. Lock and Dam is being undertaken by the USACE. Gaining a greater understanding of fish abundance, behavior, and movements in and adjacent to Brandon Rd. Lock and Dam will help to inform potential GLMRIS actions at Brandon Rd. and allow for evaluations of the efficacy of any measures that are implemented. During fall 2014 we conducted preliminary hydroacoustic surveys within and near the Brandon Rd. Lock chamber to quantify the extent of fish utilization of the structure and illuminate the potential for lock chamber mediated fish dispersal between reaches.

Objectives:

1) Evaluate the diel densities of fish directly below the barrier system throughout the year.
2) Determine the density and distribution of fish in the study reaches 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 Rd. lock structure.
5) Identify large fish targets in the study pools suspected of being Asian carp to direct targeted sampling efforts at these fish for removal.

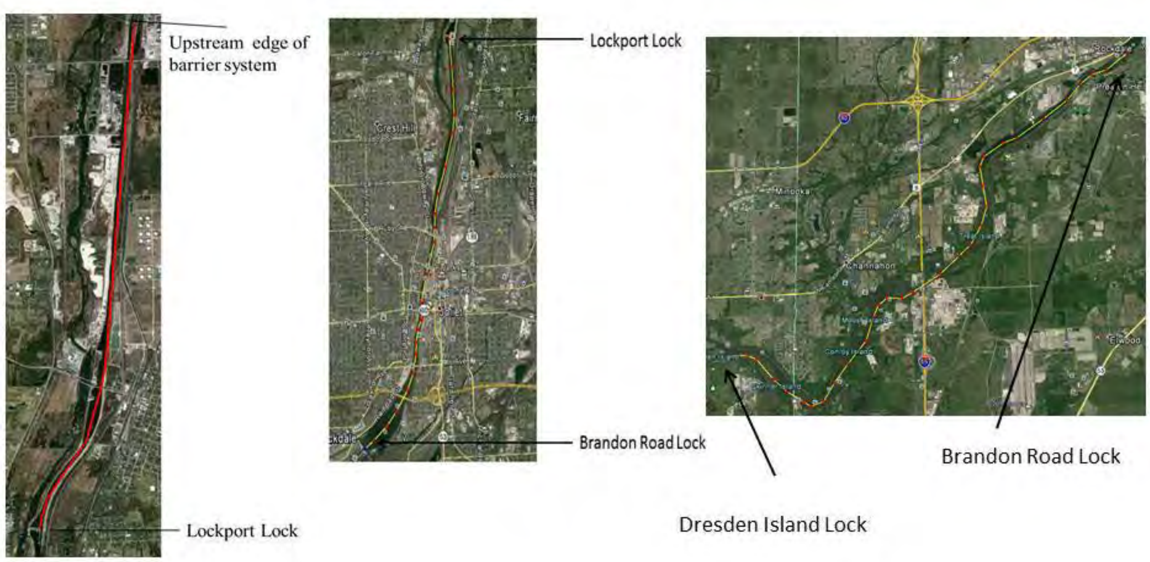

Figure 1. Satellite photos of our study areas. (A) 5.4 mile stretch of the Lockport pool in the CSSC. (B) 4.8 mile stretch of the Brandon Rd. pool and (C) 14.5 mile stretch of Dresden Island pool where split beam hydroacoustic remote sensing surveys took place.

Methods:

Diel Fish Surveys below the Electric Dispersal Barrier: A series of side-looking split beam hydroacoustic remote sensing surveys were conducted below the CSSC electric fish dispersal barrier to assess fish density and distribution patterns near the barrier throughout 24 hour periods in the spring, summer, and fall. Diel sampling below the electric dispersal barrier took place on April 22- 23, September 12-13, and November 3-4, 2014. Transects were conducted that began below the barrier system (≈ 300 m) at 41^0 38.200 N, 88^0 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 41^0 38.200 N. Three consecutive replicate hydroacoustic surveys took place during eight distinct and evenly spaced periods in the 24 hour cycle. Sampling periods included: sunrise, mid-morning, solar noon, mid-afternoon, sunset, mid-evening, midnight, and early-morning.

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 boat 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 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 was 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). Briefly, data that were collected outside of the analysis bounds (between 41^0 38.200 N and the 2A 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 periods of the 24 hour cycle. 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. Sampling periods (sunrise, mid-morning, solar noon, mid- afternoon, sunset, mid-evening, midnight, and early-morning) were grouped into day (mid-morning, solar noon, mid-afternoon), night (mid-evening, midnight, and early-morning), and crepuscular (sunrise and sunset) periods for analyses because the power of statistical tests was low when each group was analyzed independently (power = 0.299; $\alpha = 0.05$). When statistical inference power is below desired levels (power = 0.800) differences are less likely to be detected even when they actually exist (Steidl et al. 1997). One-way Analysis of Variance (ANOVA) with significance at $\alpha = 0.05$ was used to test for differences in mean densities between day, night, and crepuscular sampling periods with pairwise comparisons using the Holm-Sidak post-hoc test.

Upper Illinois River Surveys: To quantify the density and spatial distribution of the fish community in the Upper Illinois River, a series of hydroacoustic remote sensing surveys were conducted throughout the Lockport (n=12), Brandon Rd. (n=3), and Dresden Island (n=3) navigation pools. The surveys were conducted using the same equipment, collection techniques, and analysis methods as we employed in our other hydroacoustic surveys. The portion of each pool within the navigation channel was surveyed by navigating the research vessel on clockwise transects around the navigation 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. The Lockport pool was surveyed on a monthly to bi-monthly basis during both 2013 and 2014. Brandon Rd. and Dresden Island pools were surveyed on a seasonal basis during 2014 only. The Lockport pool was surveyed on the same dates as the other study reaches during 2014.

Brandon Rd. Lock Surveys: Acoustic remote sensing surveys were conducted within and adjacent to the Brandon Rd. Lock structure on September 11 and November 5, 2014 using the same equipment and methods described for diel 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 preliminary surveys were conducted this year 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.

Results and Discussion:

Diel Fish Surveys below the Electric Dispersal Barrier: During the course of the 2014 diel hydroacoustic surveys over 6.7 million cubic meters of water directly downstream of the electric dispersal barrier were ensonified. Fish abundance was relatively low during the spring survey (4-2014) with a mean density of 0.232 fish / 1000 m^3 (S.D. = 0.152) across all samples, during all periods (n= 20). Significant differences in log10 transformed mean total fish density were observed between diel periods during spring (ANOVA F= 7.217; df= 2, 19; P= 0.005) (Fig.2). Pairwise multiple comparisons by the Holm-Sidak method indicated that there was significantly greater mean fish density directly downstream of the electric dispersal barrier during the nighttime sampling periods than either the daytime (Diff. in means = 0.346; P = 0.010) or crepuscular (Diff. in means = 0.392; P = 0.010) periods. There was no significant difference between mean fish density during the daytime and crepuscular periods (Diff. in means = 0.077; P = 0.667). Repeated measures two-way ANOVA revealed no significant effect of sample replicate order within diel periods on mean fish density (F= 0.640, df= 3, 22, P= 0.542) and no significant interaction term between daily period and replicate order was observed (P=0.717). Examination of mean fish density by size class (< 150mm and >150mm) also showed significant differences; at night there was a significantly greater mean density of fish in both size classes (Fig.2). These results suggest that during spring (H_2O temp. during study = 13.8^0 C-16.1^0 C) both large and small fish mean density directly below the electric dispersal barrier is greater during nighttime hours. Total fish density throughout the study periods increased significantly (ANOVA F= 64.513, df= 3, 64, P < 0.001) during the summer survey period (9-2014) with a mean total fish density of 2.033 fish / 1000 m^3 (S.D. = 1.233). During summer mean total fish density was again greater at night than during daytime survey periods; however, there were no significant differences in log10 transformed mean total fish density between diel periods (ANOVA F= 2.515, df= 2, 20, P= 0.109). During the fall sampling period (11-2014) total fish density fell to 0.520 fish / 1000 m^3 (S.D= 0.327). The mean total fish density observed during fall was considerably lower than during the summer surveys but higher than the mean density observed during the spring sampling period. Again, no significant differences in density between diel periods were observed (ANOVA F= 1.842, df = 2, 23, P= 0.183) (Fig.3). These results suggest that during spring there is a greater risk of fish congregating directly below the electric dispersal barrier at night than during the daytime; however, the overall density of fish present directly below the electric dispersal barrier in spring is substantially lower than during summer or fall seasons across all diel periods.

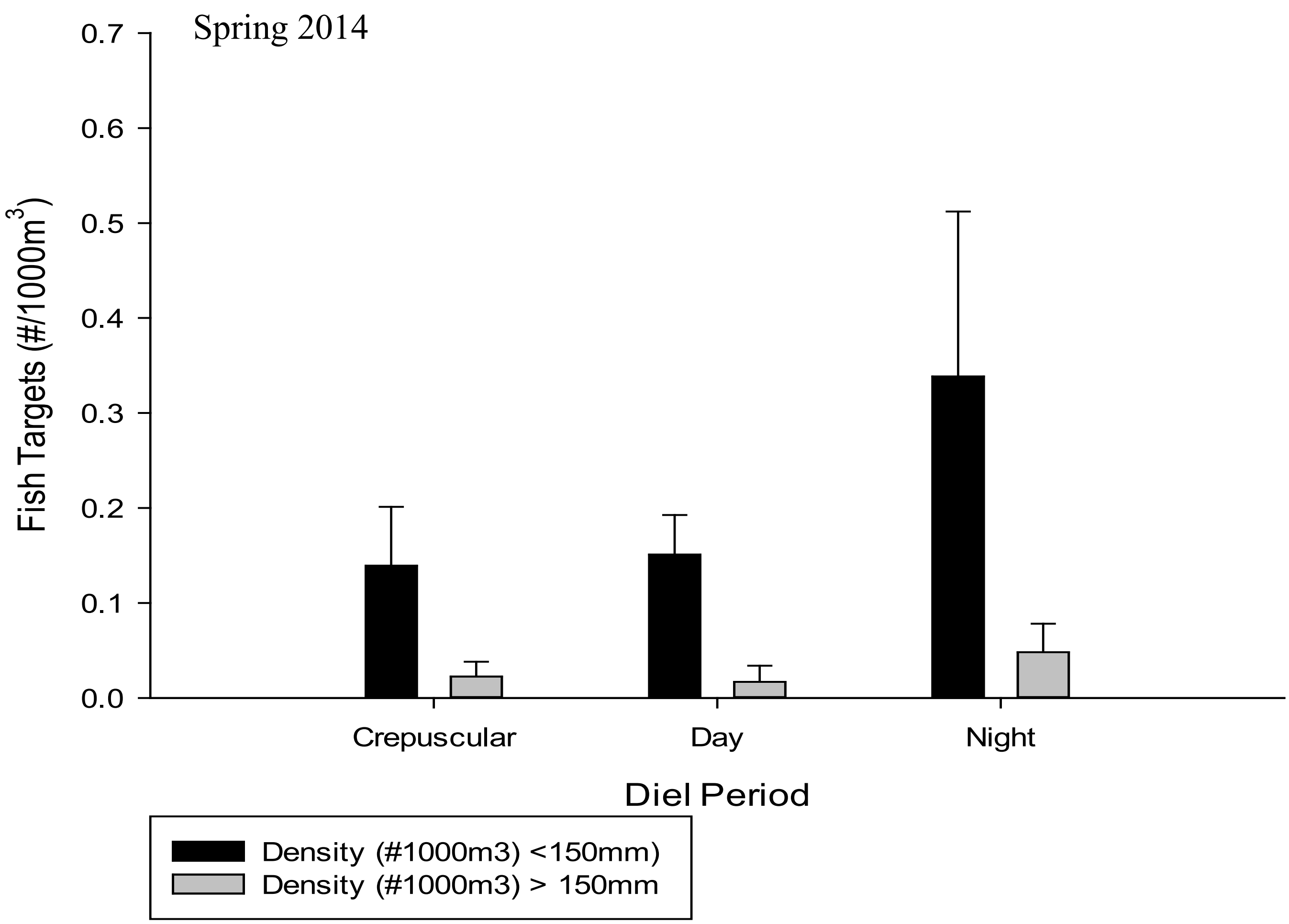

Figure 2. Grouped bar graph of mean fish density (# fish / 1000 m^3) showing differences in mean density of large (> 150 mm) and small (< 150 mm) fish between diel periods (Crepuscular n= 6; Day, n= 8; Night, n= 6), during spring 2014 surveys, directly below the Electric Dispersal Barrier (0-300 m). Significant differences in mean density were observed in both large (> 150 mm, ANOVA F= 3.90, df= 19, P= 0.04) and small fish (< 150mm) (ANOVA F= 6.750, df= 19, P= 0.007). Error bars denote S.D.

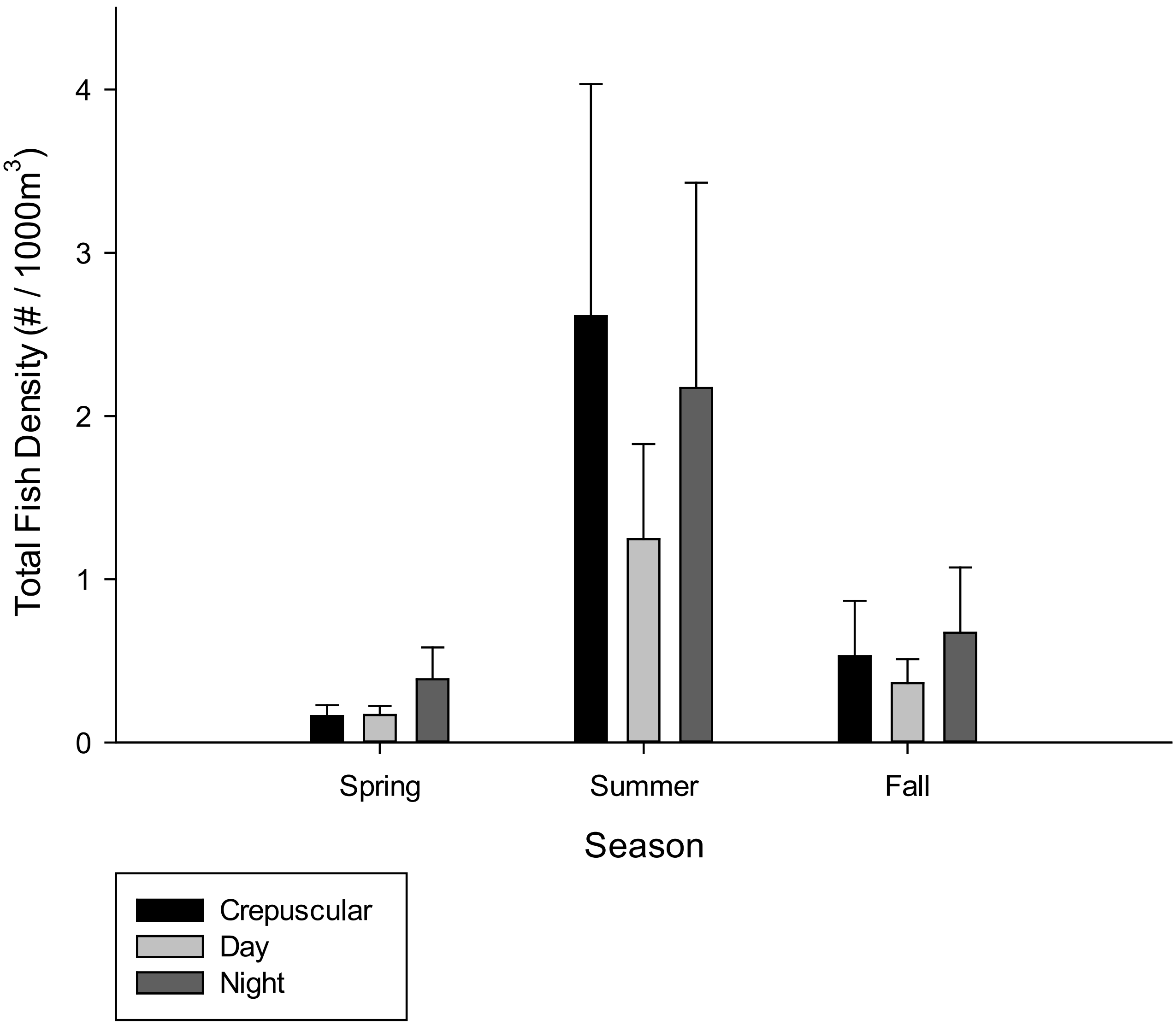

Figure 3. Grouped bar graph of mean total fish density (# fish / 1000 m^3) directly below the Electric Dispersal Barrier (0-300m) during crepuscular, day, and nighttime periods in spring (n= 20), summer (n= 21), and fall (n= 24) 2014. During spring, mean total fish density was significantly greater at night (ANOVA F= 7.217, df= 19, P= 0.005). During other seasons mean total fish density differences between diel periods were N.S.; error bars denote S.D.

Upper Illinois River Surveys: Results from the intensive acoustic remote sensing survey conducted in the Lockport pool throughout 2013 and 2014 showed relatively stable and low fish densities throughout the winter, spring, and early summer. Fish densities were then observed to increase in July and peak in August; this was followed by substantial declines as fall progressed (Fig.4). In addition, the majority of the area within the navigation channel of the Upper Illinois

River between the electric dispersal barrier and the Dresden Island Lock and Dam was surveyed using hydroacoustic remote sensing gear during spring, summer, and fall in 2014. Results suggested that during spring (4-2014) total fish density was greater in the Brandon Rd. (0.559 fish / 1000 m^3) and Dresden Island (0.652 fish / 1000 m^3) pools than in the Lockport pool (0.160 fish / 1000 m^3). During summer (7-2014) fish density in the Dresden Island pool remained consistent with the density observed in spring (0.632 fish / 1000 m^3) while fish densities in the Lockport and Brandon Rd. pools increased dramatically (1.75 and 3.52 fish / 1000 m^3, respectively). During the fall survey (11-2014) fish density in the Dresden Island pool increased greatly (2.27 fish / 1000 m^3) from the density observed during the summer. Density in the Brandon Rd. pool (1.57 fish / 1000 m^3) declined slightly from summer levels and large decreases in fish density from summer levels were observed in the Lockport pool (0.438 fish / 1000 m^3) (Fig.5). Interestingly, fish densities did not increase during summer in the Dresden Island pool in sync with the increases observed in the Lockport and Brandon Rd. pools; rather, a substantial increase was observed during the fall survey. This suggests differences in fish community composition or immigration/emigration dynamics may exist between the Lockport/Brandon Rd. pools and the Dresden Island pool. We examined this further by comparing the densities of both large (>150 mm) and small (<150 mm) fish within each pool in each different season. During spring surveys the density of large fish was relatively low across all study pools. We observed the lowest density of large fish in the Brandon Rd. 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 Rd. (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 Rd. (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) (Fig.5). Although the majority of the increases in fish density appeared to be driven by YOY recruitment to the gear, we also observed substantial increases in the density of large fish during the summer in the Lockport and Brandon Rd. pools and during the fall in Dresden Island Pool (Fig. 6).

