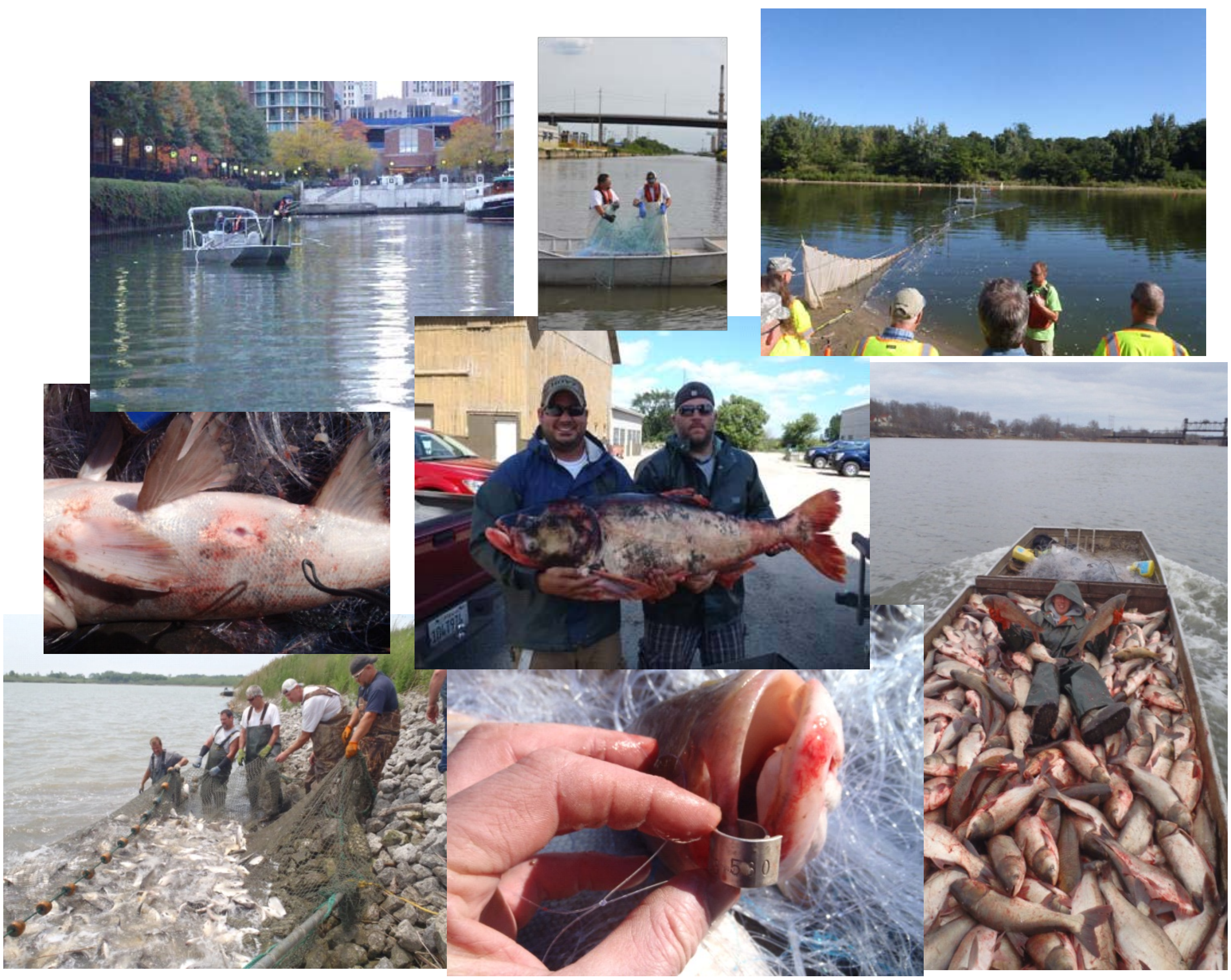
Asian Carp Regional Coordinating Committee

Monitoring and Response Workgroup

2013 Asian Carp Monitoring and Response Plan Interim Summary Reports

April 2014



ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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

ACKNOWLEDGEMENTS

This compilation of interim summary reports for projects included in the 2013 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, 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 2013 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 and J. Ziegler 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 2013. 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 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 2013 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 2013 MRP. The reports include summaries of activities completed during the 2013 and, in some cases previous results from 2010-12 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 2014 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

Fixed Site Monitoring Upstream of the Dispersal Barrier (2) **–** This project included standardized monitoring with pulsed-DC electrofishing gear and contracted commercial fishers at fixed and random sites in the CAWS upstream of the Electric Dispersal Barrier.

- Estimated over 12,030 person-hours spent sampling at fixed sites upstream of the Electric Dispersal Barrier in 2010 – 2013.
- 636.5 hours spent electrofishing and 420 km (261.1 miles) of trammel/gill net deployed at fixed sites in 2010 – 2013 and random areas in 2012 – 2013.

- Sampled 227,181 fish representing 72 species and two hybrid groups during electrofishing and trammel/gill netting at fixed sites in 2010 – 2013 and random sites in 2012 – 2013.
- 103.5 hours spent electrofishing and 153.2 km (95.2 miles) of trammel/gill net deployed at fixed sites and random areas in 2013.
- Sampled 34,418 fish representing 57 species and two hybrid groups during fixed and random electrofishing and trammel/gill netting in 2013.
- No Bighead Carp or Silver Carp captured or observed during fixed site and random area electrofishing and netting in 2013.

Strategy for eDNA Monitoring in the CAWS (11) – This project presents a strategy for bi-weekly eDNA monitoring in the CAWS upstream of the Electric Dispersal Barrier.

- Two eDNA comprehensive sampling events took place in the CAWS at four regular monitoring sites in 2013.
- June event: 18 positive detections for Silver Carp DNA, zero positive detections for Bighead Carp DNA.
- November event: 3 positive detections for Silver Carp DNA, zero positive detections for Bighead Carp DNA.
- Positive detections consistent with previous patterns of eDNA distribution in the CAWS.

Larval Fish and Productivity Monitoring (16) – Sampling for fish eggs and larvae and productivity monitoring took place biweekly from May - October 2012 at 10 sites downstream of the Electric Dispersal Barrier (LaGrange to Brandon Road pools) and 4 sites in the CAWS upstream of the barrier.

- Over 500 larval fish samples were collected from 13 sites across the length of the Illinois Waterway during May – October, 2013, capturing over 27,000 larval fish, including 344 larval Asian carp.
- Larval Asian carp were only collected in the Peoria pool in May and the LaGrange pool in June. No Asian carp larvae were observed from the upper Illinois Waterway or from Illinois River tributaries.
- Phosphorus concentrations are highest in the Des Plaines River and the lower CAWS. Chlorophyll *a* concentrations do not appear to be correlated with phosphorus concentrations, and are highest in the lower Illinois River.
- Zooplankton densities in the CAWS appear to be similar to or higher than those observed in the Illinois River, suggesting that the CAWS is capable of providing sufficient food resources for Asian carp.

Young-of-Year and Juvenile Asian Carp Monitoring (22) – 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 2013 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, and beach seine) and passive gears (small mesh gill nets, mini-fyke nets, and pound nets) in 2013.
- Completed 1,107 hours of electrofishing across all years and sites.
- Examined 102,590 Gizzard Shad <152 mm (6 in) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam and found no young Asian carp.
- Low catches of young Asian carp at all sites suggested poor recruitment years.
- Farthest upstream catch was a post larval Asian carp in the Peoria pool near Henry, Illinois (river mile 190) in 2012, over 100 downstream from the Electric Dispersal Barrier.

Distribution and Movement of Small Asian Carp in the Illinois Waterway (28) - This is a new project in 2012 that further focused on monitoring the distribution, abundance, and age structure of small Asian carp in the middle and upper Illinois Waterway using mini-fyke nets, large-frame, small-mesh fyke nets, electrofishing, and push trawls to collect fish.

- A total of 37,790 fish specimens were collected and examined. Sixty seven species and 1 hybrid combination were identified. Seven species collected were non-native exotics.
- No YOY Asian carp were collected during 2013.
- The lack of collection of YOY Asian carp suggests that little or no successful reproduction occurred upstream of the reach of river we examined during 2013. The locations where YOY Silver Carp were collected in 2012 still represent the furthest upstream documentation of YOY Asian carp in the IWW (at River Mile 194).

Fixed Site Monitoring Downstream of the Dispersal Barrier (33) **–** This project included monthly standardized monitoring with pulsed-DC electrofishing gear and contracted commercial fishers at four fixed sites downstream of the Electric 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 7696.5 person-hours spent sampling at fixed, random, and additional sites and netting locations downstream of the Electric Dispersal Barrier from 2010-2013.
- 222.5 hours spent electrofishing and 236 km (146.7 miles) of trammel/gill net deployed.
- Sampled 105,466 fish, representing 92 species and seven hybrid groups.
- No Bighead Carp or Silver Carp were captured by electrofishing or netting in Lockport and Brandon Road pools.
- Thirty Bighead Carp and two Silver Carp were collected in the Dresden Island pool during fixed, random, and additional commercial netting from 2010-2013.

- One Bighead Carp and no Silver Carp were captured at Dresden Island pool while electrofishing from 2010-2013.
- Eighteen Bighead Carp and 293 Silver Carp were captured by electrofishing in Marseilles pool from 2010-2013.
- 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 seven years.
- Asian carp spawning activity was observed on 22 May 2013 in the Marseilles pool. However, Asian carp larvae and juveniles were not detected upstream of Peoria pool or less than 161 km (100 miles) downstream of the electric barrier system and 220 km (137 miles) from Lake Michigan.

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 Electric Dispersal Barrier with conventional gear or rotenone.

- No Response actions in 2013.
- Completed three planned intensive surveillance events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier and collected eDNA samples during 2013.
- Results from "*Planned Intensive Surveillance in the CAWS*" and "*Strategy for eDNA Monitoring*" are located in their respective sections.

Planned Intensive Surveillance in the CAWS (49) – This project represents a modification to response actions in the CAWS and surveillance events will target areas that have been previously monitored through response actions. These efforts will have the benefit of advanced planning and will be in locations where the repeated detection of eDNA in previous years indicates the potential presence of Asian carp in the waterway.

- Completed three planned intensive surveillance events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier during 2013.
- Estimated 1,165 person-hours were spent to complete 45.8 hours of electrofishing, set 14.6 km (9.1 miles) of trammel/gill net and 1.1 km (0.7 miles) of deep water gill net, make three 800-yd (732 m) long commercial seine hauls, and deploy three tandem trap nets and eight hoop nets equal to 25.2 net-days of effort.
- Across all response actions and gears, sampled 22,896 fish representing 50 species and 3 hybrid groups.
- Examined 4,757 YOY Gizzard Shad and found no Asian carp YOY.
- No Bighead Carp or Silver Carp were captured or observed during response actions.

Barrier Maintenance Fish Suppression (55) – This project provides a fish suppression plan to support US Army Corps of Engineers maintenance operations at the Electric Dispersal Barrier. The plan includes fish sampling to detect juvenile or adult Asian carp presence in the Lockport pool downstream of the barrier, 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.

- Multiple agencies and stakeholders cooperated in successfully removing fish between Barrier 1 and 2A for necessary barrier fish suppression on 3 separate operations.(June 17, August 26 to 27 and November 4)
- A total of 115 fish were removed using pulsed DC-electrofishing and 9 m (30 ft) deep gill nets, with 27 fish > 305 mm (12 in) in length.
- A total of 2 hours and 20 minutes of split-beam hydroacoustics and side-scan sonar where used to assess the success of the fish clearing operation by surveying the area in and near the barrier.
- No Asian carp were captured or observed during fish suppression operations

Barrier Defense Asian Carp Removal Project (58) – 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 and assisting IDNR biologists deployed 1585 km (985 miles) of net in the upper Illinois Waterway from 2010- 2013.
- A total of 56,435 Bighead Carp, 94,071 Silver Carp, and 799 Grass Carp were removed by contracted netting. The total weight of Asian carp removed was 1006.72 tons (62.41 tons in 2010, 351.78 tons in 2011, 284.53 tons in 2012 and 308 tons in 2013).

Monitoring Asian Carp Population Metrics and Control Effort: (67) - 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.

- Although data processing is ongoing, Asian carp abundance appears to be at a low level in 2012-2013. Poor recruitment and natural mortality, perhaps coupled with harvest, contributes to this pattern.
- Continued contract harvest in the upper Illinois River (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 location of the electric defense barrier in Lockport pool.

BARRIER EFFECTIVENESS EVALUATIONS

***Telemetry Monitoring Plan (72)* –** This project uses ultrasonic transmitters implanted into Asian carp and surrogate species to assess if fish are able to challenge and/or penetrate the electric 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.

- To date, we have acquired 8.9 million detections from 315 tagged fish
- Our conclusion for testing to date from the small fish and adult fish telemetry studies is that the barriers are effectively preventing all upstream passage of tagged fish.
- Inter-pool movement of tagged fish occurs in both directions through all locks within the study area with the exception of upstream movement through the Brandon Rd lock.
- Asian carp are consistently using the Kankakee River, Hanson Material Services East Pit, and Rock Run Rookery.
- While two tagged fish have approached the Brandon Road Lock and Dam to date, it appears that the Asian carp population front is still located at river mile 281.5 near Rock Run Rookery
- Both Silver and Bighead Carp move similarly within the Illinois River
- Bighead Carp appear to be more active during the summer months
- Proportions of diel and seasonal movements are related, with the majority of the movement occurring during spring and summer as well as at night and crepuscular diel periods.

***Monitoring Fish Abundance, Behavior, and Fish-Barge Interactions at the Barrier (87)* –** 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 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.

- Of 72 10-minute DIDSON samples that were recorded, 44 of them (61%) recorded at least one school of fish breaching the barrier.
- Of the 44 samples in which a breach was recorded, 27 of them (61%) recorded multiple schools of fish breaching.
- All fish that breached the barrier did so in schools and the average sizes of the fish were 5 – 10 cm (2 – 4 in) total length as measured through the DIDSON software.
- Fish sampling within and around the zone of ultimate field strength in the Electric Dispersal Barrier revealed all Clupeidae species (Gizzard Shad, Threadfin Shad, and Skipjack Herring).
- Only 1out of 36 caged fish that were moved through the Electric Dispersal Barrier was incapacitated while inside the rake-to-box barge junction wedge.

- Several small, wild fish that were not stocked by FWS were observed being entrained beyond the Electric Dispersal Barrier within the rake-to-box junction wedge and the pocket eddy adjacent to the tow vessel.
- All barge configurations yielded some percentage of fish entrainment beyond the Electric Dispersal Barrier when loose, tethered fish were deployed either within various barge junction wedges or immediately below the barrier as the barge was approaching.
- Alternative modes of barge navigation through the Electric Dispersal Barrier were either impractical or still facilitated fish movement beyond the barrier.
- Four complete assessments of the Electric Dispersal Barrier system were performed during generator testing.
- Pre- and post-barrier switch surveys were performed on two occasions.
- On three occasions we assisted partners during rapid-response clearing events by informing crews on site of how many fish to target and how many fish were still remaining within the Electric Dispersal Barrier system.

Evaluating Asian Carp Detection Techniques with SONAR (109) - 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.

- We collected and ensonified 436 different fish and analysis is currently ongoing to determine if Asian carp can be discriminated from other fish.

Des Plaines River and Overflow Monitoring (112) **–** This project included periodic monitoring for Asian carp presence and spawning activity, in the upper Des Plaines River downstream of the Hofmann Dam. In a second component, efficacy of the Asian carp barrier fence 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 5,052 fish representing 49 species and 2 hybrid groups from 2011-2013 via electrofishing (30.5 hours) and gill netting (82 sets; 5,746 m (6,284 yd)).
- IDNR basin survey completed 17 hours of electrofishing in 2013.
- No Bighead Carp or Silver Carp have been captured or observed through all years of sampling.
- Three Grass Carp were captured in 2013. Analysis indicated all three were triploid.

GEAR EFFECTIVENESS EVALUATIONS AND DEVELOPMENT PROJECTS

Asian Carp Gear Efficiency and Detection Probability Study (117) **–** This project assessed efficiency and detection probability of gears currently used for Asian carp monitoring (e.g., pulsed-DC electrofishing, gill nets, and trammel nets) and other 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.

- Pulsed-DC electrofishing was the most effective gear for capturing Silver Carp, whereas hoop nets were the most effective gear for capturing Bighead Carp. Hybrid Asian carp were vulnerable to both electrofishing and hoop nets.
- Asian carp were most abundant in the LaGrange and Peoria pools; abundance declined at upstream sites, and no Asian carp were observed in the CAWS.
- No age-0 Asian carp were observed in 2013. Possible age-1 Asian carp (< 500 mm) were most abundant in the Peoria pool, but were relatively scarce elsewhere, suggesting populations consisting primarily of larger, older fish.
- Tributary sites were sampled with pulsed-DC electrofishing gear in the Spoon, Sangamon, Mackinaw, and Kankakee Rivers during 2013. No Asian carp were observed in the Kankakee, whereas 513 Asian carp were captured from the other three tributaries.
- Detection probabilities for Asian carp were lower at upstream sites than at downstream sites. Given the lowest estimates of detection probability for sites where Asian carp were captured, a minimum of 17 pulsed-DC electrofishing transects (15-minute duration) are necessary to achieve a 95 percent probability of capturing at least one Silver Carp, whereas a minimum of 42 hoop net-nights would be required to achieve this same cumulative detection probability for Bighead Carp. Even higher sampling efforts are likely necessary to achieve these same levels of confidence at sites with lower Asian carp abundance.

Exploratory Gear Development (126) - The goal of this project is to develop gears that will be more effective at catching all life stages of Asian carp than traditional gears. The development of these gears will consider Asian carp behavior, life history strategies, habitat types and feasibility of use. Gears will be evaluated in areas known to have low, moderate and high abundance of Asian carp populations. Gears are expected to be used for detection and monitoring of Asian carp, as well as, a tool for mass density reductions.

- Butterfly (Paupier) net electrified in 2013 allowing for capture of Asian carp ranging in size from 100 – 900mm.
- Mamou net designed and deployed in 2013 was successful at capturing small bodied fish ranging in size from 10 – 100 mm.
- Purse seine shows application for mass density removal efforts. Modifications need to be made to net to improve feasibility and effectiveness.

Unconventional Gear Development Project (130) –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.

- Large (2 m) hoop nets captured fewer fish of all taxa, and fewer Asian carp than standard (1.2 m diameter) hoop nets.

- Surface-to-bottom gill nets captured more Asian carp than traditional gill nets during 4-hour sets.
- Driving fish into surface-to-bottom gill nets with pulsed-DC electrofishing gear captured more Asian carp than drives using traditional pounding methods or control sets.
- No Asian carp were captured in pound nets at Lake Calumet in 2013. Pound nets were effective at capturing large numbers of fish, including a high proportion of Asian carp, at Materials Service Pit (Marseilles pool) and at Lilly Lake (LaGrange pool).

***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 its effects on structural components of the CAWS (e.g., canal walls and in-water equipment) and as an alternative tool to rotenone for fish suppression in support of Electric Dispersal Barrier maintenance.

- Pressure gradients around the S80 water gun(s) were mapped in three different configurations in a controlled pond and in one open water field setting.
- The maximum operating conditions of the current water gun/compressor configuration was determined to be 1,500PSI with discharge every 10 seconds.
- Behavioral responses of Asian carp and native fishes were observed with sonar and acoustic telemetry under controlled conditions. Initial results indicate fish avoid water guns during operation.
- Methods for successful implementation of water gun barriers in open water environments were demonstrated in 2013
- Incorporating water gun barrier technology into Integrated Pest Management (IPM) applications is feasible.

ALTERNATIVE PATHWAY SURVEILLANCE

***Alternate Pathway Surveillance in Illinois (158 and 162)* –** 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 Carp or Silver Carp.

Law Enforcement:

- Educational materials produced to facilitate training in invasive species enforcement.
- Active participation and leadership role in Asian carp Task Force.
- Arrest of aquatic life dealer illegally stocking and selling invasive species in Illinois.
- Plea agreements pending in court totaling over $24,000 in fines for aquatic life code violations.

- Bait dealer arrest for VHS, restricted species permits, and aquatic life dealer's license violations.
- Seizure and disposal of two shipments of illegal aquatic life.
- Discovery of illegal sale of aquatic life parts in fish markets.

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.

2013 Monitoring and Response Plan Interim Summary Reports

April 2014

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 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 latest version of the MRP was released in April 2013. 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 2013 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 Electric Dispersal Barriers 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 2013).

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 2013 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 2013 MRP. It should be viewed as a companion document to the updated 2013 MRP. Reports include summaries of activities completed during the 2013 or, for some projects; data collected beginning in 2010 and through 2012 field seasons. Also included are highlights of past activities and recommended updates to monitoring and removal actions that will be considered for the 2014 MRP. Most are interim reports with data summaries, analyses, and interpretations that are preliminary in nature but still offer a scientific basis for 2013 project updates and field activities. Results and conclusions may change as more data is collected and analyses are refined over time.

INTERIM PROJECT REPORTS

Fixed and Random Monitoring Upstream of the Electric Dispersal Barrier

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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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: Frequent and 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 invasion and informs management decisions and actions to reduce the risk of population establishment. Detections of Asian carp eDNA upstream of the Electric Dispersal Barrier during 2009 initiated the development of a monitoring plan using electrofishing and contracted commercial fishers to sample for Asian carp at five fixed sites upstream of the Electric Dispersal Barrier. Reach electrofishing sampling (performed in 2010 and 2011) was replaced with random area electrofishing and netting in 2012. Sampling results from 2010 – 2013 contributed to our understanding of Asian carp population abundance in the CAWS providing guidance for future monitoring and control efforts to prevent the spread of Asian carp.

Objectives: Standardized pulsed-DC electrofishing and contracted commercial netters will be used to:

1) Monitor for the presence of Asian carp in the CAWS upstream of the Electric Dispersal Barrier;

2) Determine relative abundance of Asian car**3** | P a g e p in locations and habitats where they are likely to congregate;
3) Determine Asian carp distribution in the CAWS; 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.

Materials and Methods: Sampling included intensive electrofishing and netting at five fixed sites where we anticipate catching Asian carp if they are present in the waterway, and at four random areas. Electrofishing took place monthly during March through December, and netting took place monthly during March and December and twice monthly April through November. To maximize the potential usefulness of netting and electrofishing, particularly given the apparent low densities of Asian carp in the generally deep-water habitat of the CAWS, stations were located in areas where the likelihood of capture is the greatest (i.e. where eDNA has been detected, below migration barriers, or both). The five fixed sites are located at the upstream-most areas of the CAWS near Lake Michigan. These areas were identified for intensive sampling under the assumption that Asian carp upstream of the Electric Dispersal Barrier would swim upstream and congregate below the next existing barriers, namely the T.J. O'Brien and Chicago Locks and the Wilmette Pumping Station. Habitat and collection conditions were taken into consideration in the selection of the locations and boundaries of the fixed sites. For a description of fixed sites and effort for each site see Fixed and Random Site Monitoring Upstream of the Electric Dispersal Barrier in the 2013 Monitoring and Rapid Response Plan (MRRP).

The entire CAWS upstream of the Electric Dispersal Barrier has been divided into four random sampling areas that were sampled one time per month with pulsed-DC electrofishing gear and two times per month with commercial trammel/gill nets. Random area sampling excluded areas of the waterway designated as fixed sites to avoid redundancy, as those areas were sampled by electrofishing and netting monthly during fixed site monitoring. Random sites were generated with GIS software from shape files of designated random areas and were labeled with Lat-Lon coordinates in decimal degrees. A list of random sites was generated for the entire year for each random area and assigned for each sample day. Sampled sites were eliminated from the list to prevent duplicate sampling. For a description of random areas and effort for each area see Fixed and Random Site Monitoring Upstream of the Electric Dispersal Barrier in the 2013 MRRP.

Electrofishing Protocol – All electrofishing used pulsed-DC current and included 1-2 dip netters. Locations for each electrofishing transect for both fixed sites and random sites were identified with GPS coordinates. Electrofishing transects 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. Fixed site sampling locations remained the same throughout the year and were sampled with each site visit. The only exception was during low water when some fixed site sampling locations could not be reached by boat; sampling was completed as close to the fixed sites as possible. Random site coordinates were randomly generated, as described above. Electrofishing boat operators were allowed to switch the safety pedal on and off at times to prevent pushing fish in front of the boat and increasing the chances 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. Young-of-year Gizzard Shad were examined closely for the presence of Asian carp and then counted.

Netting Protocol – Contracted commercial fishers were used for net sampling at the fixed and random sites. The nets used were large mesh 76-102 mm (3-4 in) trammel or gill nets 2.4-4.2 m (3-4 ft) tall, and in lengths of 183 m (200 yd). Random site coordinates were randomly generated as described above. Net sets took place within 457 m (500 yd) of a designated coordinate at a specific location agreed upon by the commercial fisher and attending IDNR biologist/technician. Net sets were of short duration and included driving fish into the nets with noise (i.e., "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 sets with "pounding" no further than 137 m (150 yd) from the net. Captured fish were identified to species and recorded on data sheets.

Results and Discussion: Crews logged over 12,030 person-hours of effort while electrofishing and netting fixed sites upstream of the Electric Dispersal Barrier during 2010 – 2013. Since 2010, approximately 542.5 hours of electrofishing was completed and 311.7 km (193.7 miles) of trammel/gill net was deployed in fixed sites. In 2013, a total of 34,418 fish representing 57 species (plus hybrid sunfish and Common Carp x Goldfish hybrids) were collected in 103.5 hours of electrofishing and 153 km (95.1 miles) of net during fixed and random site sampling (Table 1). Fixed site and random area sampling accounted for an estimated 2,430 person-hours in 2013. Monitoring efforts were high in the CAWS compared to other river monitoring programs. For example, a total of 103.5 hours were spent electrofishing at fixed sites and random areas in the CAWS during 2013 vs. approximately 50 hours of electrofishing annually in a similar length of the lower Illinois Waterway (LaGrange pool) sampled as part of the Long Term River Monitoring Program (LTRMP; Kevin Irons, personal communication). The extensive sampling effort in the CAWS was instituted by design because little was known about the abundance and distribution of Asian carp or other species upstream of the Electric Dispersal Barrier when the initial monitoring plan was developed. The work group initiated high sampling efforts to maximize the chances of capturing any Asian carp that might be present in the CAWS. The consensus was that sampling effort might be reduced in the future if supported by sound monitoring data and an increased understanding of Asian carp population demographics. A reduction in fixed site electrofishing sampling transects from 844 in 2011 to 537 in 2012, and the shift from reach sampling to random sampling in 2012 were the first examples of such reductions in effort. Scheduled fixed and random electrofishing weeks were also reduced from 18 in 2012 to 10 in 2013

Fixed Site Electrofishing – A total of 25,619 fish representing 49 species (and two hybrid groups) were sampled during 67.5 hours (270 transects) of electrofishing at fixed sites in 2013 (Table 1). Total catch and species richness was lower than previous years (33,689 fish of 51 species in 2010; 52,339 fish of 58 species in 2011; 73,596 fish of 60 species in 2012). However, effort was much less than previous years (130 hours, 519 transects in 2010; 211 hours, 844 transects in 2011; 135 hours, 537 transects in 2012). The total catch-per-unit-effort (CPUE) in 2013 (379.5 fish/hour) was down from 2012 (547 fish/hour), yet still higher than 2010 (259 fish/hour) and 2011 (248 fish/hour). Fixed Site 2 (Little Calumet River) had the highest total catch (10,615 fish), species richness (33 species), and catch per unit effort (CPUE; 590 fish/hour) among fixed sites in 2013 (Table 2). Seven fish species comprised just over 90% of the total abundance of fixed site electrofishing samples in 2013. Gizzard Shad was the most abundant species, followed by Bluegill, Common Carp, Bluntnose Minnow, Largemouth Bass, Pumpkinseed, and Spotfin Shiner. Gizzard Shad was the most abundant species across all three years of fixed site electrofishing, comprising 41-62% of the total catch per year. No Bighead Carp or Silver Carp have been captured or observed to date during fixed site electrofishing in the CAWS. In addition, we examined a total of 9,676 Gizzard Shad <152 mm (6 in) from fixed sites in 2013 and detected no Asian carp YOY.

Random Area Electrofishing – In 2012 reach monitoring upstream of the Electric Dispersal Barrier was replaced with random area monitoring. While the adopted randomized sampling protocol required fewer total electrofishing transects in one year than reach monitoring, it increased the frequency of sampling. A total of 6,407 fish representing 42 species (and one hybrid group) were sampled during 36 hours of electrofishing (144 transects) at random areas in 2013 (Table 1). This is down from 22,623 fish (51 species, and two hybrid groups) sampled during 57 hours of electrofishing (228 transects) at random areas in 2012. Total CPUE in 2013 (178.0 fish/hour) was down from 2012 (397 fish/hour) as well. Reach electrofishing produced a total of 2,734 fish of 33 species (and two hybrid groups) during 78 hours (244 transects) in 2010 and a total of 2,383 fish of 35 species (and one hybrid group) during 88 hours (348 transects) in 2011. CPUE was less for reach electrofishing (35 and 27 fish/hour in 2010 and 2011, respectively) than random electrofishing (397 and 178 fish/hour in 2012 and 2013, respectively). Though 220 fewer electrofishing transects were performed at random areas in 2012-2013, 23,913 more fish were collected than at reach sites in 2010-2011. Random Area 2 (Little Calumet River/Cal-Sag Channel) had the greatest total catch (2,019 fish) and CPUE (224 fish/hour) and Random Area 1 (Calumet Connecting Channel/ Calumet River) had the highest total species richness (29 species) among random areas in 2013 (Table 2). Seven fish species comprised over 90% of the total abundance of random area electrofishing samples in 2013. Gizzard Shad was the most abundant species, followed by Common Carp, Bluntnose Minnow, Bluegill, Pumpkinseed, Largemouth Bass, and Spotfin Shiner. Gizzard Shad was the most abundant species in the 2012-2013 random sampling as well as the 2010-2011 reach sampling, comprising 41-56% of the total catches per year. No Bighead Carp or Silver Carp were captured or observed during random site electrofishing in the CAWS. In addition, crews examined a total of 1,463 Gizzard Shad < 152 mm (6 in) from random sites in 2013 and detected no Asian carp YOY.

Fixed Site Netting – A total of 1,568 fish representing 20 species (and one hybrid group) were sampled in 88 km (54.7 miles) of net (481 sets) at fixed sites in 2013 (Table 1). Total catch was less than previous years (2,439 fish, 5,062 fish, and 1,856 fish in 2010, 2011, 2012, respectively), though species richness was greater than or equal to previous years (17 species, 19 species, and 20 species in 2010, 2011, and 2012, respectively). Effort was higher than 2010 (38.3 km (23.8 miles) of net in 208 sets) though more net was fished in fewer sets in 2011 (97.2 km (60.4 miles) of net in 352 sets) and 2012 (88.8 km (55.2 miles) of net in 467 sets). CPUE has decreased yearly from 5.8 fish/91 m (100 yd) of net in 2010, 4.8 fish/91 m (100 yd) of net in 2011, 1.9 fish/91 m (100 yd) of net in 2012 to 1.6 fish/91 m (100 yd) of net in 2013 (Table 1). Fixed Site 1 (Lake Calumet) had the highest total catch (1,035 fish), CPUE (2.9 fish/91 m (100 yd) of net), and species richness (14 species) among fixed sites in 2013 (Table 3). The four most common fish species captured in 2013, which comprised over 93% of the total abundance of fixed site netting samples in 2013, were Common Carp, Freshwater Drum, Gizzard Shad, and Black Buffalo. Common Carp were the most abundant species across all four years of fixed site netting, comprising 50-76% of total catches per year. No Bighead Carp or Silver Carp were observed or collected in fixed site net sampling upstream of the Electric Dispersal Barrier in 2013.

Random Area Netting – In addition to random area electrofishing, random area netting also began in 2012. A total of 824 fish representing 11 species (and one hybrid group) were collected in 65.1 km (40.5 miles) of net (356 sets; Table 1). CPUE for all random areas combined was lower in 2013 (1.2 fish/91 m (100 yd of net)) than 2012 (2.5 fish/91 m (100 yd) of net; Table 1). Random Area 3 (Chicago River/South Branch/CSSC) had the greatest total catch (428 fish) and CPUE (1.9 fish/hour) among random areas in 2013 (Table 3). Species richness was highest in Random Area 1 with 7 species total (Table 3). Common Carp was the most abundant species, making up over 93% of the total catch among random areas in 2013, followed by Freshwater Drum at 2.7% of the total catch. No Bighead Carp or Silver Carp were captured or observed during random area netting in the CAWS in 2013.

Recommendations: As a result of the extensive sampling with conventional gears to date, we conclude that if there are any live Bighead Carp or Silver Carp in the CAWS upstream of the Electric Dispersal Barrier, they are likely present in low numbers. This conclusion and the need to further investigate the leading edge of the Asian carp population, suggest that the sample size for fixed sites and random areas may be reduced during the 2014 sampling season. Expanded Planned Intensive Surveillance events will take the place of monthly fixed site/random area monitoring, reducing the frequency of sampling upstream of the Electric Dispersal Barrier (See Planned Intensive Surveillance in the CAWS, below). This reduction in effort upstream of the Electric Dispersal Barrier would provide an opportunity to further increase sampling downstream of the Electric Dispersal Barrier (See Fixed Site Monitoring Downstream of the Electric Dispersal Barrier, below). The increase in sampling downstream of the Electric Dispersal Barrier will help to better focus efforts on the leading edge of the Asian carp population. Furthermore, better understanding of Asian carp populations downstream of the Electric Dispersal Barrier should prove to be valuable for reducing their numbers, thus mitigating the risk of individuals moving upstream to Lake Michigan in the event of a failure at the Electric Dispersal Barrier.

Project Highlights:

- Estimated over 12,030 person-hours spent sampling at fixed sites upstream of the Electric Dispersal Barrier in 2010 – 2013.
- 636.5 hours spent electrofishing and 420.2 km (261.1 miles) of trammel/gill net deployed at fixed sites in 2010 – 2013 and random areas in 2012 – 2013.
- Sampled 227,181 fish representing 72 species and two hybrid groups during electrofishing and trammel/gill netting at fixed sites in 2010 – 2013 and random sites in 2012 – 2013.

- 103.5 hours spent electrofishing and 153.2 km (95.2 miles) of trammel/gill net deployed at fixed sites and random areas in 2013.
- Sampled 34,418 fish representing 57 species and two hybrid groups during fixed and random electrofishing and trammel/gill netting in 2013.
- No Bighead Carp or Silver Carp captured or observed during fixed site and random area electrofishing and netting in 2013.
- Based on the extensive sampling performed upstream of the Electric Dispersal Barrier, and the need for more sampling downstream of the Electric Dispersal Barrier we recommend that expanded Planned Intensive Surveys replace monthly fixed site/random area monitoring thus reducing the frequency of electrofishing and netting upstream of the Electric Dispersal Barrier, and increasing sampling downstream of the Electric Dispersal Barrier

Table 1. Electrofishing and netting efforts and catch summaries for 2013 fixed site and random area sampling upstream of the Electric Dispersal Barrier.

	Fixed Sites	Random Areas	
	2013	2013	
Electrofishing Effort	(Mar-Dec)	(Mar-Dec)	Total
Estimated person-days			108
Estimated person-hours			810
Samples (Transects)	270	144	414
Electrofishing hours	67.5	36.0	103.5
Electrofishing Catch			
All Fish (N)	25,619	6,407	32,026
Species (N)	49	42	55
Hybrids (N)	2	1	2
Bighead Carp (N)	0	0	0
Silver Carp (N)	0	0	0
CPUE (fish/hr)	379.5	178.0	309.4
	Fixed Sites	Random Areas	
	2013	2013	
Netting Effort	(Mar-Dec)	(Mar-Dec)	Total
Estimated person-days			216
Estimated person-hours			1,620
Samples (net sets)	481	356	837
Total miles of net	54.7	40.5	95.1
Netting Catch			
All Fish (N)	1,568	824	2,392
Species (N)	20	11	21
Hybrids (N)	1	1	1
Bighead Carp (N)	0	0	0
Silver Carp (N)	0	0	0
CPUE (fish/100 yards of net)	1.6	1.2	1.4

Table 2. Numbers of fish sampled with pulsed-DC electrofishing in fixed sites and random areas of the CAWS upstream of the Electric Dispersal Barrier in 2013. (*) Common Carp were counted by observation.

Species	Fixed Site 1	Fixed Site 2	Fixed Site 3	Fixed Site 4	Fixed Site 5	Random Area 1	Random Area 2	Random Area 3	Random Area 4	Total
Gizzard Shad	2,511	7,517	2,825	2,220	813	143	1,113	578	1,143	18,863
Common Carp*	418	699	181	74	159	26	488	581	275	2,901
Bluegill	71	238	953	347	691	8	47	162	74	2,591
Bluntnose Minnow	115	413	254	123	157	41	167	286	85	1,641
Pumpkinseed	82	465	245	20	111	31	17	166	16	1,153
Largemouth Bass	272	367	87	54	183	86	47	12	25	1,133
Spotfin Shiner	16	82	147	135	132	12		34	123	681
Golden Shiner	2	70	122	59	180	1	7	16	41	498
Emerald Shiner	25	180	21	20	26	6	20	10	9	317
Brook Silverside	65	166	1			36			1	269
Alewife	145			2	110	3				260
Banded Killifish	59	143	1	1	1	8	3			216
Green Sunfish	3	67	46	8	14	3	30	14	21	206
Yellow Bullhead	1	45	29	11	1		2	24	10	123
White Sucker		8	2	54	37		1	1	16	119
Yellow Perch	101	6	1			5				113
Mosquitofish				1				91		92
Channel Catfish	14	17	26	7	5	2	10	4	2	87
Rock Bass	29				1	45				75
Smallmouth Bass	37	7			3	27				74
Black Bullhead	20	37	1	6	3				4	71
Goldfish		32	17	4	9	1	2		2	67
Round Goby	9	9	2			18	22			60
Freshwater Drum	14	9	1			8	19		1	52
White Bass	38	8	2			2				50
Smallmouth Buffalo	37					9				46
White Perch	28	2	4		4				4	42
Oriental Weatherfish		4	20		1			5	1	31
Black Crappie	1		2	11	8				6	28
Spottail Shiner		6	1	2	13	1				23
Blackstripe Topminnow				6	10				1	17
Fathead Minnow		1	3	1	2	1	5	1	2	16
Creek Chub		8					5			13
Common Carp x Goldfish hybrid	1	1	1	1	1		3		1	9
Hybrid Sunfish	2		3	4						9
Yellow Bass							9			9
Bigmouth Buffalo	5					3				8
Chinook Salmon	8									8
River Carpsucker		1	2	5						8
White Crappie		1			6					7
Black Buffalo						5				5
Northern Pike				1					4	5
Warmouth		1			2		1	1		5
Brown Bullhead		1	1		1					3
Coho Salmon	1		1		1					3
Orangespotted Sunfish	2	1								3

Table 2. Continued.

Species	Fixed Site 1	Fixed Site 2	Fixed Site 3	Fixed Site 4	Fixed Site 5	Random Area 1	Random Area 2	Random Area 3	Random Area 4	Total
Burbot			2							2
Highfin Carpsucker						2				2
Largescale Stoneroller		2								2
River Shiner			2							2
Bowfin				1						1
Brown Trout						1				1
Flathead Catfish	1									1
Johnny Darter							1			1
Quillback					1					1
Rainbow Trout						1				1
Silver Arowana				1						1
Unidentified Salmonid		1								1
Total Caught	4,133	10,615	5,006	3,179	2,686	535	2,019	1,986	1,867	32,026
Species	30	33	31	26	30	29	21	17	23	55
Hybrid Groups	2	1	2	2	1	0	1	0	1	2

Table 3. Numbers of fish sampled with trammel nets and gill nets in fixed sites and random areas of the CAWS upstream of the Electric Dispersal Barrier in 2013.

Species	Fixed Site 1	Fixed Site 2	Fixed Site 3	Fixed Site 4	Fixed Site 5	Random Area 1	Random Area 2	Random Area 3	Random Area 4	Total
Common Carp	455	303	167	5	21	29	110	421	208	1,719
Freshwater Drum	291	1				21	1			314
Gizzard Shad	152	1	2							155
Black Buffalo	63	1				3				67
Channel Catfish	17	1	2	2					2	24
Goldfish	1	5	5					4	9	24
Quillback	20									20
Bigmouth Buffalo	10					3				13
Common Carp x Goldfish hybrid		1	1	1	4			2	2	11
Smallmouth Buffalo	8	1						1		10
Chinook Salmon	1	3				4				8
Brown Trout	6					1				7
Unidentified *Ictiobus sp.*	5									5
Smallmouth Bass	3									3
White Bass	2									2
Yellow Bullhead			1						1	2
Black Crappie					1					1
Brown Bullhead		1								1
Grass Carp			1							1
Lake Trout						2				2
Pumpkinseed		1								1
White Perch	1									1
White Sucker				1						1
Total Caught	1,035	319	179	9	26	63	111	428	222	2,392
Species	14	10	6	3	2	7	2	3	4	21
Hybrid Groups	0	1	1	1	1	0	0	1	1	1

Strategy for eDNA Monitoring in the CAWS

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Participating Agencies: US Army Corps of Engineers, US Fish and Wildlife Service – Carterville, Columbia, and La Crosse Fish and Wildlife Conservation Offices, Whitney Genetics Lab, 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 2013
- June event: 18 positive detections for Silver Carp DNA, zero positive detections for Bighead Carp DNA
- November event: 3 positive detections for Silver Carp DNA, zero positive detections for Bighead Carp DNA
- Positive detections consistent with previous patterns of eDNA distribution in the CAWS

Introduction and Objectives

As outlined in the 2013 Monitoring and Response Plan, eDNA as a surveillance tool was used to monitor for the genetic presence of Bighead Carp and Silver Carp as a complementary monitoring tool in the CAWS. However, in 2013 these data were not used as a trigger for response actions. Rather, the prescribed objectives of eDNA sampling were to:

1) Determine whether Asian carp DNA is present 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 Chicago Area Waterway System (CAWS) was sampled for eDNA of Bighead Carp and Silver Carp twice in 2013 (June and November sampling events). The reduced frequency of sampling (compared to previous years) is consistent with the removal of the use of data as a trigger for response action, yet retains the overall surveillance data for vigilance in the system. Similar to previous years, sample collection and processing followed the Quality Assurance Project Plan (http://www.fws.gov/midwest/fisheries/eDNA/QAPP-2013.pdf). FWS crews collected 120 samples in four reaches of the CAWS, and samples were filtered in a new mobile filtering trailer. Samples were preserved on dry ice until they were shipped overnight to the FWS Whitney Genetics Lab for analysis. Results were posted on the internet after sample processing was complete.

Locations - Comprehensive sampling in the CAWS occurred in June and November 2013. The fall sampling event was delayed until November due to the Federal Government shutdown that occurred for 16 days during October. Sample locations and numbers per site were as follows: North Shore Channel (June and Nov: 60 samples); South Branch Chicago River to the Chicago Lock (June: 60 samples, Nov: 20 samples due to CSO event); Little Calumet River downstream of O'Brien Lock (June and Nov: 60 samples); Lake Calumet (June and Nov: 60 samples).

Results and Discussion

A total of 417 along with 23 control samples were collected and analyzed upstream of the Electric Dispersal Barriers (Table 1). The June event (Table 2, Figure 1) had 18 positive detections for Silver Carp and the November event (Table 3, Figure 2) had three positive detections for Silver Carp. There were no positive detections for Bighead Carp during either event. All eDNA results are available at:
http://www.fws.gov/midwest/fisheries/eDNA/Results-chicago-area.html

Laboratory quality assurance/quality control

During the June sampling event, there was one cooler blank from the Little Calumet River that tested positive for Silver Carp (Table 1), so any other positive detections in samples from that cooler were discarded (1). However, the other two coolers from the Little Calumet River had clean cooler controls and confirmed positive samples.

Based on these results and the continuity of sample collection in the CAWS since 2009, it is recommended that the CAWS continue to be monitored with eDNA during 2014.

Table 1. Summary table for all samples collected during two eDNA monitoring events in the CAWS at four sites above the electric barrier. Fewer samples were collected in the Chicago River due to a sanitary overflow event during the November event.

Location	Samples collected	Silver Carp		Bighead Carp	
		Negative	Positive	Negative	Positive
North Shore Channel	114 (120*)	107	7	114	0
Chicago River	76 (80*)	75	1	76	0
Lake Calumet	114 (120*)	107	7	114	0
Little Calumet River	113** (120*)	107	6**	113	0
TOTAL	417 (440*)	396	21	417	0

*Cooler blanks (field controls) included in number of samples collected
**Samples that failed positive controls discarded

Table 2. Summary table for samples collected during June eDNA monitoring event in the CAWS at four sites above the electric barrier. Samples collected June 18-19, 2013, Results reported on September 18, 2013.

Location	Samples collected	Silver Carp		Bighead Carp	
		Negative	Positive	Negative	Positive
North Shore Channel	57 (60*)	51	6	57	0
Chicago River	57 (60*)	56	1	57	0
Lake Calumet	57 (60*)	51	6	57	0
Little Calumet River	56** (60*)	51	5**	56	0
TOTAL	227 (240*)	209	18	227	0

*Cooler blanks (field controls) included in number of samples collected
**Samples that failed positive controls discarded

Table 3. Summary table for samples collected during November eDNA monitoring event in the CAWS at four sites above the electric barrier. Samples collected November 5-7, 2013, Results reported on December 3, 2013. Only 20 samples were collected in the Chicago River due to a sanitary overflow event.

Location	Samples collected	Silver Carp		Bighead Carp	
		Negative	Positive	Negative	Positive
North Shore Channel	57 (60*)	56	1	57	0
Chicago River	19 (20*)	19	0	19	0
Lake Calumet	57 (60*)	56	1	57	0
Little Calumet River	57 (60*)	56	1	57	0
TOTAL	190 (200*)	187	3	190	0

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

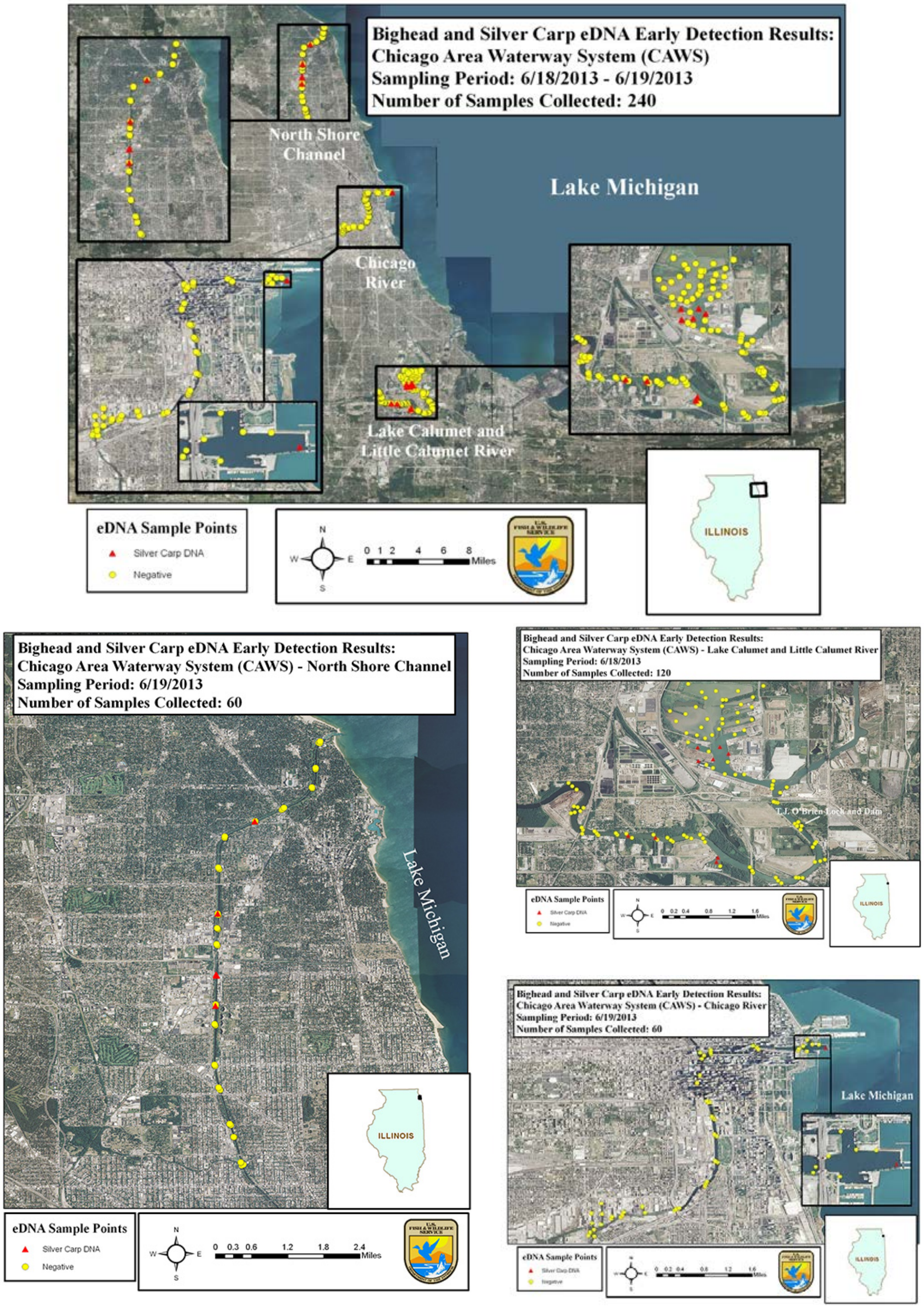

Figure 1. Geo-referenced sampling locations within each of four reaches of the CAWS during June 2013. Only positive and negative results are indicated for Silver Carp eDNA because all samples were negative for Bighead Carp.

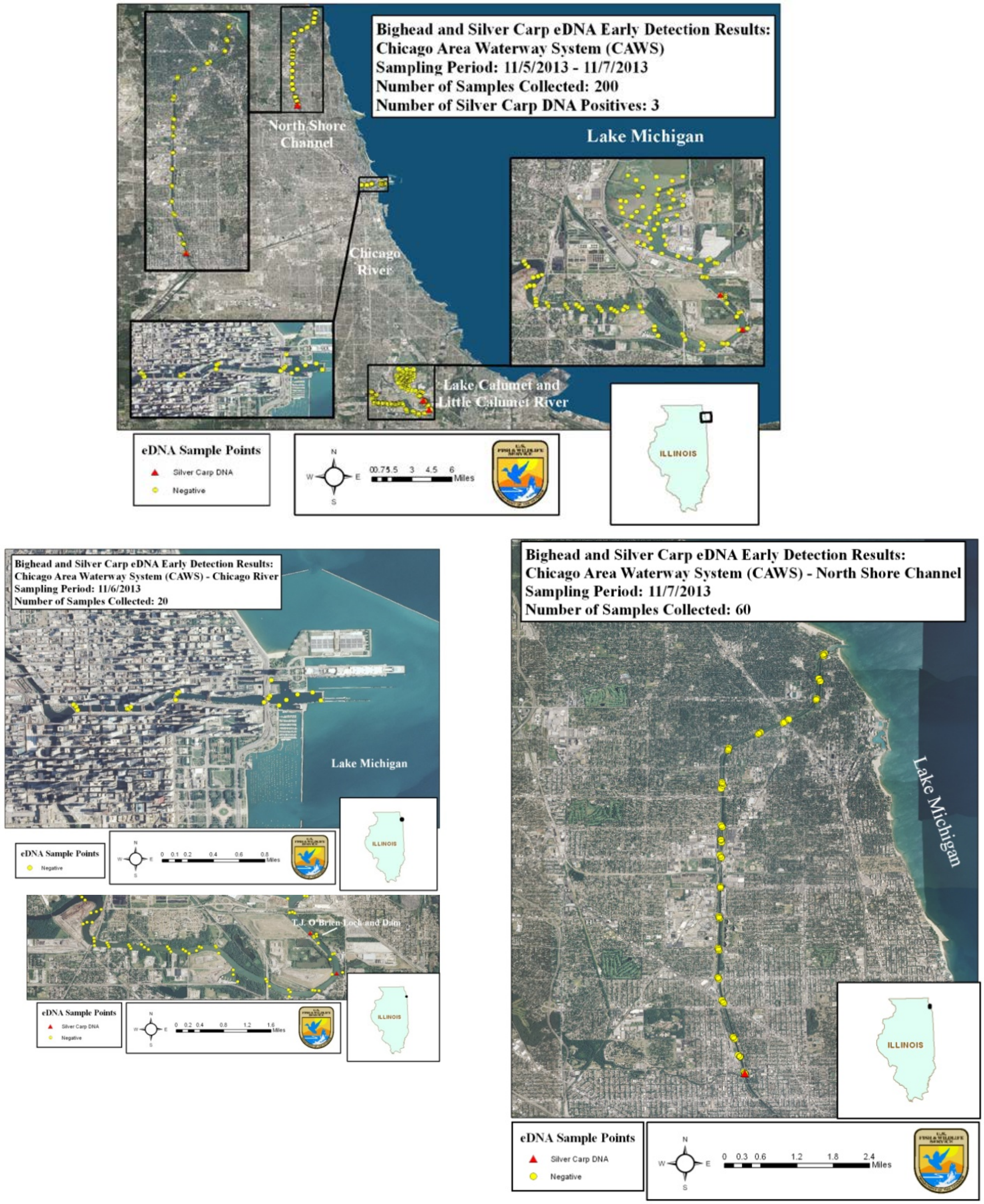

Figure 2. Geo-referenced sampling locations within each of four reaches of the CAWS during November 2013. Only positive and negative results are indicated for Silver Carp eDNA because all samples were negative for Bighead Carp.

Larval Fish and Productivity Monitoring

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

Asian carp are filter-feeding planktivores that have the ability to deplete plankton densities and alter zooplankton community composition. Because Asian carp require sufficient food resources to optimize feeding and maximize their growth, identifying patterns in nutrient concentrations, chlorophyll *a* concentrations, and zooplankton abundance may indicate sites where Asian carp are most likely to be located. This information will also be useful for examining relationships among nutrients, phytoplankton, zooplankton, and the abundances of Asian carp and other planktivorous fishes throughout the Illinois Waterway.

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.

Productivity variables are being measured to:

1.) Identify high-productivity areas where Asian carp may be more likely to be located;
2.) Determine relationships between productivity variables and the abundance of Asian carp and other planktivorous fishes; and
3.) Examine relationships among nutrients, phytoplankton, and zooplankton density in the Illinois Waterway.

Methods: Larval fish and productivity sampling is occurring at 14 sites throughout the Illinois Waterway (Figure 1). Sampling is occurring at approximately bi-weekly intervals from May to October. 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. Additional sampling was conducted in four tributaries of the Illinois River (Spoon, Sangamon, Mackinaw, and Kankakee rivers) in 2013, with a site near the confluence with the Illinois River and an upstream site near the first impoundment on each river sampled monthly from June to October. Samples are collected using a 0.5 m-diameter ichthyoplankton push net with 500um mesh. 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.

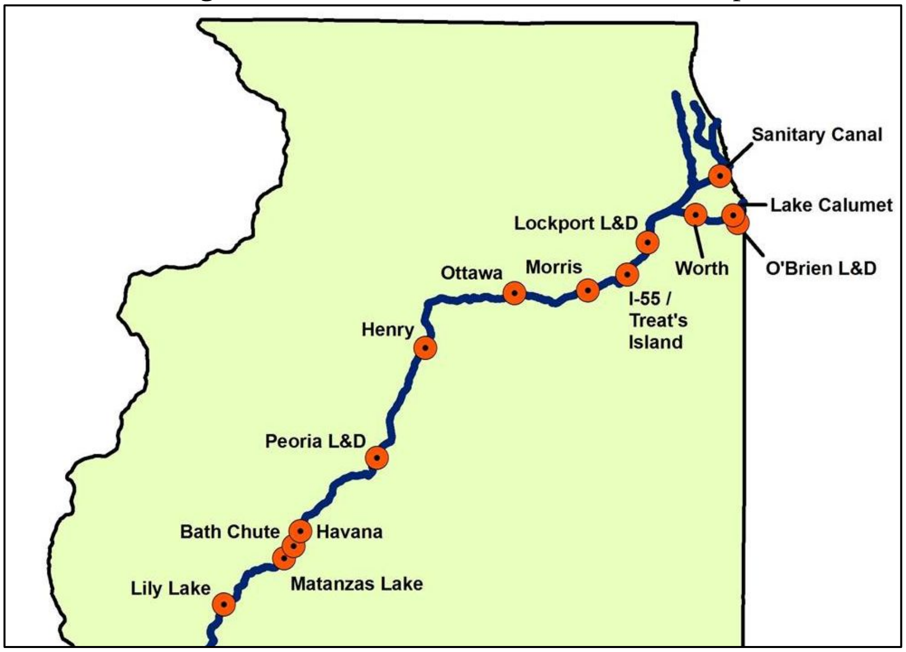

Figure 1. Map of larval fish and productivity sampling sites in the Illinois Waterway.

Productivity patterns are being evaluated by measuring total phosphorus and chlorophyll *a* concentrations, as well as zooplankton abundance. Water samples are collected at upstream and downstream locations at each site using a vertically-integrated tube sampler. Chlorophyll *a* concentrations are estimated fluorometrically following acetone extraction, whereas total phosphorus concentrations are determined by measuring sample absorbance with a spectrophotom after an acid molybdate extraction. Zooplankton are being collected by obtaining vertically-integrated water samples obtained using a diaphragmatic pump. At each location, 90 L of water is filtered through a 55 μm mesh to obtain crustacean zooplankton, whereas 10 L of water is filtered through a 20 μm mesh to obtain rotifers. Organisms are transferred to sample jars and preserved in Lugols solution (4%). In the laboratory, individual organisms are being identified to the lowest possible taxonomic unit, counted, and measured using a digitizing pad. Zooplankton densities are being calculated as the number of individuals per liter of water sampled.

Results and Discussion: In 2013, over 500 larval fish samples were collected from April 30 to October 9, capturing over 27,000 larval fish. Larval fish densities were highest in June, but declined substantially from August to October (Figure 2). As in previous years, Clupeids dominated the ichthyoplankton drift at most sites, although Cyprinid larvae (excluding Asian carp) were abundant in the Starved Rock and Marseilles pools (Figure 3). Centrarchid larvae, primarily *Lepomis* species, were common in and upstream of the Starved Rock pool. Lesser numbers of Catostomids, Sciaenids, Moronids, Percids, Ictalurids, and Atherinids were also captured in larval fish samples. Larval Asian carp (n = 344) were collected from Henry (Peoria pool; river km 306) in May, and from multiple sites in the LaGrange pool (river km 134 – 251) during June. No evidence of Asian carp reproduction was observed at any upstream pools, and no Asian carp eggs or larvae were collected in the CAWS. No larval Asian carp were captured in the Illinois River tributaries during 2013. The numbers of Asian carp larvae captured in the lower Illinois River are similar to those collected in 2012, and are substantially higher than numbers collected in 2010 and 2011. During 2010 and 2011, Asian carp were only found at a single site on a single sampling date. During both 2012 and 2013, Asian carp larvae were present at multiple sites across a several-week period, suggesting that conditions in the Illinois River were more conducive to reproduction during the past two years than in previous years. However, despite these higher numbers of larvae, recruitment to the juvenile stage appears to have been poor again in 2013 (see Young-of-Year and Juvenile Asian carp Monitoring summary), suggesting that larval or juvenile survival rates were very low. Consistently low recruitment of Asian carp in the Illinois River over the past several years, combined with evidence that reproduction appears to be limited to the lower Illinois River may indicate that Asian carp populations in upstream reaches are composed largely of immigrants from downstream rather than from local sources. However, the origin of Asian carp eggs and larvae is uncertain. Eggs and larvae may have drifted considerable distances before being sampled and additional investigation to determine where Asian carp spawning is occurring is warranted.

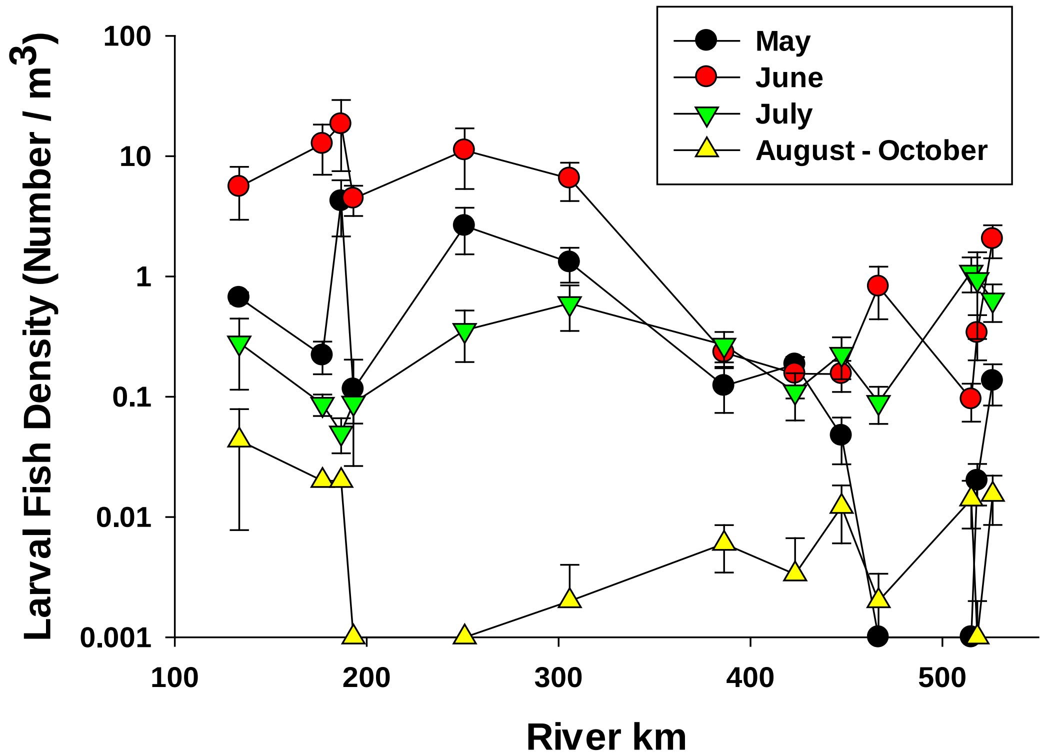

Figure 2. Monthly mean (± SD) densities of larval fish (all taxa) in the Illinois Waterway during 2013. River km is measured as distance upstream from the Mississippi River. Note the logarithmic scale on the y-axis.

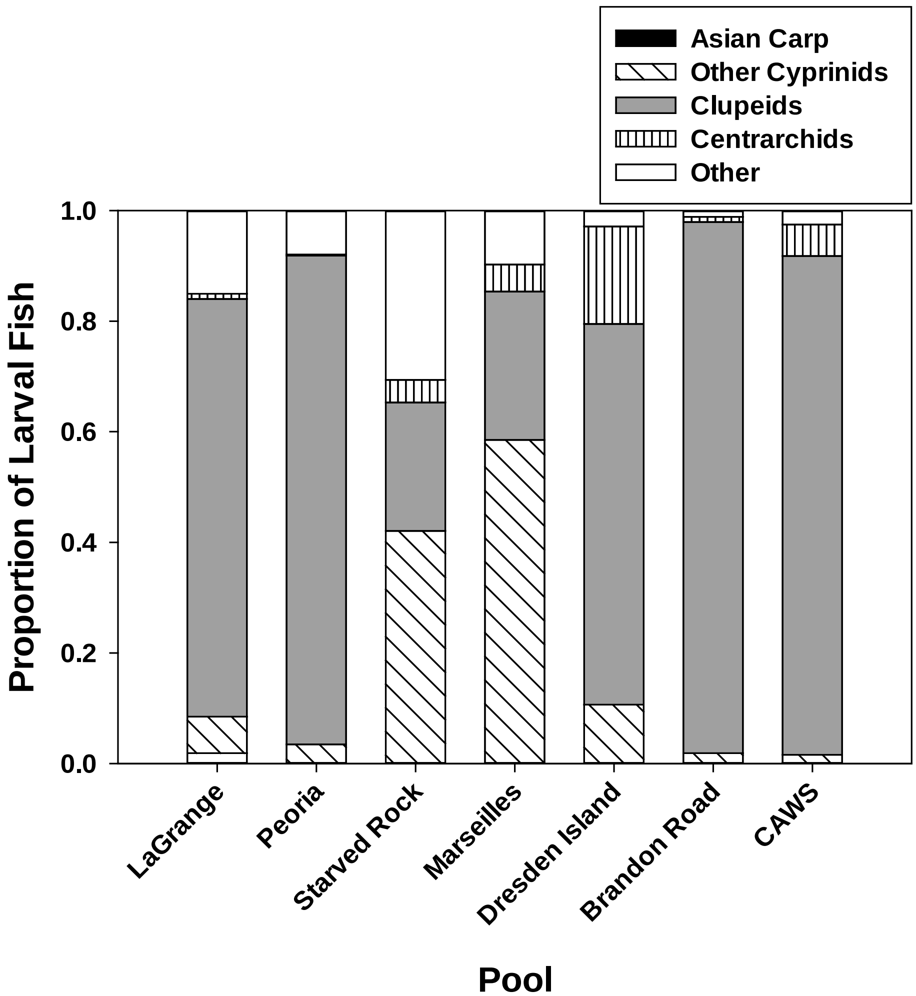

Figure 3. Taxonomic composition of larval fish captured in ichthyoplankton samples in each navigation pool of the Illinois Waterway during 2013.

Productivity sampling coincided with larval fish sampling during 2013, and sample processing from 2013 is ongoing. Analysis of previous years' data reveals that total phosphorus concentrations increase with increasing distance upriver, and are highest in the Des Plaines River and in the lower CAWS, but phosphorus concentrations decline to their lowest observed levels at sites closest to Lake Michigan. Phosphorus and chlorophyll concentrations do not appear to be correlated, with the highest chlorophyll concentrations occurring in the lower Illinois River. This lack of correlations indicates that other factors (e.g., water residence time, depth, turbidity, other limiting nutrients, etc.) are contributing to observed patterns in chlorophyll concentrations. High chlorophyll concentrations may make the lower Illinois River particularly well suited to Silver Carp, which are capable of filtering phytoplankton.

Cladoceran and copepod densities vary little among sites in the Illinois River, but increase in abundance in the Des Plaines River and are highest in the CAWS. Mean densities of dreissenid veligers appear to be relatively low in the Illinois River, but increase substantially in the Des Plaines River and in the CAWS. Densities of all macrozooplankton groups are highest in the

Little Calumet River and in Lake Calumet. Rotifer densities are highest in the lower Illinois River and decline with increasing distance upriver, but attain high densities in Lake Calumet. The upper Illinois Waterway, and the CAWS in particular, appear to offer abundant food resources for planktivorous fishes, suggesting that they would provide a favorable foraging environment for Asian carp if they were to become established there. Food resources do not appear to be limiting the expansion of Asian carp into this region. The particularly high densities of all zooplankton groups in the Little Calumet River and Lake Calumet may indicate that these locations would be the most likely areas to support Asian carp within the CAWS.

Recommendations: Larval fish sampling should continue in future years in order to monitor for Asian carp reproduction. The continued poor recruitment of Asian carp in the Illinois River suggests that recent environmental conditions have not been conducive for Asian carp reproduction or larval/juvenile survival. Larval and juvenile fish sampling across both low and 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, Spoon, Mackinaw, and Kankakee rivers) is also warranted to examine the potential for these systems to serve as sources for Asian carp populations in the Illinois Waterway, and to evaluate the potential for similar rivers in the Great Lakes region to serve as spawning tributaries. An 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.
Continued productivity sampling will allow for a more thorough analysis of patterns in potential Asian carp food resources. Data from 2013 is still being analyzed and will provide additional information for assessing spatial and temporal patterns in productivity variables. Future analyses should examine relationships among productivity variables and the abundance and condition of Asian carp and other planktivorous fishes. Examining seasonal changes in productivity variables will allow for evaluation of how Asian carp food resources change throughout the yearly cycle. Examining differences between main channel and backwater sites will offer insight into Asian carp habitat selection and the potential for different habitats to serve as nursery areas.

Project Highlights:

- Over 500 larval fish samples were collected from 13 sites across the length of the Illinois Waterway during May – October, 2013, capturing over 27,000 larval fish, including 344 larval Asian carp.
- Larval Asian carp were only collected in the Peoria pool in May, and the LaGrange pool in June. No Asian carp larvae were observed from the upper Illinois Waterway or from Illinois River tributaries.
- Phosphorus concentrations are highest in the Des Plaines River and the lower CAWS. Chlorophyll *a* concentrations do not appear to be correlated with phosphorus concentrations, and are highest in the lower Illinois River.
- Zooplankton densities in the CAWS appear to be similar to or higher than those observed in the Illinois River, suggesting that the CAWS is capable of providing sufficient food resources for Asian carp.

Young-of-year and Juvenile Asian Carp Monitoring

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and
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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: We will use multiple gears suitable for sampling small fish 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, 2013 sampling for young-of-year and juvenile Asian carp will take place through other projects of the MRRP. Young fish were targeted in the following projects: Larval Fish and Productivity Monitoring, Fixed and Random Site Monitoring Upstream of the Dispersal Barrier, Fixed Site Monitoring Downstream of the Dispersal Barrier, Gear Efficiency and Detection Probability Study, Planned Intensive Surveillance (PIS) in the CAWS, Des Plaines River and Overflow Monitoring Project, and Barrier Maintenance Fish Suppression Project. See individual project summary reports and the 2013 MRRP for specific locations of sampling stations.

Pulsed-DC electrofishing was the principal gear used to monitor for young Asian carp. Fixed site monitoring in the CAWS upstream of the barrier occurred ever month from March-December in 2013 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. Forty-five hours of electrofishing was completed over three PIS events in June and October of 2013. Electrofishing at fixed sites downstream of the Electric Dispersal Barrier occurred monthly from March-November in 2013 at four sites in each of the Lockport, Brandon Road, Dresden Island, and Marseilles pools (16 15-minute transects per month). Random site monitoring occurred in all four pools as well, for a total of 16 15-minute electrofishing runs per month. Finally, three barrier maintenance fish suppression events occurred in the Lockport pool in June, August and November 2013. Electrofishing for these events totaled 5.75 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 pulsed DC-electrofishing, small fish were targeted with mini-fyke nets, small mesh gill nets, and beach seine in the gear efficiency study. Each site visit included 4 x 4-hour gill net sets, 8 mini-fyke net-nights and 3-4 beach seine hauls for the gear efficiency study. Also for this study, Marseilles pool was sampled 46 net-nights with pound nets, LaGrange pool was sampled with 8 net-nights with pound nets, and Peoria pool was sampled with 3 hauls of a purse seine (see Gear Efficiency Report).

Results and Discussion: Young Asian carp were targeted with six gears in 2010, eight gears in 2011, ten gears in 2012 and 6 gears in 2013. Sampling included active gears, (electrofishing, purse seining, and beach seining and passive gears) and passive gears, (small mesh gill nets, pound nets and mini-fyke nets). Small mesh gill nets accounted for the highest effort with 352 hours combined for Illinois River, Upper Des Plaines River and CAWS in 2013(Table 3). The second highest effort was mini-fyke nets with 144 net-nights and beach seine with 96 hauls (Table 3). Pulsed DC electrofishing in all pools accounted for 37 hours of sampling (Table 3). Sampling effort was highest in the CAWS upstream of the Electric Dispersal Barrier and lowest in the upper Des Plaines River between Hofmann Dam and the CSSC-Des Plaines River confluence (Table 3).

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 the past four years. Overall, we examined 102,590 Gizzard Shad <152 mm (6 in) long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam from 2010 to 2013 and found no young Asian carp.

Recommendations: We used multiple gears coordinated throughout several projects to monitor for young Asian carp in the CAWS, Des Plaines River, and Illinois River from 2010-2013. We found no Asian carp juveniles upstream of Starved Rock Lock and Dam and only low numbers downstream of the 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 2013 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, and beach seine) and passive gears (small mesh gill nets, mini-fyke nets, and pound nets) in 2013.
- Completed 1,107 hours of electrofishing across all years and sites.
- Examined 102,590 Gizzard Shad <152 mm (6 in)long in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam and found no young Asian carp.
- Low catches of young Asian carp at all sites suggested poor recruitment years.
- Farthest upstream catch was a post larval Asian carp in the Peoria pool near Henry, Illinois (river mile 190) in 2012, over 100 downstream from the Electric Dispersal Barrier.
- Recommend continued monitoring for young Asian carp, and a new project to enhance understanding of young Asian carp distribution and habitat selection.

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

Distribution and Movement of Small Asian Carp in the Illinois Waterway

Jeff Stewart, US Fish and Wildlife Service

Participating Agencies: USFWS Carterville Fish and Wildlife Conservation Office (lead).

Introduction: The Bigheaded Carps, herein referred to as Asian carp, include the introduced exotic Silver Carp (*Hypophthalmichthys molitrix)* and Bighead Carp (*H. nobilis).* Populations of these two 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 Asian carp spreading to previously uncolonized areas as "high" and assigned this rating a "very certain" degree of certainty. Asian carp are 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.

At present a system of electric fish barriers 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 Electric Dispersal Barrier are sufficient to stop large bodied Silver Carp from passing through (Holliman 2009). However, more 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 these reasons there exists concern that small sized Asian carp, if present, would 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 Illinois River Waterway (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 and recruitment 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 (age 0 to age 2) Asian carp occur in the Illinois Waterway (IWW) through intensive, directed fish sampling which targeted these life stages. This study was complimentary to other MRRP efforts to sample small Asian carp and unique because of the shallow water, off channel habitats that were sampled. For the purposes of this study, fish specimens less than 300mm total length were considered "small fish" based on previously published estimates of age 1 and age 2 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, pulsed-DC electrofishing, and an experimental boat mounted push-trawl. 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). The experimental push-trawl developed by USFWS has been shown to effectively capture juvenile Asian carp under 50 mm total length in the Missouri River system (Wyatt Doyle USFWS per.com.).

Objectives:

1) Determine the relative distribution, abundance, and age structure of small Asian carp in the middle and upper Illinois River Waterway.
2) Determine the movements of small Asian carp in the middle and upper Illinois River Waterway.
3) Combine distribution, abundance, and movement data to characterize the risk that small Asian carp pose to the Great Lakes via the Chicago Area Waterway System.

Methods: Nets used were Wisconsin style mini-fyke nets and large-frame, small-mesh fyke nets which were set and fished overnight. Fyke nets were set as shoreline sets and as tandem sets in open water areas. Electrofishing consisted of 15 minute daytime pulsed-DC boat electrofishing runs made with a Midwest Lakes Electrofishing System Infinity control box. Push-trawl samples were made with a bow mounted skate-balloon trawl net of 4 mm mesh, 1.8 m body length, 0.76x0.38 m otter boards, 2.4 m rope, and an effective net fishing width 1.8 m across. Trawl hauls were between 25 and 100 m in length and varied with the amount of fishable habitat present at a given location.

Sample sites were selected within side channels and contiguous backwater habitats for each pool. Sites were selected within habitats at the discretion of the field crew. We outfitted a sampling boat with a surface drive outboard motor in order to access and sample very shallow backwater areas. This shallow water boat allows us to access areas which are too shallow for traditional fisheries boats to navigate.

All fish collected were identified to the lowest possible taxonomic level, enumerated, and most live native fish were released. Some collections of very small bodied fishes were preserved and returned to the laboratory for identification and enumeration. Voucher specimens of small Asian carp, other exotic species and incidentally taken state listed threatened and endangered species will be deposited into the fish collection at Southern Illinois University at Carbondale.

Physical and chemical habitat measurements were made at each collection site. Habitat measurements were recorded at the time of each net retrieval, electrofishing run, and push trawl run. Physical measurements included: depth, Secchi depth, and substrate composition (i.e., mud, sand, silt, vegetation, gravel). Water quality measurements taken with an YSI Professional Series multi-m included: temperature, salinity, specific conductance, dissolved oxygen, and pH. Sampling occurred within selected pools of the IWW (Peoria, Starved Rock, Marseilles, and Dresden Island). Push-trawl sampling was completed during June. Electrofishing and netting was completed from June through October.

During the course of fish sampling, all equipment necessary to implant fish with ultrasonic transmitters was maintained in a ready state with the field crew. If small Asian carp of sufficient health and weight were encountered they would be surgically implanted with ultrasonic transmitters (Vemco, Model V7-4L; 69 kHz, 7 mm diameter, 22.5 mm long) for remote individual identification and released at the point of capture.

Results and Discussion: Between the dates of 10 June and 24 October a total of 211 sites distributed among the Peoria, Starved Rock, Marseilles, and Dresden Island pools of the IWW were sampled for small fishes. Samples included 67 - 15 minute electrofishing runs (16.75 hours of shocking time); 65 experimental push trawl runs; 69 net nights of mini-fyke nets, and 31 net nights with large frame, small meshed fyke nets. All sites sampled in 2013 were in contiguous backwaters and side channels. Isolated backwaters were scheduled to be sampled but were not due to the federal furlough which occurred during the period of time scheduled for isolated backwater sampling.

A total of 37,790 fish specimens were collected and examined. Sixty-seven species and 1 hybrid combination were identified. Seven species collected were non-native exotics but no young-of-the-year (YOY) Asian carp were collected from these pools during 2013. Due to the lack of appropriate sized small Asian carp specimens, telemetry was not possible within these pools targeted during the 2013 field season.

The absence of collection of YOY Silver Carp suggests that at little or no reproduction occurred upstream of the reach of river we examined during of 2013. The two YOY specimens collected at River Mile 194 during 2012 still represent the farthest upstream documented occurrence of YOY Silver Carp in the IWW (total lengths of 16 mm, and 19 mm).

Numerically dominant taxa collected are presented in Table 1 and represent 94% of the total catch. State threatened and endangered fish species captured included the threatened Banded Killifish (N=19); and the endangered Blacknose Shiner (N=14). Of 37,790 specimens collected, over half (20,742 – 55%) were YOY specimens. All four gears employed proved effective and complimentary and helped to collect a comprehensive sample of the fish communities of the four pools studied. Mini-fyke nets and push-trawl gears were especially effective for collection of YOY fish.

Taxon	Total	% of total catch
Ictiobinae YOY	13,481	35
Silver Carp* (*Hypophthalmichthys molitrix*)	7,554	20
Clupeidae YOY	5,504	14
Spotfin Shiner (*Cyprinella spiloptera*)	2,664	7
Bluegill (*Lepomis macrochirus*)	1,740	5
Gizzard Shad (*Dorosoma cepedianum*)	1,162	3
Bullhead Minnow (*Pimephales vigilax*)	1,134	3
Emerald Shiner (*Notropis atherinoides*)	1,111	3
Spottail Shiner (*Notropis hudsonius*)	603	2
***Morone* sp. YOY**	511	1
Total	35,463	94

Table 1. Top 10 numerically dominant taxa collected in 2013.

During the course of the sampling season Asian carp of the desired size range were not captured in the four pools targeted. For this reason we moved downstream and collected Juvenile Silver Carp at Spunky Bottoms (Emiquon Preserve). We surgically implanted them with Vemco V7 ultrasonic transmitters, and released into the Illinois River at approximately River Mile 74 (in the open river below LaGrange Lock and Dam). Twenty putative Silver Carp (total lengths ranged from 191-282 mm) were surgically implanted with ultrasonic transmitters on 17 September. During an initial attempt to track them on 22 September, six of the twenty fish were located by mobile tracking. All six were located within 11.2 river km (7 river miles) downstream of their point of release. None of the 20 tagged fish were detected upstream of the LaGrange Lock and Dam. Due to a lapse in federal appropriations, mobile tracking was interrupted during the month of October. Because the transmitters used in 2013 had a relatively short battery life and this interruption occurred during the prime time to track those fish, little can be said about their movements. An additional attempt to locate these fish was made on 31 October and 1 November and two were located but were apparently dead not having moved from their earlier position. At least two other transmitters were detected but their signal was too weak for the receiver to lock onto, precluding identification of those tags.

Recommendations: Continued vigilance with respect to small bodied Asian carp in the IWW is recommended. We feel from our data that similar sampling type and effort will capture small Asian carp if they are present in the study area during better spawning conditions. Continued monitoring of the uppermost YOY and juvenile Asian carp limits in the IWW is needed and should provide valuable knowledge about the source pool(s) for juvenile Asian carp in the middle and upper IWW. Expansion of the use of mini-fyke nets and push-trawl gears is recommended as these two methods target small bodied fishes effectively.

Further study of small Asian carp life history, particularly in this area, is needed including the investigation of the role of tributary streams to the recruitment of juvenile Asian carp to the IWW. It is possible that these tributary streams (e.g. the Kankakee River) could be a source of Asian carp spawning that may contribute YOY fish to the Dresden Island pool; these may have the ability to swim upstream, presenting a potential risk to the Electric Dispersal Barrier system.

Telemetry of age one and age two Asian carp (big enough to effectively receive ultrasonic transmitter implantation and survive) should be conducted to determine movements of juvenile fish which may have the ability to swim upstream and pose a risk to the Electric Dispersal Barrier.

Project Highlights:

- A total of 37,790 fish specimens were collected and examined. Sixty seven species and 1 hybrid combination were identified. Seven species collected were non-native exotics.
- No YOY Asian carp were collected during 2013.
- The lack of collection of YOY Asian carp suggests that little or no successful reproduction occurred upstream of the reach of river we examined during 2013. The locations where YOY Silver Carp were collected in 2012 still represent the furthest upstream documentation of YOY Asian carp in the IWW (at River Mile 194).

Fixed Site Monitoring Downstream of the Dispersal Barrier

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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 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 2013 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 Barrier system.

Objectives: Standardized sampling with conventional gears were 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 2013, randomly generated sites were sampled with electrofishing and commercial netting in each of the four pools.

Electrofishing Protocol – Fixed and random electrofishing samples in 2013 occurred bi-weekly 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 2013, commercial netting took place bi-weekly from March through December in all four pools. We conducted net sampling at random locations downstream of the Electric Dispersal Barrier in 2013 to better monitor Asian Carp abundance and distribution in pools below the Electric Dispersal Barrier. Contracted commercial fishers were used for net sampling at all fixed 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 100 or 200 yd (91 and 183 m). An IDNR biologist or technician was assigned to each commercial net boat to monitor operations, record data, and check for telemetry 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). 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 137 m (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 2013 field season. In 2013, nets were deployed at four fixed sites within each of the target pools, once per month, starting in May 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 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) 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 fish were identified and enumerated. All captured Asian carp were exterminated.

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 (0.125 in) in diameter and was nylon coated with green dip. A 5 m (15 ft) long, by 0.6 m (2 ft) high lead was connected to the cab. When fully extended the cab was 3.0 m (100 ft) long, making the entire net 7.62 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). Captured fish were identified and enumerated.

Results and Discussion: *Electrofishing Effort and Catch* – An estimated 2,552.5 person-hours were expended completing 222.5 hours of electrofishing at fixed and random sites downstream of the Electric Dispersal Barrier from 2010-2013. Electrofishing captured 71,930 fish representing 90 species, and seven hybrid groups (Table 2). Gizzard Shad, Bluegill, Emerald Shiner, Common Carp, Largemouth Bass, Bluntnose Minnow, Threadfin Shad, Smallmouth Buffalo, Green Sunfish, Spotfin Shiner, Pumpkinseed, and Bullhead Minnow accounted for over 90% percent of the total catch in 2013.

Fixed site electrofishing catch-per-unit-effort (CPUE) in 2013 (CPUE = 359 fish / hour) decreased from 2012 (CPUE = 466.5 fish / hour), and was still lower than 2011 (CPUE = 384.4 fish / hour) (Table 1). Greater electrofishing CPUE in 2012 might be linked to lower river stages. Random site electrofishing was added to the monitoring plan in 2013 and had a lower (CPUE = 109.7 fish / hour) than fixed site electrofishing (CPUE = 359 fish / hour) (Table 1). Fixed sites were chosen based on habitats likely preferred by Asian carp, while many of the random electrofishing sites were located on main-channel borders and yielded lower catches. No Bighead Carp or Silver Carp were sampled by electrofishing in Lockport or Brandon Road pools in any year, and one Bighead Carp and no Silver Carp were captured at Dresden Island pool fixed sites. In contrast, 17 Bighead Carp and 279 Silver Carp were sampled by electrofishing at fixed sites in Marseilles pool from 2010-2013. In 2013, a total of 7,040 Gizzard Shad ≤ 152 mm (6 in) were examined at fixed and random electrofishing sites downstream of the Electric Dispersal Barrier system and detected no Asian carp YOY.

Gill and Trammel Netting Effort and Catch – An estimated 3,869 person-hours were expended setting and running 236 km (146.7 miles) of net at fixed and random sites and additional netting locations downstream of the Electric Dispersal Barrier from 2010-2013. Netting caught 6,023 fish representing 29 species (Table 3). Common Carp, Smallmouth Buffalo, Bighead Carp, Silver Carp, Bigmouth Buffalo, and Channel Catfish accounted for 92.0% of the total catch in 2013.

No Bighead Carp or Silver Carp were caught by netting in the Lockport or Brandon Road pools. Catches of Bighead Carp and Silver Carp at fixed and random sampling sites increased downstream of the Brandon Road Lock and Dam. Five Bighead Carp and two Silver Carp were collected in the Dresden Island pool during fixed and random commercial netting in 2013. Net catches of Bighead Carp in the Marseilles pool in 2013 (N = 58) were less than catches in 2012 (N = 105). Silver Carp were captured at both fixed sites (N = 125) and random sites (N = 6) in the Marseilles pool in 2013. Fixed site netting CPUE decreased from 2011 (CPUE = 4.80 fish / 91 m (100 yd) of net) to 2012 (CPUE = 1.87 fish / 91 m (100 yd of net) and reached the lowest CPUE by 2013 (CPUE = 0.014 fish /91 m (100 yd) of net) (Table 1).

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 2012-2013 an estimated 1,275 person hours were expended setting and running 172 hoop nets and 112 mini-fyke nets for 344 and 180 net nights, respectively. Hoop netting captured 249 fish, representing 11 species from

2012-2013 (Table 4). Mini-fyke netting captured 27, 275 fish, representing 53 species and 5 hybrid groups from 2012-2013 (Table 5).

In 2013, 249 fish from 11 species (Table 4) were collected in hoop nets. Catches from 2012 were lower by fish count (*N* = 88) and species diversity (*N* = 8). However, sampling in 2012 did not begin until August, and there were fewer samples in 2012 (*N* = 64) compared to 2013 (*N* = 108). Common Carp, Channel Catfish, Silver Carp, Smallmouth Buffalo, Black Buffalo, and Bighead Carp accounted for over 90% of the 2013 hoop net catches. No Asian carp were captured in hoop nets in the Lockport or Brandon Road pools in 2012 or 2013. In 2013, one Silver Carp and one Bighead Carp were captured in the Dresden Island pool. A total of 29 Silver Carp and eight Bighead Carp were captured in hoop nets in the Marseilles pool from 2012-2013.

Mini-fyke nets captured 7,367 fish, representing 46 species and five hybrid groups (Table 5). Bluegill, Bluntnose Minnow, Spotfin Shiner, Pumpkinseed, Mosquitofish, Green Sunfish, and Orangespotted Sunfish accounted for nearly 90% of the 2013 mini-fyke net catches. No YOY or adult Bighead Carp or Silver Carp were captured in mini-fyke nets in any pool during 2012 or 2013.

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 Carp 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 about 76 km (47 miles) from Lake Michigan (Chicago Harbor = river mile 327). The USACE first identified a small population of Bighead Carp in Dresden Island pool near Moose Island in 2006 (river mile 276; Kelly Baerwaldt, personal communication). For reasons unknown, the detectable population front has made little upstream progress in the past six years.

The Marseilles pool (river mile 245-272) contained moderately abundant populations of both Bighead Carp 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 running ripe in Marseilles pool during 2010 through 2012. Spawning activity was observed on 22 May 2013 by B. Ruebush and J. Zeigler at River Mile 269.5 in the Marseilles pool. To reduce propagule pressure on the Electric Dispersal Barrier, located just 39 km (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 2010-2012. 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.

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 recommend continued and increased monitoring of Asian carp populations at fixed sites downstream of the Electric Dispersal Barrier with electrofishing gear, hoop and mini-fyke netting, and contracted commercial fishers. We propose to continue hoop and mini-fyke netting in 2014. 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. Shifting more sampling efforts from the CAWS to the Upper Illinois Waterway will provide more information about the detectable population front. We recommend continuing fixed site electrofishing below the Electric Dispersal Barrier on a bi-weekly schedule as well as conducting random electrofishing twice per month. We also propose to continue fixed and random contracted commercial netting in the downstream pools (Dresden Island and Marseilles) while shifting sampling efforts from the CAWS to Lockport and Brandon Road pools. Increased sampling in the Lockport and Brandon Road Pools will further provide information on habitat preferences of other fishes in areas where Asian carp have not been detected. Netting efforts in all four pools, outside of barrier defense, will increase removal efforts in the Upper Illinois Waterway and reduce propagule pressure on Lake Michigan.

Project Highlights:

- Estimated 7696.5 person-hours spent sampling at fixed, random, and additional sites and netting locations downstream of the Electric Dispersal Barrier from 2010-2013.
- 222.5 hours spent electrofishing and 236 km (146.7 miles) of trammel/gill net deployed.
- Sampled 105,477 fish, representing 92 species and seven hybrid groups.
- No Bighead Carp or Silver Carp were captured by electrofishing or netting in Lockport and Brandon Road pools.
- Thirty Bighead Carp and two Silver Carp were collected in the Dresden Island pool during fixed, random, and additional commercial netting from 2010-2013.
- One Bighead Carp and no Silver Carp were captured at Dresden Island Pool while electrofishing from 2010-2013.
- 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 seven years.
- Asian carp spawning activity was observed on 22 May 2013 in the Marseilles pool. However, Asian carp larvae and juveniles were not detected upstream of Peoria pool or less than 161 km (100 miles) downstream of the electric barrier system and 220 km (137 miles) from Lake Michigan.
- Recommend continued and increased sampling in the upper Illinois Waterway with electrofishing, hoop netting, mini-fyke netting, and gill and trammel netting. Propose to shift sampling efforts from the CAWS towards an increase in commercial fixed and random netting below the Electric Dispersal Barrier in the Lockport and Brandon Road pools.

Table 1. Fixed and random electrofishing, fixed and random gill and trammel netting, hoop netting, and minnow fyke netting efforts and catch summaries for 2013 sample sites below the Electric Dispersal Barrier.