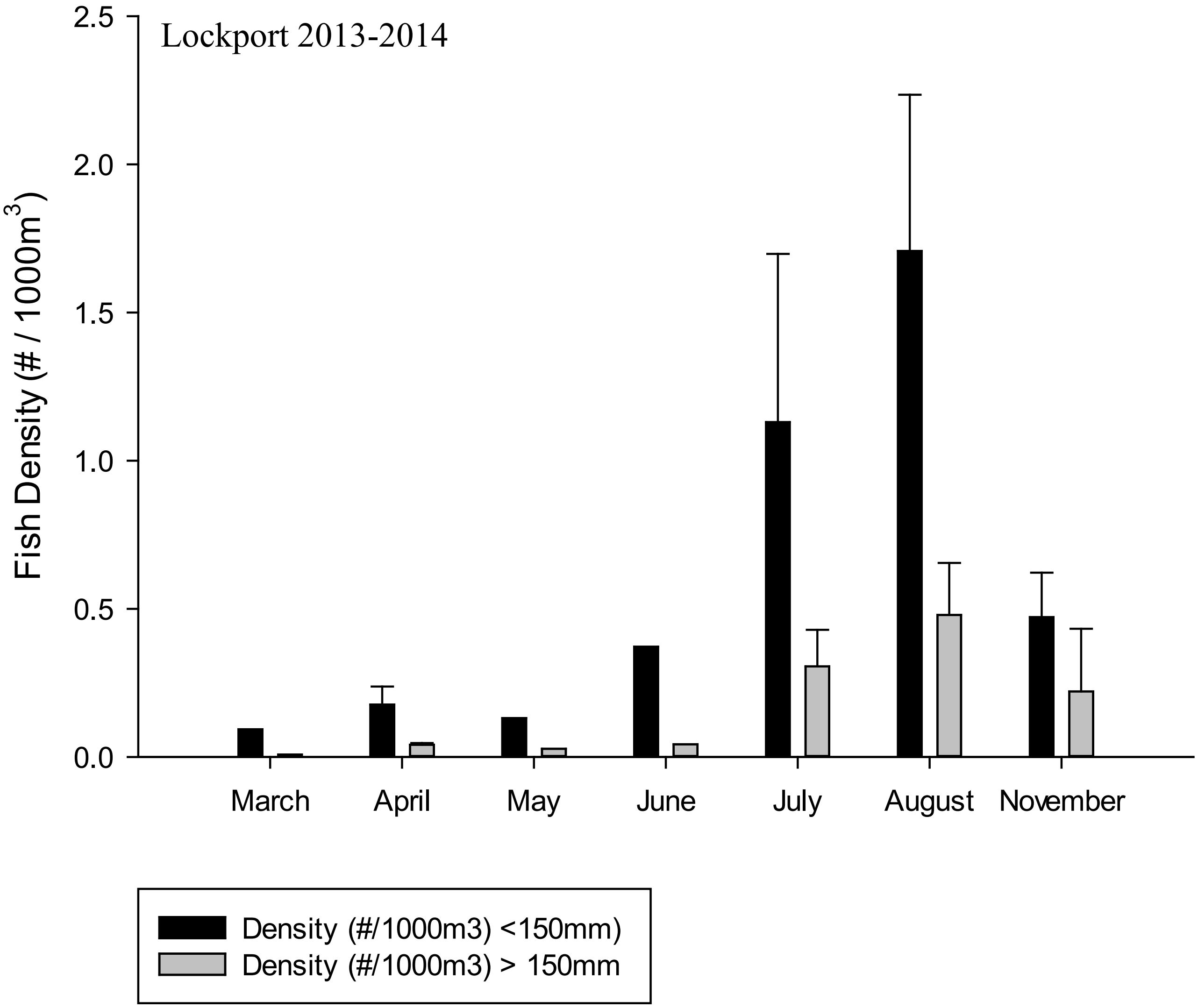

Figure 4. Bar graph comparing large (> 150 mm) and small (< 150 mm) mean fish densities observed through acoustic remote sensing surveys in the Lockport pool of the Upper Illinois River during 2013 and 2014 (data pooled among years). In months where multiple surveys were conducted n= 2. Error bars denote S.D.

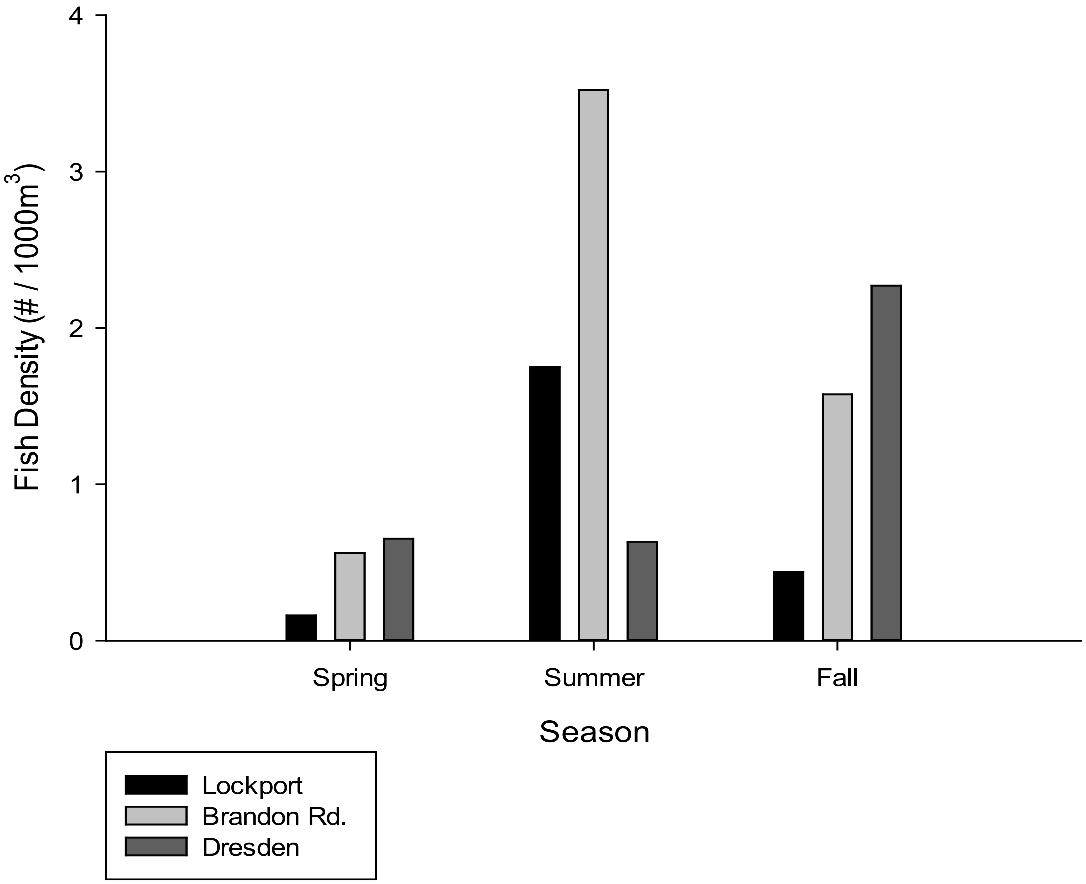

Figure 5. Bar graph comparing total fish densities (# fish / 1000 m^3) in the Lockport, Brandon Rd, and Dresden Island pools of the Upper Illinois River observed during spring, summer, and fall 2014 acoustic remote sensing surveys.

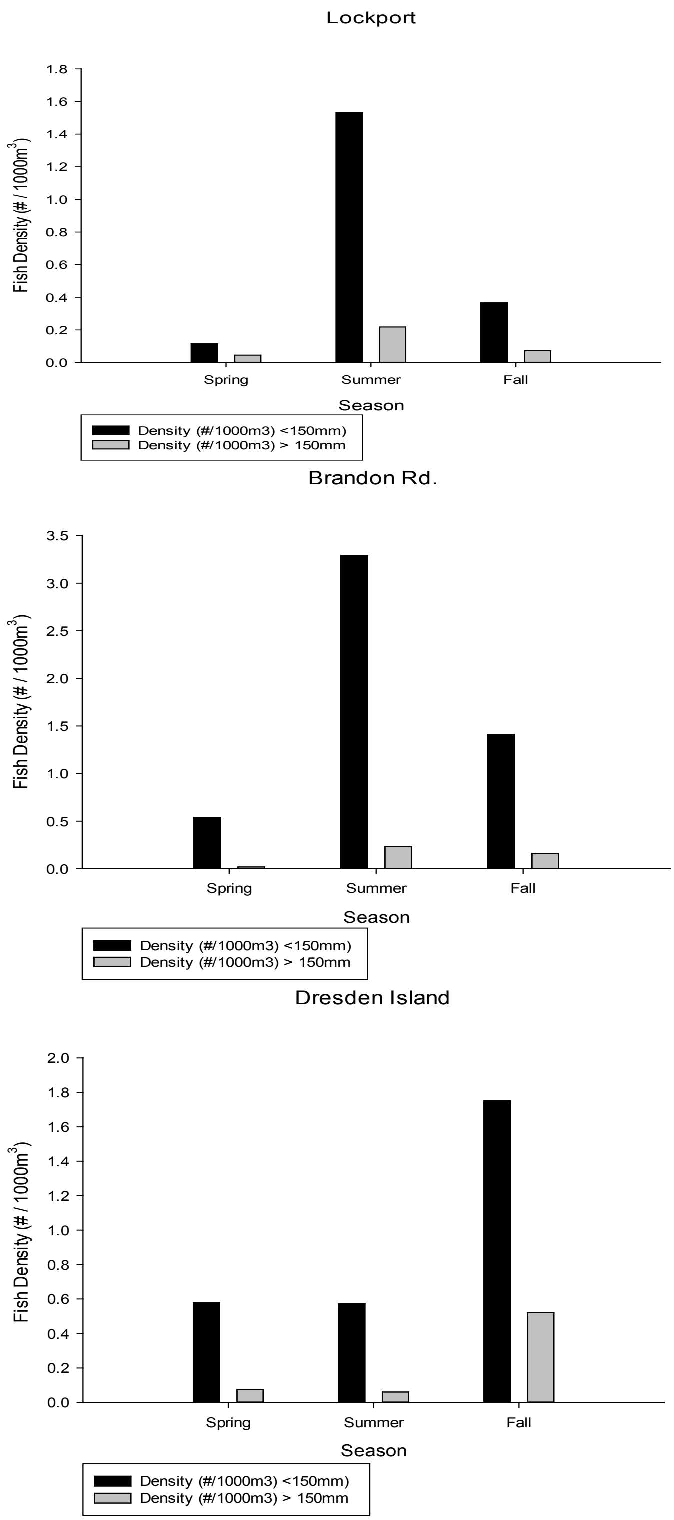

Figure 6. Bar graphs comparing large (>150 mm) and small (<150 mm) fish densities in each study pool during spring, summer, and fall 2014.

Brandon Rd. Lock Survey: Preliminary surveys of the inside of the Brandon Rd. Lock structure answered the questions we posed this year. First, fish are utilizing the Brandon rd. Lock structure as habitat and were present at densities greater than we observed in the Lockport, Brandon Rd., or Dresden Island study reaches during the same season, despite the lock doors being closed except to receive in-coming vessel traffic. We observed mean total fish densities in the Brandon Rd. Lock during summer that were well above any densities observed throughout our remote sensing study (mean = 38.625 fish / 1000 m^3). During fall, densities decreased dramatically but remained higher than levels throughout the remainder of the study area (mean = 4.407 fish / 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 while 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. From the knowledge we have gained this season we are preparing to deploy a stationary acoustic remote sensing system on the upstream side of several lock chambers in the Upper Illinois River to quantify lock mediated fish passage rates.

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	**38.625**	**4.407**
Lockport Pool	**1.75**	**0.438**
Brandon Rd. Pool	**3.52**	**1.57**
Dresden Pool	**0.632**	**2.27**

The synthesis of these observations provides insight on community dynamics and potential patterns of migratory behavior in the fish community present in the Upper Illinois River. First, a combination of recruitment by YOY fishes coupled with immigration appears to be a major factor in increasing fish density in the Lockport and Brandon Rd. pools during summer. If within pool recruitment was a singular source of increasing fish density during summer, we would expect to observe increases in the density of YOY fish only. In contrast to that scenario, we observed increases in both large and small fish density during summer in our two upstream reaches. The downstream reach (Dresden Island pool) did not show increases in density during summer, suggesting populations in the Dresden Island reach could be acting as a source to the upstream reaches. Second, the distinct decrease in densities of both large and small fish in the Lockport and Brandon Rd. reaches during fall, while the Dresden reach concurrently exhibited increases in both large and small fish density, suggests that differential rates of mortality or emigration events are acting on communities within each pool. It is likely that both scenarios do take place. The Lockport and Brandon Rd. reaches possess considerably less desirable fish habitat (Stainbrook et al. 2007) and are characterized by great sources of anthropogenic risk (i.e. barge traffic and electric dispersal barriers) that could lead to increased mortality rates especially for YOY fishes. It has also been shown through telemetry studies that between pool movements in both the upstream and downstream direction do occur (Shanks and Barkowski 2014). Third, we present evidence here that suggests the lock chambers on the Upper Illinois River are being heavily utilized as fish habitat and could potentially serve as a primary means of migration and dispersal between reaches.

Conclusion: These studies provided insights on the dynamics of fish communities throughout the Upper Illinois River that would be unattainable using traditional fisheries survey gear and allowed changes in density across large spatial areas and throughout multiple temporal scales to be examined. 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. An inherent limitation of acoustic remote sensing surveys is the inability to positively identify individual targets to the species level. However, because of their relatively large size and the distinctive behavioral response that Asian carp exhibit while fleeing from motorized vessels, we are able to identify suspicious targets. During the spring 2014 Dresden Island reach survey suspicious targets were identified and reported to the Illinois Department of Natural Resources. During subsequent netting actions two Asian carp, one Bighead Carp and One Silver Carp, were captured near the location of the remote sensing report (Fig. 8).

Recommendations:

1) Continue monitoring spatial and temporal dynamics in Upper Illinois River fish communities to detect changes in biomass or habitat utilization that could be indicative of changes in community structure.
2) Expand efforts to quantify between pool migration patterns. We are currently working to implement a stationary acoustic remote sensing deployment to be utilized upstream of lock structures to document upstream migration events.
3) Continue real time monitoring of survey data to inform management agencies of suspected ANS observations.

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 fall.
- During spring both large and small mean fish densities were significantly greater directly below the barrier at night than during daytime or crepuscular periods.
- We observed differences in fish density patterns between study reaches that could be indicative of between reach migrations.
- High relative densities of fish were shown to be present within the Brandon Rd. Lock structure during both summer and fall.
- Acoustic remote sensing was used to communicate the presence of suspect ANS fish targets to state agencies that subsequently successfully captured Asian carp in the area.

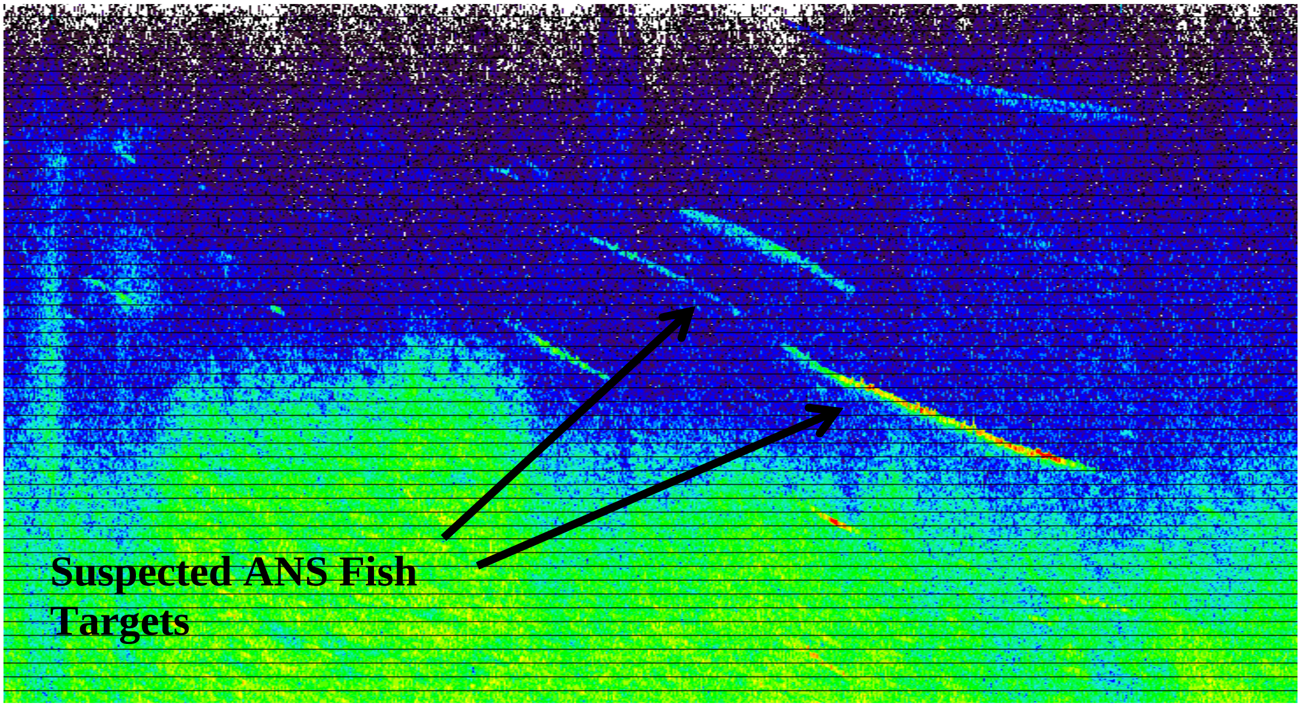

Figure 8. Split beam hydroacoustic echogram showing suspected ANS fish targets in the Dresden Island pool, spring 2014. One Bighead Carp and One Silver Carp were later captured by the Illinois DNR in the same area.

Des Plaines River and Overflow Monitoring

Nicholas Bloomfield
US Fish and Wildlife Service- La Crosse Fish and Wildlife Conservation Office

Participating Agencies: US Fish and Wildlife Service- La Crosse Fish and Wildlife Conservation Office (lead); Metropolitan Water Reclamation District of Greater Chicago, US 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 Chicago Sanitary and Shipping Canal (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 taken in 2012, 2013, or 2014). 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. The construction of a physical barrier to reduce the likelihood of this movement was completed in the fall of 2010. The physical barrier was constructed by the US Army Corps of Engineers (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 and/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 determine 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) During high flow events when water moves laterally from the Des Plaines River into the CSSC, monitor for Bighead and Silver Carp eggs and larvae around the physical barrier and monitor the effectiveness of the barrier.

Methods: In 2014, sampling was conducted in the upper Des Plaines River from Romeoville, IL upstream to the Columbia Woods area near Willow Springs, IL. Sampling was performed using pulsed-DC electrofishing and short term top to bottom gill net sets using 3 inch, 3.5 inch, and 4 inch bar mesh. Fish were driven to the nets using electrofishing boats and pounding. Sampling was performed at times of increased water levels to improve accessibility to the sampling sites. Targeted sites included four lentic areas determined to provide the most suitable Asian carp habitat (Figure 1). Illinois Department of Natural Resources (IDNR) biologists also conducted a scheduled basin electrofishing survey at four sites between Rosemont and Riverside. All fish were identified and released with the exception of two grass carp that were dispatched.

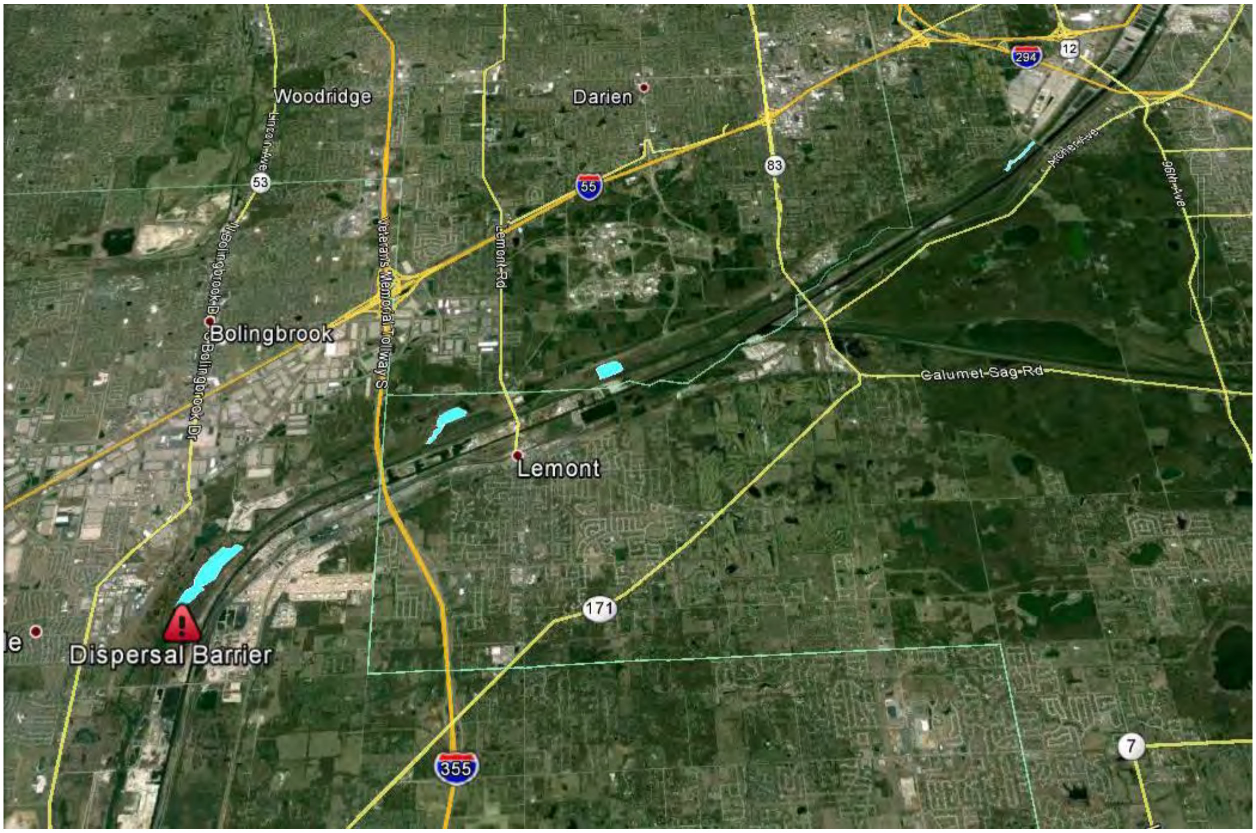

Figure 1. Target sampling areas outlined in blue on the upper Des Plaines River: Columbia Woods, a backwater above the Lemont railroad bridge, Goose Lake, and a widened section of river near Romeoville, IL.

No overtopping events, defined by water flowing laterally from the Des Plaines River to the CSSC, occurred in 2014.

Results and Discussion: During the four years of sampling (2011-2014), 38.65 hours of electrofishing and 111 sets covering 10,501 meters of gill nets resulted in a total catch of 6,656 fish. Fifty two species and three hybrid groups have been collected. Common Carp have been the most commonly collected species, followed by Bluegill and Spotfin Shiner. In 2014, sampling occurred during three weeks while water levels were elevated: 3/24/14, 5/19/14, and 6/30/14. Low flow conditions the remainder of the sampling season resulted in targeted sampling areas of the river being largely inaccessible. Sampling effort in 2014 included: 8.15 hours of electrofishing resulting in 1,293 fish and 4,755 meters of gill net resulting in 311 fish. 2014 sampling yielded 40 species and two hybrid groups. No Bighead or Silver Carp have been seen or captured during the four years of sampling. Two Grass Carp were captured in the backwater area near Lemont, IL. Eyeballs were removed and transported to Whitney Genetics Laboratory for ploidy testing. Results showed that both fish were triploid. In addition, the 2013 and 2014 IDNR basin surveys yielded no Bighead or Silver Carp.

Table 1. Numbers of fish sampled 2011-2014 on the upper Des Plaines River.

	Electrofishing		Gill Netting		
	2011-2013	2014	2011-2013	2014	Totals
Common Carp	893	139	162	273	1,467
Bluegill	776	22	2		800
Spotfin Shiner	404	341			745
Gizzard Shad	226	389	8		623
Largemouth Bass	433	55	4	1	493
Bluntnose Minnow	414	51			465
Channel Catfish	296	9	25	6	336
Black Crappie	212	16	2		230
White Sucker	155	28	7		190
Green Sunfish	152	3			155
Spottail Shiner	88	57			145
Sand Shiner	113	27			140
Northern Pike	72	15	24		111
Orangespotted Sunfish	101				101
Golden Shiner	59	21			80
Bowfin	53	11	1	1	66
Sauger	53	1	2		56
Longnose Gar	18	27	4		49
Blackstripe Topminnow	28	10			38
Fathead Minnow	32	4			36
Yellow Bullhead	27	1			28
Emerald Shiner	25	3			28
Round Goby	26				26
Pumpkinseed	20	6			26
Spotted Sucker	14	10	2		26
Smallmouth Bass	9	8	1		18
Rock Bass	14	2	1		17
Quillback	7	2	2	4	15
GoldfishXCarp Hybrid			5	8	13
Blackside Darter	14				14
Bigmouth Buffalo		2	6	3	11
Goldfish	3	8	2		13
River Carpsucker	6	1	1	1	9
Black Buffalo			5	2	7
Black Bullhead	3	6			9
Walleye	3	4	1		8
Grass Carp	1		3	2	6
Warmouth	6				6
Hornyhead Chub	6				6
Creek Chub	5	1			6
Smallmouth Buffalo	1		1	10	12
Freshwater Drum		4			4
Central Stoneroller		3			3
Grass Pickerel		3			3
Western Mosquitofish	2				2
Yellow Perch	2				2
Oriental Weatherfish	2				2
Johnny Darter	1	1			2
Logperch	1	1			2
Longear Sunfish	1				1
Hybrid Sunfish	1				1
White Crappie	1				1
White Perch	1				1
Muskellunge	1				1
StripedXWhite Bass Hybrid		1			1
Totals	**4,781**	**1,293**	**271**	**311**	**6,656**

To date, five Grass Carp have been tested for ploidy. All five 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.

Recommendations: Continue monitoring for adult and juvenile Bighead and Silver Carp in the upper Des Plaines River with emphasis in the four target areas. 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. Given the limitations of the physical barrier, we will initiate young-of-year sampling via mini-fyke netting to document any potential spawning success.

Project Highlights:

- Collected 6,656 fish representing 52 species and 3 hybrid groups from 2011-2014 via electrofishing (38.65 hours) and gill netting (111 sets; 10,501 meters).
- IDNR basin survey completed 3.75 hours of electrofishing in 2014.
- No Bighead or Silver Carp have been captured or observed through all years of sampling.
- Two Grass Carp were captured in 2014. Analysis indicated both were triploid. Three Grass Carp tested in 2013 were also triploid.

Evaluation of Gear Efficiency and Asian Carp Detectability

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

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 determine relative abundances of Asian carp. Data gathered from gear evaluations can also be used to model the probability of detecting Asian carp with each sampling gear in different areas of the Illinois Waterway, which will allow for determination 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.

Methods: The high spawning success and subsequent recruitment of Asian carp to the juvenile life stage that occurred in 2014 (see Larval Fish Monitoring and Young-of-Year and Juvenile Asian Carp Monitoring summaries) provided the opportunity to evaluate gears for capturing juvenile Asian carp. Sampling was conducted at seven sites in 2014 (Figure 1), with sampling at two of these sites (Lily Lake and Morris) occurring in both backwater and main channel locations. Following the detection of larval Asian carp by ichthyoplankton sampling, pulsed-DC electrofishing was conducted at all sites biweekly during July and August in order to determine the extent of juvenile Asian carp occurrence. Additional evaluation using all sampling gears then occurred during summer and fall at sites where juvenile Asian carp were found to be present (LaGrange and Peoria Pools). Additional sampling using all gear types also occurred in the Marseilles Pool, although no juvenile Asian carp were detected there during 2014. All captured

fish were identified to species, and measured for total length and weight. Subsamples of juvenile Asian carp were retained for later diet and age analysis.
Gears used to target juvenile Asian carp in 2014 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

Figure 1. Map of gear evaluation sites sampled during 2014. Sites on the main channel and backwaters of the Illinois River are represented by circles. Tributary sites are represented by triangles.
During 2014, four tributaries of the Illinois River (Spoon, Sangamon, Salt Fork of the Sangamon, and Mackinaw Rivers) were also sampled for Asian carp to assess characteristics of tributary populations. Each tributary was sampled near its confluence with the Illinois River and at an upstream location below the first impoundment on each river (Figure 1). Pulsed-DC electrofishing (15 minutes on each site-visit) was conducted monthly at each site from April to

October. All captured Asian carp were measured for total length and weight. Sex and reproductive condition were assessed, and postcleithra were removed for age analysis.

Results and Discussion: Pulsed-DC electrofishing monitoring was conducted in the LaGrange, Peoria, Starved Rock, and Marseilles Pools during July and August 2014, capturing 3,730 juvenile Asian carp. Juvenile silver carp were captured in the LaGrange (n = 3,694) and Peoria (n = 36) Pools, but none were captured or observed in the Starved Rock or Marseilles Pools. Subsequent evaluation using all sampling gears resulted in the capture of 101,191 fish, including 67,882 juvenile silver carp. The vast majority of these were captured in the LaGrange Pool (n = 67,869), with only small numbers being captured in the Peoria Pool (n = 12). No juvenile Asian carp were captured or observed by gear evaluation sampling in the Marseilles Pool. Most juvenile silver carp were captured during sampling in late July or early August (n = 67,714), with substantially lower numbers being collected during late September (n = 167) despite equivalent sampling effort. Mini-fyke nets captured the highest numbers of juvenile silver carp (n = 56,054, average = 637.0 per net-night), followed by beach seines (n = 7,211, average = 163.9 per haul), purse seines (n = 4,063, average = 92.3 per haul), electrofishing (n = 419, average = 9.5 per 15-minute transect), and cast nets (n = 135, average = 3.1 per throw). Gill nets failed to capture any juvenile Asian carp. Gear types targeting juvenile Asian carp in 2014 were also found to capture different size distributions of these fish (Figure 2). Beach seines captured the smallest juvenile silver carp (mean = 38.0 mm), and captured the highest proportion of silver carp in the 20-29 mm (38% of catch) and 30-39 mm (23% of catch) size ranges. Purse seines captured the largest average sizes of juvenile silver carp (mean = 52.5 mm), likely because they rarely captured any silver carp smaller than 40 mm. Cast nets (mean = 40.6 mm), pulsed-DC electrofishing (mean = 48.1 mm), and mini-fyke nets (mean = 48.6 mm) were more effective for the intermediate sizes of juveniles, capturing primarily 30 – 60 mm silver carp. Electrofishing, however, was the only gear type that consistently captured juvenile silver carp larger than 90 mm.

During 2014, a total of 796 Asian carp (6 bighead carp, 790 silver carp) were captured during 12.25 hours of pulsed-DC electrofishing in tributary rivers. Silver carp were captured at both upstream and downstream sites in all tributaries. Bighead carp were only captured in the Sangamon (n = 3) and the Salt Fork of the Sangamon River (n = 3). The highest catch-per-unit-effort of Asian carp was obtained in the Mackinaw River (mean ± SE = 65 ± 19per hour), whereas the lowest was from the Spoon River (48 ±13 per hour). Only adult Asian carp (440 – 880 mm) were captured by electrofishing in tributaries. No juvenile Asian carp were captured or observed with this gear type in tributary rivers during 2014. Higher numbers of male than female silver carp were observed in all tributary rivers (Figure 3), and both upstream and downstream sites were male-dominated. The highest silver carp gonadosomatic indices(GSI) were observed in June (Figure 4), and GSI declined considerably, particularly for female fish, after July. Age analysis of postcleithra is ongoing and results will be reported once available.

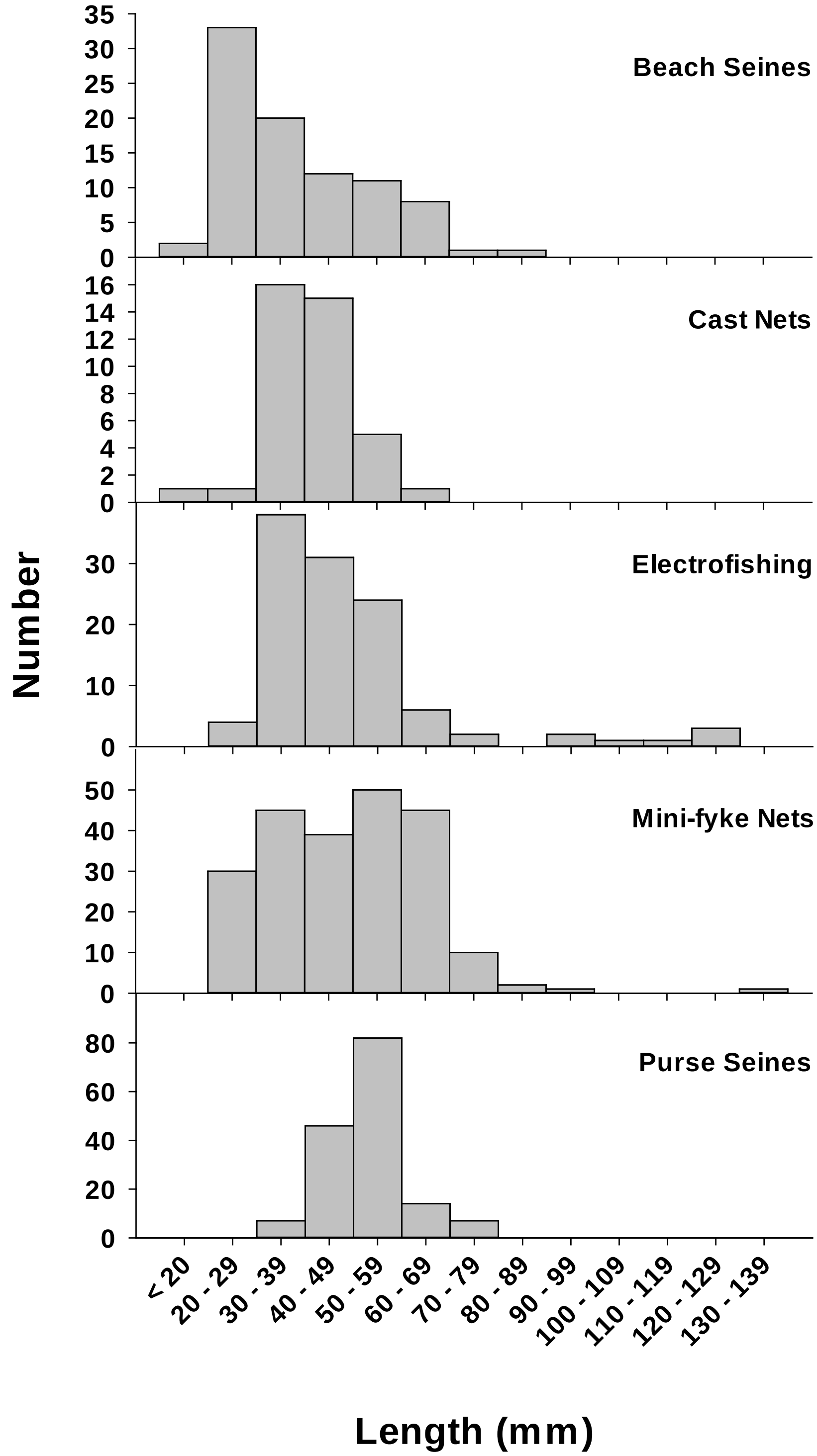

Figure 2. Size distributions of juvenile silver carp captured by different gear types from the Illinois River during 2014.

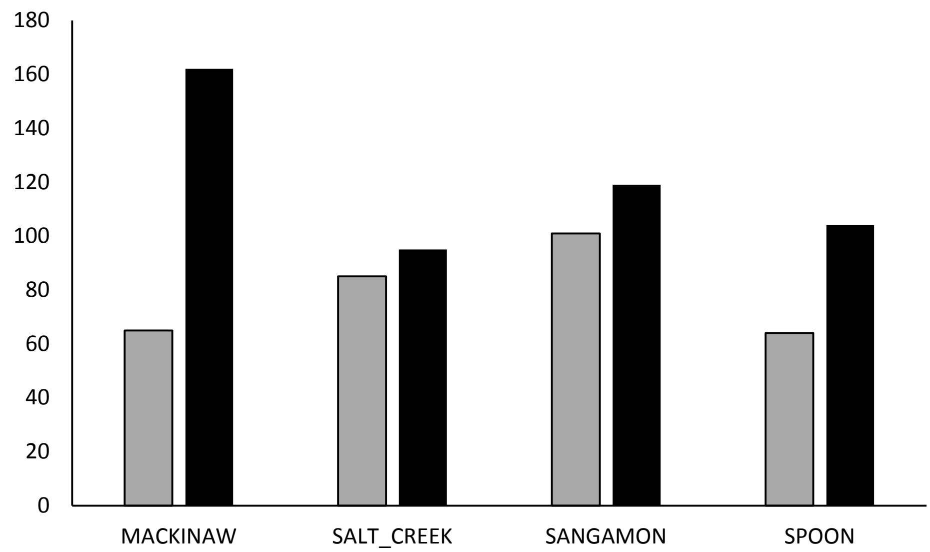

Figure 3. Numbers of female (grey bars) and male (black bars) silver carp captured in the Mackinaw, Salt Creek of the Sangamon, Sangamon, and Spoon Rivers during 2014.