Fixed Electrofishing Effort - 2013

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	18 Mar - 19 Nov		18 Mar - 14 Nov	18 Mar - 13 Nov	
Person-days	16	17	16	16	65
Estimated person-hours	120	127.5	120	120	487.5
Electrofishing hours	16	16	16	16	64
Samples (transects)	64	64	64	60	252
All Fish *(N)*	5,925	3,196	5,802	8,054	22,977
Species *(N)*	26	41	49	62	73
Hybrids *(N)*	2	2	5	4	7
Bighead Carp *(N)*	0	0	0	0	0
Silver Carp *(N)*	0	0	0	94	94
CPUE (fish/hour)	370.3	199.8	362.6	503.4	359.0

Random Electrofishing Effort - 2013

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	21 Mar - 20 Nov		18 Mar - 14 Nov	18 Mar - 15 Nov	
Person-days	16	16	16	16	64
Estimated person-hours	120	120	120	120	480
Electrofishing hours	16	16	16	16	64
Samples (transects)	64	64	64	64	256
All Fish *(N)*	1,996	3,317	4,007	2,882	12,202
Species *(N)*	25	33	45	44	67
Hybrids *(N)*	1	2	5	1	5
Bighead Carp *(N)*	0	0	0	0	0
Silver Carp *(N)*	0	0	0	14	14
CPUE (fish/hour)	124.8	207.3	250.4	180.1	190.7

Fixed Gill and Trammel Netting Effort - 2013

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	21 Mar - 5 Dec	21 Mar - 21 Nov	22 Mar - 4 Dec		
Person-days	18	18	18	18	72
Estimated person-hours	135	135	135	135	540
Samples (net sets)	72	68	72	72	284
Total miles of net	8.18	7.73	8.18	8.18	32.27
All Fish *(N)*	15	244	202	311	772
Species *(N)*	2	3	9	13	15
Hybrids *(N)*	0	0	0	0	0
Bighead Carp *(N)*	0	0	2	54	56
Silver Carp *(N)*	0	0	1	125	126
CPUE (fish/100 yard of net)	0.001	0.018	0.014	0.022	0.014

Random Gill and Trammel Netting Effort - 2013

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	21 Mar - 5 Dec	21 Mar - 21 Nov	22 Mar - 4 Dec		
Person-days	18	17	18	18	71
Estimated person-hours	135	127.5	135	135	532.5
Samples (net sets)	76	72	72	74	294
Total miles of net	8.64	8.18	8.18	8.41	33.41
All Fish *(N)*	9	130	266	59	464
Species *(N)*	1	3	12	12	16
Hybrids *(N)*	0	0	0	0	0
Bighead Carp *(N)*	0	0	3	4	7
Silver Carp *(N)*	0	0	1	6	7
CPUE (fish/100 yard of net)	0.001	0.009	0.018	0.004	0.008

Hoop Netting Effort - 2013

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	1 May - 1 Nov		3 May - 28 October	1 May - 28 Oct	
Person-days	14	14	14	12	54
Estimated person-hours	52.5	52.5	52.5	45	202.5
Net Nights	56	56	56	48	216
Samples (net sets)	28	28	28	24	108
All fish *(N)*	95	21	62	54	232
Species *(N)*	9	2	9	6	17
Hybrids *(N)*	0	0	0	0	0
Bighead Carp *(N)*	0	0	3	4	7
Silver Carp *(N)*	0	0	1	6	7
CPUE (fish/net)	3.39	0.75	2.21	2.25	2.15

Minnow Fyke Netting Effort - 2013

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	29 Apr - 30 Oct	1 May - 30 Oct	1 May - 28 Oct		
Person-days	14	14	14	14	56
Estimated person-hours	52.5	52.5	52.5	52.5	210
Net Nights	28	28	28	28	112
Samples (net sets)	28	28	28	28	112
All fish *(N)*	1,280	1,360	1,515	3,150	7,283
Species *(N)*	19	35	28	29	46
Hybrids *(N)*	3	2	4	2	5
Bighead Carp *(N)*	0	0	0	0	0
Silver Carp *(N)*	0	0	0	0	0
CPUE (fish/net)	45.71	48.57	54.11	112.50	65.03

Table 2. Total number of fish captured and percentage of total catch from 2013 fixed and random electrofishing and 2010-2013 totals for fixed and random site electrofishing below the dispersal barrier. Common Carp were counted by observation

	2013 Fixed						2013 Random						2010-2013	
	Pool				Number		Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Gizzard Shad	3,284	1,420	2,257	3,597	10,558	46.0%	1,040	1,558	1,391	818	4,807	39.4%	34,837	49.0%
Bluegill	301	172	1,516	563	2,552	11.1%	126	204	1,054	124	1,508	12.4%	6,815	9.6%
Emerald Shiner	504	431	77	740	1,752	7.6%	71	228	200	507	1,006	8.2%	4,461	6.3%
Common Carp	279	405	342	57	1,083	4.7%	61	482	172	22	737	6.0%	3,843	5.4%
Largemouth Bass	145	91	401	152	789	3.4%	55	102	296	22	475	3.9%	2,386	3.4%
Bluntnose Minnow	224	91	215	294	824	3.6%	119	83	258	102	562	4.6%	2,374	3.3%
Threadfin Shad	388	31	45	401	865	3.8%	196	126	3		325	2.7%	2,309	3.2%
Smallmouth Buffalo			126	259	385	1.7%		2	83	235	320	2.6%	1,940	2.7%
Green Sunfish	299	21	192	60	572	2.5%	140	44	117	21	322	2.6%	1,711	2.4%
Spotfin Shiner	19	52	18	592	681	3.0%	4	2	77	364	447	3.7%	1,684	2.4%
Pumpkinseed	308	155	106	4	573	2.5%	127	250	89	1	467	3.8%	1,260	1.8%
Bullhead Minnow			2	288	290	1.3%			6	188	194	1.6%	842	1.2%
Smallmouth Bass	8	30	28	60	126	0.5%		29	8	82	119	1.0%	523	0.7%
Freshwater Drum	16	27	53	45	141	0.6%	5	31	20	53	109	0.9%	449	0.6%
Golden Redhorse			27	97	124	0.5%			10	37	47	0.4%	443	0.6%
Channel Catfish	18	31	39	29	117	0.5%	3	34	13	45	95	0.8%	420	0.6%
River Carpsucker			13	79	92	0.4%			18	36	54	0.4%	415	0.6%
Longnose Gar	4	2	57	58	121	0.5%		1	18	5	24	0.2%	327	0.5%
Bigmouth Buffalo			1	67	68	0.3%			3	6	9	<0.1%	312	0.4%
Yellow Bullhead	23	44	29		96	0.4%	16	22	11		49	0.4%	310	0.4%
Silver Carp				94	94	0.4%				14	14	0.1%	293	0.4%
Quillback		1	3	62	66	0.3%			18	14	32	0.3%	261	0.4%
Golden Shiner	19	27	46	9	101	0.4%	7	17	17		41	0.3%	224	0.3%
Spottail Shiner	4	6	14	27	51	0.2%		10	19	3	32	0.3%	221	0.3%
Hybrid Sunfish	29	7	53	6	95	0.4%	1	7	14		22	0.2%	213	0.3%
White Bass		5	6	25	36	0.2%		2		43	45	0.4%	206	0.3%
Goldfish	10	33	11	3	57	0.2%	1	40	16		57	0.5%	185	0.3%
Sand Shiner		1	1	119	121	0.5%				17	17	0.1%	153	0.2%
Orangespotted Sunfish	15	18	3	32	68	0.3%	2	7		4	13	0.1%	152	0.2%
Shorthead Redhorse			9	45	54	0.2%			5	9	14	0.1%	151	0.2%
Black Buffalo			19	25	44	0.2%			19	69	88	0.7%	146	0.2%
Oriental Weatherfish	6	2			8	<0.1%	3	1			4	<0.1%	100	0.1%
White Sucker	1	17	4	5	27	0.1%		1	12		13	0.1%	96	0.1%
Brook Silverside	5		7	32	44	0.2%			4		4	<0.1%	93	0.1%
Black Crappie		7	15	8	30	0.1%		2	3	2	7	<0.1%	82	0.1%
Rock Bass		3	8	2	13	<0.1%		1	1		2	<0.1%	49	<0.1%
Round Goby		7	3	1	11	<0.1%		7	2		9	<0.1%	47	<0.1%
White Crappie	1	1		9	11	<0.1%			1		1	<0.1%	43	<0.1%
Common Carp x Goldfish Hybrid	1	37			38	0.2%		2	2		4	<0.1%	42	<0.1%
Shortnose Gar			1	15	16	<0.1%			2		2	<0.1%	39	<0.1%
Mosquitofish				1	1	<0.1%	1				1	<0.1%	37	<0.1%
Logperch			1	12	13	<0.1%			1	1	2	<0.1%	37	<0.1%
Silver Redhorse			5	3	8	<0.1%				4	4	<0.1%	34	<0.1%
Northern Hog Sucker				3	3	<0.1%				1	1	<0.1%	30	<0.1%
Bluegill x Green Sunfish Hybrid			23	2	25	0.1%			2	3	5	<0.1%	30	<0.1%
Yellow Bass		1	1	11	13	<0.1%				2	2	<0.1%	29	<0.1%
Banded Killifish	11			1	12	<0.1%	11		2		13	0.1%	29	<0.1%
Blackstripe Topminnow		1	3	1	5	<0.1%	1		4	2	7	<0.1%	25	<0.1%
Skipjack Herring	2	1	1	5	9	<0.1%	1	2			3	<0.1%	24	<0.1%
Northern Pike		2	1		3	<0.1%		1		3	4	<0.1%	24	<0.1%
River Shiner				1	1	<0.1%						<0.1%	23	<0.1%
Flathead Catfish				6	6	<0.1%				5	5	<0.1%	22	<0.1%
Highfin Carpsucker				16	16	<0.1%				5	5	<0.1%	21	<0.1%
Bighead Carp						<0.1%						<0.1%	18	<0.1%
Sauger				2	2	<0.1%				1	1	<0.1%	15	<0.1%
White Perch		1		1	2	<0.1%	1				1	<0.1%	14	<0.1%
Brown Bullhead			3		3	<0.1%						<0.1%	14	<0.1%
Grass Carp		4	1	2	7	<0.1%	1	1		4	6	<0.1%	13	<0.1%
Mimic Shiner						<0.1%						<0.1%	12	<0.1%
Alewife		1			1	<0.1%		8			8	<0.1%	10	<0.1%
Spotted Gar				7	7	<0.1%						<0.1%	10	<0.1%
Warmouth		1	1		2	<0.1%	1	2	1		4	<0.1%	9	<0.1%
Longear Sunfish			1	2	3	<0.1%			5	1	6	<0.1%	9	<0.1%
Redear Sunfish				4	4	<0.1%			1	1	2	<0.1%	8	<0.1%
Bowfin		2	2	1	5	<0.1%			1	1	2	<0.1%	8	<0.1%
Walleye		1	1	3	5	<0.1%			2		2	<0.1%	7	<0.1%
Blackside Darter			3		3	<0.1%			1		1	<0.1%	6	<0.1%
Pumpkinseed x Green Sunfish Hybrid			5		5	<0.1%			1		1	<0.1%	6	<0.1%
Brassy Minnow						<0.1%		6			6	<0.1%	6	<0.1%
Spotted Sucker		4			4	<0.1%						<0.1%	6	<0.1%
Black Bullhead						<0.1%				1	1	<0.1%	5	<0.1%
River Redhorse						<0.1%				1	1	<0.1%	4	<0.1%
Black Redhorse				1	1	<0.1%			1	2	3	<0.1%	4	<0.1%
Trout Perch						<0.1%						<0.1%	4	<0.1%
Johnny Darter		1		1	2	<0.1%				1	1	<0.1%	3	<0.1%
Fathead Minnow						<0.1%	2	1			3	<0.1%	3	<0.1%
Yellow Perch			1	2	3	<0.1%						<0.1%	3	<0.1%
Banded Darter						<0.1%						<0.1%	3	<0.1%
Suckermouth Minnow						<0.1%						<0.1%	3	<0.1%

Table 2. Continued

	2013 Fixed						2013 Random						2010-2013	
	Pool				Number		Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Black Bullhead						<0.1%				1	1	<0.1%	5	<0.1%
River Redhorse						<0.1%				1	1	<0.1%	4	<0.1%
Black Redhorse				1	1	<0.1%			1	2	3	<0.1%	4	<0.1%
Trout Perch						<0.1%						<0.1%	4	<0.1%
Johnny Darter		1		1	2	<0.1%				1	1	<0.1%	3	<0.1%
Fathead Minnow						<0.1%	2	1			3	<0.1%	3	<0.1%
Yellow Perch			1	2	3	<0.1%						<0.1%	3	<0.1%
Banded Darter						<0.1%						<0.1%	3	<0.1%
Suckermouth Minnow						<0.1%						<0.1%	3	<0.1%
Slenderhead Darter				1	1	<0.1%			1		1	<0.1%	2	<0.1%
Striped Shiner						<0.1%			1		1	<0.1%	2	<0.1%
Goldeye				1	1	<0.1%						<0.1%	2	<0.1%
American Eel	1				1	<0.1%						<0.1%	2	<0.1%
Central Mudminnow						<0.1%						<0.1%	2	<0.1%
Common Shiner						<0.1%						<0.1%	2	<0.1%
Silver Chub						<0.1%						<0.1%	2	<0.1%
Unidentified Notropis						<0.1%						<0.1%	2	<0.1%
Blue Catfish						<0.1%			1		1	<0.1%	1	<0.1%
Unidentified Catostomid						<0.1%		1			1	<0.1%	1	<0.1%
Central Stoneroller				1	1	<0.1%						<0.1%	1	<0.1%
Greenside Darter				1	1	<0.1%						<0.1%	1	<0.1%
Striped Bass x White Bass Hybrid				1	1	<0.1%						<0.1%	1	<0.1%
Pumpkinseed x Bluegill Hybrid			1		1	<0.1%						<0.1%	1	<0.1%
Tadpole Madtom			1		1	<0.1%						<0.1%	1	<0.1%
Hornyhead Chub		1			1	<0.1%						<0.1%	1	<0.1%
Greater Redhorse						<0.1%						<0.1%	1	<0.1%
King Salmon						<0.1%						<0.1%	1	<0.1%
Paddlefish						<0.1%						<0.1%	1	<0.1%
White Perch Hybrid						<0.1%						<0.1%	1	<0.1%
Total Caught	5,970	3,300	5,915	8,246	23,320	100.0%	2,043	3,378	4,091	2,971	12,399	100.0%	71,930	100.0%
Species	26	41	49	62	73		25	33	45	44	67		90	
Hybrid groups	2	2	5	4	7		1	2	5	1	5		7	

Table 3. Total number of fish captured and percentage of total catch from 2010-2013 fixed and random contracted commercial netting below the Electric Dispersal Barrier. 2011 and 2012 data includes data from additional netting and 30' gill netting done in each reach.

	2013 Fixed						2013 Random						2010-2013	
	Pool				Number		Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Common Carp	14	242	107	22	385	49.9%	9	128	134	12	283	61.0%	2,901	48.2%
Smallmouth Buffalo			56	33	89	11.5%		1	100	13	114	24.6%	1,129	18.7%
Bighead Carp			2	54	56	7.3%			3	4	7	1.5%	684	11.4%
Silver Carp			1	125	126	16.3%			1	6	7	1.5%	415	6.9%
Bigmouth Buffalo				42	42	5.4%			1		1	0.2%	263	4.4%
Channel Catfish			6	6	12	1.6%			6	3	9	1.9%	152	2.5%
Black Buffalo			17	3	20	2.6%			9	4	13	2.8%	109	1.8%
Freshwater Drum			4	11	15	1.9%			6	2	8	1.7%	95	1.6%
Grass Carp				1	1	0.1%		1		7	8	1.7%	67	1.1%
Carp x Goldfish Hybrid						<0.1%						<0.1%	63	1.0%
Goldfish	1				1	0.1%			2		2	0.4%	36	0.6%
River Carpsucker			1	6	7	0.9%			1	1	2	0.4%	30	0.5%
Longnose Gar			8	4	12	1.6%						<0.1%	21	0.3%
Flathead Catfish		1		3	4	0.5%				2	2	0.4%	19	0.3%
Quillback						<0.1%				1	1	0.2%	8	0.1%
Largemouth Bass						<0.1%			2		2	0.4%	5	<0.1%
Skipjack Herring						<0.1%						<0.1%	4	<0.1%
Unidentified Catostomid						<0.1%				4	4	0.9%	4	<0.1%
Goldeye				1	1	0.1%						<0.1%	3	<0.1%
Northern Pike						<0.1%						<0.1%	3	<0.1%
Gizzard Shad		1			1	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%			1		1	0.2%	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	15	244	202	311	772	100.0%	9	130	266	59	464	100.0%	6,023	100.0%
Species	2	3	9	13	15		1	3	12	12	16		29	
Hybrid groups	0	0	0	0	0		0	0	0	0	0		2	

Table 4. Total number of fish captured and percentage of total catch from 2012-2013 fixed hoop netting downstream of the Electric Dispersal Barrier.

	2013						2012-2013	
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Common Carp	18	12	22	0	52	32.3%	81	32.5%
Channel Catfish	5	9	15	12	41	25.5%	63	25.3%
Smallmouth Buffalo	0	0	15	11	26	16.1%	44	17.7%
Silver Carp	0	0	1	26	27	16.8%	30	12.0%
Black Buffalo	0	0	5	0	5	3.1%	5	2.0%
Bighead Carp	0	0	1	2	3	1.9%	9	3.6%
Flathead Catfish	0	0	0	2	2	1.2%	6	2.4%
Freshwater Drum	0	0	1	1	2	1.2%	7	2.8%
River Carpsucker	0	0	1	0	1	0.6%	2	0.8%
Goldfish	1	0	0	0	1	0.6%	1	0.4%
Longnose Gar	0	0	1	0	1	0.6%	1	0.4%
Total Caught	24	21	62	54	161	100.0%	249	100.0%
Species	3	2	9	6	11		11	
Hybrid groups	0	0	0	0	0		0	

Table 5. Total number of fish captured and percentage of total catch from 2012-2013 fixed minnow fyke netting downstream of the Electric Dispersal Barrier.

	2013						2012-2013	
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Bluegill	188	523	359	136	1,206	16.37%	12,649	46.38%
Bluntnose Minnow	251	243	892	1,035	2,421	32.86%	3,650	13.38%
Spotfin Shiner	10	10	10	1,586	1,616	21.94%	2,596	9.52%
Pumpkinseed	219	248	48	0	517	7.02%	2,414	8.85%
Mosquitofish	290	2	3	2	297	4.03%	1,670	6.12%
Green Sunfish	218	45	77	13	353	4.79%	1,316	4.82%
Orangespotted Sunfish	3	64	0	3	70	0.95%	1,144	4.19%
Emerald Shiner	2	4	4	53	63	0.86%	305	1.12%
Bullhead Minnow	0	1	29	97	127	1.72%	256	0.94%
Blackstripe Topminnow	67	4	10	27	108	1.47%	243	0.89%
Gizzard Shad < 6"	32	24	2	5	63	0.86%	142	0.52%
Sand Shiner	0	2	1	74	77	1.05%	95	0.35%
Yellow Bullhead	16	21	4	0	41	0.56%	92	0.34%
Spottail Shiner	0	8	16	18	42	0.57%	88	0.32%
Tadpole Madtom	0	59	0	11	70	0.95%	78	0.29%
Hybrid Sunfish	7	3	20	24	32	0.43%	61	0.22%
Round Goby	0	29	6	0	35	0.48%	60	0.22%
Golden Shiner	1	9	1	13	24	0.33%	56	0.21%
Oriental Weatherfish	23	12	2	2	39	0.53%	44	0.16%
Largemouth Bass	10	7	9	11	37	0.50%	40	0.15%
Unidentified Notropis	0	0	0	0	0	<0.1%	34	0.12%
River Shiner	0	0	0	0	0	<0.1%	24	<0.1%
Channel Catfish	6	1	1	0	8	0.11%	23	<0.1%
Yellow Bass	0	0	0	0	0	<0.1%	19	<0.1%
Warmouth	3	3	0	1	7	<0.1%	16	<0.1%
Brook Silverside	0	0	0	11	11	0.15%	14	<0.1%
Common Carp	1	4	2	1	8	0.11%	13	<0.1%
Sauger	0	13	0	0	13	0.18%	13	<0.1%
Rock Bass	0	2	1	0	3	<0.1%	10	<0.1%
Gizzard Shad > 6"	3	2	1	1	7	<0.1%	10	<0.1%
Banded Killifish	9	0	1	0	10	0.14%	10	<0.1%
Goldfish	0	3	0	1	4	<0.1%	8	<0.1%
Black Crappie	0	1	1	4	6	<0.1%	8	<0.1%
White Crappie	0	3	0	5	8	0.11%	8	<0.1%
Green Sunfish x Bluegill Hybrid	1	1	3	2	7	<0.1%	7	<0.1%
White Perch	1	0	0	0	1	<0.1%	6	<0.1%
Longear Sunfish	0	0	2	4	6	<0.1%	6	<0.1%
Creek Chub	0	1	0	0	1	<0.1%	5	<0.1%
Smallmouth Buffalo	0	0	3	0	3	<0.1%	4	<0.1%
White Sucker	0	4	0	0	4	<0.1%	4	<0.1%
Redear Sunfish	0	0	0	0	0	<0.1%	3	<0.1%
Shortnose Gar	0	0	0	1	1	<0.1%	3	<0.1%
Striped Shiner	0	0	0	2	2	<0.1%	3	<0.1%
Black Bullhead	0	2	0	1	3	<0.1%	3	<0.1%
Yellow Perch	0	0	0	3	3	<0.1%	3	<0.1%
Smallmouth Bass	0	0	0	0	0	<0.1%	2	<0.1%

Table 5. Continued

	2013						2012-2013	
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Threadfin Shad	0	0	1	0	1	<0.1%	2	<0.1%
Longnose Gar	0	0	2	0	2	<0.1%	2	<0.1%
Flathead Catfish	0	0	0	2	2	<0.1%	2	<0.1%
Brown Bullhead	0	0	0	0	0	<0.1%	1	<0.1%
Skipjack Herring	0	0	0	0	0	<0.1%	1	<0.1%
Suckermouth Minnow	0	0	0	0	0	<0.1%	1	<0.1%
Green Sunfish x Warmouth Hybrid	1	0	0	0	1	<0.1%	1	<0.1%
Bowfin	0	1	0	0	1	<0.1%	1	<0.1%
Northern Pike	0	1	0	0	1	<0.1%	1	<0.1%
Fathead Minnow	0	0	1	0	1	<0.1%	1	<0.1%
Green Sunfish x Pumpkinseed Hybrid	0	0	1	0	1	<0.1%	1	<0.1%
Johnny Darter	0	0	1	0	1	<0.1%	1	<0.1%
Pumpkinseed x Bluegill Hybrid	0	0	1	0	1	<0.1%	1	<0.1%
Slenderhead Darter	0	0	0	1	1	<0.1%	1	<0.1%
Total Caught	1,362	1,360	1,515	3,150	7,367	100.0%	27,275	100.0%
Species	19	35	28	29	46		53	
Hybrid groups	3	2	4	2	5		5	

Response Actions in the CAWS

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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 2012 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 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

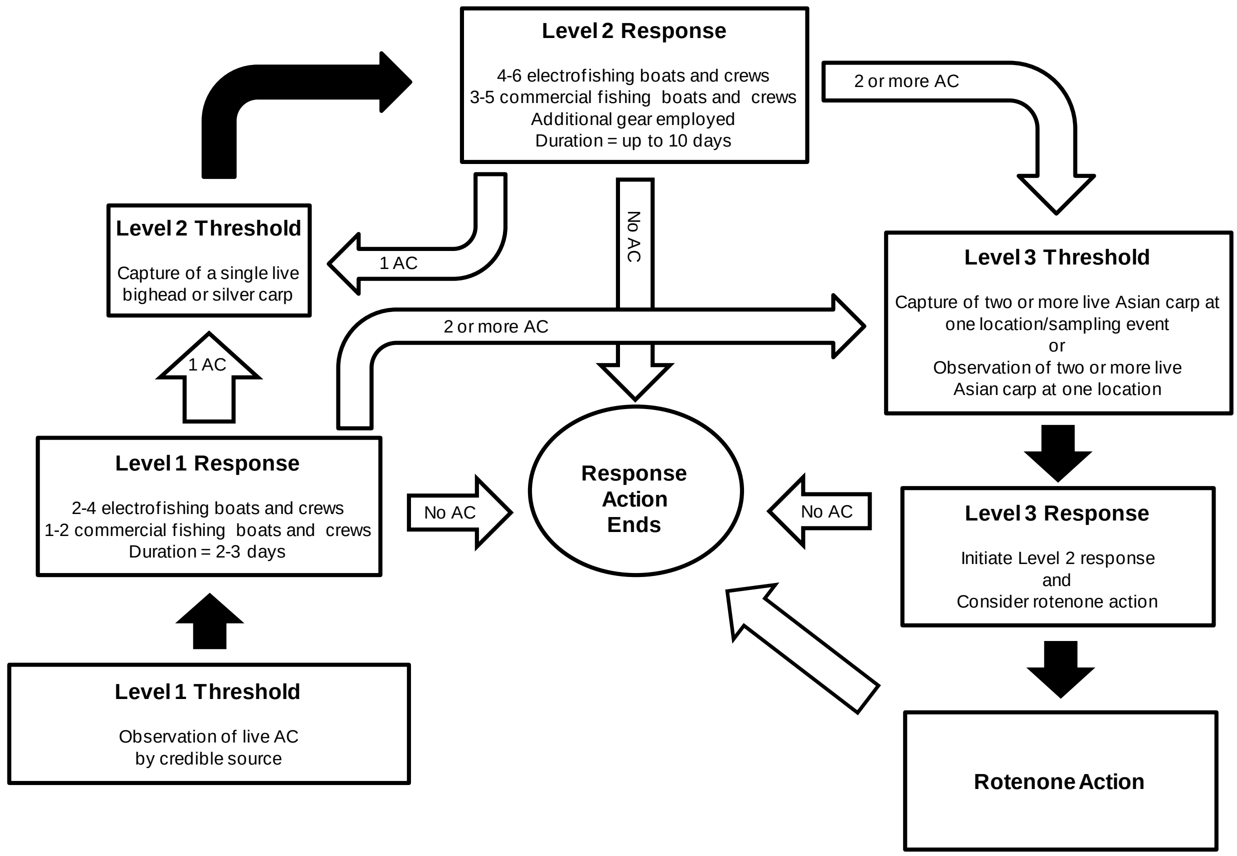

Figure 1. Thresholds for Asian carp (AC) response actions with conventional gears and rotenone.

would include the capture of a single live Bighead Carp 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 2013 no "Response" actions were utilized in the CAWS based on the established thresholds put forth in the 2013 MRP. However three Planned Intensive Surveillance 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 planned intensive events are summarized within this report in the "*Planned Intensive Surveillance in the CAWS*" 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 2013 prior to the planned intensive surveillance events and scheduled monitoring above the Electric Dispersal Barrier to minimize the potential for eDNA

contamination and the MRWG will develop a Hazard Analysis and Critical Control Points (HACCP) plan to address the transport of eDNA and unwanted aquatic nuisance species. The initial 2013 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 417 along with 23 control eDNA samples were collected and analyzed upstream of the Electric Dispersal Barriers. The June surveillance event (Lake Calumet) had 18 positive detections for Silver Carp and the November event (North Shore Channel, Chicago Rive and South Branch Chicago River/Bubbly Creek) had three positive detections for Silver Carp. There were no positive detections for Bighead Carp during either event. The "*Strategy for eDNA Monitoring*" section summarizes the events from 2013 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 events and previous Rapid Response actions, we would recommend a seasonal intensive monitoring approach in the CAWS plan. This approach would be considered a hybrid of the Fixed and Random Site Monitoring Upstream of the Dispersal Barrier and Planned Intensive Surveillance in the CAWS plans. The plan would suggest 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. Since monitoring results demonstrate no fish captured in the Lockport and Brandon Road pool we feel that Asian carp abundance are nonexistent or extremely low upstream of the Electric Dispersal Barrier. We do recommend additional monitoring effort be applied in Lockport, Brandon Road and Dresden Island pools to establish if there is a 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:

- No Response actions in 2013
- Completed three planned intensive surveillance events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier and collected eDNA samples during 2013.
- Results from "*Planned Intensive Surveillance in the CAWS*" and "*Strategy for eDNA Monitoring*" are located in their respective sections
- Recommend seasonal intensive monitoring approach in CAWS

Planned Intensive Surveillance in the CAWS

Tristan Widloe, David Wyffels, John Zeigler, Blake Ruebush, Brennan Caputo, Matthew O'Hara, Kevin Irons, and Victor Santucci; 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: To date, intensive sampling during rapid 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 cannot discern the source of the eDNA or the characteristics of the fish, verify whether live Asian carp are present, the number of Asian carp in an area, or whether a viable population of Asian carp exists. As further calibration of the eDNA method is completed the MRWG has proposed suspending the use of eDNA as a trigger for rapid responses, instead using this information to establish planned intensive surveillance at key locations where Asian carp eDNA has been found to accumulate. These efforts will have the benefit of advanced planning and will be in locations where the repeated detection of eDNA indicates the likely presence of Asian carp in the waterway. All planned surveillance activities will be preceded by eDNA sampling events. This coordination of monitoring for Asian carp using eDNA and traditional fishery sampling techniques (electrofishing and netting) will enhance the eDNA Calibration Study (ECALS) which aims to reduce the uncertainty surrounding eDNA results. Information gained from such actions may also benefit monitoring protocols, research efforts, or Asian carp removal and control efforts.

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: A variety of gears were used during planned intensive surveillance events in 2013, including pulsed DC-electrofishing, trammel and gill nets, deep water gill nets, commercial seine, trap nets and hoop nets, to capture and remove any Asian carp present in areas where eDNA has been found to accumulate. Trammel and gill nets were typically 3-4 m (10-14 ft) deep x 91 m (300 ft) long in bar mesh sizes ranging from 89-102 mm (3.5-4 in). Deep water gill nets were 9 m (30 ft) deep x 91 m (300 ft) long with bar mesh sizes ranging from 70-89 mm (2.75-3.5 in). The commercial seine was 731-m (2400 ft) long x 9 m (30 ft) deep and had a cod end made of 51-mm (2 in) bar mesh netting. Trap nets had 1- x 2-m (4-x 6- ft) boxes and were equipped with single circular throats and 15.2-m (50 ft) leads. Hoop nets were 6.7-m (22 ft) long and had seven 1.8-m (4 ft) diameter hoops with 64 mm (2.5 in) bar mesh netting. For most response actions, electrofishing and netting protocols were similar to those used for fixed site monitoring (15-minute electrofishing transects and "pounded" short duration net sets). However, for the Lake Calumet planned intensive surveillance we were able to leave nets fishing for longer duration, including overnight, when recreational boating was temporarily suspended.

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 in 2013 monitoring above the Electric Dispersal Barrier to minimize the potential for eDNA contamination and the MRWG will develop a Hazard Analysis and Critical Control Points (HACCP) plan to address the transport of eDNA and unwanted aquatic nuisance species. The initial 2013 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 is site-specific to the CAWS and will only be used for monitoring efforts above the Electric Dispersal Barrier.

North Shore Channel - Sampling took place between the Argyle Street Bridge, located just downstream from the North Shore Channel and North Branch Chicago River confluence, and the Wilmette Pumping Station. Teams began at the upper and lowermost site boundaries and worked towards the middle. Each team of two electrofishing boats and one net boat set nets across the channel and drove fish into nets with noise and electrofishing gear. Three nets were set by each team at 457-to 732 m (500- to 800-yd) intervals apart, after which electrofishing and noise drove fish in between the nets. The net closest to the outer site boundary was then be pulled and reset 457-to 732 m (500 to 800 yd) closer to the site center and the process repeated. The idea was to leapfrog the nets after each electrofishing and fish driving episode so that each team gradually moved toward the site midpoint.

Chicago River and South Branch Chicago River/Bubbly Creek - Electrofishing occurred around the entire shoreline of the basin between Lake Shore Drive and Chicago Lock and near Wolf Point (confluence of the North Branch Chicago River and Chicago River). During this time net boats set deep water gill nets in areas off of the main navigation channel. Nets were set for short duration and attended at all times. Noise from “pounding” on the hull of boats and racing trimmed up motors was be used to drive fish into the nets. When sampling in these areas was completed crews traveled down river and sample eight barge slips and backwater areas in the South Branch Chicago River near Bubbly Creek. Block nets were set at the entrance of the barge slips. Electrofishing boats shocked from the back of the slip out towards the main channel, driving fish into the net and collecting fish along the way.

Lake Calumet - Comprehensive eDNA sampling in the Lake Calumet was completed prior to planned intensive surveillance activities. Fifty-seven water samples and three controls (blanks) were collected. Sampling for eDNA was complementary to the locations of conventional gear sampling in Lake Calumet. A commercial beach seine was fished by a commercial crew once per day. Commercial seining occurred in the North section for two days, then in the South section for one day. Commercial gill/trammel net, deep water gill net and hoop net operations were performed within Lake Calumet, Lake Calumet Connecting Channel and Calumet River; tandem trap nets were strictly set in Lake Calumet. Gill/trammel nets were set for short duration with fish driven into the nets with noise as described above. Deep gill nets were set short duration during the day, while two nets were set each night. Agency electrofishing crews operated one crew in each section of the operation each day. Electrofishing samples were collected 15 minutes at a time.

Results and Discussion: We completed three planned intensive surveillance events in 2013: Lake Calumet, North Shore Channel and Chicago River. The Lake Calumet event was preceded by eDNA sampling, which yielded 6 positive detections for Silver Carp DNA. North Shore

Channel and Chicago River planned intensive surveillance events were not preceded by eDNA sampling due to government furlough.

Planned intensive surveillance was labor intensive and employed extensive sampling effort targeting any Asian carp that might be present in the waterway. We spent an estimated 1,165 person-hours during 2013 planned intensive surveillance (Table 1). Effort for all events in 2013 was 45.8 hours of electrofishing (174 transects), 9.1 miles of trammel/gill net (110 sets), 0.7 miles of deep gill net (12 sets), 1.4 miles of commercial seining (3 hauls), 8.8 trap net-days and 16.4 hoop net-days. Across all events and gears in 2013, we sampled 22,896 fish representing 50 species and 3 hybrid groups (Table 2). Gizzard Shad, Common Carp, Bluegill and Freshwater Drum were the predominant species sampled. No Bighead Carp or Silver Carp were captured or observed during any of the surveillance events to date. In addition, we examined 4,757 YOY Gizzard Shad and found no Asian carp YOY.

Recommendation: We recommend continued use of planned intensive surveillance in place of rapid response actions triggered by the detection of Asian carp DNA until further calibration of the eDNA method is completed. These efforts have the benefit of advanced planning and are in locations where the repeated detection of eDNA indicates the potential presence of Asian carp in the waterway. This coordination of monitoring for Asian carp using eDNA and traditional fishery sampling techniques (electrofishing and netting) will enhance the eDNA Calibration Study (ECALS) which aims to reduce the uncertainty surrounding eDNA results. Planned intensive surveillance with conventional gears represents the best available tool for localized removal or eradication of Asian carp to prevent them from becoming established in the CAWS or Lake Michigan. We also recommend continued assessment of experimental gears during planned intensive surveillance as an alternative means for capturing Asian carp.

Project Highlights:

- Completed three planned intensive surveillance events with conventional gears in the CAWS upstream of the Electric Dispersal Barrier during 2013.
- Estimated 1,165 person-hours were spent to complete 45.8 hours of electrofishing, set 15 km (9.1) miles of trammel/gill net and 1.1 km (0.7 miles) of deep water gill net, make three 732 m (800 yd) long commercial seine hauls, and deploy three tandem trap nets and eight hoop nets equal to 25.2 net-days of effort.
- Across all response actions and gears, sampled 22,896 fish representing 50 species and 3 hybrid groups.
- Examined 4,757 YOY Gizzard Shad and found no Asian carp YOY.
- No Bighead Carp or Silver Carp were captured or observed during response actions.
- Recommend continued use of planned intensive surveillance in place of rapid response actions triggered by the detection of Asian carp DNA until further calibration of the eDNA method is completed.

Table 1. Summary of effort and catch data for Planned Intensive Surveillance in the CAWS upstream of the Electric Dispersal Barrier, 25 June – 1 November 2013.

	Sample Effort			Catch				
Operation (date) and Gear	Estimated person-hours	Samples (*N*)	Total effort	All fish (*N*)	Species (*N*)	Hybrids (*N*)	Bighead Carp (*N*)	Silver Carp (*N*)
2013 Planned Intensive Surveillance								
Lake Calumet (25-28 June)								
Electrofishing	270	59 transects	14.8 hours	2,028	35	2	0	0
Commercial seine	135	3 hauls	1.4 miles	7,577	15	1	0	0
Trammel/gill nets	120	34 net sets	4.8 miles	719	8	1	0	0
Deep gill nets	-	12 net sets	0.7 miles	809	8	0	0	0
Tandem trap nets	-	3 sets	8.8 net-days	54	12	0	0	0
Hoop nets	-	8 sets	16.4 net-days	39	7	0	0	0
North Shore Channel (29-30 October)								
Electrofishing	238	68 transects	16.8 hours	4,646	32	1	0	0
Trammel/gill nets	102	36 net sets	2 miles	68	5	1	0	0
Chicago River (31 October-1 November)								
Electrofishing	210	47 transects	14.2 hours	6,749	26	0	0	0
Trammel/gill nets	90	40 net sets	2.3 miles	207	7	0	0	0

Table 2. Total number of fish captured with electrofishing, trammel/gill nets, deep water gill nets, commercial seine, tandem trap nets and hoop nets during Lake Calumet, North Shore Channel and Chicago River Planned Intensive Surveillance, 25 June – 1 November 2013.

	Lake Calumet 25-28 June						North Shore Channel 29-30 October		Chicago River 31 Oct-1 Nov		
Species	Electro-fishing	Commercial seine	Trammel/ Gill nets	Deep water gill nets	Tandem trap nets	Hoop nets	Electro-fishing	Trammel/ Gill nets	Electro-fishing	Trammel /Gill nets	All actions
Gizzard Shad > 6 in.	257	5475	3	251		7	1432		1450	2	8,877
Gizzard Shad < 6 in.	14						194		4549		4,757
Common Carp	153	479	624	171	7	1	242	42	172	192	2,083
Bluegill	117						1124		180		1,421
Freshwater Drum	28	812	52	362	8	21	1				1,284
Channel Catfish	25	715	15	5		2	11	3	7	4	787
Spotfin Shiner	21						435		180		636
Largemouth Bass	218	6			4		189	1	88		506
Pumpkinseed	206				8		153		32		399
Bluntnose Minnow	125						236		3		364
Banded Killifish	245						4				249
White Sucker	8				1		235		1		245
Golden Shiner	4						110		27		141
Rock Bass	117								3		120
White Perch	92	7			9				3		111
Round Goby	103						2		3		108
Emerald Shiner	30						44		22		96
Alewife	32						56				88
Yellow Perch	66										66
Green Sunfish	12						45		1		58
Bigmouth Buffalo		56									56
Smallmouth bass	48	3			1					4	56
Brook Silverside	32								10		42
Black Buffalo	2	3	19	12		3					39
Black Crappie		3					23		6		32
Smallmouth Buffalo	18	6	3	1		4					32
Blackstripe Topminnow							26		1		27
Chinook Salmon							5	20			25
White Bass	12	6			5				1		24
White Crappie		2			1		20				23
Black Bullhead	6		1		3		10		1		21
Goldfish	2	2					10	1	4		19
Yellow Bullhead	1	1	1		3		11		1		18
Quillback	12			3						1	16
Spottail Shiner	2						13				15
Orangespotted Sunfish	11										11
Sunfish hybrid	2						4				6
Flathead Catfish				4		1					5
Walleye							1		1	3	5
Brown Bullhead					4						4
Carp x Goldfish hybrid	2		1					1			4
Fathead Minnow							4				4
Brown Trout	2									1	3
Northern Pike									2		2
Oriental Weatherfish							2				2
Tilapia							1		1		2

Table 2. Continued.

	Lake Calumet 25-28 June						North Shore Channel 29-30 October		Chicago River 31 Oct-1 Nov		
Species	Electro-fishing	Commercial seine	Trammel/ Gill nets	Deep water gill nets	Tandem trap nets	Hoop nets	Electro-fishing	Trammel/ Gill nets	Electro-fishing	Trammel /Gill nets	All actions
Bowfin	1										1
Creek Chub							1				1
Rainbow Smelt	1										1
Rainbow Trout	1										1
White Perch x Y. Bass hybrid		1									1
Warmouth							1				1
Yellow Bass							1				1
All species	2,028	7,577	719	809	54	39	4,646	68	6,749	207	22,896
Species (*N*)	35	15	8	8	12	7	32	5	26	7	50
Hybrids (*N*)	2	1	1	-	-	-	1	1	-	-	3

Barrier Maintenance Fish Suppression

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Illinois Department of Natural Resources
and
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and
Mathew Shanks, Kimberly Kubiak, Richard Tollefson, Will Thompson and Nicholas Barkowski: US Army Corps of Engineers

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 and hydrogun operation); 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 Electric Dispersal Barriers (Barrier 1, 2A and 2B) in the Chicago Sanitary and Ship Canal at approximate river mile 296.1 near Romeoville, Illinois. Barrier 1 (formerly the Demonstration Barrier) became operational in April 2002 and is located farthest upstream (about 243.8 m (800 ft) above Barrier 2B). Barrier 1 is operated at a setting that has been shown to repel adult fish (Holliman 2011). Barrier 2A became operational in April 2009 and is located 67 m (220 ft) downstream of Barrier 2B. Both Barrier 2A and 2B can operate at parameters shown to repel juvenile and adult fish >137 mm (5.4 in) long at a setting of 2.0 volts per inch or fish >64 mm (2.5 in) long at a setting of 2.3 volts per inch (Holliman 2011). The higher setting has been in use since December 2011.

Barrier 2A and 2B must be shut down for maintenance approximately every 6 months and the Illinois Department of Natural Resources has agreed to support maintenance operations by providing fish suppression at the barrier site. Fish suppression can vary widely in scope and may include application of piscicide (rotenone) to keep fish from moving upstream past the barriers when they are down. This was the scenario for a December 2009 rotenone operation completed in support of Barrier 2A maintenance and 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 has operated as the principal barrier from the time it was brought on line and tested in April 2011. Barrier 2A is held in warm standby mode, which means it can be energized to normal operating level in a matter of seconds. Because the threat of Asian carp invasion is from downstream waters, there is a need to clear fish from the 67-m (220 ft) length of canal between Barrier 2A and 2B each time Barrier 2B is shut down for scheduled maintenance. The suppression plan calls for Barrier 2A to be energized during the fish clearing operation and function as the principal barrier until maintenance is completed, after which Barrier 2B can be re-energized and 2A brought back to warm standby mode.

By selecting a cut-off of 305 mm (12 in), we will be targeting sub adult and adult Asian carp, and excluding young-of-year fish. Excluding young-of-year Asian carp from the assessment is based on over two years of sampling in the Lockport pool with no indication of any young of the year Asian carp present or any known location of spawning. Additionally, eggs, larvae, or young-of-year have not been observed upstream of Starved Rock Lock and Dam in a decade.

A key factor to any response is risk of Asian carp being at or in the barrier. The MRWG (Monitoring and Response Workgroup) 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 Dispersal Barriers is necessary to maintain appropriate response measures. With budgetary costs and responders safety in mind, and continued monitoring in reaches directly below the barrier, the MRWG will continue to consider the surveillance findings and response needs as best professional judgment suggests. A barrier maintenance clearing event will be deemed successful when all fish >305 mm are removed from the barrier or until MRWG deems the remaining fish in the barrier a low risk.

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

1) Remove fish >305 mm(12 in) long between Barrier 2A and 2B before maintenance operations are initiated by collecting or driving fish into the net 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 >305 mm (12 in) long in the between-barrier area, as determined with remote sensing gear or MRWG deems the remaining fish in the barrier as a low risk.

Methods:

Fish Clearing Operation – Sampling took place at the Electric Dispersal Barriers between Barrier 1 and 2A on three occasions in 2013. A clearing event is deemed successful when all fish >305 mm (12 in) are removed from the barrier or until MRWG deems the remaining fish in the barrier a low risk.

June 17 – Hydroacoustics and side scan sonar were taken between Barrier 1 and 2A to enumerate fish >305 mm (12 in) in length prior to and after clearing actions to evaluate the success of fish clearing. The gill net was 91.4 m (300 ft) long x 9.1 m (30 ft) deep with bar mesh ranging from 70-89 mm (2.75-3.5 in). The net was dead set (stationary set as opposed to drifting) across the canal between Barrier 1 and the most upstream barrier parasitic structure. A boat was used to drive fish into the net with noise (pounding on the boat hull and revving the motor in a tipped up position). In addition to netting, two surface water shock boat operating with pulsed-DC current were used to target and stun or drive fish towards the stationary gill net that was in place across the canal.

August 26 and 27 – Two surface water shock boats operating with pulsed-DC current were used to target and stun or drive fish downstream of the barrier. After the two day event, hydroacoustics and side scan sonar were taken between Barrier 1 and 2A to enumerate fish >305 mm (12 in) in length to evaluate the success of fish clearing.

November 4 – Hydroacoustics and side scan sonar were taken between Barrier 1 and 2A to enumerate fish >305 mm (12 in) in length prior to and after clearing actions to evaluate the success of fish clearing. The gill net was 91.4 m (300 ft) long x 9.1 m (30 ft) deep with bar mesh ranging from 70-89 mm.(2.75-3 in) The net was dead set (stationary set as opposed to drifting) across the canal between Barrier 1 and the most upstream barrier parasitic structure. A boat was used to drive fish into the net with noise (pounding on the boat hull and revving the motor in a tipped up position). In addition to netting, two surface water shock boat operating with pulsed-DC current were used to target and stun or drive fish towards the stationary gill net that was in place across the canal.

Results and Discussion: An estimated 248 person-hours were spent sampling in the Eletric Dispersal Barrier during barrier maintenance events in 2013 (Table 1). Effort for each gear across all three maintenance events was 5.75 hours of surface pulsed DC-electrofishing, 2.3 hours of hydroacoustics transects and 183 m (200 yd) of surface to bottom gill nets (Table 1). Across all gears and all events, we sampled a total of 115 fish representing 12 species with 1 hybrid collected (Table 2). Bluntnose Minnow and Common Carp were the most abundant species accounting for 50% of the total catch (Table 2). Other abundant species in the catch were Banded Killifish, Bluegill, Largemouth Bass and Green Sunfish, which made up 37% of the total catch (Table 2). No Bighead Carp or Silver Carp were captured or observed during sampling.
All three clearing events were deemed successful by the MRWG and Electric Dispersal Barrier operations were allowed to proceed as planned.

Project Highlights:

2013 Barrier Maintenance Fish Suppression

- Multiple agencies and stakeholders cooperated in successfully removing fish between Barrier 1 and 2A for necessary barrier fish suppression on 3 separate operations.(June 17, August 26 to 27 and November 4)
- A total of 115 fish were removed using pulsed DC-electrofishing and 9 m (300 ft) deep gill nets, with 27 fish > 305 mm (12 in) in length.
- A total of 2 hours and 20 minutes of split-beam hydroacoustics and side-scan sonar where used to assess the success of the fish clearing operation by surveying the area in and near the barrier.
- **No Asian carp were captured or observed during fish suppression operations**
- Recommend continued use of hydroacoustics to survey in between Barriers 1 and 2A for fish > 305 mm (12 in) and sample using surface pulsed DC-electrofishing alongside with 9 m (300 ft) deep gill nets to effectively remove all threats in the barrier.

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 Barrier. By decreasing Asian carp numbers, we anticipate decreased migration pressure towards the barrier 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 population abundance and movement between pools of the Illinois Waterway. The project was initiated in 2010 and has continued through 2013 using ten contracted commercial fishing crews to remove Asian carp with large mesh 76-127 mm (3.0 - 5.0 in) trammel nets, gill nets and other gears on occasion (e.g., seines and hoop nets).

Objectives: Ten commercial fishing crews will be employed 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 16 km (10 miles) downstream of the Electric Dispersal Barrier, Marseilles pool is 39 km (24 miles) downstream, and Starved Rock pool is 82 km (51 miles) downstream. This target area is closed to commercial fishing by Illinois Administrative Rule; therefore an IDNR biologist was required to accompany commercial fishing crews working in this portion of the river. Contracted commercial fishing took place from June-September 2010, April-December 2011, March-December 2012 and March-December 2013. Commercial Fishing was also completed December 2012 – early March 2013 as part of a winter harvest project (See Appendix). Five commercial fishing crews per week with assisting IDNR biologists fished 4 days of each week, 1-2 weeks each month of the field season. Due to fishing pressure driving fish out of areas and greatly reducing catches, harvest events were scheduled at every-other week intervals to allow fish to repopulate preferred habitats in between events. Fishing occurred in backwater areas known to hold Asian carp, main channel, and side channel 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) trammel and gill net were used and typically set 20-30 minutes with fish being driven to the nets with noise (e.g., pounding on boat hulls, hitting the water surface with plungers, running with motors tipped up). Nets were occasionally set overnight off the main channel, and non-public backwaters with no boat traffic. Biologists enumerated and recorded the catch of Asian carp and identified by-catch to species. Asian carp and Common Carp were checked for ultrasonic tags. Ultrasonic tagged fish and by-catch were returned live to the water. All harvested Asian carp were removed and transferred to a refrigerated truck and taken to a processing plant where they were used for non-consumptive purposes (e.g., converted to liquid fertilizer). Each harvest event a representative sample of up to 30 of each Asian carp species (Bighead Carp, Silver Carp, 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:

Contracted commercial fishing crews and IDNR biologists spent an estimated 4,140 person-hours in 2010, 6,750 person-hours in 2011 and 7,650 person-hours in 2012 and 2013, netting for Asian carp during barrier defense removal efforts. A total of 1585 km (985 miles) of net has been deployed in the upper Illinois Waterway to date (Table 1). The combined catch of Asian carp (Bighead Carp , Silver Carp, and Grass Carp) was 6,073 fish during 2010, 41,054 fish during 2011, 45,501 fish during 2012 and 56,677 in 2013 (Table 1). The total weight of Asian carp caught and removed from 2010-2013 was 2,013,440 pounds or 1006.72 tons (Table 1). Bighead Carp, Silver Carp, and Grass Carp accounted for 53.5%, 46.2%, and 0.3% of the total tons harvested since 2010 respectively.

Bighead Carp accounted for 82.0% of all Asian carp harvested in 2010, 56.3% in 2011, 39.4% in 2012 and 20.1% in 2013. Silver Carp accounted for 17.7% of all Asian carp harvested in 2010, 43.4% in 2011, 63.0% in 2012 and 79.4% in 2013. Grass Carp accounted for 0.3% of all Asian carp harvested in 2010, 0.4% in 2011, 0.6 % in 2012 and 0.5% in 2013. The total harvest of Asian carp 2010-2013 consisted of 37.3 % Bighead Carp, 62.2% Silver Carp, and 0.5% Grass Carp.

The annual catch per unit effort (CPUE *N*/914 m (1000 yd) of net) of all pools combined was higher in 2013 (97.0 Asian carp per 914 m (1000 yd) of net) than in 2012 (87.6 Asian carp per 914 m (1000 yd) of net) and 2011 (86.9 Asian carp per 914 m (1000 yd) of net). A trend line fitted to monthly CPUE for all pools combined can be found in Figure 1.

Catch of Asian Carp within Pools –

<u>Dresden Island Pool:</u>

The Dresden pool was fished March through November in 2013. A total of 849 Bighead Carp, 45 Silver Carp, and 3 Grass Carp were harvested in 2013 from Dresden Island pool (Table 1). The increase in the numbers of Asian carp caught in 2013 in the Dresden Island pool is attributed to catches at Rock Run Rookery Lake. Rock Run Rookery Lake is an 84 acre lake, owned and operated by the Forest Preserve District of Will County, which sits just off the main river channel and is connected to the river by a small channel. A total of 817 Bighead Carp and 43 Silver Carp were caught in Rock Run Rookery Lake accounting for 96.2% and 95.6% of the total Bighead Carp and Silver Carp from the Dresden Island pool. Bighead Carp dominated the harvest accounting for 91.8% of the harvest in Dresden Island pool since 2010. Silver Carp have accounted for 6% of the harvest since 2010. Monthly CPUE for Asian carp captured in the Dresden pool from 2011 -2013 can be found in Figure 2.

Marseilles Pool:

The Marseilles pool was fished from March through early December in 2013. A total of 7,134 Bighead Carp, 10,154 Silver Carp, and 76 Grass Carp were harvested in 2013 from the Marseilles Pool (Table 1). Silver Carp accounted for 58.5 % of the total catch, unlike previous years when Bighead Carp were the predominate species captured in the Marseilles pool. Bighead Carp harvest numbers fell from a high of 20,087 in 2011 to 7,134 in 2013, in the same time Silver Carp harvest numbers increased from 7,023 in 2011 to 10,154 in 2013 (Table 1). The annual CPUE of Asian carp in the Marseilles pool has fallen from 72.1 Asian carp per 914 m (1000 yd) of net in 2011to 56 Asian carp per 914 m (1000 yd) of net in 2012 to 50.9 Asian carp per 914 m (1000 yd) of net in 2013. Monthly CPUE for Asian carp captured in the Marseilles pool from 2011-2013 can be found in Figure 2.

Starved Rock Pool:

Starved Rock pool was fished for the first time in 2011 and has continued through 2013. A total of 40,416 Asian carp were harvested in 2013, an increase of 15,950 Asian carp from 2012 (Table 1). Silver Carp were the dominate species harvested in 2013 (90.1%) (N=36,398) (Table 1). Annual CPUE of Asian carp increased from 174.4 Asian carp per 914 m (1000 yd) in 2011 to 221.9 Asian carp per 914 m (1000 yd) of net in 2012 and 246.19 Asian carp per 914 m (1000 yd) of net in 2013. Monthly CPUE for Asian carp captured in the Starved Rock pool from 2011-2013 can be found in Figure 2.

Catch of By-Catch Species –

A total of 75,146 fish representing 34 species and 2 hybrid groups were caught in trammel and gill nets during the 2013 Asian carp removal effort (Table 2). Asian carp (Bighead Carp, Silver Carp, and Grass Carp) made up 78.1% of the catch and the three *Ictiobus* spp. (Bigmouth Buffalo, Smallmouth Buffalo, and Black Buffalo) and Common Carp made up an additional 19.0% of the total catch. These percentages are very similar to 2012 in which Bighead Carp, Silver Carp and Grass Carp made up 77.4% of the catch and three *Ictiobus* spp. and Common Carp made up an additional 19.5%. A total of 842 fish from 12 species and 1 hybrid species made up the total game fish captured in 2013. Game fish represented 1.1 % of the total catch in 2013, this is similar to 2012 when game fish represented 0.9% Flathead and Channel Catfish were again the most dominate game fish captured in 2012 accounting for 87.6 % of the game fish captured

Recommendations: We recommend continuing the Asian carp removal program 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 and assisting IDNR biologists deployed 1585.2 (985 miles) of net in the upper Illinois Waterway from 2010- 2013.
- A total of 56,435 Bighead Carp, 94,071 Silver Carp, and 799 Grass Carp were removed by contracted netting. The total weight of Asian carp removed was 1006.72 tons (62.41 tons in 2010, 351.78 tons in 2011, 284.53 tons in 2012 and 308 tons in 2013).
- 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.

Table 1: Gill and trammel netting effort and harvest of Asian carps from Dresden, Marseilles and Starved Rock pools during 2010-2013 using contracted commercial fisherman.

	Effort		Harvest							
Year and river Pool	Net Sets (*N*)	Miles of Net	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
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
2010-2013										
Dresden Island	409	90.9	1,084	72	25	1,181	11.99	0.50	0.23	12.72
Marseilles	3,043	694.1	44,235	26,996	185	71,416	459.05	157.59	0.51	617.15
Starved Rock	585	200.0	11,116	67,003	589	78,708	67.72	307.31	1.83	376.85
All pools	4,037	985.1	56,435	94,071	799	151,305	538.76	465.40	2.57	1006.72

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 -2013. All Species other than Asian carp and Common Carp were returned to the River immediately after capture.

	2011		2012		2013	
Species	Number Captured	Percent %	Number Captured	Percent %	Number Captured	Percent %
Bighead Carp	23117	43.68%	16560	28.36%	11777	15.67%
Silver Carp	17776	33.59%	28632	49.03%	46597	62.01%
Smallmouth Buffalo	3853	7.28%	3749	6.42%	7397	9.84%
Bigmouth Buffalo	3850	7.27%	5043	8.64%	3567	4.75%
Common Carp	2574	4.86%	2386	4.09%	2685	3.57%
Freshwater Drum	573	1.08%	689	1.18%	1055	1.40%
Flathead Catfish	313	0.59%	299	0.51%	417	0.55%
Channel Catfish	201	0.38%	137	0.23%	321	0.43%
Black Buffalo	188	0.36%	262	0.45%	432	0.57%
Grass Carp	171	0.32%	299	0.51%	303	0.40%
Paddlefish	78	0.15%	51	0.09%	37	0.05%
River Carpsucker	61	0.12%	26	0.04%	105	0.14%
Quillback	37	0.07%	46	0.08%	49	0.07%
Largemouth Bass	28	0.05%	22	0.04%	28	0.04%
Sauger	19	0.04%	31	0.05%	12	0.02%
Shortnose Gar	16	0.03%	37	0.06%	44	0.06%
White Bass	13	0.02%	11	0.02%	40	0.05%
Longnose Gar	11	0.02%	25	0.04%	68	0.09%
Walleye	9	0.02%	12	0.02%	7	0.01%
Skipjack Herring	9	0.02%	14	0.02%		
Blue Catfish	8	0.02%	7	0.01%	8	0.01%
Gizzard Shad	6	0.01%	22	0.04%	5	0.01%
Yellow Bass	3	0.01%	5	0.01%	9	0.01%
Hybrid Striped Bass	2	< 0.01%	7	0.01%	2	< 0.01%
Spotted Gar	1	< 0.01%				
White Crappie	1	< 0.01%	2	< 0.01%	1	< 0.01%
Bluegill			1	< 0.01%		
Black Crappie	1	< 0.01%	1	< 0.01%	2	< 0.01%
Shorthead Redhorse		< 0.01%	1	< 0.01%		
Golden Redhorse			2	< 0.01%	6	0.01%
River Redhorse	1	< 0.01%				
Rock Bass			1	< 0.01%		
Muskellunge	1	< 0.01%			2	< 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%
Goldeye	1	< 0.01%				
Goldfish					20	0.03%
Unidentified Buffalo Species					137	0.18%
White Perch					1	< 0.01%
Bowfin					4	0.01%
Blue Sucker					1	< 0.01%
Total all Species	52924		58391		75146	

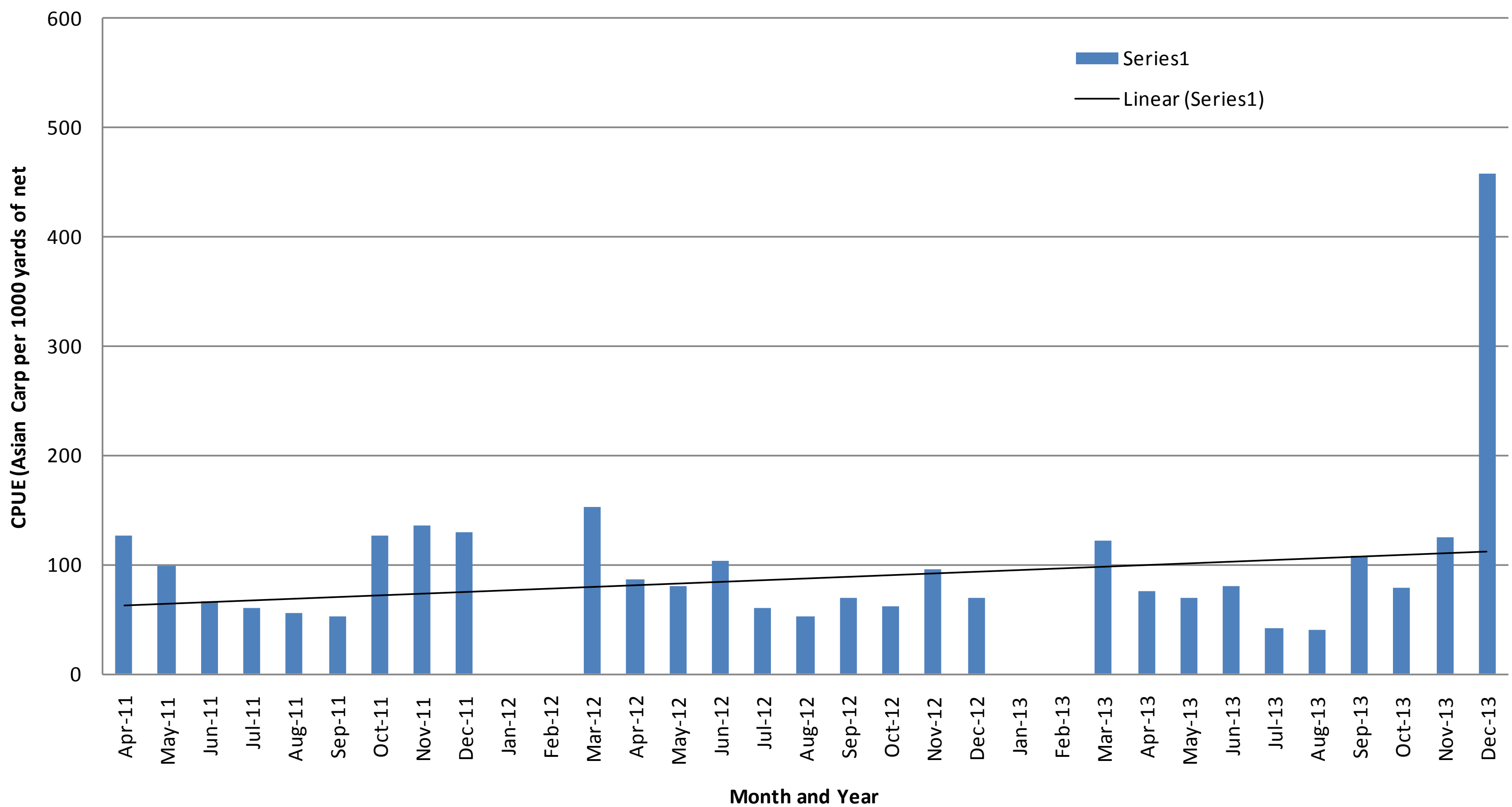

Figure 1: Monthly Catch per unit effort (CPUE; Asian Carp/914 m (1000 yd) of gill/trammel net) for all pools combined in 2011-2013.

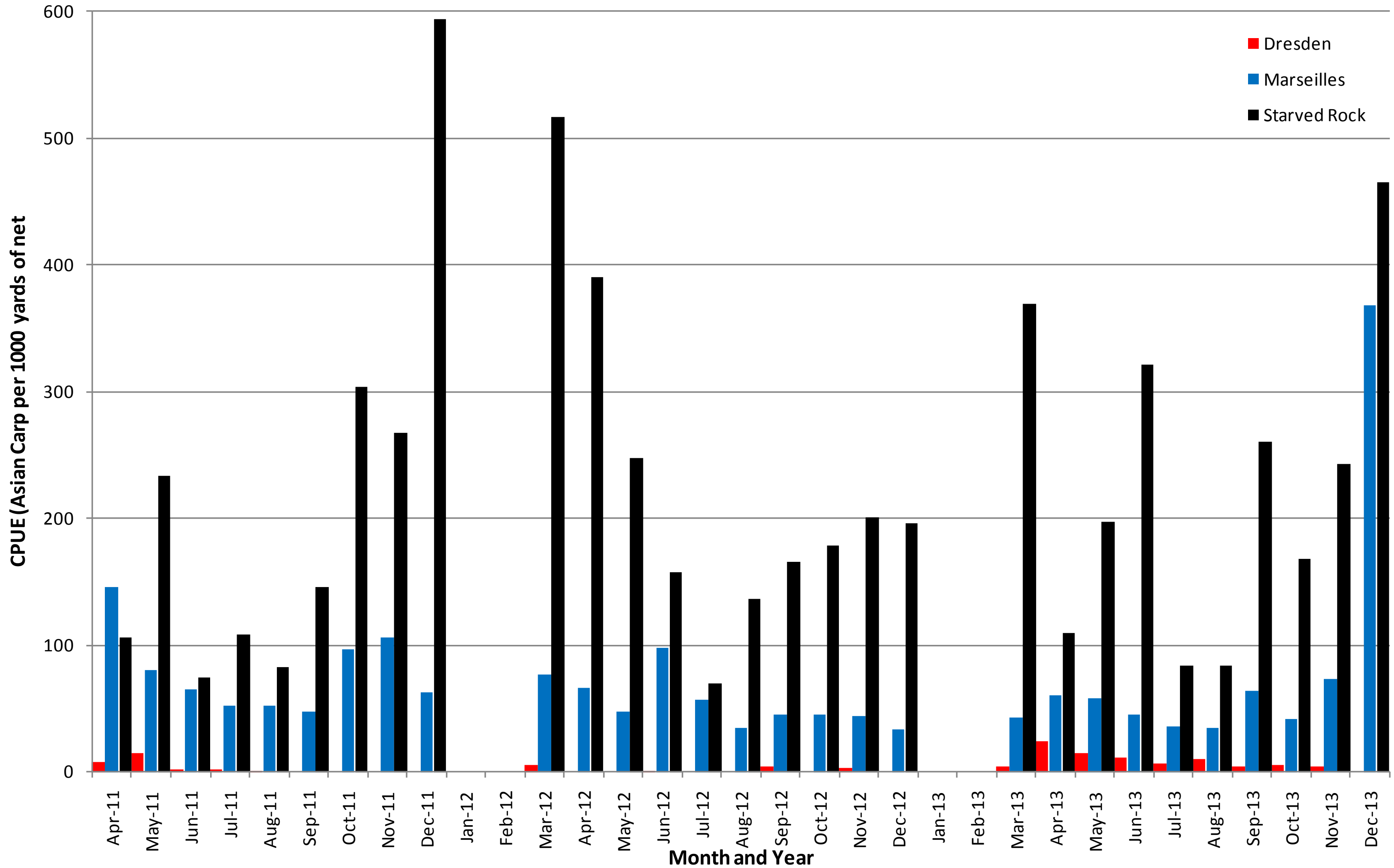

Figure 2: Monthly Catch per Unit Effort (CPUE; Asian Carp/914 m (1000 yd) of gill/trammel net) for Dresden, Marseilles and Starved Rock pools 2011- 2013. No barrier defense effort was completed for the Dresden Island pool for the months of November-December 2011, January-February 2012, May 2012, and July 2012. No barrier defense effort was completed for the Marseilles and Starved Rock pools for the months of January-February 2012. No barrier defense effort was completed for Dresden in December 2013.

Table 1. Summary of effort and catch data for Lockport Pool Barrier Maintenance fish sampling events, 17 June, 26-27 June and 4 November 2013.

		Sample Effort		Catch (captured and observed)				
Operation and Gear	Estimated person-hours	Samples (*N*)	Total effort (varies)	All fish (*N*)	Species (*N*)	Hybrids (*N*)	Bighead carp (*N*)	Silver carp (*N*)
June Sampling	86							
DC electrofishing		6 transects	1.5 hours	23	4	0	0	0
Surface to bottom gill nets		1 net set	100 yards	2	1	0	0	0
Hydroacoustics		2 transects	40 minutes	--	--	--	--	--
August Sampling	96							
DC electrofishing		13 transects	3.25 hours	86	11	1	0	0
Hydroacoustics		3 transects	1.0 hour	--	--	--	--	--
November Sampling	76							
DC electrofishing		4 transects	1.0 hour	1	1	0	0	0
Surface to bottom gill nets		1 net sets	100 yards	3	1	0	0	0
Hydroacoustics		2 transects	40 minutes	--	--	--	--	--

Table 2. Total number of fish captured with pulsed DC-electrofishing gear and surface to bottom gill nets in Lockport Pool Barrier Maintenance Fish Sampling in 2013.

	June 17		August 26-27	November 4		
Species	DC Electro-fishing	Surface to Bottom Gill Nets	DC Electro-fishing	DC Electro-fishing	Surface to Bottom Gill Nets	Total
Gizzard Shad <6 in.			6			6
Banded Killifish			10			10
Bluntnose Minnow			30			30
Common Carp	20	2	2		3	27
Bluegill	1		15	1		17
Green Sunfish	1		7			8
Mosquitofish			1			1
Largemouth Bass			8			8
Fathead Minnow			1			1
Pumpkinseed			5			5
Oriental Weatherfish	1					1
Hybrid Sunfish			1			1
All species	23	2	86	1	3	115
Species (*N*)	4	1	11	1	1	12
Hybrids (*N*)	0	0	1	0	0	1

Monitoring Asian Carp Population Metrics and Control Efforts

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This is considered an executive summary of the "Monitoring Asian Carp Population Metrics and Control Efforts" report; the comprehensive report can be found in Appendix B.

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

Project Goal: Evaluate the efficacy of harvest and other control methods on 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, our research is intended to develop a predictive model of Asian carp dispersal in the Illinois River as a function of density, demographics, and environment (e.g., hydrograph).

Introduction and Need: Bighead Carp, Silver Carp, and their hybrids invaded the Illinois River at least 15 years ago. The density of these fish increased rapidly, and the fish have neared the Chicago Area Waterway System (CAWS), being present in Dresden pool. Our efforts have focused on the dynamics of these invasive species since 2010. Catch per unit effort (CPUE) across multiple gears have been the only method available for assessing abundance. Using CPUE is a valuable technique for assessing population status. However, it varies with gear, environmental conditions, fish behavior, fishing activity, and many other factors. A mark-recapture effort was conducted in LaGrange Reach in the early 2000s (Sass et al. 2010), which provided local densities. However, we recognized that other techniques are needed to generate "hard" density and biomass estimates in the river. Hydroacoustics coupled with other gear types are showing promise for generating robust density and biomass. Asian carp recruit regularly in the lower Mississippi River (Lohmeyer and Garvey 2009). Immigration may contribute to populations in the Illinois River and may vary with environmental and biotic factors. Our group is collaborating with other researchers to quantify movement with telemetry. Harvest is occurring commercially in the lower Illinois River and contracted control fishing is ongoing above Starved Rock Lock and Dam. The population consequences of harvest are being quantified with modeling. These factors affect patterns of population dynamics, movement, and ultimately the risk of Asian carp establishing in the reaches directly below the electric barrier separating the lower river with the CAWS. Population changes in Asian carp may lead to modifications of the Illinois River ecosystem. We are quantifying this to determine whether changes in density, demographics, and movement of Asian carp affect primary production, zooplankton, and native fishes.

Methods and Materials: Standardized fish sampling in the lower river, hydroacoustic surveys, acoustic transmitters, otolith microchemistry, water quality samples, and plankton analysis 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). First, 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 5-9, 2013 (Table 1). Two pulsed-DC electrofishing transects were conducted along each main channel and backwater site. Using information gathered during standardized sampling mean length-at-age, mortality, length-weight relationships, indices of spawning condition, sex ratio of Asian carp, and molecular identification of Asian carp were calculated.

Harvest in Upper Illinois River (Chapter 2). To estimate exploitation rates, population size, and movement patterns in the Hanson Material Service Corporation (HMSC) pits, SIUC initiated a mark-recapture study (320 Asian carp were tagged) in spring 2012 within the HMSC east and west pits to estimate exploitation rates for Asian carp. In 2013, another mark-recapture study was initiated to bolster mark-recapture information from 2012. With the assistance of IDNR contracted commercial fishermen, an additional 276 fish were captured and tagged in the HMSC east pits. SIUC also initiated a mark-recapture study in the Starved Rock pool in 2013. On 8 May 2013, 263 Asian carp were jaw tagged in the Sheehan Island backwater of the Starved Rock pool (near Buffalo Rock). A Link-Barker Jolly-Seber mark-recapture model (Link and Barker 2005) for open populations was employed in Program MARK® to calculate an overall survival rate (φ), capture probability (p), and immigration rate (f) for all available commercial fishing periods (30 April 2012 – 17 November 2013) as well as weekly estimates of survival, exploitation, rate of population change, and immigration for 2012 and 2013 independently.

Movement (Chapter 3). Immigration and emigration rates throughout the Illinois River, as well as movement between the east and west gravel pits of the HMSC backwater, are also being estimated with acoustic telemetry. To date, with assistance from IDNR-contracted commercial fishermen and Illinois Natural History Survey (INHS), 691 acoustic transmitters have been implanted in Asian carp in the Illinois River or Pool 26 of the Mississippi River In 2012, 372 Asian carp were implanted with acoustic transmitters (2013 N=337; 2012 N = 372). A network of 30 Vemco® VR2W receivers was deployed in the Illinois River by SIUC in 2012 to monitor movement of acoustically tagged Asian carp. This network has been continuously monitored and VR2Ws 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 three receivers were specifically placed within the HMSC gravel pits to better understand the factors affecting Asian carp immigration and emigration within this area.

Acoustics (Chapter 4). In the fall of 2012, hydroacoustic surveys (i.e., side-looking and down-looking) and standardized sampling (i.e., pulsed-DC electrofishing and trammel netting) were used to estimate the abundance, size distribution, and biomass of Asian carp 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. In general, hydroacoustic sampling was conducted to estimate the total number and size distribution of all fishes within each reach. Data from standardized sampling will then be used to determine length-specific proportional abundance of Asian carp to other fishes to distribute acoustic-derived abundance among species as a function of size. Reach-specific length-weight regressions will be determined for each group of fishes to estimate total biomass as a function of total length. Total abundance and biomass of Asian carp and other fishes will be extrapolated to the total interpolated volume based on the proportion of water volume sampled. This approach will also be adopted for hydroacoustic surveys conducted in the fall of 2013. Additionally, side-scan sonar was used in conjunction with the hydroacoustic surveys on all main channel and associated side channels, backwater lakes, tributaries, and harbors surveyed in 2013.

Recruitment Sources—Otolith microchemistry (Chapter 5). Adult Bighead Carp and Silver Carp were collected from each of three reaches of the Illinois River (Alton, LaGrange-Peoria, and upper river) during 2012-2013 by electrofishing and trammel netting. Caudal fin clips were obtained from each fish and sent to Jim Lamer at Western Illinois University for identification of Bighead Carp, Silver Carp, and hybrids. Both lapilli otoliths were extracted from each fish. One otolith per fish was sectioned and analyzed for strontium:calcium ratio (Sr:Ca) along a transect from the core to the edge of the sectioned otolith using laser ablation-ICPMS. A 250 μg subsample from the core of the second otolith from each fish was obtained using a micromill; a core subsample of this mass represents otolith carbonate deposited during age-0. The core subsample from the second otolith from each fish was analyzed for stable oxygen and carbon isotope ratios ($\delta^{18}O$ and $\delta^{13}C$). Previously established relationships between water and otolith Sr:Ca and water and otolith $\delta^{18}O$ for Asian carps were used to characterize expected otolith Sr:Ca and $\delta^{18}O$ signatures for fish that originated in the Illinois, Missouri, and Mississippi rivers and for fish that used floodplain lake habitats during their early life history. Sr:Ca, $\delta^{18}O$ and $\delta^{13}C$ of the otolith core (which reflects early life history) were used to infer natal environment for individual fish. Changes in Sr:Ca across sectioned otoliths were used to assess timing and long-term patterns of inter-river movement for individual fish.

Ecosystem Responses (Chapter 6). Plankton sampling occurred monthly (May-Oct) at 18 sites throughout the Illinois Waterway (Alton, La Grange, Peoria, Starved Rock, Marseilles, Dresden) from May thru October of 2011-2013 and at a subset of 6 sites during 2009 and 2010. Productivity was evaluated by measuring total phosphorus and chlorophyll *a*. Asian carp reduction activities through commercial fishing occurred predominately in the upper river section (Starved Rock, Marseilles, and Dresden reaches). During 2010, removals were limited to only the Marseilles and Dresden reaches, whereas from 2011 to 2013 they occurred in all three upper reaches. Removals from the lower river section (Alton, La Grange, and Peoria reaches) only occurred once during 2012. Based on the distribution of commercial fishing pressure, river geomorphology, and natural differences in ecology, we grouped sites into upper and lower river sections (Theiling 1999, McClelland et al. 2006) to compare productivity and plankton between sections.

Results and Discussion (See Appendix B. for chapters and additional details).

Demographics in the Illinois River (Chapter 1). Catch per Effort (CPE) estimates in late summer 2013 suggest that densities of Asian carp are lower than in 2011 and 2012. Apparent densities are highest in Peoria pool. This may be due to the large amount of shallow-water areas and higher catch rates rather than actual density in this reach. Significant recruitment leading to a strong year class has not been detected for over 6 years. Sampling in the lower reaches revealed some production of age-0 Asian carp in 2013. Also, in 2013, the predominant "2008" year-class declined. Sampling is a continuation of 2011 sampling. Thirty-six fish species were encountered at fixed sampling locations in late summer 2012 and 2013 using electrofishing and trammel nets. Catch per unit effort of Asian carp declined during 2011 through 2013 in the two lower reaches; however, no change was observed in the Peoria pool. Age distributions of Asian carp from the lower three reaches show no recruitment and declining population's older fish. The sex ratio did not deviate from 1:1 in 2013, although it was skewed toward males in 2012. The results of genetic testing revealed that a large number of carp in the Illinois River are hybrids between Bighead Carp and Silver Carp (N = 394; 196 were pure Silver Carp, 4 were pure Bighead Carp; the rest were hybrids).

Harvest in Upper Illinois River (Chapter 2). In 2013, 16,025 Asian carp were harvested from the Hanson Materials Service (HMS) east and west pits. Results from the mark-recapture studies conducted in these pits showed that the return rate of tagged fish declined through time. Modeling of catch rates and tag returns through time in Program MARK revealed that harvest in the HMS pits is very effective, contributing to mortality of 89% in 2012. However, tag returns and the exploitation rate declined to 38% in 2013, suggesting greater net immigration into the backwater.

Movement (Chapter 3). Data from acoustic transmitters revealed that tagged fish were distributed from Dresden pool to the Mississippi River. Thirty-eight Asian carp were caught and tagged in Dresden pool, the furthermost location for tagging Asian carp to date. Redetection of fish on receivers was about 30%. In 2010-2011, flooding in the Illinois River led to a 30% immigration rate of Asian carp from the Mississippi River. With the low water in 2012, average immigration dropped to 8.1%. Net movement of Asian carp was downstream in 2012-2013. Spawning behavior of Asian carp was quantified by IDNR personnel in the Marseilles pool. These events corresponded with movements of Asian carp out of the HMSC pits with elevated main-channel discharge and temperatures above 18ºC.

Acoustics (Chapter 4). Acoustics conducted during 2010 through 2011 provided a conservative estimate for the three lower reaches of the Illinois River; 1,413 metric tons were estimated. Asian carp comprised greater than 60% of biomass. During 2012 through 2013, we have completed surveys from Dresden down to the confluence; this approach allowed us to get into the backwaters. We used 70 plus 200 kHz, side-looking transducers and completed 3711 km (2,306 miles) of survey in 2012 and 3265.4 km (2,029 miles) of survey in 2013. Analysis is ongoing. We will be able to compare to CPE and determine whether there is a correlation between the CPE and abundance estimates following further analyses.

Recruitment Sources—Otolith microchemistry (Chapter 5). Water chemistry data continue to indicate that Sr:Ca is consistently higher in the middle Mississippi and Missouri rivers compared to the Illinois River, thus enabling use of this marker as an indicator of fish that have immigrated into the Illinois River from these other rivers. Using otolith core Sr:Ca data, we estimated that 28-53% of adult Silver Carp and 26-48% of hybrids in the Illinois River were immigrants that originated in the middle Mississippi or Missouri Rivers**.** Only 5% of the fish analyzed had otolith core $\delta^{18}O$ and $\delta^{13}C$ signatures indicative of use of floodplain lake habitats during early life, consistent with data from prior years. Among Silver Carp and hybrids that were immigrants to the Illinois River, the vast majority originated in the middle Mississippi River; only 2-8% of the total number of Silver Carp and hybrids captured in the Illinois River originated in the Missouri River. In contrast to Silver Carp and hybrids, otolith core Sr:Ca indicated that 91-98% of Bighead Carp analyzed originated in the Illinois River, with 2% originating in the middle Mississippi River, consistent with data from prior years.

Ecosystem Responses (Chapter 6). The reduction of Asian carp through controlled commercial fishing did not significantly influence zooplankton densities, gizzard shad relative weight, or gizzard shad catch-per-unit effort. In terms of zooplankton, rotifers are proportionally dominant in terms of abundance in both upper and lower river sections, but rotifers tended to be more abundant in the lower section when compared to the upper section. Cladocerans tended to be more abundant in the upper section when compared to the lower section**.** Measurements of primary productivity (i.e., chlorophyll-*a* concentration) as well as total phosphorus ($mg \cdot L^{-1}$) decreased from upstream to downstream.

Modeling (Chapter 7). A paper on population responses of Asian carp to harvest has recently been published in Fisheries magazine (Tsehaye et al. 2013). In 2013, we convened a group of modeling experts in fish ecology. This group provided an outline for a spatially explicit model of movement of Asian carp as a function of density, demographics, and environmental conditions. This model is currently in development.

Project Highlights:

- Although data processing is ongoing, Asian carp abundance appears to be at a low level in 2013-2014. Poor recruitment and natural mortality, perhaps coupled with harvest, contributes to this pattern. Continued contract harvest in the upper Illinois River (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 location of the Electric Dispersal Barrier in Lockport pool.

Telemetry Monitoring Plan

US Army Corps of Engineers

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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 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 and Marseilles pools and associated surrogate fish species 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** Determine if there is adequate detection coverage to effectively assess efficacy of the electric dispersal barriers.
- **Objective** Analyze behavior and movement patterns of fish near the barriers as they interact with barge traffic. (New objective to 2013)

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 Marseilles, Dresden Island, Brandon Road, and Lockport Locks and Dams using stationary receivers (N=8) placed above and below each dam.

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.

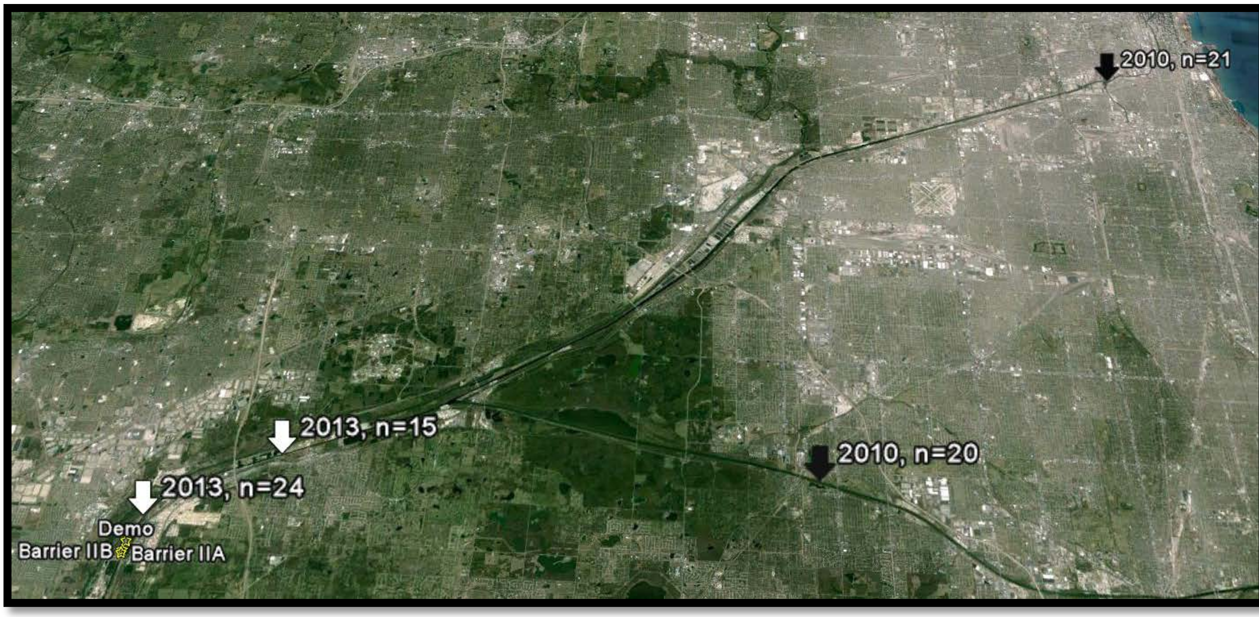
Methods: Based on MRWG expert opinion, it was recommended that a total of 200 active transmitters in fish be maintained within the study area for telemetry monitoring. At the end of the 2012 season there were approximately 99 large fish (V16 Vemco transmitters) that remained active into 2013 and 14 small fish (V6 Vemco transmitters) that remained active into December of 2012 (included within 2013 analysis). Additional tagging was required to sustain the recommended levels of the large fish 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. In addition, small tags deployed in proximity to the barriers were specifically programmed to stagger their period of operation to reduce overlapping transmissions near the barriers. A total of 130 transmitters (Vemco V7 and V16; 69 kHz) were implanted into both Asian carp and surrogate species in 2013 to maintain adequate transmitter saturation within each pool between the Cal-Sag Channel and the Marseilles lock and dam. 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 within Lockport pool were released on the opposite side of the barriers than their capture point in an effort to induce higher barrier approaches through site fidelity. An additional 13 transmitters were implanted into Common carp and released immediately below the electric dispersal barrier system during an ad hoc trial to assess interactions between fish and barges. Table 1 identifies all fishes containing active transmitters within the winter of 2012 and the field season of 2013 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
Chicago Sanitary and Shipping Canal Upstream of Barriers	Common carp	27
	Largemouth Bass	12
Between Barriers (Demo and IIB)	Common carp	12
	Largemouth Bass	12
CSSC Lockport Pool Downstream of Barriers	Common carp	76
	Common carp (released via barge just below IIA)	13
	Freshwater Drum	3
	Channel Catfish	1
Brandon Rd Pool	Common carp	20
Dresden Island Pool	Bighead Carp	20
	Silver Carp	3
	Silver-Bighead Hybrid	2
	Smallmouth buffalo	5
	Common carp	5
Marseilles Pool	Bighead carp	16
	Silver carp	15
Total		**230**

In July of 2010 a total of 41 tagged fish were released above the barriers at the Alton boat launch and the Bubbly Creek turning basin with no barrier approaches recorded. Largemouth Bass, *Micropterus salmoides* (n=12, 209.6 ± 82.7 mm (8.25 ± 3.3 in) and Common carp (n=27, 566.9 ± 69.8 mm (22.3 ± 2.7 in) were released upstream of the barriers in five groups from 8 October through 15 November 2013 to replace expired transmitters. Fish were released closer to the barriers location compared to the 2010 releases in an attempt to elicit more barrier approaches with 15 fish released within a barge slip just upstream of the I-355 overpass and 24 released just upstream of the demonstration barrier (Figure 01).

Figure (01): Map of release locations within the Upper Lockport pool for 2010 and 2013



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 2012 were redeployed in late March, 2013 with a few minor revisions to the layout of receiver positions within the study area. Those receivers close to the lock gates were relocated several hundred feet further away from the structures to reduce interference from mechanical and engine noise which could potentially mask detections from transmitters. The receiver network was expanded in the Marseilles pool and increased detection capabilities at exit points within the system, such as tributaries and large backwaters. The study area was covered by 38 stationary receivers extending for approximately 77 river miles from the Calumet-Saganashkee Channel in Worth to the Marseilles Lock on the Illinois River.

Small Fish Study – On 3 and 4 October 2012, USACE biologists captured and surgically implanted ultrasonic transmitters (Vemco V6 180 kHz) into 14 small fish captured from the Lockport pool at or within 3 miles downstream of the Dispersal Barrier Systems. Species captured included 13 Green Sunfish (*Lepomis cyanellus*) and one Pumpkinseed (*Lepomis gibbosus*). In general, the total length of fish averaged 106 mm (4.2 in) with a minimum of 92mm (3.6 in) and a maximum of 132 mm (5.2 in). Species for tagging were selected based on body type, total length, swimming characteristics (speed, position in water column), and availability of our catch. Fish were captured using mini-fyke nets and modified minnow traps. All fishes were surgically implanted using the same methods documented in the Monitoring and Rapid Response Plan (MRRP) Interim Summary Report (2012). Fish were released after they were deemed viable and able to freely swim under their own power. Tagged fish were released in two batches with seven fish released upstream of the active Barrier IIB and seven fish downstream. Fish movements were continuously tracked by stationary receivers and mobile tracking occurred in the area one week after release.

Barge Interaction Trial – Barge traffic through the electric dispersal barrier system has been identified as a pathway of concern for potential fish bypassing the electric dispersal barriers. Research conducted by the USFWS (Carterville) in the field and the USACE (Engineering Research and Development Center) in the laboratory has indicated barrier bypass mechanisms may be possible. Preliminary findings indicated that 1) vessel-induced residual flows can trap model fish and transport them beyond the electric dispersal barriers; 2) slow vessel speeds tend to transport model fish the farthest in the direction of the tow; 3) high vessel speeds produce the strongest reverse current, which transports model fish in the opposite direction of the vessel; and 4) the dominant transport mechanism in the direction of the tow movement is in voids between barges or between a barge & the towboat and in wake flow behind the trailing barge(s) and beside the towboat (USACE, 2013). Results from both agencies were derived from either the study of model fish in the lab (soft plastic lures) or tethered and caged fish in the field. Ultrasonic telemetry was identified as an alternative method to assess fish reaction to commercial vessels in situ.

On 4 November 2013, USACE biologists captured and surgically implanted ultrasonic transmitters (Vemco V6 180 kHz) into 13 large bodied Common Carp (*Cyprinus carpio*) (TL_{mean} ± SD =552 ±78mm (21.7 ± 3.1 in)). All fishes were captured from the barge slips just upstream of the I-355 overpass, approximately 3.5 miles upstream of the electric dispersal barriers. Fish were implanted with transmitters following protocols referenced in the above sections and were released from the bow deck of a moving barge as it approached the barriers in the upstream direction. A single tow was pushing two barges in series with a rake-to-box junction between them. The fish were released in two groups of 4 and one group of 5 specimens which were held on standby in a holding tub on deck. All releases occurred between the Romeoville Road Bridge and barrier IIA via a fitted, angled tube through the bow to reduce the impact stress imposed. All fish movements were recorded with the existing Vemco Positioning System established with VR4 receivers around the electric dispersal barriers.

Movement and Habitat Analysis – During the end of the 2012 sampling season and the beginning of 2013, 56 Asian Carp were tagged within the Marseilles and Dresden Island pools. In Marseilles, 16 Bighead Carp (886 ± 65 mm (34.9 ± 2.6 in)) and 15 Silver Carp (738 ± 43 mm (29.1 ± 1.7 in)) were tagged while 20 Bighead Carp (931 ± 79 mm (36.7 ± 3.1 in), 3 Silver Carp (788 ± 18 mm (31 ± 0.7 in)), and 2 hybrids (837 ± 173 mm (33 ± 6.8 in)) were tagged in Dresden Island. Mobile tracking and VR2W receiver data were combined together for analysis beginning in early spring 2013 and imported into ArcMap 10.1. Distance was measured between detections by following the main channel of the river and converted to km/day. For analysis, only fish with more than 14 days of data were used. It is assumed that fish with less than 14 days were removed from the system before sufficient data could be obtained. Fish that demonstrated no movement for the life of the tag or only downstream movement were also removed from the analysis. In addition, the mobile tracking unit and VR2W receivers are said to have a range of 0.8 km (0.5 mi). When a fish was detected, it is assumed that the fish is at that GPS location of the detection therefore the distances provided may obtain a measurement error up to 1.61 km (1 mi) between two separate detections. A one-way analysis of variance (ANOVA) was used to determine total movement differences between Silver and Bighead Carp within Marseilles pool as well as compare differences between total Bighead Carp movements across Marseilles and Dresden Island pools.

Seasonal movements were determined from fish that were detected within 24 hours between two different receivers. Distances were measured and converted to km/h traveled. The season were split into four categories spring (March, April, and May), summer (June, July, and August), fall (September, October, and November), and Winter (December, January, and February). A two-way ANOVA was used to determine if there were differences in seasonal movements (Spring and Summer) of Bighead Carp across both pools. Data from spring of 2013 through Fall of 2013 was used for this analysis. In addition, differences between seasonal movements of Silver and Bighead Carp within the Marseilles pool were investigated via a two-way ANOVA. Since Silver Carp and Bighead Carp were tagged in the Marseilles pool in Fall of 2012, data started from that time period through Fall of 2013.

Diel movement patterns, movement throughout the 24 hour daily period, of Asian Carp were also investigated. Days were split into three diel periods: day, night, and crepuscular. Crepuscular was defined 2 hours before and after sunrise and sunset as defined in Bauer et al. (2009). Sunrise and sunset calendars were used to determine approximate times for crepuscular periods for each month. Movement time was determined by the first and last detection on each receiver. For instance, when a fish entered the detection range of a receiver the time was recorded and a time period was given to that detection. Then a time period was assigned to the last detection on that receiver, indicating movement out of receiver range. A 3 x 3 chi-square analysis was conducted to determine if proportions of movements within seasons (fall, summer, and spring) and diel period (night, day, and crepuscular) are related. Statistical analyses were conducted with SAS 9.2 (Cary, N.C) and a significance level $p<0.05$ set.

Results and Discussion: The results discussed in this section will address the three goals of the study. As of December 2013, 8.9 million detections from 315 tagged fish have been recorded within the study area. Results to date have indicated that no tagged fish have crossed any of the electric dispersal barriers in the upstream direction.

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

Large Fish Testing above barriers: Common Carp and Freshwater Drum (*Aplodinotus grunniens*) were tagged and released above the barriers in 2010 to assess behavioral reactions to the barriers from the upstream direction as well as preferred waterway usage within the CSSC and Cal-Sag Channel. Previous interim summary reports from these years have explained that tagged fish above the barriers displayed minimal movement in the downstream direction toward the barriers with the southernmost detection occurring near Lemont, IL on the CSSC (10.6 miles downstream of release point). The majority of detections occurred on receivers located around the confluence of the CSSC and Cal-Sag Channel. While many of the tags implanted in 2010 expired due to transmitter battery life by December 2012, a portion of these fish (n=20) maintained active tags through 12 February 2013. No detections were recorded however for these tags during the 2012-2013 winter indicating they were outside the detection range of existing receivers or had been removed from the waterway.

All fishes released just upstream of the demonstration barrier in 2013 (n=24) were detected on receivers located at the barriers while only one of fifteen Common Carp released just upstream of I-355 was detected at the barriers. Of the 25 fish to approach the barrier system, 2 Common Carp and 6 Largemouth Bass passed downstream into the Lower Lockport pool through the barriers. A Fishers exact test was used to determine if there was a significant difference among the proportion of each species released just upstream of the barriers that passed downstream. Downstream passage occurred with 50% of the Largemouth Bass (n=12, 209.6 ± 82.7 mm (8.25 ± 3.3 in)) and 8.3% of Common Carp (n=12, 528.9 ± 70.5 mm (20.8 ± 2.8 in)). Although no significant differences were observed (P=0.068), observationally, it appears that smaller fish were more likely to move through the electric dispersal barrier system.

Large Fish Testing at and below barriers: There have been 86 tagged fish (69 kHz, V16 transmitters) greater than 300 mm (12 in) 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 December 2013. During this period of analysis, 27 individual fish (31.4%) 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 (16.3 in) and 665 mm (26.2 in) with a mean total length of 567 mm (22.3 in). 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 160.2 meters. There was only one occasion in which a fish was able to penetrate the wide array and was positioned 3.43 meters (±9.8 m) 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. The mean distance to the active barrier for approaches was analyzed between Barrier IIA and Barrier IIB (paired two sample t-test; *P=0.07*) and found to be not significant. This result could be skewed by the low sample size (n=3) of individuals who were detected by the VPS to approach both barriers independently. It is hypothesized that this relationship will become significant as more data is collected. To further examine the trends that were being observed, an un-paired two sample t-test was conducted on the total groups approaching the barriers. The mean distance to Barrier IIB for approaches was found to be further than the mean distance for approaches to Barrier IIA (*P=0.01*). Mean distance to barrier for approaches was related to the placement of parasitic arrays downstream from the active barrier's electrode array. The mean distance to active Barrier IIB for approaches was 43.9 m which lined up with the downstream edge of parasitic 2 (42.7 m). Similarly, the mean distance to active Barrier IIA for approaches was 26.3 m, only 2.3 m off from the distance between the downstream edge of parasitic 1 and the wide array of Barrier IIA (28.9m). Figure 02 shows a typical approach for a fish detected at Barrier IIB to further illustrate this relationship. Upon analyzing barrier electric field mapping conducted by the Engineer Research and Development Center's Construction Engineer Research Laboratory (ERDC-CERL) it can be seen that tagged fish were reacting to field strengths between .1 and .5 V/in (Figure 02).

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 103 minutes with a range from 2 to 287 minutes. Residency time was positively correlated with mean daily discharge (cubic feet per second, cfs) (Figure 03) with greater flows equating to longer time spent within the VPS array. This relationship can be explained by the rheotactic response of Common Carp to swim against the flow of water (Smith el al, 2005). However, it should also be noted that this relationship is only present in the data collected for fish that approached the barriers. The maximum mean discharge per total approaches recorded for an individual fish was 4515 cfs. The maximum discharge for a single approach to the barrier for any fish was 6853 cfs. Throughout the period of analysis, daily mean discharge rates periodically peaked as high as 17249 cfs. It is expected that a maximum discharge rate exists for fish to challenge the barrier before they are no longer able to maintain position in the open canal before experiencing fatigue.

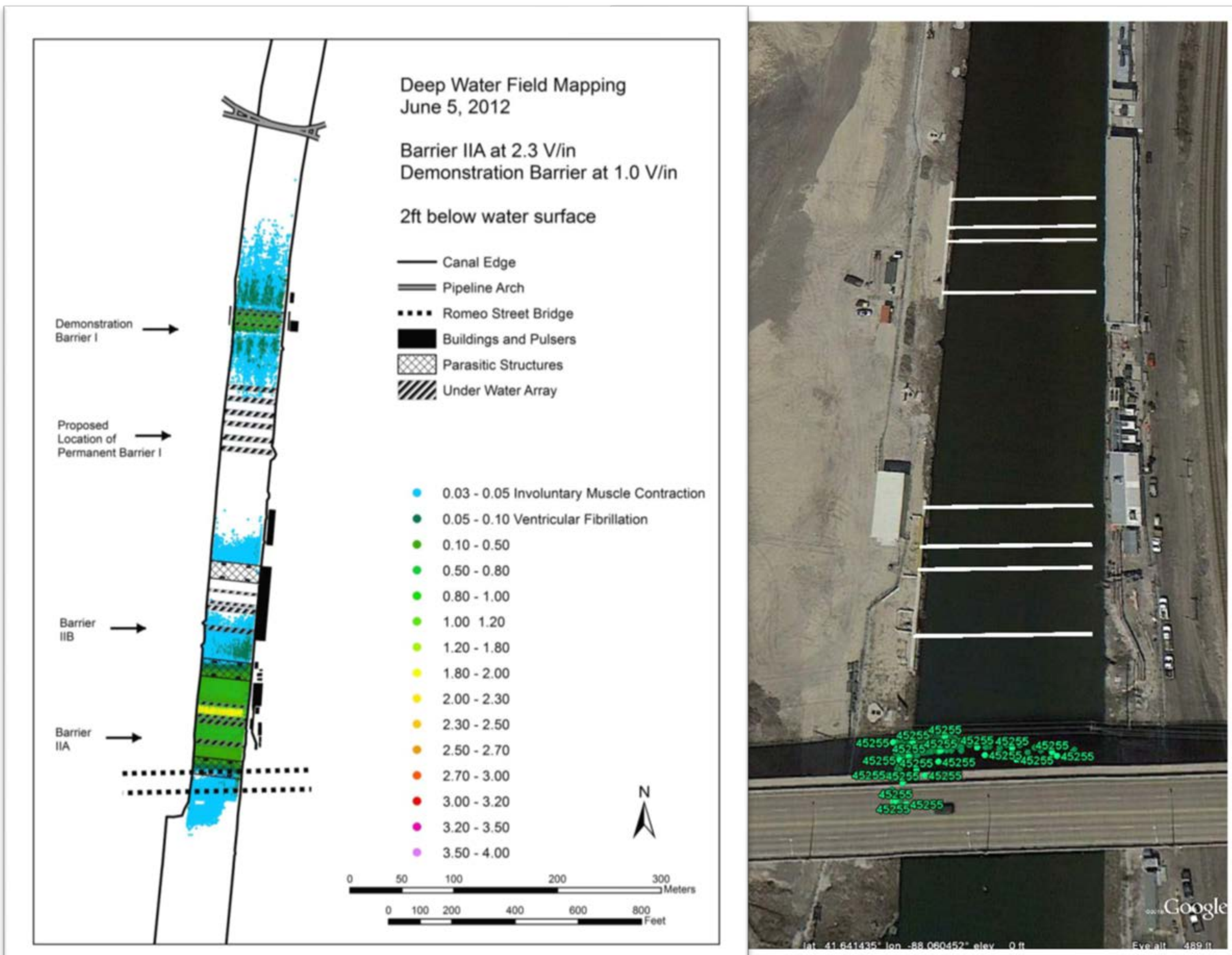


Figure 02: Left: Electrical field mapping by ERDC-CERL of the Dispersal Barriers indicating an increased electrical field beginning at the parasitic 1 array. Right: Typical fish approach displayed as positional data points just downstream of Barrier IIA.

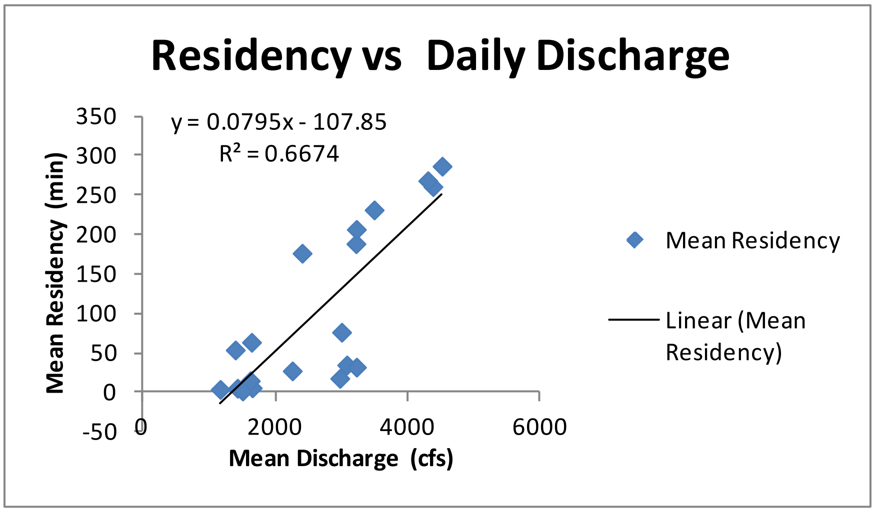


Figure 03: Mean residency time (min) of individual fishes compared to the mean daily discharge (cfs) during those periods.

Small Fish Testing at barriers: Mobile tracking and VPS results of the small fish study on 3-4 October indicated that a majority of the tagged fish (57%) had left the vicinity of the barrier seven days after deployment. As tracking occurred using the mobile VR100 receiver, only 6 unique tag IDs were detected near the Dispersal Barrier System indicating the remaining 8 fish were no longer in the study area. Mobile tracking upstream of the Dispersal Barrier System did not indicate any upstream passage. All fish movements near Barriers IIA and IIB were recorded by the Vemco Positioning System. Positional data confirmed that there was no upstream passage through the active Barrier IIB from the seven fish released downstream and only two of those fish moved upstream toward the active barrier. Both upstream movements were made by Green Sunfish released downstream of Barrier IIB and approached the barrier on 6 and 7 October. The fish that approached on 7 October (105 mm, 4.13 in) reached the wide array before turning back downstream. The fish that approached on 6 October (120 mm, 4.73 in) moved upstream through the wide array and then remained between the wide and narrow array for several hours before losing detections. All seven fish released downstream utilized crevices within the west canal wall at one point during the period of analysis with short range movements into the canal both up and downstream.

Out of the seven fish released upstream of Barrier IIB, two fish moved downstream through both the narrow and wide array. One of these fish maintained its position along the west bank just upstream of the narrow array for seven days before moving downstream. Three additional fish moved downstream into the narrow array where they maintain position for several days before drifting downstream or losing signal. Because of the period of time elapsed while the fish were inside the narrow array and no indications of upstream movement after that exposure, these fish were assumed to have died within the narrow array. The remaining two fish did not have positions detected within or below the narrow array of Barrier IIB.

Barge Interaction Trial: The VPS triangulated no positions for any tagged fish released during the barge interaction trial. Four carp were detected via mobile tracking below the Romeoville Road Bridge approximately 2 days (6 Nov) after release. Mobile tracking data also indicated no detections upstream of the barriers. Upon release on 4 November, all tagged fish were detected on the most downstream receivers with detection rates dropping on receivers in the upstream direction. These results strongly suggest that no fish were carried into or over the barrier arrays via entrainment by the barge combination from which they were released. However, it should also be noted that noise generated from barge traffic has been observed to reduce the detection rate of transmitters in close proximity. This may have obscured detection data for transmitters during the passage of the barge at the onset of the trial. Our conclusion has accounted for this by taking into account mobile tracking and receiver data after the barge had passed.

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

In 2013, there were thirteen occurrences of tagged fish moving downstream and three occurrences of upstream movement between navigation pools by a total of 13 individual fish. Inter-pool movement was greatest across the Dresden Island Lock and Dam between the Dresden Island and Marseilles pools accounting for 62.5% (10/16) of all inter-pool movements. Of the ten transfers recorded between these two pools, eight occurred in the downstream direction and two upstream. Movement between the Lockport and Brandon Road pools comprised 31.3% (5/16) of all inter-pool movement with the dominant direction being downstream (80%). There was only one movement detected between the Brandon Road and Dresden Island pools in the downstream direction. Table 2 below displays the total inter-pool passages in 2013.

Table 02: Total detections of tagged fish inter-pool movement in 2013.

Lock and Dam	**Total Passages**	**Direction of Travel**
Lockport	1	Upstream
Lockport	4	Downstream
Brandon Rd	0	Upstream
Brandon Rd	1	Downstream
Dresden Island	2	Upstream
Dresden Island	8	Downstream

A two-sample T-test (assuming unequal variance) was used to compare discharge rates during up and downstream inter-pool movements. As in previous years, downstream inter-pool movement occurred at higher discharge rates than upstream movements (P=0.0005) with mean discharge around 9251 cfs and 2757 cfs respectively. Although the disparity between upstream movements (n=3) and downstream movements (n=13) was relatively high, it was quite evident that the results of the T-test were correct. Both upstream movements from the Marseilles to the Dresden Island pool were initiated by Bighead Carp originally released within the Dresden Island pool. It should also be noted that both upstream movements occurred within 24 hours of one another on 16 and 17 July. The final upstream movement through the Lockport lock occurred in late spring on 17 May by a Common Carp. The majority (53.8%) of downstream movements occurred within the spring months (March-May) when high flow events within the waterways were more prevalent. Within the Lockport pool, there were two paths of movement identified for fish moving into the Brandon Rd pool. Two fish were recorded moving through the Lockport Lock, while the remaining two fish were recorded moving through the Lockport Controlling Works spillway into the Des Plaines River. These fish proceeded downstream past the confluence with the CSSC just below the Lockport Lock and continued movements both up and downstream within the Brandon Rd pool indicating they were still alive and active following the transition.

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

During the end of the 2012 sampling season and the beginning of 2013 56 Asian Carp were tagged within the Marseilles and Dresden Island pools. In Marseilles, 16 Bighead Carp and 15 Silver Carp were tagged while 20 Bighead Carp, 3 Silver Carp, and 2 hybrids were tagged in Dresden Island. Movements of these fish were recorded mainly through the use of mobile tracking and supplemented by multiple VR2W receivers located throughout both pools (Map A). Since the fish were tagged and released within the system, 64% of the fish were successfully tracked or detected on a VR2W receiver at least once during the 2013 sampling season. Within the Dresden Island pool, total distances traveled by Asian Carp ranged from 7.75 to 240 km with km/day ranging from 0.08 to 3.28. In the Marseilles pool, total distances and km/day for Asian carp ranged from 3.78 to 124 and 0.01 to 0.44, respectively. Total distances (km/day) were not significantly different between species of Asian Carp with Marseilles pool (ANOVA; $F = 4.19$, $df = 1, 28$, $P=0.49$). Total distances (km/day) traveled by Bighead Carp were significantly greater within Dresden Island pool than in Marseilles (ANOVA; $F=4.19$, $df = 1,28$, $P=0.002$). While significant, these differences are most likely due to the unequal receiver coverage across both pools.

Due to the lack of tagged Silver Carp within Dresden Island pool, seasonal movement analyses across pools were confined to just Bighead Carp. In addition, winter and fall data were minimal (i.e. only one fall movement within Marseilles pool during 2013) and did not allow for proper analysis so these data points were excluded. The overall model to determine differences in seasonal movements of Bighead Carp amongst both pools was significant (ANOVA; $F=4.08, df=3,48$, $P=0.01$) with greater movements occurring in summer than spring ($F=6.37$, $df=1$, $P= 0.01$, Figure 04). Increased summer movements may be due to increase foraging activity as productivity within the river increases. However, the data show a much larger increase in movement within the Dresden Island pool and appears to be driving the relationship. The increase movement in the Dresden Island pool may be due to the greater amount of receiver coverage. No significant seasonal differences in movement were observed amongst species within the Marseilles pool (ANOVA; $F=0.99$, $df=5,55$, $P=0.43$).

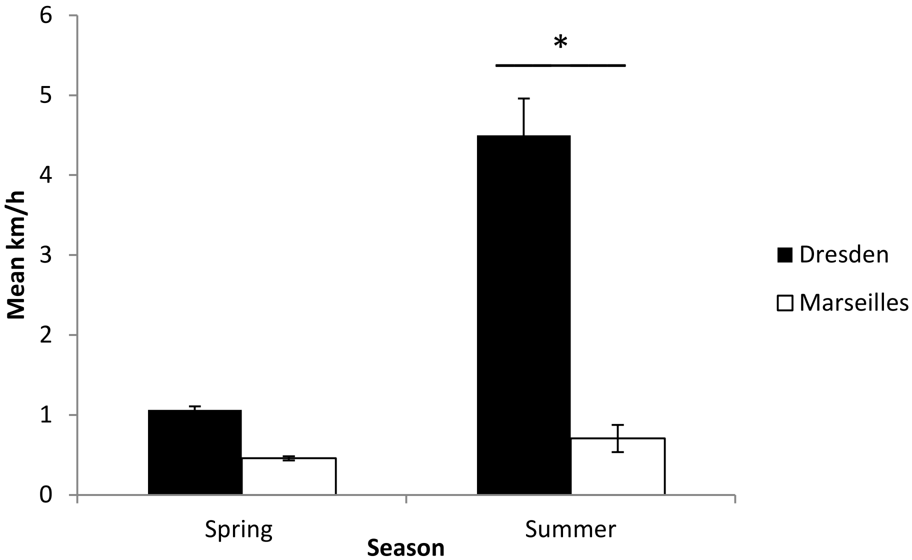


Figure 04.— Mean differences (SE) in seasonal movements of Bighead Carp within pools and across seasons. Asterisk (*) indicates a significant difference across season at a critical value of P<0.05.

Proportions of observed movements within season and diel periods were significant (χ^2=52.02, df=4, P=<0.0001). Fall movement observations were much lower than spring and summer. Fish in the fall tended to stay put for longer periods of times which is the likely cause for the observed differences. Similarly, greater number of observed movements occurred during the crepuscular and night diel periods (Figure 05). These data are expected as many fish tend to be more active during crepuscular and night periods.

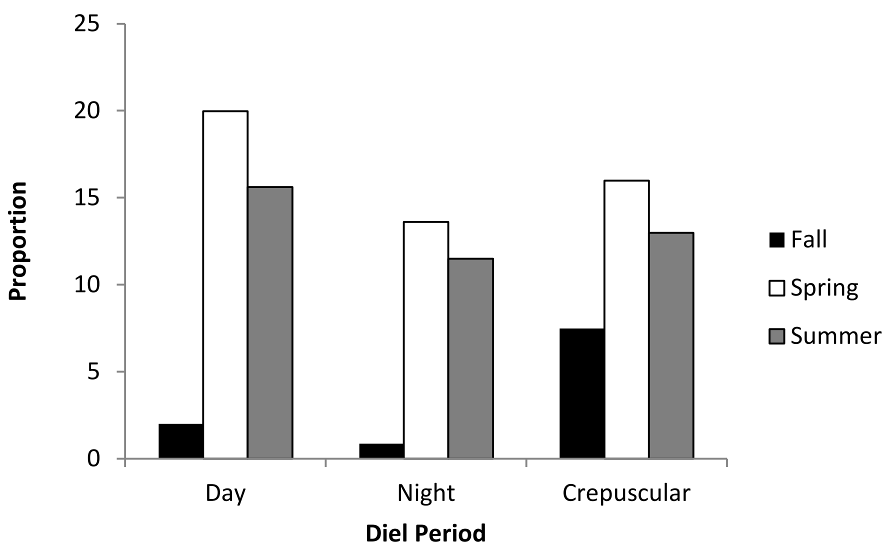


Figure 05.— Proportions of Silver and Bighead Carp movements by season and diel period. Day, night, and crepuscular consisted of 25.97%, 36.45%, and 37.58% of observed movements, respectively. In addition, fall, spring, and summer consisted of 10.36%, 49.56%, and 40.07% of

the observed movements, respectively. A chi-square analysis was found to be significant ($p=<0.0001$), indicating differences in proportions.

Twenty tagged Asian Carp were released at Big Basin Marina and 5 were released in Rock Run Rookery within the Dresden Island pool. Every fish included within this analysis was at least tacked once within the vicinity of the Kankakee River Confluence with 14 fish (70%) tracked approximately 2 miles upstream within the Kankakee River. In addition, 17 (85%) of the tagged fish utilized Rock Run Rookery at some point throughout 2013. One tagged fish was detected by a stationary receiver just below Brandon Road Lock and Dam before moving back downstream. The leading edge of the Asian Carp population, based on tagged fish, still appears to be at river mile 281.5 near Rock Run Rookery. In the Marseilles pool, 15 Silver Carp and 16 Bighead Carp were tagged and released. All fish tagged were released within Hanson Material Services (HMS) East Pit except for 13 Bighead Carp which were tagged at the Stratton Boat Ramp. Twenty-nine (94%) of the fish tagged within Marseilles utilized the HMS East Pit at some period of time. All fish tagged at the Stratton Boat Ramp returned to the HMS east pits. Five Bighead Carp and 8 Silver Carp swam upstream and were detected below the Dresden Island Lock and Dam, but no fish were located upstream of the lock. This observational data demonstrates the high usage of the HMS East Pits, Rock Run Rookery, and the Kankakee River by Asian Carp. The lack of receiver coverage within the Kankakee limits our ability to determine how important the Kankakee River is and should be addressed in future studies.

Recommendations:

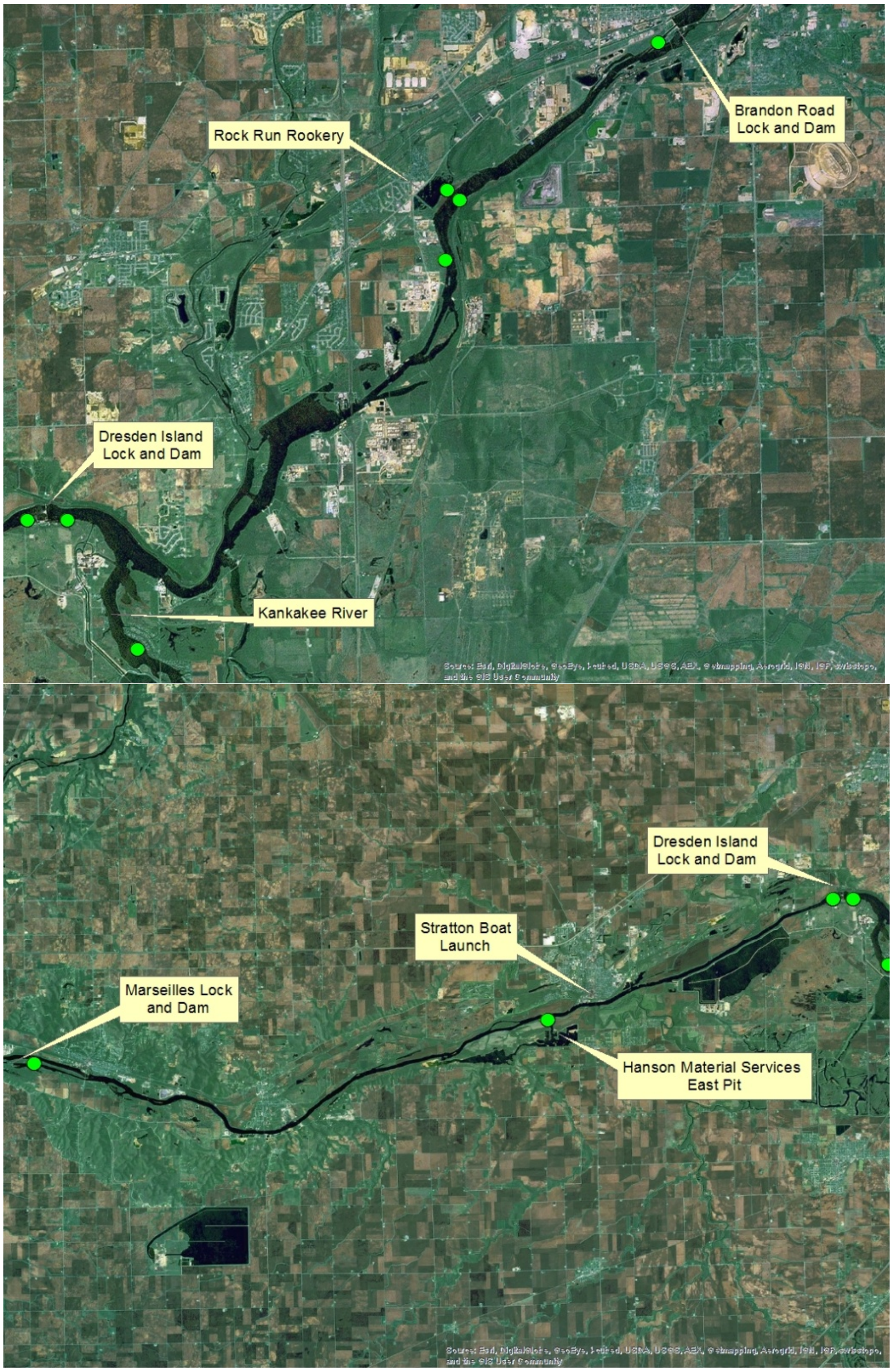
USACE recommends continuation of the telemetry program and maintaining the current level of surrogate species tags within the system while increasing the number of tagged Asian carp within the Dresden Island pool. Currently, USACE receiver coverage overlaps significantly with receiver coverage from Southern Illinois University Carbondale within the Marseilles pool. USACE recommends moving receivers within the Marseilles pool into the Dresden Island pool and Kankakee River to increase detection resolution while maintaining open communication with SIUC for data sharing and recovery downstream. In order to increase the chances of future tagged fish approaching the barriers, additional tagged fish within the Lockport pool should be captured on the opposite side of the barriers than their release. Also, it is recommended that a portion of our fish released in vicinity of the barriers should contain depth sensor tags to begin analyzing how fish use the entire water column in response to the barriers, barge traffic and clearing events between the electric dispersal barriers.

Project Highlights:

- To date, we have acquired 8.9 million detections from 315 tagged fish
- Our conclusion for testing to date from the small fish and adult fish telemetry studies is that the barriers are effectively preventing all upstream passage of tagged fish.
- Fish approaching the Dispersal Barriers spend a greater amount of time challenging the barriers with increased discharge rates
- Common Carp over 381 mm in total length are repelled by electric field strengths as low as .1 to .5 V/in

- Inter-pool movement of tagged fish occurs in both directions through all locks within the study area with the exception of upstream movement through the Brandon Rd lock.
- Asian Carp are consistently using the Kankakee River, Hanson Material Services East Pit, and Rock Run Rookery.
- While two tagged Asian Carp have approached the Brandon Road Lock and Dam to date, it appears that the Asian Carp population front is still located at river mile 281.5 near Rock Run Rookery
- Both Silver and Bighead Carp move similarly within the Illinois River
- Bighead Carp appear to be more active during the summer months
- Proportions of diel and seasonal movements are related, with the majority of the movement occurring during spring and summer as well as at night and crepuscular diel periods.

Map A.



Top: Map of Dresden Island pool with important areas marked. Bright green circles indicate VR2W receiver placement. Bottom: Marseilles pool with important landmarks and receiver placement.

Monitoring Fish Abundance, Behavior and Fish-Barge Interactions at the Barrier

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

Part I of this report addresses the following objective from the 2013 Monitoring and Response Plan for Asian Carp in the Upper Illinois River and Chicago Area Waterway System : #5: Evaluate fish behavior between the narrow arrays where the highest-voltage electrical field is located.

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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), USACE-Champaign Construction Engineering Research Laboratory (field/logistical support).

Introduction

Beginning in June 2011, the U.S. Fish and Wildlife Service's (USFWS) Carterville Fish and Wildlife Conservation Office (FWCO) began evaluating wild fish populations and their behavior within the Electric Dispersal Barrier system located in the Chicago Sanitary and Ship Canal (CSSC). Using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, WA) unit, we evaluated fish populations throughout the entire barrier system, which covered the entire gradient of barrier voltages (0 – 0.91 V/cm), and also performed concentrated evaluations directly over the strongest part of the barrier. Results of our sampling across the entire Electric Dispersal Barrier system using DIDSON equipment revealed a significant accumulation of fish below the active barrier, similar to the findings of Godlewska et al. (2007). Some of the fish that were immediately below the active barrier were observed persistently probing and challenging the barrier, which was consistent with other observations of fish behavior at electric barriers (Stewart 1981; Savino et al. 2001; Holliman 2011). We defined "probing" behavior as persistent movement up and down and/or sideways along an invisible plane (in this case the barrier). "Challenging" was defined as fish swimming upstream into the barrier and being able to penetrate further than the other fish that were probing.

Because of the significant amount of fish accumulating below the active barrier and the persistent probing and challenging behavior observed, a secondary set of sampling began, in April 2012, focusing solely on the portion of the Electric Dispersal Barriers containing the ultimate field strength of 2.5 ms, 30Hz, 0.91 V/cm (2.3 V/in). The ultimate field strength of 0.91 V/cm covers approximately 2 m of the water surface between the narrow arrays of the Electric Dispersal Barrier, which are 9 m apart at the canal bottom (Holliman 2011). Sampling this area required positioning a DIDSON-equipped boat between the narrow arrays of the Electric Dispersal Barrier, and ensonifying the volume of water immediately below the surface and adjacent to the western canal wall (Figure 1).

We focused our concentrated sampling effort on the water surface near the western canal wall within the zone of ultimate field strength. This sampling location was chosen following previous DIDSON sampling events, which had covered multiple areas within the zone of ultimate field strength. Those surveys showed that when fish occupied that part of the barrier, that they were most abundant at the water surface, near the canal walls.

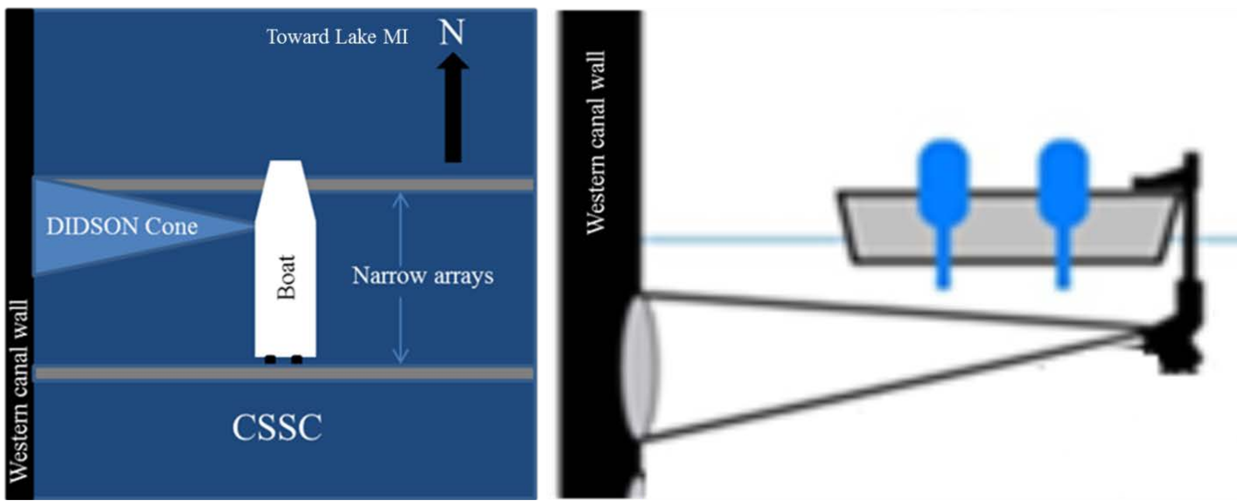

Figure 1. Top- and side-views of a single boat-mounted DIDSON unit ensonifying a section of the western canal wall between the two narrow arrays of the Electric Dispersal Barrier.

During this sampling, we again observed numerous fish persistently challenging the Electric Dispersal Barrier including within the ultimate-field-strength zone, especially during the fall of 2012. During this time, the sizes of fish that were observed challenging the barrier ranged in size from 7 – 18 cm (2.8 – 7 in) total length, and some of the schools of fish that were observed challenging the barrier were estimated to contain as many as 300 fish. No fish were observed becoming incapacitated by the barrier during these observations.

During this concentrated sampling, there were also multiple incidences in which fish were observed swimming across the entire DIDSON viewing cone both upstream and downstream. However, no conclusions could be drawn as to whether actual breaches of the Electric Dispersal Barrier had occurred. The hesitancy to draw definitive conclusions regarding breaches was due, in part, to the limited amount of water that a single DIDSON viewing cone was able to ensonify. While the width of the narrow array structures of the barrier is 9 m, the maximum width of our single DIDSON viewing cone is 5.5 m. Further complicating the interpretation of the DIDSON footage between the narrow arrays was the movement of the boat (and subsequently the viewing cone) within the canal as we tried to hold position using the boat's engine (for safety reasons the boat could not be anchored to the bottom or fixed to shore).

Based on these data suggesting potential fish breaches of the barrier could have occurred, we began pursuing options for deploying two DIDSON units off of a fixed structure. From July 30 to August 1, 2013, we were able to perform our first sampling event over the narrow arrays using two DIDSON units that were deployed from a fixed structure. This report is intended to briefly describe the methods and preliminary results of the use of stationary dual DIDSON equipment at the Electric Dispersal Barrier system.

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 arrays could be ensonified (Figure 2). On the western bank along the canal, workers from the U.S. Army Corps of Engineers (USACE) Champaign Construction Engineering and Research Laboratory (CERL) determined the exact locations of the inside narrow array margins and the area of highest 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 (Figure 3). The location of the highest in-water voltage was determined using a Pacific Instruments 6000 Series Data Acquisition System (Pacific Instruments, INC., Concord, CA; Figure 3). These locations were marked with flagging tape and were used as reference points to deploy square, plastic buckets into the water. The buckets were filled with foam and had a hollow tube in the middle, which allowed a rope to be placed through it. A non-conductive weight was then tied to the end of the rope and deployed underwater until it was about 1 m above the canal bottom. After the other end of the rope was tied to the shore, the tautness of the rope, and the flat edges of the buckets against the canal wall, kept the bucket markers in a steady position throughout the sampling periods to serve as points of reference. The foam inside of the bucket and hollow tube in the middle of the foam allowed the bucket to move up and down the rope freely in the unlikely event of water level changes. Throughout the time in which the buckets were serving as reference markers, the USFWS worker on duty periodically checked them to ensure that they were correctly aligned with the land markers.

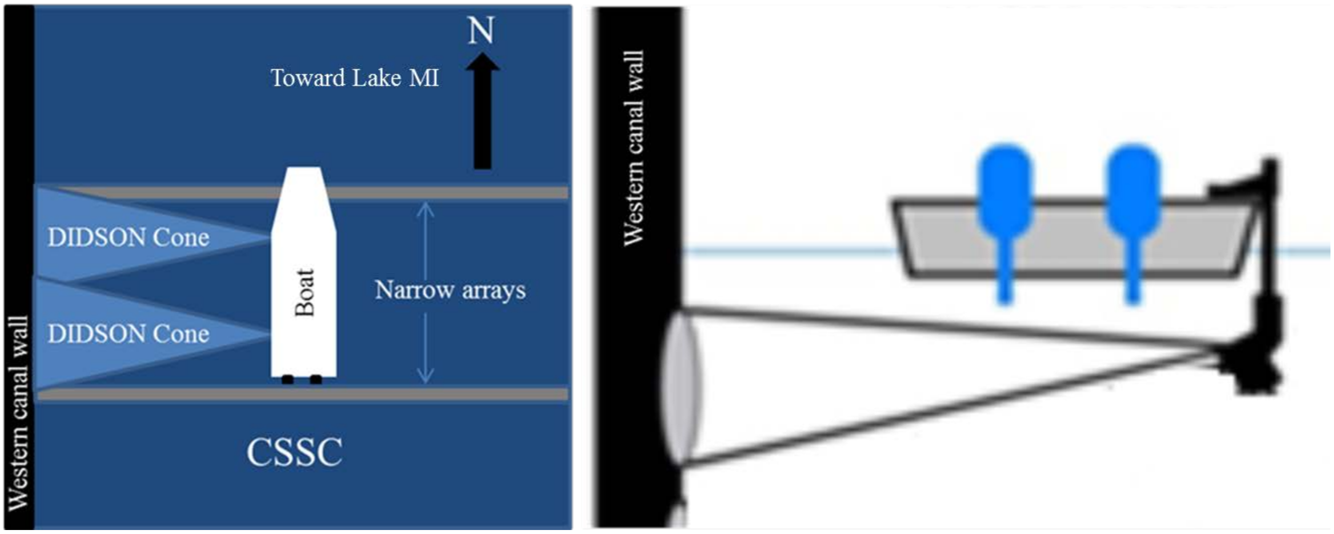

Figure 2. Top- and side-view schematics of two boat-mounted DIDSON units ensonifying a section of the western canal wall between the two narrow arrays of the Electric Dispersal Barrier.

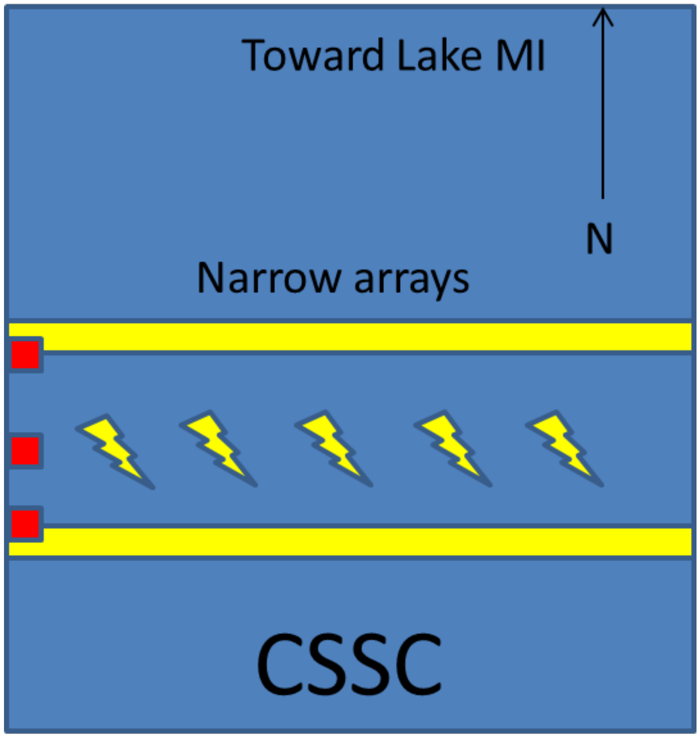

Figure 3. Schematic of the narrow array barrier structures within the CSSC. The red squares denote where the reference markers (buckets) were placed signifying the locations of the inner narrow array margins and the location of the ultimate field strength.

To deploy the DIDSON units into the canal from the western canal bank, a mobile telescopic boom lift was used (Figure 4A-C). The DIDSON units were attached to custom-made mounts including a dielectric coupler, which attached the DIDSON mount to the cage at the end of the boom, thus electrically isolating the boom lift from the Electric 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 (Figure 4D).

Figure 4. Two DIDSON units being deployed into the CSSC using a telescopic boom lift (A-C) and the two DIDSON units being operated on one computer (D).

The two DIDSON units were able to ensonify the entire width of the 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 (Figure 5).

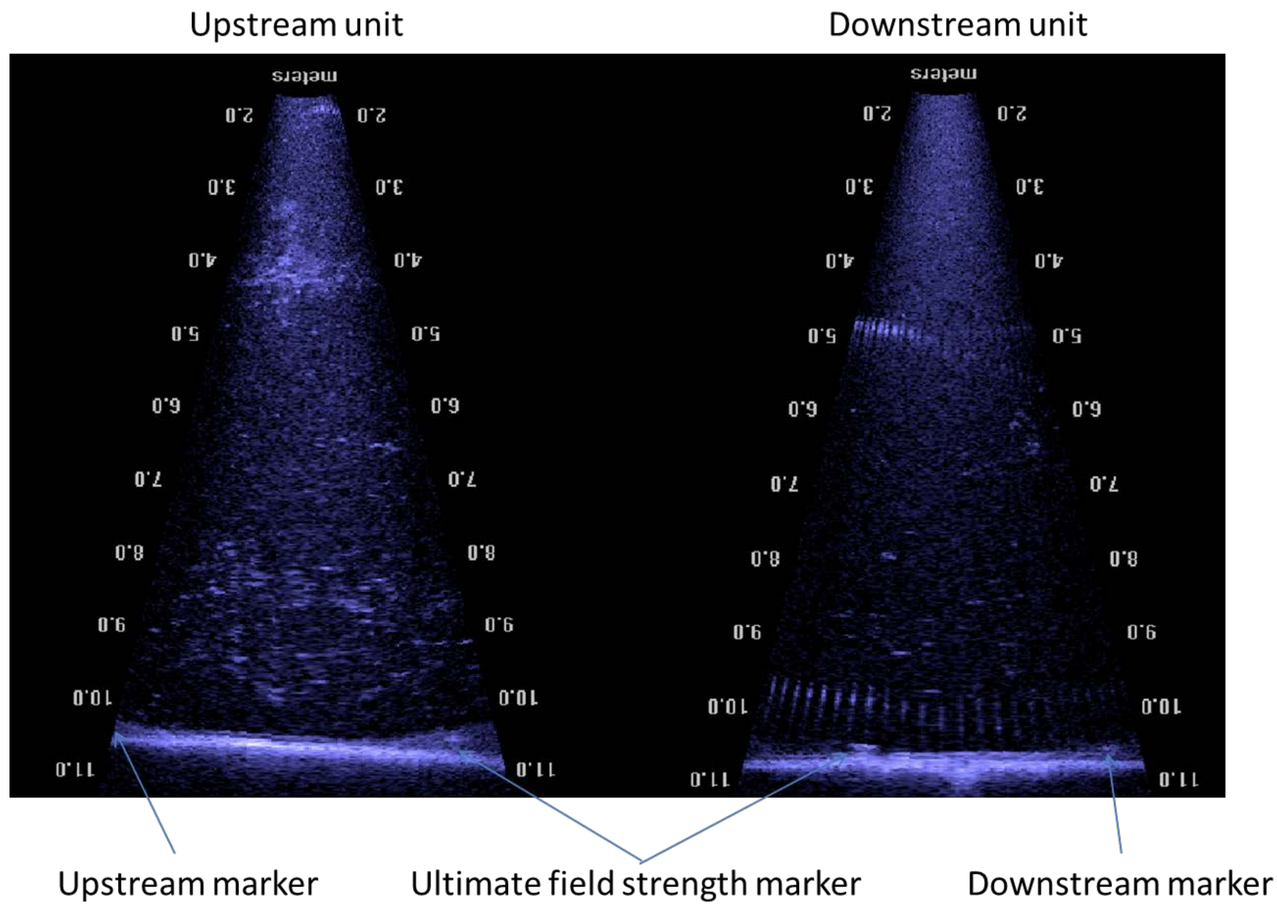

Figure 5. Viewing cones of the upstream and downstream DIDSON units and the three markers along the western canal wall.

In total, 72 DIDSON recordings took place in 10-minute intervals and occurred back-to-back as much as possible, with the only interruptions occurring during barge passages through the Electric Dispersal Barrier. The DIDSON samples were taken back-to-back in order to obtain the maximum amount of data possible during our allotted sampling period. When barges traversed the Electric Dispersal Barrier, the DIDSON units were removed from the water and the boom was rotated over land.

The initial review of the DIDSON footage consisted solely of enumerating the number of ten-minute recordings in which a breach occurred and measuring the average sizes of the fish that breached using the DIDSON software measurement tool. A breach was considered to have occurred when fish were observed swimming past the ultimate-field-strength marker and then proceeded to swim upstream through the upstream DIDSON viewing cone and out of view. Because the viewing windows produced by the DIDSON units are cone-shaped, there was the potential for fish to briefly swim out of the viewing areas if they were physically closer to the DIDSON units and thus within the narrow parts of the viewing cones. In these cases, if a fish or a school of fish were observed swimming upstream out of the downstream viewing cone and then immediately observed swimming into the upstream viewing cone, a breach was recorded.

Results and Discussion

From July 30 to August 1, 2013, we were able to obtain 72, 10-minute recordings with the paired DIDSON units. The number of recordings that we were able to perform was reduced during the first two days because of inclement weather, which created unsafe working conditions. Although we were not able to record as much footage as we intended, the results that we did obtain were revealing. Throughout the entire sampling period, large schools of fish were observed between the narrow arrays persistently probing and challenging the Electric Dispersal Barrier.

Out of the 72 recordings that were taken, 44 (61%) of them captured at least one occurrence of fish breaching the Electric Dispersal Barrier. Of those 44 recordings which captured fish breaches, 27 (61%) of those revealed multiple fish breaches of the Electric Dispersal Barrier (Figure 6). The sizes of the fish that breached the barrier were estimated to range from approximately 5 to 10 cm (2 to 4 in) total length. All of the fish observed breaching the barrier did so in schools. 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. Our results appear to be similar to those of Holliman (2011) who found that schools of Bighead Carp (*Hypophthalmichthys nobilis*) were more likely to challenge an electric barrier than individual fish.

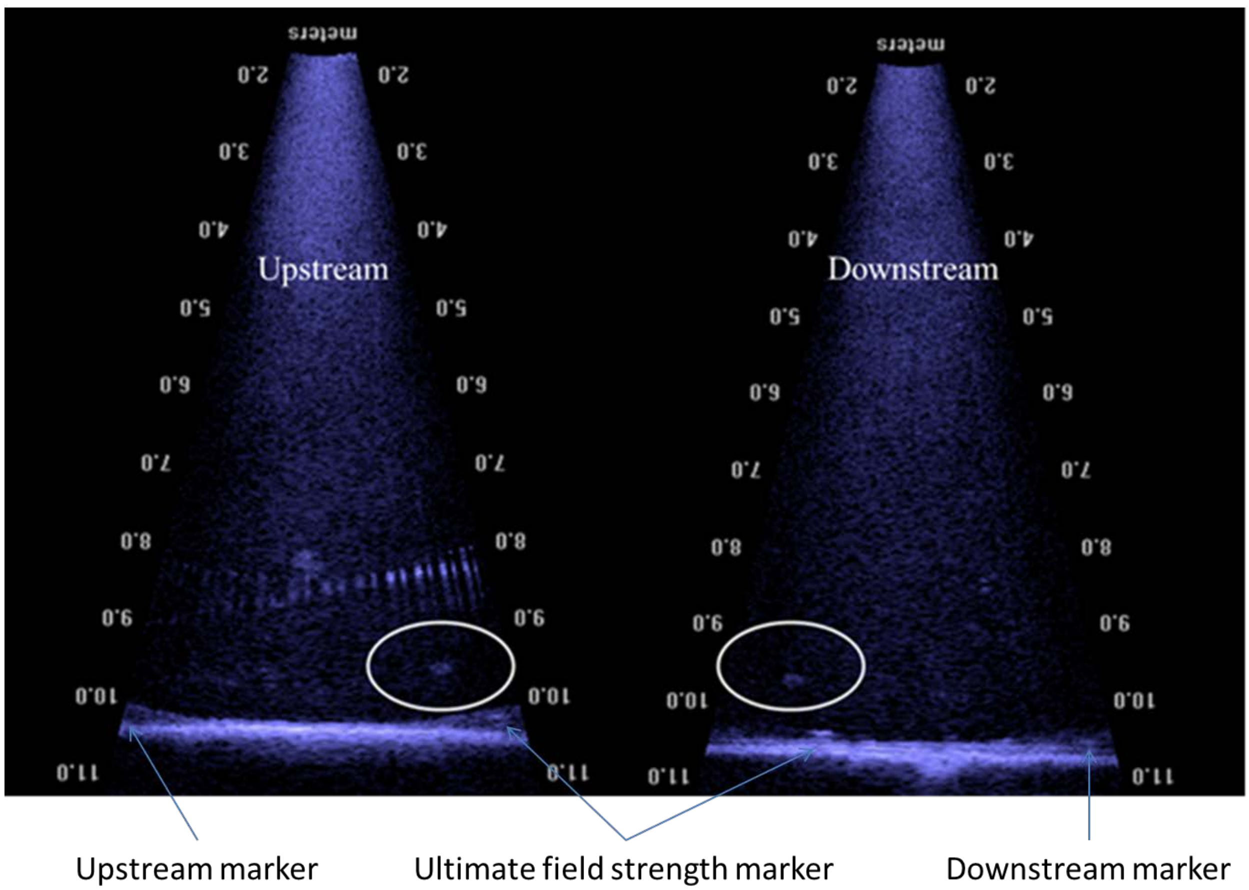

Figure 6. Example of both the upstream and downstream DIDSON units ensonifying the same school of fish (in white circles) as it swims upstream past the ultimate field strength marker before swimming further upstream and out of the DIDSON view.

During the period of time that the DIDSON recordings were taking place, field personnel were not able to directly see the fish swimming in the water because of high turbidity in the CSSC. However, several fish that appeared to be Clupeidae species were observed being preyed upon by birds following barge passages through the barrier. Furthermore, the USFWS Columbia FWCO sampled fish near and within the narrow arrays on September 27, 2013, and sampled Gizzard Shad (*Dorosoma cepedianum*), Threadfin Shad (*Dorosoma petenense*), and Skipjack Herring (*Alosa chrysochloris*).

The accumulation of fish below the Electric Dispersal Barrier is not surprising given that fish migrate upstream in lotic systems for numerous reasons, such as foraging, migration, reproduction, and escape from predation (Northcote 1978; Dingle 1980; Stewart 1990). Our observations of the fish continuously probing and challenging the Electric Dispersal Barrier is also consistent with other findings of fish repeatedly challenging an electrical barrier (Stewart 1981; Savino et al. 2001; Holliman 2011). In some cases, fish that have a strong desire to move upstream will continuously challenge an electrical barrier until they breach it, are harmed, or even killed (Stewart 1990; Bullen and Carlson 2003).

To date based on all available monitoring data, the probability of small Asian carp being present at the Electric Dispersal Barrier is low. However, both Bighead Carp and Silver Carp (*H. molitrix*) have been shown to exhibit positive rheotaxis (directed upstream movement against water current) and make long upstream movements (Peters et al. 2006; DeGrandchamp et al. 2008; Holliman 2011; Hoover et al. 2012). Holliman (2011) found that when small Bighead Carp were placed in a laboratory raceway with flowing water and a small electrical barrier, that the fish continuously challenged the barrier. Some fish even re-challenged the barrier immediately upon regaining muscle control after being incapacitated and swept downstream out of the electrical field. This persistent challenging of the electrical field resulted in some fish breaching the barrier (Holliman 2011).

Recommendations

- We will continue to perform fixed DIDSON monitoring of the electric barrier using the telescopic boom lift in summer and fall 2014, when abundances of small fish at the barrier are greatest (USFWS unpublished data). Our intent was to conduct sampling during 4 weeks in fall 2013; however, due to space limitations we were only able to conduct work at Barrier IIB, and it was not the primary operating barrier during our sampling period.
- Once additional data are collected, we will conduct a more thorough analysis of all data.
- Additional study is underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper. The research, consisting of six tasks conducted in the USACE Engineer Research and Development Center (ERDC), will include:
    - Simulations of a variety of fish behaviors during encroachment into the electric fields of Barriers IIA and IIB including extended stays in the low field (wide array) of the barriers, cross-channel swimming at the downstream edge of the high field (narrow array), and multiple challenges of the barriers;

- Simulations of fish behavior at seasonal extremes of water temperature, water current velocity, and water conductivity;
- Evaluation of the relationships between duration of electrical exposure and fish stress, injury, and mortality;
- Evaluation of volitional challenges of electric fields by groups of fish; and
- Simulations using other fish observed in the CSSC near the barriers, such as Gizzard Shad and Common Carp, to evaluate how similar their responses are to those of the Bighead Carp and Silver Carp.

Project Highlights

- Out 72 10-minute DIDSON samples that were recorded, 44 of them (61%) recorded at least one school of fish breaching the barrier.
- Out the 44 samples in which a breach was recorded, 27 of them (61%) recorded multiple schools of fish breaching.
- All fish that breached the barrier did so in schools and the average sizes of the fish were 5 – 10 cm (2 – 4 in) total length.
- Fish sampling within and around the zone of ultimate field strength in the Electric Dispersal Barrier revealed all Clupeidae species (Gizzard Shad, Threadfin Shad, and Skipjack Herring).

Part II: Preliminary results of fish-barge interaction work at the Electric Dispersal Barrier in the Chicago Sanitary and Ship Canal

Part II of this report addresses the following objectives from the 2013 Monitoring and Rapid Response Plan for Asian carp in the Upper Illinois River and Chicago Area Waterway System for: #6: Evaluate behavior of fish that are placed within moving barge vessel junctions and that are immediately below the barrier as a barge traverses the barrier both upstream and downstream.

Introduction

Beginning in the summer of 2012, the U. S. Fish and Wildlife Service (USFWS) Carterville Fish and Wildlife Conservation Office (FWCO) has been performing fish-barge interaction evaluations at the Electric Dispersal Barrier system in the Chicago Sanitary and Ship Canal (CSSC). Concerns about large, metal-hulled vessels facilitating barrier breach by fish were first raised by Sparks et al. (2010) and Dettmers et al. (2005). Sparks et al. (2010) and Dettmers et al. (2005) directly tested the effectiveness of the first Electric Dispersal Barrier, the Demonstration Barrier. Sparks et al. (2010) released 130 Common Carp (*Cyprinus carpio*) with surgically-implanted, combined radio-and-acoustic transmitters downstream of the Demonstration Barrier. Movements were recorded from 2002 to 2006, and during that time one fish was able to breach the Demonstration Barrier on April 3, 2003, which was operating at 0.39V/cm, 5 Hz, 4ms (0.39 V/cm). This breach was determined to have occurred at the same time that a steel-hulled barge traversed the barrier, which gave rise to speculation that the fish may have either been involuntarily entrained by the barge, or that the barge may have distorted the electrical field enough that the fish could have swam alongside the barge in an electrical void. However, after the breach, the fish remained in the same area that was 3 km upstream of the barrier, indicating that the fish was either dead when it crossed the barrier or died shortly after crossing (Sparks et al. 2010).

During November 11-14, 2003, Dettmers et al. (2005) passed caged fish alongside a barge through the Demonstration Barrier. Again, the barrier was operating at 0.39 V/in. Fish used were Catastomidae (sucker) species, Moronidae (temperate basses) species, and Common Carp. They found that these fishes took longer to exhibit effects from the barrier moving downstream than upstream through the barrier. The effects of the electrical field were also delayed when caged fish swam alongside conductive (steel) barge hulls compared to non-conductive (fiberglass) hulls. Some caged fish that were towed along the steel-hulled barges were never incapacitated as they swam through the barrier. The fishes that did not become incapacitated were < 150 mm total length.

Dettmers et al. (2005) noted that metal-hulled barges warped the electrical field of the barrier and created void spaces that fish could swim along and not be affected by the electricity. Besides distorting the electric field, barges also create a complex suite of hydrodynamic water motions (detailed in Figure 1) as they navigate through riverine waterways (Bhowmik and Mazumder 1990; Maynord and Siemsen 1990; Wolter and Arlinghaus 2003). The direct (Killgore et al. 2001; Gutreuter et al. 2003; Killgore et al. 2011) and indirect (Wolter and Arlinghaus 2004; Gutreuter et al. 2006; Kucera-Hirzinger et al. 2009) impacts of tow-barge vessel navigation on fish has been well investigated. However, the actual distances that fish are physically displaced by barges, especially near electrical barriers, is a topic that warrants further investigation.

Briefly, as a barge moves through the water past a fixed point, it first creates a bow current in front of the vessel followed by a bow wave. This bow wave creates a rise in the water level in front of the vessel, which causes a water drawdown along the hull of the vessel. This drawdown then creates a return velocity of water moving in the opposite direction of the vessel. The water level then rebounds at the stern of the barge, and the water directly behind the stern travels in the direction of the barge vessel as wake flow. Finally, the water directly behind the tow vessel is moved away from the tow by the propeller jet velocity (Figure 1; Bhowmik and Mazumder 1990; Maynord and Siemsen 1990; Wolter and Arlinghaus 2003). The end result of a tow-barge vessel passing a fixed point is accelerated downstream flow if the vessel was navigating upstream, or a temporary reverse of flow if the vessel is navigating downstream (Bhowmik 1991). The magnitude and extent of these water movements is dependent on the size of the vessel, relative to the water body, and the speed at which it is travelling (Wolter and Arlinghaus 2003). These barge-induced water movements are more exaggerated in confined channels. A confined channel is one which has a simple shape and has a significant cross-sectional area taken up by navigating vessels (Martin 1997; Maynord 2004; Taylor et al. 2007), as opposed to a large riverine system with sloped banks that can attenuate wave and flow energy. The section of the CSSC that encompasses the Electric Dispersal Barrier system is rectangular in cross-sectional shape and is a confined channel. Another noteworthy aspect of the complex hydrodynamics created by barges is the wedges of water between barge junctions (Figure 1G). These wedges of water typically exhibit weak recirculation patterns that are isolated from the adjacent water. The magnitude of water movement and isolation in these wedges depends on the barge junction used (Figure 2C-E), but some can transport debris for long distances.

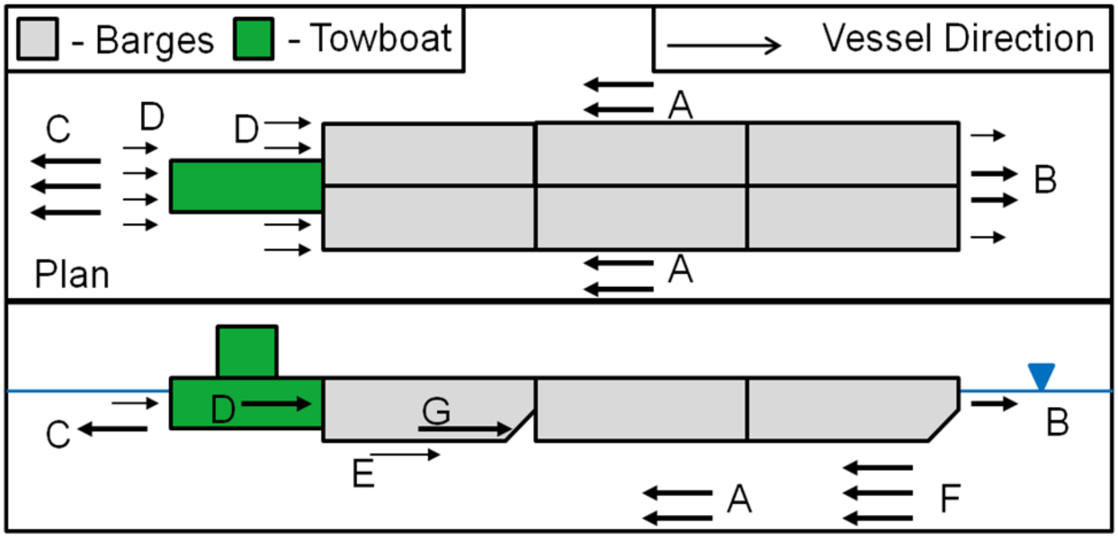

Figure 1. Water motions around tows moving left to right in confined channels. A = return velocity, B = bow wave, C = propeller jet, D = wake flow, E = flow in boundary layer along hull, F = displacement flow at bow between hull and channel bottom having short duration and G = pocket recirculation. Figure created by the USACE Engineer Research and Development Center – Coastal and Hydraulics Laboratory and reprinted with permission.

To date, the Carterville FWCO has worked with the U. S. Army Corps of Engineers (USACE)-Chicago District and the USACE Champaign Construction Engineering and Research Laboratory (CERL) on six separate occasions evaluating the interactions between fish and large metal barges traversing the Electric Dispersal Barrier system within the CSSC. The purpose of this report is to provide a brief summary of the results of this work.

Methods

In an attempt to understand the hydraulic and electrical effects on fishes near barges traversing the Electric Dispersal Barrier, initial work in 2012 consisted of placing wild-caught fish within non-conductive cages either alongside different parts of a barge (four trials along the side and two trials at the barge front; Figure 2A) or within the wedge of water created between various barge junctions (ten trials in the rake-to-box, nine trials in the rake-to-rake, and four trials in the rake-to-tow configurations; Figure. 2B-E). The barge and fish were then moved through the Electric Dispersal Barrier, and the effect of it on the fish (incapacitated or not incapacitated) was recorded with a video camera that was mounted above the cage. Incapacitation was defined as the complete cessation of all movement by the fish, which caused it to either be impinged against the downstream end of the cage or lay motionless on the bottom of the cage. All fish used in the barge trials were measured after each trial was complete in order to reduce handling stress. Fish that were used in the trials were primarily Gizzard Shad (*Dorosoma cepedianum*), but Common Carp and Freshwater Drum (*Aplodinotus grunniens*) were used in some trials, depending on availability. Specifically, we used progressively larger fish in subsequent runs, generally beginning with Gizzard Shad and moving to Freshwater Drum and Common Carp, to investigate if a size threshold existed at which fish in each tested configuration would be incapacitated. The first caged-fish evaluations were performed with Barrier IIB operating, whereas during the second caged-fish evaluation both Barriers IIA and IIB were operating. All trial runs began below the Electric Dispersal Barrier in non-electrified water and ended after the entire barge vessel completely traversed Barrier IIB. All fish that were used for these evaluations were collected via electrofishing within the CSSC.

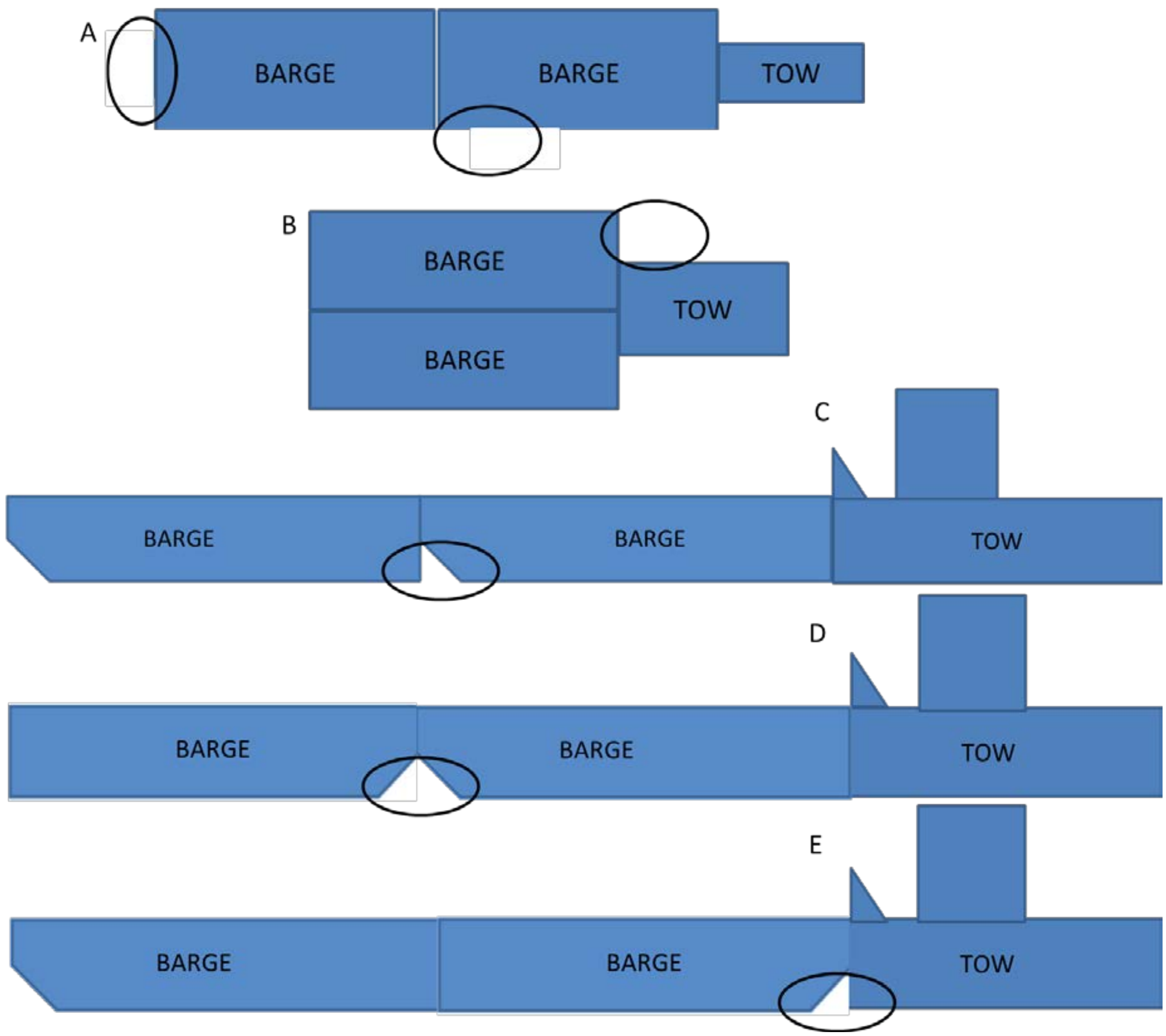

Figure 2. Various barge configurations used for fish-barge interaction work. Circles denote locations where fish were placed in a cage or directly deployed into the water, without a cage, after being tagged. These junction wedges served as potential void spaces to transport unconfined fish that had been deployed in front of the barge, after the barge struck them. A = locations of the cage placed along the side and in front of series configured barges. B = parallel

barge configuration in which the tow vessel is centered on the two barges. As the barges move forward a "pocket eddy," of water forms in the wake flow that can move debris forward with the barge. C = rake-to-box configuration. D = rake-to-rake configuration. E = rake-to-tow configuration.

After all of the caged-fish trials were completed in the fall of 2012, we focused solely on using tethered, unconfined Gizzard Shad (not placed in cages) to evaluate fish-barge interactions. Unconfined, tethered Gizzard Shad were used for one day in October 2012 to assess the value of the new methodology. After a successful evaluation with the unconfined, tethered fish in October 2012, all evaluations in 2013 utilized this methodology. Fish were tethered to high-visibility floats using 0.45 kg tensile strength, 0.06 mm diameter, dynema line to enable recovery of the fish, similar to methods described in Hasler (1958) and Sass and Ruebush (2010). The floats were attached to 1 m of dynema line. To attach the line to the fish, a sewing needle was used to thread the line through the soft tissue between the premaxillary and maxillary bones of the mouth and two overhand knots were tied. During each trial, ten tethered Gizzard Shad were either placed directly into the various barge junctions as the barge was approaching the Electric Dispersal Barrier, or deployed in the water across the width of the CSSC, below the active barrier prior to a barge approaching and traversing it. Barges approached the deployed fish in two-wide parallel (Figure 2B), rake-to-box (Figure 2C), rake-to-rake (Figure 2D), and rake-to-tow (Figure 2E) configurations. The two different methods of the unconfined-fish placement were employed to investigate two different sets of questions: 1) by placing the unconfined, tethered fish directly into the various junction wedges, we were evaluating the likelihood of a fish remaining within that wedge of water either on its own volition (in the event that it did not become incapacitated) or as a result of the hydrodynamics within the wedge retaining the fish after it was incapacitated; and 2) we placed tethered fish below the active barrier to address the likelihood of a fish initially becoming entrained by the barge and then remaining within a junction wedge as it moves through the barrier. After the barge completely traversed the Electric Dispersal Barrier system, the tagged fish were collected and their locations recorded. If fish were found above the Electric Dispersal Barrier but the tether was entangled on the barge, or if any fish entangled their tethers together with other fish tethers, those fish were not recorded as breaching since the entanglement may have facilitated the breach.

In November 2013, three different unconventional modes of barge navigation were employed to investigate alternative methods to reducing the possibility of fish entrainment. The first method consisted of having a tow vessel pull, rather than push, a rake-to-rake barge configuration upstream after fish were deployed below the active barrier. This was done in order to eliminate a small void space (Figure 4), which had facilitated earlier fish breaches when the barges were pushed upstream. We also directly placed tethered fish within the rake-to-box junction wedge (Figure 2C) as the barge was approaching the Electric Dispersal Barrier; however, during three trials, the barge stopped all movement and held position below the active barrier for two minutes. This was done in an attempt to allow the fish to swim out of the junction wedge on their own volition prior to entering the Electric Dispersal Barrier. Four additional trials were also performed in which Gizzard Shad were placed into the rake-to-box junction wedge; however, during these navigations, the barges took an angled approach towards the Electric Dispersal Barrier and alternated angles in a "zig-zag" pattern. This was done in an attempt to increase the water flow moving through the rake-to-box junction wedge and flush out the fish.

Results and Discussion

All caged fish along the side (4 trials, 19 fish in total) and in the front of a barge (2 trials, 10 fish in total; Figure 2A) were incapacitated as the barge traversed the Electric Dispersal Barrier. All caged fish that were placed in the pocket eddy of a parallel configuration (3 trials, 15 fish in total; Figure 2B) were incapacitated (Table 1). However, there was a minimal amount of flow in the eddy, and unlike the fish in the bow or side, these incapacitated fish were not impinged against the back of the cage. This raised concerns that stunned fish may still remain entrained in the eddy beyond the Electric Dispersal Barrier. Also of concern were wild (not stocked by USFWS) Mosquitofish (*Gambusia* spp.) that remained within the junction on their own volition beyond the Electric Dispersal Barrier in this eddy during the barge runs. We confirmed that what we observed were indeed Mosquitofish by netting and identifying some of the fish when the barge was stopped.

Of the 36 caged fish that were placed in the wedge of water in the rake-to-box configuration (10 trial runs; Figure 1C), only one was incapacitated. The one fish that was incapacitated was a large Common Carp (Table 1). Similar to the pocket eddy results, a small wild fish remained within the junction on its own volition past the Electric Dispersal Barrier in this wedge of water during one run. One possible explanation of this phenomenon was noted by CERL workers measuring the in-water voltage within the cage. They confirmed that the voltage between the rake-to-box junction wedge was reduced as the barge traversed the Electric Dispersal Barrier from the normal operating voltage of 0.91 V/cm to 0.06 V/cm.

All caged fish that were placed in the rake-to-rake junction (9 trials; 37 fish in total; Figure 2D), appeared to be briefly incapacitated when they were directly over the strongest part of the Electric Dispersal Barrier. CERL researchers confirmed that at the time when the fish were briefly incapacitated there was a spike of in-water voltage directly over the strongest part of the Electric Dispersal Barrier. Caged fish that were placed in the wedge of water between a rake-to-tow vessel configuration (4 trials; 16 fish in total; Figure 2E) were all incapacitated (Table 1). Of all of the junction wedges where in-water voltage was measured by CERL workers, the rake-to-tow wedge had the highest level, approximately 0.39V/cm, compared to the normal operating voltage of 0.91 V/cm.

Table 1. Numbers and sizes of different fish species that were caged along different parts of a barge and within barge junction wedges with one and two barriers operating. A length was not obtained for the one Common Carp that did become incapacitated, in the rake-to-box junction, because it escaped confinement after traversing the Electric Dispersal Barrier.

Cage placement	Fish species	Number used	Size range (cm; TL)	Incapacitated?
		July 2012, Barrier IIB operating		
Side of barge	Gizzard shad	18	5.8 – 34.3	YES
Side of barge	Common carp	1	53.3	YES
Front of barge	Gizzard shad	10	5.8 - 26.2	YES
Barge stern "pocket eddy"	Gizzard shad	15	14.2 - 23.9	YES
Rake-to-box junction	Gizzard shad	15	16.8 - 25.7	NO
Rake-to-box junction	Common carp	2	41.2 - 51.1	NO
Rake-to-box junction	Freshwater drum	1	37.1	NO
		October 2012, Barriers IIA and IIB operating		
Rake-to-tow junction	Gizzard shad	15	15.0 - 21.3	YES
Rake-to-tow junction	Freshwater drum	1	37.1	YES
Rake-to-rake junction	Gizzard shad	35	10.4 - 29.2	YES
Rake-to-rake junction	Common carp	1	43.9	YES
Rake-to-rake junction	Freshwater drum	1	34.5	YES
Rake-to-box junction	Gizzard shad	15	16.0 - 22.6	NO
Rake-to-box junction	Common carp	1	37.1	NO
Rake-to-box junction	Common carp	1	~75*	YES
Rake-to-box junction	Freshwater drum	1	38.1	NO

*Estimated length. Fish escaped confinement after trial run.

During the unconfined, tethered fish trials, the results varied depending on fish deployment method used and the barge configuration (Figure 3). All barge configurations evaluated yielded some percentage of entrainment beyond the Electric Dispersal Barriers, except for rake-to-tow, when fish were directly placed in that junction wedge. The 41 Gizzard Shad entrained beyond the Electric Dispersal Barriers ranged in size from 9.9 – 24.7 cm TL. Instances of entrainment beyond the Electric Dispersal Barrier occurred both after direct placement into a junction wedge or deployment below the barrier. Of the 340 Gizzard Shad used during the tethered fish evaluations, 21 breached after direct placement into a junction wedge whereas 20 breached after deployment below the Electric Dispersal Barrier. (Note: measurements were not made on all fish that breached the Electric Dispersal Barrier. In three cases, tethered fish were observed beyond the Electric Dispersal Barrier but were able to elude recapture by field personnel. In these cases, only the location coordinates were recorded where they were observed.)

Both deployment methods yielded similar percentages of fish breaches beyond the Electric Dispersal Barrier, via the pocket eddy, when the barges were in a parallel configuration. This suggests a similar likelihood of fish remaining within the pocket eddy either when placed in this space, or upon surfacing in this space after a barge strike (observed during tethered fish evaluations when they were run over by a moving barge). Small, wild Mosquitofish observed being transported through the Electric Dispersal Barrier in this pocket eddy further supports the idea that fish may remain in this space on their own volition. The percentage of fish that remained within the rake-to-box junction wedge when placed directly in this space was higher than those that were entrained within it following a barge strike. Evidence of fish entering and remaining within the rake-to-box wedge on their own volition was also supported by the observation of a small wild fish that was entrained across the Electric Dispersal Barriers during our caged-fish evaluations.

Placing fish directly into the rake-to-tow junction wedge yielded no fish breaches. This was most likely because of the high amount of water turbulence between the tow and the barge vessel. After the fish were placed within the rake-to-tow junction wedge, the fish and tethers were observed immediately moving in an uncharacteristic manner in this turbulent area until they eventually were flushed out behind the barge. Some of the fish did remain within the small pocket eddy for a short period before they exited this space, prior to the vessel reaching the Electric Dispersal Barrier. The difference between entrainment percentages in the rake-to-tow configuration may be explained by the number of barges that the tow vessel was centered on. When we directly placed the fish into the rake-to-tow junction wedge, the tow was centered on one barge vessel (see Figure 2A). However, when the fish were deployed below the Electric Dispersal Barrier before barge strikes, the tow vessel was centered on a two-wide rake-to-tow configuration (see Figure 2B for an example of a tow centered on a two-wide barge configuration), which created a larger pocket eddy behind the barge than the one-wide configuration and entrained some fish past the barrier. Therefore, the fish breaches in that configuration were most likely a result of the pocket eddy formed by the two-wide configuration as opposed to the smaller junction wedge between the tow and the barges. The different placement methods were performed during two separate time periods, in which different numbers of barge vessels were contracted.

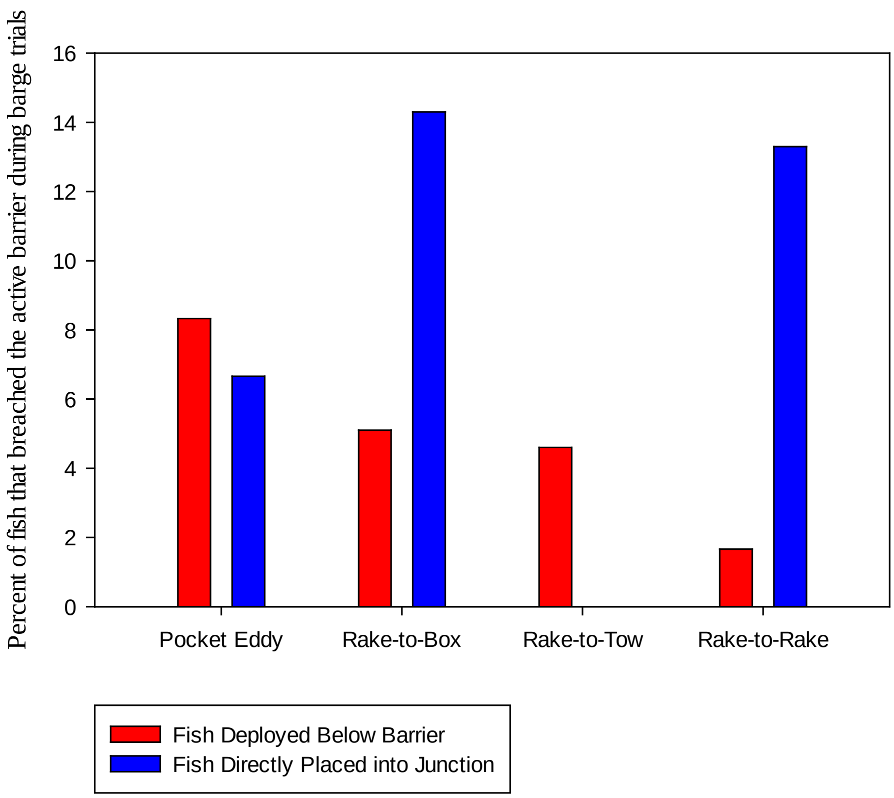

Figure 3. Percentages of live tethered fish that breached the Electric Dispersal Barrier system via different barge junction configurations and fish deployment methodologies.

The rake-to-rake configuration showed the largest discrepancy in the number of fish breaches as a result of deployment method. Some fish remained within the rake-to-rake junction wedge when directly placed in this space and subsequently breached the Electric Dispersal Barrier. However, only a small percentage of fish breached the Electric Dispersal Barrier via barge-strike entrainment. When the barges were attached in a rake-to-rake junction, the square end of the lead barges were what the fish first encountered as the barge tow moved upstream. Most of the fish were observed being displaced to the side of the barge tow before it moved to the Electric Dispersal Barriers. There were only two fish that became entrained beyond the Electric Dispersal Barriers in this instance by swimming into a small void space between the two square ends of the barge (Figure 4). No fish that were deployed below the Electric Dispersal Barrier ended up entrained within the rake-to-rake junction wedge. These results suggest that while the rake-to-rake junction wedge is conducive to entraining some fish past the Electric Dispersal Barrier, the possibility of fish initially becoming entrained within that wedge appears low.

We were able to perform nine trials using unconventional modes of barge navigation in order to investigate possible modes of transportation to reduce the possibility of fish entrainment. Twenty fish were deployed in front of the rake-to-rake configuration as the barges were pulled upstream by the tow vessel. None of the fish were entrained beyond the Electric Dispersal Barrier; however, that method of transport will most likely not be a feasible alternative for commercial navigation traversing the barrier. The first trial run, which consisted of the barges moving through the entire Electric Dispersal Barrier system, took over an hour to complete (as opposed to a normal passage time of around five minutes). This was because the current in the canal, as well as the propeller jet from the tow vessel flowing against the boxed ends of the barges created more drag. The second run had to be prematurely interrupted after the tow vessel stalled several times and could no longer pull the barges forward. Three trial runs were performed in which the barge vessel ceased movement for two minutes prior to entering the Electric Dispersal Barrier. Of the 30 fish that were used, 3 of them remained within the rake-to-box junction wedge for the entire two minutes, and were then entrained beyond the Electric Dispersal Barrier. Four trials were performed in which the barge alternated approach angles in a zig-zag pattern across the Electric Dispersal Barrier. Of the 40 fish that were used, 6 of those fish remained within the rake-to-box junction wedge and were entrained beyond the Electric Dispersal Barrier. We were able to observe some of these fish swimming within the junction wedge either as it was moving or when the barge stopped, indicating that the fish remained within the rake-to-box junction on their own volition (as opposed to involuntarily after being incapacitated). The sizes of the Gizzard Shad that breached the Electric Dispersal Barrier during our unconventional navigation approaches ranged from 21 – 26.5 cm total length.

Figure 4. Picture of the front of a rake-to-rake barge configuration traversing the Electric Dispersal Barrier with the square ends in the front. The circle denotes the small void space that two live fish swam into and remained inside beyond the barrier.

All fish, during all trials, were alive when recovered. We observed several instances where the fish did not reappear until after the barge had traversed the Electric Dispersal Barrier, suggesting that the fish were entrained along the bottom of the barge vessel as it crossed the barrier. This would have placed the fish deeper in the water column, 2.7 m closer to the barrier arrays on the bottom of the canal where the electrical fields are magnified (Holliman 2011). According to CERL researchers, the fish would be exposed to electrical fields as high as 2.76 V/cm at this depth.

Based on our findings, all barge junctions have the capacity to provide a transport mechanism for fish to cross the Electric Dispersal Barrier. However, the level to which these barge junctions may entrain individual fish seems to vary. Barge configurations with raked front ends appear to entrain the most fish; whereas, a configuration with square ends moving forward appeared to entrain the least amount of fish. In the event that fish near the Electric Dispersal Barrier system are struck by a barge with a raked front end, the results suggest that the fish will likely be moved along the underside of the barge towards the stern until it encounters a junction wedge or pocket eddy at the barge's stern. At that point the hydrology around these junctions may entrain the fish, where it would likely experience low hydraulic flow and diminished voltage, as the barge continues to move across the Electric Dispersal Barrier system.

Others have shown that fish are entrained by towboats (Gutreuter et al. 2003; Miranda and Killgore 2013), including Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*; Killgore et al. 2011). These studies took place in large, wide rivers that are very different from the narrow and confined CSSC. Killgore et al. (2011) found that, at times, fish entrainment was highest in narrow sections of water with slow velocity suggesting that fish entrainment in the CSSC may be higher when compared to a natural system. Undoubtedly, the Electric Dispersal Barrier system in the CSSC presents a different barge-fish interaction scenario than what others have studied given the presence of a large electric barrier. The Electric Dispersal Barrier may act as a "third wall" in the canal system that does not allow fish to escape from oncoming barge vessels. Or as fish swim to avoid barge traffic, they could move inadvertently into the barrier making them more susceptible to barge-induced entrainment. In an associated study, fish behavior was recorded within the Electric Dispersal Barrier system using dual-frequency identification SONAR (DIDSON). The results of that study suggest that fish will accumulate below the barrier and persistently probe it (Parker et al. 2013). This accumulation of fish in the middle of an open channel again presents a very different scenario than studies in natural rivers without electric barriers. Ultimately, with increased fish assemblages in the vicinity, the Electric Dispersal Barrier itself may limit the places that fish can escape from an oncoming barge and provide further opportunity for fish incapacitation and possible entrainment.

As mentioned above, DIDSON sampling has recorded large accumulations of wild fish immediately below the Electric Dispersal Barriers, including small fish, approximately 5 - 10 cm, within the zone of ultimate field strength (Parker et al. 2013). At that location, these small fish are estimated to be approximately 2 m away from breaching the barrier. In the tethered fish evaluations, fish were deployed immediately below the wide arrays of the barrier, where in-water voltage is minimal (~ 0.08 V/cm). However, the fish were observed swimming away from the Electric Dispersal Barrier and consequently towards the barge as it moved upstream. Because of this situation, the actual fish-barge strikes occurred over 100 m away from the barrier. Yet some of these fish were still entrained beyond it. Based on the results of the DIDSON sampling, which has shown large accumulations of fish in and directly below the electric field of the Electric Dispersal Barrier, coupled with the possibility of the barges to entrain fish for long distances, we would expect that a fish struck by a barge in closer proximity to the barrier would increase the likelihood of that fish being entrained across it.

An important aspect of these results is that they do not take into account the number of deployed fish that were never struck by the barge. Some fish avoided the barges, and other barge-fish interactions were not able to be observed due to safety precautions. Because these observations could not be made, we cannot quantify the proportion of deployed fish that were struck by the barge, which may affect the number of entrainments observed for the deployed fish method.

Another important consideration when interpreting these results is the effects that the attached tethers and floats may have on the swimming ability of the fish. The use of tethered floats has been used to evaluate the movements of small, aquatic animals by others (Hasler et al. 1958; Witherington 1995; Okuyama et al. 2009; Sass and Ruebush 2010); however, we are unaware of any research that has addressed the effects that the floats may have on the swimming ability of fish. Although the floats and tethers may have contributed to the fish being struck by the barge, there is also research to suggest that un-tethered, wild fish are frequently struck by barges as well (Gutreuter et al. 2003; Killgore et al. 2011; Miranda and Killgore 2013). Personnel in the field noted during the evaluations that many fish were able to pull the floats and tethers under water and were in some cases able to elude recapture. Furthermore, after a tagged fish is struck by a barge, the force of the moving barge likely has more influence on the body of the fish as opposed to the influence of the float and tether. We recognize that the tethers and floats may have had some effect on results, but these effects would likely be minimal in regards to the duration of entrainment. We also deployed floats that were unattached to fish, and floats that were attached to recently deceased fish as part of a broader comparison of the mechanisms affecting fish-barge interactions. The results of those comparisons in the future may answer some questions about the effect that the floats and tethers have on fish.

The current barrier operating parameters are based on laboratory trials using Bighead Carp (Holliman 2011). Our studies primarily used Gizzard Shad that may not exhibit the same response to the electric barrier as Bighead Carp. Currently, plans are underway with USACE to evaluate the comparability of Gizzard Shad and Bighead Carp susceptibility to the current barrier settings, which may help us further clarify and interpret the results of this study.

Recommendations

The findings of this study, in conjunction with concurrent work completed by our project partners have triggered discussions regarding the likelihood of barge facilitated barrier breaches and possible preventative measures that could be put in place to further protect against aquatic invasive species. We continue to work with our partners towards better understanding barrier-barge interactions and their possible impacts on aquatic organism movements within the CSSC.

Project Highlights

- Only 1out of 36 caged fish that were moved through the Electric Dispersal Barrier was incapacitated while inside the rake-to-box barge junction wedge.
- Several small, wild fish that were not stocked by FWS were observed being entrained beyond the Electric Dispersal Barrier within the rake-to-box junction wedge and the pocket eddy adjacent to the tow vessel.
- All barge configurations yielded some percentage of fish entrainment beyond the Electric Dispersal Barrier when loose, tethered fish were deployed either within various barge junction wedges or immediately below the barrier as the barge was approaching.
- Alternative modes of barge navigation through the Electric Dispersal Barrier were either impractical or still facilitated fish movement beyond the barrier.

Part III: Hydroacoustic Assessments of the Electric Dispersal Barrier and Lockport Pool

Part III of this report addresses the following objectives from the 2013 Monitoring and Rapid Response Plan for Asian carp in the Upper Illinois River and Chicago Area Waterway System for: #1-4: Determine the abundance of fish between the Lockport pool and the Demonstration Barrier throughout the year; Evaluate the diel abundances of fish around and within the electric barrier system; Determine fish abundances immediately below Barrier IIB and between Barrier IIB and the Demonstration Barrier before and after required monthly barrier maintenance shutdowns; Evaluate fish behavior during monthly shutdowns to see if feral fish opportunistically swim upstream during the planned outages.

Introduction

Beginning in June 2011, the U.S. Fish and Wildlife Service's (USFWS) Carterville Fish and Wildlife Conservation Office (FWCO) began evaluating wild fish populations and their behavior within the Electric Dispersal Barrier system located in the Chicago Sanitary and Ship Canal (CSSC). Using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, WA) unit, we evaluated fish populations throughout the entire barrier system, which covered the entire gradient of barrier voltages (0 – 0.91 V/cm), and also performed concentrated evaluations directly over the strongest part of the barrier. Results of our sampling across the entire Electric Dispersal Barrier system using DIDSON equipment revealed a significant accumulation of fish below the active barrier, similar to the findings of Godlewska et al. (2007). Some of the fish that were immediately below the active barrier were observed persistently probing and challenging the barrier, which was consistent with other observations of fish behavior at electric barriers (Stewart 1981; Savino et al. 2001; Holliman 2011). We defined "probing" behavior as persistent movement up and down and/or sideways along an invisible plane (in this case the barrier). "Challenging" was defined as fish swimming upstream into the barrier and being able to penetrate further than the other fish that were probing.

Starting in early 2013, the US Army Corps of Engineers – Chicago District, which maintains the Electric Dispersal Barrier, began a routine maintenance procedure in which the back-up generators to the barrier were tested monthly. This process of switching power sources from the standard electrical grid to a back-up generator causes the Electric Dispersal Barrier to be without power for anywhere from 10-27 seconds. Because of the significant amount of fish that had been observed accumulating below the active barrier and the persistent probing and challenging behavior observed, concerns were raised about the possibility of fish opportunistically moving upstream after the barrier is de-energized. Others have found that fish will move upstream soon after an electrical barrier is de-energized (Stewart 1981; Swink 1999; Godlewska et al. 2007; Holliman 2011). Holliman (2011) noted that small Bighead Carp "immediately" swam upstream after a laboratory barrier was de-energized. In order to indirectly assess whether fish were opportunistically moving upstream during the period that the Electric Dispersal Barrier was de-energized we performed SONAR scans within the barrier system before and after the generator testing. SONAR scans were also performed within Lockport pool from the Electric Dispersal Barrier to the Lockport Lock. This was done in order to assess any spatio-temporal trends in fish distributions within the pool throughout the year.

Methods

Scans of the barrier system took place in conjunction with planned monthly barrier maintenance shutdowns at the beginning of each month. Three full scans were performed before the generator testing and three scans were performed after the testing. Scans of Lockport pool were performed on the same day that scans were done for generator testing. Scans were performed using two 200 khz split-beam transducers and one 1200 khz side-scan SONAR unit. The two split-beam transducers were mounted next to each other on the starboard side of the boat 0.15 m below the water surface. One transducer was set to -3.5˚ and the other set to -10.5˚ below the water surface. Each complete scan consisted of three transits through the barrier. The side-scan SONAR unit was deployed 1 m below the water surface. The first two transits along the walls required driving the boat about 1 m away from the west and east walls. The final transit was through the middle of the channel. The mid-channel transit only required operation of the side-scan SONAR unit.

Split-beam SONAR data were collected using Visual Acquisition 6 from 1.15 to 15-m depth at a ping rate of 5 pings per second and a 0.40-ms pulse duration. Data collection was set to begin at 1 m from the transducer face in order to avoid the near-field effect (Simmonds and MacLennon 2005; Garvey et al. 2011). Temperature was recorded with a Hydrolab unit and input into Visual Acquisition 6 prior to data collection to compensate for the effect of water temperature on two-way transmission loss via its effect on the speed of sound in water and absorption coefficients. The split-beam acoustic transducers were calibrated on-axis with a 200 kHz tungsten carbide sphere throughout the duration of sampling following Foote et al. (1987). Preliminary post-processing has begun on the split-beam samples using Echoview software.

In addition to our regular sampling events, we also performed pre- and post-scans following a barrier switch from Barrier IIB (the upstream barrier) to Barrier IIA (the downstream barrier) in May and June. In August, three scans were performed within the Electric Dispersal Barrier system following an unplanned switch from Barrier IIB to IIA. In June, August and November, we assisted partners during rapid response clearing events by performing scans before and after the clearings and informing them of fish numbers.

Results and Discussion

Four scans before and after barrier generator tests were completed in 2013 beginning in April (April, May, July, November). Generator tests were not performed during three months because Barrier IIA was the primary barrier that was operating (June, August, and September). Barrier IIA is the downstream barrier and isn't de-energized for generator testing if Barrier IIB can't be used to prevent further movement by fish. We were not able to perform pre- and post-generator testing scans during October due to a lack of federal appropriations at the time (government shutdown) and a generator test was not performed in December. Scans of Lockport pool took place during all months except October. Post-processing of samples using Echoview is on-going.

During the June clearing event, 22 fish (> 30 cm TL; "large fish" hereafter) were initially detected between the active barriers. After the initial scan, 22 large fish were captured by IDNR and USACE partners on site. However, a subsequent scan, revealed three large fish remaining between the barriers. On August 26 and 27 clearing efforts took place and two large fish were removed. A scan of the Electric Dispersal Barrier afterwards revealed that as many as 23 large fish were still remaining between the barriers. A SONAR scan had not been performed prior to the removal efforts starting August 26. On November 4, eight large fish were detected between the barriers prior to removal efforts. Three fish were removed and four fish were later detected between the barriers.