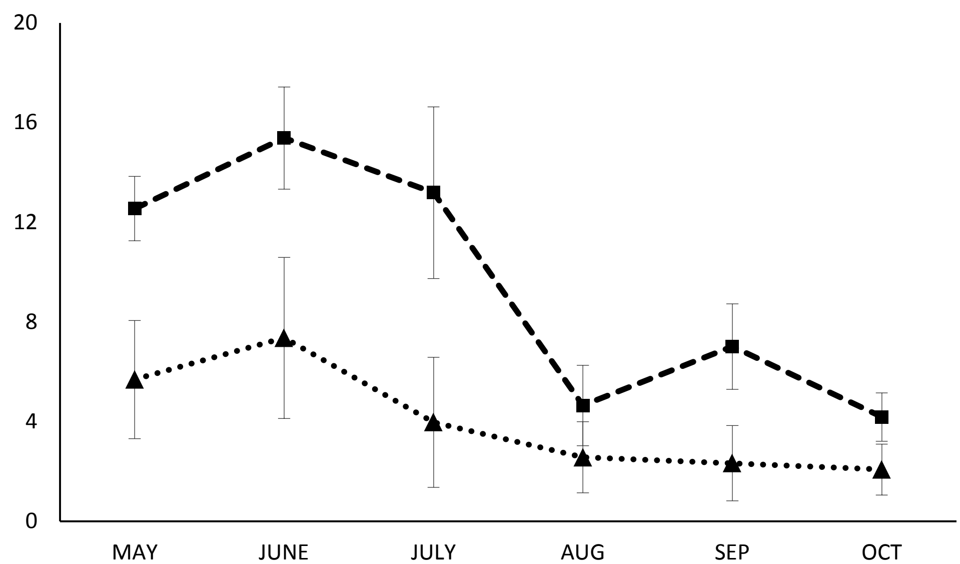

Figure 4. Mean (± SE) gonadosomatic indices for male (triangles, dotted line) and female (squares, dashed line) silver carp captured in Illinois River tributaries during May – October 2014.

The observation of large numbers of juvenile silver carp in the LaGrange Pool, but none upstream of the Peoria Pool during 2014 is consistent with the findings of other studies being conducted during the same time (see Larval Fish Monitoring and Young-of-Year and Juvenile Asian Carp Monitoring summaries), which have found no evidence to date of larval or juvenile Asian carp upstream of the Starved Rock Lock and Dam. Continued monitoring will be necessary to evaluate the potential for Asian carp reproduction and recruitment in the upper Illinois Waterway. However, if the current pattern is found to be consistent, it suggests that recruitment into the Asian carp population of the Illinois Waterway is largely attributable to downstream sources. All juvenile Asian carp observed during gear evaluation sampling in 2014 were identified as silver carp based on gill raker morphology, coloration, and the presence of a ventral keel. It is uncertain if bighead carp reproduction or recruitment to juvenile stages also occurred during 2014, and continued monitoring will be necessary to monitor for juveniles of this species as well as for silver carp. Mini-fyke nets captured by far the highest numbers of juvenile silver carp during 2014, and collected a wide size range of individuals. This gear type is particularly useful in shallow-water and other near-shore areas, and is likely a useful tool for targeting the smaller size groups of juvenile Asian carp. Beach seines were also fairly effective at capturing juvenile silver carp, and may be useful for rapid monitoring purposes when overnight gear sets are not practical. However, these gear types primarily target shallow-water (< 1 m) habitats, and may not be as useful for targeting larger sizes of Asian carp as they shift to deeper-water habitats. Purse seines were effective, although highly variable, at capturing somewhat larger sizes of juvenile Asian carp in deeper-water (2 – 4 m) areas. No juvenile Asian carp were captured in gill nets during 2014, and we do not recommend this gear type for juvenile monitoring, at least for Asian carp less than 100 mm. Very few juvenile Asian carp larger than 100 mm were observed during 2014, though, and almost all of this larger size group was obtained by electrofishing. Further evaluation will be required to determine the effectiveness of these sampling gears for larger size groups of juvenile Asian carp. As only one year of sampling with gears targeting juveniles has been possible thus far, additional years of sampling when juvenile Asian carp are present will be required to answer these questions. Additionally, further sampling will be necessary in order to provide sufficient data to develop detection probability estimates for juvenile Asian carp.

Asian carp appear to be present in all Illinois River tributaries sampled during 2014, and considerable numbers can be found large distances upstream from the Illinois River mainstem. The absence of juvenile Asian carp in tributaries during 2014 suggest that Asian carp either did not recruit within these waterbodies, or that recruits emigrated downstream to the mainstem Illinois River. High GSI values observed in tributaries during June are consistent with the observation of large numbers of larval Asian carp in the Illinois River during June and July. However, it is uncertain at this time if Asian carp spawned in tributary rivers during 2014 or if any spawning that might occur in these systems contributes to the populations present within these rivers or to downstream populations in the Illinois River. The large numbers of Asian carp present in these waterbodies, however, should not be ignored, and further assessment of how these fish contribute to the wider population of Asian carp throughout the Illinois River watershed should be pursued.

Recommendations: Evaluation of sampling gears targeting juvenile Asian carp was possible during 2014 due to high reproductive output and subsequent recruitment to juvenile stages.

Continued analysis of size distributions and locations where juveniles were captured (main channel vs backwater sites) may reveal additional insight into the early life history of these species. Additional sampling for juvenile Asian carp larger than 90 mm is necessary to determine the habitats these fish associate with and the most effective gears for targeting these sizes. Additionally, as all the juvenile Asian carp observed during 2014 were silver carp, 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. As only one year of sampling with gears targeting juveniles has been possible thus far, additional years of sampling will be required to answer these questions, evaluate the consistency of observed patterns, and provide sufficient data for robust detection probability analyses for juvenile sampling gears. Tributary sampling should continue to evaluate demographic characteristics of Asian carp populations within tributary rivers. Sampling for juveniles within these systems should also occur to determine if recruitment occurs within tributaries. Results of this future research will be reported as they become available to allow for adaptation of management activities.

Project Highlights:

- Large numbers of juvenile Asian carp were captured in the LaGrange and Peoria Pools during 2014, but none were captured or observed upstream of the Peoria Pool. All juvenile Asian carp observed during 2014 were silver carp. No juvenile bighead carp were identified.
- Mini-fyke nets captured by far the highest number of juvenile silver carp in 2014. Beach seines and purse seines were also moderately effective. Pulsed-DC electrofishing and cast nets captured smaller numbers of juvenile silver carp. No juvenile Asian carp were captured in gill nets.
- Beach seines captured the smallest sizes of juvenile Asian carp (mean = 38 mm), whereas purse seines captured larger average sizes (mean = 53 mm). Cast nets (mean = 41 mm), pulsed-DC electrofishing (mean = 48 mm), and mini-fyke nets (mean = 49 mm) captured more intermediate sizes. However, electrofishing was the only gear that consistently captured juvenile Asian carp larger than 90 mm.
- Tributary sites were sampled with pulsed-DC electrofishing gear in the Spoon, Sangamon, Salt Fork of the Sangamon, and Mackinaw Rivers during 2014. A total of 796 adult Asian carp (6 bighead carp, 790 silver carp) were captured from tributaries. No juvenile Asian carp were observed in tributaries during electrofishing sampling.

Exploratory Gear Development Project

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Participating Agencies: Columbia Fish and Wildlife Conservation Office (lead)

Introduction: Invasive carps are difficult to catch (Hayer et al 2014) therefore new techniques are being developed to improve capture efficiency of these nuisance fish. Over the last several years, the USFWS-Columbia Fish and Wildlife Conservation Office (FWCO) has worked to develop multiple gears to detect, monitor, and remove invasive carps of all sizes in varying habitats. In 2014, a new boat was designed and built specifically for rigorous testing of the butterfly trawl (paupier), the electrified paupier, and surface trawls (mamou or scalene). Pilot studies focused on gear comparison and time of day. Each pilot study provided opportunity to look at size classes and bycatch. Silver Carp of all size classes were effectively collected in tributaries and big rivers during 2014 trials.

Objectives: Develop new gears that will:
- be more effective than traditional gears at capturing carp
- be used to sample various habitat types
- be used for mass population reduction and detect presence in areas of low density
- target all sizes of carp

Methods:
Gear Comparison.
Four staff from the Columbia Fish & Wildlife Conservation Office (CFWCO) joined Illinois Natural History Survey (INHS) in sampling an off-channel lake, Lily Lake, in the La Grange Pool of the Illinois River near Beardstown, IL, July 28 – 31, 2014. CFWCO used the *Magna Carpa*, custom trawling boat, to sample with 3 different gears: non-electrified paupier, electrified paupier, and mamou surface trawl.

The paupier utilizes paired nets extending on either side of the boat attached to out-riggers. The paupier fishes a maximum of 3 meters (10 feet) below the surface of the water but can be raised to sample in water as shallow as 1 meter. The electrified paupier is outfitted with a MLES or ETS electrofishing box delivering a pulsed DC waveform.

The mamou is a surface trawl that samples 1-2 meters (3-6 feet) below the surface while being pulled behind the boat. All gears were outfitted with small mesh in the cod-ends. Six, two-minute transects of each gear type was trawled in the area of Lily Lake where INHS was concurrently sampling with overnight mini-fyke nets and a trap net. Three, two-minute transects were sampled with each gear type in the lower 1.3 kilometers (km, 0.8 miles) of the Lamoine River, a tributary to the Illinois River 1 km (0.6 miles) upstream of Lily Lake. The species composition, size classes, and catch per two minute transect (CPUE) were compared among gear types.

A crew returned to Lily Lake and the Lamoine River on October 9, 2014. The non-electrified paupier and scalene (a surface trawl very similar to the mamou with larger and lighter weight mesh tapering to a small mesh cod end) were deployed in Lily Lake and the Lamoine River. Six non-electrified paupier transects and four scalene transects were trawled in the Lamoine River and seven non-electrified paupier and one scalene transect were trawled in Lily Lake. The CPUE of the non-electrified paupier transects conducted in October were compared with those conducted in July.

The majority of fish captured using these trawls were small-bodied. The lengths of 25 randomly selected individuals of each species were measured while the remaining individuals were counted. Every effort was made to return native species to the water alive. Invasive carps were euthanized on-site or preserved for lab processing. Large samples were batch processed using a 1,000 milliliter (ml) sub-sample collected and preserved and the remaining catch was measured in milliliters. The preserved 1,000 ml subsample was identified, counted and measured in the laboratory. Total catch was estimated by extrapolation.

Night verse Day sampling during Barrier Defense

Columbia FWCO joined barrier defense efforts the weeks of August 4, September 1, and November 4, 2014. All collection efforts utilized electrified paupier, targeting the densely populated Fox River upstream of the confluence with the Illinois River in the Starved Rock Pool of the Illinois River. Multiple transects were sampled in the 1.3 km (0.8 miles) upstream of the Illinois River confluence.

Sampling was conducted in both day (30 minutes after sunrise to 30 minutes before sunset) and night (30 minutes after sunset to 30 minutes before sunrise) to compare Silver Carp captures with the electrified paupier. Comparisons were made by calculating CPUE as number of Silver Carp caught per 2 minutes.

All fish were identified upon capture. The lengths of 25 randomly selected individuals of each species were measured while the remaining individuals were counted. Every effort was made to return native species to the water unharmed. Invasive carps were transferred to commercial fishing vessels for transport to a refrigerated trailer in Morris, IL, or eviscerated on–site.

Anode Configurations

Electrified paupier was tested with various anode configurations including cables, spheres, and hemispheres of various surface areas, weights and water depths. Anode configurations were tested in several Illinois and Missouri waterbodies to explore electrical efficiency and fish response in differing conductivities.

Juvenile silver carp detection with surface trawls

Sampling was conducted in five Missouri River tributaries and a side channel of the Missouri River in 2014 in an effort to detect juvenile Silver Carp with surface trawls (mamou in July, scalene in October). Of the 14 transects sampled in July, eight were in the Lamine River and six were in Perche Creek. Sampling was repeated in the Lamine River in October 2014 and high water allowed sampling to be conducted in three smaller Missouri River tributaries and a side channel in the mainstem Missouri River.

Results and Discussion:

Gear Comparison.

Over 20,000 young-of-year (YOY) invasive carps were captured in Lily Lake and were, on average, 58% of the total catch with many samples exceeding 90% the week of July 28-30, 2014. Mamou surface trawls averaged 63% YOY silver carp, the electrified paupier averaged 55%, and the non-electrified paupier averaged 57% (Figure 1). There were 20 other species of fish captured. The dominant bycatch species included Gizzard Shad (21% of total catch) and Emerald Shiners (12%).

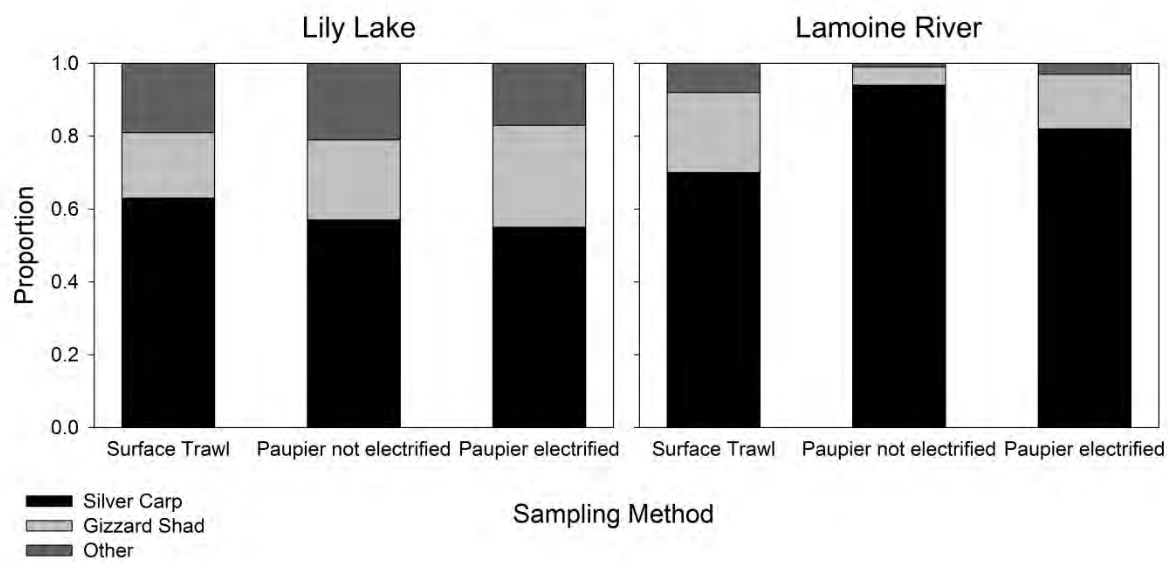

Figure 1. Species composition of experimental gears in Lily Lake and Lamoine River, July 28-30, 2014.

Regardless of gear, YOY Silver Carp captured measured 28-76 mm in Lily Lake (Figure 2). The non-electrified paupier caught the largest YOY Silver Carp at 76 mm and the electrified paupier caught smallest fish at 28 mm.

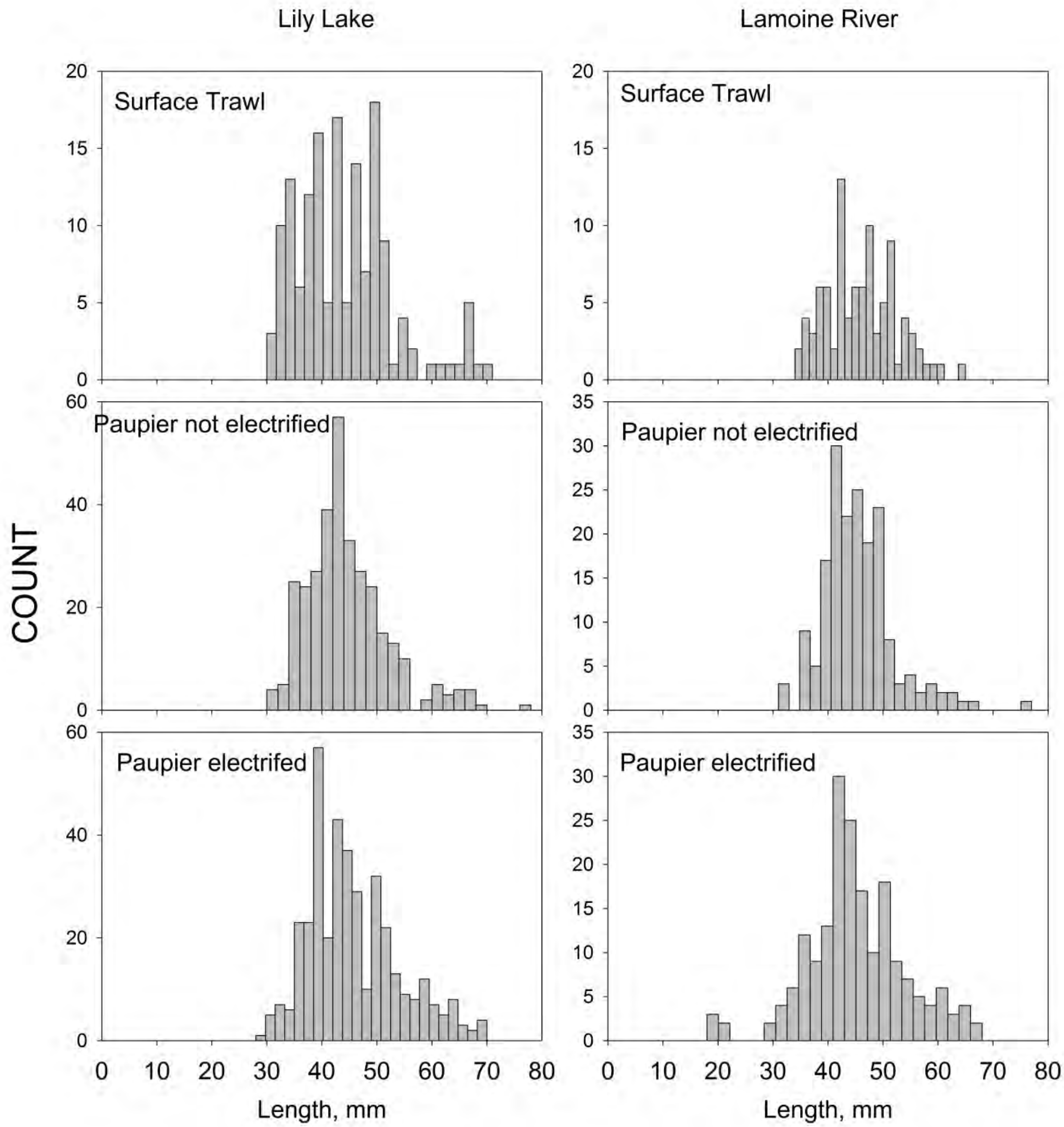

Figure 2. Length histograms of a subsample of YOY Silver Carp captured with experimental gears in Lily Lake and the Lamoine River, July 28-30, 2014.

The electrified paupier caught seven adult Silver Carp greater than 500 mm long. A total of 28 Bighead Carp were caught in Lily Lake. The non-electrified paupier caught six YOY Bighead Carp measuring 56-166 mm and the electrified paupier caught 21 YOY (32-67 mm) and 1 adult (748 mm).

Capture rates were highly variable among transects, however, the non-electrified paupier had a higher average catch rate for YOY Silver Carp (1,350/2 mins) than the surface trawl (251/2 mins) or electrified paupier (1188/2 mins) (Figure 3).

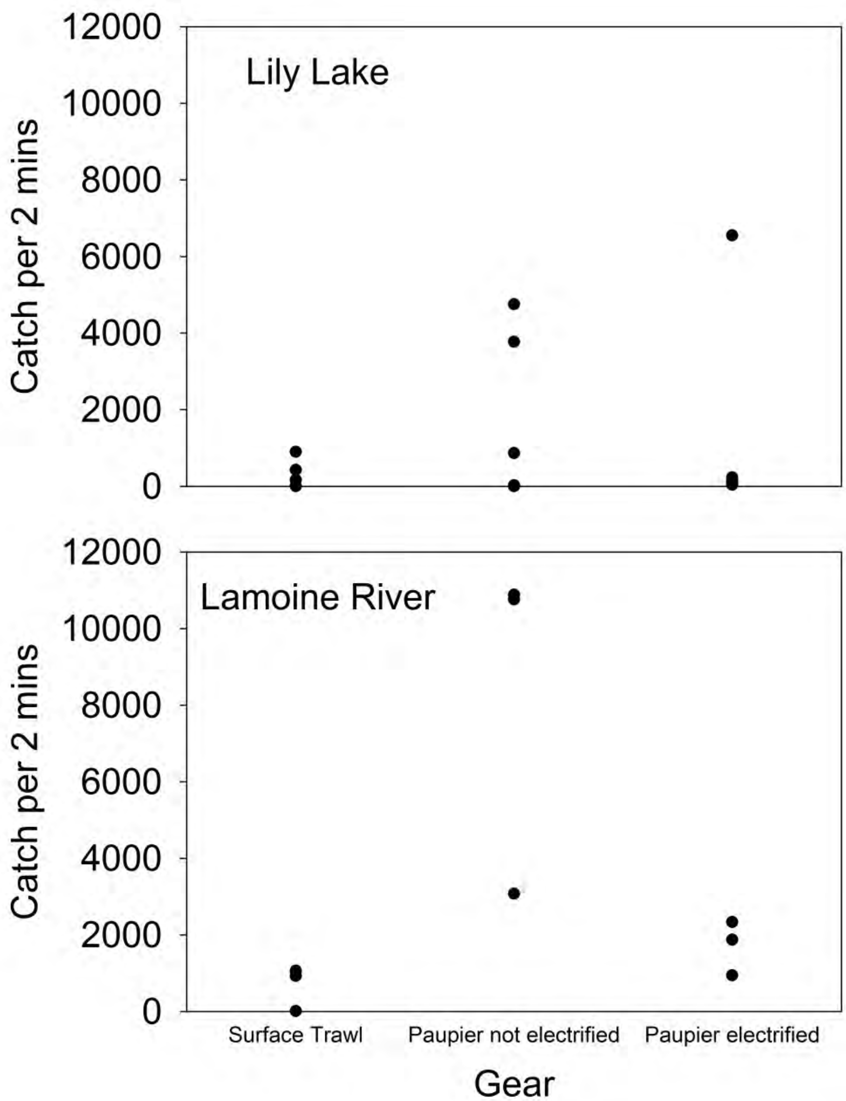

Figure 3. YOY Silver Carp CPUE in Lily Lake and Lamoine River with experimental gears July 28-30, 2014.

The YOY Silver Carp were abundant in Lamoine River and made for a good location to replicate gear comparisons conducted in Lily Lake. Over 30,000 YOY Silver Carp and no Bighead Carp were captured in the Lamoine River. The size structures (Figure 2) of Silver Carp captured in Lamoine River was very similar to that represented in Lily Lake. However, the species composition (Figure 1) was dominated by YOY Silver Carp in all gears more so than in Lily Lake. Also similar to Lily Lake, CPUE of YOY Silver Carp was greatest with the non-electrified Paupier (8,239/2 minutes) than the surface trawl (668/2 minutes) or electrified paupier (1719/2 minutes) (Figure 3).

Upon return in October, very few juvenile invasive carps were captured, however, the ones that were captured were larger (Figure 4). Sampling in the Lamoine River on October 9, 2014, yielded one juvenile Silver Carp measuring 99 mm captured with the scalene surface trawl. Sampling in Lily Lake that same day yielded 326 juvenile Silver Carp averaging 107 mm and one adult Silver Carp at 551 mm. The one adult and four juveniles were captured in the surface trawl while the other 322 juvenile Silver Carp were captured with the non-electrified paupier in shallow habitats less than 1 meter deep. Silver Carp CPUE in Lily Lake was 22 fish per two minutes of trawling and comprised 43% of the total catch. Only three juvenile Bighead Carp, averaging 134 mm in length, were caught.

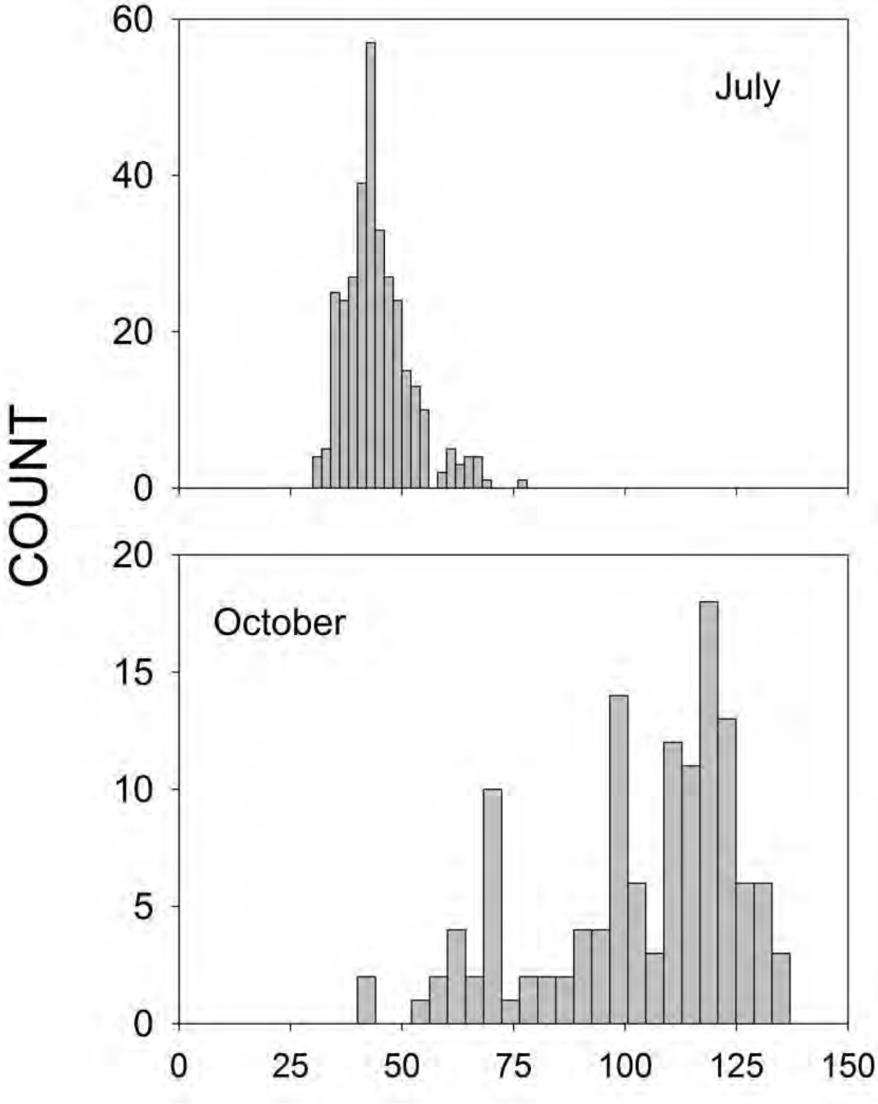

Figure 4. Length frequency histogram of juvenile Silver Carp captured in Lily Lake with the non-electrified paupier net in July (top) and October (bottom) 2014.

Night versus Day Sampling During Barrier Defense

Using the electrified paupier, CFWCO captured 2,822 Silver Carp in the Fox River tributary near the Illinois River confluence in the Starved Rock pool during barrier defense efforts in August, September and November 2014. Catch rates were highly variable during all three months; however, September efforts yielded the highest mean CPUE with 58 fish/2 minutes of electrified trawling followed by November (34 fish/2 minutes) and August (25 fish/2 minutes) (Figure 5).

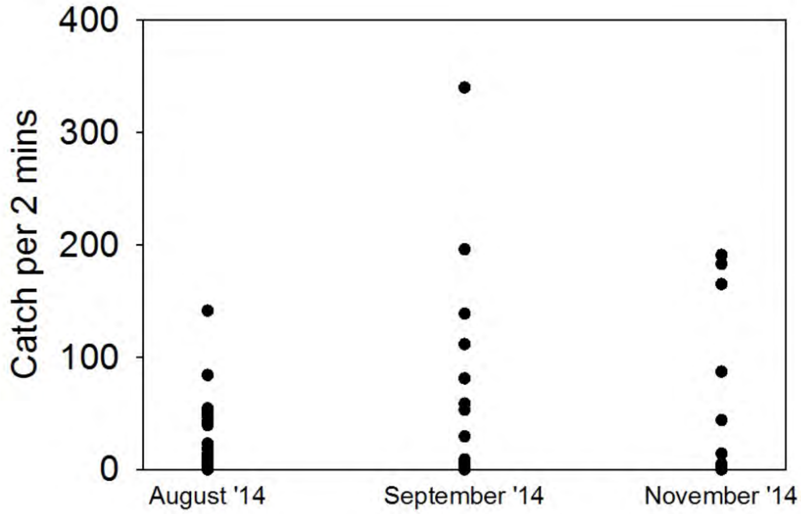

Figure 5. CPUE of Silver Carp captured by electrified paupier during barrier defense efforts in the Fox River, August, September and November 2014.

Nighttime sampling was conducted to compare with daytime sampling to determine whether catch rates differed. Catch rates were highly variable; however, night sampling resulted in a mean CPUE of 99 fish/2 minutes while day sampling had a mean of 52 fish/2 minutes (Figure 6).

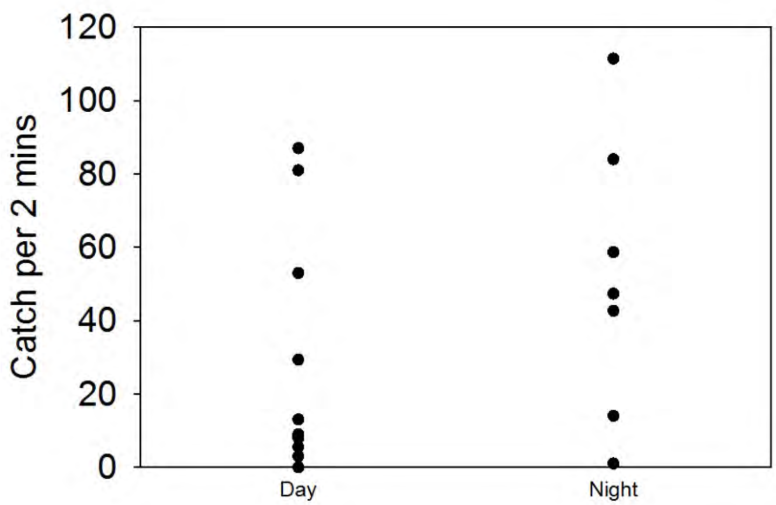

Figure 6. CPUE of Silver Carp captured in day and night by electrified paupier in the Fox River during Barrier Defense efforts in August, September and November 2014.

Efforts were most successful in the Fox River where invasive carp densities were high, depths were moderate (5-13 feet), and flows slower (<0.4 mph). Electrified trawling runs targeted dense pockets of fish and averaged 2 minutes in duration. Small mesh bags were installed in the cod-end of paupier nets to retain any captured YOY invasive carps. No YOY invasive carp species were collected from the Illinois River during Barrier Defense efforts in Starved Rock Pool or Fox River.

Regardless of month or time of day, Silver Carp dominate the catch in Fox River comprising 95% of the samples. Gizzard Shad are the second most abundant species at 3% and a variety of other species make up the remaining 2%.

The size class of Silver Carp captured in Fox River is consistent throughout the season with approximately 95% ranging in length from 500 to 700 mm. No adult Bighead Carp were captured during these efforts.

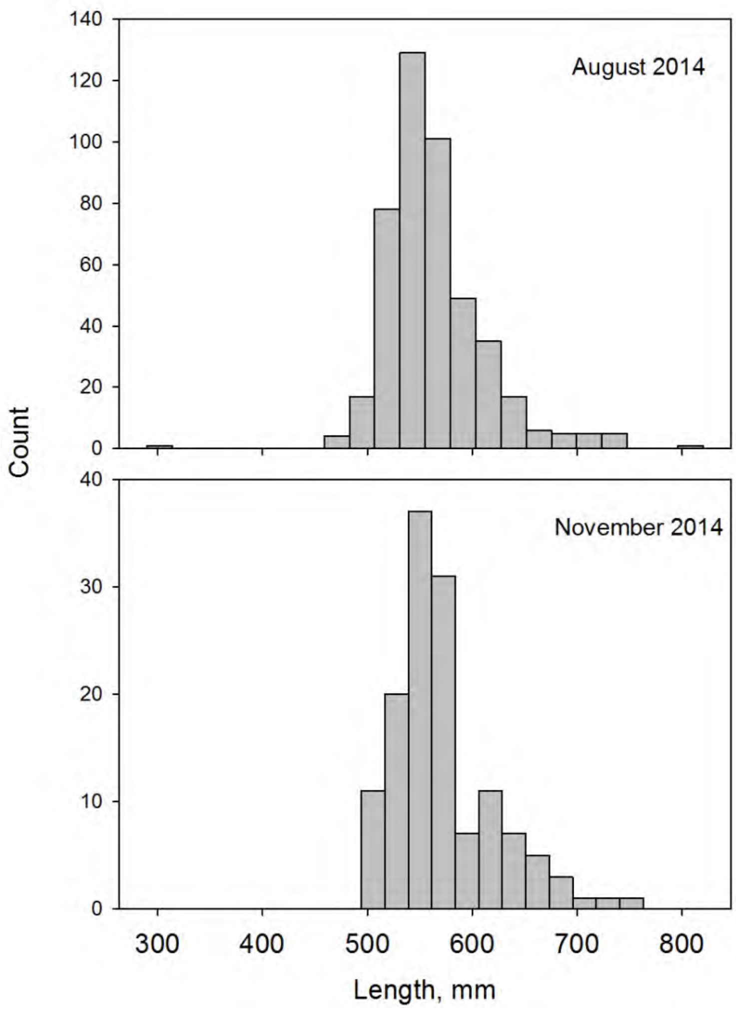

Figure 7. Length frequency histogram of Silver Carp captured in Fox River with the electrified paupier in August (top) and November (bottom) 2014.

Water temperatures in the Fox River decreased to 9.4°C in November 2014 from 25.2°C in September 2014. Although many fish were observed on the depth finder, catch rates were highly variable; and anecdotally, not as many fish appeared to be jumping above the surface of the water. Future research will focus on decreasing capture variability through gear modifications and integration of capture techniques.

Juvenile Silver Carp Detection with Surface Trawls
July 2014 efforts to detect juvenile Silver Carp in tributaries of the Missouri River resulted in 71% of the samples being successful whereas only 38% of the October 2014 samples detected juveniles. The average length of juvenile Silver Carp specimens collected in July was 37 mm and average length in October was 94 mm.

The lower detection rate is likely due to a combination of factors including habitat shifts, lower population numbers, and environmental variables, including river levels. In July the Missouri river was at normal flows whereas in October sampling took place during a moderate flood event. The observed growth of juvenile carp catches and our ability to consistently capture juveniles of various length classes was encouraging for planning future sampling activities.

Field crews have begun utilizing GoPro® video cameras during sampling to facilitate conversations with the net maker. These video cameras allow us to capture functionality of experimental nets and rigging, fish response and behaviors, as well as, safety and feasibility for crews. These are preliminary steps in developing a protocol for the use of video to document fish response to experimental gears.

Recommendations: Similar to the use of traditional boat electrofishing for the detection and capture of all sizes of invasive carps, the electrified paupier trawl shows great success in open-water habitats. The electrified paupier would be a good addition to a protocol for sampling island side channels, channel borders, backwater lakes, and reservoirs. Incorporating the paupier trawl, electrified or not, and surface trawls into the monitoring protocol for juvenile invasive carps would complement the suite of gears currently being used in the Illinois River system. The paupier can be used in large or smaller backwater habitats greater than .6 meters (2 feet) deep while the surface trawls are ideal for sampling the pelagic fish community in 1 meter (3 feet) or more of water. The surface trawls spread open approximately 30’ and can be towed behind an average flat-bottomed river boat. These attributes make the surface trawls ideal for sampling a large area of open-water in a short period of time.

Project Highlights:

- The paupier captures juvenile carp without electricity.
- The surface trawls capture juvenile carp.
- All sizes of Silver Carp were readily captured throughout the year in all habitats sampled.
- Juvenile invasive carp occupy lower reaches of tributary stream habitats of large rivers in the early life stages.
- YOY invasive carps transition to occupy shallow, still water habitats in the fall.

Unconventional Gear Development

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

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

Introduction: Traditional sampling gears vary widely in their ability to capture Asian carp. Additionally, the ability of some of these gears to capture Asian carp in the conditions found in the CAWS is questionable. A working group composed of fisheries scientists and commercial fishers was convened to develop gears specifically targeting Asian carp in areas of low density and in the deep-draft channels of the CAWS. This committee decided to pursue evaluation of three new sampling gears: large (2 m) hoop nets, deep (10 m) tied-down gill nets, and Great Lakes style trap (pound) nets. Capture efficiency and size selectivity of these new methods is being evaluated and compared with selected traditional gears to determine 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.

Methods: In 2014, unconventional gears were employed at multiple sites in order to evaluate their effectiveness across a range of Asian carp densities. We continued to evaluate the effectiveness of driving Asian carp into surface-to-bottom gill nets (91.4 m long x 8.5 m tied down to 6.1 m depth; 6.4, 7.6, 8.9, and 10.2 cm mesh panels) at four sites (LaGrange, Peoria, Starved Rock, and Marseilles Pools) during July 2014. Treatments included a control set, a set where fish were driven into the net with traditional pounding methods, and a set where fish were driven via pulsed-DC electrofishing, each lasting 15 minutes. Five replicates of each treatment were performed at each site. Great Lakes trap (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 at the Material Service Pit (Marseilles Pool) and at Lily Lake (LaGrange Pool) for one week each during summer and fall. Pound nets were checked daily during each set, at which times all captured fish were removed from the pots for identification and measurement. Hoop nets (1.2 m x 4.8 m, 3.8 - 6.4 cm mesh) and fyke nets (15 m x 1.3 m lead, 0.9 x 1.8 m frame, 3.8 cm mesh) were also set for multiple net-nights at each site concurrent with pound nets for comparison purposes. All captured fish were identified to species, and measured for total length and weight. Sex and reproductive condition of Asian carp were determined by removal of gonads in the field. Two pound nets were also set for two weeks in the Material Service Pit in collaboration with USGS to test food attractants for Asian carp.

The attractants are being tested by deploying food on one net and using the other as a control. Results of these tests will be presented by USGS.