Recommendations

We will continue to collect fish data before and after barrier generator testing through the spring of 2014. We will also continue to assist partners during rapid-response clearing events. After all data have been post-processed, a thorough analysis of the data will be conducted, which could be used to inform partners about the effects of generator testing on fish movement.

Project Highlights

- Four complete assessments of the Electric Dispersal Barrier system were performed during generator testing.
- Pre- and post-barrier switch surveys were performed on two occasions.
- On three occasions we assisted partners during rapid-response clearing events by informing crews on site of how many fish to target and how many fish were still remaining within the Electric Dispersal Barrier system.

Evaluating Asian Carp Detection Techniques with SONAR

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Participating agencies: U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office and Southern Illinois University – Carbondale, Center for Fisheries, Aquaculture, and Aquatic Sciences (CFAAS).

Introduction

Currently, an intensive sampling program using traditional fish sampling gear takes place throughout the Chicago Area Waterway System (CAWS) upstream of the Electric Dispersal Barrier system in an effort to capture live Asian carp if present. Additionally, water samples are taken throughout the CAWS and later filtered and analyzed for the presence of Asian carp environmental DNA (eDNA). The eDNA sampling has yielded numerous positive detections of both Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*Hypophthalmichthys molitrix*) throughout the CAWS, although traditional fish sampling has only yielded one Bighead Carp above the Electric Dispersal Barrier system to confirm a positive result using eDNA in the CAWS (Jerde et al. 2011). On several occasions, consecutive detections of Asian carp eDNA in particular water bodies of the CAWS, such as the North Shore Channel and Lake Calumet have triggered rapid response fish sampling events in attempts to capture live Asian carp that may have been responsible for the positive eDNA detections. The use of eDNA has the potential to narrow down the possible location of a live Asian carp to a certain water body. However, capturing a live individual in a particular body of water later on using traditional fish sampling gear, and without knowledge of the specific location in the water body where a fish may be present, is very difficult. Therefore, we performed an experiment using multiple hydroacoustic SONAR frequencies in order to assess whether live Asian carp can be specifically identified apart from other fish species. These identifications could significantly reduce the amount of water targeted for future rapid response efforts.

The use of hydroacoustics to assess fish stocks has become increasingly common in open water environments (Parker-Stetter 2009; Simmonds and MacLennon 2005) and more recently in riverine environments including the Illinois River (Garvey et al. 2011). Yet, a limitation in the use of hydroacoustics for fish stock estimation is that detected fish cannot be readily identified to species. Therefore, hydroacoustic fish stock sampling is typically accompanied by traditional fish sampling in order to verify species identifications (Brandt 1996). However, progress has been made with species identifications using hydroacoustics (e.g. Rose and Leggett 1988; Crockett et al. 2006). Kloser et al. (2002) were able to successfully distinguish Orange Roughy (*Hoplostethus atlanticus*) from other marine fish using three SONAR frequencies. This method was useful for managers, because Orange Roughy are rarely sampled with traditional fish sampling gear (Kloser et al. 2002).

Because sampling a small number, or even a single individual, of a specific species of fish is very difficult using traditional fish sampling gear, we are exploring the possibility of identifying unique acoustic properties of Asian carp using multiple hydroacoustic SONAR frequencies. If successful, this method of species-specific sampling could be used to identify leading edges of invasion, as well as targeted removal efforts. Asian carp have larger gas bladders than other similarly-sized native fish, which may facilitate distinguishing them from other fish.

Methods

During the spring of 2013, Asian carp, Common Carp (*Cyprinus carpio*), and Buffalo spp. (*Ictiobus* spp.) were collected in the Big Muddy River and Horseshoe Lake in Southern Illinois using a combination of electro-fishing and gill-netting. The fish were then transported to the Touch of Nature Environmental Center Reservoir in Makanda, Illinois. At the reservoir, the different fish were suspended in the water from the end of a dock with four different split-beam transducers (38-, 70-, 120-, and 200 khz) aimed at the fish in a side-looking aspect. The fish were manipulated at different aspects relative to the SONAR beams including dorsal- and side-looking aspects at a distance far enough away that allowed the entire fish to be within the beams. Each fish was ensonified for 30 seconds in each aspect, which is equivalent to 100 pings from each transducer per fish. After the fish were ensonified, the gas bladders were extracted from the fish and the volumes measured (ml). Prior to any acoustic or gas bladder volumetric estimates, all fish were immersed in a lethal dose of tricane-methanosulfate until five minutes after cessation of gill ventilation.

Results and Discussion

We collected a total of 96 Silver Carp, 46 Bighead Carp, 6 Silver × Bighead Carp hybrids, 22 Grass Carp (*Ctenopharyngodon idella*), 78 Common Carp, and 188 Buffalo species from the Big Muddy River and Horseshoe Lake. Fish target data collected included target strength, width, shape, and incidental angle. These data will be incorporated into a baseline category logit model to determine whether we can reliably distinguish species with the gear based on unique acoustic properties of the fish. These data will also be used to quantify the frequency specific peak target strength to body size and gas bladder size relationships for each species and to determine the uncertainty in these relationships. Currently, data analysis is still ongoing.

Recommendations

Analyses will continue and if we conclude that Asian carp do exhibit unique acoustic properties, then further “blind” testing may occur, in which more fish are ensonified and a worker who was not present during the ensonification will attempt to discriminate Asian carp from the other fish that were ensonified in post-hoc analyses.

Project Highlights

- We collected and ensonified 436 different fish and analysis is currently ongoing to determine if Asian carp can be discriminated from other fish.

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 or 2013). 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 6.4 mm (0.25 in) mesh fencing built along 21.7 km (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. An overtopping event in 2011 created scour holes underneath the fencing in places and allowed small fish to pass. These areas and other low lying areas were reinforced with chicken wire buried in gravel 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 Carp and Silver Carp and their spawning activities in the Des Plaines River above the confluence with the CSSC; and
2) Monitor for Bighead Carp and Silver Carp eggs and larvae around the physical barrier when water moves laterally from the Des Plaines River into the CSSC during high flows.

Methods: In 2013, sampling was conducted in the upper Des Plaines River from Romeoville, IL upstream to the former Hofmann dam site at Riverside, IL. Sampling was performed using pulsed-DC electrofishing and short term gill net sets using 76 mm (3 in), 89 mm (3.5 in), and 102 mm (4 in) 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. Targeted areas included four main 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 that included 17 hours of electrofishing along the entire Illinois section of the upper Des Plaines River. Electrofishing for this survey was performed using a 3-phase AC boat electrofisher. All fish were identified and released with the exception of three grass carp

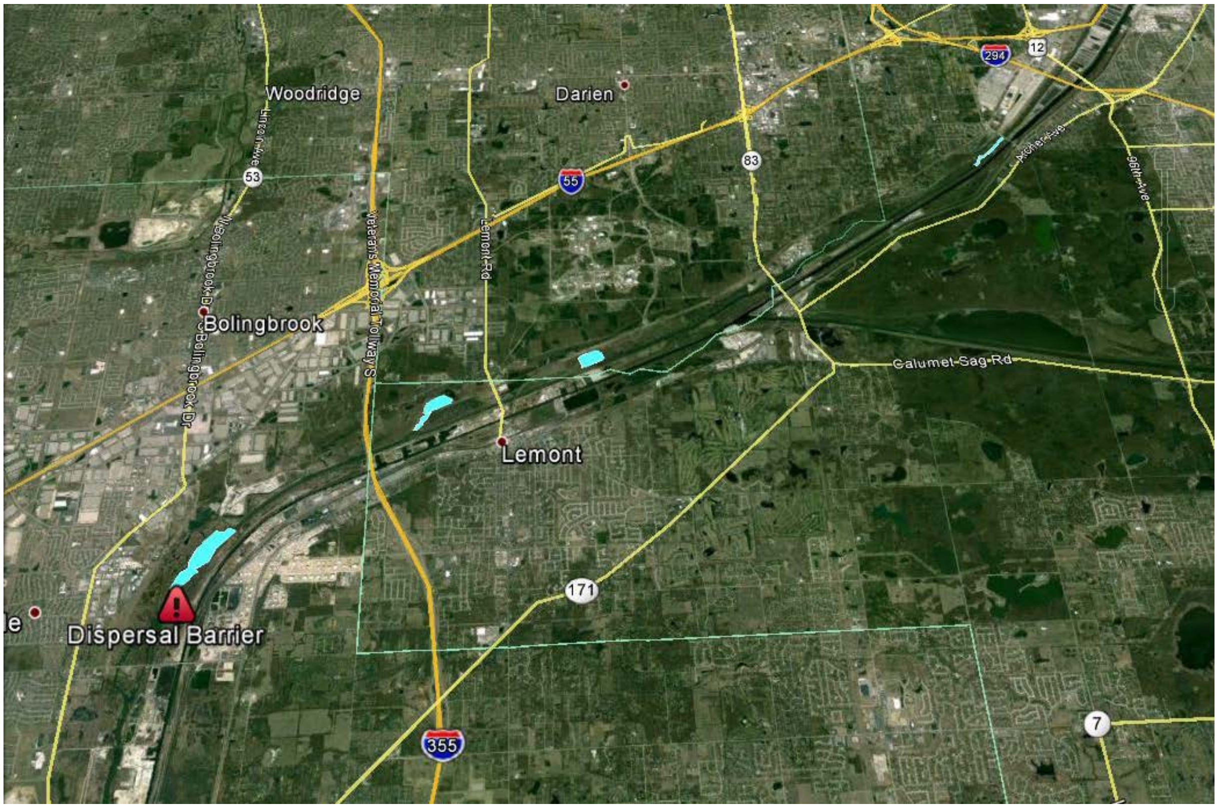

Figure 1. Four main target areas outlined in blue for sampling on the upper Des Plaines River: Columbia Woods, a backwater above the Lemont railroad bridge, Goose Lake, and a widened section of river near Romeoville, IL.

that were captured while sampling. These were transported to Whitney Genetics Laboratory (WGL) for ploidy testing.

An overflow event was monitored on one occasion in two separate areas of the physical barrier. Trammel nets (89 mm (3.5 in) bar mesh), a minnow seine (3.1 mm (0.125 in) mesh), and a pulsed-DC backpack electrofisher were used to search for fish passing in areas of overflow and to attempt to temporarily block compromised areas of the physical barrier.

Results and Discussion: To date, a total of 5,052 fish have been collected during the three years of sampling (2011-2013) (Table 1). Overall, effort has included 30.5 hours of electrofishing and 82 net sets covering 5,746 m (6,284 yd). Forty-nine species and two hybrid groups have been collected. Common Carp have been the most commonly collected species, followed by Bluegill and Largemouth Bass. In 2013, sampling occurred during two weeks while water levels were elevated: 4/14/13 and 6/2/13. Sampling effort included 7.4 hours of electrofishing resulting in 528 fish as well as 30 gill net sets covering 2,529 m (2766 yd) resulting in 175 fish. 2013 sampling yielded 30 species and one hybrid. No Bighead Carp or Silver Carp have been seen or captured during the three years of sampling. In addition, the 2013 IDNR basin survey yielded no Asian carp. Three Grass Carp were captured in a backwater area near Lemont, IL. Eyeballs were removed and transported to WGL for ploidy testing. Results showed that all three fish were triploid.

Table 1. Numbers of fish sampled 2011-2013 on the upper Des Plaines River.

	Electrofishing		Gill Netting		
	2011-2012	2013	2011-2012	2013	Totals
Common Carp	703	190	36	126	1,055
Bluegill	711	65	2		778
Largemouth Bass	403	30	2	2	437
Bluntnose Minnow	409	5			414
Spotfin Shiner	388	16			404
Channel Catfish	258	38	6	19	321
Gizzard Shad >6"	160	54	3	5	222
Black Crappie	171	41	2		214
White Sucker	148	7	7		162
Green Sunfish	150	2			152
Sand Shiner	113				113
Orangespotted Sunfish	90	11			101
Northern Pike	66	6	22	2	96
Spottail Shiner	87	1			88
Golden Shiner	53	6			59
Sauger	51	2	2		55
Bowfin	45	8		1	54
Fathead Minnow	32				32
Blackstripe Topminnow	27	1			28
Yellow Bullhead	19	8			27
Round Goby	26				26
Emerald Shiner	6	19			25
Longnose Gar	17	1	4		22
Pumpkinseed	13	7			20
Spotted Sucker	13	1	2		16
Rock Bass	14		1		15
Blackside Darter	14				14
Gizzard Shad <6"	12				12
Smallmouth Bass	9		1		10
Quillback	6	1		2	9
River Carpsucker	6		1		7
Bigmouth Buffalo			1	5	6
Warmouth	4	2			6
Hornyhead Chub	6				6
Goldfish		3	1	1	5
GoldfishXCarp Hybrid			1	4	5
Creek Chub	5				5
Black Buffalo				5	5
Walleye	3		1		4
Grass Carp	1			3	4
Black Bullhead	1	2			3
Smallmouth Buffalo	1		1		2
Western Mosquitofish	2				2
Yellow Perch	2				2
Oriental Weatherfish	1	1			2
Longear Sunfish	1				1
Hybrid Sunfish	1				1
White Crappie	1				1
Johnny Darter	1				1
Logperch	1				1
White Perch	1				1
Muskellunge	1				1
Totals	4,253	528	96	175	5,052

Drought conditions the remainder of the sampling season resulted in target sampling areas of the river being largely inaccessible.

The four sites outlined in Figure 1 have been determined to provide the most suitable habitats for Asian carp. These sites share characteristics of areas they are found in where they are plentiful. The capture of Buffalo species and Grass Carp in these areas, whereas these species have not been captured in previous surveys or in other areas, increases confidence that this is the case. However, only Columbia Woods is accessible during low river stages. The remaining sites will continue to be sampled when conditions allow.

There was one overflow event during which water flowed laterally from the upper Des Plaines River into the CSSC. Heavy rains hit the Chicago area the week of 15 April 2013 with storm totals approaching seven in many areas. Overflow began on 18 April 2013 and continued until 23 April 2013. The Riverside gage operated by the United States Geological Survey indicated the river reached the 7.0 foot flood stage by 2:00 AM on 18 April 2013 and crested at 11.13 feet at 1:00 AM on 19 April 2013. There were three main areas of overflow: immediately below the Willow Springs Road bridge, the "prairie area" approximately 2.1 km (1.3 miles) above the Route 83 Kingery Highway bridge, and the "jungle area" immediately below the Route 83 Kingery Highway bridge. USACE engineers reported minimal overflow in the jungle area with no problems. The prairie area and the Willow Springs area were investigated by USFWS and USACE biologists 19 April 2013, 20 April 2013, and 22 April 2013. In the prairie area, reinforcements in areas of prior scouring were mostly working as designed. Minnow seines deadset below small scours did not capture any fish. During the early morning hours of 19 April 2013, two panels of the physical barrier were blown out by floodwaters. One large fish (>305 mm (12 in)) was seen passing. An attempt was made to block the area using a trammel net, but the set was ineffective due to high current velocities. A temporary patch was put in place by USACE personnel late afternoon on 19 April 2013. Upon inspection the morning of 20 April 2013, the patch was deemed highly ineffective due to high water velocities funneled through the breach, creating a difficult work environment. In the Willow Springs area, three holes that were of sufficient size to pass large fish were scoured under the physical barrier. A trammel net set (60 m (66 yd); 89 mm (3.5 in) bar mesh) was placed on the path blocking the largest scour overnight on 19 April 2013 until USACE personnel could place temporary patches. Five Common Carp were captured. On 22 April 2013, backpack electrofishing was conducted in remaining pools on the CSSC side of the physical barrier. Several centrarchids and small cyprinids were captured and one adult Common Carp was spotted.

Overflow events in 2011 and 2013 have both allowed passage of fish larger than the intentional design. In 2011, scouring underneath the fence allowed the passage of fish < 76 mm (3 in). To alleviate this concern, chicken wire was attached to the bottom of the fence and buried in gravel. Following the 2013 event, actions have been taken to prevent future scouring and blowouts of the physical barrier. In areas where scouring has occurred, concrete has been poured to prevent future problems. In the prairie area where panels were breached, a dike has been created to completely prevent water passage to the CSSC. This is the area that has been subject to the most intense flooding in the previous two events and the most likely place for future breaches to occur.

Recommendations: Continue monitoring for adult and juvenile Bighead Carp and Silver Carp in the upper Des Plaines River with emphasis in the four target areas. Continue to explore areas upstream of the former Hofmann Dam for potential Asian carp habitat. 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 5,052 fish representing 49 species and 2 hybrid groups from 2011-2013 via electrofishing (30.5 hours) and gill netting (82 sets; 5,746 m (6,284 yd)).
- IDNR basin survey completed 17 hours of electrofishing in 2013.
- No Bighead Carp or Silver Carp have been captured or observed through all years of sampling.
- Three Grass Carp were captured in 2013. Analysis indicated all three were triploid.
- Recommend to continue monitoring in 2014 and include extra efforts to detect young-of-year and juvenile fish.

Asian Carp Gear Efficiency and Detection Probability Study

Steven E. Butler, Matthew J. Diana, Jonathan A. Freedman, David H. Wahl (Illinois Natural History Survey), Robert E. Colombo (Eastern Illinois University)

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: Gear evaluations were conducted at 10 sites located throughout the Illinois Waterway (Figure 1). Sampling gears were evaluated at sites in the middle Illinois River (where Asian carp are present in high densities), the upper Illinois/Des Plaines River (where Asian carp are present in low to moderate densities), and in the CAWS (where Asian carp are either absent or present in very low densities). All sampling gears were tested seasonally (spring, summer, and fall) at each site. All captured fish were identified to species and measured for total length and weight. Sex and reproductive condition of Asian carp was determined by removal of gonads in the field.

Figure 1. Map of gear evaluation sites in the Illinois Waterway. Rkm = river kilom, measured as distance upstream of the Mississippi River.

Gear / Method	**Target**	**Effort per site-visit**
Hoop net	Adults	12 net-nights
Trammel net w/ pounding	Adults	4 sets
Large mesh gill net – sinking	Adults	4 x 4 hour sets
Small mesh gill net – floating	Juveniles	4 x 4 hour sets
Mini-fyke net	Juveniles	8 net-nights
Beach seine	Juveniles	3-4 hauls
Pulsed-DC electrofishing	Both	6 x 15 minute transects
Hydroacoustics	Both	2 x 15 minute transects

During 2013, four tributaries of the Illinois River (Spoon, Sangamon, Mackinaw, and Kankakee Rivers) were also sampled for Asian carp. Each tributary was sampled near its confluence with the Illinois River and at an upstream location below the first impoundment on each river. Pulsed-DC electrofishing (15 minutes on each site-visit) was conducted monthly at each confluence site and bi-monthly at each upstream site from June to October. All captured Asian carp were measured for total length and weight. Sex and reproductive condition were assessed, and cleithra were removed for age analysis. Otoliths were removed from a subsample of 25 individuals per site for age validation.

We estimated detection probabilities for Bighead Carp with hoop nets, and for Silver Carp with pulsed-DC electrofishing using PRESENCE 5.2 software. Detection probabilities represent the probability of capturing at least one individual of a species in a sample, given that the species is actually present at a site. Valid estimates of detection probability can only be calculated for sites where a species is actually detected, so only sites where Asian carp were actually captured with each gear type were used for these analyses. Because all sites used for analysis were obviously occupied, we modeled the occupancy parameter as a constant in order to minimize model variation. Additionally, although season was included as a covariate in some models, all models were run under a single-season framework, as single-season models assume that sites are closed to immigration and emigration at a species level, i.e. occupancy does not change during the sampling period.

Results and Discussion: Each site was sampled two to three times from April 29 to October 3, 2013. Extensive flooding during spring 2013 prohibited every site from being sampled during this time period, but all locations were sampled during summer and fall. Using all gears, we captured a total of 51,657 fish, including 1,837 Asian carp (1,693 Silver Carp, 94 Bighead Carp, and 50 hybrid Asian carp). Pulsed-DC electrofishing was the most effective gear for sampling Silver Carp (84.1% of Silver Carp), followed by hoop nets (10.3%). Hybrids were also most effectively captured by hoop nets (56.0%), followed by electrofishing (28.0%), and trammel nets (12.0%). Bighead Carp were most effectively captured using hoop nets (79.8%) and trammel nets (11.7%). These results are consistent with findings from previous years of sampling, suggesting that some combination of pulsed-DC electrofishing, hoop netting, and trammel netting may be best suited for Asian carp monitoring purposes. Gears targeting juvenile Asian carp (beach seines, small mesh gill nets, and mini fyke nets) were generally effective at capturing small fishes; however, few Asian carp were captured. No age-0 Asian carp were captured in our sampling during 2013. Although spawning activity and larval drift have been observed during the past several years (see Larval Fish and Productivity Monitoring summary), recruitment to post-larval stages appears to have been very low in the Illinois River since 2007.

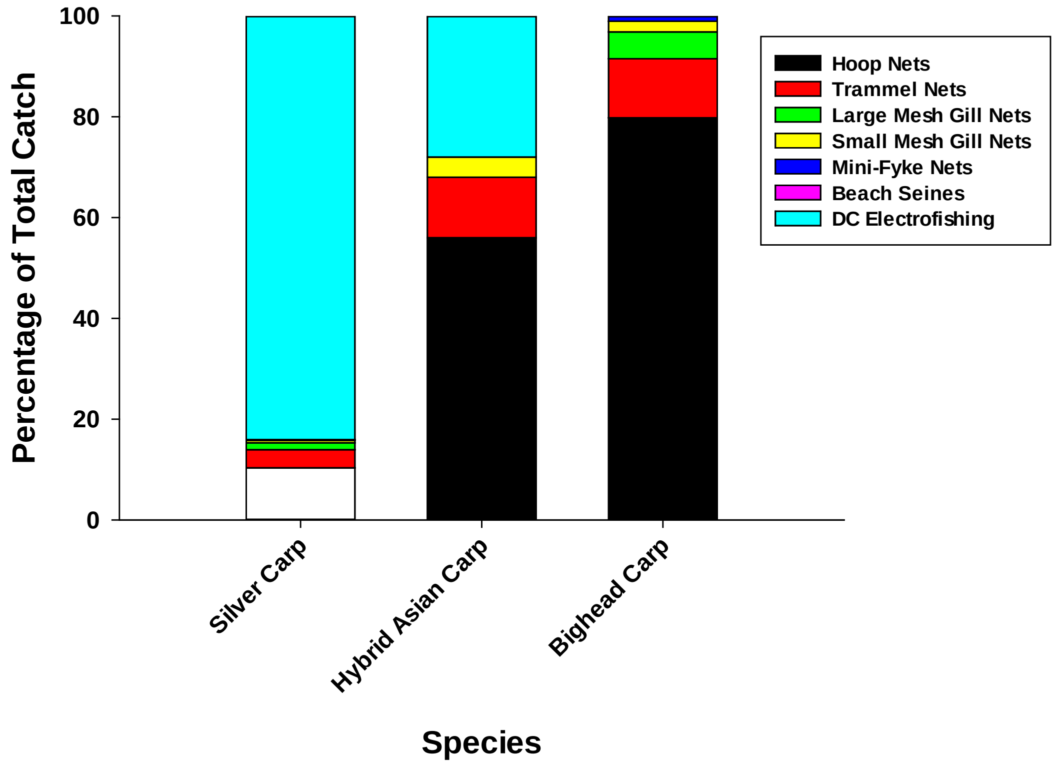

Figure 2. Percentage of total catch of Silver Carp, Bighead Carp, and hybrid Asian carp captured by each gear in the Illinois Waterway in 2013.

In 2013 samples, all taxa of Asian carp were most abundant in the LaGrange and Peoria pools; relative abundance decreased through the Starved Rock, Marseilles, and Dresden Island pools, and no Asian carp were captured or observed in the CAWS. The furthest upstream that we captured Bighead Carp and Silver Carp was at Morris in the Marseilles pool (river km 423), and the farthest upstream that hybrid Asian carp were captured was at I-55 in the Dresden Island pool (river km 447). The highest numbers of all Asian carp taxa were captured at Henry (Peoria pool; river km 306). We captured 374 potential age-1 (< 500 mm) Asian carp (371 Silver Carp, 1 Bighead Carp, and 2 hybrid Asian carp), which were most abundant at Henry, but were generally scarce elsewhere, and none were captured upstream from Morris. This indicates that Asian carp populations in the Illinois River consist primarily of larger, older fish, which is another indication of poor recruitment of Asian carp in the Illinois River in recent years. Additionally, as Asian carp may not reach 500 mm until age-2, the 500 mm threshold used to define age-1 Asian carp may actually overestimate the total number of age-1 fish. Further research is therefore needed to refine length-at-age estimates for Asian carp in the Illinois River.

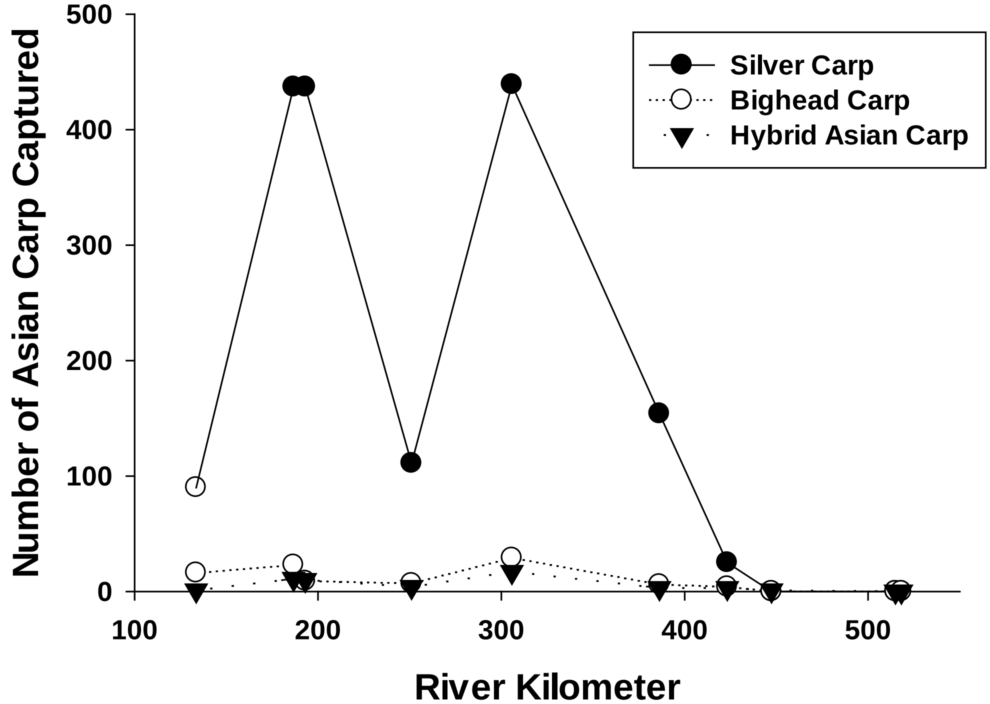

Figure 3. Total number of Silver Carp, Bighead Carp, and hybrid Asian carp captured at each sampling site in the Illinois Waterway in 2013. River kilometer is measured as distance upstream from the Mississippi River.

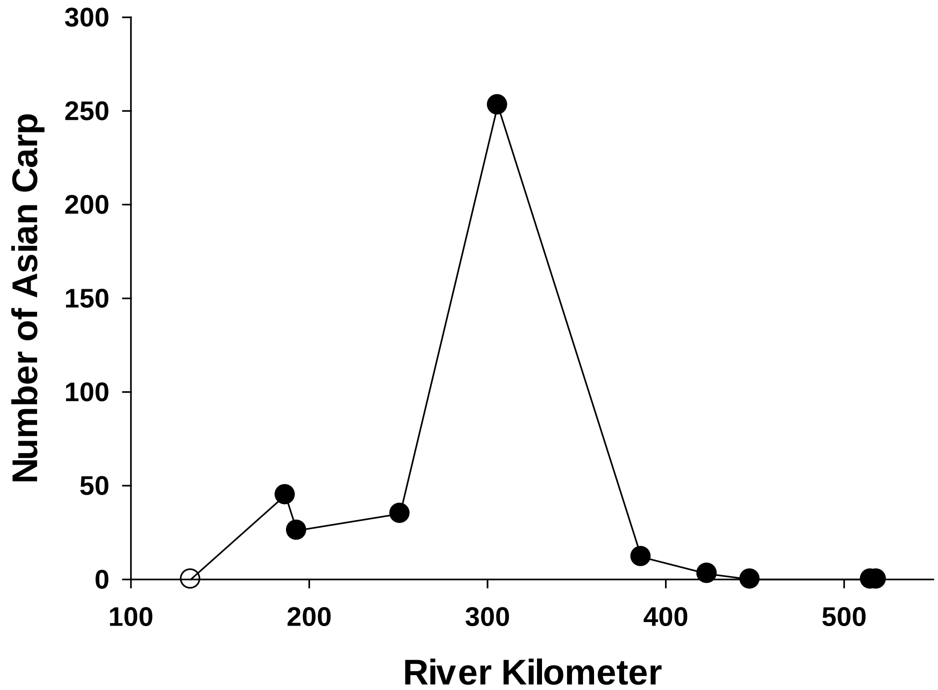

Figure 4. Number of possible age-1 (< 500 mm) Asian carp captured at each sampling site in the Illinois Waterway in 2013. River kilometer is measured as distance upstream from the Mississippi River.

During 2013, 513 Asian carp (506 Silver Carp, 7 Bighead Carp) were captured during tributary sampling. No Asian carp were captured or observed in the Kankakee River, 144 were captured in the Mackinaw, 157 in the Sangamon, and 212 in the Spoon River. All cleithra have been sectioned and age analyses are proceeding.

Detection probabilities for Asian carp were generally lower at upstream sites than for downstream sites, and were found to be strongly correlated with catch-per-unit-effort for both pulsed-DC electrofishing and hoop nets. The probability of capturing at least one Silver Carp in a 15-minute pulsed-DC electrofishing transect ranged from 0.17 at Morris (Marseilles pool) to 0.87 at Matanzas Lake (LaGrange pool; river km 187). All sites in the LaGrange pool had single-sample detection probabilities higher than 0.83, whereas Morris was the only site where Silver Carp were captured that had a detection probability less than 0.70. Cumulative probability curves indicated that a minimum of seventeen 15-minute electrofishing transects would be required to achieve a 95 percent probability of capturing at least one Silver Carp, given the abundance of this species present at Morris. The probability of detecting Bighead Carp with hoop nets ranged from 0.07 at Ottawa (Starved Rock pool; river km 386) to 0.52 at Matanzas Lake. Cumulative probability curves indicated that a minimum of 24 hoop net-nights would be required to achieve a 95 percent probability of capturing at least one Bighead Carp in a hoop net given the abundance of Bighead Carp and the site characteristics present at Morris, whereas a minimum of 42 hoop net-nights would be required to achieve this same cumulative detection probability at Ottawa. Required sample size estimates from Morris for Silver Carp, and from Ottawa and Morris for Bighead Carp, may be used as the very minimum recommended sampling effort necessary to detect Asian carp at upstream sites, or at other locations with low population densities. However, as both Silver Carp and Bighead Carp are known to occur at our sampling site in the Dresden Island pool, but were not detected by our sampling efforts at this location using either hoop nets or pulsed-DC electrofishing, even larger sample sizes are likely warranted in areas of lower abundance.

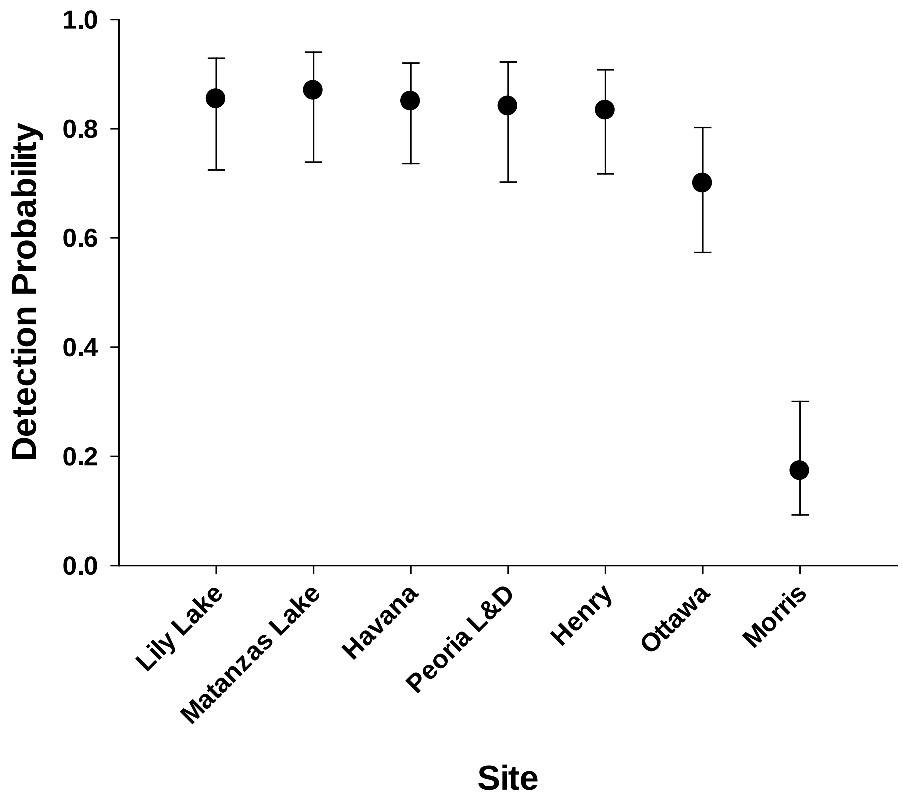

Figure 5. Estimates and 95 percent confidence intervals of the mean probability of capturing at least one Silver Carp during a 15-minute pulsed-DC electrofishing transect at different sites in the Illinois Waterway. Sites are ordered from downstream (left) to upstream (right). Estimates are derived from models generated using PRESENCE software.

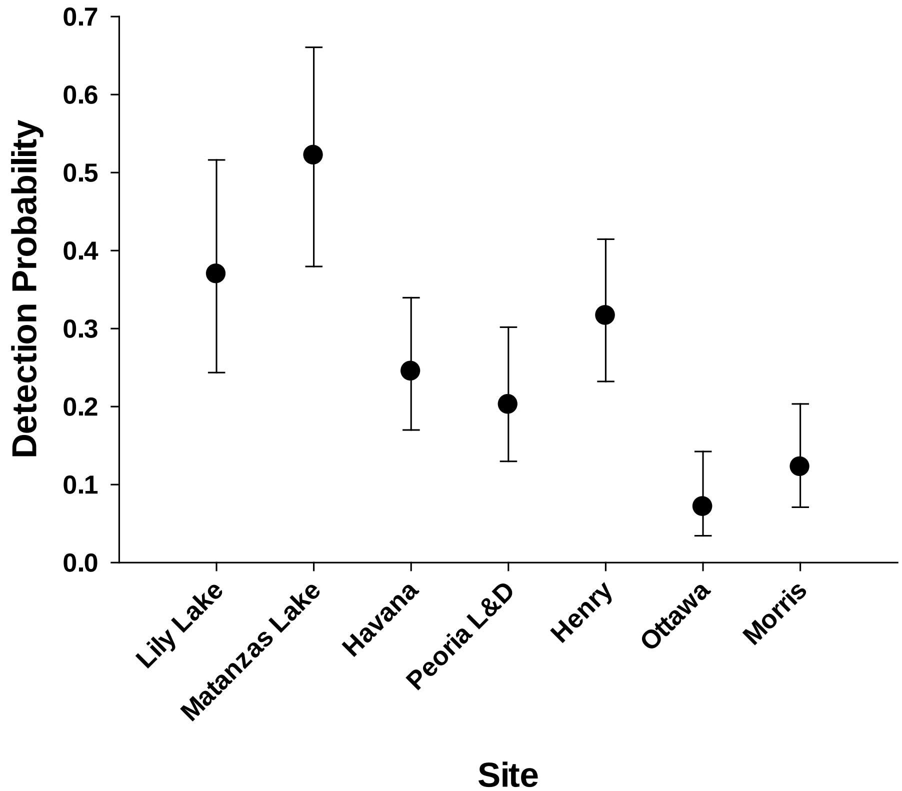

Figure 6. Estimates and 95 percent confidence intervals of the mean probability of capturing at least one Bighead Carp with a single hoop net-night at different sites in the Illinois Waterway. Sites are ordered from downstream (left) to upstream (right). Estimates are derived from models generated using PRESENCE software.

Recommendations: Because 2013 represented another poor recruitment year for Asian carp, sampling during high recruitment years will be necessary to determine sampling efficacy for age-0 Asian carp across gears and to monitor for Asian carp recruitment in the upper Illinois Waterway. Continued analysis of gear evaluation data will examine size selectivity among gears, variation in Asian carp condition and sex ratios across the length of the Illinois Waterway, and potential relationships between Asian carp and native fish species. Analysis of 2010 - 2013 hydroacoustic data is ongoing and may help to evaluate relationships between Asian carp abundance and catch-per-unit-effort. Video collected during electrofishing transects is also being analyzed as a potential alternative tool for determining Silver Carp densities. Tributary sampling will continue to evaluate demographic characteristics of Asian carp populations within tributary rivers and help assess the potential for these rivers to serve as sources of recruitment to the Illinois River. All detection probability estimates presented in this report should be considered preliminary, as additional analyses will continue to explore factors that affect the probability of detecting Asian carp. We hope to examine other gear types, multi-gear models, and incorporate other sources of data into our modeling efforts to better understand relationships between Asian carp abundance, site characteristics, gear efficiency, and detectability. Results of this future research will be reported as they become available to allow for adaptation of management activities.

Project Highlights:

- Pulsed-DC electrofishing was the most effective gear for capturing Silver Carp, whereas hoop nets were the most effective gear for capturing Bighead Carp. Hybrid Asian carp were vulnerable to both electrofishing and hoop nets.
- Asian carp were most abundant in the LaGrange and Peoria pools; abundance declined at upstream sites, and no Asian carp were observed in the CAWS.
- No age-0 Asian carp were observed in 2013. Possible age-1 Asian carp (< 500 mm) were most abundant in the Peoria pool, but were relatively scarce elsewhere, suggesting populations consisting primarily of larger, older fish.
- Tributary sites were sampled with pulsed-DC electrofishing gear in the Spoon, Sangamon, Mackinaw, and Kankakee Rivers during 2013. No Asian carp were observed in the Kankakee, whereas 513 Asian carp were captured from the other three tributaries.
- Detection probabilities for Asian carp were lower at upstream sites than at downstream sites. Given the lowest estimates of detection probability for sites where Asian carp were captured, a minimum of 17 pulsed-DC electrofishing transects (15-minute duration) are necessary to achieve a 95 percent probability of capturing at least one Silver Carp, whereas a minimum of 42 hoop net-nights would be required to achieve this same cumulative detection probability for Bighead Carp. Even higher sampling efforts are likely necessary to achieve these same levels of confidence at sites with lower Asian carp abundance.

Exploratory Gear Development Project

Wyatt Doyle, USFWS-Columbia Fish and Wildlife Conservation Office

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

Objectives: Develop new gears that will:

- be more effective than traditional gears at capturing carp
- be used in all habitat types
- be used for mass density reductions as well as detection in low density
- target all sizes of carp

Paupier (Butterfly Net)

Introduction: Originally, this gear was used without electricity and shown to be effective at capturing Silver Carp and other small bodied native species under 300 mm. Without electricity this gear remains effective for smaller size Asian carp. However, the nets were not effective at capturing large adult carp. The gear has subsequently been modified in 2013 to incorporate electricity. All age classes of Silver Carp have since been effectively captured with the gear using a variety of targeted mesh sizes. Silver Carp were effectively collected in reservoirs, tributaries and big rivers during 2013 trials.

Methods: A 7 m (24 ft) river boat was customized to hold two 4x2 m (12 x 6 ft) aluminum frames that supported a trawl type net. Each frame was electrified with booms and a support cable. As electricity was pulsed by an Infinity brand control unit the boat was operated at about 3.2 kph (2 mph) which enabled taxis and capture of Silver Carp. We used a separate boat with a DIDSON camera to observe fish interaction with the nets.

Results and Discussion: During 7-minute trawl runs in tributaries of the Missouri River, the mean average and SE of Asian carp captured was 0.23 ± 0.06 fish per square m or approximately 30 carp per trawl tow using 4X2-m frames, with the highest capture of 137 during a single tow. Relative to efficiency, 143 of 162 (or 88.2%) of the trawl runs captured Asian carp, and all runs caught at least one fish of some species. Using 80 mm (3 in) stretch mesh nets, 2,306 Silver Carp were captured ranging in size from 100 mm to 900 mm (Figure 1). Using 38 mm stretch mesh trawls we sampled at the electrical barrier of the CAWS and captured 25 fish ranging in size from 62 mm -294 mm. Fish species at the CAWS barrier were Gizzard and Threadfin shad and Skipjack Herring.

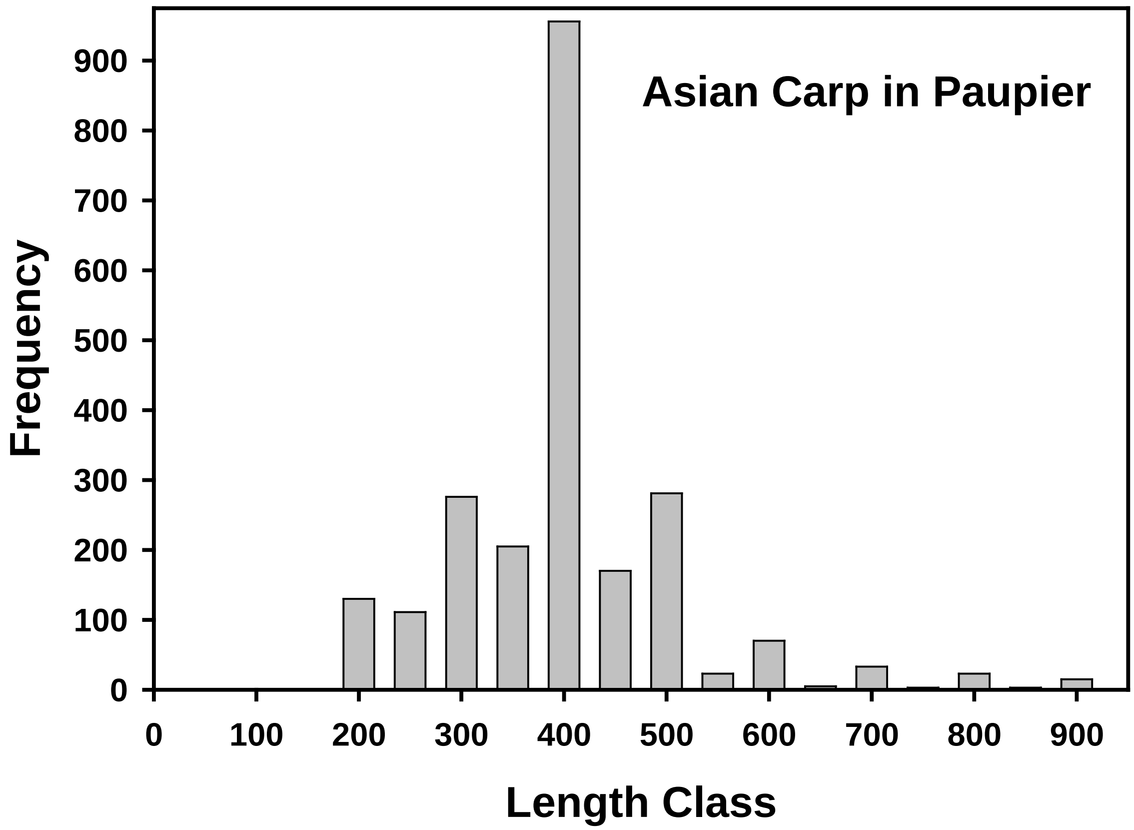

Figure 1. Silver Carp collected in 2013 using electrified paupier net within Missouri River tributaries.

Recommendations: Observations using this gear to date suggest that successful taxis can occur only under a specific range of boat resistance, electrode configuration, power output and pulse frequency range. Although taxis was observed in many circumstances there are still many unknowns relative to target parameters. As water temperatures warmed throughout the year, Silver Carp were much more evasive and it became harder to achieve taxis, although some fish were always captured. We experienced certain parameters whereby Silver Carp taxis was profound and fish literally jumped into the nets, however targeted replication of the electrical variation of those events was not always possible. More trials will be performed throughout 2014 to determine best electrical settings and application of the gear in different habitats including the CAWS.

Project Highlights:

- The Paupier captures juvenile carp without electricity
- All sizes of Silver Carp were readily captured throughout the year in all habitats sampled
- Appears to be a valuable tool for sampling paddlefish

Mamou Surface Trawl

Introduction: This trawl was designed to sample in shallow (1-2 m) backwaters and tributaries. The trawl was made of 'Sapphire or Spectra' brand material #9 size twine. The net was 8.38 m wide at the mouth with 25 mm stretch mesh for the body tapering down to a 4 mm 'Ace' mesh cod. The net could be modified with an 'accelerator funnel' that increased velocity at the mouth of the bag effectively flushing and trapping fish into the cod.

Methods: The net was deployed from the side of a 6 m long work boat powered by a 90 hp outboard. The net was pulled behind the boat in a zig-zag or arching manner so as to prevent prop disturbance. Sampling locations included backwaters of the Illinois River and tributaries of the Missouri River.

Results and Discussion: The gear collected 22,565 small bodied fishes in 32 seven minute tows with highly variable catches (N=1 to 11,600). The bulk of the catch consisted of Gizzard Shad and juvenile Asian carp. Fish ranged in size from 10 mm to 700 mm. The maximum effective size fish the net could capture was approximately 60 mm without the accelerator funnel and 100 mm with the accelerator funnel.

Recommendations: We anticipate this gear could be used to measure strength of spawning events or early recruitment in Asian carp. Additionally, the gear could be used for mass removal efforts of unwanted young carp. Additional mamou nets being designed will be larger, built of sleeker material with larger mesh and pulled with new 'Icelandic' type trawl doors which will enable us to target larger carp from surface to mid-water. Based on observations of the Paupier, we expect to be able to collect Asian carp up to around 350 mm before electricity is needed to prevent escape. The ability to collect larger fish declines with warmer water temperatures due to the fish's activity and ability to escape. Before the Paupier was electrified, Asian carp up to 350 mm were easily captured in the spring months leading us to expect we could effectively capture age-1 carp at colder temperatures with a larger surface trawl.

Project Highlights: The gear could effectively capture YOY carp in very shallow habitats of backwaters and tributaries and could be used inexpensively out of existing work boats.

PURSE SEINE

Introduction: The purse seine has application in removal of tonnage at specifically identified locations. Challenges for this gear compared to oceanic applications are shallow water and snags. Purse seines by nature rely on a bag effect throughout the entire net when pursing. However, Asian carp habitats rarely have deep water unless it is concentrated in a small area and they are found mostly in rivers which are flowing and this confounds the deployment of this net. Our trials tested the limitations of this gear with the habitats available.

Methods: Oceanic Purse Seine was used to encircle and bottom purse around large schools of carp. A floating 183 m (600 ft) long net x 4 m (12 ft) deep with #22 twine and 133 mm (5 ¼ in) stretch nylon mesh was custom built for the trials. The net has 3 removable panels of 61 m (200 ft) each. Trials sites were performed at two locations. Trial one was conducted during May at a Missouri River scour that measured 10 m (34 ft) deep and the second trial was during June at an oxbow lake in Iowa that was 1.5 m – 4.6 m (5-15 ft). deep. The net was deployed by casting an anchor and allowing the net to come off the bow of the boat while the boat encircled the school of observed carp. A tear-drop encirclement occurred at which time the tom weight was retrieved and attached to the other end of the net. The purse line was attached to the boat which was cinched tight by motoring in reverse.

Results and Discussion: In the scour effort, many fish were observed challenging the net and only one fish was captured. A 61 m (200 ft). section was used alone but was not effective since the fish could not be encircled without evading the closure. We therefore used the full 183 m (600 ft) t. of net which was sufficient to encircle the fish without spooking them. We hypothesized that fish's awareness of the net led to them escaping through a gap around the tom weight or through the bottom of the net before closure.

At the oxbow lake we saw 47 adult Silver Carp jump over the top of the net and only captured 6 carp. It appears that carp coral easily and if the net is pursed slowly do not exhibit a fright response. Once a fright response starts the school quickly challenge any opening in the net including jumping over the top.

Recommendations: Pursing should be done against a shallow bank to ensure no bottom opening is available during the process. A flat purse net of a depth reasonable for the waters of the Illinois River and its' tributaries will likely not work because of Silver Carp's ability to jump. There may still be opportunity to capture Bighead Carp, however observing large schools of fish to target will be a challenge. Pursing in cold water may have different results, however we did not try it outside of the spring and summer periods since the net had been dismantled for modification.

The net will be modified to include a long bag sewn into the seine that is commonly used in catfish aquaculture facilities in an attempt to give the fish an escape hole other than over the top. The purse mechanism was problematic because of size of the net and absence of a hydraulic capstan. In keeping with the objective of developing a usable tool by commercial fisherman or researchers, we are modifying the net to a Danish Seine design whereby the net will be slowly pulled in from the bottom along the side of the boat. If the bag concept doesn't work, a hood for the net may be installed.

Project Highlights:

- Conceptually the seine worked, but not practically
- Fish jumping out of the net will be problematic in capturing Silver Carp
- The bulk size of the net was problematic to a 4 person crew without an appropriate boat
- A modification of the net is being done and it will be re-tested

Unconventional Gear Development Project

Steven E. Butler, Matthew J. Diana, Jonathan A. Freedman, 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: Unconventional gears were employed at multiple sites in order to evaluate their effectiveness across a range of Asian carp densities. In 2013, large hoop nets and surface-to-bottom gill nets were set at eight sites throughout the Illinois Waterway. Additionally, the effectiveness of driving Asian carp into surface-to-bottom gill nets using both traditional pounding methods and electrofishing was tested at these same sites. Great Lakes trap (pound) nets were deployed at Lake Calumet (CAWS; O'Brien pool), at the Hansen Materials Service Corporation area (Marseilles pool), and at Lily Lake (LaGrange pool). All gears were evaluated for the numbers and sizes of Asian carp and other fishes they were able to capture in comparison with traditional sampling gears. 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.

- Large hoop nets (2 m diameter, 6.4 cm square mesh) were set overnight for a minimum of 8 net-nights on each sampling trip for comparison with standard (1.2 m diameter) hoop nets.
- 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) were deployed for a minimum of 4 four-hour sets during each season at each site. They were compared with small-mesh floating gill nets (45.7 m x 3.0

m; 1.9, 2.5, 3.2, 3.8, 5.1 cm mesh), and large-mesh sinking gill nets (4.57 m x 1.8 m; 6.4, 7.6, 8.9, 10.2, 12.7 cm mesh).

- Driving fish into surface-to-bottom gill nets was tested at each site during summer and fall. Treatments included a control set, a set where fish were driven into the net with traditional pounding, and a set where fish were driven via pulsed-DC electrofishing, each lasting 15 minutes.
- Great Lakes trap (pound) nets (100 m lead, 6.1 x 3.0 x 3.0 m pot, 7.6-9.1 m wings, 3.8-7.6 cm mesh) were set for extended periods (1-2 weeks) at each site during summer. Pound nets were checked periodically (1-3 day intervals) 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 centimeter mesh) and fyke nets (15 m x 1.3 m lead, 0.9 x 1.8 m frame, 1.8 centimeter mesh) were also set for multiple net-nights at each site concurrent with pound nets for comparison purposes.

Results and Discussion: Large hoop nets captured fewer fish of all taxa in 2013, as well as fewer Silver Carp, Bighead Carp, and hybrid Asian carp. This is similar to results observed during 2012, suggesting that large hoop nets consistently underperform relative to standard hoop nets. The reason for this pattern is unknown, but we cannot recommend the use of large hoop nets for Asian carp sampling activities given these findings. Additional modification of this gear may result in higher catch rates, but will require further evaluation before it can be recommended for routine use.

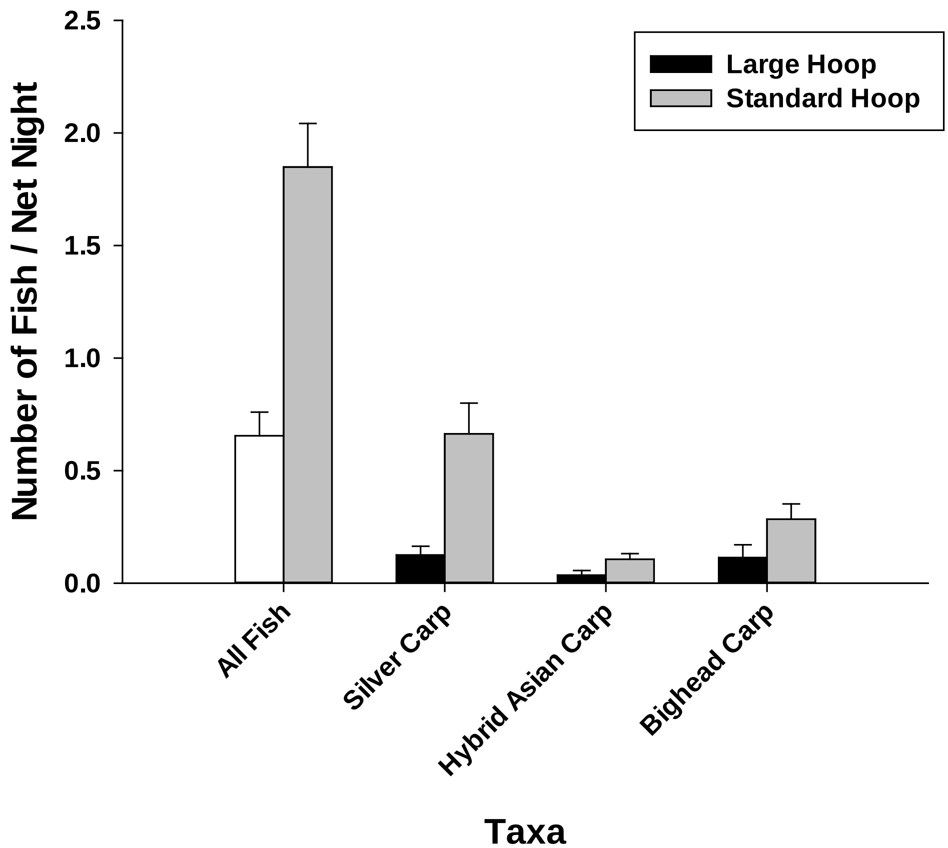

Figure 1. Catch-per-unit-effort of all fish, Silver Carp, hybrid Asian carp, and Bighead Carp in large and standard-sized hoop nets in the Illinois Waterway during 2013.

Although small-mesh floating gill nets were found to produce a higher average catch of all fish taxa in 2013, surface-to-bottom gill nets captured more Silver Carp, Bighead Carp, and hybrid Asian carp per set than either small-mesh floating or large-mesh sinking gill nets. This result is consistent with findings from 2012, and suggests that surface-to-bottom gill nets may be an effective tool for sampling Asian carp, particularly in deeper habitats where electrofishing is less effective. The effectiveness of this gear may be due to the vertical coverage that prevents Asian carp from passing over or under the net, or due to the bags of mesh created by the hobbled configuration (8.5 m tied down to 6.1 m depth) of this gear.

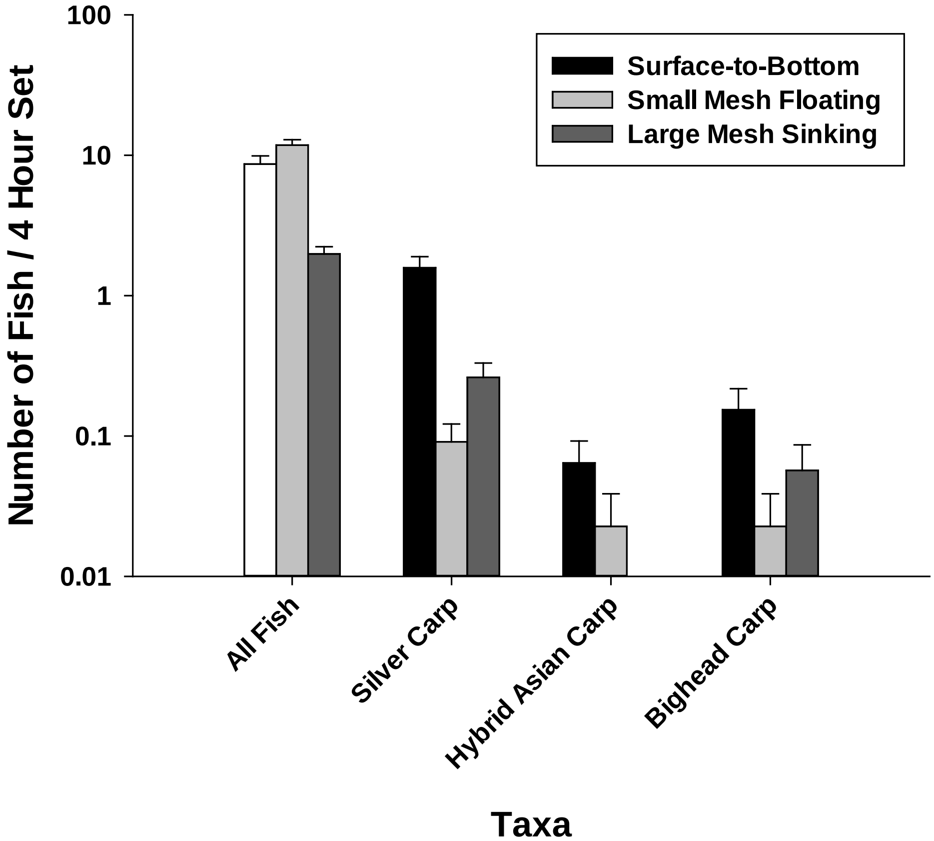

Figure 2. Catch-per-unit-effort of all fish, Silver Carp, hybrid Asian carp, and Bighead Carp in surface-to-bottom, small-mesh floating, and large-mesh sinking gill nets in the Illinois Waterway during 2013. Note the logarithmic scale on the y-axis.

Driving fish into surface-to-bottom gill nets proved effective for capturing Asian carp, and drives using pulsed-DC electrofishing captured more Silver Carp and Bighead Carp than either control sets or drives using pounding. However, fewer hybrid Asian carp were captured in either drive treatment than in control treatments. Using 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.

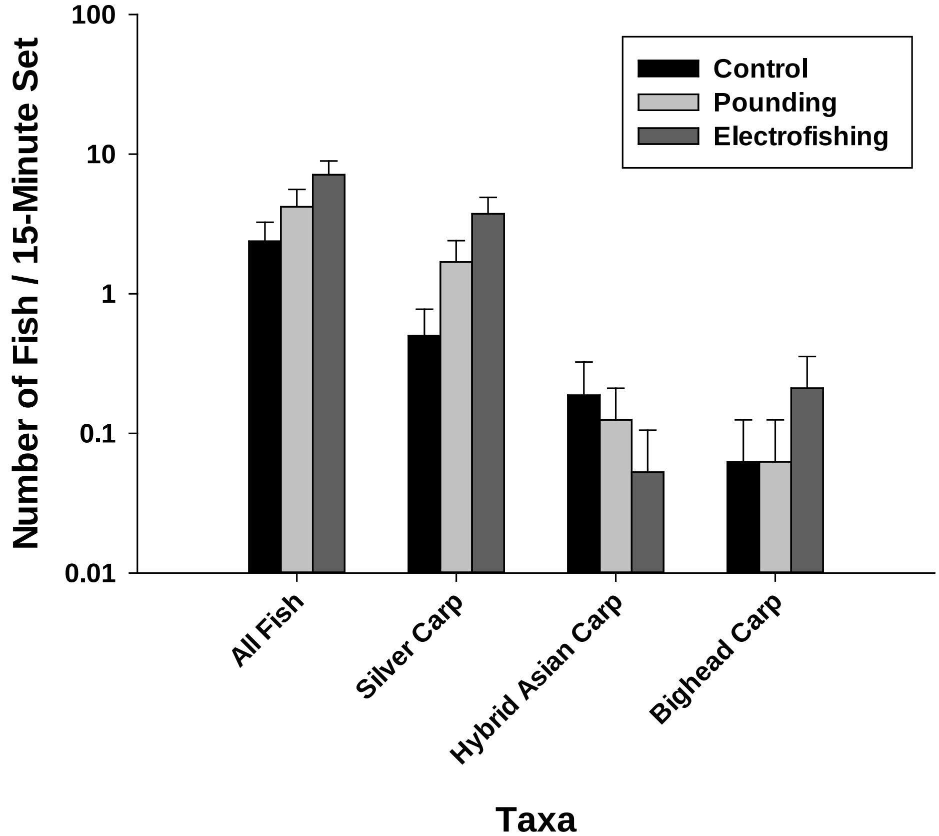

Figure 3. Catch-per-unit-effort of all fish, Silver Carp, hybrid Asian Carp, and Bighead Carp in surface-to-bottom gill nets set for 15-minutes with a control treatment, a treatment where fish were driven into the net with traditional pounding, and a treatment where fish were driven into the net via pulsed-DC electrofishing. Note the logarithmic scale on the y-axis.

In 2013, Great Lakes trap (pound) nets were set for 18 net-nights at Lake Calumet, capturing 263 fish (14.6 fish/net-night). No Asian carp were captured at Lake Calumet during these efforts. Pound nets were set at the Materials Service Pit at Morris for 46 net-nights, capturing 1,470 fish (32.0 fish/net-night), including 194 Silver Carp, 223 Bighead Carp, and 99 hybrid Asian carp. Pound nets were set at Lily Lake for 8 net-nights, capturing 229 fish (28.6 fish/net-night), including 72 Silver Carp, 66 Bighead Carp, and 2 hybrid Asian carp. These nets appear to catch a variety of fishes, including a high proportion of Asian carp where these species are present. Indeed, over 61 percent of the fish captured at Lily Lake consisted of Asian carp. Pound nets may therefore be a useful tool for long-term monitoring in appropriate habitats. However, pound nets at Lake Calumet were vandalized again in 2013, resulting in nets that were not fishing properly and therefore producing lower catch rates, in addition to requiring extensive repair. Vandalism has occurred every time pound nets have been set at Lake Calumet, suggesting that this pattern is likely to continue if improved public relations or increased law enforcement are not pursued at this location.

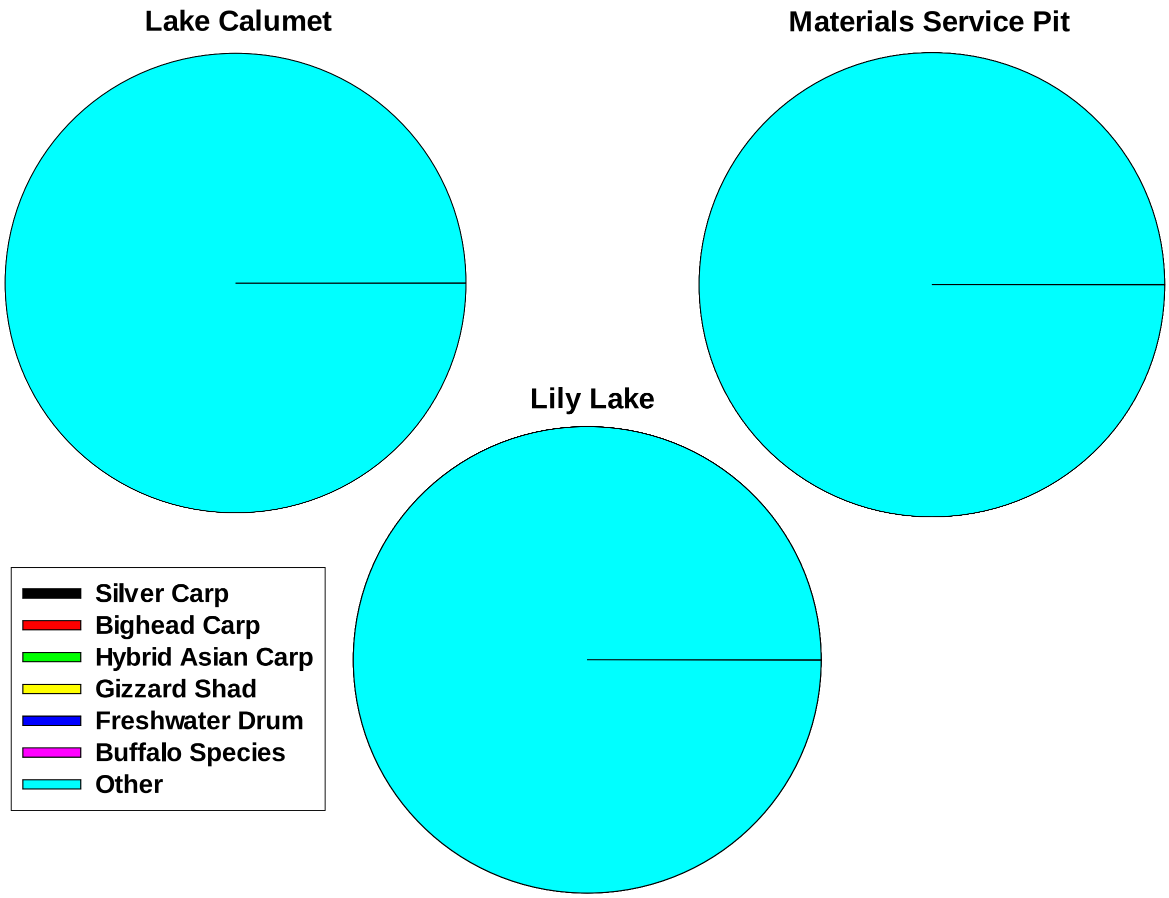

Figure 4. Relative catch of Silver Carp, Bighead Carp, hybrid Asian Carp, and other fish species in pound nets set at Lake Calumet, the Materials Service Pit, and Lily Lake in 2013.

Both hoop nets (Lake Calumet = 0.13 fish/net-night; Materials Service = 3.2 fish/net-night; Lily Lake = 0.46 fish/net-night) and fyke nets (Lake Calumet = 12.3 fish/net-night; Materials Service = 10.9 fish/net-night; Lily Lake = 8.6 fish/net-night) that were set concurrent with pound nets produced lower catch-per-unit-efforts than pound nets and captured far fewer Asian carp (Hoop nets: 3 Silver Carp, 4 Bighead Carp, 2 hybrid Asian carp at Materials Service Pit; 3 Silver Carp, 1 Bighead Carp, 1 hybrid Asian carp at Lily Lake / Fyke nets: 2 Bighead Carp and 1 hybrid Asian carp at Materials Service Pit; 1 Silver Carp and 1 Bighead Carp at Lily Lake).

Recommendations: Due to poor performance relative to standard-sized hoop nets, we do not recommend large hoop nets for Asian carp sampling purposes. Surface-to-bottom gill nets appear to be an effective tool for capturing Asian carp, and may be a useful tool when used in conjunction with driving via electrofishing. However, sample sizes for treatments that drive fish into surface-to-bottom gill nets are still relatively low, so additional study of these methods is warranted. The ability of pound nets to be deployed for extended periods, capture large numbers of fish, and for non-target fishes to be released alive after capture makes this gear a potentially attractive tool for Asian carp monitoring purposes. However, pound nets are a consistent target of vandalism at some locations and may not be appropriate for setting in flowing water.

Project Highlights:

- Large (2 m) hoop nets captured fewer fish of all taxa, and fewer Asian carp than standard (1.2 m diameter) hoop nets.
- Surface-to-bottom gill nets captured more Asian carp than traditional gill nets during 4-hour sets.
- Driving fish into surface-to-bottom gill nets with pulsed-DC electrofishing gear captured more Asian carp than drives using traditional pounding methods or control sets.
- No Asian carp were captured in pound nets at Lake Calumet in 2013. Pound nets were effective at capturing large numbers of fish, including a high proportion of Asian carp, at the Materials Service Pit (Marseilles pool) and at Lilly Lake (LaGrange pool).

Water Gun Development and Testing

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US Geological Survey – Illinois Water Science Center and Upper Midwest Environmental Sciences Center; Northern Illinois University; Southern Illinois University; Ohio State University; Illinois Department of Natural Resources; Hanson Material Service.

Introduction:
There is an immediate need to develop and implement control strategies to prevent Asian carp from entering the Great Lakes Ecosystem from the Mississippi River. Seismic technology or other sound related technologies show potential as deterrents to fish movement. Seismic sound waves can be produced by pneumatic water gun(s) that compress water with a piston traveling through a cylinder. The resulting burst of water induces cavitation which generates a pulsed sound-pressure wave as the cavity collapses. These sound-pressure wave may deter or even kill fish depending on proximity to the wave source and water guns may be operated in either fixed or mobile deployments (Gross et al., 2013). Other underwater sounds (e.g. boat motors) have been shown to stimulate Asian carp jumping are also being investigated. In addition to the need to assess physiological and behavioral effects of the water guns and sound on Asian carp, the seismic energy produced by water guns specifically needs to be evaluated because of its potential impacts on in-water structures (e.g. canal walls, lock structures). This summary provides some examples of data collections for water gun discharge mapping, fish behavioral responses to sound energy stimuli, and water gun barrier field applications.

Objectives: There were three main objectives for 2013 water gun developments and testing:

1) Establish physical characteristics of water gun discharge to establish an effective barrier and evaluate potential impacts on in-water structures
2) Characterize the response of Asian carp and select native fishes to water gun discharge and complex sounds in man-made ponds
    a. Pond trials were conducted in 2012-13 at UMESC
3) Implement an integrated pest management demonstration including a water gun barrier to control movements of Asian carp

Establish physical characteristics of water gun discharge to establish an effective barrier set up and evaluate potential impacts on in-water structures

In 2013, water gun pressure gradient measurements were collected to help answer questions from the Army Corp of Engineers Rock Island District about the underwater pressures exerted upon in-water structures from a water gun. Data collections included a series of investigations at the USGS-UMESC in La Crosse, WI, including one- and two-gun static water gun barrier set-ups and multiple pressure gradient measurement schemes in a man-made pond. Water gun field data collections also occurred in Morris, IL allowing for an in-field pressure gradient measurement set to be collected quantifying the magnitude and extent of the pressure wave produced by the water guns.

A single water gun size (Model S80) was used in 2013. One-gun and two-gun set ups were included in pond trials (Figure 1) and field trials measured pressures generated from a static two-gun barrier set up in an off-channel site on the Illinois River. Each gun set included guns suspended 1.1 m below the water surface (depth at discharge ports). Hydrophones were suspended at specific points within the test pond and measured pressures at 0.46, 1.1, and 1.7 m (1.5, 3.5 and 5.5 ft) below the water surface. The guns were operated at 1,000, 1,500 and 2,000 PSI for pressure testing. The data collected for each hydrophone were averaged (five water gun discharges per location) and then pressure maps were prepared to define the pressure distribution horizontally and vertically in the water column. Additionally, robust underwater blast sensors measured the maximum PSI values approximately 4.6 m from the S80 water gun and fixed, three-component geophones were positioned on the berm of the pond to provide a consistent point of reference to judge the repeatability of the water gun pressure levels and determine the impact of the water gun on earthen structures.

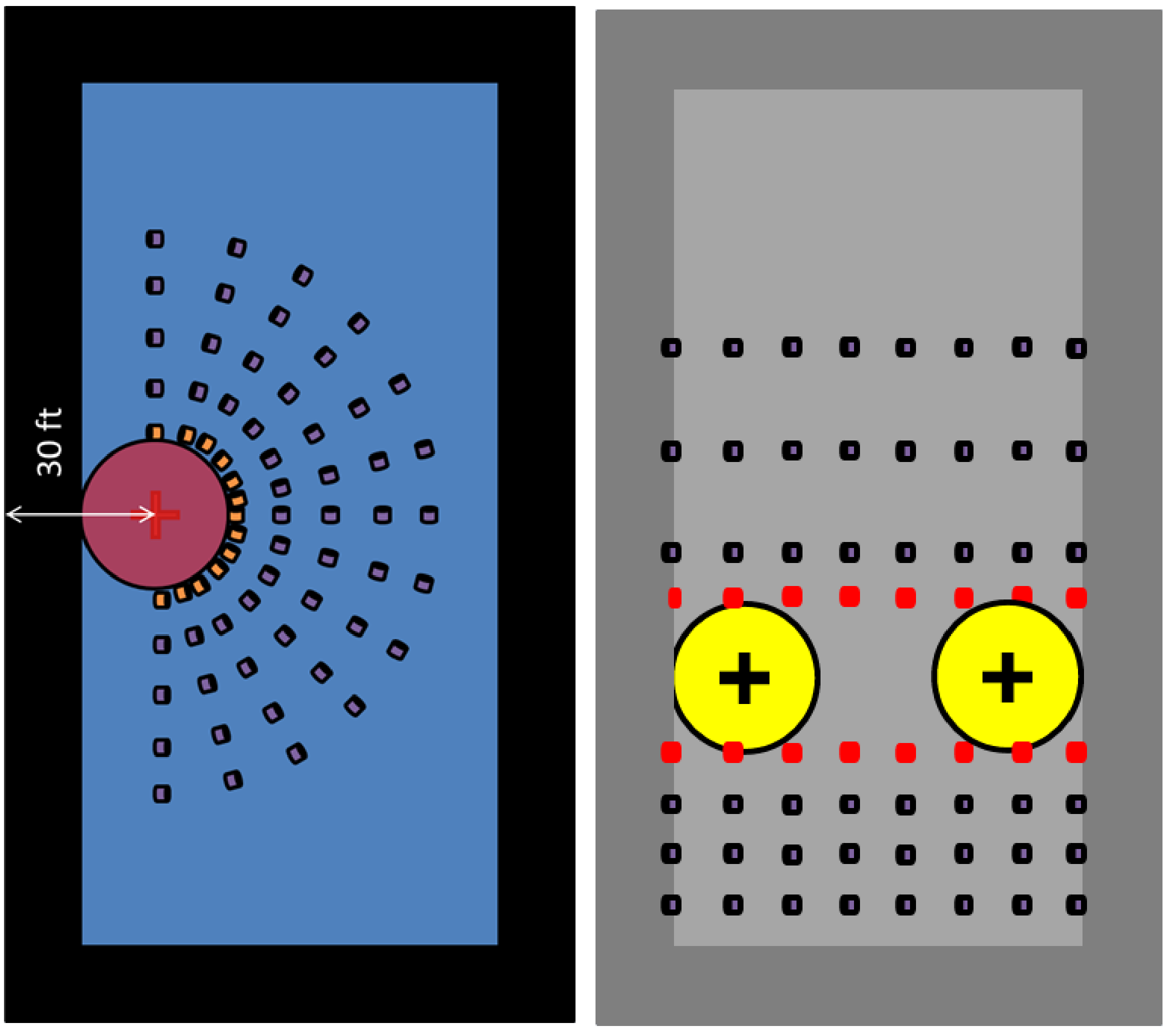

Figure 1. Schematics of water gun pond-trial pressure mapping set-ups for 2013. One-gun radial set (right) and two-gun set (left). For each scheme large circles indicate approximate gun locations and dots indicate hydrophones. Dots closest in proximity to gun circles indicate blast sensors.

Results and Discussion:

Concerns about the potential structural impacts and weather conditions prevented planned field testing during 2012-13 specifically targeting in-water structures on the Illinois River. However, to address concerns regarding potential structural impacts, the USGS completed additional analyses of the existing data, begun developing pressure gradient maps, and started plans to demonstrate the safety and effectiveness of the water guns at “surrogate” sites that approximate the conditions at the O'Brien Lock and Dam. Two sites near Lamont, IL have been targeted for structural tests in 2014. Processing of the data sets is ongoing, but initial pressure distribution maps have been prepared for one-gun sets (Figure 2) and two-gun sets where measurements were taken between two guns at varying distances to observe blast wave interactions (Figure 3). Water gun pressure maps were also generated during deployment at Morris, IL (Figure 4).

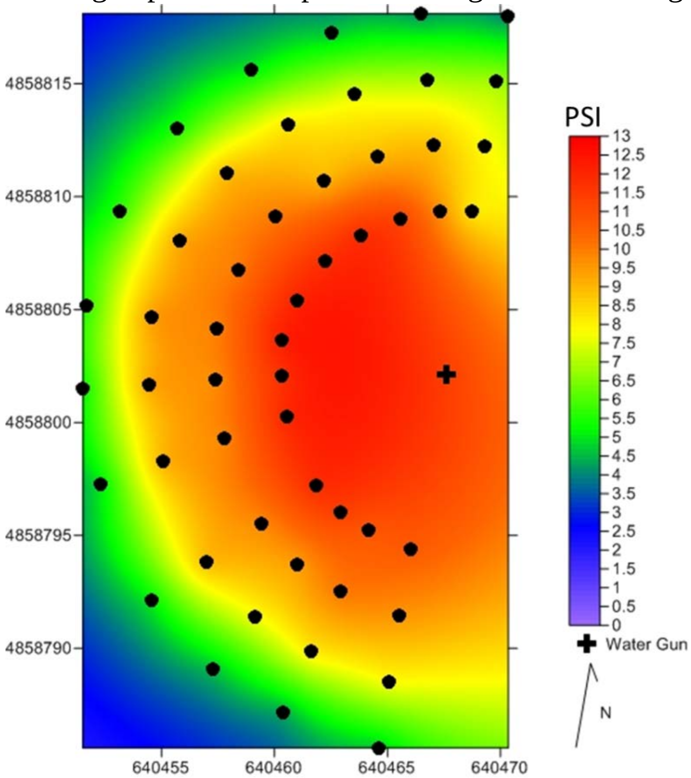

Figure 2. An example pressure map from the one-gun set in the UMESC test pond at a depth of 1.2 m and water gun operating pressure 1,500 PSI. Black cross indicates gun location and black dots are hydrophones.

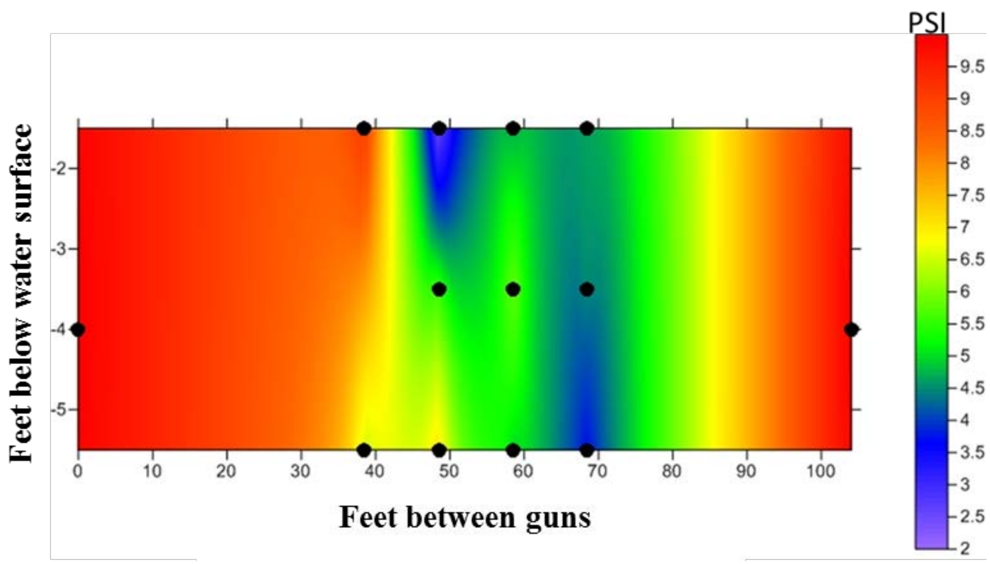

Figure 3. An example pressure map from the two-gun set in the UMESC test pond between two guns firing simultaneously approximately 32 m at an operating pressure of 1,500 PSI. Black dots indicate hydrophone locations; guns were positioned 31.7 m (104 ft) apart.

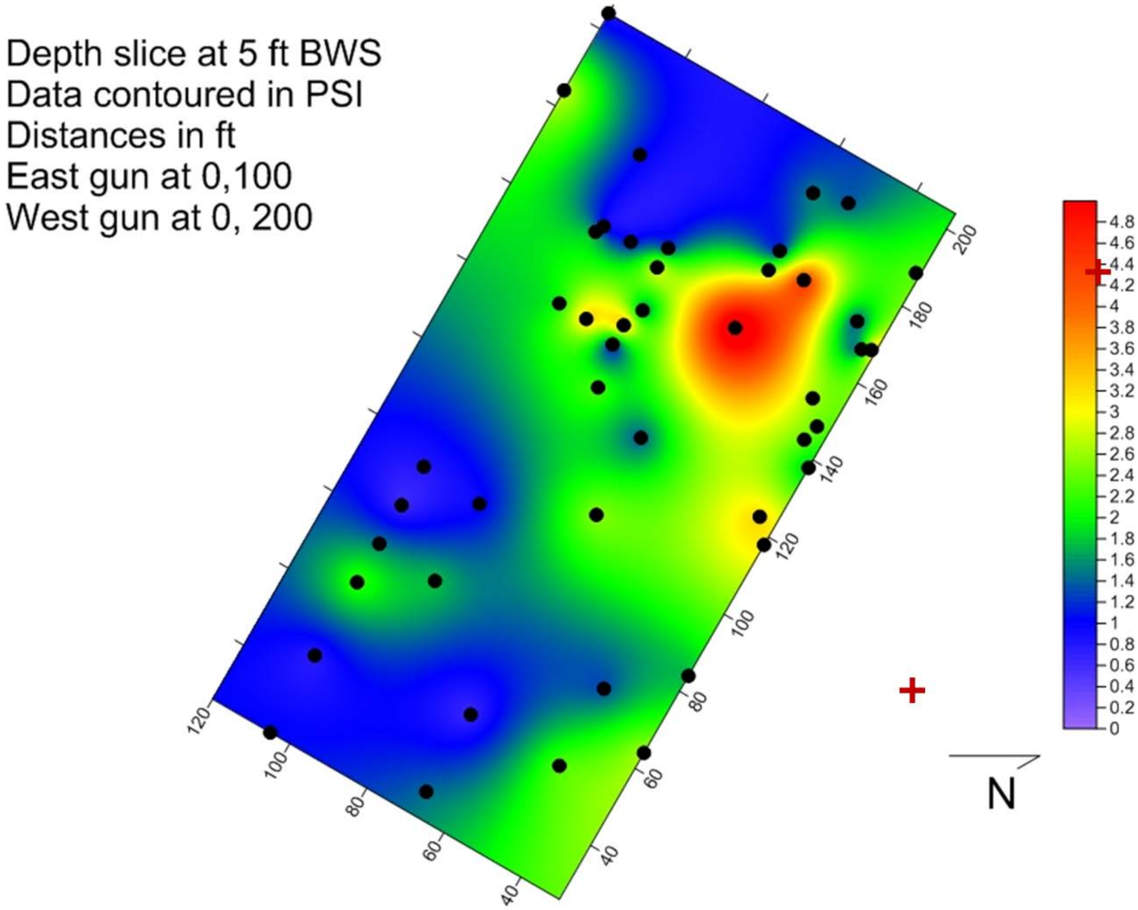

Figure 4. An example of a pressure map generated from a two-gun set in the Hanson Material Service field site 1 at a depth of 1.5 m and water guns operating at 1,500 PSI. Black dots indicate hydrophone positions and guns are positioned at map coordinates of: 0, 100 and 0, 200.

Modeling (3D) of the water gun pressure data sets are in progress to understand the volume of space affected by the water guns, i.e., the volume surrounding the water gun whose pressure gradient exceeds certain threshold levels.

Characterize the response of Asian Carp and select native fishes to water gun discharge and complex sounds in man-made ponds

Behavioral responses and movements of fish during water gun operation were made at UMESC in a 0.2 ha earthen pond. The test pond had security cameras and physical observer surveillance, a netted kettle, and bird flashing suspended over the pond to prevent avian and mammalian predation on test fish. Six preliminary trials were done in 2012 and seven trials were conducted in 2013 specifically using hydroacoustics and acoustic telemetry to monitor fish movement in relation to the discharge of two static model S80 water guns (Figure 5).

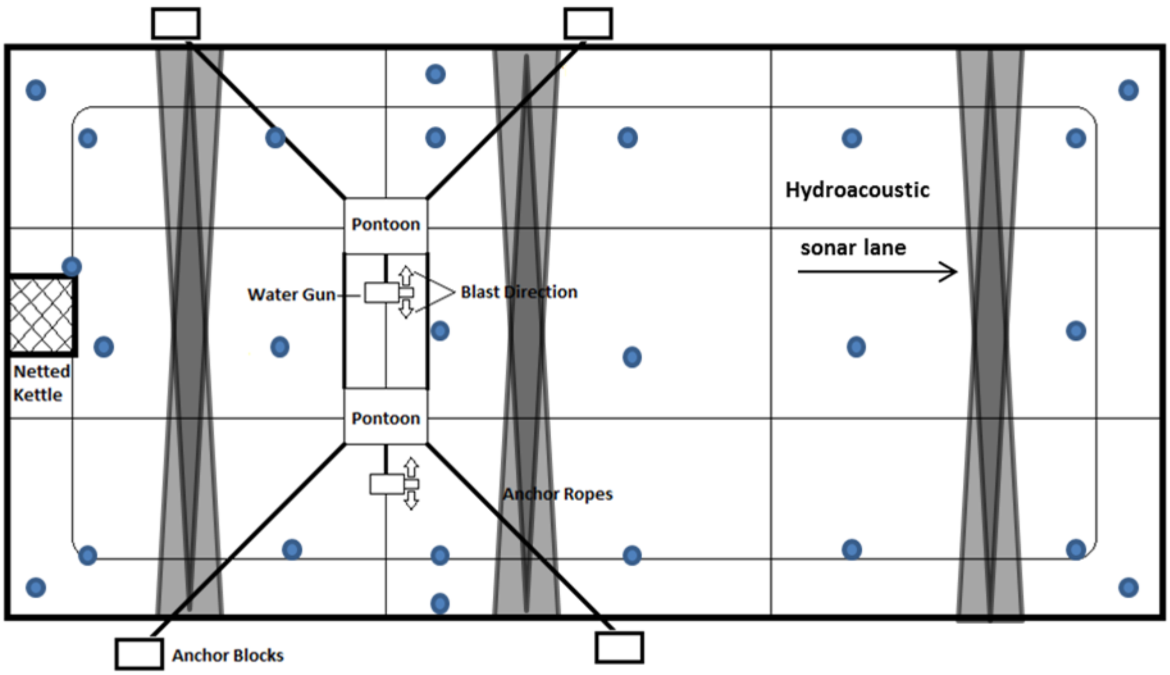

Figure 5. UMESC test-pond used for 2013 water gun trials. Hydroacoustic lanes; shaded in grey, were numbered lane 1 to 3 from S to N. Water guns were positioned in the southern portion of the pond between lanes 1 and 2. Blue circles indicate approximate positions of acoustic telemetry hydrophones. Not to scale.

Pond trials evaluated the response of Asian carp (Bighead Carp *Hypopthalmycthis nobilis* and Silver Carp *H. molitrix*) and four native fish species (Yellow Perch *Perca flavescens*, Channel Catfish *Ictalurus punctatus*, Paddlefish *Polyodon spathula*, Bigmouth Buffalo *Ictiobus cyprinellus*).

Water gun positions were selected to create a 5 PSI gradient across the short axis of the pond; water guns were operated overnight when fish activity was greatest. Two model S80 water guns were placed equidistant across the short axis of the pond and at about 1/3 the pond long axis, closest to the deep end of the pond, during the 2013 pond trials (Figure 5). Trials 1-4, evaluated the response of Bighead Carp (n=30) and Silver Carp (n=30) exposed to water guns fired every 10 seconds in one hour intervals (one hour on, one hour off…) at 1000, 1300, and 1600 PSI after a minimum of 24 h pond acclimation period; however, Trial 4 was also used to observe fish movements when water guns were kept silent >24 h. Trials 5, 6, 7 included Bighead Carp (n=10) and Silver Carp (n=10) and four native fish species (n=5 of each species). For Trials 5-7, fish were not allowed pre-firing pond acclimation to observe if fish would challenge an active 1300 PSI water gun barrier; however, Trial 7 was a control and water guns were kept silent to observe fish movements in the test pond in the absence of seismic stimuli. Regarding external attachment of acoustic tags, 10 of 30 of each species of Asian carp were externally tagged for Trials 1-4, and all fish in Trials 5-7 were externally tagged with acoustic transmitters. At the end of each test trial fish were harvested out of the pond, euthanized, weighed and measured, and necropsies were performed. Survival, tag retention at the point of insertion, and tissue/organ damage were also observed.

Fish movements in the test-pond were monitored two ways: 1) Hydroacoustic sonar systems (BioSonics Inc., Seattle, WA, USA) were used to detect fish in specific regions of the pond, and 2) Acoustic telemetry systems (Hydroacoustic Technology Inc.; HTI; Seattle, WA, USA) were used to position tagged fish during pond trials (Figure 5). For fixed side-looking sonar lanes, six 200 kHz echosounder transducers were aligned to create 3 lanes of 2 opposing-faced transducers. The HTI acoustic telemetry system consisted of two Model 290-16 acoustic tag receivers (ATR) with GPS and Hardware Key for real-time display of tag positions and tag track marking software. Data were collected with AcousticTag™ and MarkTags™ software packages and Geo-Ref Imaging software option was included for mapping tag track locations with Google Earth Maps. Twenty-five hydrophones were placed within the pond for sub-m positioning of fish (Figure 5).

For acoustic tag tracking and data collections, four metrics were included to assess behavior before, during, and after the gun firing: 1) average swimming speed, 2) average distance from the guns, 3) average persistence velocity, and 4) average turning velocity. Kernel density plots are being created to illustrate fish location within the pond during the before, during and after selected time periods.

Results and Discussion:
Preliminary 2012 pond trials indicated behavior/movement patterns changed night or during heavy overcast weather conditions; fish detections (sonar and video) increased and schooling patterns appeared to relax. Preliminary trial data were used to establish 2013 experimental designs.

Average weights and lengths of fish used in 2013 pond trials included:
Bighead Carp 93g, 201mm;
Silver Carp 215g, 259mm;
Bigmouth Buffalo 144g, 05mm;
Paddlefish 337g, 297mm (measured eye to fork);
Channel Catfish 107g, 186mm;
Yellow Perch 80g, 189mm.

No external tagged fish mortality occurred for trials 1-4. However, there were two Bighead Carp and one Silver Carp mortalities in trial 4 (6.6% and 3.3% mortality respectively). These fish were not externally tagged for acoustic tracking and it remains unknown if these fish expired due to seismic energy. All fish in trials 5, 6, and 7 were externally tagged to track their movements.

For trial 5, two Bighead Carp mortalities (20%) and five paddlefish mortalities (100%) occurred. Trial 6 had 1 Bighead Carp mortality (10%) and five paddlefish mortalities (100%). Fish/tag losses due to predation did not allow accurate survival estimates for all trials with Asian carp and native species combined (Table 1). Thus, acoustic tag tracking was lost for some fish in pond trials.

Table 1. Fish stocking, harvest, predation losses, and external transmitter tag retention for seven fish behavior pond trials conducted at UMESC May-June 2013.

Species	Total fish stocked	Fish stocked with external tags	External tagged fish recovered	Predation losses	Tag retained	Tag lost	% Tag loss
Bighead Carp	150	70	61	9	58	3	4.9
Silver Carp	150	70	69	1	69	0	0.0
Bigmouth Buffalo	15	15	10	5	5	5	50.0
Paddlefish	15	15	11	4	11	0	0.0
Yellow Perch	15	15	8	7	8	0	0.0
Channel Catfish	15	15	15	0	14	1	6.7

% Tag loss did not include predation losses because the disposition of these fish is unknown

Figure 7. An example of predator inflicted wounds on a Bigmouth Buffalo. Arrows point to fin damage, scale loss, and petechia inflicted by a fish predator. External tag injection site wound can be seen sub-dorsal, posterior to predator wounds indicated by arrows.

It is likely that predators may have contributed to some of the observed tag losses based on wounds observed on a portion of Bigmouth Buffalo that lost tags (Figure 7). Gross necropsies revealed 4 of 5 (80%) paddlefish from trial 5 had ruptured swim bladders following water gun exposures. Ruptured swim bladders were only observed in paddlefish. Aside from predator inflicted external wounds and varying degrees of tag injection site wounds, no other evidence suggested that water guns wounded or killed fish in 2013 pond-trials.