Results and Discussion: Experiments testing the effectiveness of driving Asian carp into surface-to-bottom gill nets captured a total of 80 fish in 2014, including 37 Asian carp (31 silver carp, 6 bighead carp). Analysis of combined 2013 and 2014 data indicates that drives using pulsed-DC electrofishing captured more total fish (all taxa) than drives using traditional pounding or control sets (Figure 1). Catch rates of silver carp were highest in electrofishing treatments, which were nearly 4 times higher than control sets, but similar to traditional pounding treatments. Bighead carp catch rates were highest in traditional pounding treatments, although these were not significantly different than control or electrofishing treatments. A majority of all fish and of silver carp captured in surface-to-bottom gill nets were captured in the smaller mesh panels, particularly the 6.4 cm mesh size (Figure 1). However, bighead carp appear to be more vulnerable to larger mesh sizes, and drives using pounding in particular captured higher numbers of bighead carp in the 10.2 cm mesh panel. Driving fish into surface-to-bottom gill nets therefore appears to be an effective method for capturing Asian carp and other fishes. Use of surface-to-bottom gill nets in conjunction with electrofishing may be a useful system for capturing Asian carp in some situations, especially where electrofishing alone is ineffective due to water depth. This combination system may also be useful for targeting both bighead carp and silver carp simultaneously, as electrofishing alone rarely captures bighead carp, whereas 15 minute drives using surface-to-bottom gill nets captured comparable numbers of bighead carp, on average, to 4-hour sets without driving.
A total of 1,207 fishes were captured in pound nets at Lily Lake and Material Service Pit during 2014. Of this catch, 135 were bighead carp and 881 were silver carp. Collectively, Asian carp comprised 84% of all fishes caught during 2014 in pound nets. Analysis of combined 2012 - 2014 data indicated that catch rates of fishes, including Asian carp taxa, were consistently higher in pound nets in comparison to traditional entrapment gears set in backwater habitats (Figure 2). Average nightly catch of all fish species was, on average, 134 times higher in pound nets than in hoop nets and 5-6 times higher than in fyke nets. Overnight catch rates of bighead carp were 113 times higher in pound nets than in hoop nets, and 41 times higher than in fyke nets. Average silver carp catch rates were 3200 times higher in pound nets than in hoop nets, and 360 times higher in pound nets than in fyke nets. Pound nets tended to capture larger bighead carp (mean ± SD = 829 ± 103 mm) than hoop nets (619 ± 99 mm) or fyke nets (681 ± 140 mm). However, sizes of silver carp did not differ significantly among pound nets (582 ± 62 mm), hoop nets (572 ± 75 mm), and fyke nets (557 ± 78 mm). These data suggest that the use of pound nets in backwater habitats is an effective means of capturing large numbers of Asian carp relative to conventional approaches. Additionally, as by-catch mortality of native fishes was typically low, pound nets may be a useful tool for removing Asian carp without adversely affecting native fish populations. However, this outcome requires daily attendance and maintenance of pound nets. Additional ongoing analyses are evaluating the costs and benefits of unconventional gears by accounting for effectiveness in terms of catch rates and the effort (e.g. labor hours) required to deploy and maintain these gears. Results of these cost-benefit analyses will be reported once available.

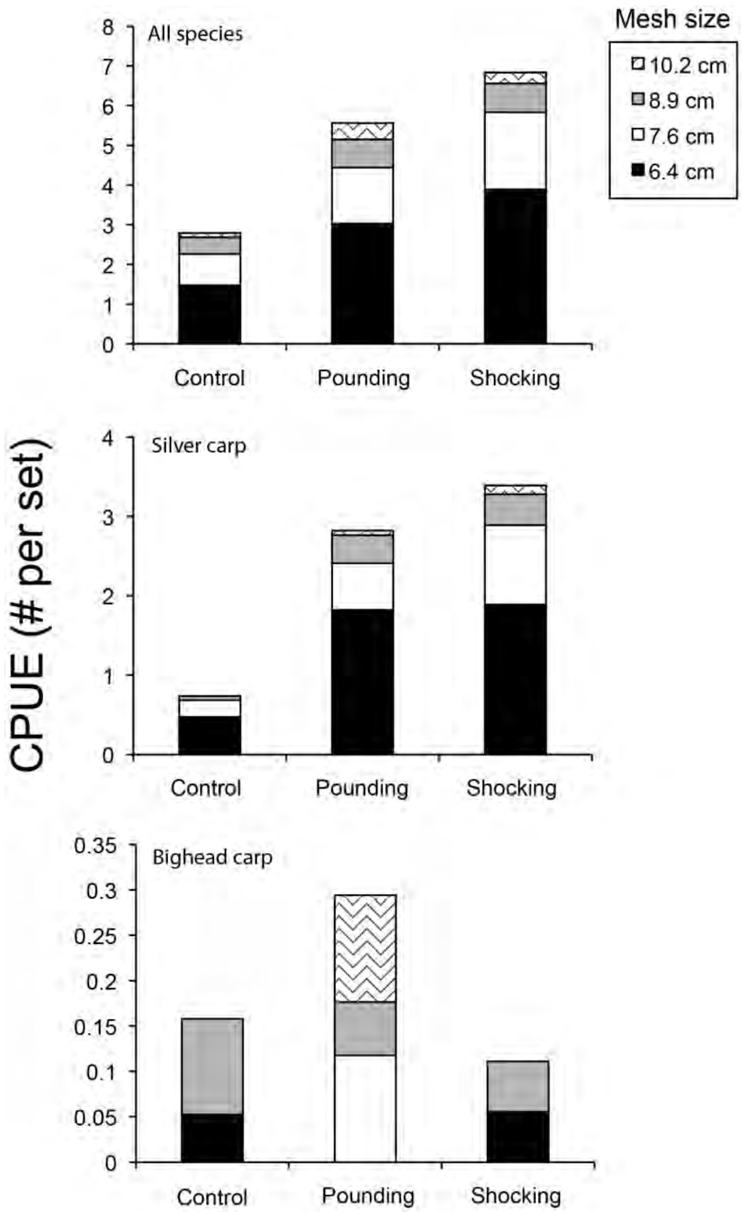

Figure 1. Mean catch per unit effort (CPUE; number / set) of all fish taxa, silver carp, and bighead carp captured in different mesh sizes (6.4 – 10.2 cm) of surface-to-bottom gill nets set for 15-minutes with a control treatment (no driving), a treatment where fish were driven into the net using traditional pounding methods, and a treatment where fish were driven into the net via pulsed-DC electrofishing.

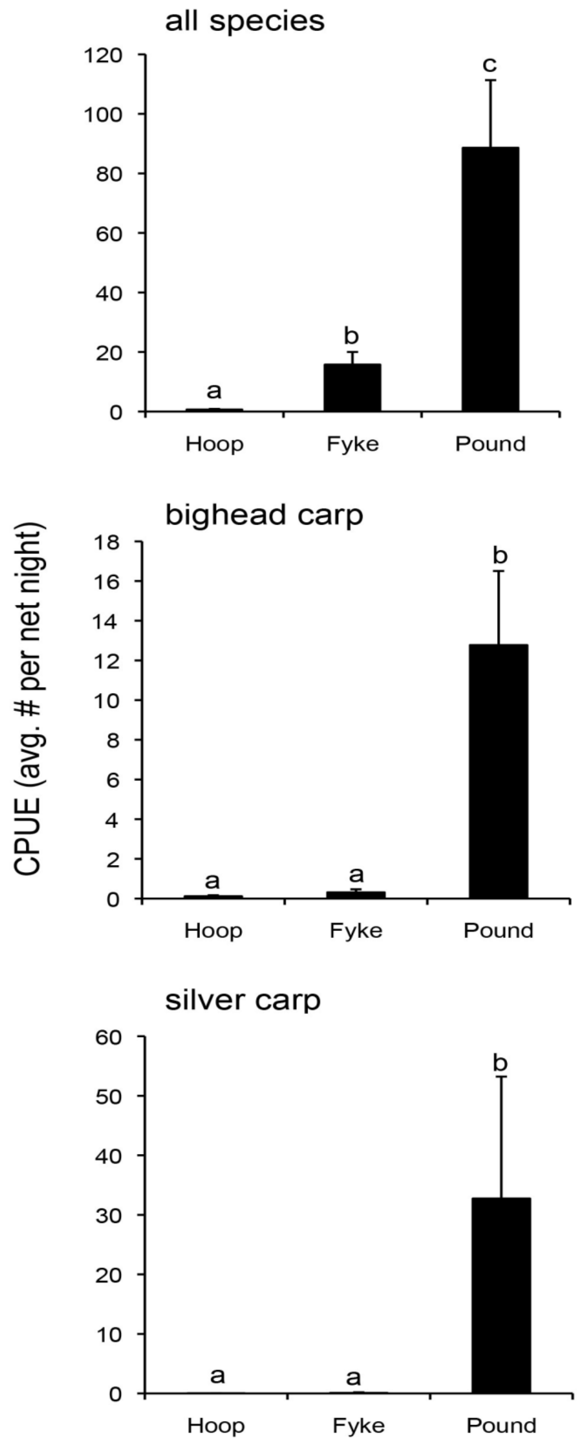

Figure 2. Mean (± SE) catch rates of all fish taxa, bighead carp, and silver carp from hoop nets, pound nets, and fyke nets set at Lily Lake and the Material Service Pit at Morris during 2012 – 2014.

Recommendations: Driving fish into surface-to-bottom gill nets appears to be an effective technique for capturing Asian carp, particularly for silver carp in conjunction with pulsed-DC electrofishing. This method could be particularly useful in deeper-water habitats where electrofishing alone is ineffective, and may also allow for a better representation of bighead carp than electrofishing alone is capable of producing. Smaller mesh sizes (6.4 – 7.6 cm) appear to be most effective for the majority of fish species, including silver carp, whereas larger mesh sizes (7.6 – 10.2 cm) are more effective for bighead carp. Pound nets appear to be highly effective for capturing large numbers of adult Asian carp in backwater habitats relative to traditional entrapment gears and may be useful tools for monitoring or removal purposes in such areas. Daily attendance of pound nets is recommended to ensure that pound nets are fishing effectively and to minimize mortality of native species. The effort (e.g. labor hours) involved in deploying and maintaining hoop, fyke, and pound nets varies considerably. Additional cost-benefit analyses are needed to determine which gears are most effective not only in terms of fish captured but in terms of maximizing catch rates for the personnel time expended.

Project Highlights:

- Driving fish into surface-to-bottom gill nets resulted in higher catch rates of all fish species and of silver carp than control sets. The highest catch rates were obtained by driving fish using a pulsed-DC electrofishing boat.
- The majority of fish species, including silver carp, were more vulnerable to smaller mesh sizes (6.4 – 7.6 cm) of surface-to-bottom gill nets, whereas bighead carp appear to be more vulnerable to larger mesh sizes (7.6 – 10.2 cm).
- Pound nets captured large numbers of fish, primarily consisting of Asian carp, and produced substantially higher catch rates of Asian carp than traditional entrapment gears in backwater habitats.
- Pound nets captured larger sizes of bighead carp than hoop nets or fyke nets, but sizes of captured silver carp did not differ among these gear types.

Water Gun Development and Testing

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Introduction

Silver (*Hypophthalmichthys molitrix*) and bighead carp (*H. nobilis*), two invasive Asian carp species, have become established in the Mississippi River watershed, and there is potential for these fish to invade the Great Lakes waters in the near future. Currently, prevention of the movement of Asian carp from the Mississippi watershed into the Great Lakes rests on a set of electric barriers installed in the Chicago Area Waterway System (CAWS). Additional barriers and/or supplements to the electric 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 during periods when the electric 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 which 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 which 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 the firing of 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 standalone deterrent in other locations (e.g. locks, connecting waterways, etc.).

Even though water guns have previously been shown to cause damage to trout and northern pike, they seem to have limited utility in killing on the bigheaded carps. Only 11% of the bigheaded carps 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 Hansen Material Service in Morris, Illinois in 2013 and 2014 had inconclusive results when the deployment enabled a 2-gun array to fire every 10 seconds. Using hydroacoustics, fish appeared to stay more than 50 m 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. Prior to deploying seismic water guns 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 (e.g. air guns) cause increased fish movement (as evidenced by greater catch rates of marine fishes in gillnets [a gear which required fish to encounter it]) and decreased feeding (as evidenced by decreased catch using long line sets [a gear which requires active feeding] and decreased stomach contents). Movement response appears to vary with the habitat preference of the species – those with specific habitat preferences, e.g. 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 freshwater suggests that the pelagic nature of bighead carp and silver carp may cause them to disperse in response to the sound/pressure pulse generated from water gun discharge. Therefore, the goal of this project was to determine if bighead carp, silver carp and a native planktivorous fish modify their behavior in response to the firing of a two gun array and if native mussels are affected by the firing of a water gun.

Methods

Bigheaded Carps Behavioral Response (Morris Field Trials)

A 50 ft block net was placed perpendicular to the south shore of the west pit of Hansen Material Service near Morris, Illinois. A second 50 ft block net was placed directly across the channel perpendicular to the north shore. Two 80 in^3 water guns were then suspended from rafts at mid depth equal distances from the ends of the block nets. To assess fish behavior, 16 HTI hydrophones were affixed to metal stands and placed on each side of the block net water gun barrier. Also, 12 autonomous nodes for HTI telemetry were placed throughout west pit. To completment telemetry data, we also placed six stationary Biosonics recorders, three on each side of the barrier. To determine the population of fishes, mobile hydroacoustic surveys were performed on both sides of the barriers prior to and after the running of the water guns.

A total of 184 fish were tagged and released in the west pit of HMS. Initial tagging was performed on 5 bighead carp, 5 silver carp and 5 bigmouth buffalo on July 24. These tags were surgically implanted. These 15 fish were released and served as a control for behavior when water guns were not firing. On August 7, 61 bigmouth buffalo were tagged (5 internally and 51 externally), 47 bighead carp (internally and jaw tagged) and 46 silver carp (internally and jaw tagged). Due to very high mortalities observed following the initial tagging, an additional 2 bigmouth buffalo and 13 silver carps were externally tagged with HTI transmitters.

Both water guns were fired on August 6, two weeks after releasing the 15 control fish. This test verified that the guns were functioning properly prior to starting the trials. Therefore the guns were only fired 8 times from 300 PSI to 1500 PSI. 61 bigmouth buffalo, 47 bighead carp and 46 silver carp were released from a holding pen on August 7. The initial trial began with water guns firing at 1500 PSI at 1445 on August 8, by 1545 both guns malfunctioned and were restarted within one minute. Both guns remained firing for more than 14 hours, when the south gun malfunctioned and the north gun remained firing. All guns were turned off at 1200 on the August 9. Water guns were fired intermittently from August 10 until August 12. At 1900 on August 12, 2 buffalo and 12 silver carp were externally tagged and released near the barrier. Water guns began firing at 2000 and continued to fire until the compressor malfunctioned at 1530 on August 13.

Effects on Native Mussels

Threeridge (*Amblema plicata*), Plain Pocketbook (*Lampsilis ovata ventricosa*), and Giant Floater (*Anodonta grandis*) were supplied from Genoa National Fish Hatchery (GNFH); Genoa, WI. These mussels were chosen for their different shell densities: Threeridge are thick-shelled, Plain Pocketbook have a shell of medium thickness and the Giant Floater is thin-shelled. Two independent studies were simultaneously conducted in a 0.1 ha test pond. Nine cages were arranged and placed into the pond at three distances (three cages per location) from the water guns. Four or five mussels of each species were randomly assigned to each cage. These caged mussels were used to determine if the pressure generated from the firing of the water gun caused damage to the animal. As controls for shell damage, we held 7 individuals of each species in a separate tank during the exposure. To determine if the mussels moved in response to the firing of the water gun, seven mussels of each species were placed on top of the pond sediments in a line perpendicular to the long axis of the test pond in a random order. The caged mussels were placed 1 m directly in front (toward water gun) of the cage-free mussels. All mussels in this study were assigned a unique identification code and individual lengths, widths, heights, wet weights were recorded and photographs taken.

The pond was filled with well water (12-13°C) and then one $100in^3$ water gun was suspended from a floating raft at a fixed location. The water gun was manually fired 100 times. The pond was then drained. Mussels from cages were collected, photographed and transported to a local veterinarian clinic where they were x-rayed to evaluate shell integrity. Movements and burrowing of "cage-free" mussels were recorded. All mussels were then placed into a tank supplied with flow-thru well water and fed a shellfish diet and mortalities were recorded during the 30 d post-exposure period.

Results and Discussion

Bigheaded Carps Behavioral Response (Morris Field Trials)

Mobile acoustic surveys indicated no change in fish distribution throughout the west pit at Hansen Material Serv firing (Figure 2). Additionally, the use of telemetered fish suggested that fish would actively test the water gun barrier when firing and were observed passing through the two-gun array. These results are contrary to previous controlled pond studies where fish were found to actively move away from the guns while firing. However, the two-gun array was only able to fire every ten seconds and equipment malfunctions plagued these field trials.

Bathymetric data indicated that the south gun was placed in water with a depth of less than 3 m, while the north gun was placed in water more than 4 m deep. The depth of the water will significantly affect the pressure field generated by the firing of a water gun. In shallow water, the bottom can attenuate much of the pressure and therefore decrease the effective pressure field. This would provide an unbalanced pressure gradient, with greater pressures around the north gun and much less around the south gun. This would enable fish to potentially penetrate the water gun barrier near south gun. It was observed using the telemetered fish, which fish typically approached the barrier on the south and much less on the north.

All trials conducted in 2014 had water gun(s) or the compressor malfunction during a portion of the each 24 h trial. Compressor malfunctions occurred on multiple occasions and the water gun malfunctioned once. Therefore, limited information can be obtained that assesses the use of a two-gun array from these trails.

Effects on Native Mussels

No mussels exhibited any shell damage, even the thin-shelled Giant Floaters that were placed closest to the water gun (Figure 3). Preliminary observations suggest the firing of the water gun does not affect the movement or burrowing behavior of any of the species tested in this trial. Lastly, all mussels survived until the end of this trial. Therefore, initial data suggests that Threeridge, Plain Pocketbook and Giant Floater can withstand 100 firing of a 100in^3 water gun.

Alternate Pathway Surveillance in Illinois - Law Enforcement

Brandon Fehrenbacher & Heath Tepovich
Illinois Department of Natural Resources

Participating Agencies: Illinois Department of Natural Resources (lead)

Introduction: The illicit trade and transportation of live invasive species increases the potential threat of them being introduced in the CAWS. Enforcement of laws regulating the movement of live aquatic species is essential to preventing them from establishing in the Great Lakes basin. The Invasive Species Unit (ISU) is the Illinois Department of Natural Resources' specialized law enforcement unit formed two and a half years ago dedicated to detecting and apprehending those individuals or companies involved in the illegal trade and/or transportation of invasive species. The unit consists of two officers with over twenty-two years of combined law enforcement experience with the Illinois Conservation Police who work directly with the Division of Fisheries. The Invasive Species Unit is a member of the multi-agency Asian Carp Task Force established in 2012 to combine enforcement efforts throughout the United States in preventing the spread of invasive species. The ISU has been recognized as a leader in the Asian Carp Task Force for conducting successful law enforcement operations against violators of invasive species laws. The ISU has allocated time to teach each new class of Conservation Police Officer Trainees the techniques and importance of enforcing invasive species regulations which will provide present and future benefits.

Objectives: Continue to build on the IDNR Invasive Species Unit activities. Also, collaborate with other agencies for intelligence gathering and combined enforcement efforts on invasive species issues and illegal fish importation we proposed to:

- ISU will continue to attend training opportunities in order to better equip the unit with the skills and knowledge necessary to effectively conduct investigations and operations.
- Educate and train officers throughout the State utilizing previously developed standardized inspection procedures in order to maximize the detection and interdiction of illegally transported aquatic life.
- Organize and implement details focusing on fish truck inspections in the Chicago metropolitan area and document these inspections on the newly created fish truck inspection form.
- Conduct follow-up compliance checks on fish markets that were previously inspected and determined to be in violation of the law. Charge and seek harsher penalties for repeat violators.
- Expand the search for fish markets in the Chicago metropolitan area operating illegally and conduct surveillance and record searches of them to gain information on wholesale aquatic life dealers and transporters.

- Conduct surveillance and enforcement operations within the commercial fishing industry, especially those areas determined from previous operations to be considered “areas of interest.”
- Increase enforcement efforts focusing on the illegal bait trade in Chicago metropolitan area. Document any violations and ensure bait suppliers transporting bait within the State are in compliance of all regulations.
- Manage and review all ongoing cases by determining what resources are needed and then allocating the time to further the case or bring it to a conclusion.
- Conduct details to be implemented at boat launches which will focus on enforcing laws and educating fishermen on regulations established to prevent the spread of invasive species by them. The details will document violations and enforcement actions.
- Network with members of the multi-agency invasive species task force for the sharing of intelligence, resources, and strategies related to preventing the spread of Asian Carp.
- Represent Illinois, the IDNR, and the Invasive Species Unit at various conferences, meetings, and seminars which discuss topics related to Asian Carp and law enforcements responses and experiences.

Methods: With the sensitive nature of this program, detailed investigation methods cannot be described, however more commonly used methods were; ISU utilized internet searches, leads provided through networking, surveillance, on-site observations, and information provided from those involved within the industry. The unit used un-marked vehicles for everyday operations and surveillance. The ISU does not wear an identifiable police uniform while working, but, utilized uniformed Conservation Police Officers for some take-down operations and large scale inspections. Record searches and compiling the evidence within those records was very beneficial for the initial and spin-off investigations. The IDNR Point of Sale Licensing system and Accurint Search database were commonly accessed for investigative purposes.

Results and Discussion: ISU attended and successfully completed the 35 hour Detective and New Investigator Course hosted by the Public Agency Training Council in Andover, Minnesota; successfully completed an Undercover and Rolling Surveillance Course hosted by the Indiana Department of Natural Resources Covert Unit; instructed and participated in the 2014 annual Firearms and Defensive Tactics training for sworn law enforcement officers.

ISU instructed the recruit class of 2014 in invasive species and mussel enforcement for law enforcement officers at the IDNR Academy in Springfield. ISU assisted Conservation Police Officers throughout the year with questions and cases related to invasive species enforcement. ISU conducted several fish truck inspections details. One of these inspections detected an out of state aquatic life dealer selling aquatic life without a license and VHS susceptible species without permits. Another inspection revealed a wholesale aquatic life dealer selling aquatic life without the required license. Additional inspections found the transportation companies in compliance with the regulations.

Follow up compliance checks on fish markets identified as “previous violators” resulted in five fish markets being cited for no aquatic life dealer’s license and another market was cited for selling bluegill and largemouth bass caught in the wild. Other follow up compliance checks determined the businesses were operating legally.

ISU identified 94 retail markets, 25 wholesale, and 2 non-resident aquatic life dealers selling aquatic life in Illinois without the required licenses. These investigations helped identify those aquatic life dealers who are selling Asian Carp, so future efforts can be concentrated on them to ensure no live Asian Carp are being sold. All of the dealers purchased the required licenses.

Surveillance and a planned operation of a commercial fisherman determined by the ISU as a “person of interest” resulted the fisherman being arrested for selling 1800 pounds of live Bighead and Silver Carp. His brother was arrested for possession of live Bighead and Silver Carp.

Two intrastate retail minnow dealers in Northern Illinois were issued warnings and brought into compliance for selling minnows without a valid license. ISU conducted two random commercial inspections of Wholesale Intrastate Minnow Dealers and found no violations.

ISU managed ongoing cases and successful closed many of them resulting in over $67,000 in fines/restitution being deposited in the Illinois Conservation Police Operations Assistance Fund in 2014. The case management strategy prevented the statute of limitations for the crimes from expiring and freed up time, so that future cases could be concentrated on.

The VHS enforcement detail objective at boat launches wasn’t completed because of time constraints and other obligations such as ISU surveillance of IDNR Fishery nets in Lake Calumet and a lengthy water pollution investigation.

ISU worked closely with member states of the Asian Carp Task Force to share information relevant to invasive species enforcement. All requests for assistance were completed and the ISU is currently working with Indiana DNR on a wildlife investigation.

ISU attended the Upper Mississippi River Conservation Committee in La Crosse Wisconsin; Great Lakes Law Enforcement Committee meeting in Windsor, Ontario; Midwest Investigator’s Association Conference in Cable, Wisconsin; IDNR Division of Fisheries meeting in Bloomington, IL; and the Great Lakes Law Enforcement Committee Conference in Huron, Ohio. The ISU is an active participant in the Illinois Attorney General’s Office Environmental Crimes Task Force.

Recommendations: We recommend continuing the current cooperative efforts of the Invasive Species Unit and Division of Fisheries towards the common goal of preventing the spread of invasive aquatic species. A strong emphasis should be placed on providing the public with an easy understanding of legalities within the aquatic life industry. Penalties such as fines or restitution sought out in court for violations of the law should be consistent in order to establish a baseline for future cases. An annual review should be conducted to look for deficiencies and/or the need for modifications in Illinois invasive species laws. Any suspicious activities or requests for assistance from the ISU should be made as soon as the need arises.

Project Highlights:

- January 2014 - Sweetwater Spring Fish Company and owner each pled guilty to importing live VHS susceptible species without permits and paid a fine of $25,400.00 which was deposited in the Illinois Conservation Police Operations Assistance Fund.
- In August 2014, an Indiana bait dealer arrested for selling minnows and grass carp in Illinois without an aquatic life dealer's license, VHS permits, or a restricted species permit pled guilty and paid a $4000 fine which was deposited in the Illinois Conservation Police Operations Assistance Fund.
- November 2014 – A commercial fisherman targeted in an ISU investigation was arrested for the unlawful sale of 1,800 pounds of Bighead and Silver Carp – Class 3 Felony. His brother was arrested for possession of live Bighead and Silver Carp – Class A Misdemeanor.
- On December 01, 2014, Farm Cat Fish Transportation Company and the owner pled guilty to importing VHS susceptible species w/o permits and paid a $2,500 fine and $22,500 to the Illinois Conservation Police Operations Assistance Fund. They were also arrested for selling aquatic life without a license.
- Operation JabberJaw in Chinatown identified retail markets illegally selling shark fin. The operation resulted in the issuance of 8 citations for selling aquatic life without a license and 12 citations for illegally selling shark fin. A total of 80 shark fin violations were documented and 33 shark fin items seized. $3700 was awarded to the Illinois Conservation Police Operations Assistance Fund.
- A Commercial Fisherwoman was charged by ISU with 11 counts of falsifying roe harvester reports, 5 counts of fraudulently obtaining commercial device tags, 2 counts of fraudulently obtaining resident roe harvester permits, 2 counts of fraudulently obtaining resident commercial fishing licenses, 57 counts of unlawful commercialization of sturgeon roe, and 1 count of fraudulently obtaining a resident sport fishing license. On December 2014, she pled guilty to 3 counts falsifying records, paid $5000 to the Illinois Conservation Police Operations Assistance Fund and a $300 fine.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

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

As a further response to the Bighead Carp in Flatfoot Lake and Schiller Pond, IDNR reviewed Asian carp captures in all fishing ponds included in the IDNR Urban Fishing Program located in the Chicago Metropolitan area. To date, seven of the 21 urban fishing ponds in the program have verified captures of Asian carp either from sampling, pond rehabilitation with piscicide, or natural die offs; one pond had reported sightings of Asian carp that were not confirmed by sampling (McKinley Park) (Table 1). 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 Chicago Area Waterway System (CAWS) waterways 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 CAWS waterways, most are isolated and have no surface water connection to the Lake or CAWS upstream of the Dispersal Barrier (Table 1). Ponds in Gompers Park, Jackson Park, and Lincoln Park are the exceptions. The Lincoln Park South Lagoon is no longer a potential source of Asian carp because the fish population was rehabilitated with piscicide in 2008, after which it was dropped as a Chicago pond stocking site. Lagoons in Gompers Park and Jackson Park have 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 CAWS waterways or Lake Michigan continues to be of importance due to the potential of human transfers of Asian carp between waters within close proximity to one another.

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 resulted in positive detections for Asian carp, two of which are also IDNR urban fishing ponds (Jackson Park, Flatfoot Lake) (Table 2). Asian carp have been captured and

Table 1. A list of Chicago area urban fishing ponds, reported and verified occurrence of Asian Carp, distance to Lake Michigan (LM) and the Chicago Area Waterway System (CAWS), and surface water connection to LM and CAWS. NR indicates none reported or observed/captured during routine electrofishing samples. DCEL is DC electrofishing and TN/GN is trammel/gill net. Waterways are: LM=Lake Michigan; CALSC = Cal-Sag Channel; CALR = Calumet River; DESPL = Des Plaines River; CSSC = Chicago Sanitary and Ship Canal; NBCR = North Branch Chicago River; LCALR = Little Calumet River; BUBCR = Bubbly Creek; DH = Diversey Harbor; and JH = Jackson Harbor.

Urban Fishing Pond	County	Town	Presence of Bighead Carp (number-year)	Distance to LM (miles)	Distance to CAWS (miles-waterway)	Surface water connection to LM and CAWS
Commissioner's Park Pond	Cook	Alsip	NR	9.7	0.9-CALSC	None
Auburn Park Lagoon	Cook	Chicago	NR	3.7	5.1-CALR	None
Columbus Park Lagoon	Cook	Chicago	3 winterkill-2011	7.8	2.9-DESPL	None
Douglas Park Lagoon	Cook	Chicago	NR	4.2	1.8-CSSC	None
Garfield Park Lagoon	Cook	Chicago	1 summerkill-2010 2 TN/GN-2012	5.0	3.2-NBCR	None
Gompers Park Lagoon	Cook	Chicago	NR	4.1	0.01-NBCR	Overflow to NBCR
Humboldt Park Lagoon	Cook	Chicago	3 TN/GN-2012 5 TN/GN-2013 1 winterkill-2014	3.8	2.2-NBCR	None
Jackson Park Lagoon	Cook	Chicago	NR	0.1	4.7-CALR	Overflow to JH
Lincoln Park South Lagoon	Cook	Chicago	3 pond rehab-2008	0.1	1.3-NBCR	Overflow to DH
Marquette Park Lagoon	Cook	Chicago	NR	6.3	4.2-CSSC	None
McKinley Park Lagoon	Cook	Chicago	Reported, NR	3.8	0.9-CSSC	None
Sherman Park Lagoon	Cook	Chicago	1 winterkill-2014*	3.6	1.9-BUBCR	None
Washington Park Lagoon	Cook	Chicago	NR	1.7	3.3-BUBCR	None
Riis Park Lagoon	Cook	Chicago	NR	7.7	2.3-DESPL	None
Flatfoot Lake	Cook	Dolton	15 DCEL-2011 2 TN/GN-2011 1 TN/GN-2013	5.0	0.2-LCALR	None
Lake Owens	Cook	Hazelcrest	NR	12.2	4.8-LCALR	None
Cermak Quarry	Cook	Lyons	NR	10.7	0.2-DESPL	None
Lake Shermerville	Cook	Northbrook	NR	6.6	0.8-DESPL	None
Schiller Pond	Cook	Schiller Park	3 DCEL-2011	10.1	0.9-DESPL	None
Elliot Lake	DuPage	Wheaton	NR	25.7	14.5-CSSC	None
Community Park Pond	Lake	Mundelein	NR	9.2	3.8-DESPL	None

removed from two of the eight ponds yielding positive eDNA detections. The distance from ponds with positive eDNA detections to Lake Michigan ranges from 4.8 to 31.4 km (3 to 19.5 miles). The distance from these ponds to Chicago Area Waterway System (CAWS) waterways upstream of the electric dispersal barrier ranges from 0.05 to 7.6 km (0.03 to 4.7 miles). Though positive eDNA detections do not necessarily represent the presence of live fish (e.g., may represent live or dead fish, or result from sources other than live fish, such as DNA from the guano of piscivorous birds) they should be examined for the presence of live Asian carp given the proximity to CAWS waterways.

Objective: Urban pond monitoring objective was to:

- 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/gill nets).

Table 2. A list of Chicago area ponds with positive detections for Asian carp eDNA, verified occurrence of Asian carp, proximity to Lake Michigan (LM) and the Chicago Area Waterway System (CAWS), and surface water connection to LM and CAWS. NR indicates none reported or observed/captured during routine electrofishing samples. DCEL is DC electrofishing and TN/GN is trammel/gill net. Waterways are: LM = Lake Michigan; CALSC = Cal-Sag Channel; CALR = Calumet River; GCALR = Grand Calumet River; LCAL = Lake Calumet; LCALR = Little Calumet River; JH = Jackson Harbor. (*) denotes IDNR urban fishing ponds.

Pond	County	Town	Presence of Bighead carp (number-year)	Distance to LM (miles)	Distance to CAWS (miles-waterway)	Surface water connection to LM and CAWS
Jackson Park*	Cook	Chicago	NR	0.1	4.7-CALR	Overflow to JH
Powderhorn Lake	Cook	Chicago	NR	3.5	0.5-GCALR	None
Harborside Lake	Cook	Chicago	NR	3.0	0.03-LCAL	Overflow to LCAL
Flatfoot Lake*	Cook	Dolton	15 DCEL-2011 2 TN/GN-2011 1 TN/GN-2013	5.0	0.2-LCALR	None
Sag Quarry West	Cook	Lemont	NR	19.5	0.06-CALSC	None
Horsetail Lake	Cook	Palos Park	NR	18.0	1.2-CALSC	None
Tampier Lake	Cook	Palos Park	NR	19.5	2.7-CALSC	None
Joe's Pond	Cook	Willow Springs	1 TN/GN-2012	17.0	0.9-CALSC	None

Methods: Due to widespread winterkills in Chicago area fishing ponds, no formal pond sampling was completed in 2014.

Typically, pulsed DC-electrofishing and trammel/gill nets are used to sample urban fishing ponds. Trammel and gill nets used are approximately 3 m (10 ft) deep x 91.4 m (300 ft) long in bar mesh sizes ranging from 88.9-108 mm (3.5-4.25 in). Electrofishing, along with pounding on boats and revving tipped up motors, are used to drive fish into the nets. Upon capture, Asian carp are removed from the pond and the length and weight is 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: Two winterkill Asian carp were removed from Chicago fishing ponds in 2014; one Bighead Carp with a total length of 1,010 mm was removed from Humboldt Park Lagoon on March 28th and one Silver Carp (732 mm, 6,000 g) was removed from Sherman Park Lagoon on March 31st. Additionally, two winterkill Asian carp were reported from downstate Crystal Lake in Urbana; one Silver Carp (~457 mm) and one Bighead Carp (~1,270 mm, 24,720 g). Age estimation and otolith microchemistry analysis of both Bighead Carp as well as the Silver Carp from Sherman Park Lagoon will be conducted Dr. Greg Whitledge at SIUC. This will be the first analysis of a Silver Carp otolith from an Illinois urban fishing pond to date.

Though photos of the Silver Carp from Crystal Lake were taken, it was disposed of prior to IDNR biologists visiting the site.

Approximately 80% of the otoliths examined to date exhibited a decline in Sr:Ca from high values in the otolith core (750-1,900 umol/mol; within 50-150 microns of the otolith center) to lower values (range 400-650 umol/mol) toward the edge of the otolith (mean 618 umol/mol within 50 microns of the otolith edge) (Figure 1). Mean otolith Sr:Ca of 618 umol/mol near the otolith edge is consistent with expected otolith Sr:Ca for a resident fish in these Chicago fishing ponds based on Sr:Ca of water samples taken from these sites during 2010-2012 (range 1.5-1.8 mmol/mol) and a regression relating water and Asian carp otolith Sr:Ca (Norman and Whitledge, in press). The higher Sr:Ca near the otolith core suggests these fish were transferred into the lagoons during age-0 or age-1. These data indicate that the fish spent their early life in water(s) with higher Sr:Ca ratios and the remainder of their life as residents of the urban ponds. In addition, the otolith core Sr:Ca values are high when compared to that of Bighead Carp of Illinois River origin as well as other sites previously examined in northern Illinois (Figure 2) (Whitledge 2009). Therefore, Bighead Carp removed from Chicago area ponds were likely not transplanted adult fish nor bait bucket introductions of juveniles from nearby rivers. Given the size (age) of these fish at the time of introduction its plausible that they were contaminants in shipments of desirable fish species stocked in the lagoons, likely before the State of Illinois banned transport of live Bighead Carp in 2002-2003. This corresponds to a time when Bighead Carp were raised for market in ponds with Channel Catfish in certain regions of the U.S. (Kolar et al. 2007). Shipments of Channel Catfish may be the most likely source of contamination in Illinois urban fishing ponds as catchable-sized catfish are stocked frequently and extensively in these waters throughout the State (IDNR 2010).

Recommendations: We recommend additional sampling of ponds from which Asian carp have previously been collected to ensure that no carp remain (Figure 3). We will investigate reports of Asian carp sightings in Chicago area ponds via phone or email communication as well as site visits. We will also continue to work with Dr. Whitledge at SIUC to obtain additional environmental history information on Asian carp captured from Illinois urban fishing ponds.

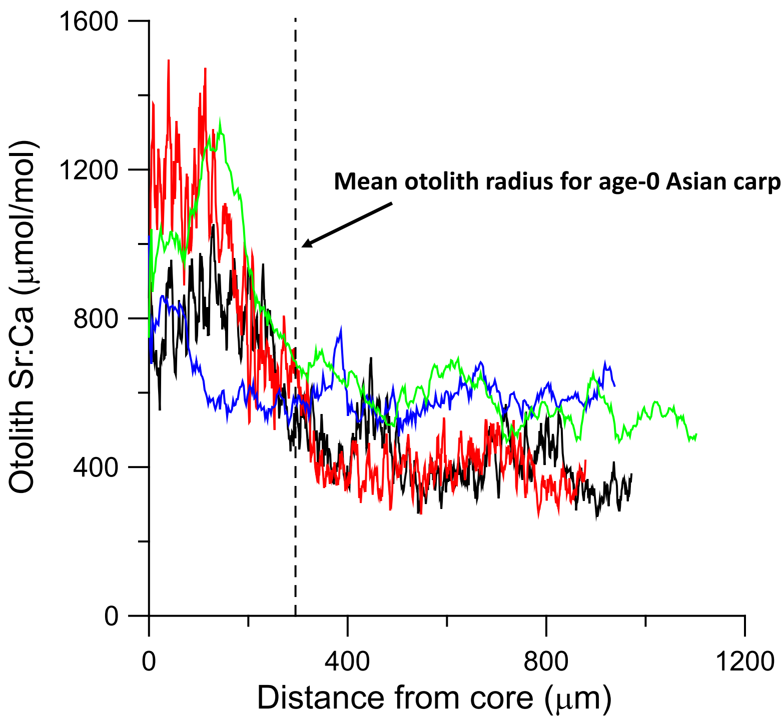

Figure 1. Example of laser ablation transects for four Chicago pond Bighead Carp otoliths. The dashed line represents the mean otolith radius for age-0 Asian carp taken from rivers.