The hydroacoustic sonar data collected from fixed transducers in pond trials indicated fish responded to water gun discharges at each pressure level tested. Initial observations suggest that water gun operation caused Bighead Carp and Silver Carp to leave the area around the water gun as evidenced by changes in detection rates by the hydroacoustic sonar. Trial 1 provided a complete set of hydroacoustic detection data within the pond when water guns were discharged at 1,000, 1,300, and 1,600 PSI (Figure 8). Fish were detected in all three lanes before water gun discharge suggesting the fish were well distributed within the pond. At the onset and during firing of the water guns at 1,000 PSI, fish detections in the sonar lanes closest to the guns decreased and detections increased in the lane furthest from the water gun barrier. Fish were detected in all three hydroacoustic lanes during the quiet period after water gun operation at 1,000 PSI. This pattern was observed again as the trial proceeded (Figure 8). For Trials 5-7, fish were added to the pond when water guns were active. An example of fish detections is provided for Trial 6 (Figure 9) showing fish were detected in all three lanes soon after being added to the pond. It appears that some fish challenged and crossed the barrier soon after being added to the pond.

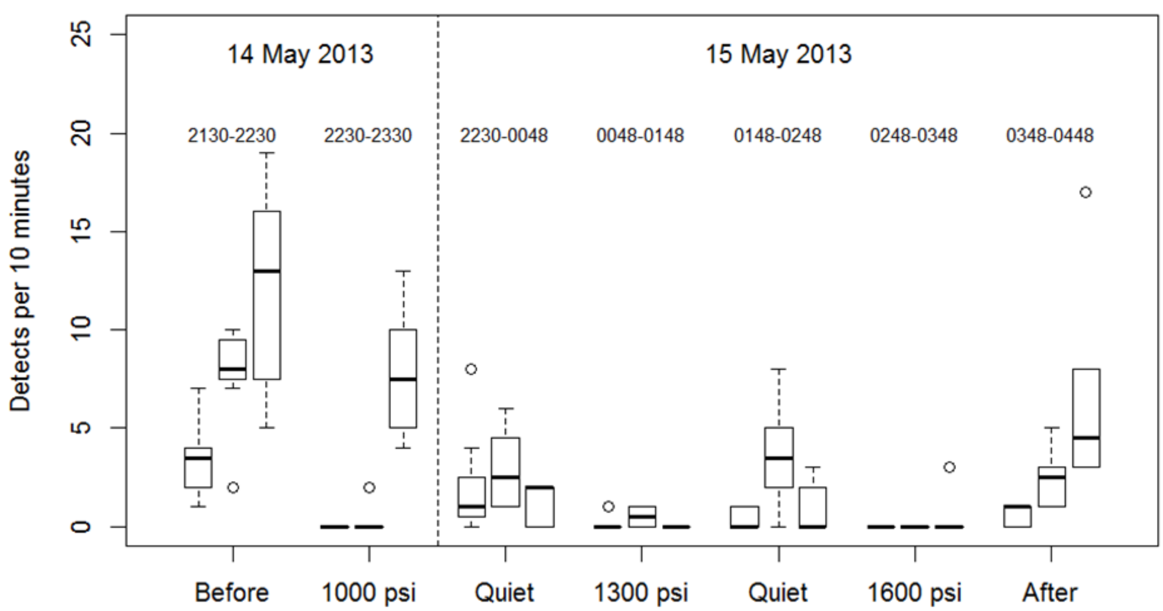

Figure 8. Box plots for Silver Carp and Bighead Carp detections for each split-beam hydroacoustic lane (Lane 1 to Lane 3, left to right) before, during and after operation of the S80 water guns

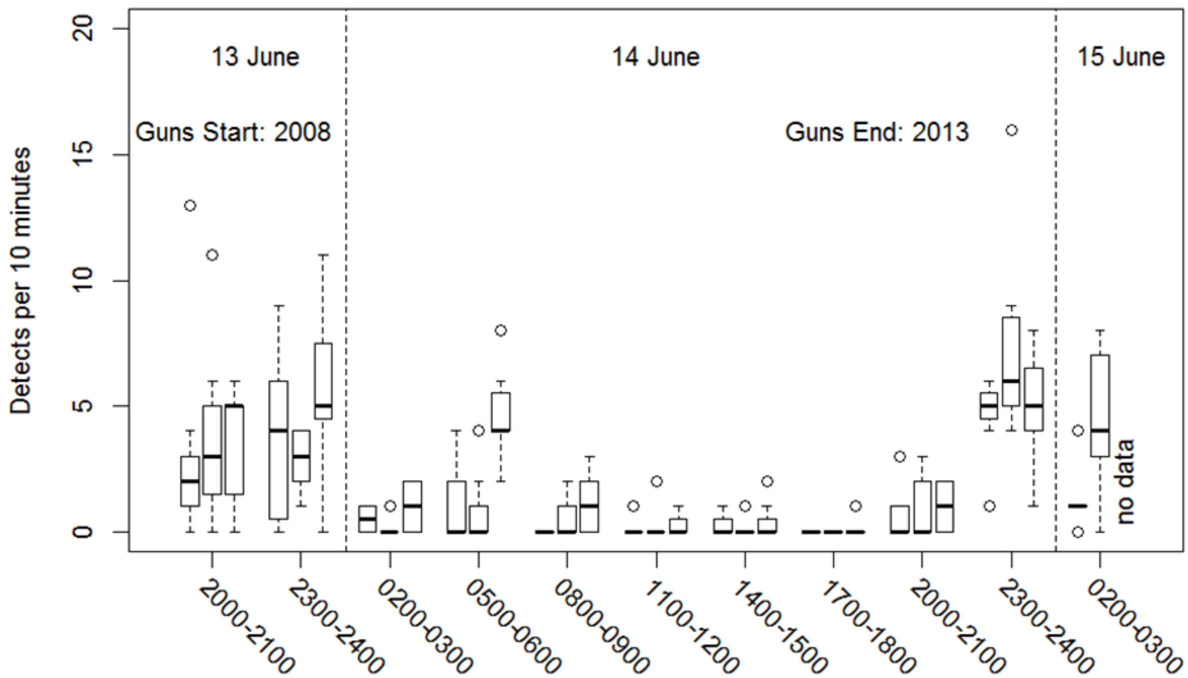

Figure 9. Box plots for fish (Silver Carp, Bighead Carp, and native species) detections for each split-beam hydroacoustic lane (Lane 1 to Lane 3, left to right) during and after a 24 hour operation of the S80 water guns.

Acoustic tag positioning of fish showed fish were observed along the periphery of the pond in the vicinity of operating water guns (Figure 10). Kernel density plots are being created to show where fish positions were most dense in the pond to show fish avoidance behavior when water guns were firing (Figure 11) and general movement patterns when water guns were not firing (Figure 12). Pressure gradients were not measured at all locations within the pond where acoustic tags were tracked. If pressure gradient overlay to the pond are applied the measured pressure gradient fish were exposed to was <6 PSI. Preliminary analysis indicates that Silver Carp and Bighead Carp were not detected in the immediate vicinity of the water guns during operation, but returned to the area around the water gun when it was not operating. Data from 1-4 have been summarized, and data analysis of trials 5-7 are in progress.

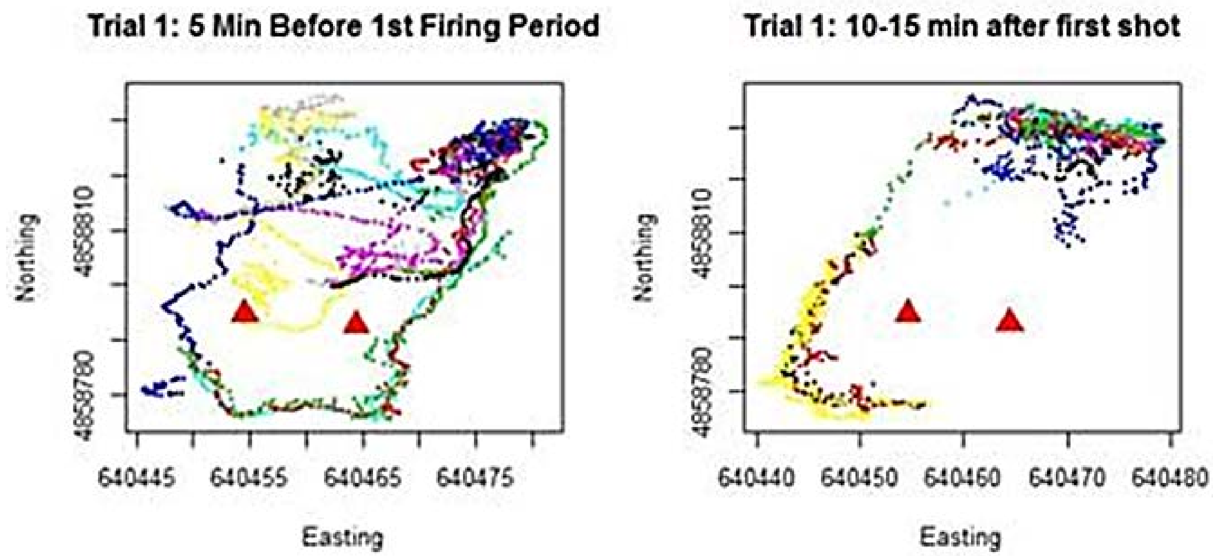

Figure 10. Acoustic telemetry positions of fish in pond trial 1 five minutes before the first water gun firing period (left) and 10-15 minutes after water gun firing began (right). Water gun positions in the pond are represented by red triangles.

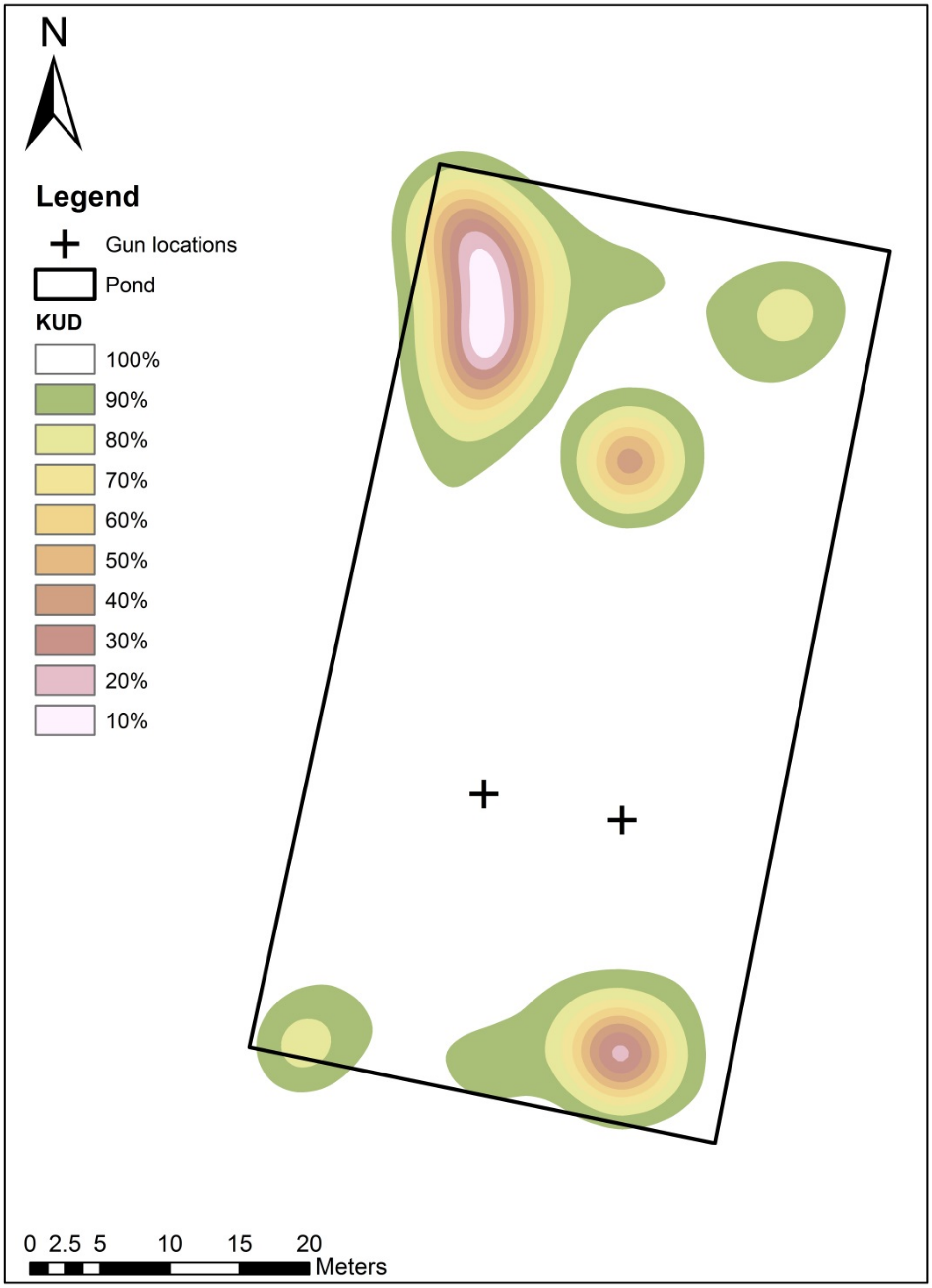

Figure 11. Bighead Carp kernel utilization distributions (KUD) during Trial 6. The lowest value (10%) represents the highest density of locations. In general, fish were located at in the northwest corner of the pond during Trial 6.

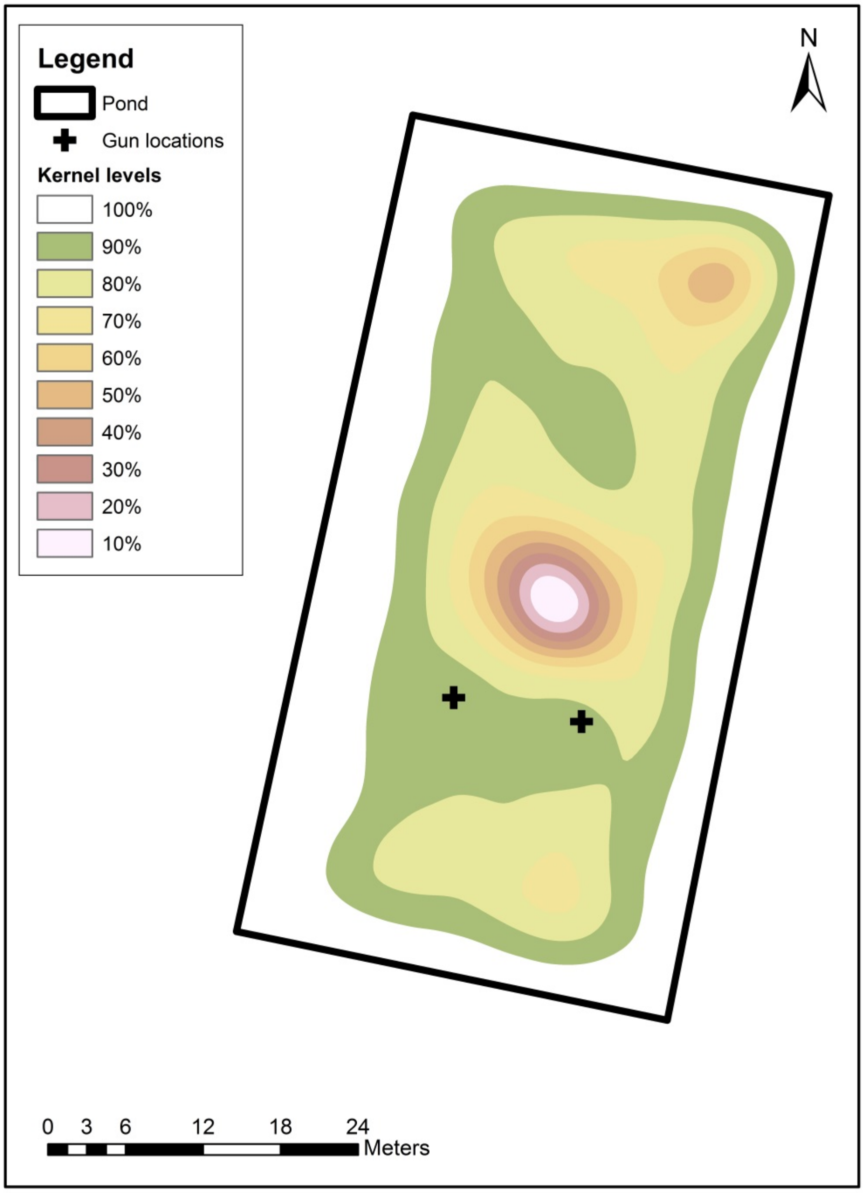

Figure 12. Bighead Carp kernel utilization distributions (KUD) during Trial 7. The lowest value (10%) represents the highest density of fish locations. In general, fish were located throughout the pond during this trial.

Implement an integrated pest management demonstration including a water gun barrier to control movements of Asian Carp

In-field water gun barrier observations were conducted in 2013 in two locations in near Morris, IL (UTM 16T 379954 E, 4577708 N) at the Hanson Material Service (HMS)-sand and gravel mine. The mining site was chosen because it had been previously used to demonstrate water gun operations (Layhee et al. 2013) in the presence of Asian carp. Test locations selected for 2013 water gun barrier observations differed from those previously used. Observational results of pressure testing and fish behavior studies conducted at UMESC in controlled pond trials in 2012-13 were used to inform project objectives for water gun testing in Morris, IL in 2013. Site 1 was a channel that connects the Illinois River and the HMS (Figure 12). A water gun barrier was operated from 21-28July2013 (Figure 13). The first site was chosen based on access, known Asian carp inhabitance and general similarities (width, depth) to the navigation channel where the USACE electrical barriers are located. The channel surface area of site 1 (measured from mouth of channel opening into HMS to confluence with Illinois River) was 15.8 ha; channel length was 1.1 km long and 0.1 km wide at the gun barrier. Site 1 was primarily used to establish and refine effective methods that could later be applied to an integrated pest management (IPM) application. Site 2, selected for the IPM evaluation, was a 135 ha backwater area (inactive mining site) where feeding stations, commercial fishing efforts and a water gun barrier were integrated (Figure 14) to collectively concentrate and reduce Asian carp populations. Water gun operations occurred at this site from 12-15August2013.

In both field sites, fixed hydroacoustic sonar lanes were set up to detect fish on both sides of the water guns. Site 1 had four lanes at distances of 16 and 32 m on either side of the water gun barrier. Site 2 had two lanes on one side and one lane on the other at the same distances as site one. Data were collected using similar methods established during controlled pond trials at UMESC to detect fish movements. Thus, four hydroacoustic lanes were used to observe fish detections/movements before, during and after water guns were discharged at both field sites. Mobile hydroacoustic data were also collected to monitor and quantify fish population densities with respect to proximity of the water gun barrier.

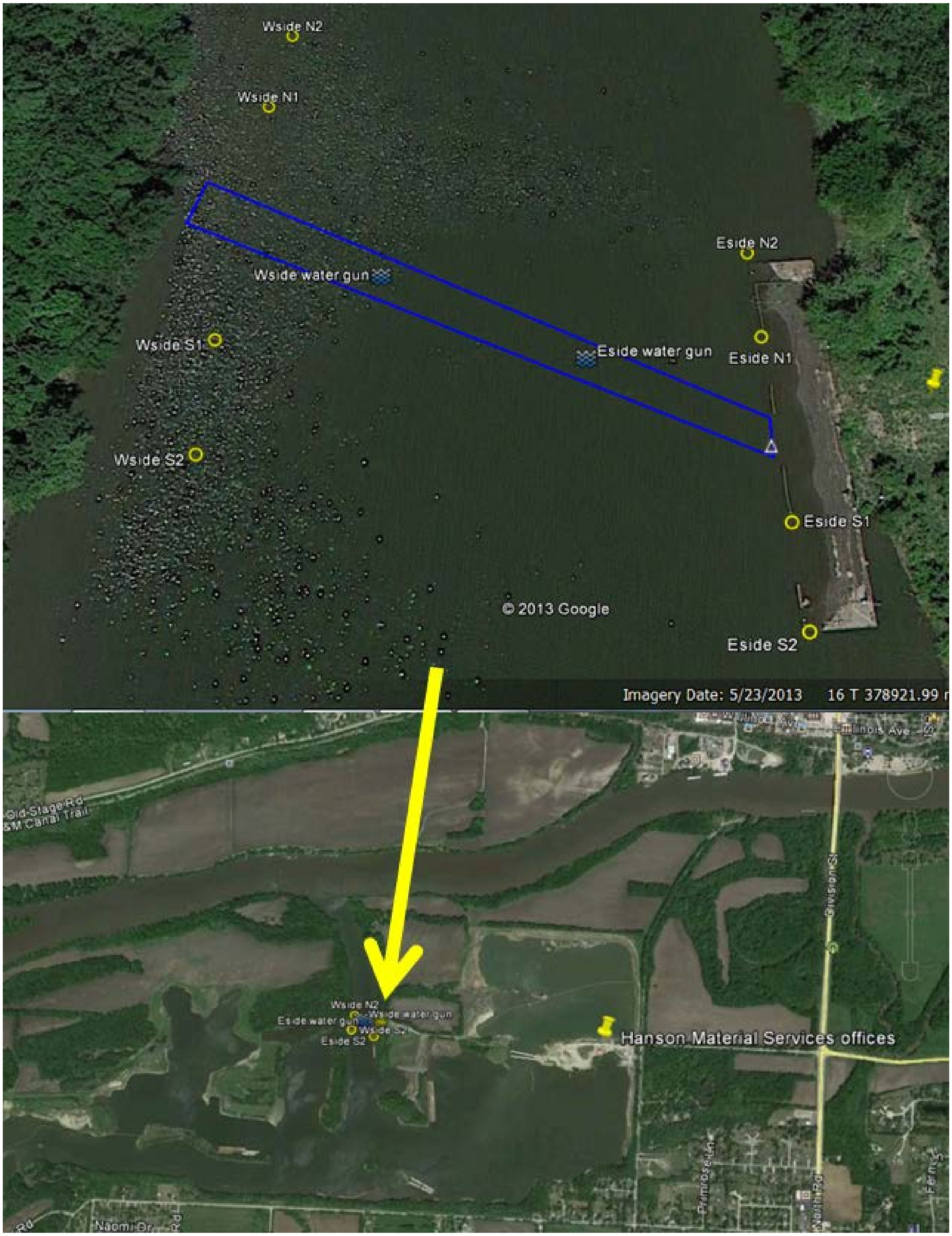

Figure 12. Plan-view satellite imagery of the first water gun barrier site used for 2013 field operations. Fixed hydroacoustic transducer positions (yellow circles) and water gun placement and barrier (blue box) can be seen in the channel (TOP); and yellow arrow indicates channel location relative to Hanson Material Services, Morris, IL (BOTTOM).

Figure 13. Image of the first test site for water gun barrier observations in the channel connecting Hanson Materials Sand and Gravel Mine to the Illinois River. Water guns are suspended from pontoons floating mid-channel. A hydroacoustic transducer mount can be seen in the lower left corner (black arrow).

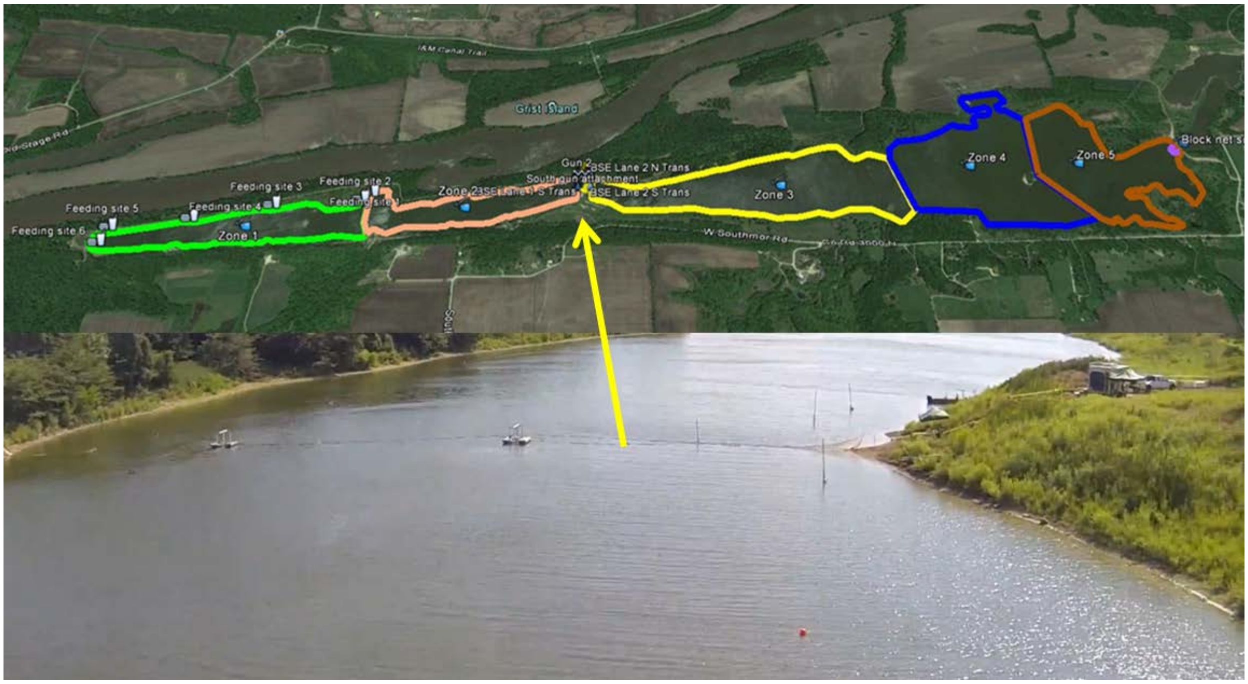

Figure 14. Integrated pest management demonstration site located on the west end of the Hanson Materials mining site, Morris, IL. Five commercial fishing zones are highlighted (TOP) and the water gun barrier (BOTTOM) is located between zones 2 and 3 (yellow arrow).

Hydroacoustic sonar data were collected for both field sites including fixed and mobile data collections. These data were compiled and are currently being analyzed. Many fish detections were recorded with fixed hydroacoustics (Figure 15) at both locations. The number of transducers and duration of monitoring resulted in the collection of volumes of data orders of magnitude larger than typically collected. Work is on-going to data management protocols to streamline fish detection analyses to eliminate noise disruptions (e.g. air bubbles, stationary objects etc.) that occur with the fixed side-looking site locations and/or when water gun were firing (Figure 16).

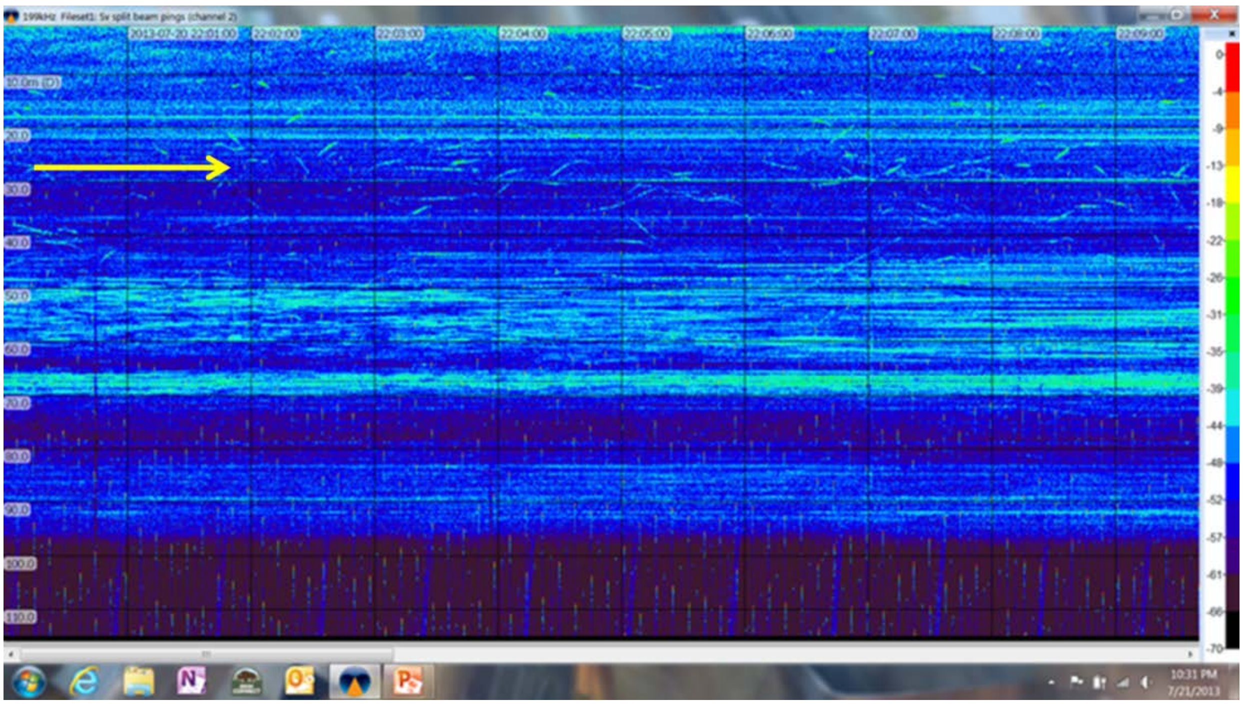

Figure 15. An example echogram from a side-looking transducer at water gun barrier site 1; water guns not firing. Many fish (light blue arches; yellow arrow) were detected 20-30 m from the transducer and high noise levels are apparent when water guns are silent.

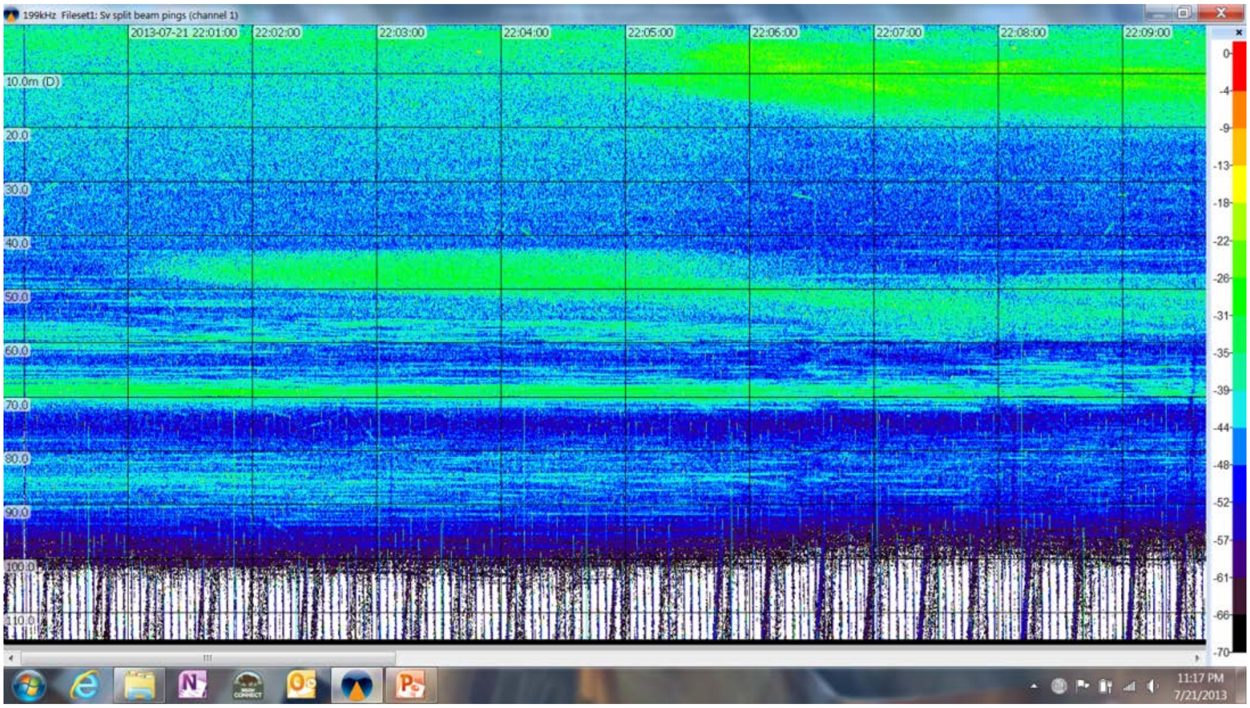

Figure 16. An example echogram collected from a side-looking transducer at water gun barrier site 1; water guns firing. Fish arches can be observed 20-30 m from the transducer and high noise levels are apparent. Air bubbles (green shading) are apparent during water gun operation.

The number of fish detected appears to be reduced during water gun firing but refined data analyses are in progress to determine the numbers of fish present. Hydroacoustic target strength data are also being refined that specifically identify Bighead Carp and Silver Carp for further refinement of hydroacoustic analyses.

At site 2, water guns were operated for a total of 66 hours and commercial fisherman caught >1,300 fish (Table 2). As a percentage, approximately 77% of fish caught were Asian carp. It was estimated that 14,800 pounds of Bighead Carp and Silver Carp were removed during the IPM evaluation. The water gun barrier was set between commercial fishing zones 2 and 3, and catch data shows fewer fish caught in zones 1, 2 when compared to zones 3, 4, and 5. In general, catches decreased in each zone from day 1 of the demonstration to day 3 of the demonstration (Table 2).

Table 2. Fish catch (Total, Bighead Carp [BHC] and Silver Carp [SVC]) per day per zone for an integrated pest management study conducted at Hanson Material Service from 12-15August2013.

Date	Total Per Day	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
8/13/2013	636	34	58	105	236	203
8/14/2013	434	13	32	101	162	126
8/15/2013	312	39	35	91	81	66
Total	1382	86	125	297	479	395

Date	BHC,SVC Total Per Day	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
8/13/2013	502	27	35	99	187	154
8/14/2013	323	12	24	84	94	109
8/15/2013	244	32	29	81	49	53
Total	1069	71	88	264	330	361

Discussion:
A complete understanding of the pressures put forth from water guns on various man-made in-water structures remains unknown. Two sites near Lamont, IL have been targeted for structural tests in 2014. Processing of the data sets collected in 2013 is ongoing, but initial pressure distribution maps have been prepared for one-gun and two-gun sets in a man-made pond and additional water gun pressure maps were generated from data collected near an active in-field water gun barrier. Structural tests in 2014 are expected to produce the information needed to answer USACE questions regarding the potential for water guns to cause damage to in-water structures.

Water guns appear to elicit behavioral effects on Asian carp in a man-made 0.2 ha pond and in open water field applications. These results agree with past research involving observations of Asian carp responding to discharge of seismic water guns. Additional research on the effects of water guns on native mussels and alternative water guns (e.g. hydraulic water guns) should be tested using the methods established in 2013 for in-pond and in-field water gun barrier applications.

Methods for successful implementation of water gun barriers in open water environments were demonstrated in 2013. Field applications of seismic technologies to specifically affect Asian carp behavior appear to be feasible and their application/integration as a tool for IPM shows promising results.

Recommendations:
The effects of water gun seismic pressure waves on in-water structures needs to be completed before this technology can be employed in critical navigational waters where critical in-water structures may be affected. Potential structural test locations have been identified in the Illinois River and are being evaluated for potential use in 2014.

Additional research using seismic technology to affect fish behavior as a deterrent and control strategy is warranted. Additional testing of this technology with alternative seismic sources (e.g. hydraulic water guns) is recommended based on the logistical obstacles associated with pneumatic water guns (e.g. requires a ~1,600 kg, 4-stage air compressor). Thus, additional controlled tests should be completed in the UMESC test pond to further clarify the response of Silver Carp and Bighead Carp to alternative sources of seismic energy. Additional field trials should be completed to establish water gun barriers in open water environments. Low light conditions appear to increase fish detections and schooling patterns appeared to relax. This information should be considered for future testing of deterrent technologies. It is recommended that the IPM evaluation be repeated in 2014 to observe if 2013 results can be repeated.

Project Highlights:

- Pressure gradients around the S80 water gun(s) were mapped in three different configurations in a controlled pond and in one open water field setting.
- The maximum operating conditions of the current water gun/compressor configuration was determined to be 1,500PSI with discharge every 10 seconds.
- Behavioral responses of Asian carp and native fishes were observed with sonar and acoustic telemetry under controlled conditions. Initial results indicate fish avoid water guns during operation.
- Methods for successful implementation of water gun barriers in open water environments were demonstrated in 2013
- Incorporating water gun barrier technology into IPM applications is feasible.

Alternate Pathway Surveillance in Illinois - Law Enforcement

Brandon Fehrenbacher, Heath Tepovich, Matt O'Hara, and Kevin Irons;
Illinois Department of Natural Resources

Participating Agencies: Illinois Department of Natural Resources (lead)

Introduction: The Invasive Species Unit was formed in July of 2012 to create an effective enforcement component of IDNR's invasive species program. The unit consists of two officers with over twenty years of combined law enforcement experience with the Illinois Conservation Police. The Invasive Species Unit is fully dedicated to enforcing State and Federal regulations to prevent the spread of invasive species and is a member of the multi-agency Asian carp Task Force established December 2012 to combine enforcement efforts throughout the United States.

There are only a little more than a hundred Conservation Police Officers in the State of Illinois and their responsibilities and duties are extensive which makes it difficult to allocate the necessary time to investigate invasive species cases which can be very complicated and time consuming. Conservation Police Officers are knowledgeable of their assigned areas and activities within them and a valuable asset to the unit. CPOs have the ability to refer invasive species cases to the Invasive Species Unit for investigation. Standardized procedures for inspecting fish haulers, aquaculture facilities, aquatic life dealers, and bait shops combined with the training of CPOs and other law enforcement personnel will add to the ability of the department to regulate and detect illegal activities within the industry.

Bait dealers have the potential to sell and introduce invasive species into the environment if they are not properly regulated and inspected. The opportunity to make money may encourage these dealers to by-pass regulations which must be adhered to.

Fish transportation companies have previously been caught illegally transporting live Asian carp. The monetary incentive to sell this species alive versus dead creates the potential for this to happen again. Transportation companies throughout the United States and Canada are coming to Illinois to transport Asian carp to fish markets.

Commercial and sport fishermen can spread invasive species and diseases by illegally transporting and stocking fish into Illinois waters. Education and enforcement of all applicable laws must continue in order to prevent intentional and unintentional introduction of invasive species.

Objectives: To continue building upon the newly formed IDNR Invasive Species Unit activities. Also collaborate with other agencies with intelligence gathering and enforcement on invasive species along with illegal fish importation we proposed to:

1) Invasive Species Unit (ISU) along with USFWS will provide training, a power point presentation, quick reference guides, and standardized inspection procedures to ISP

personnel and CPOs throughout the State to maximize efforts to detect and interdict the illegal transportation of aquatic life.

2) Design and recommend the implementation of a fish transportation inspection form to be completed by the primary law enforcement officer coming into contact with a fish hauler.
3) Attend and represent Illinois at the 2013 multi-agency invasive species task force conference in Arkansas. ISU members will provide a presentation relating to invasive species issues and laws in Illinois. Task Force members will tour fish farms and interact with the Asian carp business community to get an inside look into the industry.
4) Conduct surveillance and enforcement operations within the commercial fishing industry.
5) Step up surveillance of fish haulers, area fish production facilities, live fish markets and food establishments.
6) Use intelligence previously gathered from surveillance to conduct operations and continue ongoing operations in efforts to apprehend violators of federal and state laws dealing with invasive species.
7) Continue enforcement efforts focusing on the illegal bait trade in Chicago metropolitan area.
8) Organize details to be implemented at boat launches throughout the State by uniformed CPOs which will focus on enforcing laws and educating fishermen on regulations established to prevent the spread of invasive species by them.
9) ISU members will continue to attend training opportunities to remain updated on the enforcement of invasive species.
10) 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.

Results and Discussion: The ISU prepared course material, quick reference guides, test questions, and a PowerPoint presentation to instruct Conservation Police Officer Trainees, Conservation Police Officers, and other law enforcement personnel on invasive species enforcement. The ISU designed a Fish Truck Inspection Form to assist with gathering information on fish haulers, suppliers, and buyers. The form will assist primary law enforcement officers with determining what permits the haulers are required to possess and actions to take if violations are detected. The Invasive Species Unit organized and provided training for the Wisconsin DNR Special Operations Unit on invasive species enforcement techniques and case review. ISU provided instruction on invasive species enforcement to the CPO recruit class at the IDNR academy.

ISU attended training, a task force meeting, and toured a Fish Farm raising Asian carp in Arkansas. ISU attended the Association of Midwest Fish and Game Law Enforcement Officers conference and Asian carp Task Force in Michigan. ISU presented PowerPoint presentations pertaining to ISU activities and Illinois laws pertaining to invasive species at both locations.

ISU gathered information on Asian carp producers, harvesters, and processors throughout the State of Illinois to facilitate task force efforts in compiling information from all participating member states. Surveillance was conducted on commercial fishermen, fish dealers, fish markets, and transportation companies. Investigations into the commercial fishing industry revealed the illegal storing of live invasive species, unlawful commercialization of protected species, fraudulent application for commercial licenses/device tags, and Lacey Act violations. ISU discovered an individual operating a small scale aquaculture facility without a license. An investigation of a fish farm suspected of illegally transporting and selling Grass Carp was conducted. Some of the fish were sent to a lab to test for triploidy. The test results and investigation determined the company was in compliance. An operation was successful in apprehending an out of state fish dealer who was selling stocking an invasive species in private ponds in Illinois waters. The shipment and fish truck were seized. The ISU apprehended a fisherman transporting live Smallmouth Bass from a VHS infected area into Illinois without a permit and unlawfully releasing the fish into Illinois waters without permission. ISU investigated a complaint of an unreported fish kill and the illegal taking of State listed endangered fish on two lakes in Northern Illinois. ISU arrested and individual for illegally breeding and selling native snakes in Illinois without an aquaculture license and falsifying records. ISU discovered the illegal selling of aquatic life parts in Illinois and is involved in an ongoing investigation into the violations.

ISU inspected bait dealers in Northern Illinois to gather information on wholesale dealers / suppliers. It was determined that the same company was the supplier for all of the inspected bait shops. ISU discovered one bait dealer had been in operation for several years without the required aquatic life dealer's license. Another business remains under investigation for operating without a license. ISU investigated an out of state bait dealer illegally selling bait in Illinois without an aquatic life dealer’s permit and transporting aquatic life without the required VHS and restricted species permits. The ISU conducted surveillance on the bait store the company was delivering to and apprehended the dealer delivering the bait. Samples were seized for testing, and the live bait on the truck was destroyed.

ISU prepared a quick reference guide and an outline for VHS enforcement details. The detail was implemented twice in Northern Illinois focusing on enforcing the administrative rules to prevent the spread of VHS by fishermen. The detail revealed one fisherman illegally transporting live fish in his livewell after leaving the water, but the majority of fishermen were aware of the laws and in compliance.

Invasive species unit attended/completed Reid Interview and Interrogation School in Chicago and task force training in Arkansas and Michigan.

ISU provided information and assistance to the Wisconsin Special Operations Unit, Indiana DNR, Michigan DNR, Ontario MNR, and USFWS for cases involving fish transportation companies, ginseng, wildlife, and aquatic life violations.

Recommendations: We recommend the IDNR website be updated to better inform the public of the requirements, regulations, and permit procedures for aquatic life dealers, the aquaculture industry, and fish transportation companies. Surveillance of people and businesses involved in illegal activities needs to continue in order to identify additional violators. Time and resources should be allocated by the ISU to educate other law enforcement personnel in the regulations and procedures to identify, inspect, and arrest violators of invasive species laws. Expanded implementation of details focusing on the transportation of aquatic life and VHS regulations should be conducted throughout the State now that standardized procedures have been made. Inspections and enforcement on the bait trade within Illinois should continue and focus on areas not recently checked. ISU needs to seek training opportunities and network with task force members in order to keep updated on aquatic life topics and enforcement techniques.

Project Highlights:

- Educational materials produced to facilitate training in invasive species enforcement.
- Active participation and leadership role in Asian Carp Task Force.
- Arrest of aquatic life dealer illegally stocking and selling invasive species in Illinois.
- Plea agreements pending in court totaling over $24,000 in fines for aquatic life code violations.
- Bait dealer arrest for VHS, restricted species permits, and aquatic life dealer's license violations.
- Seizure and disposal of two shipments of illegal aquatic life.
- Discovery of illegal sale of aquatic life parts in fish markets.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

Tristan Widloe, John Zeigler, Blake Ruebush, David Wyffels, Brennan Caputo, Matt O'Hara, Kevin Irons, and Victor Santucci; Illinois Department of Natural Resources

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 the wild. 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 gear 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 (> 48 pounds) were captured by electrofishing and netting in Flatfoot Lake and Schiller pond, both urban 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 lakes included in the IDNR Urban Fishing Program located in the Chicago Metropolitan area. Of the 21 urban fishing lakes in the program, seven have verified captures of Bighead Carp either from sampling, pond rehabilitation with piscicide, or natural die offs; one has reported sightings of Asian carp that were not confirmed by sampling (Table 1). The distance from urban fishing ponds to Lake Michigan ranges from 0.2 to 41.3 km (0.1 to 25.7 miles). The distance from ponds to Chicago Area Waterway System (CAWS) waterways upstream of the Electric Dispersal Barrier ranges from 0.02 to 8.2 km (0.01 to 5.1 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 Electric Dispersal Barrier (Table 1). Lagoons 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 in 2008, after which it was dropped as a Chicago urban stocking site. Gompers Park Lagoon and Jackson Park Lagoon 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 is of importance due to the increased likelihood of human transfers of fish between waters within close proximity to one another.

In addition to ponds once supported by the IDNR Urban Fishing Program, ponds that yielded positive detections for Asian carp eDNA were also reviewed. A total of eight ponds had positive detections for Asian carp eDNA, two of which were IDNR urban fishing ponds (Jackson Park and Flatfoot Lake; Table 2). The distance from these ponds to Lake Michigan ranges from 4.8 to 31.4 km (3 to 19.5 miles). The distance from ponds to Chicago Area Waterway System (CAWS) waterways upstream of the Electric Dispersal Barrier ranges from 0.05 to 4.3 km (0.03 to 2.7 miles). Though positive eDNA detections do not necessarily represent the presence of a live fish (e.g., do positive detections represent live or dead fish, or result from sources other than live fish, such as DNA from the

Table 1. A list of Chicago area urban fishing ponds, reported and verified occurrence of Bighead 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 pulsed-DC electrofishing and TN/GN is trammel/gill net. Waterways are: LM=Lake Michigan; CALSC = Cal-Sag Channel; CALR = Calumet River; CSSC = Chicago Sanitary and Ship Canal; NBCR = North Branch Chicago River; LCALR = Little Calumet River; BUBCR = Bubbly Creek; NSC = North Shore Channel; 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	4.1-CSSC	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	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	NR	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	4.8-NBCR	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	1.3-CSSC	None
Lake Shermerville	Cook	Northbrook	NR	6.6	4.8-NBCR	None
Schiller Pond	Cook	Schiller Park	3 DCEL-2011	10.1	7.1-NBCR	None
Elliot Lake	DuPage	Wheaton	NR	25.7	14.5-CSSC	None
Community Park Pond	Lake	Mundelein	NR	9.2	22.7-NSC	None

guano of piscivorous birds), they should be examined for the presence of live Asian carp given their proximity to CAWS waterways.

Objective: Urban pond monitoring objective was to:

- Sample all 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).

Methods: Pulsed DC-electrofishing and trammel/gill nets were used to sample urban fishing ponds in 2013. Trammel and gill nets were 3 m deep x 91.4 m (300 ft) long in bar mesh sizes ranging from 89-108 mm (3.5-4.25 in). Electrofishing, along with pounding on boats and racing tipped up motors, was used to drive fish from both shoreline and open water habitats into the nets. Upon capture, Asian Carp were removed from the pond and the length and weight of each fish was recorded.

Table 2. A list of Chicago area ponds with positive detections for Asian Carp eDNA, verified occurrence of Bighead 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 pulsed-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

Results and Discussion: Four Chicago area ponds were sampled in 2013 with an estimated 165 person-hours spent on sampling and 2.9 km (1.9 miles) of trammel/gill net set (Table 3). We sampled a total of 179 fish representing 5 species and 1 hybrid group. Eighty-five percent of the fish sampled were Common Carp, 9% were Grass Carp and the remaining 6% were comprised of Bighead Carp, Northern Pike, Goldfish and 1 Common Carp x Goldfish hybrid. Five Bighead Carp were removed from Humboldt Park ranging in weight from 48-66 pounds, with a mean weight of 58.7 pounds. One Bighead Carp was captured and removed from Flatfoot Lake with a length of 1354 millimeters and a weight of 82 pounds, which is the largest Bighead Carp collected during urban pond monitoring to date (Figure 1); a replica of this fish has been made for outreach and educational events.

The source of Bighead Carp in urban fishing ponds has not been confirmed to date and identifying a specific source may prove impossible. However, it seems likely that young Bighead Carp may have been unintentionally stocked in urban fishing ponds with shipments of desirable fish species. The fact that all Bighead Carp obtained from Chicago area ponds to date have been large fish (> 48 pounds) also points towards stocking as a potential source. These demographics indicate that stocking probably occurred during a limited number of events sometime before 2005 and 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 because catchable-sized catfish are stocked frequently and extensively in these waters throughout the State (IDNR 2010).

Table 3. Summary of effort and catch data for urban pond monitoring 31 July – 6 August 2013.

	Effort		Catch					
Operation (date) and Gear	Estimated person-hours	Netting total (miles)	All fish (*N*)	Species (*N*)	Hybrids (*N*)	Bighead carp (*N*)	Silver carp (*N*)	Grass carp (*N*)
Humboldt Park (31 July 2013)	30	0.3 miles	37	3	0	5	0	11
Flatfoot Lake (1 August 2013)	60	0.6 miles	6	3	0	1	0	1
Powderhorn Lake (5 August 2013)	52.5	0.7 miles	3	2	0	0	0	0
Lake Shermerville (6 August 2013)	22.5	0.3 miles	133	4	1	0	0	5

Recommendations: We recommend additional sampling of ponds Asian carp were collected from to ensure that no carp remain. We also recommend repeat sampling of ponds that had positive detections for Asian carp eDNA.

Project Highlights:

- 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.

Figure 1. IDNR Aquatic Nuisance Species Program biologists with the 82 pound Bighead Carp removed from Flatfoot Lake, Chicago, Illinois.

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

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Appendix B. Assessing Harvest as a Factor Affecting Density, Demographics, and Movement of Asian Carp in the Illinois River

Assessing Harvest as a Factor Affecting Density, Demographics, and Movement of Asian Carp in the Illinois River

Annual Report to the

Illinois Department of Natural Resources

January 2014

Prepared By:

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Center for Fisheries, Aquaculture, and Aquatic Sciences

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EXECUTIVE SUMMARY

Project Goal: Evaluate the efficacy of harvest and other control methods on 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

Major Finding: Although data processing is ongoing, Asian carp abundance appears to be at a low level in 2013-2014. Poor recruitment and natural mortality, perhaps coupled with harvest, contributes to this pattern. **Continued contract harvest in the upper Illinois River (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 location of the electric defense barrier in Lockport Pool.**

Need: Bighead carp, silver carp, and their hybrids invaded the Illinois River at least 15 years ago. The density of these fish increased rapidly, and the fish have neared the Chicago Area Waterway System (CAWS), being present in Dresden Pool. Our efforts have focused on the dynamics of these invasive species since 2010. Catch per unit effort (CPE) across multiple gears have been the only method available for assessing abundance. Using CPE is a valuable technique for assessing population status. However, it varies with gear, environmental conditions, fish behavior, fishing activity, and many other factors. A mark-recapture effort was conducted in LaGrange Reach in the early 2000s (Sass et al. 2010), which provided local densities. However, we recognized that other techniques are needed to generate “hard” density and biomass estimates in the river. Hydroacoustics coupled with other gear types are showing promise for generating robust density and biomass. Asian carp recruit regularly in the lower Mississippi River (Lohmeyer and Garvey 2009). Immigration may contribute to populations in the Illinois River and may vary with environmental and biotic factors. Our group is collaborating with other researchers to quantify movement with telemetry. Harvest is occurring commercially in the lower Illinois River and contracted control fishing is ongoing above Starved Rock Lock and Dam. The population consequences of harvest are being quantified with modeling. These factors affect patterns of population dynamics, movement, and ultimately the risk of Asian carp establishing in the reaches directly below the electric barrier separating the lower river with the CAWS. Population changes in Asian carp may lead to modifications of the Illinois River ecosystem. We are quantifying this to determine whether changes in density, demographics, and movement of Asian carp affect primary production, zooplankton, and native fishes.

Goal: Our research is intended to develop a predictive model of Asian carp dispersal in the Illinois River as a function of density, demographics, and environment (e.g., hydrograph). How harvest in both the lower and upper Illinois River affects these patterns will be assessed with this model.

Timeline of Study: This report focuses on 2013 research and modeling efforts. This research began in Fall 2010 and has been ongoing since this time.

- **2010**
  - Developed sampling protocols and assessed feasibility of using down-looking split-beam hydroacoustics for quantifying Asian carp.
  - Released Asian carp with implanted transmitters in the Mississippi River Pool 26 at the confluence with Illinois River; quantified upriver movement into the Illinois River with a receiver network.
  - Planned ecosystem sampling.
  - Initiated a basic population model of Asian carp in the Illinois River, as a function of harvest mortality. Now published in *Fisheries* (Tsehaye et al. 2013)
- **2011-2012**
  - Moderate flow during summer.
  - Completed first down-looking survey of Asian carp density and biomass in lower three reaches of the Illinois River.
  - Collected demographics and CPE of Asian carp.
  - Completed acoustic receiver array throughout the Illinois River, extending from the Mississippi River confluence to the CAWS.
  - Ecosystem data collected.
  - Began assessing efficacy of contract harvest in the upper Illinois River, particularly in Marseilles Reach.
  - Otolith microchemistry collected to assess source of Asian carp (upper Mississippi River, lower Mississippi River, Missouri River, and Illinois River main channel and floodplain lakes).

- **2012-2013**
  - Drought conditions. Low flow and high temperatures during summer.
  - Completed "fishing experiment" in spring 2012, with three million pounds of Asian carp removed from the lower three reaches of the Illinois River.
  - Deployed side-looking split-beam hydroacoustics survey, in combination with down-looking technique. Added the upper river to sampling. Increased data input by factor of four.
  - Determine hybridization.
  - Quantified second year of standardized sampling of Asian carp.
  - Increased number of fish with transmitters in the upper Illinois River.
  - Ecosystem data collected.
  - Conducted mark-recapture of Asian carp to quantify contracted harvest impact and immigration in Marseilles Reach.
  - Emplaced receivers in lock chambers.
  - Otolith microchemistry collected to assess source of Asian carp (upper Mississippi River, lower Mississippi River, Missouri River, and Illinois River main channel and floodplain lakes).

- **2013-2014**
  - Wet conditions during summer.

- Developed a refined model "2.0"; dispersal and immigration as a function of density, environmental conditions, and harvest and other mortality factors.
- Repeat hydroacoustics survey.
- Demographics collected.
- Determine hybridization.
- Movement of fish throughout the Illinois River quantified.
- Increased number of fish with transmitters in the upper Illinois River.
- Ecosystem data collected.
- Conducted mark-recapture of Asian carp to quantify contracted harvest impact and immigration in Marseilles Reach.
- Quantified movement via receivers in lock chambers.
- Otolith microchemistry collected to assess source of Asian carp (upper Mississippi River, lower Mississippi River, Missouri River, and Illinois River main channel and side channel).

Summary of 2013-2014 Activity.

- **Demographics in the Illinois River (Chapter 1).**
  - CPE estimates in late summer 2013 suggest that densities of Asian carp are lower than in 2011 and 2012. Apparent densities are highest in Peoria Pool. This may be due to the large amount of shallow-water areas and higher catch rates rather than actual density in this reach.
  - Significant recruitment leading to a strong year class was not detected for over 6 years.
  - Sampling in the lower reaches revealed some production of age-0 Asian carp in 2013.
  - In 2013, the predominant "2008" year-class declined.

- **Sampling and Demographics (Chapter 1).**
  - Sampling is a continuation of 2011 sampling. Fixed locations were sampled in late summer 2012 and 2013. Used electrofishing and trammel nets.
  - 36 fish species were encountered.
  - Catch per unit effort of Asian carp declined during 2011 through 2013 in the two lower reaches. Peoria Pool did not change.
  - In 2013, age-0 Asian carp were sampled in the lower reaches.
  - Age distributions of Asian carp from the lower three reaches show no recruitment and declining older fish.
  - Sex ratio did not deviate from 1:1 in 2013, although it was skewed toward males in 2012.

- **Hybridization (Chapter 1).**
  - 394 putative Asian carp were genotyped in 2012.
  - Of these fish, 196 were pure silver carp, 4 were pure bighead carp; the rest were hybrids.

- **Harvest in Upper Illinois River (Chapter 2).**
  - Deployed jaw tags (N=276) in the Hanson Materials Service (HMS) east and west pits.
  - 16,025 Asian carp were harvested from the HMS in 2013. Return rate of tagged fish declined through time.
  - Modeling using recapture rates of Asian carp revealed that harvest in the HMS is very effective, contributing to mortality of nearly 100%. However, fish density increased during both years and tag return declined, suggesting net immigration into the backwater.

- **Movement (Chapter 3).**

- In 2012, 372 Asian carp were implanted with acoustic transmitters.
- In 2013, 337 Asian carp were implanted with acoustic transmitters.
- Fish tagged were captured and released at the same locations. Fish were distributed from Dresden Pool to the Mississippi River. Thirty-eight Asian carp were caught and tagged in Dresden Pool, the furthermost location for tagging Asian carp to date.
- Acoustic receiver network was expanded, particularly in the pools above Starved Rock Lock and Dam. Thirty-six receivers are maintained by SIU Carbondale. Receivers are now present in all lock chambers of the Illinois River to assess differential movement through locks versus gates. Redetection of fish on receivers was about 30%.
- In 2010-2011, flooding in the Illinois River led to a 30% immigration rate of Asian carp from the Mississippi River. With the low water in 2012, average immigration dropped to 8.1%.
- Net movement of Asian carp was downstream in 2012-2013.
- Spawning behavior of Asian carp was quantified by IDNR personnel in Marseilles Pool. These events corresponded with movements of Asian carp out of the HMS with elevated main-channel discharge.

- **Acoustics (Chapter 4)**
  - Acoustics conducted during 2010 through 2011 provided a conservation estimate for the three lower reaches of the Illinois River; 1.4 metric tons were estimated. Asian carp comprised greater than 60% of biomass.
  - During 2012 through 2013, we have completed surveys from Dresden down to the confluence; this approach allowed us to get into the backwaters. We uses 70 plus 200 kHz, side-looking transducers
  - 2012 – 2,306 miles of survey were completed.
  - 2013 – 2,029 miles of survey were completed.
  - Analysis is ongoing. We will be able to compare to CPE and determine whether there is a correlation between the two.

- **Recruitment Sources—Otolith microchemistry (Chapter 5)**
  - Water chemistry data continue to indicate that Sr:Ca is consistently higher in the middle Mississippi and Missouri rivers compared to the Illinois River, thus enabling use of this marker as an indicator of fish that have immigrated into the Illinois River from these other rivers.
  - Using otolith core Sr:Ca data, we estimated that 28-53% of adult silver carp and 26-48% of hybrids in the Illinois River were immigrants that originated in the middle Mississippi or Missouri Rivers
  - Only 5% of the fish analyzed had otolith core $\delta^{18}O$ and $\delta^{13}C$ signatures indicative of use of floodplain lake habitats during early life, consistent with data from prior years.
  - Among silver carp and hybrids that were immigrants to the Illinois River, the vast majority originated in the middle Mississippi River; only 2-8% of the total number of silver carp and hybrids captured in the Illinois River originated in the Missouri River.
  - In contrast to silver carp and hybrids, otolith core Sr:Ca indicated that 91-98% of bighead carp analyzed originated in the Illinois River, with 2% originating in the middle Mississippi River, consistent with data from prior years.

- **Ecosystem Responses (Chapter 6)**

- Reduction of Asian carp through controlled commercial fishing did not significantly influence zooplankton densities, gizzard shad relative weight, or gizzard shad catch-per-unit effort
    - Rotifers are proportionally dominant in terms of abundance in both upper and lower river sections
        - Rotifers tended to be more abundant in the lower section when compared to the upper section
        - Cladocerans tended to be more abundant in the upper section when compared to the lower section
    - Primary productivity (i.e., chlorophyll-*a* concentration) decreased from downstream to upstream
    - Total phosphorus (mg/L) decreased from upstream to downstream

- **Modeling (Chapter 7)**
    - A paper on population responses of Asian carp to harvest is now published in Fisheries magazine.
    - In 2013, we convened a group of modeling experts in fish ecology. This group provided an outline for a spatially explicit model of movement of Asian carp as a function of density, demographics, and environmental conditions.
    - This model is currently in development.

References:

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Chapter 1:

Standardized sampling on the 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 for years, monitoring downstream populations is essential for predicting changes in upstream population growth and further movement of carp towards the Chicago Area Waterway System

(CAWS). In addition, information collected via standardized sampling will allow us to better parameterize predictive models and better forecast population dynamics in the future. This will better facilitate decisions concerning control measures. 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 use a variety of collection methods and analyses to assess the population dynamics of bighead carp, silver carp, and hybrid 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 of the Illinois River to:

1) Determine demographic responses of Asian carp in response to commercial fishing in terms of changes in relative abundance, growth, condition, mortality rates, sex ratios, hybridization, and indices of spawning condition.
2) Provide length-specific proportions of bighead and silver carp relative to other species to incorporate into hydroacoustic estimates of abundance, density, and biomass of Asian carp.

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) from August 5-9, 2013 (Table 1). Two pulsed-DC electrofishing transects (Smith-Root GPP 5.0 electrofisher; fifteen minutes each), with two netters, were 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, one electrofishing 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 Long Term Resource Monitoring Program (LTRMP) protocols (Gutreuter et. al 1995). The second transect was an experimental technique developed in an attempt to maximize silver carp catch rates and to provide more realistic estimates of silver carp abundance; this transect was conducted on the opposite side of the channel or backwater from the first transect. The experimental technique involved cooperation between the boat and pedal operators. The boat operator moved the boat in a rapid scalloped pattern down the shoreline, while the pedal operator selectively applied power at the peak of the loop and when near the shore or any apparent structure/habitat breaks. This was an attempt to use the boat and electrical field to corral fish against the shoreline or other structure, and to reduce evasion of the electrical field by silver carp. While electrofishing effort remained the same between the two electrofishing methods (i.e., 15 min of applied electrical current), overall transect duration and area covered by the electrofishing boat during the experimental technique was approximately double that of the standard protocol. At each site, it was randomly decided which electrofishing method would be used first, and which side of the channel or backwater would be sampled first. All fish species were collected during each electrofishing method. Although this experimental electrofishing approach has commonly been practiced by others in the field to capture Asian carp for various purposes, to our knowledge this approach has not been conducted in a standardized fashion to quantify its effectiveness relative to standard LTRMP electrofishing protocols.

During electrofishing runs, Asian carp that jumped into the boat while current was being applied to the water were kept and also processed to increase sample size and confidence in certain population metrics (e.g. sex ratio, mortality, condition, length-at-age, 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.

Trammel nets (91.44-m long x 2.44-m deep, 8.89-cm mesh, 45.72-cm outer walling with #10 monofilament) were set in backwater areas only. Net sets (two reps at each backwater area) consisted of attaching three trammel nets end-to-end, anchoring from the bank and creating a C-shaped set that ran back to the shoreline, or if possible, to the opposite shoreline. Trammel nets were set for 15 minutes, during which fish were driven into the net by banging rebar or other objects against the side of the boat, as well as raising the motor to create a rooster-tail similar to methods practiced by the Illinois Department of Natural Resources (IDNR) personnel and commercial fishermen. Trammel net effort varied by size and depth of backwater habitats (Table 1).

All fish collected with electrofishing and trammel netting were identified in the field, weighed (nearest g), measured (nearest mm TL), and released, with the exception of Asian carp. Asian carp were euthanized prior to necropsy by immersion in 300 ppm tricaine methanesulfonate (MS-222) until opercular movement ceased. Additional information collected from Asian carp included sex, and in some cases gonad weight (nearest 0.1 g), and removal of post-cleithra. Post-cleithra were removed for age determination and stored in coin envelopes with date, location, species, and identification number. To maximize efficiency, post-cleithera were removed and gonad weight taken from a subset of five male and five female silver carp within each 10-mm length group per reach. After this minimum sample size was achieved, silver carp were only measured, weighed and sexed.

Asian carp fin clips to identify, quantify and determine maternal contribution of parental bighead carp, silver carp, and their hybrids were not collected during standardized sampling in 2013. However, tissue samples were taken for genetic testing from all fish that were implanted with acoustic transmitter (~50 fish per reach, from Alton to Dresden) in 2013. Samples were placed in 75% ethanol and sent to Jim Lamer at Western Illinois University for processing. Results from 2012 have been received and DNA extraction, genotyping, and data processing are currently underway for 2013 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 silver carp, and gizzard shad. Experimental and LTRMP electrofishing runs were combined; CPUE included only fish that were netted. Changes in silver carp and gizzard shad CPUE from 2011, 2012 and 2013 were compared for the whole river, and by each reach using an Analysis of Variance (ANOVA) with each sampling location treated as a unit of replication. Tukey's Highly Significant Difference (HSD) test was used to test for differences in CPUE by reach and year.

Mean length-at-age

All electrofishing and trammel netting data were combined for analyses to reduce gear-specific size-selective biases. 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 side illumination from a fiber optic light; 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. Age distributions were developed for each reach using an age-length key. Silver carp mean length-at-age was compared among reaches and years using a two-way 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.

Mortality

Catch-curve analysis was used to determine annual mortality rates for silver carp. Excluding four age-0 silver carp, carp less than age-3.5 were not collected in our sampling efforts, likely due to poor recruitment in 2011 and 2012. Analysis of covariance (ANCOVA) was used to test for differences in mortality rates (i.e., slopes) among reaches and years. If no differences in mortality rates were detected, age frequencies from all reaches were pooled and analyzed to determine annual mortality rate (A) for the entire sampled area.

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 weight and total length 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, as well as among years, using an 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 (D. Glover, 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 analysis 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. All statistical analyses were conducted using SAS 9.2 (SAS Institute 2009).

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

Combined electrofishing and trammel net effort at 19 sites resulted in the collection of 9,424 fishes, including 36 different species (Table 2). An additional 176 silver carp jumped into the boat voluntarily during electrofishing. No bighead carp were collected in 2013, but overall, nearly four times as many individual fish were collected in 2013 compared to 2012, driven primarily by large numbers of gizzard shad. During electrofishing 670 gizzard shad were collected in 2012 compared to 8,148 in 2013. Age-0 silver carp (N = 4) were collected in 2013 for the first time since data collection began in 2011. Only 11 fish were collected in trammel nets in 2013 (3.645 fish/ 1,000 m). Based on these low catch rates, an increase in effort, changing the net mesh-size, or abandoning trammel nets may be warranted. Further analyses will be conducted to determine whether native fish relative abundance has increased relative to Asian carp from previous data collections.

Catch per unit effort

Silver carp CPUE differed significantly by reach (ANOVA; $P < 0.0001$), with significantly greater catches of silver carp in the Peoria reach compared to the Alton or La Grange reaches (Figure 1). There was no significant difference between years ($P = 0.0673$) although CPUE for silver carp has declined each year, specifically in the La Grange reach where CPUE has decreased 60% since 2011. Overall, silver carp CPUE has decreased 42% since 2011 across all reaches. There was no significant interaction between reach and year ($P = 0.5415$). Lack of interaction between reach and year is probably related to the high variability in CPUE among sites and years. Tukey's HSD showed a significant difference in CPUE (alpha = 0.05) among reaches, all years combined, with CPUE in the Peoria reach being significantly higher than Alton and La Grange. Although CPUE for all reaches combined decreased from 2011 to 2013, there was no significant difference detected, likely due to the high variability in CPUE among years. In addition to commercial fishing pressures, lower CPUE of silver carp in the lower reaches may be the result of multiple poor year classes or possibly the result of density dependent effects or competition.

Overall gizzard shad CPUE was greater in 2013 than in previous years (ANOVA; $P < 0.0001$; Figure 2). Increases in gizzard shad CPUE were most dramatic in the Alton and La Grange reaches, where mean number of fish per hour increased from 58.7 (SE = 16.7) and 77.0 (SE = 38.9) in 2012, to 1,301.7 (SE = 323.7) and 1,150.7 (SE = 583.3) in 2013 (Figure 2). However, likely due to the high degree of variability among sites and apparent decline in CPUE in the Peoria reach, there were no significant differences in CPUE by reach (ANOVA; $P = 0.258$) or the year*reach interaction ($P = 0.104$). Mean total lengths (± SE) of collected shad were 65 ±0.86 mm (Alton), 71 ± 1.15 mm (La Grange), and 76 ± 2.45 mm (Peoria). It is unclear why an increase in gizzard shad CPUE was not observed in the Peoria reach, but increases in gizzard shad CPUE in the Alton and La Grange reaches may have been due to favorable environmental conditions for spawning and a strong year-class in 2013. During a multi-year study on the La Grange reach, Irons et al. (2007) did not document any change in gizzard shad CPUE during a coinciding, significant increase in silver carp abundance. Thus, although there was significantly greater CPUE of silver carp in the Peoria reach compared to Alton and La Grange in 2013, it is unlikely that the robust silver carp population in the Peoria reach is suppressing gizzard shad abundance.

The lack of bighead carp in 2013 is likely due to sampling and gear inefficiencies. Of the 2.88 million lbs of Asian carp harvested in the three lower reaches of the Illinois River in spring 2012 for conversion to fishmeal, 45% was composed of bighead carp according to subsamples taken at the fish processor. Bighead carp continue to make up a large portion of the Asian carp commercial harvest, and additional analyses regarding total catches from commercial fishermen brought to processing plants for fish meal and other purposes may provide a better indication of whether declines in bighead carp abundance are occurring.

Age-0 silver carp (N=4) were collected this year for the first time since data collection began in 2011, indicating some level of successful spawning activity in 2013. All age-0 silver carp were collected in the Alton reach. The youngest Asian carp year class captured in either 2011 or 2012 was the 2010 year class, albeit with lower sampling efficiency for these sized fish.

Mean length-at-age

In 2013, four age-0 silver carp were collected in the Alton reach, with a mean total length of 101.8 mm (SE = 0.63). No other age-classes were collected in any reach until age-3.5, when all age classes were present in each reach up to age-6.5 (Figure 3). In the Alton, La Grange and Peoria reaches, the mean lengths of fish age-3.5 has remained relatively unchanged among years within a reach; however, length at age-3.5 has been significantly larger in the La Grange reach across all years sampled ($P \leq 0.029$). For silver carp age-4.5 there have been fluctuations in mean length-at-age across years for all reaches, with the Peoria reach trending toward lower mean total lengths over time, and having a significantly lower mean length compared to Alton and La Grange in 2013 ($P \leq 0.0015$; Figure 3). Silver carp age-5.5 had lower mean total lengths in 2013 compared to other years, though only significantly lower in the La Grange and Peoria reaches ($P \leq 0.0003$). Peoria also had shorter age-5.5 silver carp compared to Alton and La Grange within 2013 ($P \leq 0.0001$; Figure 3). Age-6.5 silver carp in the Peoria reach had significantly lower mean total lengths compared to fish collected from that reach in 2012 (P = 0.036), though not different from 2011. These fish also had greater mean lengths than age-6.5 fish from the Alton reach (P = 0.023), but were not different from fish in the La Grange reach.

While it is difficult to detect trends between separate reaches and years, combining length-at-age data for the lower three reaches yields a clear and significant trend towards shorter mean lengths at age over time (Figure 4). Comparing ages 3.5 to 6.5 (the age classes present in all reaches during all years of sampling) we see that while mean total lengths remained similar for age-3.5 fish, the mean lengths of each proceeding age class decreased significantly from 2011 to 2012, and again from 2012 to 2013, with the exception of age-6.5 fish, (Figure 4). The observed decline in mean total length at age across multiple ages and years could be evidence of commercial removals having an effect on silver carp populations in the Illinois River, but also could be indicative of variation in habitat conditions or resource availability among years, and emigration or immigration among reaches or river systems. However, the necessary data to make any strong conclusions about these observed changes in size-at-age are currently not available.

Mortality

Due to the lack of fish less than age-4.5 in our sample, catch curves were developed using only silver carp aged 4.5-7.5. The annual mortality rate for silver carp collected in all reaches combined was estimated to be 0.775 (95% CI = 0.595 - 0.875; Figure 5). This was not significantly different from the combined annual mortality rate calculated in 2012 (A =0.675; P = 0.47). No differences in annual mortality were evident between Alton (A = 0.647), La Grange (A = 0.694), or Peoria reaches (A = 0.779; $P > 0.26$) in 2013, nor did estimated annual mortality differ between reaches from 2012 to 2013 ($P > 0.52$).

Several factors may be affecting the strength of our annual mortality estimates. First, due to multiple years of extremely poor recruitment, no fish age 1.5 or 2.5 were collected in 2013, and very few age-3.5 fish were collected. Additionally, the effect of a dominant 2008 year class is evident in all reaches and strong carryover of this year class into 2013 resulted in a reduced number of age 4.5 fish compared to age 5.5 fish. This may have decreased the slopes of the catch curves, producing artificially low annual mortality rates.

In 2012 there appeared to be a reduction in the 2008 year class in the Peoria and La Grange reaches as the 2007 year class became dominant. We hypothesized, given that silver carp growth rates are generally slower in Alton compared to La Grange and Peoria that the 2008 year class may have recruited to commercial fishing gear more so in these upper reaches relative to Alton, causing reach-specific changes in age distributions. With the 2008 year class now returning to dominate all reaches, it is possible that the larger members of the 2007 year class received the brunt of commercial fishing pressure in 2013. Evidence to support the fishing down of the largest carp is observed in the length-at-age of remaining age-4.5 and age-5.5 silver carp, with mean total lengths-at-age only 12 mm apart, compared to 2011, when age 5.5 fish were approximately 100 mm longer. There may also be some level of emigration by the 2008 year class into the lower three reaches from the Mississippi River, or from reaches further upstream, given that more fish from the 2008 year class were collected in 2013 (N = 355) than in 2012 (N = 334; Figure 6, Figure 7). Movement studies have shown that silver carp are capable of passing upstream and downstream through the lock chambers of the Illinois River and are capable of migrating through multiple reaches within several months.

Length-weight relationships

Silver carp length-weight relationships were analyzed twice; once including the four, young-of-year fish collected in the Alton reach, and again removing them from the analysis. With the age-0.5 fish included, the intercept and slope of the length-weight relationships were significantly different among reaches for silver carp collected in 2013 (ANCOVA; slope: $P < 0.0001$; intercept: $P < 0.0001$; Table 3). Specifically, the intercept and slope of the length-weight relationships in the Alton reach were different from those in the La Grange and Peoria reaches ($P \leq 0.0035$). However, with the age-0.5 fish removed, although the slope and intercept trended the same, there were no significant differences among reaches (slope: $P \geq 0.518$; intercept: $P \geq 0.516$; Table 3). In general, silver carp collected from Alton tended to be lighter at smaller sizes and heavier at larger sizes relative to other reaches (i.e., fish became more stocky). Silver carp from La Grange and Peoria tended to be the heavier at smaller sizes, and were lighter at larger sizes compared to the Alton reach. This is opposite from trends observed in 2011 and 2012 (Table 3).

Trends in length-weight relationships reversed from 2012 to 2013. With the four, age-0.5 fish removed, the intercept of the length-weight relationship changed significantly between years for La Grange and Peoria ($P \leq 0.0009$) but not Alton, where the change was not significant ($P = 0.908$). The slope of the relationship was significantly different between years for La Grange and Peoria reaches ($P \leq 0.001$), but not for Alton ($P = 0.914$). When the age-0.5 fish remained in the analysis, all comparisons of slope and intercept between reaches from 2012 to 2013 were significant ($P \leq 0.028$). Regardless of the inclusion of age-0.5 fish, the intercepts and slopes of the overall length-weight relationship were significantly different from 2012 to 2013 ($P \leq 0.0003$).

The observed shifts in length-weight relationships among reaches may be evidence of some sort of population response to commercial harvest or emigration and immigration of fish among the reaches. Mean CPUE did increase slightly in the Alton reach in 2013, if commercial fishing pressures have shifted more to the La Grange and Peoria reaches, larger fish in the Alton reach may be experiencing increased growth.

Indices of spawning condition

The size at which variation in female silver carp GSI increased, such that the probability of having a higher GSI increased, was 540.5-mm TL for the Alton reach ($P = 0.001$), and 478.5-mm TL for the Peoria reach ($P = 0.0054$) and was indicative of the size at maturity (Figure 8).

Based on our age-length key, these estimates correspond to age-4 at-maturity in the Alton reach and age-3 in the Peoria reach. For the La Grange reach, variation in GSI was statistically homogenous across TL (P = 0.187). While our sample sizes doubled in 2013, there was an absence of fish younger than 3.5 in the sample, which, if silver carp were expected to become mature by age-3.5, it would be difficult to identify their potential size at maturation. Mean GSI ± SE for female silver carp ranged from 0.0098 ± 0.0008) to 0.0172 ± 0.0024) across reaches (Table 4). Although mean GSI values decreased in 2013 compared to 2012, they followed trends seen in previous years, with fish in the Alton reach generally having lower mean GSI values than La Grange and Peoria. Conclusions made from comparisons of GSI values among years should be taken 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 2013 were not significantly different from 1:1 at the reach level (P = 0.737), or for all reaches combined (P = 1.0), with 338 males and 339 females collected overall. While this contrasts data collected from 2012 sampling efforts that indicated that the sex ratio had shifted away from 1:1, with 17% more males overall, it does mirror overall sex ratios observed from our sampling in 2011 that were not different 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

In sum, 394 Asian carp individuals were genotyped in 2012 (Table 5). . Both "pure" bighead carp and "pure" silver carp were identified in 2012. However, only four "pure" bighead carp were collected in 2012, (Alton = 2, La Grange = 2), suggesting that back-crosses of bighead carp has been occurring for longer than for silver carp. Interestingly, one F1 (first generation cross between parental bighead carp and parental silver carp) carp was identified in the Alton reach, signifying the existence of "pure" bighead and silver carp in the population. From the field identification notes, this fish exhibited morphology characteristic of a hybrid Asian carp: twisted gill rakers and extreme overlap of the pectoral fins (when flat against the body). Genotyping is still underway for an additional 341 tissue samples from 2013 and should be completed by March 2013. 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.

Recommendations:

The results of this study, along with conclusions from other similar data being collected by various agencies along other reaches of the Illinois River (e.g., Illinois Natural History Survey), will serve as baseline information for determining the effects of commercial fishing on Asian carp populations. Although we appear to be seeing immediate demographic responses due to size-selective harvest of Asian carp, we remain cautiously optimistic. For example, 2012 results suggested that the sex ratio of Asian carp had shifted to a more male dominated population; however, results from 2013 suggest that the sex ratio has returned to 1:1. These demographics need to be monitored continually to determine whether factors such as increased growth rates, condition, and reproductive success will occur as a result of reduced intraspecific competition. 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, if hydroacoustic surveys are to be continued in the future, the data garnered from field collections concerning species-specific proportional abundance and changes in length-weight relationships among fishes is critical in the analysis and interpretation of our collected hydroacoustic data, given that hydroacoustic data cannot reveal species composition at this point.

Project Highlights:

- Changes in the population size structure, relative abundance, and sex ratios were evident in 2013 relative to 2012 for silver carp in the three lower reaches of the Illinois River.
- Young-of-year Silver carp were collected in the Alton reach (N=4). This is the first time YOY Asian carp have been collected since standardized sampling began in 2011, indicating a successful spawning event in the Illinois and/or Mississippi Rivers in 2013.
- CPUE of silver carp decreased across years for all reaches combined (overall CPUE down 42% since 2011), and for the La Grange reach in particular (CPUE down 60% since 2011), although no statistically significant difference was found.
- There have been significant reductions in mean length-at-age across multiple age-classes from 2011 to 2012, and again from 2012 to 2013, indicating selective removal of larger individuals from the population, most likely through commercial fishing.
- Asian carp sex ratios in the combined lower three reaches of the Illinois River appear to be gradually shifting from a more male dominated population in 2012 with approximately 17% more males than females, back to a population of 1:1 males and females, similar to what was observed in 2011.
- In general, trends in length-weight relationships reversed in 2013 compared to 2012. Silver carp collected from Alton tended to be skinnier at smaller sizes and heavier at larger sizes relative to other reaches. Silver carp from La Grange and Peoria tended to be the heavier at smaller sizes, and were skinnier at larger sizes compared to the Alton reach. This is the reverse of trends observed in 2011 and 2012
- Gizzard shad overall CPUE increased from 74.6 (SE = 20) fish per hour of electrofishing in 2012, to 964.9 (SE = 274.7) fish per hour in 2013, these increases were isolated to the Alton and La Grange reaches.
- Genetic identification of showed 49.24% hybridization of Asian carp in the lower reaches of the Illinois River. “Pure” bighead and silver carp are still being identified. One F1 backcross (bighead carp x silver carp) was also detected in the Alton reach.

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Table 1. Standardized sampling locations and effort for the three lower reaches of the Illinois River, 2013. Main channel (MC) and backwater (BW) sites were sampled in each reach, electrofishing effort was reported as total amount of pedal time (min) and trammel net effort was total length of net fished (m) during the 15 minute soak duration at each site. Note that trammel nets were not set in main channel habitats.

Reach			Electrofishing (min)		Trammel Nets		
Code	Location name	Habitat type	LTRMP	EXP.	(m)	Latitude	Longitude
Alton							
A-MC1	Grafton	Main channel	15	15	-	38°58'14.19"N	90°27'42.26"W
A-MC2	Hardin	Main channel	15	15	-	39° 9'23.29"N	90°36'47.83"W
A-BW2	Mortland Island	Side channel	15	15	548.64	39°7'39.04"N	90°36'48.17"W
A-MC3	Florence	Main channel	15	15	-	39°37'42.20"N	90°36'26.60"W
A-BW3	Big Blue Island	Side channel	15	15	548.64	39°39'34.14"N	90°37'21.09"W
A-MC4	Meredosia	Main channel	15	15	-	39°49'55.62"N	90°33'58.36"W
A-BW4	Meredosia Lake	Backwater lake	15	15	584.64	39°52'57.27"N	90°32'44.18"W
LaGrange							
L-MC1	MC near Lilly Lake	Main channel	15	15	-	39°58'42.00"N	90°30'44.12"W
L-BW1	Lilly Lake	Backwater lake	15	15	548.64	39°59'16.39"N	90°30'29.33"W
L-MC2	Frederick	Main channel	15	15	-	40° 7'29.25"N	90°22'3.85"W
L-BW2	Wood slough	Backwater lake	15	9.33	274.32	40° 4'52.82"N	90°22'46.42"W
L-MC3	Havana	Main channel	15	15	-	40°20'12.76"N	90° 2'57.76"W
L-BW3	Quiver Lake	Backwater lake	7.5	-	274.32	40°20'10.72"N	90° 2'45.20"W
L-MC4	Peoria Lock and Dam	Main channel	15	15	-	40°37'21.76"N	89°38'12.47"W
Peoria							
P-MC1	Upper Peoria Lake	Main channel	15	15	-	40°47'34.08"N	89°33'43.45"W
P-MC2	Chillicothe	Main channel	15	15	-	40°55'3.85"N	89°28'42.78"W
P-BW2	Sawmill Lake	Backwater lake	0	0	-	41° 7'14.69"N	89°19'30.50"W
P-MC3	Henry	Main channel	15	15	-	41° 6'18.07"N	89°21'26.53"W
P-BW3	Senachwine Lake	Backwater lake	0	0	274.32	41° 9'35.61"N	89°20'12.00"W
P-MC4	Hennepin	Main channel	15	15	-	41°15'30.63"N	89°20'54.70"W

Table 2. Common name, scientific name, species code, and total number of fish collected for each species by reach from the Illinois River in 2013, all gears combined.

Common name	Scientific name	Code	Alton	La Grange	Peoria
Bighead carp	*Hypopthalmichthys nobilis*	BHCP	0	0	0
Bullhead minnow	*Pimephales vigilax*	BHMW	0	2	2
Black buffalo	*Ictiobus niger*	BKBF	8	13	42
Black crappie	*Pomoxis nigromaculatus*	BKCP	1	6	0
Brook silverside	*Labidesthes sicculus*	BKSS	2	0	0
Bluegill	*Lepomis macrochirus*	BLGL	13	13	2
Bigmouth buffalo	*Ictiobus cyprinellus*	BMBF	9	18	4
Bowfin	*Amia calva*	BWFN	0	2	0
Common carp	*Cyprinus carpio*	CARP	57	16	8
Channel catfish	*Ictalurus punctatus*	CNCF	15	24	4
Emerald shiner	*Notropis atherinoides*	ERSN	17	26	2
Flathead catfish	*Pylodictis olivaris*	FHCF	4	4	0
Freshwater drum	*Aplodinotus grunniens*	FWDM	50	64	13
Golden Redhorse	*Moxostoma erythrurum*	GDRH	0	1	1
Grass carp	*Ctenopharyngodon idella*	GSCP	3	4	2
Gizzard shad	*Dorosoma cepedianum*	GZSD	4,556	3,491	101
Hybrid sunfish	*Lepomis hybrid*	HYSF	1	0	1
Logperch	*Percina caprodes*	LGPH	0	1	0
Largemouth bass	*Micropterus salmoides*	LMBS	2	1	1
Longnose gar	*Lepisosteus osseus*	LNGR	0	8	0
Orangespotted sunfish	*Lepomis humilis*	OSSF	0	1	0
Quillback	*Carpiodes cyprinus*	QLBK	39	48	4
River carpsucker	*Carpiodes carpio*	RVCS	2	8	1
River redhorse	*Moxostoma carinatum*	RVRH	2	3	1
Sauger	*Stizostedion canadense*	SGER	2	0	5
Shorthead redhorse	*Moxostoma macrolepidotum*	SHRH	1	0	4
Skipjack herring	*Alosa chrysochloris*	SJHR	3	2	4
Smallmouth buffalo	*Ictiobus bubalus*	SMBF	1	7	3
Smallmouth bass	*Micropterus dolomieu*	SMBS	0	0	1
Shortnose gar	*Lepisosteus platostomus*	SNGR	8	8	5
Spotted bass	*Micropterus punctulatus*	STBS	0	1	0
Spotfin shiner	*Cyprinella spiloptera*	SFSN	6	0	0
Spottail shiner	*Notropis hudsonius*	STSN	1	0	1
Silver carp	*Hypopthalmichthys molitrix*	SVCP	129	143	233
Walleye	*Stizostedion vitreum*	WLYE	0	5	1
White bass	*Morone chrysops*	WTBS	49	49	22
White crappie	*Pomoxis annularis*	WTCP	0	5	1
Unique Species			2	5	1
Total fish sampled			**4,981**	**3,974**	**469**

Table 3. Parameter values from the length-weight relationships ($\log_{10}\text{mass} = a' + b \cdot \log_{10}\text{TL}$) for silver carp collected from the lower three reaches of the Illinois River in 2012 and 2013. Parameter estimates with different letters indicate significantly different values between reaches ($P < 0.05$) as determined by ANCOVA. Asterisk indicates the removal of four, age-0.5 silver carp collected in the Alton reach from the regression; with these fish removed parameter estimates were not significantly different among reaches.

Reach	*a*'	SE	*b*	SE	R^2	*P*	*N*
				2012			
Alton	-4.807[a]	0.187	2.926[a]	0.069	0.93	<0.0001	144
La Grange	-5.622[b]	0.098	3.226[b]	0.036	0.95	<0.0001	417
Peoria	-5.302[c]	0.068	3.110[c]	0.025	0.97	<0.0001	530
Combined	-5.346	0.054	3.125	0.020	0.96	<0.0001	1091
				2013			
Alton	-5.223[a]	0.057	3.079[a]	0.021	0.99	<0.0001	157
Alton*	-4.768[b]	0.282	2.913[b]	0.103	0.84	<0.0001	153
La Grange	-4.536[b]	0.215	2.828[b]	0.079	0.87	<0.0001	194
Peoria	-4.695[b]	0.163	2.887[b]	0.061	0.88	<0.0001	324
Combined	-5.091	0.050	3.032	0.019	0.98	<0.0001	675
Combined*	-4.623	0.095	2.860	0.035	0.91	<0.0001	671

Table 4. Mean gonadosomatic index (GSI) for silver carp by reach and sex in the Illinois River, 2012 and 2013.

Year	Sex	*N*	Mean GSI	SE
		Alton		
2012	F	15	0.013	0.0043
	M	24	0.0009	0.0002
2013	F	42	0.0098	0.0008
	M	51	0.0016	0.0004
		La Grange		
2012	F	23	0.06	0.0074
	M	23	0.0019	0.00045
2013	F	54	0.0172	0.0024
	M	53	0.0018	0.0002
		Peoria		
2012	F	23	0.064	0.0168
	M	25	0.0016	0.00042
2013	F	57	0.0122	0.0010
	M	62	0.0026	0.0004
		Combined		
2012	F	61	0.053	0.013
	M	72	0.0015	0.0002
2013	F	153	0.013	0.001
	M	166	0.002	0.0002

Table 5. Genetic identification of 394 Asian carp collected in Alton, La Grange, and Peoria in 2012. SV = silver carp, BH =bighead carp, BxBH = first generation bighead carp backcross, Bx3BH = third generation bighead carp backcross, F1 = first generation cross between parental bighead carp and parental silver carp, Fx = advanced generation cross containing both bighead carp and silver carp homozygous genotypes (e.g., backcross x backcross), Bx2SV = second generation silver carp backcross, Bx3SV = third generation silver carp backcross, Bx4SV+ = at least a fourth generation backcross.

Reach	BH	Bx2SV	Bx3BH	Bx3SV	Bx4SV+	BxBH	F1	Fx	SV	Total
ALTON	2	1		19	46		1	1	67	137
LA GRANGE	2	1	1	20	43	1		1	63	132
PEORIA				13	46				66	125
Total	**4**	**2**	**1**	**52**	**135**	**1**	**1**	**2**	**196**	**394**

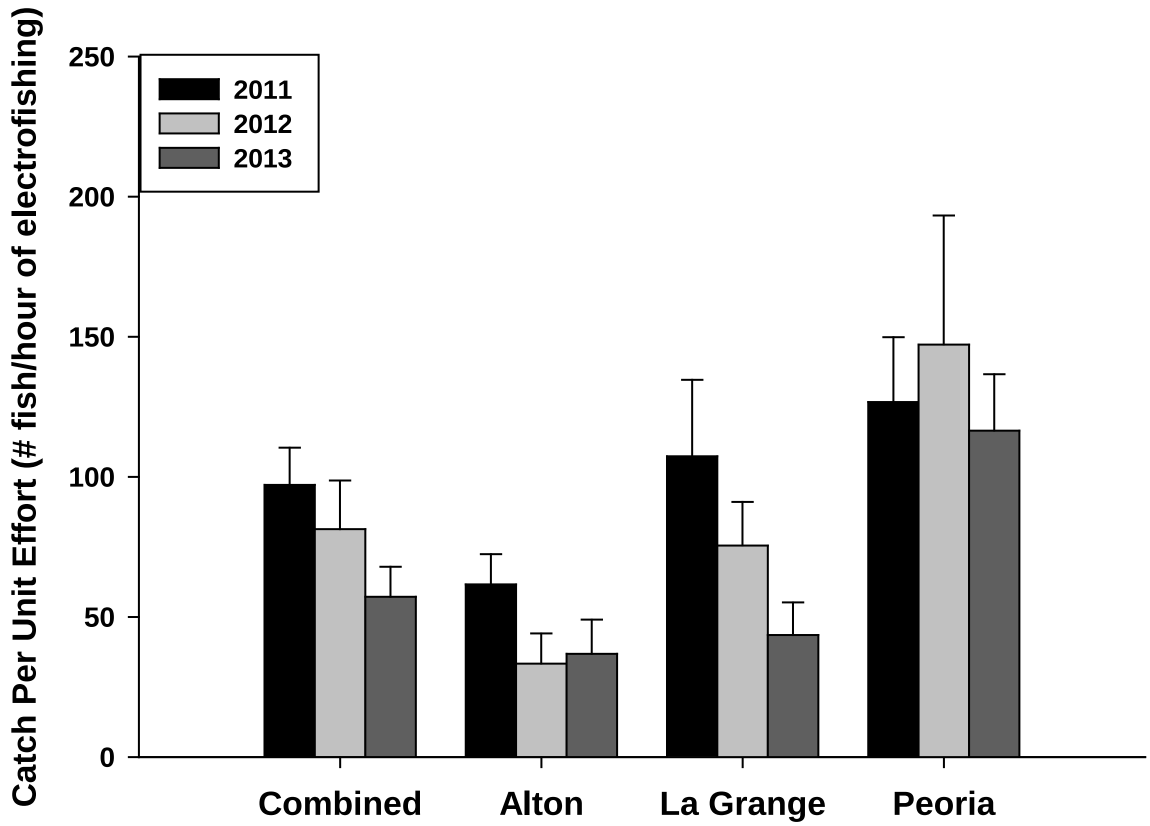

Figure 1. Silver carp mean electrofishing catch per unit effort and standard error from standardized fish sampling conducted in 2011, 2012, and 2013 for the lower three reaches of the Illinois River combined and for each reach.

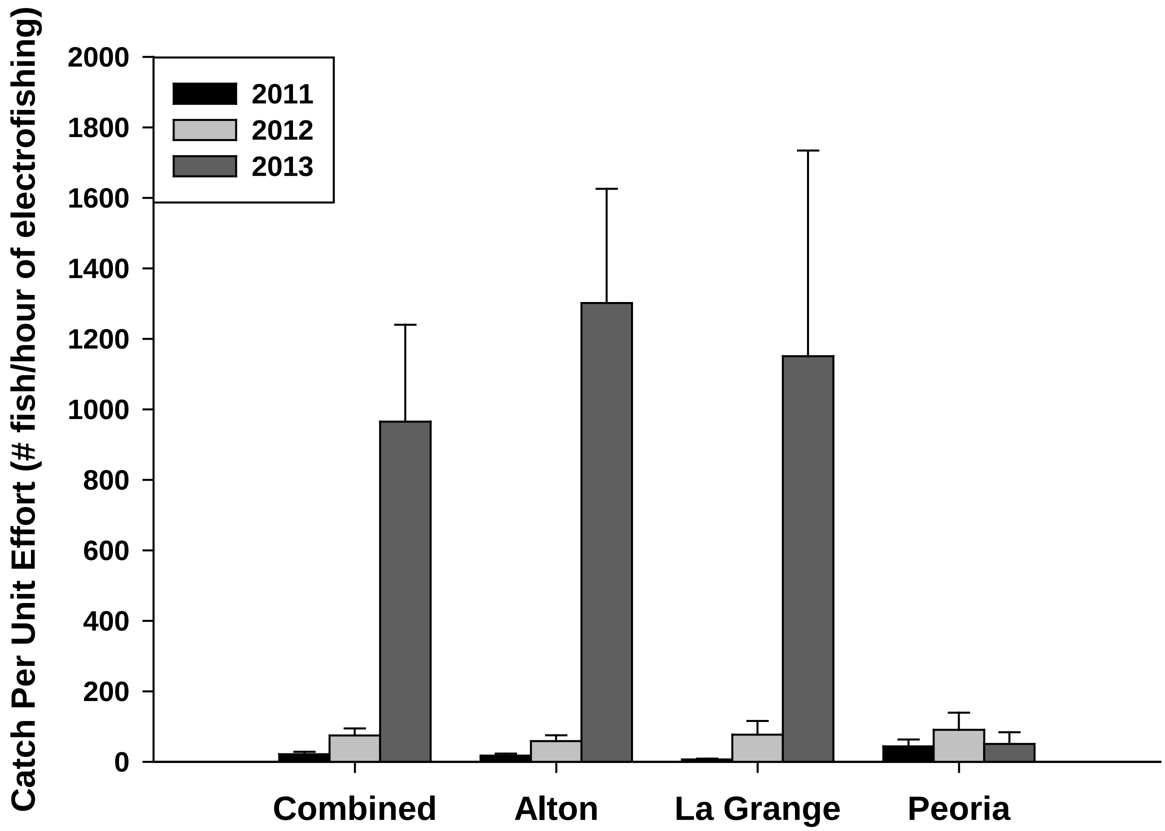

Figure 2. Gizzard shad mean electrofishing catch per unit effort and standard error from standardized fish sampling conducted in 2011, 2012, and 2013 for the lower three reaches of the Illinois River combined and for each reach.

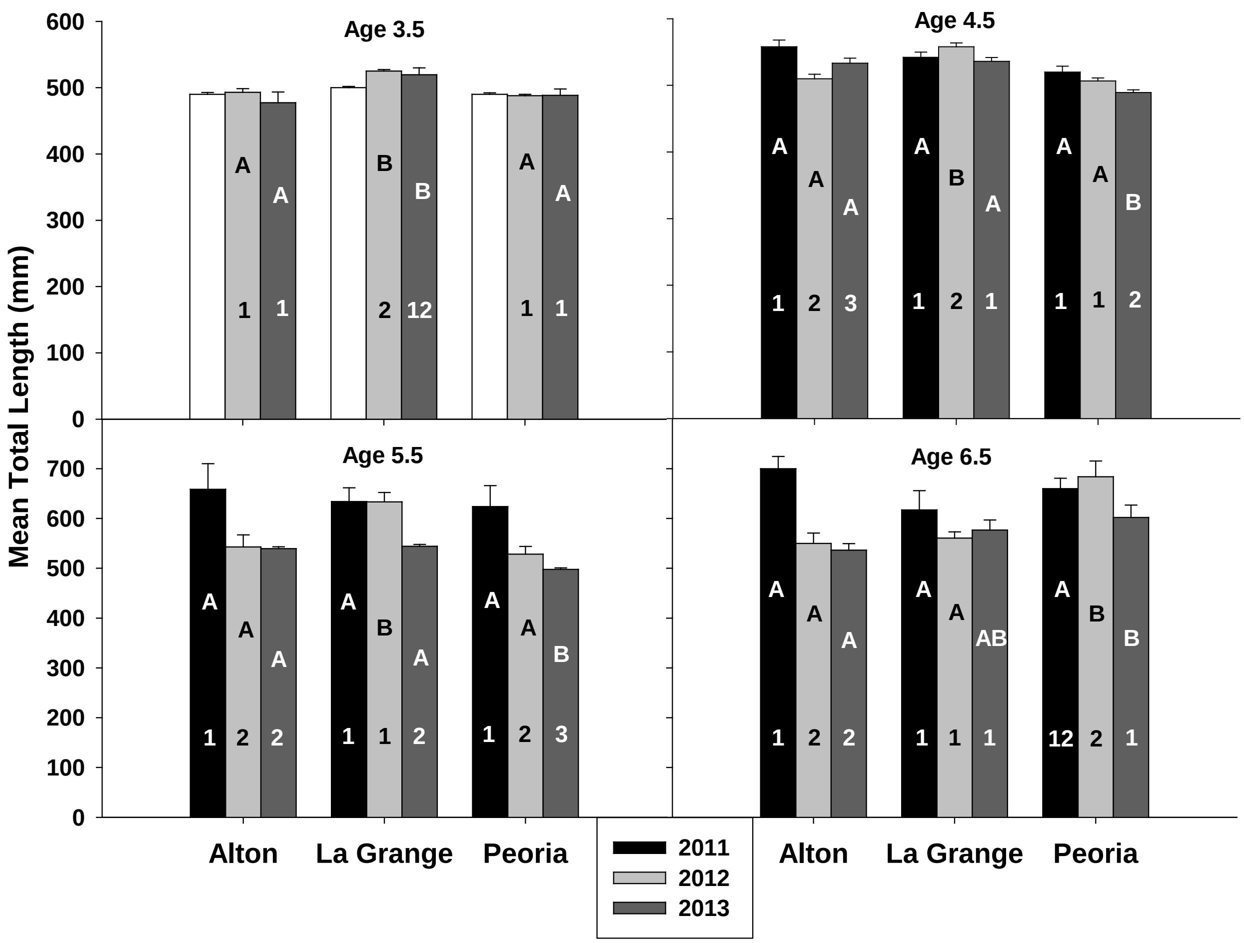

Figure 3. Mean length-at-age with associated standard error for silver carp in the three lower reaches of the Illinois River collected in 2011, 2012 and 2013; different numbers denote a significant difference in mean total length among years, within a reach, different letters indicate significantly different mean total lengths among reaches within a year ($P \leq 0.05$), as determined by a two-way ANOVA. Note different scales on the Y-axis.

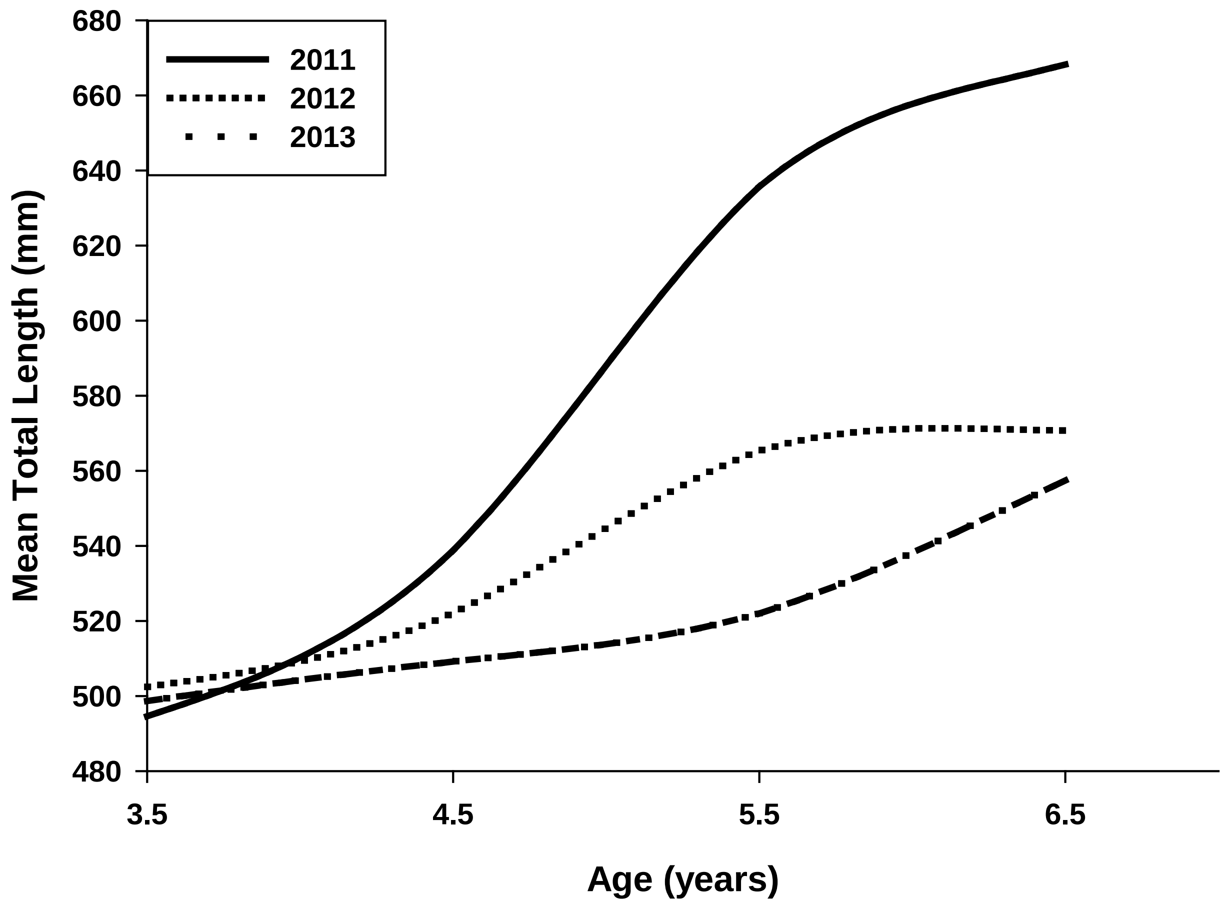

Figure 4. Mean length-at-age of silver carp collected from the lower three reaches of the Illinois River combined, 2011, 2012, and 2013.

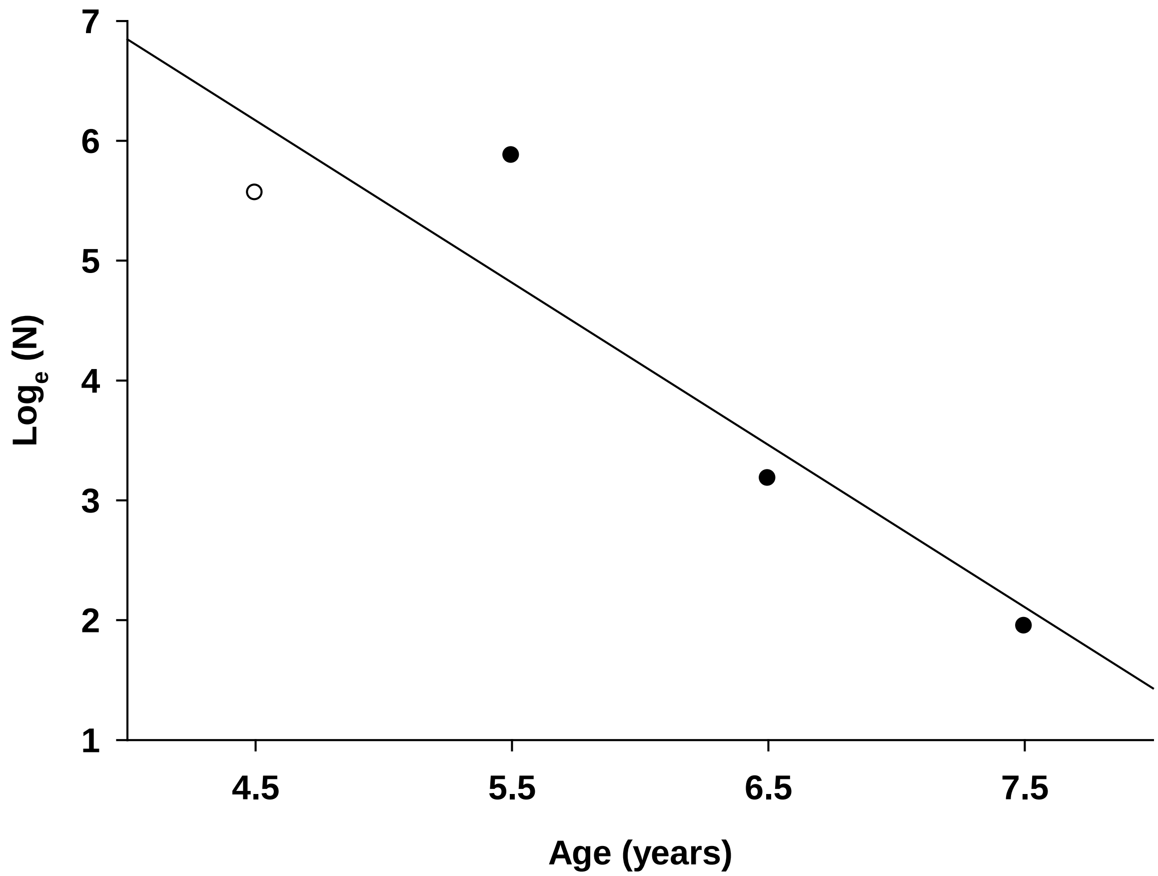

Figure 5. Natural-log transformed number of silver carp plotted as a function of age for the three lower reaches of the Illinois River and all sampling gears combined, 2013.

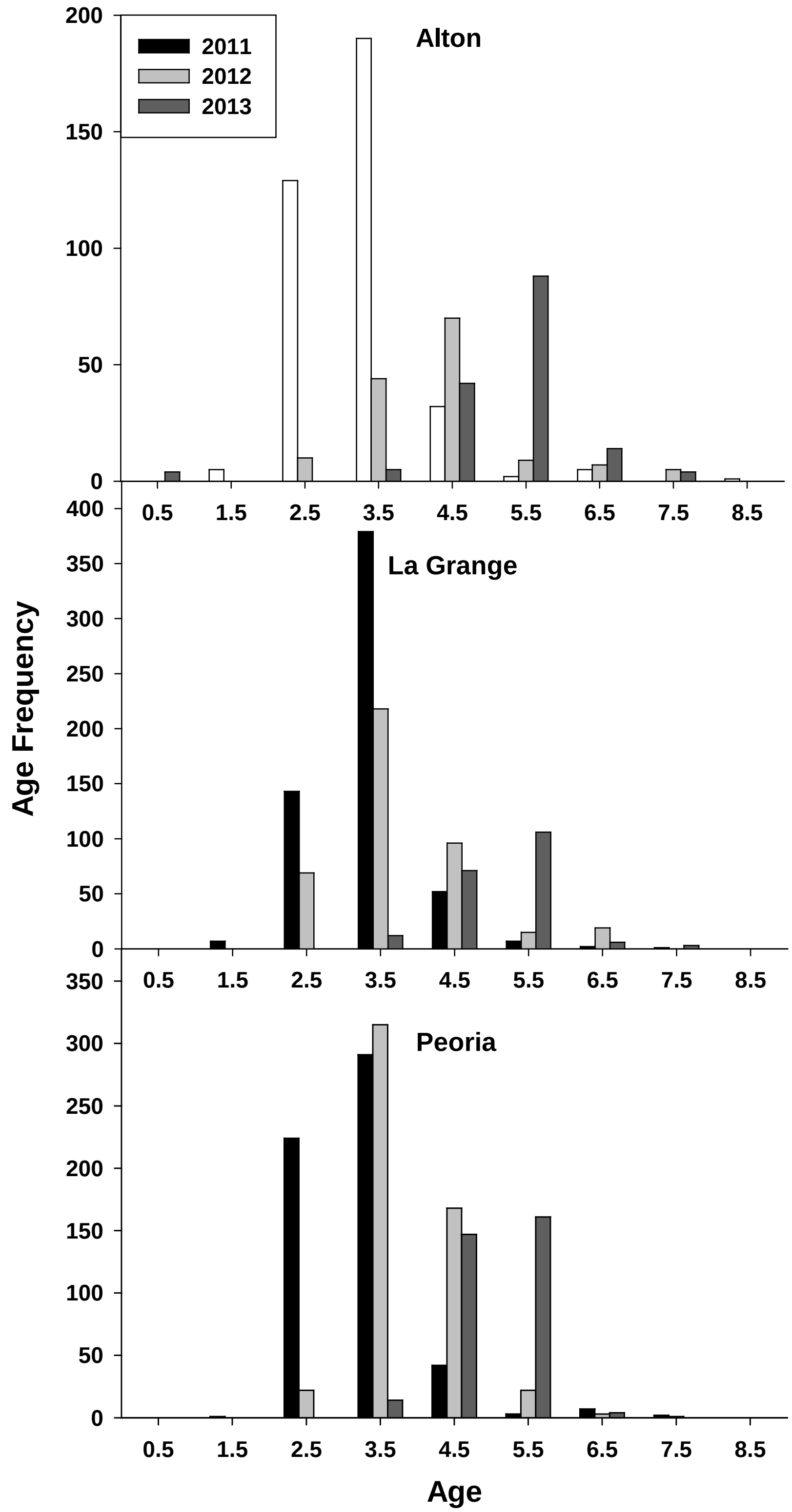

Figure 6. Age frequency for silver carp by reach for 2011-2013 collected in the Illinois River using pulsed-DC electrofishing and trammel netting.

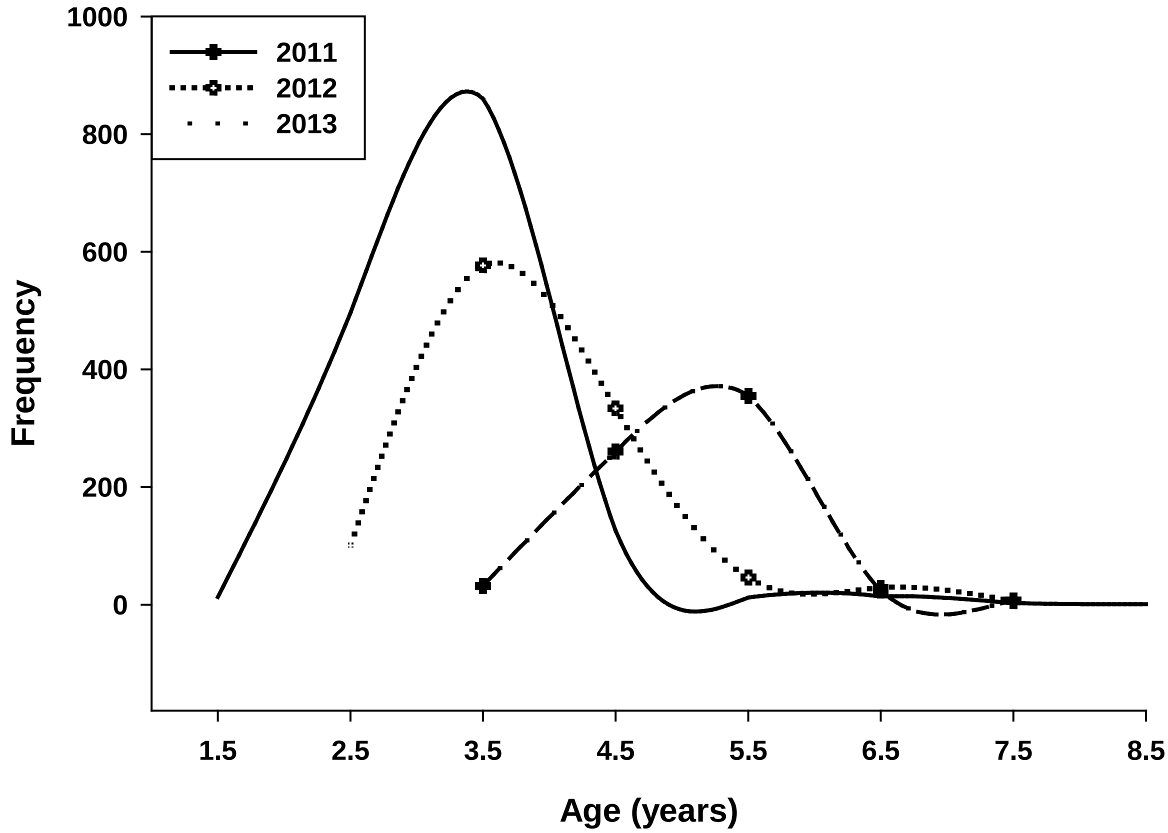

Figure 7. Age frequency of silver carp, lower three reaches of the Illinois River combined, for 2011-2013 collected in the Illinois River using pulsed-DC electrofishing and trammel netting.

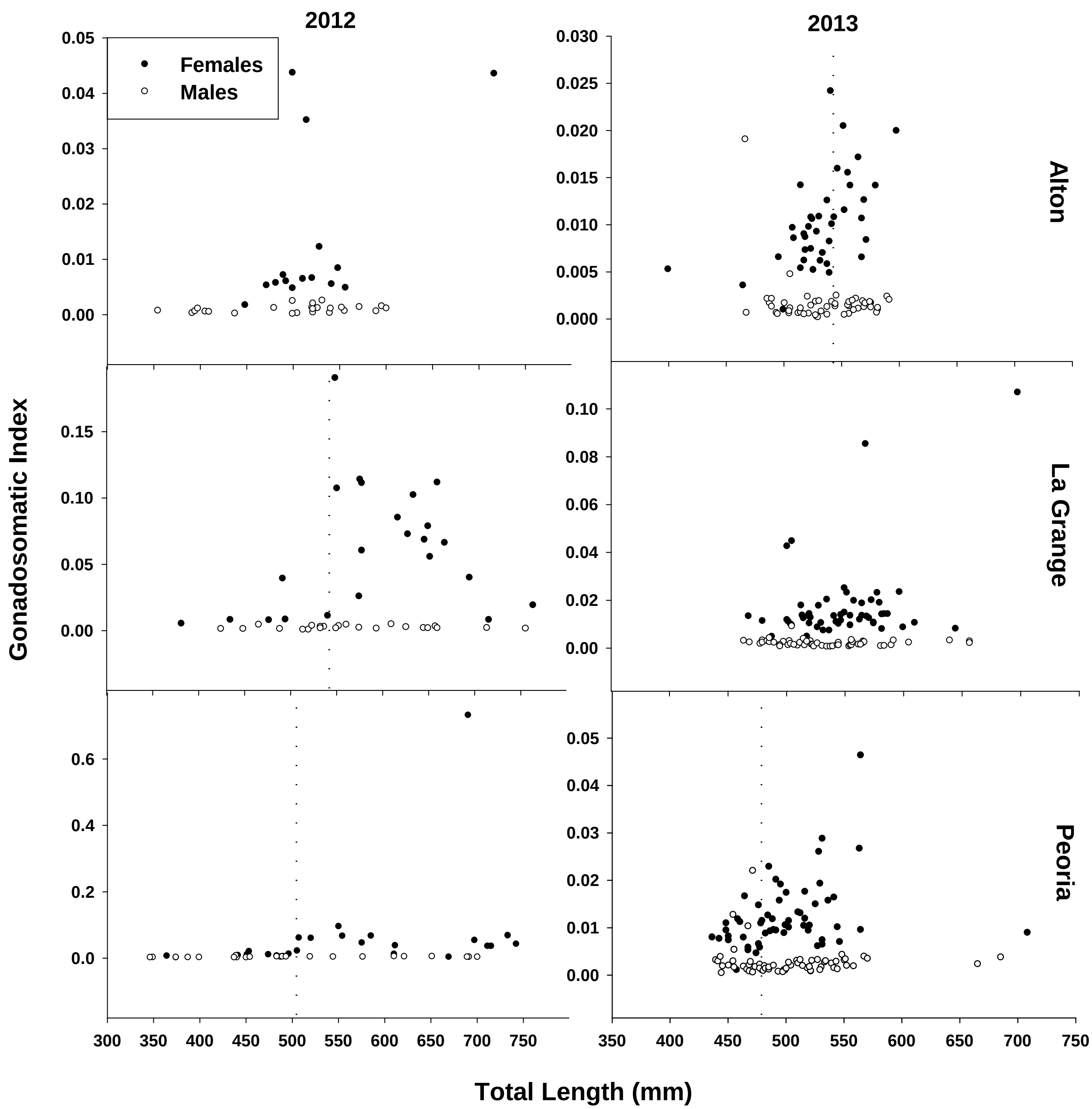

Figure 8. Gonadosomatic index (GSI) of silver carp plotted by total length for each sex for the three lower reaches of the Illinois River, 2012 and 2013. The dashed vertical line shows the total length at which variation in GSI increases for female silver carp as determined by a two-dimensional Kolmogorov Smirnov test ($P \leq 0.031$ for La Grange and Peoria reaches, 2012; $P \leq 0.0054$ for Alton and Peoria reaches, 2013), GSI was statistically homogenous across TL in the Alton reach in 2012 and the La Grange reach in 2013. Note the varying magnitude of scale for GSI among graph panels.

Chapter 2:

Evaluating the efficacy of upstream harvest of Asian carp

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

Introduction: Harvest efforts in the upstream portions of the Illinois River, initiated in 2011, have continued to be part of an integrated control strategy for reducing the risk of Asian carp from gaining access to the Great Lakes. In 2011, Illinois Department of Natural Resources (IDNR)-contracted commercial harvest resulted in the removal of 351.6 tons of Asian carp from the Dresden, Starved Rock, and Marseilles reaches, eliminating the possibility that those fish will progress any further upstream toward the Chicago Area Waterway System (CAWS). In 2012, the number of Asian carp harvested dropped to 284.53 tons, even though fishing effort was similar.

In addition to declines in harvest, three separate hydroacoustic surveys, conducted by Southern Illinois University Carbondale (SIUC) in 2011, indicated a rapid decline in total fish abundance from 300,250 to 198,090 fish in the Hanson Material Service Corporation (HMSC) east pit. These pits are located on the Marseilles reach near Morris, IL and are fished as part of the Barrier Defense Asian carp Removal project. The declines in abundance were consistent with a reduction in CPE observed in that area, yet harvest alone could not account for the decline in total fish abundance. In this study, we sought to better understand how other factors, such as emigration from the study area, could help explain Asian carp population dynamics in these upstream areas.

In 2013, we built on the information gained in 2011 and 2012 and continued to monitor the efficiency of upstream harvest of Asian carp in the upper reaches, but most closely in the HMSC backwater of the Marseilles Reach. This information is important for determining the efficacy of harvest in these upper reaches of the Illinois River, defining the role of immigration from the lower river to the upper reaches, and ultimately reducing propagule pressure of Asian carp on the Great Lakes.

Objectives: SIUC will use multiple approaches within the east and west pits of the HMSC to:

1) Estimate the population size of Asian carp;
2) Determine immigration and emigration rates of Asian carp, as well as movement patterns between the east and west pit;
3) Estimate exploitation rates.

Methods and Materials: SIUC initiated a mark-recapture study (320 Asian carp were tagged) in spring 2012 within the HMSC east and west pits to estimate population size, movement patterns, and exploitation rates for Asian carp. In 2013, another mark-recapture study was initiated to bolster mark-recapture information from 2012. With the assistance of IDNR contracted commercial fishermen, an additional 276 fish (92 bighead carp, 148 silver carp, and 36 hybrid Asian carp) were captured with gill nets and tagged in the HMSC east pits on 7 April 2013. Using the same protocol as in 2012, fish were weighed (nearest g), TL measured (nearest mm), tagged with individually numbered reward jaw tags (aluminum, size 1242-9C, National Band and Tag Co.), and released at the site of capture. To better estimate exploitation, survival, and immigration to the upper reaches of the Illinois River, SIUC also initiated a mark-recapture study in the Starved Rock pool in 2013. On 8 May 2013, 263 Asian carp (43 bighead carp, 211 silver carp, and 9 hybrid Asian carp) were jaw tagged in the Sheehan Island backwater of the Starved Rock pool (near Buffalo Rock) following the same protocol used in the Marseilles backwater. Recoveries of tagged fish from both areas were recorded from contracted commercial fishermen throughout the Barrier Defense Asian Carp Removal Project. Fliers were provided to IDNR personnel, contracted commercial fishermen, bow fishing groups, and fish processing plants to increase awareness of the mark-recapture study and to provide reporting instructions. The jaw tag number, "REWARD," and contact information for SIUC were clearly marked on each jaw tag.

A Link-Barker Jolly-Seber mark-recapture model (Link and Barker 2005) for open populations was employed in Program MARK® to calculate an overall survival rate (φ), capture probability (p), and immigration rate (f) for all available commercial fishing periods (30 April 2012 – 17 November 2013) as well as weekly estimates of survival, exploitation, rate of population change, and immigration for 2012 and 2013 independently. For annual mark-recapture models, φ, p, and f were allowed to vary temporally (between sampling periods). For the combined 2012-2013 model, φ, p, and f were held constant to decrease the parameters in the model and increase precision of the estimates.

Immigration and emigration rates throughout the Illinois River, as well as movement between the east and west gravel pits of the HMSC backwater, are also being estimated with acoustic telemetry. To date, with assistance from IDNR-contracted commercial fishermen and Illinois Natural History Survey (INHS), 691 acoustic transmitters have been implanted in Asian carp in the Illinois River or Pool 26 of the Mississippi River. In addition to the 354 fish that were tagged in 2012, 337 Asian carp were tagged with Vemco® acoustic transmitters (v16, v13, v9, or v6 transmitting at 69 KHz) in the Illinois River in 2013 (Table 1). A total of thirty-six fish were tagged in the Dresden Island pool, with10 fish being released in Rock Run Rookery and 28 released near the confluence with the Kankakee River. In the Marseilles pool, 96 fish were tagged with transmitters; 56 were released in the main channel at the Morris boat ramp, and 38 were released in the HMS pits (21 in the west pit, 17 in the east pit). In the Starved Rock pool, 54 fish were tagged and released at the Starved Rock Marina. To determine the amount of movement between pools in the lower Illinois River and Upper Illinois River, additional fish were tagged in the Peoria (51 fish near Lacon, IL), La Grange (54 fish near Havana, IL) and the Alton pools (46 fish near Hardin, IL).

A network of 30 Vemco® VR2W receivers was deployed in the Illinois River by SIUC in 2012 to monitor movement of acoustically tagged Asian carp (Alton = 9, LaGrange = 7, Peoria = 6, Starved Rock = 4, and Marseilles = 4). This network has been continuously monitored and

VR2Ws 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 three receivers were specifically placed within the HMSC gravel pits to better understand the factors affecting Asian carp immigration and emigration within this area (Figure 1). All fish with acoustic transmitters 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. Temperature loggers (HOBO Pendant® model UA-002-64) were deployed with all receivers to examine how this may influence movement of Asian carp. Please see Chapter 3 for more details concerning acoustic telemetry.

Results and Discussion:

Harvest

IDNR contracted commercial fishermen harvested a total of 16,025 Asian carp (6,756 bighead carp, 9,223 silver carp, 46 grass carp) from the east and west pits of the HMSC during the 2013 Barrier Defense Asian Carp Removal Project. This was slightly fewer fish (~14%) than the total number harvested in 2012 (18,712 bighead and silver carp). Although fewer fish were removed from the HMSC pits in 2013 there was no significant difference (ANOVA; $P < 0.001$) in commercial fishing effort (catch per effort; CPE (fish/1000 yards of gill net)) between 2012 (61.4 $\pm$ 0.4 fish/1000 yards) and 2013 (52.7 $\pm$ 0.4 fish/1000 yards), suggesting that Asian carp numbers have declined or are declining in this backwater. Average CPE for 2013 in the Starved Rock pool (277.3 $\pm$ 28.9 fish/1000 yards) was significantly greater (ANOVA; $P<0.001$) than for either year in the HMSC pits.

Mark-recapture

Of the 320 Asian carp externally tagged in the HMSC gravel pits in 2012, a total of 156 marked individuals were harvested (49%) during 2012. By December of 2013, only 11 additional carp from this tagging cohort were harvested (total of 167 carp, 52.2%). To date, 71 out of 276 fish (25.6%) from the 2013 tagging cohort have been harvested. This is a significantly smaller proportion of the tagged population than was recaptured during the 2012 mark-recapture study. Assuming that natural mortality has been constant, this suggests that fish have either moved out of areas where commercial fishing is taking place (but still within the backwater) or that they have moved out of the HMSC pits entirely. Not surprisingly, a much lower recapture rate was observed for fish tagged in Starved Rock pool. Not including three fish that were harvested by bow fishermen, 32 of the 263 fish tagged (~12.2%) were harvested by commercial fishermen over a 30-week period (5 May 2013 – 7 December 2013).

Only two individuals (tagged in the HMSC pits) were recaptured outside of the backwater where they were tagged. One was captured in nearby Peacock Slough and another in Sheehan Island in the Starved Rock Pool. This number is similar to the number of jaw tagged fish detected outside of their tagging location in 2012 (three fish), suggesting that emigration rates of Asian carp (outside their original pool) were very low, which increased their susceptibility to harvest.

Acoustically telemetered fish, however, indicated that movement in and out of this area is relatively high with 57% of fish tagged in the HMSC pits moving out at some point in 2012. Data are still being processed for August – December 2013; however, when telemetry data are combined with estimated immigration rates from 2012 and 2013 (through 14 August 2013), a positive correlation exists (R = 0.57) between the number of fish moving into the HMSC pits and the estimated mark-recapture immigration rate. Combining these data suggests that Asian carp are residents in the backwater, make short forays into the main channel, but eventually may return to this backwater, and that additional immigration may be occurring more frequently than just the spring and fall movement periods. Further analyses should be conducted to test the significance of this relationship.

Excluding the three Asian carp that were caught outside of the HMSC backwater in 2012 and 2013 and the 15 that were recaptured during the USGS water gun experiments in this area, the estimated exploitation rate for this backwater area for the 2012 commercial fishing period (30 weeks; 7 May 2012 – 3 December 2012) was 0.89 (95% CI = 0.86 -0.91) for non-immigrants (i.e., the fish present at the beginning of the mark-recapture study). Immigration rates during this time period were very low (close to zero), likely contributing to the high exploitation rate. In 2013 the estimated immigration rate rose to 0.22 individuals per individual in the population (Table 1), contributing to a much lower exploitation rate. It should be noted that although this rate is lower, a 0.38 exploitation rate is still respectable for the goal of carp removal in this backwater. When data from 2012 and 2013 were combined, the estimated exploitation rate was 0.55. In addition, in 2012 and 2013, CPE of Asian carp declined at a slower rate than the proportion of marked individuals (Figures 2a and 2c), suggesting that immigration into this backwater increased at a faster rate than those removed through harvest. In fact immigration estimates from Link-Barker mark-recapture models indicated that immigration into the HMSC pits was cyclic (Figure 2b, Figure 3d), with more immigration occurring during spring and early summer in 2012 and 2013 (Figure 2b, Figure 3d)

Estimates from Link-Barker mark-recapture models indicated that the rate of population change was greater than one for half of the sampling periods. It is likely that pulses of commercial harvest allowed the population growth rate to dip below one for periods of time throughout the year. It appears that early spring and fall are two time periods when harvest was able to outpace the lower immigration rates (Figure 3). Harvest may be particularly necessary during these time periods to keep population rate of change below one. In *annual* mark-recapture models the rate of population change decreased from increased from 2012 to 2013, exhibiting a downward trend (Figure 2b), suggesting that fish were still being removed faster than they immigrated. However, more immigration in 2013, as indicated by mark-recapture estimates and telemetry data, may have kept the population growth rate greater than one for periods in July and October. This suggests that continued harvest throughout the year may be necessary to keep Asian carp populations at bay, and increased harvest during the fall and spring may allow commercial fishermen to more significantly lower carp numbers.

Because confidence intervals were extremely wide for annual mark-recapture models where capture probability (p), immigration (f), and survival probability (φ) varied with time, these variables were held constant and one estimate of p,f, and φ were calculated for each year (Table 2). The rate of population change was still estimated for each sample period (Figure 3b).

Exploitation rate increased to 1.0 in 2013 from 0.89 in 2012, signifying that any fish present at the beginning of the study (in 2013) had a 100% chance of mortality (if they did not emigrate) if they remained in the HMSC backwater. Thus, commercial fishing is effective, especially against resident fish in the backwaters. However, estimates of immigration rate increased in 2013 to 0.08 fish per fish in the population per week, from nearly zero in 2012. This may be a function of the high water and increased flow in 2013, attracting fish into the backwaters.

Telemetry

Continued analysis of telemetry data indicates that movement into and out of the HMSC pits from the Marseilles main channel, and from the east pit to the west pit, is high and likely correlates with river discharge and temperature (during spawning periods; Figure 5). However, movement in the reverse direction, between the HMSC west to the east west pits was relatively low. Of the 22 fish that were tagged with acoustic transmitters in the HMSC west pit in 2013, 4 (~18%) were detected in the east pit, but 22 fish that were tagged outside the west pit (either in the Marseilles main channel, in the east pit, or in another pool) were detected in the west pit.

Asian carp movement into and out of the HMSC pits seems to correspond with changes in river discharge (Figure 4). In the spring, movement increased starting in early march and continued until early June, when river discharge increased. In the fall, Asian carp movement increased in early September and ceased by December. Increased commercial fishing prior to and during times of peak movement may target individuals emigrating out of or immigrating into the HMSC pits, thus targeting transient fish.

Hydroacoustics

Data collected with fixed-station hydroacoustics conducted in 2012 are currently being processed and data from telemetry receivers are continuously being downloaded to improve immigration and emigration rates and movement within the HMSC gravel pits. The hydroacoustic estimate of abundance within the HMSC is also ensuing, and may facilitate transformation of rate estimates into actual numbers.

Modelling Summit and Spatially Explicit Model: A spatially explicit model that incorporates movement among reaches is currently underway. This model will help us better understand these population dynamics and to determine how immigration and emigration affect these estimates. A modeling summit was held in St. Louis in February 2013 to discuss modeling approaches. More information about the model and the modeling summit can be found in Chapter X.

Recommendations: Although overall return rate was exceptionally high for a mark-recapture study, weekly estimates of exploitation and population rate of change had extremely high standard errors due to a small proportion of tagged individuals in the population. Adding additional fish in 2013 helped slightly, but we recommend putting more faith in the annual model estimates (i.e., estimates with very tight 95% CI) than the weekly estimates. Using the trends we observed this year, an increase in the number of tagged individuals is still warranted. nearly 1000 fish should be tagged to yield more precise weekly estimates of survival and population growth rate. In addition, instead of removing tagged individuals from the population each week, it would be helpful for commercial fishermen to return all tagged fish to the water. This should increase the number of fish available for capture each week, thus decreasing the error in our models.

We also assumed that tag loss was negligible for these analyses and could therefore have affected these results. We know that some fish that were tagged on the upper jaw early in the season had some tag loss. We modified our tagging technique so that all fish are tagged, tightly, on the lower jaw. Given that estimates of emigration appeared to be exceptionally high due to the declining proportions of marked individuals harvested, determining tag loss is still needed.

Immigration, at least to the HMSC pits, seems to be the driving factor keeping the population growth rate above one in this area. Estimates concerning the population rate of changed combined with estimated immigration in 2013 suggest that harvest was unable to outpace immigration for most of 2013 (and 2012) even though CPE decreased as effort remained the same. This suggests that continued harvest during all times of year is necessary, and additional harvest from source populations (i.e., lower Illinois River) is encouraged, to limit the number of immigrants to the upper river and decrease propagule pressure on the CAWS

Project Highlights:

- Of the 320 Asian carp externally tagged in the HMSC backwater near Morris, IL in May 2012 a total of 167 (~52.2%) marked individuals were harvested through IDNR-contracted commercial fishing efforts by the end of December 2013. The majority these individuals (~47%) were harvested in 2012.
- Estimates of the population rate of change in the Asian carp population in the HMSC pits using mark-recapture models still indicate a declining population, suggesting commercial fishing is effective at the current population size.
- Emigration of Asian carp from the HMSC backwater appeared low in 2012, but was much higher in 2013. Thirty-two of the 39 fish (82%) that were tagged with acoustic transmitters in 2013 left the HMSC backwater at some point, possibly decreasing susceptibility to harvest in 2013.
- Of the 22 fish that were tagged with acoustic transmitters in the HMSC west pit in 2013, 4 (~18%) were detected in the east pit during 2013. Only one fish tagged in the east pit moved to the west pit, but 22 fish that were tagged outside the west pit (either in the Marseilles main channel, in the east pit, or in another pool) were detected in the west pit.
- The estimated exploitation rate for this backwater area was 100% over an 82-week period for non-immigrants (i.e., the fish present at the beginning of the mark-recapture study in 2013 and 89% in 2012, suggesting that commercial fishing is effective at the current population size.
- Estimates concerning the population rate of changed combined with estimated immigration in 2013 suggest that harvest was unable to outpace immigration for most of 2013 (and 2012). This suggests that continued harvest during all times of year is necessary and additional harvest from source populations (i.e., lower Illinois River) is encouraged to limit the number of immigrants to the upper river and decrease propagule pressure on the CAWS.

References

Link, W. A. and R. J. Barker. 2005. Modeling association among demographic parameters in analysis of open population capture-recapture data. Biometrics 61(1): 46-54.

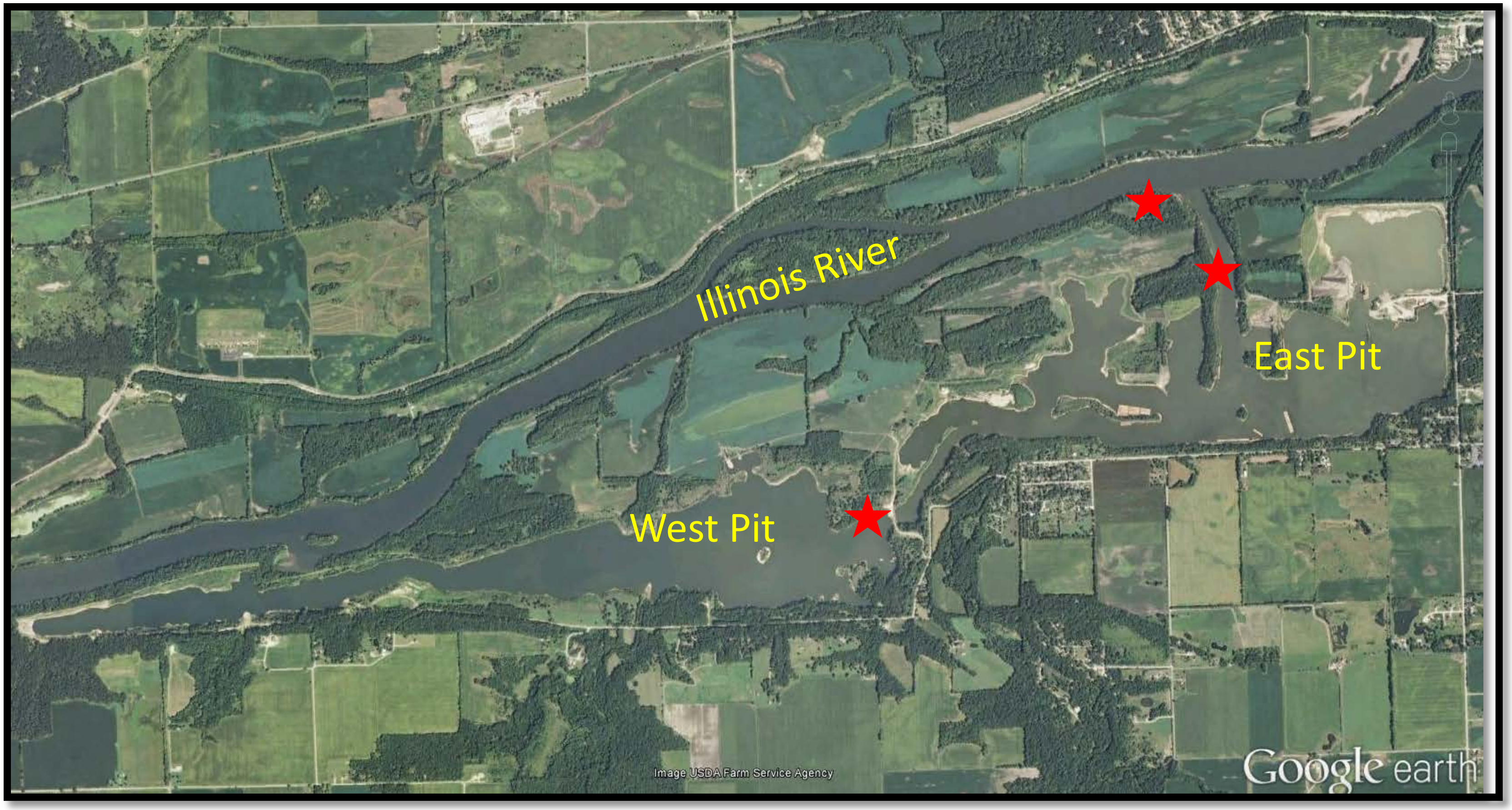

Figure 1. Map of Hanson Material Services Corporation backwater near Morris, IL indicating locations of VR2 receivers to quantify movement in/out of this backwater and between the west and east pits.

Table 1. Link-Barker mark-recapture estimates and 95% confidence intervals (95% CI) of weekly exploitation rate (1-φ) and immigration rate (*f*) for the HMSC pits in 2012 and 2013, run on an annual basis (30 weeks; φ(.)*p*(.)f(.)) for each year (reported as weekly rates), for the HMSC pits with both years combined (82 weeks).

	HMSC 2012		HMSC 2013		HMSC 2012-2013 combined	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Exploitation rate	**0.89**	0.86 - 0.91	**0.38**	0.27- 0.52	**0.55**	0.555 -0.557
Immigration rate	**3.4×10^{-9}**	1.4×10^{-13} - 9.4×10^{-7}	**0.22**	0.23 - 0.27	**7.9×10^{-64}**	0.154-0.181

Table 2. Number of bighead and silver carp tagged with acoustic transmitters per pool or backwater of the Illinois River in 2012 and 2013.

2012	Bighead carp	Silver carp	Total
Pool 26	19	129	148
Dresden	8	5	13
Marseilles	33	1	34
Starved Rock	56	103	159
Total	116	238	354

2013	Bighead carp	Silver carp	Total
Rock Run Rookery	10		10
Dresden	26	2	28
Marseilles	2	54	56
HMSC Pits	19	19	38
Starved Rock	8	46	54
Peoria	6	45	51
La Grange	21	33	54
Alton	13	33	46
Total	105	232	337

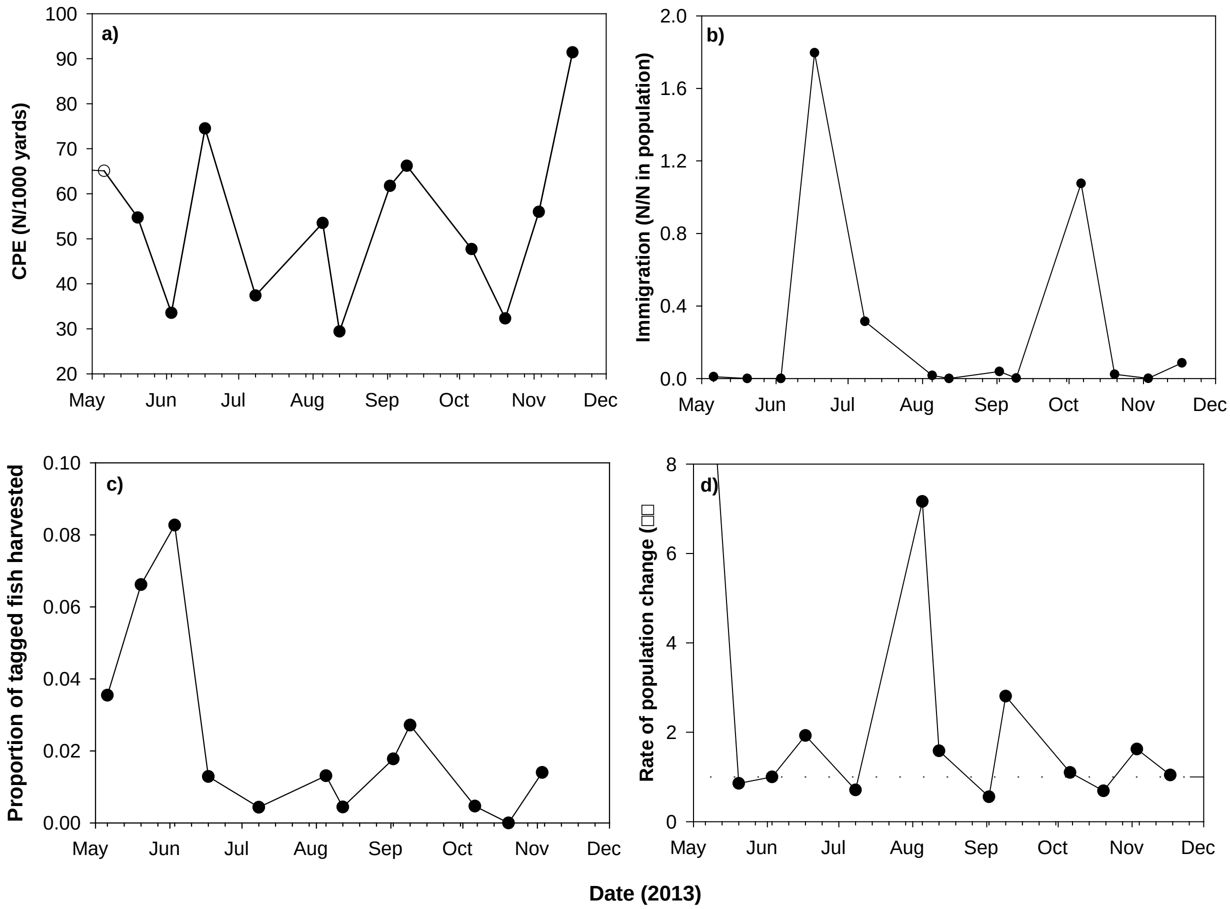

Figure 2. a) Catch per effort (CPE) of Asian carp from IDNR-contracted commercial fishermen in 2013 for the time-period fish were tagged, b) immigration (number of fish entering per fish in the HMSC pits) estimated by Link-Barker mark-recapture model for 2013 data only, c) proportion of tagged Asian carp recaptured correcting for those previously removed (only for fish tagged in 2013), and d) rate of population change with values near one indicating no population change.

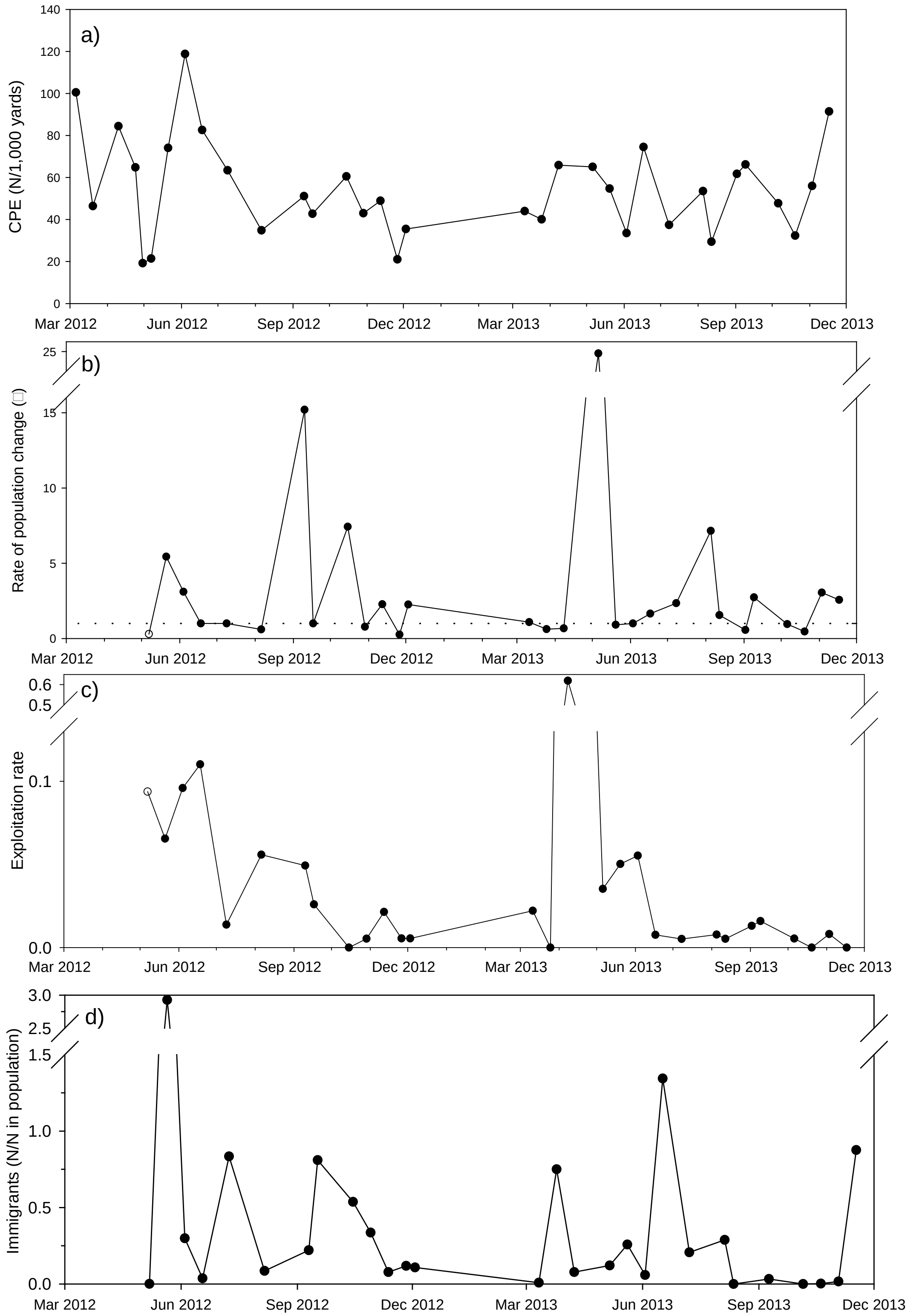

Figure 3. a) Catch per effort (CPE) of Asian carp from IDNR-contracted commercial fishermen, b) estimated weekly rates of population change with values near one indicating no population change, c) exploitation rate as a function of time, and immigration (N/N in population) for the HMSC pits in 2012 and 2013 (82-week model with all available data).

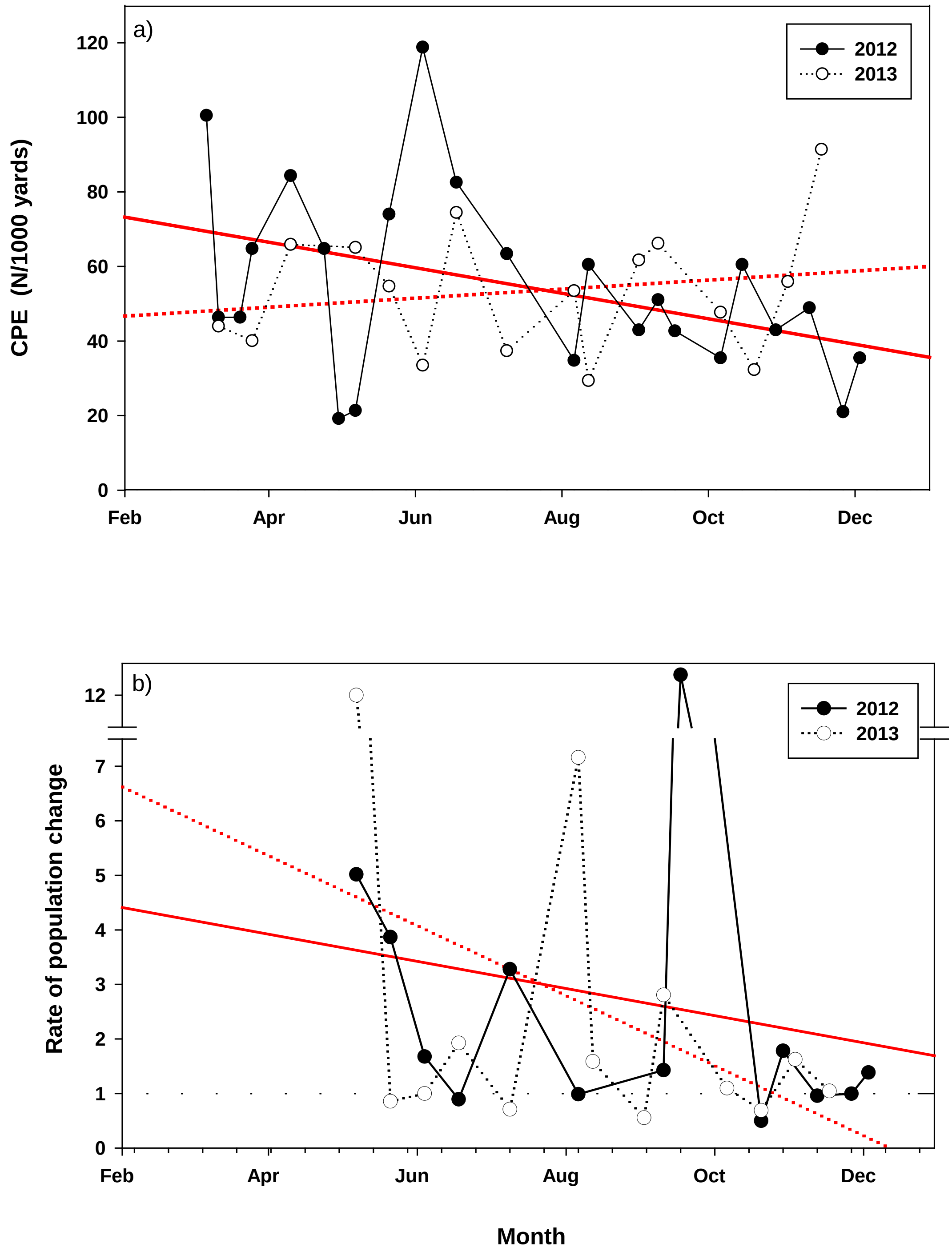

Figure 3. A comparison of a) CPE (number of fish per 1000 yards of gill net) and b) the rate of population change (values below one represent a declining population), between 2012 and 2013. Solid lines show the linear regression for 2012 and dashed lines represent the linear regression for 2013.

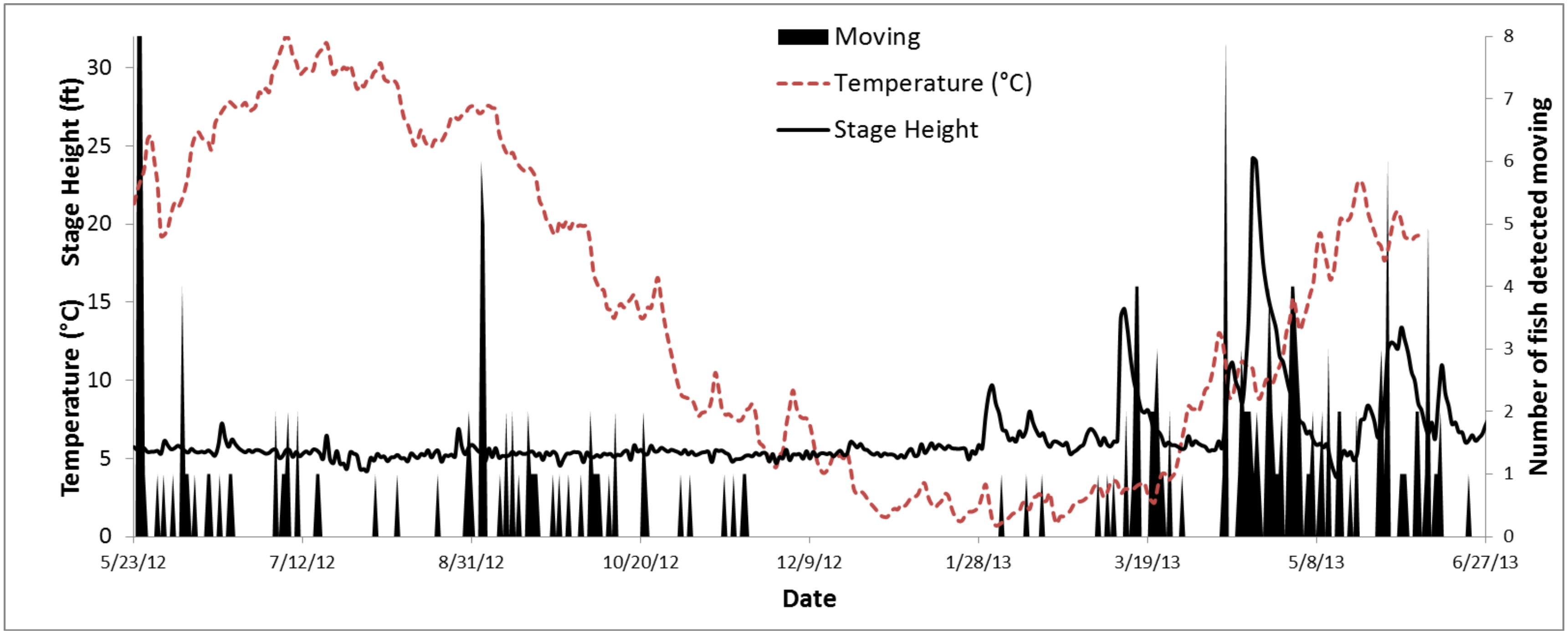

Figure 4. Asian carp movement, into or out of the HMSC backwater, as a function of water temperature (°C) and river stage height. The most movement is observed in the spring and early fall.

Chapter 3:

Asian Carp Movement in the Illinois River

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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 was 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, 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 potential 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.

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 north and south river reaches, we will determine whether this is true. The alternate is that all fish in the north are transient "visitors" to the north 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 if movement is density dependent.

Methods:

Acoustic transmitters—tagging

In 2012, 372 Asian carp were tagged with Vemco® acoustic transmitters (v16, v13, v9, or v6 transmitting at 69 KHz) in the Marseilles, Starved Rock, and Dresden Pools of the Illinois River and in Pool 26 of the Mississippi River (124 bighead carp, 243 silver carp, and nine hybrid Asian carp). In early summer and late fall, when water temperatures were optimal for fish recovery, acoustic transmitters were implanted into Asian carp (77 in early summer and 296 in late fall). One hundred and sixty-four fish were tagged in the Starved Rock pool near Sheehan Island, 41 were tagged within the east pit of Hanson’s Material Services Corp. near Morris, IL, 13 were tagged in the Dresden pool near the confluence with the Kankakee River, and 155 were tagged in Pool 26 of the Mississippi near Alton, IL (see Table 1 for breakdown by species).

In 2013, an additional 337 Asian carp were tagged with acoustic transmitters in the Illinois River (Table 1). A total of thirty-eight fish were tagged in the Dresden Island pool, with10 fish being released in Rock Run Rookery, a backwater lake in the Dresden pool, and 28 fish released near the confluence with the Kankakee River. In the Marseilles pool, 96 fish were tagged with transmitters; 56 were released in the main channel at the Morris boat ramp and 38 were released in the Hanson Material Service Corporation (HMSC) pits (21 in the west pit, 17 in the east pit). In the Starved Rock pool, 54 fish were tagged and released at the Starved Rock Marina. To determine the amount of movement between pools in the lower Illinois River and Upper Illinois River, additional fish were tagged in the Peoria (N = 51 fish near Lacon, IL), La Grange (N = 54 fish near Havana, IL) and the Alton pools (N = 46 fish near Hardin, IL). For a breakdown by species, refer to Table 1.

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 36 Vemco® VR2W receivers have been deployed in the Illinois River to monitor movement of acoustically tagged Asian carp (Alton = 7, Swan Lake = 1, LaGrange = 7, Peoria = 6, Starved Rock = 7, and Marseilles = 3; Figure 1). One receiver has also been placed in each lock chamber (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 (receivers maintained by the USACE) and Marseilles (only downstream). 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 Hanson Material Service Corporation gravel pits to better understand the factors affecting Asian carp immigration and emigration within that area. Finally, active tracking by boat using a Vemco® VR100 receiver was conducted in the Sheehan Island area of the Starved Rock Pool on 21 November and 6 December 2012 and in the Marseilles reach and HMSC pits on 24 May 2013.

Discharge and temperature

To relate fish movement to changes in river discharge, we needed to create discharge-gage height (or state height) relationships for each reach of the river. Discharge (Q; $m^{-1}s^{-1}$) measurements were collected using an Acoustic Doppler Current Profiler (ADCP) in the Starved Rock reach, Alton reach, and at the confluence of the Mississippi and Illinois Rivers in 2012 and 2013. Measurements were taken near Buffalo Rock (Starved Rock reach; ~RM 234) on 8 May, 17 July, 12 August, 23 October, 21 November, and 6 December in 2012 and 15 January, 13 February, 10 April, and 8 May in 2013. Discharge measurements were taken at the confluence and on the IL River at Grafton, IL on 12 July, 23 August, 26 October, 20 November, and 6 December in 2012 and the 18 January, 20 February, and 5 April 2013. Second order polynomial relationships were fit to discharge and river gage height or river stage height (depending on available data from USGS gaging stations) for these areas (Figure 2 and Figure 3). These relationships will be used to determine how change in discharge is related to fish movement. Additional ADCP measurements will be taken in the Marseilles and Peoria pools in 2014.

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.

Results and Discussion:

General movement

Over 1.4 million positive (known transmitter) detections have been recorded on passive VR2W receivers from May 2012 to December 2013 on VR2W receivers located along the Illinois River (from Grafton, IL to Dresden Island Lock and Dam). From these detections, 273 individual Asian carp have been identified (including fish tagged by USACE and SIU fish tagged in 2010 with active transmitters). The redetection rate of fish tagged in 2012 was 31.2% and 27.0% in 2013 (Table 1).

Of the 348 Asian carp that were tagged in the Mississippi River by SIU in October/November 2010 (with active transmitters during this study), 47 were redetected in the Illinois River (Table 2). Five of those fish immigrated into Swan Lake, a backwater of the Alton reach located between RM 5 and RM 13. Including the fish that moved into Swan Lake, the immigration rate from the Mississippi River to the Illinois River over ~2.5 years was 13.5%. 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 relocated in Swan Lake, the 1-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.

Passage through locks and dams and between reaches

Fish detections in lock and dams increased in 2013, in part due to the additional receivers in the lock chambers. Eighty-one fish were detected in lock chambers. Two bighead carp and one silver carp were detected in the lock chamber of the Marseilles Lock and Dam. The two bighead carp (originally tagged by the USACE in the HMSC pits in October 2012) passed successfully downstream (one back upstream, then downstream again). Both were last detected moving further downstream through Starved Rock Lock and Dam into the Peoria pool in September 2013. The silver carp, which was initially tagged in the Sheehan Island backwater in the Starved Rock pool, did not successfully pass upstream through the Marseilles Lock and Dam and returned back downstream to the Sheehan Island backwater in the Starved Rock reach.

In addition to the two bighead carp that passed downstream through the Starved Rock Lock and Dam, seven additional fish attempted to pass downstream. One bighead carp successfully passed and continued to move downstream, while the other six moved back and forth near the receiver before turning back upstream to the Sheehan Island backwater area. No fish were detected moving upstream through the Starved Rock Lock chamber in 2013, although one fish (from Pool 26) was detected in the Starved Rock pool.

In the Dresden Island lock chamber, seven fish were detected, all during the months of May and June. One fish, originally tagged in the Dresden pool, successfully passed downstream (multiple attempts; 10-12 May 2013). Another moved from the HMSC pits into the lock chamber and back to the HMSC pits (25-26 June). The other five fish only show detections in the lock chamber. We do not have receivers upstream of Dresden Island Lock and Dam and therefore rely on the USACE for any detection above that area. These five fish were not detected again downstream of the dam, they likely passed upstream.

Fish tagged in the Starved Rock and Marseilles pools showed extremely high site fidelity, with 50% of all fish tagged in the Starved Rock pool relocating within that pool and 78.8% of redetected fish staying in that pool (Table 3). In 2012, nearly 20% (thirty-six individual fish) of the fish tagged in the Sheehan Island backwater were relocated there up to seven months post-tagging, suggesting that Starved Rock may act as a staging area (waiting area for fish until conditions become favorable for moving, either to spawn or migrate) for Asian carp and/or a natural barrier to upstream movement. The receiver in Sheehan Island has been sent to Vemco for repairs, but we suspect the number of fish redetected in that backwater is still high. Fish tagged in the HMSC pits in the Marseilles reach in 2012 also showed high site fidelity. Of fish tagged and subsequently redetected, 72.5% stayed within the Marseilles pool, 10% moved upstream, and 17.5% moved downstream (Table 3).

Spawning movements

Spawning aggregations were observed for the first time in the Marseilles reach in 2013 (22 May). Fish detections and movement in the HMSC 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 HMSC pits, we were able to tell when fish moved out of the pits, into the pits, or stayed in the connecting channel (staging). Staging fish were fish that stayed within detection range of the receiver in the connecting channel for an extended period of time without moving into or out of the pits. Fish that were "moving" were detected on both the receiver in the connecting channel and the receiver at the mouth of the pits (Figure 4). Staging fish were most abundant from the 1 May – 8 May, at which time fish began to move (Figure 5). 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). No movement and minimal staging was detected on the 9-10 May, 21 May, 28 May, or 3 June 2013. Each period of no fish detections (number of fish moving or staging is zero) is a likely spawning event when all fish were in the main channel. Each of these periods corresponded to elevated river discharge and river temperatures above 18°C, and a significant, albeit weak, positive correlation between the number of fish staging and the stage height of the Marseilles reach ($R = 0.16$; $P = 0.001$), suggesting that each rise in river stage height (elevated discharge) triggered a spawning event during this period. Although spawning aggregations were only observed during the 22 May, there were likely three additional spawning movements in the spring.

Movement, river discharge, and temperature

Many fish species exhibit movement related to river discharge (Taylor and Cooke 2012), and carp do not appear to be an exception. Sharp rises in river stage and current velocity have been shown to trigger movement in Asian carp in China (Wang et al. 2013). For the Illinois River, the number of unique fish moving upstream and downstream was calculated per day and a three day moving average was taken (Figure 6). Overall, the most movement (upstream or downstream) occurred from April to mid-July and in November. The greatest upstream movement occurred during the end of April, and the greatest downstream movement occurred during the end of May and beginning of November. Fish were possibly cuing on increased river discharge in the spring for movement. Additional analyses are being conducted to determine reach specific cues for movement.

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. No Asian carp were detected near the CAWS, so no fine scale movement monitoring was necessary. Additional active tracking should be conducted to locate fish tagged in the Dresden Island pool and in the Rock Run Rookery. Additional "proxy" fish should also be tagged in the upper reaches (above Dresden Island) to determine how Asian carp may respond to environmental cues in that area.

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. However, if the current immigration rate were to continue, there would still be a constant influx of fish from downstream reaches. An increase in downstream harvest may be necessary to ultimately decrease the propagule pressure at the CAWS.

River discharge, river gage height, and temperature in the Illinois River were related to movement patterns of Asian carp. Movement in 2013 appeared to be greater than in 2012, likely due to the increased river discharge in 2013. 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 yet able to relate carp movement to biomass of fish in the river due to the long processing time of our hydroacoustics data, we will continue to monitor Asian carp movement though the Illinois River in 2013 and make such comparisons as soon as data become available. 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 2013, an additional 337 Asian carp were tagged with acoustic transmitters in the Illinois River (Rock Run Rookery = 10, Dresden Island = 28, Marseilles = 93, Starved Rock = 54, Peoria = 51, La Grange = 54, Alton = 46).
- Of the 348 Asian carp that were tagged in the Mississippi River by SIU in October/November 2010, 47 were redetected in the Illinois River. The immigration rate from the Mississippi River to the Illinois River over ~2.5 years was 13.5%.
- Over 1.4 million positive (known transmitter) detections have been recorded on passive VR2W receivers from May 2012 to December 2013 on receivers located along the Illinois River. From these detections, 273 individual Asian carp have been identified. The redetection rate of fish tagged in 2012 was 31.2% and 27.0% in 2013
- Fish were detected in all lock chambers in 2013. No successful upstream movement was detected through the Marseilles Lock and Dam, although attempts were made. Two fish did successfully pass downstream. This is the first record of fish moving through the Marseilles Lock and Dam.

- In the Dresden Island lock chamber, seven fish were detected, all during the months of May and June. One was confirmed passing downstream and five potentially moved upstream (awaiting USACE detection data).
- Spawning was observed for the first time in the Marseilles reach on 22 May 2013. A significant, positive correlation between the number of fish staging in the HMSC pits and the stage height of the Marseilles reach was found, suggesting that elevated discharge and temperatures above 18°C triggered multiple spawning events in May 2013.
- River-wide, the most movement (upstream or downstream) occurred from April to mid-July and in November. The greatest upstream movement occurred during the end of April, and the greatest downstream movement occurred during the end of May and beginning of November.

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Table 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 2. The number of fish tagged in the Mississippi River by SIU in October and November 2010 (with active transmitters during 2012-2013) that were redetected in the Illinois River. Numbers show the furthest upstream reach in which fish were last detected.

		To Illinois River Reach				
		Alton	Swan Lake (Alton BW)	La Grange	Peoria	Starved Rock
From Mississippi River Pool: (tagged 2010)	22	1		1	1	
	26	8	5	18	11	1
	27	1				

Table 3. The probability of a detected fish being tagged in a pool (left column), and moving to another pool (top row). Only the furthest pool from the tagging location was counted (e.g., although a fish tagged in Marseilles had to move through the Starved Rock pool to reach Peoria, Starved Rock is not the final destination, so that fish would not be included in the Starved Rock count), so all probabilities will sum to one (within rounding error) per tagged pool.

		Movement to:					
		Alton	La Grange	Peoria	Starved Rock	Marseilles	Dresden Is.
Movement from:	Pool 26	0.57	0.21	0.21			
	Starved Rock		0.03	0.15	0.79	0.03	
	Marseilles			0.05	0.13	0.73	0.10
	Dresden Is.					0.40	0.60

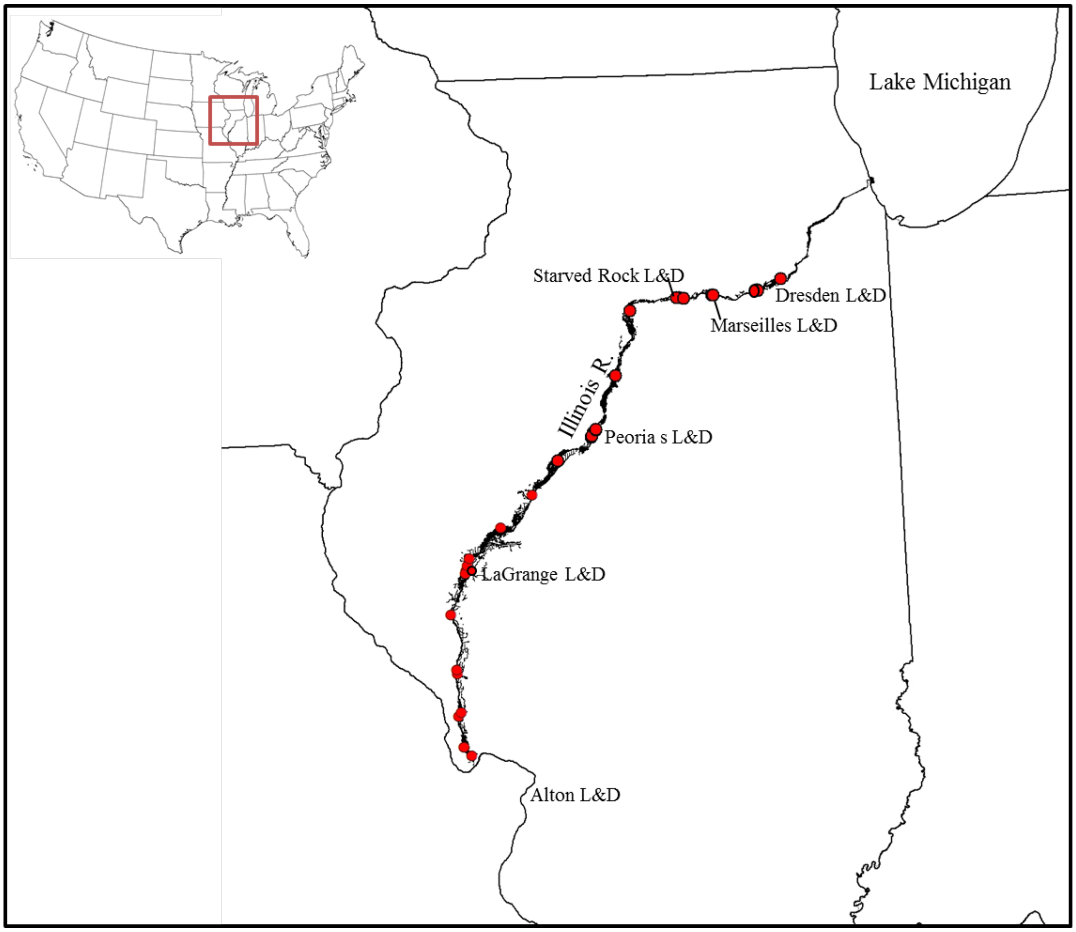

Figure 1. Locations of all active VR2W receivers along the Illinois River.

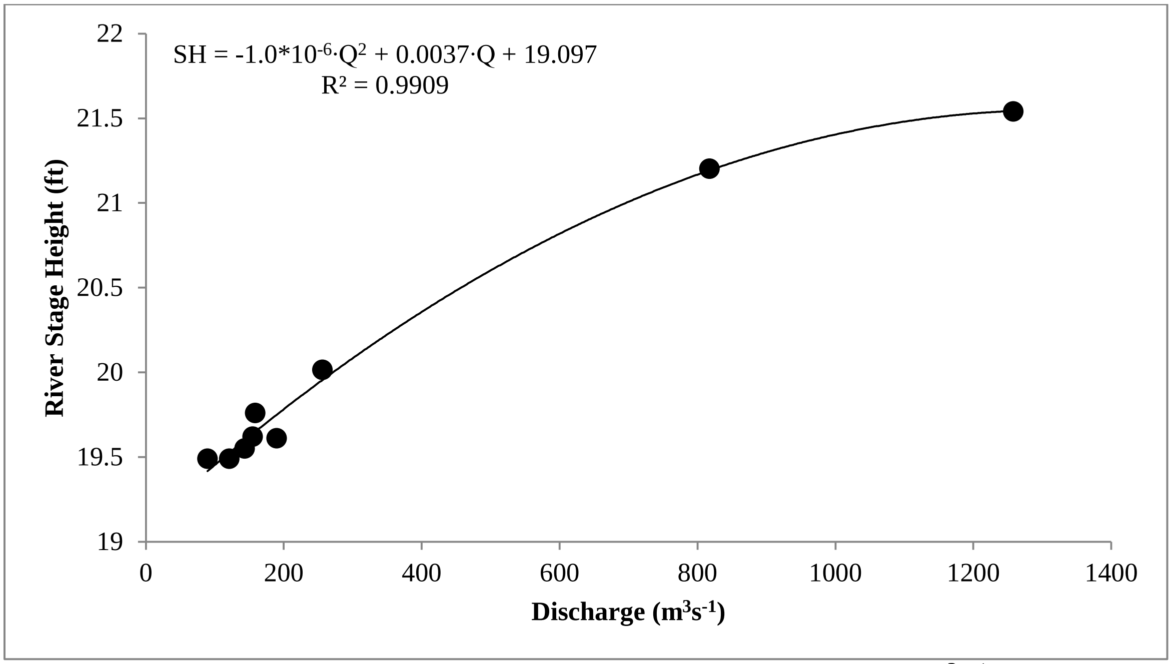

Figure 2. Second order polynomial relationship between discharge (Q; m^3s^{-1}) and Illinois River stage height (SH; ft.) for Hardin, IL (Alton reach) developed using Acoustic Current Doppler Profiler to measure discharge every approximately two months from spring 2012 – spring 2013 in Alton, IL. River gage height measurements were obtained from the USGS gaging station in Hardin, IL.

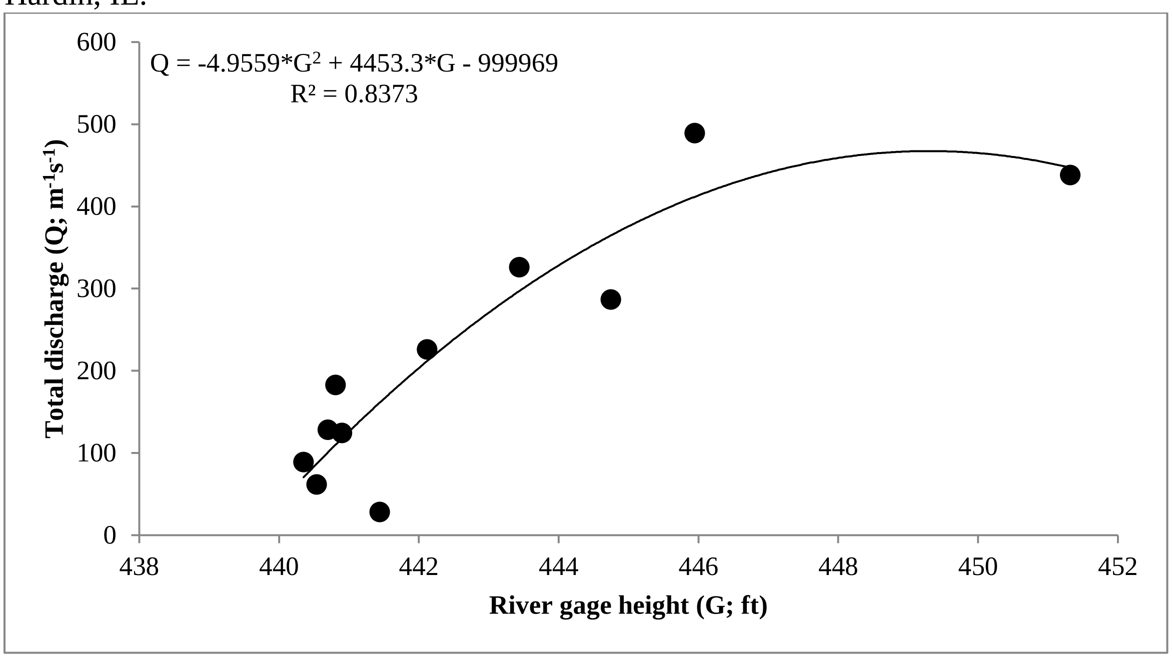

Figure 3. Second order polynomial relationship between river gage height (G; ft.) and total discharge (Q; $m^{-1}s^{-1}$) for the Starved Rock reach of the Illinois River. Discharge was measured downstream of Sheehan Island.

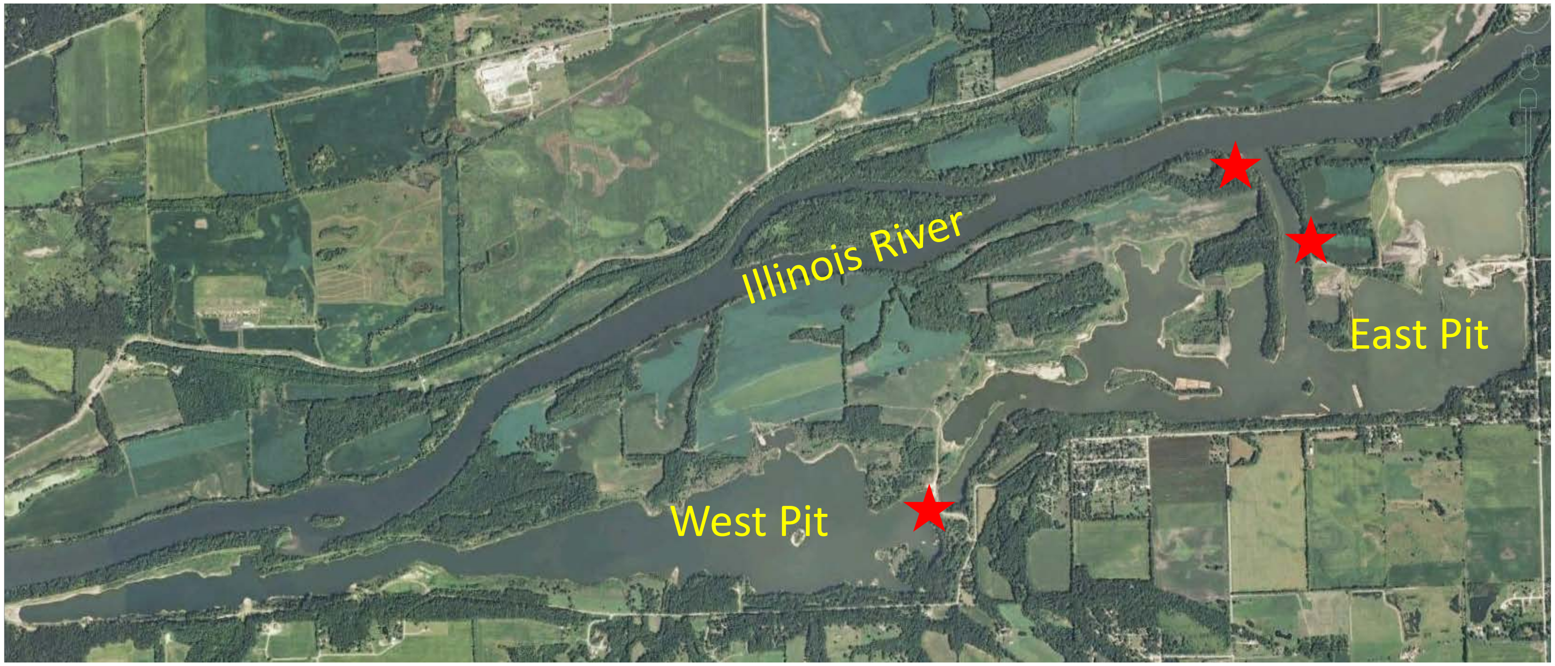

Figure 4. Map of Hanson Material Services Corporation (HMSC) backwater near Morris, IL indicating locations of VR2 receivers to quantify movement in/out of this backwater and between the west and east pits.

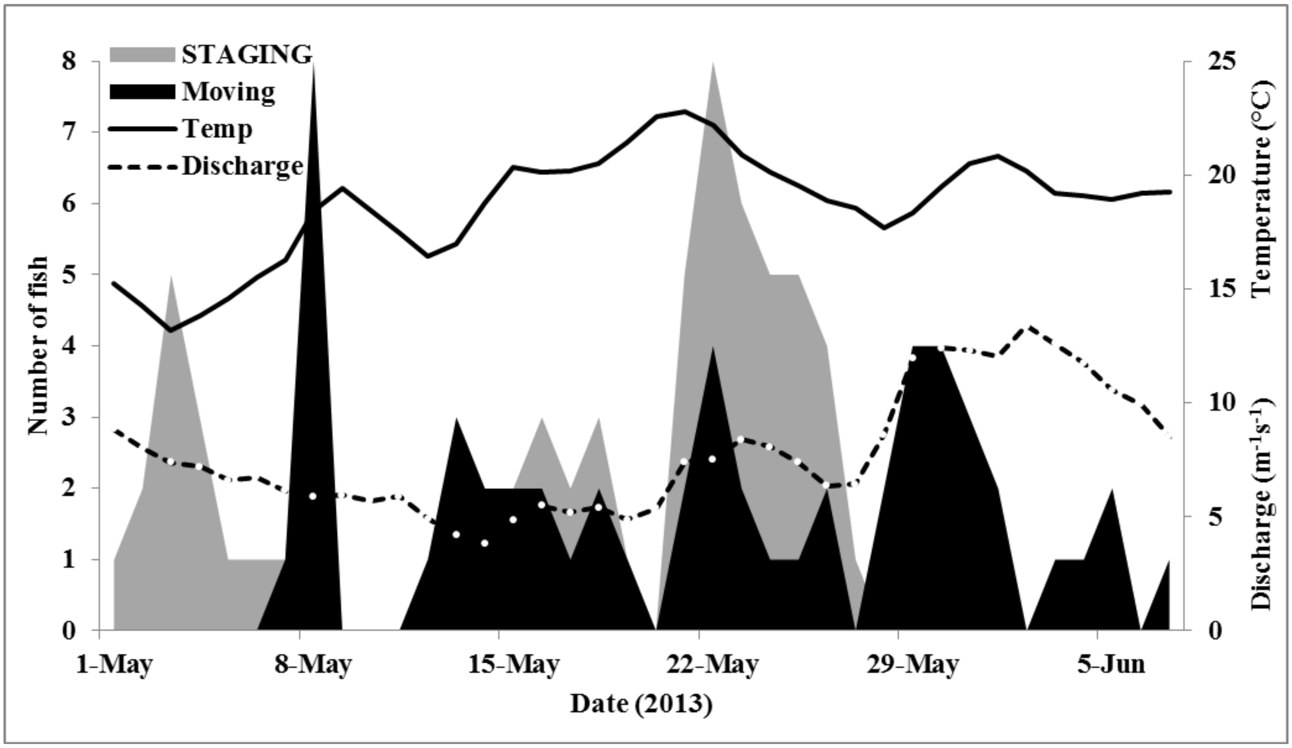

Figure 5. The number of fish detected staging in (grey) and moving to or from (black) the HMSC pits, along with corresponding river discharge and temperature over May 2013. Each period of no fish detections (number of fish moving or staging is zero) is a likely spawning event when all fish were in the main channel. Spawning was observed in the reach on 22 May.