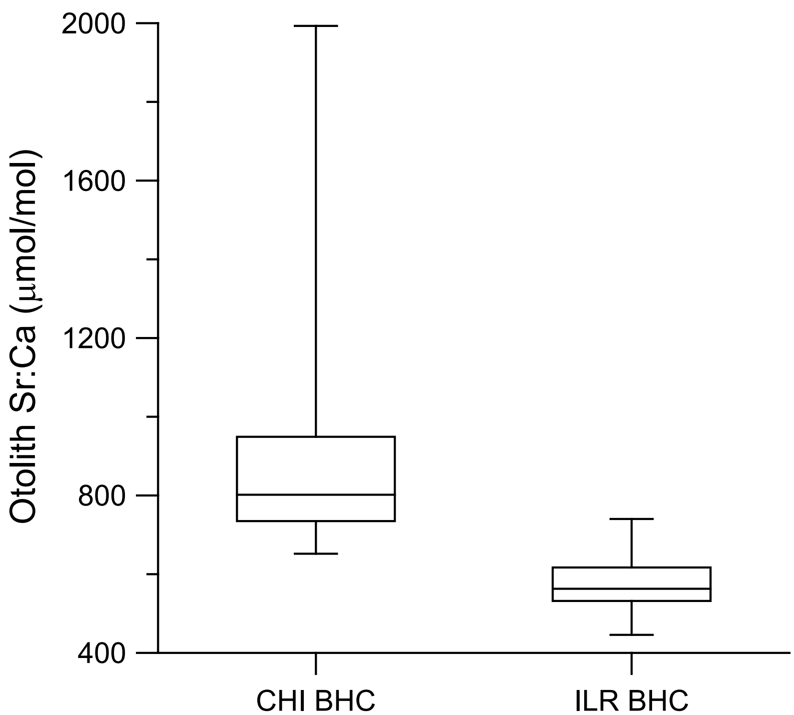

Figure 2. Boxplots of otolith core Sr:Ca for Chicago pond (N = 23) and Illinois River (N = 81) Bighead Carp.

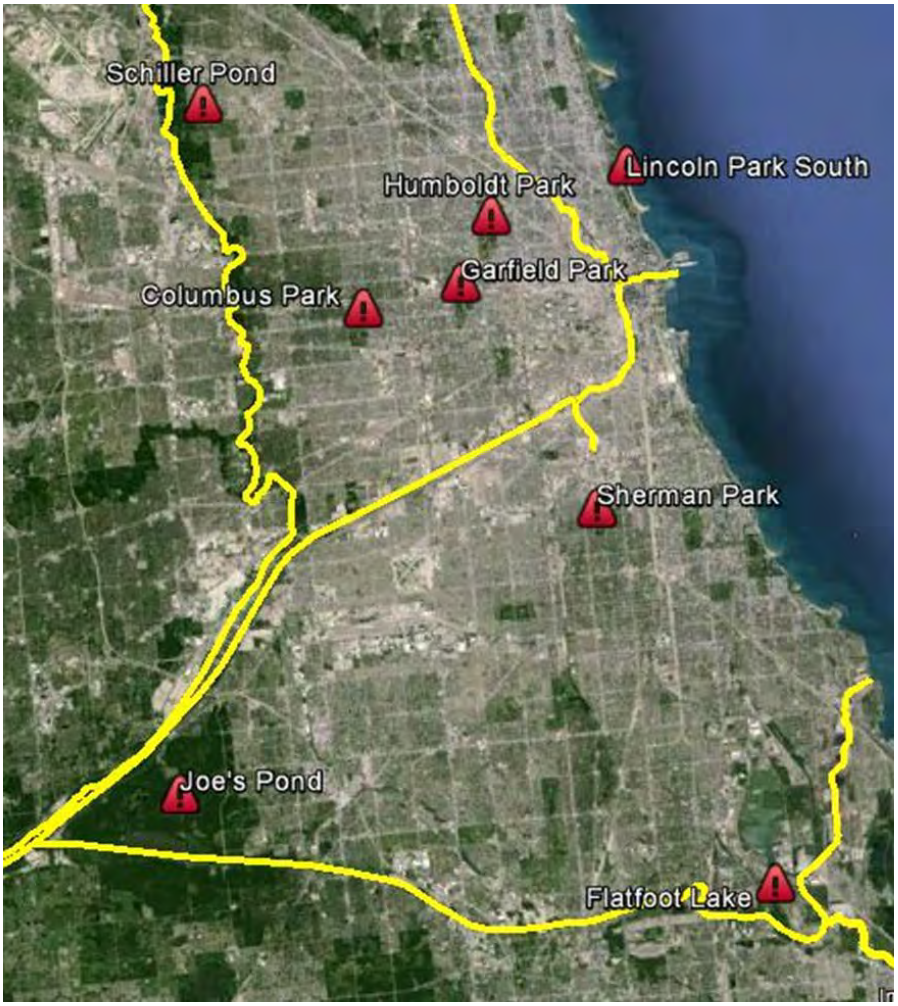

Figure 3. Map of the Chicago area fishing ponds from which Asian carp have been removed. The CAWS upstream of the Electric Dispersal Barrier is highlighted in yellow.

Project Highlights:

- Four winterkill Asian carp (two Bighead Carp, two Silver Carp) were removed from Illinois urban fishing ponds in 2014.
- Age estimation and otolith microchemistry analysis of both Bighead Carp as well as the Silver Carp from Sherman Park Lagoon will be conducted Dr. Greg Whitledge at SIUC. This will be the first analysis of a Silver Carp otolith from a Chicago area pond to date.
- 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. The remaining three ponds were visited and visually inspected.
- All eight Chicago area fishing ponds with positive Asian carp eDNA detections have been sampled with electrofishing and trammel/gill nets.

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Appendix A. Participants of the Monitoring and Response Workgroup, Including Their Roles and Affiliations.

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Appendix B. Ecosystem Responses to Barrier Defense Asian Carp Removal Project.

Ecosystem Responses to Barrier Defense Asian Carp Removal Project

ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

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Participating Agencies: Illinois Natural History Survey (lead)

Highlights:

- Since Asian carp establishment in 2000, both total zooplankton abundance and biomass have significantly decreased (Figures 1 and 2).
- Since Asian carp establishment in 2000, small bodied rotifers are consistently the most abundance type of zooplankton (Figures 3).
- Prior to Asian carp establishment in 2000, the biomass of zooplankton was fairly equally divided among all taxa but by 2014 the biomass of large bodied zooplankton taxa were significantly reduced while the biomass of small bodied rotifers was largely unaffected (Figures 3 and 4).
- Evidence to date suggests that a single reduction of Asian carp through controlled commercial fishing did not produce any significant response in zooplankton densities (figure 5). That said, samples bracketing only 1 of 4 commercial reductions been fully analyzed.

Introduction: 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 through their filter-feeding on plankton. Thus it is hoped that any reductions in Asian carp numbers should produce a corresponding increase in zooplankton density and biomass. Controlled commercial fishing reductions of Asian carp (*Hypophthalmichthys* spp.) initiated in 2010 in an attempt to reduce migration pressure on the Dispersal Barrier, thus reducing the risk of Asian carp entering 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.

Objectives: 1) Document differences in zooplankton abundance and biomass between pre- and post-Asian carp establishment

2) Evaluate the influence of commercial fishing of Asian carp on zooplankton composition and density

Methods: Plankton sampling occurred monthly during the May – October season at 18 sites throughout the Illinois Waterway (Alton, La Grange, Peoria, Starved Rock, Marseilles, Dresden reaches) from 2011-2014 and at a subset of 6 sites during 2009 and 2010 (Table 1). At each site-date combination, three vertically-integrated 55-µm 30-L sample replicates were obtained by pumping water through 55-µm mesh. In addition, samples were collected at the Hanson Material Service (HMS) pits, located in the Marseilles reach just below Morris, IL. A single 55-µm 30-L replicate was collected at 15 random sites in each service pit (east and west). Samples were collected the week before and after Asian carp removal events. Plankton sample dates for 2014 include: July 3; August 1, 14, 21, 28; September 18, 26; October 2.

Zooplankton were preserved in the field using a 12% sugar-buffered formalin solution with Rose Bengal stain added after returning to the laboratory. For microscopic analyses, these field samples were concentrated to a known volume from which a homogenized subsample (10% 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 the US EPA, 2003. Historical samples from Illinois River mile 121.1 (Havana, IL) collected using the same May – October period, field procedures, and sample volumes were also analyzed. Assessment of changes in the long-term zooplankton community composition since the establishment of Asian carp, simple t-tests tested for differences in average abundance and biomass between the pre-Asian carp (1997-2000) and (2014) samples.

Productivity for 2011-2014 was evaluated by measuring total phosphorus and chlorophyll *a*. Two replicate water samples were collected 0.5 m 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). 2014 chlorophyll a and total phosphorus analysis are currently in progress with no results to report yet.

To investigate whether Asian carp reduction through commercial fishing affected zooplankton community composition, differences in median zooplankton abundance was evaluated using a Kruskal-Wallis one way analysis of variance on ranks. Densities of each taxa as well as total density were tested among time periods before and after the removal event. The preliminary analysis was limited to samples from Hanson Material Services Pit collected in August (1, 14, 21, and 28) when the Asian carp removal occurred August 7-8.

Preliminary Results and Discussion:

Pre- vs post-Asian carp invasion zooplankton abundance and biomass

There are a statistically significant differences between pre- and post-Asian carp total zooplankton abundance and biomass (Table 2; Figures 1 and 2). When zooplankton are examined by classes, the abundance and biomass of cladocerans and both copepod adults and nauplii all declined strongly as Asian carp abundance increased (Table 2; Figures 3 and 4). While rotifer abundance also fell, the biomass of rotifers was not statistically significantly different. We can conclude that there has been a strong decline in zooplankton a decade after the Asian carp arrived, and generally that all classes of plankton, large bodied strong swimmers like copepods as well as the more numerous small-bodied rotifers, are strongly affected. However it is also worth noting that rotifer biomass was not affected. One potential but as yet unexamined explanation for this would be a shift in species dominance among the rotifers. For example, a larger, more poorly adapted rotifer may have taken advantage of the Asian carp suppression of a dominant, competing species to allow its population to expand. The net result would be no change in biomass even though the taxa do change appreciably. Because the current sampling protocol identifies rotifers to genus, completion of the remaining samples should allow us to determine if this is the case.

Zooplankton response to commercial removal of Asian carp at the Hanson Material Safety Pits

Not surprisingly zooplankton were more abundant in off channel HMSP than in the adjacent main channel of the river. There were no differences in the response over time for the most abundant zooplankton between the main channel and HMSP (total zooplankton $p=0.311$, rotifers $p=0.344$, cladocerans $p=0.067$, or copepods ($p=0.396$) (Table 3; Figures 4 and 5). These data suggest that a single commercial fishing event that removed 2.4 tons of Asian carp did not have a measurable increase in zooplankton at HMSP. However, the caveat is that there were other commercial fishing events that produced much larger yields of Asian carp. For instance, the weeks of September 5th and 12th, a total of 19.2 tons of Asian carp was removed from the HMS service pits. Analysis of the zooplankton samples surrounding this much larger reduction event may provide different results and are currently in progress.

In a previous study, increasing densities of silver carp lead to significant reductions in larger bodied plankton like cladocerans and to a lesser extent copepods, but had no effect on rotifer densities (Domaizon and Dévaux 1999). These patterns may be attributed to the lower prey escape ability of cladocerans in conjunction with longer generation times making them more susceptible to suppression by planktivory and competition (Domaizon and Dévaux 1999, Li et al. 2002). Therefore, higher rotifer concentrations coinciding with higher carp densities may be an indication of Asian carp foraging suppressing specific classes of zooplankton. Similarly, our results showed a significant decrease in macrozooplankton. However, unlike Domaizon and Dévaux (1999), our results showed a decrease in rotifer abundance, though rotifers still dominate the zooplankton community.

Next steps: More resolution on the question of ecosystem response (zooplankton, chlorophyll-a, and phosphorus) will come with the completion of the remaining 2014 samples from the main channel and from the other 3 Hanson Materials Safety pit sample dates. Because of the importance of these questions, analysis of these will be prioritized over collection of new 2015 samples. In addition, completion of the 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 during high water, reductions could occur during periods of isolation to account for immigration and emigration. Concurrent ecosystem monitoring could also be conducted at more frequent and time intervals around the removal events. *In situ* experimental enclosures or experimental ponds may also be beneficial to manipulate carp densities and initial ecosystem parameters (e.g. zooplankton, phytoplankton, 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.

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Appendix C. Investigation and Development of Novel Chemical Barriers to Deter the Movement of Asian Carp.

Investigation and Development of Novel Chemical Barriers to Deter the Movement of Asian Carp

ILLINOIS

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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. Results to date have shown that exposure of fishes to approximately 30 mg/L CO_2[1] induces a suite of stress responses, including activation of 'stress genes' and plasma ion imbalances, indicating discomfort when placed in elevated CO_2 zones. More importantly, studies from field and laboratory settings have demonstrated that both small Asian carp (2-4 inches), as well as adult Asian carp, demonstrate active avoidance of CO_2 at approximately 70-100 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 upon release. 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 2014-15 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.

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[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/guide-to-best-practices-for-ocean-acidification-research-and-data-reporting.html).

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 objective was to quantify the short- and long-term effects of elevated CO_2 on physiological (e.g., calcium, sodium, magnesium) and molecular (gene expression) variables of freshwater mussels to better understand potential consequences of using CO_2 in a natural environment.

Methods:

In fall, 2014, Wabash Pigtoe mussels (*Fusconaia flava*) were collected by benthic grab from Big Four Ditch, Paxton, IL and transported to the Aquatic Research Facility at the University of Illinois, Champaign-Urbana, IL. 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 = 16) were placed in two closed, recirculating systems each containing eight 0.71 L containers. After a 24 h acclimation period, compressed CO_2 gas was bubbled into a central basin to the target CO_2 concentration of either ~275 µatm (12 mg/L) for control conditions, ~14800 µatm (35 mg/L) or ~18200 µatm (225 mg/L) for 6 h representing CO_2 barrier levels. Mussels were either sampled directly after the 6 h CO_2 treatment (N = 8), or after an additional 6 h 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 RNAlater.

The chronic exposure study consisted of mussels (N = 16) housed in 128.7 L recirculating tank systems and exposed to either ambient (~980 µatm; 16 mg/L) or elevated (~22700 µatm; 40 mg/L) CO_2 levels for up to 32 d. Mussels were sampled at 4, 8, or 32 d after the onset of the CO_2 treatment and were processed as described above.

Tissues are currently being analyzed in the laboratory for ion concentrations (e.g., chlorine, magnesium, and calcium), glucose, and RNA:DNA ratios. Collected tissues will also be used to quantify gene expression, including heat shock protein 70 (HSP70; indicator of stress), chitinsynthase (indicator of shell growth) and carbonic anhydrase (CA; indicator of acid-base regulation). Gene expression analysis is expected to begin March 2015.

Results:

Experimental work for this study was completed in Fall 2014, and laboratory analysis of samples is underway. Preliminary results indicate physiological responses related to elevated CO_2 are likely occurring in exposed mussels. Once laboratory work has been completed and data analyzed, results and trends will be communicated through both conference presentations and peer-reviewed papers.

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, due to climate change, even over short time spans, can have negative impacts on several aspects of fish behavior (i.e., impaired ability to detect predators, 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 using CO_2 as a barrier in natural environments. To begin to understand behavioral impacts of elevated CO_2 on freshwater fish, the responses to alarm and predator cues of native fish species (Fathead Minnow and Bluegill) and Silver Carp, as well as the neurological function of Bluegill were investigated.

Methods:

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 of experimental conditions for 5-12 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 (e.g., velocity, acceleration, distance travelled) and alarm behaviors (e.g., darts and 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.

Beginning in spring 2015, further work will be completed to address potential behavioral impacts of elevated CO_2, including:

- Undertaking a similar experiment at the Upper Midwest Environmental Center (UMESC) in La Crosse, WI to assess potential impairment of alarm cue responses of Silver Carp
- Completing an experiment to whether elevated CO_2 impacts boldness, anxiety, and learning in Bluegill.

Results:

Laboratory work for this study was completed in Fall 2014, and analysis of videos is underway. Results are forthcoming and will be shared at a later date. Preliminary results indicate there are changes to the behavioral responses of Fathead Minnow following CO_2 exposure, but recovery may occur.

Objective 3: Understand the behavior of dissolved CO_2 to facilitate large-scale field deployment

Work to date with CO_2 has largely occurred in a laboratory setting using small-scale studies. Deployment of a CO_2 barrier in a field setting (e.g., river, shipping lock, backwater area, etc.) 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 level CO_2 across a range of tanks sizes, coupled with studies to define how CO_2 'behaves' in flowing water (i.e., will it sink? Will it float? Does it disperse evenly? Etc.).

Methods

Multiple sized tanks (76 L, 379 L, 1136 L (20, 100, and 300 gal) were filled with water from a 0.04 ha natural, earthen-bottom pond. Tanks were either treated with compressed CO_2, compressed CO_2 coupled with aeration, or not treated (i.e., 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.

A subsequent study is underway to define how CO_2 behaves in flowing water. For this, a ~300 gal annular tank containing flowing water will receive CO_2-rich water at various depths, and the position of the CO_2-plume within the flowing water over time will be defined.

Results:

Work for the static water study was completed in Fall 2014, and analysis of data is underway. Results are forthcoming and will be shared at a later date. Preliminary results indicate that the amount of CO_2 necessary to raise CO_2 is proportional to the volume of water. Also, CO_2 dissipates faster when tanks are aerated, even slightly. Work with flowing water is ongoing and expected to be completed by April 2015.

Objective 4: 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 will be built at the Hanson Material Services gravel mine near Morris, IL. Telemetered Silver and Bighead Carp will be used to determine how fish interact with a CO_2 barrier prototype, and if the zone is an effective barrier in this setting. Freshwater mussels will also be exposed to the barrier using stationary cages. Lastly, a 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 (e.g., pulse-pressure water guns, netting, etc.).

Methods:

This field experiment will be 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 will use 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, will be built on site and used to create an enclosed area of elevated dissolved CO_2; the size of this elevated CO_2 zone will approximate a shipping lock and/or approach channel to a shipping lock. Asian carp will be externally tagged on the dorsal musculature with an acoustic transmitter to track and monitor fish movement (3-D) at sub-meter accuracy. Tagged individuals will placed into the enclosure and allowed to acclimate for a period of time. Monitoring of movement and activity patterns will occur during a "control" period prior to CO_2 being infused. Upon completion of the control period, water flowing through the venturi system became supersaturated with CO_2 and be pumped into the enclosure through a discharge manifold. The elevated CO_2 area of the enclosure will be maintained for a period of time, and fish monitoring will continue. The CO_2 infusion system will then be turned off allowing a post-injection monitoring period. The experiment will be repeated several times.

Results:

Protocols are currently being developed for this objective and fieldwork is expected to occur June/July 2015. Once experiments are complete, data processing is required and thus results should be ready to share by December 2015.