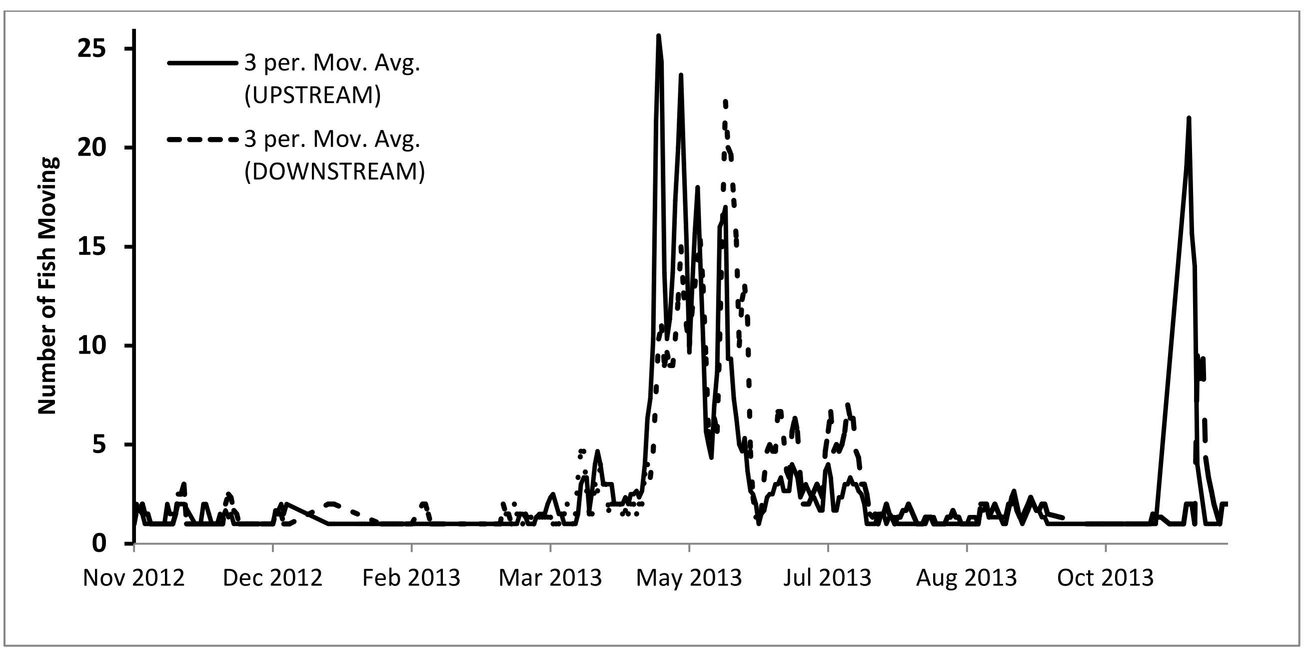

Figure 6. Three period moving averages of upstream (solid line) and downstream (dashed line) Asian carp movement by date for the entire Illinois River for all fish redetected in 2012 and 2013.

Chapter 4:

Hydroacoustic estimate of Asian carp abundance, size distribution, and biomass in the Illinois River

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Participating Agencies: Southern Illinois University at Carbondale (lead)

Introduction: Hydroacoustic estimates of Asian carp abundance and biomass within the main channel of the three lower reaches of the Illinois River (i.e., Alton, La Grange, and Peoria) were 743,435 and 1,413 metric tons, respectively, determined from surveys conducted by Southern Illinois University at Carbondale (SIUC) in 2010-2011. Although comparisons to previous mark-recapture estimates of silver carp abundance in the La Grange reach (i.e., Sass et al. 2010) suggested that these acoustic estimates were reasonable for the main channel of the Illinois River, there are several reasons to suggest that the acoustic estimates were conservative. Specifically, the down-looking hydroacoustic techniques used in the 2010-2011 surveys did not allow surface waters (i.e., upper 1.28 m of the water column) to be sampled, where Asian carp are often observed, particularly surface feeding bighead carp (Kolar et al. 2007). In addition, the extent to which evasion of Asian carp from the acoustic beam affected these estimates is unknown. These surveys did not incorporate backwater lakes, side channels, and tributaries where high densities of Asian carp occur (Kolar et al. 2007) and therefore may have missed a major proportion of the Asian carp population for determining absolute abundance. Lastly, despite the intensive sampling directed toward these surveys, only a small proportion of the water column was actually surveyed (i.e., 0.39%), albeit due to the stratified sampling design that focused on the shallower main channel borders where Asian carp are typically found (Kolar et al. 2007) opposed to directly over the thalweg.

There is a need to address the limitations of the 2010-2011 surveys to provide more accurate estimates of abundance, biomass, and size distribution of Asian carp for incorporation into predictive models that will facilitate decision making in terms of appropriate control strategies. Moreover, there is a need to evaluate whether increased harvest of Asian carp is having an impact on Asian carp demographics in the lower reaches, as well as the reaches extending up to the purported population front, which has remained at the Dresden reach for several years. This information is essential for evaluating the efficacy of commercial harvest downstream and the Illinois Department of Natural Resources (IDNR) harvest efforts in the upper reaches of the Illinois River on decreasing the probability of Asian carp progression upstream toward the Great Lakes. Many of these shortcomings, if not all, can be addressed through new sampling techniques and protocols implemented in 2012 and 2013.

Objectives: SIUC will conduct annual hydroacoustic surveys to:

1) Estimate the reach-specific abundance, biomass, and size distribution of bighead carp and silver carp in the fall 2012 (using down-looking and side-looking hydroacoustics), and in the fall of 2013 (using down-looking and side-looking hydroacoustics, and side-scan sonar). All surveys undertaken from the confluence of the Illinois River and Mississippi River 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) Compare estimates of reach-specific abundance, biomass, and size distribution of bighead carp and silver carp between down-looking hydroacoustics, side-looking acoustics and side-scan sonar techniques, to quantify the Asian carp potentially missed near the surface and through potential evasion using down-looking hydroacoustic techniques only;
4) Create correction factors to increase the accuracy of estimates from previous hydroacoustic surveys in 2010-2011 that incorporated only down-looking techniques;
5) Determine whether abundance, biomass, and size distribution of bighead carp and silver carp have changed in response to increased harvest.

Methods and Materials:

General overview

In the fall of 2012, hydroacoustic surveys (i.e., side-looking and down-looking) and standardized sampling (i.e., pulsed-DC electrofishing and trammel netting) were used to estimate the abundance, size distribution, and biomass of Asian carp 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. In general, hydroacoustic sampling was conducted to estimate the total number and size distribution of all fishes within each reach. Data from standardized sampling will then be used to determine length-specific proportional abundance of Asian carp to other fishes to distribute acoustic-derived abundance among species as a function of size. Reach-specific length-weight regressions will then be determined for each group of fishes to estimate total biomass as a function of total length. Total abundance and biomass of Asian carp and other fishes will then be extrapolated to the total interpolated volume based on the proportion of water volume sampled. This approach will also be adopted for hydroacoustic surveys conducted in the fall of 2013. Additionally, side-scan sonar was used in conjunction with the hydroacoustic surveys on all main channel and associated side channels, backwater lakes, tributaries, and harbors surveyed in 2013.

Hydroacoustic sampling

In both years (2012 and 2013), the entire main channel was surveyed with hydroacoustics in the Dresden, Marseilles, and Starved Rock reaches due to their relatively smaller size and lower densities of Asian carp relative to the three downstream reaches. Backwater lakes, side channels, tributaries, and harbors were surveyed, as time and accessibility permitted. Specifically, we typically attempted to survey a 10-river mile (RM) stretch of the main channel and associated habitats within one day. Lack of accessible associated habitats allowed for increased survey distances along the main channel, but also slowed main channel survey progress when large backwaters were accessible. Within the Peoria, La Grange, and Alton reaches of the Illinois River, we used a stratified sampling design. We chose seven 4-RM stretches along the main channel of each reach that, in general, provided equidistant spacing among surveyed areas and were also near standardized sampling locations. We typically attempted to survey two 4-RM stretches of the main channel and associated habitats within one day. While not all associated backwaters, side channels, and tributaries could be sampled within a timely fashion, we attempted to sample at least one of these provided that accessibility was not an issue.

In 2012, down-looking hydroacoustic surveys conducted on the main channel were similar to our 2010-2011 methodology and were conducted simultaneously with side-looking techniques using BioSonics, Inc. hydroacoustic equipment. We used a stratified random sampling design to compensate for the spatial distribution of Asian carp. Nearshore transects on either side of the channel were conducted parallel to the shoreline approximately following the 1.5-m depth contour using a down-looking 200 kHz split-beam transducer mounted on the port side of the research vessel. Two side-looking 70 kHz split-beam transducers, located on the starboard side, were used simultaneously: one 70 kHz transducer was set to maintain an angle perpendicular to the surface that extended 7 degrees downward, and the second transducer was offset downward such that a total of 14 degrees of the water column was sampled (Figure 1). Both transducers were mounted on dual axis rotators that readjusted the pan and/or tilt every 45 seconds if necessary. Unless obstructions were struck with the transducers, adjustments were typically not necessary as the braking system of the rotators provided sufficient resistance to suppress movement. Subsequent transects were conducted at distances progressively closer to the middle of the channel. Specifically, the second set of transects were conducted parallel to the first two transects ~3 m closer to the middle of the channel, again using the port-side down-looking 200 kHz transducer in combination with the side-looking 70 kHz transducers. The last transect was conducted at ~5-m distance from the second set of transects, but incorporated the use of the 200 kHz transducers on both the port and starboard side, which were mounted approximately 3.7 m apart. Altogether, the data consisted of eight spatially separated down-looking transects that will be used for channel bathymetry and estimation of Asian carp density using down-looking techniques, and four transects that will be used to estimate density of surface-oriented Asian carp. It should be noted that the majority of side-looking transect were conducted with two 70 kHz transducers, but damage to one of the 70 kHz transducers required the use of a combination of one 70 kHz transducer and one 200 kHz transducer.

In 2013, the hydroacoustic array was reversed to optimize target detection in the side-looking orientation; surveys were conducted using the down-looking 70 kHz transducer mounted on the port side of the research vessel and two side-looking 200 kHz transducers located on the starboard side. The latter were controlled using the dual axis rotators and orientated to cumulatively sample 14 degrees of the water column, as in 2012. Nearshore transects on either side of the channel were conducted parallel to the shoreline approximately following the 1.5-m depth contour. Subsequent transects were conducted closer to the middle of the channel, at a distance which reduced overlap of the side-looking acoustic beams and provided complete coverage of the surface. Survey transects for a 4-RM stretch of the Illinois River (i.e., Alton main channel, RM 68.5-72.5) are shown in Figure 2 a using 2012 protocols and in Figure 2 b using 2013 protocols.

In 2013, a 1200 kHz Marine Sonics HDS side-scan sonar, which was previously used during remote sensing within the electric dispersal barrier, was used during all hydroacoustic surveys. The sonar (40° beam angle in either direction with a 10° offset from 90°) was deployed at 1-m depth at the stern of the research vessel to provide additional coverage and to help determine Asian carp avoidance behavior.

Although hydroacoustic surveys from 2010-2011 were conducted by traveling downstream with the current at approximately 9.5 km/hr to limit the amount of Asian carp evasion as it relates to outboard motor noise, this was not possible during the 2012 or 2013 surveys. Specifically, the dual axis rotators and transducers are too heavy to lift manually and require the use of a davit that is mounted on the starboard side. Therefore, we were only able conduct side-looking surveys with the port side of the research vessel towards the shore, whether transecting upstream or downstream. Although we were able maintain similar speeds in 2012 travelling downstream in comparison to the 2010-2011 survey, it was necessary to conduct the upstream transects at a slightly slower speed because the increased resistance from flow would cause air pockets to form at the transducer face, blocking the acoustic signal. Rather, we maintained a similar RPM in both the upstream and downstream transects, which was approximately 1500 RPMs.

Hydroacoustic surveys conducted in side channels and tributaries followed similar methodology as described above for the main channel for 2012 and 2013 respectively. To survey backwater lakes and harbors, our first transect followed the 1 to 1.5-m contour (depending on maximum depth) adjacent to the shoreline, or as much of the shoreline that was accessible, using the port-side down-looking transducer (i.e., 200 kHz in 2012 and 70 kHz in 2013) and two side-looking transducers (i.e., 70 kHz in 2012 and 200 kHz in 2013). Each subsequent transect was conducted far enough away to reduce overlap of the side-looking acoustic beams and to provide complete coverage of the surface or as much that was accessible. In 2012, additional transects were conducted using both down-looking 200 kHz transducers (port and starboard mounted) to fill in any spatial gaps. This was primarily to provide bathymetric information for volumetric estimates, particularly when depth was not uniform.

Hydroacoustic data in both years were collected using Visual Acquisition 6 from 1.28 to 15-m depth for down-looking transducers and from 1 to 50-m distance for side-looking aspects, both of which were set at a ping rate of 5 pings per second and a 0.40-ms pulse duration. Pings were multiplexed, or offset in time, between transducers of a similar frequency to eliminate cross-talk. Temperature was recorded and input into Visual Acquisition 6 prior to data collection to compensate for the effect of water temperature on two-way transmission loss via its effect on the speed of sound in water and absorption coefficients. Each split-beam acoustic transducer was calibrated on-axis with a tungsten carbide sphere specific to the frequency of the transducer throughout the duration of sampling following Foote et al. (1987). In 2013, side-scan sonar data was collected from 0 to 30-m to the port and starboard side using Sea Scan Survey V2.3.

Data Analysis:

Total fish abundance and size distribution

All hydroacoustic data will be analyzed using EchoView 5.4 (Myriax Software Pty Ltd). Estimates of density, abundance, biomass, and size distribution of Asian carp will be similar to the methodology used for our 2010-2011 survey. Briefly, fish targets will be identified using the split-beam single target detection algorithm (method 2) and the volume of water column ensonified (or sampled) will be determined to estimate transect-specific density. Stratified analyses will be used to estimate total fish density (Scheatter et al. 1996; Parker-Stetter et al. 2009). The bathymetry of the surveyed area from down-looking transducers will then be used to determine total volume of each survey area in ArcMap 10.0 so that density estimates can be extrapolated to total fish abundance. The size of each fish target will be estimated using the relationship between aspect-specific (side or dorsal) and frequency-specific (70 or 200 kHz) target strength and total length currently being developed in this study and in collaboration with the US Fish and Wildlife Service and Illinois Natural History Survey. The length-frequency distribution of acoustic-detected fish will be used to inform the length-frequency distribution of the extrapolated abundance within each reach. Specifically, the proportion of fish within each 1-mm interval will be determined for each reach and multiplied by total estimated abundance. Side-scan sonar data will be analyzed using Sea Scan Survey V3.4.0.

Species-specific abundance, size distribution, and biomass

Data collected from standardized sampling conducted in each reach during summer 2012 and summer 2013 will be used to inform acoustic estimates to determine species-specific abundance, length distribution, and biomass (specific methods concerning standardized sampling can be found in Chapter 3). Length-frequency distributions will be determined for silver carp, bighead carp, and other fishes at 20-mm TL increments. The proportion of silver carp, bighead carp, and other fishes will then be determined for each 20-mm length group; these proportions will be linearly interpolated for each 1-mm TL. The length-specific proportion of fish groups will be applied to the acoustic-derived length-frequency distribution to estimate the length-specific total number of silver carp, bighead carp, and other fishes. Reach-specific length-weight regressions will be determined for each fish group based on standardized sampling. Length-specific biomass of each fish category will be estimated by 1-mm TL increments by multiplying mass determined from length-weight regressions by total estimated species-specific abundance. Finally, species-specific total biomass will be determined by summing length-specific biomass.

Asian carp evasion and correction factors

Estimates of Asian carp density and size distribution will be compared between down-looking and side-looking hydroacoustic methods using a paired t-test design for each specific habitat type. If differences are found between these methods, we will determine whether habitat-specific correction factors can be used to increase or decrease estimates from down-looking only surveys. Specifically, we will use a portion of the data that were collected with both side-looking and down-looking methods to construct a correction factor and use remaining data that also incorporated both methods to determine the appropriateness of these correction factors. Side-scan sonar data from 2013 will be used to help quantify Asian carp evasion and determine the appropriateness of correction factors.

Given that the 2012 and 2013 surveys were conducted traveling both upstream and downstream, we will test whether the direction of travel affects the discrepancy between down-looking and side-looking estimates due to Asian carp evasion. Caution will be used when testing differences between these methods for main channel to ensure that estimates from the methodologies are not biased by differences in channel morphology such as a greater amount of outside bends surveyed while traveling in one direction.

Evaluating temporal changes in abundance, size distribution, and biomass

We will compare acoustic estimates of abundance, size distribution, and biomass between all survey years (2010-2011, 2012 and 2013). If a correction factor is deemed appropriate, we will test whether main channel estimates have changed using corrected data from 2010-2011 surveys that incorporated only down-looking acoustic methods. If a correction factor is not appropriate, we will use down-looking derived estimates only for these comparisons. Given that the entire main channel habitat was sampled during the 2010-2011 surveys, it will be necessary to extract data specific to the areas sampled during the 2012 and 2013 surveys.

Results and Discussion:

During 2012, hydroacoustic surveys were conducted across a total distance of 2,306 nmi along the Illinois and Des Plaines rivers from the confluence with the Mississippi River to Brandon Road Lock and Dam, when accounting for the multiple acoustic transducers simultaneously being operated (Table 1). Across each habitat type surveyed, SIUC sampled 1,910 nmi along the main channel (82.9%), 120 nmi of backwater lakes (5.2%), 119 nmi of contiguous lakes (5.1%), 113 nmi of side channels (4.9%), 34 nmi of tributaries (1.5%), and 9 nmi of harbors (0.4%). Many of the backwater lakes that we attempted to sample were inaccessible due to shallow depths; those that were accessible could not be sampled completely for similar reasons (Table 1). During 2013, the hydroacoustic surveys were conducted in the same locations along the Illinois and Des Plaines rivers (Table 2), with the exception of Brandon Road Lock and Dam Release (Dresden reach), and Buckhorn and McEvers Islands (Alton reach), due to accessibility issues. A total distance of 2029 nmi of hydroacoustic surveys were conducted in 2013, slightly lower than in 2012 due to the use of fewer transducers and transects. Across each habitat type, 1612.5 nmi of the main channel (79.5%), 145.8 nmi of backwater lakes (7.2%), 135.5 nmi of contiguous lakes (6.7%), 90.4 nmi of side channels (4.4%), 37.6 nmi of tributaries (1.8%), and 7.3 nmi of harbors (0.4%) were surveyed. As in 2012, many of the backwater lakes that we attempted to sample were inaccessible or could not be sampled completely due to shallow depths (Table 2).

These hydroacoustic data are currently being processed by a team at SIUC to define the bottom, which is a necessary first step for defining the water column in which the single target detection algorithm will search for potential fish targets. Although bottom-picking algorithms available in EchoView 5.0 facilitate this process for the down-looking hydroacoustics data, these data still have to be processed visually because changes in sediment type across the entire survey area will affect the algorithm performance. The data collected with side-looking techniques will have to be analyzed in a different fashion. Specifically, Asian carp were observed swimming erratically, possibly to evade our research vessel (Figure 3). This creates a unique challenge for estimating density from mobile acoustic surveys. Because Asian carp were not stationary, the increased frequency that a fish is detected, or counted, will cause an overestimation of density. As such, the fish tracking module in EchoView will be used to reduce multiple targets from the same fish to a single fish track. This has the added benefit of being able to calculate the evasive behavior of Asian carp in terms of direction and speed of travel while correcting for movement of the vessel, but adds another complexity for analyses. Specifically, for down-looking estimates we do observe multiple pings per fish, yet this is due to the fact that the ping rate is fast enough to provide multiple samples per fish. This oversampling of fish targets is compensated by the fact that the ping rate also oversamples the same volume of water (also known as the “beam volume sum") and therefore this bias is negated. Thus, side-looking estimates will have to use a different estimate for volume sampled given that the oversampling of the fish targets is already accounted for using the fish track module. As such, it will be necessary to quantify the "wedge volume" which essentially is the transect distance multiplied by the average range of the acoustic beam across the entire transect. While EchoView can produce these estimates, and we are currently developing a script which will help automate some of the procedures, these extra steps combined with the large amount of data that has to be visually inspected will increase processing time.

Although a complete analysis is needed, it was apparent during these surveys that the side-looking technique was successful in sampling a much larger volume of the water column due to the greater distances that the acoustic beam traveled before intersecting the bottom. Moreover, this method appeared to be well-suited to detect Asian carp given that large schools identified with the acoustics gear was often immediately accompanied by numerous jumping silver carp (Figure 3). The erratic behavior of Asian carp during these surveys caused them to be quite distinct. Specifically, silver carp were most often observed swimming with and away from the research vessel and then would make a hard turn that produced a series of pings that resembled a check mark before exiting the acoustic beam. Although further analyses are needed to test whether this erratic behavior actually decreased the number of detections on our down-looking transducer, this does suggest that down-looking techniques are more likely to underestimate density due to this evasive behavior, particularly at shallower depths. The side-scan sonar could also prove useful in this regard.

Recommendations:

Species-specific information cannot presently be determined merely from the acoustic properties of a fish detected with hydroacoustics from these surveys. Therefore, we originally decided that hydroacoustic sampling would not be informative upstream of the Dresden reach because of the reliance of hydroacoustic estimates on abundance of Asian carp from some form of directed sampling with traditional sampling gears (i.e., the estimated number of Asian carp would be zero if no Asian carp were detected in the survey area with traditional sampling). However, knowledge of the age- and species-specific behavior and depth/habitat use of fishes has allowed for separation of age- and species-specific density estimates. The evasive behavior of Asian carp, at least silver carp, cause them to be quite distinct, and this may facilitate detections of these fish in areas without a form of directed sampling. Side-looking hydroacoustics could therefore be used to facilitate targeted removal of Asian carp where they exist in low number. Hydroacoustic surveys conducted in 2012 within the Starved Rock reach facilitated the identification of two sites (the mouth of the Fox River and Heritage Harbor) for the Barrier Defense Asian Carp Removal Project, where close to 50,000 lbs of Asian carp were subsequently removed between 18 October 2012 and 29 November 2012. No new sites were identified as a result of our 2013 surveys.

Although we made an effort to sample as many backwaters as time permitted, most were either completely inaccessible or portions were inaccessible due to low water levels (Tables 1 and 2). While some of these backwaters do have sufficient depths for hydroacoustic and side-scan sonar sampling, the entrance to many of these areas have sand deposits that make accessibility impossible with our research vessel. It may be necessary to use a boat that drafts less water to access these areas. Nevertheless, the hydroacoustics gear will not be useful for abundance estimates in depths less than 1 m, which is the minimum amount of depth required for our research vessel. Therefore, a shallow running boat will not completely overcome the issue of not being able to provide complete sampling coverage. Further, the shallow areas of these backwaters risk destroying the sampling gear. Therefore, the use of other technologies may be warranted if estimates of abundance from these extremely shallow areas are desired.

Project Highlights:

- Collected over 2300 nmi and 2000 nmi of hydroacoustic data 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 in 2012 and 2013, respectively.
- The incorporation of side-looking hydroacoustics in 2012 and 2013, and side-scan sonar in 2013, will address most, if not all, shortcomings of previous surveys conducted in 2010-2011 by increasing the volume of water column sampled, sampling the surface, reducing potential bias from evasion of Asian carp from the acoustic beam, and allowed sampling of shallow areas provided the depth is sufficient for our research vessel.

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Table 1. Locations sampled with hydroacoustics within each reach in 2012, the habitat type represented, approximate river mile (RM), date sampled, and cumulative distance sampled (nmi) across all transducers. 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)	Dates sampled (or attempted)	Cumulative distance sampled (nmi)	Notes
			Dresden		
Illinois River and Des Plaines River	MC	271.5-286.0	9/23/12 - 9/24/12	155.88	
Brandon Road L&D release	SC	285.3-286.0	9/24/12	0.72	Majority inaccessible (shallow and rocky)
Treats Island side channel	SC	279.0-280.2	9/24/12	0.88	Majority inaccessible (shallow and highly vegetated)
Mobile Oil Corp. Bay	BW	278.2	9/24/12	0.99	Majority inaccessible (shallow and highly vegetated)
Big Basin Marina	HB	277.8	9/24/12	-	Inaccessible (shallow and moderately vegetated)
Moose Island	SC	276.0	9/24/12	-	Inaccessible (shallow and highly vegetated)
Breezy Harbor Marina	HB	273.6	9/24/12	1.29	
Kankakee River (~1st mile)	TR	273.0	9/23/12	21.54	Portions moderately to highly vegetated
			Reach total	**181.30**	
			Marseilles		
Illinois River (including lock channel)	MC	245.7-271.5	9/20/12 - 9/23/12	385.12	
Big Dresden Island	SC	271.0	9/23/12	-	Inaccessible (entrance too shallow)
Peacock Slough	BW	264.6	9/22/12	-	Inaccessible (shallow and rocky)
Hanson Material Services Corp. east pit	BW	262.0	9/18/12 - 9/19/12	67.79	Portions inaccessible (shallow)
Hanson Material Services Corp. west pit	BW	262.1	9/20/12	34.89	Portions inaccessible (shallow)
Sugar Island side channel	SC	260.3-261.2	9/19/12	6.78	
			Reach total	**494.58**	
			Starved Rock		
Illinois River	MC	231.0-247.0	9/25/12, 10/2/12	139.65	
Bell's Island / Marseilles dam release	SC	244.0-247.0	9/25/12	-	Inaccessible (shallow and rocky)
Heritage Harbor Marina	HB	242.3	9/25/12	6.35	
Bulls Island and Scherer Island	SC	240.0-241.6	9/25/12	9.75	Portions inaccessible (shallow)
Fox River (~1st mile)	TR	239.7	9/25/12	4.7	
Hitt Island and Mayo Island	SC	237.0-239.0	10/2/12	9.9	
Sheehan Island	SC	235.2-236.4	10/3/12	15.6	
Sheehan Island	BW	235.8	10/3/12	-	Inaccessible (entrance too shallow)
Shallow bays near Starved Rock L&D	CL	231.0-235.0	10/3/12	-	Inaccessible (shallow and debris ridden)
			Reach total	**185.95**	

Table 1, continued.

Location	Habitat type	Approximate location (RM)	Dates sampled (or attempted)	Cumulative distance sampled (nmi)	Notes
			Peoria		
Illinois River (near Ogelsby)	MC	226.3-231.0	10/3/12	63.16	
Illinois River (near Spring Valley)	MC	215.0-219.0	10/4/12	61.48	
Clark Island	SC	215.1-215.6	10/4/12	2.64	
Illinois River (near Hennepin)	MC	208.0-212.0	10/5/12	55.43	
Illinois River (near Henry)	MC	196.0-200.0	10/5/12 - 10/6/12	56.74	
Senachwine Lake	BW	199.0	10/5/12	-	Inaccessible (entrance tooshallow)
Sawmill Lake	BW	197.0	10/6/12	-	Inaccessible (entrance too shallow)
Illinois River (near Chillicothe)	MC	181.0-185.0	10/6/12	64.03	
Meadow Lake	BW	183.2	10/6/12	-	Inaccessible (entrance tooshallow)
Babbs Slough	BW	182.8	10/6/12	-	Inaccessible (entrance too shallow)
Illinois River (near Peoria)	MC	167.0-173.0	10/7/12	76.85	
Upper Peoria Lake	CL	166.6-177.4	10/8/12	54.06	Portions inaccessible (shallow)
Illinois River (near Peoria)	MC	162.0-166.0	10/7/12 - 10/8/12	62.59	
Peoria Lake	CL	163.0-166.1	10/8/12, 10/10/12	64.59	Portions inaccessible (shallow)
			Reach total	**561.57**	
			La Grange		
Illinois River (near Pekin)	MC	157.6-153.6	10/9/12	59.17	
Illinois River (near Copperas Creek Management Area)	MC	135.5-139.5	10/9/12 - 10/10/12	63.75	
Copperas Creek	TR	137.4	10/9/12	-	Inaccessible (entrance too shallow)
Duck Island	SC	135.4-135.8	10/9/12	-	Inaccessible (shallow)
Illinois River (near Havana)	MC	118.5-122.5	10/11/12	62.83	
Spoon River (~1st 0.4 mile)	TR	120.5	10/11/12	2.49	
Quiver Island	SC	120.8-122.0	10/11/12	9.27	Portions inaccessible (shallow)
Illinois River (near Bath)	MC	105.0-109.0	10/12/12	53.48	
Bath Chute	SC	106.7-113.4	10/12/12	18.93	Portions inaccessible (shallow)
Illinois River (near Browning)	MC	97.0-101.0	10/13/12	51.03	
Chain Lake	BW	98.7	10/13/12	2.88	Majority inaccessible (shallow)
Illinois River (near Frederick)	MC	90.0-94.0	10/16/12	61.02	
Treadway Lake	BW	91.8	10/16/12	-	Inaccessible (entrance too shallow)
Wood Slough	BW	91.8	10/16/12	-	Inaccessible (entrance too shallow)
Illinois River (near La Grange)	MC	81.0-85.0	10/17/12	55.22	
Lily Lake	BW	83.1	10/17/12	13.86	Portions inaccessible (shallow)
			Reach total	**453.93**	

Table 1, continued.

Location	Habitat type	Approximate location (RM)	Dates sampled (or attempted)	Cumulative distance sampled (nmi)	Notes
			Alton		
Illinois River (near Beardstown)	MC	76.2-80.2	10/18/12	53.36	
Illinois River (near Meredosia)	MC	68.5-72.5	10/18/12	54.89	
Meredosia Lake	BW	71.3	10/18/12	-	Inaccessible (shallow)
Illinois River (near Florence)	MC	56.0-60.0	10/19/12	44.14	
Big Blue Island	SC	57.5-59.8	10/19/12	7.74	
Illinois River (near Bedford)	MC	46.0-50.0	10/20/12	54.75	
Buckhorn Island	SC	45.9-46.3	10/20/12	1.08	Portions inaccessible (shallow)
McEvers Island	SC	48.4-49.6	10/20/12	6.84	Portions inaccessible (shallow)
Illinois River (near Kampsville)	MC	32.0-36.0	10/21/12	56.07	
Illinois River (near Hardin)	MC	22.0-26.0	10/22/12	54.2	
Diamond Island (Dark Chute)	SC	22.8-25.5	10/22/12	23.32	
Macoupin Creek (1st 0.8 mile)	TR	23.1	10/22/12	5.04	
Illinois River (near Grafton)	MC	0.0-4.0	10/23/12	65.47	
Swan Lake	BW	5.2	10/23/12	-	Inaccessible (shallow)
Grafton Harbor	HB	2.1	10/23/12	1.5	
			Reach total	**428.4**	
			Grand total	**2305.73**	

Table 2. Locations sampled with hydroacoustics within each reach in 2013, the habitat type represented, approximate river mile (RM), date sampled, and cumulative distance sampled (nmi) across all transducers. 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)	Dates sampled (or attempted)	Cumulative distance sampled (nmi)	Notes
			Dresden		
Illinois River and Des Plaines River	MC	271.5-286.0	10/22/13-10/23/13	153.06	
Brandon Road L&D release	SC	285.3-286.0	10/22/13	-	Inaccessible (shallow and rocky)
Treats Island side channel	SC	279.0-280.2	10/22/13	1.08	Majority inaccessible (shallow and highly vegetated)
Mobile Oil Corp. Bay	BW	278.2	10/22/13	0.86	Majority inaccessible (shallow and highly vegetated)
Big Basin Marina	HB	277.8	10/22/13	-	Inaccessible (shallow and moderately vegetated)
Moose Island	SC	276.0	10/23/13	-	Inaccessible (shallow and highly vegetated)
Breezy Harbor Marina	HB	273.6	10/23/13	1.35	
Kankakee River (~1st mile)	TR	273.0	10/23/13	23.60	Portions moderately to highly vegetated
			Reach total	**179.95**	
			Marseilles		
Illinois River (including lock channel)	MC	245.7-271.5	10/18/13 - 10/21/13	304.64	
Big Dresden Island	SC	271.0	10/20/13	-	Inaccessible (entrance too shallow)
Peacock Slough	BW	264.6	10/20/13	-	Inaccessible (shallow and rocky)
Hanson Material Services Corp. east pit	BW	262.0	10/20/13	74.78	Portions inaccessible (shallow)
Hanson Material Services Corp. west pit	BW	262.1	10/21/13	53.36	Portions inaccessible (shallow)
Sugar Island side channel	SC	260.3-261.2	10/19/13	5.37	
			Reach total	**438.15**	
			Starved Rock		
Illinois River	MC	231.0-247.0	10/16/13 - 10/17/13	212.33	
Bell's Island / Marseilles dam release	SC	244.0-247.0	10/16/13	-	Inaccessible (shallow and rocky)
Heritage Harbor Marina	HB	242.3	10/16/13	4.30	
Bulls Island and Scherer Island	SC	240.0-241.6	10/16/13	9.77	Portions inaccessible (shallow)
Fox River (~1st mile)	TR	239.7	10/16/13	3.69	
Hitt Island and Mayo Island	SC	237.0-239.0	10/16/13	10.99	
Sheehan Island	SC	235.2-236.4	10/17/13	16.93	
Sheehan Island	BW	235.8	10/17/13	-	Inaccessible (entrance too shallow)
Shallow bays near Starved Rock L&D	CL	231.0-235.0	10/17/13	-	Inaccessible (shallow and debris ridden)
			Reach total	**258.01**	

Table 2, continued.

Location	Habitat type	Approximate location (RM)	Dates sampled (or attempted)	Cumulative distance sampled (nmi)	Notes
			Peoria		
Illinois River (near Ogelsby)	MC	226.3-231.0	10/14/13-10/15/13	45.33	
Illinois River (near Spring Valley)	MC	215.0-219.0	10/15/13	42.66	
Clark Island	SC	215.1-215.6	10/15/13	2.77	
Illinois River (near Hennepin)	MC	208.0-212.0	10/15/13	44.36	
Illinois River (near Henry)	MC	196.0-200.0	10/11/13	43.40	
Senachwine Lake	BW	199.0	10/11/13	-	Inaccessible (entrance tooshallow)
Sawmill Lake	BW	197.0	10/11/13	-	Inaccessible (entrance too shallow)
Illinois River (near Chillicothe)	MC	181.0-185.0	10/7/13 - 10/8/13	50.46	
Meadow Lake	BW	183.2	10/8/13	-	Inaccessible (entrance tooshallow)
Babbs Slough	BW	182.8	10/8/13	-	Inaccessible (entrance too shallow)
Illinois River (near Peoria)	MC	167.0-173.0	10/8/13	63.15	
Upper Peoria Lake	CL	166.6-177.4	10/10/13	90.11	Portions inaccessible (shallow)
Illinois River (near Peoria)	MC	162.0-166.0	10/9/13	42.58	
Peoria Lake	CL	163.0-166.1	10/9/13	45.35	Portions inaccessible (shallow)
			Reach total	**470.17**	
			La Grange		
Illinois River (near Pekin)	MC	157.6-153.6	10/7/2013	49.30	
Illinois River (near Copperas Creek Management Area)	MC	135.5-139.5	10-6-2013	43.85	
Copperas Creek	TR	137.4	10/6/13	-	Inaccessible (entrance too shallow)
Duck Island	SC	135.4-135.8	10/6/13	-	Inaccessible (shallow)
Illinois River (near Havana)	MC	118.5-122.5	10/6/13	41.56	
Spoon River (~1st 0.4 mile)	TR	120.5	10/6/13	3.80	
Quiver Island	SC	120.8-122.0	10/6/13	5.54	Portions inaccessible (shallow)
Illinois River (near Bath)	MC	105.0-109.0	10/5/13	42.55	
Bath Chute	SC	106.7-113.4	10/5/13	23.30	Portions inaccessible (shallow)
Illinois River (near Browning)	MC	97.0-101.0	10/5/13	43.40	
Chain Lake	BW	98.7	10/5/13	0.55	Portions inaccessible (shallow)
Illinois River (near Frederick)	MC	90.0-94.0	10/4/13	43.31	
Treadway Lake	BW	91.8	10/4/13	-	Inaccessible (entrance too shallow)
Wood Slough	BW	91.8	10/4/13	-	Inaccessible (entrance too shallow)
Illinois River (near La Grange)	MC	81.0-85.0	10/4/13	45.34	
Lily Lake	BW	83.1	10/4/13	16.19	Portions inaccessible (shallow)
			Reach total	**358.69**	

Table 2, continued.

Location	Habitat type	Approximate location (RM)	Dates sampled (or attempted)	Cumulative distance sampled (nmi)	Notes
			Alton		
Illinois River (near Beardstown)	MC	76.2-80.2	10/3/13	39.21	
Illinois River (near Meredosia)	MC	68.5-72.5	10/3/13	41.23	
Meredosia Lake	BW	71.3	10/3/13	-	Inaccessible (shallow)
Illinois River (near Florence)	MC	56.0-60.0	10/2/13	40.33	
Big Blue Island	SC	57.5-59.8	10/2/13	0.20	
Illinois River (near Bedford)	MC	46.0-50.0	10/2/13	45.28	
Buckhorn Island	SC	45.9-46.3	10/2/13	-	Inaccessible (shallow)
McEvers Island	SC	48.4-49.6	10/2/13	-	Inaccessible (shallow)
Illinois River (near Kampsville)	MC	32.0-36.0	10/1/13	50.07	
Illinois River (near Hardin)	MC	22.0-26.0	9/4/13	40.92	
Diamond Island (Dark Chute)	SC	22.8-25.5	9/4/13	14.45	
Macoupin Creek (1st 0.8 mile)	TR	23.1	9/4/13	6.51	
Illinois River (near Grafton)	MC	0.0-4.0	9/3/13	44.15	
Swan Lake	BW	5.2	9/3/13	-	Inaccessible (shallow)
Grafton Harbor	HB	2.1	9/3/13	1.64	
			Reach total	**323.99**	
			Grand total	**2028.96**	

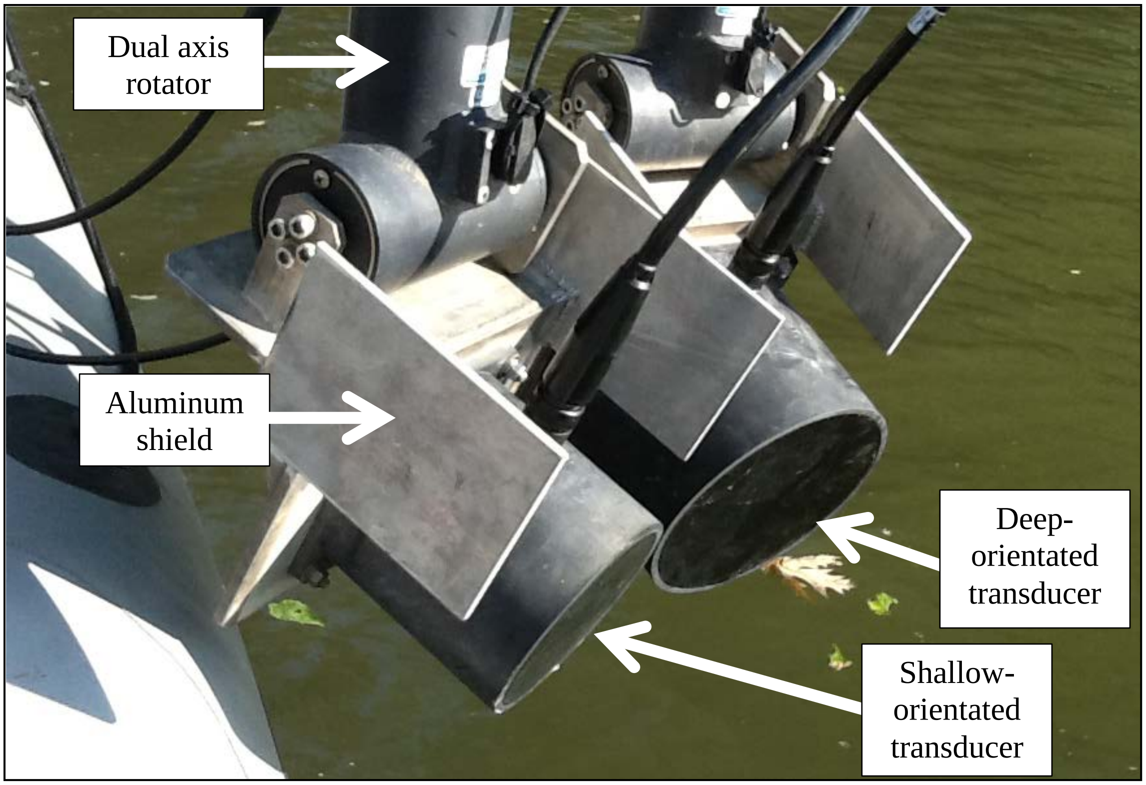

Figure 1. Photograph of split-beam hydroacoustics transducers mounted on dual axis rotators prior to deployment.

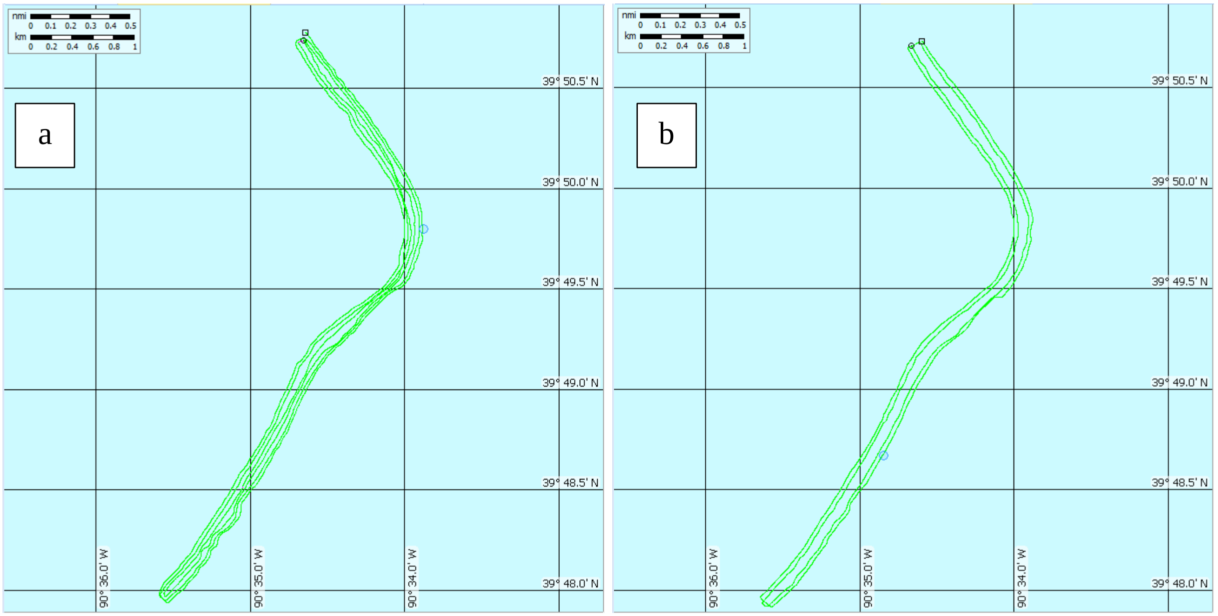

Figure 2. Hydroacoustic survey transects conducted on the main channel of the Illinois River in the Alton reach (RM 68.6-72.5) in (a) 2012 and (b) 2013.

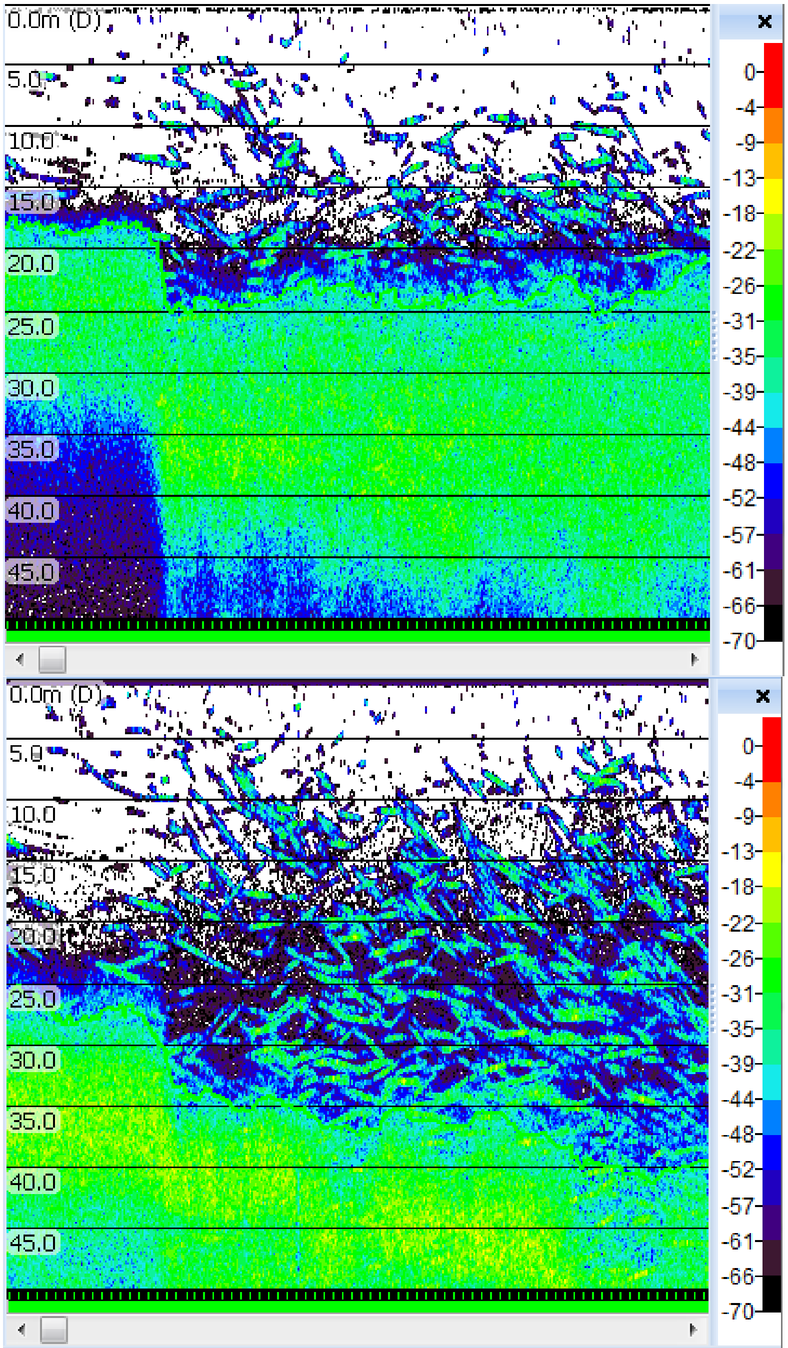

Figure 3. Echogram created in EchoView 5.4 from data collected in 2013 in the side channel of the Alton reach behind Diamond Island (Dark Chute), using the shallow-orientated (top echogram) and deep-orientated (bottom echogram) side-looking hydroacoustic transducers. Bottom lines, where the acoustic beam intersects the bottom, have been drawn for the shallow-orientated (approximately 20–25 m range) and deep-orientated (approximately 30-40 m range) transducers. The amplitude of the echoes are indicated on the right (dB) and represent uncompensated target strength.

Chapter 5:

Monitoring recruitment sources of adult Asian carps in the Illinois River in response to enhanced commercial harvest using otolith microchemistry and stable isotope analyses

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

Introduction: Asian carps are known to be reproducing in the Illinois, middle Mississippi, and lower Missouri Rivers. Initial estimates of the extent to which Asian carp stocks in the Illinois River are derived from recruits from within the Illinois River itself vs. immigrants from the Mississippi and Missouri Rivers were obtained from otoliths collected during 2010-2011 sampling. We also estimated the contribution of floodplain lake habitats to Asian carp recruitment in the Illinois River. Asian carps are known to exhibit substantial inter-annual variation in recruitment and also within-river movement rates by adult fish. Thus, there is a need to determine whether the principle natal environments of Asian carps in the Illinois River may also differ among years. Knowledge of Asian carp recruitment sources is also needed to: 1) determine whether enhanced commercial harvest of Asian carps in the Illinois River is effectively reducing recruitment of these species within the Illinois River (as indicated by a decrease in the relative abundance of Illinois River-origin fish), 2) assess the degree to which Asian carp stocks in the Illinois River may be replenished by immigrants from other rivers (immigration rates are an important component of population models) and the potential need to expand the geographic scope of enhanced commercial harvest efforts and 3) direct commercial fishing and other control efforts to target locations that are supporting Asian carp populations.

Objectives: Estimate the relative abundances of resident (Illinois River origin) and immigrant (Mississippi or Missouri river origin) bighead carp, silver carp, and hybrids of these two species in four reaches of the Illinois River (Alton, LaGrange-Peoria, and upper river [upstream from Starved Rock Lock and Dam]) to assess inter-annual variability in recruitment sources of Asian carps and evaluate potential effects of enhanced commercial harvest on proportions of resident and immigrant fish. Characterize timing and patterns of inter-river movement for immigrants. Refine estimates of the proportion of Asian carp that use floodplain lakes along the middle and lower Illinois River as larval and juvenile nursery areas.

Methods: Adult bighead and silver carps were collected from each of three reaches of the Illinois River (Alton, LaGrange-Peoria, and upper river) during 2012-2013 by electrofishing and trammel netting. Caudal fin clips were obtained from each fish and sent to Jim Lamer at Western Illinois University for identification of bighead carp, silver carp, and hybrids. Both lapilli otoliths were extracted from each fish. One otolith per fish was sectioned and analyzed for strontium:calcium ratio (Sr:Ca) along a transect from the core to the edge of the sectioned otolith using laser ablation-ICPMS. A 250 μg subsample from the core of the second otolith from each fish was obtained using a micromill; a core subsample of this mass represents otolith carbonate deposited during age-0. The core subsample from the second otolith from each fish was analyzed for stable oxygen and carbon isotope ratios ($\delta^{18}O$ and $\delta^{13}C$) using a ThermoFinnigan Delta plus

XP isotope ratio mass spectrometer interfaced with a Gas Bench II carbonate analyzer. Previously established relationships between water and otolith Sr:Ca and water and otolith $\delta^{18}O$ for Asian carps were used to characterize expected otolith Sr:Ca and $\delta^{18}O$ signatures for fish that originated in the Illinois, Missouri, and Mississippi rivers and for fish that used floodplain lake habitats during their early life history. Sr:Ca, $\delta^{18}O$ and $\delta^{13}C$ of the otolith core (which reflects early life history) were used to infer natal environment for individual fish. Changes in Sr:Ca across sectioned otoliths were used to assess timing and long-term patterns of inter-river movement for individual fish.

Water samples were collected from the Illinois River (Alton and LaGrange reaches and the upper river), five of its floodplain lakes, the upper and middle Mississippi River, and the lower Missouri River during June, August, and October 2010, 2011, 2012, and 2013 to verify persistence of distinct water chemical signatures among these locations that were observed in prior studies. Water samples were analyzed for Sr:Ca and stable oxygen isotope ratio ($\delta^{18}O$).

Results and Discussion: Water chemistry data continue to indicate that Sr:Ca is consistently higher in the middle Mississippi and Missouri rivers compared to the Illinois River, thus enabling use of this marker as an indicator of fish that have immigrated into the Illinois River from these other rivers. The water $\delta^{18}O$ signature of floodplain lakes frequently differs from that of the Illinois River, enabling use of $\delta^{18}O$ as a marker of Asian carp use of floodplain lake habitats during early life, although flooding can temporarily eliminate the distinct water $\delta^{18}O$ signature of connected floodplain lakes during some years.

Two hundred two adult Asian carp (59 silver carp, 70 bighead carp, 73 hybrids) collected from the Illinois River during 2012-2013 were analyzed for $\delta^{18}O$ and $\delta^{13}C$ of the otolith core. All fish identified as bighead carp based on external morphology were confirmed to be bighead carp based on genetic analysis; all hybrids had initially been identified as silver carp based on external morphology. Only 5% of the fish analyzed had otolith core $\delta^{18}O$ and $\delta^{13}C$ signatures indicative of use of floodplain lake habitats during early life, consistent with data from prior years. Limited evidence for use of floodplain lake habitats during early life may be due to the limited number and connectivity of floodplain lakes along the Illinois River or recent floods that may have temporarily eliminated the distinct signature of connected floodplain lakes. Our data indicate that most adult Asian carp in the Illinois River used river channel habitats during their first year of life, suggesting that low-velocity, near-shore areas within the river represent the predominant nursery habitat for larval and young juvenile Asian carp. Collection of some adult fish in the upper river that had used floodplain lake habitat during age-0 suggests that these fish immigrated from downriver where most of the floodplain lakes occur.

Otoliths from adult Asian carp collected from the Illinois River during 2012-2013 were also analyzed for Sr:Ca to determine river-of-origin. Forty seven percent of adult silver carp and 52% of hybrids had otolith core (first 10 μm of laser transect) Sr:Ca signatures indicative of Illinois River origin. Using otolith core Sr:Ca data, we estimated that 28-53% of adult silver carp and 26-48% of hybrids in the Illinois River were immigrants that originated in the middle Mississippi or Missouri Rivers (the range in our estimate of the percentage of immigrants reflects some uncertainty in our statistical model used to assign natal environment to individual fish). We have also observed (based on changes in Sr:Ca across sectioned otoliths) several silver carp and hybrids that entered, exited, and re-entered the Illinois River from the Mississippi River at multiple times during their life. Our estimates of percent immigrants for silver carp and hybrids were slightly higher than the estimated contribution of immigrants to the Illinois River adult silver carp stock in 2010-2011 (11-39% immigrants). Among silver carp and hybrids that were immigrants to the Illinois River, the vast majority originated in the middle Mississippi River; only 2-8% of the total number of silver carp and hybrids captured in the Illinois River originated in the Missouri River. The percentage of immigrants to the Illinois River declined from downstream to upstream reaches of the Illinois River for both silver carp and hybrids. Estimates of percent immigrants for silver carp and hybrids combined ranged from 41-75% for the Alton reach, 29-41% for the LaGrange reach, and 3-25% for the upper river. These results suggest that dams may reduce the replenishment rate of the Asian carp stock in the upper Illinois River by immigrants from the Mississippi River if control efforts are successful in reducing Asian carp abundance in the upper Illinois River. In contrast to silver carp and hybrids, otolith core Sr:Ca indicated that 91-98% of bighead carp analyzed originated in the Illinois River, with 2% originating in the middle Mississippi River, consistent with data from prior years.

Recommendations: Our results indicate that Asian carp stocks in the Illinois River are primarily supported by recruitment from within the Illinois River itself, suggesting that control efforts should continue to focus on the Illinois River. However, the substantial percentage of silver carp and hybrids that immigrate into the Illinois River continues to suggest that sustainable control of silver carp in the Illinois River will likely require expanding control (e.g., commercial harvest) efforts for this species to include the middle Mississippi River. Whether the higher percentage of immigrant silver carp in the Illinois River compared to prior years is at least partly due to enhanced commercial harvest or if this simply represents natural year-to-year variation is presently unclear; monitoring to determine the principle natal environments of Asian carp in the Illinois River during future years could be used to assess whether control efforts reduce recruitment of Asian carps within the Illinois River.

Chapter 6:

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), Eastern Illinois University (support), Western Illinois University (support).

Introduction: Controlled commercial fishing for the reduction of Asian carp (*Hypothalmychthyes* spp.) was instituted during 2010 in an attempt to reduce migration pressure on the Dispersal Barrier and thus reduce the risk of Asian carp entering the CAWS and Lake Michigan (see Barrier Defense Asian Carp Removal Project Description/Chapter). High densities of Asian carp are believed to exert a strong direct impact on ecosystem structure and function, primarily by the consumption of plankton. Thus, it is plausible that Asian carp reduction efforts (i.e. commercial fishing) may produce detectable responses in variables such as zooplankton community structure, density, and productivity. Short-term changes in these direct response variables could provide insight into any of Asian carp's lagged impact on the native fish community. Monitoring of zooplankton response has been conducted since 2009 and riverine fish monitoring has been conducted by the Long-Term Illinois, Mississippi, Ohio, and Wabash River Fish Population Monitoring program (LTEF) since 1989. The results of these surveys are presented with the objective of increasing our understanding of the ecosystem responses that may have occurred as a result of Asian carp removal efforts.

Objectives:

1) Evaluate the influence of commercial fishing reductions of Asian carp on:
    a) zooplankton composition and density
    b) abundance and condition of native fishes
2) Investigate productivity patterns

Methods: Plankton sampling occurred monthly (May-Oct) at 18 sites throughout the Illinois Waterway (Alton, La Grange, Peoria, Starved Rock, Marseilles, Dresden) from May thru October of 2011-2013 and at a subset of 6 sites during 2009 and 2010. At each site-date combination, three vertically-integrated 55-µm 30-L sample replicates were obtained by pumping water through 55-µm mesh. 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, samples were concentrated to a known volume from which a homogenized 5 mL subsample 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. Productivity 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).
Asian carp reduction activities through commercial fishing occurred predominately in the upper river section (Starved Rock, Marseilles, and Dresden reaches). During 2010, removals were limited to only the Marseilles and Dresden reaches, whereas from 2011 to 2013 they occurred in all three upper reaches. Removals from the lower river section (Alton, La Grange, and Peoria reaches) only occurred once during 2012. Based on the distribution of commercial fishing pressure, river geomorphology, and natural differences in ecology, we grouped sites into upper and lower river sections (Theiling 1999, McClelland et al. 2006).

Analyses

To investigate how the reduction through commercial fishing affected measured ecosystem responses, we only considered the upper section of the river where most of the reduction activities have occurred. Zooplankton density was evaluated using mixed model one-way ANOVA with commercial fishing (presence/absence) as the fixed effect, and site and year as random effects (2009 and 2011-2013, respectively). We indexed zooplankton density as the mean of three replicate samples taken during June of each year. We only considered June zooplankton data because a complete set of all site-month data was not available for all years.

Although Asian carp now comprise the greatest proportion of planktivore biomass in the Illinois Waterway, native planktivores are still important components of the aquatic food web. Therefore, we also included an analysis of the effect of Asian carp reductions on gizzard shad, as gizzard shad can be an indicator for other native plankton-feeding fishes. Gizzard shad (*Dorosoma cepedianum*) are a dominant water column planktivore within the Illinois Waterway and have previously been shown to exhibit reduction in body condition in relation to Asian carp establishment (Irons et al. 2007). If Asian carp can outcompete gizzard shad for plankton, then gizzard shad and the species that utilize them may be indirectly impacted. Thus in an effort to determine if reductions of Asian carp are having a positive effect on gizzard shad, we evaluated gizzard shad abundance and condition using mixed model one-way ANOVA with commercial fishing as the fixed effect, and site and year as random effects. Condition was indexed as relative weight (W_r; see Irons et al. 2007) and abundance was indexed as catch-per-unit effort ($CPUE_n$).

Independent of commercial fishing, mean annual zooplankton densities and mean annual productivity (chlorophyll *a* and total phosphorus) were compared by section and year using mixed model, two-way ANOVA with section (upper/lower) and year as fixed effects and site as a random effect. Zooplankton density was indexed as the mean of three monthly replicate samples averaged among the six months sampled each year. Similarly, productivity was indexed as the mean of the two monthly replicate samples averaged among the six months sampled each year. Data from 2009-2010 could not be included with data from 2011-2013 because the same site-date combinations were not sampled during each period. In addition, three other sites were excluded from the analysis because they only occurred in one reach (La Grange) and were deemed different enough from the more standard main channel conditions and would therefore obscure results. These included two backwater sites and one side channel site.

Results – Effects of Asian Carp Reduction on Ecosystem Responses: The presence of commercial fishing did not significantly influence rotifer (f = 0.20, p = 0.70), cladoceran (f =

0.54, p = 0.54), copepod (f = 3.31, p = 0.21), nauplii (f = 0.22, p = 0.68), or total zooplankton densities (f = 0.22, p = 0.69; Figure 1). Furthermore, there were no statistically significant effect of reduction activities on gizzard shad condition (f = 0.65, p = 0.42) or abundance (f = 0.06, p = 0.94; Figure 2).

Results – Ecosystem Variability in Relation to River Mile: Independent of commercial fishing, rotifer density and total zooplankton density varied by year and river section ($p < 0.02$ and $p < 0.001$, respectively), with rotifers tending to be proportionally more abundant in the lower section (Table 1; Figures 3 and 4). There was also a significant year by section interaction for both rotifer and total zooplankton density (both $p < 0.01$), likely a result of high rotifer densities in the upper section during 2012 (Figure 4). Cladoceran density varied by river section (p = 0.03) as they tended to be more abundant in the upper river and by year (p = 0.002) with 2012 significantly different from 2011 and 2013. Nauplii density differed by year (p = 0.05) and there was a significant year by section interaction (p = 0.01) as higher nauplii abundances were observed in the lower river during 2013(Figure 4). Only copepod density did not differ between river section or year.

Chlorophyll-*a* concentration differed by river section ($p < 0.001$). Trends indicate chlorophyll-*a* concentration tended to decrease from downstream to upstream, primarily a consequence of dramatic decreases within the upper river (Figure 5). Conversely, total phosphorus tended to be progressively greater upstream and was significantly different between river section and year (both $p < 0.001$; Figure 6) with 2012 significantly different from 2011 and 2013.

Discussion: Based on our analysis, we were unable to detect an influence of controlled commercial fishing of Asian carp on those ecosystem responses measured during the course of the study. However, several factors aside from commercial fishing pressure on Asian carp, may explain our findings. These include:

- The inherent biotic and abiotic differences that exist between the upper and lower river sections regardless of the establishment of Asian carp (Theiling 1999, McClelland et al. 2006). The lack of a significant response suggests that the differences we observed in productivity and zooplankton communities should not be directly attributed to commercial reductions of Asian carp.
- The relative paucity of zooplankton data collected prior to the onset of Asian carp reduction efforts in 2009. Moreover, small-sample sizes and ineffective sampling designs may have failed to detect year-to-year or site-to-site variation and could obscure broader patterns that may have emerged with additional pre-reduction data.
- In addition to the lack of a plankton response, there was also no response of gizzard shad abundance ($CPUE_n$) or condition (W_r). This lack of response could be attributed to a possible lagged response due to longer generation times of fishes.

Aside from these results, several other notable conclusions may be reached.

- While small bodied rotifers dominated the zooplankton community, they were more abundant in the lower section of the Illinois River where Asian carp densities are highest. 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, Lu et al. 2002). Therefore, higher rotifer concentrations coinciding with higher carp densities may be an indication of greater Asian carp foraging. Additionally, cladocerans were observed to be more abundant in the upper river, which may be a function of both reduction efforts and/or lower ambient Asian carp densities of the upper river.

- In terms of productivity, total phosphorous and chlorophyll-*a* concentrations did not appear to be correlated; total phosphorous increased upstream while chlorophyll *a* decreased upstream. However, it is worth noting general upstream decreases in the chlorophyll-*a* concentration are largely driven by a greater magnitude of decrease in the upper river.

Recommendations: Monitoring of productivity and zooplankton 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 specific time intervals coinciding with 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).

Project Highlights:

- Reduction of Asian carp through controlled commercial fishing did not significantly influence zooplankton densities, gizzard shad relative weight, or gizzard shad catch-per-unit effort
- Rotifers are proportionally dominant in terms of abundance in both upper and lower river sections
    - Rotifers tended to be more abundant in the lower section when compared to the upper section
    - Cladocerans tended to be more abundant in the upper section when compared to the lower section
- Primary productivity (i.e., chlorophyll-*a* concentration) decreased from downstream to upstream
- Total phosphorus (mg/L) decreased from upstream to downstream

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Theiling C. 1999. River geomorphology and floodplain habitats. Pages 4:1-4:21 i*n* Delaney, R.L., K. Lubinski, and C. Theiling, editors. Ecological status and trends of the Upper Mississippi River system 1998: a report of the Long Term Resource Monitoring Program. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. April 1999. LTRMP 99-T001.

Table 1. Zooplankton density (mean (± SD); individuals/L) by river section and year (May-Oct).

Section	Year	No. Samples	Rotifers/L	Cladocerans/L	Copepods/L	Nauplii/L	Total Zoop/L
Lower (12 sites)	2011	199	131.2 (133.0)	1.9 (2.3)	0.4 (0.7)	2 (2.1)	135.6 (134.5)
	2012	213	153.9 (83.2)	3.8 (6.0)	0.4 (0.7)	2.2 (2.4)	160.3 (82.5)
	2013	211	213.9 (146.1)	2.1 (2.9)	0.7 (1.0)	5.7 (7.2)	222.4 (148.1)
	2011-2013	623	167.0 (128.1)	2.6 (4.2)	0.5 (0.8)	3.3 (4.9)	173.5 (129.7)
Upper (3 sites)	2011	53	23.3 (16.5)	2.1 (2.4)	0.5 (0.4)	3.5 (6.3)	29.6 (19.9)
	2012	54	102.7 (149.7)	7.9 (15.8)	0.6 (0.7)	3.2 (3.2)	114.4 (157.8)
	2013	54	40.3 (42.5)	4.8 (8.3)	0.4 (0.6)	3.0 (3.0)	48.6 (42.2)
	2011-2013	161	55.6 (96.3)	5 (10.6)	0.5 (0.6)	3.3 (4.4)	64.4 (101.5)

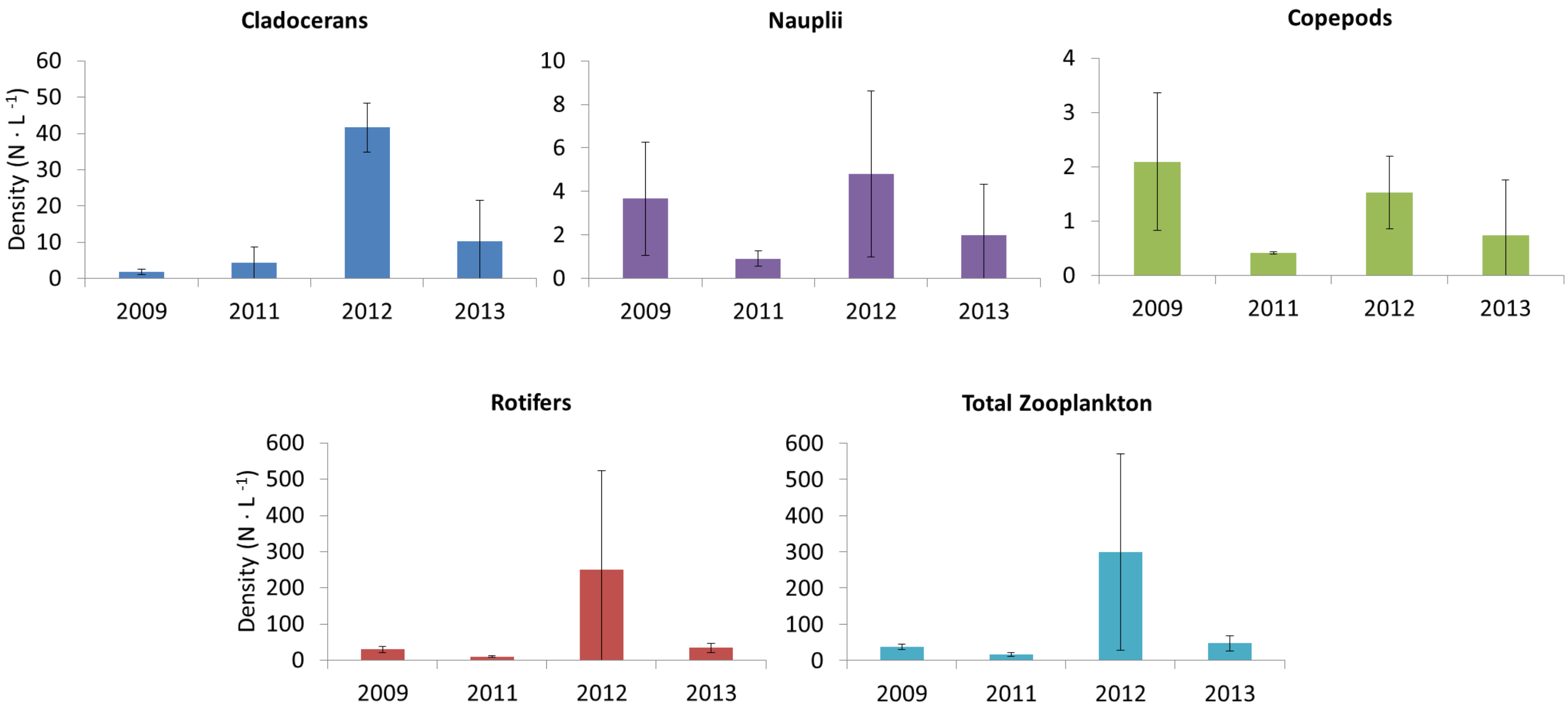

Figure 1. Mean (± SD) June zooplankton densities by year within the upper river.

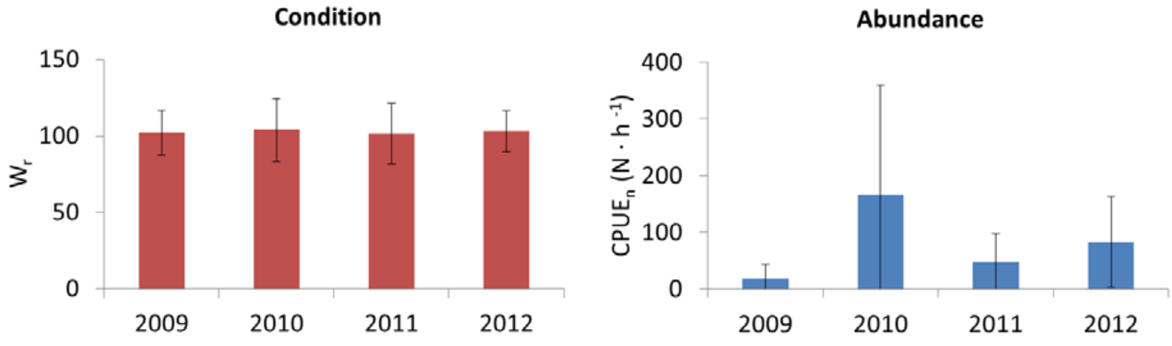

Figure 2. Condition (W_r; mean ± SD) and catch-per-unit effort ($CPUE_n$; mean ± SD) of gizzard shad by year within the upper river.

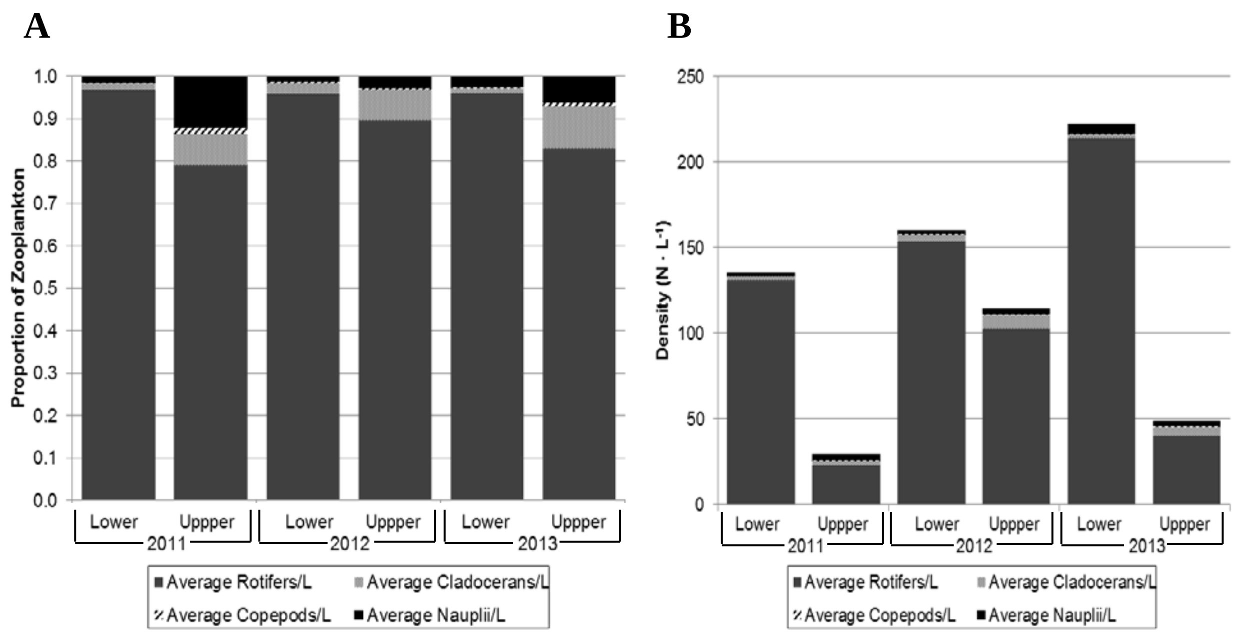

Figure 3. A) Proportion of zooplankton and **B)** zooplankton density by section and year (May-Oct). Note: actual densities differ between river sections.

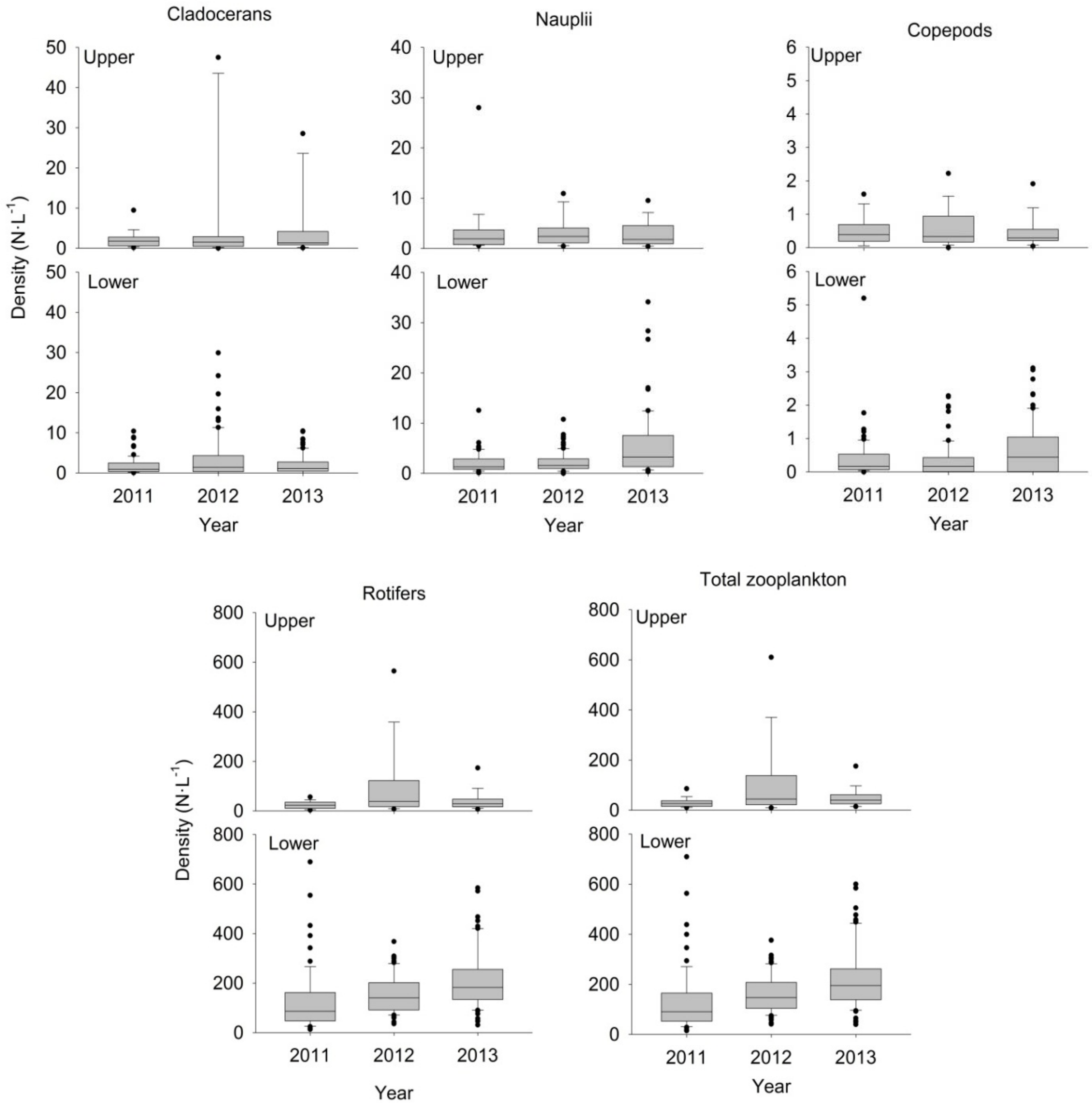

Figure 4. Density of zooplankton (May – Oct) including rotifers, nauplii, copepods, cladocerans and total zooplankton by river section and year.

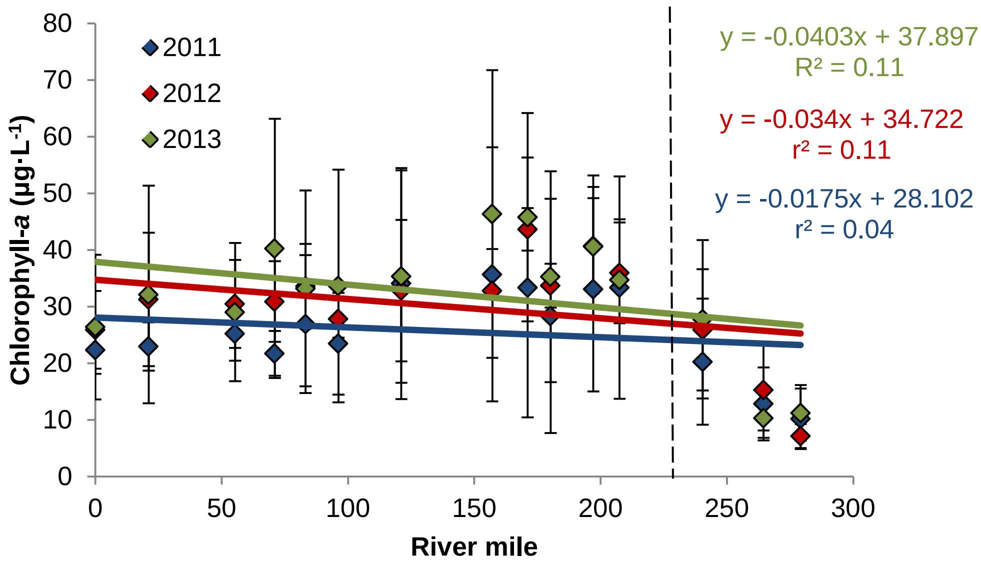

Figure 5. Mean (± SD) annual (June-October) chlorophyll *a* concentration as a function of river mile. Dashed vertical line separates river sections.

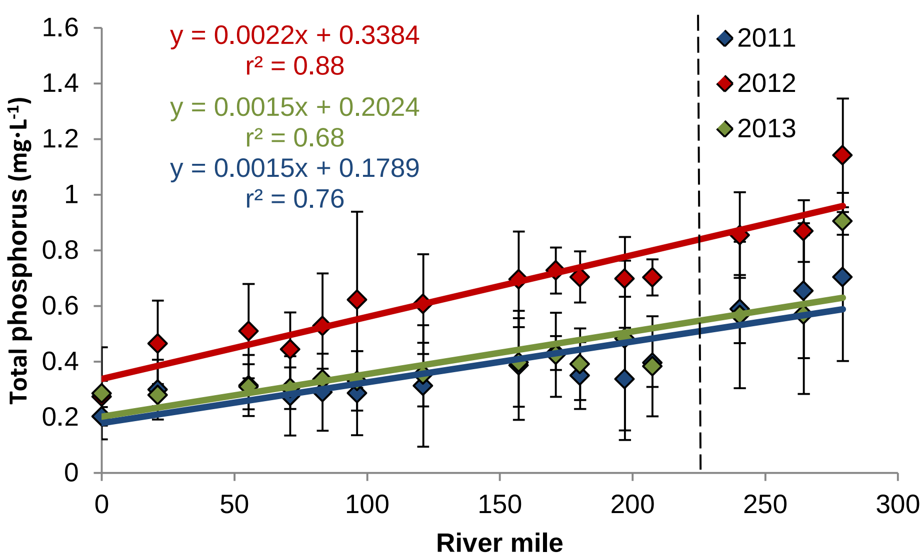

Figure 6. Mean (± SD) annual (June-Sept) total phosphorus concentration as a function of river mile. Dashed vertical line separates river section.

Chapter 7:

Spatially Explicit Population and Movement Model of the Illinois River

SIU CARBONDALE
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Participating Agencies
Southern Illinois University-Carbondale (lead), Ohio State University (modeling), Illinois Department of Natural Resources (field support).

Introduction: During two days of February 2013, fisheries investigators with broad experience in marine and freshwater systems convened to discuss ways to model the populations of Asian carps (bighead and silver) in the Illinois River, with particular focus on the potential for these species to increase densities in proximity to the electrical barrier in the Chicago Sanitary Ship Canal (CSSC) within the Chicago Area Waterway System (CAWS). Contracted harvest is occurring in the upper Illinois River to reduce the potential "propagule pressure" of Asian carp on the CSSC. We identified two modeling approaches. The first (Version 1.0) is a stochastic, stage-structured model exploring the impact of size-dependent harvest on the population trajectory of both species in the Illinois River. The model was developed as part of a research effort conducted during 2010-2011 and is coded in statistical modeling software (see results in Garvey et al. 2012 and Tsehaye et al. 2013). The output of Version 1.0 showed that the response of the population to fishing pressure is highly variable, with the conclusion that harvest must occur on all sizes of Asian carp with a high exploitation rate (> 70%) to cause the mean population growth rate to decline.

Although the current model structure and approach are sound, the output might not be all that useful to managers interested in assessing "risk" of the population reaching the barrier system. Thus, a model Version 2.0, which does not yet exist, will need to be constructed. The group agreed that this model must start from "scratch" and will require a significant amount of data. Importantly, the currency of the model needs to be decided and kept consistent. <u>The critical output of the model will be the probability that carp will establish in the proximity of the electrical barrier in the CAWS.</u> Different management strategies will be incorporated into the model to assess the change in this probability from a strategy of no control. Contracted fishing in the upper Illinois River is removing up to 1.5 million pounds annually. In the lower river, commercial fishing is occurring. The model will allow us to assess what would happen to the population in proximity to the CSSC if current harvest strategies are stopped or redistributed throughout the Illinois River. Management strategies such as size-selective control, reduction in reproductive output, and selective barriers may also be built into the model.

Model Structure (Figure 1):

- The model will be spatially explicit. Responses near the barrier will depend on control efforts both in the upper river (defined as above Starved Rock Lock and Dam) and in the lower river.
- The model will allow managers to forecast population dynamics and "risk" to the barrier for 50 years.

- The approach will generally be Eulerian in design. Rather than following individuals, population dynamics will be divided into temporally and spatially discrete cells. The distribution of responses will be followed within those cells and they will interact.
- Recruitment needs to be understood with research and incorporated as an independent process. Fish produced will be distributed throughout the lower river where recruitment is known to occur.
- The “Adult” component of the population model will have explicit temporal and spatial components.

Data Collection and Parameterization: Data for Version 2.0 are being collected and exist in the literature. The group agreed that building a model skeleton with place-holder variables is possible within a few months, but the challenge will be assembling data and getting them into the proper currency for the model. Data needed include larval growth and survival, spatial distribution of larval settling sites, density-dependent demographic relationships for adults, and dependence of movement on hydrology, density, and size (Figure 1). Simulations of the Version 2.0 will provide a response surface by which management strategies will be assessed.

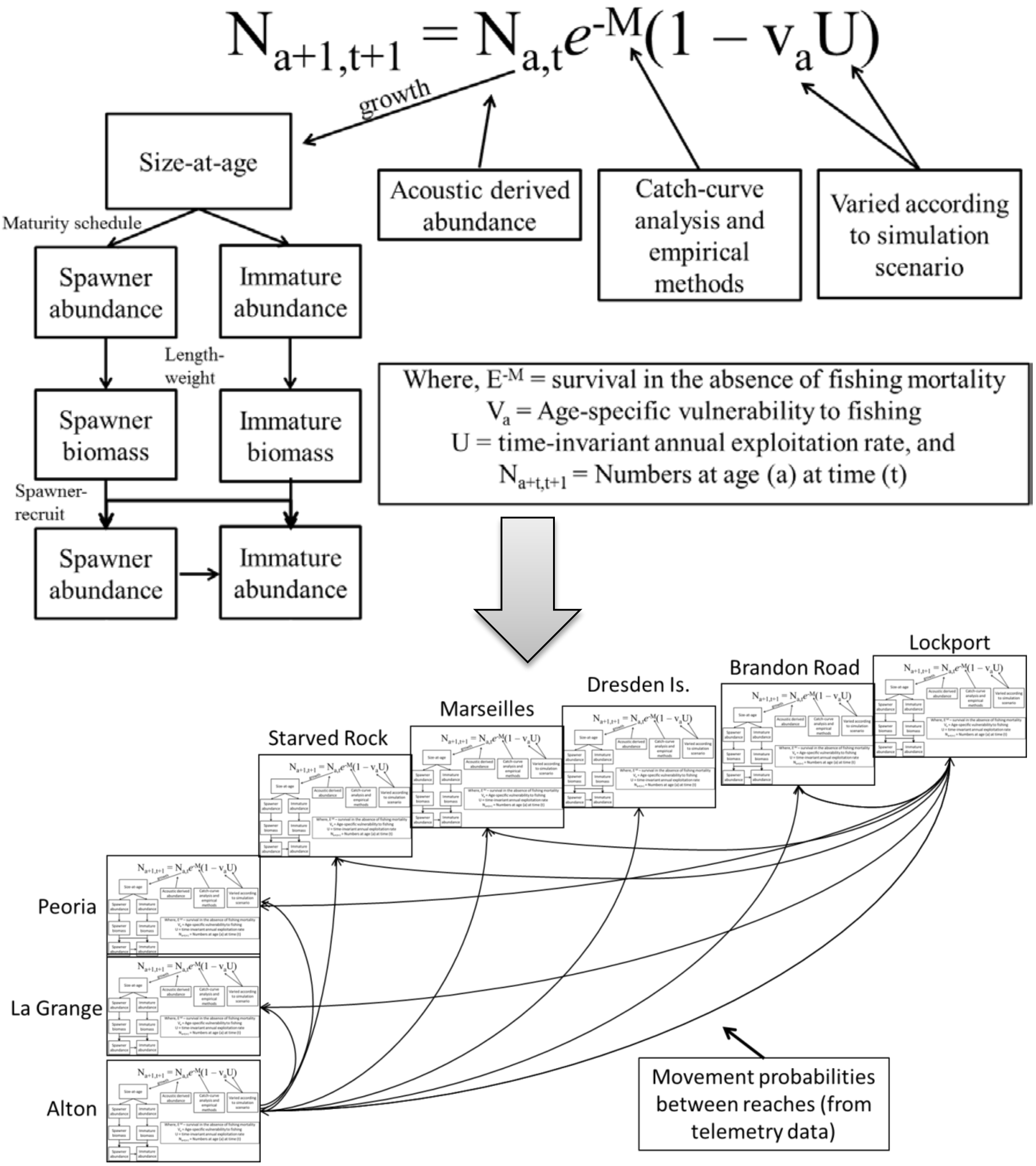

Figure 1. Structure of model Version 2.0.

Appendix C. Winter Barrier Defense Asian Carp Removal Project

Winter 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 Barrier. By decreasing Asian carp numbers, we anticipate decreased migration pressure towards the barrier 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 population abundance and movement between pools of the Illinois Waterway. The project was initiated in 2013 using ten contracted commercial fishing crews to remove Asian carp with large mesh (3.0 - 5.0 inch) trammel and gill nets and other gears on occasion (e.g., seines and hoop nets).

Objectives: Ten commercial fishing crews will be employed to:

3) 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
4) 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: Contract commercial fishing occurred in the target area of Dresden Island, Marseilles, and Starved Rock pools. Dresden Island Pool is located 10 miles downstream from the Electric Dispersal Barrier, Marseilles Pool is 24 miles downstream, and Starved Rock Pool is 51 miles downstream. This target area is closed to commercial fishing by Illinois Administrative Rule; therefore an IDNR biologist was required to accompany commercial fishing crews working in this portion of the river. Commercial Fishing was completed December 2012 – Early March 2013 as part of a winter harvest project. Five commercial fishing crews per week with assisting IDNR biologists fished 4 days of each week, 1-2 weeks each month of the field season. Due to fishing pressure driving fish out of areas and greatly reducing catches, harvest events were scheduled at every-other week intervals to allow fish to repopulate preferred habitats in between events. Fishing occurred in backwater areas known to hold Asian carp, main channel, and side channel 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) trammel and gill net were used and typically set 20-30 minutes with fish being driven to the nets with noise (e.g., pounding on boat hulls, hitting the water surface with plungers, running with motors tipped up). Nets were occasionally set overnight off the main channel, and non-public backwaters with no boat traffic. In addition to gill and trammel net, commercial seines were also used in the winter barrier defense project. Biologists enumerated and recorded the catch of Asian carp and identified by-catch to species. Asian carp and common carp were checked for ultrasonic tags and ultrasonic tagged fish and by-catch were returned live to the water. All harvested Asian carp were removed and transferred to a refrigerated truck and taken to a processing plant where they were used for non-consumptive purposes (e.g., converted to liquid fertilizer). Each harvest event a representative sample of up to 30 of each Asian carp species (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:
Contracted commercial fishing crews and IDNR biologists spent an estimated 1,755 person-hours, netting for Asian carp during winter barrier defense removal efforts. Effort equal to 69.6 miles of gill and trammel net and 1.8 miles of commercial seine were deployed in the upper Illinois Waterway (Table 1). The combined catch of Asian carp (Bighead, Silver, and Grass Carp) was 9,351 fish (Table 1). The total weight of Asian carp caught and removed from during the winter barrier defense program was 124,280.94 pounds or 62.1 tons (Table 1). Bighead Carp accounted for 28.4 %, Silver Carp accounted for 67.4% and Grass Carp accounted for 4.2% of the total winter barrier defense catch.

Catch of Asian Carp within Pools –

Dresden Island Pool:
A total of 240 Bighead Carp, 45 Silver Carp, and 5 Grass Carp were harvested from Dresden Island Pool (Table 1). 98% (N=235) of the Bighead Carp and 77.8% (N=35) of the Silver Carp harvest in the Dresden Island Pool came from Rock Run Rookery Lake. Rock Run Rookery Lake is an 84 acre lake, owned and operated by the Forest Preserve District of Will County, which sits just off the main river channel and is connected to the river by a small channel.

Marseilles Pool:
A total of 2,378 Bighead Carp, 3,588 Silver Carp, and 284 Grass Carp were harvested from the Marseilles Pool (Table 1). Four commercial seine hauls were completed as part of the winter barrier defense project. All four hauls were completed in the West Pit of the Hanson Material Services (HMS) a private backwater in the Marseilles Pool. The seine hauls accounted for

72.2% (N= 1,716) of the Bighead Carp, 59% (N= 2,115) of the Silver Carp and 9.5% (N= 27) of the Grass Carp catch from the Marseilles Pool.

Starved Rock Pool:
A total of 34 Bighead Carp, 2,671 Silver Carp, and 106 Grass Carp were harvested from the Starved Rock Pool (Table 1). Bighead Carp accounted for 0.20 tons harvested, Silver Carp accounted for 9.90 tons harvested and Grass Carp accounted for 0.70 tons harvested (Table 1).

Catch of By-Catch Species –
A total of 65,959 fish representing 31 species and 1 hybrid groups were caught in trammel and gill nets and commercial seine during the winter barrier defense Asian carp removal effort (Table 2). Gizzard Shad accounted for 66.35% of the total winter barrier defense catch. The large percentage of Gizzard Shad catch is from the commercial seine hauls (N =43,759) (Table 2). A total of 1417 fish from 10 species and 1 hybrid species made up the total game fish captured. Game fish represented 2.1 % of the total catch. *Morone* spp. (White Bass, Yellow Bass, and Hybrid Striped Bass) were the most dominate game fish captured, accounting for 75.2 % of the game fish captured

Project Highlights:

- Contracted commercial fishers and assisting IDNR biologists deployed 69.6 miles of net and 1.8 miles of commercial seine in the upper Illinois Waterway 2013.
- A total of 2,652 Bighead Carp, 6,304 Silver Carp, and 395 Grass Carp were removed by contracted netting. The total weight of Asian carp removed was 62.1 tons

Table 1: Commercial seine, gill and trammel netting effort and harvest of Asian carps from Dresden, Marseilles and Starved Rock pools during winter barrier defense using contracted commercial fisherman.

	Effort				Harvest							
Year and river Pool	Net Sets (*N*)	Miles of Net	Seine Hauls (*N*)	Miles of Seine	Bighead Carp (*N*)	Silver Carp (*N*)	Grass Carp (*N*)	Total (*N*)	Bighead Carp (tons)	Silver Carp (tons)	Grass Carp (tons)	Total (tons)
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	69.6	4	1.8	2,652	6,304	395	9,351	26.90	32.40	2.80	62.10

Table 2: Asian carp and by-catch captured in the Dresden Island , Marseilles and Starved Rock Pools of the upper Illinois waterway during winter barrier defense. All Species other than Asian carp and Common Carp were returned to the River immediately after capture.

	Seine Hauls		Gill/Tarmmel Net		Total	
	Number	Percent	Number	Percent	Number	Percent
Species	Captured	%	Captured	%	Captured	%
Bighead Carp	1716	3.09%	936	8.94%	2652	4.02%
Silver Carp	2115	3.81%	4189	40.03%	6304	9.56%
Smallmouth Buffalo	2629	4.74%	2265	21.65%	4894	7.42%
Bigmouth Buffalo	845	1.52%	842	8.05%	1687	2.56%
Common Carp	9	0.02%	1101	10.52%	1110	1.68%
Freshwater Drum	1529	2.76%	368	3.52%	1897	2.88%
Flathead Catfish			25	0.24%	25	0.04%
Channel Catfish	106	0.19%	95	0.91%	201	0.30%
Black Buffalo	8	0.01%	56	0.54%	64	0.10%
Grass Carp	27	0.05%	368	3.52%	395	0.60%
Paddlefish						
River Carpsucker	567	1.02%	23	0.22%	590	0.89%
Quillback	994	1.79%	18	0.17%	1012	1.53%
Largemouth Bass	30	0.05%	15	0.14%	45	0.07%
Sauger			3	0.03%	3	< 0.01%
Shortnose Gar	7	0.01%	19	0.18%	26	0.04%
White Bass	431	0.78%	2	0.02%	433	0.66%
Longnose Gar	2	< 0.01%	70	0.67%	72	0.11%
Walleye						
Skipjack Herring			1	0.01%	1	< 0.01%
Blue Catfish			1	0.01%	1	< 0.01%
Gizzard Shad	43759	78.85%	7	0.07%	43766	66.35%
Yellow Bass	624	1.12%	1	0.01%	625	0.95%
Hybrid Striped Bass	3	0.01%	4	0.04%	7	0.01%
Spotted Gar			1	0.01%	1	< 0.01%
White Crappie	37	0.07%	1	0.01%	38	0.06%
Bluegill						
Black Crappie	38	0.07%			38	0.06%
Shorthead Redhorse						
Golden Redhorse	3	0.01%	1	0.01%	4	0.01%
River Redhorse						
Rock Bass						
Muskellunge						
Northern Pike						
Common Carp x Goldfish Hybrid						
Mooneye						
Goldeye	1	< 0.01%			1	< 0.01%
Goldfish			4	0.04%	4	0.01%
Unidentified Buffalo Species			45	0.43%	45	0.07%
White Perch	16	0.03%	1	0.01%	17	0.03%
Bowfin						
Blue Sucker			1	0.01%	1	< 0.01%
White Perch Hybrid						
Smallmouth Bass			1	0.01%	1	< 0.01%
Total all Species	55496		10464		65960	

Appendix D. Training, certification, pilot incentive, marketing and removal research project for the long-term strategy in reducing and controlling Asian Carp populations

Training, certification, pilot incentive, marketing and removal research project for the long-term strategy in reducing and controlling Asian Carp populations.

Completion Report to the

Illinois Department of Natural Resources

November 2013

Prepared by:

Wes Bouska

Center for Fisheries, Aquaculture, and Aquatic Sciences

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INTRODUCTION

Examples of commercially valuable fish stocks being depleted through overfishing abound. Overexploitation has threatened paddlefish *Polyodon spathula* fisheries in the U.S. (Bettoli et. al 2009), destroyed the Atlantic cod *Gadus morhua* fishery of the North Atlantic (Hutchings and Myers 1994), the Pacific sardine *Sardinops sagax* fishery of California (Helfman et. al 2009), the Peruvian anchoveta *Engraulis ringens* fishery in Peru (Helfman et. al 2009), and many others. It has been estimated that over half of commercially valuable marine fisheries are in need of rebuilding (Worm et. al 2009). Inland waters are not immune to overfishing (Allan et. al 2005). Within the U.S., many historically lucrative commercial fisheries have closed due to overfishing (Quinn 2009). Our ability to decimate fisheries is well documented, but examples of using exploitative fishing practices to successfully control invasive species are less common.

Asian carp is a collective term for silver carp *Hypopthalmichthys molitrix*), bighead carp *Hypopthalmichthys nobilis*, grass carp *Ctenopharyngodon idella*, and black carp *Mylopharyngodon piceus*. These fish most likely escaped from aquaculture and sewage treatment ponds in Arkansas and elsewhere in the 1970's, the result of a misguided campaign by the Department of Agriculture to promote these fish as a non-chemical means of improving water quality. Asian carp have since spread through much of the Mississippi River basin (Tucker et. al 1996). Asian carp, primarily silver and bighead carp, became common in the Illinois River in the late 1990's (Chick and Pegg 2001). Presently, these invaders now dominate the fish community in the Illinois River (Garvey et. al 2013). Mobile hydroacoustic surveys of the Illinois River in 2011 and 2012 have conservatively estimated that Asian carp now account for more than 60% of the total fish biomass in the river system (Garvey et. al 2013).

As filter feeders, Asian carp do compete for resources with native fishes like paddlefish, gizzard shad *Dorosoma cepedianum*, and bigmouth buffalo *Ictiobus cyprinellus*, and studies have shown reduced fitness in these native species where they share habitat with Asian carp (Irons et. al 2007; Schrank et. al 2003). Perhaps of most concern is the possibility that Asian carp will migrate into the Laurentian Great Lakes via the Chicago Sanitary and Shipping Canal, a man-made connection between the Mississippi River Basin and the Great Lakes Basin. Although the impacts of Asian carp establishing populations in the Great Lakes are unknown and there is debate about whether Asian carp could establish thriving populations within the Great Lakes (e.g., Kolar and Lodge 2002, Cooke and Hill 2010, Rasmussen et al. 2011), these species could jeopardize important commercial and recreational fisheries. In addition to the ecological threats posed by Asian carp, their erratic leaping behavior (> 3 m out of the water) that is exhibited when disturbed by vibrations such as a motor boat driving by, also poses a risk to public safety.

In order to reduce Asian carp abundance, to improve conditions for native fishes, and to reduce the likelihood of Asian carp migrating towards the Great Lakes, an enhanced Asian carp commercial harvesting strategy was developed and implemented through collaborations among commercial fishermen, processors, researchers (e.g., Illinois Natural History Survey and State Universities), agencies (e.g., Sea Grant, IL Department of Natural Resources, IL Department of Economic Opportunity), and fisheries managers. Asian carp populations were monitored to provide information about the impact of commercial harvest and potential responses of the populations to increased harvest as marketing efforts are implemented.

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Component 1: Pilot training, certification, and incentive program

To fulfill the first component of the harvesting strategy, the Center for Fisheries, Aquaculture, and Aquatic Sciences (CFAAS), Southern Illinois University, instituted a training, certification, and incentive program to support the removal of Asian carp throughout the Mississippi and Illinois River systems via Illinois licensed commercial fishermen.

METHODS:

A list of commercial fishermen interested in participating in an Asian carp training, certification and incentive program was developed with input from the Illinois Commercial Fishing Association (ICFA), and a lottery was used to select the finalists. The training and certification program included training on safe handling of Asian carp for consumption in foreign and domestic markets, how to properly license and safely operate a commercial fishing fleet, and how to coordinate and communicate Asian carp harvest data to other stakeholder groups.

A pilot program was completed in spring 2011 and evaluated with input from the ICFA, the CFAAS, the participant fishermen, and IDNR to develop and implement a full incentives program for fishing Asian carp that began in summer/fall 2011. Following training and certification, those fishermen who proved to be the most proficient at removing Asian carp became eligible for incentives to aid them in quickly and efficiently meeting growing market demand. For participating fishermen enrolled in the incentives program, the cost of membership to the ICFA, the commercial fishing license fee, certification training fee, and commercial fishing tag fees were all waived. Furthermore, participating fishermen were given a $1,000 bonus to help pay for fuel and net costs after they removed 50,000 pounds of Asian carp, and another bonus of $3,000 after 100,000 pounds of Asian carp were removed. Commercial fishermen enrolled in the incentives program were issued a handheld GPS device and were required to report to CFAAS the locations from which the Asian carp were being removed.

RESULTS AND DISCUSSION:

The pilot training and certification program successfully identified a group of ten commercial fishermen and their deckhands who were most proficient at harvesting Asian carp. These fishermen were then chosen to participate in the full incentives program that began in the Summer of 2011. Although the fishermen were successful in removing Asian carp from the Illinois River, the data collection goals of the incentives program were not fully achieved. Specifically, commercial fishermen were wary to report to CFAAS important data such as fishing location (GPS coordinates), despite their eligibility for cash incentives, and despite knowing before they joined the incentives program what their obligations would be. It is suspected that these fishermen ultimately placed a greater value on their proprietary information (i.e. fishing locations and methods) than what they could gain from the incentives by fully participating in the program, suggesting that the incentives package was too low to achieve full compliance.

Of the ten commercial fishermen enrolled in the incentives program, harvest data was collected from only five fishermen, of which only three fully participated. These three fishermen provided GPS locations and dates of their fishing efforts, harvested a combined total of 496,859 pounds of Asian carp from the Illinois River, and received a total of $8,000 in incentive payments (Table 1). Although these three fishermen technically fulfilled the obligations of the incentive program, review showed the GPS coordinates provided by the fishermen were typically those of the boat access ramp at which they launched, delivering little if any information to managers on specific removal locations. The other two fishermen for which data was available harvested a total 97,343 lbs. of Asian carp, but no GPS coordinates were provided. Overall harvest of Asian carp by fishermen enrolled in this program was 594,202 lbs., and was composed of approximately 83% silver carp and 17% bighead carp.

If future incentives programs are considered, better communication must be established between the commercial fishermen and the data collecting agency to ensure that participating fishermen know and fulfill their obligations. It may also be necessary to increase incentive amounts to make participation more attractive to commercial fishermen for full program compliance.

Table 1. Commercial fishermen who fully participated in the incentive fishing program including harvest information, processor information, and fishing coordinates. Bolded row indicates when harvest requirements were met for incentive payments.

Fisherman	License #	Processor	Delivery Date	lbs SVCP	lbs BHCP	lbs total	GPS N	GPS W
O. Briney	945	Schafer	11/01/11	6389	753	7142	41.06.648	89.21.113
O. Briney	945	Schafer	11/02/11	8202	190	8392	40.45.234	89.33.505
O. Briney	945	Schafer	11/04/11	4528	377	4905	40.45.228	89.33.879
O. Briney	945	Schafer	11/07/11	4209	100	4309	40.45.223	89.33.520
O. Briney	945	Schafer	11/08/11	5004	3350	8354	40.06.444	89.21.367
O. Briney	945	Schafer	11/09/11	5315	561	5876	40.42.059	89.34.305
O. Briney	945	Schafer	11/11/11	6438	1193	7631	41.06.495	89.21.365
O. Briney	**945**	**Schafer**	**11/14/11**	**5038**	**330**	**5368**	**40.45.225**	**89.33.516**
O. Briney	945	Schafer	11/15/11	1989	1336	3325	40.01.450	89.24.894
O. Briney	945	Schafer	11/16/11	7002	1085	8087	41.06.650	89.21.107
O. Briney	945	Schafer/B.R.	11/21/11			5479	41.01.502	89.24.893
O. Briney	945	Schafer	11/22/11			0	41.01.502	89.24.887
O. Briney	945	Schafer	11/23/11	11464	4386	15850	41.06.495	89.01.367
O. Briney	**945**	**Schafer**	**11/25/11**	**15536**	**2219**	**17755**	**41.064.492**	**89.21.362**
O. Briney	945	Schafer	11/28/11	4138	35	4173	41.06.495	89.21.331
O. Briney	945	Schafer	11/30/11	8891	1931	10822	41.06.500	89.21.336
O. Briney	945	Schafer	12/06/11	5809	1907	7716	41.06.502	89.21.337
O. Briney	945	Schafer	12/07/11	7671	2410	10081	41.06.500	89.21.35
O. Briney	945	Schafer	12/08/11	10185	1745	11930	41.06.502	89.21.337
O. Briney	945	Schafer	12/08/11				41.06.500	89.21.337
O. Briney	945	Schafer	12/09/11	4361	850	5211	41.06.502	89.21.337
O. Briney	945	Schafer	12/09/11	4361	830	5191	41.06.502	89.21.337
O. Briney	945	Schafer	12/12/11	8182	1252	9434	40.45.221	89.33.575
O. Briney	945	Schafer	12/13/11	11317	94	11411	40.54.919	89.28.967
O. Briney	945	Schafer	12/14/11	3029	511	3540	40.42.047	89.34.310
O. Briney	945	Schafer	12/15/11	5162	434	5596	40.42.066	89.34.300
O. Briney	945	Schafer	12/19/11	8033	77	8110	41.06.500	89.21.335
O. Briney	945	Schafer	12/20/11	7922		7922	41.06.500	89.21.335
O. Briney	945	Schafer	12/22/11	5836	2564	8400	41.11.282	89.977
O. Briney	945	Schafer	12/26/11	9536	813	10349	39.52.225	90.32.981
O. Briney	945	Schafer	12/28/11	4341	941	5282	41.06.497	89.21.335
O. Briney	945	Schafer	12/29/11	1785	1556	3341	41.06.497	89.21.335
O. Briney	945	Schafer	12/29/11	4804	1653	6457	41.06.497	87.21.335
L. Gregerson	4037	Big River	10/31/11			1552	40.00.956	90.26.510

Table 1 continued.

Fisherman	License #	Processor	Delivery Date	lbs SVCP	lbs BHCP	lbs total	GPS **N**	GPS **W**
L. Gregerson	4037	Big River	11/05/11			2446	40.19.094	90.03.647
L. Gregerson	4037	Big River	11/12/11			2957	40.03.831	90.25.593
L. Gregerson	4037	Big River	12/05/11			11424	GPS error	Bath, IL
L. Gregerson	4037	Big River	12/10/11	4316	1598	5914	40.11.490	90.09.734
L. Gregerson	4037	Big River	12/12/11			6922	40.05.879	90.25.387
L. Gregerson	4037	Big River	12/17/11	3137	825	3962	40.11.526	90.08.703
L. Gregerson	4037	Big River	12/19/11	4690	760	5450	40.05.878	90.25.387
D. Riley	217	Schafer	11/04/11	4528	377	4905	40.45.228	89.33.879
D. Riley	217	Schafer	11/07/11	4209	100	4309	40.45.223	89.33.520
D. Riley	217	Schafer	11/08/11	5004	3350	8354	40.06.444	89.21.367
D. Riley	217	Schafer	11/09/11	5315	561	5876	40.42.059	89.34.305
D. Riley	217	Schafer	11/14/11	5038	330	5368	40.45.225	89.33.516
D. Riley	217	Schafer	11/15/11	1989	1336	3325	40.01.450	89.24.894
D. Riley	217	Schafer	11/16/11	7002	1085	8087	41.06.650	89.21.107
D. Riley	217	Schafer/B.R.	11/21/11			5479	41.01.502	89.24.893
D. Riley	**217**	**Schafer**	**11/23/11**	**11464**	**4386**	**15850**	**41.06.495**	**89.01.367**
D. Riley	217	Schafer	11/25/11	15536	2219	17755	41.06.492	89.21.362
D. Riley	217	Schafer	11/28/11	4138	35	4173	41.06.495	89.21.331
D. Riley	217	Schafer	11/30/11	8891	1931	10822	41.06.500	89.21.336
D. Riley	**217**	**Schafer**	**12/01/11**	**6389**	**753**	**7142**	**41.06.648**	**89.21.113**
D. Riley	217	Schafer	12/06/11	5809	1907	7716	41.06.502	89.21.337
D. Riley	217	Schafer	12/07/11	7671	2410	10081	41.06.500	89.21.35
D. Riley	217	Schafer	12/08/11	10185	1745	11930	41.06.502	89.21.337
D. Riley	217	Schafer	12/12/11	8182	1252	9434	40.45.221	89.33.575
D. Riley	217	Schafer	12/13/11	11317	94	11411	40.54.919	89.28.967
D. Riley	217	Schafer	12/14/11	3029	511	3540	40.42.047	89.34.310
D. Riley	217	Schafer	12/15/11	5162	434	5596	40.42.066	89.34.300
D. Riley	217	Schafer	12/16/11	4903	245	5148	41.01.501	89.24.891
D. Riley	217	Schafer	12/19/11	8033	77	8110	41.06.500	89.21.335
D. Riley	217	Schafer	12/20/11	7922		7922	41.06.500	89.21.335
D. Riley	217	Schafer	12/22/11	5836	2564	8400	41.11.282	89.977
D. Riley	217	Schafer	12/26/11	9536	813	10349	39.52.225	90.32.981
D. Riley	217	Schafer	12/28/11	4341	941	5282	41.06.497	89.21.335
D. Riley	217	Schafer	12/29/11	4804	997	5801	41.06.497	89.21.335
D. Riley	217	Schafer	12/30/11	3516	3112	6628	40.03.876	90.25.627
Total				388369	72231	496859		

Component 2: Population Metrics of Commercially Caught Asian Carp, the Ecological Effectiveness of Asian Carp Removal and the Commercial Suitability of Carp Meal.

The second commercial harvest component was conducted independently of the certification and incentives project and fishermen were not eligible for harvest incentives. The second component was a targeted, research-oriented fishing effort to understand the ecological effectiveness of Asian carp harvest, and to determine the commercial suitability of Asian carp fish meal for inclusion in aquafeeds. Prior to the implementation of this harvest component, CFAAS initiated an ongoing standardized sampling program in the Illinois River that includes electrofishing, trammel netting, and split-beam hydroacoustic surveys, allowing comparisons of Asian carp population metrics in the river pre- and post-harvesting efforts (Garvey et al. 2013).

The Asian carp removed through this research component were processed into fish meal that was delivered to CFAAS. Portions of this meal were used in feed inclusion experiments and remaining fish meal was sold to private markets, with revenue generated used for the express purpose of conducting further research or aiding in Great Lakes restoration (Appendix 1).

The taxonomic, seasonal, and geographic variation in nutritional composition of bighead and silver carp were determined to assess their suitability for rendering and subsequent use as a protein source in aquafeeds. This data has since been published in peer-reviewed literature (Bowzer et al. 2013; Appendix 2).

METHODS:

Through a competitive bidding process, Big River Fish Company, a processing plant in Pearl, IL, was selected to hire and pay licensed Illinois commercial fishermen to harvest at least one million pounds of Asian carp from the lower three reaches of the Illinois River (Alton, La Grange, and Peoria). Researchers from the CFAAS visited the processing plant approximately every two weeks from 1 February 2012 thru 8 May 2012 while fishing was occurring, and collected data from harvested bighead and silver carp. During each visit, up to 100 silver carp and 100 bighead carp from each IL river reach were randomly selected from the delivered commercial harvest. Fish were weighed and measured, additionally, post-cleithra for age determination, sex, and gonad weights were collected from a subsample of up to five fish of each species and each reach within 50-mm total length group intervals.

Mean length-at-age

Post-cleithra were sectioned transversely across the center with a Buehler 1.5 amp diamond-blade low-speed isomet saw following Johal et al. (2000). Sections were read by two independent readers using side illumination from a Dolan-Jenner MI-150 fiber optic light; if disagreements between readers could not be resolved the age was omitted from analyses. Age distributions were developed for the entire sample using an age-length key. Silver carp and bighead carp mean length-at-age was compared among reaches using a two-way analysis of variance (ANOVA). Comparisons were made for age classes 2.5 through 8.5 for silver carp and 2.5 through 11.5 for bighead carp. If the F-test detected significant differences, post-hoc t-tests were conducted to determine where differences existed. A two-way ANOVA was also used to compare mean length-at-age between silver carp harvested by commercial fishermen and silver carp collected by electrofishing in 2012 (Garvey et al. 2013).

Length-weight relationships

Length-weight relationships were developed for commercially caught silver and bighead carp within each reach as well as all reaches combined after $\log_{10}$-transforming weight and total length 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 using an analysis of covariance (ANCOVA).

Mortality

The types of commercial gears used by commercial fishermen were varied and generally not reported. Examination of the catch data appeared to show gear selectivity towards larger individuals. Because the statistical models used to estimate mortality assume the sampling gear adequately represents the standing length distribution of the population, an accurate estimate of mortality could not be developed from commercially harvested Asian carp data (Miranda and Bettoli, 2007).

Indices of spawning condition

Commercially harvested Asian carp were collected before the spawning period. As such, we tested for changes in gonadosomatic index (GSI) as a function of TL for female silver and bighead 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 commercially harvested Asian carp were investigated within and among reaches. A chi-squared goodness of fit analysis was conducted to determine whether overall sex ratios differed from 1:1, and a chi-squared test of independence tested whether the sex ratios differed spatially among reaches. All statistical analyses were conducted using SAS 9.2. (SAS Institute 2009).

RESULTS AND DISCUSSION:

The initial goal of harvesting 1 million pounds of Asian carp to be processed into fish meal was quickly surpassed, and by the completion of this component, nearly 3 million pounds of Asian carp were removed and processed. Between 25 January 2012 and 11 June 2012, commercial fishermen harvested 1,776,656 pounds of Asian carp from the Alton reach, 493,636 pounds from the La Grange reach, and 609,708 pounds from the Peoria reach, for a total of 2.88 million pounds (Figure 1).

Researchers from CFAAS weighed and measured 2,778 Asian carp (1,761 silver and 1,017 bighead). Of these fish, 662 were sexed, and GSI's were calculated for 298 fish. Post cleithra were removed and aged from 292 fish (133 silvers, 159 bighead).

Mean length-at-age

Mean length-at-age for silver carp harvested by commercial fishermen differed significantly among reaches for most age classes ($P < 0.05$; Figure 2). Mean length-at-age was significantly higher than all other reaches for fish harvested from the Peoria reach for age classes 2.5, 3.5, and 4.5. In age classes 5.5, 6.5, and 7.5, mean length-at-age tended to be highest in the Alton reach. Mean length-at-age was actually quite homogenous for fish harvested from the Peoria reach, ranging from 613-694 mm TL across all sampled age classes, indicating a bias in commercial gears towards larger fish.

Comparisons of mean length-at-age from commercially harvested silver carp and those collected from electrofishing in 2012 further demonstrated the size selectivity of commercial gears. Commercially harvested fish had significantly greater mean lengths-at-age compared to silver carp collected with electrofishing for all age classes and reaches ($P < 0.05$) except for age-6.5 in the Peoria and La Grange reaches, where although mean TL was larger in commercially caught fish, it was not significant (Figure 3).

Due to low sample sizes of bighead carp collected during standardized sampling, we did not compare their mean length-at-age to commercially caught bighead carp. Comparisons of mean length-at-age of commercially harvested bighead carp among reaches showed harvested bighead carp tended to have greater mean TL from the Alton pool up to age 7.5,with no differences among reaches observed after age 7.5 (Figure 4).

Age and length frequency of harvested Asian carp

Over 25% of commercially harvested silver carp were age 5.5 and older, compared to just over 7% of silver carp collected during standardized electrofishing (Figure 5). The length frequency histogram comparing commercial harvest to standardized sampling shows a bimodal distribution of commercially caught silver and bighead carp for most reaches and for all reaches combined (Figure 6). This suggests that not only are commercial fishermen harvesting more larger, older fish, compared to our standardized sampling, but they are also harvesting the largest fish within younger age classes. This is supported by the lack of a bimodal distribution in the age-frequency histogram of commercially harvested fish (Figure 5).

These data indicate that commercial fishermen are successfully removing larger and older individuals from the population. While standardized sampling does not collect as many of these larger fish, the length-frequency histograms developed from that sampling are likely a better representation of the population size-structure as a whole. Continued monitoring of the age and length-frequency of commercially harvested fish and continued standardized sampling in the IL River will further help us to determine the efficacy of electrofishing as a tool for estimating size structure of Asian carp populations, and the efficacy of commercial fishing in controlling the Asian carp population as a whole. Commercial harvest modeling has suggested that in order to deplete Asian carp populations in the IL River, all age classes must be targeted for removal (Tsehaye et al. 2013). Currently, it does not appear that commercial removal of smaller Asian carp is occurring.

Length-weight relationships

Analysis of covariance indicated that the intercept and slope of the length-weight relationships were significantly different among reaches for commercially caught silver carp (slope: $F_{2, 1752}$ = 90.76; P < 0.0001; intercept: $F_{2, 1752}$ = 90.74; P < 0.0001), and bighead carp (slope: $F_{2, 1006}$ = 0.077; P < 0.0001; intercept: $F_{2, 1006}$ = 0.078; P < 0.0001; Table 1). Specifically, silver carp length-weight relationship parameters were different among all reaches (P < 0.05), with smaller TL silver carp in the Alton and Peoria reaches being generally heavier than those in the La Grange reach, and longer TL silver carp being heaviest in the La Grange reach, and least heavy in the Alton reach. These same differences in length-weight relationships by reach were also observed in the 2012 standardized sampling data (Garvey et al. 2013). Bighead carp length-weight relationship parameters differed among Alton and Peoria reaches, but not between Alton and La Grange, or between La Grange and Peoria. Specifically, smaller TL bighead carp tended to be heavier in the Peoria reach compared to the Alton reach, while larger TL bighead carp were heavier in the Alton reach compared to the Peoria reach (Table 1). Comparisons of bighead carp length-weight trends in commercial catches to standardized sampling was not attempted due to low sample size. Future research may want to investigate habitat or forage differences among reaches that may better explain the observed differences in fitness between different size classes of silver and bighead carp among reaches

Indices of spawning condition

The size at which variation in commercially harvested female silver carp GSI increased, such that the probability of having a higher GSI increased, was 506-mm TL for the Alton reach (P = 0.026), and was indicative of the size at maturity. Based on our age-length key, these estimates correspond to an age-at-maturity between age 3 and 4. For the Peoria and La Grange reaches, female silver carp variation in GSI was statistically homogenous across TL (P = 0.09; 0.671) respectively. This could be an artifact of low sample size and a lack of GSI values for multiple size classes of fish (in the Peoria reach, GSI values were only available for female silver carp >700 mm TL). Mean GSI of commercially harvested female silver carp ranged from 0.016 (SE = 0.0033) to 0.022 (SE = 0.0054) among reaches (Table 2). Mean GSI for female silver carp from 2012 standardized sampling ranged from 0.0017 (SE = 0.0028) to 0.0064 among reaches. These fish were collected post-spawn, which is reflected in their lower GSI values. However, the estimated size at maturity for commercially caught silver carp, pre-spawn, was comparable to the estimates made for fish collected during standardized sampling, post-spawn (Garvey et al. 2013).

The size at which variation in female bighead carp GSI increased, such that the probability of having a higher GSI increased, was 674-mm TL for the Alton reach (P = 0.002), and 636-mm TL for the La Grange reach (P = 0.001) and was indicative of the size at maturity. Based on our age-length key, these estimates correspond to an age-at-maturity between age 3 and 4. For the Alton reach, female bighead carp variation in GSI was statistically homogenous across TL (P = 0.209) potentially due to small sample size (N = 15) and lack of small, immature individuals in which we would expect to see low GSI values with low variation. Mean GSI for female bighead carp ranged from 0.0142 (SE = 0.0042) to 0.0149 (SE = 0.0049) among reaches (Table 5). Standardized sampling activities have not historically collected enough female bighead carp to make comparisons of GSI to the commercial catch.

Future efforts should include increasing our sample size and our confidence in these values. Continued monitoring of GSI in Asian carp populations in the Illinois River will be important in determining trends in reproductive success.

Sex ratio of Asian carp

Sex ratios were not significantly different from 1:1 for commercially harvested silver carp when all reaches were combined (217 females, 236 males; χ_1^2 = 0.80; *P* = 0.398) but did differ from 1:1 when reaches were treated separately (χ_2^2 = 12.68; *P* = 0.002). Specifically, the Alton and La Grange commercial catches were composed of roughly 55% males and 45% females, whereas the Peoria reach was 63% male and 37% female for a 1.73:1 ratio.

Sex ratios of commercially harvested bighead carp also did not differ from 1:1 when all reaches were combined (95 females, 114 males; χ_1^2 =1.727; *P* = 0.213). Bighead carp sex ratios did not significantly differ from 1:1 among reaches (χ_2^2 = 4.67; *P* = 0.099) although there tended to be more females harvested in the Alton reach, and more males harvested in the La Grange and Peoria reaches. Given the tendency for commercial gears to harvest larger fish, it was counter to our expectations that commercial catches did not harvest proportionately more females, particularly larger females from younger age classes. It will be important to continue monitoring sex ratios in the future to make inferences about the potential intrinsic rate of increase of Asian carp abundance.

Catch per unit effort pre and post harvest

We observed a 33% reduction in silver carp electrofishing CPUE for the three lower reaches of the Illinois River combined, from 151.9 fish/hour (SE = 19.7) in summer 2011 (before harvest component 2) to 102.1 fish/hour (SE = 22.8) in summer 2012, after the harvest component (*P* = 0.0027; Figure 7). By reach, silver carp mean CPUE was significantly reduced from 2011 to 2012 in the Alton reach by more than half (*P* = 0.0007), but was not different between years for the La Grange reach (*P* = 0.07) or the Peoria reach (*P* = 0.59) despite a trend of lower CPUE in both of these reaches. The reduction in CPUE may indicate that commercial removals are lowering silver carp abundance in the Illinois River. Reduced abundance of silver carp may also be related to water level fluctuations in the Illinois River over the last two years. Specifically, the summer of 2011 was characterized by above-average precipitation and high water levels. In contrast, 2012 was an abnormally dry year, and water levels on the Illinois River were significantly lower, which could have triggered an emigration of silver carp out of the system.

Electrofishing CPUE for bighead carp was not different from 2011 to 2012 for the lower three reaches of the Illinois River combined or among reaches ($P \geq 0.28$). Despite the lack of statistical difference between years, overall bighead carp CPUE was reduced from 2.9 fish/hr in 2011 to 0.3 fish/hr in 2012 among all reaches. The relatively low abundance of bighead carp along with the variability in catch rates, to some extent due to our inefficiency at capturing bighead carp, is likely the reason for not detecting differences in CPUE between years. Specifically, of the 2.88 million lbs. of Asian carp harvested in the three lower reaches of the Illinois River in Spring 2012 for conversion to fish meal, 45% was composed of bighead carp. As such, we would have expected strong declines in relative abundance of bighead carp. Additional analyses regarding total catches from commercial fishermen brought to processing plants, and continued monitoring by our standardized sampling program may provide a better indication of whether declines in bighead carp and silver carp abundance are occurring, or will continue to occur.

Discussion Points:

While a limited number of commercial fishermen reported using seines, which would harvest all sizes of Asian carp, the majority of fishermen used gill or trammel nets to target larger fish (personal communication). This selectivity for larger fish was apparent when comparing age frequencies, length frequencies, and mean length at age of commercially caught Asian carp to those caught by electrofishing during standardized sampling. Standardized sampling is limited in its ability to collect as many large fish as commercial gears, but the data that is collected is likely more representative of the population as a whole. Additional monitoring may be necessary to determine whether larger fish in the population are underrepresented in our standardized sampling regimen, and to investigate whether the lack of strong recruitment in recent years could also have facilitated some of our observed results. Continued population and harvest monitoring will help us to determine what compensatory responses Asian carp populations may experience as a result of ongoing fishing pressures.

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Table 1. Parameter values from the length-weight relationships ($\log_{10}\text{mass} = a' + b \cdot \log_{10}\text{TL}$) for commercially caught silver carp and bighead carp from the lower three reaches of the Illinois River, 2012. Parameter estimates with different letters indicate significantly different values among reaches at the α = 0.05 level, as determined by ANCOVA.

Reach	*a*'	SE	*b*	SE	R^2	*P*	*N*
			Silver carp				
Alton	-4.552[a]	0.101	2.845[a]	0.036	0.91	<0.0001	646
La Grange	-5.806[b]	0.074	3.294[b]	0.027	0.96	<0.0001	580
La Grange*	-5.294	-	3.122	-	-	<0.001	1,451
Peoria	-3.237[c]	0.173	2.374[c]	0.061	0.74	<0.0001	526
			Bighead carp				
Alton	-4.123[a]	0.104	2.688[a]	0.036	0.94	<0.0001	338
La Grange	-4.723[ab]	0.074	2.889[ab]	0.026	0.97	<0.0001	382
La Grange*	-4.838	-	2.952	-	-	<0.001	73
Peoria	-3.878[b]	0.164	2.592[b]	0.057	0.88	<0.0001	286

* Results from Irons et al. (2007) for comparison purposes to data collected from the La Grange reach from 1990-2006.

Table 2. Mean gonadosomatic index (GSI) for commercially harvested bighead carp and silver carp by reach and sex in the Illinois River, 2012.

Species	Sex	*N*	Mean GSI	SE
		Alton		
Bighead carp	F	32	0.0148	0.0034
Bighead carp	M	30	0.0019	0.0003
Silver carp	F	38	0.0160	0.0033
Silver carp	M	23	0.0042	0.0018
		La Grange		
Bighead carp	F	20	0.0142	0.0042
Bighead carp	M	36	0.0019	0.0003
Silver carp	F	26	0.0165	0.0042
Silver carp	M	20	0.0042	0.0019
		Peoria		
Bighead carp	F	15	0.0149	0.0049
Bighead carp	M	26	0.0019	0.0003
Silver carp	F	7	0.0220	0.0054
Silver carp	M	24	0.0043	0.0018

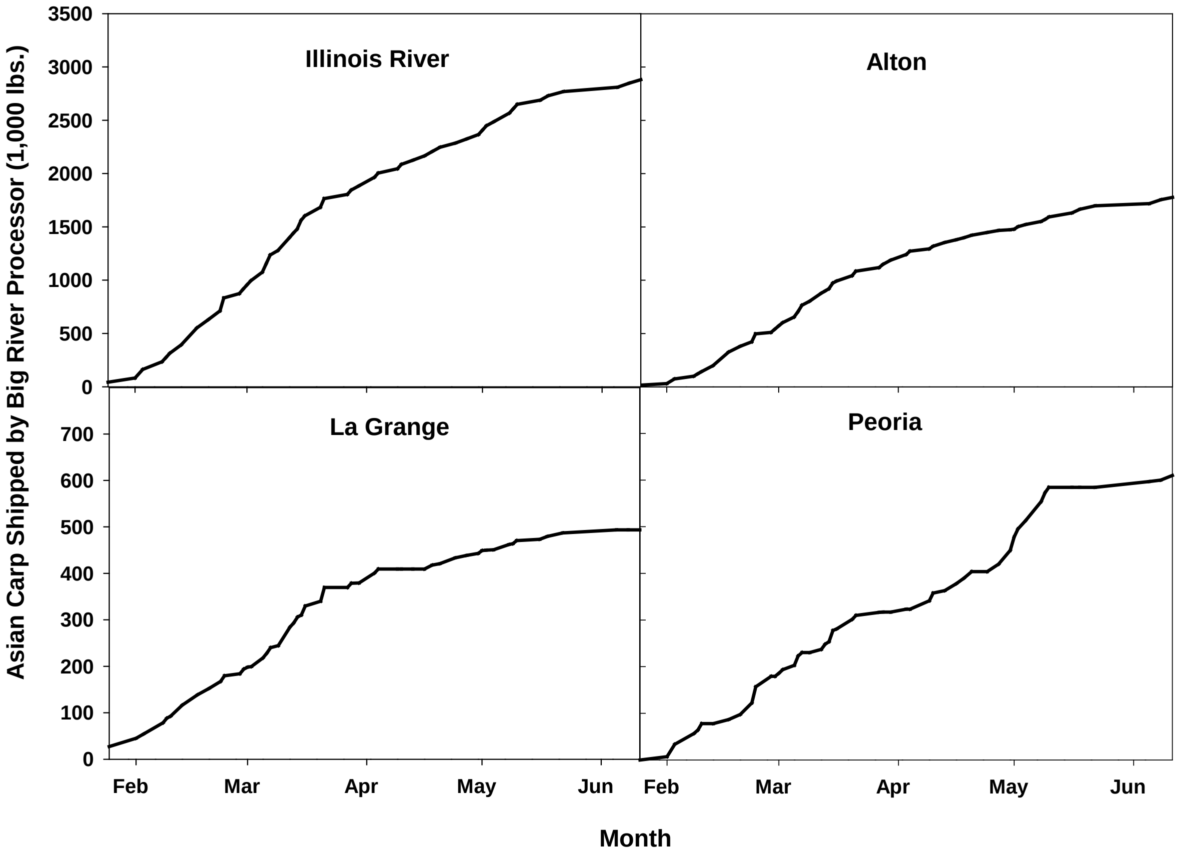

Figure 1. Cumulative commercial harvest of Asian carp for fish meal production by reach and month, IL River, 2012.

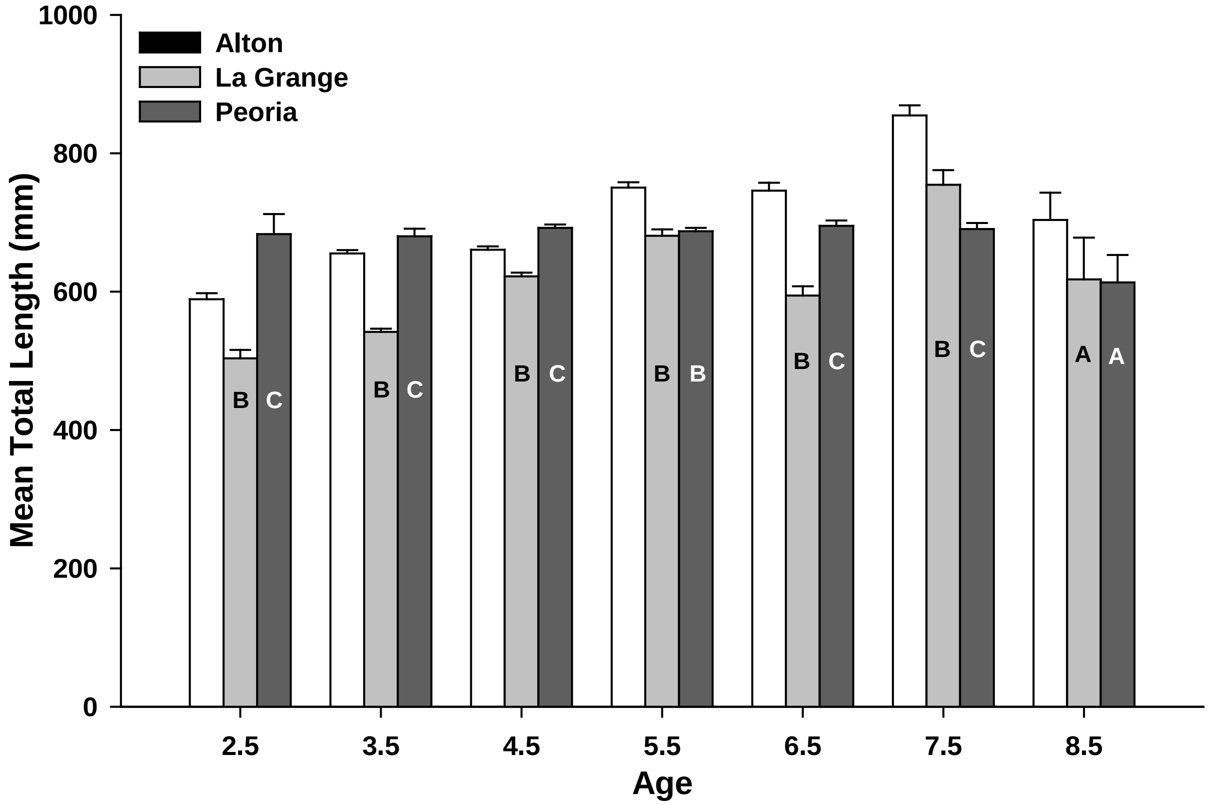

Figure 2. Mean length-at-age with associated standard error for commercially caught silver carp in the three lower reaches of the Illinois River; different letters indicate significantly different mean total lengths among reaches ($P \leq 0.05$), as determined by a two-way ANOVA.

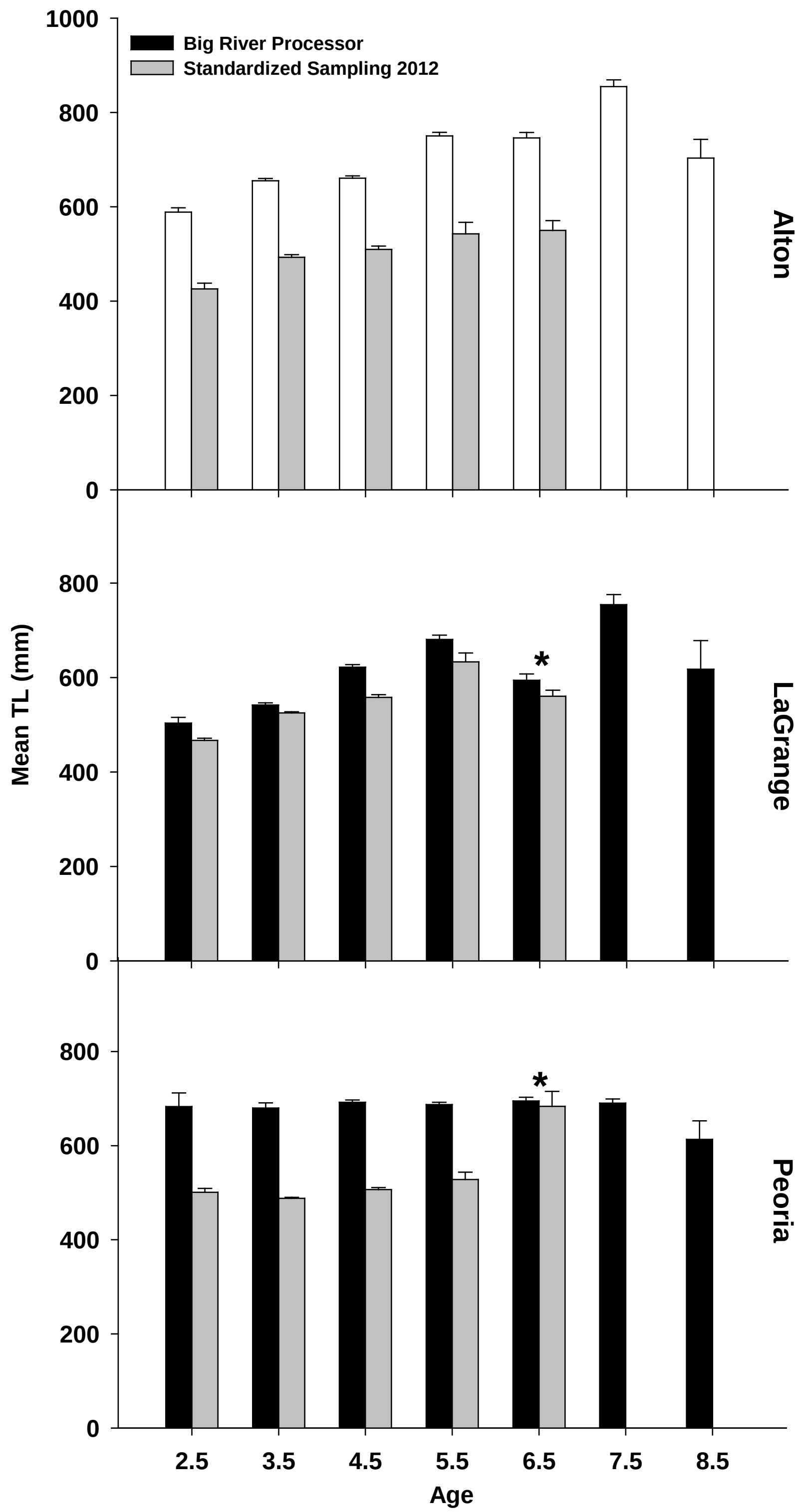

Figure 3. Mean length-at-age and associated standard error of commercially harvested silver carp, and silver carp collected by electrofishing during standardized sampling, IL River, 2012; Asterisk denotes a nonsignificant difference in mean total length ($P \leq 0.05$), as determined by a two-way ANOVA.

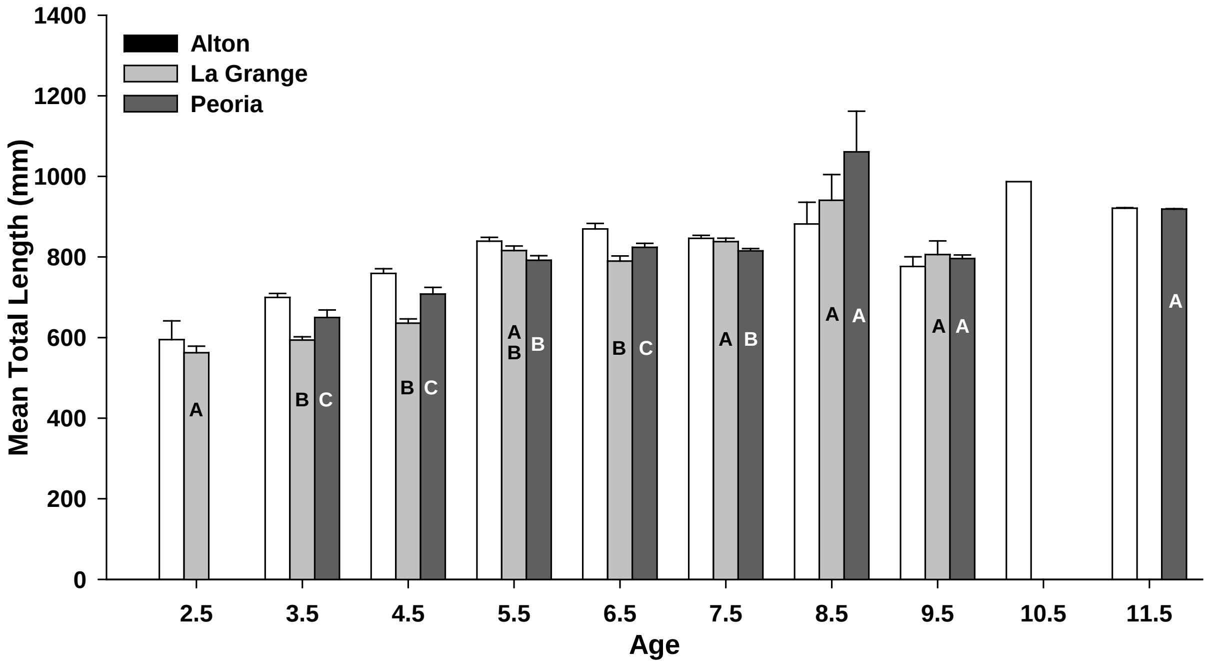

Figure 4. Mean length-at-age with associated standard error for commercially caught bighead carp in the three lower reaches of the Illinois River; different letters indicate significantly different mean total lengths among reaches ($P \leq 0.05$), as determined by a two-way ANOVA.

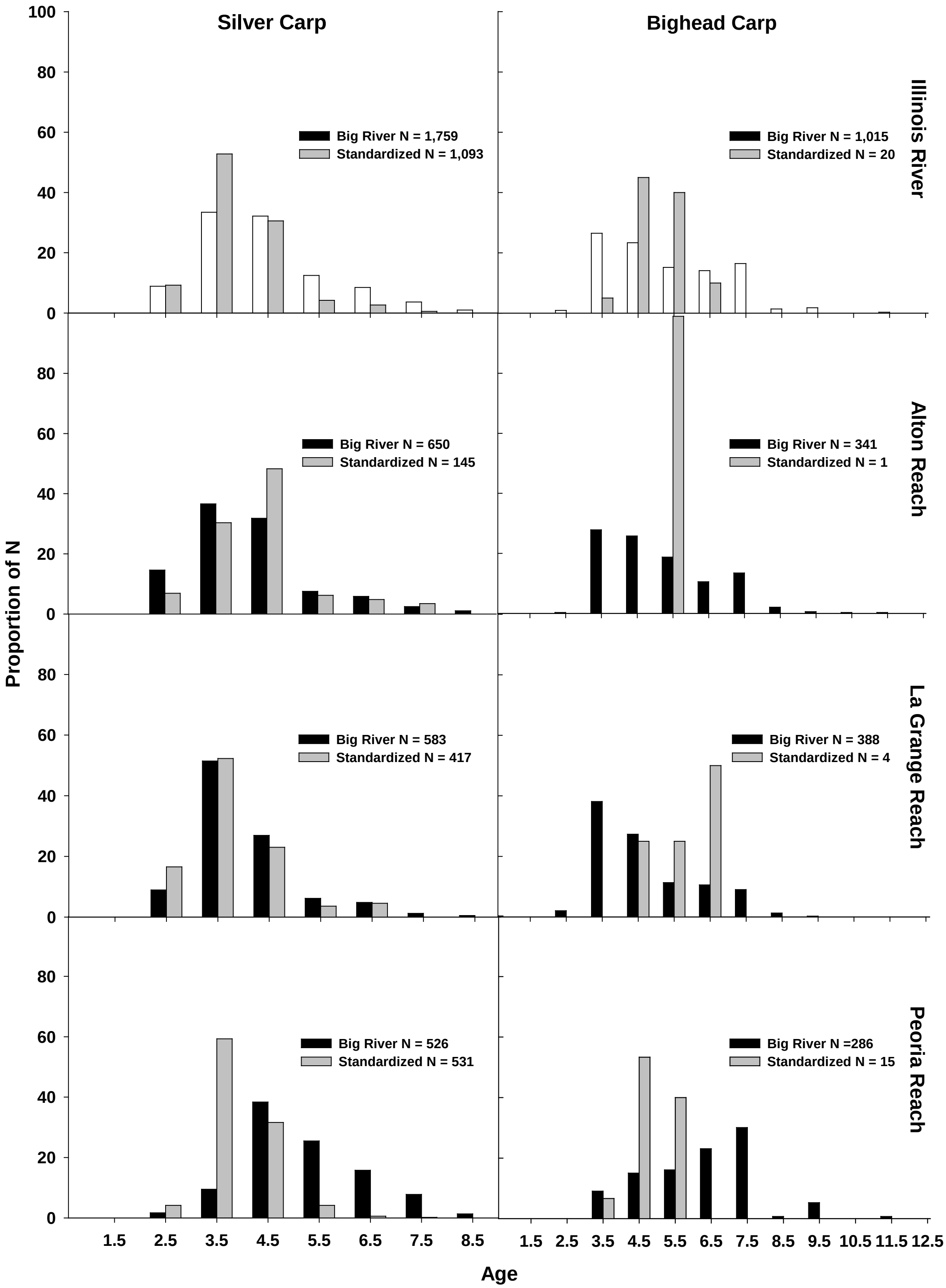

Figure 5: Age frequency of commercially harvested silver and bighead carp compared to carp collected during standardized sampling, IL River, 2012.

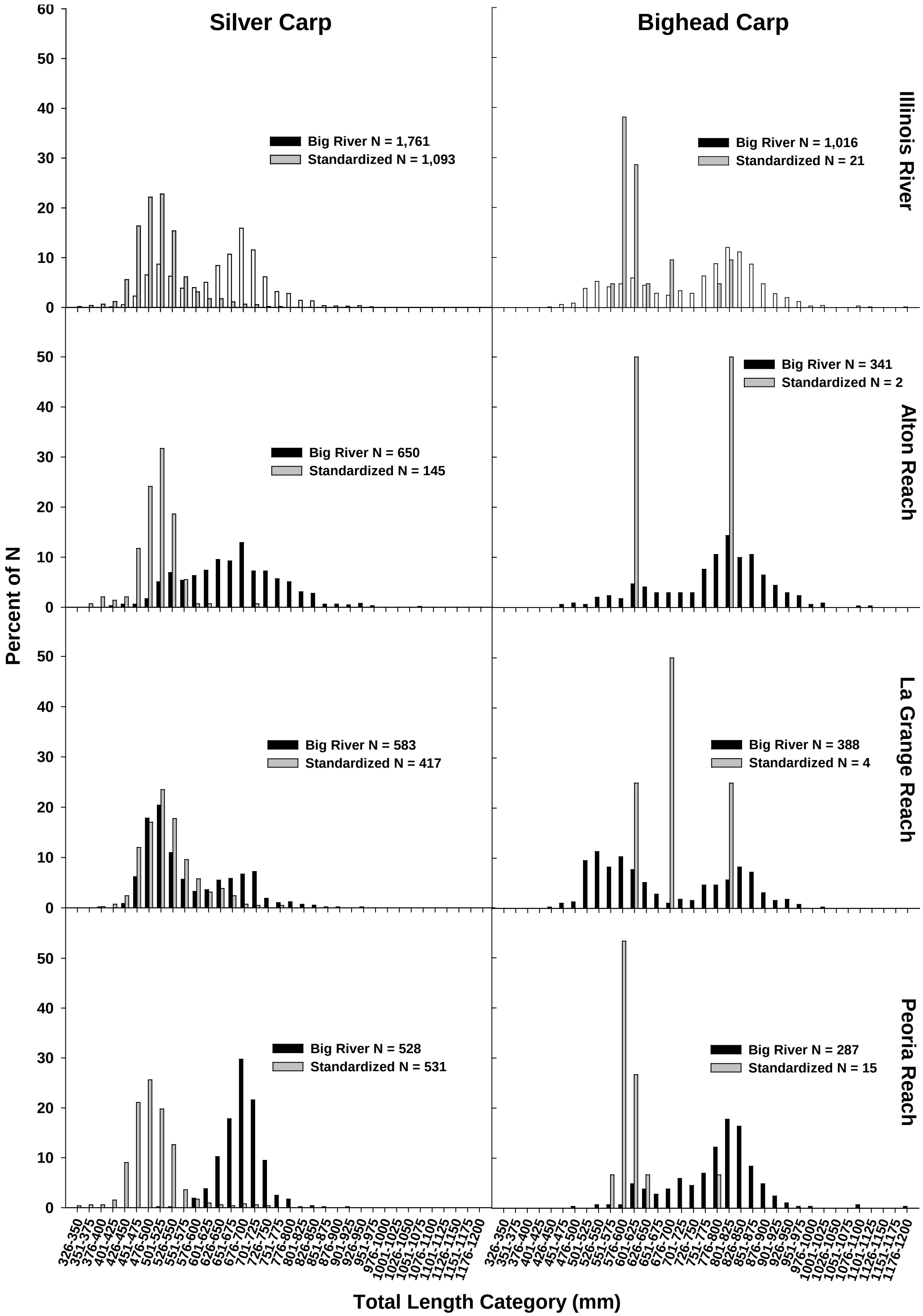

Figure 6: Length frequency of commercially harvested silver and bighead carp compared to carp collected during standardized sampling, IL River, 2012.

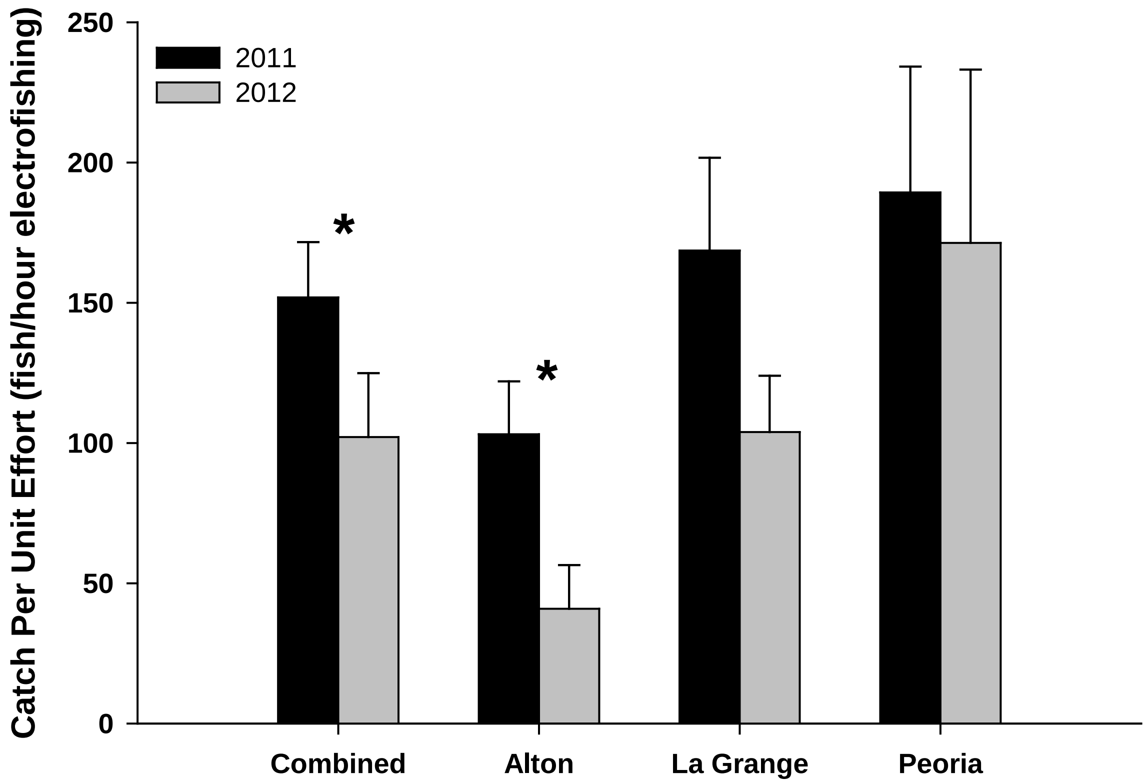

Figure 7. Electrofishing catch per unit effort from standardized fish sampling conducted in 2011 (pre-harvest) and 2012 (post-harvest) for the lower three reaches of the Illinois River combined and for each reach; asterisk indicates a significant difference in CPUE among years ($P \leq 0.05$).

Appendix 1

Asian Carp Fish Meal Report:
Paul Hitchens
REPORT DATE: 3/4/13:

I. 3/4/13:

A. A. Current Stock of fish meal at Pinckneyville storage facility :

Ship Date	Delivery Date	PO#	Lbs shipped
12/28/11	12/29/11	37498-0-7370	15,160 lbs (WITHOUT stabilizer added) on 9 skids BOL# 37498
02/20/12	02/21/12	103162	37,020 lbs Asian Carp WITH stabilizer on 14 skids on BOL# 37826
02/27/12	02/28/12	103162	30,860 lbs Asian Carp WITH stabilizer on 12 skids on BOL# 37881
		Total =	**83,040 Lbs.**
12/6/12	12/7/12	FSLC	**8,080 Lbs.** Shipped to Zeigler for Feed Preparation (from 2/28/12 delivery = Bag #'s 4, 5, & 8)

*** 3/4/13** = Jim Berzinski, Carterville will pick up all remaining stock of carp meal = 83,040 Lbs or 41.5 Tons. Will pay 41 tons @ $350/ton = **$14,350** to SIU. Will bring check when pick up 1st load at the end of this week. Analysis of both stabilized & non-stabilized carp meal samples checked out fine(protein level = 60%).

Total Remaining in Stock = 83,040 Lbs.

B. A. Current Stock of Zeigler Fish Feed with carp meal at Pinckneyville storage facility :

Ship Date	Delivery Date	Lbs shipped	# Pallets	Number of Bags	# Tons
1/31/13	2/1/13	32,720 lbs	17	818	16.36

- **1/31/13:** Meeting with Timpner Farm & Waeltz Farms to organize production trials in both farms for feed tesing on HSB cage culture. Explained procedures and objectives of study.
- Bags will be split up between the two HSB producers (Timpner Farm & Waeltz Farms) for production testing this starting this spring.
- Control bags for production tests have not arrived from Zeigler to date.

II. 2/12/13: Gray Magee, Grafton - Progress Report

1. Plan on construction of plant this March 2013.
2. Will produce fish meal only.

3. In connection with Caterpillar group in Peoria & Falcon Protein Products.
4. Will be no odor or waste.
5. Estimated production figures of 15,000,000 Lbs. of carp meal/year.
6. Will be able to process 50-60,000 Lbs./day.
7. Will E-Mail letter with further update to me & Dr. Garvey.
8. Interested in buying carp meal & will send sample for analysis.

III. 2/13/13:

1. Mailed Gray Magee samples for analysis.

IV. 2/13/13:

1. Phone conversation with Rick Smith@ **Big Rivers** concerning USDA Asian carp certification for USAID/FAS project. Retrieved data on whole fish prices, shipping, supplies, etc. Production figures from 2012
   a. Big Head & Silver = **3,110,000**

V. 2/13/13:

1. Called Jeff Gay for results on carp meal analysis and progress on purchasing of excess carp meal in Pinckneyville freezer unit = Does not want to buy any, due to age of the product.

VI. 2/13/13:

1. Phone conversation with Jill Rendleman concerning carp meal for fertilizer. Discussed price & amount for sales. Needs organic only & sample for analysis. Concern of stabilizer & excessive heat.

VII. 2/14/13:

1. Called Jeff Gay for results on carp meal analysis and data on processing for maximum temperatures, stabilizer ingredient, etc. for fertilizer sales.
2. Stabilizer = Ethoxyquin @ 500 ppm(I Lb./Ton) & T= 275 F.
   a. Dissipates out over time. Probably none left in product.
   b. Commonly used in Pet Foods.

VIII. 2/15/13:

1. Called Maschhoff for possible carp meal sale. Want sample.

IX. 2/15/13:

1. Phone conversation with Mike Schafer @ **Schafer Fisheries** concerning USDA Asian carp certification for USAID/FAS project. Retrieved data on processed & value added fish prices, shipping, supplies, etc. Production figures from 2012:
   a. Big Head = 1,740,045
   b. Silver = 4,382,461
   c. Grass Carp = 338,949
   d. Common Carp = 1,833,226
   e. Total = **8,294,681**

X. 2/15/13:

1. Meeting with Jill Rendleman at farm for sample delivery & sales possibilities/price.

XI. 2/18/13:

1. Mailed Maschhof samples for analysis.

XII. 2/18/13:

1. Called Jim Berzinski for possible carp meal sale in hog diets.
2. Want sample. Will meet @ freezer tomorrow to promote product & collect samples.

XIII. 2/19/13:

1. Met Berzinski @ freezer in P'Ville to promote product & collect samples.
2. Interested in buying all for $350/ton if analysis verifies quality. Waiting results.

XIV. 2/20/13:

1. Phone conversation with Rick Smith @ Big Rivers. Low fishing month for January, as Lisa McKee is out of commission from heart attack suffered over holidays. Is recovering, but slowly. Actual Lbs. of product purchased will have to wait until she gets back.
2. Griggsville packing plant is should be ready to receive product in March or April, 2013.

XV. IATS Carp Sales for February 2013 Report = 1/31/13 through 2/28/13 :

1. Coordinated 3 carp shipments for food fish sales to 1 Toronto buyer/hauler with Big Rivers:
2. Channel Catfish = 0 Lbs. @ $1.00/Lb.
3. Common Carp (Live) = 2,056 Lbs. @ $0.70/Lb.
4. Buffalo Carp (Live) = 0Lbs. @ $0.90/Lb.
5. Big Head (On Ice) = 11,177 Lbs. @ $0.35/Lb.
6. Grass Carp (On Ice) = 2,056 Lbs. @ $0.55/Lb.
7. Total Asian carp sold = **13,233 Lbs.**
8. Total Lbs. sold through IATS = **15,109 Lbs.**
9. IATS will receive $0.05/Lb. on brokerage fees.

Appendix E. Rock Run Rookery Asian Carp Removal

Rock Run Rookery Asian Carp Removal Project

David Wyffels, Tristan Widloe, Kevin Irons, Matt O'Hara, Blake Ruebush, John Zeigler, Brennan Caputo
Illinois Department of Natural Resources

Introduction: Rock Run Rookery is an 84 acre lake that is owned by the Forest Preserve District of Will County and is located approximately 15 miles downstream of the Electric Dispersal Barrier within the Dresden Island Pool (Figure 1). It is connected to the lower Des Plains River by a shallow 60 foot wide channel (Figure 1). In 2012 the Illinois Department of Natural Resources (IDNR) was informed that dead Asian carp were found on the boat ramp of Rock Run Rookery after a flood event. In November 2012 the Forest Preserve of Will County allowed contract commercial fishermen accompanied by IDNR biologist to sample for Asian carp as part of the IDNR Barrier Defense Project. 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 Barrier. By decreasing Asian carp numbers in this area we anticipate decreased migration pressure towards the Electric Dispersal Barrier and the upstream waters of the CAWS and Lake Michigan. Trends in commercial harvest data over time contribute to our understanding of Asian carp population abundance and movement between pools of the Illinois Waterway. This project utilizes ten contracted commercial fishing crews to remove Asian carp with large mesh (3.0 - 5.0 inch) trammel and gill nets, as well as other gears on occasion (e.g., seines and hoop nets).

Methods: Commercial fishing in Rock Run Rookery was conducted from November 2012 through December 2013, with the exception of December 2012, January 2013 and February 2013, as part of the IDNR Barrier Defense Project. The Rock Run Rookery is located within the Dresden Island Pool which is closed to commercial fishing by Illinois Administrative Rule; therefore an IDNR biologist is required to accompany commercial fishing crews working in this portion of the river. Commercial fishing crews with assisting IDNR biologists typically fished 1-2 days during each month of the field season at Rock Run Rookery. 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) trammel and gill net were set for 20-30 minutes with fish driven into the nets with noise (e.g., pounding on boat hulls, hitting the water surface with plungers, running with boat motors tipped up). Biologists enumerated and recorded the catch of Asian carp and identified by-catch to species. Asian carp and Common Carp were checked for ultrasonic tags. Ultrasonic tagged fish and by-catch were returned live to the water.

All harvested Asian carp were removed and transferred to a refrigerated semi-trailer and taken to a processing plant where they were used for non-consumptive purposes (e.g., converted to liquid fertilizer). A representative sample of up to 30 individuals of each Asian carp species (Bighead, Silver, and Grass Carp) were measured in total length (mm) and weighed (g) to provide estimates of total weight harvested from Rock Run Rookery.

Results and Discussion:
Contracted commercial fishing crews and IDNR biologists spent an estimated 1,005 person-hours setting 35.5 miles of gill and trammel net for Asian carp in Rock Run Rockery (Table 1). The combined catch of Asian carp (Bighead, Silver, and Grass Carp) was 1,152 fish (Table 1). The total weight of Asian carp removed from Rock Run Rookery was 27,720 pounds or 13.86 tons (Table 1). Bighead Carp, Silver Carp and Grass Carp accounted for 92.8%, 7.0% and 0.2% of the total catch, respectively. A graph of monthly catch data for Bighead and Silver Carp can be found in Figure 2.

By-Catch:
A total of 6,799 fish representing 19 species were caught in trammel and gill nets during the Asian carp removal effort in Rock Run Rookery (Table 2). Three *Icitobus* spp. (Smallmouth Buffalo, Bigmouth Buffalo and Black Buffalo) made up 75% of the catch. Ninety-three fish from 5 species (Channel Catfish, Largemouth Bass, Northern Pike, White Bass and Muskellunge) were game fish, which comprised 1.37 % of the total catch. Channel Catfish accounted for 77.4 % of all game fish captured.

Project Highlights:

- Contracted commercial fishers and assisting IDNR biologists deployed 35.5 miles of gill and trammel net in Rock Run Rookery since November 2012.
- A total of 1,069 Bighead Carp, 80 Silver Carp, and 3 Grass Carp were removed by contracted netting. The total weight of Asian carp removed was 13.86 tons.

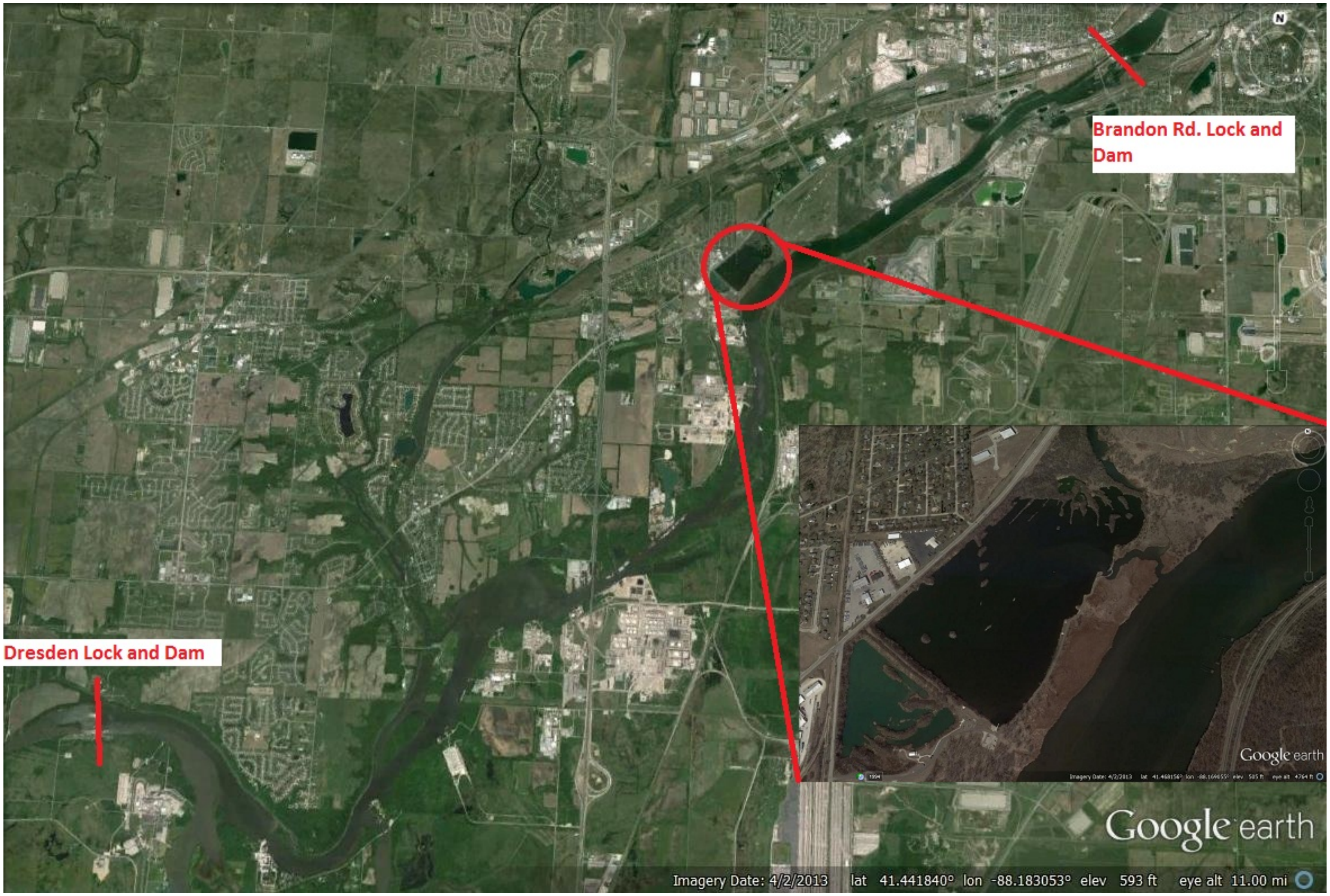

Figure 1: Map of Dresden Island Pool, Rock Run Rookery indicated by red circle.

Table 1: Gill and trammel netting effort and Asian carp harvest data from Rock Run Rookery from 2012 and 2013. Weight data was not collected in 2012.

	Effort		Harvest							
Year	Net Sets (*N*)	Net Length (mi)	Bighead Carp (*N*)	Silver Carp (*N*)	Grass Carp (*N*)	Total (*N*)	Bighead Carp (tons)	Silver Carp (tons)	Grass Carp (tons)	Total (tons)
2012	2	0.9	18	0	0	18	N/A	N/A	N/A	N/A
2013	95	34.6	1,051	80	3	1,134	13.27	0.55	0.04	13.86
Totals	97	35.5	1,069	80	3	1,152	13.27	0.55	0.04	13.86

Table 2: Total Number and percentage of fish captured by gill and trammel nets at Rock Run Rookery during 2012 and 2013. All by-catch were returned to Rock Run Rookery immediately after capture.

	Gill/Trammel Net	
Species	Number Captured	Percent %
Smallmouth Buffalo	3730	54.86
Bighead Carp	1069	15.72
Bigmouth Buffalo	1030	15.15
Common Carp	330	4.85
Black Buffalo	185	2.72
Longnose Gar	133	1.96
Silver Carp	80	1.18
Freshwater Drum	75	1.10
Channel Catfish	72	1.06
Shortnose Gar	27	0.40
River Carpsucker	23	0.34
Quillback	17	0.25
Largemouth Bass	17	0.25
Grass Carp	3	0.04
Goldfish	3	0.04
Northern Pike	2	0.03
White Bass	1	0.01
Spotted Gar	1	0.01
Muskellunge	1	0.01
Total Catch	6799	100.00
Species (*N*)	19	

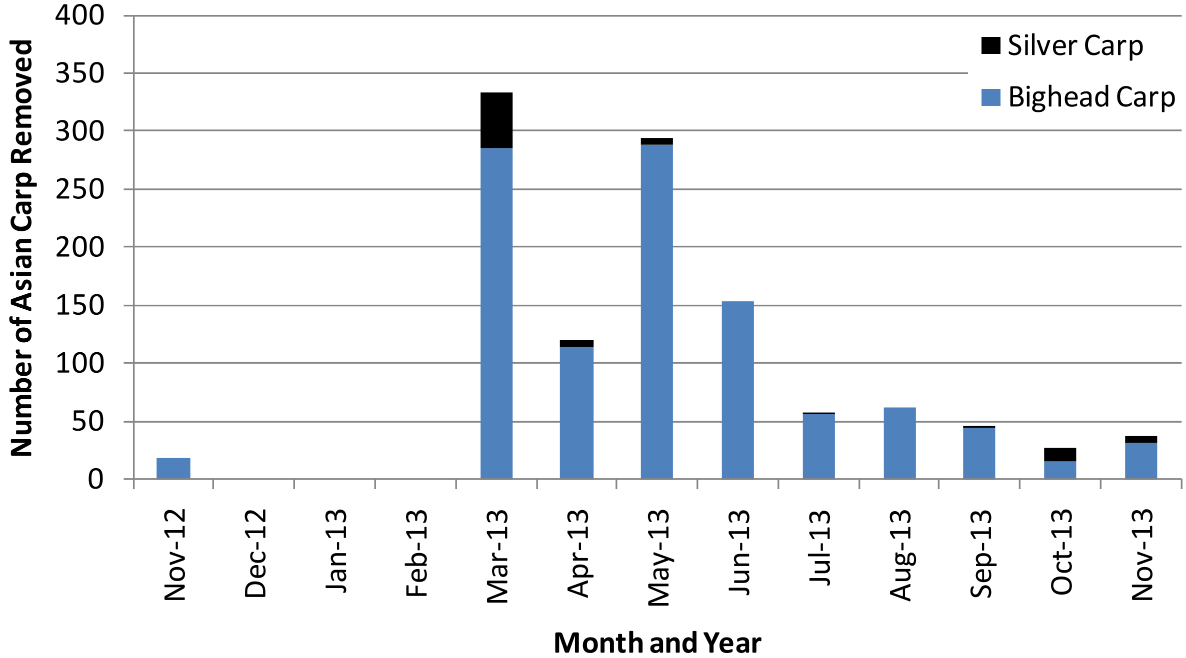

Figure 2: Number of Bighead and Silver Carp removed from Rock Run Rookery by month. No removal effort was completed in December 2012, January 2013 and February 2013.

Appendix F. Investigations 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

Shivani Adhikari, Clark E. Dennis III,
Adam Wright, and Cory D. Suski;
University of Illinois – Urbana-Champaign

Participating Agencies: University of Illinois – Urbana-Champaign (lead), Illinois Department of Natural Resources (funding/field support) and United States Geological Survey (funding/field support).

Introduction: Invasions of non-native nuisance species can have a tremendous negative effect of the receiving environment ranging from severe ecological problems (decreasing biodiversity, collapse of established food chains) to crippling economic woes, and invasive species are estimated to cost the U.S $120 billion annually. Of particular concern are Asian Carp (specifically Silver Carp and Bighead Carp), which are currently contained within the Mississippi River basin by a pair of electrified barriers in the Chicago Area Waterway System (CAWS). While these barriers have been effective to date, no non-physical barrier is 100 % effective at stopping all fish, and there is potential for Asian Carp to either avoid or pass through the existing barrier, with small fish being less susceptible to electricity than larger fish. Therefore, research and development of additional barrier technologies, especially those that would be effective against small fishes, would provide needed redundancy to the current invasive species control scheme for the CAWS, and introduce an essential method to deter fish movements when other non-physical barriers cannot be deployed.

Recently, 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 induces a suite of stress responses, including activation of 'stress genes' and plasma ion imbalances, indicating discomfort when placed in elevated CO_2 zones. Adult Silver Carp, Largemouth Bass, and Bluegill were also shown to initiate active avoidance at approximately 100 mg/L CO_2, with fish swimming away from water with increased CO_2. To date, however, work in this area has only been investigated using adult (mature) fishes in a controlled laboratory setting. The ability of carbon dioxide to impact smaller fishes (fry, fingerlings) has not been defined, and more information needs to be gathered involving the logistical and financial costs associated with large-scale field deployment of a CO_2 chemical barrier. Improving our understanding of these two areas will help determine the efficacy of CO_2 as a deterrent to prevent the movement of Asian Carp.

Objectives: The current investigation explores the use of carbon dioxide gas as a chemical barrier to deter the movement of Asian Carp, and has the following four objectives.

1. ***Determine response of early life-stages of Asian Carp to elevated carbon dioxide:*** Investigate the effect of elevated CO_2 on Asian Carp eggs, fry, and fingerlings in an

effort to determine the efficacy of a CO_2 chemical barrier to deter the movement of small Asian Carp.

2. ***Quantify the effectiveness of a carbon dioxide barrier in a field setting:*** Use a medium-scale arena (i.e., experimental pond) to test the effectiveness of a CO_2 chemical barrier to deter the movement of Asian Carp in a quasi-natural setting (i.e., not in a laboratory).

3. ***Perception of barrier chemicals over short time scales:*** Quantify the ability of fishes to perceive elevated CO_2 environments following short exposure durations.

4. ***Potential for fish to acclimate to a high CO_2 environment:*** Determine the capacity of fish to acclimate to an elevated CO_2 environment (i.e., can fish 'get used' to CO_2 environments?) by quantifying changes in the physiological response, swimming performance, and avoidance response to hypercarbia following long-term exposure.

Objective 1 Methods:

The response of early life-stage Asian Carp to elevated carbon dioxide was investigated using three different stages: eggs, 8 day old fry, and 5-8 cm fingerlings. Field experiments involving Silver Carp and Bighead Carp eggs and fry took place during June, 2012, at Osage Beach, MO. Following the spawn of Asian Carp, developing eggs were collected and subjected to a physiological challenge. Briefly, 100 eggs were transferred to individual perforated cups (10 eggs/cup) and then moved to either a cooler that contained control water or elevated CO_2 water. To better understand the physiological impact of varying concentrations and durations of CO_2 exposure, fish were subjected to trial durations of 30 minutes or 60 minutes at ambient (10 mg/ L CO_2), 70 mg/L CO_2, or 120 mg/L CO_2 conditions. Immediately following exposure of developing eggs to these concentrations of carbon dioxide for these durations, eggs were transferred to an RNA stabilizing solution and stored until further laboratory processing. Approximately one week later, this same set of experiments were performed on Asian Carp fry coming from the same hatching tank the developing eggs were obtained.

To investigate the response of fingerlings to elevated carbon dioxide, two separate but complementary experiments were performed. Bluegill and Largemouth Bass fingerlings were obtained from a local fish hatchery and held at the INHS Aquatic Research Facility in Urbana, IL, while Asian Carp fingerlings were obtained and held at the Upper Midwest Environmental Science Center (UMESC) at La Crosse, WI, in December 2012. The physiological challenge for fingerlings largely follows the experiments performed on Asian Carp eggs and fry, however a 24 hour acclimation period was provided to allow fish to return to resting conditions following the netting/handling of fish necessary to place them in individual darkened, sound-resistant containers. Following the acclimation period, fish were exposed to the durations and concentrations of CO_2 previously used in the egg/fry experiments. Fish were then euthanized with an overdose of anesthetic and tissues were excised and stored in RNA stabilizing solution for further laboratory processing.

In addition to the physiological challenge, ten fingerlings of each species were subjected to a behavioral avoidance challenge. Briefly, fingerlings were placed into a 'shuttle box' choice arena consisting of two large holding tanks connected by a narrow central tunnel. Following a 2 hour acclimation period, CO_2 was slowly applied to the tank that the fish has settled. The time, pH, and dissolved CO_2 concentration was recorded when the fish a) displayed signs of agitation (surface ventilations, twitching, and erratic/elevated swimming activity) and b) when the fish shuttled to the opposite holding tank. After the fish had shuttled, compressed air was added to both tanks for ten minutes to strip the CO_2 from the water. Once the fish had settled on one side of the tank, CO_2 was slowly added to that side of the 'shuttle box' and pH/CO_2 will be recorded as stated above. The behavior trial was repeated in this manner until roughly 4-6 measurements had been collected or until the fish had lost equilibrium and become unresponsive.

Laboratory analyses will consist of quantification of stress gene expression using real-time PCR (qPCR) studies. The genes that will be examined to determine general and specific stressors to elevated carbon dioxide are hypoxia inducible factor 1 alpha (HIF1-α), heat shock protein 70 (HSP70), glucocorticoid receptor 2 (GR-2), and proto-oncogene c-Fos (c-fos).

Objective 1 Results:

A total of 10 samples (either containing 10 eggs or 30 fry per sample) were collected for each treatment-duration pair for each species and life-stage resulting in a total of 240 samples. RNA extraction for all samples has been completed. Gene expression analysis has been completed for fry samples and data analysis is currently being performed. Results of gene analyses are expected in spring 2014.

Native and invasive fingerlings were tested for their response to elevated CO_2 during fall 2012. For the physiological experiment, 10 fingerlings per treatment-duration pair were sampled for three tissues (gill, liver, and muscle) resulting in a total of 720 samples. RNA extraction for all samples has been completed. Gene expression assays for juvenile Silver Carp, Bighead Carp, and Largemouth Bass gill samples were completed in January 2014. These data are currently being analyzed and will be available in spring 2014.

During the behavioral trials, Silver Carp and Bighead Carp fingerlings displayed agitation at approximately 80 mg/L CO_2 (Table 1). Native and invasive juvenile fishes tended to initiate shuttling behavior and avoid waters with elevated CO_2 at concentrations between 150 – 210 mg/L CO_2 (Table 1).

Table 1. Concentration of CO_2 at which Bluegill (105mm; 4.1in), Largemouth Bass (104mm; 4.1in), Silver Carp (67mm; 2.6in), and Bighead Carp (71mm; 2.8in) displayed agitation responses or active avoidance from a high CO_2 environment into a lower CO_2 environment. Differences in the CO_2 concentration that induced agitation (t-Test, t = 1.22, P = 0.23) and active avoidance behavior (analysis of variance, $F_{[3]} = 1.84$, P = 0.16) were not statistically different across species. Sample size for fish displaying agitation responses is ten for Silver Carp and Bighead Carp, while sample size for fish displaying active avoidance behaviors is ten for all species. Approximately 3 (agitation) or 4 measurements (shuttles) were collected from each subject.

	CO_2 - Agitation Response	CO_2 – Avoidance Response
Bluegill		151.17±10.27
Largemouth Bass		184.59±15.48
Silver Carp	96.99±11.19	170.14±14.48
Bighead Carp	76.17±10.29	214.85±16.49

Objective 1 Discussion:

Fingerling Silver and Bighead Carp display signs of distress at CO_2 concentrations around 80 mg/L, and will eventually actively leave areas of elevated CO_2 once concentrations reach approximately 150-200 mg/L. This finding is in agreement with previous research in our group involving adult Asian Carp, which showed active avoidance behavior and obvious signs of distress around 100 mg/L, suggesting that a CO_2 barrier could be effective at influencing swimming behavior for both adult (mature) fish as well as juvenile fishes. While this shows that CO_2 has the potential to influence the movement of juvenile and adult Asian Carp, further results from this current research project are needed to determine exactly how Asian Carp are affected by elevated CO_2 and whether Asian Carp eggs/fry are similarly susceptible to CO_2 comparable to juvenile and adult Carp. Results from the gene portion of the study will help support or refute these findings.

Recommendations: Studies to investigate the use of CO_2 as a non-physical barrier should continue. The use of CO_2 appears to be effective at deterring the movement of small (5-8 cm) Asian Carp, which would help augment the existing electric barrier.

Objective 2 Methods:

The field experiment used to test the effectiveness of a CO_2 chemical barrier in deterring the movements of free-swimming Asian Carp was carried out in September, 2013, at the Upper Midwest Environmental Science Center (UMESC) in La Crosse, WI. A CO_2 infusion system (Fig 2a, 2b), based on venturi principles, was built on site and used to create an area of elevated dissolved CO_2 encompassing approximately one third of a 0.5 acre pond (approximately 1.5 million gallons of water). A pump drew water from the pond, and a discharge manifold (Fig 2c) was used to distribute water infused with CO_2 into the test portion of the pond. The remaining two-thirds of the pond remained at ambient CO_2 concentrations, allowing fish to actively choose which side of the pond to inhabit.

Trials were run in duplicate and each trial used 10 Bighead Carp, 10 Silver Carp, and 20 non-invasive species (5 each of channel catfish, paddle fish, yellow perch, and bigmouth buffalo). Each fish was externally tagged on the dorsal musculature with an acoustic transmitter (Fig 3) to track and monitor fish movement (3-D) at sub-meter accuracy. Tagged individuals were placed into the pond and allowed 12-14 hours to recover from stress associated with handling/tagging procedures. Following this recovery time, fish were allowed to acclimate to the pond for 22 hours. During the acclimation period, the pump feeding the CO_2 infusion system was turned on, but water bypassed the venturi system itself, thus circulating water in the pond and controlling for any effect of pump noise on fish movement. Upon completion of the acclimation period, water flowing through the venturi system became supersaturated with CO_2 and was pumped into the pond through the discharge manifold. The elevated CO_2 area of the pond was then maintained for a 24 hour period. Following the 24 hour CO_2 infusion period, the CO_2 infusion system was ceased and 6 hours were devoted to monitoring fish movement upon completion of the CO_2 infusion trial. In addition to telemetry, water quality measurements were also collected at selected sites and time intervals and included parameters such as dissolved oxygen, temperature, pH, dissolved CO_2 and total alkalinity.

Fig 2: a) pump feeding water from the pond to the CO_2 infusion system, b) the CO_2 infusion system, and c) the discharge manifold.

Fig 3: Fish tagged with acoustic tag.

Objective 2 Results:

Columbia River Research Laboratory (CRRL) is taking the lead to analyze telemetry data and is currently processing the data. The data will be shared via oral presentation at the 2013 Midwest Fish and Wildlife conference in Kansas City, MO.

Objective 3 Methods

Experiments to quantify the ability of fish to perceive elevated CO_2 environments at short time scales were performed at the INHS Aquatic Research Facility in Urbana, IL during fall, 2012.

Juvenile Bluegill were exposed to either an elevated CO_2 environment (90 mg/L CO_2 ; ≈ 41000 µatm) or ambient CO_2 conditions (10 mg/L CO_2; ≈ 450 µatm) for either 30 seconds or 2 minutes. Fish were then sampled either immediately after the conclusion of the short-term exposure (i.e., 0 min recovery), or after a recovery period (10, 30, or 60 minutes) in ambient water. The experimental design for the study is shown in Table 2. A total of 170 fish were used, and tissue samples for gill, liver and muscle were collected from each fish. In addition, samples were also collected from 10 fish before being exposed to the short-term trials.

Table 2. Experimental deign for response of juvenile fish to short term exposure of elevated CO_2.

CO_2 concentration	Exposure Duration	Recovery Duration	Number of Bluegill Sampled
Control (15 mg/L, 450 µatm)	30 Seconds	0 min	10
		10 min	10
		30 min	10
		60 min	10
	2 Minutes	0 min	10
		10 min	10
		30 min	10
		60 min	10
90 mg/L CO2 41000 µatm	30 Seconds	0 min	10
		10 min	10
		30 min	10
		60 min	10
	2 Minutes	0 min	10
		10 min	10
		30 min	10
		60 min	10

Objective 3 Results:

RNA extraction has been completed for gill tissue in all 170 samples collected. Gene expression analysis is expected to begin January 2014 and will be achieved by performing qPCR for a suite of stress genes: hypoxia inducible factor 1 alpha (HIF1-α), proto-oncogene c-Fos (c-Fos), glucocorticoid receptor isoform 2 (GR-2) and inducible heat shock protein 70 (Hsp70). RNA extraction from additional tissues is expected to begin in January 2014 if necessary.

Objective 4 Methods:

Two groups of juvenile Largemouth Bass, one group held in water at ambient CO_2 concentrations (10 mg/L; ≈ 450 µatm) and the other group held at elevated CO_2 concentrations (30 mg/L; ≈ 9000 µatm) for 2 months, were used to determine how acclimation to elevated CO_2

may impact the behavior, performance, and blood chemistry of fishes exposed to high CO_2 concentrations. Three separate, yet complimentary, studies were performed at the INHS Aquatic Research Facility in Urbana, IL, between September and December, 2013, to determine the capacity of these fishes to acclimate to an elevated CO_2 environment. The first study used a ‘shuttle box’ choice arena to determine the concentration of CO_2 that is necessary to induce agitation and active shuttling behaviors in fishes exposed to hypercarbia (n=12 Largemouth Bass acclimated to elevated CO_2, and 12 Largemouth Bass acclimated to ambient CO_2 concentrations). The second study used a ‘swim tunnel’ to determine the swimming performance of fishes when exposed to a high CO_2 environment (n=8 Largemouth Bass per acclimation tank). While the last experiment, exposed fishes to an elevated CO_2 environment for 1 hour and then sacrifices these fish to determine changes in blood/tissue stress parameters between fish acclimated to high CO_2 and control fish (n=10 Largemouth Bass from each acclimation tank).

Objective 4 Results:

Preliminary results from the ‘shuttle box’ trials show that Largemouth Bass acclimated to an elevated CO_2 environment do not display agitation behaviors until CO_2 concentrations higher than fish that acclimated to ambient CO_2 concentrations (high CO_2 acclimated – 160 ± 16 mg/L CO_2; ambient CO_2 acclimated – 107 ± 21 mg/L CO_2). Largemouth Bass acclimated to a high CO_2 environment were also able to spend more time within a CO_2 environment during the ‘shuttle box’ trials compare to control fish before succumbing to CO_2 and losing equilibrium (high CO_2 acclimated – 35 min; ambient CO_2 acclimated – 23). However, there was no difference in the CO_2 concentration that was required to induce shuttling between Largemouth Bass acclimated to elevated CO_2 and Bass acclimated to ambient CO_2 conditions (high CO_2 acclimated – 227 ± 16 mg/L CO_2; ambient CO_2 acclimated – 200 ± 14 mg/L CO_2).

Preliminary results from the ‘swim tunnel’ trials show that Largemouth Bass acclimated to a high CO_2 environment have greater burst swimming speeds under a hypercarbia exposure of 120 mg/L CO_2 compared to Bass that acclimated in ambient CO_2 conditions (high CO_2 acclimated – 56 ± 4 cm/s; ambient CO_2 acclimated – 26 ± 4 cm/s).

Laboratory analyses (qPCR, ions, cortisol, hematocrit, etc.) of the collected blood/tissues samples will begin January 2014.

Project Highlights:

-In summer 2012, experiments were completed at Osage Beach, MO, to quantify the impacts of CO_2 exposure on the stress response of larval Silver Carp and Bighead Carp. Data analysis is currently underway.

-In fall 2012, experiments were completed at UMESC and INHS Aquatic Research Facility to quantify the impacts of CO_2 exposure on the behavior and stress response of invasive and native fingerlings. Data analysis is currently underway. Preliminary analyses indicate that fingerling Asian Carp will actively avoid water with CO_2

-In fall 2013, experiments were completed at UMESC to quantify movement and activity of free-swimming Carp in a pond following exposure to CO_2. Data analysis is currently underway.

-In fall 2013, experiments were carried out to test the potential for fish to acclimate to a high CO2 environment. Data analysis is currently underway.

- In fall 2013, experiments were carried out to test potential for chlorine to act as a chemical fish barrier using a ‘behavioral choice tank’. Three concentrations of chlorine (0 mg/L [control], 0.1 mg/L chlorine and 0.5 mg/L chlorine) were tested with 6-8 Largemouth Bass used for each concentration. Data analysis is currently underway.